# REPORT

OF THE

# STATE GEOLOGIST

ON THE

## MINERAL INDUSTRIES AND GEOLOGY

OF

# VERMONT,

## 1913 - 1914.

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NINTH OF THIS SERIES.

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GEORGE H. PERKINS,

State Geologist and Professor of Geology,
University of Vermont.

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BURLINGTON, VT.:
FREE PRESS PRINTING COMPANY,
1914.

## STAFF OF THE VERMONT GEOLOGICAL SURVEY, 1913-1914.

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Professor of Geology, University of Vermont.

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D. B. GRIFFIN, *Field Assistant.*

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STATE OF VERMONT.

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BURLINGTON, VT., December 1st, 1914.

*To His Excellency, Allen M. Fletcher, Governor of Vermont:*

SIR:—In accordance with Section 279, Statutes of 1900, I herewith present my Ninth Biennial Report as State Geologist.

The introduction following gives a summary of the work which has been carried forward during the years 1913-1914 by several who have aided greatly in the study of the Mineral Resources of the State.

There can be no doubt that such investigations as are recorded in the following pages will materially advance the interests of the State.

A very important part of the work accomplished during the past two years has cost the State little or nothing. This is especially true of the extensive work of Professor T. N. Dale as, through the assistance of the United States Geological Survey, his papers on the Marble of Vermont, by far the most valuable ever prepared on this subject, have been supplied entirely without cost and all the illustrations have been furnished by the Director at a small fraction of the original cost.

It has been with much satisfaction that in our work we have been able to make use of some of the maps produced by the Topographical Survey which has been in progress during the last two years. These maps are absolutely essential to accurate geological work and it is to be greatly hoped that the necessary cooperation with the National Government on the part of the State will be continued.

The usual office work of this Department has been carried on.

The importance of the quarries of Vermont as well as that of some of the mines has been for some years steadily increasing and their products are exceedingly valuable to the State and form a not inconsiderable part of its revenue, amounting, as shown on following pages, to nearly one-half that of all agricultural products.

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As was done with Bulletin 404 on the "Granites of Vermont" it has been thought best to reissue this Bulletin 521 in the present report for, although not inaccessible to the people of the State in its original form, it is less easily obtained by Vermonters than is a publication issued by their own State. Moreover, in the opinion of the writer all such material should be included in the scientific literature of the State.

Certainly none of our products are more important than is marble and any literature that bears upon this subject must necessarily be of the highest interest and importance to our citizens.

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As it is here published with the original maps and illustrations the expense would have been prohibitive had not this aid been granted and full acknowledgement is due the Survey for the use of the stones from which the four colored maps were printed and for permission to make electrotypes of the illustrations as well as free use of the text.

Following the more technical discussion by Dr. Dale there will be given a general account of the marble industry as it has been from the first and is now carried on.

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Just in time to add it to the above Bulletin, an advance proof of Dr. Dale's latest Bulletin on the Marbles and Limestones of Eastern Vermont has been very kindly supplied by the Director of the U. S. Geol. Survey and with this we have by far the most complete discussion of these materials in Vermont that has ever been made. Therefore it is with great satisfaction that these two Bulletins can be presented in this Report. This would not have been possible without the cordial assistance of the National Survey.

In order that the whole subject might be as fully treated in this Report as possible the Geologist has supplemented Dr. Dale's work with an account of the history, methods of manufacture and varieties of marble which it is hoped will be found useful for reference by anyone interested. The Vermont Marble Company have rendered much assistance in this part of the work by supplying information and the loan of a number of illustrations.

During the last two years the State in cooperation with the United States Geological Survey has carried on Topographical work in Chittenden and Franklin Counties and the maps of these counties are now completed. That this most desirable work may be continued by future Legislatures is very important.

In order that anyone wishing to know just what portions of the State have been mapped up to the present time may be informed the Geologist has written an account of the Survey in general and has tabulated the different areas which have been mapped so that it is not at all difficult to determine speedily whether maps of any part of Vermont have been mapped. It is also stated how the maps may be obtained. Professor C. H. Richardson of Syracuse University has gone on with his work which for ten years he has been carrying on in the northern part of the State, studying the rocks of different towns from year to year. His contribution to the present Report will be found to cover the towns of Greensboro, Woodbury and Hardwick.

Professor C. E. Gordon of Massachusetts Agricultural College has for several years been studying the rocks of Bennington County and in the article published under his name has given some of the results which he has obtained.

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PLATE I

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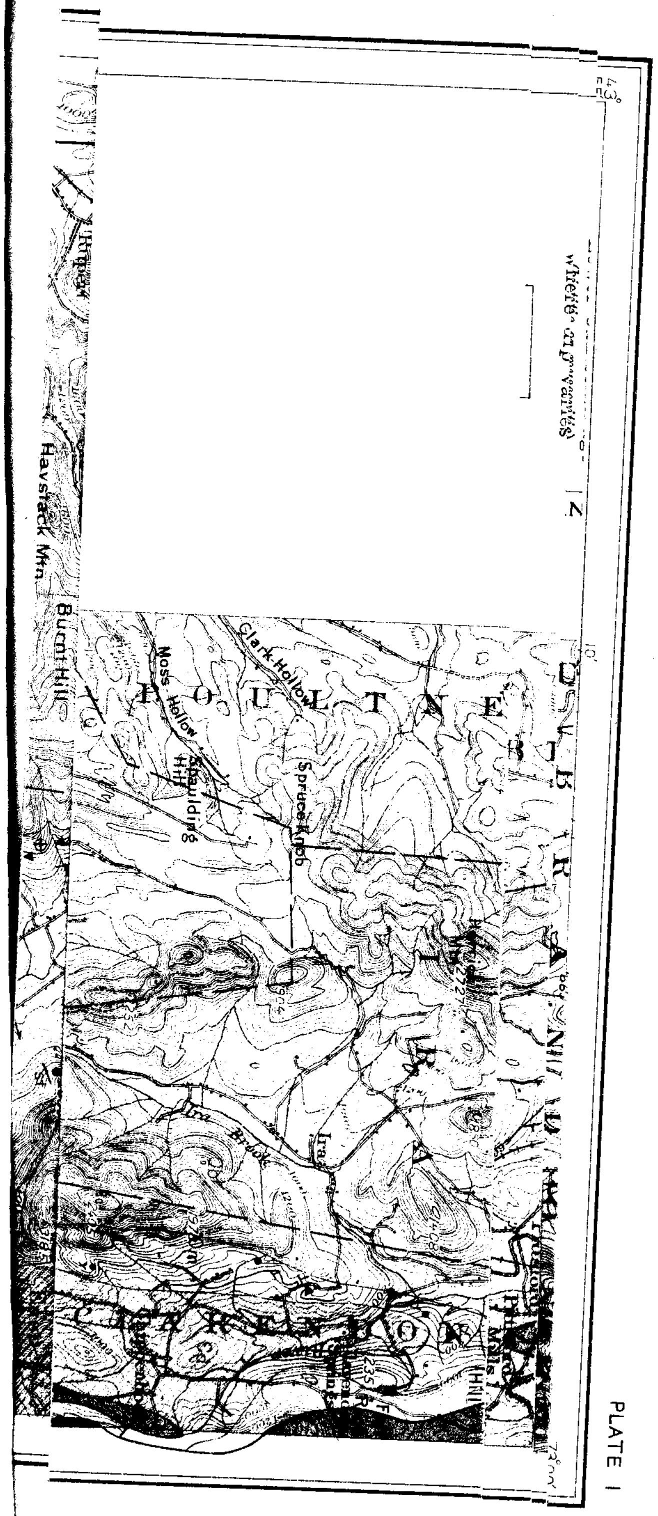



PLATE I

# THE COMMERCIAL MARBLES OF WESTERN VERMONT.

By T. Nelson Dale.

## INTRODUCTION.

This publication has a twofold object—to bring the science of geology to bear upon the problems of the marble industry in western Vermont and briefly to make known the more important scientific results obtained in the course of the mapping of the marble belts of that part of the State and in the study of its marbles.

The marble district specially considered lies west of the Green Mountain Range in Bennington, Rutland, and Addison Counties, but the reddish dolomite marble quarried at Swanton, in Franklin County, and the black calcite marble quarried on Isle la Motte, in Grand Isle County, are also described. The green serpentine of Roxbury, nearly in the center of the State, in Washington County, and the chrome mica schist of Shrewsbury, in Rutland County, have also been included. The bulletin covers all the quarries of commercial marble that were in operation in the State in 1910. The marble deposits on the east side of the Green Mountain axis, including the small disused quarries in Orange County, are not here considered.

The field work was done by the writer in parts of the summers of 1888, 1899, 1900, 1903, and 1904. Mr. F. H. Moffit spent the summers of 1899 and 1900 and a month in 1902 on the areal and structural geology of the marble belt and adjacent schist masses in Arlington, Sandgate, Manchester, Dorset, Danby, and Tinmouth. His maps, notes, sections, and specimens have been used in the preparation of this bulletin. Mr. N. C. Dale assisted the writer in the summer of 1903. The writer also spent most of the summer of 1910 in visiting all the active marble quarries of the State and in otherwise completing the work begun in 1888.

The notes on the texture of marble (pp. 43-47) are based on the study of 200 thin sections.

Mr. George Steiger, of the Geological Survey, has contributed a quantitative determination of the graphite in the gray marble of West Rutland. Mr. W. T. Schaller, also of the Survey, has made a qualitative examination of a dolomitic bed near Brandon, and he and Mr. J. S. Diller have made an examination of the chrome mica schist marble of Shrewsbury. Mr. E. S. Larsen has also made a few petrographic determinations.

The marble companies have materially aided the work by placing their core-drill records at the writer's service, by facilitating his investigations, and by furnishing sawed cubes for thin sections and polished specimens.

The elementary geologic principles which should guide the quarryman and the prospector in the marble belts of western Vermont are outlined on pages 71-79.

In order to render the bulletin more widely serviceable as few technical terms as possible have been used, even in the more scientific parts. A glossary of such technical terms as have unavoidably been used will be found on pages 156-158.

It is proposed to supplement this bulletin by one on the marbles of eastern Vermont.

## THE WORK OF VERMONT GEOLOGISTS.

Much work has been done by geologists of Vermont on the geology of its marbles.

The State report of Hitchcock and Hager, published in 1861, laid the foundation for all future work. Next in importance were the discoveries of Rev. Augustus Wing, published by James D. Dana in 1877, determining the geologic age and structural relation of various parts of the marble and limestone areas. Then came the general summary of the geologic features of the marble belt by President Ezra Brainerd, in 1885, and in connection with it the interesting economic papers published the same year by Prof. Henry M. Seeley on the marble industry of western New England and its early beginnings in Vermont. These were followed, in 1898 to 1908, by several annual reports by Prof. George H. Perkins, State geologist, in which the location and characteristics of the quarries were given, the marble firms and plants noted, and the colors and shades of all the marbles carefully described. The report for 1908 also contains two important papers by Prof. Perkins on the geology of Franklin and Chittenden Counties and the formation to which the "Champlain marbles" belong. The same report also includes a paper by George E. Edson on the geology of Swanton. Finally, the State geologist's report for 1910 contains a brief reference to the marble industry and some photographs of unusual folds in the great marble belt in Leicester.

The design of this bulletin is not to supplant or duplicate, but to complement the work of the geologists of the State. It is expected that this will be accomplished not only by means of the geologic maps and sections and the results of the microscopic study of the marbles but also by furnishing those engaged in the marble industry a brief key to the structural geology of the marble beds.



The reader will be frequently referred to the reports of the State geologists for information on special points. A bibliography of Vermont marbles will be found on pages 49-53.

## MARBLE IN GENERAL.

### LIMESTONE AND MARBLE.

If a chemical precipitate of carbonate of lime is examined microscopically, it will be found to consist of irregular, infinitesimal granules of uncrystalline matter. When analyzed, this material will be found to have essentially the composition of what is technically known as marble or crystalline limestone. A thin section of marble, when placed under a microscope, is seen to be an aggregate of translucent to transparent crystalline plates, generally of irregular outline, of calcite or dolomite, with the rhombohedral cleavage characteristic of these minerals, and also generally crossed by twinning planes. These twinning planes, which are so conspicuous in thin section of marble, are due to the growth of two crystals in such juxtaposition (but not parallel) that there is a uniform mathematical relation between the axes of the two crystals. The twinning plane seen in the crystalline grain of a thin section of marble is the plane along which the two crystals meet. But as this twinning process generally repeats itself in the same crystalline mass or particle, a single microscopic grain may contain several such planes. The difference between a collection of individual crystals of calcite and a piece of calcite marble is that the former, like granulated sugar, consists of complete crystals, whereas in calcite marble the crystals have been formed so close to one another that no one crystal has been able to complete itself. There has been no space for the formation of the faces of individual crystals.

Many so-called granular limestones when examined microscopically are found to consist of exceedingly minute, irregular plates of polarizing but untwinned calcite. Such limestones are really part-way marbles.

A few specimens of limestones were examined microscopically to throw light on the relation of limestone and marble:

A very fine-grained limestone, Chickamauga (201), collected by Dr. C. W. Hayes near Attalla, Ala., with flintlike fracture, brownish-gray color, and strong effervescence with Hcl, consists of irregular polarizing particles 0.0028 to 0.006 millimeter in diameter, with sparse polarizing plates, some of them of rhombic form (dolomite), 0.008 to 0.02 millimeter in diameter, and sections of fossils.

Another limestone, Chickamauga (202) collected also by Dr. Hayes near White Cliff Springs, near Starrs Mountain, in Tennessee, has a very fine texture, is dark brown in color, effervesces strongly, is finely veined and fossiliferous. In thin section this rock shows irregular nodules of very fine polarizing granules of irregular form in a matrix of polarizing calcite particles. Nodules and matrix are crossed by fine veins of calcite. The fossil sections polarize.

An oolitic limestone from Short Creek, Galena, Kans., with a light-brownish cement and strong effervescence, consists of slightly flattened spherules, 0.02 to 0.05 millimeter in diameter, of polarizing irregular grains (0.006 to 0.014 millimeter) lying in a matrix of polarizing and twinned calcite plates.

It is usually assumed that natural chalk is uncrystalline, but the crystalline nature of chalk has been determined by Kauffmann and verified by Renard.[1]

The difference between one of these semigranular limestones and a true marble appears in polishing. The marble alone yields a brilliant surface, which is due to the effect of light upon its uniformly crystalline particles.[2]

## DEFINITIONS OF MARBLE.

The distinctions indicated lead to the following definitions:

Marble in the technical sense is a rock consisting mainly of crystalline particles of calcite or dolomite or of both. But marble in the commercial sense includes a wide variety of stones and even some of very different composition and history. A Vermont serpentine is described on page 41 and a chrome mica schist on page 42. Both are commercial "marbles."

## CHEMICAL COMPOSITION.

The chemical composition of marble varies primarily according as it consists of calcite or of dolomite or of an admixture of both. White calcite marble is almost entirely carbonate of lime. In white dolomite marble carbonate of magnesia takes the place of part of the carbonate of lime. As the colored marbles of these two sorts contain small percentages of other minerals (graphite, quartz, hematite, limonite, magnetite, pyrite, muscovite, actinolite, tremolite, etc.), their analyses differ slightly from those of the white marbles.

A few reliable analyses of typical American and European marbles follow:

*Analysis of white calcite marble from West Rutland, Vt.*[3]

| | |
|---|---|
| Insoluble | 8.00 |
| Alumina ($Al_2O_3$) | .39 |
| Ferrous oxide (FeO) | .14 |
| Magnesia (MgO) | Trace |
| Lime (CaO) | 50.79 |
| Water ($H_2O$) at and above 105° | 1.01 |
| Carbon dioxide ($CO_2$) | 39.80 |
| | 100.13 |

[1] Renard, A. F., Des caractères distinctifs de la dolomite et de la calcite dans les roches calcaires et dolomitiques du calcaire carbonifère de Belgique: Bull. Acad. roy. Belgique, vol. 47, 1879, p. 555.

[2] See, for a discussion of the effect of light on polished stone surfaces, Seipp, H., Italienische Materialstudien, Stuttgart, 1911, pp. 76-105.

[3] By L. G. Eakins, Bull. U. S. Geol. Survey No. 419, 1910, record No. 1213, p. 189.



*Analysis of white calcite marble, slightly mottled with gray, from the Columbian quarry, Proctor, Vt.*[1]

| | |
|---|---|
| Calcium carbonate ($CaCO_3$) | 93.37 |
| Magnesium carbonate ($MgCO_3$) | .77 |
| Iron carbonate ($FeCO_3$) | .034 |
| Manganese and aluminum oxides | .005 |
| Siliceous matter insoluble in acid | .63 |
| Organic matter | .08 |
| | 99.889 |

As is shown on page 33, these clouded marbles contain minute lenses and beds of dolomite, which account for the $MgCO_3$.

*Analysis of white dolomite marble from Lee, Mass.*[2]

| | |
|---|---|
| Insoluble | 0.19 |
| Alumina ($Al_2O_3$) } Ferric oxide ($Fe_2O_3$) } | .24 |
| Calcium carbonate[3] ($CaCO_3$) | 55.14 |
| Magnesium carbonate[4] ($MgCO_3$) | 43.88 |
| | 99.45 |

*Analyses of Norwegian dolomite marbles.**

| | 1 | 2 |
|---|---|---|
| Insoluble | 0.106 | 0.46 |
| Calcium carbonate ($CaCO_3$) | 54.05 | 54.16 |
| Magnesium carbonate ($MgCO_3$) | 45.93 | 45.09 |
| Iron carbonate ($FeCO_3$) | .086 | .32 |
| Manganese carbonate ($MnCO_3$) | .032 | .... |
| | 100.204 | 100.03 |

*Vogt, J. H. L., Norsk Marmor, 1897, p. 20. 1, Cream colored, from Hammarfald, Rosvik; 2, white, from Hemnæs Seljeli.

The following are two analyses of calcite marbles from the quarries worked by the ancient Greeks:

*Analyses of Greek Marbles.**

| | 1 | 2 |
|---|---|---|
| Calcium carbonate ($CaCO_3$) | 100.002 | 100.09 |
| Ferric oxide ($Fe_2O_3$) | .122 | ..... |
| | 100.124 | 100.09 |

*Lepsius, G. R., Griechische Marmorstudien, Berlin, 1890, pp. 18, 29. 1, "Lower white Pentelicon" marble from Mount Pentelicon, northeast of Athens, milk-white color; 2, "Lower white Attic marble" from Agrilesa Valley, 2½ miles north of Cape Sunium or 25 miles southeast of Athens, light bluish-gray tint.

[1] By S. L. Penfield, Yale University, Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, continued, 1899, p. 447.

[2] By E. A. Schneider, Bull. U. S. Geol. Survey No. 419, 1910, record No. 1279, p. 189.

[3] Recalculated from CaO and $CO_2$ of original.

[4] Recalculated from MgO and $CO_2$ of original.

Lepsius states that the Pentelicon marble contains a few grains of quartz and scales of muscovite and chlorite, some pyrite with a zone of limonite stains, and more rarely very minute grains of magnetite. The golden-brownish film noticeable on the Parthenon and other Greek structures made of this marble is attributed to this content of $Fe_4O_9H_6$. In contrast with this he finds that the marble of the Agrilesa Valley, which is chemically pure calcium carbonate, forms no such crust in ancient sculptures.

*Analysis of white Norwegian calcite marble from Velfjorden, Troviken.*[1]

| | |
|---|---|
| Calcium carbonate ($CaCO_3$) | 99.27 |
| Iron carbonate ($FeCO_3$) | .137 |
| Manganese carbonate ($MnCO_3$) | .0026 |
| Magnesium carbonate ($MgCO_3$) | .68 |
| Insoluble | .77 |
| | 100.86 |

*Analysis of Carrara marble.*[2]

| | |
|---|---|
| Calcium cabonate ($CaCO_3$) | 99.77 |
| Magnesium carbonate ($MgCO_3$) | .90 |
| Silica ($SiO_2$) | .16 |
| Alumina and iron sesquioxide ($Al_2O_3$, $Fe_2O_3$) | .08 |
| | 99.91 |

Giampaoli[3] gives for Carrara marble: Calcium carbonate ($CaCO_3$), extremes 98 to 99 per cent; magnesium carbonate ($MgCO_3$), maximum 0.9 per cent; silica ($SiO_2$), maximum 1.0 per cent.

*Analyses of Carrara and Tyrolese marbles.**

| | Carrara, white mottled. | Schlanders, Tyrol. | |
|---|---|---|---|
| | | Mottled, coarse. | White to grayish, very hard. |
| Calcium carbonate ($CaCO_3$) | 99.236 | 99.010 | 97.040 |
| Magnesium carbonate ($MgCO_3$) | .284 | .521 | 2.109 |
| Iron oxides ($FeO$, $Fe_2O_3$) and phosphoric oxide ($P_2O_5$) | .251 | .062 | .360 |
| Silica ($SiO_2$) | ..... | ..... | Trace |
| | 99.771 | 99.593 | 99.509 |
| Specific gravity at 16.25° C. | 2.732 | 2.700 | 2.566 |

*Wittstein, G. C., Untersuchungen einiger weissen Marmorarten, 1851.

It will be noticed that the calcite marbles in all the analyses show a range of 99.04 to 100 per cent of calcium carbonate.

[1] Vogt, J. H. L., Norsk Marmor, 1897, p. 19.
[2] Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, p. 521.
[3] Giampaoli, A., I marmi di Carrara, Pisa, 1897.



A composite analysis by H. N. Stokes of 498 constructional limestones is given for comparison. The principal difference is in its high percentage of silica (14.09) and its small percentage of calcium carbonate (72.50).

*Composite analysis of 498 constructional limestones.*[1]

| | |
|---|---|
| Silica ($SiO_2$) | 14.09 |
| Titanium dioxide ($TiO_2$) | .08 |
| Alumina ($Al_2O_3$) | 1.75 |
| Iron oxides ($Fe_2O_3$, $FeO$) | .77 |
| Manganese oxide ($MnO$) | .03 |
| Calcium carbonate ($CaCO_3$) | 72.50 |
| Magnesia ($MgO$) | 4.49 |
| Potash ($K_2O$) | .58 |
| Soda ($Na_2O$) | .62 |
| Lithia ($Li_2O$) | Trace |
| Water combined ($H_2O$) | .30 |
| Water uncombined and organic matter | .88 |
| Phosphorus oxide ($P_2O_5$) | .42 |
| Carbon dioxide ($CO_2$) | 3.68 |
| Sulphur (S) | .07 |
| Sulphur trioxide ($SO_3$) | .07 |
| Chlorine (Cl) | .01 |
| | 100.34 |

The dolomite marbles in the analyses show a range of 30.27 to 30.88 per cent of lime and of 21.42 to 21.87 of magnesia, but a pure dolomite contains 30.4 per cent of lime and 21.9 of magnesia.[2]

Dieulafait[3] determined the presence of diffused manganese in the marbles of Carrara, Paros, and the Pyrenees. Many of the exceedingly minute black particles present in all the white marbles examined by the writer may be an oxide of manganese. Two analyses of rose-colored calcite marble from eastern Vermont made by George Steiger, of the Survey, for another bulletin by the writer show 0.23 and 0.49 per cent of manganese oxide.

Lepsius[4] notes that several of the Greek marbles (Paros, Naxos, Pentelicon, Hymettos, etc.) yield a marked bituminous odor when struck, which he attributes to the presence of a small amount of hydrocarbon.

Egenter[5] calls attention to the odor of the contact-metamorphic marble of Carinthia, in Austria, which he attributes to sulphureted hydrogen.

[1] Clarke, F. W., The date of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, p. 533, analysis H. In copying the analysis part of the $CO_2$ of the original has been combined with the CaO to show the percentage of $CaCO_3$.
[2] Clarke, F. W., op. cit., p. 544, analysis F.
[3] Existence du manganèse à l'état de diffusion complète dans les marbres bleus de Carrare, de Paros et des Pyrénées: Compt. Rend., vol. 98, 1884, pp. 589-591.
[4] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.
[5] Egenter, Paul, Die Marmorlagerstätten Kärntens: Zeitschr. prakt. Geologie, vol. 17, 1909, pp. 419-439.

Lindenmann[1] reports that the Bardiglio marble of Carrara and the marble of Sterzing, in the Tyrol, both emit a very strong odor when struck.

Further chemical details as to the marbles will be given in the description of the different marbles.

## PHYSICAL PROPERTIES.

Marble, besides possessing the qualities of hardness, cohesiveness, compressive strength, porosity, expansiveness under heat, thermal conductivity, sonorousness, translucence, and flexibility, is polishable and can be deformed in confinement under powerful compression. Its color, texture, specific gravity, hardness, and porosity will be considered under other heads.

Tests made at the Watertown Arsenal give the white dolomite marble of Lee, Mass., an ultimate compressive strength of 18,047 pounds to the square inch;[2] the calcite marbles of West Rutland and Proctor a compressive strength of 11,525 to 14,397 pounds to the square inch,[3] and the coarse calcite marbles of South Dorset an ultimate compressive strength averaging 11,300 pounds when placed on bed and 9,100 pounds when placed on edge.

Tests of the dolomite marble of Lee give it a shearing strength of 2,052 pounds to the square inch and a maximum fiber strength of 1,585 pounds to the square inch.[2]

Vogt[4] gives the compressive strength of a Norwegian dolomite marble as 24,891 to the square inch, of Carrara marble as 6,329 pounds, and of Tyrolese statuary marble (Laas) as 16,036 pounds.

Geikie[5] in an interesting petrographic study of Edinburgh gravestones describes some slabs of white marble, presumably from Italy, firmly set into sandstone monuments, which in consequence either of their porousness and the freezing of interstitial water or else of their greater expansiveness than sandstone, or from both causes, had bulged out 2½ inches from their original vertical position and showed a series of rents along the crest of the bulge.

The Watertown Arsenal tests referred to above give the coefficient of expansion of dolomite marble from Lee as only

[1] Lindenmann, Bernhard, Ueber einige wichtige Vorkommnisse von körnigen Carbonatgesteinen mit besonderer Berücksichtigung ihrer Entstehung und Structur: Neues Jahrb., Beilage Band 19, 1904, pp. 197-317.

[2] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, continued, 1899, pp. 405, 406.

[3] Tests Nos. 9059, 9060, 9063, made for the Vermont Marble Co., April, 1893, at the Watertown Arsenal. See p. 121.

[4] Vogt, J. H. L., Norsk Marmor: Norges geologiske Undersogelse, No. 22, Christiania, 1897, p. 355.

[5] Geikie, Archibald, Rock weathering as illustrated in Edinburgh churchyards: Proc. Roy. Soc. Edinburgh, vol. 10, 1880, pp. 518-532; fig. 1, Thin sections of fresh and weathered marble after 87 years exposure; Pl. XVI, *A*, Bowed marble slab in frame of sandstone; *B*, Marble slab, cracked diagonally, in frame of sandstone. See also Geikie's Geological sketches at home and abroad, London, 1882, Chapter VIII, Rock weathering measured by the decay of tombstones, pp. 162-174.



0.00000562 under a difference of temperature of 156° F. Bartlett[1] found the expansion of marble to be 0.000005668 inch to the foot for each degree Fahrenheit.

Yamagawa[2] determined the thermal conductivity of marble as averaging 0.00728 centimeter a second. A previous determination by Depretz was 0.0077 centimeter.

Thin slabs of ordinary Carrara marble have a marked sonorousness when struck with a hammer. The Vermont calcite marbles are only feebly sonorous, but on the other hand the dolomite marbles of Lake Champlain possess more sonorousness than the Carrara marble.

White marbles become transparent or nearly so in thin sections prepared for the microscope, but differ considerably in translucence on the rough or polished face. Some have a waxy look, which is probably attributable to the greater transparence of their grains; others are milk-white and opaque. Lepsius[3] in connection with his study of Greek marbles determined that the best Pentelicon marble admits light to a depth of 0.59 inch, and the Parian to 1.37 inches. Upon this feature largely rested the reputation of Parian marble. Lindenmann[4] gives the translucence of Carrara statuary marble as from 1.18 to 1.57 inches. The coarse calcite marble formerly quarried at Adams, Mass., referred to on page 46, is unusually translucent.

The flexibility of marble has long been known. It probably depends largely on the shape and cohesion of its grains.[5]

The important experiments of Adams, Nicholson and Coker[6] show that marble when tightly inclosed can be deformed—that is, it flows. They fitted cylinders of Carrara and Vermont marble tightly into steel tubes and applied great pressure to the ends of the cylinders, which caused them to bulge out on the sides, distending the inclosing tube. When the deformed marble was sliced and examined microscopically it was found to be solid, but many molecular changes had taken place in the individual

[1] Bartlett, W. C., Experiments on the expansion and contraction of building stones by variation of temperature; Am. Jour. Sci., 1st ser., vol. 22, 1832, pp. 136-140.

[2] Yamagawa, Kenjiro, Determination of the thermal conductivity of marble: Jour. Coll. Sci., Imp. Univ. Japan, vol. 2, 1888. Review in Neues Jahrb., 1892, vol. 2, p. 43.

[3] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890, p. 47.

[4] Lindenmann, Bernhard, Ueber einige wichtige Vorkommnisse von körnigen Carbonatgesteinen mit besonderer Berücksichtigung ihrer Entstehung und Structur: Neues Jahrb., Beilage Band 19, 1904, p. 273.

[5] See Dewey, Chester, Notice of the flexible or elastic marble of Berkshire County: Am. Jour. Sci., 1st ser., vol. 9, 1825, p. 241. Julien, A. A., The durability of building stones: Tenth Census, vol. 10, 1884 (on the flexibility of marble, pp. 366, 367; describes the curvature of a marble slab in the Alhambra). Winslow, A., An illustration of the flexibility of limestone [white crystalline]: Am. Jour. Sci., 3d ser., vol. 43, 1892, pp. 133, 134.

[6] Adams, F. D., assisted by Coker, E. G., An experimental investigation into the flow of rocks—The flow of marble: Am. Jour. Sci., 4th ser., vol. 29, 1910, pp. 465-487; Pl. III, *A*, Thin section of Carrara marble magnified 40 diameters; *B*, The same caused to flow under pressure of 296 to 725 pounds to the square inch, showing schistosity, magnified 60 diameters. See Mr. Adams's other papers in bibliography, p. 55.

crystalline plates, such as slippage and twinning. They also found that the marble if deformed at ordinary temperature was stronger under slow than under rapid deformation, that the deformed marble was stronger when the experiment was tried at a higher temperature than at ordinary temperature, and that when deformed in the presence of moisture (water gas) and a high temperature the deformed marble was actually stronger than the original marble. These experiments are very instructive, for they throw light on the causes of the remarkable folds in the marble beds of Vermont and similar regions and the conditions under which they were formed.

## GENERAL TEXTURE.

The difference between a limestone and a marble has been stated (p. 4). In marble the grains are all crystalline, with rhombohedral cleavage, mostly twinned, and more or less interlocked but never in such an intricate way as they are in granite. To this fact and the marked cleavage of calcite and dolomite the generally lower cohesiveness of marble than of granite is largely due. Hirschwald[1] figures two kinds of grain form in calcite marble—the denticulate and the smooth—and this distinction appears to be generally valid, although the grains in most of the Vermont calcite marble are not denticulate. In some dolomite marbles the grains do not interlock and some of the grains even have a rhombohedral form so that the texture under the microscope appears less cohesive than that of the other marbles. In both calcite and dolomite marbles the cleavage and twinning of each grain is independent of that of other grains.

Although the form of their grains is generally irregular, in some marbles one or two axes of the grains are much longer than the others and the longer axes of different grains are parallel, giving to the rock a certain schistosity which is usually parallel to the bedding. (See figs. 6, 22). A thin section of such a marble from the St. Gotthard is figured by Rosenbusch.[2] This elongation, however, may be confined to but a part of the grains and these may not be arranged. A marble at Leicester Junction (p. 141 and fig. 25) exhibits alternate tiers of large and small grains. As the marble is intensely folded this arrangement may be due to granulation or it may be the result of the interbedding of dolomite and calcite, the small grains being dolomite.

Lepsius[3] in his study of Greek marbles found that those of Pentelicon, Hymettos, and the vicinity of Cape Sunium and of Doliana, in Arcadia, consist of irregularly bounded grains of twinned calcite, lying in a matrix of much more minute calcite grains without cleavage or twinning planes, and that the proportionate amount of the matrix varies in different beds and localities. He regards the matrix in these marbles as a remnant of the limestone out of which the twinned grains were formed under metamorphism.

[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, Pl. XVI, figs. 1, 2.
[2] Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, fig. 78.
[3] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.



Vogt[1] figures a Norwegian marble in which interlocking grains of calcite alternate irregularly with angular ones of dolomite.

In some Vermont marbles minute beds and lenses of dolomite are intercalated in the calcite mass and other interesting combinations of calcite and dolomite occur. (See p. 125, fig. 20). Vogt[2] figures a marble in which the calcite plates, owing to secondary compression, due to contact metamorphism, have suffered granulation and had their twinning planes bent. Hirschwald[3] also figures thin sections of marble with bent twinning planes. One of the marble beds of West Rutland shows this also.

A thin section of calcite marble with flexed twinning planes is shown in figure 1.

FIGURE 1.—Thin section of white calcite marble from the Goodale or Girard College quarry in Sheffield, Mass., with flexed twinning planes due to secondary compression. Texture very coarse and irregular. Dotted particles are quartz. Enlarged 20 diameters. This quarry supplied columns for Girard College, in Philadelphia. The curvature of the calcite plates can be detected, even in a hand specimen.

In a brecciated marble each fragment has its texture more or less differently oriented and the texture of the fragment differs from that of the secondary cement. The same is also true of the pebbles in a marble conglomerate, except that more or less parallelism in the texture of the smaller pebbles may be expected.

There is also a variation in the grade of texture. The grains may be large, medium, or small and a further variation may be traceable to the regularity or irregularity in the size of the grains in the same marble.

[1] Vogt, J. H. L., Der Marmor in Bezug auf seine Geologie, Structur und mechanische Eigenschaften: Zeitschr. prakt. Geologie, January, 1898, p. 14, fig. 10.
[2] Op cit., p. 14, fig. 12; also Norsk Marmor, 1897, p. 59, fig. 8.
[3] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, Pl. XVI, figs. 4, 5.

The presence of sericite (fibrous potash mica), tremolite, actinolite (varieties of hornblende), or other fibrous minerals complicates the texture of marble. (See pp. 34, 35).

The texture is indirectly affected by the character of the bedding, which may be even or plicated or elongated. This is more apparent in the graphitic and micaceous marbles. In some Vermont marbles sharply plicated planes of bedding are intersected at intervals by slightly undulating planes of slip cleavage and both sets of planes are laden with graphite. (See p. 119 and Pls. V, *A*, and VIII, *B*, *b*).

The texture of marble thus depends on the form, size, evenness, and arrangment of its grains and on the nature and size of the grains of other minerals in it and is affected by the amount of plication or elongation of the bedding, by the relative abundance of the planes of slip cleavage which cross it, and by any secondary compression that the marble may have suffered.

### COLORS.

It would require very elaborate methods to determine the precise causes of the more delicate tints of marble, such as the bluish, ivory, and smoky. The causes of other tints are not far to seek.

The black and grayish marbles owe their shade to the presence of carbon, usually in the form of graphite in infinitesimal scales and powdery particles disseminated throughout the plates of calcite or dolomite.

The reddish, pinkish, and reddish-brown marbles contain minute particles of a compound with manganese oxide ($MnO$) or of hematite ($Fe_2O_3$) or of both.

The brownish, yellowish, and cream-colored marbles owe their color to limonite or hydrous iron sesquioxide (ferric oxide) ($2Fe_2O_3.3H_2O$) in varying amounts. In thin sections of some marbles this limonite stain can be seen emanating from oxidized particles and crystals of pyrite.

The greenish marbles (of course exclusive of the serpentines), of Vermont at least, owe their color mainly to fibrous muscovite (sericite), with which in the brighter marbles chlorite and epidote are associated.

A purplish tint in one of the dolomites of Lake Champlain (p. 138) appears to be due to the combination of hematite and magnetite.

The more uncommon colors of marble are purplish, as in the Pavonazzo and Seravezza breccias, imported from Italy, bright yellow, as in the "Giallo Antico" from North Africa, and orange-yellow, as in some marbles from Norway. Among the uncommon combinations of colors is that of rose-pink and deep green in the "Leifset Gloire" from Norway.



Vogt[1] is inclined to attribute the sky-blue, bright-red, and orange tints of some Norwegian marbles to organic compounds. He states that the blue disappears on heating for a short time to 100° C., or after five years exposure to the light, and that the red changes after heating for a short time to 300° or for a longer time to 150° to 200° but returns on cooling.

### ORIGIN OF LIMESTONE AND MARBLE.

The origin of marble can not well be considered without considering that of the limestone from which it has been formed. The origin of dolomite marble will be considered after describing the relations of dolomite and calcite marble.

Some of the simplest illustrations of the formation of calcareous deposits are to be found at no great distance from the Vermont marble belt. About 4 miles nearly north of Fair Haven, in Rutland County, Vt. (see topographic map of Whitehall quadrangle, U. S. Geol. Survey), is Inman Pond, which is about half a mile long. When the pond is low a snow-white calcareous deposit, which consists mainly of fragments of fresh-water snail shells (Limnæa and Planorbis), is exposed on the shore. The pond is surrounded by hillocks of slightly calcareous slate and the glacial gravels probably contain some limestone from the limestone areas to the north and west. The brooks, supplied with carbonic acid by the rain, have taken up calcium carbonate from the slates and the gravel and furnished the pond with slightly calcareous water, which the snails have taken into their systems and out of which they have secreted shells of calcium carbonate. The death of generations of snails has formed the white marl.

Queechy Lake, also half a mile long, lies in a minor limestone valley within the Taconic Range in Canaan, Columbia County, N. Y. (See topographic map of Pittsfield quadrangle, U. S. Geol. Survey). The bottom of the east side of the lake is covered with certain foliaceous algæ, the leaves of which are incrusted with calcium carbonate. As generations of these plants die a calcareous sediment forms. It is supposed that the chemical precipitation of lime by water in such a case is accelerated by the exhalation of oxygen by the plants and the consequent decomposition of the calcium bicarbonate.

As most limestones are seen by the character of their fossils to be of marine origin, we must consider processes like those illustrated to have taken place in the sea—that is, calcium carbonate has been either deposited through the agency of life or chemically precipitated. An ordinary limestone would result from any great accumulation of such organic or chemical calcareous sediments compressed under their own weight. The formation of organic calcareous sediments is going on today in the ocean on a large

[1] Vogt, J. H. L., Norsk Marmor, 1897, p. 354.

scale about coral reefs and shell beds and wherever the minute calcareous shells of rhizopods rain down on the ocean floor, also wherever lime-secreting algæ abound.

Two places are cited, one in the Mediterranean and another on the west coast of Florida, where river water charged with calcium bicarbonate forms crystalline calcareous sediments as it enters the sea. The Florida deposit is of two sorts—a calcareous mud and a crystalline calcium carbonate that is essentially a calcite marble.[1] But it is generally assumed by geologists that such deposits are exceptional, that most limestones have been formed through the medium of marine organisms, and that those limestones which abound in fossil crinoids, corals, brachiopods, gastropods, or rhizopods convey to us what is probably the most correct conception not only of the origin of limestone but also of the original condition of most calcite marbles.

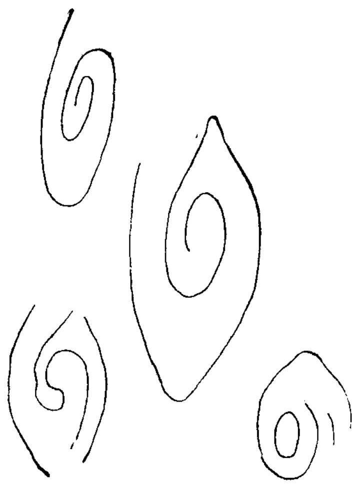


FIGURE 2.—Sections of marine snail shells in light marble on dumps at West Rutland in 1890. A little less than one-half natural size.

Some fossiliferous limestones that have not been subjected to a crustal movement great enough to destroy the outline of their fossils are yet crystalline and therefore marble. It may be uncertain whether the crystallization of such limestones took place before or after their emergence. In either case where the fossils have become crystalline we have to assume the percolation of acid waters, dissolving the calcareous shells, etc., and then redepositing the lime thus taken up as crystalline calcite. This process has taken place in the black and gray marbles of Isle la Motte (see p. 39) and in all the crinoid or shell marbles of commerce, such as the Tennessee marbles.

That the calcite marbles of western Vermont were partly if not wholly of organic origin is shown by the fossils they still contain. One of the beds of bluish-gray marble at West Rutland abounds in section of Maclureas (large marine snails), as may be seen by examining the slabs coming from the sawing sheds. A photograph of one of these slabs polished, taken by the State

[1] Lyell, Charles, Principles of geology, 9th ed., 1853, pp. 260, 279. Dall, W. H., and Harris, G. D., Correlation papers—Neocene: Bull. U. S. Geol. Survey, No. 84, 1892, pp. 99-101, 154. Willis, Bailey, Conditions of sedimentary deposition: Jour. Geology, vol. 1, 1899, pp. 512-514.



geologist, has been reproduced in one of his reports.[1] Figure 2 is taken from drawings made by the writer. Some of the grayish marble beds above the quarries at West Rutland are very fossiliferous, as is a ledge beside a brook about one-fourth mile south of the Eastman quarry. (See Pl. IV). The bluish marble at Day's quarry, in Ira, long worked for lime, contains sections of large gastropods, probably Maclureas also.[2] Most of the Vermont calcite marbles, however, have no traces of fossils.

It is assumed that the general absence of fossil forms from calcite marble is due to their having been obliterated in the process of dynamic crystallization. This process has been reproduced experimentally, uncrystalline calcium carbonate having been changed to calcite marble by pressure alone, heat alone, or both together.[3]

The simplest of all these experiments consisted in exposing limestone and chalk in a closed gun barrel to great heat,[4] which resulted in transforming them into marble.

That the horizontal massive strata which now constitute the marble beds of western Vermont were subjected to very great compression is evident from the folding they have undergone. This is shown in the general and detailed sections (Pls. II and III; figs. 10, 11, 14, and 18, pp. 72, 73, 97, and 120). Such folding can be produced only by powerful lateral compression, and such compression would generate heat. Furthermore, the micaceous marbles that are interbedded with the others and the small beds of mica schist that are interbedded with the clear marbles owe their fibrous mica to the micasization of particles of clayey sediment, and the process of micasization, as reproduced experimentally, has been found to require heat at well as pressure.[5]

For these reasons the calcite marbles of western Vermont and of regions of like geologic character are regarded as limestones of marine and mostly of organic origin, which have been metamorphosed under great pressure accompanied by heat.

In view of what has been stated as to the origin of limestone and calcite marble we should distinguish between (*a*) a fine-grained limestone in which the particles are exceedingly minute and of irregular form and polarize but are without twinning planes; (*b*) a fossiliferous limestone in which percolating waters have dissolved calcareous fossils and deposited crystalline calcite;

[1] Perkins, G. H., Report of the State geologist on the mineral industries and geology of certain areas of Vermont: Report for 1907-1908, Pl. V.

[2] Letter from C. D. Walcott.

[3] See Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 531, 532.

[4] See Hall, James, Trans. Royal Soc. Edinburgh, vol. 6, 1812, pp. 71-185; Becker, Arthur, Min. pet. Mitt., vol. 7, 1886, pp. 122-145; and Le Chatelier, H., Compt. Rend., vol. 115, 1892, pp. 817-820, 1009-1011.

[5] A. Daubrée (Etudes synthétiques de géologie expérimentale, 1879, pp. 176, 177; Smithsonian Rept. 1861, p. 285), by exposing moist clay in a closed steel tube to the heat of a gas furnace for several days, succeeded in manufacturing minute crystals of a uniaxial mica or a chlorite. On the subject of micasization or sericitization see Clarke, F. W. The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 566-568.

and (*c*) a fully crystalline calcite marble, the product of metamorphism, in which calcite plates, larger than those in the matrix of *b*, are mostly twinned. Hirschwald,[1] in his exhaustive work on the testing of the weathering qualities of building stones, divides the finer-grained limestones (excluding marbles) into two groups—cryptocrystalline, in which the interlocking ill-defined crystalloids polarize light, and pelitomorphic, which consist of roundish granules 0.003 to 0.005 millimeter in diameter, that feebly but clearly operate upon polarized light.[2]

The metamorphism by which a bed of limestone is changed to marble is not always traceable entirely to lateral compression of the strata. It may also be caused in part by the heat proceeding from an igneous intrusive.

Renwick[3] mentions an interesting occurrence at Middleton, near Wirksworth, in Derbyshire, where beds of limestone have been traversed by a dike at a very low angle. The limestone below the dike has been changed to marble, and is quarried for marble uses, but the limestone above the dike is unaltered and is used for lime burning, etc.

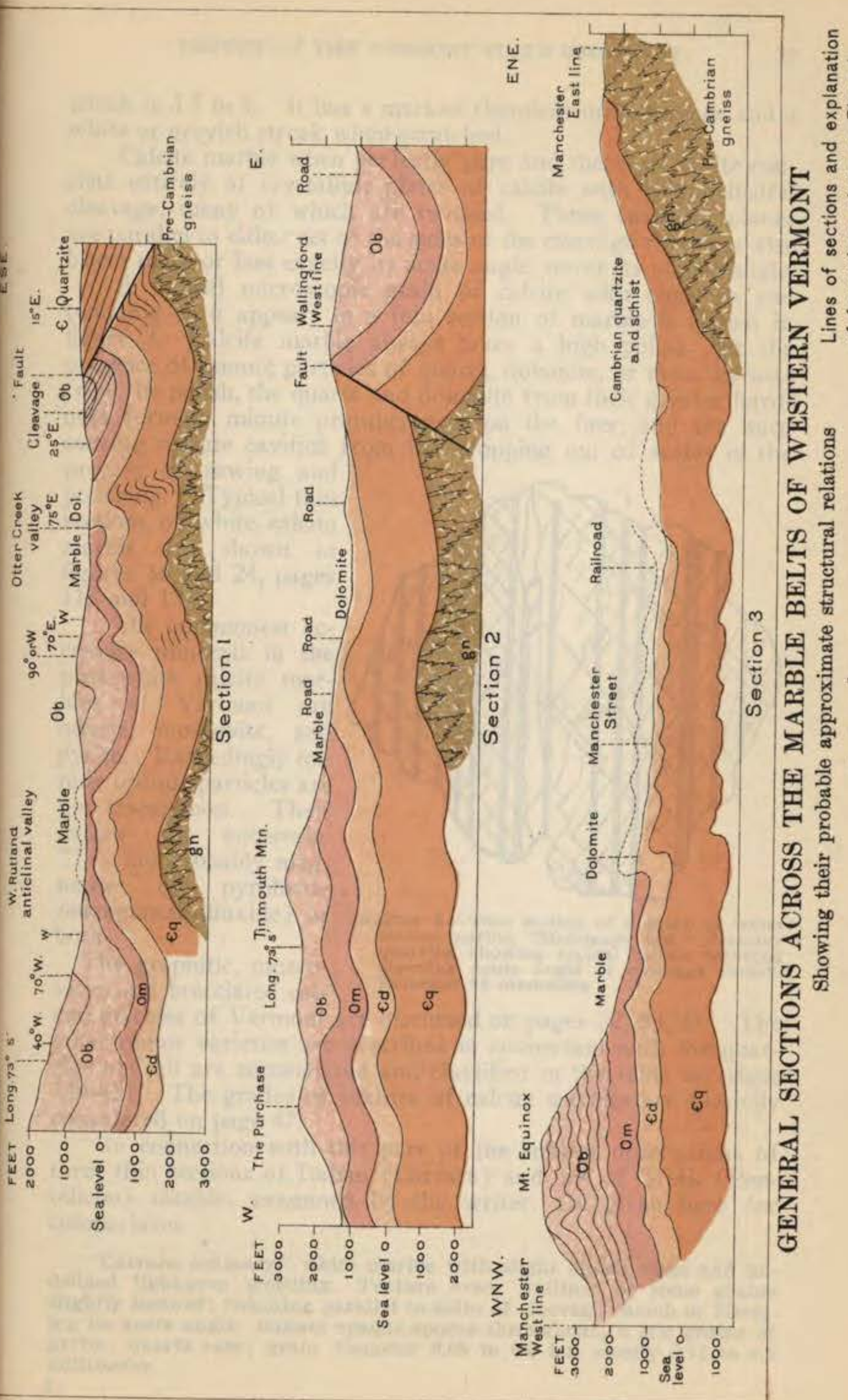
Conybeare[4] described the conversion of chalk into marble in the north of Ireland, in these words: "Here within the distance of 90 feet three [basalt] dikes may be seen traversing the chalk, which is converted into a finely granular marble where contiguous to the two outer dikes and through the whole of the masses included between these and the central one."

Finally, the metamorphism by which a bed of limestone passes into marble may be of any geologic age. Naturally we look for marbles in the strata formed after marine life became abundant and in those places where organic deposits have been subjected to powerful crustal movements or exposed to igneous intrusion.

## CALCITE MARBLE.

If calcite marble contained nothing but calcite its chemical composition and properties and many of its physical properties would be identical with those of calcite. Calcite ($CaCO_3$), or calcium carbonate, contains 56 per cent of CaO (lime) and 44 per cent of $CO_2$ (carbon dioxide). It effervesces strongly with cold dilute hydrochloric acid and is entirely soluble in cold dilute acetic acid. When burned it loses $CO_2$ and becomes CaO (quicklime). It has a specific gravity of 2.72 and a hardness of 3, being a little harder than gypsum, which is 2, and softer than dolomite,

[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit Berlin, 1908, p. 382.
[2] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, pp. 443, 444; sec. 532; Pl. XVII, figs. 10, 11, 12.
[3] Renwick, W. G., Marble and marble working, London, 1909, p. 4, fig. 1.
[4] Conybeare, W. [Descriptive notes referring to the outline of sections presented by a part of the coasts of Antrim and Derby, from the joint observations of Rev. W. Buckland and himself during a tour in the summer of 1813]: Trans. Geol. Soc. London, vol. 3, 1816, p. 210.




GENERAL SECTIONS ACROSS THE MARBLE BELTS OF WESTERN VERMONT
Showing their probable approximate structural relations
Lines of sections and explanation of formations given on Plate I

which is 3.5 to 4. It has a marked rhombohedral cleavage and a white or grayish streak when scratched.

Calcite marble when perfectly pure and therefore white consists entirely of crystalline plates of calcite with rhombohedral cleavage, many of which are twinned. These twinning planes are parallel to either set of the sides of the cleavage rhomb or else bisect more or less exactly its acute angle, never its obtuse angle.

A typical microscopic grain of calcite with cleavage and twinning as it appears in a thin section of marble is shown in figure 3. Calcite marble always takes a high polish, but the presence of minute particles of quartz, dolomite, or mica detracts from the polish, the quartz and dolomite from their greater hardness forming minute protuberances on the face, and the mica causing minute cavities from the dropping out of scales in the process of sawing and polishing. Typical thin sections of white calcite marble are shown in figures 16 and 24, pages 113 and 135.

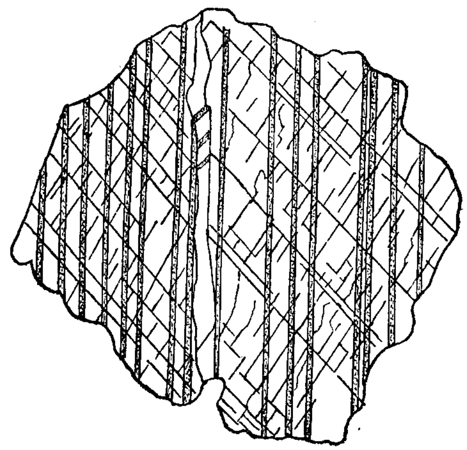


FIGURE 3.—Thin section of a grain of white calcite marble, "Mahogany bed," Freedley quarries, showing typical calcite twinning bisecting acute angle of cleavage rhomb. Enlarged 55 diameters.

The commonest accessory minerals in the pure-white calcite marbles of Vermont are quartz, muscovite, and pyrite. Exceedingly minute opaque particles are not uncommon. Their nature is uncertain. They are probably magnetite or pyrolusite (manganese dioxide) or both.

The graphitic, muscovitic, and brecciated calcite marbles of Vermont are discussed on pages 32, 33, 41. The other minor varieties are described in connection with the quarries and all are summarized and classified in the table on pages 144-151. The grades of texture of calcite marbles are specially considered on page 47.

In connection with this part of the subject descriptions of three thin sections of Italian (Carrara) and one of Greek (Pentelicon) marble, examined by the writer, are given here for comparision.

**"Carrara ordinary," white marble with slight bluish tinge and undefined light-gray mottling. Texture even; outlines of some grains slightly toothed; twinning parallel to sides of cleavage rhomb or bisecting its acute angle; minute opaque specks throughout; a few grains of pyrite; quartz rare; grain diameter 0.05 to 0.5 but mostly 0.12 to 0.3 millimeter.**

"Pentelicon," modern commercial, white, less bluish than marble above described. Texture somewhat irregular, less regular than that of Carrara marble; outlines of grains not toothed; twinning parallel to sides of cleavage rhomb or bisecting its acute angle; minute opaque specks throughout; a few grains of pyrite; quartz sparse; muscovite scales very rare; grain diameter 0.05 to 0.75, but mostly 0.12 to 0.37 millimeter, more of 0.12 than in Carrara marble.

The interesting study of Greek marbles by Lepsius[1] already referred to (p. 5) was based on the examination of thin sections obtained from outcrops at the chief quarries worked by the ancient Greeks, at some of which unfinished columns or statues still remained, and on a comparison of such sections with others obtained from chips of similar marbles in ancient Greek buildings and sculptures. These quarries were on the islands of Paros and Naxos, in the archipelago; on Mounts Pentelicon and Hymettos, about northeast of Athens; in the Agrilesa Valley, 2½ miles north of Cape Sunium and 25 miles southeast of Athens; and at Doliana, in Arcadia, southwest of Corinth. As Lepsius's book is one of the most thorough works on the texture of marble yet published but is inaccessible in translation, a brief summary of its conclusions is here given:

"Lichnites Lithos" of Paros, "Parian statuary," from the northwest side of the island, was obtained from a bed 6½ to 13 feet thick with an average dip of 30° into the hill, reached by tunneling from a point 656 feet above sea level along the bed to a depth of 195 to 260 feet. From this excavation at least 1,000,000 cubic feet of marble, from which, of course, the waste should be deducted, had been excavated in ancient times for statuary. This marble is snow white, with a faint bluish-gray tint. It is very translucent and was also noted among Roman stone-cutters for its hardness—that is, its cohesion—which was probably due to its being quarried so far underground. It consists entirely of cleft and twinned calcite grains with diameter mostly of 1 to 1.5 millimeters, many grains 1.5 to 2, some 2 to 3, and a few 3 to 5. It contans some grayish particles, mostly translucent, also some extremely minute black ones (magnetite or carbon?). In some parts of the quarry the marble has dark-gray streaks due chiefly to magnetite, as determined by the form of the crystals.[2]

The Naxos marble beds dip 25° to 70°, but were quarried diagonally. The marble has a light-gray tint with dark-gray spots and streaks and some gray grains. It is opaque and coarse with an average grain diameter of 2 to 3 millimeters and many grains 3 to 5 millimeters, here and there with some fine interstitial grains. Many of the grains contain minute gray, black, or colored particles to which the marble owes its tint. In places the dark particles are so plentiful as to cloud the otherwise clear calcite.[3]

The "lower white Pentelicon marble" is somewhat milk white with a faint yellowish tint and rare light-gray streaks. The grain diameter is mostly 0.5 to 1 millimeter, never over 2 millimeters. The grains lie in an opaque milk-white groundmass of fine grains, without cleavage or twinning planes. Both large and small grains contain very minute and indeterminable inclusions. Muscovite, chlorite, a reddish-violet potash mica, pyrite with a zone of limonite, more rarely magnetite, and rare

[1] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890.
[2] Idem, pp. 43-52.
[3] Idem, pp. 52-55.

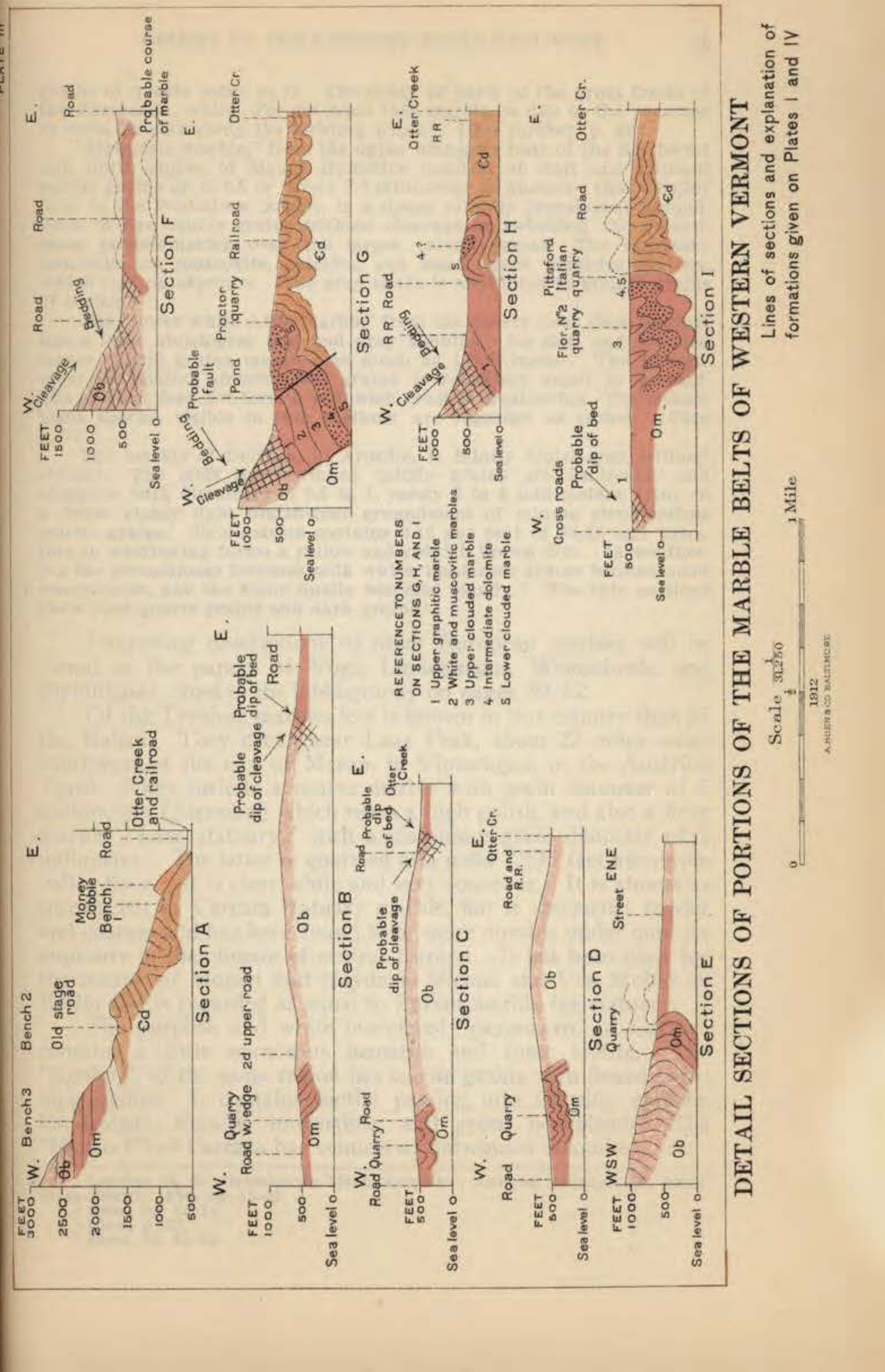


PLATE III

DETAIL SECTIONS OF PORTIONS OF THE MARBLE BELTS OF WESTERN VERMONT

Lines of sections and explanation of formations given on Plates I and IV grains of quartz occur in it. The decay of parts of the great frieze of the Parthenon, which was cut from this marble, is due to the presence of mica streaks along the bedding plane.[1] (See further, p. 29).

"Hymettic marble," from the upper blue-gray beds of the northwest and north slopes of Mount Hymettos consists of cleft and twinned calcite grains up to 0.5 or rarely 0.8 millimeter in diameter thus smaller than in the Pentelicon marble, in a dense, slightly translucent groundmass of fine calcite grains without cleavage or twinning, the groundmass predominating over the larger calcite grains. The accessory minerals are muscovite, chlorite, and small black particles of iron, which rust on exposure. The gray shade is attributed to minute grains of carbon.[2]

The "lower white Attic marble" from the quarry near Cape Sunium has a light bluish-gray tint and gray banding. Its cleft and twinned larger calcite grains measure as much as 1 millimeter. The groundmass of smaller structureless grains is relatively small in amount. The amount does not form a yellowish crust in weathering. The minute black specks, visible in thin sections, are regarded as carbon.[3] (See p. 7).

The marble of Doliana, in Arcadia, is faintly bluish-gray without streaks. The cleft and twinned calcite grains are denticular and elongate, with diameters of 0.5 to 1, rarely 2 to 4 millimeters, lying in a dense glassy light bluish-gray groundmass of minute structureless calcite grains. This marble contains 0.12 per cent of $Fe_2O_3$ and therefore in weathering forms a yellow and reddish brown film. In weathering the groundmass becomes milk white, the larger grains become more conspicuous, and the stone finally becomes "sandy." The thin sections show rare quartz grains and dark grains.[4]

Interesting descriptions of other European marbles will be found in the papers of Vogt, Lindenmann, Weinschenk, and Steinhäuser, cited in the bibliography on pages 49, 52.

Of the Tyrolese marbles less is known in this country than of the Italian. They occur near Laas Peak, about 22 miles west-southwest of the city of Meran, in Vintschgau, in the Austrian Tyrol. They include a coarse marble with grain diameter of 5 millimeters (Sterzing) which takes a high polish, and also a finer marble, "Laas statuary," with a maximum grain diameter of 1 millimeter. The latter is quarried at a point 7,535 feet above the valley floor. It is clear white and very sonorous. It is almost as translucent as Carrara statuary marble, but is somewhat harder and coarser and has been found to be more durable under outdoor exposure in the climate of central Europe. It has been used for the statues of Mozart and Haydn in Vienna and Von Moltke in Berlin and is regarded as equal to Parian marble for statuary.

The purplish and white brecciated "pavonazzo" of Carrara contains a little micaceous hematite and some biotite. The "cipolino" of the same region has calcite grains with flexed twinning planes. It contains biotite passing into chlorite, epidote, klinozoisite, titanite, tourmaline, and green hornblende. The "bianco P" of Carrara has veinlets of untwinned dolomite.

[1] Lepsius, G. R., Griechische Marmorstudien: Anhang Abhandl. K. Akad. Wiss. Berlin, 1890, pp. 15-22.
[2] Idem, pp. 22-24.
[3] Idem, p. 27.
[4] Idem, pp. 31-33.

## DOLOMITE MARBLE.

A pure dolomite marble would have the chemical and many of the physical properties of dolomite. It has greater compressive strength than calcite marble, as is shown by the tests recorded on page 8.

Dolomite ($CaMgC_2O_6$), a carbonate of lime and magnesia, contains 54.35 per cent of $CaCO_3$ (calcium carbonate) and 46.65 per cent of $MgCO_3$ (magnesium carbonate). It effervesces less readily with cold dilute hydrochloric acid than calcite and is next to insoluble in cold dilute acetic acid. It burns like calcite. It has a specific gravity of 2.83 and a hardness of 3.5 to 4, being thus a little heavier and harder than calcite. It has a marked rhombohedral cleavage and crystallizes in rhombohedra, the faces of which are usually curved.

Dolomite marble is of two kinds. One is like that of Lee, Mass., which consists of crystalline plates of dolomite of irregular outline, with rhombohedral cleavage and twinning planes that are either parallel to a side of the cleavage rhomb or bisect its obtuse angle, as in figure 4. Rarely it bisects the acute angle. In a section of dolomite from Plymouth, Vt., a grain was found in which twinning planes bisect both acute and obtuse angles. In calcite the twinning plane never bisects the obtuse angle, being either parallel to one of the sides of the rhomb or bisecting its acute angle. This distinction between dolomite and calcite is based on the difference in the rhombohedra of the two minerals and affords a simple means of distinguishing the two marbles in thin sections.[1] When both minerals occur in the same thin sections without twinning and the dolomite is not in rhombs, the microchemical test may be used.[2] In the dolomite marble of Lee the grains are as much interlocked as they are in many calcite marbles, but in some dolomite marbles as of this class the texture is somewhat granular, resembling that of loaf sugar, in which the grains simply cohere. In such a marble the

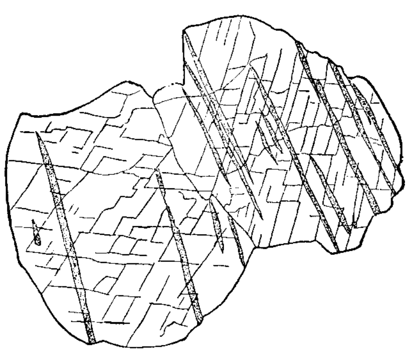


FIGURE 4.—Thin section of white twinned dolomite marble from Gross quarry, Lee, Mass., showing two grains of dolomite with typical dolomite twinning bisecting obtuse angle of cleavage rhomb. Enlarged 77 diameters.

[1] See Rosenbusch, H., Elemente der Gesteinslehre, 3d ed., 1910, p. 523; also Vogt, J. H. L., Der Marmor in Bezug auf seine Geologie, Structur, und seine mechanische Eigenschaften: Zeitsch. prakt. Geologie, Berlin, 1898, p. 11.

[2] See Lemberg, J., Zur mikroskopischen Untersuchung von Calcit, Dolomit und Predazit: Zeitschr. Deutsch. geol. Gesell., vol. 40, 1888, pp. 357-359.



cohesion is less than that of a calcite marble or of the dolomite marble of Lee, although the material is harder than calcite.

In the other variety of dolomite marble the texture is finer and more granular or mixed coarse and fine, and a larger or smaller percentage of the grains have a rhombic outline but are not twinned. (See fig. 8, p. 36). Exceptionally, however, a lens or veinlet with twinned plates of dolomite occurs in these marbles. To this variety belong the marbles of Lake Champlain fully described beyond.

Dolomite marbles of both kinds take a high polish but of course are harder to polish than calcite marble. Some dolomite marble becomes minutely pitted in polishing from the dropping out of powdery magnesia as a result of the decomposition of some of the dolomite grains.

The commoner accessory minerals of white dolomite marble are quartz, pyrite, muscovite, and tremolite.

The colored dolomite marbles of Vermont, containing hematite or graphite, are described on pages 35-38, and are summarized and classified in the table on pages 147-148. Their grades of texture are specially considered on pages 137-138.

Descriptions of a few thin sections of dolomite marble from Massachusetts, Connecticut, and Norway, studied by the writer, are added for reference and comparison.

White dolomite marble, Gross quarry, Lee, Mass. Pale bluish white without tremolite, which, however, abounds in certain beds. Texture, even; grain outlines but slightly toothed; twinning bisects obtuse angle of cleavage rhomb. (See fig. 4). Grain diameter 0.07 to 1, mostly 0.02 to 0.5 millimeter.[1]

Bluish dolomite marble, Ashley Falls Marble Co.'s quarry, Ashley Falls, Mass. Light bluish gray, rarely with prisms of tremolite and minute pyrite. Texture even; grain outlines somewhat toothed; twinning planes bisect obtuse angle of cleavage rhomb; minute opaque specks throughout; a few muscovite scales; quartz rare and small; no pyrite or tremolite in sections. Grain diameter 0.02 to 0.75, mostly 0.05 to 0.5, average 0.27 millimeter.

Light bluish gray, very fine grained dolomite (not commercial marble) from a drill core 35 feet below rock surface at Agricultural National Bank, Pittsfield, Mass. Texture uneven; grain outline roundish or angular, not rhombic and without twinning. Some muscovite scales; quartz and plagioclase feldspar grains; pyrite crystals. Diameter of grains 0.02 to 0.17 but mostly 0.05 to 0.12, average 0.08 millimeter. Some lenses or veins of coarse particles abounding in minute opaque specks, diameter 0.12 to 1.25 millimeters, with twinning bisecting obtuse angle of cleavage rhomb.

White dolomite marble from near Amenia, N. Y., but in Connecticut. White to cream color, granular appearance. Texture even; grain outlines straight or roundish; twinning bisects obtuse angle of cleavage rhomb; one bisecting acute angle. (See p. 20). Grain diameter 0.05 to 0.62, mostly 0.12 to 0.25, average 0.18 millimeter.

White dolomite marble from Norway. Milk-white with parallel grayish streaks. Texture very irregular; grain outlines not toothed;

[1] This marble has been described by J. S. Diller in Bull. U. S. Geol. Survey No. 150, 1898, pp. 299, 300.

twinning planes parallel to sides of cleavage rhomb or bisecting its obtuse angles. Minute opaque specks throughout. Several large muscovite flakes; pyrite minute, sparse. In finer parts grain diameter 0.05 to 0.25, average 0.15 millimeter; in coarser parts 0.12 to 1.37, many 0.25 to 0.62 millimeter.

## RELATION OF CALCITE MARBLE TO DOLOMITE IN VERMONT.

As will be seen from the geologic map (Pl. I) and the discussion of the geologic formations on page 58, the lower 650 feet, approximately, of the Vermont calcareous belt consist mainly of dolomite, described in detail on page 59 and the marble is confined almost entirely to the upper half of the formation. The most productive quarries appear to be in the upper part of this upper half, although some occur also in the lower part. But, as appears from the detailed sections and the stratigraphic succession on page 59, the marble beds themselves are interbedded with dolomite.

At the now disused Sutherland Falls or Proctor quarry (see Pl. I) the calcite marble beds, roughly estimated at 170 feet thick but in part doubled over so as to measure apparently 200 feet, are overlain on the west by dolomite and also underlain on the east by another dolomite. The dolomite on the west side, which is followed farther west by calcite marble, consists of dolomite granules, rarely rhombs, having an average grain diameter of 0.04 millimeter and some dolomite plates reaching 0.25 millimeter, with twinning planes bisecting the obtuse angle; also sparse quartz grains, muscovite flakes, and pyrite oxidizing to limonite. The whitish dolomite on the east side consists of dolomite plates, some of them twinned, all crowded with dark granules, having diameters mostly 0.12 to 0.45 millimeter, lying in a matrix of smaller untwinned clear dolomite grains. The outlines of the larger plates, being governed by those of the small ones, appear denticulate.

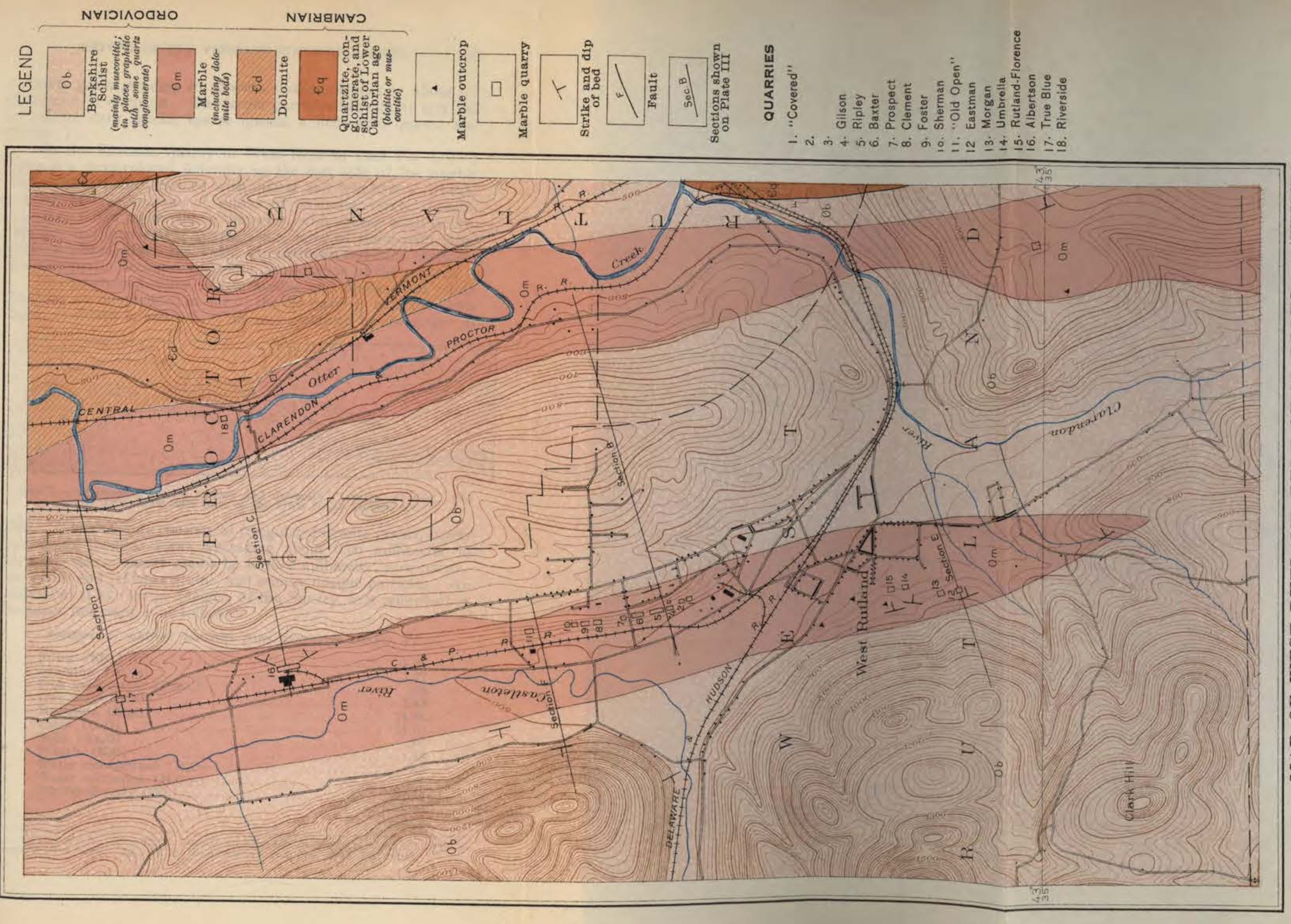
At the True Blue quarry (see Pl. XV, *A*, and fig. 18, p. 120) there is a 15-foot bed of dolomite with calcite marble on both sides of it. A drill core at West Rutland shows nine dolomite beds from 1.8 inches to 16 feet thick, alternating with beds of calcite marble. The whole series measures 250 feet 7 inches, out of which the dolomite beds measure 73 feet 9 inches.

A drill core at the Albertson quarry shows three or four dolomite beds from 4 to 22 feet thick alternating with beds of calcite marble, the whole series measuring 94 feet 4 inches.

At the Florentine quarry in Pittsford the bluish-gray calcite marble contains nodules of very dark gray dolomite. The nodules are brecciated and veined with calcite and quartz. In thin section they are seen to consist of graphitic dolomite.

At the Valley quarry of the Norcross-West Marble Co. at South Dorset there is a 10-foot bed of dolomite at the northeast end of the quarry in contact with the marble. This consists of

PLATE IV




MAP OF WEST RUTLAND BELT OF MARBLES
Showing quarries and probable distribution of the marbles
Scale $\frac{1}{31250}$
0 ½ 1 Mile
1912

dolomite grains tending to rhombic outline, averaging about 0.1 millimeter in diameter. The larger particles are cloudy and full of minute dark specks, sparse quartz, a little vein quartz, and pyrite (?).

At the Eastman quarry in West Rutland (see Pls. I, IV) there is a dove-colored dolomite on the east side of the marble beds, which is finely veined with quartz and weathers a delicate pale brown. It consists of grains of dolomite, rarely rhombs, averaging 0.028 millimeter in diameter, with sparse small quartz particles and intersecting quartz veins, some of these with large dolomite plates; also a few flakes of muscovite and dark particles, probably pyrite, accounting for the discoloration of the surface.

Coarse-grained white calcite marble and fine-grained white dolomite are interbedded in one of the old quarries near the Owls Head, as shown in figure 5. This was described by the writer in

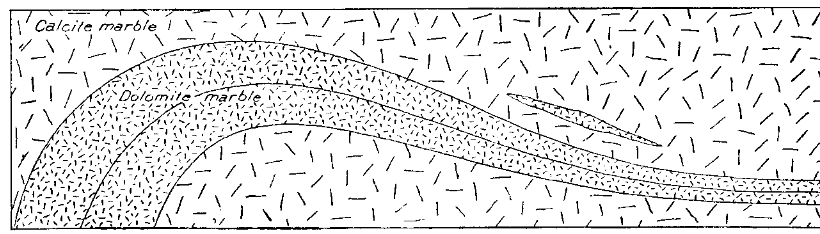



FIGURE 5.—Interbedded calcite marble and dolomite. Length, 40 feet. Old quarry three-fifths mile west of the Owls Head, Dorset, Vt.

1902.[1] The dolomite consists of irregular dolomite grains, rarely tending to rhombic form, averaging about 0.06 millimeter in diameter, sparse quartz grains up to 0.12 millimeter, rare muscovite plates and feldspar grains, and minute opaque particles. An analysis of it by George Steiger, of the Survey, first published in the paper just cited, is as follows:

*Analysis of whitish dolomite from quarry in Dorset, Vt.*

| | |
|---|---|
| Silica ($SiO_2$) | 8.36 |
| Alumina ($Al_2O_3$) | 1.77 |
| Iron sesquioxide ($Fe_2O_3$) | .22 |
| Iron oxide (FeO) | 1.08 |
| Magnesia (MgO) | 16.68 |
| Lime (CaO) | 29.03 |
| Soda ($Na_2O$) | .06 |
| Potash ($K_2O$) | 1.08 |
| Water uncombined ($H_2O-$) | .03 |
| Water combined ($H_2O+$) | .42 |
| Carbon dioxide ($CO_2$) | 41.66 |
| | 100.39 |

[1] Dale, T. N., Structural details in the Green Mountain region and in eastern New York: Bull. U. S. Geol. Survey No. 195, 1902, pp. 13-15.

Between the dolomite and the calcite is a small quartzose bed, which contains sparse quartz grains, stringers of sericite, pyrite, quartz lenses, and calcite plates. As shown in figure 5, there is also a lens of dolomite in the marble and near the dolomite bed.

On the west side of Pine Hill, in the upper part of the marble series close to its contact with the overlying schist, 1½ miles south-southeast of Proctor (see Pls. I and IV), is a bed of gray and white mottled calcite marble containing angular and roundish fragments of dolomite,[1] which, being less soluble by atmospheric acid than the rest of the rock, project on the weathered surface. The marble shows calcite with grain diameter of 0.05 to 0.37 millimeter; the dolomite consists of large irregular plates 0.25 to 1.5 and small grains averaging roughly 0.07 millimeter. The dolomite fragments range from an inch or over down to 0.1 inch in diameter. This association of dolomite and calcite appears to be due to the brecciation of a series of alternating small beds of dolomite and calcite marble.

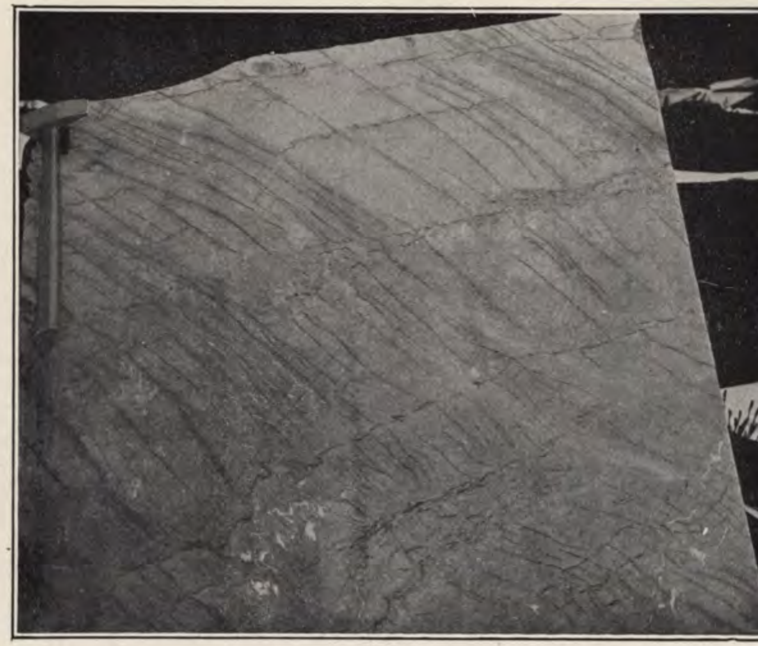
The calcite marble of the Florence No. 2 quarry in Pittsford (see map, Pl. I) is of a very light bluish-gray color wtih dark-gray mottlings, which form minute projections on the polished face that can be scratched with a knife. In thin sections this is seen to be a medium-textured marble, with grain diameter averaging 0.24 millimeter, inclosing minute bands or lenses of dolomite, some of it in rhombs, with a grain diameter averaging, roughly, 0.15 millimeter, and a few quartz grains and muscovite scales. The mottled calcite marble of the Turner quarry, "Pittsford Italian," has similar minute beds of dolomite. A sketch of one of these in natural size is shown in figure 20, page 125. The marble of the Landon quarry has similar little dolomite beds. (See p. 129).

The slightly bluish-white, gray-streaked calcite marble near the base of the marble beds, quarried near Clarendon village (see p. 110), has calcite grains mostly from 0.12 to 0.5 millimeter in diameter, and contains bands of dolomite of irregular and rhombic grains averaging roughly 0.06 millimeter.

A banded calcite marble at a disused quarry three-fourths of a mile southwest of the top of Boardman Hill, in Clarendon, belonging near the top of the marble beds, consists of black, dark-gray, and whitish parallel bands from 0.02 to 0.5 inch thick. In thin section some of these little beds are seen to consist of calcite grains from 0.12 to 0.75 millimeter in diameter, some of them full of graphite; others have calcite with a grain diameter from 0.07 to 0.25 millimeter. But some of the beds are dolomite with an average grain diameter of 0.06 millimeter and with some large dolomite plates of 0.09 millimeter. Some of the calcite bands also contain small lenses of dolomite.

[1] This bed was referred to by Hitchcock and Hager (Geology of Vermont, vol. 1, 1861, p. 399).





*A.* SAWN SLAB OF GRAPHITIC CALCITE MARBLE FROM THE TRUE BLUE QUARRY, WEST RUTLAND.
Showing planes of bedding and of slip cleavage laden with graphite. The beds are inclined to the left and the cleavage to the right. Hammer 18 inches.

*B.* ROUGH BLOCK OF HEMATITIC DOLOMITE MARBLE FROM SWANTON.
Cut across the bed. The ground is bright reddish. Hammer 18 inches.

The most interesting combination of calcite and dolomite is the black marble of Isle la Motte. (See p. 39 and fig. 9). The dark bluish-gray weathered surface of this black marble, which effervesces freely with acid, shows little irregular beds of brownish-gray color which effervesce less freely and form a network about and between the fossil fragments. In thin section this rock is seen to consist of irregular alternations of dolomite in rhombs 0.02 to 0.1 millimeter in diameter and of fossiliferous calcite bands. In the gray crinoid marble beds of the same quarry (p. 40) some of the crinoid columns are of calcite with twinning planes bisecting the acute angle of the cleavage rhomb, but the matrix contains rhombs of dolomite.

The black unmetamorphosed marble of Isle la Motte, with its large Maclureas and other Chazy fossils, may be safely regarded as a close approximation to the condition of the Chazy limestone in the metamorphic marble belt of Vermont before metamorphism took place; and the association of dolomite and calcite in the one throws light on their association in the other, particularly in those parts of the rock where the dolomite forms minute lenses or bands in the calcite marble. These bands were there prior to regional metamorphism.

Exploration of the marbles in eastern Vermont, the results of which will appear in a later bulletin, brings out the fact that the calcite marbles there are also interbedded with dolomite, but generally in beds from a fraction of an inch to several inches thick, and that this dolomite, although fine grained, is almost everywhere twinned, whereas in western Vermont it is mostly untwinned, "granular."

## THE ORIGIN OF DOLOMITE.

Much has been written on the origin of dolomite, and some facts have been definitely established.

Dolomite may be formed in the ocean by the chemical action of sea water substituting magnesium for part of the calcium in a deposit of calcium carbonate or in a coral. The best evidence of this is the drill core obtained by a boring made on the coral island of Funafuti under the direction of the Royal Society.[1] The bore hole was 1,114 feet deep and penetrated a rock of organic origin, consisting of various alternations of calcitic and dolomitic rock. The percentage of $MgCO_3$ (magnesium carbonate) was inconsiderable down to 640 feet, where it was 26.33 per cent. From 698 feet down to 1,114 feet it ranged from about 39 to 41 per cent. As the percentage of magnesium carbonate in living coral and in the calcareous parts of other marine organisms is insignificant, and as the salts of the sea, which make up 3.737 per cent of the water, contain 1.676 per cent of CaO (lime), or 1.196

[1] The atoll of Funafuti, Royal Soc. London, 1904.

per cent of Ca (calcium), and 6.209 per cent of MgO (magnesia), or 3.769 per cent of Mg (magnesium), it is thought that the magnesium in the dolomitic beds of this organic rock may have been supplied by the sea through a process of dolomitization.[1]

Dolomite has also been formed by the dolomitization of a limestone after its emergence from the sea. Unmistakable evidences of this process have been found in Ireland and other places.[2]

In these localities dolomitization was brought about after emergence by percolating water carrying magnesium carbonate in solution, which was substituted for part of the calcium carbonate in the limestone. Whether these magnesian waters came indirectly from the sea or directly during a second submergence is not clear.

Dolomite has also, it is asserted by some geologists but disputed by others, been formed by chemical precipitation in the sea. Archibald Geikie[3] says that dolomite "occurs sometimes in beds of original deposit, associated with gypsum, rock salt, and other results of the evaporation of saturated saline waters; it is also found replacing what was once ordinary limestone." Zirkel[4] maintains that the direct precipitation of dolomite is just as possible as that of calcite. Strahan[5] describes a 4-foot seam of coal in one of the English collieries which in a space of 750 feet passes into a 3-foot bed of pure dolomite and the origin of which is attributed to direct deposition.[5]

Loretz[6] described certain fine foliaceous dolomites, the texture of which in his opinion points strongly to direct deposition. Gümbel[7] regards the interbedding of dolomite and limestone, the occurrence of lenses of dolomite in limestone, the strict separation of dolomite from overlying limestone, and the distinct bedding of the dolomite as all pointing to the original sedimentation of dolomite.

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[1] Instructive papers on this subject are those of Skeats, E. W., The chemical composition of limestones from upraised coral islands, with notes on their microscopic structures: Bull. Mus. Comp. Zool. Harvard Coll., vol. 42, 1903, p. 53; On the chemical and mineralogical evidence as to the origin of the dolomites of southern Tyrol: Quart. Jour. Geol. Soc. London, vol. 61, 1905, p. 97.

[2] See Wyley, Andrews, On the character and mode of occurrence of the dolomite rocks of Kilkenny: Jour. Geol. Soc. Dublin, vol. 6, 1856, pp. 114-119, figs. 1-3, showing a vertical "dike" of dolomite 1 to 2 feet thick crossing horizontal beds of limestone, also dolomite replacing the upper part of a series of horizontal and undulating beds of limestone, the boundary between the two rocks zigzagging most irregularly across the bedding planes. See also Harkness, Robert, On the jointings in the Carboniferous and Devonian rocks in the district around Cork; and on the dolomites of the same district: Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 100. Dolomitization has operated along the joints of the limestone.

[3] Textbook of geology, vol. 2, p. 193.

[4] Zirkel, F., Lehrbuch der Petrographie, 2d ed., vol. 3, 1894, p. 502.

[5] Strahan, A., On the passage of a seam of coal into a seam of dolomite: Quart. Jour. Geol. Soc. London, vol. 57, 1901, pp. 297-306.

[6] Loretz, H., Untersuchungen über Kalk und Dolomit: Zeitschr. Deutsch. geol. Gesell., vol. 30, 1878, pp. 387-414, pls. XVII, XVIII; vol. 31, 1879, pp. 756-774.

[7] Gümbel, C. W., Die geognostischen Verhältnisse des Ulmer Cementmergels, seine Beziehungen zu den lithographischen Schiefer und seine Foraminiferen Fauna: Sitzungsb. K. b. Akad. München, 1871, pp. 38-62.

PLATE VI.

On the other hand, Doelter and Hoernes regard the greater part of dolomite as due to the calcareous secretions of marine organisms dolomitized probably by magnesium chloride in sea water.[1]

Klement[2] regards it as formed by concentrated sea water in solarly superheated closed basins acting upon aragonite deposited by marine organisms. Aragonite is that form of $CaCO_3$ which constitutes corals, shells, etc.

Pfaff[3] attributes dolomite to the dolomitization of $CaCO_3$ (either as chemical precipitate or of organic origin) during or after its deposition.

Hunt's early experiments[4] demonstrated that precipitations of a mixture of calcium carbonate and hydrated magnesium when heated above 120° pass into dolomite.

Van Hise[5] and Clarke[6] do not consider the chemical precipitation of dolomite as probable under any conditions.

Linck[7] attributes the origin of dolomite largely to ammonium salts arising from organic decomposition, basing this theory on certain laboratory experiments.

In connection with the question of the origin of dolomite, attention should be called to the alternation of dolomitic and calcitic beds observed in many places besides those described in the previous pages.

Vogt[8] gives a section at Furuli, in Fauske, Norway, showing a series of beds 146 feet thick consisting of 48 feet of slate overlying 57 feet of plicated fine-grained limestone, which overlies a series made up of two beds of yellow calcite marble alternating with two of dolomite marble, each bed about 12 feet thick and all plicated and without any transition from the dolomite to calcite marble. It is evident that such repeated alternations of dolomite and calcite can not be explained by dolomitization after emergence, nor can the kindred occurrences in the Vermont marble belt at West Rutland and in Dorset (described on pp. 22-25) be explained in that way.

The interbedding of dolomite and limestone is very characteristic of the limestone belt in Lehigh County, Pa., particularly in the town of South Whitehall. At a quarry visited by the

[1] Doelter, C., and Hoernes, K., Chemisch-genetische Betrachtungen über Dolomit: Jahrb. K.-k. geol. Reichsanstalt, vol. 25, 1875, pp. 297-332.

[2] Klement, C., Sur l'origine de la dolomie dans les formations sédimentaires: Mém. Soc. belge géol. pal. et hydrol., vol. 9, 1895, pp. 3-23; abstract in Geol. Mag., London, new ser., dec. 4, vol. 2, 1895, p. 329.

[3] Pfaff, F., Ueber Dolomit und seine Entstehung: Neues Jahrb., Beilage and Band 23, 1907, pp. 529-580.

[4] Hunt, T. S., Am. Jour. Sci., 2d ser., vol. 28, 1859, pp. 170, 365; vol. 42, 1866, p. 49.

[5] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904, pp. 798-808.

[6] Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 534-543, particularly p. 540.

[7] Linck, G., Monatsh. Deutsch. geol. Gesell., 1909, p. 230. See also Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, p. 536.

[8] Vogt, J. H. L., Der Marmor: Zeitschr. prakt. Geologie, 1898, p. 9, fig 5.

writer in 1892, on the south side of Jordan Creek near Jordan Bridge (see map of Slatington quadrangle, U. S. Geol. Survey), three beds of dolomite, each 18 inches to 2 feet thick, alternate with four beds of limestone averaging about 15 feet thick. The whole series is intricately folded, there being three anticlines and three synclines in a length of 100 feet; and the limbs of these folds measure from 12 to 35 feet in length. The limestone emits a fetid odor when struck with the hammer. In thin section the limestone is seen to consist of finely stratified irregular plates of polarizing calcite, 0.004 to 0.02 millimeter in diameter, crossed by irregular beds or veinlets of black carbonaceous matter, with lenses of calcite and rhombs reaching 0.2 millimeter, and a little pyrite. The dolomite consists of grains, mostly rhombs, of dolomite, from 0.05 to 0.15 millimeter in diameter, averaging about 0.1 millimeter, in a slight very dark matrix.

Chemical analyses of both rocks made for the writer's study of this subject in 1903 by W. F. Hillebrand follow. The limestone was taken immediately under one of the dolomite beds.

*Analyses of limestone and dolomite, near Jordan Bridge, South Whitehall, Pa.**

| | Limestone. | Dolomite. |
|---|---|---|
| Silica ($SiO_2$) | 3.72 | 2.80 |
| Alumina ($Al_2O_3$), Ferrous oxide ($Fe_2O_3$), Ferric oxide ($FeO$), Phosphoric acid ($P_2O_5$), Titanium dioxide ($TiO_2$) | .81 | .84 |
| Magnesia ($MgO$) | 3.17 | 17.87 |
| Lime ($CaO$) | 48.95 | 31.68 |
| Carbon dioxide ($CO_2$) | 41.58 | 43.62 |
| Manganese oxide ($MnO$) | .... | Faint trace |
| Water, alkali (?), and carbonaceous matter | 1.77 | 3.19 |
| | 100.00 | 100.00 |

*Bull. U. S. Geol. Survey No. 419, 1910, p. 190 (slightly abbreviated from original).

The carbonates in these analyses figure out as follows: magnesium carbonate ($MgCo_3$), 37.52; calcium carbonate ($CaCO_3$), 55.65. These analyses show that both rocks contain quartz and carbonaceous matter and that the dolomite contains 10 per cent more $CaCO_3$ and about 7 per cent less $MgCO_3$ than a normal dolomite.

In the dolomites of Green Peak, Vt. (p. 25), the percentage of $SiO_2$ (silica) is 8.36, most of which, according to the sections, occurs as quartz and the rest in mica and feldspar. The statuary-marble bed of the Goodell quarry, near Brandon (p. 132), is in contact with a graphitic quartzose dolomitic calcitic rock. The presence of more silica in the dolomite beds of the Vermont marble belt than in the adjacent calcite marble beds points to conditions of sedimentation different from those which prevailed when the calcite beds were being deposited.



How shall these microscopic beds of dolomite in the black unmetamorphic marbles of Isle la Motte and in some of the finely banded metamorphic marbles of the Vermont valleys (p. 24) be explained? The same question may be asked as to the minute interbedding of dolomite and sericite schist, each a millimeter thick, in a plicated rock in the Alps, in which, of course, the schist was of mechanical sedimentary origin.[1] However the alternation of dolomitic and calcitic beds may be explained, the sharply defined and repeated alternations indicate great differences in the conditions of original sedimentation or in those conditions which brought about and arrested the process of submarine dolomitization.

## WEATHERING OF MARBLE.

The weathering of marble is governed by four factors—the chemical composition of the marble, its texture, the general character of the climate to which it is exposed, and the local artificial condition of the surrounding atmosphere.

Both calcite and dolomite marble are soluble in carbonic acid, which is brought down from the atmosphere in every drop of rain water; but as dolomite is less readily soluble in this acid than calcite a dolomite marble, the other factors being equal, will prove more durable than a calcite marble. (See p. 20).

It has been thought that a fine-textured marble, by offering the rain water a greater length of grain boundary than a coarse-textured one, would weather more readily, but on the other hand a coarse-textured, loosely compacted marble will weather readily because acid water, once admitted between the grains, will travel more rapidly.[2] Marbles containing silicates in large flakes or crystals are more susceptible to weathering, for acid water gains free access along the boundaries of the silicates.

It is generally known that carvings in European marbles will stand exposure in the climate of southern Europe much better than in that of our Eastern States. Vogt states that in the dry atmosphere of Egypt, Greece, and Italy marble statues after an exposure of 1,000 years lose some of their fine lines but become coated with a fine protective crust. Lepsius found that this protecting film on ancient Greek monuments was ferruginous and that it was formed only on the marble containing a small percentage of $Fe_4O_9H_6$. On the other hand Vogt refers to a number of Norwegian churches built partly or entirely of Norwegian calcite marble which have stood six or seven centuries exposed to the raw, windy, and cold climate of northern and western Norway

[1] See Allenspach, G., Dünnschliffe von gefälteltem Röthidolomit-Quartenschiefer am Piz Urlaun: Vierteljahrsschr. Naturforsch. Gesell. Zürich, vol. 45, 1900, pp. 227-237.

[2] Vogt, J. H. L., Der Marmor: Zeitsch. prakt. Geologie, 1898, pp. 48, 49.

with but very little if any weathering. In contrast with this Hirschwald[1] reproduces a thin section of marble, presumably Italian, which had been exposed in a monument in Berlin for 192 years and which shows the erosion of the grain surfaces, the loosening of their cohesion, and the deposition of an ocher-like substance between them.

The amount of weathering, other things being equal, is probably related to the degree of humidity of the atmosphere and the amount of rainfall. Though it is mainly due to carbon dioxide brought down by rain, it is probably due in part, as pointed out long ago by Joseph Henry, to nitric acid generated by lightning.[2]

The effect on white marble of such a climate as that of New England, outside of the cities, can be observed in many country churchyards and cemeteries. As the epitaphs on tombstones and monuments give the approximate date of their erection the amount of solution by weathering in a century can be calculated. The cemetery on Burial Hill, at Plymouth, Mass., offers some pertinent data. On a marble stone in horizontal position, dated 1825, the lettering is almost effaced, and one of the same year in vertical position is badly weathered. On a horizontal stone of 1854 the edges of the letters are rounded. But slate stones from England, Wales, and New England in the same cemetery, dated 1683, 1743, 1745, 1773, and 1828, have well-preserved lettering. The good state of preservation of epitaphs on slate dating back to the early settlement of New England is noticeable in many other cemeteries. The climatic conditions at Plymouth were doubtless aggravated by fogs and salt air. At the other extreme may be cited a block of white marble taken in 1910 from a building near South Dorset, Vt., and probably quarried there, inscribed "A. D. 1831," in which the edges of the letters and figures are fairly sharp, having stood 79 years without perceptible weathering. Generally in New England, however, the lettering on white marbles 75 to 100 years old is so far weathered that it will probably be completely effaced within 300 years of the date of the cutting. It is also a question how long the letters on the marble headstones in the national cemetery at Arlington, Va., will stand the humid atmosphere of that region.

Geikie[3] in his paper on the weathering of tombstones notes the relative durability of epitaphs on marble and slate at Peterhead, in northeast Scotland. Epitaphs 100 to 150 years old on marble were half effaced, but some 110 years old on slate had retained their sharpness.

In considering the weathering of marble in the smoke-laden atmosphere of great cities and industrial centers we must take

[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, 1908, Pl. XVIII, fig. 3.

[2] See Hall, James, Report on building stones: Thirty-ninth Ann. Rept. New York State Mus. Nat. Hist., 1886, p. 218.

[3] Geikie, Archibald, Rock weathering as illustrated in Edinburgh churchyards: Proc. Royal Soc. Edinburgh, vol. 10, 1880, p. 531.



into account, besides the action of atmospheric acids, that of sulphuric acid arising from the smoke of railroads, factories, foundries, and steam plants where soft coal is used.

Geikie[1] reproduces two thin sections of white marble, presumably Italian, one of the fresh stone obtained in an Edinburgh marble worker's yard, the other taken at right angles to the surface of an urn that had been exposed for 87 years in an Edinburgh cemetery. The second one shows that the acids have penetrated between the calcite grains and along the cleavage and twinning planes, widening them by solution, also that by a combination of sulphuric acid from the atmosphere with the lime of the calcite grains a crust of calcium sulphate (gypsum) has been formed in the openings and along the surface. Moreover this gypsum is full of dust and soot particles. From Geikie's examination of the marbles in that cemetery he estimates that weathering under the conditions at Edinburgh proceeds at the rate of 0.33 inch, or roughly 9 millimeters, a century. In other words lettering or designs cut 0.5 inch into marble would under such conditions be completely effaced in 150 years. In line with this conclusion is the fact stated by Goodchild[2] that dressed surfaces of limestone in the north of England lose an inch of surface in from 240 to 500 years.

In this connection attention should also be directed to the rapid blackening of all light marbles by soot wherever much soft coal is used and to the fact that the amount of this disfigurement increases with the elaborateness of the ornamentation, which prevents its removal by rain.

Renwick,[3] an English writer on marble, describes the effect of the London atmosphere on various marbles in these words:

> Generally speaking, it appears that while certain varieties of marble are available for exterior work, their general use is inadvisable, for the reason that discoloration and disintegration will ensue as a result of atmospheric impurities, generally sulphuric acid, generated by the action of rain water falling through a smoke-laden atmosphere on a soot-covered building, the effect sought to be produced by their use being thus speedily lost, even if nothing worse happens. The red marbles mostly contain clayey veins and patches, which disintegrate under the action of sun, rain, and frost. With the greens effervescence results; the violets lose their color; while with breccias the colors fade and a leaching out becomes apparent along the line of the cementing medium of the material. Laminated marbles waste in their softer layers, leaving the harder parts exposed, and these in course of time will break away.

Seipp[4] has recently published an interesting study of the ments. weathering of various marbles in Italian buildings and monu- With the aid of a botanist he found that the blackening

[3] Geikie, Archibald, Rock weathering as illustrated in Edinburgh churchyards: Proc. Royal Soc. Edinburgh, vol. 10, 1880, fig. 1, p. 520.

[2] Goodchild, J. G., Geol. Mag., 1890, p. 466.

[3] Renwick, W. G., Marble and marble working, London, 1910, pp. 58, 59.

[4] Seipp, H., Italienische Materialstudien, Stuttgart, 1911, pp. 23-35, 62-70, 117-153.

which is so conspicuous in exposed marble statues and carvings in that climate is due to a coating of the lichens Verrucaria, Opegrapha, and probably also Lithoicea, to particles of dust and soot adhering to the lichens, and to the film of humus arising from their decomposition.

## THE MARBLES OF WESTERN VERMONT.

### GRAPHITIC CALCITE MARBLE.

One of the marked varieties of Vermont marble is the gray, which ranges in shade from light to very dark and is generally of bluish tinge. Some of it is finely banded, light and dark, with some bands almost or quite black, as in the specimens from a disused quarry on Boardman Hill, in Clarendon (p. 24), and from the Clarendon Marble Co.'s quarry in the same township (p. 105). Some of this gray marble is in sharply plicated beds crossed by planes of slip cleavage, as shown in the slabs photographed in Plates V, *A,* and VIII, *B, b,* in both of which the two sets of planes are conspicuous for their blackness.

In thin section all these gray marbles are characterized by a greater or less abundance of minute black particles, rarely scales of carbon disseminated in the calcite grains. An analysis (No. 2534) made by George Steiger, of this Survey, shows that in a typical specimen of this marble, "West Rutland blue," this carbon is graphite and that its percentage in the marble amounts to 0.03. Mr. Steiger adds the following explanation to his analysis:

This determination of graphite was made by the method proposed by Brodie. One hundred grams of the marble were dissolved in dilute hydrochloric acid, filtered through asbestos, and the insoluble residue (which contained all the carbon), together with the asbestos used in filtering, treated for eight days with strong nitric acid and potassium chloride. The residue from this treatment was light colored and showed no indication of any carbon being left unattacked. According to Brodie, who is confirmed by others, by this treatment amorphous carbon is oxidized to $CO_2$, while graphite is oxidized to what is called graphitic acid, this compound being a light-yellow or brownish material. The solution was next filtered and the residue treated with a solution consisting of chromic and sulphuric acid, which oxidizes graphitic acid to $CO_2$; the latter was passed through barium hydrate solution and the precipitated barium determined as sulphate.

Some few recent authorities do not consider this formation of graphitic acid as an absolute proof of graphite, but it is the most reliable test that can be made by chemical means.

In some of these marbles that are a little darker the percentage of carbon would be very little higher. The thin sections show that besides carbon a little quartz and pyrite are generally present, and less commonly muscovite.

If the calcite in these marbles is attributed to the calcareous parts of crinoids, brachiopods, and mollusks, the graphite is probably to be regarded as derived from the decomposition of marine algæ, and the fine interbedding of more or less graphitic parts to be attributed to alternating periods of dominant plant or animal marine life, but the abundance of the graphite in the planes of slip cleavage would have to be explained by transfers of graphite from the adjacent calcite grains during metamorphism.

These gray marbles take a high polish and are very attractive.



### CLOUDED CALCITE MARBLE.

In the clouded calcite marble of Vermont the "clouds" generally follow the bedding planes, which in places are sharply plicated. An examination of the polished surface of one of these marbles with a magnifying glass shows that the cloudy bands project an infinitesimal distance above the general surface, and are therefore harder than calcite. As they can be scratched with a knife, they are softer than quartz. This is corroborated by a microscopic examination of thin sections, which shows that the cloudy parts consist mainly of dolomite with a grain diameter ranging from 0.02 to 0.25 millimeter, averaging, roughly, 0.15 millimeter. Associated with the dolomite are plentiful minute particles of graphite, which account for the dark shade; also some quartz, pyrite, and rarely muscovite. A still further corroboration is furnished by Penfield's analysis (p. 5) of one of these clouded marbles from the Columbian quarry, at Proctor, which shows 0.77 per cent of $MgCO_3$ (magnesium carbonate). A sketch of one of these dolomite beds is shown in figure 20, page 125.

Where the small cloudy beds are plicated, a slab sawn in the general direction of the stripe will intersect the tops of minute meandering anticlines, but if sawn in the direction of the dip it will intersect several superposed series of such plications. In either case the marble will be clouded, but the distribution of the "clouds" or bands will differ. Where the plication has been extreme, the mottling will be very irregular on the slab. A polished slab of one of these clouded calcite marbles containing some slightly graphitic calcitic beds is shown in Plate VI, *B*.

### MUSCOVITIC CALCITE MARBLE.

Many of the banded marbles of western Vermont owe their banding to fibers and scales of muscovite mingled in varying amounts with the calcite grains and forming little beds which alternate with beds of calcite grains alone. The marble has a grayish or greenish tint of varying intensity. The whole series of beds is generally more or less intricately plicated. Slabs showing cross sections of such a series are used for ornamental wainscoting and panels. (See Pls. VI, *A,* and XIV, *B*).

In these marbles the long axes of the calcite grains are generally parallel to the bedding, as shown in figure 6, so that the marble has under compression acquired a certain schistosity. In thin section the fibrous muscovite is found associated with quartz grains, rarely one of the plagioclase feldspar, also with epidote and chlorite, which emphasize the greenish tint proceeding from the muscovite. In some beds the muscovite, epidote, and chlorite are distributed so uniformly through the calcite as to produce a bright-greenish marble. Along with these minerals are usually found small dark lenses of uncertain character, minute opaque specks, and a little pyrite.

The fibrous muscovite of these marbles must have originated in clayey (feldspathic, quartzose) sediment, of which the few plagioclase grains are unaltered remnants and most of the quartz possibly also. The epidote and chlorite must have originated in minerals containing magnesia, silica, iron, and alumina, with which, to form the epidote, lime from the calcareous sediments became combined. These mechanical sediments, combined with calcareous sediments, presumably of organic origin, were metamorphosed, as already explained (p. 15), into muscovitic calcite marble containing small quantities of accessory minerals.

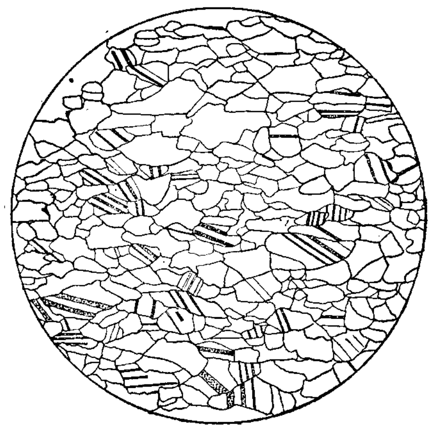

FIGURE 6.—Thin section of graphitic calcite marble showing elongate texture. From "17-foot bed," Eastman quarry, West Rutland. Enlarged 27 diameters.

About 1½ miles southwest of Brandon in the marble belt (see Pl. I) is a knoll rising 120 feet above the Otter Creek flood plain and consisting of rusty-weathering impure bluish marble that illustrates well the effect of metamorphism on a mass of calcareous sandy and clayey marine sediments. Part of a thin section of this rock is reproduced in figure 7. In some places the rock is a medium-grained calcite marble, containing some quartz. In others it is a fine-grained dolomite, including lenses of calcite and quartz. In still others it is a graphitic, pyritiferous sericite schist. The whole mass is intricately plicated and crossed by planes of slip cleavage. It combines some of the features of a marble with some of quartzite, some of dolomite, and some of a muscovite (sericite) schist. The muscovitic calcite marbles are the result of the same processes which produced this rock, but the sediments were more dominantly calcareous.

Owing to their considerable content of mica, the muscovitic calcite marbles do not take a perfect polish.



## ACTINOLITIC CALCITE MARBLE.

Exceptional among the Vermont marbles are those quarried a mile northwest of South Dorset or 1¼ miles southwest of the Owls Head, in Dorset. (See Pl. I and p. 93). They are coarse textured and range from faintly greenish or cream to smoke colored. Some beds are banded with fine dark-green to grayish-green beds, acutely plicated at intervals. Thin sections show that these little beds consist of fibrous actinolite and quartz with some pyrite and minute dark lenses of uncertain composition. The smoke-colored parts appear to owe their shade to thinly disseminated lenses of this kind.

FIGURE 7.—Thin section of quartzose dolomitic and sericitic calcite marble from knoll near Brandon. Dotted particles are quartz; finer-grained area at upper left side is dolomite; the fibrous portions consist of sericite, which, where shaded, is graphitic; the black particles are pyrite; the larger clear particles and the banded particles are calcite. Enlarged 27 diameters.

This actinolite (a variety of hornblende, a silicate of lime, magnesia, and iron) must be attributed to the metamorphism of material of mechanical sedimentary origin containing magnesia, iron, and silica, combined with lime from the calcareous sediments.

Plate VII shows two pilasters of this actinolitic marble cut parallel to the strike, with some plication and a little brecciation along the strike.

## DOLOMITE MARBLES OF LAKE CHAMPLAIN.

The marbles commercially known as "Champlain marbles" differ greatly in composition, texture, color, and physical qualities from the marbles that are extensively quarried along the Taconic Range. They owe their name to their occurrence in a strip along or near the east shore of the northern part of Lake Champlain. They include the marbles of Swanton, which are of Lower Cambrian age, and those of Monkton, along the foot of the Green Mountain range, which are probably areally continuous with and of the same geologic age as those of Swanton.

For the geology of these marbles the reader is referred to the writings of the Vermont and other geologists.[1]

SWANTON.

The marbles of Swanton are all quartzose dolomites, most of the quartz being in angular particles (0.02 to 0.15, generally under 0.07 millimeter across) and thus of mechanical sedimentary origin. The quartz grains have cavities with moving vacuoles. Rare grains of feldspar (orthoclase, microcline, and plagioclase) occur with them. The dolomite is in irregular untwinned plates and rhombs (0.02 to 0.3, averaging roughly 0.1 millimeter in diameter). The rock is more or less pinkish or reddish from minute particles of hematite ($Fe_2O_3$) disseminated in the dolomite grains and also as a matrix between them. This reddish matrix is not slaty, for in cross sections it fails to show aggregate polarization. As the marble has a marked argillaceous odor, kaolin may be present. The hematite in places is seen to arise from the oxidation of black metallic particles which also show on the polished face and easily cling to a common magnet when the rock is powdered, do not appear reddish on edges, and have a blackish streak. The rock in which the magnetite abounds has a purplish color. A grayish to reddish variety near the base of the series and certain bluish-gray beds near the top, weathering yellow, show limonite stain proceeding from abundant minute grains of pyrite. The first variety shows magnetite also, rarely oxidized to hematite. Some of the sections of the "red" show a little mica (muscovite and biotite). Chlorite forms on some of the joints, also orange-colored calcite; and felty asbestos "mountain leather" is reported as occurring between the beds. A typical thin section of the reddish variety of dolomite at Swanton is shown in figure 8.

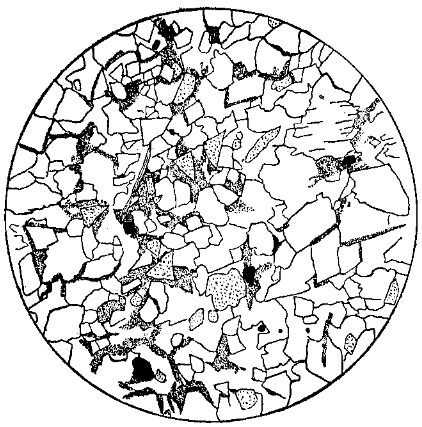

FIGURE 8.—Thin section of hematitic quartzose dolomite from Swanton. Dotted particles are quartz; black are magnetic; shaded areas are hematite stain; a black-banded particle is plagioclase, a long-streaked one, muscovite; the rest are dolomite. Enlarged 77 diameters.

[1] See Perkins, G. H., The Winooski or Wakefield marble of Vermont: First Rept. State Geologist, 1898, pp. 30-37; Second Rept., 1900, pp. 55, 56; Sixth Rept., 1908, pp. 28-30, 224-245. Hitchcock, C. H., The Winooski marble of Colchester, Vt.: Proc. Am. Assoc. Adv. Sci., vol. 16, 1867, p. 119. Billings, E., Note on the discovery of fossils in the Winooski marble at Swanton, Vt.: Am. Jour. Sci., 3d ser., vol. 10, 1872, pp. 145-146. Edson, G. E., Geology of the town of Swanton: Sixth Rept. State Geologist, 1908, pp. 217-219.



POLISHED PILASTERS OF ACTINOLITIC CALCITE MARBLE FROM "GREEN BED," VALLEY QUARRY, SOUTH DORSET.
Showing some brecciation along the strike. Length 11 feet 3 inches, width 20 inches.

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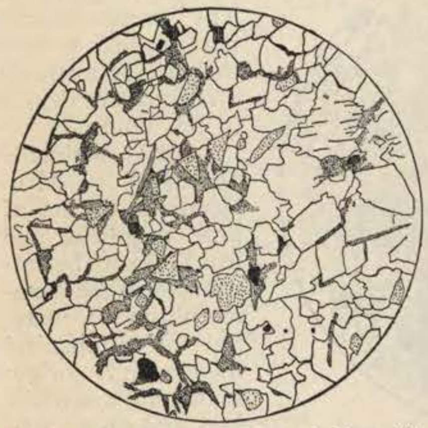

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POLISHED PILASTERS OF ACTINOLITIC CALCITE MARBLE FROM "GREEN BED," VALLEY QUARRY, SOUTH DORSET.
Showing some brecciation along the strike. Length 11 feet 3 inches, width 20 inches.

Some of the marble beds of Swanton are of a uniform dark reddish-brown color; others, however, are mottled with white, consisting of twinned dolomite associated here and there with vein quartz. Still others, and these are the more typical marbles of Swanton, have a reddish or pinkish matrix containing very irregular light-pink to white dolomitic lenses or beds 0.1 to 0.7 inch wide and up to 9 inches long, generally with their long axes parallel to the bedding but in some beds at all angles to it, even perpendicular. Some of these lenses consist of coarse twinned dolomite and calcite with a nucleus of vein quartz. These are regarded by Walcott[1] as Actinozoa (corals), Archæocyathinæ, originally more or less conical in form but now greatly distorted.

Perkins regards the present position of some of these lenses as due to brecciation, but however that may be the nucleated structure and general shape of some of them is good evidence of organic origin. Possibly some of the lenses were originally dolomite beds which alternated with ferruginous clayey beds but now lie brecciated in a hematitic argillaceous matrix, and only the nucleated lenses are distorted dolomitized corals, but some of these are also clearly brecciated. Perkins[2] reproduces a photograph of a slab of marble from Swanton filled with *Salterella*. A photograph of rough blocks of marble from Swanton is reproduced in Plate V, *B,* and one of a polished piece with corals in Plate VIII, *A, c.*

These marbles are thus mainly magnetitic quartzose dolomites partly of sedimentary and partly of organic origin. The magnetite may have been originally deposited as a carbonate. In most of the beds the magnetite has become more or less oxidized into hematite, giving the marbles their reddish color. The corals have evidently been largely dolomitized and the central cavities, partly original and partly made by solution, have become filled with quartz from siliceous solutions. Whether this dolomitization took place in the sea or after emergence is uncertain. The marbles are thus the result of an interesting series of processes—sedimentation, both mechanical and organic, if not chemical also; dolomitization; metamorphism, accompanied by siliceous infiltration; brecciation; and underground oxidation.

The marbles of Swanton are very sonorous and, of course, harder than calcite marbles or even twinned dolomite marbles.

## MONKTON.

The dolomite marble of Monkton occurs along the west foot of the Green Mountain range from Bristol to East Monkton,

[1] Walcott, C. D., The fauna of the Lower Cambrian, or Olenellus zone: Tenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1890, pp. 587, 588 In a letter of recent date Dr. Walcott adds: "As far as we know, this group of fossils on the North American continent, both on the coast of Labrador and in southwestern Nevada, is associated with the Lower Cambrian, and the same is true in northwestern Vermont."

[2] Perkins, G. H., Sixth Rept. State Geologist Vermont, 1908, Pl. XXXIX.

where it is in contact with the quartzite that forms the west side of the range.[1] In its mottling this marble resembles slightly that of Swanton, but the ground is pink or pinkish and the blotches have a less regular form and are white or of a delicate rose color. On continued outdoor exposure these colors become more faint and on long weathering they disappear altogether and the rock either whitens or becomes dull greenish gray. In thin section the rock is seen to consist of dolomite plates and rhombs, mostly under 0.1 millimeter in diameter, and of more or less angular quartz grains up to 0.07 millimeter, with rarely one of feldspar (orthoclase and plagioclase), magnetite grains up to 0.005 millimeter, mostly altered to hematite, rare pyrite altered to limonite, a little sericite, and in places vein quartz.

The rock has fine beds or films of fibrous muscovite at short intervals. In thin section one of these, 1 to 2 millimeters thick, is seen to consist of minutely plicated sericite with many grains of magnetite; next and parallel to it runs a ¼-inch vein of quartz with calcite, dolomite, sericite, and magnetite.

The dolomite marble of Monkton is therefore also a hematitic quartzose dolomite, but with less hematite than the marble of Swanton, and is interbedded with fibrous muscovite. The hematite and the pinkish tint are derived by oxidation from the magnetite, as in the marbles of Swanton. The quartz and feldspar grains are of mechanical sedimentary origin, as was also the clay from which the fibrous muscovite was formed during metamorphism; vein quartz was deposited by siliceous waters at the same time.

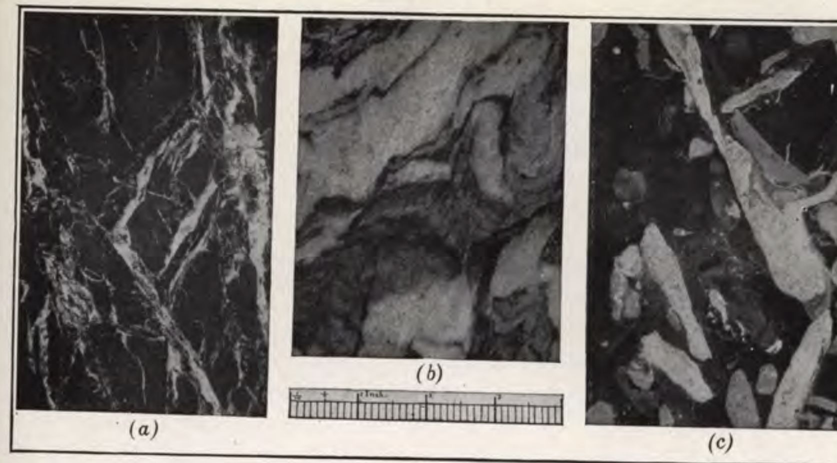
The dolomite marble of Monkton is attractive on account of its very delicate color, but this color is not durable under outdoor exposure and the stone can be utilized only for indoor decoration.

## DOLOMITE MARBLES OF PROCTOR AND PITTSFORD.

In the dolomite series which underlies the calcite marbles of the Otter Creek valley (see Pl. I and p. 59) a graphitic dolomite has recently been prospected for marble at a point about 1¾ miles southwest of Pittsford village, in the township of Proctor (see p. 123), and found to take a good polish. This dolomite marble is of bluish-black color and consists of greatly plicated, extremely fine black and white laminae or beds not over 0.1 inch thick, suggesting a possible organic origin.[2] Thin sections show it to be a dolomite of irregular plates from 0.02 to 0.25 millimeter in diameter, some of them twinned, and rare quartz grains. The white beds, from 0.12 to 0.25 millimeter thick, in places widen to lenses with vein quartz and dolomite plates up to 0.75 millimeter. The graphitic beds are from 0.12 to 0.5 millimeter

[1] See Seely, H. M., Seventh Rept. State Geologist Vermont, 1910, p. 298.
[2] See Perkins, G. H., Fourth Rept. State Geologist Vermont, 1904, Pl. LXXII (*Stromatocerium lamottense* Seely, which it somewhat resembles).

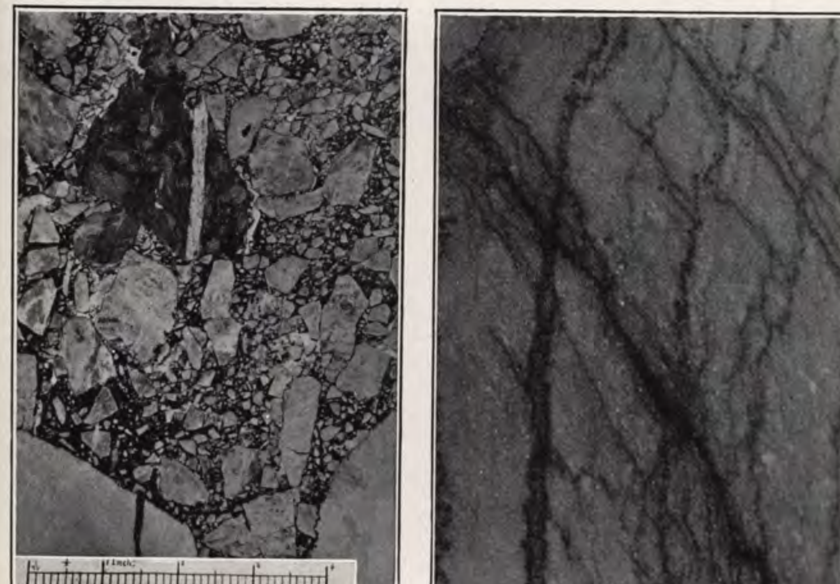





A.
*a*, SERPENTINE FROM ROXBURY, SHOWING VEINING

*b*, "KIEL'S GREEN MARBLE," FROM EASTMAN QUARRY, WEST RUTLAND.
Alternating beds of cream-colored calcite marble and dark-green muscovitic and chloritic marble, both plicated and crossed by slip cleavage.

*c*, "JASPER" MARBLE FROM SWANTON.
The ground is bright-reddish quartzose hematitic untwinned dolomite. The white objects are distorted and brecciated corals of twinned and untwinned dolomite and quartz.




(a) (b)

B.
*a*, POLISHED SPECIMEN OF BRECCIATED CALCITE AND DOLOMITE MARBLE FROM DYER QUARRY, MANCHESTER.
The cement is bright reddish and the fragments are bluish-gray or cream-colored. The dark one with light vein is dull reddish-brown.

*b*, SAWN SPECIMEN OF GRAPHITIC CALCITE MARBLE FROM ALBERTSON QUARRY, WEST RUTLAND.
Showing plicated bedding planes running lengthwise, crossed by planes of slip cleavage inclined to the right, both laden with graphite.

POLISHED MARBLE SPECIMENS.

thick. A medium bluish-gray dolomite near the graphitic beds is of similar character, but the darker bands are less graphitic. None of the sections show any conclusively organic texture.

From the now disused Whelden quarry at the Florence cross-roads, 2½ miles northwest of Pittsford village, in Pittsford Township (see Pl. I), dolomite was shipped in 1900 to Bellows Falls for its magnesia, which is said to have been used in the manufacture of paper. The quarry is in a series of pink and cream-colored dolomites 40 feet thick. Some of the beds are ivory colored, others delicate rose, and others cream, spotted or banded with pink. In thin section these beds are seen to be slightly quartzose dolomites, with a grain diameter of 0.009 to 0.17 millimeter, averaging from 0.04 to 0.09, with lenses of quartz and of twinned dolomite. They owe their tints to limonite or oxidized pyrite or to hematite from oxidized magnetite. There are small intercalated beds of sericite schist, quartz, and dolomite. The dolomite beds can be followed from this point for 2 miles along the strike.

This whole set of dolomite beds contains a variety of attractively colored fine-grained dolomite marbles, which but for the thinness of the beds and a possible tendency to fracture along intersecting fine quartz veins would possess economic value. Even as they are and quite irrespective of their colors these dolomites would serve well for mosaic flooring and terrazzo.

These pinkish and cream-colored dolomites, generally weathering light brown, form hillocks northeast and north-northeast of Brandon village and occur also in Chittenden, on Mount Chaffee, and form the summit and west side of the 2,547-foot hill south-southeast of that mountain, as shown on the map.

## UNMETAMORPHIC CALCITE MARBLE OF ISLE LA MOTTE.

Although, as was explained on page 25, the black marble of Isle la Motte contains a little dolomite, it is essentially calcite marble and mainly of organic origin, as shown by its abundant fossils and its carbon, but its calcite has crystallized without the aid of great compression and mainly as a result of chemical processes. The crinoids, gastropods, etc., still retain their forms, but their calcareous parts have been dissolved and redeposited as crystalline calcite and their internal cavities have also been filled with it or with the original fine calcareous sediment which has also been redeposited in crystalline condition. The geology of this marble has been described by Vermont geologists.[1]

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 776-778. Brainerd, Ezra, The Chazy formation in the Champlain Valley: Bull. Geol. Soc. America, vol. 2, 1891, pp. 297-298. Perkins, G. H., First Rept. State Geologist, 1898, pp. 40-42; Second Rept., 1900, p. 31; Sixth Rept., 1908, pp. 22-23, Pl. VI.

The fresh rock has an extremely dark gray ("black"), finely crystalline surface, but it weathers a dark bluish gray, in places with fine brownish-gray streaks parallel to the bedding. A typical thin section of it is shown in figure 9. In some thin sections it consists of small irregular, finely granular but crystalline masses in a matrix of coarse and crystalline particles of calcite throughout which dolomite rhombs are more or less thickly disseminated. In others it consists of irregular bands of dolomite in rhombs measuring from 0.025 to 0.1 millimeter, alternating with bands of fossiliferous granular limestone in which most of the grains are crystalline untwinned calcite. There are some dolomite rhombs, however, both in the fossils and in the granular calcite. Some dolomite rhombs occur in the central tubes of crinoid stems which are twinned dolomite or calcite, probably the latter. The rock contains a few grains of quartz, carbonaceous particles, and spherules of pyrite oxidizing to limonite.

A bed of very dark brownish crinoid limestone shows in thin section crinoids and other fossils changed to twinned calcite lying in a matrix of extremely fine grained, in places pyritiferous material containing dolomite rhombs. Some of the dolomite rhombs lie in meandering fractures and carbonaceous streaks within plates of calcite.

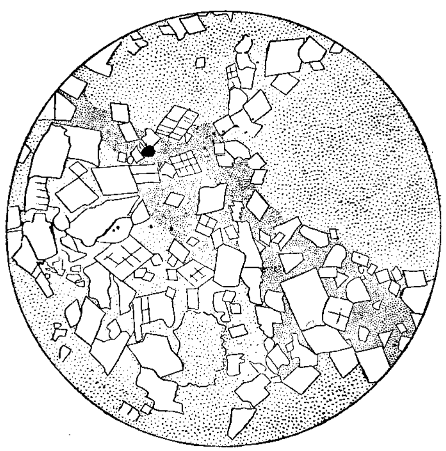


FIGURE 9.—Thin section of carbonaceous unmetamorphic calcite marble from Isle la Motte, showing dolomite crystals in groundmass of fine-grained, obscurely crystalline limestone. The darker parts are more carbonaceous; black particles are pyrite.

An analysis of the marble from Isle la Motte by Olmstead, published by Hager[1] in 1858, shows a small percentage of magnesium carbonate.

*Analysis of "Isle la Motte black marble."*

| | |
|---|---|
| Calcium carbonate ($CaCO_3$) | 87.94 |
| Magnesium carbonate ($MgCO_3$) | 4.56 |
| Alumina and iron sesquioxide ($Al_2O_3$, $Fe_2O_3$) | 2.60 |
| Insoluble, mostly silica ($SiO_2$) | 4.80 |
| Water ($H_2O$) and loss | .10 |
| Manganese oxide (MnO) | Trace |
| | 100.00 |

[1] Hager, A. D., The marbles of Vermont, 1858, p. 6.



## "MANCHESTER BRECCIA."

A "breccia" is a rock which has been more or less crushed by crustal movement but the particles of which have been recemented together by minerals deposited by percolating solutions. A breccia can always be distinguished from a rock made up of waterworn pebbles by the angularity of its particles. Breccias from the very mode of their origin are weak, and even when used for decorative purposes usually have to be fortified by cementing them at the back to slabs of solid marble or slate. Some of the most attractive imported marbles are breccias from Italy and North Africa.

Aside from the dolomite and calcite marble breccia on the west side of Pine Hill, in Proctor (p. 24), and an outcrop in Sudbury (p. 134), the only marble breccia yet known in Vermont is that in Manchester, 2 miles S. 10° E. from the top of Mount Equinox. (See p. 91 and Pl. I).

A photograph of a polished specimen of this marble breccia is reproduced in Plate VII, *B, a*. The cement is brick-red and the fragments, of very unequal size, are of three sorts—(1) a light-pinkish or cream-colored calcite marble with a grain diameter from 0.05 to 0.37 millimeter and the long axes of the grains parallel, containing a little sericite and some quartz grains; (2) a deep-reddish hematitic dolomite marble, containing some calcite, with a grain diameter averaging roughly 0.09 millimeter, some of the particles veined with quartz; and (3) a light bluish-gray calcite marble with a grain diameter from 0.12 to 0.5 millimeter. The cement owes its bright-red color to hematite stain proceeding from particles of magnetite. It contains many very minute particles of the three kinds of marble in the breccia, and calcite plates, quartz grains, up to 0.2 millimeter, and rarely a feldspar grain (microcline). It owes its cementing property to calcite and hematite.

The rock takes a good polish but like other breccias needs to be fortified. Some of the fragments in it are so large as to deprive the rock of that degree of uniformity which would make it all of commercial value.

## SERPENTINE OF ROXBURY.

The serpentine of Roxbury[1] is a marble only in a commercial sense. Roxbury is on the east side of the Green Mountain axis, in Washington County, 14 miles southwest of Montpelier. The quarry is about half a mile south of the station, on the east side of a north-south ridge. The serpentine there is 50 to 60 feet

[1] See Hitchcock, Edward, and Hager, A. D., Geology of Vermont, 1861, vol. 1, p. 543; vol. 2, p. 780; also the following reports of the State geologist: First, 1898, pp. 37, 38; Second, 1900, p. 56; Third, 1902, pp. 89, 90; Fifth, 1906 (Marsters, Origin of serpentine), pp. 53-61; Sixth, 1908, p. 31; Seventh, 1910 (Richardson, Serpentine), pp. 318, 319.

wide, dips 45°-65° roughly west, and is reported to continue for several miles in a north-northwest to south-southeast direction, with varying width but in places tapering out altogether. It is in contact on the east with a schist whose foliation strikes N. 15°-20° W. and dips from 65° N. 73° E. to vertical, and on the west with a similar schist whose foliation has about the same strike but dips 65°-70° W. These rocks, in thin sections, are found to be chlorite or chloritized biotite schist with epidote, calcite, and rarely muscovite, also tremolite schist with chlorite. The tremolite schist is on the west side. These schists may be altered eruptives. Their poverty in quartz is significant.

Dark colored serpentine is a hydrous silicate of magnesia and iron. Some serpentines are of metamorphic sedimentary origin; others are metamorphosed eruptive rocks, and to this class that of Roxbury probably belongs. The nature of the original dike rock is uncertain. It may easily have been peridotite, which has a large content of magnesia and iron oxides. The serpentine in thin section shows a fibrous and radial texture with veinlets of magnesite and talc and with large particles of magnetite, which also appear on the polished face. The rock is of dark purplish or greenish color in the mass and is plentifully veined with white magnesite. Polished faces are almost black but crossed by a network of veins and veinlets of white and of light green wherever the magnesite is mingled with the serpentine. As many of these veins are faulted and sheared, the rock has evidently since its alteration to serpentine been subjected to compression. These sheared veins in thin sections show alternating blades of magnesite and foliated serpentine bent at right angles to the direction of the vein, forming "shear zones" like those in slates.

It is uncertain when the rocks on either side of the serpentine acquired their schistosity. Some of their minerals probably originated in emanations from the dike material, now serpentine, and are due to the heat accompanying the intrusion.

The serpentine of Roxbury takes a fairly good polish and its striking contrasts of shade and color and the irregularity of its veining make it a very attractive ornamental stone for interior work. (See Pl. VIII, *A, a*).

## CHROME MICA SCHIST OF SHREWSBURY.

The newly discovered green "marble" of Shrewsbury is a chrome mica schist and is included among marbles for commercial reasons only. It occurs in a small saddle on the north side of Round Hill, on the west flank of the Green Mountain range, 3¾ miles southeast of the Rutland station and about 900 feet above it, in the northwestern part of Shrewsbury Township. The schist, which is about 100 feet thick, strikes N. 15°- 30° W., dips steeply east, and probably belongs in the Lower Cambrian schist. The discoverer and prospective operator is Edward H. Foley, 147 South Main Street, Rutland, Vt.



The schist in the rough has a bright verdigris-green to faintly greenish gray color. Its luster ranges from glistening to waxy and its texture is foliaceous and plicated. The polished stone has a brilliant dark emerald-green color varied with fine streaks, more or less plicated, of lighter green. It resembles talc in places but is considerably harder. J. S. Diller and W. T. Schaller, of this Survey, find that it consists largely of chrome mica (fuchsite) with some chlorite, quartz, and tourmaline, and the writer finds also magnetite present.[1]

The brilliant green color and high polish of this stone make it very suitable for internal decoration. Its commercial value will depend on the size and soundness of the blocks obtainable.

The fuchsite schist is cut by a 5-foot dike of rhyolite porphyry, somewhat micasized and kaolinized, of light-grayish color at the surface and stained with limonite. On the west side of the schist is a quartz vein with a little pyrrhotite (magnetic iron pyrites).

## MICROSCOPIC TEXTURE OF THE CALCITE MARBLES.

### GRAIN FORM.

The grains of calcite in calcite marble never show crystallographic outlines. Their forms are altogether irregular, being bounded, as seen in cross section, by irregular curves or straight lines making reentrant or projecting angles which are usually obtuse. Only where calcite and dolomite grains are mixed do the calcite grains appear to have jagged or denticulate outlines. The grain form in some of the typical Vermont marbles is shown in figures 13, 15, 16, 21, and 24, pages 93, 102, 112, 129, 135.

In beds which have suffered much compression the grains are very perceptibly elongated in at least one direction and probably in two. This is shown in figures 6 and 22 (pp. 34 and 131). This grain elongation characterizes the muscovitic marbles on both sides of the West Rutland anticline. The effect is to give a degree of schistosity to the marble, so that it breaks more readily along the bedding plane.

As has already been explained (p. 24) the clouded marbles are marked by fine passages or lenses of untwinned grains of dolomite marble which are in general not only very much smaller

[1]Fuchsite is briefly described in E. S. Dana's Descriptive mineralogy, 6th ed., 1892, p. 616. It was first described by Schafhäutl, who examined some from Schwarzenstein, in the Zillerthal, Tyrol, and gave its composition as follows: $SiO_2$, 47.95; $Al_2O_3$, 34.45; $Fe_2O_3$, 1.80; MgO, 0.72; $K_2O$, 10.75; F, 0.35; $Cr_2O_3$, 3.95; $Na_2O$, 0.37; Ca, 0.42; total, 100.76. Its content of chrome sesquioxide, to which it owes its brilliant color, is thus only 3.95 per cent. Schafhäutl, in 1843, described another chrome mica with 5.91 per cent of $Cr_2O_3$. For analysis of a fuchsite from Montgomery County, Md., by T. M. Chatard, see Bull. U. S. Geol. Survey No. 419, 1910, p. 286, analysis J. This specimen contained only 2.03 per cent of $Cr_2O_3$.

in diameter than the calcite but of more regular outline and here and there of crystallographic (rhombic) form. The marbles of the Clarendon Valley, Landon, and Hollister quarries show this feature. (See pp. 112, 128, 130).

### GRAIN DIAMETER.

In measuring the diameters of the grains in thin sections for this bulletin the method followed has been first to measure the smallest and the largest particle, then to note the general maximum and minimum diameter. The actual minimum differs far less in most of the marbles than the maximum, so that an average based on it is misleading. In a few of the more even-grained marbles the average grain diameter has been obtained by the Rosiwal method. This average appears to be always less than the average of the general maximum and minimum estimated with the micrometer.

The most noticeable fact as to the grain diameter of Vermont marbles is the coarseness of some and the fineness of others. The Danby and Dorset constructional marbles (Dorset Mountain and Green Peak types) have a grain diameter from 0.05 to 1.5 millimeters, mostly 0.12 to 0.5, and an average diameter from 0.20 to 0.24 millimeter, or 0.005 inch. At the other extreme the statuary marble of both sides of the West Rutland anticline and at the Goodell quarry, in Brandon, has a grain diameter of 0.02 to 0.5 millimeter, mostly 0.07 to 0.16, averaging 0.1 millimeter or about 0.0025 inch. Furthermore, about half a mile southeast of the village of Sudbury, about 5½ miles west of Brandon, is an outcrop of light bluish gray calcite marble, probably of no commercial value, in which the grain diameter ranges from 0.02 to 0.2 millimeter, mostly from 0.05 to 0.1, averaging probably about 0.05 millimeter, or 0.0013 inch—that is, about half the grain diameter of the statuary "Rutland."

The other marbles fall naturally into two intermediate groups —one of finer grain, comprising marbles like those of Middlebury and Brandon, the "second statuary" of West Rutland, and bed F (cream) of the Eastman quarry, having extremes of 0.02 to 0.75 millimeter, mostly 0.1 to 0.25, and averaging about 0.12 millimeter, or 0.003 inch; and one of coarser grain, comprising marbles like those of the True Blue, Shangrow, and several of the beds of the Eastman quarry, with grain diameters from 0.12 to 0.75 millimeter, mostly 0.12 to 0.37, and some of the beds of the Hollister quarry and the Pittsford and Brandon "Italian" marbles, with grain diameters of 0.05 to 1 millimeter, mostly 0.12 to 0.5. These coarser marbles together range mostly from 0.12 to 0.31 and average 0.15 millimeter, or 0.004 inch.

Another noticeable textural feature is the great variation in regularity or evenness. The "True Blue" and "statuary Rutland" are even textured, but the "mahogany bed" of the Freedley quarry on Dorset Mountain, the "Pittsford Italian" the "Brandon Italian," and the "Clarendon" are uneven. The most irregular in grain diameter is the fossiliferous graphitic marble of the Day lime quarry, in Ira, which has a range from 0.02 to 2 millimeters. This subject will be further considered under the next heading.



### GRAIN ARRANGEMENT.

As shown in the drawings (figs. 13, 15, 16, 21, and 24, pp. 93, 102, 112, 129, and 135), many of the marbles show no arrangement of their particles. This absence of arrangement is as characteristic as the irregularity of grain form.

Where the grains are elongated there is generally a parallelism between the long axes of the different grains, and it is this arrangement which imparts a slight schistosity to the marble. This parallelism characterizes many of the muscovitic marble beds but is not confined to them. (See figs. 6 and 22, pp. 34 and 131).

The marble quarried for lime at Leicester Junction consists of fine and coarse grains in alternate parallel bands averaging about 0.05 millimeter in width. The larger grains are from 0.04 to 0.09 millimeter long and the smaller ones 0.009 to 0.03 millimeter in diameter. (See fig. 25, p. 142).

On the other hand, the marble of the "mahogany bed" at the Freedley quarry, on Dorset Mountain (p. 100), consists of large plates measuring 0.02 to 1.25 millimeters, mixed with small ones of 0.07 to 0.25 millimeter, without any arrangement whatever. The same irregularity of size but not of arrangement appears in the section of "Brandon Italian" shown in figure 22 (p. 131).

In the clouded marbles (Hollister, Landon, Florence No. 2, etc.), which contain lenses and little plicated beds of dolomite grains in a mass of calcite grains, and also in some of the banded graphitic marbles (Clarendon) the grain arrangement is chemical and stratigraphic.

The arrangement of grains is affected not only wherever the beds have been elongated in folding but also at the intersections of plicated beds and planes of slip cleavage, as in the marble of the Albertson quarry (Pl. VIII, *B*, *b*).

### COMPARISON WITH EUROPEAN MARBLES.

Vogt[1] classifies Norwegian and European marbles in six textural groups, as follows:

1. Entirely compact (extra fine grained) with a grain diameter of mostly 0.02 to 0.03 millimeter (Värra, near Trondhjem), and almost entirely compact, 0.03 to 0.06 millimeter (Carrara "white P").

[1] Vogt, J. H. L., Der Marmor: Zeitschr. prakt. Geologie, 1898, p. 12.

2. Very fine grained, 0.1 to 0.3 millimeter (Carrara, ordinary).
3. Moderately fine grained, 0.25 to 0.75 millimeter (Carrara, statuary).
4. Slightly coarse, 0.75 to 1 millimeter.
5. Moderately coarse, 1 to 3 millimeters (most of the Norwegian marbles).
6. Very coarse, 2 to 5 millimeters.

In comparing Vermont marbles with this classification the "statuary Rutland" and "second statuary Rutland" belong in group 2; the Florence No. 2, "light Rutland Italian," "brocadillo," "Pittsford Italian," and some of the beds of the Hollister quarry belong in group 3; and the "Dorset" and "Danby" marbles belong in group 5.

The measurements of ancient Greek marbles made by Lepsius (pp. 18, 19) are here summarized and referred to Vogt's scale:

*Classification of ancient Greek marbles according to grain diameter.*

| | Diameter in millimeters. | | Scale No. |
|---|---|---|---|
| | Average. | Maximum. | |
| Hymettos (excluding fine grains of groundmass) | Under 0.5 | 0.8 | 3 |
| Doliana, Sunium, white Pentelicon (groundmass excluded) | 0.5-1 | 2-4 | 4 |
| Parian (no groundmass) | 1-1.5 | 5 | 5 |
| Naxos (exclusive of fine-grained groundmass, small in amount) | 2-4 | 8 | 6 |

## GRADES OF TEXTURE.

In grading the marbles of western Vermont by texture alone the simplest system appears to be to divide them into five grades defined by the maximum grain diameter in connection with the average grain diameter, and to refer each grade to a well-known type or types. To these five grades a sixth has been added in the table below to cover a very coarse Massachusetts marble, which has also been found in eastern Vermont.

In this scheme the Parian statuary (p. 18) would belong in grade 6, the modern commercial Pentelicon (p. 18) in grade 3, and the Carrara ordinary (p. 46), the Laas statuary (Tyrol), and the dolomite marbles of Lee and Ashley Falls, Mass., in grade 4.



*Classification of Vermont marbles by grades of texture.*

| Grade. | Grain diameter. | | | | Grade types. |
|---|---|---|---|---|---|
| | Maximum (millimeter). | Average (millimeter). | General average. | | |
| | | | Millimeter. | Inch. | |
| 1. Extra fine | 0.2 | 0.05-0.10 | 0.06 | 0.0023 | Dolomite marbles of Swanton, Sudbury outcrop of calcite marble, dolomitic lenses in mottled calcite marbles. |
| 2. Very fine | .5 | .07- .16 | .10 | .0039 | "Statuary Rutland," Goodell quarry, Brandon. |
| 3. Fine | .75 | .10- .25 | .12 | .0047 | "Second statuary Rutland," bed IJ of Eastman quarry. |
| 4. Medium | 1.0 | .12- .31 | .15 | .0059 | "Brandon Italian," "True Blue," bed K of Hollister quarry, excluding dolomite streaks. |
| 5. Coarse | 1.5 | .20- .60 | .24 | .0094 | "Dorset A," "White Stone Brook," Dorset Mountain. |
| 6. Extra coarse | 2.54 | .30-1.35 | .50 | 0.196 | Adams, Mass., and eastern Vermont. |

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## THE MARBLE BELTS OF WESTERN VERMONT.

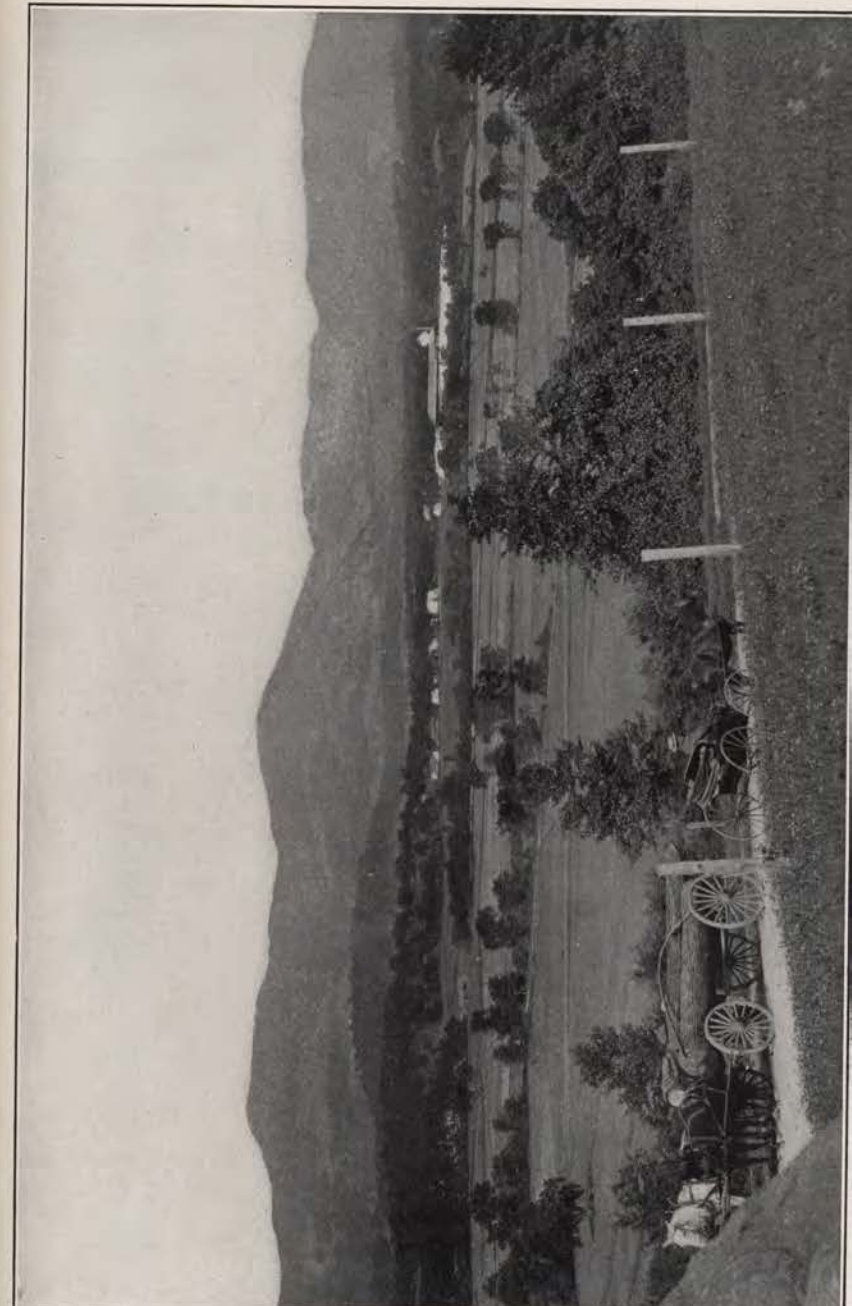
### PHYSIOGRAPHY.

Before considering the geologic relations of the marble beds of western Vermont it may be useful to recall the surface features of this part of the State, which are somewhat complex.

Beginning at latitude 44° 15′, or about 15 miles south of the latitude of Burlington, near the Addison-Chittenden county line, the west flank of the Green Mountain range lies near longitude 73° 5′ and extends thence southward with minor deviations for 36 miles to Coxe Mountain, a little north of Pittsford village, about latitude 43° 44′ and longitude 73° 3′. From this point the range curves eastward, forming an embayment that is 6 miles wide near Rutland, where it reaches longitude 72° 56′. This embayment extends 43 miles south from Coxe Mountain, gradually curving westward to the Manchester-Sunderland line, where the west flank is again at longitude 73° 5′. From that line it curves 3 miles farther west in a distance of 8½ miles and reaches longitude 73° 9′ near the Shaftsbury-Glastenbury line. The length of the flank of the range here considered is thus 87½ miles.

West of the Green Mountain range and 3 miles southwest of Brandon village, at about latitude 43° 46′ and near longitude 73° 7′, is the north end of the Taconic range, which extends with a course more or less parallel to that of the Green Mountain range to latitude 43°, the south limit of the area under consideration, near the Arlington-Shaftsbury line and beyond. The valley between these two ranges, known as the Vermont Valley, varies greatly in width, being 4 miles wide near Manchester, 2 miles near Brandon, but in places between East Dorset and Danby only one-fourth of a mile. This narrowing is due to the fact that for 6 miles, between the Manchester-Dorset line on the south and lati-

PLATE IX.



tude 43° 20′ on the north, the Taconic range widens out eastward for 5 miles in the Dorset Mountain mass, which rises to an altitude of 3,000 feet above the valley bottoms. Opposite the Rutland embayment there is a minor range between the Taconic and Green Mountain ranges. This intermediate range begins with Pine Hill, in Proctor, 945 feet above the valley (latitude 43° 40′), and extends 23 miles south to Danby Hill, 1,500 feet above the valley, a little north of Dorset Mountain (latitude 43° 20′). The width of this range is from 1½ to 2½ miles, averaging about 2 miles.

North of the north end of the Taconic Range the surface between the Green Mountain range and Lake Champlain presents only minor irregularities, but between Middlebury and Monkton (latitude 44° 3′ and 44° 15′) and to the west Snake, Buck, and Hogback mountains rise 700 to 900 feet above the valleys.

The longest marble belt lies partly in the Vermont Valley, between the Green Mountain and Taconic ranges, and partly between the Taconic Range and the intermediate range from Pine Hill to Danby Hill. It also extends north of the Taconic Range, ending between Middlebury and Bristol, and its total length from north to south is about 80 miles.

Beginning in the northern parts of Charlotte and Hinesburg and extending north into Shelburne, Burlington, and Colchester, according to the Vermont report of 1861, is another marble belt, which, however, is not considered in this bulletin. One or two quarries were once opened in it.

Within the Taconic Range itself west of Rutland is still another marble belt, 6 miles long and half a mile wide, occupying a minor longitudinal valley, through which Castleton River flows in the north-south part of its course. This is the West Rutland belt of marble.

At several other points within the Taconic Range, north and south of this minor belt, there are small marble areas which will be considered more fully beyond. Most of these geographic features are shown on the map (Pl. I; see also Pl. IX).[1]

## AREAL GEOLOGY.

The geologic map (Pl. I) shows the probable areal distribution of the geologic formations which include or are closely related to the marble areas. Such maps represent the general character of the rock surface as it would probably appear if divested of sand, gravel, clay, soil, marsh, and vegetation.

[1] The surface features of nearly all this territory and their relations to the calcareous rocks which include the marbles are shown in the colored relief map, Plate I, of Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905, also a view of the Vermont Valley in Plate IV of the same bulletin. Plate LXVI of the Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, shows views of the three ranges referred to, and Plate LXX the north face of Dorset Mountain.

The rocks of the Green Mountain Range on the east include various gneisses, mostly of igneous origin, mantled on the west side by a belt of quartzite and schist, which prior to metamorphism consisted of sandstone and shales that in turn were originally marine deposits of sand and clay. This formation of quartzite and schist passes under the Vermont Valley and reappears on the intermediate ridge. On the west it is succeeded by a belt of more or less quartzose dolomite, associated in places with quartzitic beds. This extends along the valleys and immediately underlies the belt of calcite marble. To this formation belong the dolomite marbles of Pittsford and East Monkton, described on pages 39-40. Then follows the marble belt proper, consisting of beds of calcite marble alternating with beds of dolomite and in places of graphitic mica schist. The localities where marble has actually been observed, whether of commercial value or not, are indicated on the map by a special symbol and so are also the marble quarries in operation and most of the idle ones. The direction of the dip of the beds is also shown by symbols.

Overlying the marble on the west side of the Vermont Valley is a great mass of schist, a roughly slaty rock, consisting mainly of fibrous white mica and quartz, together with the soda feldspar (albite), graphite, chlorite, pyrite, etc. It includes here and there small beds of quartzite, originally sandstone, of fine quartz conglomerate, and of more or less crystalline limestone, and is generally veined with quartz and contains many quartz lenses. These schists were originally clays of marine deposition brought into the sea by rivers from the erosion of granitic and other rocks on the east. When the calcareous sediments of the underlying series were metamorphosed into marble these clays passed into mica schists and the small sandy beds into quartzite. These schists constitute the considerable mountains of the Taconic Range—Dorset, Bear, Equinox, Red, and Grass mountains and Green Peak.

It will be observed from the contours of the map that the boundary between the marble and the schist in the towns of Dorset and Manchester runs at a considerable elevation, being in places at the 2,000-foot and in others even at the 2,500-foot contour, or from 1,350 to 1,850 feet above the valley bottom. The intricate course of this boundary, as shown on the map, is due to the fact that the schist once completely covered the marble area and has been unequally eroded from it. It will be noticed that the reentrant angles in the boundary line generally follow the courses of the streams. This is because the streams have, as it were, eaten their way in the long lapse of time through the schist capping down into the underlying marble. This is a marked feature of the boundary about Dorset, Equinox, and Red mountains. The triangular schist capping of Green Peak in Dorset is a remnant of the schist mass which once connected Dorset and Equinox mountains and filled the Vermont Valley. In the same way the west Rutland belt of marble has become exposed by the erosion of the schist mass which once overlaid it, and so has the small marble area 4 miles north-northwest of it. Between Proctor village and the West Rutland belt of marble are several small marble outcrops which indicate either the presence of small calcareous beds within the schist or else the thinness of the schist mass along a north-northwest line about half a mile east of Castleton River. But the little marble area in Ira seems to be an exposure of the marble series itself.



Attention should be called to a simple but important feature of the marble belts—that the upper part of the marble will always be found, except where faulting has occurred, next to the schist and the lower part next to the underlying dolomite. At the present time the most productive quarries are near the schist.

Finally, where two formations which do not follow one another in the natural order of superposition are brought together at the surface, as shown by a geologic map, a fault or fracture along which one or the other has ridden up or down must have occurred to cause the anomalous juxtaposition. Such faults abound on the intermediate range. There is one at its south end between Danby Hill and Dorset Mountain. Another begins on Clark Mountain and extends to Pine Hill, Proctor, and beyond, bringing the quartzite that underlies the dolomite to the level of the schist that overlies the marble. But these faults have no immediate bearing on the economic geology of the marble belt.[1] Two others, however, not shown on the map because of their uncertain course, do affect the marble belt and will be referred to under "Structural relations" (pp. 84, 87).

## THE STRATIGRAPHIC SUCCESSION.

Next in importance to determining the boundaries of the marble areas and of the contiguous formations is to ascertain the probable thickness of these formations and to refer them to their respective geologic systems.

The older gneisses of the Green Mountain range have little to do with the marble, and the overlying quartzites and schists not much more. A measurment of the latter on Bald Mountain near Bennington amounts to 1,600 feet, and it is all of Lower Cambrian age. The thickness of the overlying dolomite is still uncertain. It can not be less than 500 feet and may in places be much more. The discovery of Lower Cambrian fossils by Wolff and Foerste in 1890 on the east side of the intermediate range, about 1½ miles north of Rutland, near East Creek, opposite the

[1] These faults are described in detail in the writer's paper On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 525-549.

Baxter farm, in dolomite 500 feet east of the quartzite, fixed the age of the lower 300 feet of the dolomite.[1]

Measurements made in 1891 by the writer near Chippenhook, in Clarendon, along the axis and on the west side of the intermediate range, showed that the dolomite and marble together measure there about 1,200 feet, of which at least the lower 470 feet is mostly dolomite and of Lower Cambrian age.[2]

A measurement made by the writer in 1903 across the syncline of the dolomite cut by Sucker Brook east of Lake Dunmore gives it an approximate maximum thickness of 765 feet.

One estimate of the thickness of the dolomite and marble is 1,200 feet; from this deducting 500 feet for the dolomite would leave 700 feet for the marble. Another estimate made near North Adams, Mass., between the north end of Mount Greylock and the base of the Green Mountain range—that is, between the schists over the marble and the quartzite below the dolomite and marble—yielded 1,400 feet for both; allowing 500 feet for the dolomite would leave 900 feet for the marble.[3] Another estimate, made between the top of Cambrian quartzite at the north foot of Danby Hill and the base of the schist on the northeast shoulder of Dorset Mountain, gives 1,400 feet for the entire thickness of both, divided about equally between the dolomite and the marble. Hitchcock and Hager[4] estimated the thickness of both on Green Peak (Mount Eolus) as 1,970 feet, of which they assigned 707 feet to the marble and 1,263 feet to the dolomite ("limestone"); but as the actual vertical distance between the valley floor at East Dorset (788 feet) and the base of the schist cap (2,500 feet; see contours on geologic map, Pl. I) is 1,712 feet, only 1,005 feet should be assigned to the dolomite, and that figure should be further reduced to allow for the folding in the Vermont Valley.

An estimate by F. H. Moffit, based on the map and his barometric observations at the same locality, makes the thickness of the marble from the dolomite below the Folsom & Kent (now Blue Ledge) quarry to the base of the schist about 500 feet.

The marble has been shown by the investigations of Wing and others to include beds of Chazy age and probably some of Trenton age above them and possibly some of Beekmantown age below them. There is, however, a question as to whether any or how much of the dolomite is of Beekmantown age. As this formation along Lake Champlain is largely dolomite, it would naturally be sought among the dolomite beds of the Vermont Valley. Seeley[5] is inclined to correlate some if not the whole of the dolomite with the Beekmantown.

[1] See Wolff, J. E., On the Lower Cambrian age of the Stockbridge limestone: Bull. Geol. Soc. America, vol. 2, 1891, pp. 331-338.

[2] Dale, T. N., On the structure and age of the Stockbridge limestone in the Vermont Valley: Bull. Geol. Soc. America, vol. 3, 1892, p. 514; Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 540, 541, 549, Sections A, I, Pls. LXVII, LXVIII.

[3] See Mon. U. S. Geol. Survey, vol. 23, 1894, p. 190.

[4] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 1, 1861, pp. 417, 418, fig. 264.

[5] Seely, H. M., Preliminary report on the geology of Addison County: Seventh Rept. State Geologist, 1910, p. 257, Pl. XLVIII.

*Stratigraphic table of the marble areas and adjacent formations.*

| Map symbol. | Formation. | Rock characteristics. | Geologic age. | Approximate thickness. |
|---|---|---|---|---|
| | | | | *Feet.* |
| Ob | Berkshire schist. | Greenish (chloritic), purplish (hematitic and chloritic,) black (graphitic and chloritic) fibrous muscovite (sericite) schist, with quartz, soda feldspar (albite), pyrite, magnetite, pyrophyllite, in places speckled with actinolite. Much quartz in lenses and blades containing chlorite and siderite ($FeCO_3$) more or less altered to limonite. This schist is interbedded with quartzite (much of it chloritic) in small beds (in a few places with chalcocite ($CuS_2$), siderite, and pyrophyllite). These quartzite beds in places attain 10, 15, 20, or 35 feet in thickness. Within them or separate are beds of conglomerate 1 to 2 feet thick, with pebbles of blue quartz up to three-fourths inch in diameter. The schist is also interbedded here and there with small beds of more or less quartzose dolomite and more rarely with a few feet of bluish calcite marble. The schist is almost everywhere finely plicated, with ensuing slip cleavage, which in many places is so pronounced as to obscure the bedding foliation, and this cleavage itself may in turn have become plicated. Near its contact with the marble the schist is generally graphitic. | Ordovician, probably Upper and Middle (Trenton) Ordovician. | 2,000-2,500 |
| Om | Marble | Alternating beds of calcite marble of various grades of texture, white, gray (graphitic), greenish banded (muscovitic, actinolitic), interbedded with bluish or grayish untwinned dolomite, and with muscovite schist in small beds, in places graphitic and up to 40 feet thick. Some of the marble beds are very quartzose and muscovitic. The uppermost part of the marble is generally more or less graphitic, and therefore of various shades of bluish gray. (See for details p. 96.) | Trenton, Chazy, and Beekmantown(?) | 500-900 |
| Cd | Dolomite | Thin-bedded crystalline untwinned dolomite, fine grained (grain diameter 0.009 to 0.17 millimeter), generally more or less quartzose, white, grayish, dove, cream, or ivory colored (pyritiferous or pinkish hematitic), with many intersecting microscopic joints or quartz veinlets along which the surface weathers in grooves. The pink and cream-colored beds have a brownish weathered surface. Small beds and films of fibrous muscovite schist are common in these dolomite beds. Some of the dolomites, such as the light-gray bed just under the marble at Proctor, consist of dolomite plates, some of which are twinned (grain diameter up to 0.45 millimeter), crowded with dark granules, lying in a matrix of smaller untwinned clear dolomite grains. A black and gray graphitic dolomite in Proctor (p. 128) consists of dolomite plates, some of them twinned, with a grain diameter up to 0.25 millimeter, and graphite in minute bands. (For details as to these dolomites see pp. 46-47.) Near the top of the dolomite and exposed for one-fourth mile on the west side of the intermediate range in West Clarendon (half a mile northeast of Tinmouth River bridge) is a 25-foot bed of dark-gray graphitic dolomite filled with fossil pteropods (Hyolithes) and oolitic nodules up to three-fourths inch in diameter. Each nodule has a pteropod shell as a nucleus. On a polished surface the pteropod sections appear as small white triangles and cones. (See Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 534, fig. 54, and polished specimen in U. S. National Museum.) The base of the dolomite as exposed in Sunderland consists of thick beds of quartzite alternating with quartzose, dolomite, fibrous muscovite schist, calcareous quartzite, and exceptionally a few feet of calcite marble. Some of these beds are pyritiferous, and some of them were evidently derived from a mixture of calcareous, quartzose, and argillaceous material. Some of the lower dolomite beds in Sugar Hollow, Brandon, carry small pebbles of fresh purplish potash feldspar and of quartz; and 2 miles south of Silver Lake, in Leicester, the lower beds contain a little metallic and red hematite, the latter in small lenses of concretionary or organic origin. Galenite and zinc blende have been prospected in the dolomite 2½ miles north of Brandon. | Beekmantown(?) and Lower Cambrian. | 500-800 |
| Cq | Quartzite and schist. | Largely quartzite (metamorphic sandstone), more or less feldspathic and micaceous, with some beds of conglomerate containing pebbles of blue quartz and of gneiss, in places attaining large dimensions.* Interbedded and in places possibly interfolded with these quartzites are various schists and in a few places small beds of dolomite. Some of these schists are coarse biotite-quartz schist, others are muscovite (sericite)-chlorite schist with abundant magnetite, others are very fine grained dark biotite-sericite schist banded with minute quartz and feldspar grayish beds. Generally the dark schist is biotitic, whereas the dark schist of the Ordovician (Berkshire) is graphitic. | Lower Cambrian | 1,600 |
| gn | | Gneiss of Green Mountain range | Pre-Cambrian | |

*See Dale, T. N., The Cambrian conglomerate of Ripton, in Vermont: Sci., Am. Jour. 4th ser., vol. 30, 1910, pp. 267-270, figs. 2, 3.

The thickness of the marble as obtained from the records of drill cores and from sections at the quarries (pp. 80, 82, 87, 89) ranges from 335 to 851 feet, measured from the base of the schist downward. A fair average of all the estimates is 663 feet.

The question as to the presence of the Middle and Upper Cambrian in the dolomite can not be discussed here. Thus far no fossils typical of these time divisions have been found in either the dolomite or the marble of the Vermont Valley. From what is known of the Ordovician formations about the Adirondack Mountains and on Lake Champlain it seems probable that the total thickness of the dolomite and marble, after deducting the Lower Cambrian part of the dolomite, is inadequate to fully represent Beekmantown and Chazy time, and that for this reason the two must include some intervals of extremely slow deposition or of nondeposition.

The schist which overlies the marble has been found to range between 2,000 and 2,500 feet in thickness at several points in the Taconic Range in Massachusetts and Vermont. It is in many places much thinner than this, owing to erosion. Its age is regarded as Middle (Trenton) and Upper Ordovician.

The preceding table is based on the foregoing more or less incomplete data. For each of the formations is given a condensed summary of its rock characteristics. The symbols in the first column correspond to those used on the geologic map (Pl. I).

## STRUCTURE OF THE MARBLE BELTS.

### ORIGIN.

All the materials which now constitute these different series of rocks must, from their parallelism, as far as observations to the present extend, be supposed to have been originally laid down in the sea in horizontal position. Their present generally inclined attitude and incomplete extension are explained by two important events.

1. In consequence of a powerful crustal contraction at the close of Ordovician time, operating mostly in a west-northwest to east-southeast direction, the sediments not only became crystalline, but were intensely folded and in places faulted. It will be noticed from the geologic map (Pl. I) that in the southern part of the marble belt (Arlington, Sunderland, and Manchester) the Vermont Valley and the axes of the folds (strike) have a general north-northeast trend; that in Dorset, Danby, Tinmouth, and Clarendon their trend is more nearly north; that from a point a little north of the Clarendon-West Rutland line the trend changes to north-northwest, and so continues to the north end of the Taconic Range, in Brandon; and that from there on it is again nearly north.



2. During the lapse of ages the crests of these folds have become eroded by atmospheric acids and stream action, so that the schist mass has been removed from the tops of the marble folds and in one place even from the trough of the fold. This erosion has also in places penetrated the underlying marble and thus exposed the dolomite.

### GENERAL SECTIONS.

The three general sections on Plate II show the approximate original outlines of these folds and the portions left by erosion. The location of these sections is shown by numbered lines on the geologic map (Pl. I).

Section I runs from a point a mile north of Center Rutland west-northwestward to the top of the Taconic Range, near the Castleton town line. Beginning on the east, it crosses the fault on the intermediate range which begins on Clark Mountain, in Tinmouth, and extends nearly to or possibly beyond the Pittsford-Chittenden line. By this fault the schist and quartzite of the Lower Cambrian have been thrust over the Ordovician (Berkshire) schist, which forms the west side of Pine Hill and which there overlies a narrow belt of marble. This hill is a syncline (trough). The section crosses Otter Creek Valley, which here corresponds to a complex anticline (arch), the dolomite appearing in the center with the marble on both sides. The schist ridge between the West Rutland (Castleton River) Valley and Center Rutland-Proctor (Otter Creek) Valley is a complex syncline. The next section crosses the West Rutland Valley at the Albertson quarry. This valley is an anticline of marble from which the schist has been eroded. The same anticline reappears in the small marble area east of Biddie Knob and 1½ miles west of Fowler. On the west side of the West Rutland Valley the marble dips west under the Berkshire schist, which forms the synclinorium of the Taconic Range. The dolomite is probably not far below the marble floor of the West Rutland Valley.

Section II, made by F. H. Moffit, begins at the east foot of Clark Mountain, in Tinmouth, runs nearly west-northwest, passing about half a mile north of Tinmouth Pond, and extends to the Wells township line. The east side of Clark Mountain is a trough of Berkshire schist underlain by the marble. The fault passes near the top of the mountain, where the Lower Cambrian quartzite and schist have been thrust up, so as to be in contact with the Berkshire schist. West of this the folds are again normal. The quartzite near Tinmouth Pond dips west under the dolomite of the central part of the valley. There must be an anticline on its west side. The marble beds above the dolomite dip west under the schist mass of Tinmouth Mountain and The Purchase. That the structure of these masses is complex is shown by the reappearance of the marble 1½ miles south of the top of Tinmouth Mountain and along its strike between Harrington Hill and Dutch Hill, in Danby and also by the small area of dolomite, probably belonging in the marble, at the west foot of The Purchase.

Section III begins on the Green Mountain range near the head of Downer Glen (Bourn Brook), on the Manchester-Winhall township line, and runs about west-northwest through Manchester village ("Street") and the top of Equinox Mountain, ending at the Sandgate-Manchester town line. At the east end of the section crop out the pre-Cambrian gneisses of the Green Mountain range, whose unconformable relations to the overlying Lower Cambrian are finely exposed in the bottom of Downer Glen.[1] This locality affords evidence of a crustal movement and erosion in the region prior to Cambrian time. In section III the foliation of the pre-Cambrian gneiss is therefore represented as not parallel to the bedding of the overlying Cambrian and also as eroded before the deposition of the latter. These gneisses formed the ocean floor upon which the Cambrian quartzite and schist and the overlying dolomite and marble were deposited. The section next crosses the entire quartzite and schist formation which flanks the range. In the lower part of Lye Brook this formation lies in a syncline in which the lower beds of the dolomite have been preserved from erosion. On this brook near the Manchester-Sunderland town line, about 2½ miles south of the line of section III, a loose rectangular block of coarse micaceous quartzite, probably from a near-by ledge, was found in 1899 full of impressions of the spines of the trilobite Olenellus, typical of the Lower Cambrian. Between the lower part of Lye Brook and Batten Kill the quartzite forms an anticline. The Vermont Valley from the Batten Kill to a point about three-fourths of a mile west of the Equinox House is occupied by the dolomite and consists of a broad syncline made up of minor folds. The steep east slope of Equinox Mountain up to elevations of 2,300 to 2,400 feet consists of the marble, but with dips indicating at least two minor folds (two anticlines and two synclines). The brecciated marble at the Dyer quarry (p. 91), 2½ miles south of the line of section III, points to a possible fault running between Manchester Street and the beginning of the steep slope of the mountain. Equinox Mountain itself appears to be a flat-topped anticline and thus exceptional among the mountains of the Taconic Range, which are, as a rule, more or less complex synclines.

[1] Dale, T. N., Structural details in the Green Mountain region and in eastern New York (second paper): Bull. U. S. Geol. Survey No. 195, 1902, p. 18, fig. 7. By error the strike symbol of the gneiss and its foliation are drawn in this figure No. 68° E. instead of N. 68° W., as marked.



These sections taken together with the geologic map (Pl. I), will answer as a key to the general geology of the marble belts.

### DETAILED SECTIONS.

The general sections are supplemented by nine detailed sections (Pl. III), drawn on the scale of the enlarged map of the West Rutland belt of marble (Pl. IV), as follows:

**A, across the east foot of Dorset Mountain north of the Dorset-Danby line.**
**B, C, D, across the east side of the West Rutland belt of marble.**
**E, F, across the west side of the same belt.**
**G, through the village of Proctor.**
**H, a little south of G.**
**I, through the Pittsford quarries.**

These sections must be regarded merely as approximations and are designed to afford such assistance by way of suggestion as approximations can give. By means of large-scale mapping and careful instrumental work sections of much greater mathematical value could be constructed.

### STRUCTURAL NOTES.

The following notes are designed to call special attention to a few points in the map and the sections and also to some structural features which could not be represented or explained in either.

*Equinox and Bear mountains.*—The contours show that the marble makes up the lower 1,000 to 1,300 feet of these mountains. They are masses of marble and dolomite capped by 1,300 to 1,500 feet of schist.

*South Dorset.*—The symbols on the map show the unusual change in strike on both sides of the valley near South Dorset and extending to Owls Head, a change from about north to northeast—that is, of 40° to 45.°

*Dorset Mountain.*—In this mountain the schist cap extends from the 2,000-foot level (exceptionally on the east side of Dorset Hollow 1,600 feet) to the summits, 3,436 and 3,804 feet, and the marble generally from the 1,600-foot to the 2,000-foot level. The mountain is deeply furrowed by erosion and the marble is exposed on its three sides. As shown in section A, the basal dolomite lies in sharp minor folds up to the second bench on the east side. A little above that the marble begins in almost horizontal attitude and extends to the third bench, on the west side of which it is overlain by schist which from that point constitutes the steeper upper 1,600 feet of the mountain. The newly opened quarries are on this third bench. There is a marked southerly pitch in this part of the mass.

*West Rutland anticline* (Pl. IV).—In exploring the schist mass on the west side of the valley, about half a mile west of the West Rutland station, the schist foliation (slip cleavage) clearly dips 30° E., striking in some places N. 10°-20° E., in others N. 25° W. The bedding, shown by plicated quartz veins, strikes clearly N. 25° W. and dips across the cleavage at steep angles east or west. The underlying marble, therefore, dips either steeply west at the contact or, by overturn, steeply east.

On the north side of the Castleton River east-west cut in the western schist range, about a mile west-northwest of the West Rutland station, the slip cleavage strikes N. 5°-10° W. and dips 10°-20° E., but the bedding strikes N. 30° W. and dips steeply to the west in minor folds, parts of which dip east. On the north side of a disused road which sets off from the highway on the west side of the West Rutland Valley several outcrops show the structure finely.

A little north of the line of section F, about 300 feet east of the road going north, a mass of schist several hundred feet long rises 10 feet above the meadow. It shows slip cleavage dipping 20° E., crossed by plicated bedding dipping steeply west. This is the most easterly outcrop of schist in this part of the west side of the anticline, and its contact with the marble can not be far from it on the east.

In the western schist range at a point about 200 feet above the north-south highway and N. 47° W. of the red schoolhouse above the West Rutland quarries there is a cliff of schist 40 feet high. The bedding, shown by calcareous beds 3 inches thick, dips alternately east and west in minor undulations, with a general horizontal course crossed by low eastward-dipping slip cleavage. The exposure is 60 feet long.

All these data and the observations in the conspicuous schist ledges near the highway, referred to on page 75, have been incorporated in the western part of section F and show conclusively the general westerly dip of the bedding in the schist mass and the probable anticline structure of the valley. The marble of at least this part of the anticline probably also dips west.

In the southern part of the anticlinal valley the schist a little south of the Eastman quarry appears to dip 20°-35° E., as it does at the quarry, but on the west side of the first schist knoll half a mile west of that quarry the bedding dips clearly 50° W. and is crossed by slip cleavage dipping 15° E.

That the West Rutland anticline is probably made up of minor folds is indicated by the small synclinal schist tongues which overlie the marble at the north end and near the True Blue quarry, as shown on the map (Pl. I).

*Schist ridge west of Proctor and Fowler.*—The complex structure of this ridge is indicated by the lenses of marble or dolomite, probably the tops of minor anticlines, shown on the map about midway between the West Rutland and Proctor belts of marble.



The problem as to the dip of the bedding in the schist range west of the West Rutland anticline, and thus as to the dip of the underlying marble, recurs on the east side of the schist ridge west of Proctor and Fowler. Where the quarry railroad cuts the schist nearly west of the north end of the pond the cleavage strikes N. 5°-10° E. and dips 60°-65° E., but the bedding, shown by plicated quartz veins and lenses, dips at a low angle to the west. At a point S. 85° E. of the tower on the Proctor School the schist has a cleavage strike of N. 10° E. and dips 55° E., but with a magnifying glass traces of westward-dipping plicated bedding can be made out in places and are corroborated by plicated quartz veins a little beyond. Again at a point half a mile north-northwest of this last point the cleavage dips 65° E. and the bedding dips at a low angle to the west or is horizontal.

At a point 1¾ miles south of Fowler marble and schist occur in contact. Some large glacial boulders rest on the marble near by.[1] The marble strikes N. 15° W. and dips in coarse plications at steep angles to the west or stands vertical, and the schist in immediate contact is in like position, but its plicated bedding is crossed by an eastward-dipping slip cleavage. The boundary here turns to a northwest course, and at a point one-fourth mile northwest the two rocks are within a foot of each other, but both strike N. 21° W. and dip 40° E., owing probably to a minor fold in the schist mass.

Opposite the road corner nearly 2½ miles south of Proctor the schist shows cleavage dipping 40° E., but plicated bedding dipping west. This structure is shown in the general section I (Pl. II) which passes half a mile south of this point.

*Structure north and south of Center Rutland.*—The narrowing of the Proctor-Pittsford belt southwest of Center Rutland, as shown on the map is not more than would result from the presence of the top of a close-folded anticline at that point. The disappearance of the basal dolomite below the marble a few miles south and 300 feet above that point is presumably the result of a northerly pitch of the folds, and the corresponding disappearance of the dolomite north of Center Rutland (although there are no marble outcrops to fix the exact termination of the dolomite) would be due to a corresponding southerly pitch. These inferential north and south pitches would be just the opposite of those implied in the disappearance of the West Rutland anticline both at the south and the north under the overlying schist.

[1] Dale, T. N., Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905, Pl. VIII, *A*.

## TRAP DIKES IN THE MARBLE BELTS.

After the folding of the marble and the overlying schist, a shearing or stretching took place which opened narrow fissures here and there, generally more or less transverse to the folds and deep enough to reach the zone of rock fusion. Along these fissures both marble and schist became injected with lava-like but dense molten material which crystallized as it cooled and solidified. Out of sixteen dikes which were measured one was 25 feet wide, eleven 4 to 10 feet, three 1 to nearly 4 feet, and one 2 to 4 inches. Out of twenty whose courses were taken three ran N. 80° to 90° W., eight N. 25° to 40° E., and nine N. 60° to 70° E. Out of eleven which were examined microscopically ten proved to be augite camptonite (plagioclase feldspar, hornblende, augite, magnetite, olivine) and one a camptonite (same as above, with little or no augite). A thin section of the 3-foot augite camptonite dike, which crosses the dolomite half a mile north of Proctor and is exposed in the railroad cut, shows slender crystals of labradorite feldspar, larger augite crystals, fine needle-like prisms of brown hornblende, magnetite, apatite, and calcite.

J. F. Kemp made an analysis of a 3-foot camptonite dike cutting a marble quarry about 2 miles south of Proctor. He found on microscopic examination that it consisted of hornblende, augite, plagioclase, and magnetite.[1]

*Analysis of camptonite from quarry south of Proctor.*

| | |
|---|---|
| Silica ($SiO_2$) | 41.00 |
| Alumina ($Al_2O_3$) | 21.36 |
| Iron sesquioxide ($Fe_2O_3$) | 13.44 |
| Lime (CaO) | 10.40 |
| Magnesia (MgO) | 3.85 |
| Potash ($K_2O$) | 1.31 |
| Soda ($Na_2O$) | 2.86 |
| Loss | 5.00 |
| | 99.22 |

A dike described by Hitchcock and Hager[2] as 4 feet thick and 30 feet long, and crossing one of the old marble quarries on Green Peak ("Mount Eolus") was examined by Kemp and found to be an olivine camptonite consisting of olivine, augite, brown hornblende, plagioclase, and a little glassy base.[3]

Near the quarry operated by the Vermont Marble Co. north of the Eastman quarry (see map, Pl. IV), south of West Rutland, a dike with a N. 60°-70° E. course cuts the marble beds. It is

[1] Kemp, J. F., and Marsters, V. F., Camptonite dikes near Whitehall, Washington County, N. Y.: Am. Geologist, vol. 4, 1889, p. 101. Analysis repeated in Bull. U. S. Geol. Survey No. 107, 1893, p. 31. See also Am. Jour. Sci., 3d ser., vol. 36, 1889, p. 250.

[2] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, p. 587.

[3] Kemp, J. F., and Marsters, V. F., The trap dikes of the Lake Champlain region: Bull. U. S. Geol. Survey No. 107, 1893, p. 39, fig. 31.



A. PART OF THE PLATEAU QUARRY AT SOUTH DORSET.
Showing stripping and in the distance the Owls Head and Green Peak. The block being hoisted is for a 32-foot column for the Art Building at Montreal. The black stains on the quarry walls are caused by the smoke of the cutting machines.

B. TUNNEL OF NEW YORK QUARRY, DORSET MOUNTAIN, DANBY, FROM THE NORTHEAST.
Showing two sets of joints at the left of the tunnel due to a trap dike at the south (not shown in the picture). The marble at the tunnel and north of it is free from joints.

about 185 feet long, is 10 feet wide at one end and 4 feet at the other, and reappears at a point about 114 feet east-northeast. It sends out branches 75 feet long southward into the graphitic crinoidal marble beds. In thin section the dike rock has a fine matrix of plagioclase and brown hornblende with porphyritic crystals of micasized plagioclase, of hornblende, and a few augite, more or less altered to chlorite or to chlorite, hornblende, magnetite, and calcite. It contains also a little magnetite and apatite and some biotite. This rock is an augite camptonite.

On the schist ridge between Proctor and the West Rutland anticline about one-third mile northeast from the now disused Columbian Quarrying Co.'s quarry and 1¼ miles west-southwest of the Proctor station there is an 8-foot dike with a N. 60° E. course, which cuts and terminates on the north a small area of bluish limestone or marble surrounded by schist. In thin section this dike is found to consist of plagioclase, chloritized augite, much magnetite, apatite, and calcite amygdules, and is thus a diabase. This dike probably reappears in Proctor.

The geologic age of these dikes has not been fully determined. They have not suffered metamorphism and are therefore later than the crustal movement which closed Ordovician time, but they can not well be later than the Triassic.

Some of these dikes have a finer-textured, almost glassy rim, due to the more rapid cooling of the part in contact with the rock, and this rim weathers whitish. These dikes have considerable negative economic significance in this region, as the marble for several feet on one or both sides of the dike is usually close jointed parallel to the dike. Plate X, *B*, a view of the tunnel to the New York quarry on Dorset Mountain, shows the marble full of joints over a space of 80 feet from the upper side of an augite camptonite dike, but the marble is sound on the under side of it. It is not clear whether these joints were formed by the strain that opened the fissure occupied by the dike or whether they were due to the heat of the dike rock.

Hager[1] gave a sketch of two dikes in limestone (dolomite?) on Danby Mountain which shows such joints parallel to a dike crossing the bedding. Many of the dikes extend for hundreds or thousands of feet horizontally and some of them send off minor ramifications where the rock was shattered.

## GEOLOGIC HISTORY OF THE MARBLE BELTS.

The origin of marble and dolomite has been treated (pp. 7, 19); the areal geology of the region has been explained (p. 56 and Pl. I) and its structure shown in the sections (Pls. II, III, and p. 61); and the stratigraphic succession has been given (p. 54). In order to bind all these facts together and complete the geologic treatment of the marble belts it remains to outline very briefly

[1] Hager, A. D., Geology of Vermont, 1861, vol. 2, p. 586, fig. 318.

from all these data the probable geologic history of the marble region.

1. After a very long period of atmospheric erosion the gneiss mass which is now exposed on the Green Mountain Range and which must also be supposed to continue westward under the Vermont Valley and the Taconic Range became gradually submerged, at least in its western part. The ocean which then occupied the central portion of the continent advanced eastward. The action of its waves and the erosion by the streams which emptied into it supplied beach and stream pebbles and sand from the gneisses of the land. At times and in places the product of erosion was clay or a mixture of clay and sand. These pebbles, sands and clays were spread over the ocean floor throughout the region of the marble belts, the coarser material remaining near shore. From the great thickness of the Cambrian rocks which these sediments now form this kind of sedimentation must have continued for a very long period.

2. Next came the calcareous sedimentation represented by the dolomite of the table (p. 59). In view of the uncertainty which still hangs over the origin of dolomite we may suppose either the deposition, largely by the agency of marine organisms, of several hundred feet of calcitic sediments which subsequently suffered dolomitization under water or else the existence of conditions favorable to the chemical precipitation of magnesium and calcium carbonate or dolomite. In either case the sedimentation during this period included a little mechanical sedimentation of clay and quartz and feldspar sand. The graphitic dolomite beds point to a carbonaceous sediment of organic origin, possibly from marine algæ. The pteropods of the graphitic dolomite of West Clarendon (p. 59) are gastropods adapted for swimming. At the present day pteropods frequent the ocean surface.

During periods 1 and 2 we must suppose a slow subsidence of the sea bottom to make room for sediments of such great thickness. Whether this subsidence was intermittent or alternated with slight reelevations can not yet be determined.

3. Conditions of sedimentation suffered a marked change at the time corresponding to the beginning of the formation of the marble deposit, so that the sediments became very largely calcitic and but exceptionally dolomitic, or, if the theory of dolomitization is accepted, there came a time when dolomitization occurred only at intervals, most of the beds retaining their calcitic composition. The calcitic sediments out of which the calcite marble beds were later formed were largely of organic origin. Crinoids, corals (not reef builders), gastropods, cephalopods, and brachiopods were the principal animals concerned in the physiologic process of extracting lime from sea water and contributing their calcareous parts to the calcitic sediment. There may have been at the same time also chemical precipitation of calcium carbonate. In order



to account for the dolomite interbedded with the calcite marble we must suppose intervals of the submarine dolomitization of calcitic beds largely of organic origin or else intervals during which the conditions were favorable to the chemical precipitation of dolomite, and organic sedimentation largely ceased.

Even during this period of mainly organic calcareous sedimentation the streams continued to bring into the sea, again and again, a little clay and sand which were distributed over the ocean floor and became interstratified with the fragments of crinoids, corals, etc., and the calcitic ooze originating from their disintegration and partial solution. During the later part of the calcitic deposition the sediments in many places became darkened by carbonaceous matter, probably derived from decaying marine algæ, etc.

4. Owing to some far-reaching geographic change on the land mass, probably an elevation of the land that increased the erosive power of streams, the sea, which during the entire period of calcareous sedimentation (corresponding to both the dolomite and the marble) had received but little clay or sand from the land, began now to receive large amounts of these materials, particularly of clay. This was distributed throughout the area of calcareous sedimentation and, to judge from the great thickness of the schists into which this material was later metamorphosed, this kind of sedimentation must have continued for a long time. A gradual subsidence of the ocean floor along the coast line must have kept pace with the accumulating sediments.

5. At the close of Ordovician time a powerful but slow crustal movement took place, affecting the whole eastern part of the United States. It consisted in a contraction across a laterally undulating axis with a general northeast to north-northeast trend. The effect of this movement upon this region was fourfold. (*a*) It metamorphosed all the sediments overlying the pre-Cambrian gneisses; the sands and sandstones became quartzite, the clays and shales became mica schist, and the calcareous beds became crystalline dolomite and calcite marble. (*b*) It folded the entire series and these folds became more or less compressed and inclined, mostly to the east; and, owing possibly to a minor contraction operating at right angles to the main one, the axes of the folds were made to undulate in a vertical direction, thus producing pitching folds. (*c*) One of the first effects of this folding was emergence of the rock surface above the sea and the westward retreat of the shore line. (*d*) One of the later effects of the folding was microscopic faulting throughout the schist mass and in some of the marble beds, producing an eastward-dipping slip cleavage, and also the formation of secondary mica along these fault planes or the transfer of graphite to them. Faulting on a large scale also occurred, thrusting whole series of beds up or down in places a quarter of a mile. Various longitudinal

and transverse strains, compressive and tensional or torsional, formed various systems of joints.

6. As soon as the rock surface emerged from the sea atmospheric erosion began to operate upon it. The streams, taking advantage of joints, made transverse cuts in the schist folds and also eroded longitudinally in the ruptures along anticlinal axes. In the course of time erosion reached the marble beds, forming both anticlinal and synclinal valleys; and the solubility of the marble by carbonic acid greatly accelerated the process. In places the entire set of marble beds was eroded, exposing the underlying dolomite, as shown on the map.[1]

7. The region probably suffered again during the crustal movements which occurred at the close of Devonian and Carboniferous time. The metamorphism of the conglomerate of Bird Mountain, which lies only 3 miles west of West Rutland, in the Taconic Range, on the Berkshire schist, and contains pebbles of calcareous quartzite and dolomite, may have to be assigned to one of these movements.[2] The trap dikes described on page 66 afford tangible evidence of a crustal movement which affected all the formations, but was unaccompanied by metamorphism. This movement produced many fractures in the marble beds.

8. To a still later date, the close of Cretaceous time, some geologists assign the general elevation of the region to an altitude that is considered greater than the present height of the Vermont Valley above sea level; the erosion of the lower part of the valley must therefore have taken place subsequent to this elevation. To the several post-Ordovician crustal movements is probably to be attributed the shattering of so many beds of otherwise good marble.

9. Of comparatively recent geologic date was the covering of the entire region by the continental ice sheet, which moved across it, according to the striated ledges, in south, south-southeast, southeast, and east-southeast directions, gouging, scratching, polishing, and potholing the exposed marble and other beds, strewing the hillsides and valleys with boulders and leaving mounds of gravel. Some furrowed and polished marble surfaces are shown in Plates XV, *B*, and XVI, *A*.

10. The glacier in its retreat so blocked the natural drainage of the valleys into Hudson River and Lake Champlain as to dam the rivers swollen from the thawing ice and to fill the valleys of the marble belts with lakes. These lakes deposited finely stratified clay upon the glaciated marble surfaces, protecting them from further erosion. (See Pl. XVI, *A*). They also formed the horizontal sand terraces and shore lines which are so conspicuous

[1] The process and effects of erosion in western Vermont are more fully elucidated in Taconic physiography: Bull. U. S. Geol. Survey No. 272, 1905.

[2] Dale, T. N., A study of Bird Mountain, Vermont: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 15-23.



in Dorset Hollow, Manchester, and Sunderland at the 1,000, 1,100, and 1,200 foot levels.

## GEOLOGIC PRINCIPLES GOVERNING THE MARBLE BELTS.

The following paragraphs treat of those elementary geologic principles a knowledge of which should underlie the quarrying of marble in the Taconic region. Such knowledge is even more important than that required to qualify a mining engineer in the anthracite region of Pennsylvania, for the stratigraphy of the marble in this region of folds is quite as complex as that of the Pennsylvania coal beds and the difficulties are much enhanced by the intense metamorphism which the beds have undergone.

### CONTINUITY OF THE STRATUM.

Other things being equal, the same kind of marble is more likely to be found along the same bed than across adjacent beds for the reason that marine sediments of the same sort are generally formed at the same time over considerable areas, but are more apt to vary from time to time at the same place. The distance of a few feet across the stratum represents a considerable number of years, and therefore much greater probability of change of character than the same distance along the stratum. Of course there are changes along the stratum, due to contemporary changes of sediment, as one stream may carry more sand into the ocean at one point while another, a mile or two away, may be discharging more clay at the same time. On the other hand, geologic history may in smaller cycles repeat itself. Similar conditions of erosion and sedimentation may after many years recur at the same place and result in similar beds. The marble series illustrates these facts very well. Where a bed has been elongated or faulted the original continuity has been modified or interrupted.

### FOLDED BEDDING.

The western Vermont marble region, as shown by the general and detailed sections (Pls. II, III), is one of folding, so that horizontal beds are exceptional. They are only to be expected at the bottoms of the troughs or the tops of the arches of the folds, and therefore can hardly retain their horizontality for any great distance. An idea of the folds of the region can be obtained by observing the minute folds in the little grayish dolomitic beds within the clouded marbles. These small folds, as it were, epitomize the large ones. The folding of the strata is the fundamental character of the region and the primary factor controlling the vertical and horizontal distribution of the marble. If a series of beds plunges in at one point it should emerge at another, for it is but part of a fold, and for the same reason if a series of beds emerges at one point, unless it is at the actual offshore beginning of the formation or unless faulting has occurred, the beds should be found to the east or west going down again and completing the original arch of the fold. The whole marble region should be thought of as originally corrugated on a large scale, the corrugations running in a north-northeast or north-northwest direction.

### CHARACTER OF THE FOLDS.

The folds are rarely symmetrical—that is, with both sides equally inclined—and the angles of a symmetrical fold may vary from a few degrees away from the horizontal to the vertical. Folds are known as open or close. A close normal fold is one shaped somewhat like a letter U, with both limbs parallel and pressed together. Most of the folds in the Taconic region are made up of minor folds. This is shown on a large scale in the east limb of the anticline exposed in the West Rutland quarries (fig. 17, p. 117, and Pl. XII). The limbs of close folds in this region are in places so compressed as to resemble in cross section the longitudinal section of a bottle. A small fold of this kind near Brandon is shown in figure 10. When such a fold makes up a ridge or hill and stands erect a syncline may easily be mistaken for an anticline.

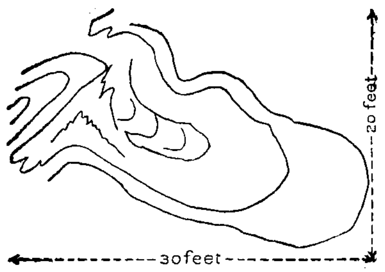



FIGURE 10.—Bottle-shaped fold in disused marble quarry 3 miles south of Brandon.

### LATERAL INCLINATION OF THE FOLDS.

Folds of the various sorts described may be laterally inclined at any angle. Those on Green Peak (fig. 14, p. 97) have horizontal axial planes. The bottle-shaped marble fold shown in figure 10 is inclined 20°. The compressed marble folds shown in figure 11 have axial planes dipping about 50°.

### PITCH OF THE FOLDS.

One of the more important economic features of a fold is the pitch of its axis. In the region here discussed this pitch will be found to be alternately north-northeast and south-southwest, or north-northwest and south-southeast, or north and south, according to the general direction of the corrugation of the portion of the belt containing the fold. The degree of pitch is generally small, 5° to 20°, but it may be greater. The practical effect of



the pitch is that in working along the strike of a series of beds the same bed will be found at greater or lesser depth. A syncline at the Albertson quarry pitches alternately north and south. (See p. 111). The termination of the West Rutland anticline both on the north and south (Pls. I, IV) is presumably due to pitch, the marble fold pitching under the overlying schist mass. The low southerly dips in the northern part of the Dorset Mountain mass are evidently due to pitch. The cause of pitching folds is not perfectly understood.

### ELONGATION AND FLOWAGE.

The weight of nearly half a mile of superincumbent schist upon the calcareous sediments at the time of the folding and the intensity of the compressive force which produced the folds were both so great that the calcareous beds became effectually plastic. Had this compression occurred with less overlying weight the beds would have either been simply folded or possibly brecciated or granulated. The result of this plasticity is seen in the elongation and thinning of the beds along the limbs of the folds and their thickening at the ends, as in the marble folds shown in figure 11. To this process the variation in the thickness of the

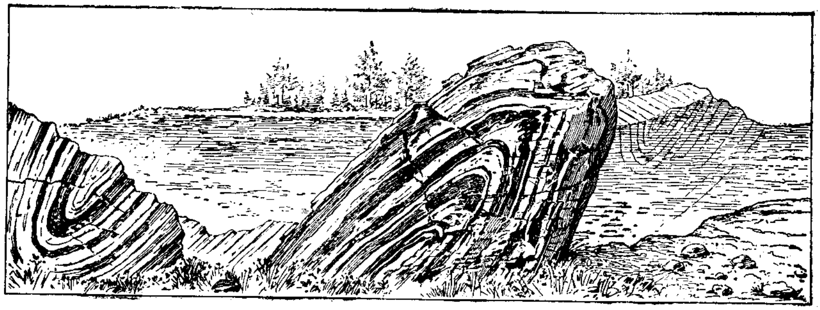


FIGURE 11.—Overturned marble folds with eastward-dipping axial planes at Lenox, Mass., north side. The dark layers, really yellowish, are due to oxidation of iron. The folds are thickened at the apex and drawn out, and some faulting has occurred in the upper beds of the anticline.

marble beds is largely due. The process did not stop here but in places resulted in actual flowage. The extremely extended compressed folds on Green Peak (fig. 14) and such structures as that in the center of the bottle-shaped fold near Brandon (fig. 10) and that near the Owls Head (Pl. XVI, B) can be explained in no other way. As the flowage of marble under compression has been demonstrated experimentally (p. 13), the probability that the crystallization of the limestone beds into marble occurred during an early stage in the process of folding does not involve any theoretical difficulties. The economic bearing of this feature of the marble in the Taconic region is that wherever the folding has been very intense thinning, thickening, and flowage are to be expected in the marble beds. This is probably the greatest irregularity to be met with in a stratified calcareous rock.

### PINCHING OUT OF BEDS.

At the True Blue quarry (p. 120), there is a fine exposure of an unusual occurrence in the marble belts. (See Pl. XV, *A*). A 15-foot bed of alternating graphitic dolomite and calcite marble stops abruptly along an eastward dipping cleavage plane, but a 3-foot bed of black dolomite veined with white calcite and quartz which forms the upper part of the 15-foot bed resolves itself into a series of lenses that continue in the marble in the direction of the dip of the original bed and have been found in the tunnel below on the right. The first of these lenses is about 3 by 2 feet. It is more probable that this change of a stratum into a series of lenses is the result of the elongation and pinching out of the bed rather than of diminished sedimentation or of dolomitization. The continuation of the rest of the 15-foot bed, consisting of banded dolomite and calcite marble, has not yet been found. If its disappearance is due to faulting the bed should reappear at the west.

This illustrates what may happen to a bed of dolomite within a series of marble beds. The fact that the position of a missing bed may be fixed by that of a series of lenses is a principle which may be very helpful in solving certain practical stratigraphic problems.

### RELATION OF MARBLE TO SCHIST.

The relations of the marble to the overlying schist have been shown in the general sections, Plate II, and in the detailed sections on Plate III.

The first inference from the parallelism of the two formations is that wherever the base of the schist occurs the marble should immediately underlie it.

The next inference is that the strike and dip of the bedding of the schist at its base indicate approximately those of the underlying marble.

These inferences are of economic importance wherever the marble along the marble-schist boundary is covered. Thus on the west side of the West Rutland anticline, opposite the quarries of the east side, the marble is covered, but unless a fault intervenes, of which there is no indication, the probable dip of the marble can be determined by ascertaining that of the schist.

### BEDDING AND CLEAVAGE IN SCHIST.

As the bedding of the schist is locally obscured by slip cleavage and the two foliations in many places dip in opposite



directions, cleavage is easily mistaken for bedding. The two features can be distinguished by the following criteria:

Slip cleavage is generally, although not invariably, in straight or very slightly undulating planes; bedding is in small or minute plications, in places even of microscopic size, and is generally crossed by the cleavage at various angles.

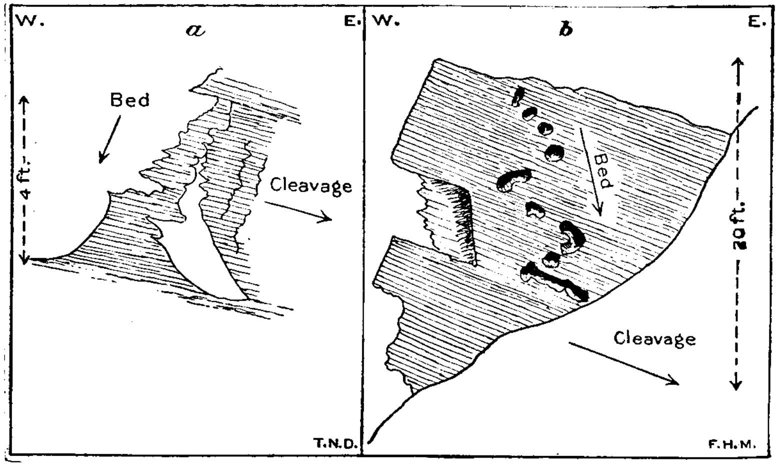



FIGURE 12.—Bedding and cleavage in schist. *a*, On Dorset Mountain; *b*, (by F. H. Moffit), on Bear Mountain, Sandgate. In *a* a columnar plicated bed has been isolated by the erosion of a bed which may have been slightly calcareous. In *b* the course of the bedding is shown by cavities 6 to 8 inches wide formed by the partial erosion of a calcareous bed.

Bedding is determinable by the course of small calcareous or quartzitic beds (not to be confounded with quartz veins, which occur in both cleavage and bedding foliation). In those rare localities where the cleavage foliation has been subsequently plicated so as to resemble bedding the evidence of such small beds of different sediment is very necessary.

One of the most interesting localities where these phenomena may be studied in the Taconic region, described and illustrated in 1892 and 1893,[1] is opposite (west of) the eastern West Rutland quarries. (See Pl. IV and p. 61). The marble which crops out on the line of the strike south of West Rutland, about the Eastman and adjacent quarries, is here covered by meadows. A line of conspicuous schist ledges forms the base of the hill (Taconic Range) west of the highway, and the schist appears to dip east and thus to underlie any marble that might be concealed by the meadows, but closer inspection shows low westward-dipping calcareous beds in the schist crossing the deceptive eastward-dipping

[1] Dale, T. N., Plicated cleavage foliation: Am. Jour. Sci., 3rd ser., vol. 43, 1892, p. 317; The Rensselaer grit plateau in New York: Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1893, pp. 321-324.

cleavage and indicating that the marble of the meadows dips under the schist and should be found under the schist with that dip. As this eastward-dipping cleavage in parts of these ledges is plicated, the usual criterion as to bedding fails here. The structure of the schist at this locality and the probable structure of the concealed marble are shown in section F, Plate III. Other illustrations of the same principle in Sandgate and Dorset are given in fig. 12.[1]

At a point 1¼ miles northwest of Proctor station similar relations exist between the marble and schist. The schist has a cleavage dipping 65° E., but its bedding is horizontal or dips at a low angle to the west. On the other hand at a point 1½ miles southwest of Pittsford station marble and schist are in contact, both dipping 40° E. and the cleavage and bedding of the schist being parallel.

### CLEAVAGE IN MARBLE.

Some of the structural features of the schist recur in the marble. The planes laden with graphite which intersect the marble beds at the Albertson and True Blue quarries (p. 117; Pls. V, *A*, and VIII, *B*, *b*) are planes of slip cleavage. As graphite is here hardly a secondary mineral its abundance along the cleavage planes may be accounted for by transfer during the compression and its attendant metamorphism. The planes dipping 30° E. crossing the 80° W. plicated beds at the Landon quarry in Pittsford are possibly planes of slip cleavage also. But there are other parallel close fractures crossing the marble beds at many points and known as "reeds" by quarrymen which are not so clearly slip cleavage. They may be close joints due to some later crustal disturbance. These are rather common on Dorset Mountain and generally dip eastward, as, for example, at the Imperial and White Stone Brook quarries (pp. 102, 103). At the abandoned quarry about half a mile south of the Proctor quarry the marble beds dip 70° E. but the reeds 20°. Of course, wherever the marble is very "reedy" it is valueless.

### JOINTING.

Certain joints or systems of joints characterize the marble beds generally; others, to be considered later, are related to the trap dikes or are altogether irregular joints. The most prevalent set of joints strikes N. 65°-80° W. with its complementary set N.

[1] The whole subject of the relation of cleavage and bedding in schist is more fully explained in the following papers: Pumpelly, Raphael, Wolff, J. E., and Dale, T. N., Mon. U. S. Geol. Survey, vol. 23, 1894, pp. 139-140, 149-154, 158, 188; Dale, T. N., On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 537, 538, 546; Structural details in the Green Mountain region and in eastern New York: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 559-568; Slate deposits and slate industry of the United States: Bull. U. S. Geol. Survey No. 275, 1906, pp. 24, 25.



10°-20° E.; another set strikes N. 75°-80° E. with its complementary set N. 10°-20° W. There are also two less common diagonal sets striking N. 30°-55° E. and N. 30°-35° W., the former of which is probably related to dikes.

### IRREGULAR FRACTURES.

Some fractures, like those shown in figure 19 (p. 124), are so irregular that it may be inferred that they were produced by an exceptional crustal movement.

### FAULTS.

The faults along the intermediate range and on Pine Hill are shown on the map (Pl. I) and on sections I and II, Plate II, and section G, Plate III, and are explained on pages 60-61. Faulting has also been regarded as possible between South Dorset and the Owls Head quarries (p. 88) and in Sunderland near the Dyer quarry. Wherever in quarrying operations such a dislocation is encountered the first thing to do is to ascertain the direction of the thrust and then the amount of vertical or lateral displacement so as to know where to look for the continuation of the lost bed or beds. For these purposes some core drilling may be necessary. Wherever in the marble belts the folding is very sharp faulting is likely to occur. The displacement in many such faults may, however, amount to only a few feet.

### DIKES AND THEIR EFFECTS.

The subject of dikes and their effects has been dwelt upon already (p. 66) and illustrated in Plate X, *B*. The dikes are usually associated with close jointing in the marble, on one or both sides, and in some places with two sets of such joints. Therefore the presence of a dike should be regarded as an indication of close jointing in the marble in proximity to it. The dikes also send out small ramifications into the marble. It is the practice, therefore, to allow a generous unworked margin in the neighborhood of a dike. The most prevalent course of the dikes is N. 60°-70° E.; the next N. 25°-40° E. A few run about east and west.

The marble which underlies the dikes at the New York quarry, on Dorset Mountain (p. 104), which dip 65°, has no close joints, but at the White Stone Brook quarry, not far away, there are close joints on the upper side of the dike and an intersecting set on the under side (p. 97). In view of the origin of these dikes it is hardly necessary to state that they can not be eradicated. Where a stone crusher is available they furnish the best material for quarry roads. Owing to its considerable content of magnetic iron the dike rock is apt to deflect the magnetic needle. Surveyors therefore need to be cautious in running lines near them.

EROSION OF FOLDS.

The importance of erosion in the history of the region has already been pointed out. As all the marble strata which crop out at the surface must once have been horizontal, and as they can not be put together in imagination as blocks in their original position, and as in exposed cross sections the beds are found forming arches and troughs, their present fragmentary condition is manifestly to be attributed to the truncation of folds by erosion. The correctness of this view is corroborated by the presence of the schist formation on the uneroded portions of the marble folds.

At the West Rutland quarries of the east side the first question which suggests itself to a structural or economic geologist is as to the location of the continuation of the beds whose edges border the quarries and form the hillside. If these beds are part of an eroded fold, the same beds should recur, in inverse order, between the quarries and the schist ledges on the west. The arch which joined the east and west limbs of the anticline has been removed by erosion, as shown in the sections. The exposures to the north and south are insufficient to enable us to reconstruct the minor folds in the eroded arch, but that it is an anticline is evident south of West Rutland, where some of the beds of the east side recur. The practical outcome of such schematic reconstruction of the marble folds is to facilitate the search for those remnants of them which are concealed by gravel, sand, or clay, of glacial and postglacial date. The principle of the erosion of folds should be applied to the explanation of every considerable exposure of marble beds in this region.

UNDERGROUND SOLUTION.

The formation of caves in limestone and marble regions by the solution of underground water carrying carbonic acid of atmospheric origin, if not also organic acids of plant origin, is a familiar occurrence. Such caves are not uncommon in the marble belt of the Taconic region. The best known of them is that on Green Peak[1] (see Pl. I, point C), which is in marble near the overlying schist, about on the 2,400-foot level. Exploration of it reported to be dangerous owing to the presence of carbonic-acid gas. A little over a mile farther north, on the west side of the north-south part of Dorset Mountain, at the contact of marble and schist, near the 1,700-foot level, a brook flowing west toward Dorset Hollow disappears in a cave. Nearly a mile west of this and a little east of the road corner a small brook, known as Cold Brook from its very low temperature in midsummer, passes out of a dolomite or marble cave 600 feet north of the bed of the brook coming down from the other cave. This brook is usually dry.

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, p. 891.



The process of cave formation by solution is finely shown on a small scale in the wall of the Florence No. 1 quarry in Pittsford (Pl. XVII) and also on the walls of the disused Proctor quarry. The water gains admittance along steeply inclined bedding planes and thence passes along intersecting joints, forming a series of small caves along both sets of planes. Although some of the larger caves may be helpful in locating marble beds, these smaller ones are a serious hindrance in channeling. Their occurrence can not be foretold.

EFFECTS OF GLACIATION.

The gouged, striated, and polished marble ledges, their large potholes (p. 121), the sand, stony clay, and gravel which conceal large parts of them, and the abundant boulders are the effects of glacial erosion. In view of the great thickness of the ice sheet under which the region was buried these mechanical effects are not surprising. Plate XVI, *A*, shows a broad glacial gouge at a now disused quarry in Pittsford, and Plate XV, *B*, shows a recently exposed striated and polished surface of graphitic marble near the Florentine quarry in Pittsford.

PROTECTION BY CLAY BEDS.

Where the glacial deposits have been removed from the marble beds or where the marble is covered by sand and gravel, it is generally more or less weathered to a depth of 20 feet. But where the marble is covered by pebbly glacial clay (till) or by beds of clay deposited in a postglacial lake, the imperviousness of the clay has protected the marble from the action of surface water. In such places fresh marble can usually be obtained within a few inches of the surface, as at the Riverside quarry in Proctor and at the quarry shown in Plate XVI, *A*. The glaciated marble surface shown in Plate XV, *B*, is also very fresh. The imperviousness of the clay is shown by the preservation of the most delicate striation and the polish, which, however, soon disappear on exposure to the weather.

## THE MARBLE BEDS.

From the detailed sections made at the quarries and the core-drill records obtained the general facts as to the succession and thickness of the marble beds can be determined. These facts will be grouped geographically.

EAST SIDE OF WEST RUTLAND ANTICLINE.

Measurements made by the writer with a steel tape of the beds between the east wall of the upper Gilson quarry and the probable line of contact between the marble and the schist on the east give the following succession. The schist contact is about

248 feet east of the east side of the red schoolhouse on the brow of the ridge.

*Section of marble beds between Gilson quarry and schist contact.*

| | Ft. | in. |
|---|---|---|
| East wall of Gilson quarry. | | |
| White marble | 11 | 6 |
| Graphitic marble, including fossiliferous beds | 135 | 6 |
| Light marble | 2 | |
| Graphitic marble | 73 | |
| East side of schoolhouse. | | |
| White marble with small lenses of dolomite | 25 | |
| Covered interval, probably graphitic marble with interbedded dolomite; estimated dip 15° | 58 | |
| Schist. | | |
| | 305 | |

These measurements generalized and added to those obtained from core-drill records and other measurements made by the Vermont Marble Co. in its quarries give the following succession for the east side of the West Rutland anticline, beginning at the schist:

*Section of marble beds on east side of West Rutland anticline.*

| Marble varieties. | *Feet.* | Series. |
|---|---|---|
| Schist. | | |
| Covered area, probably graphitic ("blue") marble with interbedded dolomite | 58 | Upper graphitic series (293 feet). |
| White marble with dolomite lenses | 25 | |
| Graphitic ("blue") marble, including 2 feet white | 210 | |
| White marble (11 feet 6 inches of this is east of east wall of Gilson quarry) | 31 | Mixed marble series (261 feet). |
| White marble, finely banded with gray | 90 | |
| White, graphitic ("blue"), and muscovitic ("green") marble in alternating beds (for details see pp. 107, 108) | 140 | |
| Dolomite | 40 | |
| Mainly graphitic marble, but with 18 feet 6 inches of white, 34 feet of muscovitic (green), and 73 feet 9 inches of dolomite in beds 1.8 inches to 16 feet thick | 250 | Lower graphitic series (296 feet). |
| Muscovitic (green) marble | 12 | |
| Graphitic marble | 34 | |
| | 890 | |

The True Blue quarry is situated in the upper graphitic series of the foregoing table—that is, in the unquarried beds on the ridge east of the West Rutland quarries. The beds at this quarry are approximately these:

*Section of marble beds at True Blue quarry.*

| | Feet. | |
|---|---|---|
| Schist. | | |
| Graphitic marble, about | 30 | Upper graphitic series (112 feet). |
| Graphitic dolomite and marble | 15-20 | |
| Graphitic marble of various shades, average | 62 | |
| Graphitic schist | 40 | |



At the Albertson or Esperanza quarry the following section is exposed:

*Section of marble beds at Albertson quarry.*

| | Feet. |
|---|---|
| Graphitic marbles above floor of tunnel | 105 |
| Graphitic marbles below floor of tunnel | 20 |
| Dolomite | 23 |
| Marble, some of it greenish | 19 |
| Dolomite | 22 |
| | 199 |

As the schist boundary is a considerable distance east of the east wall of the Albertson quarry, and as the series exposed at the True Blue quarry only measures about 112 feet from the schist down, the series at the Albertson quarry either includes but a part of the True Blue section or else is entirely below it. The absence of the 40-foot schist bed here would have to be accounted for thus, or else by a change in sedimentation in the space of a mile along the strike. The open syncline of the Albertson tunnel is probably a continuation of one of the minor folds at the True Blue but lower down.

It will be noticed that the graphitic beds of both the True Blue and the Albertson quarries belong to the upper graphitic series in the West Rutland section.

WEST SIDE OF WEST RUTLAND ANTICLINE.

The most complete exposure on the west side of the West Rutland anticline is at the Eastman quarry, about 1½ miles nearly south of the West Rutland station, where, however, owing to a minor westward overturned fold in the western half of the anticline the beds dip east at the surface. (See section E, Pl. III). The schist boundary on the west is covered by pasture land. Graphitic marble is exposed for 100 feet from a point 50 feet west of the west edge of the quarry. If a dip of 35° E., like that at the quarry, is assumed for this marble and also for the 50 feet covered by turf, the series generalized is as follows:

*Section of marble beds at Eastman quarry.*

| | Feet. |
|---|---|
| Graphitic marble, exposure 100 feet wide, at 35° | 57 |
| Graphitic marble, covered area, 50 feet, at 35°. Of this 28 feet 22 feet has been found by core drilling from the quarry to be graphitic marble | 28 |
| West edge of quarry. | |
| Graphitic marble | 17 |
| Total graphitic marble | 102 |

| | Feet. |
|---|---|
| Assorted marbles, cream colored, muscovitic (green), white, etc. (for details see p. 107) | 73⅓ |
| East edge of quarry. | |
| Gray dolomite (from core drilling) | 3 |
| Graphitic marble (from core drilling) | 3½ |
| White marble (from core drilling) | 13½ |
| | 195⅓ |

In the gravel pit north of the new Roman Catholic Church and cemetery about a quarter of a mile west-southwest of the West Rutland station a probable outcrop of graphitic marble has been exposed with the normal strike of the West Rutland belt, N. 25°-30° W., and dips on the east of 30° E. and on the west of 60°-70° W. The nearest schist outcrop and the probable boundary between marble and schist is about 400 feet west of this graphitic marble.

If the space between the two rocks here is all marble and the dip is 60° W. the thickness of the marble would be 320 feet, or, roughly, 300 feet. If the graphitic beds in and west of the Eastman quarry are regarded as part of this series, it would only be necessary to add to these beds the rest of the beds in the Eastman quarry in order to obtain an estimate of the series on the west side of the West Rutland anticline as far as exposed or indicated. The succession would be as follows, beginning on the west:

*Section of marble beds on west side of West Rutland anticline.*

| | Feet. |
|---|---|
| Graphitic marble, possibly with some interbedded dolomite | 300 |
| Cream-colored, white, muscovitic, and other marbles of Eastman quarry | 73⅓ |
| Gray dolomite (from core drilling east of quarry) | 3 |
| Graphite marble (from core drilling east of quarry) | 3½ |
| White marble (from core drilling east of quarry) | 13½ |
| | 393⅓ |

Inasmuch as the graphitic beds on the east side of the West Rutland anticline aggregate 293 feet (p. 80), the prognostication of 300 feet for the west side is but very little out. Furthermore, inasmuch as the marble of the Eastman quarry aggregates only 111 feet there should be, to judge from the succession on the east side of the anticline, some 200 feet more of assorted marbles east of the Eastman quarry unless some structural feature not shown at the surface intervenes to cut them off.

That the marble of the Eastman quarry does not correspond bed for bed to that exposed in the quarries on the east side of the anticline is probably to be attributed to minor changes of sedimentation in the distance of a mile along the strike and a quarter of a mile from east to west. A little more clayey sediment in the sea at one point than another would suffice to make the difference between a muscovitic (green) marble and an almost white one.



### PROCTOR.

There is no place in the marble belts where the need of a large-scale topographic map accurately showing all the surface details, coupled with ample time for geologic investigation, is more striking than the area extending from Otter Creek on the east three-fourths of a mile to the schist ridge on the west and a mile from north to south, containing the village of Proctor. A complex topography of more or less wooded little hills and hollows and an irregular network of streets coincide here with an area of complicated stratigraphy. The main features, however, are the schist ridge on the west under which the marble dips and the dolomite on the east dipping under the marble, as shown at the Proctor or Sutherland Falls quarry. The marble belt thus bounded is here from 1,650 to 2,200 feet wide. The general structure is shown approximately in sections G and H, Plate III.

The marble beds of the Proctor and Columbian quarries and of a disused quarry between these belong apparently to the base of the marble series, as do also the beds of the Riverside quarry, 2 miles south of Proctor. At the Proctor quarry the thickness exposed is less than 200 feet, for the beds are doubled over in a minor anticline on the west. At the disused quarry on the knoll one-third mile to the south marble about 185 feet thick is exposed. At the Riverside quarry marble measuring 85 feet is in sight and 170 feet more have apparently been crossed by core drilling westward, giving a total of about 250 feet. As the dolomite series and the overlying marble a little farther south dip in the opposite direction from those in the quarry, there is probably a syncline here and the beds prospected east of the quarry may be mostly the same as those in the quarry.

West of the Proctor quarry the marble dips under an overlying mass of dolomite 840 feet wide which extends to the pond. Its thickness depends on the number of folds and the inclination of their sides. The dips range from 35° to 75° E. If there is one syncline and one anticline in this mass the thickness would be about 264 feet, which, to judge from that of the corresponding dolomite in the Pittsford section, is probably not far from correct.

The conspicuous marble knoll half a mile south of Proctor and north of the Columbian quarry (see map, Pl. I) presents an interesting problem. Its probable structure is shown in section H, Plate III. Its west side is pretty clearly an anticline with an almost vertical west limb and a narrow horizontal or nearly horizontal top and core, followed on the east by a compressed syncline overturned to the west, the upper beds of the dolomite overlying the marble with easterly dip, as at the Proctor quarry. In this dolomite a test pit has exposed a graphitic dolomite like that of the prospect 2 miles north of Proctor (p. 122). Although the marble of this knoll apparently belongs to the Proctor quarry line of beds, yet its strike is in line with the marble beds of the Shangrow quarry and with the pond west of the Proctor quarry. Furthermore, in the dolomite east of the knoll there is a small strip of white marble about 20 feet wide cut off by dolomite on the south, which is in line with the marble of the disused quarry in the village and of the Proctor quarry. There may be a lateral dislocation here along a fault line passing between the north side of the marble knoll and the dolomite cliff on the next knoll north; and this 20 feet of marble may be a small bed in the basal dolomite. If there is such a dislocation the intermediate dolomite which lies west of the Proctor quarry passes west of the marble knoll and is covered by drift. As a large part of the top of the knoll is covered by vegetation, it is uncertain whether the intermediate dolomite is represented in the synclinal part of the knoll. Hence the interrogation mark over that part of the section. The entire thickness of the marble beds here approximates 264 feet, but if they were quarried in the mass across the folds from east to west it would measure not far from 740 feet.

West of the intermediate dolomite, which at any rate forms the hill west of the Proctor quarry, is an upper set of marble beds well exposed in the now disused Shangrow quarry and other neighboring quarries and at several points in the village. This marble is mostly graphitic and in places finely banded. The space between the dolomite at the pond and the schist boundary on the west is roughly about 600 feet and that between the marble knoll three-fourths of a mile south of the Proctor quarry and the schist boundary, after deducting 272 feet for the covered dolomite, is about 500 feet. The structural relations call for an easterly inclined syncline next to the dolomite and a normal anticline west of it. If these folds were compressed and vertical the space at the pond would admit of beds 200 feet thick, but as the beds dip from 55° to 65° E. on the east side and 25° to 45° W. on the west their thickness can hardly exceed 150 feet. If the folds are steeper west of the steep marble knoll to the south their thickness might be 150 feet. The greatest thickness of the graphitic beds exposed at any one quarry is 135 feet. The reason for the fault shown in section G will appear after considering the Pittsford section. (See p. 85).

These graphitic marbles extend to the schist ridge, where they dip west under the schist, the plicated bedding of which also dips west, although crossed by a more conspicuous eastward-dipping slip cleavage. The presence of at least one anticline in the basal dolomite at Proctor is shown by the 50° westward dip of the dolomite back of the Y. M. C. A. building and the town hall. This dip becomes 75°-80° W. a few hundred feet farther



south, back of the post office, whereas the prevalent dip west of these points is 70° E.

The marble of the entire Proctor section thus appears to consist of the following members, so far as the data obtained indicate, beginning on the west and at the top.

*Section of marble beds at Proctor.*

| | Feet. |
|---|---|
| Schist. | |
| Graphitic marble of Shangrow and other neighboring quarries, with some interbedded dolomite.. | 150 |
| Dolomite (knoll west of Proctor quarry) .......... | 264 |
| Marble, bluish white, clouded .................... | 172-264 |
| Dolomite. | |
| | 586-678 |

## PITTSFORD.

In Pittsford the marble belt widens out to 0.7 mile west of Fowler and to 0.9 mile east of the Florentine quarry. The first inference from this widening is that the schist has been eroded from a wider surface of the marble belt and that its structure consists of minor folds. The difficulty in obtaining satisfactory estimates of thickness in this locality is great. A view across the marble belt here is given in Plate IX.

At the Florentine quarry, where the contact between schist and marble is visible, the graphitic upper part of the marble beds is well exposed and measures about 150 feet.

At the old Hollister quarry, beginning at a point about 127 feet west of the west wall of the quarry and counting eastward and downward, the following section has been made out:

*Section of marble beds at Hollister quarry.*

| | Ft. | in. |
|---|---|---|
| Marble, mostly light bluish-gray, about.......... | 90 | |
| Clouded marble ................................ | 16 | |
| Bluish marble, "blue vein" .................... | 14 | |
| Marble, white and muscovitic, including beds M and N .................................... | 15 | |
| West edge of quarry. | | |
| Light bluish-gray marbles, including beds K and I. | 12 | 6 |
| Inferior ...................................... | 7 | |
| Marbles, light bluish-gray, mottled, beds A-F, 9 to 32 feet, average ........................... | 20 | 6 |
| East edge of quarry. | | |
| Marble, white or light bluish-gray (core drilling).. | 47 | 10 |
| | 222 | 10 |

East of these beds there are 146 feet of strata to a dolomite. If these are all marble and dip not higher than 50° they would amount to a thickness of 112 feet. In view of the uncertainties these strata are not counted. As beds A to F measure 32 feet at a depth of 175 feet but only 9 feet at the surface, and dip 87° E. on the east side but 90° on the west, they might be regarded as the core of an anticline, but the quarrymen report that the character of the marbles does not indicate duplication here. The entire series is so thick, however, as to point strongly to such duplication.

At the Florence No. 1 or Hogback quarry, besides the 85 feet of pale-gray mottled marble exposed in the quarry, core drilling has crossed 110 feet of similar marbles on the west and 50 feet on the east followed by 20 feet of white near the dolomite. The succession here, beginning on the west, is as follows:

*Section of marble beds at Florence No. 1 quarry.*

| | Feet. |
|---|---|
| Marble west of quarry crossed by core drilling, 110 feet; if dipping 70° measures | 102 |
| Light-gray clouded marbles exposed in quarry | 85 |
| Similar beds crossed by core drilling east of quarry, 50 feet at 70° | 47 |
| White marble crossed by core drilling east of quarry, 20 feet at 70° | 18 |
| | 252 |
| Dolomite east of above beds, 270 feet at 70° | 252 |
| Outcrops of light marbles east of dolomite, 100 feet at 70° | 93 |
| Dolomite. | |
| | 597 |

Another estimate of the lower part of the marble of the Pittsford section was obtained at the Pittsford Italian and Florence No. 2 quarries. At the Florence No. 2 quarry there are 45 feet of light-gray mottled marbles, including a 9-foot bed of dark-gray marble, dipping 82°. Drilling has been done to a point 170 feet east of the quarry, showing the same marbles extending almost to the underlying dolomite. The succession at both quarries is as follows:

*Section of marble beds at Florence No. 2 and Pittsford Italian quarries.*

| | Feet. |
|---|---|
| Florence No. 2 quarry, light-gray clouded marble and beds east of it, 215 feet at 76° (average of 82°, dip at quarry, and 70°, dip of dolomite) | 208 |
| Dolomite east of this, 259 feet at 70° | 242 |
| Pittsford Italian quarry, white clouded marble exposed at quarry, 70 feet at 75° | 65 |
| Outcrops at either side of quarry, 150 feet at 75° | 142 |
| Dolomite. | |
| | 657 |

At the Landon quarry about 80 feet of mottled light-gray marble has been exposed, belonging near the base of the Pittsford section.

From these several sets of measurements and estimates the marble of the Pittsford section appears to consist approximately of the following members, beginning at the top and west:



*Section of marble beds at Pittsford.*

| | Feet. |
|---|---|
| Schist. | |
| Graphitic marble, with some interbedded dolomite (Florentine quarry), about | 150 |
| "Florence No. 2" and "Hollister" marble beds, light bluish-gray, mottled with dark gray (208 to 252 feet), average | 230 |
| Intermediate dolomite (242 to 252 feet), average | 247 |
| "Pittsford Italian" marble beds, slightly bluish-white mottled with medium gray (92 to 209 feet), average | 151 |
| Dolomite. | |
| | 778 |

SOUTH DORSET.

The marbles of South Dorset not only differ texturally and mineralogically from those already described, being generally coarser and containing actinolitic beds, but they appear to be structurally isolated from the marble beds on Dorset Mountain and Green Peak by a fault or faults whose course is concealed. The marble in the quarries about a mile northeast and 500 feet above the Norcross-West South Dorset quarries lies in nearly horizontal folds of unusual character, as shown in figure 14 and on page 96. If such horizontal or low-dipping folds have been produced by extreme lateral compression and a subsequent erection of folded series so as to give the beds a general dip across the folds of about 80° S. 45° W., a fracture must have occurred between those beds and the gently folded beds exposed in the Norcross-West Valley quarry. In any case the structure west and southwest of the Owls Head is evidently very different from that southeast of Green Peak.

The exposures at the two quarries of the Norcross-West Marble Co. and the core-drill records of the company indicate the following succession, beginning at the top:

*Section of marble beds at Norcross-West quarries, South Dorset.*

| | Feet. |
|---|---|
| Alternating white and white mottled with light and dark gray marble, with some actinolitic beds, 125 feet, dipping 20° (the dip of 20° is assumed here)—that is, crossed by drill at 70° | 116 |
| Dolomite exposed in Main quarry (10 feet) and also crossed by drill, 20 feet at 30° (crossed by drill at 60°) | 10– 17 |
| Gray marbles, 60 feet, dipping 30° (crossed by drill at 60°) | 51 |
| | 177–184 |

As there is no evidence that the drilling reached the basal dolomite series nor any obtainable data as to the vertical distance between the uppermost bed in these quarries and the base of the schist mass, the figures simply show the thickness explored thus far. The entire marble series here should be much thicker. The problem is to ascertain how much marble has been eroded from the surface now quarried and how much intervenes between the lowest bed reached by drilling and the top of the underlying dolomite series.

### DORSET MOUNTAIN, OWLS HEAD, AND GREEN PEAK.

The State report of 1861 in a section[1] referred to on page 64, shows 86 feet of "blue compact siliceous limestone," presumably gray dolomite, immediately under the schist mass, and states[2] that near the cave "blue limestone" about 100 feet thick underlies the schist and overlies about 100 feet of coarse marble. Mr. Moffit found on the east side of Green Peak a quartzose dolomite 50 feet below the schist cap and on the north side a 4-foot bed of quartzite 10 feet below the schist. Below the cave he noted 60 to 80 feet of marble. The upper tier of quarries west of the Owls Head is reported by the owners as capped by 50 feet of dolomite. At the Blue Ledge quarry (p. 152) dolomite 25 feet thick overlies 60 feet of mottled marble, which the State geologists[2] report as being 100 feet thick 10 rods west of the quarry; and Mr. Moffit found the upper beds of the dolomite series along the 1,900-foot level about 100 feet below this quarry. The inference from these data is that on Green Peak there is an upper set of marble beds, separated from the overlying schist in places by at least 50 to 100 feet of dolomite, and a lower set of marble beds, separated from the upper set by an intermediate dolomite in places 100 feet thick, and that these lower marble beds rest upon the basal dolomite.

At the Freedley quarries, on the east side of Dorset Mountain, the following section is exposed, beginning at the top:

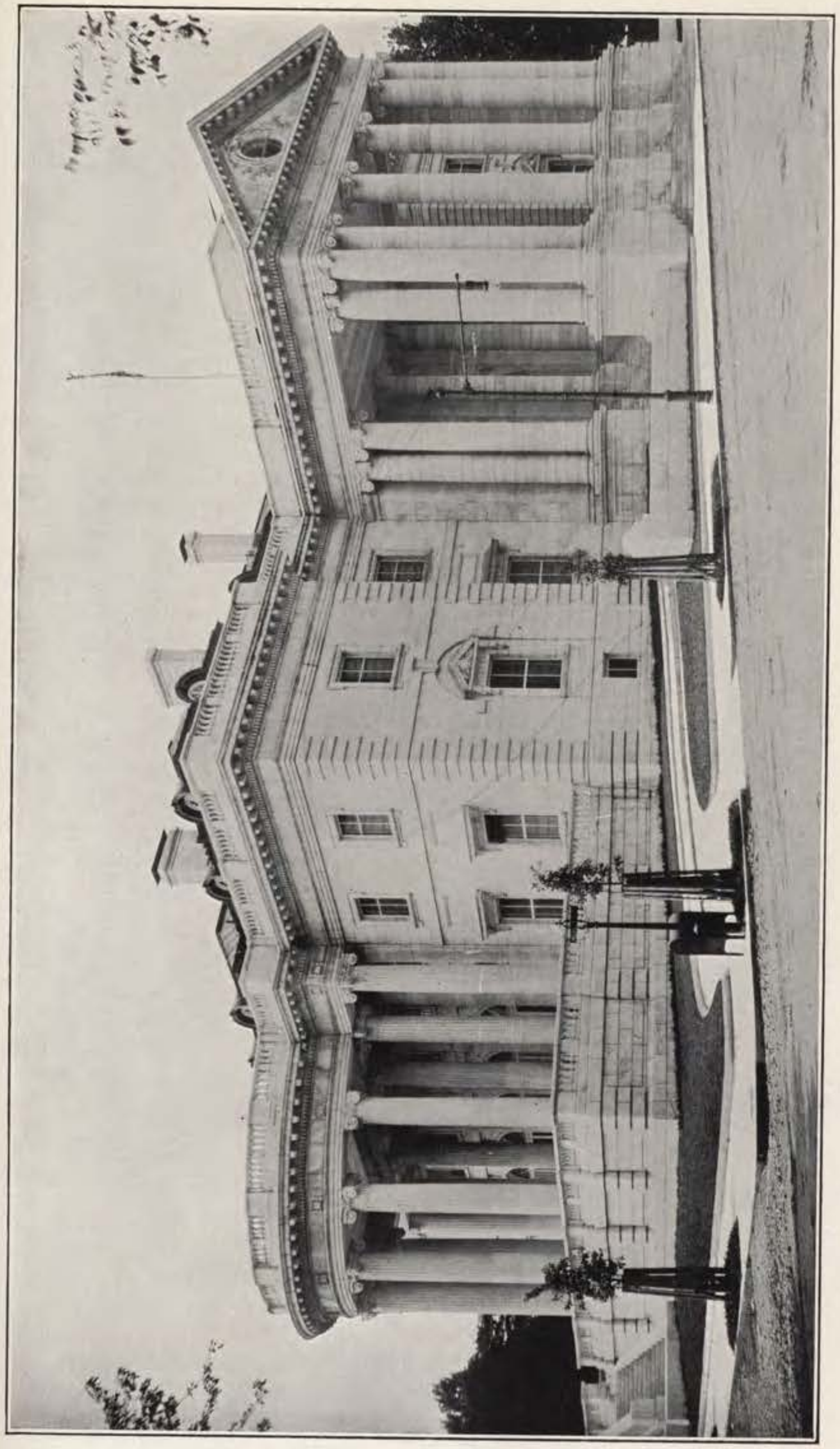
*Section of marble beds at Freedley quarries.*

| | Feet. |
|---|---|
| Schist. | |
| Covered, dolomite (probably) | 90-100 |
| Bluish dolomite | 10 |
| Marble, graphitic or banded with muscovite | 92 |
| Dolomite | 8 |
| Marble, including gray beds | 70 |
| White marble | 45 |
| Micaceous bed | 1 |
| White marble | 44 |
| Dolomite. | |
| | 360-370 |

At the White Stone Brook quarry of the Norcross-West Co., on the east side of Dorset Mountain, north-northwest of North Dorset, the series includes the following beds:

[1] Geology of Vermont, vol. 1, 1861, p. 418.
[2] Idem, vol. 2, 1861, p. 759.

PLATE XI.



MEMORIAL CONTINENTAL HALL, WASHINGTON, D. C.
With columns of calcite marble from South Dorset.

*Section of marble beds at White Stone Brook quarry.*

| | Feet. |
|---|---|
| Dolomite | 10 |
| Graphitic marble | 10 |
| White marble | 68 |
| Graphitic marble | 13 |
| White marble | 3 |
| Banded marble | 5 |
| | 109 |

At the Imperial and New York quarries of the Vermont Marble Co., a little farther north in Danby Township, the following series has been made out by quarrying and core drilling:

*Section of marble beds at Imperial and New York quarries.*

| | Feet. |
|---|---|
| Dolomite (?) | 10+ |
| White marble, exposed in New York quarry | 35 |
| Marble, white, mottled, gray in alternating beds and including three beds of dolomite 1 foot 6 inches to 6 feet thick, crossed by core drilling from bottom of tunnel in New York quarry | 105 |
| Marble and dolomite (50 feet [?]) between end of above drill core and roof of tunnel in Imperial quarry | 135 |
| Marble, white, mottled, striped and light gray, in alternating beds, crossed by core drilling from top of tunnel in Imperial quarry; 198 feet, dip 10° from surface = 198 feet at 80° to drill hole = | 192 |
| | 477 |

There may be a few feet (25 to 50?) between the dolomite series and the lowest point reached by core drill from the tunnel in the Imperial quarry.

By collating these various estimates the following section is obtained for Dorset Mountain and Green Peak:

*Section of marble beds on Dorset Mountain and Green Peak.*

| | Feet. |
|---|---|
| Schist. | |
| Quartzose dolomite | 20-100 |
| Marbles, white, graphitic, mottled, banded, muscovitic in alternating beds and including small micaceous beds and a few of dolomite | 100-175 |
| Dolomite | 50-100 |
| Marbles, generally white or mottled | 165-242 |
| Dolomite. | |
| | 335-617 |

## THE ENTIRE MARBLE SECTION.

By abridging and arranging the West Rutland, Proctor, Pittsford, and Dorset Mountain and Green Peak estimates in one table we obtain a view not only of the general character of the marble but also of its local variations, as well as somewhat satisfactory estimates of its maximum and minimum thickness. The beds of South Dorset can not well be tabulated with the others, as their position either with reference to the base or top of the marble can not yet be determined.

*Marble beds in western Vermont.*

| | West Rutland anticline, east side. | West Rutland anticline, west side. | Proctor. | Pittsford. | Dorset Mountain, Owls Head and Green Peak. |
|---|---|---|---|---|---|
| Schist. | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| Upper graphitic marbles, including some dolomite and, exceptionally, schist. | 199-293 | 300 | 150 | 150 | *20-100 |
| Average | (246) | ............ | ........ | ........ | ........ |
| White, graphitic, and muscovitic marbles, alternating. | 180-222 | 93 Rest not reached. | Absent.. | Absent.. | } 100-175 |
| Average | 201 | ............ | ........ | ........ | |
| Upper clouded light-gray marbles | Absent.. | Probably absent. | Absent.. | 230 | |
| Intermediate dolomite | 40 | Not reached | 264 | 247 | 50-100 |
| Lower clouded white marbles | Absent.. | Probably absent. | 172-264 | 151 | } 165-242 |
| Lower graphitic marbles | 296 | Not reached | Absent.. | Absent.. | |
| Dolomite. | | | | | |
| Total | 715-851 | ............ | 554-678 | 778 | 335-617 |
| Average | 783 | ............ | 616 | ........ | 476 |

*Mostly if not all dolomite.

Among the most striking features in the table is the disparity in thickness of the intermediate dolomite in the West Rutland and Dorset Mountain sections on the one hand and the Proctor-Pittsford belt on the other. The absence in the Proctor section of both the West Rutland assorted marbles and the Pittsford clouded light-gray marbles, between the intermediate dolomite and the upper graphitic marbles, points to the possibility of a longitudinal fault between the dolomite and the graphitic marbles. The irregularity of the relations north of the anticlinal marble knoll between the Columbian and Proctor quarries has already been pointed out, and the Pine Hill overthrust fault is only 2 miles east. (See map, Pl. I). Section G (Pl. III) has been drawn tentatively to explain the anomalous character of the Proctor succession. The upper clouded marbles and the white and muscovitic marbles, which normally occur above the intermediate dolomite, are shut out by an overthrust fault which brings that dolomite next to the upper graphitic marbles. Furthermore, the thinning out of the upper graphitic marbles in the Dorset Mountain and Green Peak sections should be noticed. Some of these differences are evidently due to local changes in the character of the sediments in which the marble beds originated.

This table is to be regarded as a summary of such measurements and estimates as are practicable at present and is designed to afford a basis for the more exact determination which further quarrying, core drilling, and geologic exploration will make possible. It is a tentative section of all the marble beds.



# THE MARBLES AND MARBLE QUARRIES.

## CALCITE AND DOLOMITE MARBLES.

The details as to the quarries and their product will be given in the following order: (1) Name and location of quarry; (2) approximate dimensions; (3) operator's name and address; (4) marble section and thickness of marble beds; (5) principal marbles, scientific and trade names; (6) their colors and mineral composition; (7) texture and textural grade number; (8) analyses and tests, if any; (9) geologic structure; (10) uses of product; (11) location of specimen edifices or monuments.

The more improved machinery in use either at the quarries or the finishing works is referred to on page 152.

The quarries are taken up by groups in geographic order from south to north. Some idle ones are included on account of their economic or scientific interest.

### MANCHESTER.

#### DYER QUARRY.

The Dyer quarry is on the south foot of Equinox Mountain, on the D. H. Dyer farm about 250 feet south of the Dyer house (see map, Pl. I), a mile north-northwest of the Sunderland station in the town of Manchester. The quarry is not operated. The opening is small and only 30 feet deep.

The marble is a breccia with bright brick-red cement and fragments of (1) pinkish to cream-colored and (2) bluish-gray calcite marble, and also of (3) a deep-reddish hematitic calcite dolomite marble. The breccia is described more fully on page 41 and its general character is shown in Plate VIII, *B, a*. The pinkish marble belongs to grade 4, the bluish gray to grade 5, and the reddish to grade 2.

The beds undulate in small folds, striking N. 20°-25° E. The brecciated bed is reported to have been core drilled to a vertical depth of 200 feet. It is bordered on both the east and the west by a light bluish-gray calcite marble like that of some of its fragments. At a point about 3,400 feet S. 25° W.—that is, along the strike—close to the Sunderland line, a much jointed gray marble has been prospected, which has dolomite east of and under it. West and south of this prospect, on the crossroad, the dips are low to the west. These facts indicate that the breccia will probably be found to be underlain by the dolomitic series at no great depth. There may, however, be a fault along the brecciated bed.

Columns of the breccia 13 feet long have been obtained. The problem is to determine how much of the brecciated bed is free from fragments large enough to deprive it of ornamental quality.

The weakness of the marble as a whole is no more of a detriment than that of the imported breccias.

## SOUTH DORSET.

A few data were obtained in or as to three idle quarries near South Dorset village. The locations are shown on the map (Pl. I).

### BENNINGTON QUARRY.

The Bennington quarry, a little east of the village, is owned by the Bennington Marble Co., St. James Building, Broadway and Twenty-sixth Street, New York.

### KENT & ROOT QUARRY.

The Kent & Root quarry, a little south of the village, is 50 by 60 feet in area and more than 100 feet deep. The marble strikes N. 5°-10° E. and dips 45° W., but to judge from the blocks on the dumps is much folded.

### CONTINENTAL MARBLE CO.'S QUARRY.

The Continental quarry is a mile west-northwest of the village. The marble is gray and white banded and is overlain by dolomite. The beds, though nearly horizontal, show a minor fold striking clearly N. 55° E. One set of joints strikes N. 30° W.; another N. 65° W.

### VALLEY QUARRY (NORCROSS).

The Norcross-West Marble Co.'s Valley quarry is a mile north-northwest of South Dorset village, and about 2½ miles S. 79° W. from the top of Green Peak, the southern outlier of Dorset Mountain, in the southwestern part of Dorset Township. (See map of Equinox quadrangle, U. S. Geol. Survey, and geologic map, Pl. I). It was opened in 1785, was worked in 1870, and reopened in 1902. It measures about 500 feet in a northeast direction by 100 feet across and averages 70 feet in depth.

Operator, Vermont Marble Company, Proctor.

The marble beds consist, beginning at the top, of 116 feet of marbles, white and white mottled with light and dark gray, underlain by 10 to 17 feet of dolomite, and that in turn by 51 feet of gray marbles. (See p. 87).

The marbles of this quarry are known as "Dorset A" and "Dorset green bed."

"Dorset A" is a calcite marble of cream tinted to very light, faintly greenish smoke color, and of coarse irregular texture with grain diameter of 0.07 to 1.25, exceptionally 2 millimeters, but



mostly of 0.25 to 0.75, averaging by a Rosiwal estimate 0.208 millimeter and thus of grade 5 (coarse). (See p. 46). It contains semitranslucent nodules of uncertain composition (carbonate? or silicate) and sparse small grains of quartz. The greenish smoky tint, in places in streaks, appears to be due mainly to the nodules and muscovite, but in places also to pyrite, which measures up to 2 millimeters. The polish when examined with a magnifier is only fair. A thin section of this marble is shown in figure 13.

The following analysis of this marble, recently made at the Worcester Polytechnic Institute for the firm, is published here for reference:

*Analysis of calcite marble from South Dorset.*

| | |
|---|---|
| Calcium carbonate ($CaCO_3$) | 98.43 |
| Magnesium carbonate ($MgCO_3$) | .26 |
| Iron oxide (FeO) | .38 |
| Moisture ($H_2O$) | .44 |
| Loss and undetermined | .49 |
| | 100.00 |

The results of physical tests of this marble will be found on page 95.

FIGURE 13.—Thin section of "white" calcite marble, "Dorset A," from the Norcross-West Valley quarry near South Dorset. Texture, grade 5. Dotted particles are quartz. Enlarged 20 diameters.

"Dorset green bed" is an actinolite-calcite marble of faintly greenish to pale cream color with very dark to light greenish-gray streaks, really beds, not over 0.1 inch thick (where single and straight), acutely plicated at intervals. Its texture is coarse but more regular than that of "Dorset A." As its grain diameter is 0.12 to 1, mostly 0.25 to 0.62 millimeter, it is also of grade 5. The little gray-greenish beds consist of fibrous actinolite with a little quartz and irregular semitranslucent nodules of uncertain character and bluish-green tourmaline. Pyrite is plentiful up to 0.5 millimeter in diameter. Some limonite stain appears, presumably from the oxidation of the pyrite. The polish over the actinolite streaks is naturally poor.

The pilasters of the "green bed" shown in Plate VII, which were cut parallel to the strike of the bed, seem to indicate some brecciation in that direction.

The structure at this quarry seems to be that of a very gentle anticline with a N. 70° E. strike, but at the northeast end of the quarry the beds rise in minor folds with an average dip of 30°-40° NNW. and a pitch of 10° N. 30° E. and the dolomite bed which underlies the marble of the center of the quarry reaches the surface with a thickness of 10 to 12 feet. This indicates a syncline between the northeast wall and the anticline of the quarry. Two vertical joints occur along the east wall with strike of N. 20° E. The strike of the marble (N. 70° E.) seems to be related to the N. 55° E. strike at the Continental quarry, a mile nearly southwest, and at the quarries near the Owls Head, a mile northeast. The dolomite is crossed by cleavage planes filled with quartz dipping about 20° E. A thin section of this rock is described on page 22.

The product of this quarry will be given in connection with the Plateau quarry for the reason that in many structures the marbles have been combined.

## PLATEAU QUARRY.

The Plateau quarry of the Vermont Marble Co., formerly Norcross-West Marble Co., situated 480 feet northeast of the Valley quarry, is of irregular form and averages about 90 by 80 feet and 15 to 40 feet deep. The stripping consists of 10 to 16 feet of gravel and fine sand. A view of part of the quarry is shown in Plate X, *A*.

The relation of the marble beds in this quarry to those in the Valley quarry is very uncertain, as neither the outcrops nor the core-drill records make it clear. These records indicate at least 80 to 100 feet of marble beds at this quarry. The marble, known as "Dorset B," is of a darker shade than "Dorset A."

"Dorset B" is a calcite marble of light cream color, clouded with light-gray to smoke tint, and of coarse texture, somewhat less irregular than that of "Dorset A," with a grain diameter of 0.07 to 1.12, mostly 0.25 to 0.62 millimeter, of grade 5. It contains some grains of quartz, groups of grains of granitic or vein quartz, rare grains of potash feldspar (microcline), stringers of fibrous muscovite, and plates of white mica, also irregular minute semitranslucent nodules like those of "Dorset A" and a little pyrite in fine particles and crystals and limonite stain. The gray shade appears to be due to the muscovite, the pyrite, and the nodules.

The structure at the northeast end of this quarry shows a strike of N. 70° W. At the southeast end the marble is intensely



and acutely plicated; the little folds are 6 inches wide and 5 feet long. It is not clear whether these are horizontal folds in a vertical stratum or minor folds along a very gently dipping one.

Tests of compressive and transverse strength of the marbles of the Valley and Plateau quarries were made for the company at the United States arsenal at Watertown, Mass., on March 5, 1903, with the following results:

*Results of physical tests of marble from South Dorset.*

COMPRESSION TESTS.

[6-inch cubes].

| Marble. | Strength per square inch, tested on bed. | Strength per square inch, tested on edge. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| Dorset A | 11,270 | 8,400 |
| Dorset B | 11,170 | 9,460 |
| Dorset green bed | 11,460 | 9,440 |
| Average | 11,300 | 9,100 |

TRANSVERSE TESTS.

[Samples 26 inches long and 3 inches square; supports 24 inches apart; load applied at middle].

| Marble. | Ultimate transverse strength. | | | |
|---|---|---|---|---|
| | Tested on bed. | | Tested on edge. | |
| | Pounds. | Modulus of rupture. | Pounds. | Modulus of rupture. |
| Dorset A | 657 | 860 | 655 | 840 |
| | 605 | 780 | 564 | 720 |
| Dorset B | 787 | 1,010 | 774 | 1,010 |
| | 776 | 1,010 | 682 | 890 |
| Dorset green bed | 594 | 780 | 650 | 850 |
| | 625 | 620 | 781 | 1,010 |
| Average | 674 | 843 | 684 | 886 |

The marble of the Plateau quarry, "Dorset B," and the "Dorset A" from the Valley quarry are used for construction and the "green bed" for internal decoration.

Specimens: A triangular block of white marble taken from a building close to the main quarry, inscribed "A. D. 1831," in which the letters and figures have preserved their sharp edges and which in all probability came from the adjacent quarry opened 46 years earlier, is regarded as the best evidence of the weathering quality of "Dorset A" marble.

The more important edifices made from these marbles are the New York Public Library, Forty-second Street and Fifth Avenue (except the approaches); the entire group of buildings of the Harvard Medical School; the John Hay Memorial Library, Brown University, Providence, R. I.; the Memorial Continental Hall, Washington (except northwest corner), including 13 monolithic 27-foot columns, (Pl. XI); the Royal Bank of Canada, Toronto; the Art Association Building, Montreal, with four 32-foot monolithic columns (see Pl. X, *A*); the portico and columns of the residence of Mr. W. T. Sessions, Bristol, Conn.; and the Congregational Church at Dorset, Vt.; and of "Dorset B" the exterior of the residence of Henry Phipps, Fifth Avenue and Eighty-seventh Street, New York.

The "green bed" supplied the panels and wainscoting of the National Commercial Bank, Albany, N. Y.; the interior of the American Trust & Savings Bank, Chicago; and the interior marble (except flooring) of the Hampden County courthouse at Springfield, Mass., including the columns in the rotunda and the pilasters shown in Plate VII.

### OWLS HEAD QUARRY.

There are two quarries in an upper and two in a lower tier, situated about half a mile west of the Owls Head, about 1½ miles north of South Dorset village, on the 1,400 and 1,670 foot levels —that is, 500 and 770 feet above the village. The Owls Head is the western summit of the schist outlier of Dorset Mountain, of which Green Peak is the eastern and higher point. (See map, Pl. I). One of these quarries is reported to have been reopened in 1903; the others have been idle many years. The property is said to be controlled by the Dorset Mountain Marble Co., of East Dorset, Vt.

The marble of the upper two quarries is reported as measuring altogether 150 feet, covered by 50 feet of dolomite, and that of the lower ones as consisting of 80 feet of mixed white and gray marbles. That these apparent thicknesses are not the actual ones is evident from the facts given in the discussion of structure (p. 92).Wherever the beds are not doubled over on themselves the thickness must be much less.

A specimen of white marble from the northwestern or tunnel quarry of the upper tier is a coarse white calcite marble with grain diameter of 0.05 to 1.37, mostly 0.25 to 0.75 millimeter, and belongs to grade 5. A specimen of clouded white marble from the lower tier has a grain diameter of 0.07 to 1.12, mostly 0.25 to 0.62 millimeter, and is also of grade 5. It contains plentiful quartz grains in places, with stringers of muscovite and a little pyrite.



The structure at these quarries is of very intricate character,[1] as shown by figure 14 and Plate XVI, *B* (p. 127). In the northwestern upper quarry, where an apparent thickness of 100 feet is exposed with an apparent dip of 5°-10° N. 55° E., the marble consists of minor folds drawn out in an almost horizontal direction by flowage, so that a fold measuring only a foot in thickness at its thickest part, where doubled, has its apex 60 feet away. One fold 25 feet long by 5 feet in width, doubled, is probably altogether 50 feet long and 6 feet across at its widest part. (See fig. 14, *a*). In the southeasterly quarry of the upper tier marble and dolomite are interbedded, as shown in figures 5 and 14, *b*. In the lower tier of quarries similar compressed and elongated folds occur (fig. 14, *c* and *d*).[2] The axes of these folds strike N.

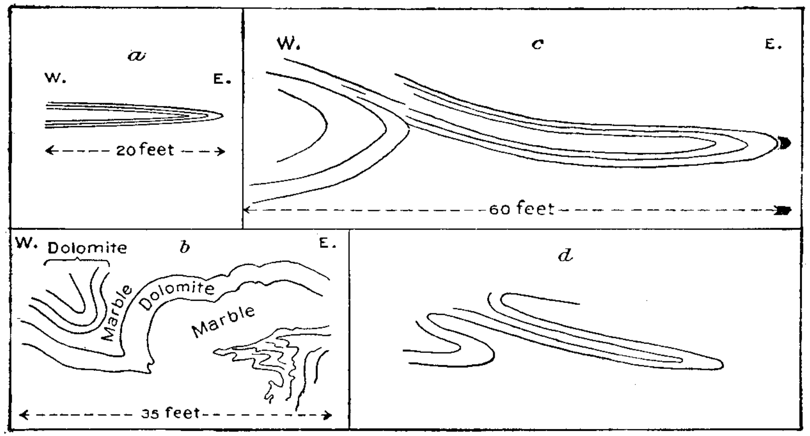



FIGURE 14.—Marble folds in quarries near Owls Head. *a*, Elongated fold; *b*, untwinned dolomite and calcite marble interbedded; *c*, present structure; *d*, probable structure of *c* at an earlier stage.

15°-60° E. The first inference from such structure is that no reliable measures of the thickness of the marble can be taken in this part of the mountain. A vertical joint in the tunnel quarry strikes N. 50°-55° E., and at the eastern one the joints strike N. 25° E. and dip 35° S. 65° E.

### GREEN PEAK QUARRIES.

Green Peak (Hitchcock's Mount Eolus), altitude 3,185 feet, although popularly confounded with Dorset Mountain, is properly an outlier of that mountain and of its schist mass. (See map, Pl. I; also maps of Pawlet and Equinox quadrangles, U. S. Geol. Survey). Marble was early quarried on its southeast side at the

[1] Hitchcock and Hager noticed some structural irregularity here (Geology of Vermont, vol. 2, 1861, p. 756, fig. 325).

[2] This interbedding of dolomite and marble has been referred to on p. 31 and also in Bull. U. S. Geol. Survey No. 195, 1902, pp. 13-15.

2,100-foot level, or about 1,300 feet above the Vermont Valley at East Dorset.

### DEAF JOE QUARRY.

There are two small and disused marble openings about three-fourths of a mile and 1 mile roughly southwest of Green Peak, one of which is known as the Deaf Joe quarry. At the lower one, on the 1,450-foot level, a white marble strikes N. 60° E. and dips 25° N. 30° W. At the upper one, on the 1,800 to 1,870-foot level, mottled marble about 20 feet thick is exposed with a very low westerly dip.

### BLUE LEDGE QUARRY.

The Blue Ledge quarry, opened in 1825 or earlier, was known as the Holley, Fields & Kent, or Kent quarry, later as the Blue quarry.[1] It is about on the 2,000-foot level, half a mile S. 60° E. from Green Peak and a mile S. 80° W. from East Dorset village, in the township of Dorset. (See map, Pl. I). The view from the top of the dumps of this quarry, looking down the Vermont Valley, is one of the finest in the State. The quarry measures about 350 feet north to south by 100 feet across and has walls 60 to 85 feet high. It has recently been reopened. Operator, Norcross-West Marble Co., Dorset, Vt.

The marble beds exposed here consist of 60 feet of mottled marble overlain by 25 feet of bluish dolomite, but the 1861 Vermont report[2] states that this dolomite bed measures about 100 feet 10 rods west of the quarry. As there is marble above the dolomite this may be an intermediate dolomite.

The marble, "Dorset Mountain," is a calcite marble of faintly bluish-white tint, irregularly mottled with very light gray and of irregular texture, consisting in the darker mottling of untwinned dolomite grains with a diameter of 0.02 to 0.12 millimeter and thus of grade 1, but in the general white mass of twinned denticular calcite grains with a diameter of 0.25 to 0.75 millimeter and thus of grade 5. It contains sparse quartz grains up to 0.32 millimeter, somewhat plentiful, pyrite crystals and particles, rare muscovite, and very minute undetermined black particles. The stone takes a fair polish, but the dolomitic mottling, being harder than the calcite ground, projects in minute relief on the polished face.

The marble and dolomite beds dip 10° SSE. and 5° NNW., forming a very gentle anticline with an axis pitching gently south. The chief joints strike N. 10° E. and N. 80° W. and are steep or vertical. The marble beds or some of them are separated by beds an inch thick of white pyritiferous, quartzose, micaceous

[1] Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 757-759.
[2] Idem, p. 759.



dolomitic calcite marble which weathers light brown. In thin section this rock consists of calcite grains up to 0.5 millimeter in diameter, with finely disseminated limonite and crystals of pyrite passing into limonite, many quartz grains, fibrous muscovite, large scales of chlorite and muscovite, and also nodules of dolomite up to 0.3 inch. This marble has not yet been used to any great extent.

### FOLSOM QUARRY.

Between one-fourth and one-third of a mile south-southwest of the Blue Ledge quarry is the long disused Folsom quarry (see map, Pl. I), the floor of which is but a few feet higher than that of the Blue Ledge. The quarry is about 100 feet square and has walls 50 feet high. Its floor is underlain by 10 feet of dolomite, upon which lies more or less mottled calcite marble, about 50 feet thick.

The beds strike N. 60° W., dip 10° N. 30° E., and are crossed by vertical joints striking N. 80° W. and N. 15° E., which form three walls of the quarry. At the west wall is a vertical dike from 1 foot to 2 feet 6 inches wide, becoming 8 feet a little beyond, with a N. 35°-40° E. course. The dike above the quarry floor has been quarried away or is covered with débris. The marble on either side of it is incrusted with limonite and stained red with hematite. On the quarry side the marble for 2 to 3 feet from the dike is much shattered and veined with calcite in crystals.

### EAST DORSET ITALIAN QUARRY.

The East Dorset Italian quarry, also idle in 1910, is between the Folsom and Blue Ledge quarries about 300 feet south of the latter. Owner, Dorset Mountain Marble Co., East Dorset, Vt.

In 1900 marble about 35 feet thick was in sight and drillings at the bottom of quarry showed 17 feet more—beginning above, three 3-foot beds, one 2-foot, and one 6-foot.

Specimens M, IV, 192, a, to d, from the west side, floor and 10 and 20 feet up, and from the south side, show a coarse white calcite marble of grade 5, in places with grayish bands or with limonitic bands from oxidized pyrite. A polished specimen is of light bluish-gray color, with little plicated dark-gray graphitic beds.

The beds are horizontal; vertical joints strike N. 80° E. and N. 10° W., and one dipping 70° N. 55° W. strikes N. 35° E.

## Quarries on Dorset Mountain.

### FREEDLEY QUARRIES.

The Freedley quarries include four openings: (1) The Tunnel quarry, opened about 1790, is about a mile west of

Freedleyville, 1,160 feet above it, on the 2,040-foot level. It is on the east side of the southern and eastern spur of Dorset Mountain, in the town of Dorset. (See map, Pl. I, and map of Pawlet quadrangle, U. S. Geol. Survey). This quarry has an east-west tunnel 160 feet long. (2) The Upper quarry, north of the Tunnel quarry, is also of very early date. (3) The Open quarry, begun in 1909, is about 500 feet northeast of the Tunnel quarry and about 100 feet lower. (4) The Scotchman's quarry, begun in 1910, is over half a mile north of the Open quarry.

Operator, Manchester Marble Co., East Dorset, Vt., also Graham Avenue and East River, Astoria, Long Island City, N. Y.

The marble beds, as reported by the superintendent, include the following:

*Section of marble beds at Tunnel and Open quarries, Freedleyville.*

| | Feet. |
|---|---|
| Tunnel quarry: | |
| Marble, mostly banded with muscovite | 92 |
| Dolomite | 8 |
| Marble, white and gray | 70 |
| Open quarry: | |
| White marble | 45 |
| Micaceous bed | 1 |
| White marble | 44 |
| Dolomite | |
| | 260 |

Mr. Moffit in 1900 noted the following section at the Upper quarry:

*Section of marble beds at Upper quarry, Freedleyville.*

| | Feet. |
|---|---|
| Bluish dolomite | 10 |
| Light-gray marble ("Manchester blue") | 26 |
| White marble | 4 |
| White marble ("mahogany bed"), including two 1-foot micaceous and quartzose beds | 10 |

At the Tunnel quarry Mr. Moffit observed a dolomite overlying 15 feet of coarse white marble. He reported 110 feet of marble in all, three-fourths of which was good. He also found the schist boundary a little farther north, 100 feet above the bluish dolomite.

The marble of the Open quarry is a translucent, faintly cream tinted coarse white calcite marble with a grain diameter of 0.12 to 1, mostly 0.25 to 0.5 millimeter, and thus of grade 5. The "Manchester blue" (specimen M, V, 6, j) of the Upper quarry is a very light bluish-gray coarse calcite marble with a grain diameter of 0.05 to 1.37, mostly 0.25 to 0.75 millimeter, also of grade 5. It contains rare minute quartz grains, a few stringers of fibrous muscovite and plates of muscovite, and cubes and



spherules of pyrite, to the oxidation of which the cream tint is probably due. The "mahogany" of the same quarry is a milk-white calcite marble of very irregular texture, with grain diameter ranging from 0.05 to 1.5, mostly 0.125 to 0.75 millimeter, and thus also of grade 5. It contains a few small quartz and feldspar (plagioclase) grains.

A hand specimen from the 15-foot bed of the Tunnel quarry resembles the white of the Open quarry. A polished specimen of the "white" from one of the beds now worked is of extremely light bluish-gray color and of irregular texture, with grain diameter up to 2 millimeters. A polished specimen of the "cloud" is of very light bluish-gray color with a medium gray dolomitic bed up to 0.2 inch wide and irregular gray spots near. The texture is uneven and irregular, with grain diameter in the calcitic part up to 1.5 millimeters. Both specimens take a good polish, but the dolomitic bands project in minute relief. A specimen of one of the micaceous beds consists of light bluish-gray and white calcite marble with grayish micaceous and pyritiferous lenses or beds, some not over 0.02 inch and others 0.1 inch thick. In thin section these lenses consist of fibrous muscovite and quartz with lenses and crystals of pyrite. The marble parts also contain a few quartz grains, muscovite scales, and a little pyrite.

The older openings were made between two trap dikes about 200 feet apart. The eastern dike is about 6 feet wide, strikes N. 25° E. and dips 80° W. The marble beds are horizontal. Vertical joints strike N. 10° E. and N. 65° W.; others strike N. 30° E. and dip 65° E., and still others strike N. 20° E. and dip 60° W., which is not far from the course of the eastern dike.

The marble is used for interiors and exteriors of buildings. Specimens: Soldiers and sailors' monument, Riverside Drive; Drexel Building, southeast corner of Wall and Broad streets, New York.

### WHITE STONE BROOK QUARRY.

The recently opened White Stone Brook quarry is on the east flank of the northern part of Dorset Mountain, about 200 feet above the most conspicuous bench or shoulder, the second one from below, and about 1,180 feet above the railroad in the valley. It lies about N. 80° W. of a steep ravine in the Green Mountain range, shown in Plate III, section A. The quarry is a little south of the Danby-Dorset town line, which is also the Rutland-Bennington county line in the township of Dorset. It has a working face 78 feet high. Operator, Vermont Marble Co., Proctor.

The marble beds exposed here and prospected by drilling are, in natural order:

*Section of marble beds at White Stone Brook quarry.*

| | Feet. |
|---|---|
| Dolomite | 10 |
| Gray marble | 10 |
| White marble in beds 5 to 10 feet thick separated by 2 or 3 inches of schist | 68 |
| Gray marble | 13 |
| White marble | 3 |
| Banded white and gray marble | 5 |
| | 109 |

The marble beds mostly alternate with beds of slickensided pyritiferous quartzose mica schist a few inches thick, the pyrite crystals elongated in the direction of slickensiding. This schist consists of calcite and vein quartz in lenses or beds alternating with fibrous muscovite, containing chlorite and lenses up to 0.25 millimeter thick, probably of some carbonate. In parts calcite, quartz, and sericite also occur mingled.

The marble, "White Stone Brook," is a coarse calcite marble of faintly cream-tinted, somewhat translucent color, with fine yellow-greenish-gray streaks and spots hardly apparent in the rough but showing on a polished or rubbed face, and of very irregular texture, with grain diameter of 0.05 to 1.5, exceptionally 2.5 millimeters, mostly 0.25 to 0.75 millimeter, and of grade 5. An estimate by the Rosiwal method shows the average grain diameter to be 0.239 millimeter. The marble contains also sparse quartz in grains up to 0.3 millimeter in diameter, pyrite next in abundance, a few muscovite scales, rare grains of feldspar (plagioclase), and minute black particles of uncertain nature. The streaks and spots are caused by collections of these accessory minerals. This marble takes a good polish. A thin section of it is shown in figure 15.

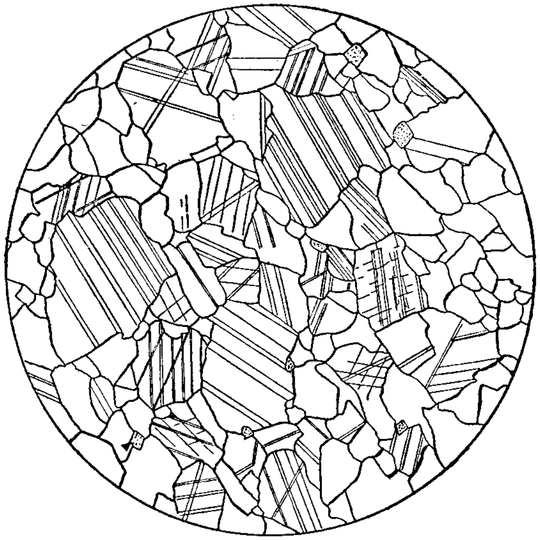


FIGURE 15.—Thin section of white calcite marble from White Stone Brook quarry, Dorset Mountain. Dotted particles are quartz; black are pyrite. Enlarged 20 diameters.



The beds dip in gentle undulations 5° to 10° E. In the front (east) part of the quarry is a trap dike, not studied microscopically, 3 to 4 feet thick, with a N. 35° E. course and a dip of 70° N. 55° W. Joints in the marble parallel to the dike and also fractures east of it, striking N. 55° E. and dipping 50° SE., deprive the marble there of value. The outer surface of the marble beds is also crossed by cleavage planes ("reeds"), striking N. 27° E., dipping 30° S. 63° E., and spaced 2 inches to 0.25 inch apart, which have the same effect.

The product is used for construction.

### IMPERIAL QUARRY.

The Imperial quarry is on the east flank of the northern part of Dorset Mountain, in the town of Danby, in Rutland County, a little north of the Danby-Dorset town line, about 700 feet above Danby station, or 1,690 feet above sea level, N. 60° W. of a conspicuous steep ravine in the Green Mountain range. For its general position see Plate I and map of Pawlet quadrangle, United States Geological Survey, and for the general form of benches and knolls of this side of Dorset Mountain, see Plate III, section A. The quarry, opened since 1900, consists of a tunnel running 160 feet in a N. 70° W. direction by 45 feet in a N. 10° E. direction and 50 feet high, with an offset 25 feet square on the floor level. Operator, Vermont Marble Co., Proctor, Vt.

The marble beds here, as exposed in quarrying and core drilling, consist, measuring from the roof of the tunnel downward and making deduction for inclination of the bed, of about 192 feet of light marbles, creamy white, bluish white, mottled, banded, clouded, or gray in various alternations. Beds of marble 4 to 8 feet thick are separated by very thin beds of mica schist. In a now disused open cut above and west of the tunnel from 30 to 40 feet of light marbles are exposed. Here the schist beds are as much as a foot thick, are rather quartzose, and contain calcite crystals an inch across.

The marble, "Danby," is a coarse calcite marble of faintly cream-tinted, somewhat translucent color with yellow-greenish-gray irregular streaks or mottlings which are much more conspicuous on the polished face than on the rough, of irregular texture, with a grain diameter of 0.07 to 1, mostly 0.17 to 0.62 millimeter, and thus of grade 5. It contains sparse quartz grains and some pyrite (rarely as large as 2 millimeters), some muscovite scales, and minute black specks. The greenish-gray streaks and clouds are due to muscovite and pyrite in very minute particles. The polish is good but is affected slightly by the composition of the little beds. The general texture of the marble is similar to that shown in figure 15.

The beds strike N. 40° W. and dip 10° S. 50° W. In the open cut above the tunnel the marble is in open folds 50 feet in diameter, with a N. 40° E. strike. At the mouth of the tunnel cleavage planes ("reeds") strike N. 15° E. and dip 35° E.; these decrease in abundance within the tunnel. Joints in upper beds of the open cut strike N. 33° E. and also less commonly N. 57° W., both sets being of steep dip. There is a 3-foot bed in the open cut full of "reeds" dipping 40° E. These are reported by the foreman as being less abundant in the micaceous beds.

### NEW YORK QUARRY.

The New York quarry of the Vermont Marble Co. is about one-fourth mile west of the Imperial quarry and about 240 feet above it (see map, Pl. I) and of more recent date. It has a tunnel 150 feet wide and 35 feet high running 215 feet southwest. The northeastern part of this tunnel has been deepened to 100 feet over a space 55 feet square; 125 feet north of this tunnel is another 40 feet wide and 20 feet high, running 80 feet southwest. This northern tunnel is shown in Plate X, *B*.

The marble beds here include, in natural order:

*Section of marble beds at New York quarry.*

| | Feet. |
|---|---|
| Dolomite (?) above tunnel | 10 |
| White marble exposed in south tunnel | 35 |
| Bluish, cream, white mottled, and light-gray calcite marbles in alternating beds, including three beds of dolomite (1 foot 8 inches, 1 foot 6 inches, and 6 feet) all crossed by drilling | 105 |
| | 150 |

The marbles are not essentially different from those of the Imperial quarry, described above.

The beds are inclined 10° to 15° S. 15° W. This probably represents a very low, nearly west dip combined with a southerly pitch of the fold. At the north side of the southern tunnel is a dike of augite camptonite (see p. 66) 5 feet 6 inches wide with a N. 25° E. course and a dip of 65° N. 65° W. For a space of 80 feet northwest of the dike—that is, above it—the marble is crossed by many joints parallel to the dike, and these are crossed by another set, as shown in Plate X, *B*. Although the marble above the dike has been thus rendered valueless, that on the other side, under the dike in the southern tunnel, is sound. Fifty feet northwest of the northern tunnel another dike of augite camptonite only 2 to 4 inches thick cuts the marble with a N. 30° E. course and a dip of 70° N. 60° W., and the marble for a space of 30 feet above and northwest of this dike also is much jointed.

The marble of both the Imperial and New York quarries is used largely for construction, but some is suitable for monuments. The Chelsea Bank, Chelsea, Mass., and the Wheeler residence, Chicago, were made almost entirely of this marble.



## CLARENDON QUARRIES.

### CLARENDON VALLEY QUARRY.

The Clarendon Valley quarry is on the east side of the intermediate range, on the J. D. Pratt farm, about 1¼ miles south-southeast of Clarendon village church and 2 miles southwest of East Clarendon, in the Otter Creek Valley, half a mile east of the creek, in Clarendon Township. (See map of Rutland quadrangle, U. S. Geol. Survey). The quarry, opened in 1909-10, is 50 by 35 feet and 9 feet deep.

The marble beds exposed here consist of at least 70 feet of calcite marble.

The marble, "Clarendon Valley gray," is a calcite marble of very light bluish-gray color, with fine, closely and acutely plicated dark-gray dolomite beds. The calcite marble of the ground is of irregular texture, with grain diameter of 0.5 to 2, mostly 0.12 to 0.5 millimeter, and thus of grade 5 (coarse). The little dolomite beds consist of irregular and rhombic untwinned dolomite with a grain diameter of 0.025 to 0.1, mostly 0.05 to 0.07 millimeter, and thus of grade 1. Graphite abounds in the dolomite beds, but occurs also sparsely throughout the calcite marble, as does also quartz. There are rare grains of feldspar (orthoclase, plagioclase, and microcline), muscovite flakes, sericite stringers, and small particles of pyrite in the calcite, but pyrite abounds in the dolomite bands. The polish is good except on the dark bands. Some of the marble, "Clarendon white," is a trifle lighter and has fewer gray streaks.

The beds strike N. 55°-60° E. and dip 25° N. 33° W. They are crossed by cleavage dipping 25° E. There are large exposures of either the basal dolomite or the intermediate dolomite with a westerly dip between the quarry and Clarendon village, on the east side of the road. The marble of the quarry evidently belongs between the basal and intermediate dolomite, probably near the former.

### CLARENDON QUARRY.

The Clarendon quarry is east of the foot of the Taconic Range, 3 miles south-southeast of West Rutland, in the township of Clarendon. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey). The quarry, an old one, abandoned before 1900 but reopened in 1909, is about 100 feet north to south by 51 feet across, with an average depth of 30 feet. Its length is being extended 40 feet. Operator, Clarendon Marble Co., West Rutland, Vt.

The marble beds exposed and prospected are, in natural order, as follows:

*Section of marble beds at Clarendon quarry.*

| | Feet. |
|---|---|
| Graphitic marble | 50 |
| Graphitic schist | 7 |
| Graphitic banded marble | 19 |
| White marble, slightly mottled ("Clarendon A") | 17 |
| White marble, mottled and banded | 34 |
| Mixed mottled marble | 99 |
| Dolomite | 20 |
| Graphitic variegated marble | 81 |
| | 327 |

The schist boundary must be very near the top of the series.

"Clarendon A" is a calcite marble of bluish-white color, with little bands or rows of spots of medium gray shade. It is of uneven texture, consisting of coarser white parts with grain diameter of 0.12 to 1, mostly 0.25 to 0.62 millimeter, and thus of grade 5, and of finer dolomitic gray parts from 0.1 to 0.2 inch in width, and thus of grade 1. The white parts contain some minute grains of quartz and of pyrite and minute black specks of uncertain nature. The gray spots and bands are graphitic. The marble takes a high polish, the dolomitic bands and spots standing out in minute relief.

The dark-gray banded marble of the 19-foot bed is a graphitic calcite marble, in some beds almost black, alternating with dark bluish-gray bands from 0.05 to 0.2 inch wide without plications, but in other beds of light-gray calcite marble alternating with similar bands of dark-gray shade. It has a grain diameter of 0.05 to 0.5, mostly 0.12 to 0.37 millimeter, and is thus of grade 4. It is graphitic throughout but particularly so in the dark bands, and pyritiferous, with quartz grains rare and small, and limonite stain. This marble takes a high polish.

The variegated rock of the lowest bed is a graphitic calcite marble of very dark bluish-gray color, mottled or irregularly banded with very light bluish-gray, almost bluish-white, and of grade 4.

The beds strike N. 10° W. and dip 42° W. A section of the graphitic schist (7-foot bed) shows it to be a sericite-quartz-graphite-calcite schist. It is finely plicated and crossed by slip cleavage and is veined with quartz, calcite, and pyrite. This is the typical schist of the base of the schist formation of the Taconic Range. The marble is cut by joints striking N. 35° W., dipping 45° N. 55° E., and spaced 3 to 7 feet. The marble beds at the surface are finely glaciated and the glacial polish has been preserved by a bed of clay which at the back of the quarry, over the small schist bed, is very graphitic and measures 7 feet in thickness, and a little farther west measures 30 feet and contains boulders and sand.



The marble is used for construction. Specimen of "Clarendon A": The free-standing, iron-centered columns of the State Educational Building at Albany.

## Rutland Quarries.

### FOLEY PROSPECT.

The Foley prospect is about three-fourths of a mile west of the southeast corner of Rutland Township. The outcrop extends here and there, it is reported, into the township of Clarendon, toward a well-known bed of kaolin on the north bank of Cold River. Prospective operator, Edward H. Foley, 147 South Main Street, Rutland, Vt.

The beds, to judge from their geographic position, probably belong not far above the basal dolomite.

The marble consists of alternating beds of very light-gray calcite marble from 0.2 to 0.5 inch wide, alternating with irregular beds of very dark-gray graphitic untwinned dolomite from 0.04 to 0.1 inch wide, both sets being most intricately plicated together. The calcitic parts polish well but the dolomitic not at all. Associated with these beds are also whitish calcitic marble more faintly mottled with graphitic dolomite.

The beds are reported to lie in vertical position.

## West Rutland Quarries, West Side.

### EASTMAN QUARRY.

The Eastman quarry is at the east foot of the Taconic Range, on the west side of the West Rutland anticline, about 0.7 mile S. 10° W. from the West Rutland station, in the township of West Rutland. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey). The quarry, which was reopened a few years ago, now measures 126 feet north to south by 105 feet across (at the bottom) and is 135 feet deep. Operator, George P. Eastman, Rutland, Vt., or care of Tompkins-Kiel Marble Co., 505 Fifth Avenue, New York.

The marble exposed in and west of the quarry and by core drilling on both sides of it comprises the following beds, in natural order:

*Section of marble beds at Eastman quarry.*

| | Ft. | in. |
|---|---|---|
| Graphitic gray marble | 57 | |
| Graphitic (?) | 6 | |
| Graphitic gray marble | 22 | |
| West edge of quarry. | | |
| Graphitic gray marble | 14 | |
| Same with some white bands | 3 | |
| Cream-colored marble | 4 | |
| Muscovitic (green) marble with beds of cream-colored marble in coarse plications ("Kiel's green") | 7 | |
| Purplish-gray marble | 1 | 6 |
| Muscovitic (green) marble, plicated with slip cleavage dipping 5° to 10° E. | 2 | |
| Dolomite and marble mixed | 2 | 10 |
| Cream-colored marble with faint green and yellow bands (bed H) | 4 | 6 |
| Muscovitic (green solid) marble | 11 | |
| White marble, pure | 4 | |
| Cream-colored marble with muscovitic (green) bands | 4 | 6 |
| Muscovitic calcite marble (bed F) | 3 | |
| Muscovitic plicated marble (bed BC) | 4 | 6 |
| Cream-colored marble | 4 | 6 |
| White marble (bed IJ) | 5 | |
| Muscovitic (green) marble, plicated (bed K) | 4 | 6 |
| White marble (bed L) | 5 | 6 |
| White marble with small muscovitic (green) beds (bed M) | 5 | |
| East edge of quarry. | | |
| Gray dolomite | 3 | |
| Graphitic marble | 3 | 6 |
| White marble | 13 | 6 |
| | 196 | 4 |

Eight of these marbles, the more important and typical ones, were examined microscopically.

"Eastman blue," the 14-foot bed, is a graphitic calcite marble of medium bluish-gray color and of even and fine texture, with grain diameter of 0.05 to 0.37, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). The texture is peculiar in that the particles are elongate and the longer axes of the different grains are parallel, imparting some schistosity to the marble. (See fig. 6, p. 34). The marble contains sparse quartz and muscovite grains. The polished specimen, which was cut across the bed, shows little beds alternately more and less graphitic and in places (by the raised surface) dolomitic; all are in somewhat angular plications with a tendency to slip cleavage.

"Kiel's green" consists of interbedded cream to flesh-colored calcite marble of coarse irregular texture, with grain diameter of 0.05 to 1.5 millimeters and thus of grade 5, and of a bright greenish-gray schistose muscovitic and chloritic calcite marble of medium elongated texture, with grain diameter of 0.05 to 0.55, mostly 0.12 to 0.37 millimeter, and thus of grade 4. The cream-colored beds are from 0.5 to 1 inch thick and the green beds from 0.1 to 1 inch thick. Both are acutely plicated, the limbs of the plication reaching 5 inches in length, and crossed by slip cleavage. A small polished specimen is shown in Plate VIII, *A, b*. Both marbles contain extremely fine black particles of uncertain nature. The light beds abound in quartz grains up to 1.87 millimeters in diameter, contain some muscovite, and show the effect of secondary strain in bent twinning planes. The green beds contain some fine grains of quartz and its calcite grains are elongated and roughly parallel. In the lower part of the 7-foot bed which furnishes this marble the light beds give place to the green ones and the marble becomes a solid greenish muscovitic calcite marble of medium texture. Although the quartz of the light beds and the muscovite of the green ones interfere somewhat with the polish, the colors and designs of this marble are so unusual and attractive as to offset such imperfections.



A slightly purplish-gray marble is a sericitic calcite marble with grain diameter mostly under 0.02, rarely 0.37 millimeter, and thus between grades 1 and 2. A little of the calcite is twinned. The rock contains abundant magnetite in plates and some quartz. The schistosity is parallel to the bed, with traces of secondary minute plications transverse to it.

"Green-veined cream statuary," bed H, is a calcite marble of delicate cream color in bands up to 2 inches thick alternating with slightly plicated bands (beds) of yellowish and very pale greenish tint up to 0.1 inch thick. It is even and regular in texture, with grain diameter like that of bed F, averaging about 0.2 millimeter, and is of grade 3. Exceedingly fine black specks occur sparsely throughout. The bands appear to be due to the oxidation of varying quantities of pyrite in very minute particles. The marble takes a high polish.

The green marble of the 11-foot bed, "solid green" is a muscovitic quartzose calcite marble of bright greenish-gray color and of irregular elongated parallel texture, with grain diameter of 0.02 to 0.3, mostly 0.04 to 0.09 millimeter, and thus of grade 1. The larger elongated and parallel grains are irregularly mingled with smaller ones of more or less roundish outline. Quartz is very plentiful. The muscovite is in scales and fibers.

"Cream statuary," bed F, is a calcite marble of delicate cream color with very pale brown, minutely plicated beds up to 0.1 inch thick. It is even and regular in texture, with grain diameter of 0.05 to 0.37, mostly 0.12 to 0.25 millimeter, and is thus of grade 3. It contains rare small grains of quartz and sparse exceedingly minute black specks of uncertain nature. The stone takes a high polish.

"Light cipolin," bed BC, is a muscovitic calcite marble of light greenish-gray color in which the muscovite occurs in many close, fine, broadly plicated beds. In texture it belongs in grade 4. The polish is only fair because of the mica.

"Blanc clair," bed IJ, is a calcite marble of milk-white to faintly clouded milk-white color and of irregular fine texture, with grain diameter of 0.04 to 0.42, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains sparse minute black grains, rare pyrite, and quartz, and takes a high polish. Its texture is less regular and a grade coarser than that of Rutland Italian (p. 113).

"Dark cipolin," bed K, is a muscovitic calcite marble of generally bright light-greenish color, with alternating more muscovitic (greenish) and more calcitic (whitish) little beds in broad plications 1 to 2 inches wide. Its texture is medium, with a grain diameter of 0.05 to 0.67, mostly 0.12 to 0.37 millimeter, and it is thus of grade 3. The grain form is elongate and also irregular. There are quartz grains up to 0.37 millimeter, muscovite in scales and fibers, and chlorite mingled with a little epidote, besides some minute nodules (possibly titanite) and a little blue-green tourmaline. The green color is due mainly to the muscovite and chlorite. The polish is only fair owing to the mica.

The white marble with greenish bands of bed M is a calcite marble of milk-white color, with straight, parallel delicate green muscovitic beds from 0.1 to 0.4 inch wide. Its texture is regular and fine, with grain diameter of 0.05 to 0.5, mostly 0.12 to 0.25 millimeter, and it is thus of grade 3. It contains rare particles of quartz and sparse minute black grains of uncertain nature. The bands are largely sericite.

Owing to the variation in the proportion and arrangement of the accessory minerals in each bed the varieties of commercial marbles produced by this quarry are many.

The probable structure is shown in section E, Plate III. The beds strike N. 20° W., but owing to a minor overturned fold they dip east (35°) instead of west and are therefore in inverse order. At the bottom of the quarry, 135 feet below the surface, they begin to turn, being almost vertical. The dolomite at the east edge of the quarry is described on page 17.

The product is used mainly for interior decorative work, the blocks being shipped to Astoria, N. Y., where the cutting and polishing are done. Specimens: Interior of Greenpoint Savings Bank, Brooklyn, N. Y. (green beds); interior of Prudential Building, Newark, N. J. (green and cream-pink); mantels in United States Senate Office Building, Washington (cream and white); carved work border near ceiling and a large mantel, New York Public Library (cream and white); interior of Connecticut Savings Bank, New Haven, Conn. (white); interior of railroad station, Schenectady, N. Y.



#### MORGAN QUARRY.

The Morgan quarry is a few hundred feet north of the Eastman quarry. (See Pls. I and IV). It has been recently reopened by the Vermont Marble Co. The beds are the same or very nearly the same as those at the Eastman quarry; the strike is N. 25° W. and the dip vertical, changing to east. There is a very low eastward-dipping cleavage in some of the beds. An augite camptonite dike with a N. 65° E. course cuts the beds near the quarry. (See further, p. 67).

#### UMBRELLA QUARRY.

The Umbrella quarry, a disused opening belonging to the Columbian Marble Co., lies a few hundred feet north of the Morgan quarry. (See Pl. IV). An 8-foot bed of fine-grained marble is exposed, striking N. 5° W. and dipping 40° E.

#### RUTLAND-FLORENCE QUARRY.

The Rutland-Florence quarry is about 300 feet north of the Umbrella, and is also out of use. It is owned by the Vermont Marble Co., Procor, Vt. There are beds of white marble in the quarry, west of it lie 57 feet of beds covered by turf, and west of these are 70 feet of graphitic marbles. The strike in and west of the quarry is N. 15° W. and the dip 35° N. 75° E.

#### MCGARRY QUARRY.

At the McGarry quarry, a small disused opening south of the schoolhouse (see Pl. IV), graphitic marble about 10 feet thick overlies white marble, with a strike of N. 30° W. and dip of 30° N. 60° E. Back of the schoolhouse and about 225 feet northwest of the quarry is a small anticline of dolomite 5 feet thick, the axis of which appears to pass west of the beds exposed in the quarry but may really pass each of it.

### West Rutland Quarries, East Side.

#### VERMONT MARBLE CO.'S WEST RUTLAND QUARRIES.

The West Rutland quarries of the Vermont Marble Co. lie on the east side of the West Rutland anticlinal valley, along the west foot of the synclinal schist ridge which intervenes between the Taconic Range proper and the intermediate range. (See Pls. I and IV). There are in all 11 openings, including the disused ones: Three (Covered quarry, New opening 1906, and Upper Gilson quarry) in an eastern upper series of beds, and eight (Gilson, Ripley, Baxter, a prospect, Clement, Foster, Sherman, and Old open quarries) in an adjoining western and lower series of beds. Inasmuch as the slope of the schist and marble ridge near West Rutland bends around to the southeast, the quarries (with the exception of the Upper Gilson), although apparently in line, are on different sets of beds. The entire line, beginning at a point about 0.4 mile north-northwest of the West Rutland station, extends 0.8 mile north-northwest. These quarries will not be described in detail, as it will suffice to bring out the general facts concerning them all. They are narrow openings along the strike and follow the dip of the beds more or less closely, with foot and head walls dipping 35° to 45° E. In some places the supporting walls between the quarries have been excavated below, leaving narrow rock bridges at the top, as shown in Plate XII. As the beds turn eastward in synclinal attitude the quarrying has followed them, and by means of an irregular distribution of the supporting piers the Gilson, Ripley and Baxter quarries have at the turn of the syncline, at a depth of 250 feet, been so combined as to admit of a continuous electric mine railroad 1,300 feet long. In the Ripley quarry, at a depth of 225 feet, tunneling has been done in a westerly direction for a distance of 340 feet, and in the Gilson quarry the beds have been followed eastward to a point 300 feet east of the west wall of the quarry.

The complete succession of the beds will be found in generalized form on page 80. Some of the best-known commercial marbles of these West Rutland quarries belong between the upper graphitic marble and the intermediate dolomite and occur as shown in the following section, beginning with the beds of the Upper Gilson quarry on the east in natural order:

*Section of marble beds at West Rutland quarries of Vermont Marble Co.*

| | Feet. |
|---|---|
| White marble ("top white"), about | 50 |
| Graphitic (gray) marble | 20 |
| White and graphitic (includes green bed, "olivo") | 50 |
| White (includes "second statuary") | 3 |
| Muscovitic, banded | 4-5 |
| White and graphitic ("monument," light cloud) | 6 |
| White ("Rutland statuary"; only 4 feet thick east of turn in syncline) | 7-11 |
| Muscovitic (dark greenish, "average") | 4 |
| White | 3-4 |
| Muscovitic, fine banded, plicated ("light brocadillo," "brocadillo," "pavonazzo") | 5-6 |
| White ("mottled Smith," "best light cloud") | 6-10 |
| Muscovite banded ("Jackman," "light Smith," "listavena") | 4 |
| White | 1-4 |
| Muscovitic, banded (dark greenish, "hard layer," ("verdoso") | 2-4 |
| White | 1-3 |
| Dolomite | 1-4 |
| Muscovitic, banded ("double belt") | 2-3 |
| White ("Rutland Italian") | 3-6 |
| Graphitic, with abundant Maclureas in upper part ("dark blue," "extra dark blue," "livido") | 8-25 |
| Dolomite | 40 |
| | 220-262 |

PLATE XII.

VIEW FROM THE SOUTH WALL OF THE GILSON QUARRY, WEST RUTLAND, AT A POINT 70 FEET BELOW THE SURFACE.

Showing part of the east limb of the West Rutland anticline and three of the quarry openings. Vertical black streaks at the left due to smoke.

The bridge of marble and part of the roof have fallen since the view was taken.

Graphitic marbles are worked for 300 feet west and below this series, in the west tunnel of the Ripley quarry. Core drilling has also been done west from the west end of that tunnel, exposing the following succession:

*Section of marble beds west of west tunnel of Ripley quarry.*

| | Ft. | in. |
|---|---|---|
| Graphitic marble | 8 | |
| White marble | 11 | |
| Dolomite | 10 | |
| White marble | 4 | |
| Muscovitic marble (light green) | 1 | 4 |
| White marble | 3 | 6 |
| Muscovitic marble (light green) | 1 | |
| Graphitic marble in 12 beds aggregating 105 feet, alternating with 12 beds of dolomite aggregating 106 feet 8 inches | 211 | 8 |
| | 250 | 6 |

A number of the marbles have been examined microscopically with these results: "Statuary Rutland" is a calcite marble of milk-white color and of very fine, regular, somewhat even texture, with grain diameter of 0.05 to 0.5 mostly 0.07 to 0.25 millimeter. By the use of the Rosiwal method the average diameter was found to be exactly 0.1 millimeter and the texture is therefore of grade 2 (very fine). A camera-lucida sketch of a thin section of this marble is reproduced in figure 16. There are rare grains of quartz and plagioclase feldspar and infinitesimal opaque particles of irregular form, some of which, to judge from the effect of a magnet on the powdered marble, are magnetite. The marble takes a high polish.

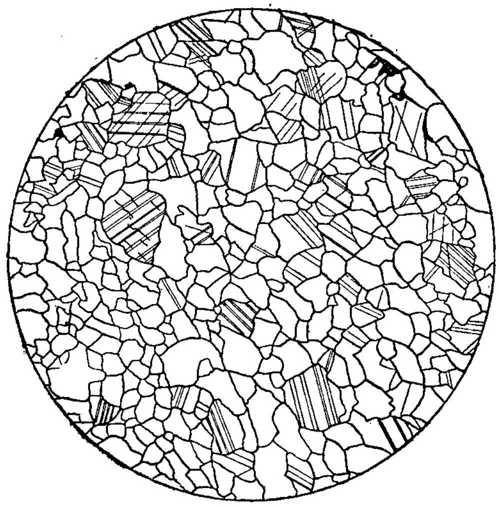


FIGURE 16.—Thin section of white calcite marble, "statuary Rutland," of texture grade 2. Enlarged 27 diameters.

The "second statuary Rutland" is a calcite marble of milk-white color with faint grayish-yellow clouds and of fine, somewhat irregular texture, with grain diameter of 0.05 to 0.57, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains minute sparse black particles and very rare quartz grains. The polish is high.

"Rutland Italian" is a calcite marble of faintly bluish-white color with faint irregular grayish and yellow-brownish mottlings. The mottling is more pronounced than in the "second statuary." It is somewhat irregular in texture, with grain diameter of 0.05 to 0.87, mostly 0.12 to 0.5 millimeter, and thus of grade 4. It contains minute black specks and some spherules of pyrite, some quartz grains, and rare scales of muscovite. The polish is high.

"Dark-blue Rutland" is a graphitic calcite marble of dark bluish-gray color mottled with white, apparently in fine plications, and with some fine black streaks. Its texture is irregular, with a grain diameter of 0.05 to 0.57, mostly 0.12 to 0.25 millimeter, and it is thus of grade 3 (fine). It contains minute grains of graphite and rare scales of muscovite. It takes a high polish. This is the bed which carries in places sections of Maclureas (see p. 16) in white calcite.

A section of "extra dark blue" obtained in 1900 is of similar irregular texture, with grain diameter of 0.025 to 0.37, mostly 0.075 to 0.175, and averaging possibly about 0.11 millimeter and thus of grade 2.

"Brocadillo" is a muscovitic calcite marble of faintly greenish-white ground, with fine greenish-gray plicated beds and straight streaks (cleavage planes?) to 0.2 inch wide. Its texture is irregular, in places elongated parallel, with grain diameter of 0.05 to 0.62, mostly 0.12 to 0.37 millimeter, and it is thus of grade 4 (medium). The accessory minerals, in descending order of abundance, are quartz, with some feldspar (plagioclase), up to 0.62 millimeter in diameter, muscovite in scales and fibers, epidote with a little zoisite, brownish translucent lenses (carbonate?), chlorite, minute spherules and crystals of pyrite, and still more minute opaque particles (pyrite?). The marble takes a high polish, to which the sparseness of the micaceous bands contributes.

"Livido," from the bottom "blue bed" is a slightly graphitic calcite marble of medium to delicate light bluish-gray shade, with plicated dark-gray dolomitic beds up to 0.1 inch wide. Its texture is irregular and uneven. The calcitic parts have grain diameter of 0.05 to 0.62, mostly 0.1 to 0.25 millimeter, and are thus of grade 3 (fine), but the dolomite has grains measuring 0.009 to 0.02 millimeter and is thus of grade 1 (extra fine). The

PLATE XIII.

WILSON PORTRAIT STATUE, SEATTLE, WASH.
White calcite marble, "light Rutland Italian."

dolomite is very irregularly distributed in the more graphitic little beds. No mica or quartz was detected. The polish is high.

"Olivo" is a muscovitic calcite marble of light greenish-gray and pale greenish-white color, in undulating bands up to half an inch thick, and of an elongated parallel texture, with grain diameter of 0.07 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium). Besides muscovite it contains plentiful quartz, rarely a grain of feldspar (plagioclase), some irregular minute, barely translucent lenses (carbonate?), and very minute black specks. This marble is more micaceous than the "brocadillo" and its general color resembles that of specimens 29, n and o, from the Eastman quarry. The polish is fair but poor where mica abounds.

The following were not studied microscopically: "Verdoso" is a muscovitic calcite marble with minute plicated dark-greenish beds on a white ground. It may contain chlorite. The texture is medium and the polish poor.

"Rubio" is a calcite marble of very delicate pinkish tint, with thin plicated greenish muscovitic beds. The pinkish tint proceeds presumably either from a mineral containing manganese oxide or from hematite, possibly due to oxidation of magnetite, but in either case in very minute particles. Its texture is fine and its polish good.

"American pavonazzo" is a calcite marble with milk-white ground and chloritic dark blue-greenish plicated beds of irregular width and distribution. The polish is good except over the chloritic beds. The mantel and wainscoting in Plate XIV, *B*, are made of this marble.

An analysis of the graphite in the "dark-blue Rutland" is given on page 34 and one of the white marble on page 6. The following analyses of the blue, white, and statuary are quoted here for reference:

*Analyses of marbles from Vermont Marble Co.'s quarries at West Rutland.**

| | Blue. | | White. | | Statuary. |
|---|---|---|---|---|---|
| | 1 | 2† | 3 | 4† | 5 |
| Carbon dioxide ($CO_2$) | 43.82 | 44.00 | 43.66 | 43.80 | 43.65 |
| Lime (CaO) | 55.27 | 55.15 | 55.26 | 54.95 | 55.50 |
| Magnesia (MgO) | .28 | .57 | .15 | .59 | Trace |
| Alumina and iron sesquioxide ($Al_2O_3$), ($Fe_2O_3$) | .30 | .... | .20 | .... | .15 |
| Silicate of alumina ($Al_4Si_2O_9$) | .... | .22 | .... | .62 | .... |
| Insoluble | .28 | .... | .40 | .... | .70 |
| Organic matter | .... | .05 | .... | .... | .... |

*Day, W. C., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, continued, 1897, p. 985.

†Analyses by J. N. Harris.

The following compression tests were made at the United States arsenal at Watertown, Mass., April 1, 1893:

*Compression tests of marble from West Rutland quarries.*

| No. | Marble. | Compressive strength (pounds per square inch). |
|---|---|---|
| 9061 | Extra dark blue | 13,639 |
| 9063 | Rutland Italian | 14,068 |
| 9059 | Rutland Statuary | 11,525 |

The following transverse tests were made at the same place in November, 1895. The blocks were supported 20 inches apart and loaded in the middle.

*Transverse tests of marble from West Rutland quarries.*

| No. | Marble. | Modulus of rupture per square inch. |
|---|---|---|
| 414 | Rutland White | 1,202 |
| 415 | Rutland blue | 2,069 |
| 416 | do. | 2,045 |

The following shearing tests were made at the same time and place. The distance between supports was 6 inches, the width of block to which pressure was applied 5 inches, and the thickness of block tested 6 inches.

*Shearing tests of marble from West Rutland quarries.*

| No. | Marble. | Shearing (area square inches). | Transverse fraction developed (pounds). | Shearing strength per square inch (pounds). | Surfaces sheared. |
|---|---|---|---|---|---|
| 272 | Rutland white | 47.72 | 18,400 | 1,100 | 2 |
| 273 | do. | 48. | 18,200 | 946 | 1 |
| 274 | Rutland blue | 48.32 | 20,600 | 1,519 | 1 |
| 275 | do. | 48.04 | 22,100 | 914 | 2 |

Tests of expansion made at the Watertown Arsenal in November, 1895, determined the coefficient of expansion in water per degree Fahrenheit of Rutland white marble as 0.00000312 inch; that of the mottled marble of the Proctor quarry was 0.00000550 inch, and that of a dark graphitic marble from the Shangrow quarry was 0.00000433 inch. These tests were made in water baths between temperatures of 32° and 212° F. The transverse strength was found to be greatly lowered by such treatment.



The probable general structure of the West Rutland anticline is given in sections B and F, Plate III. The quarries lie on the east limb of the anticline, the top of which has been eroded, or along the west limb of a syncline of marble overlain by schist. In passing from quarry to quarry along the strike, the supports left between the walls and also between adjacent quarries show on their smoothly cut surfaces various minor undulations in the limb of the syncline, so that in a series of cross sections of the limb 200 feet apart no two would be identical. Here and there a little faulting or pinching out of smaller beds is also evident.

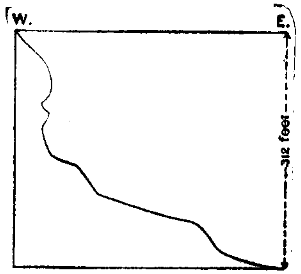



FIGURE 17.—Course of east limb of the West Rutland anticline or the west limb of the syncline.

Figure 17 shows the approximate character of the anticlinal or synclinal limb at the Ripley quarry. The steeper upper part of it is also shown in Plate XII. At the prospect (quarry No. 7 on map, Pl. IV) a trap dike 10 inches to 6 feet wide cuts the marble beds with a N. 60° E. course and a dip ranging from steep to 30° S. 40° E. The dike has a glassy rim 0.12 inch wide, weathered whitish. The presence of many joints on the south side parallel to the dike wall probably caused the discontinuance of the quarry.

The marbles from these quarries serve a great variety of purposes. Many of the beds are used for interior decoration panels, wainscoting, etc., some for interior or exterior carving, and others for construction. Some of the graphitic marbles are in demand for electric switchboards. Among the more notable buildings and attractive monuments of recent date made of the marble of these quarries are the Senate office building, Washington, from West Rutland marble, with some from Danby; the marble and statues of the Chamber of Commerce Building, New York, from West Rutland marble; the Wilson portrait statue at Seattle, Wash. (Pl. XIII), of "light Rutland Italian"; the Taylor mausoleum, Woodlawn Cemetery, New York, of "best white Rutland building marble"; the Kimball monument at Graceland Cemetery, Chicago (Pl. XIV, *A*), of "second statuary" and the mantel and wainscoting in the First National Bank, Hazleton, Pa. (Pl. XIV, *B*), of "American pavonazzo."

### ALBERTSON QUARRY.

The Albertson quarry (formerly known as the Esperanza) is also on the east side of the West Rutland anticlinal valley, 2¼ miles north-northwest of West Rutland station in the township of West Rutland. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey). The quarry measures 500 feet in a

N. 17° W. direction by 110 feet across and 115 feet in depth. An area 150 by 110 feet at the north end is worked out as far down as a certain dolomite bed. There is a tunnel, 80 to 175 feet wide and 40 feet high, on the west side, extending about 630 feet in a N. 30° W. direction and reaching a point 75 feet west of the west wall of quarry. Operator, Vermont Marble Co., Proctor, Vt.

The marble exposed and explored here consists of the following beds:

*Section of marble beds at Albertson quarry.*

| | Feet. |
|---|---|
| Graphitic marble | 135 |
| Dolomite | 23 |
| Marble, some of it greenish | 19 |
| Dolomite | 22 |
| | 199 |

The marble, "extra dark Albertson" is a graphitic calcite marble of medium bluish-gray shade, with thin, minutely plicated black streaks (beds) and here and there whitish streaks of like character, both crossed at various angles by cleavage planes slightly undulating and also black. A piece of this marble is shown in Plate VIII, *B, b.* The texture is regular, with grain diameter of 0.05 to 0.62, mostly 0.17 to 0.37, millimeter, and it is thus of grade 4 (medium). It abounds in graphite, particularly along the little black beds and the planes of slip cleavage, and contains rare minute cubes of pyrite and still more muscovite scales and quartz grains. The amount of graphite in it is probably like that in the West Rutland blue (p. 32). The marble takes a high polish without dolomitic protuberances.

The beds strike about N. 25° W. The north wall shows a syncline in cross section, and for about 400 feet south of that point the syncline pitches 10° about north, and then for 130 feet 5° about south. On the north face of a jog in the west face near the south end the west limb of this syncline dips 15° to 20° E. The tunnel, which makes an angle of 13° with the west wall of the quarry, follows the axis of a syncline. About 315 feet from that wall this syncline on its west side strikes N. 35°-40° W. and dips 28° E., and its east side also dips at a low angle. The entire width of the syncline is about 200 feet and it opens northward. The beds on the east wall of the quarry are crossed by a conspicuous slip cleavage dipping 20°-30° east or southeast. (See for general structure Pl. III, section C).

The marble of this quarry is used largely for monumental and electric work, but some for construction. St. Ann's Roman Catholic Church at Fall River, Mass., is made of it.



TRUE BLUE QUARRY.

The True Blue quarry is also on the east side of the West Rutland anticlinal valley, three-fourths of a mile north-northwest of the Albertson, and 3 miles north-northwest of West Rutland station, in West Rutland Township. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey). The quarry is about 112 feet north to south by 100 feet east to west in its southern half and 75 feet in the northern half, and about 100 feet deep. From the south wall, at a point 75 feet below the surface, a tunnel, 50 to 75 feet wide and 30 to 40 feet high, extends 113 feet southward, to a point where its floor is about 130 feet below the surface.

Operator since May, 1911, Vermont Marble Co., Proctor, Vt.

The marble beds exposed and explored here consist of the following:

*Section of marble beds at True Blue quarry.*

| | Feet. |
|---|---|
| Schist. | |
| Graphitic marble | 30 |
| Dolomite with some graphitic marble | 20 |
| Graphitic marble of various shades | 60-65 |
| Graphitic schist | 40 |
| | 150-155 |

The marble, "True Blue," is a graphitic calcite marble of medium-gray shade, with more or less finely plicated black (graphitic) bedding planes crossed at various angles by slightly flexed slip-cleavage planes, also black and graphitic. A photograph of a slab showing this feature is reproduced in Plate V, *A*. Its texture is even, regular, and on the fine side of medium, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4. It abounds in graphite in minute grains and contains a few minute cubes of pyrite and rare and small grains of quartz. It takes a high polish without dolomitic protuberances.

As will be seen by the geologic map, the quarry is very near a southward-pointing tongue of schist. In 1900 the north wall of the quarry was at the south end of this synclinal tongue. The structure on the north wall of the present quarry (75 feet south of the old north wall) shows four minor folds overturned toward the east in a space of about 70 feet and these folds consist of graphitic marble, dolomite, and schist about 50 feet below the rock surface. This is probably the same schist which reappears at the bottom of the tunnel and which has been core drilled to a depth of 40 feet. On the south wall (as shown in Pl. XV, *A*) east of the tunnel a 15-foot bed of graphitic dolomite veined with white (calcite and quartz probably) dips west, toward the tunnel, but has been partly faulted out along an eastward-dipping cleavage foliation and partly pinched out during elongation and flowage and has been transformed into a series of oblong or spherical nodules of graphitic dolomite up to 3 by 2 feet, which continue in the direction of the dip within the quarry. The approximate structure at this quarry is shown in figure 18. The general structure is shown in section D, Plate III. The pitch of this whole series here is about 15° S. and the slip cleavage in the marble dips 30° E. This structure is shown in the slab pictured in Plate V, *A*. The proximity of the schist tongue shows that the beds here belong to the uppermost part of the upper graphitic series, and the presence of the lower schist bed shows that during the closing part of the period of calcareous deposition argillaceous sediments alternated with calcareous sediments for a time before crowding out the latter altogether. The presence of such schist beds near the top of the limestone formation is not unusual along the Taconic Range. They should not be confounded with synclinal tongues or lenses belonging to the main schist mass itself. Marble should recur below the schist bed of the True Blue quarry.

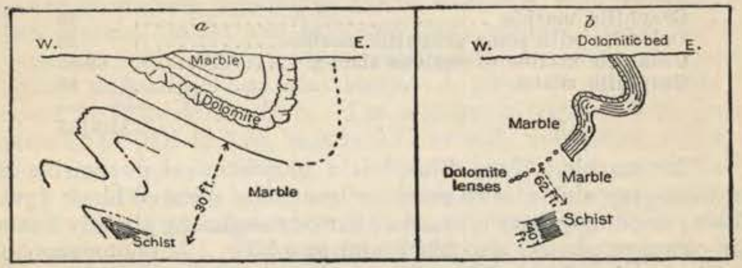



FIGURE 18.—Approximate structure at True Blue quarry. *a*, Structure on north wall; *b*, general relations in quarry and on south wall.

The schist of the top of the 40-foot bed is very graphitic and contains veins and lenses of pyritiferous quartz parallel to its schistosity. The schist consists of stringers of muscovite and chlorite with graphite and quartz, rarely a grain of feldspar (plagioclase). It is a pyritiferous graphite-calcite-quartz-muscovite-chlorite schist.

About 300 feet south of the south wall of the quarry is a 4-foot trap dike with a N. 70° E. course, and many joints parallel to it occur in a space of 30 feet on its north side.

## PROCTOR.

### RIVERSIDE QUARRY.

The recently opened Riverside quarry is 2 miles south of Proctor station, between Otter Creek on the west and the railroad on the east, in the township of Proctor. (See Pls. I and IV and map of Castleton quadrangle, U. S. Geol. Survey). It is about

PLATE XIV.

*A*. KIMBALL MONUMENT, GRACELAND CEMETERY, CHICAGO, ILL.
Columns of "Second Statuary Rutland" calcite marble.

*B*. MANTEL AND WAINSCOTING IN FIRST NATIONAL BANK, HAZLETON, PA.
Muscovitic calcite marble, "American pavonazzo," from West Rutland.

100 feet square and 70 feet deep. Operator, Vermont Marble Co., Proctor, Vt.

Assuming that the dip of 60°, which is that of the beds exposed in the quarry, prevails throughout the 200 feet of marble which has been core drilled west of it, the marble here measures 255 feet and is close to the top of the dolomite, which crops out a little farther east. Some 100 feet of marble beds have been explored between the east edge of the quarry and the dolomite, but as the dolomite and overlying marble a little to the south dip west, most of these beds are probably continuations of those in the quarry.

The marble, "Riverside," is a coarse calcite marble of translucent, slightly bluish-white color, with dark-gray spots and bands at irregular intervals along the planes of bedding, and of uneven texture, with grain diameter in the white calcitic ground of 0.05 to 1.0, mostly 0.25 to 0.5 millimeter, and thus of grade 5 (coarse). The thin sections did not cross any of the dark spots. That these spots are largely dolomite is evident from their standing out in minute relief on the polished face and being easily scratched with a knife; and that they are also graphitic is evident from the nature of other similar clouded marbles. The average grain diameter in the dolomitic passages would be about 0.05 to 0.1 millimeter. The calcitic parts contain sparse quartz particles, some up to 0.32 millimeter, and also pyrite, some of which is oxidized.

The marble beds strike N. 5° W. and dip 60° E. The dolomite along the base of the Pine Hill ridge one-fourth mile southeast of the quarry has a like strike but dips about 50° W., and the marble at an idle quarry a little south and west of the dolomite boundary strikes N. 15° W., dips about 67° W., and has an exposed thickness of 90 feet. Unless faulting intervenes a synclinal axis passes between these two quarries. The marble surface at the Riverside quarry had a glaciated surface protected by a covering of till. Glacial potholes 10 to 15 feet by 6 to 8 feet were found, and near the old quarry to the south-southeast are others 8 to 10 feet in diameter.

### COLUMBIAN QUARRY.

The Columbian quarry, in operation in 1900, was idle for some time prior to August, 1910, but was then about to be reopened. It is about three-fourths of a mile south-southwest of Proctor station in Proctor Township. (See Pl. I). It is 100 feet or more in diameter and 150 feet deep. Operator, New Columbian Marble Co., State Street, Rutland, Vt.

The marble is white clouded. The beds strike N. 10°-15° W. and dip 50° E. A complete analysis of the stone is given on page 15.

About 100 feet north of the quarry along the strike the same beds, recently uncovered, with a glaciated surface and pothole 5 feet by 4 feet 6 inches, strike N. 20° W. and dip very steeply to the east. The marble exposed measures about 60 feet. East of it is the boundary of the dolomite series.

The general structure on both sides of the quarry is shown in section H, Plate III.

### PROCTOR QUARRY.

The Proctor quarry, in full operation in 1900 but idle since 1907 and full of water in 1910, is about 0.4 mile northwest of Proctor station, on the north side of the village, a mile north of the Columbian quarry. (See Pl. I). It is about 200 feet square, with an offset on the east side, and in 1900 was 175 feet deep. Owner, Vermont Marble Co., Proctor, Vt.

Marble 70 to 185 feet thick is exposed, lying between the uppermost bed of the dolomite series on the east and the intermediate dolomite on the west.

The marble, "Sutherland Falls," is a calcite marble of bluish-white color with thin dark-gray spots and bands, probably dolomitic, along the bedding plane. Its texture is uneven and of grade 5 (coarse). It resembles very closely the "Riverside" marble, described on page 120.

The general structure is shown in section G, Plate III. The marble beds form the eastern limb of a syncline about 150 feet in depth, but, instead of curving over directly on the east to form an anticline, they turn sharply to dip at a low angle to the east for a space of 50 feet and then turn again to resume the direction of the synclinal limb. The effect of this minor fold in the anticlinal part of the fold is to double over some of the marble beds in the lower eastern part of the quarry and reduce the apparent thickness. Between 1900 and 1907 the quarry was also worked toward the east. The section on the north wall of this eastern extension shows the eastward-dipping beds of this minor easterly overturned fold crossed by low eastward-dipping joints, along which several caves as much as 3 feet in height have been eroded by percolating water. The dolomite which overlies the marble on the west differs microscopically from that of the dolomite series which underlies it on the east. (See p. 22).

It is reported that reasons for abandoning this quarry were the abundance of joints and the thinning of the beds at the turn of the syncline.

### PARKER & PINCKNEY PROSPECT.

The Parker & Pinckney prospect, tested in 1910, is 1½ miles north of Proctor and 1¾ miles south-southwest of Pittsford



village, in Proctor Township. (See Pl. I). Operators, Parker & Pinckney, Pittsford, Vt.

The marble is a bluish-black or very dark bluish-gray graphitic dolomite marble, already described on page 38. It belongs in the basal dolomite. It takes a good polish.

The beds explored consist, beginning on the west, of 75 feet of bluish-black dolomite, followed by about 250 feet of buff dolomite and then by about 250 feet of bluish dolomite of various shades. The structural relations of these beds are not clear. The eastern and western belts probably belong at the same horizon. The strike is N. 5° W. and the dip 60° E., but this may vary, reducing the figures given for at least the larger thicknesses.

### SHANGROW QUARRY.

The Shangrow quarry, abandoned between 1900 and 1910, is 1¼ miles north-northwest of Proctor station and 1½ miles N. 15° W. of the Proctor quarry, in Proctor Township. (See Pl. I). Owner, Vermont Marble Co., Proctor, Vt.

The marble exposed in 1900 consisted, beginning at the top, of 32 feet of banded graphitic marble overlying 14 feet of graphitic quartzose dolomite veined with quartz, under which was an unknown thickness of banded marbles like those above it. The beds belong to the upper graphitic series of the marble formation.

The marble, "mountain dark," is a graphitic banded calcite marble of alternating dark-gray to black and light bluish-gray bands (beds) ranging from 0.1 to 0.3 inches in width and of uneven and irregular texture, with grain diameter of 0.05 to 0.62, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium); one grain seen measured 0.37 by 2.37 millimeters. In the graphitic bands the calcite grains are generally of smaller diameter, ranging from 0.05 to 0.17 millimeter. The marble contains small quartz particles, small cubes of pyrite, quartz lenses up to 0.37 millimeter in diameter, and in the dark bands abundant graphite. Some bands are muscovitic and pyritiferous.

## PITTSFORD.

### FLORENCE NO. 2 QUARRY.

The Florence No. 2 quarry is 0.9 mile southwest of Fowler station and 1¼ miles nearly west of Pittsford station, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey). The quarry measures 70 feet north to south by 45 feet across, and is 63 feet in depth. In May, 1911, it passed into the hands of the Vermont Marble Co.

The marble beds exposed in the quarry and explored by drilling to a point 170 feet east of it consist of about 210 feet of light and grayish calcite marbles including 8 feet of dark stone. They belong above the intermediate dolomite. (See p. 87).

The marble, "Florence No. 2," is a calcite marble of very light bluish-gray color with whitish and dark-gray (graphitic and dolomitic) streaks and spots parallel to the bedding. It is uneven in texture, with grain diameter, in the calcitic parts, of 0.075 to 1, mostly 0.12 to 0.37 millimeter, and is thus of grade 4 (medium). The very irregular dolomitic lenses, which in thin section are not sharply separated from the calcitic ground, have a grain diameter mostly of 0.05 to 0.25 millimeter and are thus of grade 3 (fine). The dolomite is untwinned and some of the grains have rhombic outlines. Associated with it are a few small quartz grains and muscovite scales. Minute black grains (probably graphite) occur throughout, but more abundantly in the dolomitic lenses, and also a little pyrite. The marble takes a high polish, but the dolomite mottling shows in minute relief on the polished face.

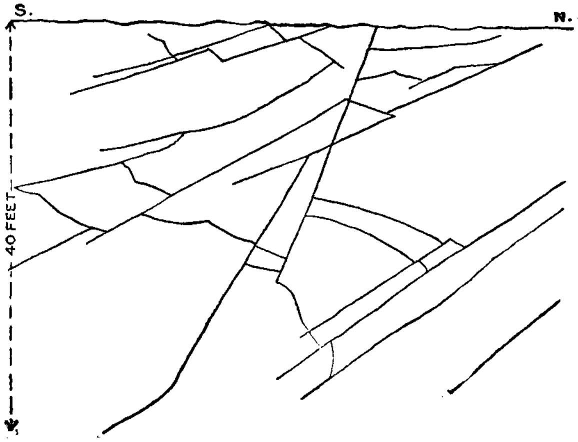



FIGURE 19.—Irregular joints and fractures on west wall of Florence No. 2 quarry, Pittsford.

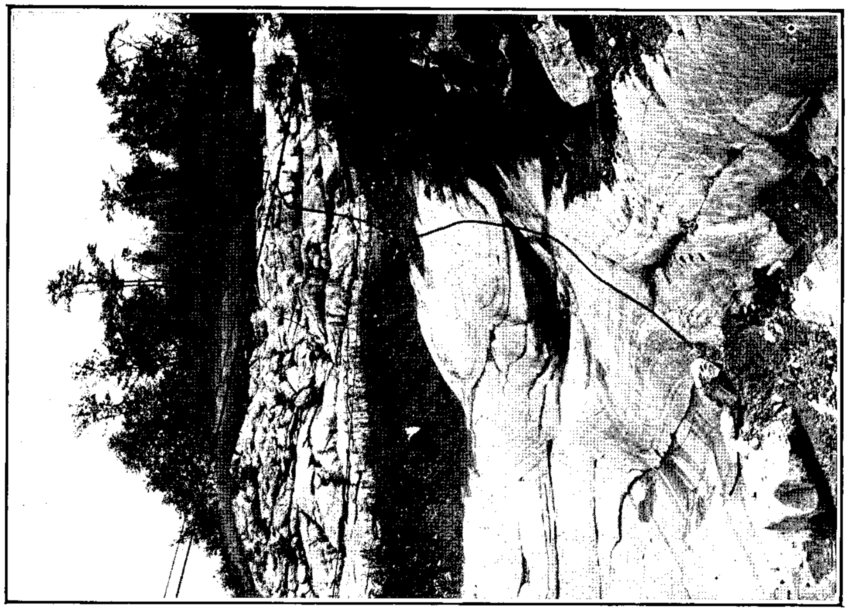
The general structure here is shown in section I, Plate III. The beds strike N. 25° W. and dip 82° N. 65° E. The west wall shows very irregular jointing. (See fig. 19).

PROSPECT WEST OF FLORENCE NO. 2 QUARRY.

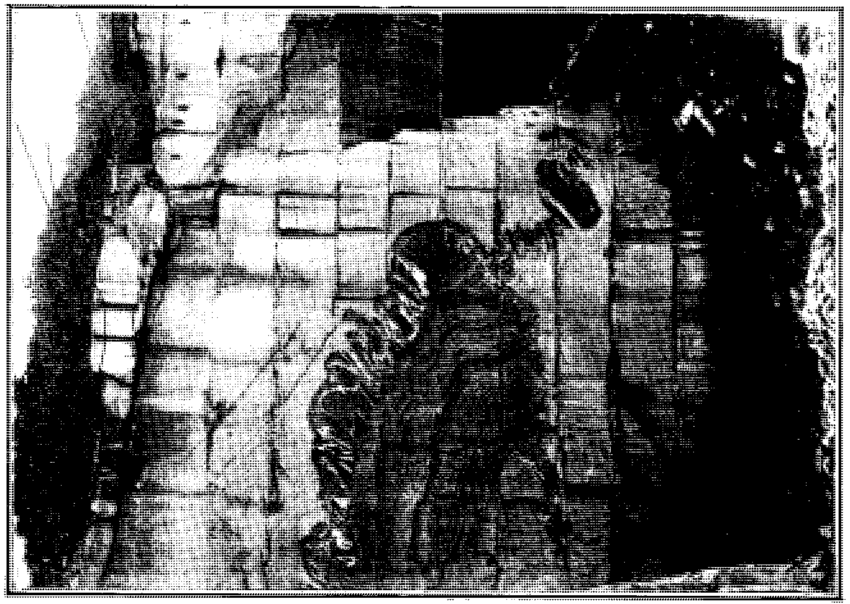
An east-west trench dug in 1900 across the low ridge immediately west of the site of the Florence No. 2 quarry exposed a handsome white marble interbedded with a coarser one of medium bluish-gray banded with black, containing a few scales of biotite.

The white (202, a) is a calcite marble of milk-white color and of irregular texture, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.5 millimeter and of about grade 4 (medium). It contains a few pyrite grains up to 0.03 millimeter, rare grains of quartz, and sparse very minute black particles of uncertain nature.

PLATE XV.



*B.* RECENTLY UNCOVERED GLACIATED BEDS OF GRAPHITIC CALCITE MARBLE AT FLORENTINE QUARRY, PITTSFORD.
Looking S. 32° E., nearly along the strike of the beds.



*A.* SOUTH WALL OF TRUE BLUE QUARRY, WEST RUTLAND.
Westward-dipping beds of graphite and dolomite marble. The upper part of the 15-foot bed, consisting of very dark dolomite veined with calcite and quartz, passes into a series of nodules. The lower part of the bed seems to

and grayish calcite marbles including 8 feet of dark stone. They belong above the intermediate dolomite. (See p. 87).

The marble, "Florence No. 2," is a calcite marble of very light bluish-gray color with whitish and dark-gray (graphitic and dolomitic) streaks and spots parallel to the bedding. It is uneven in texture, with grain diameter, in the calcitic parts, of 0.075 to 1, mostly 0.12 to 0.37 millimeter, and is thus of grade 4 (medium). The very irregular dolomitic lenses, which in thin section are not sharply separated from the calcitic ground, have a grain diameter mostly of 0.05 to 0.25 millimeter and are thus of grade 3 (fine). The dolomite is untwinned and some of the grains have rhombic outlines. Associated with it are a few small quartz grains and muscovite scales. Minute black grains (probably graphite) occur throughout, but more abundantly in the dolomitic lenses, and also a little pyrite. The marble takes a high polish, but the dolomite mottling shows in minute relief on the polished face.

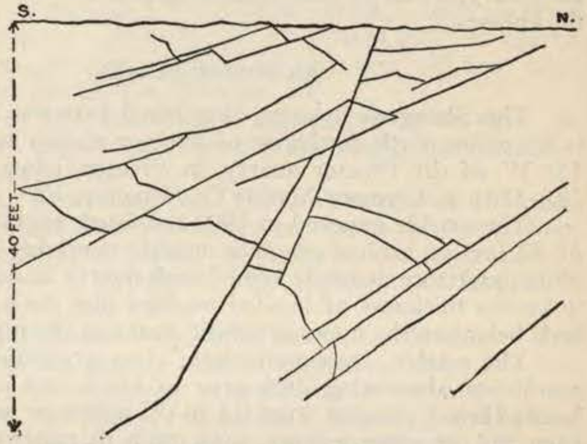


FIGURE 19.—Irregular joints and fractures on west wall of Florence No. 2 quarry, Pittsford.

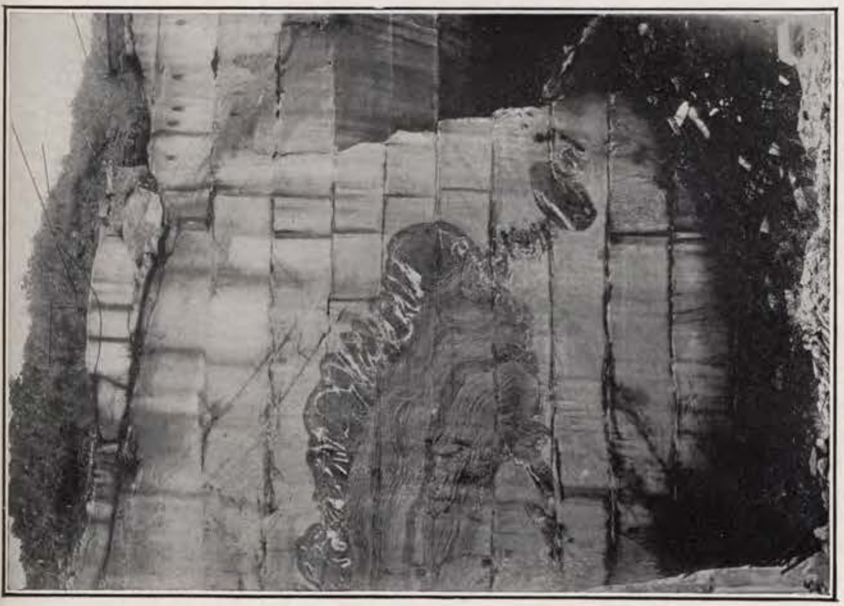
The general structure here is shown in section I, Plate III. The beds strike N. 25° W. and dip 82° N. 65° E. The west wall shows very irregular jointing. (See fig. 19).

PROSPECT WEST OF FLORENCE NO. 2 QUARRY.

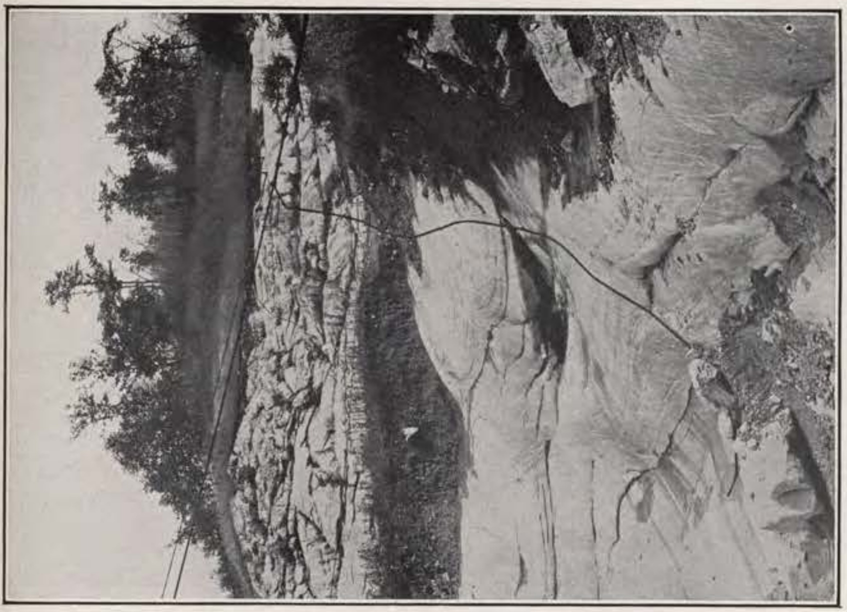
An east-west trench dug in 1900 across the low ridge immediately west of the site of the Florence No. 2 quarry exposed a handsome white marble interbedded with a coarser one of medium bluish-gray banded with black, containing a few scales of biotite.

The white (202, a) is a calcite marble of milk-white color and of irregular texture, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.5 millimeter and of about grade 4 (medium). It contains a few pyrite grains up to 0.03 millimeter, rare grains of quartz, and sparse very minute black particles of uncertain nature.

PLATE XV.



A. SOUTH WALL OF TRUE BLUE QUARRY, WEST RUTLAND.
Westward-dipping beds of graphite and dolomite marble. The upper part of the 15-foot bed, consisting of very dark dolomite veined with calcite and quartz, passes into a series of nodules. The lower part of the bed seems to



B. RECENTLY UNCOVERED GLACIATED BEDS OF GRAPHITIC CALCITE MARBLE AT FLORENTINE QUARRY, PITTSFORD.
Looking S. 32° E., nearly along the strike of the beds.

TURNER QUARRY.

The Turner quarry is less than 1,000 feet northeast of the Florence No. 2 and about three-fourths of a mile southwest of Florence station, in Pittsford Township. (See Pl. I). The opening, which is of recent date, is about 500 feet north of the Central Vermont Marble Co.'s quarry, which was operated in 1900 but is now disused. It is about 140 feet north to south by 70 feet across and 86 feet deep in one half and 49 feet in the other. It has a tunnel at the south end, 43 feet below the rock surface, 70 feet wide, and extending 35 feet to the south.

In May, 1911, this quarry passed into the hands of the Vermont Marble Co., Proctor, Vt. The marble exposed in the quarry and cropping out on both sides of it consists of the following beds, beginning at the top and west:

*Section of marble beds at Turner quarry.*

| | Feet. |
|---|---|
| Intermediate dolomite | 242 |
| White mottled marbles | 207 |
| Dolomite series. | |
| | 449 |

Its position is therefore identical with that of the marble in the Proctor quarry (p. 122).

The marble, "Pittsford Italian," is a calcite marble of slightly bluish-white color, with finely plicated beds and irregular mottlings of medium gray (graphitic dolomite). One of these little

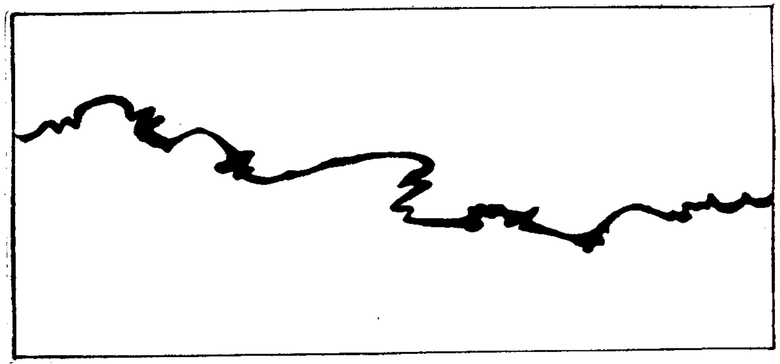


FIGURE 20.—Minute dolomite bed in lower mottled marble, "Pittsford Italian" Natural scale.

beds is shown in figure 20. They are from half an inch to 3 inches apart. The calcitic part has a grain diameter of 0.05 to 0.87, mostly 0.12 to 0.37 millimeter, and is thus of grade 4 (medium). The grain diameter of the little dolomite beds and lenses (not crossed by the sections obtained) is probably, like that in the "Pittsford Italian," mostly 0.05 to 0.25 millimeter, and these are thus of grade 3 (fine). The general texture is irregular and uneven. There are very minute black particles (graphite?), a few of pyrite, and rare small quartz grains. The marble takes a high polish, but the darker dolomitic passages project in very minute relief on the polished face.

The beds strike N. 25°-30° W. and dip 75° ENE. The dolomite on the west strikes N. 20° W. and dips 70° N. 70° E. Both the underlying and overlying dolomite and the intervening marble belong to the east limb of an eastward-inclined syncline, as shown in section I, Plate III. The economic significance of this relation is that eventually, as the quarry deepens, the underlying dolomite will be encountered.

### FLORENCE NO. I (HOGBACK) QUARRY.

The Florence No. 1 is a new opening, southwest of the now disused "Valley quarry," about three-fourths of a mile west of Florence station, in Pittsford Township. (See Pl. I). It is 90 feet east to west by 70 feet across. One-half of it is 112 feet deep and the other 70 feet. In May, 1911, the quarry passed into the hands of the Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here, beginning above and on the west, are as follows:

*Section of marble beds at Florence No. 1 quarry.*

| | Feet. |
|---|---|
| Light mottled marble including a 9-foot bed of darkish gray "mountain dark" | 234 |
| White marble | 18 |
| Intermediate dolomite | 254 |

The position of the beds is thus above the intermediate dolomite and corresponds to that of the beds in the Florence No. 2 quarry. (See p. 86).

The marble, "Florence No. 1," is a calcite marble of light bluish-gray color with fine dark-gray streaks (graphitic and dolomitic beds) parallel to the bedding. On the bed face these dolomite beds appear as an irregular mottling. It is practically identical with "Florence No. 2," described on page 124. Its texture is medium (grade 4), but it is regarded as slightly coarser than "Pittsford Italian."

The beds strike N. 25° W. and dip 70°-75° ENE. The marble and the intermediate dolomite east of it both belong to the east limb of an eastward-inclined syncline. Therefore as the quarry is deepened the underlying intermediate dolomite should eventually be struck, although no indications of dolomite or of any turning of the beds have been found at a depth of 70 feet below the bottom of the quarry. Conspicuous joints dip to the southwest at low angles. Percolating water has by means of its content of carbonic acid formed a series of caves, first along the bedding and



then along these joints, as shown in Plate XVII. One of these caves 100 feet below the surface is 10 feet high. These caves occasion much inconvenience in adjusting the cutting machines. An east-west compressive strain has been noticed at this quarry.

### FLORENTINE QUARRY.

The Florentine quarry is at the east foot of the Taconic Range, 1½ miles N. 72° E. of Biddie Knob and 1¼ miles west of Florence station, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey). The quarry, a new opening a little west of a disused quarry, measures about 200 feet north to south by 100 feet across and is 100 feet deep in one half and 42 feet in the other. In May, 1911, it passed into the hands of the Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here include 150 feet of graphitic marbles immediately underlying the base of the schist of the Taconic Range and thus belong to the upper graphitic series. In the quarry there is an irregular bed of graphitic untwinned dolomite veined with quartz and white calcite.

The marble, "Florentine blue," is a graphitic calcite marble of dark bluish-gray color, with fine very dark and light gray unplicated bands, and of even, regular texture, with grain diameter of 0.05 to 0.75, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It abounds in minute particles of graphite and contains rather plentiful pyrite up to 0.12 millimeter in diameter and rare grains of quartz. This stone takes a very high polish without any protuberances.

The marble strikes N. 25° W. and dips 60° W. at the surface of the quarry, turning to 70° at the bottom. In the disused quarry about 200 feet farther east the dip is at a low angle to the west. At the contact with overlying schist 60 feet west of the quarry the schist is graphitic and has a cleavage foliation striking N. 5° W. and dipping 20°-25° E. The marble at the contact curves from 90° to steep west, and the bedding of the schist, obscured by cleavage, is presumably parallel to it. The marble beds belong to the east limb of a syncline. Between the quarry and the schist contact the marble beds, recently divested of their protective covering of till, are highly glaciated, as shown in Plate XV, *B*.

### HOLLISTER QUARRIES.

The Hollister quarries are 1¼ miles northwest of Florence station and half a mile west of Florence Cross Roads, in Pittsford Township. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey). The quarries comprise two openings on the same beds—the southern one, the original Hollister quarry, which at the surface measures 150 feet north to south by 25 feet across, but at the bottom, 316 feet down, is 189 by 125 feet, and a new one, 200 feet north, the Valley quarry, which measures 100 feet north to south by 25 feet across at the surface, but 125 feet at the bottom, 85 feet down. From the south end of the original quarry a tunnel, 60 feet wide and 40 feet high, has been drilled 70 feet west.

Operator, Vermont Marble Co., Proctor, Vt.

The marble beds exposed and prospected here, given in more detail on page 85, comprise, beginning on the west and above:

*Section of marble beds at Hollister quarries.*

| | Feet. |
|---|---|
| Light bluish-gray marbles | 90 |
| Clouded marble | 16 |
| "Blue vein" | 14 |
| Alternating clouded muscovitic, and light bluish-gray marbles | 102 |
| | 222 |

This set of beds apparently lies a little above the intermediate dolomite. (See p. 87).

The marble, "Pittsford Valley," is a calcite marble of light bluish-gray color with little medium to dark gray (graphitic and dolomitic) plicated beds which on the bed surface appear as irregular mottling. Its texture is uneven. The grain diameter in the calcitic parts is 0.05 to 0.75, mostly 0.12 to 0.37 millimeter, and thus of grade 4 (medium). In the dolomitic parts the grain diameter is 0.02 to 0.25, mostly 0.07 to 0.12 millimeter, and thus of grade 2 (very fine). Minute black particles (probably graphite) occur throughout but are more plentiful in the dolomitic parts, which also contain very little pyrite and muscovite. The marble takes a high polish, but the dolomitic mottling projects in very minute relief.

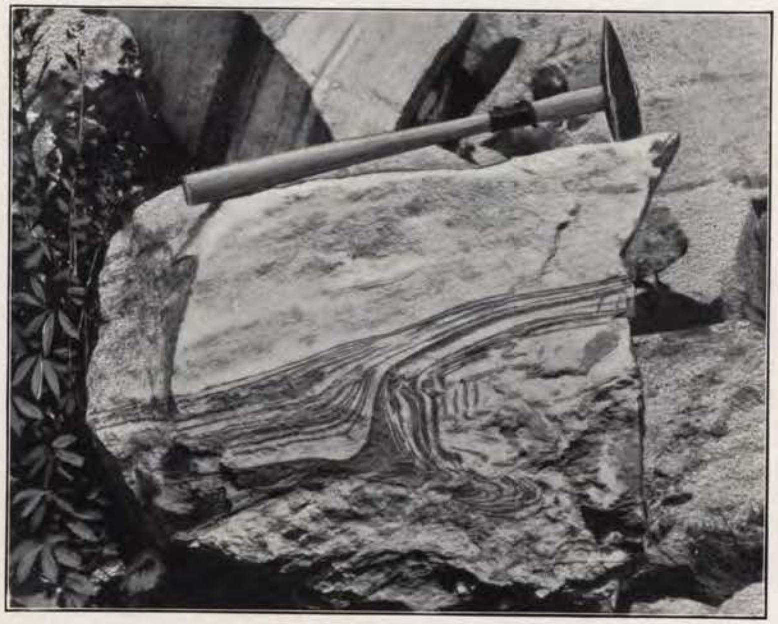
A specimen of bed K is a calcite marble of light bluish-gray color without mottling and of regular, even texture, with grain diameter of 0.05 to 0.87, mostly 0.12 to 0.5 millimeter, and thus also of grade 4 (medium) but a trifle coarser than that of bed A. (See fig. 21). The average grain diameter of the calcitic parts, determined by the Rosiwal method, is 0.1484 millimeter.

In general the marbles of these quarries are more bluish than those of the Proctor and Riverside quarries.

The beds strike N. 5° W. and dip 80° E. to 90°. Although the beds at a depth of 316 feet are still vertical, they will be found eventually to be underlain by the dolomite, which crops out east of the quarry. The character of the folds here is not clear. There are four sets of joints—set *a*, strike N. 80° E., vertical, spaced 2 to 5 feet for a distance of 50 feet between the two openings; set *b*, strike east to west, dip 10° N., few, spaced




*A.* GLACIAL FURROW IN WHITE CALCITE MARBLE, PITTSFORD.
The marble is in close erect folds striking N. 20° W., but the furrow runs S. 20° E. Thin-bedded clay 20 feet thick, probably deposited by a glacial lake, overlies the marble and has preserved it from weathering, so that good stone occurs at the rock surface.



*B.* PINCHED FOLD OF WHITE CALCITE MARBLE, DUMPS OF OWLS HEAD QUARRIES, SOUTH DORSET.
Showing the prolongation of the apex of the fold by flowage. The bed about and below the fold is dolomite. Hammer 21 inches.

3 to 20 feet; set *c*, same strike, dip 55° N., spaced 3 to 50 feet; set *d*, same strike, dip 10°-15° S. The quarry is at the east foot of a marble cliff 100 feet high. On the east side of the northern opening the marble at the surface is not over 5 feet thick. In drilling eastward at a depth of 75 feet the marble was found to extend but 25 feet. It is possible that the beds have suffered considerable erosion at this point.

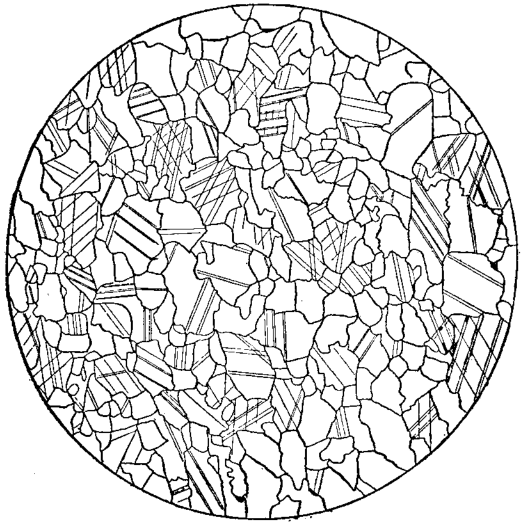


FIGURE 21.—Thin section of coarser part of light-gray clouded calcite marble from bed K, Hollister quarry, Pittsford. Enlarged 20 diameters.

Specimens: Champlain apartment house, Washington, D. C.; fourteen columns 29 feet 9 inches long and from 2 feet 10 inches to 3 feet 4 inches in diameter in Curtis Publishing Co.'s building, Philadelphia. These columns were cut parallel to the bed and show the small grayish plicated dolomitic beds. (See also Pl. VI, *B*).

## LANDON QUARRY.

The recently opened old prospect known as the Landon quarry is 1½ miles N. 10° W. from the Hollister quarries and close to the Brandon-Pittsford line, in Pittsford Township. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey). The opening measures 84 feet east to west by 50 feet across and 20 feet in depth.

Operator: Vermont Marble Co., Proctor, Vt.

The marble exposed consists of 80 feet of calcite marble. The upper part of the dolomite series is but a few hundred feet east of the quarry.

The marble, "Landon," is a calcite marble of slightly bluish-white color, with medium to dark-gray, intricately plicated dolomitic beds up to 0.1 inch thick, which project slightly on the weathered face. Its texture is uneven, with grain diameter in the calcitic parts of 0.05 to 0.75, exceptionally 1.5, mostly 0.12 to 0.37, averaging 0.24 millimeter, and thus of grade 4 (medium), and in the dolomitic parts as much as 0.02 millimeter, but also with large cloudy plates 0.75 to 1.75 millimeters across having rhombic cleavage and rarely dolomitic twinning. These plates show under a 450 enlargement a peculiar granular texture. The marble contains very little quartz, some muscovite, pyrite, limonite, and sparse very minute black particles throughout. Its general texture is a little finer than that of the beds of the Hollister quarry and its little dolomitic beds are more numerous, producing more mottling.

The beds shown by the plications strike N. 20°-25° W. and dip 80° WSW. A close jointing or cleavage spaced in places 1 inch to 2 feet dips 30° E. One set of joints strikes N. 30° E. and a single vertical joint on the north wall runs east to west. The relation of the beds to the two dolomite series is not clear.

### BRANDON.

There were but two active quarries in Brandon in 1910. The marbles of four idle ones which were visited in 1903 were examined microscopically. Two new prospects were opened in 1911.

#### QUARRY 238.

The abandoned quarry at locality No. 238 is a mile north of the Landon, a little east of the railroad, and about 2 miles S. 25° E. of Brandon station. (See Pl. I).

The marble is a calcite marble of milk-white color, with little cloudy dolomitic and muscovitic beds. The calcitic parts are irregular in texture and have a grain diameter of 0.05 to 0.75, mostly 0.12 to 0.38 millimeter, being thus of grade 4 (medium). The marble contains some pyrite and a little quartz.

The plicated bedding is vertical and is crossed by low eastward-dipping cleavage ("reeds").

#### BRANDON ITALIAN QUARRY.

The Brandon Italian quarry is half a mile south of Brandon station and 0.7 mile west of the west boundary of the basal dolomite. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey). The quarry measures about 600 feet north to south by 60 feet across and 75 feet in depth.

Operator since 1909, Vermont Marble Co., Proctor, Vt.

The marble is of uncertain thickness owing to close folding, as explained below. The character of the marble is regarded by the operators as identical with that of the Hollister quarries.

The marble, "Brandon Italian" is a calcite marble of light bluish-gray color crossed by small dark-gray graphitic dolomitic

PLATE XVII.

EFFECT OF UNDERGROUND SOLUTION, SOUTH WALL OF FLORENCE NO. 1 QUARRY, PITTSFORD.
The lowest cave is 15 feet long. The smaller ones are along a bedding plane.

beds which on the bed face produce an irregular mottling. Its texture is uneven and somewhat elongated, with grain diameter in the calcitic parts of 0.05 to 0.87, mostly 0.17 to 0.5 millimeter, and it is thus of grade 4 (medium). The grain form and texture are shown in figure 22. An estimate of the average grain diameter by the Rosiwal method yields 0.155 millimeter. The section did not cross any of the dolomitic beds. Quartz grains, somewhat plentiful, measure 0.05 to 0.07 millimeter. A little pyrite and rarely muscovite are also present.

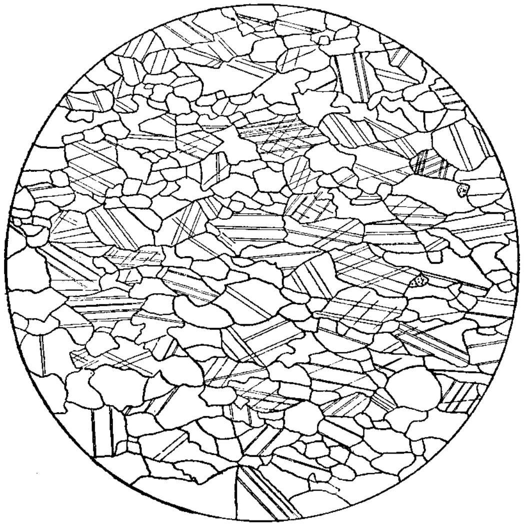


FIGURE 22.—Thin section of calcitic part of clouded calcite marble from the Brandon Italian quarry, showing irregular grain form and elongate texture. Dotted particles are quartz. Enlarged 20 diameters.

The beds strike N. 20°-25° W. and on the east side dip steeply to the east at the south end but stand vertical at the north end. In the center of the quarry they zigzag in a horizontal direction, indicating a synclinal or anticlinal structure. A repetition of the beds on either side of the synclinal axis is therefore to be expected. Core drilling at a point 200 feet east of the quarry shows continuous marble. In breaking the blocks an obscure vertical cleavage parallel to the bedding on the east side of the quarry is utilized. The possible synclinal structure is

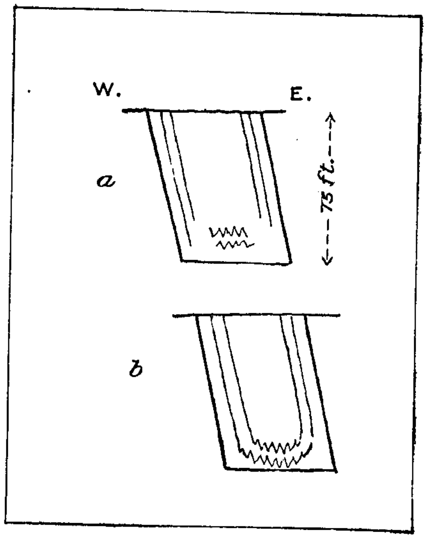



FIGURE 23.—Structure at Brandon Italian quarry. *a*, Actual; *b*, an interpretation.

shown in figure 23, *b*. The marble in 1903 was reported as affording evidence of compressive strain.

Specimen: Roman Catholic Church at Middlebury.

### BRANDON ITALIAN HIGH STREET QUARRY.

The Brandon Italian High Street quarry is 0.6 mile northeast of the Brandon Italian quarry and half a mile east-southeast of Brandon station. (See Pl. I).

Operator since 1909, Vermont Marble Co., Proctor, Vt.

The marble beds consist of 107 feet of light bluish-gray marbles situated very near the underlying dolomite. The marble closely resembles that of the Brandon Italian quarry.

The marble beds strike about north and dip 50° W. The knoll east of the quarry consists of the bluish-gray basal dolomite, striking N. 25° W. and dipping 90°. The first dolomite west of the quarry should be the intermediate dolomite.

### GOODELL QUARRY.

The Goodell quarry is at the foot of the north end of the Taconic Range about 2½ miles southwest of Brandon station. (See Pl. I). It is a small opening abandoned soon after it was made owing to the smallness of the marble bed.

The beds include 15 feet of fine white marble, apparently both underlain and overlain by a dark gray graphitic quartzose dolomite. Some of the marble is in thin beds and the whole was reported as running out or covered along the strike. It probably belongs toward the upper graphitic series.

The marble is a calcite marble of milk-white color and of regular, even texture, with grain diameter of 0.02 to 0.37, mostly 0.07 to 0.25 millimeter, and thus of grade 2 (very fine). It takes a high polish.

The marble bed and the dolomitic rock on both sides of it strike N. 30° E. and dip 35° S. 60° E. Of the overlying dolomite a thickness of 15 feet is exposed. It is uncertain whether the two dolomitic beds are one bed doubled over or two distinct beds. The rock in thin section has a grain diameter of 0.009 to 0.094, mostly 0.02 to 0.04 millimeter. Its character as dolomite is not shown by twinning. It contains sparse grains of quartz and rarely one of plagioclase (feldspar). A very graphitic and quartzose bed a millimeter thick and another of twinned calcite particles with quartz grains appear in the section.

W. T. Schaller, of the Geological Survey, who examined the rock qualitatively, reports that "calcite and dolomite together form a large part of it, but dolomite itself does not form the chief constituent."



A railing with balusters of this marble can be seen at the side of the pulpit in the Congregational Church at Brandon.

### CONNELL QUARRY.

The Connell quarry is about 1,800 feet ENE. of the Goodell quarry and 2¼ miles southwest of the bench mark in Brandon village. (See Pl. I). Operator, Brandon Marble Co., Brandon, Vt.

The quarry measures 60 by 30 feet and is 24 feet deep; there is a second opening 175 feet to the north.

The beds here consist of 30 feet of marble, both overlain and underlain by graphitic dolomite. The stratigraphic position is like that of the Goodell quarry. The thickness of 30 feet includes a 7-foot bed of fine white statuary, 13 feet of mottled, and 10 feet of gray marble.

The white marble is a calcite marble of very faint ivory tint and of regular, even texture, with grain diameter of 0.05 to 0.45, mostly 0.1 to 0.24 millimeter. A Rosiwal measurement of a thin section shows an average grain diameter of 0.1 millimeter. It therefore belongs to grade 2 (very fine), as does also the "statuary Rutland." It contains rare quartz grains and sparse minute black specks. It takes a high polish.

The beds are on the strike of the beds in the Goodell quarry (N. 30° E.) and dip 40° S. 60° E. The excavations have not proceeded far enough to show the relations of the two dolomite beds to one another.

### ROYCE QUARRY.

The long idle Royce quarry is three-fourths of a mile northwest of Brandon station at the west foot of a ridge 100 feet high. (See Pl. I). The quarry measures about 150 feet along the strike. The marble exposed measures about 70 feet, underlying (really overlying in consequence of overturned folds) grayish dolomite which may be the intermediate dolomite.

The marble is of two kinds. One is a calcite marble of very light bluish-gray color, with inconspicuous medium-gray dolomitic (?) mottlings (beds), and of even texture, with grain diameter in the calcitic part of 0.02 to 0.37, mostly 0.1 to 0.25 millimeter, and thus of grade 3 (fine). It contains some small quartz grains and some pyrite. There is a rough parallelism of the twinning planes of different particles. The other is a calcite marble of milk-white color, with little grayish micaceous dolomitic beds. The calcitic part has a grain diameter of 0.02 to 0.5, mostly 0.1 to 0.25 millimeter, and is thus also of grade 3. It contains small sparse quartz grains and very minute black particles of uncertain nature.

The marble and the dolomite east of it strike N. 15°-20° W. and dip steeply to the east. The upper marble beds are crossed by joints dipping 30° W.

### PROSPECT 255.

Prospect 255 is 2¼ miles north of Brandon station, just west of the boundary of the basal dolomite east of the road to Leicester. (See Pl. I).

The marble is white and light bluish-gray. A specimen of the latter shows small medium gray dolomitic bands up to 0.1 inch wide. The calcitic part is of irregular texture and has a grain diameter of 0.05 to 0.75, mostly 0.12 to 0.5 millimeter, being thus of about grade 4 (medium). It contains minute quartz grains and some pyrite. A large plate of untwinned dolomite, 1.12 millimeters across, with rhombic cleavage, is crowded with graphite. This marble is coarser than that of the Royce quarry.

The beds strike N. 10° E. and dip 35° E. Dolomite lies east of the marble with like dip, both forming part of an overturned fold. The marble thus belongs at base of the marble series.

### VERMONT ITALIAN MARBLE CO.'S QUARRY.

The quarry of the Vermont Italian Marble Co., of Brandon, is 1½ miles N. 20° W. of the bench mark in Brandon village. (See Pl. I). It was opened in 1911.

The marble is reported as practically identical with that of the Brandon Italian quarry, 2 miles to the south, and is said to measure 600 feet in width, without reference, of course, to any duplication in folding. The beds dip about 18° roughly eastward. One or more of them attain a thickness of 8 feet.

## SUDBURY.

### SUDBURY BRECCIA PROSPECT.

A reddish hematitic dolomite resembling some of the fragments in the breccia of the Dyer quarry, in Manchester (p. 97), occurs at a point 4 miles WSW. of Brandon, in Sudbury Township, along a brook flowing north into Otter Creek. It is about half a mile northwest of the site of the Cool farmhouse.

The bed from its location appears to be very near the top of the marble. The rock is brecciated in places and coarsely cemented with flesh-colored and colorless calcite.

## MIDDLEBURY.

### MIDDLEBURY MARBLE CO.'S QUARRY.

The abandoned quarry of the Middlebury Marble Co. is 2 miles east-southeast of Middlebury, a little west of the west limit of the basal dolomite and about 1,100 feet east of the road to East



Middlebury, in Middlebury Township. (See map of Middlebury quadrangle, U. S. Geol. Survey). This quarry has been idle for over 28 years. It measures about 100 feet east to west.

The following section is exposed, beginning on the west:

*Section of marble beds at Middlebury Marble Co.'s quarry.*

| | Feet. |
|---|---|
| Calcite marble, bluish | 6 |
| milk-white | 9 |
| white, tranlucent | 14 |
| fine grained, faintly pink | 17 |
| white (like 14-foot bed) | 22 |
| | 68 |

The marble of the 9-foot bed is a calcite marble of milk-white color and of regular texture, with grain diameter of 0.02 to 0.37, mostly 0.12 to 0.25 millimeter, and thus of grade 3 (fine). It contains rare quartz grains and spherules of pyrite. The texture of this rock is that of a normal marble and very different both in grade and in grain arrangement from the section obtained of Brandon Italian, as will be noticed by comparing figures 24 and 22. An estimate by the Rosiwal method shows its average grain diameter to be 0.11 millimeter.

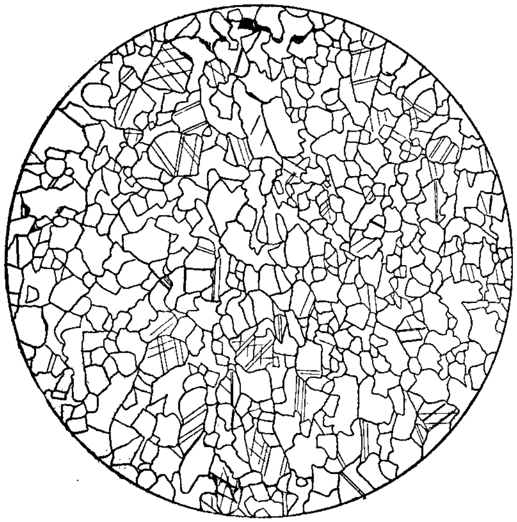


FIGURE 24.—Thin section of white calcite marble from abandoned quarry of Middlebury Marble Co. Enlarged 20 diameters.

The structural relations are not clear. The marble, however, probably belongs not far from either the dolomite series or the intermediate dolomite. The dip on the west side of the quarry is 40°-50° W. About 600 feet east of the quarry a whitish dolomite and very quartzose beds strike N. 10° W. and dip about 72° E. At an old disused quarry a mile north marble about 40 feet thick strikes north and dips 45° E.; and at another opening a quarter of a mile west of this one white marble about 70 feet thick, with muscovitic streaks, strikes N. 10° E. and dips 90°.

### MARBLE LEDGE QUARRY.

The long disused Marble Ledge quarry is about 3¼ miles N. 25° E. of Middlebury and 1¾ miles east of Beldens. (See map of Middlebury quadrangle, U. S. Geol. Survey).

A body of white marble about 60 feet thick is exposed, striking north and dipping 50° E. Muddy Branch here flows through a small gorge along the strike and there seems to be a syncline between the stream and the quarry.

## MONKTON AND BRISTOL.

The dolomite of Monkton has been described on page 38. It belongs apparently to the dolomite which underlies the calcite marbles. The only quarry operated in recent years was idle in 1910.

### VERMONT MARBLE CO.'S MONKTON QUARRY.

The Monkton quarry of the Vermont Marble Co. is at the west foot of the so-called Hogback Mountains, really the west flank of the Green Mountain range, about 1½ miles north-northeast of East Monkton and 6 miles N. 10° W. of Bristol, in Monkton Township, Addison County. (See map of Middlebury quadrangle, U. S. Geol. Survey). The opening is 30 by 15 feet and 5 feet deep. The quarry is not now used, the company having withdrawn the marble from the market.

The beds exposed consist of about 270 feet of dolomite. The marble, "Ruvaro," is a mottled pink and white quartzose hematitic dolomite marble. It contains thin beds of sericite and quartz. Descriptions of these will be found on page 38.

The dolomite strikes N. 25°-30° W., dips 30°-40° W., and is crossed by slip cleavage dipping 40° E. and in places by close east-west joints dipping steeply to the north. About 315 feet east of the dolomite is an outcrop of quartzite, slightly calcareous in places, striking N. 15° W. and dipping at a steep angle to the west, crossed by cleavage dipping 60° E. A little farther south, at the head of a brook flowing southward, dolomite and quartzite are in contact, both rocks for the depth of a foot dipping steeply to the east, whether by faulting or minor overturned folding is not evident.

This marble was polished by the company and sold for decorative use.

### COLUMBIAN MARBLE CO.'S MONKTON QUARRY.

The Monkton quarry of the Columbian Marble Co. is 0.6 mile S. 32° W. of the Vermont Marble Co.'s quarry, on the south side of the east-west crossroads in the same township. The opening is about 20 feet square and 5 to 10 feet deep and has been long disused.



The marble is identical with that of the Vermont Marble Co.'s quarry. The weathered parts have a muddy gray color. The beds strike north, dip 45° E., and show many minor fractures along the bedding.

### CHAPIN PROSPECT.

The same dolomitic marbles crop out between the two quarries last described, on the farm of L. O. Chapin, of Bristol, Vt.

### JIMMO PROSPECT.

The Jimmo prospect is in Bristol Township 1¼ miles west-southwest of the Bristol bench mark. (See map of Middlebury quadrangle, U. S. Geol. Survey). Owner, Harry Jimmo, Bristol, Vt.

The marble is a quartzose hematitic dolomite marble of deep-pink color, differing from that of the Monkton quarries and prospects by its less conspicuous mottling and deeper shade. It also has films of sericite. The thickness exposed is 8 feet.

## SWANTON.

The dolomite marbles of Swanton have already been described in a general way on page 33. The quarries, opened about 1870, are about a mile S. 65° E. from Swanton, on a ridge on the south bank of Missisquoi River and rising to 165 feet above it, in Franklin County. Five openings situated at different elevations and on different beds are now in occasional use. They have working faces on the east ranging from 15 to 40 feet in height and from 50 to 100 feet or more in length. Operator, Barney Marble Co., Swanton, Vt.

The marble beds are about 150 feet thick. The character of the beds is shown in the descriptive sections given below. Some of the beds are uniformly reddish brown and recur at irregular intervals. Others, near the top, are uniformly bluish gray. Some at the base are greenish gray, with brecciated dolomitic lenses or beds and distorted corals. Others have a reddish or purplish matrix with similar brecciated beds and corals.

The marbles are known commercially as "Champlain marbles." There are five more marked varieties described in the following paragraphs.

"Royal red" is a quartzose hematitic untwinned dolomite marble of dark reddish-brown color, with irregular, slightly lighter clouds and some whitish streaks. It consists, in descending order of abundance, of (*a*) dolomite plates of irregular form, tending to rhombic outline, and of some rhombs with grain diameter of 0.02 to 0.3, mostly 0.02 to 0.12 millimeter, averaging 0.07 and thus of grade 1 (extra fine); (*b*) interstitial reddish-brown hematitic (kaolin), in places more abundant, forming streaks along the bedding; (*c*) plentiful angular quartz grains, 0.02 to 0.15 but mostly under 0.07 millimeter with rare grains of feldspar (plagioclase); (*d*) a few opaque particles (magnetite?); and (*e*) rare muscovite flakes. The dolomite plates have very minute reddish specks. The quartz grains have cavities with moving vacuoles. This marble is very sonorous, emits an argillaceous odor, effervesces very slightly with acid test, and takes a high polish. A thin section of it is shown in figure 8, page 36.

"Jasper" is a quartzose hematitic untwinned dolomite marble of bright-reddish ground containing pinkish and white irregular lenticular objects from 0.1 to 0.7 inch in width and from an inch or less to 8 inches in length, generally with the long axis parallel to bedding but in places at all angles. The white ones are highly crystalline and effervesce as little as does the ground under acid test, and some have a nucleus of milky quartz. The ground has the same composition as the "royal red" but contains magnetite grains, giving rise to hematite stain. The corals are in part coarsely crystalline twinned dolomite and in part granular dolomite. In sonorousness, effervescence, and polish this marble is like the "royal red." A photograph of a specimen of this marble is reproduced in Plate VIII, *A, c;* and blocks of it are shown in Plate V, *B*.

"Lyonnaise" is a quartzose hematitic untwinned dolomite marble of brownish-red ground or of merging forms of roundish cylindrical or irregular outline in brownish red with the interspaces filled with whitish crystalline dolomite. One of these forms has crystalline quartz in the center. The ground is of the same composition and texture as the "royal red." Some of the white twinned dolomite incloses granular dolomite. In sonorousness and effervescence of ground this marble is like the "jasper" and the "royal red." The polished face shows some dull (kaolinic?) streaks.

"Oriental" is a quartzose hematitic and magnetitic untwinned dolomite marble with ground of dark reddish brown inclosing dark purplish-gray areas of very irregular curving outline and concentrically banded, also with some irregular spots of white calcite having a nucleus of crystalline quartz. The ground is like that of "royal red" in texture and composition. The dark purplish-gray parts abound in magnetite grains, more or less oxidized to hematite, and contain rare minute scales of biotite. The coarsely crystalline white parts appear to be part calcite and part dolomite. There are veinlets of white twinned dolomite. The sonousness, effervescence of ground, and polish of this marble are like those of "royal red."

"Olive" is a quartzose untwinned dolomite marble of light, faintly greenish-gray ground, inclosing very irregular lenses or



elongated cones, more or less parallel, some of them brecciated, of light pinkish-gray color. Some of these lenses have a nucleus of white twinned dolomite surrounding crystalline quartz; most of them have a dark-brownish rim of limonite from the oxidation of pyrite. The dolomite plates of the ground carry minute dark grains. The ground also contains pyrite and grains of magnetite, mostly not oxidized to hematite. There are rare muscovite scales in the finer parts. This marble is also very sonorous, emits an argillaceous odor, and effervesces very slightly with acid test. The polish is fair but shows some dull (kaolinic?) streaks.

The dolomite marble beds of Swanton are underlain on the west by a calcareous bed containing the brachiopod Kutorgina, of Lower Cambrian age, and are overlain on the east by the Lower Cambrian shales of St. Albans.[1] The following sections were taken at the quarries:

1. At the top of the hill, strike N. 30° E., dip 10° S. 60° E.: Beginning at the top, 17 feet of mottled red and white dolomite marble, 3 feet of bluish-gray dolomite, 2 feet of plain red ("royal red"), 16 feet of mottled red and white. A joint face is coated with salmon-colored calcite. The bluish-gray dolomite has a marked argillaceous odor and weathers light ocher color; its effervescence is slight. In thin section this is a quartzose untwinned dolomite with a few grains of magnetite, passing into hematite, and some light-yellow grains, probably from oxidized pyrite. Interspersed among the quartz grains are a few feldspar (orthoclase and microcline).

2. At the next quarry down: 12 feet of mixed dolomite beds, overlying 7 feet of hematitic and magnetitic dolomites with purplish spots ("oriental"). Some joints strike N. 35° E., stand vertical, and are spaced 5 to 18 feet; others strike N. 50° W., are vertical to steep, and are spaced 5 to 20 feet. Some diagonal fractures are coated with chlorite and salmon-colored calcite.

3. At a disused quarry next below: Beginning at the top, 8 feet of alternating mixed dolomite marbles, 2 feet of plain red ("royal"), 8 to 10 feet with white lenses or corals, discolored, and 2 to 3 feet plain red ("royal"). On some of the weathered surfaces the red argillaceous hematitic cement projects above the white lenses. The brecciation of the lenses is distinct.

4. Below the disused quarry and near the gateway, strike N. 50° E., dip 10°-15° S. 40° E.: Beginning at the top, 10 feet of hematitic dolomite with light lenses and corals, rather short and mostly parallel to bed, 3 feet of plain red ("royal," measuring 5 to 6 feet at a disused opening a little east), and 10 feet of hematitic dolomite ("jasper"), with long, narrow white corals on

[1] See Hitchcock, Edward, and Hager, A. D., Geology of Vermont, vol. 2, 1861, pp. 773-775. Edson, G. E., Geology of the town of Swanton: Sixth Rept. Vermont State Geologist for 1907, 1908, pp. 210-220, fig. 5. Perkins, G. H., Preliminary report on the geology of Chittenden County: Idem, pp. 224-245, Pl. XXXIX (a slab of marble from Swanton with a number of pteropods, *Salterella pulchella*).

bright-reddish ground, the corals at all angles, some vertical, but in places mostly parallel to bed. Joints strike N. 60° W., dip 70° N. 30° E. to 90°, and are spaced 6 to 10 feet. Joints in the "royal" bed strike N. 30°-35° W. and dip 25°-30° E. or W.; some are coated with chlorite.

5. At the west foot of the hill near the river and 60 feet above it, lower than section 4, the following series dips 15° about southeast, beginning at the top: Uncertain thickness of hematitic dolomite with white lenses, etc., 1 foot of plain red rock, 5 feet like upper bed, and 14 feet of finely laminated grayish dolomite with lenses and corals ("olive").

The marbles of Swanton are used for columns, wainscoting, and tiling. Their attractive and unusual coloring makes them as desirable for interior decoration as does their hardness for floor wear. This hardness is due to their dolomitic and quartzose composition and to their texture. Specimens: Columns and wainscoting in Detroit post office; columns and panels of "royal red" in numismatic room, United States Mint, Philadelphia; wainscoting and counter, Southern California Savings Bank, Los Angeles; wainscoting in Auditorium, Chicago; "olive" wainscoting in Columbus Despatch Building, Columbus, Ohio; tiling in city hall, Indianapolis, Ind. The length of columns is limited by the joint spacing to 10 feet.

### Isle la Motte.

#### FISK QUARRY.

The Fisk quarry, first opened (for lime burning) in 1664 and furnishing building stone in 1788, is on the west side of the south end of Isle la Motte, in Lake Champlain, 11½ miles south of the Canada line, in Grand Isle County. The western edge of the quarry is only 100 feet from the shore. The quarry covers several acres and has a depth of 20 feet. Operator, N. W. Fisk, Fisk, Vt.

The series consists in natural order of the following beds which are of Chazy age:

*Section of marble beds at Fisk quarry.*

| | Feet. |
|---|---|
| Black unmetamorphic calcite marble | 20 |
| Dark-gray crinoidal calcite marble | 4-6 |
| Dark-gray and black alternating calcite marble | 12 |
| | 36-38 |

The marbles, "Fisk black" and "Fisk gray" have already been described in detail on pages 39-41. (See also fig. 9). They are slightly dolomitic carbonaceous fossiliferous calcite marbles of unmetamorphic origin and of very dark gray shade and are susceptible of high polish. The weathered surface of the black is dark bluish gray in places, with irregular brownish-gray dolomitic bands. The polished surface is almost black, with here and there sections of Maclureas in white calcite. The stone, except the dolomite bands, effervesces freely with acid and is very sonorous. Certain tests and analyses of these marbles made for the architect of the Bennington Monument and the Buffalo Pan-American Exposition, are in Mr. Fisk's possession.

The beds dip 5° to 7° NE. and had a glaciated surface in places, with polished grooves protected by 2 to 4 feet of sand and clay, carrying a few boulders.[1] The black beds are subdivided into beds half an inch to 2 inches thick by dolomitic films or bands as thick as half an inch.

The polished product is supplied to the market by the Barney Marble Co., of Swanton. The black has long been used for tiling all over the United States. In the post office at Worcester, Mass., it has been combined with marble from Swanton in wainscoting. The waste of the quarry is sold as crushed stone.

## LIME MARBLES.

### Ira and Leicester.

The lime marbles of Ira and Leicester are included here because of their geologic and petrographic relation to the constructional and monumental marbles already described.

#### DAY QUARRY.

The Day quarry is 3¼ miles south-southwest of West Rutland, 1¼ miles southeast of the top of Mount Herrick, in the Taconic Range, on the 1,300-foot level, in the town of Ira, Rutland County. (See Pl. I and map of Castleton quadrangle, U. S. Geol. Survey). The quarry is reported as having been in operation in Revolutionary times. Operator in 1900, D. D. Day, of Ira, Vt.

The marble belongs either to the upper graphitic beds close to the base of the schist formation, or else within the schist.

The marble is a graphitic calcite marble with fine black and grayish bands, and of very uneven texture, with grain diameter of 0.02 to 0.37, rarely 2, mostly 0.07 to 0.25 millimeter, and thus of grade 3 (fine). It contains some quartz and feldspar grains, pyrite, and much graphite in bands. In places it abounds in sections of a large gastropod, resembling Maclurea.[2]

[1] See Sixth Rept. Vermont State Geologist for 1907, 1908, Pl. VI, for photograph of one of the glacial grooves.

[2] This locality is referred to by Hitchcock and Hager (Geology of Vermont, vol. 1, 1861, p. 432), also by Wing (Dana, J. D., Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 339). In February, 1901, Dr. C. D. Walcott expressed the opinion in a letter to the writer that there was no reason why the fossils of this locality, which resemble those occurring more or less abundantly to the north in the upper part of the Chazy or lower part of the Trenton, should not occur well up in the Trenton.

The marble area is about 300 feet east to west by 800 feet northeast to southwest, and is surrounded by the Berkshire schist of the range. It either protrudes through the overlying schist in consequence of erosion, or else forms a lens within it. On the west side of the quarry a tongue of graphitic sericite schist is dovetailed in the marble and the strike of the marble appears to be nearly east to west and the dip 10°-20° S. The strike of the schist mass east of the marble, however, is N. 30° E. and the dip 20° N. 60° W.; west of the marble the schist strikes east and west and dips at a low angle to the north. The marble seems to occur at the intersection of a minor transverse fold with the usual folds of the Taconic Range. A synclinal axis passes between the quarry and the top of Mount Herrick. The schist next the marble is slickensided, the grooves running N. 5° W. and dipping 45° E. The marble is much jointed, fractured, and veined with calcite and quartz. Vertical joints strike N. 20° E. and are coated with felty asbestos, "mountain leather," indicating metamorphism subsequent to jointing.

### HUNTLEY QUARRY.

The Huntley quarry is about 800 feet west of Leicester Junction, 5¼ miles northwest of Brandon station, in Leicester Township, Addison County. (See Pl. I and map of Brandon quadrangle, U. S. Geol. Survey). Operator, Brandon Lime & Marble Co., Leicester Junction, Vt.

The stratigraphic position of the marble beds of this quarry can hardly be determined, owing to the scarcity of outcrops and the distance of the quarry from the basal dolomite on the east and the schist on the west, 2 miles in each case. Marble more than 20 feet thick is exposed in beds which are doubled over on themselves two or three times.

FIGURE 25.—Thin section of marble from Huntley quarry, Leicester Junction, showing elongate alternate grain texture. Enlarged 77 diameters.

The marble is of translucent but dull aspect, light buff-pinkish color, and uneven parallel elongate texture, as shown in figure 25, with alternate irregular tiers of large and small grains. The larger grains, whose longer axes are parallel, have a diameter of 0.04 to 0.2, mostly 0.04 to 0.09 millimeter, and are thus of grade 1 (extra fine); the smaller grains are more roundish, with a tendency to rhombic form, and have a grain diameter of 0.009 to 0.03, averaging possibly about 0.02 millimeter, finer than grade 1. The larger grains show rhombic cleavage and twinning parallel to that cleavage, and are presumably calcite; the smaller ones, with neither cleavage nor twinning, may be dolomite, or else calcite crushed along its cleavage. (See p. 11). The stone effervesces with acid more freely than dolomite. The marble of these quarries seems to be referred to by Hitchcock and Hager.[1]



The strike of the beds is N. 15° E. Beginning on the east there are within a width of 60 feet three synclines, two anticlines, and part of a third, with their axial planes inclined 45°-55° E. From the manner in which the rock breaks from the mass it is evidently still under compressive or tensional strain. It is also rather sonorous. Some of these folds are shown in Perkins's seventh report.[2]

### SWINNINGTON QUARRY.

About 0.7 miles southeast of the Huntley quarry is the Swinnington quarry of the Leicester Marble Lime Co., not visited by the writer but described by Perkins,[3] in which a dark-gray (graphitic) marble forms a completely compressed (isoclinal) fold with an almost horizontal axial plane. The fold is about 7½ feet in diameter and 100 feet long.

The structure at both of these quarries indicates that Leicester Junction marks the location of a north-south zone or axis of intense crustal compression similar to that which passes near the Owls Head, in Dorset. (See p. 87).

## SERPENTINE.

### ROXBURY.

The Serpentine quarry, opened before 1858, is about half a mile south of Roxbury station, and about 600 feet west of the railroad, in Washington County. It measures at the surface 100 feet north to south by 35 feet across, but at the bottom, 70 to 75 feet down, 120 feet north to south by 48 to 50 feet across. A new opening, 500 feet south of the old one, was begun in 1910. Operator, Barney Marble Co., Swanton, Vt.

The Serpentine, "Vermont verde antique" and its geologic relations have been described on page 41.

The Serpentine is finished at Swanton and is used for columns, wainscoting, counter tops, base, and tiling. A photo-

[1] Geology of Vermont, vol. 2, 1861, p. 768.
[2] Perkins, G. H., Rept. Vermont State Geologist for 1909-10, Pl. LXIX.
[3] Idem, pp. 349-351, Pls. LII, LXXI.

graph of a small polished piece is reproduced in Plate VIII, *A, a*.

Specimens: Wainscoting, post office, Danville, Ill.; the Delaware Hotel, Fort Worth, Tex.; New St. Charles Hotel, New Orleans. Columns and panels (10 feet 6 inches by 4 feet 2 inches), Hall of Justice, San Francisco. Counter tops and base, Union Station, Washington, D. C. Base, First National Bank, Chicago. Tiling, city hall, Indianapolis, Ind. The length of columns is limited to 15 feet.

## CLASSIFICATION OF VERMONT MARBLES.

### Economic Classification.

In the following table an attempt has been made to classify for economic purposes all the Vermont marbles described. The grade of texture and the petrographic name of each marble are also given, with page reference to the fuller description.

As the same marble is sometimes used for different purposes the subdivisions are not rigid. Some of the graphitic monumental marbles are used for electric switchboards.

The number of varieties of interior decorative marbles is so large that only the more distinct and important ones are given.



### Scientific Classication.

The marbles of western Vermont fall naturally into the following 12 petrographic groups:

*Scientific classification of western Vermont marbles.*

| | | |
|---|---|---|
| 1. | Calcite marbles | Statuary Rutland.<br>Light Rutland Italian.<br>Middlebury. |
| 2. | Graphitic calcite marbles | True Blue.<br>Florentine.<br>Dark-blue Rutland. |
| 3. | Muscovitic calcite marbles | Brocadillo.<br>Solid green (Eastman). |
| 4. | Chloritic and muscovitic calcite marbles | American pavonazzo.<br>Dark cipolin. |
| 5. | Actinolitic calcite marbles | Dorset green bed. |
| 6. | Calcite marbles with minute dolomitic lenses and beds, usually graphitic | Hollister.<br>Pittsford Italian.<br>Brandon Italian. |
| 7. | Brecciated calcite and dolomite marble with hematitic cement | Manchester. |
| 8. | Carbonaceous slightly dolomitic unmetamorphic calcite marble | Fisk black. |
| 9. | Graphitic dolomite marble | Parker & Pinckney. |
| 10. | Hematitic untwinned dolomite marble with quartz grains | Swanton. |
| 11. | Serpentine | Vermont verde antique. |
| 12. | Chrome mica (fuchsite) schist | Foley quarry, Shrewsbury. |

Some of the calcite marbles of groups 1, 5, and 6 are tinted cream color, probably by oxidized pyrite or bluish by graphite, both in grains of infinitesimal size. Group 3 contains a very little chlorite and in some marbles epidote.

## RELATIVE VALUES OF VERMONT MARBLES.

To assist the reader in getting a correct idea of the relative qualities and abundance of these marbles, the prices current in 1910 of a few of them are given. These prices are all f. o. b. at the nearest railroad for blocks of ordinary sizes in the rough.

*Prices per cubic foot of Vermont marbles, 1910.*

| | |
|---|---|
| Dorset A and Dorset green bed | $2.00 |
| Dorset Mountain quarries, for exteriors | 1.00 |
| Pittsford Valley and Riverside | 2.75 |
| Common Rutland blue | 2.00 |
| Other "blue" marbles | 2.75-4.00 |
| Statuary Rutland | 11.50 |
| Other Rutland fine white marbles | 4.00-8.50 |
| Colored Rutland marbles (Vermont Marble Co.) for interiors | 2.00-6.50 |
| Eastman colored marbles for interiors | 2.75-4.50 |

*Economic classification of western Vermont marbles.*

CONSTRUCTIONAL.

| Trade name. | Quarry. | Location. | Color. | Texture. | Grade. | Grain form. | Grain arrangement. | Petrographic name. |
|---|---|---|---|---|---|---|---|---|
| Dorset A | Norcross-West Valley. | South Dorset | Cream to very light, faintly greenish smoke. | Coarse | 5 | Irregular | Normal | Calcite marble |
| Dorset B | Norcross Plateau | do. | Light cream, clouded with light gray to smoke tinted. | do. | 5 | do. | do. | do. |
| | Dorset Mountain Marble Co., upper northwest quarry. | Owls Head, Dorset. | White and also clouded white. | do. | 5 | Regular | do. | do. |
| Dorset Mountain | Blue Ledge | Green Peak | Faintly bluish-white, mottled with very light gray. | do. | 5 | Irregular | Uneven | Calcite marble with dolomite lenses of grade 1. |
| Manchester blue | Freedley quarries | Dorset Mountain (Dorset). | Very light bluish-gray | do. | 5 | do. | do. | Calcite marble |
| Mahogany | do. | do. | Milk-white. | do. | 5 | Very irregular. | do. | do. |
| Cloud | do. | do. | Light bluish-gray with medium-gray bands up to 0.2 inch wide. | do. | 5 | Irregular | do. | Calcite marble with little dolomite beds and lenses of grade 1. |
| White Stone Brook. | White Stone Brook. | do. | Faintly cream, tinted white, with fine yellow-grayish streaks and spots. | do. | 5 | Very irregular. | Normal | Calcite marble |
| Danby | Imperial | Dorset Mountain (Danby). | do. | do. | 5 | Irregular | do. | do. |
| Clarendon Valley gray. | Clarendon Valley | Clarendon | Very light bluish-gray, with fine, closely and acutely plicated dark-gray streaks. | do. | 5 | do. | Uneven | Calcite marble with little graphitic dolomite beds of grade 1. |
| Clarendon A | Clarendon | do. | Bluish-white, with bands 0.1 to 0.2 inch wide or rows of spots of medium-gray. | do. | 5 | Regular | do. | do. |
| Clarendon dark. | do. | do. | Light to dark bluish-gray bands up to 0.2 inch wide alternating with dark gray to black bands. | Medium | 4 | do. | do. | Graphitic calcite marble in alternating little beds more or less graphitic. |
| CONSTRUCTIONAL—Continued. | | | | | | | | |
| Albertson extra dark. | Albertson | West Rutland | Medium bluish-gray, with minutely plicated black streaks and some whitish ones, both crossed at various angles by slightly undulating black streaks (cleavage planes). | do. | 4 | do. | Normal | Graphitic calcite marble, the graphite abundant along little plicated beds and also along cleavage planes across them. |
| True Blue | True Blue | do. | do. | do. | 4 | do. | do. | do. |
| Riverside | Riverside | Proctor | Slightly bluish-white, with dark-gray bands and spots. | Coarse | 5 | do. | Uneven | Calcite marble, with little lenses and beds of graphitic dolomite of grade 1. |
| Florence No. 2 | Florence No. 2 | Pittsford | Light bluish-gray, with whitish and dark-gray streaks and spots. | Medium. | 4 | do. | do. | Calcite marble, with little lenses of graphitic dolomite of grade 2. |
| Unnamed | Prospect west of Florence No. 2. | do. | Milk-white. | do. | 4 | Irregular | Normal | Calcite marble |
| Pittsford Italian. | Turner | do. | Slightly bluish-white, with finely plicated streaks of medium-gray. | do. | 4 | Regular | Uneven | Calcite marble, with finely plicated beds of graphitic dolomite up to 0.1 inch thick of grade 2. |
| Florence No. 1 | Florence No. 1 | do. | Light bluish-gray, with fine dark-gray streaks. | Slightly coarser than above. | 4 | do. | do. | Calcite marble, with little lenses of graphitic dolomite of grade 2. |
| Pittsford Valley. | Hollister quarries | do. | Light bluish-gray, with little medium to dark-gray plicated streaks which on bed surface appear as irregular mottling. | Medium. | 4 | do. | do. | Calcite marble with little beds of graphitic dolomite of grade 2. |
| Bed K | do. | do. | Light bluish-gray without mottling. | do. | 4 | do. | Even | Calcite marble |
| Landon | Landon | do. | Slightly bluish-white, with medium to dark, intricately plicated beds up to 0.1 inch wide, appearing on bed surface as irregular mottling. | do. | 4 | do. | Uneven | Calcite marble, with little beds of graphitic dolomite of grade 1; also with dolomite plates up to 1.75 millimeters thick. |
| Brandon Italian. | Brandon Italian | Brandon | Light bluish-gray, with small dark-gray beds which on bed surface produce an irregular mottling. | do. | 4 | Irregular | do. | Calcite marble, with little beds of graphitic dolomite. |

*Economic classification of western Vermont marbles.*—Continued.

INTERIOR DECORATION.

| Trade name. | Quarry. | Location. | Color. | Texture. | Grade. | Grain form. | Grain arrangement. | Petrographic name. |
|---|---|---|---|---|---|---|---|---|
| Dorset green bed | Norcross-West Valley. | South Dorset | Faintly greenish to pale cream color, with very dark to light greenish-gray streaks, acutely plicated at intervals. | Coarse. | 5 | Regular | Normal | Actinolitic calcite marble, with little beds of fibrous actinolite, quartz, etc. |
| Eastman blue | Eastman | West Rutland | Medium bluish-gray in angular plications in cross section. | Fine. | 3 | Elongate | Even | Graphitic calcite marble, with more or less graphitic laminæ, some dolomitic. |
| Kiel's green | do. | do. | Cream to flesh colored alternating with bright greenish-gray bands, both up to 1 inch thick and in acute folds up to 5 inches long. | Coarse (cream). Medium (gray). | 5<br>4 | Irregular<br>Elongate | Uneven | Calcite marble, interbedded with muscovitic and chloritic calcite marble. |
| Green-veined cream statuary. | do. | do. | Delicate cream-colored bands up to 2 inches thick, alternating with slightly plicated bands of yellow to pale greenish tint up to 0.1 inch thick. | Fine | 3 | Regular | Even | Calcite marble, slightly limonitic from oxidation of pyrite in very minute grains. |
| Cream statuary. | Eastman | West Rutland | Delicate cream color, with very pale brown beds up to 0.1 inch thick. | Fine | 3 | Regular | Even | Calcite marble, slightly limonitic. |
| Solid green | do. | do. | Bright greenish-gray | Extra fine. | 1 | Irregular, elongate. | Parallel | Muscovitic quartzose calcite marble. |
| Light cipolin | do. | do. | Light greenish, with broad plications. | Medium. | 4 | (?) | (?) | Muscovitic calcite marble. |
| Dark cipolin | do. | do. | Bright light greenish, with broad plications and alternations in amount of color. | do. | 4 | (?) | (?) | Muscovitic calcite marble, with chlorite, epidote, and green tourmaline. |
| Bed M | do. | do. | Milk-white, with straight parallel bands of delicate green. | Fine | 3 | Regular | Even | Muscovitic (sericitic) calcite marble. |
| Brocadillo | Vermont Marble Co., West Rutland, east side. | do. | Faintly greenish-white ground, with fine greenish-gray plicated beds and straight streaks up to 0.2 inch wide. | Medium. | 4 | Irregular, elongate. | Parallel | Muscovitic (sericitic) calcite marble with epidote and chlorite. |

INTERIOR DECORATION—Continued.

| Trade name. | Quarry. | Location. | Color. | Texture. | Grade. | Grain form. | Grain arrangement. | Petrographic name. |
|---|---|---|---|---|---|---|---|---|
| Livido | do. | do. | Medium to delicate light bluish-gray, with plicated dark-gray beds up to 0.1 inch wide. | Fine | 3 | Irregular | Uneven | Slightly graphitic calcite marble, with little dolomitic lenses of grade 1. |
| Olivo | do. | do. | Light greenish-gray and pale greenish to white undulating bands up to one-half inch wide. | Medium. | 4 | Regular, elongate. | Parallel | Muscovitic calcite marble, more micaceous than brocadillo. |
| American pavonazzo. | do. | do. | Milk-white ground, with thin dark blue-greenish plicated beds of irregular width and distribution. | Fine | 3 | (?) | (?) | Chloritic muscovitic calcite marble. |
| Rubio | do. | do. | Very delicate pinkish ground, with thin plicated greenish beds. | Very fine probably. | 2 probably. | (?) | (?) | Very slightly muscovitic calcite marble. |
| Ruvaro | Monkton Vermont Marble Co. | Monkton | Mottled pink and white. | Extra fine. | 1 | Plates and rhombs. | Uneven | Hematitic untwinned dolomite. |
| Royal red | Barney | Swanton | Dark reddish-brown, with irregular slightly lighter clouds and some whitish streaks. | do. | 1 | do. | do. | Hematitic untwinned dolomite with quartz grains and kaolin. |
| Lyonnaise | do. | do. | Merging forms of brownish-red, with interspaces filled with white. | do. | 1 | do. | do. | Hematitic untwinned dolomite with interspaces of white twinned dolomite and quartz. |
| Jasper | do. | do. | Bright reddish ground, with pinkish and white irregular lenticular objects up to 0.7 inch wide and 9 inches long. | do. | 1 | do. | do. | Ground like that of royal red, with magnetite, corals of coarsely twinned and of granular dolomite, some with nucleus of quartz. |
| Oriental | do. | do. | Dark reddish-brown ground, with irregular areas of dark purplish-gray and some white spots. | do. | 1 | do. | do. | Ground like that of royal red; purplish parts of magnetite more or less oxidized; white parts of calcite and dolomite. |
| Olive | do. | do. | Light, faintly greenish-gray ground, with lenses more or less parallel or brecciated of light pinkish-gray, some with white nucleus. | do. | 1 | do. | do. | Ground of untwinned dolomite with quartz grains and kaolin. The lenses contain twinned dolomite and have border of oxidized pyrite. |

*Economic classification of western Vermont marbles*—Continued.

INTERIOR DECORATION—Continued.

| Trade name. | Quarry. | Location. | Color. | Texture. | Grade. | Grain form. | Grain arrangement. | Petrographic name. |
|---|---|---|---|---|---|---|---|---|
| Vermont verde antique. | Roxbury | Roxbury | Dark purplish-greenish ground, black when polished, with network of intersecting white and light greenish veins and black metallic particles. | | | | | Serpentine of fibrous and radial texture, with veins of magnesite and talc and large particles of magnetite. |
| Chrome mica schist. | Foley | Shrewsbury | Verdigris-green to faintly greenish-gray, but when polished brilliant dark emerald-green. | Fine to medium. | | Fibrous | Parallel schistose. | Chrome mica (fuchsite) schist, with chlorite, quartz, tourmaline, and magnetite. |
| Manchester breccia. | Dyer | Manchester | Bright brick-reddish cement inclosing fragments of cream-colored, bluish-gray, and deep reddish marble. | Fine<br>Medium-<br>Extra fine. | 3<br>4<br>1 | Elongated<br>Regular<br>... do. | Parallel<br>Normal<br>... do. | Calcite and dolomite marble breccia and hematitic calcitic cement. |
| Fisk black | Fisk | Isle la Motte | Extremely dark gray ("black") almost jet-black when polished, with here and there sections of large white marine gastropod shells. | | 4<br>1 | Irregular | Uneven | Carbonaceous, slightly dolomitic fossiliferous, calcite marble of unmetamorphic origin. |
| **MONUMENTAL.** | | | | | | | | |
| Blanc clair | Eastman | West Rutland | Milk-white, in places faintly clouded. | Fine | 3 | Regular | Normal | Calcite marble |
| Brandon statuary. | Connell, Brandon Marble Co. | Brandon | Faintly ivory-tinted | Very fine | 2 | ... do. | ... do. | do. |
| Statuary Rutland. | Vermont Marble Co., West Rutland, east side. | West Rutland | Milk-white | ..do. | 2 | ... do. | ... do. | do. |
| Second statuary Rutland. | .... do. | .... do. | Milk-white, with faint grayish to yellowish clouds. | Fine | 3 | Somewhat irregular. | ... do. | do. |
| Rutland Italian. | .... do. | .... do. | Faintly bluish-white, with faint irregular grayish and yellow-brownish mottling. | Medium. | 4 | ... do. | ... do. | do. |
| **MONUMENTAL—Continued.** | | | | | | | | |
| Dark blue Rutland. | Vermont Marble Co., West Rutland, east side. | West Rutland | Dark bluish-gray, mottled with white and fine black streaks (Maclureas). | Fine | 3 | Irregular | Normal | Graphitic calcite marble |
| True Blue | True Blue | .... do. | Medium gray, with more or less finely plicated black streaks crossed at various angles by slightly flexed ones. | Medium. | 4 | Regular | ... do. | do. |
| Florentine blue. | Florentine | Pittsford | Dark bluish-gray, with fine very dark and light gray straight bands. | Fine | 3 | ... do. | ... do. | do. |
| Middlebury | Middlebury Marble Co. | Middlebury | White, translucent | do. | 3 | ... do. | ... do. | Calcite marble |
| **FLOOR.** | | | | | | | | |
| Royal red | Barney | Swanton | Dark reddish-brown, with irregular slightly lighter clouds and some whitish streaks. | Extra fine. | 1 | Plates and rhombs. | Uneven | Hematitic untwinned dolomite, with quartz grains and kaolin. |
| Lyonnaise | .... do. | .... do. | Merging forms of brownish-red, with interspaces filled with white. | ..do. | 1 | ... do. | ... do. | Hematitic untwinned dolomite, with interspaces of white twinned dolomite and quartz. |
| Vermont verde antique. | Roxbury | Roxbury | Dark purplish-greenish ground, black when polished, with network of intersecting white and light greenish veins and black metallic particles. | | | | | Serpentine of fibrous radial texture, with veins of magnesia and talc and large particles of magnetite. |
| Fisk black | Fisk | Isle la Motte | Extremely dark gray ("black"), almost jet-black when polished with here and there sections of large white marine gastropod shells. | | 1, with some 4. | Irregular | Uneven | Carbonaceous, slightly dolomitic fossiliferous calcite marble of unmetamorphic origin. |

## MARBLE MACHINERY.

No attempt has been made to list the machines in use at the quarries. The purpose of this publication will, however, be served by a brief reference to the most improved marble machinery and by designating the quarries and works where it has been introduced.

The channeler and gadder for vertical and horizontal cutting are in general use. The recent improvements consist in the substitution of electricity for steam in these operations and in the introduction of carborundum wheels in the finishing department.

The Vermont Marble Co. is using in its West Rutland tunnels channeling and drilling machines driven by air compressed by electricity at each machine. It also has an electric railroad 1,300 feet long at a depth of 240 feet connecting several of its West Rutland quarries.

The most improved marble mill is that erected by the Rutland-Florence Marble Co. at Fowler, which in May 1911, passed into the hands of the Vermont Marble Co. This mill has a capacity for 60 gangs of marble saws, 43 of which are installed. A derrick car running on a central track the entire length of the building delivers the blocks to transverse tracks running under the gangs of saws on either side.

The Vermont Marble Co. uses a vertical diamond saw one-sixteenth of an inch thick and 7 feet in diameter and the Norcross-West plant includes one 5 feet in diameter. The diamonds are about 1 inch apart.

The Manchester Marble Co. and the Barney Marble Co. use a carborundum coper and molder.

The Norcross-West Mill now owned by the Vermont Marble Co. uses a coring machine for monolithic circular columns up to 7 feet long and 3 feet 6 inches in diameter. Also lathes for columns 22 feet long and 4 feet in diameter. The Vermont Marble Co. has one in Proctor for columns 29 feet 9 inches long and 3 feet 4 inches in diameter. The most systematic storage yard is that of the Vermont Marble Co. at West Rutland, with its great traveling crane for the distribution of blocks.

## ADAPTATIONS OF THE MARBLES OF WESTERN VERMONT.

The table on pages 146-151 shows the general adaptations of the marbles of western Vermont for construction, interior decoration, monuments, statuary, and flooring. The constructional marbles range from the coarse whitish ones of South Dorset and the milk-white and cream-tinted ones of Dorset Mountain to the mottled ones of Green Peak, Pittsford, Proctor, and Brandon and the medium bluish-gray of the Albertson, Florentine, and True Blue quarries. These graphitic marbles are particularly well suited for rock-faced construction in the soot-laden atmosphere



of cities, where white marbles become streaked in a very few years. They are also much in demand for electric switchboards, on account of their content of graphite and their lack of magnetite.

The range of marbles suitable for interior decoration is very wide, including the variously tinted West Rutland marbles, the "Champlain marbles," the serpentine of Roxbury, and the dark emerald-green chrome mica schist of Shrewsbury. The prevalent use of large panels of polished banded marbles has brought about in recent years a considerable demand for these West Rutland marbles and for the actinolite marble of South Dorset. The supply of the finer grades of monumental marbles, particularly of the "statuary Rutland," is at present somewhat scanty, but there is reason to hope that as the marble belts are explored more scientifically it will be found to be much more ample.

The at present unused fine-grained dolomite marbles of Pittsford, which from their fine quartz veining and thin bedding can hardly be expected to furnish many large slabs, are yet very well adapted for mosaic work and terrazzo.

The lists of architectural specimens given after the description of each of the typical marbles, supplemented by Plates VII, XI, XIII, and XIV, illustrate their more important adaptations.

## GENERAL OBSERVATIONS AND PROGNOSTICATIONS.

Upon careful inspection of the geologic map and of the stratigraphic and marble succession, as tabulated on pages 59, 90, it will be noticed that between Shaftsbury on the south and Middlebury on the north marble is to be expected chiefly along two geologic boundaries—that with the underlying dolomite series and that with the overlying schist series. It will also be observed from the symbols on the map that the portions of these boundaries along which marble has been or is being quarried constitute but a very small part of the entire boundaries.

The boundary with the dolomite, between Shaftsbury and Middlebury, actually measures 91 miles, to which should be added a few miles between Clarendon and Rutland. The boundary with the schist, between Shaftsbury and the north end of the Taconic Range in Brandon in the main valleys—that is, exclusive of the areas in Sandgate and the West Rutland Valley and the small marble area east of Biddie Knob in Pittsford—measures 93 miles. The boundary with the schist on both sides of the West Rutland anticlinal valley and in the small area east of Biddie Knob measures 15½ miles. The total length of these boundaries is 199½ miles.

From these figures should be deducted those portions of the boundary already fully prospected or being worked. These amount to 8 miles in Pittsford, Proctor, Brandon, and Middlebury, along the lower boundary; 7 miles in Clarendon, Pittsford, and

Proctor along the upper boundary; and 2 miles along the upper boundary in the West Rutland Valley—a total of 17 miles.

As large portions of the boundary are covered with a thick over-burden of sand, gravel, or clay, the removal of which would be very costly, and as in many other places the marble is defective from much jointing, due to dikes or from reeds or irregular fractures, a considerable deduction should be made from the marble boundaries on this account. In order to err on the safe side, this unprofitable part is estimated at 75 per cent.

After making these deductions, the estimates of the unworked parts are as follows: Parts of marble belt contiguous to basal dolomite, 20 miles; parts contiguous to schist, 21 miles; parts in West Rutland Valley and in area east of Biddie Knob, 3½ miles. The unworked profitable portions of the marble boundaries thus probably aggregate 44½ linear miles.

The folded character of the structure should always be kept in mind. If good marbles occur on the east side of the schist mass which forms the southern part of Dorset Mountain, the same marbles should be expected on the west side of that ridge in Dorset Hollow. Similarly, the marble beds exposed on the east side of the West Rutland Valley, dipping east under the synclinal schist ridge, should be expected under normal geologic relations to recur on the east side of that ridge, about three-fourths of a mile west of Center Rutland.

The actual depth of the glacial and postglacial deposits upon the eroded marble surface can not be prognosticated. It must be determined by boring. If the aid of a geologic map and sections, even with all their uncertainties, is to be discarded, 10 feet of gravel or clay may be sufficient to conceal the presence of marble beds of as fine a quality as any now being worked.

In view of the great variety and value of the marble exposed on both sides of the West Rutland anticline, it would seem that, on scientific principles, the portion of the marble boundary which should first be explored is that on the west side of the West Rutland anticlinal valley and next that on the east side of the synclinal ridge east of that valley, or, more exactly, from the intersection of the West Rutland and Rutland town lines with the highway, about three-fourths of a mile southwest of Center Rutland, north and northwestward for a distance of 2 miles, to a point about a mile south of the Riverside quarry.

Finally, inasmuch as some members of the marble succession are absent between the basal dolomite and the schist ridge west of Proctor—possibly as shown in section H, Plate III, owing to faulting—and as the structural conditions appear to be much more favorable in Pittsford, the half-mile strip west of Fowler, between the railroad branches and the schist ridge on the west, ought to be carefully explored for these missing beds, and in like manner the territory between the Hollister quarry and the schist ridge.



## SCIENTIFIC PROSPECTING FOR MARBLE.

While the practical judgment of a competent marble quarryman or marble cutter will always be required to determine whether a particular bed of a certain quality of marble is conveniently situated for quarrying and is also free from reeds or other blemishes, the scientific basis for marble prospecting in this region is afforded by the geologic maps (Pls. I and IV), the section (Pls. II and III), and the table of the marble series as given on page 90. With these and a careful reading of the paragraphs in the section entitled "Geologic principles governing the marble belt," pages 71-79, correct methods of prospecting will readily suggest themselves. The following hints may be helpful to some readers:

On the map the marble-schist boundary shows where the upper part of the marble series is to be expected and the dolomite-marble boundary where its lower part will probably be found. The first step is to determine the approximate position in the marble succession of the locality or beds to be prospected. This can be done by estimating their vertical distance from one of the determined stratigraphic levels, either the schist or the dolomite boundary, or from the intermediate dolomite, if its course has been traced. That vertical distance, of course, is the distance at right angles to the beds, but the prospector should make sure that these are not duplicated by folding. The same result may be obtained in some places by measuring the distance of the locality or bed from the line of strike of any quarried bed of known position. If the schist is near at hand, the beds to be expected in its vicinity are those of the upper graphitic marbles, except on Dorset Mountain. Where the upper graphitic marbles occur, if the white and muscovitic marbles are desired, they should be sought below the graphitic marbles. If the area lies between the basal dolomite and the intermediate dolomite, the lower clouded marble is, of course, to be expected in that position.

After the beds have been exposed by the usual cross trenching, their character should be carefully studied to determine the nature of the folding. If repetitions occur, then the arch or trough form of the fold and the degree of its pitch should be ascertained. In general, the part of a fold upon which a quarry is situated or is to be opened should be known and its remaining parts theoretically located, so that when quarrying operations are extended this may be done on rational principles.

If a quarry or proposed quarry lies immediately west of the intermediate or basal dolomite, the depth at which the dolomite underlies the marble at the turn of the trough should be determined by drilling.

Wherever the beds between two highly inclined parallel beds of dolomite show a tendency to form horizontal zigzags, the probability is that the beds on either side are continuous either below or above—that is, they constitute a compressed fold, anticline or syncline. Core drilling should then be done to determine whether the fold is a syncline and to ascertain its depth. In all core drilling the cores should be carefully inspected with a view to determining any duplication of beds—that is, evidence of folding—as it may have an important bearing on the operations of the quarry.

A wide margin should be given to dikes and reedy passages, and in opening quarries places with protective clay or till should be preferred.

## TESTING OF MARBLE.

The more important tests of marble for economic uses are described below.

*Chemical analysis.*—This should have special reference to the content of iron sulphide or oxide.

*Microscopic analysis.*—For this purpose a number of thin sections should be made from cubes sawed, not hammered, from blocks taken at different heights in the same bed and horizontally far apart, and some sections should be cut transverse to the bed, others parallel to it.

The microscopic analysis should determine the grain form, the grain regularity, the average grain diameter by the Rosiwal method, the associated minerals and their relative abundance, and the presence of minute beds or lenses of dolomite and of divisional planes of bedding or cleavage.

*Absorption.*—Hirschwald[1] found that after Carrara marble was exposed on all the 23 rainy days of November and December, 1900, its maximum water absorption was 0.45 per cent and that the same marble when tested experimentally in the laboratory showed after one hour's immersion 0.49 per cent of absorption. He also found[2] that the water absorption of a coarse Tyrolese marble under slow immersion amounted to 0.74 per cent of the stone, in vacuum 0.82 per cent, and under pressure of 50 to 150 atmospheres 0.92 per cent, and that the water absorption of this stone thus tested amounted to 81.37 per cent of its total pore space, or in vacuum 90.01 per cent.

*Porosity.*—One of the simplest methods of determining porosity is to expose sawed blocks 2 by 1 by 1 inch for a few hours to a temperature of about 104° F. and then to immerse them for 48 hours in a concentrated 4 per cent alcoholic solution of nigrosine, a deep-blue dye soluble in alcohol.[3] After drying for half an hour the blocks are to be broken squarely across with hammer and

[1] Hirschwald, J., Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit, Berlin, 1908, p. 212.
[2] Idem, p. 156.
[3] Made by Jäger at Barmen, Germany, and recommended by Hirschwald (op. cit., p. 163).



chisel. The degree of porosity will be indicated by the extent to which the dye has penetrated the blocks.

The importance of determining the porosity of marble and the disregard of it by some architects and builders is shown by the frequent combination of metals and marble on exposed faces. The metal inevitably oxidizes and the marble absorbs the oxide and becomes discolored. In the Forefathers' Monument at Plymouth one of the delicate bas-reliefs of white marble in the buttress of the base is stained bright vermilion. The stain appears to have been derived from red lead used in fastening the marble to the granite and to have been absorbed by the marble at the back of the slab and thus found its way to the carving on the front.

*Compressive strength.*—This should be tested on 6-inch sawed cubes with hydraulic compressor, as in the Watertown Arsenal tests. One set of blocks should be tested on the bed and another on edge.

*Transverse strength.*—This should be tested on sawed blocks between supports and both on bed and on edge.

*Tensional strength or cohesion.*—This should be tested by a method described by Hirschwald.[1] A sawed block of certain shape with lateral grooves in the center is fastened at each end into a steel frame provided with a hook. The tensional weight is applied to one of the hooks and the block is suspended by the other.

*Magnetism.*—A marble for use in electric switchboards should contain little or no magnetite. There is probably a slight difference in the amount of this mineral in different marbles, although the quantity in any one is exceedingly small. Its effect on an electric current should therefore be tested.

*Translucence.*—Marbles differ considerably in translucence, which can be tested by sawing very thin pieces of measured thickness and superposing them in order to determine the thickness traversed by light.

*Polish.*—A polished surface should be examined with a magnifier and the pits or protuberances noted.

*Durability of color.*—This can be determined by exposing a sand-rubbed and a polished surface to the south for three years and then comparing the surfaces with those of unexposed pieces prepared from the same block at the same time.

*Sonorousness.*—This is an index of cohesion. It can be tested by hammering sawed slabs 2 inches thick, 4 to 6 inches wide, and 1 to 2 feet long.

*Statuary test.*—Renwick[2] makes this recommendation:

**Marble for statuary purposes should never be selected in bright weather. Veinings and discolorations are more difficult of discovery at**

[1] Op. cit., pp. 171, 172.
[2] Renwick, W. G., Marble and marble working, London, 1909, p. 61.

this time than at any other. A dull day with a good light is the best time for inspections; if after a shower of rain so much the better. Provided no rain has fallen, the blocks should be soused with water; veins and stains can then be more readily perceived. If possible, have each block slung and struck with a hammer. If the sound of the blow is dull and heavy, look out for cracks. Should a hard, metallic tone be emitted the marble will be heavy in working; but if a soft clear ring is heard the material is sound and will both work and wear well.

## GLOSSARY OF TECHNICAL TERMS.

**Actinolite.** A greenish mineral of the hornblende group, a silicate of lime, iron, and magnesia $(MgFe)_3CaSi_4O_{12}$.

**Amygdule.** A small globular cavity in an eruptive rock caused by steam or vapor at the time of its eruption, and generally lined afterwards with secondary minerals.

**Anticline.** The arch part of a wavelike bed of rock.

**Bed.** A continuous mass of material (sediment) deposited under water at about one time.

**Biotite.** A brownish to black mica containing a considerable percentage of iron and magnesia.

**Brachiopod.** A small marine animal, generally with a bivalve shell and provided with two ribbon-like respiratory organs near the mouth, which also serve to draw currents of water to the mouth.

**Breccia.** Rock made up of angular fragments produced by crushing due to a crystal movement and then recemented by infiltrated mineral solutions.

**Calcite.** The mineral consisting of lime carbonate $(CaCO_3)$ which constitutes most of the commercial white marbles. (See p. 16).

**Cambrian.** The lowest division of Paleozoic time. Marked by abundant marine invertebrate life. Preceded the Ordovician.

**Cephalopoda.** The most highly organized of the mollusks, represented by the modern nautilus, squid, and cuttlefish, but in early geologic periods by many species with coiled or straight shells having compartments for air or gas.

**Chlorite.** A soft bluish-green foliaceous mineral, a hydrous silicate of alumina, iron, and magnesia.

**Cleavage.** When applied to a mineral designates a structure consequent upon the geometric arrangement of its molecules at the time of its formation.

**Conformity.** When one bed overlies another in parallelism, without any disturbance of the crust having affected the lower one before the deposition of the second, they are said to be in conformity.

**Crinoids.** Marine animals related to starfishes and sea urchins but mostly with plantlike calcareous skeletons rooted and provided with an articulated stem bearing a cup containing the alimentary organs.

**Cryptocrystalline.** Applied to a rock whose crystalline texture is obscure.

**Crystalline.** When the molecules of a mineral are arranged in geometric order the mineral is said to be crystalline.

**Dike.** Natural molten material erupted through a narrow fissure in rock.

**Dip.** The degree and the direction of the inclination of a bed, cleavage plane, joint, etc.

**Drift.** Sand and boulders deposited by a glacier, continental or local.

**Dolomite.** A lime and magnesia carbonate. (See p. 20).

**Dolomitization.** The process by which a limestone (lime carbonate) may be changed to a dolomite. (See p. 25).



**Epidote.** A grass-greenish mineral, a silicate of alumina, iron, and lime—$Ca_2$ $(AlOH)$ $(AlFe)_2$ $(SiO_4)_3$.

**Erosion.** The wear of a rock surface by natural, mechanical, or chemical agencies.

**Fault.** A fracture resulting in the dislocation of the bedding or cleavage of a rock or vein, one part sliding up or down or both changing positions along the fracture.

**Formation.** A group of beds possessing some common general characteristic or fossil forms differing from those of the beds above and below.

**Galenite.** A mineral composed of lead sulphide (PbS), the common ore of lead.

**Gastropods.** A group of mollusks including land, fresh-water, and marine snails.

**Gneiss.** When the minerals of a granite or granite-like rock under powerful compression assume a certain parallelism it becomes a gneiss.

**Hematite.** An oxide of iron $(Fe_2O_3)$ which when scratched or powdered gives a cherry-red color or "streak."

**Kaolin.** A hydrous silicate of alumina derived from the alteration of feldspar.

**Limonite.** A hydrous oxide of iron $(2Fe_2O_3.3H_2O)$; a hydrated hematite, which, when scratched or powdered, gives a brownish rust color.

**Maclurea.** An extinct marine gastropod in which the whorls of the shells lie in one plane. Some of the Maclureas of the Lake Champlain region attain several inches in diameter.

**Magnetite.** A black metallic mineral (FeO and $Fe_2O_3$) known by its strong magnetism and its black streak. One of the principal ores of iron.

**Matrix.** The general mass of a rock which has isolated crystals or mineral particles, sometimes called the groundmass.

**Metamorphism.** The process, partly physical, partly chemical, by which a rock is altered in the molecular structure of its constituent minerals and frequently in the arrangement of its particles. If the cause of the process is a general crustal movement the metamorphism is said to be regional or dynamic, but if its cause is mainly the contact with a molten intrusive rock, it is called contact metamorphism.

**Millimeter.** French decimal linear measure, the thousandth part of a meter or the tenth part of a centimeter. It is equivalent to 0.03937 inch, the meter being 39.37 inches.

**Monolith.** A column or monument of one stone.

**Muscovite.** Potash mica, the most common of the micas, generally of whitish to greenish color. Mainly a silicate of alumina and potash.

**Oolitic.** Term applied to limestone and other rocks when they consist largely of minute spherules and resemble the roe of fishes.

**Ordovician.** One of the great divisions of Paleozoic time, formerly called "Lower Silurian."

**Pelitomorphic.** Literally, having clay or mud form. Applied to a rock of clay-like texture.

**Pitch.** The inclination of the axis of a fold of rock.

**Plagioclase.** A term applied to all those feldspars that are not potash feldspars.

**Polarized light.** Light whose vibrations, unlike those of ordinary light, which extend in all directions, are in only one plane. Polarized light is used to distinguish minerals, particularly colorless, transparent ones, under the microscope. Minerals, like calcite or dolomite, that polarize light are of crystalline texture, but these do not polarize light in the direction of their vertical crystal axis.

**Porphyritic.** A term applied to rock texture to designate the presence of isolated crystals in a general mass (matrix or groundmass) of finer material.

**Pteropod.** An order of gastropod mollusks living at or near the surface of the ocean and provided with a pair of fleshy appendages on either side of the mouth which serve as fins. Many of them have more or less conical shells which form extensive deposits on the ocean floor. Shells closely resembling those of pteropods abound in rocks of Cambrian age. (See p. 59).

**Pyrite.** Iron disulphide ($FeS_2$), the common light brasslike metallic mineral, generally injurious to building stones.

**Quartzite.** A metamorphosed quartz sandstone in which the cement which unites the quartz grains is also quartz.

**Rhizopods.** Animals of very low order and organization, consisting mainly of transparent protoplasm. Some of them have a calcareous case. They abound in the ocean, and their remains form extensive oozes on the ocean floor.

**Rhombohedron.** A crystal form bounded by six faces of rhombic outline.

**Schist.** A crystalline rock made up of flattish particles arranged in rough parallelism, some or all of which have crystallized under pressure.

**Sedimentation.** The deposition of particles, usually under water. A sedimentary rock is one consisting of particles thus deposited.

**Sericite.** A ribbon-like or fibrous form of muscovite or potash mica.

**Serpentine.** A hydrous silicate of magnesia and iron. (See p. 41).

**Slickensides.** The polished and grooved faces of a joint or bed caused by the motion and friction of adjacent rock masses.

**Slip cleavage.** A cleavage arising from slippage along fractured microscopic folds.

**Specific gravity.** The weight of a rock or mineral compared to that of a body of distilled water of the same bulk.

**Strike.** The direction at right angles to the inclination of a plane of bedding, joint, etc.

**Syncline.** The trough part of a wavelike sheet or bed of rock.

**Trilobite.** A crustacean with affinities to the horseshoe crab of the eastern coast and generally marked by the division of the back into three lobes lengthwise and crosswise. Trilobites were very abundant in early geologic time.

**Twinning plane.** In calcite and dolomite this is the plane which separates two adjacent crystals which have formed with the poles of their main axes in different directions.

**Unconformity.** When the lower one of two contiguous deposits affords evidence of having been exposed to atmospheric erosion before the deposition of the upper one, there is said to be an unconformity between them.

**Vein.** When correctly used, denotes a more or less irregular, sometimes ramifying mineral mass within a rock. It should never be confounded with a bed.

PLATE XVIII.

CORNER IN THE MONUMENT SHOP, VT. MARBLE CO.

# HISTORY OF THE VERMONT MARBLE INDUSTRY.

G. H. Perkins.

For more than a hundred and twenty-five years marble has been quarried in Vermont and has brought gain to the state, a gain which has slowly, but with great uniformity increased as the years passed and during the last twenty years the value of the stone which has been sold has been large.

It is well known that from the earliest times Vermont has led by a long distance all the other states in the production of marble. This is the more remarkable when not only is the small area of the state considered, but the small part of this small area in which marble occurs.

Reference to the map, Plate LXXVIII, makes plain the small, narrow space, mostly in Rutland County from which nearly all the commercially valuable stone is obtained. And much of even this does not afford good stone, or at least has not hitherto, for it is hardly necessary to remark that there is a great deal of marble which cannot be used because of its imperfections. Yet from this small area Vermont has quarried and sold many millions of dollars worth of marble of various sorts.

For many years this State had almost a monopoly of the marble trade of the United States, and although, as large beds of the stone have been discovered and worked in other states, this monopoly has passed, yet Vermont still sells more than three times as much marble as does any other state.

Vermont and Massachusetts were probably the pioneers in the marble business and for a long time very little was quarried elsewhere, but, one after another, different states offered the stone from their hills and now good marble is quarried and sold in eighteen, and several as Colorado, Georgia and Tennessee sell a large amount.

Probably many of these deposits would have remained untouched had not the demand for fine stone for building purposes greatly increased. It is only within a comparatively few years that stone of any kind has been used in the United States very much except in the walls of the exterior of buildings.

A very noticeable difference between the finer buildings in America and Europe has been the free use of stone in the interior of the palaces, churches and public buildings found in European cities and the absence of it in the interior of even the most expensive structures in this country. Hence there has not until lately been any large demand for stone here, and of course, the supply could not be large.

As wealth and taste have grown the use of stone has also increased, until now few large and expensive public or other buildings are finished without the use of stone, and in the inside, marble is that which is most commonly desired and most desirable.

One need only enter such places as the Congressional Library, New York Public Library or newer government and office buildings to appreciate the change from the older style to the new.

Other materials, notably granite, have come largely into use for the exterior of large buildings and for large monuments and mausoleums, but the use of marble for these is continually increasing.

Very likely, because of the very great increase in the cost of preparing stone, it cannot be expected that its use will ever be as lavish as in the temples of Asia or the palaces and churches of Europe or at any rate that such abundant and intricate carving will be produced, yet it appears to be obvious that stone is to be, more than any other material, selected for the finest and most costly buildings of the future.

Because of the endless variety in color and veining and of the character of this stone which makes it unrivalled as the material for carved work of the finest sort, marble has been used more than any other material for statues, busts and interior work which was to be elaborately wrought. That fine work can be executed from Vermont marble has been abundantly proved many times and that it can be executed not only in Vermont marble, but in Vermont mills is shown by the Portrait Statue shown on Plate XIII, and by the very elegant sarcophagus shown on Plate XXI and the monuments on Plate XIV or Plates XIX and XX. As a building material for inside work, mantels, wainscoting, paneling and the like, it is safe to say that nothing equals marble.

In some of our finest modern buildings we are beginning to finish the entire surface of a room or passage even including the ceiling in marble as is so often seen in the palaces or public buildings of Europe. The library buildings already mentioned are examples of this.

For the exterior of buildings granite will always be preferred by many, but even here marble is largely used and its enduring qualities are shown in the preservation of many Greek and Roman temples constructed, as for example the Parthenon, wholly of marble and which though in ruins, usually because of other assailants than the elements, have so far endured exposures that much of their original beauty remains after all the centuries




MEMORIAL TABLET CUT FROM A SINGLE PIECE OF WHITE MARBLE.
Vermont Marble Co.

that have passed since they were built. The choice between marble and other stone for the outer walls of any building must always be a matter of taste to some extent at least. Perhaps nowhere can one see the best examples of marble buildings as well as in Washington. Plate XI illustrates what has been said.

In the early pioneer days marble was used for little else than gravestones, hearths and occasionally mantels in the inside of houses. As late as the year nineteen hundred the Vermont Marble Company sold nearly three times as much marble in the form of monuments as for building, while at present much more is sold in building material than for other purposes.

As has been noticed in former reports, this change in the demand for marbles has been and is greatly to the advantage of the industry for very much marble formerly rejected and thrown upon the dump is now sold for outside building. This is not because poor, much less worthless, stone can be used in the outside walls of a building, but because a stone used in monument must be flawless and of finest grain, although a less perfect or more coarsely grained stone may be quite as strong and quite as attractive in the walls of a building.

As is often the case, the beginnings of the marble industry in Vermont are obscure.

There is good evidence that quarrying of some sort was carried on in the state as early at least as 1785. In a letter written some years ago by Mr. G. E. Royce of Rutland I find the following:—"I would say that without any doubt the first marble quarry opened in Vermont was on the property now owned by the True Blue Marble Company and was situated by the side of and underneath the present mill of the company and according to the town records of Rutland, was opened in 1785 and was worked continuously in a small way for about fifty years.

The record shows that from the beginning it was described as a 'stone quarry, so called marble' and in 1795 it was sold for £400, about $2,000. In 1812 our member of Congress, Ezra Meech, took a contract to supply for a government building in Charleston, S. C., a quantity of it and it was hauled with wagons to Troy and shipped by water to New York and to Charleston by vessel.

Almost all of the headstones standing in the cemeteries from Bennington to Burlington, dating from 1785 to 1830 came from this quarry and are almost all in good condition.

They were worked before sawing was done and tooled by hand. The quarry was 150 feet long, 125 feet wide and 16 feet deep."

Another quarry was worked in Dorset in the same year, 1785, and gravestones from this have endured exposure in a remarkable manner. Most of the stones from these quarries in the cemeteries mentioned were made before 1830, after that time marble and other stone from different quarries was bought so that the Rutland marble was less exclusively used.

Like many another area which in later time became very valuable, the ridge at West Rutland in which there are so many quarries, and from which for many years past millions of feet of stone have been taken and sold and from which millions uncounted may yet be taken was at first regarded as of little value.

I cannot assert the absolute historical accuracy of the story, but it may very likely be true, that the original owner of the land where now there are a number of quarries having tried in vain to raise crops upon the barren, rocky soil made a trade with some one, taking an old horse in exchange and rode away with his few possessions, glad to be rid of such useless property. And so it was in those days for there were few demands for the stone even if the means for quarrying and dressing it had been available.

Like some of the coal lands of Pennsylvania, the marble land of Vermont was valueless for raising crops and there was no present demand for anything else.

It was not for many years that the demand for the marble came. Nor was there at first any one who saw the use which was coming for the hitherto worthless stone that cropped out in long white bands through the old farm. "It was not until Redfield Proctor, later United States Senator from Vermont, became receiver for the old Sutherland Falls Company that the industry took on large proportions. Mr. Proctor saw the great opportunity for the development of these stone deposits in connection with the era of building and development just beginning in this country. His vision was justified by subsequent results. Hand in hand the two have gone on together—this region supplying by far the greater portion of the finished marble used in building construction in the country." (American Stone Trade, Jan. 5, 1914).

Between 1785 and 1850 the growth of the marble business in Vermont does not appear to have been at all rapid, though there was constant increase. In 1850 the Census report shows that there were only sixty men employed in stone quarries of all kinds in the state and two hundred and sixty-five cutters and finishers. Of course only a part worked on marble.

Between 1830 and 1850 mining was far more important in Vermont than quarrying.

In 1840 nearly three times as many men were employed in the mines as in the quarries of Vermont and the value of the iron alone produced nearly equalled that of all the stone sold. But the mining industry was of comparatively short duration in this state, at least it was not carried on to any extent for a long time and it is many years since iron was mined at all, though abandoned iron mines are scattered widely over the state. Cop-

PLATE XX.


MONUMENT OF MARBLE FROM RIVERSIDE QUARRY.

per has been more recently mined, but these mines are now entirely closed and no metal is mined anywhere in Vermont.

Meanwhile, as the mines have been abandoned, the stone industry has grown, at first slowly, later rapidly.

The marble business began to develop especially after 1860. At that time there were sixteen companies operating fifty quarries and employing five hundred and fifty men. I am not able to ascertain the exact value of the marble sold at this time as all available reports give the total amount of stone but do not distinguish the different kinds. I think, however, that the marble sold must have amounted to over $500,000 in 1860. Both demand and, naturally, the product increased rather slowly during the following twenty years, but we find that by 1880 the sale of marble alone had risen to $1,340,000. In ten years more it had increased to $2,484,000 in 1890. In 1910 marble was sold to the amount of $3,562,000. In 1914 the sales amounted to not less than $4,000,000.

A great change has taken place in the manner in which the marble business has been carried on and in the methods employed in the quarries and mills.

As we have noticed, in 1840 there were sixteen different companies engaged in quarrying and finishing this stone. Of course this number does not include all the local monument makers of whom there were a large number, but only those owning and working quarries. The number of marble companies increased for some years until at one time some twenty years ago there were nearly fifty and for several years the number varied from forty to fifty, but during the last ten years there has been consolidation until now nearly all the finished marble of Vermont is controlled by the Vermont Marble Company and the Green Mountain Marble Company, although considerable is sold in the rough by others who own quarries but have no mill.

As late as 1886 there were thirty-three companies working thirty-eight quarries. In 1900 these were reduced to sixteen, while in 1905 there were only nine and, within the last five years, the larger of these have now been bought by the Vermont Marble Company. With these additions the before large corporation has become very great.

Growing out of the old Sutherland Falls Company, the Vermont Marble Company was chartered under the laws of New York in 1880. There are now, 1914, in all twenty-five mills in operation. Some of these, as those at Proctor or Florence are very large, most of considerable size and a few small ones at some of the more distant branches. These mills have not less than twenty-five acres of floor space and contain four hundred and thirty-three sawing gangs, besides of course much other machinery for smoothing, shaping, polishing, for nearly all the processes through which a piece of marble must go from rough block to finished monument, column or what not.

The main office of this company is located at Proctor, where are also the largest mills, but there are large plants at West Rutland, Center Rutland, Florence, Middlebury, Swanton, Manchester. Smaller works are at Boston, New York, Philadelphia, Cleveland, Chicago, St. Louis, San Francisco and Tacoma.

Over four thousand men are employed in these mills and quarries. Necessarily these are of many nationalities, though Swedes and Italians form the larger part of the foreign population of Proctor. The company has always been known as one that dealt fairly and even generously with its employees and perhaps this may, at least in part, account for the entire absence of strikes.

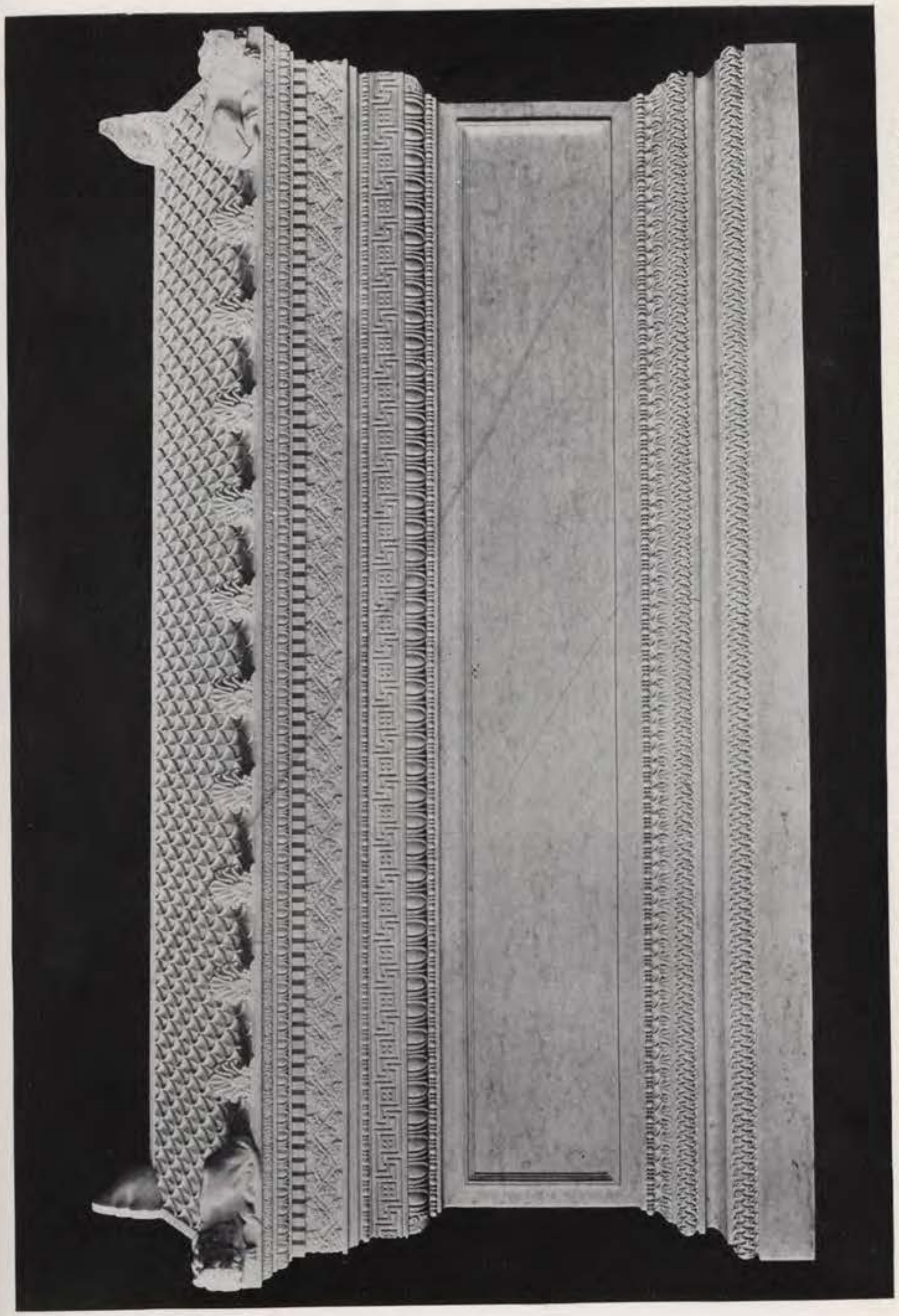
Naturally, many of the mills, as many as possible in fact, were located where there was water-power as at Proctor, Middlebury, Beldens and Swanton. This power is still used wherever possible, but not as formerly, for it has been found that water-power used to run dynamos which produce a current that can be taken where it is wanted is far better than it is to use the water-power directly so that for several years the transforming process has gone on until now a large part of the power used in mills and quarries, amounting to 8,000 horse-power, is applied electrically.

Although the monumental work is not the largest part of that executed by the company, the annual production is about eighty thousand finished monuments and a hundred and seventy thousand shipped in the rough.

In all, about one million cubic feet of marble are sold annually. The company own twenty-five thousand acres of quarry and forest land. From the latter the lumber needed for boxing the finished marble is largely obtained, 6,500,000 feet being used annually. Aside from quarries opened several years ago on an island in Alaska from which some very beautiful light marbles have been taken and from which, so far as possible, the Pacific coast is supplied. The Vermont Marble Company holds seventy-five quarries which are considered valuable. Not all of these are operated at the same time, partly because half of them can supply all the marble needed at any one time, which is of course a sufficient reason, but also because there are some varieties for which there is not a constant sale and which therefore it would not be worth while to produce except as wanted. About half of the whole number of quarries are worked at the same time.

The old mill where the Vermont Marble Company started is shown in Plate XXII. In one of the publications of this company we find the statement as to the beginning. "It all started down in the hollow, a building in which only six or eight quarry blocks could be sawed at a time. There was a track leading up to the

PLATE XXI.



ONE OF THE FINEST PIECES OF MONUMENTAL WORK DONE BY THE VERMONT MARBLE COMPANY.

quarry and the blocks were placed on a car and lowered into the mill by means of a cable. A yoke of oxen furnished the motive power needed to get the empty car back to the quarry."

A marble quarry is less rough and broken in its appearance than are most stone quarries on account of the manner in which the stone is taken out. As this will be considered farther on less may be said as to it here.

The marble quarries, as Plates X, XII, XV, XVII show, are mostly open or pit quarries, that is the stone is taken out vertically from the surface down, layer by layer.

Some of the West Rutland quarries are at present over three hundred feet deep. In a few cases as the old Freedley quarry on Dorset Mountain, there is a gallery carried under ground and at West Rutland, though most of the quarries are open, in a few cases the work has been carried in under ground, and there is an electric road eight hundred feet long which is "over three hundred feet below surface."

The geological and other features of different quarries are stated in course of the preceding pages by Dr. Dale.

The West Rutland quarries, at the southern end of the ridge in which they are located form a continuous group, or they might be considered as one huge quarry. The northern quarries are more isolated one from the other, but the southern have practically run together so that a workman may pass from one to another.

All of these quarries and others in the south part of West Rutland produce very much the same stone and furnish true marble and of the lighter varieties, though there are many shades and veinings, but the stone produced by the "True Blue" and nearby quarries is dark slate or even black in small portions. The number of varieties here and to some extent elsewhere in the state is considerable. A more complete account of the principal of these will be given later, suffice it to say here that nearly, or quite, one hundred distinctly unlike varieties can be obtained in the state, though some of these are seldom quarried and the Vermont Marble Company write that "We produce nearly fifty different varieties of marble all of which, generally speaking, can be supplied at comparatively short notice."

Indeed it is scarcely too much to say that it is more difficult to get two large slabs exactly alike than to find those that are unlike. The company give the following grades of marble referring to texture, hardness, etc., but not to color or marking: "Thirty-two grades of monumental, forty grades of interior building, ten grades of exterior building."

The maps Plates I and IV, pages 1 and 22, show the location of the various quarries in the Rutland region.

Plate II shows cross sections in several localities which may be better understood if carefully compared with the surface map of the whole region shown in Plate I. The letters placed on the different beds may be explained also by reference to Plate I. In Section G of Plate III the relative position of some of the beds is best shown.

## METHODS OF WORKING MARBLE.

As they are taken out in the quarry, the blocks naturally vary much in size according to the purposes for which they are obtained if these are known. As many thousands of these blocks are continually kept in stock to meet sudden demand, the Vermont Marble Company report 20,800 on hand in 1912, blocks of such size as it may be most convenient to quarry are taken out. Perhaps the most common stock size is, in feet, 6x4x4. The average weight of a quarry block is 40,000 pounds, though of course much larger are often needed.

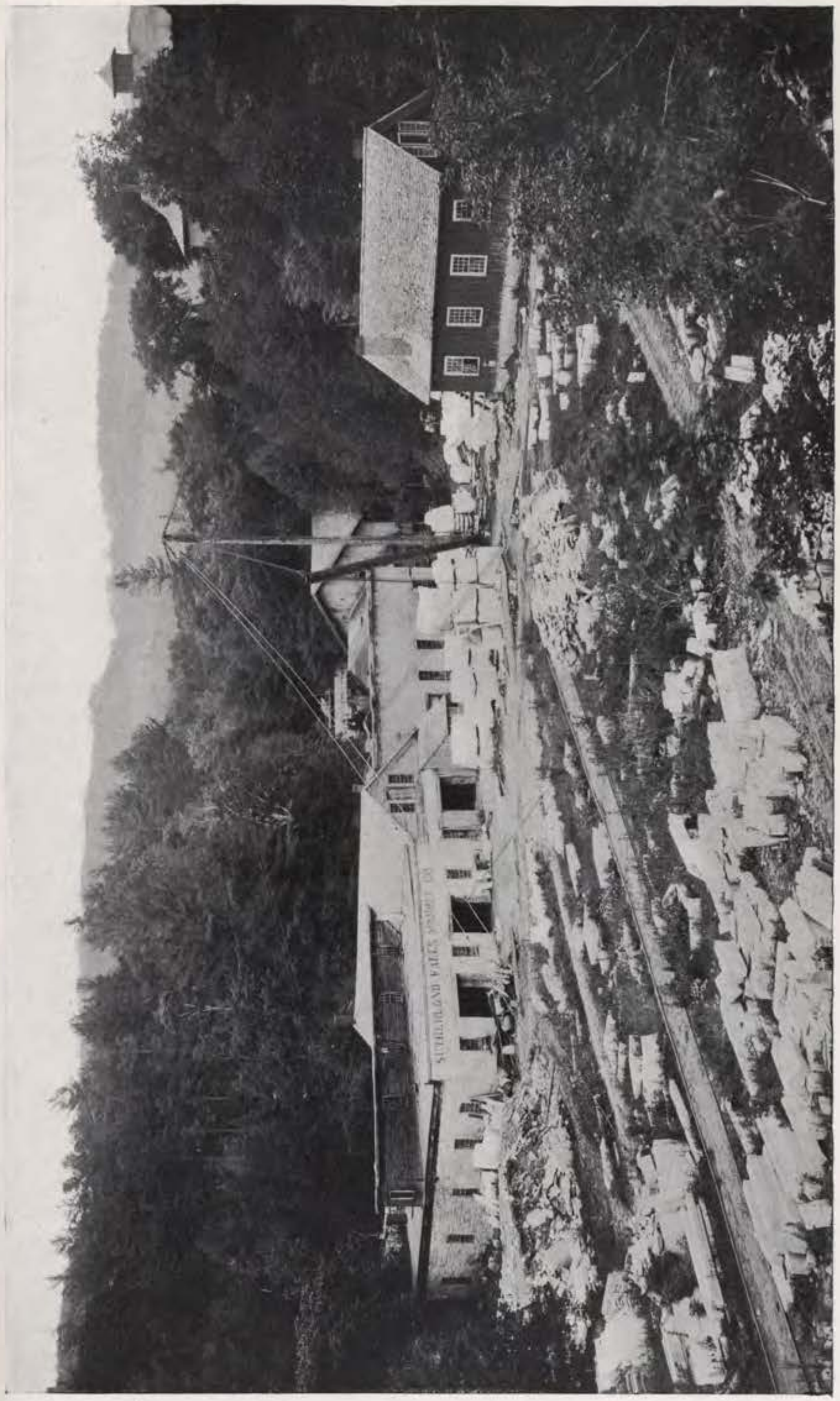
The size and arrangement of the saw gangs must be regulated by the size of the blocks. Plate XXIV shows the reserve of blocks at one of the mills.

We commonly speak of sawing the marble and perhaps there is no better term, but it is not the so-called saw that does the cutting it is the sand which is fed to the saw that cuts, the iron of the saw being only the means by which the sand is applied. Nor should the stream of water which brings the sand to the block be unmentioned for it is a most important factor in the process.

No one unfamiliar with marble sawing can realize the great amount of sand necessary to do the work effectively. If the marble be of the harder sort an amount of sand equal in weight to that of the block of stone itself may be used and in all cases the amount approaches more or less nearly that of the stone cut. It is therefore very evident that if a marble quarry is to be successful in finishing its product there must be somewhere near a good supply of sharp, clean sand. Of course if, as in some cases is the condition, the stone is sold in the rough, that is in blocks as quarried, the question of sawing does not arise.

The use of gang saws, long blades of iron arranged side by side in a frame, such as may be seen today in any marble mill, is very old. Centuries before the Christian era this method of getting slabs from blocks was used. Of course the form of the machinery used has changed with the passing centuries, though less than in most kinds of machines, but the main instrumentality, sand and water moved by the soft iron saw has always been the effective agent in cutting the slabs. The size of the saws, rather their length and the number placed in the frame which constitutes the "gang" have increased and in the modern machines iron frames are used instead of wood, but the gang is after all much the same, though more compact and often larger. It was

PLATE XXII.



FIRST MILL OF THE VERMONT MARBLE COMPANY.

moved to and fro at first by hand of man, then by water-power as it still is in many cases, and then by steam and finally by electric power. Plate XXV shows the machinery used in the most modern mills for holding a gang of blades.

The individual strips of soft iron are usually three or four inches wide and an eighth of an inch thick. The length varies more than other dimensions. Usually it is eight or ten feet, but for cutting large slabs saws over twenty feet long may be used.

The number of saws in a gang varies as thick or thin pieces are wanted. If the large block is to be cut into smaller blocks, obviously only a few saws are needed, but as the pieces to be cut out are thinner the number of saws increases until it may reach as many as sixty.

Even if the gang and its accessory parts are of the latest construction their progress through the block is slow—in ordinary marble an inch and a half or two inches per hour and in hard stone less. But once started they are kept moving back and forth continually day and night and thus in time the largest blocks are cut through.

The sand banks so abundant in Vermont are not usually regarded as a valuable asset, but aside from the value of sand in other operations, it is of utmost importance in the marble business, so much so that without sand the business could only be carried on to such extent as might be determined by the outside demand for marble in blocks as quarried.

When one drives, or worse, walks through deep sand on a hot summer day the sand is a nuisance and obstacle, but it is most fortunate for Vermont that she not only possesses great beds of marble, but also and not far distant, great beds of sand and that too of the right sort.

The work done by the great ice sheet which once covered the whole of New England and most of the northern United States is of inestimable value when its agricultural bearings are considered. A friend has called the great glacier "The Early Vermont Plow" and its greatest work was to fit the surface of the country for agricultural operations, but this was not all that resulted from the movement of the ice sheet and the subsequent events. Had it not been for this our beds of sand would largely have remained as they originally were, parts of the rock mass of the Green Mountains. But when the ice mass pushed against the rock mass it broke off immense quantities of the rock and, carrying them on, ground them to sand, the process being completed and the loose material distributed by the floods that followed the melting of the ice sheets. In general this is the way the sand beds of the state came to be what they are. And more than this the configuration of the country was left in such shape that large beds of sand were located near the far older beds of marble.

No one can study natural phenomena very long before he discovers that everything he sees is more or less dependent upon other and often apparently remote conditions.

The Green Mountains were formed in comparatively early geologic time as was shown in some fulness of detail in the last report, 1912, and the fact that in their formation conditions were such that great quantities of quartz were developed and included in the schists and gneiss which make up the bulk of the mountain mass so that when the rocks were, millions of years later, broken up and ground to sand this was hard enough to endure subsequent weathering and wear and remain till the present as hard, sharp sand. Had not just these conditions existed when the mountains were formed, our present marble industry could not have been what it is.

The amount of sand required to saw a block of marble, in addition to what has been said, may be better understood by considering the following quotation from a statement made by the Vermont Marble Company.

"In the days of the old mill a few teams could haul all the sand that was needed. When the business began to increase a short tramway was constructed, but the buckets soon began to come back empty. Finally, the cable was extended two and a quarter miles up over the mountain and the work of keeping up with the marble was again placed on a solid footing.

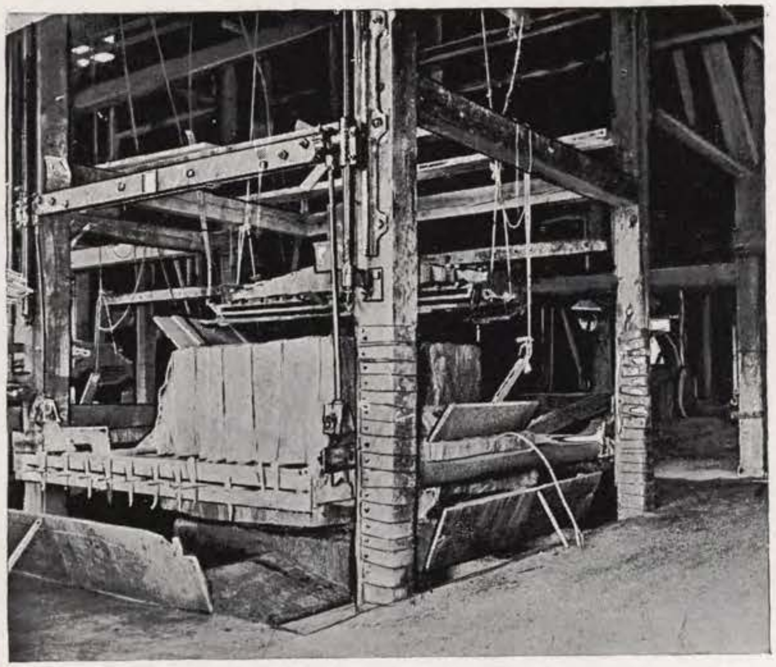
That was ten years ago. At present the tramway is still in operation and the sand is still forthcoming, although seventeen acres have been lowered sixty feet.

To express it in another way, each bucket weighs three hundred pounds and has a capacity of five hundred pounds and so rapidly are they filled and emptied that they move along the cable at the rate of one every fifty seconds or seventy-two an hour. During the day, they are in operation twenty-four hours, seventeen hundred and twenty-eight of them arrive at Proctor. Thus it will be seen that within the past ten years about 1,500,000 tons of sand have been fed to the hungry mills."

Plate XXVI shows the interior of one of the best mills in the part occupied by the gang saws.

While, as has been noticed, marble was sawn thousands of years ago, it seems to be true that all the slabs for tombstones or hearthstones in the early Vermont days were not wrought in this way, but that when such a piece of marble was wanted, as thin a piece as could be quarried was taken out and then this was reduced to the desired thickness by chiselling. Of course this was a very laborious and often unsatisfactory method, but, judging from the appearance of the old stones it was the only method. Plate XXVII shows one of these old stones and also shows how well the marble has withstood the wear of the elements during its century of exposure. There is, however, much difference in

PLATE XXIII.



GANG SAW IN OPERATION.

our marble in this respect for some of it has not endured nearly as well.

Since those early days more than a century ago when getting out a few very moderate sized pieces of surface stone was ample to supply all the needs of those primitive times to the present there has naturally been very great change in all quarrying processes. At first a crowbar and sledge were the tools employed.

Mr. F. R. Patch of Rutland has called my attention to some very well written articles in the Edison Monthly on the Marble Industry of Vermont. I am glad to quote the following which describes probably the earliest methods of quarrying on a large scale.

"The first quarrying was done with an extremely long and heavy drill and coarse grained blasting powder. A hole about four inches in diameter was started in the surface of a vein and a scaffolding was built about it. Then the long drill was inserted and a crew of a dozen men mounted the structure. By the yo-heave-ho method the drill was raised and lowered rythmically until the men grew tired. After days of this kind of work the hole would be pronounced deep enough. Then the explosive expert, usually a broad shouldered son of Erin, would insert the required amount of black powder and tamp it. About that time most of the population of Rutland and West Rutland would be gathered expectantly on the nearest hillside. The operation of charging completed, men with red flags would circle about the hole at a safe distance while the long fuse was lighted. Then all would run shouting to the hill top, there to await the shower of earth and marble accompanied by a deep rumbling explosion.

This method of getting marble was followed for years, indeed there are quarrymen in and about West Rutland today who remember when the town assembled to watch the blasting. And some of the deep drill holes are occasionally encountered still.

After the earth's surface was sufficiently stirred up by blasting to get at the marble, the quarrymen proceeded in very much the same manner as do their brother stone workers today. That is the marble was split and wedged out in great chunks by means of steel wedges or "feathers." These wedges were forced into the stone a few inches apart and when enough of them had been driven home the block would spit out from the rest of the deposit. The men found this method of handling marble particularly hard because apparently it had no grain to help their work.

The feathering method was superceded by another, much more tedious for the workmen, but better, no doubt, because less marble was wasted.

The stone cutter under the new regime, worked at a single block of marble with a long drill on the end of which was a sharp chisel. Twenty or thirty men seated about three or four feet apart on long wooden benches would work for days cutting in the same channel; a good day's work for one man being a cut four feet long by nine inches deep; the channels ranging according to the thickness of the layer."

It will be readily seen that this method of starting blocks from the original bed, that is the blasting part of it was exceedingly destructive so that by it much good stone was spoiled.

Blasting was therefore abandoned so far as possible as soon as any large quantity of marble was demanded and its value became worth considering. Later than the above account we find that the methods mentioned in the last part of the article quoted were amplified and for years were those mainly employed as the following from Professor Seely's article in the "Marble Border of Western Vermont," which he quotes from another.

"It is an interesting scene to behold two hundred quarrymen ranged in rows each with his sharp drill steadily cutting deeper those grooves that are destined to sunder the fetters that bind those valuable blocks to their parent bed. The musical ring of the quarryman's drill that reverberates to the ear from the deep vaulted quarry is pleasing to the spectator as he stands and looks down into it; and to the proprietor it is the welcome harbinger of the good time coming, for a successfully wrought quarry is sure to bring fortunes to the proprietors."

No such array of workmen is now to be seen in our quarries. Here, as everywhere else, machinery has taken the place of a large number of the former workmen and less picturesquely, but far more rapidly and efficiently does a much larger work.

The first satisfactory machine used in our marble quarries, or so far as I can ascertain, in any quarries for detaching the large blocks was the Wardwell channeler. Plate XXVIII. This machine was built in 1863 for use in the Sutherland Falls quarry and it is said that this machine was in constant use for more than twenty years. As the figure shows, the machine is an ungainly and apparently clumsy affair, but the fact above stated and the fact that it has been used in all or nearly all, of the important marble quarries in the country and is still in operation in many, proves that it has substantial value.

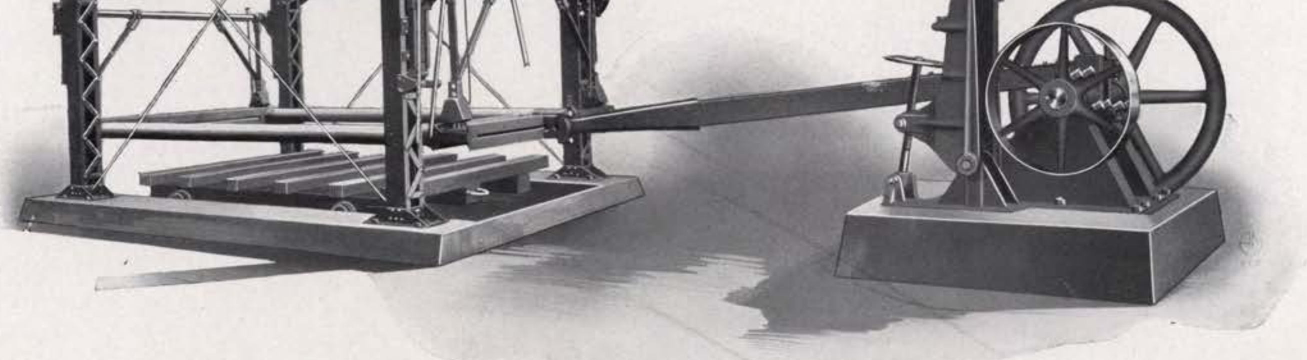
Necessarily, the first channelers were operated by steam and this has been true until recently in all quarries and is still in many. A great objection to this is the smoke and steam which often fills the quarries. Especially on a dull day when the air is light the smoke and to a less, but considerable extent, the steam settle into a deep quarry and greatly obscure the workmen and the work. Then too the smoke blackens the otherwise white walls and if this has little commercial importance, it certainly has very much to do with the appearance.

Since the use of water-power to generate electricity has been adopted the quarries have been doing away with steam and its

PLATE XXIV.

BLOCKS OF MARBLE AS TAKEN FROM THE QUARRY READY FOR THE MILL.
Vermont Marble Co.

PLATE XXV.



LINCOLN SCREW GANG FOR SAWING QUARRY BLOCKS.

necessary objections and using electricity as a motive power, first in channelers and one by one all other machines used have been changed so that the electrical current has replaced steam or water-power.

The application of electricity to every phase of the work in the quarries is suggested by the electric channelers seen in the quarry, Plate XXX.

The general appearance of a marble quarry is in many respects unlike that of most other quarries, though the granite and sandstone quarries are more and more adopting the same methods of releasing the blocks from the main mass as shown in Plate XXXI.

I do not know that any description can add very much to the views of marble quarries given on Plates X, XII, XV, XVII.

It will be noticed by those familiar with stone quarries that there is much greater regularity and order in the marble quarry. This comes from the manner of removing blocks by channelers, etc., and the absence of blasting.

"As it is plainly of first importance that the blocks of marble be as sound as possible all methods that can produce cracks or flaws are avoided so far as possible. Blasting as we have seen is only allowed in extreme cases and is practically not attempted after a prospective quarry is well opened. Usually the stone of a marble ledge is worthless for some distance from the top down and this valueless material must be removed and here blasting is necessary. Occasionally, the stone is saleable from the top layer, as in the Riverside quarry near Rutland and some of the quarries in Dorset have been sound from the start, but this is uncommon. It is because of this usual imperfection of the upper layers of the stone that it is often expensive to open a marble quarry and get it ready to produce saleable stone.

I have been told by experienced marble workers that in many cases from $25,000 to $50,000 have been laid out on a quarry before it began to give any returns. This should be remembered by anyone who proposes to exploit a new proposition in marble.

After the top waste, be it more or less, has been taken care of the regular work of getting out the stone for market is begun. So far as possible natural seams and layers are utilized but these are not always situated in the right places and the stone must be artificially broken into the desired sizes. The first layer, after the material above it has been gotten rid of is attacked, first by channeling machines.

Mr. Redfield Proctor of the Vermont Marble Company in reply to enquiries has described the process as follows:

"Vertical cuts of the required depth are channeled across the floor of the quarry parallel with the general channel cuts as planned for that floor. Of course the channel cuts over a portion of a given floor may be in one direction while those in another portion of the floor may be at an angle with the first. Three adjacent and parallel channel cuts are then united by short channel cuts at right angles to the long cuts, thus making blocks of the size desired.

One of the square blocks thus cut on four sides is then broken out by means of wedges in any way possible, usually with the assistance of a lewis hole in the center of the top which assists in removing at least a portion of this block. After one block is removed, and in many instances this is done quite easily and approximately in one piece, holes are drilled, either by hand or with a small air drill, at the bottom of the other two blocks whose lower edges have been exposed and whose sides have been as indicated above.

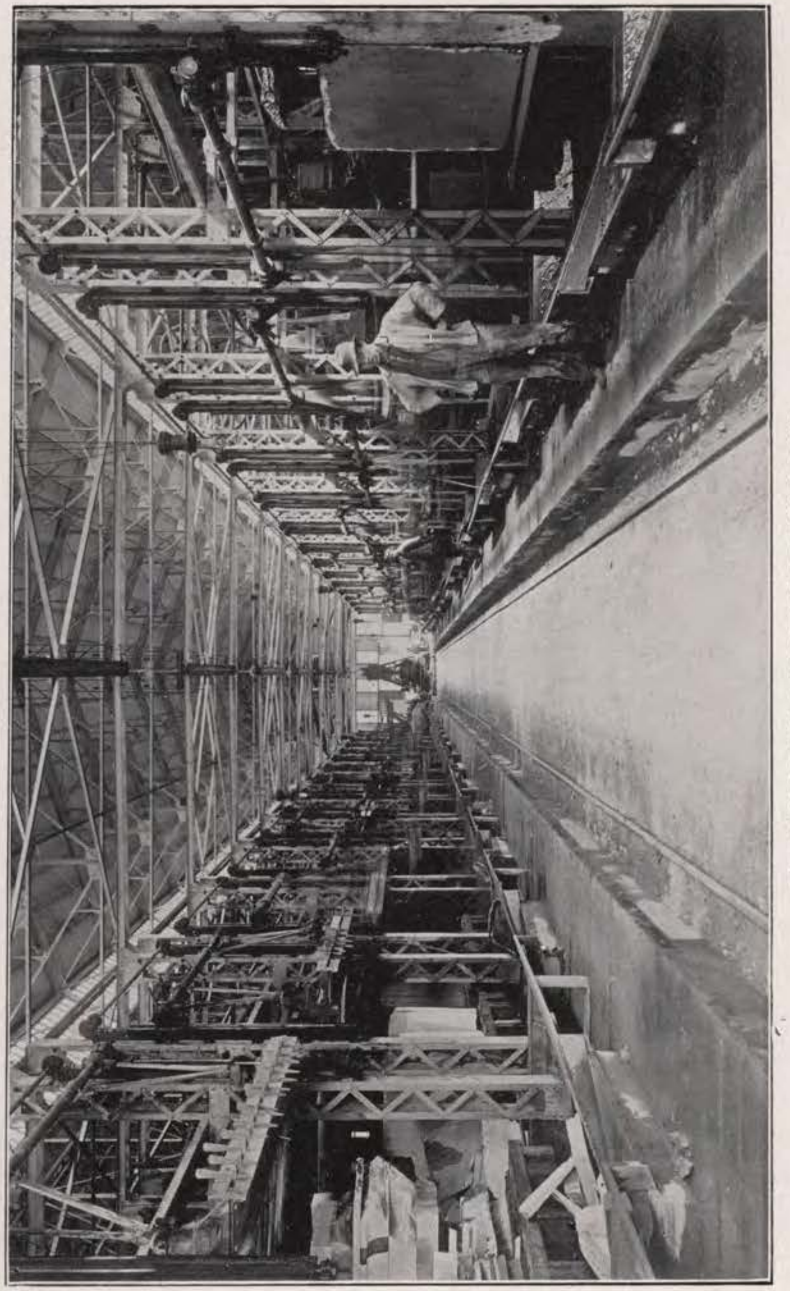
When sufficient key blocks, usually four, have been removed so as to permit the use of a power drill or gadder, the rest of the blocks in the two key way courses are thus removed. In any case whether drilled by hand, or small air drill or the regular power drill or gadder, the holes are drilled as near as possible to the level of the new floor, that is at the same level as the bottom of the channel cuts and, according to the quality of the marble and its texture are from six inches to a foot apart. The depth of these holes is also varied according to the texture of the marble. In some instances they may be quite shallow, while in others they may run back almost to the next channel cut. Into these holes half rounds or "feathers" are inserted and wedged, the wedges being driven in by hand until the crack is effected. The same method is used after the removal of all the blocks in the two key way courses to remove the other course for the entire floor of the quarry and in most instances the same method is used to insure the vertical breaks in the other courses as well as the breaks in the new quarry floor line.

It is of course necessary in addition to the cross channel cuts that all of the marble should be cut clear from the wall of the quarry. Perhaps I can make the point clearer by the simple statement that it is necessary to take out two courses across the quarry by channeling all four vertical sides of the blocks in the two courses, removing the first block as best may be by the assistance of wedges and a derrick attached by means of a lewis, the other blocks in the key way being loosened at the bottom by drill holes and wedges.

The blocks in the other courses in the quarry can all be released from the floor and can be broken apart in each course by means of drill holes and wedges though it is necessary to have a channel cut at the two wall ends of each course or strip."

As the Wardwell Channeling Machine involves most of the principles of all that have been made since, a detailed description may be added to the figure.

PLATE XXVI.



SAW GANGS IN A MODERN MARBLE MILL.
From Vermont Marble Co.


THIS STONE WAS SET IN FAIR HAVEN CEMETERY IN 1797.

The stone was washed before photographing, but nothing else was done to bring out the carving.

A temporary track is placed on the floor to be cut into blocks and on this the machine runs back and forth until the groove or channel is cut to such depth as is desired.

The cutting part consist of one cutter on one side or one on each side. These cutters, raised and dropped by an arrangement of levers and cranks consist of five chisel pointed drills arranged in such fashion that the middle one is lowest and the two on each side are stepped from it so, the whole forms, as they are clamped together, a single large drill with triangular end. Each cutter is a steel bar from seven to fourteen feet long, the middle one being the largest, and the whole weighs several hundred pounds and, when dropped, after it is raised, it falls upon the stone with much force. From the arrangement of the individual cutters it follows that when moving in one direction the center bar and two in front of it do the work and when reversed to move back the center and the other two bars are cutting. It was found that more effective work was done if the cutters were arranged so that of the five two have the edges diagonally placed and three transversely.

The machine is automatic to a great extent, that is, it is reversed when it reaches the end of the channel without stopping and the drills are carried forward at each stroke. Ordinarily the channels are cut four to six feet deep and an inch and an eighth wide.

One of these machines is expected to cut from forty to eighty square feet per day in the Rutland marble while the day's work of a good workman is not more than five to ten feet.

Steam was the only power used for a long time, but lately electricity has been applied to the channeling machines as to all others. Laterly the Wardwell machines have been gradually replaced by the Sullivan and Ingersoll channeling machines.

Not by any means so conspicuous in the quarry as the channeling machine, but in its place quite as indispensable is the gadder. This machine, now driven by compressed air or electricity, is used for boring holes for wedges or any other purpose. At first the gadder carried only a single drill, but now there may be several and one gadder may do the work of twenty men.

The coring machine is of the greatest use in prospecting. When it is desired to know as much as can be found without actual quarrying of the depth and quality of a bed of marble a core is taken. This is obtained by a revolving diamond drill by which a cylinder of stone two to three inches in diameter is taken out to almost any needed depth. While these cores can only show the character of that portion of the rock mass through which they have gone and that only within a small area, they do indicate accurately this much and indicate enough to be of the greatest value, for if a core fifty feet or more in length is taken out, sound all the way through, it gives pretty accurate knowledge as to the character of at least a part of the whole. For this reason no experienced marble quarryman would expend much labor or money upon a new quarry until it had been cored, usually in several places more or less distant from each other.

The term marble has been frequently and of necessity, used in the preceding pages and a few words as to the use of the term may be desirable. This is the more important because the word has not at all times and under all circumstances the same meaning. Strictly limited in definition, marble is a crystalline rock resulting from a more or less complete metamorphosis of sedimentary limestone. But there are numerous kinds of stone called marble in trade and popularly which are not formed in the above manner.

The Century Dictionary defines marble as "Limestone in a more or less crystalline or crystalline-granular condition." Adding, however, "Any limestone, even if very compact or showing only traces of crystalline structure may be called marble if it is capable of taking a polish or if it is suitable or desirable for ornamental purposes." Neither of the above definitions will include all the varieties sold in Vermont as marble.

The Rutland marble, and indeed most of the Vermont marble, is of the sort described by the above definitions, but an amount of the Champlain marble from Swanton, which is a calcareous member of the red sand rock not at all metamorphosed and little crystalline, and the Roxbury marble, which is a serpentine and contains comparatively little lime is continually sold to make it necessary, for trade purposes, to enlarge our definition.

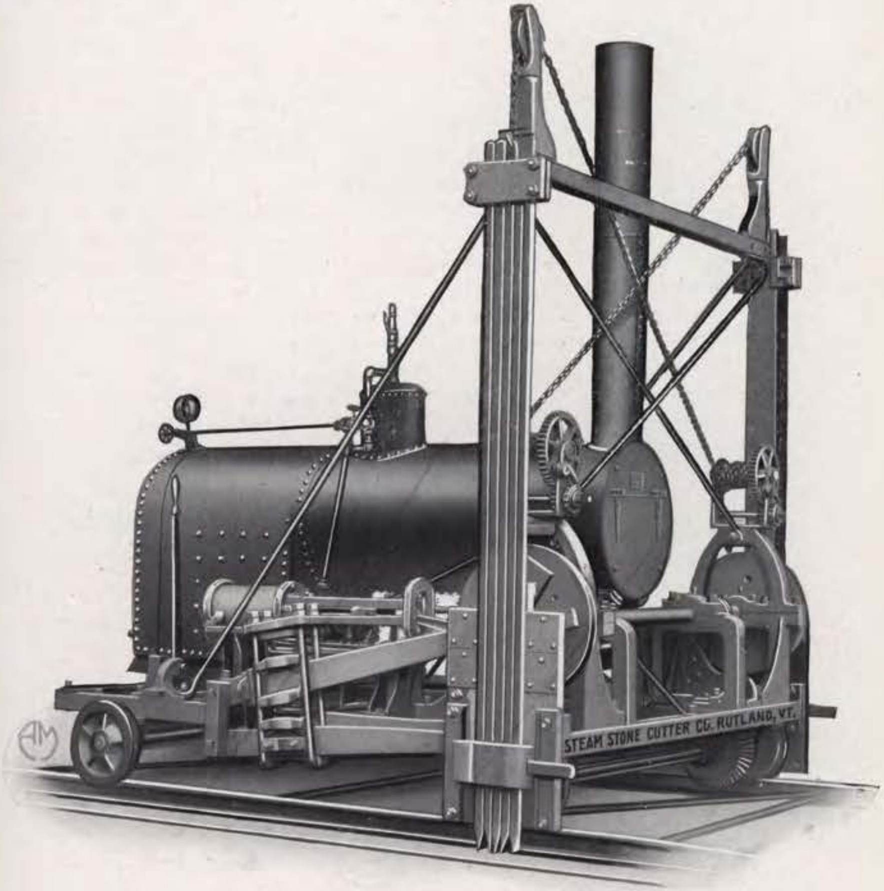
Often we find that any stone which can be used for ornamental work of any kind is called marble irrespective of its character or composition. Indeed this is true of Vermont dealers for there can hardly be found two varieties of stone more widely different than the white or light marble of Rutland and the Roxbury serpentine and yet the latter is always included in any list of Vermont marbles.

There are numerous deposits of true marble in the state which are not yet worked and some of them never will be.

It is not sufficient that the mass of rock be true marble or that it can be polished and is ornamental when finished. There are many other considerations to be taken into account such as soundness, good texture, color, veining, etc. When used as a building stone, marble may be of value even if there are flaws provided there are not too many or too large, but when used for monumental work and especially for statues it must be quite perfect.

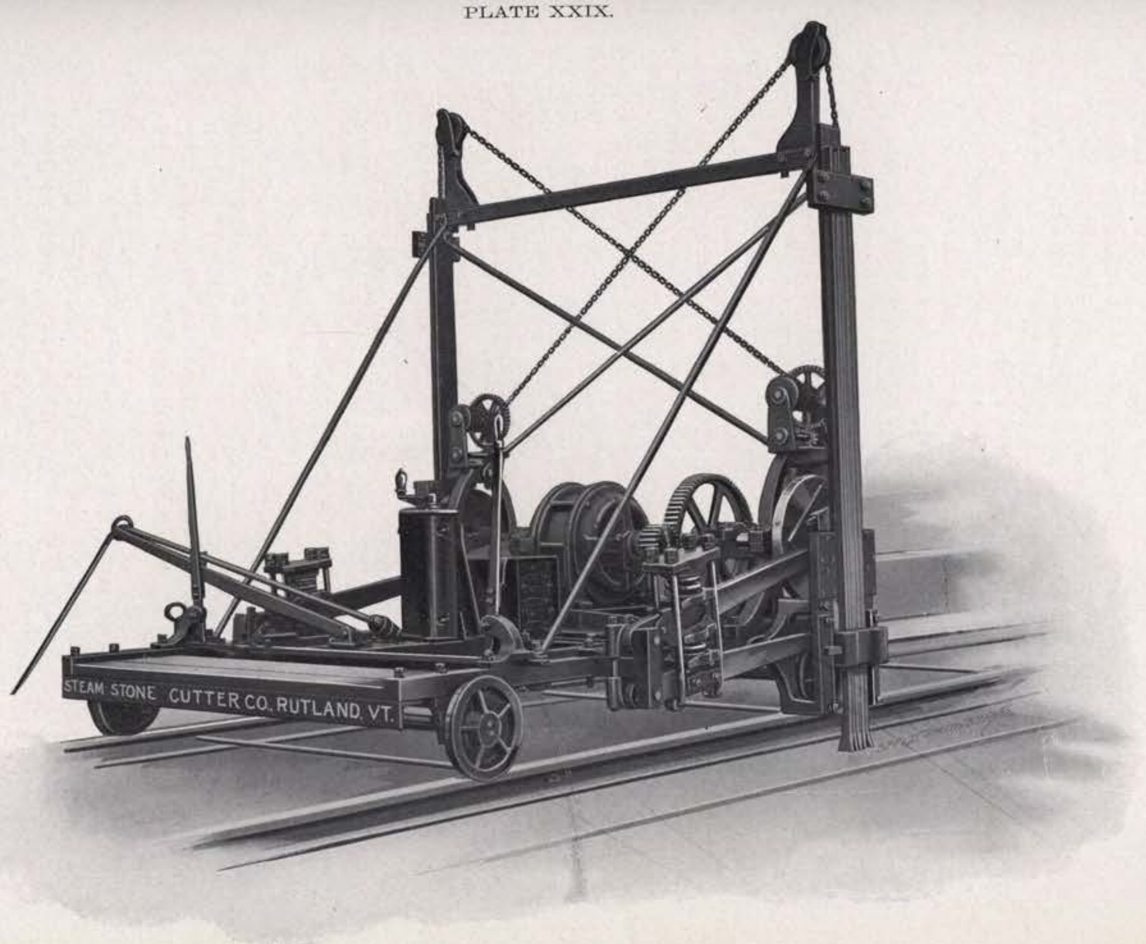
In the large blocks as quarried it is very often difficult or even impossible to detect small cracks or other imperfections which will surely appear when the stone is polished. It sometimes happens that apparently sound and perfect blocks, as they seemed when they left the quarry, prove useless when sawed into

PLATE XXVIII.




WARDWELL STEAM CHANNELING MACHINE.

PLATE XXIX.




WARDWELL ELECTRIC CHANNELER

slabs and polished and considerable loss is sometimes incurred because of this.

It is always unsafe to use layers that lie directly underneath those that are broken or in any way disturbed however sound they may seem even to a skilled quarryman. Naturally, invisible flaws or cracks are far less likely to develop so that they damage the appearance of the stone when it is used in the interior of buildings than when outside exposed to the weather.

It is of course important that the color of marble be not only agreeable when first quarried, but that it be permanent for in some kinds this, though very handsome at first, fades badly when exposed to strong light. The structure must not be too coarsely crystalline if interior work is contemplated.

A curious and interesting condition to others than the owner, is sometimes found by reason of which an otherwise good quarry must be abandoned. There have been cases in which after the top floor had been removed and the second, or it may be the third, floor had been partly loosened, as the channeling machines cut their course across the quarry the strips cut sprang to such an extent as to bind the tools and stop futher operations. The same trouble occurred with hand drills and the quarry had to be abandoned. I have heard of the same difficulty caused by the lateral pressure of the surrounding rock, occurring in granite quarries. Such conditions are, however, rare in any region. The matter of transportation, disposal of waste material, drainage, etc., must all be considered in deciding to open a quarry in a deposit of marble.

It will very likely occur to many to ask whether the supply of good marble is becoming smaller to such an extent as to cause anxiety. It is certain that some quarries have long since been worked out and that others are approaching the same condition, but at the same time new openings are made and new quarries are proving their great value. Inasmuch as a bed or deposit of marble does not by any means ensure a profitable quarry the existence of marble in considerable amount is not alone sufficient guarantee for the future. Only as a mass of marble is worked can its real quality be ascertained for stone that looks very promising in an outcrop may be found full of flaws and be useless commercially.

In his discussion of the extent of the marble beds in one of the preceding pages Dr. Dale has given an estimate of the resources of the State and as may be seen by referring to page 153, concludes that the supply remaining unworked is large, saying that "The unworked profitable portions of the marble boundaries thus probably aggregate 44½ linear miles."

The breadth of the marble is not estimated, but whatever it may be, the total amount cannot be other than very large. The reader who is interested in the marble question should by all means read what Dr. Dale has written as given on pages 153 and 154 as to the probable future of the marble industry in Vermont. Samples of most of the varieties mentioned in the following descriptions may be seen in the State Collection in the State House, Montpelier, and in the display rooms of the marble companies.

In the descriptions of varieties of marble which are given a few pages further on the various uses to which marble is put are incidentally mentioned. As all know, the common uses are in monuments, buildings, wainscoting, paneling, stairs, floors, and other interior finishing and of late a considerable quantity is used for electrical switchboards.

It is important in the use of marble in construction to know the fire-resisting qualities and often the crushing strength. This is particularly important now that marble has come into use as a building stone more by much than ever before, at least in this country. In one of the publications of the Vermont Marble Company I find the following: "The different quarry products have been given a thorough trial by the New York Underwriter, a fire insurance paper.

The results of the experiments are concisely set forth in this quotation: 'Taken as a whole the heat resisting capacity of building stone stands as follows: 1st, marble; 2nd, limestone; 3d, sandstone and freestone; 4th, granite; 5th, slate; 6th, conglomerates.'

It was proved further that Vermont marble may be subjected to a heat of 1,200 degrees fahrenheit without injury."

In the same booklet I find the following as to crushing strength: "A series of tests in a New York laboratory give our marble an average crushing strength of 18,125 pounds to the square inch. Another test undertaken by the United States Government brings out a crushing strength of 16,156 pounds to the square inch."

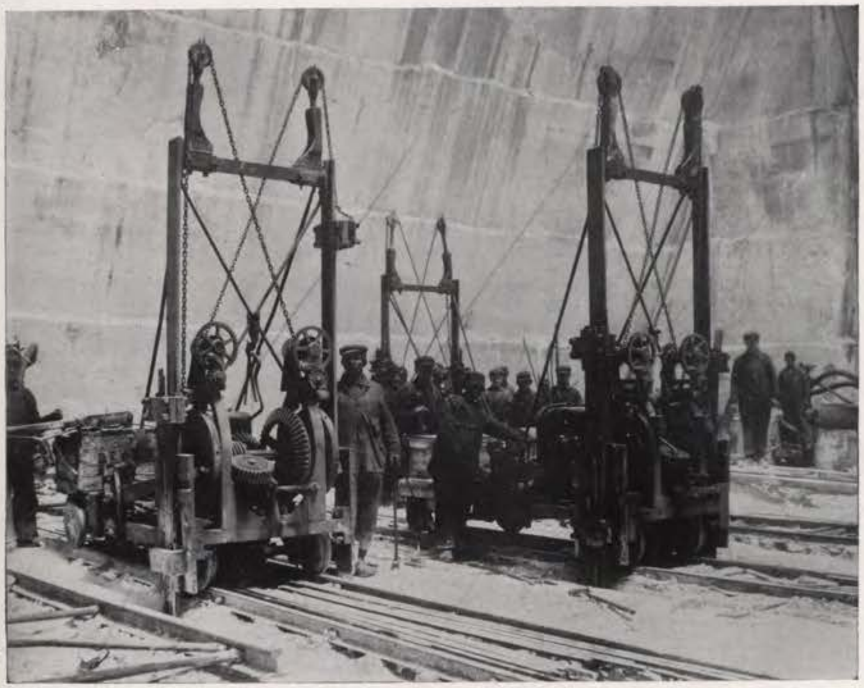
For chemical analyses of the Vermont marbles the reader is referred to page 4 and of Dr. Dale's report, preceding.

In the Eighth Report of this series, pp. 196-219, there is an article by W. A. Bristol on High Tension Testing of Vermont Slate and Marble which will be found of interest to those having to do with electric switchboards.

## DESCRIPTIONS OF MOST OF THE VARIETIES OF VERMONT MARBLE.

In the following list only those varieties are included which present sufficiently well defined characteristics to warrant special trade names. There are more or less slight variations which are innumerable.

PLATE XXX.



CHANNELING MACHINES AT WORK.

Varieties may also change as quarrying proceeds for it is very commonly the case that as a bed of marble is followed for some distance the arrangement of the colors changes often very greatly and one variety may disappear to give place to a new one. It may also happen that so small a quantity of a given sort exists that it is not worth while to put it on the market or to give it a name.

Not all the kinds mentioned are now sold or kept in stock, but it is not the intention of the writer to include any that cannot be supplied if there should be a demand for it. There are a few exceptions in case of varieties once important, but no longer to be had in considerable quantity. These are mentioned because they are needed to complete any proper list of Vermont marbles. The list includes 126 varieties and unless it is stated that they can no longer be furnished all are either kept in stock or can be promptly obtained.

As in the table of marbles on pp. 146 to 151, Professor Dale has not only given a list of the marbles under the trade name of each but in addition briefly characterizes each, it may seem somewhat of a repetition to supply the list which follows, but notwithstanding the admirable and useful table found in the bulletin by Professor Dale, there appears to be a demand for fuller descriptions of, especially, the more important varieties.

In the Sixth Report of this Survey there was published a series of descriptions of the marbles which had been exhibited at the Exposition at Jamestown, Va., in 1907.

During the years that have passed since this time quite a number of new varieties have been found, changes have been made in some names and in quarries, etc.

The present Report being devoted to an unusual extent to the Marble Industry of the State it seems proper that the pages referred to in the Sixth Report should be rewritten and additions supplied where needed and the account thus revised be included in the report. On some accounts it would be very desirable that the main varieties should be represented by colored plates, but this has not been possible and attractive as such plates may be made, it is the opinion of some of our leading marble producers that description is better than such plates inasmuch as a description may give the average characters of a given variety whereas a plate can show only the particular features of a small piece and in a variable stone, the verbal presentation is more likely to afford a fair idea of the ordinary appearance of the stone. However this may be it is the verbal account alone which can be given here. Probably if both good plates and descriptions were attainable the best results might be reached.

In most cases a block of marble is sawed in a direction parallel with the bedding of the stone in the quarry, but in some cases a block is cut across the bedding or it may be quarter sawed. In some marbles in which there is either no well defined figure in the coloring or little contrast in the colors it makes little difference in what direction the saws move through it, but in those varieties in which we find bold, striking veins, clouds or what not, slabs taken across the bedding may differ widely in appearance from these taken with it. Of course the colors will not vary, but their arrangement will vary greatly. A very few of the varieties are produced by different sawings, but most are not.

The most usual colors found in the Vermont marbles are white in many shades, that is, bluish, yellowish, etc., black, many shades of brown, yellow, blue, gray, green, red. Some of the causes of these shades are mentioned by Professor Dale on a preceding page.

It should be stated that there is very great difference in quarries as to the texture and especially color, or at any rate shade, of the stone contained in the whole mass.

There are some quarries which produce large quantities of stone that is very uniform in grain and color and there are others from which a number of very distinct varieties may be obtained. I have come upon no example of a variable mass of marble so striking as that in the south part of West Rutland. If the reader will turn back to page 107 where Professor Dale gives a detailed account of this marble as seen in the Eastman quarry he will at once see how great is the variation in different parts of a comparatively small bed of stone. And the same variation is seen in the Westland quarry of the Vermont Marble Company just north of the Eastman quarry and in the Baronial (formerly Umbrella) quarry of the Green Mountain Marble Company.

One of the workmen at the Eastman quarry stated that no less than twenty-seven varieties had been taken from the quarry. How nearly accurate this is I do not know. I have not seen so many, but the possibilities of this and the adjoining quarries are great.

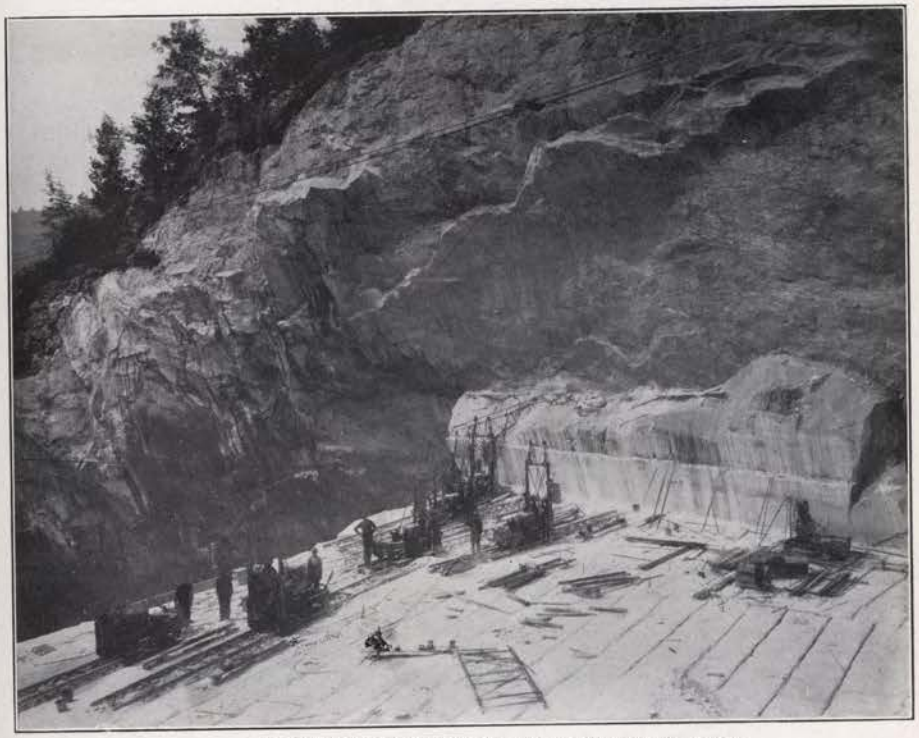
In the show room of the Vermont Marble Company at Center Rutland there is displayed a continuous series of slabs arranged as they were located in the Westland quarry and they present a remarkable appearance, remarkable for beauty, variety and unusual character. Really as a display from a single small quarry the group of polished slabs is astonishing and I have no doubt that either of the quarries adjoining could show a similar series. The pieces are of variable size being from four to nine feet long, the length of the entire series being about fifty feet. The blocks were taken from east to west across the bed which runs approximately north and south.

Beginning at the west we first meet a creamy white marble crossed by not very distinct, widely separated wavy veins of a light brown shade, after about five feet of this the brown of

PLATE XXXI.

SUTHERLAND FALLS QUARRY.

PLATE XXXII.



A SECTION OF SUTHERLAND FALLS QUARRY.

the veins suddenly changes to green, the ground at first being much as before, then this too becomes green of an olive tone, light and dark being mixed. Sparsely mingled with these are bands of whitish and brownish. Then another abrupt change gives a light surface and this ends the second block. The third block is nearly nine feet long and begins light and here the veins are very indistinct and smoky brown. As we go on the veins grow more plain and veins and blotches of a soft green replace the light brown and the ground becomes salmon pink, which grows deeper and the green of the veins is now again brownish or yellowish. In the fourth block the colors are much the same as in the second, but the shades are darker and more definite. In the fifth piece a salmon ground is crossed by more or less confluent green veins, here faint, there prominent. The sixth piece is very light, almost white, lightly veined in smoky brown which after a few feet changes to green. The seventh piece is quite light though crossed by many green veins for there are also numerous bands of pure white. A light creamy ground which is very little covered by veins gives to the eighth piece a very light appearance. The green veins are less wavy than in the other pieces and mingled with the distinct green marking are delicate and therefore much less prominent dusky or brownish veins. Thus we have in these nine pieces at least a dozen varieties of marble.

The writer has at the risk of wearying the reader given the above detailed account in order to show the wonderful variety which may be found in a single small area. All of the above were taken from one floor in the quarry.

Probably somewhat of the difference seen in the quarries is due to a difference in the metamorphism which has taken place while the marble was being formed. A difference in the materials at hand must also have been a prominent factor in determining the character of the stone. The main facts in the process of marble making as it occurred in the West Rutland region have been stated in former reports and Professor Dale has given them on page 13 of this Report so that it is not necessary to enumerate them here.

Nothing is more evident to one who visits the quarries than the difference in the disturbances which have taken place. Of course in all the marble beds there must have been much change by which the ordinary limestones of the region were converted into marble, but after this process or during its progress, some of the beds were much more disturbed, folded, crushed, etc., than others.

Curious faulting occurred in some as shown in Plate XXXIV which shows a part of a polished slab from the True Blue quarry. As Professor Dale shows, there is more or less dolomite in many of the quarries, though all of the true marbles are largely calcite, the dolomite usually being found only in comparatively small masses. The Champlain marbles of Swanton, however, are largely dolomitic.

To anyone who looks over any considerable number of pieces of marble it will soon become evident that it is no easy task to write descriptions that shall be of any value, and the writer is fully aware of the difficulty of his task and the inadequate performance which is exhibited and yet it is given with the hope that it may to some extent serve those who wish to know more concerning the Vermont marbles.

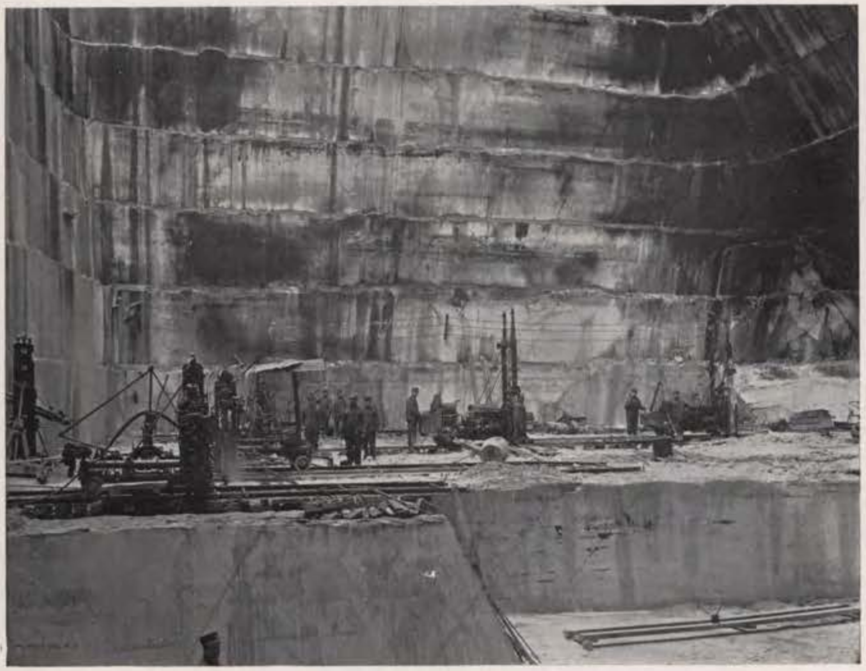
The question is sometimes asked which of the Vermont marbles is the handsomest? No one familiar with our marbles would ever ask this question, but those whose knowledge of Vermont marble is limited to verbal descriptions or at most to a few small specimens, may not unreasonably ask it or something equivalent. It is not necessary to say that it is a question that cannot be intelligently answered by anyone for there is no one nor are there several varieties that are superior to all others for all purposes.

The range in building stone is not great. All the building marbles are of the lighter sorts from pure white to some of the so-called "Blue" marbles. At any rate the darker marbles as the Albertson or dark True Blue are rarely used. When, however, the work is for interior finish a vastly greater variety is available, so great that one must be hard to please who cannot find suitable material, both as to color and texture, in some one or several of our marbles.

Of course the choice of color or pattern for a particular locality must be largely governed by individual taste, the taste of some one who has authority to decide. This, influenced by location, light and surroundings, must finally determine the choice of this or that variety. Environment must be considered carefully sometimes since a given stone may be in itself all that could be desired, but if badly lighted or unfortunately placed with other and inharmoniously colored marble its appearance may be greatly marred, while if set with proper surroundings its attractions may become more attractive. In places where a bold, striking effect is desired, such marbles as Dorset Green Bed and Royal Antique and Brocadillo should be used. Where simple elegance and the charm of quiet, restful shade is demanded these are quite out of place, but such marbles as Rubio, Westland Cream, Pink Listavena or others of that class, or if more prominent, though light and graceful veining or clouding is needed Pittsford Italian, Kiels Green, Verdoso may be used with best effect. If there is plenty of light and expense is not too limited, most superb effects are attainable by using the Champlain marbles or Verde Antique.

The above are not named as superior to other varieties but only by way of example for there are numerous other varieties

PLATE XXXIII.



RIVERSIDE QUARRY.

that to many would seem as fine as those named. Each has its appropriate place and when marble is used as freely in the United States as it is in Europe, where sometimes not only the walls, but all parts of a room, floor, walls and ceiling, are of marble all of our Vermont varieties will have a place in the costly buildings of the near future, for already, and especially within the last few years, marble is being far more largely used, as in the Congressional and New York Libraries as well as in many banks and large office buildings.

The descriptions have been written from actual examples of the marbles named, the common trade names being used.

Every opportunity to examine their marbles has been afforded by the marble companies, both in the quarries and exhibition rooms.

The following list includes so far as known, all those varieties which are now quarried in Vermont or in a few cases which, though not now quarried, exist and can easily be obtained if called for.

There are numerous lesser varieties which either occur in too small quantity to be of value or are too difficult to quarry or for other reasons can only be obtained when especially desired. The names used in the list are those recognized by dealers in 1914. Most of the standard varieties are known for a long time by the same names, but some, especially if a quarry pass into different hands, are from time to time given new titles. It also sometimes happens that two or more companies handling the same stone give it different names, but this is not commonly the case.

Any arrangement of such a list as that which follows is open to some objections, but on the whole it has seemed most convenient for reference to place the names alphabetically and in the descriptions the place where each is obtained and the company handling it will be stated.

## LIST OF VERMONT MARBLES.

Aeolian.
Africano.
Albertson, Extra Dark.
American Pavonazzo.
American Sienna.
American Yellow Pavonazzo.
Avenatto.
Baronia.
Baronial.
Best Light Cloud.
Best Light Cloud Rutland.
Blanc Clair.
Blue Building.
Brandon Italian.
Brandon Statuary.
Brocadillo.
Cipollino.
Clarendon Dark Cloud.
Clarendon Light Cloud.
Cream Lauville.
Cream Statuary.
Danby.
Dark Cipollin.
Dark Florence.

Dark Ivory Green.
Dark Vein True Blue.
Dorset A.
Dorset B.
Dorset Green Bed.
Dorset Mountain.
Dove Blue Rutland.
Electric Blue.
Esperanza.
Extra Dark Royal Blue.
Extra Dark True Blue.
Fisk Black.
Florence.
Florentine Blue.
Gray Building.
G. Green.
Green Mountain Sienna.
Green Veined Cream.
Green Vein Statuary.
Heidelburg Green.
Highland Blue.
Holland Blue, No. 1.
Holland Electric Blue.
Holland Mottled Blue.
Holland Average Blue.
Italio.
Jasper.
Jermonda.
Kiels Green.
Light Cipollin.
Light Cloud Rutland.
Light Cloud Italian.
Light Columbian Building.
Light Florence.
Light Green Cloud.
Light Ivory Green.
Light Moss Veined.
Light Rutland Italian.
Light Sutherland Falls.
Light Vein Rutland.
Listavena.
Livido.
Lyonnaise.
Mahogany.
Manchester Blue.
Manchester Breccia.
Manchester Clouded.
Manchester White.
Marine Venoso.
Medium Light Cloud.
Moss Vein.
Olive.
Olivo.
Oriental.
Ovido, Dark.
Ovido, Light.
Oxford Fleuri.
Pink Listavena.
Pittsford Italian.
Pittsford Valley.
Pittsford Valley, H Layer.
Pittsford Valley, M Layer.
Pittsford Valley, X Layer.
Plateau White.
Riverside.
Rosaro, 1.
Rosaro, 2.
Royal Antique, M Layer.
Royal Antique, N Layer.
Royal Antique, O Layer.
Royal Red.
Rubio, G Layer.
Rubio, P Layer.
Rutland Building.
Ruvaro.
Special Rutland Building.
Special Rutland Italian.
Standard Blue.
Standard Green.
Statuary Rutland.
Swanton Dove.
Tapestry Green.
True Blue.
Veined Blue.
Veined Cream Statuary.
Veined Rosaro, 1.
Veined Rosaro, 2.
Verde Antique.
Verdoso.
Verdura.
Vert Campan.
Vert de Mer.
Westland Cream.
West Rutland Italian, 1.

PLATE XXXIV.

TRUE BLUE MARBLE SHOWING FAULTS.

West Rutland Italian, 2.
West Rutland Italian, 3.
White Pavonazzo.
White Rutland Building.
White Statuary.
White Stone Brook.

## DESCRIPTIONS OF VERMONT MARBLES.

### AEOLIAN.

This marble, until within a year or two was quarried by the Norcross-West Company at Dorset and the quarry is likely to be reworked at some future time, but is at present idle.

A variety which has distinctly an individuality of its own. It is in coloring similar to the Dark Green Vein, but the materials which make up the stone are arranged quite differently so that the appearance of the polished surface is very unlike the other varieties. The ground is white and through this there are seen running in every direction green bands, veins or lines, often very wavy and more or less confluent. In some portions of the surface there is a very pretty moss-like effect. The most unique feature of the Æolian is seen in the many directions in which the colored markings extend. In most marbles there is one general direction to which all, or at any rate, most of the veins, etc., conform, but not so in this. In shade the green varies from very dark to light and there are olive shades, and now and then blotches or spots occur. The white usually has a yellowish tinge and there may be spaces of the size of one's hand without any veining and elsewhere similar spaces of green. Altogether this is a very striking and elegant marble. Examples of this may be seen in the Massachusetts Mutual Life Insurance Building at Springfield, Mass.

### AFRICANO.

This is a very dark gray or almost black marble. It has none of the bluish cast seen in most of the very dark marbles from this region, or at least usually not. The gray is somewhat varied in depth. Most of the surface is decided gray but sparsely mingled with this are bands and clouds of clear black. The Africano is the nearest to an entirely black marble that has been seen except the Fisk Black.

Quarried by the Green Mountain Marble Company at West Rutland.

### ALBERTSON, EXTRA DARK.

This dark marble has long been known as Esperanza. It is one of the darkest of our marbles. The general ground is bluish-gray. This ground which varies in shade in different samples, is thickly covered by darker veins of varying breadth, some being very fine, hair-like, others bolder and in many cases more or less confluent. Many of these are black or nearly so and they are crossed by other black veins which are really cleavage planes, so that there is an open network of wavy or crinkly veins, running through the mass. Figure B, Plate VIII, shows a small piece of this stone. Mixed here and there with the generally somber stone are small white blotches. These are much more numerous in some blocks than in others. Although the Albertson is a somber marble it is in a good light a very dignified and elegant stone. It is used both for monuments and for buildings.

Quarried at West Rutland by the Vermont Marble Company. A description of the quarry from which this marble is obtained is found on page 117.

### AMERICAN PAVONAZZO.

This is eminently one of the ornamental marbles and as such is especially used for counters, panels, etc., in interior work. It is not as delicately tinted as some of the finer marbles, but it is often beautifully shaded and the combination of colors is often very striking.

The ground, which often forms a large part of the surface, is a delicately shaded creamy white or light yellow. Running through this, in places numerous, in places sparse, are green veins or long clouded bands which form a strong contrast with the ground. These veins are of many shades from light to almost black, the darker largely prevailing. Something of the arrangement and character of the markings may be seen in figure B, Plate XIV, but in many samples the dark clouds, etc., are narrower than in that used in the mantel shown.

This is quarried at West Rutland by the Vermont Marble Company.

### AMERICAN SIENNA.

This is one of the yellow marbles though less distinctly so than the foreign sienna. It does, however, resemble quite closely a very light imported sienna. The ground is a light lemon yellow and through this are abundant, very sinuous veins of irregular width. These veins are much darker and of a brownish shade so that they form somewhat of a contrast with the main surface and the result is most elegant. The grain of this marble is unusually fine and in appearance almost as compact as that of ivory. From this it follows that the stone receives a splendid polish. Altogether this is one of the finest of the Vermont marbles for interior finish.

Quarried at the Eastman quarry, at West Rutland. There are columns of the American Sienna in the building of Black, Starr & Frost, New York City.



### AMERICAN YELLOW PAVONAZZO.

This is, at least to some, a more attractive marble even than the Pavonazzo from which, however, it does not differ greatly. Indeed, there are few more charmingly colored marbles than this. The darker veins, clouds, etc., are similar to the foregoing variety, the main difference being in the ground which, as the name implies, is a light yellow or often yellow salmon and an added charm is found when, as often happens, these colors are delicately shaded. As in the Pavonazzo, the clouds are very irregular and sinuous and their green color forms a most pleasing contrast with the light ground. As the ground occupies far more space than the rather sparsely distributed markings the marble is always very light and cheery in its effect.

Quarried at West Rutland by the Vermont Marble Company.

### AVENATTO.

This is one of the lighter marbles of the black and white series. Like most of these marbles it reminds one of the common Italian marble. There is however no really black coloring in this marble.

On a very light ground there are innumerable light brown veins fading to smoke-brown. So abundant are these veins that there is usually no clear white, the whole being shaded by the brown of the veins. The effect is the more pronounced because in addition to the quite distinct veins there are very many that are so faint that only as one notices the polished surface closely does he see them at all, although of course they have a part in producing the general effect. This is true of many of the finer marbles. They have what may be called a twofold coloration, one which is distinct and seen readily at some distance and this, naturally, gives the principal character to a slab or column, and another set of markings be they veins, clouds, blotches or what ever, which are only slightly tinted and form a sort of undertone so little pronounced that the stone must be not only well finished to bring them out, but in many cases be closely examined. Yet in many cases these half hidden tints do affect the appearance of a finely wrought piece of marble very considerably. In the Avenatto the veins are very irregular and extend in different directions.

Quarried at Florence by the Vermont Marble Co.

### BARONIA.

This is one of the marbles quarried by the Green Mountain Company, but no samples have been seen.

### BARONIAL GREEN.

This is one of the same order as the Tapestry Green, but is easily distinct. The arrangement of the color is quite unique and the shade is darker than the Tapestry and lighter than the Verdura.

Some veins are dark, but most are what may be called medium in shade. For the most part the entire surface is green, but there are now and then white spaces. All the color bands are very wavy and sinuous, sometimes astonishingly so and there are never any that approach a straight line. There is usually sufficient white or at least very light green to place the marble in the class called light. Like the tapestry green this needs a considerable surface if the best effect is to be gained and in a large slab it is a most effective marble and one that would always attract attention. In some of the large slabs the shaded bands are in billows across the surface, billows of a stormy sea. All in all this is a strikingly handsome stone.

Quarried at West Rutland by the Green Mountain Marble Company.

### BEST LIGHT CLOUD RUTLAND.

This is a nearly pure white marble and differs but little from the Light Cloud Rutland.

At a short distance the stone appears perfectly white as also when not polished, but hammered or smoothed on a sand bed. It does, however, contain a very small amount of coloring matter, which close inspection easily reveals. And sometimes the indistinct dark veins are more plainly seen.

Quarried at West Rutland by the Vermont Marble Company.

### BLANC CLAIR.

As the name indicates, this is a very white marble. Much of the surface is the purest white and as the grain is of the finest the surface is brilliantly polished. It is not however, altogether pure white for sparsely and with charming irregularity there are scattered through the mass small clouds and spots of a soft gray or almost black. By far the larger part of the surface is purest white without the bluish or yellowish shading so common in the light marbles, but here and there are the dark shaded clouds never of large size, which vary from faint suggestions of shade to distinct and therefore conspicuous clouds. This is an extremely fine variety for inside work.

Quarried at the Eastman Quarry, West Rutland.

### BLUE BUILDING.

This name, formerly used, has been changed to Gray Building.



### BRANDON ITALIAN.

This is a marble that has been long quarried at the large quarry west of the railroad from Brandon south. As the name indicates this marble has much of the appearance of the ordinary imported Italian.

There is the white or very light ground more or less thickly veined with black or more commonly bluish lines or spots and blotches. These are usually not very conspicuous. They are waved and irregular, and variously distributed so that some blocks, or at any rate slabs are lightly marked, others heavily and, of course, darker. Some of the more difficult characters of this marble are stated by Professor Dale on page 130.

Now quarried by the Vermont Marble Company,

### BRANDON ITALIAN, HIGH STREET VARIETY.

This marble has been quarried at the High Street quarry, now the property of the Vermont Marble Company. It is what is now called Pittsford Valley H. and will be described under that head.

### BRANDON STATUARY.

This has been obtained in small amount from the old Selden quarry but did not prove valuable as no large pieces could be taken out. It is a most beautiful, clear white without a suggestion of color and if it could be gotten in good blocks would be very valuable. The quarry may sometime be reworked and better pieces found.

### BROCADILLO.

This is a green marble. The ground, little of which shows, is a greenish white and through this in every direction are distributed, veins and clouds sometimes forming a mesh, of green in mostly lighter shades, but there are some darker and occasionally those that are almost black.

Like many of the conspicuously veined marbles the Brocadillo is seen at best advantage in large pieces and especially columns.

The structure and composition of this marble are stated on page 114.

Quarried at West Rutland by the Vermont Marble Company.

### CIPOLLINO.

This is one of the fancy marbles from the remarkable bed in West Rutland already mentioned, as it forms one of the beds in the Westland quarry of the Vermont Marble Company.

The general tone of this marble is a slightly yellowish-green of numerous shades, but all agreeable in effect. The entire body of the stone is in most cases entirely suffused by the green shades which in much waved masses succeed each other. With these there are more or less conspicuous narrow light greenish or brownish bands.

Three varieties are recognized, light, medium, and dark. That is the trade takes note of Light Cipollino, Cipollino, which is the medium and Dark Cipollino. These varieties are based upon the shades of the greens. In the Light Cipollino there is more white though even here there is no clear white, only greenish or yellowish-white, and the shades of green are lighter. In the medium or Cipollino, there is less white and more of the darker greens while in the Dark Cipollino there is no very light shade and some of the greens are very dark even to almost black. The marble, in any of its varieties, is quite different from most other Vermont marbles and always presents a striking and handsome appearance.

### CLARENDON DARK CLOUD.

This is a Clarendon marble and possesses the characters of these marbles. It has a bright crystalline structure which makes it less fine in grain, but more brilliant than the Rutland stone.

The main stone is pure white, through which numerous very dark, often almost black bands and clouds which are very distinct because of the contrast with the white. These markings sometimes coalesce so that the surface becomes very dark. Besides the veins and bands there are numerous black spots. The white areas are usually elongated in the direction of bedding. The marble is a very pretty variety.

Quarried by the Clarendon Marble Co.

### LIGHT CLOUD.

This is similar in general to the Dark Cloud already mentioned. As would be expected from the name, this is much whiter than the other and though the veins, etc., are very dark, there are not many of them so that the white of the ground occupies far more space and gives tone to the whole. In what is known as Select Light Cloud there are fewer still of the dark portions and the marble is almost a white stone. Like the Dark variety it is quarried at Clarendon.

### CREAM LAUVILLE.

This is one of the Clarendon marbles and like all the stone from this locality and south it is harder and more coarsely crystalline than the Rutland marbles.



Dr. Dale has given on pages 105 and 106 the lithological characters of the Clarendon marble.

Most of these marbles are very light. As the name indicates, the ground of this is a cream-white crossed by numerous not very distinct veins of a grayish, bluish or yellowish tint. When the surface is only smoothed the appearance is often that of a clear white marble, but when polished the delicately shaded veins are brought out so that they are seen, but they are never obtrusive and to see them all one must be quite near. None of the markings are clear and sharp, but always they are soft and cloudy. Here and there spots and little clouds of yellow brown are thrown over the surface.

### CREAM STATUARY.

This is not unlike the variety called Rosaro, but is deeper salmon and the veining is more distinct. The main color of the marble is a cream with a tinge of pink which gives it a salmon shade. The veins are yellowish-brown of varying shades. The lighter are quite faint and become in some cases blended with the ground, but others are darker and entirely evident. This is a very delicately tinted stone.

It is quarried at West Rutland by the Eastman Marble Company. It is also sold by the Green Mountain Company.

### DANBY.

This is especially a building marble and is also known as Mountain White. The stone is easily distinguished from the Rutland marbles as are most of those found in Danby and Dorset.

The metamorphism of the original limestone from which the marbles were made appears to have been somewhat different in the two regions and most if not all of the Danby and Dorset marbles are harder and more coarsely crystalline than those farther north, and for this reason these marbles are unusually good for building stone. Dr. Dale gives a microscopic section of one of these marbles on pages 93, figure 13.

The crystalline structure renders these marbles more brilliant and the face often presents a peculiar appearance. The stone is very light, sometimes pure white and is not usually heavily veined or shaded.

Many fine buildings have been constructed from the Danby marble as the Senate Office Building in Washington, the sixty large columns in which show the stone to excellent advantage. Some of the finest bank buildings in different parts of the country are of the Danby marble.

### DARK CIPOLLIN.

This is perhaps the most striking in appearance of any of the Eastman marbles. The general ground is of a rather dark, but decided green not shading towards olive as in many of the green marbles. The veins are very numerous, indeed they often fill the whole mass. They are very much plicated and waved so that as in the Baronial, which it resembles in some pieces, it at once suggests a turbulent sea picture in the stone. These waves are by no means of the same shade, but constantly vary from almost black, which is least abundant, to light olive. Sometimes the shading is very gradual, sometimes abrupt. Like some of the other green marbles, the Dark Cipollin needs for its finest effect to be shown in a goodly slab. When so seen it is a marble that one cannot fail to admire. In some specimens there is now and then a lighter vein or area, but in the main this is a dark marble and should be well lighted.

Quarried at the Eastman Quarry, West Rutland.

### DARK FLORENCE.

This is really about as much a light as a dark marble, and therefore might be classed with either group. On the whole, I have placed it here. It is, as the name indicates, like the Florence, except in the shade of its colors. The bluish ground is very abundantly veined by regular and fairly straight lines or bands, which are often confluent. These are dark blue.

Quarried at Florence by Vermont Marble Co.

The names Florence and Pittsford Valley are used by dealers interchangeably in a certain group of light marbles.

### DARK IVORY GREEN.

This is a very peculiar marble and unlike any other that I have seen, though naturally, it resembles most the Light Ivory Green, but is nevertheless, quite distinct. There is very little white, but much more of light gray in what seems to be the ground of the marble. This is almost completely covered by two sets of veins. Those by far most conspicuous are of several shades of moderately dark green. These are very much curved and plicated, which are thickly strewn through the mass, nowhere very large nor do they continue very far, but form a confused mass of much broken figures. In a rather irregular fashion these green veins are crossed by a series of yellowish or olive much less distinct bands and from the resemblance which many of these have to old ivory the name is given. The general tone of the marble, despite the name dark, is rather light and it is not to be classed as a dark stone. The effect of the singular coloring is quiet and pleasing. The stone receives a fair polish, but contains too much mica to make it possible to polish it as can be done in case of some of the other marbles.

The structural, chemical and mineralogical characters of this and other marbles from the same quarry are given by Professor Dale on pages 107-110 preceding.



Quarried and sold by the Eastman Marble Company, West Rutland.

### DARK VEIN TRUE BLUE.

All of the dark marbles from West Rutland, while there may be more or less black in some of the veins, are yet bluish or gray-blue in the general effect. There is also a resemblance among all these blue varieties, though there are distinguishing differences so that each of the several varieties can be recognized, in characteristic specimens. They, however, grade into each other imperceptably so that only the more clearly marked blocks show the specific characters of the variety.

This is one of the darkest of the blue marbles, but is lighter than the Albertson. The general tone is a dark bluish-gray of often a quite uniform shade. Through this are darker veins, some of them black and also lighter. These are irregular and sinuous. There are also more or less numerous white spots or blotches of variable size and abundance.

Quarried at West Rutland by the Vermont Marble Company.

### DORSET GREEN BED.

This seems to be the marble formerly called Dorset Dark Green Vein. The colors are green and white and these are arranged very differently in different blocks. The ground is white or greenish and through this run streaks and bands of shades of green. The columns shown in Plate VII are of this marble and the peculiar markings are well seen in them.

In the Exhibition Room of the New York Public Library are twenty-five columns of this marble. Sawed in slabs and set in panels this is very effective as the prominent green bands, clouds, etc., often can be so brought together in different slabs as to form striking figures.

This marble was formerly quarried by the Norcross-West Marble Company, but is now owned and worked by the Vermont Marble Company.

### DORSET A.

The Valley quarry in Dorset besides the marble mentioned below as Dorset Green Bed, produces that formerly called Light Green Cloud. It is a light marble, the ground being almost white with a slight yellowish tint clouded by more or less faint greenish or olive patches. These clouded areas are often very delicate and like shadows just fading out.

Owned by the Vermont Marble Company.

### DORSET B.

This marble, formerly Plateau White, has been extensively used in building. Although passing as a white marble it has more color than the preceding and may be considerably veined. In the New York Public Library and the Medical Buildings of Harvard this marble was almost exclusively used for the exterior construction.

The surface of a large piece has wide irregular bands of creamy white alternating or blending with streaks or clouds of greenish shades. There are wavy masses of shades of green sometimes covering the whole surface or there are masses of white displacing the color. Although there are some dark veins they are not so prominent as to give a dark tone and when simply hammered many of the blocks are altogether white. Plate X shows the quarry from which this marble is obtained, and Plate XI, Continental Hall which has thirteen single-stone columns of this marble which is also used in the walls.

Before it was sold to the Vermont Marble Company this quarry was operated by the Norcross-West Company. This is probably the oldest quarry in the state and has been worked since 1785.

## DORSET MOUNTAIN.

This is not on the market so far as I know to any extent, but could be supplied.

The stone is described by Professor Dale on page 101.

## DOVE BLUE RUTLAND.

This is of a pretty gray-blue of more uniform color than in most colored marbles. Sometimes it is almost a quaker drab and always it is most agreeable in shade.

The appearance of the stone is lighter than it otherwise would be because of numerous small, usually oblong, white patches and in contrast there are dark veins, though these are never very numerous.

This marble is especially interesting by reason of the discovery of marble near the bottom of the old quarry which though clearly metamorphic and showing all the characteristics of true marble, yet contained numerous examples of Maclurea magna which show in sawed slabs as very distinct sections and thus fixing definitely the age of this bed. Plate V of the Sixth Report and Plate XVII of the Eighth are from photographs of this marble.

This marble is also called Dark Blue Rutland as in Professor Dale's list on page 151. It is, however, not usually a very dark stone.

It is quarried at West Rutland by the Vermont Marble Company.

PLATE XXXV.

ESPERANZA QUARRY.

### ELECTRIC BLUE.

This is listed among the Vermont marbles, but it is really a term applied to a group of blue marbles which are largely used for electric switchboards and probably would not be used for monumental or building marbles.

### ESPERANZA.

This is one of the darkest of the Rutland marbles. The general ground is a dark bluish-gray and through this there are numerous lines and veins of still darker shades of the same color and others nearly black. These very dark lines are now and then confluent and everywhere form an irregular open network. Quite in contrast with the rest of the coloring are small white spots which are absent in some specimens and somewhat numerous in others, but they are never so abundant as to give a light tone to the surface. The marble, obviously, requires a well lighted location and when so placed it is often very elegant and rich.

This is quarried at West Rutland by the Vermont Marble Company.

Plate XXXV shows the Esperanza quarry.

### EXTRA DARK ROYAL BLUE.

The name would seem to indicate that this was perhaps darkest of the blue marble, but it is lighter than several others in most samples, but very dark pieces are often taken out of the quarry. Through a gray-blue mass there runs in every direction a multitude of veins of darker shades and black. These veins are greatly broken and nowhere extend far and as they are much confused they afford a mosslike effect which is very handsome. There are a few not very conspicuous white spots which are not so numerous as to change the tone of the stone.

It is to be regretted that so elegant a stone should not now be quarried. It was sold by the extinct Raleigh Marble Company at Pittsford.

### EXTRA DARK TRUE BLUE.

The long worked True Blue quarry furnishes a number of varieties of different shades and markings though the colors are the same in all. The name Extra Dark is in itself a definition of the character of the stone.

Many of the so-called blue marbles are gray as well, that is to say they may be called bluish-gray or grayish-blue. In some of the varieties there are decided blue colorings, but these are not the larger number. As this marble is essentially identical with that known as Esperanza, a description of it is given under that heading.

There is also a dark marble known as the Extra Dark Mottled True Blue. This is as dark as the foregoing, but the white mottlings are more generally distributed. There are a few light or even white veins and bands. This is from the same quarry as the former.

### FISK BLACK.

This is an unchanged Chazy limestone from the Fisk quarry on Isle la Motte. Some of the beds in this quarry are gray when polished and these have been used to a small extent, but the layers which are so dark that the stone is jet black when polished are used to a considerable extent especially for floor tile with other and lighter marble. It is also used as a contrasting material in interior work.

Formerly there were quarries of the Black River limestone in several parts of the state which were worked and the stone made a fine grained and very black marble. The most promising of these was at Larrabee's Point. For one reason or another these have none of them been in operation for many years.

The stone from the Fisk quarry is manufactured by the Vermont Marble Company, mostly at the Barney mill in Swanton.

### FLORENCE.

There are several marbles sometimes called Florence, Florence W., Florence X., Dark Florence, Light Florence, all quarried in the Florence quarries, which are sold by the Vermont Marble Company as one or another variety of Pittsford Valley and they will be considered under that name.

### FLORENTINE BLUE.

This is a marble of medium tone, lighter than most of the blue marbles and darker than others. Indeed, the general tone of this marble when polished is a dark dove shade. As the stone is usually sawed the veins, etc., run longitudinally. Besides the numerous dark blue lines and veins there are a few that are nearly black and as most of the blue marbles there are white spots and lines. The lines or bands of color are not greatly crinkled. Plate XV shows the quarry of this marble as the glaciated surface was exposed.

Quarried at Pittsford by the Vermont Marble Company.

### GRAY BUILDING.

This, sometimes called Blue Building, has been used in the construction of many buildings in which at a distance it resembles granite sometimes very closely, especially when rock-faced. It is a bluish-gray stone, mottled with white and finely veined by dark bands. It is a West Rutland marble.



### G. GREEN.

This is an entirely green marble. There is no part of the surface that is not plainly green of, on the whole, rather a light shade. Some parts of a surface are a very light greenish-white, but even these are clearly green. It has the appearance of a mass into which the green colors have been stirred till all are well mixed and everywhere they are much curved and plicated. There is no harshness of contrast, but a very soft blending of the various shades of green from, as has been noticed, very light to those that are quite dark. The lighter shades are by far more abundant and the surface as a whole is quite light. The stone is fairly fine grained and can be well polished. This closely resembles the Verdura formerly sold by Columbian Marble Company and seems to be essentially the same.

Quarried at West Rutland by the Eastman Marble Company.

### GREEN MOUNTAIN SIENNA.

This is in colors identical with Rosaro, for it is the same stone sawed across the bedding. See Rosaro.

### GREEN VEINED CREAM.

This is one of the most attractive of the Vermont marbles ranking with Westland Cream, Cream Statuary and such like.

The ground which is much more extensive than the veining, is of very charming shades of white, bluish-white to decided pink. Through this are numerous veins. Some of these are light yellowish-brown, some green and these are wider and more vivid than the yellow. The combination of ground and veins is most attractive and their beauty of the stone is rendered greater by the often fine shading from distinct color to almost disappearance which is seen in some of the veins, especially the green. The tinted bands or veins are not very sinuous but never straight. The grain is even and close and the stone takes a high polish.

Quarried at the Eastman quarry, West Rutland. This marble is used in the Fourth National Bank, New York City, also Dodd, Mead & Co.'s building.

### GREEN VEIN STATUARY.

This is one of the very light marbles. The main ground is milky-white, through which are very delicate light green veins. These are exceedingly graceful in their varied shades and wavy, much broken courses. Often they coalesce more or less completely and form clouds or bands. They may be quite distinct or they may gradually fade into the white of the main mass. In some parts the green veins are so numerous as to give tint to the whole surface, but more often the white greatly predominates. Here and there the crinkled and indistinct veins produce a dainty moss-like effect that is very pretty. Nowhere are there hard lines, but always the color is in soft clouds, though often a very clear green. The grain of this marble is unusually fine and even. It is a very attractive stone.

Quarried at West Rutland by the Green Mountain Marble Company.

### HEIDELBURG GREEN.

This is one of the darker green marbles and one of very distinct character.

Quarried by the Eastman Quarry, West Rutland.

### HIGHLAND BLUE.

A dark blue marble, though it varies in shade considerably in different specimens. Some blocks, but not all, are splashed very prettily by small white patches. These may be very irregularly strewn about or they may be arranged in some sort of lines or bands or groups. There are also light veins. In this there is a striking difference in polished and hammered surface as the latter are very much lighter. Hence there is strong contrast between any carving or lettering and the polished surface on which it may be placed.

This marble though quarried at Brandon is very similar to the Esperanza. It is not at present quarried as the marbles of the True Blue quarry meet the demand for such marble.

### HOLLAND BLUE.

The blue marbles form a class by themselves in some respects and all have a general resemblance from whatever quarry they may be taken and they do occur in a number of quarries. Still the varieties named by the different companies are quite distinguishable and deserving of separate names for trade purposes.

The Holland Blue is one of the marbles of the Green Mountain Marble Company.

The general ground, which gives it its name is a moderately dark blue-gray abundantly veined by darker and often almost black narrow lines and veins which are not straight, but waved, intersecting and otherwise irregular. Intermingled with these dark markings are spots, blotches and sometimes veins of pure white forming a strong contrast with the rest of the surface. The appearance of this, as is true of many other marbles, varies somewhat as it is sawed with bedding or across it, but in this there is less difference than in many others. There is also a difference in the arrangement of white. In some blocks there is none, the stone being of a nearly uniform blue, while in other pieces there is considerable white, sometimes in large patches which are necessarily very conspicuous because of their environment.



Quarried at Florence.

The Mottled Blue and Average Blue are varieties of the Holland Blue and are found in the same quarry.

### ITALIO.

This is one of the lighter marbles. Nevertheless it has over its entire surface a slight, but decided dusky, or perhaps it is more correct to say, bluish-white tint. Through this which is the color of by far the larger part of the mass in any block, there are rather widely distributed dashes, veins or clouds of darker shade. Many of these are quite distinct and are in sharp contrast with the main mass, but there are also many that are so faint that, while they give tone to the whole they can only be seen by close examination.

Quarried at West Rutland by the Green Mountain Marble Company.

### JASPER.

This is one of the "Champlain" marbles, a group of quite unlike character from the Rutland marbles.

The Champlain marbles are from a calcareous member of the Lower Cambrian Red Sandrock series. They are not metamorphic but only little altered sediments. They are largely dolomitic and to a considerable extent silicious. All the varieties are red or at least reddish in color and usually there is a good deal of white, calcite and quartz. They are much harder than the true marbles as the percentage of silica is much greater; the Rutland marbles generally containing only a very small amount. On this account the Champlain marbles are much harder and more expensive to work, but they receive a splendid and lasting polish and are very handsome. The red color which is so constantly and abundantly present is apparently due to iron. A photomicrograph of a section of this stone is shown by figure 8 page 36, where a discussion of the formation by Professor Dale will be found. It will be well worth while for any reader who is interested in these marbles to read Professor Dale's remarks carefully.

These marbles are found here and there along Western Vermont but have been actually quarried in but few localities.

For many years this stone has been worked by the Barney Marble Company at the mills on the Mississco River at Swanton and from their quarries a mile or more east they have obtained a great deal of stone. Though retaining the old name, this company is now controlled by the Vermont Marble Company.

South of Swanton a few miles within the limits of St. Albans the same stone was quarried for a time, but the place was finally abandoned. Farther south at Malletts Bay, six miles north of Burlington a few years ago quarries which has been worked to some extent fifty years ago, were reopened and others opened and a very good mill erected by what was called The Wakefield Marble Company and for several years active operations were carried on, but this too was given up and for nearly twenty years this plant has been idle. Steam power was alone available here and it is apparently too costly an operation to saw and finish so hard a stone except where water-power is possible.

The most southern point at which this stone has been quarried is on the west of Hogback Mountain in Monkton where the Vermont Marble Company get their "Ruvaro," which will be mentioned later.

In most of the stone no definitely determinable fossils can be found, but occasionally clusters of a little pteropod, Salterella, are seen in the sawed slabs and less easily in broken pieces. Plate XXXIX of the Sixth Report shows a small piece filled with this fossil; *c* of Plate VIII is not a very satisfactory representation of the variety of the Champlain marbles known as Jasper. As even this little figure shows the marble has much the appearance of a breccia. Dr. Walcott considers the very numerous white or light bodies in this stone as greatly distorted fossils and if these are organic the stone must be largely of this origin, though undoubtedly there is much sedimentary material.

Most of the Champlain marbles are dark, but the Jasper is somewhat lighter than some of the Swanton varieties. The ground is a decided red shading to lighter, even almost pinkish. Mingled with this are numerous fragments of varying size from a mere particle to bits several inches long. Many are white, others pink. Not uncommonly pieces are associated which evidently were parts of larger bits and they must have been included in the mass very soon after the break occurred as the edges are not worn nor the corners rounded. Very likely they were broken during the formation of the rock. The various tones of red in this marble are sometimes, indeed always fine, and in some pieces very beautifully shaded.

Quarried at Swanton by the Vermont Marble Company.

### KIELS GREEN.

This is a marble in which the green, which is the only color mingled with white, is unusually bright and clear so that it makes a very strong contrast with the white. There is some variation in the relative amount of green and white in different blocks, but in general, at least as far as I have seen, though the green seems to be in excess of the white, actually, the two colors are about equally distributed. Solid white is in larger patches or wider bands than any single vein or band of green, but the green is often grouped in much broader masses than the white so that the stone appears much more green than white. And the white is always more or less tinted with a yellow or pink shade or sometimes very light green. The greens are not as varied as in many



of the green marbles, that is, there is less range in the shades, though there is not uniformity. The green is always in wavy or zigzag masses, sometimes sinuous, sometimes sharply plicated. The texture is much coarser than that of many of the West Rutland marbles.

Quarried at the Eastman Quarry, West Rutland.

### LIGHT CIPOLLIN.

This is a light green marble of very pretty appearance. The prevailing shade is as near apple green as anything, but the very numerous and much broken and plicated veins which fill the whole body of the stone vary in shade from very light to the shade named. The veins are nowhere very distinct, but are softly shaded in very agreeable fashion. The light and darker shades are very closely mingled so that there are no large areas of any one tint. The marble is much the same shade in general as the Ivory Green in many specimens of that stone, but it has none of the yellow that is found in the Ivory. The grain is good and the surface receives a fine polish. On the whole the effect is decidedly that of a light marble, and when unpolished, but finely sawed and rubbed it has almost a gray color as the green is less in evidence than when polished.

Quarried by the Eastman Marble Company at West Rutland.

### LIGHT CLOUD.

There are several varieties of the light Rutland marbles which are sold under different trade names, but they closely resemble each other and grade into each other. In all the main portion of the stone is white, sometimes with a shade of blue or yellow and sometimes clear white. Obviously it is not easy, if it is possible to describe these variations in such fashion as to give one not familiar with the stone a very distinct idea as to its character. As one sees them in a selected series the differences can be readily noted in most cases, but they must be seen to be appreciated.

In the Light Cloud the ground is a bluish-white and at a distance little color is noticed, but close examination shows the many veins, some more distinct, some fading out. The clouds, veins are very irregular and wavy. In shade they are green or olive, often fading into very faint olive or smoke tints. What must be considered as a variety of the above is what is named Best Light Cloud. In this the ground is a purer white, with little veining and that very indistinct, though in some pieces there is enough color to give the whole a shadowy appearance. At a short distance the polished surface seems to be white, with a shaded tone.

All the varieties of Light Cloud are quarried by the Vermont Marble Company.

### LIGHT CLOUD ITALIAN.

This is much like the preceding, but the various veins, clouds, etc., are more distinct and more abundant so that they give a character that is not found in the Light Cloud.

The name is appropriate as the marble is quite like some of the imported Italian.

### LIGHT COLUMBIAN BUILDING.

This, another variety of the light marbles is not now quarried, though it may be at any time. It is a building marble which indicates that it is of poorer quality than many others, as a stone may be entirely suitable for building, though not of a quality that is used in monuments or for interior work. This marble is a bluish-white, showing little veining when finished for building, that is simply hammered.

It is quarried at the old Columbian Quarry at Proctor.

### LIGHT FLORENCE OR PITTSFORD VALLEY.

A marble not unlike some of the Light Cloud, but from a different quarry is the Light Florence.

The ground has a bluish cast or sometimes blue-gray of a uniform shade. This is abundantly covered by much darker veins and lines of the same general color. The markings are usually in rather straight or slightly waved longitudinal lines. On this account the pattern, if it may so be called, is more regular than in many marbles.

Quarried at Florence by the Vermont Marble Company.

As stated beyond this marble is now called Pittsford Valley.

### LIGHT GREEN CLOUD.

This marble was until a few years ago worked by the Norcross-West Company, but is now owned by the Vermont Marble Company.

This is a highly crystalline marble and the ground is a very bright, often sparkling white. Clouds and patches of shades of green or olive are scattered thickly or sparsely in different pieces so that the tone may be very light or quite greenish. Some of the green clouds are so faintly colored that they appear more as slightly tinted shadows than actual areas of color. It has been used in interior work.

### LIGHT IVORY GREEN.

The Ivory Green marble is found in two varieties, a dark which has already been mentioned and a light. The difference in appearance is quite noticeable and in those pieces that are most unlike they are alike mainly in the occurrence of the old ivory yellow which, in greater or less degree, is always present. The dark Ivory Green has a definite green tone, while the light is yellowish and in unpolished pieces these tones are especially evident. In the light variety the reverse arrangement of shades, as compared with the dark, is found, for while the greens are much more prominent in the dark, the yellow being altogether indistinct, in the light the green is almost hidden and the yellow bands are prominent. In both white, green and yellow are found in varying proportions, but the general arrangement is as indicated. The Ivory Green, Light, is a very quiet marble having no conspicuous character and such a stone is sometimes just what is desired.

Quarried at West Rutland by the Eastman Company.



### LIGHT MOSS VEINED.

This is, naturally, much like Moss Vein and still a slab presents quite a different appearance for in this are large areas of fairly clear white and the black clouds and bands farther apart and many of them fade out into the white ground so that it really is, as the name implies, a much lighter marble than the Moss Vein.

Quarried by the Green Mountain Marble Company at West Rutland.

### LIGHT RUTLAND ITALIAN.

This variety differs from the preceding mainly in the greater definiteness of veins and less clouding. There is the same white ground. Perhaps none of the Vermont marbles has more nearly the appearance of the common Italian marble than this.

Quarried by the Vermont Marble Company.

### LIGHT SUTHERLAND FALLS.

This is a light, but not one of the lightest marbles. Through a nearly pure white ground there are distributed numerous, quite distinct, dark bluish veins. In most specimens the light ground greatly predominates over the darker veining. In occasional samples the veins are greenish rather than bluish. This variety is quite variable in shade in different layers, some being very much darker than others. It is harder than most of the Rutland marbles.

Quarried at Proctor by the Vermont Marble Company.

### LIGHT VEIN RUTLAND.

This is also not unlike the above. We have in the Light Vein a white ground, usually very white, covered abundantly by narrow green veins which are sufficiently numerous to give their greenish shade to the whole surface in some parts, while the white predominates elsewhere. The veins are more conspicuous than in several of the preceding varieties and are more decidedly green. The quality is also inferior.

Quarried by the Vermont Marble Company.

**LISTAVENA.**

This is an exceedingly fine marble and one of the best for interior work. Instead of the usual irregular arrangement of the colored portions we find in the Listavena a quite regular series of bands of various widths extending, as the stone is usually sawed, longitudinally through the blocks. Generally the veins are grouped to form wide bands. Alternating with the veins of different shades of green or olive, are often wider bands of white with sometimes a pinkish tone. Though the shades vary more or less in different veins there is a general uniformity of shade through large blocks or slabs. One slab was sawed which gave slabs eighteen feet long and four feet wide and throughout the colors were uniform.

Quarried at West Rutland by the Vermont Marble Company.

**LIVIDO.**

The ground of this marble is a fairly uniform bluish-gray of a not very dark shade and in some samples the shade is quite light. Through this ground there run very numerous veins, lines, blotches of a much darker, sometimes nearly black color. These, as in most marbles, vary greatly in abundance, but the general effect of the surface is that of a rather light stone as rarely do the dark veins occupy so much of the surface as to make it very dark. These dark veins are often very much broken and none of them usually extends far in any one direction and they may be confluent or intersecting form a network. Additional variety is given by small spots of clear white which are scattered somewhat sparingly throughout the mass. Professor Dale says that the dark portions are dolomite of a finer grain than the lighter portions which are calcite.

Quarried at West Rutland by the Vermont Marble Company.

**LYONNAISE.**

This is another of the Champlain marbles. It is darker than most, the colors are similar to those seen in "Jasper," but considerably darker. They are differently mixed, there being in the Jasper few or no veins, while in the Lyonnaise the veins are everywhere, dark and lighter shades of red and many, though fewer, of white. The main ground is a deep red through which run the lighter red and white. There are no true veins but rather blotches of color spread out in every direction and greatly intermingled in an indescribable fashion.



Like other of these hard marbles this is much used for floor tiles, but for all sorts of interior work the unique patterns, for there are no other marbles like them, and the brilliant polish they can be given make them very valuable.

Quarried in Swanton by the Vermont Marble Company.

**MAHOGANY.**

This is a curiously named marble from one of the old Freedley quarries on Dorset Mountain. The name seems peculiar because the stone is very white. The grain is coarse and like all these coarsely crystalline marbles has when polished a brilliant surface.

Quarried by the Manchester Marble Company.

**MANCHESTER BLUE.**

This is a light bluish or lead colored marble of rather coarse grain quarried by the Manchester Marble Company at Dorset Mountain.

**MANCHESTER MARBLE. (BRECCIA).**

This is not on the market nor has it ever been to any extent, but it is mentioned here because it is quite unlike any stone that has ever been quarried in the State.

It has not proved sound enough to be of commercial value as it is a breccia, the component pieces of stone being too loosely jointed to make a solid slab when sawed. Plate VIII, figure A, shows a small piece of this marble.

On page 41 Professor Dale speaks of this stone and to his account the reader is referred.

**MANCHESTER CLOUDED.**

The Manchester Marble Company which now owns the old Freedley quarries on Dorset Mountain produce several varieties of white or very light marble which are used for building and for interior work. The grain of most of the stone is coarser than that of most Rutland marbles and gives the surface a more brilliant luster. The ground is a bluish-white with flakes or clouds of black. These are never so numerous as to make the surface dark, but they vary greatly in abundance.

The company list three varieties of the Clouded designated as numbers one, two, three. In number one the black bands are clear and distinct, while in number two they are much less in evidence, and in number three they fade out to a large extent.

**MANCHESTER WHITE.**

This is a still lighter marble. There are also three varieties like those of the foregoing, one, two, three. Number one is unspotted white, number two is white, but slightly clouded, and number three shows clouds and occasionally dark veins.

All these are quarried and sold by the Manchester Marble Company at East Dorset.

### MARINE VENOSO.

In general appearance this marble resembles some of the more striking of the Georgia marbles in that the markings are very conspicuous because of their size and definite color. As the blocks are usually sawed with the plane of bedding, the confluent veins and bands form bold masses of shades of green, darker and lighter, alternating and relieved by broad wavy bands of white and sometimes pink. Seen only at close range and forming a very pleasing contrast with the stronger coloring are delicate lines of light brown and spots of dark green. When "quarter sawed" the prominent lines are diagonally across the slabs and when four of these are arranged together a still more striking pattern is produced.

For large interior panels this is a very attractive stone.

Quarried by the Vermont Marble Company at West Rutland.

### MOSS VEIN.

This is one of the finest marbles sold by the Norcross-West Company. In some respects it is a marble of different appearance from any other Vermont marble. There are two colors—a dark gray and white, these shades are most peculiarly intermingled, but the dark predominates so that the stone is dark rather than light. There are no long bands, but a confusion of short, confluent veins and clouds with now and then a small white area. The effect of the whole is very elegant where there is plenty of light.

The quarry at Dorset is now owned by the Vermont Marble Company.

### MOUNTAIN WHITE.

As explained previously this marble is the same as that now called Danby and is mainly used as a building marble, for which purpose it is very excellent.

### OLIVE.

This is one of the Champlain marbles quarried at Swanton. This differs from the other Swanton marbles in that while there is a good deal of red in most pieces, there is also a good deal of a drab or olive drab shading. Indeed, the ground is often of this tint and the various shades of red are for the most part quite light. In different pieces of this stone there is much variation in the proportion of the colors, but in all there is a mixture of



drab, light red, pink, a little dark red, and white. The result of this mixture is often very pretty.

Vermont Marble Company.

### OLIVO.

Though similar in name this is a very different marble from the last. It is a true calcite marble. In color it is like the Brocadillo, but the arrangement of veins is very different. The general color is greenish-olive in various shades and mingled with these are numerous white bands. In many specimens the green and white are in, about equal amount so that the marble is one of the lighter grades. The bands of color are very undulating which adds to the handsome appearance of the stone. It is especially fine when made into columns as then the shading and banding are seen to best advantage.

Quarried at West Rutland by the Vermont Marble Company.

### ORIENTAL.

If small differences should be noticed the number of varieties of the Champlain marbles would be very large for almost every outcrop differs in shade and arrangement of color from every other.

When the Wakefield Company, alluded to when considering the Jasper, which was the first variety mentioned, quarried this stone at Malletts Bay they found a large number of beautiful varieties all quite unlike those obtained at Swanton, but only the main and definitely characterized varieties are advertised by the Vermont Marble Company. Formerly the Barney Company put on the market at least a dozen varieties, but since the property passed into the hands of the present company only half as many are kept in stock. These under the names not used are those mentioned in the present list.

The variety named Oriental is a very elegant and richly colored marble, but not easily described plainly. The main ground is a dark red, so far as there is any single predominant color, but there is such an intricate mingling of many shades of red, red-brown, purplish-red and clear white that no one of these overshadows the others. Some of the tints are exceedingly peculiar and beautiful, and altogether the marble is one of the very finest. As already stated the unique red, purple and pink tints in these Champlain marbles are mainly due to the presence of iron, oxide, hematite.

### OXFORD FLEURI OR EASTMAN BLUE.

This is an excellent blue marble, much resembling the Holland Blue of the Green Mountain Company, but in the latter the veins, etc., are quite straight while in this they are very wavy and undulating. It is a dark marble, though there are few of the intensely dark veins such as are found in some of the blue marbles. Some of the blocks or slabs, are all dark blue or bluish, others are thickly sprinkled with pure white spots and sometimes bands. In some specimens the white spots are assembled as in a sort of milky way, in wide bands.

The general appearance of the stone is quiet and handsome, but it requires a strong light to be seen at best advantage.

Quarried at West Rutland by the Eastman Company.

This marble has long been known as Eastman Blue, but recently the name has been changed as noted.

## PINK LISTAVENA.

As the name indicates, this marble is similar to the Listavena mentioned above. The chief difference is seen in the ground.

The Pink Listavena is a most attractive stone for fine interior work. It is very delicately shaded both in the exquisite pink ground and the equally shaded greenish veins and bands. These latter are usually very wavy or otherwise irregular, but sometimes they are more even and straighter. Although daintily colored this marble has a very decided character of its own as the veins contrast strongly with the ground. Often there are white bands between the green.

Quarried at West Rutland by the Vermont Marble Company.

## PITTSFORD ITALIAN.

This is a most charming marble of a very light tone. It comes from what was formerly known as the Turner quarry.

There are several varieties of the Pittsford Italian though only two are recognized in trade. These are the D layer and the Y layer. In the D layer the ground is shaded, white in some parts, yellow in very light shades elsewhere and one charm of the marble is in the manner in which the white and yellow are intermingled. Running through the ground are distinct veins of yellowish-brown and olive, or in another part of the stone these may be dark gray or even black. These veins are all narrow, much crumpled and irregularly distributed. In the Y layer we have a more intricate entanglement of veins and bands of a dark bluish tint. These veins never seem to coalesce as in many marbles, but although constantly changing their direction they do not mingle. Although there are the dark veins mentioned, they are not sufficiently abundant to essentially darken the marble which is always very light in general tone.



## PITTSFORD VALLEY.

As stated under "Florence" the several varieties of the Pittsford Valley include several formerly called Florence. The term Florence was used by the Rutland-Florence Company and since this property has passed into the hands of the Vermont Marble Company the various Florence marbles are known as Pittsford Valley and will be so considered here. It should be understood, however, that in trade the terms are used interchangeably.

As now used there are the Pittsford Valley, Pittsford Valley H, Pittsford Valley W, Pittsford Valley X, Pittsford Valley M, and perhaps some less varieties. The Pittsford Valley is substantially what was called Light Florence. This is of the type of the common Italian light marbles. The ground is not clear white, but has a bluish cast and is abundantly blotched and clouded by dark spots, usually elongated, and there may be distinct dark lines. The pattern is more regular than in many varieties and forms rather uneven bands and lines lengthwise or across the slabs as it is sawed from the block.

## PITTSFORD VALLEY, H LAYER.

The ground is bluish-white and pure white while the pattern quarried at the Brandon High Street quarry.

Though in most respects similar to the preceding, this variety is quite distinct from it in most cases. The two are closely alike in a few blocks and then cannot be distinguished, but generally the High Street variety is darker because the veins are both of a deeper shade and usually more numerous. In this variety, too, the ground is not as clear white, but of a light bluish tint. Rarely there are intermingled with the dark veins a few very light or white ones. All the markings are usually wavy or in some way irregular, sometimes forming what may best be described as a tangled mass or knot of lines and veins. The tint of the ground is not uniform, but shades from bluish to nearly white in different parts of a large surface. All this varies greatly in the different pieces, no two being precisely alike. In some pieces the veining is grouped so that there are large spaces nearly free from markings.

These light spaces may be as large as one's hand or larger and nearly free from markings. The veins vary greatly in width. In some slabs they are bands from a fourth of an inch wide to much more, so that the narrow band may become a mass or cloud of darker shade than the ground. Again there may be lines or at most narrow bands only a small fraction of an inch wide. Of course the width and all other characters of the markings often vary greatly in different parts of a slab or block. Great variety is, or may be, produced, as in all marble of this sort, by difference in sawing. Often in any veined marble slabs sawed in opposite directions are scarcely recognizable as of the same sort.

### PITTSFORD VALLEY, X LAYER.

This differs little from the regular Pittsford Valley, but it is somewhat darker as the greenish veins are more numerous and of deeper shade. This imparts more definite character to the stone.

### PITTSFORD VALLEY, M LAYER.

In this the darker bands and veins are replaced by lighter green bands and these are more broken and jagged. The surface varies as in some portions it is thickly covered by the green bands while elsewhere it is brightened by more white.

The W layer is similar to the above.

### PLATEAU WHITE.

When this marble was sold by the Norcross-West Company it was named as above, but since then it has been renamed Dorset B and will be found described under that name on page 94.

Owned by the Vermont Marble Company.

### RIVERSIDE.

This is a light pearl white variety. There are bluish veins, spots and bands. This is a very interesting quarry located between Proctor and Rutland, because of the evident indications of extensive glaciation seen upon the surface and in the neighborhood. Deep furrows gouged the top layer and potholes made by glacial streams existed here and there. Perhaps because the glaciation had carried off the poorer stone on top of this quarry it could be used from the first, as the usual waste found in the upper layers of most quarry openings was not found here.

Quarried by Vermont Marble Company.

### ROSARO.

This is one of the most delicately tinted of the Rutland marbles and has much the appearance of some of the oriental alabasters. Indeed, like other of these marbles it is quite as charming as alabaster and being harder is much more durable and receives a finer polish and is less liable to injury.

The general shade of Rosaro is a light yellow suffused by a salmon tone which makes a most charming surface. At a distance the whole surface seems of a uniform or only slightly shaded tint, but close inspection reveals softly indistinct and often exquisitely tinted veins of darker yellow or light olive. When, as in some blocks the veins are more conspicuous, though never



very prominent it is classed as Veined Rosaro, 1 or 2, and there are also two grades of the Rosaro proper. The texture of this marble is very fine. This marble is quarried at the Eastman quarry in West Rutland and is also sold by the Green Mountain Company.

### ROYAL ANTIQUE.

This is one of the Pittsford marbles and one of the most boldly and singularly figured of our marbles and in a large panel, and it must be seen in some such large piece to be appreciated, it presents a most effective decoration in the interior of a fine building.

The veining of this marble is shown in Plate XXXVI, where two pieces are matched so that the pattern is doubled. It is easy to see from this sample how impossible it is to describe the strangely twisted and waved arrangement of the clouds, bands and veins. As in the plate these often resemble the grain in a very knotty board of some kinds of wood.

The ground is bluish-white and pure white while the pattern is spread through this in every conceivable manner and direction. This pattern, if so it may be called for lack of better name, is in shades of green, olive, of many tones from almost white to very dark green and black. Here there may be wide white bands with light effect and there the darker shades prevail. There is a certain blending of shades everywhere and yet there is also everywhere distinctness. If a common expression may be permitted, there is something doing in all parts of a slab or column of this marble. One may see almost anything, grotesque or elegant in the figures of this marble.

There are several subvarieties of the Royal Antique known as M layer, N layer and O layer. The plate shows a slab of M layer.

### ROYAL RED.

This is one of the Champlain marbles. The name describes it very well. It is for the most part a deep Indian red which colors most of the stone, but it is not all of the same shade, but there is an exceedingly elegant blending of different shades, all dark and rich. There are also a few white lines, but these are usually insignificant.

This stone can be splendidly polished and when so finished it has the beauty of an agate. This is also used largely as floor tiling and with other marbles it makes a fine material for this purpose.

All the Champlain marbles are used extensively for floor tiling and their unusual hardness fits them especially for this.

Quarried at Swanton by the Vermont Marble Company.

### RUBIO.

This is an exceedingly dainty and charming marble for many ornamental purposes. The color which pervades the whole is a light salmon-pink, making this a very light marble. Shot through this and in delightful contrast are a greater or less number of light green or greenish veins which are nowhere obtrusively distinct, but are softly shaded, at times almost lost, at times more clear, but not usually occupying more than a small part of the surface. In places the veins are quite abundant and the whole surface is suffused by greenish tints or shades.

In parts of the surface we see only fragments, little wisps of color rather than veins. Sometimes the pink or salmon ground is seen in quite large areas, sometimes little islands are enclosed in all sorts of irregular fashion by the interlacing veins.

When properly placed as to light and surroundings this is certainly a marble that is most agreeable to look upon.

There are a few subvarieties as Rubio P, Rubio First quality, but the differences are unimportant.

This is quarried by the Vermont Marble Company at West Rutland.

### RUTLAND BUILDING.

This is one of the more common marbles, but good and durable as a building stone. It is one of the "white," that is very light marbles, so that when hammered it appears nearly or quite white and there is never much conspicuous veining. There are several subvarieties of this.

Quarried at West Rutland by the Vermont Marble Company.

### RUVARO.

Though quarried at a distance of some fifty miles from the beds which afford the Champlain marbles this is really of the same sort as to age and character. It is quite differently shaded from those, yet it has only red in lighter shades than most of the Swanton stone and though similar, is decidedly different. The colors are much intermingled so that there are no large areas of any one.

The ground is a rather light red included in which are very numerous small white and flesh colored areas, some of which are probably as in the Swanton marbles fossils of some sort.

Ruvaro takes the same splendid polish that all the hard marbles are capable of receiving and is a handsome stone.

The quarry is on the west side of Hogback Mountain in Monkton.

### SOLID GREEN.

I have seen no samples of this marble. See page 108.

PLATE XXXVI.

MATCHED SLABS OF ROYAL ANTIQUE MARBLE.

### SPECIAL RUTLAND BUILDING.

This appears to be little else than a fine variety of the common Rutland Building.

### SPECIAL RUTLAND ITALIAN.

This is like the Light Rutland Italian but less clouded and with more distinct veins. The white is of an ivory tone. The veins form often a network enclosing small spaces that are white. The veins though not indistinct are yet not at all conspicuous.

Quarried at West Rutland by the Vermont Marble Company.

### STANDARD BLUE.

This is a blue marble not unlike many of the blue marbles. The bluish ground is not very dark and is relieved by sparsely scattered white spots or blotches and there are larger or smaller clouds of darker blue or blue-gray. There are also veins of the same dark shade. Like all veined marbles, this when sawed with the bedding has a very different appearance from that seen when sawed across the plane of bedding. With the bedding the darker veins, etc., are longitudinal, very irregular and crooked, but when sawed the opposite way the coloring is less clouded and more uniform and the veining is much more regular. Sometimes a few of the veins are very dark or even black.

Quarried by the Vermont Marble Company.

### STANDARD GREEN.

As the name indicates this is a green marble, but there are varieties in some of which the green predominates while in others there are greater or less areas of light green, white or even pink or very light bluish shades. Yet in them all greenish shades are most prominent.

The many veins are confused and broken, never straight, but sinuous, and often blending into clouds. Here and there bands of pinkish tint run across the field. On the whole, this is a light marble as the greens are for the most part light, the darker veins being comparatively few.

Quarried by the Vermont Marble Company at West Rutland.

### STATUARY RUTLAND.

As would be expected, this is pure white marble and of even texture with only few, and those inconspicuous, veins. This is found in several quarries, but in not large quantity in any. Probably most comes from the West Rutland quarries.

When not perfect in texture or with some slight veins the marble is classed as Second Statuary.

Sold by the Vermont Marble Company.

### SWANTON DOVE.

Though a very quiet marble this is pretty and forms a very agreeable contrast with other marbles. It is really an unaltered limestone and for the most part is burned at the kilns of Mr. J. P. Rich and has for many years been made into excellent lime. But when sawed and polished it makes the marble named as above. The main ground is a drab or bluish-gray varied by pure white veins and often there are white spots or blotches.

This marble has been used nearly as long as any that occurs in the State, for in some of the oldest houses that must be well on towards a century old there are hearths and mantels of this stone.

The shades of drab are quite different in this stone from those in the Rutland marbles so that in this variety we have a distinct kind.

Quarried at Swanton and worked by the Vermont Marble Company.

### TAPESTRY GREEN.

This is one of the several varieties of very attractive green marbles offered by the Green Mountain Company.

It is a very effectively marked stone, the green bands alternating more or less irregularly with pure white with which they are in strong contrast. The main ground is white through which the green veins, bands, clouds, etc., are abundantly thrown. Usually the colored portions are of much greater extent than the white and of course in such cases the tone of the surface is a decided green, but sometimes the white is more in evidence than the green. The shades of the bands, veins, etc., range from almost black to quite light and some shade into yellowish olive.

A very marked feature of this marble is seen in the extremely folded and contorted appearance of the markings. Some of the bands are narrow, even lines, while most are wide and are bands or masses and this adds to the general and very attractive irregularity of the pattern.

To be shown satisfactorily the stone should be seen in large slabs, for the pattern is on a large scale and can be appreciated only as it is seen on a large scale. The general effect of this marble is light and cheerful.

Quarried at West Rutland.

### TRUE BLUE.

This is much like Standard Blue, but is darker. Plate V figure A shows something of the character of this marble.

It is not as dark as the Albertson and is about as near a gray as a blue. For the purposes of a dark marble it is very good and desirable. The marble is neither very light nor very dark

PLATE XXXVII.

RUBBING BEDS IN A MARBLE MILL.

gray-blue ground which is crossed by dark even to black bedding planes which are slightly or more strongly curved.

Quarried at the True Blue Quarry, West Rutland by the Vermont Marble Company.

### VEINED BLUE.

This is a similar term, used as the preceding, for a number of varieties of fine, dark veined marble of bluish shade.

### VEINED CREAM STATUARY.

This marble is one of the finer varieties and, as the name indicates, it is really a subvariety of Cream Statuary. Still it is distinct in appearance for the veins are very much more deeply colored and therefore much more evident. In the specimens that I have seen the ground is whiter, showing less of the yellow tinge which is plainly seen in the Cream Statuary. The veins are soft, wavy, often fading into the ground, sometimes interlacing or coalescing into broader and whatever their arrangement altogether charming. They are of a yellowish, light olive, or light smoke tint. The marble is a delicate and attractive variety.

Quarried at the Eastman Quarry at West Rutland.

### VERDE ANTIQUE.

This is one of the very hard stones and is a serpentine, not a true marbles. It, like most hard stones, takes a very fine polish when properly treated and is one of the most elegant of marbles.

As the name indicates, the principal color is green and in many specimens this is the only color, though always in different shades. Some pieces are in general a light or apple green, others are darker and much is very dark. Although by far the larger part of any piece is green there is in some blocks more or less pure white which, mingled with the dark and light shades of green and often with black, produces a very fine effect. Plate V figure A, shows quite inadequately, a small piece of this stone. An account of this rock is found on page 41.

It is scarcely necessary to say that this stone is wholly unlike any other Vermont stone and is a superb variety.

Quarried at Roxbury by the Vermont Marble Company and worked at the Barney mill in Swanton.

It does not seem probable that this Verde Antique can ever become common for the supply is by no means unlimited. In color and general character it is a true Verde Antique and appears quite equal to any found elsewhere.

### VERDOSO.

There are several Rutland varieties in which nearly the same green shades appear, viz.: Brocadillo, Olivo, Listavena and

Verdoso in considerable amount. There are others in which there are more or less numerous veins of the same colors, but these do not usually take up so much of the stone as in the varieties named.

In Verdoso the shades of green are darker than in most of the other green varieties. They range from apple green to very dark and even black. The darkest shades, however, are not especially prominent in most cases. In the other green varieties there is more or less white but in Verdoso this is reduced to a minimum though not wholly absent. Occasionally there are veins of light salmon and where these occur the effect is very pretty. There are no large veins, but a perfect tangle of narrow green lines and seams which may completely cover the whole surface that is shown.

Quarried at West Rutland by the Vermont Marble Company.

### VERDURA.

This is similar to the preceding, but the stone is of a lighter shade, varying from greenish-white to quite dark.

In the formation of this marble it is evident that the various materials are thoroughly mixed, the darker shades with the lighter and the whole is softened and the beauty enhanced by a mottling of soft olive spots. There is little or no pure white, as the whole is suffused by the green shades which in broad wavy masses blend with each other.

Quarried at the Eastman Quarry, West Rutland.

### VERMONT BLUE.

This is a term applied not to a special variety of marble as are most of those used, but it is a general term used especially by electrical apparatus makers to indicate the various bluish West Rutland marbles that have been found very desirable for electrical switch boards.

### VERT CAMPAN.

This is one of the Eastman marbles of a greenish shade, but I have seen no samples.

### VERT DE MER.

This is a very singular marble and very beautiful in appearance. Its general expression is very difficult to describe or even to show by a plate for there is a most peculiar mottled effect which causes the surface to seem covered with slightly rippling water. Much of this seems to be caused by multitudes of little irregular cracks or flaws, but if they must be called flaws, they do not spoil the stone nor apparently weaken it, but rather add greatly to its attractiveness.



The general impression is that of one of the green marbles, but the color is never dark, nor is it as light as in the lightest of the green marbles. There are a few small and dark veins, but as stated, the general tone is light. This is the more true because mingled abundantly with the greens are white spots often of an inch or two or more in diameter and these add to the mottling of the surface mentioned.

Whatever the shade of the veins or bands they are nowhere regular, but always wavy and much broken so that none can be traced for any distance before it blends with others.

For those places in interior paneling where a light marble is wanted this is a very excellent variety.

Quarried at West Rutland by the Green Mountain Company.

### WESTLAND CREAM.

This name has been given to the marble which was formerly called Rosaro. It is an exquisitely tinted stone and in many pieces resembles alabaster and it is certainly as pretty and much better as a stone, being harder and therefore a much finer polished surface is possible. And when finished the surface is far more durable and less liable to injury. The ground is not unlike that seen in Pink Listavena, or Rubio, a charming and most dainty light yellow in some cases, salmon-pink in others. That is to say, the most common tone is a light yellow with more or less of a salmon tone. And this gives character to the stone. Through this are, often so soft and delicate that they do not show at a distance, light brown and olive veins. These veins are often quite shadowy in their indistinctness, but here and there they are much more clearly defined.

Quarried at West Rutland by the Vermont Marble Company.

### WHITE RUTLAND BUILDING.

This is like Rutland Building, but is finer in grain, more evenly white and can be polished for interior work as it is good enough for the inside as well as the outside of a building.

Quarried at West Rutland by the Vermont Marble Company.

### WHITE STONE BROOK.

This is a building marble quarried on the northern part of Dorset Mountain. It is a coarse grained marble of bright crystalline appearance, white with light yellowish or grayish veins.

Figure 15 shows a thin section and on page 102 Professor Dale has given an account of the stone. This marble is essentially the same as the Danby.

This account must not be closed without mention of a very peculiar stone which Dale calls Chrome Mica Schist. Dr. Dale has written at some length of this stone on page 42 and further discussion of it is not necessary except to call attention to the finding of the extremely rare mineral fuchsite in Shrewsbury. There are only a very few localities in which fuchsite has been found.

The stone found on Round Hill is hard and difficult to polish, but very handsome when finished.

## METHODS OF MANUFACTURE AND DESCRIPTIONS OF SOME OF THE MOST COMMONLY USED MACHINES.

To one unaccustomed to marble the cost of any piece upon which work has been expended may seem large, but if this bit of stone be traced all the way from its original place in the ledge which has become a quarry to its place as monument or mantel or wainscoting and the labor which must needs be put into it before it is fit for its purpose be understood the cost does not appear too great after all.

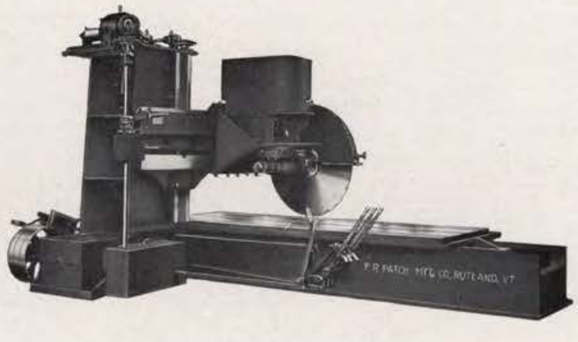
Allusion has already been made to the modern methods of working marble as resembling those used in wood working and this is no fancied likeness. More slowly and laboriously indeed is the marble fashioned from the rough block into the polished or carved piece, but in the process it may have not only been sawed and rubbed, but turned in a lathe or planed or shaped in many ways by the various and ingenious machines which have been contrived from time to time.

It will be worth while to consider some of these processes and the machines which are used instead of the old fashioned, tedious and toilsome hand methods. Through the courtesy of Mr. F. R. Patch of the F. R. Patch Manufacturing Company and that of Mr. I. I. Beinhower of the Lincoln Iron Works, both of Rutland, and of the Vermont Marble Company, I am able to illustrate several of the machines used at present in the manufacture of marble. It has been thought best to describe the Wardwell channeler in a previous connection and no further space need be given to this omnipresent machine in every marble quarry. Plate XXX shows two of these channelers of the latest sort as they appear when actually at work in the quarry.

While it is possible to take the marble from the quarry and finish it wholly without hand labor, this is not the usual method in case of the finest work. Carving, fine tooling, etc., are still done largely by hand. Nevertheless much of the work formerly done by hand is now done in all marble mills by modern machinery.

As we have seen, during the early days of getting out marble all work was hand work of the hardest sort. Even the slabs used for gravestones were most tediously wrought by hammer and chisel to the desired thickness. It seems to us strange that

PLATE XXXVIII.



*A.* DIAMOND SAW.


*B.* CARBORUNDUM COPING MACHINE.

although marble had been sawed for many centuries in the old world none was sawed in Vermont, so far as can be ascertained, before 1802 when saws seem to have been used, or at any rate not long after.

In Hall's Statistical Account of Middlebury we find the following statement (the work bears date of 1821): "The marble in this village, which is now wrought on an extensive scale and extensively diffused over the country, was discovered by Eben W. Judd—as early as 1802. A building on a limited plan was erected and machinery for sawing marble (the idea of which had its origin in the inventive mind of the proprietor) was then put in operation. In 1806 a new and commodious building two stories high and destined to comprise sixty saws to be moved by water was erected. The saws are made of soft iron without teeth and are similar in form to those used in sawing marble by hand in the large cities in Europe. The marble has been obtained until lately chiefly from a quarry situated a few feet from the mill. It is raised from its bed partly by means of wedges, but principally by blasting.

"The marble after being sawed into slabs, is manufactured into tomb stones, curriers' tables, jambs, mantel pieces, hearths, window and door caps and sills, side boards, sinks, and various other kinds of furniture. The machinery has sawed annually from five to ten thousand feet since 1808."

It is not improbable that in the near future some more rapid and economical method of cutting a quarry block into smaller pieces will be invented, for already circular saws with teeth of diamonds (black diamonds) and more recently, carborundum are used and these are being made larger and are much more efficient than formerly. Both diamond, the comparatively cheap kind called "bortz," and carborundum are used on the newer saws.

While, as has been shown before, the large gang saws are still exclusively used when pieces of large size are to be sawed, as quarry blocks, all slabs and smaller blocks are cut by the much more speedy circular saws. These work in marble as common saws do in wood, but of course more slowly. Still, though slower than wood cutting, it is astonishing to one who has never before seen one of the new style of saws work how rapidly they can make their way through the marble. Plate XXXVIII, figure A, shows a modern diamond saw, that is the figure is that of a saw with diamond teeth. This machine is chiefly used in sawing the slabs that come from the gang saws into such sizes as are needed in various building operations. The diamonds are imbedded in pieces of steel about an inch square which are fastened to the main body of the disc of the saw at the rim. The steel being softer than the diamond teeth is worn away faster by contact with the stone so that the diamonds continually project and thus are efficient for cutting.

Since the invention of carborundum its use in stone work has become very important and is rapidly increasing. Figure B of Plate XXXVIII, shows one of the carborundum wheels used for cutting slabs, capping, etc. This material is very much cheaper than diamond and is very effective. What is most important it may be moulded into almost any desired form. In the carborundum disc the whole is of this material and there are no teeth, but the edge of the wheel cuts rapidly into the stone.

Plate XXXIX shows a large diamond saw, and Plate XL, one of the simplest in construction of the larger saws.

After being sawed into such pieces as are needed they are passed on to different machines as they may be needed for one purpose or another. Most frequently they are placed on a planer. This machine, Plates XLI and XLII. There are many varieties of this machine, as of most of the others, but it is obviously impossible that more be shown.

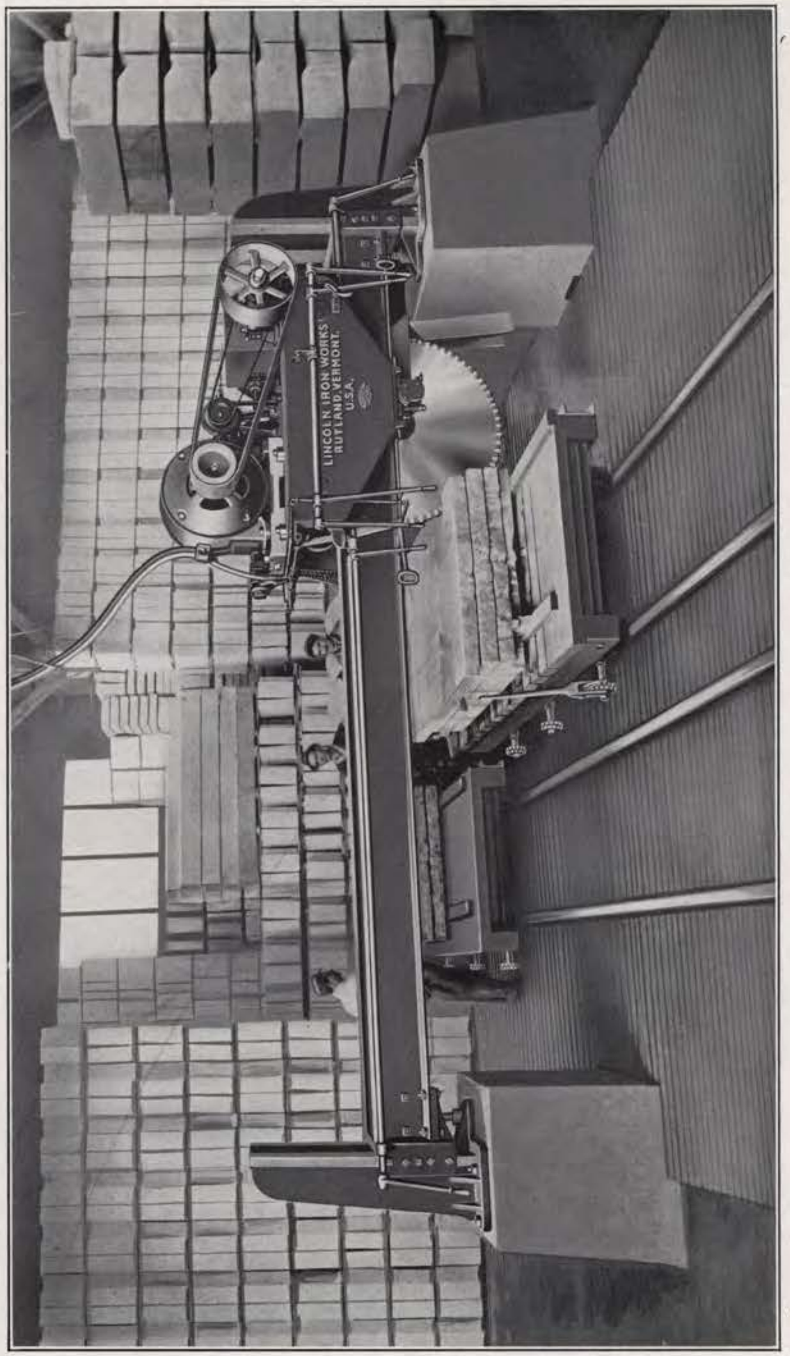
Mr. Patch says of the planer: "The work done on this machine is nearly all on building stones which are cut to pattern. These stones placed end to end comprise the moulded courses for the ornamentation of brick or stone buildings. One man operating this machine can equal the work of about twenty men cutting by hand and besides doing the work faster can make mouldings that are more uniform and even."

If a smooth surface is wanted either to be left or to prepare the stone for polishing, it goes to the rubbing bed. This is a large circular iron disc revolving horizontally. It may be from six to fourteen feet in diameter. This rubbing bed is fed constantly with water and sand and the piece, or pieces, of stone are laid upon it and held down by, most often, heavy weights.

Plate XLII, B, shows a variety of the rubbing bed fitted for smaller work. This is an "abrasive disc forty inches in diameter, the upper surface of which is used to secure a straight surface on a small piece of marble before glossing. Machines of the same design have a felt disc instead of the abrasive wheel for obtaining the high polish by the usual methods."

Floor tile, building blocks or any piece that is to be only made smooth is finished on the rubbing bed usually, but if it must be polished it goes from the rubbing bed to the polishing wheel, Plate XLIII. This somewhat awkward looking machine has proved of the greatest value and saves much slow labor. The arm can be moved in all directions—the workman holding the ring at the right of the figure and guiding the arm by this. To the clamp is attached one of the various discs shown in Plate XLIV, as it is to be further smoothed or finally polished. The use of these polishing machines has made it possible to not only put a finer polish on many marbles than could formerly be done by the slow and less efficient hand process, but as it can be done so much more quickly it can be done more cheaply.

PLATE XXXIX.




FULLER CIRCULAR DIAMOND SAW.

PLATE XL.

LARGE CIRCULAR STONE SAW.
Lincoln Iron Works.

Plate XLV shows a new machine which is said by marble workers to be of great importance in some of the processes which may be required. Carborundum wheels with variously shaped edges are used, as seen at the right of the picture, and by the abrasive force of these the marble is cut in many desired forms.

By another machine which seems to be of very great utility in making the columns so often needed in marble buildings blocks are readily shaped into the desired form. Plate XLVI shows this ingenious machine and Plate XLVII some of the work done by it. Plain columns are usually made on a strong lathe and are turned as wooden columns are, but when fluting is required until lately each groove must be laboriously cut by hand. This machine, made by the F. R. Patch Company, is described by Mr. Patch as follows:

"This manner of making stone drums for columns is entirely new; the columns of the new Post Office at Denver, Col., being the first to be finished by these machines, two of which were installed by us for the Colorado-Yule Marble Co. at their works in Marble, Col., about two years ago.

The large marble columns in the Continental Commercial Bank in Chicago were also finished on one of these machines by Fred Andres Marble Works, Milwaukee, Wisconsin.

The machine consists of a rotary table mounted on a heavy cast iron base and two large uprights or posts also attached to the cast iron base.

The rotary table is indexed to correspond to the number of flutes required and provided with a locking device to hold it firmly in position while the flutes are being cut, also a centering and clamping arrangement to secure the block of stone to the table. Each of the two uprights carries one large adjustable saddle with carborundum wheels or diamond saws attached. Each post also has an adjustable bar by means of which the drums may be made straight, tapering, or with any entasis desired, and when once set in position any number of drums may be finished to the same taper or entasis, automatically, without resetting the guide bars.

The manner of operation depends somewhat upon the size and depth, also shape, of flute to be cut. When the flutes are deep, requiring the cutting away of a large amount of stone, the operation is performed with a number of circular diamond saws of different diameters, according to the shape of the flute required to be cut, and mounted about one inch apart upon the arbors of the adjustable saddles. Feeding the diamond saws once through each flute cuts the stock into thin slabs, which is easily removed, thereby saving much work of the carborundum wheels which do the final finishing. After the flutes are entirely finished with carborundum wheels, which have been shaped to make the flutes of the shape desired, flat faced carborundum wheels are substituted and the fillet between the flutes is finished to give the drums the desired diameter.

For larger moulded bases, plinths, etc., etc., turning tools are attached to the saddles in place of the carborundum wheels and the drum revolved against the turning tool, as in a vertical lathe.

The machine has the capacity for finishing drums 7′-0″ in diameter, by 6′-0″ in height.

In case of two-thirds, or built in columns, the machine will by using diamond or carborundum saws cut out the checks and make perfect vertical joints. This in itself saves a large amount of stock and labor."

The cut shows the machine as it would appear at work. Each arbor carries a carborundum wheel. The top drum is finished and, since it has been cut while resting upon its mate, as in the finished column, the two drums must match. Both drums are now removed and a rough one placed upon the table with the partly finished one on top of it, which answers as a pattern and assures of a perfect match between all drums; in fact one of the best known building contractors in New England made this statement, after inspecting the columns of the Denver Post Office: "I never saw a better matched column job than the Denver Post Office."

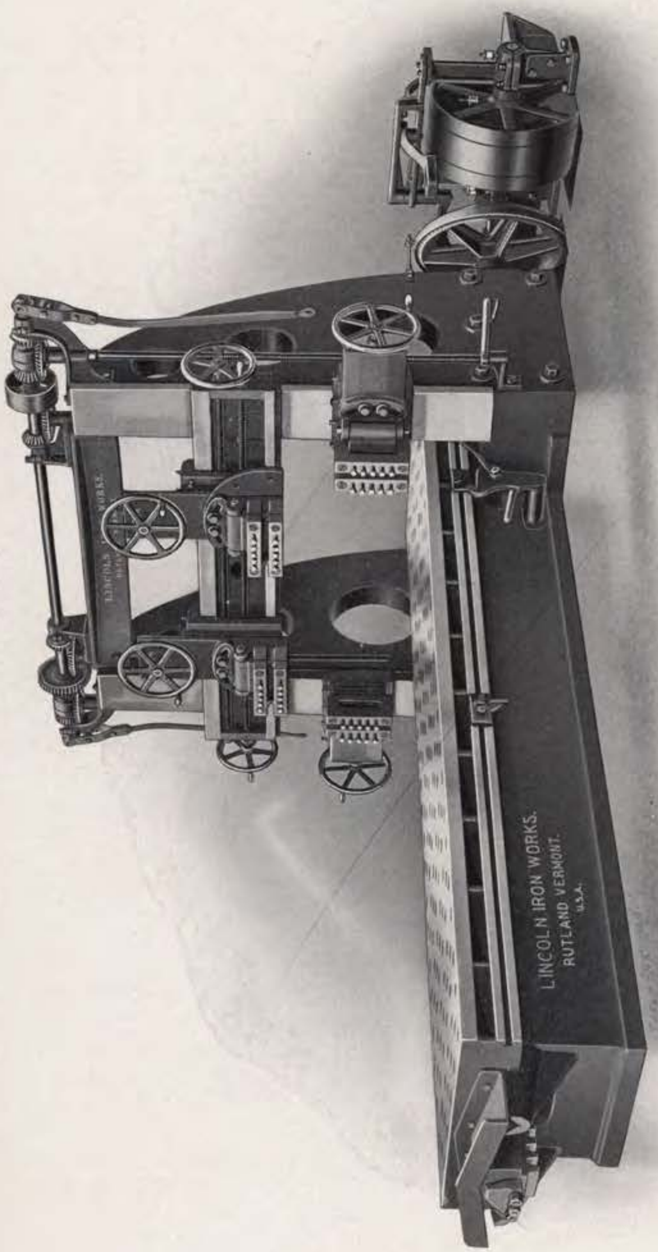
Small columns and balusters are made more expeditiously by the use of carborundum wheels of different shapes and sizes.

A baluster a couple of feet long can be turned out with comparative rapidity by a machine, one of which was seen in one of the shops at Proctor. The business part of this consists of a row of solid carborundum wheels a foot or so in diameter on the average, but some larger than others and each was more or less unlike its fellow as to the rim. These are placed side by side so that a continuous surface is formed. A long square piece of marble placed as in a lathe is brought against the edges of these disks and readily cut by the much harder material until it has assumed the concave, convex, rounded or plane cylindrical form desired, the whole forming the variously curved outline of the baluster.

It has been stated above that much of the finer work is still done by hand, but it is not done as formerly to any extent.

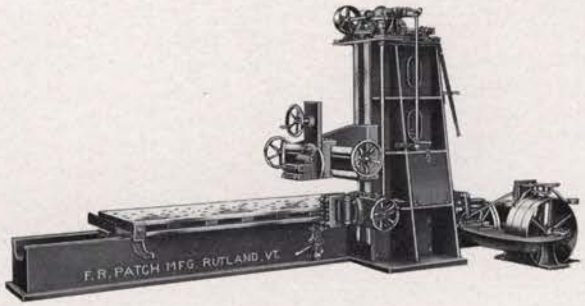
One visiting a marble or other stone mill where carving is going on no longer sees workmen holding chisels in hand and by repeated blows chipping away the stone. This may be done in special cases and where unusually delicate details are to be wrought out, but not generally. Since the invention of the pneumatic tools all this has been quite revolutionized and now such carving, moulding, turning, etc., as is not done by special machinery is done by compressed air, or to some extent later, by electric machinery. It is needless to say that under modern con-

PLATE XLI.




SPIRAL GEAR PLANING MACHINE.

PLATE XLII.




*A.* OPEN SIDE PLANING MACHINE.


*B.* SURFACING MACHINE FOR SMALL PIECES OF STONE.

ditions nothing is wrought by hand which can by any ingenuity be done by mechanism of some sort.

Through the kindness of Dr. G. O. Smith, Director of the United States Geological Survey, I am able to complete this account of the Marble of Vermont by the republication of Professor Dale's Bulletin on the Marbles of Eastern Vermont. This Bulletin of the U. S. Survey has not yet been published but will undoubtedly appear before this Report is issued.

Dr. Smith has allowed the use of advanced proof from which the following pages are printed. With this addition the portion of this Report in which the marble industry is discussed gives a much more extended and thorough account of all phases of this subject than has ever been published anywhere.

It has not been found practicable to reproduce several maps which accompany Professor Dale's Bulletin.

# THE CALCITE MARBLE AND DOLOMITE OF EASTERN VERMONT.

By T. Nelson Dale.

## INTRODUCTION.

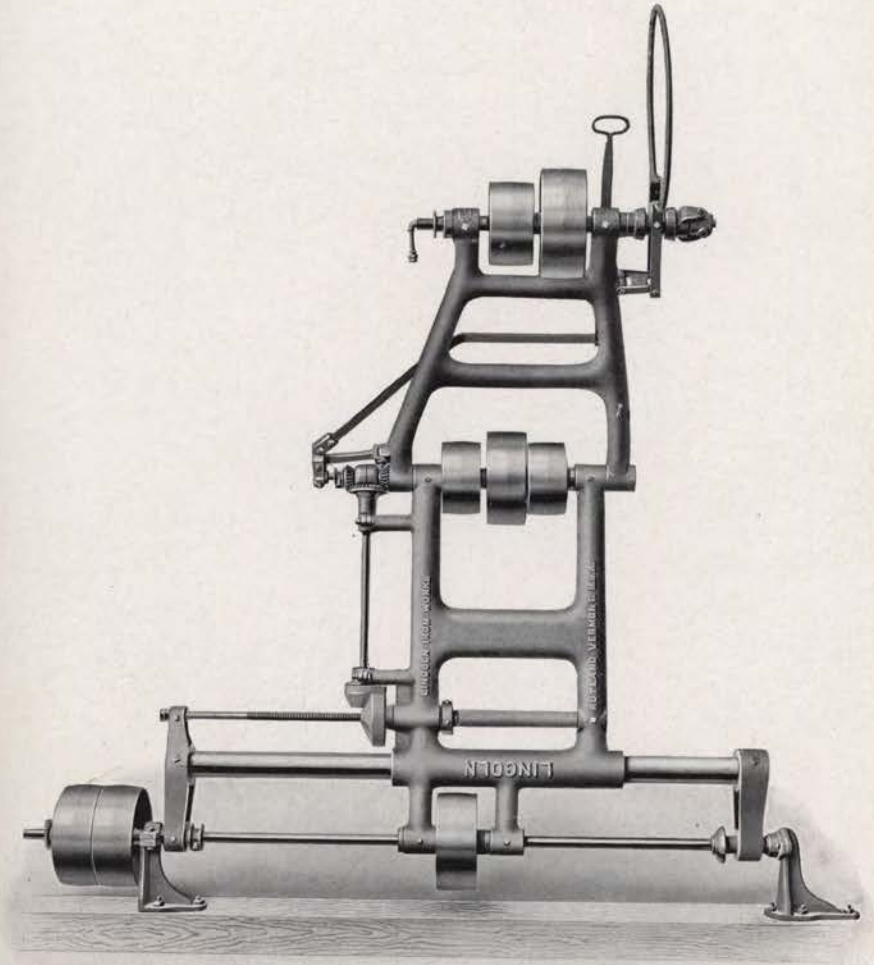
The object of this bulletin is twofold—to locate definitely and to describe accurately the marbles and dolomites of eastern Vermont, with a view to setting forth their possible economic uses and to discuss whatever features of scientific interest they may present.

The calcite marbles and dolomites of eastern Vermont generally differ from those of the western part of the State, not only by their inconsiderable thickness but by their sporadic distribution. Instead of marble or dolomite belts that can be followed for many miles, such as occur in the Vermont Valley, there are roughly aligned series of lenses and outcrops of uncertain continuity, but the quartzose marble of Orange County constitutes a formation which continues into the adjoining counties on the north and south.

This bulletin is based on a reconnaissance of the deposits of dolomite and marble in Windham and Windsor Counties, made by the writer in the execution of a plan to determine the relations of the calcareous beds east of the Green Mountain axis to those west of it, from July 12 to August 23, 1888; on a second visit to them and those of Orange County, from July 10 to September 1, 1911; and on a visit to the deposits in Franklin, Lamoille, Washington, and Addison Counties, the eastern part of Rutland County, and the western part of Windsor County in September and October, 1912. Many abandoned prospects or small openings adjacent to the remains of old limekilns had to be rediscovered from clues obtained from old inhabitants. When the entire State is geologically mapped other similar outcrops will undoubtedly be found.

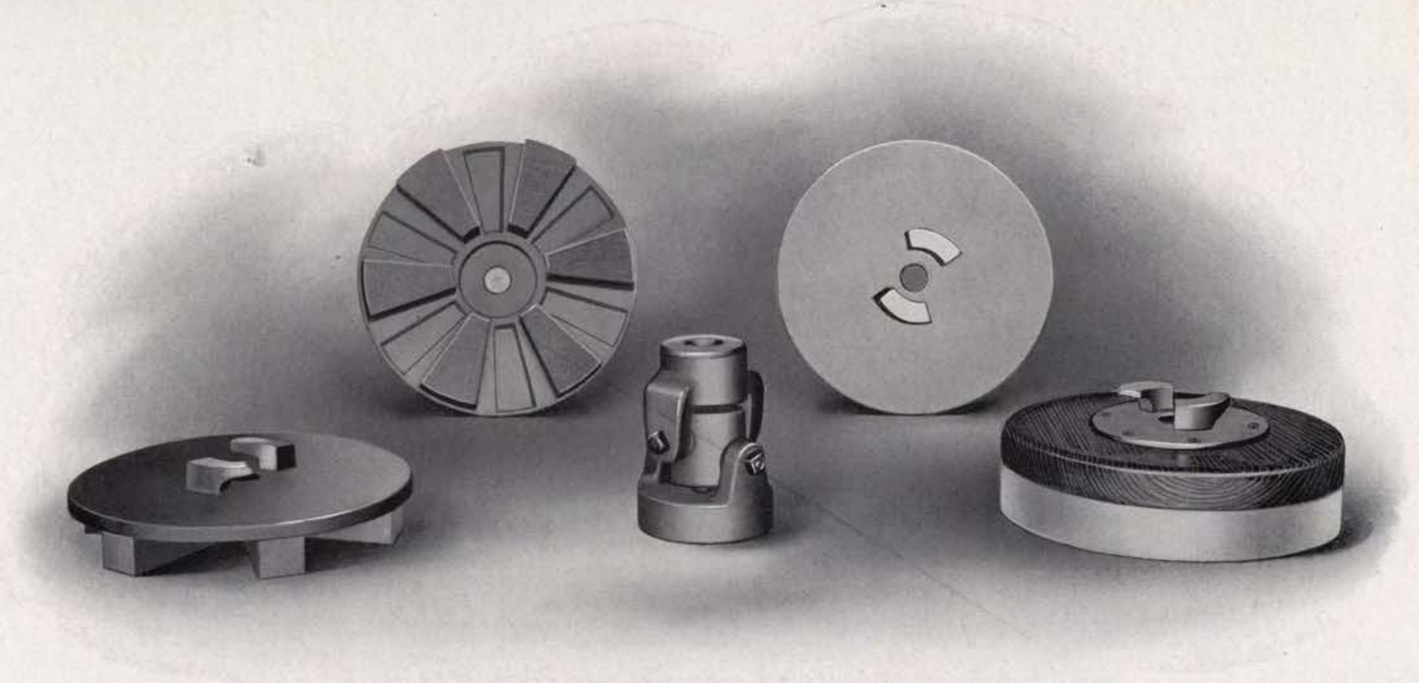
As only a part of the region has been topographically mapped and as none of it has been geologically mapped on an adequate

PLATE XLIII.



LINCOLN POLISHING MACHINE.
The discs shown on Plate XLIV are attached to this.

PLATE XLIV.



DISCS FOR RUBBING MARBLE, FELT BUFFER FOR POLISHING.
Clutch head for attaching discs to arm seen in Plate XLIII.

topographic base map, much of the geology is yet to be unraveled. Although the structural observations recorded in this bulletin are likely to be of service when the final geologic mapping is done, they are insufficient by themselves to determine the exact place in the geologic column to which many of the marble and dolomite beds should be assigned. Such indications of their age as the data afford will, however, be found in the section on geologic age.

Many of these calcite and dolomite deposits have been exploited for the manufacture of lime. Some of them were used for their purpose between 50 and 75 years ago, and a few are still being so used. Those in Orange County and one in Washington County have been prospected as marble. The calcite at Richford, in Franklin County, was used for lime and was also prospected for its content of copper ore. The possibility of utilizing the rock in all these deposits for construction or decoration is discussed in the closing section of this bulletin.

For a general discussion of the origin, composition, physical qualities, and texture of calcite and dolomite marble the reader is referred to Survey Bulletin 521.[1] The commercial marbles of western Vermont, pages 11-36. The following table, taken from that bulletin, is repeated here in order to make the numerical designations of marble texture used in this bulletin intelligible:

*Grades of marble texture.*

| Grade. | Grain diameter. | | General average. | |
|---|---|---|---|---|
| | Maximum (millimeters). | Average (millimeters). | Millimeter. | Inch. |
| 1. Extra fine | 0.2 | 0.05-0.1 | 0.06 | 0.0023 |
| 2. Very fine | .5 | .07- .16 | .10 | .0039 |
| 3. Fine | .75 | .10- .25 | .12 | .0047 |
| 4. Medium | 1.0 | .12- .31 | .15 | .0059 |
| 5. Coarse | 1.5 | .20- .60 | .24 | .0094 |
| 6. Extra coarse | 2.54 | .30-1.35 | .50 | .0196 |

The numbers given in connection with some of the specimens mentioned are the numbers borne by them in the collection at the United States National Museum.

## BIBLIOGRAPHY.

The literature on the eastern Vermont marbles consists of brief papers by C. H. Hitchcock, A. D. Hager, and C. H. Richardson, the titles of which follow:

**HAGER, A. D., Brief report on the geology of Plymouth: Report on the Geology of Vermont, vol. 2, pp. 691, 731, 732, 775, 776, Pl. XVIII, 1861.**

**HITCHCOCK, C. H., Saccharoid Azoic limestone: Idem, vol. 1, pp. 555-558; vol. 2, Pl. I. See also Limestone, vol. 2, pp. 748, 749.**

[1] Pages 3 to 29 of this Report.

Richardson, C. H., The terranes of Orange County, Vt.: State Geologist Vermont Rept., vol. 3, pp. 61-101, 1902.
Richardson, C. H., Washington limestone, The areal and economic geology of northeastern Vermont: Idem, vol. 5, pp. 86-90, 1906.
Richardson, C. H., Waits River limestone, The geology of Newport, Troy, and Coventry: Idem, vol. 6, pp. 274-276, 1907.

## GEOGRAPHIC DISTRIBUTION.

Aside from the four localities in Windsor and Orange Counties (in Bethel, Washington, and Topsham), which presumably belong to continuous belts of quartzose marble and which are also reported to extend northward into Caledonia County,[1] there are 35 localities of calcite marble and dolomite, 30 of which lie east of the axis of the Green Mountain Range. The others in Richford (Franklin County), in Mount Tabor, and Mendon (Rutland County), and in Waterville and Johnson (Lamoille County), lie either on or west of that axis.

The northernmost outcrop is within half a mile of the Canadian boundary in Richford, Franklin County. The marble of Lamoille County lies along two belts, a western belt in Waterville and another a few miles farther east, in Johnson.

In Washington County but one outcrop was found, a little south of Waterbury, in Moretown.

The outcrops in Hancock, in the southeast corner of Addison County, and in Rochester, in the northwest corner of Windsor County, belong to one belt, which may continue northward into Granville Township, where Hitchcock observed it.

The dolomites of Mount Tabor and of Mendon, in the eastern part of Rutland County, probably belong to a single belt.

The calcite marbles and dolomites of the southern half of Windsor County occur in three belts—a western belt in the townships of Plymouth and Ludlow, an eastern belt 5 miles west of Connecticut River, in the township of Weathersfield, and a central belt in Cavendish. The outcrop in Weston, in the southwestern part of Windsor County, probably belongs to the same belt as that in Mount Holly Township, Rutland County.

The marbles of Windham County also lie in three belts—an eastern belt about 8 miles west of Connecticut River, in the townships of Athens and Townshend, a central belt in the township of Jamaica, and a western belt on the ridges drained by the main branches of Deerfield River in Stratton, Dover, Somerset, Wilmington, and Whitingham.

The marbles of the eastern extension of Bennington County occur on Deerfield River in Searsburg and Readsboro and belong to the western belt of Windham County, close by.

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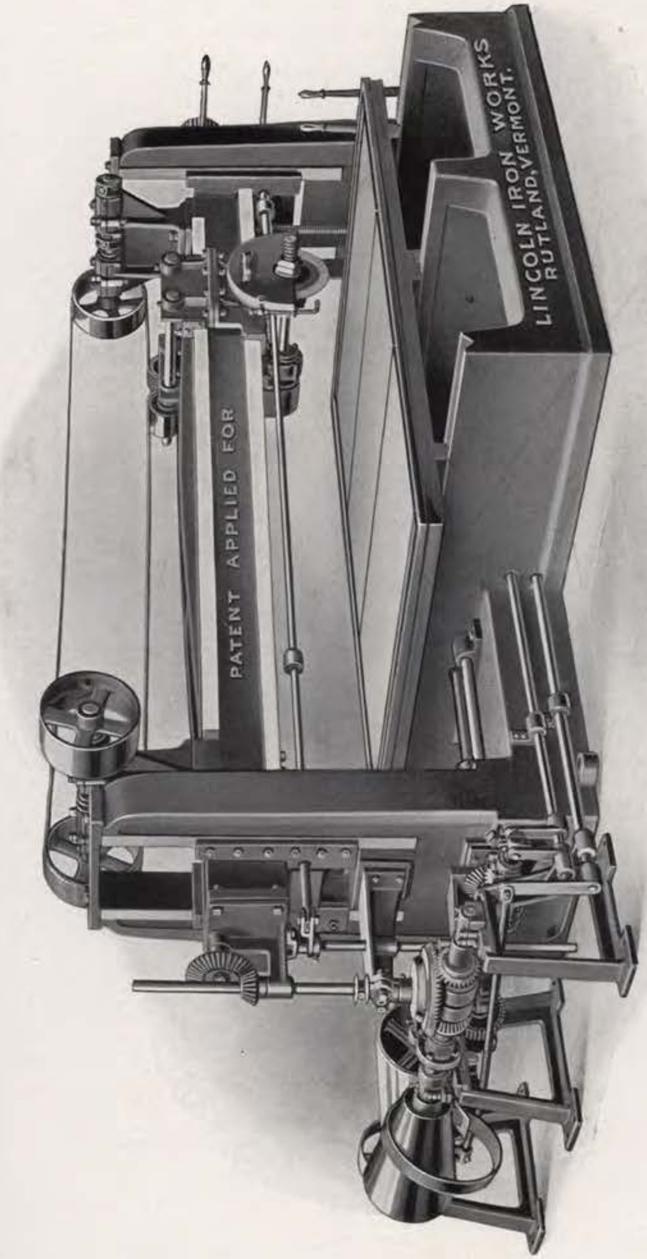
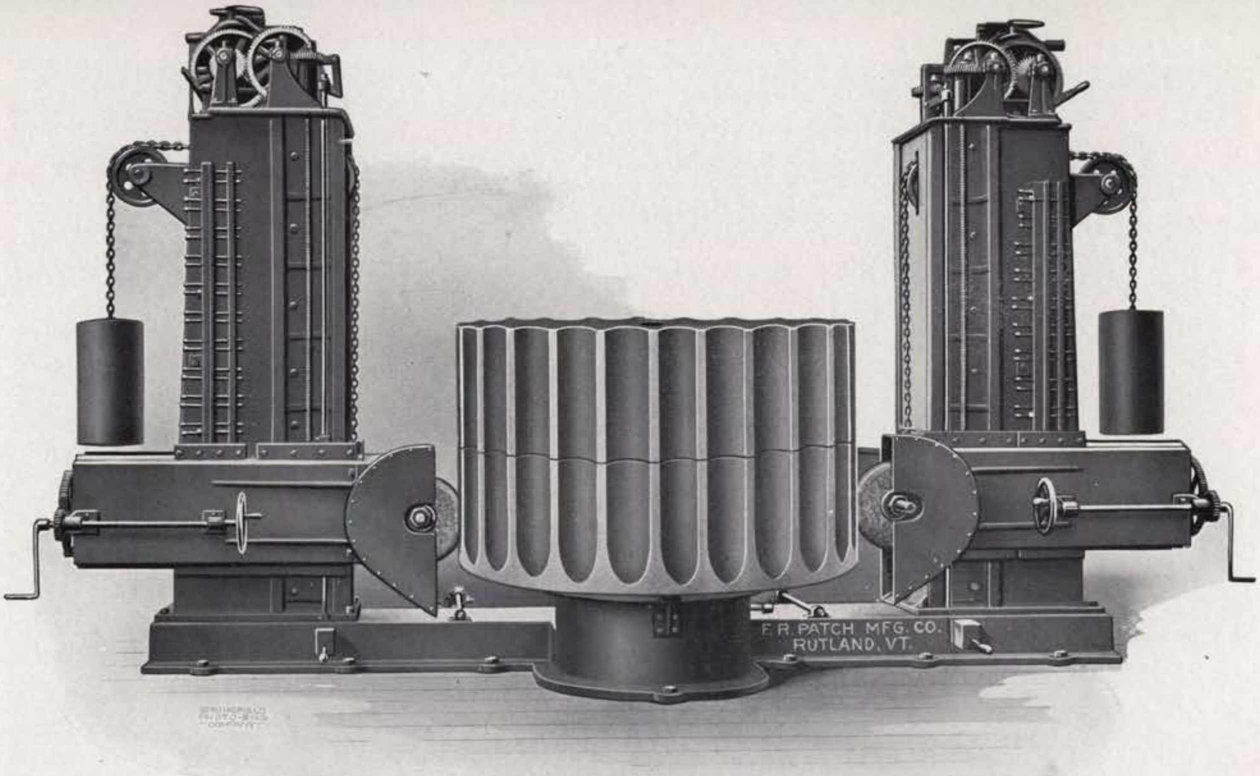
[1] See Richardson, C. H., The terranes of Orange County: State Geologist Vermont Rept., vol. 3, pp. 61-101, 1902; and "Washington limestone," The areal and economic geology of northeastern Vermont: Idem, vol. 5, pp. 86-90, 1906.

PLATE XLV.



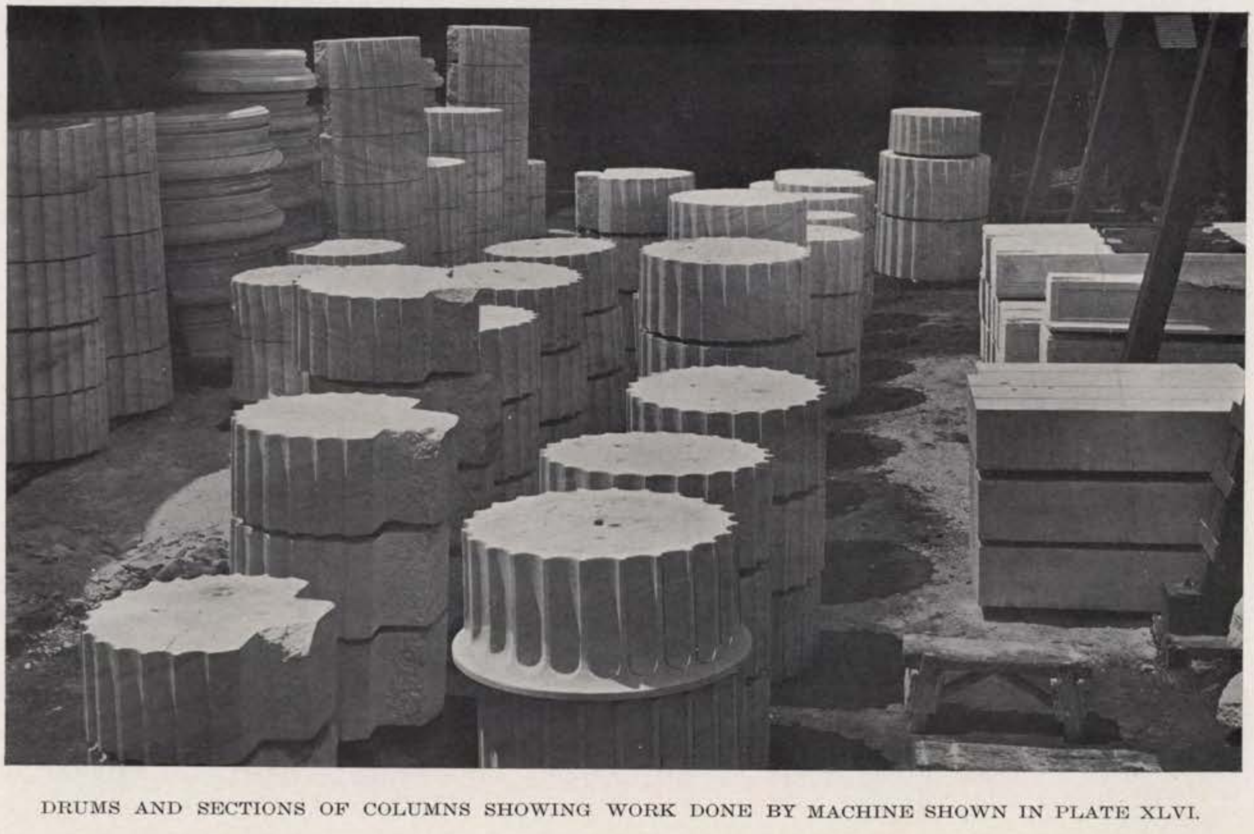

COMBINATION CARBORUNDUM COPING AND MOULDING MACHINE.

PLATE XLVI.




TURNING AND FLUTING LATHE.
For sectional columns—capacity 7'-0" dia.; 6'-0" high. Work done shown in Plate XLVII.

PLATE XLVII.



DRUMS AND SECTIONS OF COLUMNS SHOWING WORK DONE BY MACHINE SHOWN IN PLATE XLVI.

The writer failed to find the marble mentioned by Hitchcock as occurring at Andover, in Windsor County, and inquiries at Marlborough, in Windham County, as to the marble reported in that township were also fruitless. Limestone was reported by C. T. Jackson and also by H. A. Cutting to occur in Essex County, but the writer's visit to the localities in Lunenburg and Concord cited by Cutting showed something very different, as explained above.

## DEPOSITS BY COUNTIES AND TOWNS.

### FRANKLIN COUNTY.

#### RICHFORD.

Marble was quarried and burned for lime before 1861 at a point about 2 miles N. 60° E. from the village of Richford, on what was formerly the Frederick White farm, now the O. W. Corliss farm, on the road to Glen Sutton, in Canada, about half a mile south of the international boundary. The marble continues northward into the adjacent L. H. Smith farm. A tunnel was also begun near the quarry before 1861, with a view of mining the copper ore with which the marble is in places impregnated.

Here beds of calcite marble from 86 to 107 feet thick strike about N. 15° E. and dip from 60° N. 70° W. to 90°. Sericite schist, more or less graphitic, lies east and west of them and has like strike and dip but is crossed by slip cleavage. Between the marble and the sericite schist on the west side is several feet of dark green chlorite-quartz-muscovite schist abounding in minute lenses of sideritic dolomite that weathers into limonite at the surface. A few feet of this rock occurs also interfolded or interbedded with the marble. The outcrops of marble on both farms indicate a total length of about 1,000 feet for the deposit but do not afford conclusive evidence as to whether the marble lies in an anticline, a syncline, or a monocline. As the chalcopyrite must be assumed to have been brought up by ascending solutions, however, it may be more probable that the ore was concentrated in an anticline below the originally overlying schist. This is a slight indication only.[1] The amount of marble below the surface of this locality depends, of course, on the answer to the question whether the schist of both sides dips under the marble or forms an anticline over it. In the latter case the deposit might be much thicker than in the former.

The marble varies from a white to a faintly pinkish or faintly greenish calcite marble, with some local dolomitic phases and also dark bluish-green streaks. Its texture belongs to grade 4, medium, the grain diameter ranging from 0.12 to 1, mostly 0.25 to 0.6 millimeter. The colors are likely to be in bands

[1] See Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 1211-1217, 1904.

(beds). The pinkish tint is due presumably to a small percentage of an oxide of manganese and iron (see p. 252), the light green evidently to minute grains of epidote, and the dark green to chlorite and probably actinolite. The rock contains grains of quartz, some muscovite, and in places small veins of smoky quartz. The minute bed carries magnetite and chlorite.

The copper ore (chalcopyrite, $CuFeS_2$), a sulphide of copper and iron containing about 34 per cent of copper, occurs in small particles, in joint and bedding planes, and in some joints crystallized with quartz. In some beds it is altered to malachite, coloring the marble bright green in narrow streaks.

The geologic processes which have taken place at this locality thus appear to include the deposition of marine clayey sediment, either before or after the organic deposition of calcium carbonate. This was followed by the metamorphism of both deposits, the clayey sediments into mica (sericite) schist and the lime into calcite marble, and by the folding of both series of beds. Then joints were produced by various strains, and at some later time occurred the impregnation of both joint and bedding planes by ascending siliceous solutions carrying also $CuFeS_2$. Lastly came the erosion of the rock surface, truncating the tops of the folds.

The economic value of this marble is very uncertain. If the deposit is deep enough to furnish a considerable supply of large and sound blocks of white marble banded with pink and green, such blocks might be used for interior decoration.

#### BAKERSFIELD.

Marble or dolomite is reported as occurring on the Converse farm, in Bakersfield Township.

## LAMOILLE COUNTY.

#### WATERVILLE.

The Tillotson prospect is about 2 miles north of Waterville village and about 500 feet east of the road to Belvidere, on a brook flowing southward in a hollow separated from the road by a small schist ridge. A conspicuous ridge with a northerly trend lies west of the road.

The marble, which was burned for lime here 50 years ago, is 60 to 65 feet thick, strikes N. 17° E., and dips 45°-50° N. 73° W. Muscovite (sericite) schist lies east and west of it in like attitude. The schist 140 feet west of the marble is an intensely plicated graphitic, slightly pyritiferous sericite schist with slip cleavage. It contains quartz lenses and secondary feldspars (probably albite) inclosing black particles that form lines of rock bedding and show enlargement beyond those lines. An 18 by 5 foot schist mass within or east of the marble is a highly calcareous chloride-quartz-muscovite schist with feldspars (albite), magnetite, and epidote. The schist near the marble on both sides is a plicated, more or less graphitic schist. On the west side marble and schist are somewhat interbedded.



The marble is a calcite marble of irregular coarse texture, of grade 5, with grain diameter 0.07-1.37, mostly 0.25-0.75 millimeter, containing a few roundish quartz grains, a little pyrite, and rarely muscovite.

There are no outcrops to show the extent of the marble along the strike nor anything at the locality to indicate whether the structure is that of an overturned syncline or an anticline and thus to show the probable depth of the marble.

On the H. M. Start farm, about three-fourths of a mile south of the Tillotson prospect, along the strike, close to and east of the road from Waterville, is a mass of white marble 8 feet long and 4 feet thick, which strikes N. 25° E. and dips 20° S. 65° E. This may be an outcrop. About 250 feet east of it is a ridge of schist striking N. 7° E. and dipping 62° W. The marble is a faintly cream-colored calcite marble with some fine-grained dolomite beds up to a quarter of an inch thick or muscovitic streaks half an inch to 1 inch apart. The calcitic part is of grade 5 (coarse) with grain diameter 0.07-1.25, mostly 0.25-0.75 millimeter, and contains minute quartz grains.

Marble is also reported as occurring about 4,000 feet west of the Waterville-Belvidere road, on the second farm south of Westcott's. This would be in the direction of the strike of the Tillotson prospect beds.

#### JOHNSON.

Marble was quarried and burned for lime many years ago at a point about 4 miles N. 10° W. of the village of Johnson, on the south side of a low schist ridge with an easterly trend. The outcrop is about a quarter of a mile N. 60° E. of the Bradford house and 140 feet above it. The marble is about 11 feet thick, strikes N. 27° E. and dips 50° S. 33° E. Sericite-quartz-chlorite schist occurs on both sides of it—that is, both above and below it. The slip cleavage of the schist dips 70° E. or S. 33° E. The schist is very rusty from oxidation, probably of pyrite. The marble, which is much plicated and contains minor beds of cream-colored granular dolomite with sparse albite feldspars, is banded with graphite and has suffered some brecciation. At the south end the marble incloses a lens of very feldspathic schist 3 to 5 feet thick and about 10 feet long, to which the marble is closely welded and with which it is slightly interbedded. This schist consists largely of secondary albite feldspars, 0.1-0.2 inch across, many of them simply twins, in a cement of chlorite, muscovite, quartz, carbonate, magnetite, and pyrite, these minerals being named in descending order of abundance. These feldspars, like those in the marble at Waterville contain stratified particles and show secondary enlargements.

The marble also contains a few brownish to black lenses, half an inch to 3 inches in diameter, projecting on weathered surfaces. A laboratory test shows them to be rich in manganese, and a thin section shows that the manganese contains a little quartz and carbonate.

The marble is a whitish calcite marble with chloritic streaks and has a fine to medium texture (grades 3 and 4), with grain diameter 0.05-0.62, mostly 0.2-0.37 millimeter.

The outcrop at the south and lower end, near the old kiln, looks as if the schist from either side might unite, a few feet below to form a syncline. In that case, as the outcrop is only 50 to 70 feet long, the quantity of marble left would be very small.

In passing from the Bradford locality along the strike north-northeastward onto the ridge small masses of marble are found in the schist, and just over the crest on the adjoining George Butler farm is a larger outcrop of marble, also formerly quarried, and the remains of a kiln lower down, near a brook flowing south-southeastward. The marble is 70 feet thick but not much over 100 feet in length, and is bordered by plicated sericite schist on both sides, all striking about N. 27° E. and dipping 50° S. 33° E., like the beds on the other side of the ridge. The marble is a whitish calcite marble with fine black (graphitic) bands. Its texture is fine to medium (grades 3 and 4), with grain diameter 0.07-0.62, mostly 0.2-0.5 millimeter, and it contains some quartz grains and graphite.

About 15 feet west of this marble mass and separated from it by schist is a small marble outlier about 10 feet wide and 15 feet long, surrounded and underlain by schist and containing some lenses of schist and of dolomite. The marble contains some schist and dolomite lenses. It is strongly plicated, the axes of the folds having the strike of the ridge but pitching 65° S. The schist in contact with it has similar plications but a slip cleavage striking about north and dipping steeply east. At the S. 17° W. end the marble plications pitch southward under the schist, but at the N. 17° E. end the schist underlies the marble, which is only 18 to 24 inches thick. The surface form shows that the outlier was originally over 30 feet long and about 12 feet wide, though tapering to half that width at the south, but has been dissolved away. The schist has deep glacial striæ trending S. 50°-55° E. The course of the plications on the marble surface, meandering from east to west, is the result of a transverse compression that gave the normally plicated beds a steep southerly pitch (65°) and produces a system of small transverse folds along the strike in the synclinal part of one of which the little outlier has been preserved from further erosion.



The economic bearing of the outlier on the larger marble outcrops is important, for it shows that these folds are not anticlines projecting through the schist but synclines underlain by schist and therefore contain but a very small amount of marble.

## WASHINGTON COUNTY.

### MORETOWN.

The north end of Moretown Township is just south of the town of Waterbury. Winooski River bounds the township on the northeast, and Duxbury Brook, for a mile or so from its junction with the Winooski, bounds the township on the northwest. Marble was prospected in 1863-1873 at a point about 1½ miles south of Waterbury, on the west side of Moretown Hill, between the road to Moretown Center and Duxbury Brook, 200 feet above the brook and about half a mile from its mouth. The land, originally settled by Jesse Arms, is now owned by Henry Carpenter, of Waterbury. The opening is about 35 feet square and more than 25 feet deep.

The marble strikes N. 23° E., dips 75° S. 67° E., is 10 feet thick, and is bordered on both sides by schist. On the east side there is a transition from marble to schist, the marble containing schistose phases. The exposure is limited to the excavation. The schist is a dark grayish, slightly greenish sericite-chlorite-quartz schist, with a little biotite alternating with light quartzose beds up to 3 millimeters thick, both finely plicated. The little quartzose beds contain some calcite, rare grains of feldspar, and a black non-magnetic mineral.

The marble is a handsome white to cream colored calcite marble, in places mottled with light bluish-gray of somewhat irregular texture—that is, with portions of different texture. The coarser parts have a grain diameter of 0.05-0.42, mostly 0.125-0.25, averaging about 0.18 millimeter—about grade 4 (medium). The finer and greater part has a grain diameter of 0.02-0.2, mostly 0.07-0.12, averaging about 0.1 millimeter—about grade 2 (very fine). The marble has a few quartz grains.

Farther down Duxbury Brook there are large outcrops of schist similar to that in contact with the marble. This schist strikes N. 25° E. and has a steep eastward-dipping cleavage and a plicated bedding foliation of uncertain dip. A thin section from one of these outcrops consists of alternating little beds of chlorite and biotite containing some pyrite, rarely epidote, and minute nodules of uncertain character, with beds of quartz and calcite not over a millimeter thick containing some grains of feldspar.

## ORANGE COUNTY.

### TOPSHAM.

One of the principal openings in Topsham is a trifle over a mile about east of the Waits River village church and 250 feet above it, in a small brook on the east side of a road which runs northeast from the main road from Bradford, about 1,600 feet southwest of the J. Felch farmhouse. Here a finely banded and acutely plicated marble strikes about N. 15° W. The plications in places are extremely elongate, measuring up to 3 feet in length. Lenses of quartz are abundant through a bed several feet thick containing muscovite and pyrite. The beds are not sufficiently exposed for measurement, but over 10 feet of marble is in sight. The opening is small and is abandoned.

The marble is of a general medium gray shade. It consists of plicated alternating bands, from 0.02 to 0.5 inch thick, of very light bluish-gray and of dark bluish-gray color. In weathering the stone becomes dark brownish-gray and finally, as the calcite is dissolved, becomes coated with a residual brownish network of quartz grains with some scales of muscovite. In the little cemetery about 600 feet N. 25° W. of the J. Felch house are two polished stones of this marble dated 1897, but said to have been erected in 1899, but have lost their bluish tint and become light brown, particularly on the west side. Some more quartzose bands project slightly on their upper surfaces.

In thin section this marble is seen to consist of calcite grains with diameters of 0.02-0.75, mostly 0.12-0.37 millimeter; roundish and angular quartz grains, 0.05-0.5, mostly 0.07-0.25 millimeter, forming possibly 25 per cent of the rock; very much less muscovite, still less pyrite; and some very fine powdery opaque matter, probably graphite. C. H. Richardson[1] gives the insoluble residue in the marble of this or a near-by opening as 41.75 per cent. It is a very quartzose and muscovitic pyritiferous graphitic calcite marble. Some of the quartz grains cohere, as in a quartzite. The grain diameter of the calcite places the marble about in grade 3 (fine).

It takes a fair polish and the finely plicated banding of light and dark gray render it attractive, but its considerable content of pyrite and possibly also of iron carbonate is bound on oxidation by exposure to rain to give it a brownish color, and the polished surface soon will become rough owing to the large content of quartz, which also will make the cost of polishing high. It appears, therefore, to be suitable only for indoor use. Several large blocks of the marble can be seen back of the present Waits River post office, near the sawmill where the marble from the Henry C. Richardson openings was sawn.

[1] Vermont State Geologist Rept., vol. 3, p. 70, 1902.



This quartzose banded marble belongs in the formation described by C. H. Richardson[1] as the Waits River limestone. It is the calcareous member of the calciferous mica schist of the Vermont Geological Survey report of 1861. Its age is regarded as Ordovician.

At a small prospect about 2,350 feet east of the J. Felch house and about 3,150 feet east-northeast of locality 1, a calcareous schist striking N. 10° W. and dipping 50° E., is cut by a granitic dike, 12 feet 6 inches wide, with a northerly course. The banded marble crops out about 2,500 feet N. 45° W. of the dike, where it strikes about north, dips 45° W., and pitches 30° N., and outcrops of it continue toward the dike, but the relations to the schist are not well defined. It is assumed, however, that the schist and marble belong approximately to one period and that the dike is later than both. The dike rock is a dark gray porphyritic biotite granite, in which the matrix consists of quartz, microcline, and biotite (particles under 0.5 millimeter), with accessory pyrite, apatite, titanite, and secondary carbonate. The porphyritic feldspars are oligoclase under 0.2 inch, intergrown with microcline and quartz and with inclusions of biotite and carbonate. The nearest granite masses include that about Pine Mountain, in the northeast corner of the township, about 5½ miles N. 12° E., that about Knox Mountain, in Orange Township, about the same distance N. 45° W., and the Barre mass, about 10 miles N. 68° W. This dike is very probably of about the same age as these granites.

### WASHINGTON.

At a disused quarry 3,780 feet east-southeast of the Washington village church, there is a marble much like that of Topsham but with little or no banding and of darker shade. The opening is 75 by 50 feet and about 5 feet deep. The beds strike N. 15°-20° W. They are cut by quartz veins up to an inch thick with N. 80° W. course, faulted every 3 to 6 inches, also by a pegmatite dike up to 6 inches thick, consisting of smoky quartz, oligoclase-andesine much intergrown with quartz, orthoclase (probably), and pyrite.

The marble is of dark bluish-gray color. It weathers dark brownish and the surface finally becomes a very dark brownish-gray, consisting of a network of quartz grains (diameter up to 0.2 inch) with some mica. Owing to the variation in the amount of quartz it projects in ridges on the weathered surface. In thin section this marble is seen to consist, in descending order of abundance, of calcite with grain diameter of 0.07-0.87, mostly 0.25-0.5 millimeter, quartz in more or less roundish grains with a diameter of 0.05-0.5, mostly 0.12-0.25 millimeter, making up

[1] State Geologist Vermont Rept., vol. 3, pp. 84-90, 94-98, 1902; vol. 5, pp. 86-90, 112-114, 1906.

about 25 per cent of the rock; sparse muscovite and biotite up to 0.62 millimeter; pyrite in irregular particles; and a mineral that is probably graphite, though not determinable. It is a very quartzose and pyritiferous graphitic calcite marble with some muscovite and biotite. The grain diameter of the calcite places the texture in grade 3 (fine).

Several gravestones of this marble in Washington village cemetery, bearing date of 1895, have suffered more or less rusty discoloration, probably owing to the oxidation of the pyrite. Richardson[1] states that the cut surface of the fresh stone is much lighter than the polished surface, affording a more marked contrast than in other marbles. He also gives its compressive strength as 15,675 pounds. This marble is evidently as unsuited for external use as that of Topsham. It would probably do better for inscribed tablets and other polished indoor ornamentation.

The following analysis, made by C. H. Richardson[2] from a piece of a drill core, obtained 35 feet below the rock surface at a quarry near Washington village, shows a high percentage of quartz but no sulphur, whereas pyrite, which would yield sulphur, is conspicuous in the writer's thin sections and is probably one of the causes of the limonitic discoloration. If the marble analyzed became discolored like that of the monuments in the village cemetery, then its discoloration would have to be attributed to the oxidation of iron carbonate.

*Analysis of quartzose calcite marble from quarry near Washington village, Orange County, Vt.*

| | |
|---|---|
| Silica ($SiO_2$) | 35.748 |
| Titanium dioxide ($TiO_2$) | .190 |
| Carbon dioxide ($CO_2$) | 22.860 |
| Iron sesquioxide ($Fe_2O_3$) | .010 |
| Alumina ($Al_2O_3$) | 6.113 |
| Iron oxide (FeO) | .940 |
| Glucinum oxide (GlO) | .313 |
| Manganous oxide (MnO) | .076 |
| Barium oxide (BaO) | .210 |
| Lime (CaO) | 27.305 |
| Magnesia (MgO) | 3.248 |
| Soda ($Na_2O$) | .186 |
| Potash ($K_2O$) | .063 |
| Lithia ($Li_2O$) | .823 |
| Water ($H_2O$) | .108 |
| Phosphorus pentoxide ($P_2O_5$) | 1.359 |
| Chlorine (Cl) | .307 |
| Fluorine (F) | .026 |
| Carbon (C) | Microscopic trace |
| | 99.885 |
| Less oxygen = F and Cl | .079 |
| | 99.806 |

[1] State Geologist Vermont Rept., vol. 3, p. 88, 1902.
[2] Idem, p. 68.



A similar marble was prospected in 1894 on the R. F. Richardson farm, about 2½ miles S. 50° E. from Washington village church. The openings lie along a small brook that flows south, toward the house, which is on a road running about three-fifths of a mile south of the old stage road.

The beds strike N. 20°-30° E., are plicated, and are cut by pegmatite dikes as much as 2 feet thick with a N. 20° E. course. The pegmatite consists of orthoclase, smoky quartz, oligoclase-albite, and muscovite, with garnet, pyrite, and magnetite. One of the dikes is itself crossed by a quartz veinlet.[1]

On the old stage road 2⅖ miles east-southeast of the Washington village church, about 900 feet above it, and about northeast of the Richardson locality there is a small cliff of similar quartzose marble which strikes about N. 40° E. and is cut by a 2-inch granite dike with N. 20° E. course. A specimen from a small opening at the foot of the cliff, is a very dark, slightly bluish-gray quartzose and micaceous calcite marble weathering dark brown. In thin section this marble is seen to consist, in descending order of abundance, of calcite with grain diameter 0.11-0.62, mostly 0.18-0.37 millimeter; roundish to angular quartz grains, 0.03-0.44, mostly 0.11-0.37 millimeter in diameter, forming about 25 per cent of the rock; muscovite, biotite, pyrite, and probably a little graphite. Some of the calcite shows a brownish discoloration, the source of which is not apparent. This marble also belongs as to texture in grade 3 (fine).

The only difference between the marbles of Topsham and Washington is that the former are lighter in shade, finely banded, and do not contain biotite.

Richardson[2] tested the solubility of marbles from 10 localities in Orange County and found that it varied from 52.90 to 60.15 per cent.

The marbles of Washington evidently belong to the same formation as those of Topsham. Those of Washington are only 2 to 3½ miles from the granite mass of Barre and 3 to 3½ miles from that of Knox Mountain. The pegmatites described differ from those observed in some of the Barre quarries. The faulting and veining of the dikes show that the region suffered a crustal movement after the disturbance associated with the granitic intrusions.

## ADDISON COUNTY.

### HANCOCK.

In Hancock, the southeastern township of Addison County, dolomite has been burned for lime on the west side of the White

[1] These outcrops are described by Richardson, op. cit., vol. 3, p. 87, 1902.
[2] Idem., pp. 69, 70.

River valley near the Rochester town line, which is also that of Windsor County. The locality is about 750 feet above the river, nearly due west of a bridge over it, on the D. G. Marsh farm.

The dolomite is 25 feet thick, strikes N. 67° E., dips 80° S. 23° E., and is overlain, on the south, by a fine-grained banded muscovite granite gneiss. Underlying the dolomite on the north is a rock of sedimentary origin, a finely plicated chlorite-muscovite-quartz schist made up of beds of chlorite and muscovite 0.1 inch or less thick, alternating with similar beds of quartz and sideritic dolomite.

The dolomite itself is a buff-colored, rusty-weathering dolomite with films of sericite and white calcitic streaks. It is both granular and twinned with grain diameter of 0.009-0.56 millimeter, but mostly granular and under 0.09 millimeter, of about grade 2 (very fine). It has some quartz grains, rare prisms of zircon, and limonite stains from siderite combined with the dolomite.

From the fragments between this ledge and the road there must be large outcrops of muscovite-chlorite schist near by. (See further under Rochester, p. 239).

The limestone referred to by Hitchcock as occurring in Middle Granville, of this county, may be a continuation of the Hancock bed.[1]

## RUTLAND COUNTY (EASTERN PART).

### MENDON.

Dolomite was quarried in 1900 in Mendon Township at a point 7¼ miles northeast of Rutland, between the northern continuation of the central mass of the Green Mountain Range (Shrewsbury Peak, Killington, and Pico) and the masses which form its western flank (Bald and East mountains and Blue Ridge). On account of its magnesia the rock was shipped to a paper mill at Bellows Falls. The quarries are about 500 feet east of the road from Mendon to North Sherburne, on the 1,900-foot level and thus about 1,300 feet above Rutland.

The dolomite is not less than 50 feet thick, strikes N. 30° E., dips 35° S. 60° E., and has vertical close joints striking N. 40° E.

The dolomite is milk-white to very faintly rose-colored and consists of irregular but not interlocking grains, very few of which are twinned, having a diameter of 0.02-0.14, averaging about 0.03-0.06 millimeter, and is thus of grade 1 (extra fine). It contains rare grains of quartz, a few scales of a pale brown mica (phlogopite?), and minute black specks.

[1] Hitchcock, C. H., and Hager, A. D., Geology of Vermont, vol. 1, p. 557, 1861.



### MOUNT TABOR.

A trifle over 5¼ miles due east of Danby Station on the Rutland Railroad and 1,540 feet above it, on the Green Mountain Range, at the 2,200-foot level (see Wallingford topographic sheet, United States Geological Survey), at the divide which separates the drainage basin of the Connecticut from that of Lake Champlain, a little below the road from Danby to Weston, is an eastward-facing overhanging cliff known as the Devils Den. It is 50 to 75 feet high, and at its base lies a talus of large blocks which have fallen from the upper part by the opening of north-south joints and fractures and the undermining of the lower part. At the foot of this talus begins a brook which finally empties into West River 9 miles to the southeast, near Londonderry. The cliff consists of a banded garnetiferous biotite-muscovite granite gneiss with a little chlorite. Its foliation strikes N. 5°-10° W. and dips at a very low angle to the west.

A few hundred feet east of this locality, on the northeast side of the road, is a cliff 40 feet high exposing the following series, beginning at the top: Muscovitic quartzite with magnetite, 20 feet; slightly muscovitic quartzite with a few rounded grains of zircon, 10 feet; dolomite, 20 feet—all striking N. 5°-10° W., dipping 25°-30° E., and having minor plications that indicate a pitch of 10° N.

The dolomite is cream-colored and veined with quartz, consists of irregular grains, some of them twinned, and contains a few quartz grains, muscovite scales, rarely a grain of zircon, and minute black dots.

About 350 feet farther east there is an outcrop of similar dolomite that strikes N. 20° E. and dips up to 30° S. 70° E. In grain diameter these dolomites range from 0.02 to 1.12, mostly 0.07-0.5 millimeter, and are thus of grade 2 to 4 (very fine to medium).

A little east of the outcrop last mentioned are the remains of a kiln where the dolomite from these localities was burned many years ago.

The gneiss of the Devils Den is of pre-Cambrian age, and the dolomite and quartzite are presumably of Cambrian age, as are also the large outcrops of quartzite cut by Big Branch in the lower part of its course, within 1½ miles of the village of Mount Tabor, in the west flank of the range, on the road to the Devils Den.

### MOUNT HOLLY.

In the southeastern part of Mount Holly Township, 3¾ miles southeast of Mechanicsville, on the road to Weston, marble has been burned for lime at intervals for over 50 years. The locality is on the old Fuller farm, now the C. D. Edgerton farm, and was noted by C. L. Whittle in his United States Geological Survey explorations of 1891 and has been referred to by him in two papers.[1] It is on the incised plateau which lies between the western (Mount Tabor) and eastern (Terrible and Ludlow Mountains) crests of the Green Mountain Range (see Wallingford topographic sheet), at the 2,140-foot level. The marble crops out on both sides of the road northwest, southeast, and southwest of the house.

At the opening northwest of the house (Whittle's localities, 1046, 1048) marble 24 feet thick is both underlain and overlain by garnetiferous sericite-biotite-quartz schist, with epidote and magnetite, the garnets partly chloritized. The marble strikes N. 20° E. and dips 35°-40° S. 70° E. Between the marble and the underlying schist is 5 feet of actinolite schist with epidote and biotite. The marble is cut by diagonal and transverse joints, the latter filled with fibrous actinolite. The marble from this point is whitish, consists of twinned dolomite grains with diameter 0.07-2.2, mostly 0.5-1.4 millimeters, and is thus of grade 5 (coarse), but has some particles of 0.2 inch, and contains a little actinolite.

At the opening about 600 feet southeast of the house, on the southwest side of the road, marble 15 to 20 feet thick strikes N. 25° W. and dips steeply east. The rock in contact on the east and south appears to be a fine-grained hornblende granite gneiss. The marble here is a cream-colored coarse-textured calcite marble.

The marble from the locality southwest of the house, which was not visited is faintly rose-colored to cream-colored. It is a calcite marble of irregular texture with grain diameter of 0.1-2.5, exceptionally 4 but mostly 0.4-1.68 millimeters, and thus of grade 6 (extra coarse). It contains minute black particles and larger ones of magnetite (?).

## WINDSOR COUNTY.

### BETHEL.

The area mapped by C. H. Richardson[2] as Waits River limestone (Ordovician), which includes the quartzose marble of Topsham and Washington, described on page 232 extends southward into Windsor County and crops out along a small brook tributary to White River, 2 miles northeast of Bethel, a half a mile west of East Bethel, near a crossroads and the Quarry

[1] Whittle, C. L., The occurrence of Algonkian rocks in Vermont and the evidence for their subdivision: Jour. Geology, vol. 2, pp. 396-429, 1894. The general structure of the main axis of the Green Mountains: Am. Jour. Sci., 3d ser., vol. 47, pp. 347-355, 1894.

[2] The terranes of Orange County, Vt.: State Geologist Vermont Rept., vol. 3, Pls. IX, IX, A, 1902.



School. The locality is about a mile east of the granite area of Christian Hill.[1]

The marble occurs in beds 1 to 5 feet thick in graphitic sericite schist, striking north, N. 5°-15° W., and N. 30° W., and dipping 80° W., 90°, and 60° E., being evidently in minor pitching folds. It was at one time burned for lime.

A specimen from a ledge about 1,000 feet S. 10° W. of the crossroads is a dark bluish-black (weathering brownish) quartzose, muscovitic, and graphitic calcite marble. The calcite, much of which is twinned, greatly exceeds the quartz, which in turn is more plentiful than muscovite. The calcite has grain diameters of 0.05-0.25, mostly 0.07-0.2 millimeter, and is of grade 2 (very fine); the quartz has like extremes but is mostly of 0.05-0.12 millimeter, or a little finer than the calcite. The color of the weathered stone indicates that the calcite must contain some siderite.

The interbedded sericite schist is very quartzose, graphitic, garnetiferous, and magnetitic and contains isolated plates of biotite. It is much plicated and crossed by slip cleavage at an angle of 27° to the dip of the bed.

The highly metamorphic character of this marble is shown by the thin sections of both marble and schist. Owing to the thinness of the beds, its large content of quartz, and the rustiness of its weathered surface it is difficult, notwithstanding the fineness of its texture, to see any economic possibilities in this marble at this locality.

### ROCHESTER.

In the southern part of Rochester Township, 3 miles south of Rochester Center, on the west side of the White River Valley, marble was formerly quarried and burned for lime on the F. F. Kezer farm, northwest of the house. The base of the ridge consists of an eastward-dipping schist. About 200 feet above the valley, dipping under this schist and west of it, is a thin-bedded marble with streaks of bluish to greenish muscovite schist, striking N. 20° W. and dipping about 35° S. 70° E. This strike, which corresponds to the course of the valley, brings this locality in line with the dolomite of Hancock, described on page 236, and the schist of the base of the ridge here resembles the fragments so abundantly below the dolomite at that place. About 70 feet higher on the ridge the marble is coarser grained but still has schistose streaks. A little higher is an outcrop of epidote schist with quartz, carbonate, and magnetite. Both of these outcrops strike and dip like the one first mentioned.

The thin-bedded rock of the lowest outcrop consists of streaks of whitish calcite marble (grain diameter 0.06-0.5 milli-

[1] See Dale, T. N., The granites of Vermont: U. S. Geol. Survey Bull. 404, pp. 109, 110, fig. 24, 1909.

meter; grade 2, very fine) merging into or alternating with dolomite without twinning (grain diameter 0.009-0.047 millimeter; grade 1, extra fine), both containing some muscovite, quartz, plazioclase, epidote, and magnetite, and alternating with laminæ of closely plicated bluish or greenish-gray sericite schist with minute yellowish-green prisms of epidote lying transverse to the strike of the plications. The rock also contains a greenish biotite. In the little calcitic beds, the thickest 0.3 inch thick, alternate with greenish-gray dolomitic beds containing much epidote and a little muscovite.

The coarser rock higher on the ridge is a mixture of medium-grained cream-colored calcite marble (grain diameter 0.04-1.3 millimeters; some grains with curved twinning planes) and clouded cream-colored dolomite (grain diameter 0.009-0.09 millimeter, grade 1, extra fine), mostly granular but in part twinned, containing quartz, muscovite, greenish biotite, epidote, apatite, and magnetite. The rock is veined with smoky quartz and at intervals has micaceous streaks.

There is a bare possibility that these marbles, owing to their variety of color and design, resulting from their being interbedded with plicated schist, may, if obtainable in large and sound blocks, have some economic value for ornamental work.

### WESTON.

It is reliably reported that dolomite or marble was at one time burned in a very small way for lime on the Shattuck farm, in Weston Township, about 2¾ miles S. 13° W. from the Edgerton (Fuller) farm, in Mount Holly Township (p. 237).

### PLYMOUTH.

The marbles of Plymouth are dolomite and dolomite breccia, occurring either as lenses in a very quartzose mica schist formation or associated with and gradually passing into an underlying quartzite. On the west side of Lake Amherst, a little west of the dolomite, are conspicuous ledges of quartzite or conglomerate with small elongated quartz pebbles. The strike of these ledges is north and the dip east.

The Scott quarry is on the east side of the north end of Lake Amherst and 120 feet above the lake. It has a working face on the north measuring 50 feet east to west and 35 feet high. It has been idle for many years. The owner is C. H. Scott, Tyson, Vt.

The dolomite strikes N. 15°-25° W., and dips 45°-55° E. The beds are crossed at intervals for a thickness of 2 to 4 feet by steep close joints striking N. 45°-60° E. The entire thickness of the dolomite is not far from 75 feet.

The marble is a dolomite breccia with very dark bluish-gray ground and very light gray brecciated beds, the fragments of which are mostly under 4 and not over 6 inches in length, nor over 0.5 inch thick. The ground is granular or untwinned dolomite, having grain diameter of 0.009-0.094, mostly 0.03-0.076 millimeter, and thus of grade 1 (extra fine), with interstitial graphite and rare muscovite. The whitish fragments are also of granular dolomite, having grain diameters of 0.009-0.141, mostly 0.02-0.09 millimeter, of grade 1, with some coarser portions consisting of twinned dolomite plates as much as 0.47 millimeter across, large quartz grains, and rare black particles of uncertain nature.



The following analysis of a mixture of the dark and light parts was made by T. S. Hunt in 1847:[1]

*Analysis of dolomite breccia from Plymouth, Vt.*

| | |
|---|---|
| Calcium carbonate ($CaCO_3$) | 53.9 |
| Magnesium carbonate ($MgCO_3$) | 44.7 |
| Iron oxide and alumina ($FeO$, $Al_2O_3$) | 1.3 |
| | 99.9 |

The stone takes a fair polish and is very suitable for interior decoration. It has a general resemblance to some of the dolomite from Swanton, but the ground is graphitic instead of hematitic and no corals are apparent. The value of the deposit depends on the number and size of the blocks that can be obtained free from joints.

The dolomite is both underlain and overlain by very quartzose mica schist, and at a distance of a few hundred feet along the strike to the north these upper and lower schist masses unite, cutting off the dolomite. Its continuation to the south is also improbable unless it be under the lake. How far the dolomite beds extend eastward along the dip under the schist ridge can be determined only by drilling.

A dolomite breccia like that of the Scott quarry is reported on the Orich Ward farm, about a quarter of a mile east of Grass Pond and three-fourths mile N. 22° W. of Plymouth Church.

About half a mile south of Plymouth Church, on the north side of the road to Five Corners, are the remains of a limekiln and a small dolomite opening in which some of the weathered beds show brecciation. A bluish, slightly muscovitic and quartzose dolomite, in the road near by, strikes N. 50° W. and dips 32° S. 50° E. About a quarter of a mile N. 22° E. of the opening and 240 feet above it is a conspicuous ledge of quartzite and interbedded biotite schist striking north and dipping 50° E.

A little east of Lake Amherst, 1⅓ miles N. 15° E. of Tyson, near a road fork, the following section is exposed, beginning at the top:

[1] Hitchcock, C. H., and Hager, A. D., Geology of Vermont, vol. 2, p. 691, 1861.

*Section east of Lake Amherst.*

| | Ft. | in. |
|---|---|---|
| Muscovite (sericite) schist | 20+ | |
| Dolomite, quartzose, cream-colored | 2-3 | |
| Quartzite | 4 | 0 |
| Dolomite, quartzose, with some rose and smoke-colored marble | 5 | 6 |
| Quartzite | 2 | 6 |
| Dolomite | | 6 |
| Quartzite | 5 | 0 |

The strike of these beds is N. 25° W. and the dip N. 65° E. The calcite marble has a grain diameter of 0.14-2.03, mostly 0.37-0.93 millimeter, and belongs in grade 5 (coarse). The rose and smoke-colored (biotitic) bands are an inch thick. The rose color, as is shown on page 251, is due to a very small percentage of manganese oxide.

On the west side of Mount Soltudus there is a bench about 80 feet above the nearest bridge. Here 10 to 20 feet of cream-colored dolomite is overlain by a muscovite schist containing large disseminated feldspars (probably albite), all striking N. 10° W. and dipping 45° E.

About half a mile north of Plymouth Union and about 600 feet north of a schoolhouse is Hall's limekiln; some 850 feet west of which are several small openings. The stone is a very light rose-colored dolomite with films of muscovite and quartz. In thin section it shows a ground of dolomite grains, many of them twinned, with diameters of 0.02-0.4, mostly 0.04-0.09 millimeter, and is thus of about grade 2 (very fine). At irregular intervals are groups of twinned dolomite plates or single ones up to 0.75 millimeter across. There are also very minute, very dark, faintly reddish specks, shown by a test by W. T. Schaller, of this Survey, to contain both iron and manganese, which as oxides and carbonate account for the rose color. The beds strike N. 30° E. and dip 30°-50° S. 60° E.

A little over a mile north of Plymouth Union are the remains of a limekiln and, on the east side of a brook, large outcrops of dolomite in thick and thin undulating beds. In the brook is a sericitic, chloritic quartzite in vertical beds striking east. The dolomite is milk-white with delicate purplish spots. The color was found by W. T. Schaller to be also probably due to oxides of iron and manganese. The dolomite grains, some of which are twinned, have diameters of 0.02-0.16, mostly 0.37-0.094 millimeter, and a few plates reach 0.14 millimeter. The stone thus belongs about in grade 2 (very fine). This seems to be the most promising marble of Plymouth, but the thickness of the beds and their freedom from joints require careful testing.

At The Narrows, on the 1,358-foot level about midway between Black Pond and Woodward's reservoir, is a dolomite



mass 30 feet high that was formerly quarried on the east side of the road. It strikes N. 10° W. and dips 35° E. The rock is much jointed in two directions and thus unfit for "marble." It is a slightly pinkish fine-grained dolomite resembling that of locality 14, described above. A little north of the quarry the road cuts a series of beds of quartzite and dolomitic quartzite which dip under the dolomite and show a gradual transition across the beds from a pure quartzite to the overlying dolomite. At the south end of Woodward's reservoir 20-30 feet of dolomite strike N. 10° W. and dip 30° E. possibly underlying the quartzite of The Narrows.

### LUDLOW.

About 2 miles south of Ludlow, on the east side of the road to Andover, a little south of a road leading to Weston and about 3 feet north of a brook crossing, are an old dolomite opening and the remains of a kiln. The rock, which is much jointed and veined with quartz, is not over 15 feet thick, tapering out about 100 feet to the north, and dips east under a mass of finely banded muscovitic, feldspathic quartzite which is deeply cut farther east by a northward-flowing brook. Some of the minute bands in this rock are mostly quartz; others are micaceous, with plagioclase and microcline. A less micaceous quartzite overlies this rock, and west of the strike of the dolomite other schistose rocks underlie it. The dolomite may be simply a lens in these mechanical sediments. From the location and strike it is evidently more or less synchronous with the beds of the Plymouth belt.

The dolomite is of slightly bluish-gray tint with fine yellowish calcitic streaks. It consists of untwinned dolomite grains with diameter 0.02-0.05 millimeter and is thus of grade 1 (extra fine), but it contains sparse groups or single plates of twinned dolomite, mostly 0.25-0.75 millimeter in diameter or of grade 3 (fine), with a little muscovite and iron carbonate going into limonite.

### CAVENDISH.

The marbles of Cavendish Township occur in three belts—a western belt, about 4½ miles east of the Plymouth-Ludlow belt and cropping out in the northern part of the township; a central belt in Cavendish Gorge, recurring south of it in the railroad cut, and again 3 miles N. 25° E. of the north end of the gorge; and an eastern belt in the northeastern part of the township near the Weathersfield line.

#### WESTERN BELT.

About 3 miles N. 13° E. of Cavendish village, south of a road fork, a few hundred feet northwest of the old Stearns farmhouse and west of the road, white calcite marble was formerly quarried and burned. On its west side is a granite gneiss with a foliation striking N. 25° E. and dipping 42° N. 65° W. and thus apparently overlying the marble. About 100 feet north of the road fork on the eastern road the marble is in contact with an overlying granite gneiss that has a foliation striking N. 25° E. and dipping 35° N. 65° W. At the road fork is a garnetiferous schist with like strike and dip, apparently underlying the marble, which probably does not exceed 20 feet in thickness.

About half a mile southeast of Cavendish station, just south of the sharp railroad curve and a little east of the track are a disused limekiln and a quarry. Here white dolomite, 10 to 15 feet thick, exposed for about 200 feet along the strike, dips 5°-10° W. in contact with and under a considerable thickness of evenly foliated granite gneiss. The gneiss consists, in descending order of abundance, of quartz, plagioclase (probably oligoclase), microcline, muscovite, and biotite. A few rods to the east, near the kiln, is an evenly foliated, more biotitic gneiss, consisting, in like order, of quartz, biotite, microcline, plagioclase, and muscovite. This rock also dips east at a low angle toward and under the dolomite, but the lower contact is not exposed. The difference in the two gneisses is only what would be expected in any large body of gneiss. The same white dolomite reappears along the strike at the south end of the railroad cut, where it is also overlain by a granite gneiss that curves upward in such a way as to suggest the beginning of an anticline, in which case the dolomite would lie in a syncline of gneiss. The gneiss has evidently been greatly disturbed here, for east of the strike of the dolomite on both sides of the cut thick pegmatic dikes cross the steep foliation of the gneiss almost horizontally.

The dolomite is milk-white and contains some lenses of pink calcite about 1 by 0.2 inch, also veinlets of light smoky quarts 0.01-0.2 inch thick, films of muscovite, and scales of brownish mica. The calcite veins and quartz lenses are more abundant near the gneiss contact. The dolomite grains are clear and twinned, 0.05-0.062 and even 1.12 millimeters in diameter, but mostly 0.15-0.5 millimeter, and the rock is thus of grade 2 (very fine). The calcite grains are large and are much clouded from manganese oxide. Although the twinning of the dolomite makes it susceptible of high polish, the quartz veins would be troublesome and a somewhat close jointing would prevent the quarrying of large blocks.

About three-quarters of a mile south of the railroad curve the dolomite recurs. Here it is over 30 feet thick, strikes north, and dips 30° W., and the gneiss is in contact with and above it.

A preliminary exploration of the complex geology of the little canyon of Black River, called Cavendish Gorge, shows that dolomite marble about 75 feet thick, resembling that near the railroad cut but including some beds of actinolitic calcite marble and mica schist, is both underlain and overlain by a feldspathic schist or granite gneiss, which on the west side of the gorge dips west but at one point on the east side dips east. As the gorge meanders in the direction of the strike, which ranges from N. 35° E. to N. 15° W., and as the gorge is also crossed by a diabase dike and a fault, the distinction between its metamorphic igneous and metamorphic sedimentary rocks is not clear; the locality requires much further study.[1]



About 3 miles north of the north end of Cavendish Gorge and a quarter of a mile south of the road fork at school No. 6, west of the road, the following section was observed, in natural order:

*Section near school No. 6.*

| | Feet. |
|---|---|
| Garnetiferous mica schist | 15 |
| Granite gneiss | 15 |
| White and pink dolomite | 15 |
| Granite gneiss | 5 |
| Covered space. | |
| Garnetiferous mica schist on both sides of road and forming the east side of a north-south ravine | 40 |

The whole series strikes N. 10° E. and dips 20° W.

### EASTERN BELT.

The eastern belt is south of Felchville, a village of the next township on the north. It includes a long, roughly north-south ridge of granite gneiss possibly 200 feet high, with a conspicuous saddle. The highest point of the ridge is S. 70° W. from Mount Ascutney. It is separated from Little Ascutney by the wide north-northwesterly valley through which flows Felchville Brook, a tributary of Black River. The gneiss of this ridge appears to be continuous with the "Gneissic series" mapped by Daly[2] in his study of Ascutney Mountain. The principal marble outcrops occur over an area extending 600 feet across the ridge and 700 feet on it. They have been quarried on its west side, where stand the remains of a kiln. The total thickness of the marble could not be determined. The structural relations are complex, but the general strike of the gneiss is N. 25° E. Both rocks are probably interfolded and the marble may not be in continuous beds. The strike of the marble ranges from N. 25° W. to N. 10° E. On the west side of the southern knoll the dip is vertical, but farther up it is at a low angle to the west, pointing to a possible anticlinal structure for the ridge, and the pitch seems to be north. Some of the marble beds are crossed by small fault planes filled with secondary calcite. A small basaltic dike cuts the marble in the northern part of the west side of the ridge. Along the west foot is a considerable mass of schist made up of epidote, hornblende, and calcite, possibly of sedimentary origin, and associated with the marble.

[1] Hitchcock and Hager (Geology of Vermont, vol. 2, p. 931, 1861) state that the dolomite of the gorge is underlain by gneiss and overlain by schist.
[2] Daly, R. A., Geology of Ascutney Mountain, Vt.; U. S. Geol. Survey Bull. 209, Pl. VII, pp. 17, 18, 1903.

Some of the marble is a bluish or whitish-gray calcite marble, rose-colored in spots and streaks, with grain diameters up to 2.96 and 3.33 millimeters (in hand specimens even 0.25 inch), and thus of grade 6 (extra coarse), but it contains finer streaks of twinned dolomite marble with grain diameters of 0.11-1.1, mostly 0.18-0.55, millimeters, and therefore of grade 4 (medium). Muscovite and biotite occur in streaks and here and there is a little actinolite. There are also generally disseminated grains of quartz, apatite, and pyrite, rarely epidote.

Another variety of the marble is finer grained, intricately plicated, and more micaceous and contains beds 0.2 inch thick of bright-green actinolite, and this mineral has also developed secondarily along the planes of slip cleavage. If large solid blocks of this variety could be obtained it would be valuable as a decorative marble, but the outcrops are too small to indicate either the quantity or the quality of the deposit.

### WEATHERSFIELD.

The marbles of Weathersfield Township occur in three parallel belts of outcrops—a western belt on the ridge which lies west of the north-south part of Black River and is cut by it at Upper Falls; an eastern belt on the east side of the north-south ridge east of the tributary of Black River upon which Felchville and Amsden are situated, and a central belt on Pine Hill, the north-south ridge between Black River and its tributary.

#### WESTERN BELT.

About midway between Perkinsville and Upper Falls, on the Hawks Mountain ridge, in a small east-west ravine N. 70° W. of the Foster house, about 1,400 feet west of Black River and 150 feet above it, are some outcrops of marble which continue at intervals for 50 feet higher. The inclosing rock is a coarse muscovite-biotite schist containing large crystals and lenses of feldspar (presumably albite) and beds of quartzite. A few hundred feet south the schist is intruded by a mass about 300 feet square of coarse pegmatite containing feldspars up to 6 inches across. Pegmatite dikes as much as 3 feet thick run parallel to the foliation of the schist.

The marble consists of alternating plicated beds, 1 or 2 inches thick, of rose-colored and light greenish actinolitic calcite marble of grade 6 (extra coarse), with grains up to 3.33 millimeters in diameter in thin section and some attaining 0.2 inch in the hand specimen. The bunches of actinolite prisms are as much as 0.5 inch long. The rose color, as elsewhere (p. 252), is to be attributed to a small percentage of manganese oxide, and the green to actinolite. Biotite, quartz, a little plagioclase and apatite, and rarely zircon are present.

This is a very attractive stone in both longitudinal and transverse fracture. Only a few feet of marble are exposed at any point. Whether it could be obtained in large and sound blocks would have to be determined.



The Amsden quarries are east of the stream which joins Black River three-quarters of a mile east of Perkinsville. At the largest one, about half a mile south of the Amsden store, the marble exposed is about 45 feet thick, strikes N. 30° W., and has an undulating dip, in places with minor plications that have a northerly pitch. It is cut by two trap dikes, amygdaloidal in places, 4 to 5 feet thick, and about 125 feet apart. The northern dike has a N. 50° E. course and dips 65° N. 40° W.; the other has a N. 75° E. course and a vertical dip. The marble for 25 feet on the north side of the northern dike is close jointed. One of the dikes sends off small branches into the marble. The marble has north-south joint faces on which, owing to solution by underground water, the more quartzose and micaceous bands project above the more purely calcareous bands.

The marble consists of bands of milk-white, light to medium or dark bluish or slightly greenish-gray, or light buff color in irregular alternations, from 0.1 inch to over 1 inch in width. The texture varies from fine to very coarse. The fine bands consist mostly of twinned dolomite with grain diameters of 0.07-0.87, mostly 0.25-0.5 millimeter, and are thus of about grade 3 (fine). The coarse bands are of calcite with grain diameters of 0.1-2.43 millimeters, in some specimens even 0.2 inch but mostly 0.25-1.68 millimeters, and are thus of grade 6 (extra coarse). The two minerals are not confined to separate beds, there being generally a slight mixture, particularly in the dolomite beds. The colors and shades of these little beds are due to muscovite, biotite, hematite, and limonite from pyrite. The bluish tint is due to finely disseminated specular iron (metallic hematite). In places there are little beds of this iron alone and there are also lenses of it a few inches thick. The marble also contains streaks largely of biotite, and, as shown by the weathering, quartz is somewhat plentiful. This marble is properly a calcite and twinned dolomite marble, in which the two minerals occur mostly in small irregular alternating beds and which also contains quartz, hematite, biotite, and muscovite, named in descending order of abundance. At some of the now disused openings the marble contains actinolite. Here and there the marble is rose-colored, presumably from manganese oxide.

The quarries have long been worked for the manufacture of lime, and are now operated by the Amsden Lime Co., of Amsden, Vt. The lime owes its peculiar properties to the combination of the two carbonates and its cement color probably to the presence of the hematite.

The following analyses made for the company by W. U. Buch, of Palmerton, Pa., have been furnished by the manager, Mr. L. C. White, Jr. They complement the microscopic results given above.

*Analyses of calcite and dolomite marbles from Amsden, in Weathersfield, Vt.*

| | Gray. | Pink. | Pink-red. |
|---|---|---|---|
| Water ($H_2O$) | 0.04 | 0.085 | 1.0 |
| Iron sesquioxide ($Fe_2O_3$) | 1.43 | .83 | .77 |
| Manganese oxide ($MnO$) | .6 | .84 | .61 |
| Alumina ($Al_2O_3$) | 1.35 | .42 | .37 |
| Lime ($CaO$) | 38.94 | 52.78 | 50.00 |
| Magnesia ($MgO$) | 11.32 | 1.60 | 1.66 |
| Silica ($SiO_2$) | 3.33 | .49 | 5.98 |
| Carbon dioxide ($CO_2$) | 42.74 | 42.74 | 40.09 |
| Phosphorus ($P$) | .087 | .013 | .065 |
| | 99.837 | 99.798 | 100.545 |

It should be stated that in selecting the stone for lime burning the more micaceous and quartzose pieces are thrown out and that the analyses were made on the selected material.

At the most northern of the Amsden quarries, east of the brook and store, the beds strike N. 30°-50° E. and dip 50°-70° NW. under several feet of feldspathic mica schist. The marble is much jointed. Its exposed thickness is about 40 feet.

The possibility of using some of the banded marbles of Amsden for decorative work can not be determined from present exposures. Any prospecting for solid beds should be made away from the dikes, where close jointing is likely to occur.

## CENTRAL BELT.

The central belt is on Pine Hill, the ridge between the Black River and its tributary. About half a mile east of Perkinsville, at the south end of Pine Hill, about 100 feet above the east-west road, is a small opening in dolomite over 30 feet thick, which strikes N. 17° W. and dips 45° E. under more than 20 feet of muscovite-biotite schist with large disseminated crystalloids of plagioclase (probably altite). The dolomite along the contract, 60 feet north of the opening, incloses fragments of the schist as much as 14 inches in length, possibly as the result of brecciation. At the west foot of the ridge 400 feet west of the opening is another ledge of schist with a foliation dipping eastward toward and apparently under the dolomite. The schist resembles the other, but has fewer feldspars.

The dolomite is slightly cream-colored at the surface. It is twinned, with grain diameters of 0.05-0.75, mostly 0.17-0.5 millimeter, and is thus of about grade 3 (fine). It contains a little tremolite here and there.

Two miles farther north, in the hollow back of the Amsden School, west of the brook, is another disused quarry, where 10



feet of dolomite, with room for at least 30 feet more, strikes N. 35° E. and dips about 40° W. The dolomite underlies more than 50 feet of feldspathic muscovite schist and overlies similar garnetiferous, chloritic biotite schist, all dipping alike.

As outcrops 37 and 142 dip toward each other the structure of Pine Hill appears to be synclinal.

## WINDHAM COUNTY.

### ATHENS.

Marble occurs in the western part of Athens Township, just north of the west-northwesterly part of the Townshend line, on the east side of the road from Townshend to Athens, on what was formerly the Bemis farm but is now the Guilds farm. Here are several old openings and the remains of a kiln.[1]

The marble outcrops cover a width of about 200 feet and are bordered on both sides by biotite granite gneiss striking N. 55°-70° E. and dipping 45° NW. Some of the gneiss of the east side is very finely banded; some of that on the west is less finely banded and contains plagioclase as the chief feldspar and garnets and hornblende as accessory minerals. At none of the openings is the marble over 10 feet thick. The width of 200 feet probably includes some minor folds and repetitions of the same beds. At one opening the marble is interfolded with a few feet of dark yellowish-green schist, which consists of a ground of diopside containing disseminated crystals of hornblende up to 0.5 inch across and which is in contact with an epidotic calcitic biotite gneiss. This schist contains a little calcite, rare grains of zircon, and a mineral regarded by Mr. Larsen as possibly belonging to the humite group.

The marble varies considerably. Some of it is a very light pinkish and light greenish calcite marble in alternating bands from 0.2 to 0.5 inch wide. Its grain diameters are 0.18-1.8, mostly 0.37-1.1 millimeters, and it is thus of about grade 5 (coarse). The pinkish tint is probably due to manganese oxide and the green to actinolite. Some of the bands contain a brownish mica, phlogopite. Some of the marble contains more actinolite and more manganese oxide, and consequently shows a deepening of the colors. It also has black streaks of biotite. Parts of this marble are of grade 6 (extra coarse) with grain diameters up to 0.2 or even 0.3 inch.

The colors of these marbles are very attractive, but the exposures are insufficient for determining either the quantity of the stone or the solidity and thickness of its beds.

[1] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556; vol. 2, p. 618.

## TOWNSHEND.

Marble occurs at a road corner about a mile east-southeast of Townshend village and about 500 feet above it, on the Horace Gale (formerly Sharon Gray farm). Here are the remains of a kiln used about 50 years ago.[1] There are outcrops and small openings on both sides of the east-west road and about south of the house. The outcrops indicate a width of about 85 feet of marble, with finely foliated biotite gneiss on both sides striking N. 25° E. and dipping more or less steeply.

Some of the marble is in alternating white or faintly rose-tinted and light greenish beds a few inches thick. This is a calcite marble, the rose color, as in other localities, being probably due to manganese oxide and the green to actinolite. The calcite grains (in one section much twinned and slightly flexed) have diameters of 0.11-1.48 and even 2.38 millimeters, but mostly 0.37-1.48 millimeters (in a hand specimen up to 0.2 inch) and the marble is thus of grades 5 to 6 (coarse to extra coarse). It contains rare grains of twinned dolomite and of quartz. Another specimen of grade 6, is of deep pink and cream color and contains biotite and epidote.

Another variety is a greenish-gray, slightly foliaceous calcite marble with grain diameters of 0.37-2.59, mostly 0.74-1.85 millimeters, and is thus of grade 6 (extra coarse). It contains two chlorites, epidote, pyrite, and an orange-colored mineral which Mr. Larsen regards as probably belonging to the humite group.

The exposures are inadequate for determining the value of the deposit as marble.

## JAMAICA.

The marble beds of Jamaica are in the eastern half of the township, within a radius of 2.7 miles of the village of Jamaica and N. 25° E., N. 45° E., S. 45° E., and S. 25° E. of it.[2] The deposits of Turkey Mountain and Peirce farm are just east of the eastern edge of the area mapped.

The marbles consist of rose-colored calcite alternating with white twinned dolomite, or else of the latter alone, both associated with schist of sedimentary origin and with granite gneiss.

Whetstone Brook enters West River 2½-3 miles southeast of Jamaica village. At a bend in the brook, on its north bank, about 2.6 miles S. 25° E. of the village, and on the Prouty farm (formerly the Muzzy farm) 10 to 20 feet and possibly more of marble strikes N. 60° E. and dips 40° S. 30° E., conformably under about 100 feet of muscovite-biotite schist containing porphyritic plagioclase (probably albite), garnets, chlorite, and pyrite. The feldspars are crossed by plicated bedding streaks of pyrite, mica, etc.[1] The marble beds are faulted at intervals in a N. 10° E. direction, with displacement of 1 to 6 inches, and the fault planes are filled with quartz.

[1] Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556; vol. 2, p. 618.
[2] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556.



The marble consists of beds of rose-colored calcite marble an inch or so in thickness alternating with beds of white twinned dolomite from 0.3 to 1 inch thick. The calcite has grain diameters of 0.5 to 2.2, mostly 0.74 to 1.48 millimeters, and is thus of about grade 5 (coarse). The dolomite has grain diameters of .004 to 0.56, mostly 0.14 to 0.3 millimeters, and is thus of grade 2 (very fine). Both marbles contain grains of quartz and microcline and a little muscovite.

About 40 feet vertically above the marble the overlying schist contains two beds of dolomite 1 and 2 feet thick, separated by a little schist, showing that of dolomitic and argillaceous sedimentation were intimately connected.

Two miles southeast of Jamaica village and probably less than 500 feet southeast of the road corner close to the edge of the area mapped, on the N. F. Peirce farm, a white dolomite marble crops out here and there over a width of 125 feet. It strikes N. 60° E. and dips S. 30° E., corresponding in structure to the marble near Whetstone Brook, 1.2 miles to the southwest. This dolomite consists of twinned grains with diameters of 0.05 to 0.5, mostly 0.12 to 0.25 millimeters, and is thus of grade 2 (very fine).

At the west bank of West River, along the strike, this dolomite crops out again for a length of 60 feet with uncertain structure and in contact on the west with a mass of contorted gneiss. The dolomite here contains a few beds up to 1½ inches thick of pink calcite marble.

The Brattleboro and Whitehall branch of the Central Vermont Railway, at a point 1¾ miles southeast of Jamaica, on the north side of a road crossing and north of the "covered bridge" over West River, cuts a series of beds of schist, granite, gneiss, and marble that strike N. 25° E. to N. 20°-25° W. and dips 25°-30° S. 65° E. to S. 65° W. The beds occur in the following natural order.

*Section in railway cut southeast of Jamaica, Vt.*

| | Feet. |
|---|---|
| Muscovite-quartz-biotite with plagioclase crystalloids (albite) exposed above the cut, also under the road crossing | 20+ |
| Muscovite granite gneiss with some thinly foliated parts containing no mica. The foliation much plicated, possibly unconformable to adjacent beds | 18 |
| Calcite and dolomite marble, thinly interbedded | 25 |
| Muscovite-quartz-biotite schist, like upper bed | 5 |
| Calcite and dolomite marble thinly interbedded | 70 |

About 450 feet east of the carriage bridge over the river, on the north side of the east-west road, the schist that overlies the

[1] See U. S. Geol. Survey Bull. 195, pp. 16-18, 195.

highest member of the above section is finely exposed by recent blasting. It is a garnetiferous muscovite-quartz-hornblende-chlorite schist containing a little black tourmaline, graphite, and pyrite. Its thickness is probably considerable; the strike is N. 25° W. and the dip 20° N. 65° E.

About 600 feet north of the road crossing and 150 feet west of the track, opposite the north end of the marble cut, is a ledge of contorted banded muscovite gneiss or micaceous and feldspathic quartzite with a foliation that strikes about like the marble. From its situation and dip this rock appears to underlie the marble, although there is a short covered space between them. The marble beds crop out also at the river west of the track, near the south end of the cut.

The marble consists of beds of more or less intensely rose-colored calcite marble from 0.5 to 1.5 inches thick and possibly thicker, alternating with beds of like thickness of white twinned dolomite marble. Streaks of mica occur at the junctions of many of the beds or form with quartz little darker beds here and there. George Steiger, of this Survey, found that a specimen of this rose-colored calcite marble contains 0.23 per cent of manganese oxide, to which it evidently owes its color.

The calcite, with minute specks presumably of the manganese, has grain diameters of 0.18 to 2.2, mostly 0.74 to 1.48 millimeters, and thus belongs to grade 5 (coarse). The dolomite has grains, also twinned, measuring 0.07 to 0.37, mostly 0.11 to 0.26 millimeter, and is of grade 2 (very fine). These marbles contain some grains of quartz, microcline, scales of phlogopite, and a little pyrite.

Both the calcitic and the dolomitic bands take a high polish. This marble if obtainable in large and sound blocks would be well adapted for internal decoration on account of the pleasing contrast between the rose-colored and milk-white bands, but the rose-color would not be durable under outdoor exposure.

Between locality 40 and the next bridge north over West River, which is near Jamaica station, some of the same beds are finely exposed by the railroad cuts. At the foot of the knoll shown next to the letter A on the map, transversely plicated quartzite about 30 feet thick, banded with biotite, dips eastward under a thick mass of albitic biotite schist; and 200 feet to the south the quartzite is slightly calcareous and the schistose portions albitic. At a point about 550 feet south of the outlet of Adam Pond is transversely folded, more or less micaceous quartzite, 35 feet thick, contains slightly calcareous pinkish streaks. This mass appears to occur within the albitic schist. About a quarter of a mile farther south biotite-muscovite-albite schist with abundant quartz lenses containing rusty-weathering calcareous beds and lenses as much as 2 inches thick. At a point about two-fifths of a mile south of the outlet of Adam Pond the same schist contains small calcareous beds and a bed of bluish-gray dolomite up to 2 feet thick. All these occurrences indicate the association of dolomite and calcite marble with a gneissoid quartzite (with biotite, muscovite, and probably albite) and both belonging within a great mass of albitic muscovite-biotite schist typical of the Hoosick schist. Before any quarrying operations are undertaken here it will be necessary to determine how far the marble extends under the schist hill east of it.



Ball and Shatterack mountains originally formed a continuous schist mass, but have been cut down 1,000 feet across the strike by West River in its meandering course. East of Ball Mountain the river follows the strike and separates that mass from that of Turkey Mountain. Marble crops out in this vicinity at three points—along the east foot of Ball Mountain, in "Wheeler's pasture"; recurring along the strike on the south bank of the river; and about 1,000 feet east of the first locality, at the foot of Turkey Mountain, along the railway.

The "Wheeler's pasture" is above a terrace, 120 feet above the river and about 1,000 feet west of it. Here dolomite strikes N. 25° W., dips 40° N. 65° E., and measures about 160 feet in width, which, if there is no duplication by folding, would make it 100 feet thick; but this includes two or three small quartzite beds. A bed of quartzite also underlies the dolomite on the west. A hundred feet higher, at the foot of the steep east slope of Ball Mountain, muscovite-biotite schist containing feldspars and garnets strikes N. 25° W. and dips 30° N. 65° E., apparently under the quartzite and dolomite. East of the dolomite, at the west side of the terrace, similar schist dips east, apparently overlying the dolomite.

The dolomite is a glistening white to faintly cream-colored marble of twinned grains with diameters of 0.05-0.5 (one 0.87), mostly 0.125-0.25 millimeter, and is thus of grade 3 (fine). It contains a few grains of quartz and microcline and scales of muscovite. It weathers brownish, probably owing to a small content of iron carbonate. At one outcrop the dolomite includes small bodies of coarse calcite.

In following the strike of the dolomite north-northwestward to the river the dolomite is found to be cut off by large outcrops of mica schist that strike N. 25°-30° W. and dip 45° N. 65° E., and these continue 500 feet downstream, becoming more garnetiferous; but in following the strike south-southeastward marble is found on the south bank of the river. The marble here strikes N. 25° W., dips 40° N. 65° E., and is exposed for a width of about 100 feet, which gives it a thickness of 65 feet. Apparently overlying it on the east is a fine-grained epidotic muscovite-biotite gneiss whose foliation strikes N. 10° E. and dips 45° E. Apparently underlying the marble on the west is a micaceous quartzite or gneiss striking N. 25° E., and dipping 35° S. 65° E. This is exposed for a width of 70 feet. A little farther west are large outcrops of feldspathic muscovite-biotite schist like that at the east foot of Ball Mountain, striking N. 25° W. and dipping 45° N. 65° E.

This marble is in places a rather coarse rose-colored calcite, interbedded with a fine-grained white twinned dolomite, but some of the dolomite has bands and mottling of light bluish-gray. In thin section the marble consists of mixed calcite and twinned dolomite in alternating minute beds and lenses. The calcite has grain diameters of 0.25-1, mostly 0.37-0.75 millimeter, and thus belongs between grades 3 (fine) and 4 (medium), and the dolomite has grains measuring 0.03-0.3, mostly 0.04-0.14 millimeter, and thus belongs in grade 2 (very fine). The bluish-gray tint of some of the bands and lenses is due to very minute nodules of magnetite, as shown by their high magnetism. Quartz and muscovite occur sparsely.

An unsuccessful effort was made to trace this marble belt farther south-southeast.

At the west foot of Turkey Mountain, just above the point where West River turns from a due south to a due west course, at the extreme eastern part of the curve known as the oxbow, there is another marble outcrop. It extends 300 feet along the railway. As its strike of N. 40° W. makes a very acute angle with the track and the dip is east in plications, but these are crossed by joints spaced 4 to 12 inches apart striking N. 20° E. and dipping 15° W., the outcrop is misleading as to thickness, which probably does not exceed 30 feet.

The marble is a fine-grained white dolomite with some small beds of rose-colored calcite. A specimen from the river edge, shows the calcitic parts and contains some mica.

The dolomite at the north end is overlain by 10 feet of quartzite and that in turn by schist. In the river are large outcrops of muscovitic quartzite containing small dolomitic beds up to 3 feet thick, both much plicated along the strike in folds whose axes pitch 35° E. These beds all underlie the marble.

Turkey Mountain is the long, little-incised ridge east of Ball and Shatterack mountains. Only the western base of it is shown. On the west side of this ridge about 550 feet above the river (a little east of the area mapped) is a longitudinal bench or hollow, about 600 feet wide from east to west, caused by the partial erosion of beds of dolomite between harder rocks above and below. At a point about 1¼ miles south of the Windham Township line this dolomite was burned for lime, as shown by the remains of a kiln and small quarries. The dolomite strikes N. 25°-30° W. and dips 45° N. 65° E. and forms a low ridge on the bench. Its thickness is at least 125 feet, and possibly greater.

The dolomite of the southern opening is of light cream-color with grayish streaks. It consists of twinned grains with diameters of 0.05-0.25, mostly 0.1-0.2 millimeter, and is thus of grade 1 (extra fine). It contains some quartz and muscovite. The dolomite from the northern opening is of light bluish-gray tint, in places whitish, with light to very dark purplish plicated streaks, also with some faintly pinkish calcite lenses, and a little muscovite here and there. The grains are twinned and measure 0.025-0.37, mostly 0.075-0.125 millimeter, and the stone is thus of grade 2 (very fine). The bluish-purplish streaks are due to minute bluish particles of magnetite.



The probability of using these Turkey Mountain twinned dolomites as marbles is diminished by the presence in the northern opening of joints, which strike N. 35° E., dip 50° S. 55° E., and are spaced 2 to 12 inches apart.

At the east side of the bench is a cliff and talus of muscovite-chlorite schist, abounding in garnets and tourmaline, striking N. 25° W. and dipping 40° N. 65° E. On the west side of the bench are gneissoid rocks, apparently dipping under the dolomite at about 40°.

In ascending the Turkey Mountain ridge from locality 53 at the river to the bench the first satisfactory outcrops are found at 180 feet above the track. Here is a feldspathic biotite schist or gneiss with a foliation striking N. 10° E. and dipping 45° E. This becomes finer grained 200 feet higher and recurs 50 feet higher still, continuing thence to the bench, where it appears to be a granite gneiss. All the observations between Ball and Turkey mountains have been brought together in a provisional section.

The lowest rock in the West River cut is probably the granite gneiss of locality 52. Overlying that is probably the micaceous quartzite in the river at locality 53, followed by the dolomite, and this by the garnetiferous or feldspathic biotite-muscovite schists which form the east side of Ball Mountain, crop out near locality 54, and are cut by the railway at localities 50 and 51.

As schist occurs west of the dolomite at the foot of Ball Mountain and similar schist occurs east of that on the Turkey Mountain bench, and as the dolomite and schist at both places dip eastward, these dolomite outcrops may belong to the opposite limbs of one or two westward-overturned anticlines. The limestone mentioned by Hitchcock[1] as occurring in South Windham may be a continuation of that on Turkey Mountain in Jamaica.

## STRATTON.

Stratton Mountain and Haystack Mountain, south of it, are about 8 miles west of the strike of the marbles of Jamaica, along the axis of the Green Mountain Range. The marble in Stratton lies about 1½ miles east of the line connecting these summits,

[1] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556.

opposite a point about midway between them. It is 2½ miles southeast of the now deserted village of Stratton and about a mile west of the Wardsboro Township line, near a tributary of Whetstone Brook. The locality is shown approximately on Hitchcock and Hager's map of 1861.[1]

Lime was extensively manufactured a few years ago at a kiln 0.2 miles S. 45° W. of A. J. Pike's house. The quarry lies between the forks of a small brook about a quarter of a mile S. 45° W. of the kiln and 100 feet above it.

Here about 60 feet of marble striking N. 55° E. and dipping 50° S. 35° E. is in contact both above and below with mica schist and has been quarried along the strike. The overlying schist is a graphitic sericite-quartz-chlorite schist with garnets, black tourmaline, magnetite, and much limonite stain. The underlying schist resembles the other but contains apatite and no graphite or tourmaline; in places it contains a feldspar.

The marble consists of slightly bluish-white calcite marble, most of it alternating with beds 1 to 3 inches thick of fine-grained milk-white or pale bluish dolomite. The calcitic part has grain diameters of 0.148-1.48, mostly 0.37-0.92 millimeters, and thus belongs to grade 5 (coarse). The dolomite consists of twinned grains with diameters of 0.05-0.25, mostly 0.07-0.175 millimeter, and is thus of grade 1 (extra fine). It is spangled with minute flakes of muscovite. The marbles contain a little quartz, rarely feldspar, and biotite. In thin section the demarkation between the calcite and dolomite beds is abrupt.

On the northwest side of the quarry the lower 5 feet of the marble is banded with rose-colored calcite marble consisting of grains 0.18-1.85, mostly 0.37-1.1 millimeters, in diameter and thus of grade 5 (course). It has streaks of quartz, muscovite, and biotite. In the lower part of the marble there are also schistose portions consisting of quartz, muscovite, biotite chlorite, carbonate, large porphyritic (plagioclase) feldspars, also apatite, epidote, pyrite, zircon, and black tourmaline, and inclusions of apatite, two micas, and quartz in the feldspars.

But for the slight differences between the schist on the east and west sides and between the upper and lower beds of the marble the structure here might be taken for an eroded compressed fold with inclined parallel sides.

As the dolomite here is twinned it is susceptible of high polish. The marble has been so shattered by the use of explosives that it is impossible to tell whether the beds are sound enough to furnish solid blocks for decorative purposes.

In connection with the search for marble in Stratton, Kidder Brook, which rises on the east side of Stratton Mountain and flows into the North Branch of Ball Mountain Brook 2 miles west of Jamaica village, was explored in 1888 to a point 2 miles west

[1] See also their report, vol. 1, p. 555; vol. 2, pp. 613, 748.



of the Stratton-Jamaica line, but nothing except sericite schist was found.

### DOVER.

Hitchcock and Hager's map shows two marble deposits in an area which was the extreme northern part of Wilmington but which, owing to changes in township lines, is now in the northwestern part of Dover.

One of these deposits is in the northern continuation of the Haystack Mountain mass on its east side on Limekiln Brook (locality 56, fig. 8), where lime was made many years ago. Although this outcrop is only 2¾ miles southeast of that in Stratton, there is a difference of 65°-95° in the strike of the two.

The marble, exposed for a width of about 47 feet, strikes N. 10°-40° W., dips 25° N. 67° E., and is at least 19 feet thick. It crops out on the east bank of the brook about a quarter of a mile S. 45° W. of the E. J. Bartlett farmhouse, 140 feet below it, and about 400 feet upstream from the kiln location. Another outcrop is reported on the west bank of the brook which would make the thickness much greater. About 50 feet vertically above the marble and a few hundred feet up the brook are feldspathic mica schists that strike N. 10°-15° W. and dip 65° E., thus apparently underlying the marble. Graphitic muscovite schist like that in contact with the marble at locality 43, in Stratton, crops out about 1,200 feet west of the Bartlett house, where it has a N. 33° W. strike and an undulating dip. This schist probably overlies the marble. Between the Bartlett sugar house and the brook, possibly 1,000 feet south of the house, is an amphibolite dike. Finally, in descending the brook half a mile from the marble, at locality 44, is a muscovite-biotite granite gneiss striking N. 35° E. and dipping 15° E., discordantly to the marble and its associated schist.

The marble is coarse (grade 5), and rose-colored, but contains some pale greenish bands whose color is of uncertain origin and some whitish dolomitic bands and fine streaks of pyrite. It was not practicable to obtain perfectly fresh specimens. Considerable work would be necessary to obtain a complete exposure of the marble at this locality.

The other marble locality in Dover is close to the Somerset line on Mount Pisgah, the northern summit of the Haystack Mountain mass, 143 feet higher than Haystack itself. North of Mount Pisgah there is a saddle at the 2,700-foot level, which was formerly utilized by a road that ran from Dover to the sawmills in Somerset. On the south side of this saddle, 450 to 500 feet below the summit, at about 3,605 feet, rises a brook that flows N. 25° W. into Chase Pond, in Somerset, which is about to be absorbed into a large reservoir. On the 3,000-foot level and about 500 feet east of the Somerset line this brook crosses beds of white dolomite, about 50 feet thick, striking N. 25°-40° W. and dipping about 30° N. 58° E. A little farther west and 20 feet lower 10 to 15 feet of rose-colored calcite marble crops out in the woods. About 75 feet west of it are garnetiferous muscovite-graphite schists like those associated with the marble in Stratton and at Bartlett's. These schists form the steep mountain side west of the brook. They strike N. 25°-30° W. and dip 45° N. 63° E., and thus appear to underlie both calcite marble and dolomite.

The dolomite is milk white with grayish specks 0.1 inch across and 0.3-1 inch or more apart. The dolomite grains, rarely twinned, measure 0.037-0.296, mostly 0.074-0.185 millimeter, and the rock is thus of about grade 2 (very fine). The grayish specks consist of large dolomite grains (as much as 0.55 millimeter) crowded with very minute black particles, and of one or two quartz grains attaining 0.85 millimeter. The rock also contains sparse minute muscovite and minute black specks (pyrite?) that give rise to limonite stain.

The rose-colored calcite marble has grain diameters of 0.18-1.66, mostly 0.37-1.1 millimeters, and is thus of grade 5 (coarse). It contains some small roundish quartz grains. The calcite is speckled, presumably with manganese oxide. The total thickness of this marble could not be determined.

The granular texture of most of the dolomite, probably preventing a high polish, the uncertainty as to the amount of the calcite marble, and the rather inaccessible location render this deposit of very doubtful value.

### SOMERSET.

In descending the brook from locality 90 on Mount Pisgah in Dover, to the 2,715-foot level in Somerset, a fork is seen to enter the brook from the west. At this point there is a ledge of weathered cream-colored calcite marble of texture grade 5 (coarse), striking N. 25° W. and dipping 50° N. 65° E. and having an exposed thickness of at least 10 feet. This is in the line of the strike of the rose-colored marble at locality 89, in Dover. Farther down the brook, near the road crossing (locality 80), schists like those west of the marble at locality 89 strike N. 25° W. and dip 50° N. 65° E.

A conspicuous low bluff between the 2,700-foot and 2,800-foot levels a mile northeast of Chase Pond is divided by a slight depression. Two experienced local surveyors and woodsmen report "lime rock" as cropping out between the two parts of the bluff. The schist of the southern outcrop (locality 82) has the same strike as that west of the marble on Mount Pisgah and dips 55° N. 65° E. Owing to the difficulty of orienting oneself in a cut forest on a mountain side where the topography is not bold, the writer failed in a day's excursion to find this "lime rock," but he is not disposed to question its existence, as it would be in the line of the strike of the marble on Mount Pisgah.



Marble is also reported as having been found by a trapper in Somerset on one of the two masses between the East and West branches of Deerfield River, south of the road from Somerset to Dover.

### WILMINGTON.

Hitchcock and Hager's map shows marble in the northwest corner of Wilmington Township near Haystack Pond. This was found by the writer. There is another outcrop of marble 1¾ miles west-northwest of Wilmington village, where lime was burned many years ago.

About 350 feet southeast of the south end of Mud Pond, the small pond south of Haystack Pond, on the 2,760-foot level, a gully, which evidently at times is one of the outlets of Mud Pond cuts beds of marble at least 100 feet thick, striking N. 25° W. and dipping N. 65° E. The south end of the low ridge east of Haystack Pond (locality 84) consists of biotite schist with albite feldspars and quartz lenses, having a N .10° E. strike and a westward dip. As the schist of the summit presumably dips east under the marble, the latter may lie in the trough of a fold. It would not be surprising if the hollow that holds Haystack Pond were a syncline from which the marble had been largely eroded.

The marble ranges from a cream-colored to a rose-colored calcite marble that has grain diameters of 0.11-1.48, mostly 0.26-0.74 millimeter, and is thus of grade 5 (coarse). It contains some quartz, biotite, zircon, magnetite (?), and small lenses of dolomite. White the quality of this marble adapts it to decorative uses and its thickness is adequate, the extent of the beds along the strike and their soundness require careful investigation.

As the strike corresponds with that of locality 85, 2 miles S. 25° E., this marble may crop out between the two places.

Marble occurs about 700 feet west of the W. S. Grimes farm house, on the 1,800-foot level, 1¾ miles N. 60° W. of Wilmington village (locality 83). Here dolomite and calcite marble with a N. 10°-35° W. strike and easterly dip crop out over a width of at least 120 feet and are succeeded on the east by a grass-covered area twice that width. A kiln, a little north of the outcrop, is reported as not having been used for 65 years. West of the marble is a garnetiferous muscovite-quartz-chlorite schist containing a little feldspar, tourmaline, and biotite, striking N. 35° W. in minor folds, and inclosing synclinal remnants of marble up to 16 inches thick with a southerly pitch. The schist thus clearly underlies the marble and may possibly inclose it.

The marble consists of alternating little beds of fine-grained twinned milk-white dolomite marble and of coarse rose-colored calcite marble. The width of the beds varies from 1 to 1.5 inches. One specimen shows this series:

| | Inch. |
|---|---|
| Calcite | 0.6 |
| Dolomite | 1.0 |
| Calcite | 0.1 |
| Dolomite | 0.1- .2 |
| Calcite | .6 |

The calcite has grain diameters of 0.29-1.48, mostly 0.55-0.74 millimeter, and is thus of grade 5 (coarse). The dolomite has grain diameters of 0.05-0.35, mostly 0.12-0.2 millimeter, and is thus between grades 1 (extra fine), and 2 (very fine). Both marbles contain some quartz, and the dolomite contains some muscovite.

As the dolomite is twinned it takes a good polish, as does also the calcite. Pieces exposed about the opening for many years show a loss of color in the calcite bands. The exposures afford no clue as to the thickness of the deposit or the soundness of the beds. The fresh marble when polished must be very attractive.

### WHITINGHAM.

Several deposits of graphitic and micaceous marble in Whitingham Township, shown on Hitchcock and Hager's map as "Azoic saccharoid limestone," were cursorily examined by the writer in 1888. Most of them have been utilized for lime.

One of these deposits is three-fourths of a mile S. 25° W. of Whitingham village. The kiln is west of the brook, but the outcrop is east of it. The marble is a calcite marble of grain diameters 0.18-2.2, mostly 0.74-1.48 millimeters, and thus of grade 5 (coarse). It abounds in scales of phlogopite, from 0.1 to 0.6 inch across, and contains some graphite, quartz grains, and rarely actinolite. Another specimen equally coarse, is free from mica and graphite but carries numerous minute prisms of actinolite.

At a point 2 miles S. 25° W. of Whitingham village, about 1,000 feet south of the east-west road, are some old quarries which supplied Kenfield's limekiln, near the road. Some of the rock is a white calcite marble with twinned grains 0.25-1.25, mostly 0.37-1 millimeter in diameter and is thus of grade 4 (medium).

Marble recurs about a quarter of a mile S. 25° W. on both sides of the southeasterly road, where it was also burned.

In the railroad cut south of Lime Hollow, opposite the point where a carriage bridge crossed Deerfield River in 1888, marble is exposed on the east side of the track for over 100 feet, the beds striking N. 10°-22° W. and dipping on the average 45° N. 75° E. Parallel to the bedding at irregular intervals are five



schistose beds, 1 foot, 1 foot 6 inches, 2 feet, 2 feet 6 inches, and 3 feet thick, respectively. The widest space of clear marble between them is 88 feet, amounting to 62 feet measured vertically to the dip. The schistose beds are made up of a bronze-colored micaceous plicated amphibolite, consisting hornblende, biotite, chlorite, muscovite, plagioclase, magnetite or ilmenite, pyrite, apatite, zircon, and carbonate, and are evidently metamorphosed basic dikes.

The marble is a whitish calcite marble with grayish streaks abounding in graphite scales up to 0.2 inch across, lying parallel to the bedding. The calcite has grain diameters of 0.18-1.66, mostly 0.37-1.1 millimeters, and is thus of grade 5 (coarse). Some of the twinning planes are flexed. A little quartz, pyrite, and actinolite are present.

In ascending from the railroad eastward the marble is traced up a small knoll and the west side of a ravine east of it. On the steep slope east of the ravine schist or gneiss, with an eastward-dipping foliation, crops out at a point 350 feet above the railroad and again higher up.

On the west bank of Deerfield River, about 1,000 feet north of the bridge abutment above the second river terrace graphitic marble crops out, and about 500 feet west of the river and a little west of the marble albitic schist strikes N. 20° E. in minor folds. The relation of the schist to the marble is not clear.

## BENNINGTON COUNTY.

### SEARSBURG.

The marbles of Wilmington recur in the adjoining township of Searsburg, in Bennington County, less than 2 miles east of their strike. The localities are on both sides of a small north-south hollow through which a brook flows northward into Deerfield River, about a quarter of a mile west of the Searsburg-Wilmington line and a third of a mile south of the river, in the pasture of the W. C. Wheeler farm. West of the brook the outcrops indicate a width of 280 feet and a possible maximum thickness of 200 feet of dolomite and calcite marble. In contact with them on the west is an albite diorite schist consisting of biotite, albite (full of inclusions of quartz and biotite), quartz, carbonate, pyrite, and zircon. Its foliation strikes N. 5° E. and dips 60° E.

A boulder of this albite diorite schist occurs in Wilmington about a quarter of a mile N. 55° E. of the W. S. Grimes house on the east bank of a brook west of the road and about 100 feet above the village, showing that the rock probably crops out on the Haystack Mountain mass, which lies in the course of the ice motion.

A space of about 225 feet east of the brook seems to be occupied by various schist more or less albitic; then follows 20 feet of dolomite striking N. 25°-35° W. and dipping 45°-60 N. 60° E., and in contact with it, about 245 feet east of the brook is a garnetiferous muscovite schist containing chlorite, two or three feldspars, tourmaline, and magnetite. This schist forms a 40-foot cliff and in places gives way to a fine-grained biotite-muscovite gneiss. This little cliff forms the west side of a bench which is 200 feet wide. Here dolomite and calcite marble again appears in a belt about 50 feet wide, with schist east and west of it. The schist on the east contains feldspar crystalloids. It strikes N. 30°-35° W. and dips N. 60° E. at a low angle, apparently overlying the marble. The schist on the west is like that at the north end and west foot of the cliff and seems to underlie the marble on its west side. On the north this bench passes into a gully, and the marble is bordered on both sides by feldspathic schist. The schist on the west side strikes N. 25°-30° W. and has plications 8 to 10 inches wide with a general vertical dip, containing remnants of dolomite folds. The garnetiferous schist crops out within a few feet of the feldspathic schist on the west, and both probably merge a little farther north. These stratigraphic data are combined in a tentative section.

The marble of the bench consists of cream-colored dolomite with small beds of rose-colored calcite marble, but some of the calcitic beds are slightly dolomitic. The rock contains some little biotitic beds. The calcite has grain diameters of 0.18-1.48, mostly 0.55-1.1 millimeters, and is thus of grade 5 (coarse), and the dolomite plates, mostly twinned, measure 0.07-0.25 and even 2.59 millimeters, or from very fine to extra coarse. The accessory minerals are quartz, plagioclase, microcline, muscovite, biotite, and magnetite.

The thickness and extent of this deposit and the character of the beds would have to be determined to obtain a basis for economic forecasts.

### READSBORO.

About a quarter of a mile north of the Readsboro dam, on the north side of Deerfield River, a graphitic micaceous calcite marble like that of Whitingham (p. 230) was formerly quarried and burned for lime. It strikes N. 25° E. and dips west in minor folds. About 45 feet north of the marble is a high ledge of plicated schist having the same strike but an easterly dip. This ledge at the base is biotitic with large disseminated feldspars, presumably albite. Higher up it is muscovitic, and in the center incloses a small marble bed, the schist being thus clearly a metamorphic sedimentary rock. These schists continue up the hill eastward to a level 250 feet above the marble quarry.



## ESSEX COUNTY.

Jackson[1] and Cutting[2] reported the occurrence of dolomite in Essex County. Jackson says:

In Lunenburg, Vt., I visited a tract of land belonging to Col. White, where a blue and gray limestone is found in abundance, but is not sufficiently rich to make good lime, although it may serve a useful purpose in agriculture. It contains nearly 50 per cent of carbonate of lime but is liable to melt into slag in burning, on account of the formation of fusible silicates of lime, alumina, and oxide of iron. By careful burning it will make a tolerably good hydraulic lime. This limestone occurs on the east side of the hill, near a pond, is stratified, and runs N. 30° E. S. 30° W., and dips northwest. It is N. 30° W. from Lunenburg meetinghouse, and on the west side of the pond. The top of the hill is composed of a greenish clay slate of the Cambrian system, and dips 50° NW.

Crossing the Connecticut River at Lancaster, we came to Lunenburg, Vt., where a bed of limestone was formerly examined. The principal rocks in this town are mica slate, the strata of which dip very boldly to the northwest, and a greenish Cambrian clay slate, with a less steep inclination to the northwest, and occupying the summit and side of a steep hill, where a bed of blue limestone occurs embedded in the slate.

Limestone from Col. White's quarry, Lunenburg, Vt., second bed, grayish-blue, 100 grains yielded:

| | Per cent. |
|---|---|
| Siliceous matter | 40.6 |
| Carbonate lime and magnesia | 47.6 |
| Peroxide iron and alumina | 11.0 |
| | 99.2 |
| Loss | .8 |
| | 100 |

Cutting describes the dolomite as follows:

In the southern portion of Concord there is a dike of magnesian limestone that is traceable in a straight line nearly 3 miles, varying from 2 to 6 feet wide.

In the northern part of the town there are considerable deposits of limestone, yet not sufficiently pure for the manufacture of lime and probably belonging to this same talcose formation. On Miles Mountain are several caves in this rock, some of them quite small and some possessing considerable size. * * *

[In one of these caves visited by him] there were small stalactites hanging from the rock overhead—some of the longest about 3 inches. * * * There is also in the northern part of Lunenburg a cave in the same formation, nearly like the one I have described, only perhaps not so large, and one much larger than either in Maidstone. The limestone in this section has been analyzed: silica 40.5; carbonate of lime and magnesia 51.3; oxide of iron and loss 8.

[1] Jackson, C. T., Final report on the geology and mineralogy of the State of New Hampshire, Concord, N. H., pp. 147, 160, 177, 1844.
[2] Cutting, H. A., Natural history of Essex County: Gazetteer of Vermont, edited by Abby Maria Hemenway, volume for Essex County, pp. 1051, 1052, Burlington, 1867.

The writer endeavored to find the Lunenburg and Concord localities with these results: About 3 miles N. 15° W. from Lunenburg village and 400 feet above it, on Pond Hill, N. 65° E. from Mount Tug and N. 5° W. from Baldwin Hill, on the Elijah Blood farm (formerly Woods farm) is a large outcrop of fine-grained quartzite that contains microscopic sericitic beds with biotite and chlorite, also similar beds an inch or so thick of very quartzose, finely plicated chloritic sericitic schist containing biotite and magnetite, striking N. 60° E. About half a mile north of this ledge is a ridge of very quartzose, chloritic, pyritiferous sericite schist striking north and dipping 45° W., on the east side of which is a shallow hollow and talus and one or two small openings in the ledge but no indications whatever of any calcareous rock.

In Concord about half a mile west of a conspicuous saddle in the crest of Miles Mountain, on a shoulder of the mountain, 700 feet above and roughly 1¼ miles N. 23° W. of Miles Pond station, is a well-known cave about 25 by 5 to 10 feet and 4 feet in height. The roof which strikes N. 45° E. and dips 35° N. 45° W., has in places a whitish incrustation and stalactites half an inch or less in length. Some of this material effervesces with dilute hydrochloric acid and some does not. The rock of the cave is a brecciated biotite granite gneiss with a sericitic cement winding in and out between the feldspar and quartz fragments, and without carbonate. It strikes N. 45° W. and dips 65° N. 45° E. Another part of the same ledge is a fine-grained biotite quartz schist, with muscovite plates inclosing quartz and biotite particles. This schist is cut by little dikes about an inch thick of biotite granite containing much plagioclase. The rock near the mouth of the cave is cut by other little dikes (?) altered to exceedingly fine-grained feldspathic biotite schist in which garnets have formed about the other minerals.

Other ledges in the vicinity consist of an exceedingly tough, finely foliated, in places garnetiferous biotite gneiss striking N. 25° W., dipping 52° S. 65° W., and cut by little dikes of granite. Many of the glacial boulders south of the cave are granite containing basic segregations and also inclusions of a dark schist with foliation and bedding planes. The surface in the vicinity of the cave is pitted from the falling in of small caves, the cause of which is problematic. No trace of dolomite was found, and even the thin sections fail to show carbonate. The calcareous parts of the incrustations may have come from the carbonate arising from the alteration of plagioclase in the granite dikes or from a very minute amount of carbonate in parts of the schist.

Further explorations may result in the rediscovery of the locality described by Jackson.



## GENERAL PETROGRAPHIC CHARACTER OF THE MARBLES AND DOLOMITES.

The calcite marbles of eastern Vermont are generally of medium, coarse, or very coarse texture. Same carry scales of graphite and mica, or of specular hematite. Several are rose-colored from a very small content of manganese oxide. Some are greenish from actinolite or epidote. Most of the rose-colored marbles are interbedded with white dolomite, usually twinned. The gray calcite marbles of Orange County and the blue-black of Bethel, in Windsor County, are distinguished from the others by their large percentage of quartz. Some of the dolomites, especially those of Plymouth, are pinkish from hematite or manganese oxide or grayish from graphite and are brecciated. The dolomite of Mendon is pure white; that of Hancock and of Mount Tabor is cream-colored to buff from siderite.

The presence of iron sulphide, or of iron carbonate also, in the quartzose marbles producing a rusty discoloration; the excessive jointing in others (Mendon); the presence of manganese oxide in others, producing a rose tint that is liable to fade on outdoor exposure; and the inconsiderable quantity of still others (Moretown and Waterville) will prevent nearly all these marbles from being used for external construction or decoration. Their economic adaptations are given on page 276.

## CLASSIFICATION.

In the following table all the marbles and dolomites described in the foregoing pages are grouped by their chief characteristics, with page references to the descriptions. They fall into 20 varieties of marble based on differences of color, or combinations of colors, on differences of texture, or on the minerals they contain. These minerals include a red manganese oxide, red hematite, metallic hematite, magnetite, pyrite, chalcopyrite, malachite, siderite, limonite, graphite, quartz, several feldspars, muscovite, biotite, phlogopite, chlorite, epidote, actinolite, apatite, zircon and a mineral of the humite group. The variation in texture is extreme, ranging from grade 1 (extra fine), with an average grain diameter of 0.06 millimeter, to grade 6 (extra coarse), with an average diameter of 0.5 millimeter, or from a minimum of 0.02 millimeter to a maximum of 2.5 millimeters. Some of the dolomite is granular and some of it is twinned.

*Classification of the calcite marbles and dolomites of eastern Vermont.*

| | Locality. | Township. | County. | Texture, grade. | Described on page— |
|---|---|---|---|---|---|
| Calcite, cream-white, mottled with gray. | 75 | Moretown . . . | Washington. | 4, 2 | 231 |
| Calcite, white | 80 | Waterville . . . | Lamoille . . . | 5 | 228 |
| Calcite, white to pink with light and dark-green bands. | 86 | Richford . . . . | Franklin . . . | 4 | 227 |
| Calcite and granular dolomite with interbedded sericite schist. | 68 | Rochester . . . | Windsor . . . | 2, 1 | 234 |
| Calcite, rose-colored, interbedded with white twinned dolomite. | 73, 40, 53 | Jamaica . . . . | Windham . . | 15 | 250 |
| | 83 | Wilmington . . | . . . do . . . . | 22 | 259 |
| Calcite, rose-colored, with greenish actinolite bands, | 42 | Athens . . . . . | Windsor . . . | 5-6 | 249 |
| | 41 | Townshend . . | . . . do . . . . | 5-6 | 250 |
| | 36 | Weathersfield . | . . . do . . . . | 6 | 246 |
| Calcite, grayish (metallic $Fe_2O_3$) interbedded with white twinned dolomite. | 34 | Amsden . . . . . | . . . do . . . . | 16<br>23 | 247<br>257 |
| Calcite, rose to cream colored, with but little interbedded dolomite. | 89, 56 | Dover . . . . . . | Windham . . | 5 | 259 |
| | 85 | Wilmington . . | . . . do . . . . | 5 | |
| | 52 | Mount Holly . | Rutland . . . | 6 | 237 |
| Calcite, white, interbedded with white twinned dolomite. | 43 | Stratton . . . . | Windham . . | 15-6 | 253 |
| | 35 | Cavendish . . . | Windsor . . . | 21, 2 or 4 | 243 |
| Calcite, whitish, with large scales of graphite and mica. | 38, 41, (of 1888), | Whitingham . . | Windham . . | 5 | 260 |
| | 48 (of 1888)[3] | Readsboro . . . | Bennington. | 5 | 232 |
| Calcite, grayish, fine, graphite, muscovite, pyrite, much quartz. | 3, 9, 10 | Washington . . | Orange . . . . | 3 | 233 |
| Calcite, like above, but with fine light and dark gray plicated beds. | 1 | Topsham . . . . | . . . do . . . . | 3 | 232 |
| Calcite, bluish black, containing graphite, muscovite, and much quartz. Probably sideritic. | 71 | Bethel . . . . . . | Windsor . . . | 2 | 238 |
| Dolomite, white or whitish, granular or with very few twinned grains. | 108 | Ludlow . . . . . | . . . do . . . . | 1 | 243 |
| | 90 | Dover . . . . . . | Windham . . | 2 | 257 |
| | 58 | Jamaica . . . . . | . . . do . . . . | 1 | 250 |
| | 46 | Mendon . . . . . | Rutland . . . | 1 | 236 |
| Dolomite, white, twinned . . . . . | 38 | Cavendish . . . | Windsor . . . | 2 | 243 |
| | 54, 74 | Jamaica . . . . . | Windham . . | 2-3 | 250 |
| | 37 | Weathersfield . | Windsor . . . | 3 | 246 |
| | 51 | Mount Holly . | Rutland . . . | 6 | 237 |
| Dolomite, white, twinned, with faint purplish spots (MnO, $Fe_2O_3$). | 18 | Plymouth . . . | Windsor . . . | 2 | 240 |
| Dolomite, white, twinned, with fine purplish lenses and streaks ($Fe_3O_4$). | 61, 67 | Jamaica . . . . | Windham . . | 2 | 250 |
| Dolomite, pinkish, twinned ($Fe_2O_3$ or MnO). | 14, 20 | Plymouth . . . | Windsor . . . | 2 | 240 |
| Dolomite, gray, graphite, with small brecciated white dolomite beds, both granular. | 11 | . . . do . . . . . | . . . do . . . . | 1 | 240 |
| Dolomite, cream-colored, granular, some twinned grains. | 65 | Mount Tabor . | Rutland . . . | 2-4 | 237 |
| | 70 | Hancock . . . . | Addison . . . | 2 | |

[1] Calcite.
[2] Dolomite.
[3] As some of the explorations were made in 1888, others in 1911 and 1912, there was a duplication of locality numbers.



## STRATIGRAPHIC RELATIONS.

The relations of these various marble beds are evidently complex and some are very different from others. Their geologic positions can not be satisfactorily determined without extensive areal geologic work. All that can be done here is to bring together the more important stratigraphic data, draw such inductions as they justify, and show the relation of these results to what is established in Vermont geology. Each belt or group of localities will be taken up separately.

In Richford (p. 227) about 100 feet of white calcite marble with pinkish and greenish portions lies between parallel, steeply inclined beds of more or less graphitic sericite schist. The impregnation of the marble along joint and bedding planes with chalcopyrite may possibly indicate its having been overlain by the impervious schist and thus its anticlinal structure.

In Waterville (p. 228) coarse white calcite marble, about 62 feet thick, dips somewhat steeply between parallel beds of more or less graphitic sericite schist, some of it albitic.

In Johnson (p. 229) 11 to 70 feet of fine to medium whitish calcite marble is underlain by sericite schist and contains a large lens consisting mainly of secondary albite.

In Moretown (p. 231) medium-grained white to cream-colored calcite marble, 10 feet thick, with grayish clouds, dips steeply between parallel beds of sericite-chlorite schist with minute quartzose beds.

All these marbles are intimately associated with sericite schist, in Johnson the schist clearly underlying the marble and in Richford possibly overlying it.

In Hancock (p. 235) cream-colored sideritic granular dolomite, 25 feet thick, underlies (presumably by overturn) a fine banded muscovite granite gneiss and overlies (also by overturn) a slightly dolomitic chlorite-muscovite-quartz schist.

In Rochester (p. 239) a few feet of calcite marble mixed with dolomite and containing epidote is finely interbedded with sericite schist. The schist overlying this marble on the east resembles that along the base of the hill below the dolomite in Hancock. This marble is also associated with and probably underlain by several feet of epidote schist.

In Mendon (p. 236) 50 feet or more of white granular dolomite occurs in undetermined relations.

In Mount Tabor (p. 237) cream-colored granular dolomite, 20 feet thick, underlies 30 feet of more or less muscovitic quartzite, and both occur but a few hundred feet away from and a little above a considerable thickness of pre-Cambrian banded biotite-muscovite granite gneiss (Devils Den). Both series have the same strike but dip in opposite directions and are probably unconformable.

In Mount Holly (p. 237) white coarse twinned dolomite, 24 feet thick, dips at a medium angle, and sericite-biotite schist occurs above and below it. A few hundred feet south coarse, cream-colored calcite marble, about 18 feet thick, is in contact on one side and possibly underlain by what appears to be a fine-grained hornblende granite gneiss. The relations here have some similarity to those in Jamaica, 20 miles to the south-southeast (p. 250).

In Plymouth and Ludlow (pp. 237-243) fine-grained twinned white or pinkish or granular gray dolomite, from 50 to 75 feet thick, lies within a mass of more or less quartzose and felspathic mica schist and appears to be in disconnected lenticular masses. At one point (p. 242) interbedded dolomite, rose-colored and smoke-colored calcite marble, and quartzite, in all about 20 feet thick, underlie a considerable thickness of sericite schist and overlie a like thickness of quartzitic biotite-muscovite schist. The dolomite beds are intimately associated with a schist formation.

In Stratton (p. 253), about 27½ miles S. 23° W. of the Ludlow locality, coarse white calcite and fine dolomite marble, both twinned, about 60 feet thick, including a few feet of rose-colored calcite marble, are both overlain and underlain by muscovite schist having a dip of 50°, in monoclinal, synclinal, or anticlinal attitude.

In Dover (p. 257), at Bartlett's, rose-colored calcite marble, over 19 feet thick, appears to be both underlain and overlain by muscovite schist, striking N. 10°-40° W. Half a mile southeast of the marble and about 200 feet below it is muscovite-biotite granite gneiss with a foliation striking N. 35° E., unconformably to the marble. On Mount Pisgah about 50 feet of white granular dolomite and at least 10 to 15 feet of rose-colored calcite marble appear to be underlain by muscovite schist.

On Haystack Mountain, in Wilmington (p. 259) cream-colored to rose-colored calcite marble, at least 100 feet thick, is probably underlain by biotite schist containing porphyritic feldspars. Near the village, along the strike (p. 259), interbedded rose-colored calcite and white dolomite marble of undetermined thickness are underlain by muscovite schist.

In Readsboro (p. 232), about 8 miles S. 23° W. of the last-mentioned locality, is a coarse calcite marble, containing large scales of graphite and mica, associated with a biotite-muscovite schist that contains porphyritic (albite) feldspars. The strike points toward the marble of Wilmington (N. 25° E.), although that has a strike of N. 10°-35° W. Southeast of Readsboro, 1¾ miles down Deerfield River, graphitic calcite marble again appears, associated with feldspathic schist striking N. 20° E.



The outcrops in Searsburg (p. 261) belong to a belt a little west of the Wilmington belt. Calcite and dolomite marbles, 50 feet or more in thickness, are both underlain and overlain by mica schist, but at one point these marbles are underlain by a mass, probably a dike, of micadiorite schist, and at another they are in contact with a biotite-muscovite granite gneiss.

The induction from all these observations is that at the north, on the west side of the Green Mountain axis (Richford, Waterville), and also 26 miles south of Waterville (Moretown), on the east side, calcite marbles occur, associated with a schist formation. In Hancock granular dolomite overlies a granite gneiss and underlies a schist. In Mount Tabor, on the Green Mountain Range, such a dolomite, associated with quartzite, overlies a granite gneiss, and in Mount Holly a calcite marble overlies a granite gneiss, and a dolomite marble near by is associated with a schist. East of the axis, in Plymouth and Ludlow, 25 to 100 feet of dolomite or of calcite marble or of both interbedded lies within a muscovite or biotite schist formation of considerable thickness, which in places is quartzitic. These calcareous deposits seem to occur as lenses at irregular intervals within the schist. Finally, at the south, east of the axis (Stratton, Dover, Wilmington, Readsboro, Whitingham), rose-colored or white calcite marbles interbedded with dolomite are intimately associated with schist of sedimentary origin, and in Searsburg these rocks are in contact with granite gneiss and in Dover are not far from the gneiss and have a different strike.

The Jamaica localities show 70 to 125 feet of dolomite and calcite marble, in some places with some interbedded quartzite, in others with a few feet of quartzite at both the top and the bottom, the whole both underlain and overlain by muscovite-biotite schist of sedimentary origin. In some localities, however, the marble is in contact with a granite gneiss, either underlying it or, probably by an overturned fold, also overlying it. The marble apparently occurs in lenses, the schist from either side joining to cut it off.

In the belts east of the Jamaica belt the marble is still more intimately related to granite gneiss, although schist of sedimentary origin is generally also present in the more northern localities.

In Townshend (p. 250) there may be 50 feet of coarse calcite marble, in places actinolitic, in others chloritic, with biotite granite gneiss on both sides.

In Athens (p. 249) there may be 50 feet or more of coarse calcite marble, in places actinolitic or biotitic, with biotite granite gneiss on both sides of it.

In Cavendish (p. 243) the marble underlies, probably through overturn, and thus really overlies a granite gneiss, and is also overlain by a mica schist. At locality 38 (p. 244) 10 to 15 feet of white dolomite is both underlain and overlain by granite gneiss.

In the gorge (p. 244) dolomite and calcite marble, about 75 feet thick, are in similar relations to granite gneiss. At locality 139 (p. 244) about 15 feet of dolomite is in like relations. At locality 35 (p. 244 the calcite marbles appear also to occur within granite gneiss.

In Weathersfield (locality 36, p. 246) coarse rose-colored and actinolitic calcite marble appears to be inclosed in coarse muscovite-biotite schist containing porphyritic feldspars and beds of quartzite (?). Pegmatite dikes lie in the foliation, and a large intrusive mass of very coarse pegmatite is near by. At Amsden (locality 34, p. 247) coarse calcite marble not less than 45 feet thick, with finely interbedded dolomite and containing some specular iron ($Fe_2O_3$), in places also actinolite, appears to be overlain by feldspathic mica schist. At locality 37 (p. 248) dolomite over 30 feet thick is in contact with overlying feldspathic muscovite-biotite schist and appears to be also underlain by similar schist. At locality 142 (p. 248) 10 to 40 feet of dolomite is both underlain and overlain by such schist.

In the Orange County belt of marble the quartzose calcite marbles of Washington and Topsham (pp. 232-235), of uncertain thickness, but certainly 20 to 35 feet thick, are associated with more or less calcareous mica schist and are cut by dikes of pegmatite and biotite granite. This belt continues into Bethel Township, in Windsor County, where the marble is more graphitic and occurs in beds 2 to 5 feet thick in a graphitic sericite schist.

## GEOLOGIC AGE.

All but one of these deposits are unfossiliferous and the smallness and discontinuity of the areas examined prevent their definite assignment to geologic periods, yet whatever indications as to age they do afford are here given.

The granite gneisses upon which some of the marbles seem to have been deposited and with which they are interfolded are presumably of pre-Cambrian age. The presence of a mineral that is probably of the humite group in the marble of Townshend (p. 250) and in the diopside schist that is interfolded with the marble of Athens also points to the great age of the marble of those places. The relation of the gneiss associated with the marble in the northern part of Cavendish has been shown by Daly.[1] If the interfolding took place prior to the deposition of the Cambrian beds the interfolded marbles are also of pre-Cambrian age, but if the interfolding was due to a crustal movement that occurred at the close of Ordovician time then the marbles belong to the earliest Cambrian sediments. That calcareous sedimentation took place in pre-Cambrian time within the area of the Green Mountain Range has been shown by the

[1] Daly, R. A., The geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, Pl. VII, p. 17, 1903.



occurrence of an inclusion of marble with a reaction rim in the pre-Cambrian gneiss east of Mount Moosalamoo, in the town of Ripton. This determination was made by Arthur Keith in 1908. It seems probable that the marbles of Athens and Townshend, at least, possibly some of those of Cavendish and Weathersfield, and that of Mount Holly are pre-Cambrian.

The granular dolomite of Mount Tabor associated with quartzite and at a higher level than the neighboring pre-Cambrian gneiss of the Devils Den may easily be of Lower Cambrian age, as is the quartzite along the west foot of the range cut by Big Branch. The dolomites of Plymouth occur in a schist mass that is in close proximity to a quartzite and quartz conglomerate.

During a reconnaissance made in 1888 the writer observed on the west side of the Green Mountain axis, in the township of Shrewsbury, the Lower Cambrian conglomerate in contact with a large mass of muscovite (sericite) schist containing some calcareous streaks. In 1899, while exploring Downer Glen, on the west side of the Green Mountain Range in Manchester, the writer found schist up to 75 feet thick, some of it biotitic, associated with the Lower Cambrian quartzite. This schist occurs also at several other points on that side of the range, as well as on the intermediate ridge west of the Vermont Valley. The schists of Plymouth may therefore be of Lower Cambrian age.

The marbles that at various points (Jamaica, Dover, Searsburg) lie upon granite gneiss and are conformably overlain by schist of sedimentary origin may for the same reason also belong to the Lower Cambrian.

The Berkshire schist (Ordovician), which overlies the marbles of the Vermont Valley, includes here and there in Vermont and Massachusetts small areas of marble and in Vermont some thick beds of quartzite. On Mount Greylock, in Massachusetts, this formation includes an area several miles in length and width of dolomite and quartzite of variable thickness (25 to several hundred feet) and also of irregular continuity, schist taking the place of both rocks at intervals. From the foregoing facts and the occurrence of Cambrian schists west of the Green Mountain axis it follows that the schist that overlies, underlies, or incloses calcite and dolomite marbles in Richford, Waterville, Johnson, Stratton, Dover, Wilmington, Whitingham, and Readsboro may belong either to the Lower Cambrian or to the Berkshire schist (Ordovician). The age of these last-named marble deposits will probably not be determined until the reason for the absence of the Ordovician marble of the Vermont Valley east of the axis of the Green Mountain Range has been ascertained by further geologic mapping.

The quartzose calcite marbles of Topsham and Washington belong to the formation described by C. H. Richardson as the Waits River limestone, which is regarded by him on paleontologic evidence as of Ordovician age.[1]

The dikes associated with the marbles described in this bulletin differ greatly in age. The diabase dike in Cavendish may be of Triassic age. The pegmatite and biotite granite dikes of Washington and Topsham probably belong at the close of Carboniferous or in Devonian time. The metamorphism of the amphibolite dikes in Whitingham and Dover probably took place at the close of Ordovician time, but the age of the dikes themselves would in any case be later than Lower Cambrian. J. E. Wolff[2] described an amphibolite dike near Mount Holly, southeast of Rutland, which is in quartzite.

## GENERAL SCIENTIFIC SIGNIFICANCE OF THE DATA.

Perhaps the most important scientific feature of these deposits is the prevalence of a coarse-textured manganese-bearing rose-colored calcite marble, alternating in very small beds with equally small beds of fine-textured white dolomite. In thin sections the demarkation between the calcite and dolomite is usually sharp. The small percentage (0.23-0.49) of manganese oxide in one and its absence in the other set of beds point to different kinds of sediment rather than to an intermittent process of dolomization affecting only the beds without the manganese. The interval of time represented by each little bed must have been relatively short.

Some very recent chemical investigations by Bertrand and Medigreceanu[3] show that both are calcareous and soft parts of marine mollusks (Ostrea, Pecten, and Mytilus) contain manganese in percentages ranging from 0.15 to 1.91 (or in one extreme case, 3.66) and averaging about 0.5. May not the manganese to which the rose color of these calcite marbles is largely due have been extracted from sea water by the organisms whose remains produced the calcitic sediments? Does not also the absence of the manganese coloration from the intervening dolomite beds point to the possible inorganic deposition of dolomitic sediments under conditions not yet perfectly understood?[4]

As the thickness of the dolomite and calcite beds together can hardly exceed 150 feet at any of the localities visited, whereas these beds in the western part of the State measure several hundred feet each, it is evident that conditions favorable to calcareous sedimentation were of much shorter duration in the eastern part than in the western part.

Another interesting feature is that the dolomites here described are nearly all twinned, whereas those in western Vermont are generally granular. Whether this difference is due to the

[1] Richardson, C. H., The terranes of Orange County, Vt.: State Geologist, Vermont, Rept., vol. 3, p. 94, 1902.
[2] U. S. Geol. Survey Mon. 23, pp. 65-69, fig. 25, 1894.
[3] Bertrand, Gabriel, and Medigreceanu, F., The presence of manganese in animals: Am. Jour. Sci., 4th ser., vol. 35, p. 321, 1913, Abstract of article in Soc. chim: France. Bull., 4th ser., vols. 13-14, pp. 1824, Jan. 5, 1913.
[4] See, for discussion of origin of dolomite, Dale, T. N., The commercial marbles of western Vermont, p. 25-29, this Report.



pressure on the dolomite having been more intense east of the Green Mountain axis or to some more obscure cause is uncertain.

Some of the rose-colored marbles are finely interbedded with greenish actinolitic marbles. As actinolite is a silicate of magnesia, iron, and lime there must have been at some time such a change in the sediments as to have supplied manganese in a form that combined with carbonic acid to produce a carbonate and at another time a change that brought in silica, magnesia, and iron oxide, which under metamorphism combined with lime as actinolite.

The brecciated dolomite of Plymouth resembles the brecciated dolomite of Swanton, except that the ground in the former is graphitic, but in the latter hematitic, and that the breccia of Plymouth, so far as explored, is without corals.[1] The brecciation of the little nongraphitic beds must be attributed to their having been of rigidity greater than that of the intervening graphitic parts. In thin section the only other perceptible difference between them is that the white beds contain a few quartz grains.

The quartzose graphitic calcite marble of Orange County owes its peculiarity to contemporaneous calcareous and mechanical quartzose sedimentation, so that over 25 per cent of the rock is quartz. The graphite is of organic origin. This is really a quartzite (quartz sandstone) and a calcite marble combined. The banding is due to variation in the amount of quartz and graphite at intervals and to a repetition of such variation.

The history of those marble beds which are interfolded with pre-Cambrian granite gneiss involves either the deposition of calcareous sediments upon denuded intrusive granite and the alteration of these rocks by subsequent metamorphism respectively into marble and gneiss, followed by interfolding, or else the metamorphism in pre-Cambrian time of a granite intrusive into gneiss, the deposition thereon in Cambrian time of calcareous sediments, followed by their metamorphism into marble and the interfolding of both marble and gneiss in late Cambrian or late Ordovician time.

The history of the marbles inclosed in schist begins with a period of clayey and sandy sedimentation from the erosion of granitic rocks on the neighboring land masses, followed by a period of clear water and organic sedimentation, possibly accompanied by or alternating with some chemical dolomitic precipitation and followed by another period of mechanical sedimentation like the first. During the post-Ordovician crustal movement the clays and sands went into feldspathic and garnetiferous mica schist and the calcareous sediments into calcite and dolomitic marble. At this time also the beds were folded into close overturned syncline and anticline. Later movements elevated and modified them. Erosion during the long period since the close

[1] See Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bul. 521, Pls. V, *B*, and VIII, *A* (c), 1912.

of Ordovician time has produced the present surface features and exposed the edges of the marble beds.

At several points along the contact of marble or dolomite and granite gneiss chemical reactions between silicates and carbonates have taken place under regional metamorphism, resulting in the formation of a few inches or feet of actinolite or diopside schist or in the growth of crystals of actinolite or tremolite within the calcareous beds. The most interesting example of this is in Athens (p. 249), where the calcite marble is sharply interfolded with biotite gneiss, and between them are a few feet of diopside schist containing large disseminated hornblende crystals half an inch in diameter. In Cavendish (p. 243) the marble is associated on one side with a mass of calcareous epidote-hornblende schist. In Mount Holly (p. 237) the dolomite marble and garnetiferous sericite-biotite schist are separated by 5 feet of actinolite schist with a little epidote and biotite, and the dip joints in the marble are filled with fibrous actinolite. In Weathersfield, on Pine Hill, half a mile east of Perkinsville (p. 246), the dolomite at its contact with muscovite-biotite schist contains a little tremolite.

To similar reaction should be attributed the presence of "mountain leather," or felty asbestos, in bedding and joints of the dolomite and marble of Swanton and Ira;[1] also the rim of scapolite and garnet surrounding a large oval autoclastic block of hornblende granite gneiss within the pre-Cambrian calcite marble of Flat Rock, near Fort Ann, in Washington County, N. Y., visited by the writer with James F. Kemp, in 1899.[2]

Of scientific interest is the occurrence of a 10-foot lens, mostly of secondary albite, in the marble of Johnson, described on page 229. Albite feldspars occur throughout the schist of the Taconic Range, though in varying amount, and were also found in the schists associated wtih the marbles and dolomites at Waterville, Plymouth, Weathersfield, Jamaica, Stratton, Dover, Wilmington, Whitingham, Searsburg, and Readsboro.[3] In thin section the albites of this lens, many of them simple twins, measure up to 0.2 inch in diameter and contain minute objects in stratiform arrangement, and as the feldspar extends beyond the ends of the little beds it seems to have had two periods of growth. Many of the minute particles are tourmaline prisms; some are

[1] See Dale, T. N., U. S. Geol. Survey Bull. 521, pp. 44, 147, 1912.

[2] See Kemp, J. F., Crystalline limestone, ophicalcite and associated schists of the eastern Adirondacks: Geol. Soc. America Bull., vol. 6, pp. 252, 253, 1895.

[3] See literature of this subject:

Emmons, Ebenezer, Geology of the second district of New York State, p. 158, 1842.

Wolff, J. E., Metamorphism of clastic feldspar in conglomerate schist: Harvard Coll. Mus. Comp. Zool. Bull., vol. 16, No. 10, p. 183, 1891.

Whittle, C. L., Some dynamic and metasomatic phenomena in a metamorphic conglomerate in the Green Mountains: Geol. Soc. America Bull., vol. 4, pp. 164, 165, 1893.

Pumpelly, Raphael, Wolff, J. E., and Dale, T. N., U. S. Geol. Survey Mon. 23, pp. 52, 60-62, 183, 186-188, fig. 73, Pls. VII, *A*; VIII, 1894.

Dale, T. N., Structural details in the Green Mountain region and in eastern New York (second paper): U. S. Geol. Survey Bull. 195, pp. 16-18, figs. 5, 6, 1902.



exceedingly minute and opaque (graphite?). Rutile needles are present. There are also roundish to oval particles of uncertain nature. In one of the feldspars the little bed of inclusions is sharply plicated, and slip cleavage is about to arise. There can hardly be a question as to these feldspars being entirely secondary and not altered pebbles of another feldspar.

This lens of albite-chlorite-muscovite-quartz schist contains a half-inch bed of marble, plicated with it. The general inference from the facts here is that the mechanical argillaceous sediment under metamorphism passed into a very albitic schist just as the organic calcareous sediment passed into marble.

The impregnation of the marble of Richford (p. 228) with chalcopyrite is, so far as known, unique in the white marbles of the State. As the ore occurs in some of the dip joints the impregnation may not have occurred until long after the first metamorphism of the region.

The occurrence of a mineral of the humite group in the marble of Athens and Townshend should be mentioned here. Inasmuch as the humite minerals are usually found in rocks of pre-Cambrian age this occurrence affords an indication of the age of the marble; and this indication is corroborated by the presence of the granite gneiss and the unusual reaction zone of diopside schist.

The detrital zircons in the marble of Haystack Mountain, in Wilmington, are presumably derived from the pre-Cambrian gneiss of the land mass of Cambrian and Ordovician time.

Of special structural interest is the marble outlier at Johnson, described on page 229. Here are illustrated in miniature principles governing the structure of large mountain masses in a region of folding. An intensely folded marble synclinorium, as it were, having a pitching axis, has been folded transversely and in the direction of the pitch, while the surrounding and underlying schist mass has acquired slip cleavage with a strike parallel to the pitch of the folds and a steep eastward dip. Finally marble and schist have suffered glacial striation in a diagonal direction. The little outlier thus combines several of the typical structural features of the Green Mountain region.

One general characteristic of all the marble and dolomite localities is the truncation of the folds, which makes it impossible to determine whether the beds are synclines or anticlines; and in view of the number and duration of the geologic periods that have passed since the schist of the Ordovician became exposed to erosion and of the vast amount of erosion the region has consequently suffered this minor effect of it is not surprising.

## ECONOMIC POSSIBILITIES.

The possibilities here set forth for the economic use of the eastern Vermont marbles are exclusively those of architectural decoration.

The quartzose marbles of Orange County, owing to their content of pyrite or of iron carbonate or of both, are quite unsuitable for monumental work, but the banded variety described on page 232 might be used for internal decoration wherever the demand is sufficient to offset the extra cost of polishing due to its large content of quartz.

The rose-colored coarse-grained calcite marbles, finely interbedded with fine-grained white dolomite, which is also twinned and therefore polishable, is a very attractive stone well suited for internal decoration, but owing to the nondurability of its color it is unsuitable for outdoor exposure.

As stated in the descriptions some of the marble and particularly the dolomite is so cut up by close joints as to preclude a supply of large blocks suitable for sawing and polishing.

At most of the localities the exposures are insufficient to show either the entire thickness of the marble or the soundness of its beds. At Waterville and Moretown the white calcite marble, although of superior quality, occurs in so small a quantity and is so remote from railroad facilities as to have no commercial architectural value.

The following list includes those localities where the colors and quality of the stone and its possible thickness warrant prospecting by trenching and core drilling, but it is to be distinctly understood that this prospecting should be done only on such a financial basis as would stand purely negative results.

Athens (locality 42, p. 249): Coarse light pinkish and greenish calcite marble.

Cavendish (locality 35, p. 243): Coarse white and rose-colored calcite marble with some actinolitic beds.

Jamaica (locality 40, p. 250): Interbedded rose-colored calcite and white twinned dolomite.

Plymouth (locality 18, p. 240): White twinned dolomite with some purplish spots; (locality 11, p. 240; also Orich Ward prospect, p. 241); Brecciated gray and white granular dolomite.

Richford (p. 227): White calcite marble with pinkish and light greenish bands and dark greenish streaks, and local phases of malachite-green.

Rochester (p. 239): Whitish calcite marble and dolomite, thinly interbedded with sericite schist.

Townshend (locality 41, p. 250)): Coarse light pinkish and greenish calcite marble.

Weathersfield (locality 36, p. 246): Coarse rose-colored calcite and green actinolitic marble.

Wilmington (locality 83, p. 259): Interbedded rose-colored calcite and white twinned dolomite marble; (locality 85, p. 259): Cream to rose-colored coarse calcite marble.

In connection with the economic side of the subject attention should be called to the fact that wherever a bed of marble is both overlain and underlain by granite gneiss the marble must be doubled upon itself and its real thickness can be only one-half of its apparent thickness, and that in such places the extent of the doubled bed along the dip should be determined, as it may be very slight.

# THE TERRANES OF GREENSBORO, VERMONT.

Charles H. Richardson and Homer G. Turner,
Syracuse University.

## INTRODUCTION.

The report upon the terranes of Greensboro is brief. It may be considered as one of progress in the solution of the intricate geological problems of northern Vermont. The first named author traversed this area in reconnaissance work in 1895 and again in 1905, but it was not until the summer of 1912 that detailed study could be given to the field. During this season the problems involved were definitely outlined and much material collected for laboratory study. The amount .of time available for the work was inadequate for the completion of a definite unit in 1912. In the summer of 1913 C. H. Richardson, H. G. Turner, A. E. Brainerd, D. J. Jones, S. H. Camp and P. Camp pitched their tent on the southwest shore of Caspian Lake and made a detailed study of the area involved in this report.

A reason for selecting this area is that Greensboro lies in the line of the erosional unconformity between the Upper Cambrian schists and quartzites and the lowest of the Ordovician series represented in the eastern half of the State. To follow this unconformity it became necessary to make an offset of one township to the east of Craftsbury whose geology was covered in the last Annual Report of the State Geologist. If the work had been southward from Craftsbury along the line of the general strike of the rocks and the east and west town lines it would have carried the investigations into schists and quartzites of Upper Cambrian age where no intrusives of economic significance appear.

A second reason for making the offset lies in the fact that the work extended southward from Greensboro, along the line of the erosional unconformity already mentioned, embraces a series of townships whose economic possibilities in the granite industry are large. A still further extension of the work southward would include Montpelier and Northfield with a past and present recognized slate industry. The geology of Hardwick and Woodbury appears in another chapter in the present Annual Report by the State Geologist.

# REPORT

OF THE

# STATE GEOLOGIST

ON THE

## MINERAL INDUSTRIES AND GEOLOGY

OF

# VERMONT,

## 1913 - 1914.

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NINTH OF THIS SERIES.

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GEORGE H. PERKINS,

State Geologist and Professor of Geology,
University of Vermont.

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BURLINGTON, VT.:
FREE PRESS PRINTING COMPANY,
1914.

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One hundred and seventy-five new rock specimens have been collected in Greensboro, Hardwick and Woodbury and carefully trimmed to the standard uniform size, three by four inches, for laboratory study and exhibition in the State Museum at Montpelier. This brings the total number collected in my work in the eastern half of the State to six hundred and twenty-seven. The specimens represent a very important series of rocks, ranging in age from Cambrian to Triassic, in mode of origin both igneous and sedimentary, and in chemical composition both acid and basic.

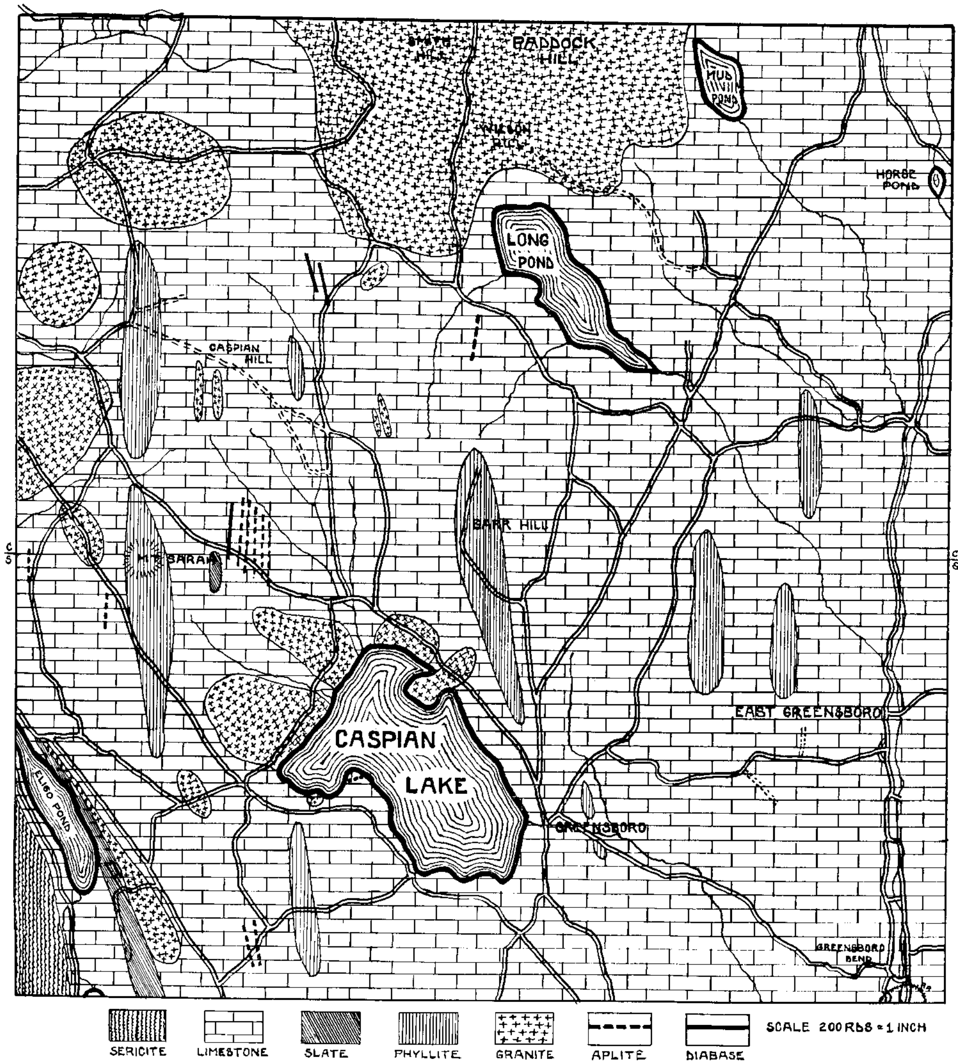
Plate XLVIII shows the geographical distribution of the terranes within the area involved, and below the map is a protracted section across the township from east to west near the center of the town and nearly at right angles to the strike of the sedimentaries. A map cannot be accurate until a topographic survey of the eastern half of the State has been made. Then it will be a pleasure to map with accuracy the geological formations represented. It is to be hoped that topographic maps of some of the townships to the south of Greensboro that have large economic possibilities may soon be made available.

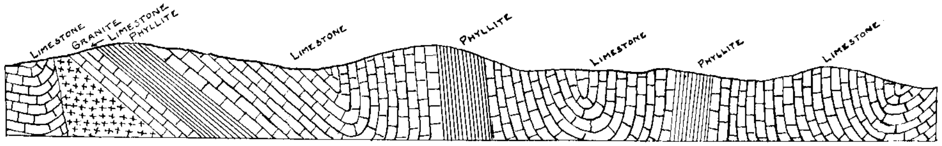
I wish also to recognize herewith my great indebtedness to Dr. Rudolf Ruedemann, State Paleontologist, Albany, N. Y., for his services in the identification of crushed graptolites in the limestones, and for his examination of the badly weathered and crushed material strikingly suggestive of fossils from Irasburg and Albany. Additional evidences of crushed graptolites from new areas were discovered this summer and these have also been forwarded to Dr. Ruedemann for examination. Furthermore, I wish to acknowledge my indebtedness to Arthur E. Brainerd, Instructor in Geology at Syracuse University, Daniel J. Jones, graduate student in Geology, Samuel H. Camp, graduate student in Mineralogy, and Philip Camp for their assistance in working out the details of the intricate problems involved in the area covered in this terse report.

## DRAINAGE.

The drainage of Greensboro is intensely interesting for in its inception the waters flow in all possible directions. The height of land separating the waters flowing north into Lake Memphramagog from those flowing south into the Lamoille River, which empties into Lake Champlain, is normally parallel with the north town line of Greensboro. In the extreme western part of the township there are several small streams that flow in a westerly direction into Craftsbury then turn in a southerly direction and flow into Black River, or the northern extremity of Eligo Pond, from which the Black River flows almost due north towards Lake Memphramagog. The waters in the central part of Greens-






MAP OF GREENSBORO.
East town line is N. 40° E.
SECTION ACROSS GREENSBORO

boro flow in a southerly direction into Caspian Lake, whose outlet is through Mill Branch into the Lamoille River. The waters in the eastern part of the township flow in a southerly direction as the head waters of the Lamoille River. One of these is the outlet of Long Pond and another is the outlet of Mud Pond. The largest river or stream of water is the Lamoille whose course is practically parallel with the eastern town line, south 40 degrees west.

In the extreme southwestern corner of Greensboro there are strong evidences of a pre-glacial drainage of the waters of Eligo Pond to the south into Little Eligo Pond which lies mostly in Hardwick, but a part of this pond is in Greensboro. The outlet of Little Eligo is Alder Creek which flows southerly into the Lamoille River. The two Eligo Ponds are separated from each other by about 200 rods. There is no marked line of elevation between them. The local report is that Eligo Pond has an outlet both at its northern and southern extremities, each flowing in opposite directions. The fact is that there is a very small sluggish stream flowing northward into Eligo Pond and another flowing southward into Little Eligo Pond. The distance between these head waters in the Eligo Valley is less than ten rods. The area is swampy and evidence of a southerly drainage of Eligo Pond in post-glacial times is not wanting. Eligo Creek and Whetstone Brook in Craftsbury were the head waters in pre-glacial times for Eligo Pond and subsequently for the Lamoille River. If the conjecture be true, we have here an excellent illustration of the migration of a divide and the beheading of a stream. This accident would explain the abrupt turn to the north of streams whose initial waters flow in a southerly direction in Craftsbury. How much of this work may have been accomplished by the ice when it moved to the south, broadening and deepening the U-shaped Eligo Valley I cannot say. According to the aneroid barometer readings this summer a rise of three feet in the waters of Eligo Pond would cause a partial drainage of its waters through Little Eligo Pond into the Lamoille Valley.

The streams of Greensboro are mostly small and rapidly flowing. Some of them have furnished small water-powers for cutting local lumber and grinding grain. An excellent water-power still in use is found on Mill Branch in the village of Greensboro. The fall in this stream from Caspian Lake to the Lamoille River exceeds 200 feet.

## TOPOGRAPHY.

The area traversed lies to the east of Craftsbury and to the south of Glover, both of which are in Orleans County, and to the west of Stannard and the north of Hardwick, both of which are in Caledonia County. The east and west town lines are parallel in their extension, north 40 degrees east or south 40 degrees west. It covers an area of approximately forty square miles.

The valley of the Lamoille River in Greensboro is broad, U-shaped and longitudinal. Its course is nearly parallel with the strike of the limestone over which it flows but in Hardwick it turns to the west and flows directly across the strike of the rocks. Its course is roughly determined in Greensboro by a less resistant belt of limestone which lies between isolated beds of non-calcareous sedimentary rocks on the west and more highly altered sedimentaries on the east. The schists to the east are not within the range covered by the accompanying areal map.

The broad pre-glacial Eligo Valley is represented only in the southwestern corner of Greensboro. Its course is determined by the general strike of the planes of schistosity in the Cambrian rocks that lie upon the west of Black River in Craftsbury and Alder Creek in Hardwick. The bed of these streams was originally farther to the east than at present for erosion has been carried downward along the planes of cleavage in the sedimentaries whose dip is here at a high angle to the westward.

Many of the smaller streams flow across the strike of the rocks and their present beds are in transverse valleys. Some of them form an angle of about 45 degrees with the strike of the sedimentaries over which they flow.

The eastern and broken belt of phyllite schist forms prominent ridges that roughly strike north 40 degrees east. These ridges are cut by Long Pond Brook which empties into the Lamoille River. This valley stretches almost due north and south. Extending in the same direction are the two valleys in the northeast part of the township and the valley of Mill Branch in the southeastern part of the township.

In the central part of Greensboro and to the northeast of Caspian Lake there appears a belt of resistant phyllites somewhat interbedded with limestone. The highest elevation of this central ridge is 1,950 feet on Barr Hill. Intensely interesting alpine valleys appear well developed on the south side of the hill and less perfectly developed on the north side. The valleys lie for the most part in beds of limestone that are interstratified with the prevailing phyllites. They conform in direction to the general strike of the rock north 20 degrees to north 40 degrees east. They bear marked evidences of ice erosion.

The westernmost ridge of phyllite extends in a general northeasterly and southwesterly direction. In its southern extension it reaches its highest altitude 2,000 feet on Mount Sarah. In its more northerly extension the Calderwood hills reach an altitude of between 1,700 and 1,800 feet.

Caspian Hill is situated between Barr Hill on the east and Mount Sarah on the west. It is almost due north from Caspian



Lake and reaches an elevation of 2,000 feet. It is from this hill that the finest view of Caspian Lake is obtainable amongst all the prominences of Greensboro.

The highest altitude in Greensboro is in the northern part of the township where Paddock Hill reaches an elevation of 2,100 feet. Smith Hill to the west of Paddock Hill reaches an altitude of 2,050 feet. These higher altitudes result from the introduction into the sedimentaries of intrusive granite. A large granite area connecting these two hills is seen on the areal map. The granite is far more resistant to erosion than the limestones and schists.

The beautiful village of Greensboro is situated on Mill Branch, the outlet of Caspian Lake, at an altitude of approximately 1,200 feet.

The ridges above mentioned are well rounded, due in part to glacial action. Between the ridges there are broad, fertile, U-shaped valleys. The highlands consist almost entirely of schists and granite while the lowlands are carved out of the less resistant limestones. Caspian Hill is perhaps an exception to the general rule, for here the rocks exposed are prevailingly limestone. Perhaps beneath the limestone there lies a granite mass that has not yet been brought into view by erosion.

The folding of the strata has been in part responsible for the formation of ridges and valleys. In the east and west cross section the ridges appear as anticlines, while the broader and older valleys are in the synclines.

## LAKES.

Greensboro is dotted with four ponds and one lake. Eligo Pond is situated in the southwestern part of the township. It lies mostly in Greensboro but it extends northward into the edge of Craftsbury. It is about one and one-half miles long and about one hundred rods wide at the widest place. Little Eligo Pond lies mostly in Hardwick but the south town line of Greensboro passes through the northern end of the pond. These ponds lie also along the contact between the Cambrian and Ordovician terranes. They are flanked on the west by the Cambrian highlands and on the east by Ordovician limestone and slate. No outcrop of Cambrian schists was found to the east of either pond.

Long Pond, in the north central part of Greensboro, lies also in the limestones. It is about one and one-half miles long and one hundred and eighty rods wide at its widest point. Its longer axis lies in the direction of one of the ice movements in Vermont and the valley appears to have been deepened by ice erosion.

Mud Pond is situated in the northeastern part of the township a little to the southeast of Paddock Hill. It is about two hundred rods long and one hundred rods wide. Its bed is in limestone. Horse Pond, as it is sometimes called, is a very small and circular pond, about fifty rods in length, that is situated in the northeastern part of the township close to the Caledonia County line. The longer axis of all the ponds extends nearly north and south. These basins may have been caused in part by the erosion of the great ice sheet, but in the main they were formed by a deposition of morainal material across the outlet of the pre-glacial valleys in which they lie. They are all shallow bodies of water.

Caspian Lake is situated in the south central part of Greensboro. It possesses some rather unusual features. Owing to the transparency of its waters and the delightful scenery surrounding the lake it was once called Lake Beautiful. Caspian Lake is two miles long and more than a mile wide at the widest point. Unlike the ponds already mentioned its bed is not entirely in the limestones and schists. The greater part of the lake, however, does lie in the limestone and interstratified Ordovician phyllite schists. The northern shore is composed of several outcrops of granite separated from each other by limestone valleys. These granite intrusions can be traced for one hundred yards beneath the surface of the lake. A careful search for intrusives reveals the presence of granite on the east side of the lake and a dike of granite extends from Burlington Point on the west side out into the lake. The existence of this interesting point is in part due to intrusives.

Another interesting feature is the altitude of the lake with respect to that of the village of Greensboro. Barometic readings gave the lake at an altitude of 1,240 feet and the main street of the village at 1,220 feet. The lake is held in by an artificial wall with narrow flood gates at its outlet into Mill Branch. This stream furnishes excellent water-power for the various mills in the village.

The lake owes its origin in part to the structure of its rock bed for a part of it at least lies in a synclinal trough. Glacial erosion appears to have deepened the pre-glacial valley in which the lake now lies. Morainal material was also deposited across the valley. It would require but a few hours' work with a shovel near the present outlet to drain the entire lake.

So beautiful is the scenery about the lake with its tree-clad banks and points jutting out into the lake, so invigorating is the atmosphere, and so full are the waters of the lake with eight different species of trout that Greensboro has come to be one of the most important summer resorts of the central part of the State.

## GLACIATION.

A considerable portion of Greensboro is covered with a mantle of morainic material. This is especially true in the southern

PLATE XLIX.

ORDOVICIAN VALLEY FOREGROUND, CAMBRIAN HILLS IN BACKGROUND, HARDWICK AND CRAFTSBURY part of the township where one may travel miles without finding a single outcrop of rocks. The general movement of the ice was in a southerly direction as proven by the presence of boulders and the striations on the more resistant rocks. In addition to the boulders of the sedimentaries in Greensboro there were found boulders of the Cambrian quartzite from Troy, serpentine from Belvidere Mountain, amphibolite, diabase, camptonite, and granite from sections to the north of Greensboro.

Evidences of glaciation and the direction of the ice movement are the striations still remaining on the more resistant rocks of the region. On a quartz outcrop to the east of Greensboro village striations were recorded south 20 degrees west. Along the road to East Craftsbury two miles from the north end of Caspian Lake striations were found on phyllite schist extending south 20 degrees east. On the phyllites of Barr Hill striations were recorded south 40 degrees east and south 10 degrees east. These varying directions imply more than one ice movement. In some instances the earlier sets of striations are plainly cut by those of a later movement.

## GEOLOGY.

### CAMBRIAN.

The Cambrian series of rocks are represented in Greensboro only in the extreme southwestern corner of the township. They extend northward into Craftsbury and southward into Hardwick. They comprise a sericite schist and a quartzite. The former passes by insensible gradations into the latter. No attempt has been made to separate these terranes on the map. Their general strike is north 20 degrees east and their dip averages about 85 degrees west. They form an almost perpendicular scarp several hundred feet above the broad, flat Eligo Valley, which lies in the Ordovician terranes. Plate XLIX shows the Ordovician valley in the foreground, Greensboro, Vermont, with the Cambrian hills in the background in Hardwick and Craftsbury.

These rocks often appear very light colored on their weathered surfaces and have sometimes been mistaken for outcrops of granite from a distance. The sericite schist lies at the base of the Cambrian highlands and therefore forms the line of contact with the Ordovician. It does not follow that the schist is older than the quartzite. The schist consists mainly of fine grains of sand with much muscovite (scaly and fibrous sericite). The mica predominates. Garnet and pyrite appear as secondary minerals.

In the Cambrian quartzite, quartz predominates over the sericite. Many samples may be cataloged as quartz schist. Certain bands of the quartzite show but little schistosity and few scales of mica but for the larger part the schistosity is pronounced and the mica abundant. In the northwesterly extension of the quartzite into Lowell it becomes a conglomerate with quartz pebbles up to an inch or more in diameter. Microscopic slides of these formations have been prepared and studied but as new slides are now in the process of preparation of these two formations as they appear in Hardwick a more complete statement as to their mineralogical composition will appear in the report on Hardwick and Woodbury.

### ORDOVICIAN.

The Ordovician terranes comprise a group of limestones, slates and phyllites extending across the township roughly parallel to the Cambrian rocks.

The Ordovician terranes are interstratified more or less with each other but the limestones predominate. These formations will be considered separately in the discussion which follows.

### IRASBURG CONGLOMERATE.

The Irasburg conglomerate which lies at the base of the Ordovician series was discovered by the first named author of this report just south of the village of Irasburg during the summer of 1904. The extent of the conglomerate was then unknown although it was known to cover a considerable area. It was deemed of large enough significance to give it a distinct geological name. It has now been followed southward along the line of contact between the Cambrian and Ordovician terranes for a distance of more than twenty-five miles. The highly contorted limestone which in Irasburg serves as the matrix of the conglomerate binding the large pebbles together now constitutes the main mass of the rock. The pebbles have diminished in both number and size. In fact many possible pebbles are now indistinct and some spheroidal masses strikingly suggestive of pebbles may be the more resistant portions of the limestone itself. These are occasionally found in the disintegrating limestone along the Eligo Pond road. However, one unmistakably porphyrite pebble was found in Greensboro in the conglomerate. It was five inches long and three inches in diameter. At Irasburg the coarseness of the conglomerate suggests a shallow water or near shore formation. It may be that in Greensboro the waters were deeper and the material finer. It may be that here erosion has not been carried as low on the formation as it has in the more northern areas.

### WAITS RIVER LIMESTONE.

The Washington phase of the Waits River limestone is the prevailing limestone of Greensboro. It is a steel gray silicious limestone bearing about thirty-five per cent of silica. It is usually quite free from pyrite save where it has been effected by intrusives. The Waits River phase which is a beautifully banded variety closely resembling Columbian marble is represented only in the eastern part of the township, if represented at all. Here the characterisitic bandings are absent and the rock as a whole is much lighter in color than the characteristic Washington phase. As the banded variety overlies the steel gray limestone in the localities from whence they derive their names it is possible that erosion has been carried deep enough in this area to remove the major part of the banded phase if it was originally deposited in Greensboro.



The Washington phase is interstratified or interbedded with slates and phyllites. In the areal map many sections are mapped as limestone where narrow bands of phyllite appear. Only the beds of non-calcareous sediments that represent mapable areas are represented as phyllite or slate. Both transverse and longitudinal valleys are pronounced in this terrane. The soil derived from the disintegration of the limestone is naturally rich in lime content, dark in color and very productive. The contact line between the Cambrian and Ordovician can be drawn with a considerable degree of accuracy by the marked change in the character of the soil.

The average strike of the limestone is approximately north 40 degrees east. It varies however from north 10 degrees east to north 60 degrees east. A strike of north 10 degrees east is found a little to the west of the north end of Caspian Lake. The strike of an outcrop on the Eligo Pond road was north 20 degrees east. In the vicinity of Eligo Pond a strike was recorded north 60 degrees east. The strike of the limestone in Greensboro is by no means a constant. It varies 50 degrees which is a small angle of variation in comparison with changes in strike in Woodbury which will be found recorded in the chapter on the Geology and Mineralogy of Hardwick and Woodbury.

The dip of the limestone beds varies from 15 degrees east to 85 degrees west. Easterly dips are found a little west of the Lamoille River in the eastern part of the township, west of the north end of Caspian Lake, to the west of Barr Hill and also near Eligo Pond. Westerly dips appear on the east along the eastern town line and alternate in crossing the township with the easterly dips above cited. The pitch of the strike is about 15 degrees north. In some instances it becomes sufficiently pronounced to suggest a northerly dip of the beds themselves.

In the lower altitudes in general where erosion has been carried deeper on the formation some of the beds of limestone are sufficiently massive and crystalline to receive an excellent polish. In such cases the rock becomes a quartzose marble. In the higher altitudes the limestone is generally shaly and often splits easily into slabs less than an inch in thickness. This feature can be seen a little to the west of Caspian Hill where the authors have split out small slabs of the limestone with hammer and chisel less than half an inch in thickness.

The limestones of Greensboro represent siliceous sediments that were largely calcareous and therefore they are all of sedimentary origin. New proofs that they are of Ordovician age will be submitted under the caption of paleontology. Plate L represents the westerly dip of the limestone with a vein of quartz on the crest of the outcrop.

## QUARTZ VEINS.

Many veins of nearly pure white secondary quartz, often pyritic and slightly auriferous traverse the limestones. Sometimes these veins conform roughly to the strike of the rock and sometimes they appear nearly at right angles to the strike. They vary in width from a few inches to several feet. They often appear as lens-shaped masses in the limestones and slates. Near the village of Greensboro and a little to the southeast there are two of these veins. One is nearly 30 feet wide and the other is 12 feet wide. Their strike is north 40 degrees east.

About two miles north of Caspian Lake on the G. Y. Spiers farm there is another quartz vein 14 feet wide with strike north 40 degrees east. It was followed almost continuously to the northward for about half a mile.

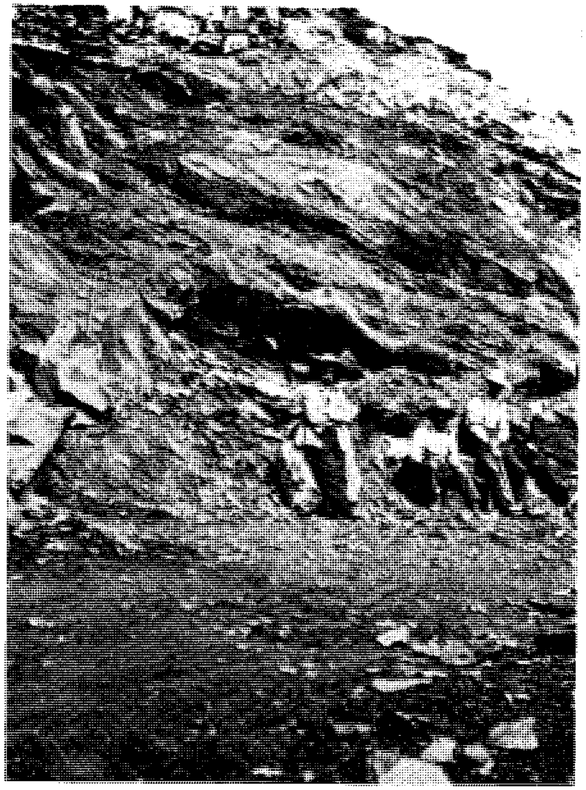
## SLATES AND PHYLLITE.

The slates and phyllites are more or less interbedded with the limestone in Greensboro as well as in the northern townships whose geology has been covered in the earlier reports. There are three main belts of phyllite traversing the township in the direction of the strike of the limestones, north 40 degrees east, which is also the average strike of the phyllites.

The western belt extends in a southerly direction from near the Barclay granite outcrop to a point almost due west from the center of Caspian Lake. It appears however to be interrupted in the valley that leads from East Craftsbury to Greensboro. In a belt about four miles long and half a mile wide scarcely any outcrop of limestone could be found. The exposures were phyllites occasionally cut by granite dikes as if granitic masses lay beneath the beds of phyllite and were in some measure responsible for the high altitudes of Sarah Mountain and the Calderwood hills to the north of Sarah Mountain and to the south of Barclay Hill which bears granite.

Where the altitude is the highest, where the folding has been the most intense and where the phyllites lie the nearest to intrusives they lose a part of their schistosity and become exceed-

PLATE L.



LIMESTONE, WESTERLY DIP SHOWING VEIN OF QUARTZ ON CREST OF OUTCROP, GREENSBORO.

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PLATE L.

LIMESTONE, WESTERLY DIP SHOWING VEIN OF QUARTZ ON CREST OF OUTCROP, GREENSBORO.

ingly tough. The blocks are formed by numerous joint planes. It is with great difficulty that museum samples are trimmed to standard size from some of these tougher masses. In the remainder of the belt mapped as phyllite the characteristic schistosity of the non-calcareous sedimentaries is everywhere present.

A little to the northeast of Caspian Lake there appears a belt of phyllite that strikes about north 40 degrees east over Barr Hill. In some cases a strike of north 20 degrees east was recorded. This belt is nearly two miles long and half a mile wide. It is in part to the presence of this more resistant phyllite that Barr Hill owes its elevation of 1,950 feet.

The eastern belt is more broken than the other two belts. One of the best exposures of the phyllite is found in the eastern part of the township on the A. S. Clary farm. Plate LI shows an outcrop of phyllite schist on the farm of A. S. Clary, Greensboro, Vermont. The dip is to the east. The northern part of this belt appears more highly metamorphosed than the southern. It may lie in closer proximity to intrusives and the folding has been more intense. Crystals of ottrelite set transverse to the planes of foliation and secondary garnets are abundant in the more highly metamorphosed phases of the schist. In all of the phyllites the ottrelite scales appear, although in some cases they are exceedingly small, almost microscopic, yet transverse to the planes of foliation.

A photomicrograph of phyllite schist from the eastern belt of mica schist in Greensboro shows light particles of quartz, and darker particles mostly biotite with some pyrite. Where pyrites are invisible to the naked eye in the phyllites as the sample is broken out in the field they appear on the sawn edges and under the microscope. Microscopic slides have been prepared of the garnetiferous phyllites and these will be described in the report on Hardwick and Woodbury.

### SLATE.

There are two narrow belts of slate in Greensboro. One of these is found about two miles northwest of Caspian Lake on the left of the road leading from Greensboro to East Craftsbury. This belt is some fifty rods wide. It is not sufficiently fissile for roofing purposes but it is quarried and used in the construction of good roads.

The second belt of slate appears on the east side of Eligo Pond in the southwestern part of the township. It is about two and one-half miles long in Greensboro and extends in a southerly direction into Hardwick. It varies in width from a few rods to about 60 rods in the widest part of the slate belt. It is fairly fissile and hand samples that would make a fairly satisfactory roofing slate have been obtained. It is magnetitic, graphitic and contains pyrite as observed on the sawn edges. Some samples from this belt have shown no effervescence with cold dilute HCl while others have shown a feeble evolution of carbon dioxide. The strike of this slate belt is about north 10 degrees east.

## INTRUSIVES.

Both acid and basic intrusives are found in Greensboro with the former in large predominance over the latter. The acid intrusives comprise those rocks which are light in color, low in specific gravity, holocrystalline in texture, high in their point of fusion and of igneous origin. The basic intrusives embrace those rocks that are dark in color, high in specific gravity, microcrystalline in texture, low in their point of fusion and of igneous origin.

## GRANITES.

The granites of Greensboro are everywhere associated with terranes of Ordovician age. Almost without exception they appear to cut the Washington phase of the Waits River limestone. The most important areas are:—(1) The northern part of the township. (2) The extreme western part of the township. (3) An area around the northern part of Caspian Lake.

The northern area is by far the largest in the township. It embraces several hills, two of which, Paddock Hill and Smith Hill, represent the highest altitudes in Greensboro. The former is 2,100 feet in height and the latter 2,050 feet. The granite covered area is about three miles wide and extends for about two miles south of the Glover line. How far north of the Glover line this granite outcrop extends is unknown.

The only quarry that appears to have been opened for purposes other than that of underpinning and bridge construction is situated on the south side of Paddock Hill. When the quarry was opened it was expected that the St. Johnsbury and Lake Champlain Railroad Company would build an extension of their road as a spur from Greensboro Bend to the base of Paddock Hill. The survey for the road was made and the expense of construction deemed too great to undertake the enterprise for the amount of freight the road would receive. The quarry was abandoned on account of the distance of the product from the nearest railroad station and the heavy expense of hauling the stone with teams.

The granite at the quarry opening is from fine to medium in texture and not so dark as the dark Barre or Hardwick granite. It possesses good rift and grain and can be cut to as fine an edge as required. It is well adapted for monumental work. It is not as good for building purposes as the Woodbury gray granite. The stone is said to take a good polish but no polished samples have been seen by the writer. Samples of this stone may be seen in the museum at Montpelier. The stone bears a little

PLATE LI.

OUTCROP OF PHYLLITE SCHIST DIP EAST, A. S. CLAY FARM, GREENSBORO.

pyrite as shown on iron stained surfaces here and there. Yet some samples of the grout exposed to atmospheric agencies for years show no iron stains whatever. It appears therefore to be the cost of transportation that keeps this old quarry from being operated at the present time.

As far as could be learned and as far as reconnaissance carried the author no quarries have been opened on Smith Hill. The granite here belongs to the same intrusive mass as that on Paddock Hill for at the higher elevations in the valley between the hills the granite was found to be continuous from one hill to the other. In its surface samples it appears a little coarser than that on Paddock Hill. The entire area in northern Greensboro appears to be a biotite granite. Microscopic slides have been prepared of the Paddock Hill granite for further study.

In the western part of the township there are several apparently disconnected granite areas. The most important of these granite masses is found on the farm of E. W. Barclay in the northwestern part of Greensboro. Four quarries have here been opened and a considerable amount of granite for local consumption produced. Here again distance from the marts of the granite industry prevents any large output from the quarries. In fact some of the quarries have already been abandoned. It is a biotite granite of rather dark gray color which microscopic slides show to be a little coarser than the Paddock Hill granite at the quarry opening.

Near the contact of this granite with the sedimentaries which it cuts there is an excellent illustration of a basic segregation and flowage of this more basic material. The lines of flowage extend somewhat into the borders of the granite proper and impart to it a gneissoid appearance. The more basic product appears to be mostly biotite with some quartz grains. Microscopic slides have been prepared of both the granite and its basic border. These require further study before giving their mineralogical characteristics in full.

About one mile east of the Barclay farm and still in the same granite mass is found the famous rocking stone which has been estimated to weigh more than fifty tons. It is a huge block of granite accurately balanced upon a bed of granite. It can be easily rocked to and fro by man. It was picked up by the great ice mantle, transported only a short distance and left perched in its present position. It is visited annually by many tourists and has often been photographed. Plate LII shows this boulder.

Southwest of the E. W. Barclay farm there is another somewhat circular granite area about two hundred rods in diameter. So far as could be ascertained no quarries have here been opened.

South of this circular area and a little to the west of it there appears a granite area some two hundred and fifty rods across it in a direction of either north and south or east and west. Its western limit is in the township of Craftsbury.

A little to the northwest of Sarah Mountain there is a small mapable granite outcrop. The direction of its longer axis lies nearly north and south. Along the east side of Eligo Pond there appears a long narrow strip of aplitic granite. It stretches southward from the S. Cloyer farm almost to the Hardwick line. It is called aplitic because the black ferromagnesian minerals of a normal granite are in many samples wanting. This condition may not hold true of the entire outcrop. East of this outcrop and near the school house on the road from the Eligo Valley to the northwestern corner of Caspian Lake there is another somewhat circular and small granite area.

Around the north end of Caspian Lake, and at its northeast corner also, there are several granite areas that can be traced back a considerable distance from the lake; and for several rods out into the lake these granite masses are seen upon its floor. These outcrops do not appear to be connected with each other at the surface but rather to be separated from each other by limestone valleys. They may however all be connected at some lower level. Burlington Point on the southwest side of Caspian Lake and Horse Shoe Point on the northeast side of the lake owe their origin in part at least to the more resistant intrusive granite. A microscopic slide of the Burlington Point intrusive shows in addition to somewhat kaolinized orthoclase finely striated crystals of oligoclase. This slide was unfortunately mounted too thick to produce a good photomicrograph.

There are many boulder strewn fields to the south of the northern granite area where the granite boulders are so large and so numerous that they have been quarried locally for underpinning and some people have been led to believe that they would find a bed rock of granite beneath the boulders.

## APLITE.

Several dikes of aplite or aplitic granite occur in Greensboro. With perhaps one exception they all lie in the western half of the township. They vary in width from a few inches to several feet. Only the larger and more pronounced dikes are shown on the areal map. The strike of these dikes varies from north 20 degrees east to north 40 degrees east. In general they roughly conform to the strike of the limestones and phyllites which they cut.

On the W. B. Simpson farm about one and one-half miles to northwest of Caspian Lake there are five of these dikes practically parallel with each other. Three of them are about five feet in width and the other two about one foot in width. Their strike is north 20 degrees east.

PLATE LII.

PERCHED BOULDER, GREENSBORO.

Many dikes extend from the granite masses out into the sedimentaries and these also vary in width and direction of strike. They are mapped in with the granite rather than represented separately. The granites and aplite dikes were probably introduced during the Devonian revolution.

## DIABASE.

The basic intrusives that are so abundant in the northern part of the State in Newport and Troy have been diminishing both in number and size of the mapable areas until in Greensboro they are nearly wanting. Only three dikes of diabase are known to occur in this township. Two of these are located one hundred rods north of the G. Y. Spiers farm about two miles south of the Glover line. They are only a few yards west of the main road that leads from the north end of Caspian Lake to Glover. They are about one hundred rods long and from thirty to fifty feet wide. Their strike is north 40 degrees east. Microscopic slides of these dikes gave lath-shaped plagioclase in abundance, augite more or less altered to hornblende, magnetite and pyrite. The abundance of the pyrite is responsible for the rapid decomposition of this rock as observed in surface samples.

The third dike of diabase was found some two miles northwest of Caspian Lake near the road that extends from Greensboro to East Craftsbury. It is about ten feet wide and fifty rods long. Its strike is north 20 degrees east.

## PALEONTOLOGY.

Owing to the general absence of fossils in this area other factors must be depended upon for the determination of the age of the terranes.

The quartzite and sericite schist of the southwestern corner of the township are continuous in their northern extension into Canada where they contain Upper Cambrian fossils. Its continuity with the same lithological characteristics furnishes the sole evidence of age so far as observed. It is unquestionably older than any of the Ordovician terranes for it is separated from them by an erosional unconformity as proven by the presence of the Irasburg conglomerate which lies at the base of the Ordovician series.

In June, 1907, the first named author of this report found the first true diagnostic feature of the age of the Waits River limestones in the township of Coventry. In carrying the work southward from the International boundary on the north each year new evidences of crushed graptolites have been discovered. The search during the summer of 1913 was not unrewarded.

A goodly number of these carbonaceous forms can be obtained on the J. Kendrick's farm near the crest of the hill in the northwestern part of the township. They occur most abundantly in the shaly portions of the Waits River limestone where the outcrops are much weathered. Their position here conforms more nearly to the planes of foliation in the calcareous sediments than in any other locality observed.

A few small crushed graptolites were also found in the limestone outcrop near the road leading past the cemetery near the village of Greensboro and also a few fragments were observed in the Waits River limestone in the extreme northeastern part of the township. Some of the above samples together with better preserved forms found in Woodbury in 1914 have been submitted to Dr. Rudolf Ruedemann, State Paleontologist of New York, for identification. Dr. Ruedemann recognizes the forms previously submitted as crushed graptolites. Their positive recognition as graptolites would establish the age of the Waits River limestone as Ordovician.

The Memphramagog slates have now been carried southward in a somewhat broken belt to the southern boundary line of Greensboro. These slates in their northern extension into Canada bear an abundance of graptolites of Lower Trenton age. There seems no logical reason for placing the slates other than Lower Trenton.

The granites which in Greensboro cut only Ordovician terranes are considered of Devonian age. They must be as late as Devonian for in Canada they cut Devonian strata.

The diabases are post-Devonian for in Woodbury and elsewhere they cut the granites. Some of them may be as late as the Triassic.

## ECONOMICS.

The most important economic product of Greensboro is the granite. As indicated under the discussion of granites, several excellent monumental stones occur in the township. Owing to their distance from the railroad and the consequent cost of transportation there are no quarries of granite being worked at the present time. Some have been opened up for monumental stone and abandoned. Local quarries both in boulders and in bed rock have been opened to secure material for the underpinnings of houses and the abutments and guards of bridges. It is doubtful if any large quarries of granite will ever be operated in Greensboro.

The diabase although mineralogically well suited for the construction of permanent roads has never been utilized in Greensboro for that purpose. The dikes cited in the manuscript are of too limited extent to furnish much of that type of road metal.

The limestones have been quarried to a small extent for underpinning for houses and barns. There are none of the



quartzose marble beds that are likely to be opened up as marble quarries.

The slate areas are few and most of the slate is not sufficiently fissile for roofing purposes. It is furthermore too pyritic.

## SUMMARY.

1. The report on Greensboro gives the results of a more detailed study of the terranes of the township than has ever before been undertaken.

2. The map represents with accuracy as far as possible without the aid of topographic maps the areal distribution of the terranes.

3. The cross section shows the stratigraphic relation of the terranes to each other. As the section is drawn across the township near its center it does not encounter the Cambrian sericite schist and quartzite in the southwestern corner of the township.

4. The report has shown that the Cambrian terranes of Craftsbury extend through the southwestern corner of Greensboro and continue into Hardwick on the south.

5. It has proved that the Irasburg conglomerate which lies at the base of the Ordovician series and is so conspicuous in Irasburg and Albany extends southward through Craftsbury into Greensboro.

6. It has proved that the siliceous Waits River limestone forms the major part of the terranes of the township.

7. It has shown that the Memphramagog slates are not continuous through Greensboro as they have previously been mapped.

8. It has shown that the phyllite schists are interstratified with the limestone and that these beds are not continuous through the township.

9. It has given the first known attempt to throw light on the true nature of these rocks by the study of microscopic slides.

10. It has added new paleontological evidence as to the age of the limestones and interstratified phyllites.

11. It has shown that the economic possibilities of the mineral products in Greensboro are somewhat limited by remoteness from railroad.

# THE GEOLOGY AND MINERALOGY OF HARDWICK AND WOODBURY, VERMONT.

Charles H. Richardson, Arthur E. Brainerd and Daniel J. Jones, Syracuse University.

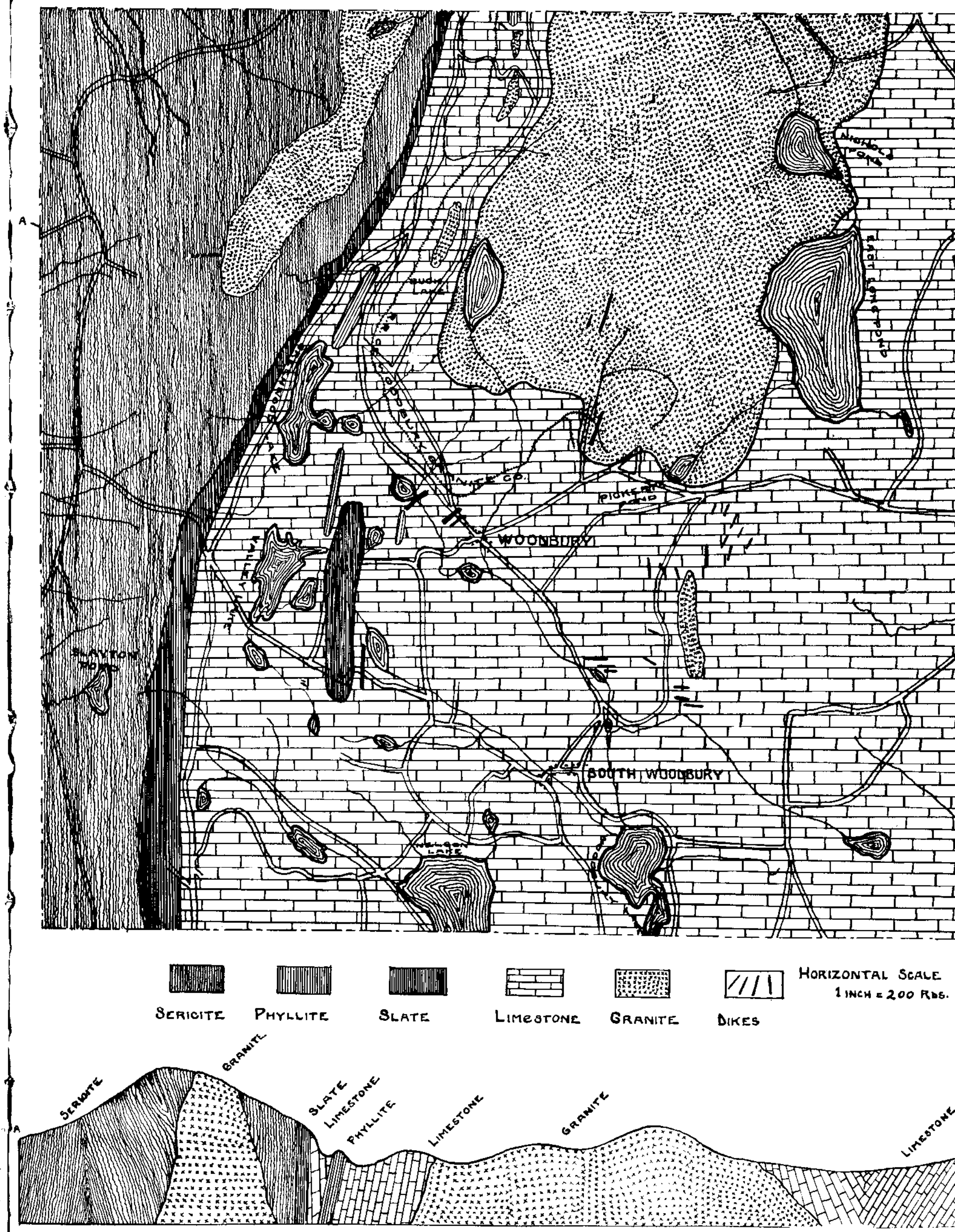
## INTRODUCTION.

The present report upon the Geology and Mineralogy of Hardwick and Woodbury, Vermont, is of necessity brief. It must be considered only as one of progress in the solution of the intricate geological problems of the eastern half of the State. The first named author traversed this area in reconnaissance work in 1895, in 1898, and in 1905, but it was not until the summers of 1913 and 1914 that detailed study could be given to the field. The time available in these two brief seasons has proven inadequate for a complete study of all of the field relations, the mapping of the area involved without the use of topographic maps, the collection of all possible museum specimens of the different types of rocks and minerals, the preparation of microscopic slides and the desired chemical analyses.

In the summer of 1913 the field party consisted of C. H. Richardson, H. G. Turner, A. E. Brainerd, each of the instructional staff of Syracuse University, D. J. Jones now Instructor in the Department of Geology in the University of Texas, S. H. Camp, graduate student in Mineralogy, and P. Camp. Turner and the two Camps did not return to the field in 1914 but C. B. Coman, L. W. Ploger and G. A. Scheutzow joined the field party. A tent was pitched on McCrillis Point on Greenwood Lake in Woodbury and from this base nearly all of the field work was directed.

The area chosen comprises two townships which lie about 30 miles north of the geographic center of the State. Hardwick falls in the westernmost part of Caledonia County and Woodbury in the northern part of Washington County. Their east and west town lines are parallel with each other and the southern boundary of Hardwick coincides with the northern boundary of Woodbury.

PLATE LIII.




MAP OF WOODBURY.
East town line is N. 40° E.
SECTION ACROSS WOODBURY.
Vertical scale 1 in. = 1,400 feet.

A little work has been done in Walden and Cabot on the east, Calais on the south, and in Elmore and Wolcott on the west.

There are three reasons for the selection of this area. (1) It lies south 40 degrees west of Greensboro, whose geology is given in another chapter in the present Annual Report of the State Geologist. (2) It falls in the line of the erosional unconformity between the Upper Cambrian terranes and the Ordovician formations represented in the eastern half of the State. (3) The large economic possibilities of Hardwick and Woodbury in the well established granite industry.

As stated in the chapter entitled "The Terranes of Greensboro, Vermont," one hundred and seventy-five new rock specimens have been collected in Greensboro, Hardwick and Woodbury thereby bringing the total number collected in the eastern half of the State to six hundred and twenty-seven. From the samples collected in these three townships over one hundred microscopic slides have been prepared for petrographic study. Some of these results will be embodied in the present report.

Over one hundred photographs have been taken in this field, a few of which appear as half-tones in this article. Two maps accompany this report. Two of them, Plates LIII and LXIV are areal, showing the geographical distribution of the terranes within the area involved. Below the map of each town is a cross-section of the rocks. The protracted section across Hardwick falls near the center of the township and is drawn from east to west nearly at right angles to the strike of the sedimentaries. The protracted section across Woodbury is not parallel to that across Hardwick for if it had been so drawn it would have crossed sedimentaries whose strike varies from north 40 degrees east to approximately east and west. It is to be regretted that no topographic maps of this section of Vermont are available and accurate mapping cannot now be executed.

I wish also to recognize herewith my great indebtedness to Dr. Rudolf Ruedemann, State Paleontologist, Albany, N. Y., for his services in the identification of crushed graptolites from the limestones in Greensboro, Hardwick and Woodbury and for his examination of other forms strikingly suggestive of fossils. A new detachment of material collected this summer is now in the hands of Dr. Ruedemann. It is a source of satisfaction to have found these diagnostic features of age in the limestones of nearly every township from the International boundary on the north for a distance of over fifty miles to the south to Woodbury, Vermont. The best preserved forms obtained in the entire area were found this summer during the closing days of our work in Woodbury. My indebtedness to T. Nelson Dale for his Bulletin on the Granites of Vermont is hereby expressed for this contribution has been freely consulted in the discussion of the granites.

## DRAINAGE.

Only one river traverses the area involved in this terse report. The Lamoille River which has its head waters in Greensboro and Stannard flows in a southwesterly direction in the eastern part of Hardwick and then turns in a westerly direction and flows across the axis of the Green Mountains and empties into Lake Champlain. This river receives from the north several small streams that flow in a southerly direction in Hardwick. The most prominent of these smaller streams is Alder Creek which forms the outlet of Little Eligo Pond and is the main supply of water for Hardwick Lake from the north. The Lamoille River flows through the southern extremity of this lake. Alder Creek receives Cascade Brook as a tributary from the west.

The Lamoille River also receives two tributaries in Hardwick that flow in a southerly direction through Wolcott from the western slope of the Cambrian hills. It also receives from the east several small streams that rise in Walden. Nichols Pond Brook has its head waters in East Long Pond and Nichols Pond in Woodbury and flows in a northwesterly direction into the Lamoille River near the village of Hardwick. This brook receives as a tributary from the south Coppers Brook which rises in Woodbury.

The Lamoille River in Hardwick also receives one small stream in Hardwick that rises on the western slope of Woodbury Mountain.

The drainage in the northern part of Woodbury is all towards the north and the northwest by the streams already mentioned. There is an easterly and southeasterly drainage in the extreme southeastern part of the township. Buck Lake Creek flows in a southerly direction and conveys the waters of that lake into Woodbury Lake whose waters ultimately reach the Winooski River on the south. This river also flows across the axis of the Green Mountains and empties into Lake Champlain. The drainage from the western slope of the Cambrian hills in Woodbury is to the west into the township of Elmore. Several of these appear to be eastern tributaries of Worcester Branch which empties into the Lamoille River in the city of Montpelier.

Three water-powers now in use are situated on the Lamoille River. One of these is at East Hardwick, one in the village of Hardwick and the third is about one mile below the village of Hardwick. The last is at the outlet of Hardwick Lake. It is used as a reserve for the electric light plant some five miles further down the Lamoille River and in the township of Wolcott.

Nichols Pond Brook possesses an excellent water-power at Mackville. This power was utilized for a considerable period of time by the owners of the old woolen mills at Mackville. More recently it has become the source of the power for the Woodbury

PLATE LIV.

TERRACE A HALF MILE WEST OF LAMOILLE RIVER, EAST HARDWICK, ALTITUDE 1,250 FEET.

Granite Company for their sheds in the village of Hardwick. To control the supply of water during periods of long drouth the Woodbury Granite Company has raised the waters in East Long Pond some four or six feet that their power may be permanent.

Smaller water-powers are found on Cascade Brook in Tuckerville in the township of Hardwick, on the small stream near the village of Woodbury and at South Woodbury. The various streams above cited are not sluggish and where rapids occur small powers could be obtained easily for cutting lumber or grinding grain and corn should occasion demand these industries.

The only railroad traversing the townships involved in this report and the one on Greensboro is the St. Johnsbury and Lake Champlain road. This road threads its sinuous way along the Lamoille River and reaches northward into Greensboro at Greensboro Bend. Its freight is in part farm products, in part lumber and other manufactured products. The largest single factor in freight for this road is found in the granite of Hardwick and Woodbury. As near as could be ascertained the shipment of granite from Hardwick during the year of 1913 approximates 500,000 cubic feet. The finished work averages about 12 feet per ton and the rough stock about 8 feet per ton. The shipment of rough stone about equals the finished products. This would give an average of 10 feet per ton on the total shipment. It would also mean that the shipments exceed 400 tons per month and approximate to 50,000 tons per year.

## TOPOGRAPHY.

The area traversed lies practically between parallels 44 degrees and 23 minutes and 44 degrees and 35 minutes north latitude, and longitude 72 degrees and 15 minutes and 72 degrees and 28 minutes west of Greenwich. It therefore comprises an area of approximately 80 square miles.

The area is furthermore located about 20 miles north of Montpelier, the Capital of Vermont. It is bounded on the north by Greensboro, on the east by Walden and Cabot, on the south by Calais and on the west by Elmore and Wolcott. It must be remembered, however, that the east and west town lines which are parallel with each other are not due north and south lines but lines that run north 40 degrees east, practically parallel with the general strike of the sedimentaries.

The principal valleys are in part longitudinal and in part transverse. The major valley of the entire area is that of the Lamoille River. In Greensboro as well as in the northeastern corner of Hardwick this valley is broad, U-shaped and longitudinal. Its course in the more northern portion is nearly parallel with the strike of the limestones over which it flows. Its course here is effected by the foldings of the limestones over which it flows. In the eastern part of Hardwick it turns in a more westerly direction and flows directly across the Ordovician limestones and schists and then across the Cambrian schists and quartzites in the western half of Hardwick. It becomes therefore in its more westerly course a broad, fertile, U-shaped, transverse valley. It is unquestionably of pre-glacial origin.

The Lamoille River Valley is also beautifully terraced. In some instances these terraces appear only upon one side of the river and in others upon both sides. The present flood plain of the river is sometimes confined to only one side of the valley but it often appears upon both sides of the river. It is extremely fertile and with its associated terraces comprises the richest tillage land of Hardwick. The terraces vary in height from about ten to twenty feet. These do not include the ancient lake terraces to be mentioned hereafter in this report. Four distinct terraces are often visible from a single view point.

The highest terrace found in the Lamoille Valley is situated about one-half mile west of the Lamoille River near East Hardwick. It is at an altitude of 1,250 feet above sea level, 389 feet above the village of Hardwick and 219 feet above the village of East Hardwick. This is not construed as a river terrace but as one of the ancient glacial lake terraces. Plate LIV shows this terrace one-half mile west of the Lamoille River, East Hardwick, Vermont, altitude 1,250 feet.

The Eligo Valley stretches towards the north from the village of Hardwick. It is a broad, U-shaped and longitudinal valley. Its course was determined in pre-glacial times by the sharp folding of the Ordovician limestone and slate against the Cambrian schists. The valley has gradually moved to the westward along the cleavage planes of the limestone and slates and now lies at or near the contact of the Cambrian and Ordovician terranes. It has been carried so low down on the Ordovician formations that the slate in the lower portions of the valley has been entirely removed. It is only natural that its course should fall in the limestones rather than in the mica schists on account of the greater solubility and rapid weathering of these calcareous rocks. Plate LV shows Eligo Valley looking south from the top of an esker, Hardwick Lake in the background.

Woodbury Gulf through which the gulf road passes represents another longitudinal valley. It extends southward from the Lamoille Valley through Hardwick and Woodbury. It follows close to the line of contact between the Cambrian and Ordovician terranes and is practically parallel with the general strike of the sedimentaries over which it flows. This condition, however, does not hold true for the west central part of Woodbury for here the strike of the rocks is often abnormal to the general strike north 40 degrees east and is east and west. The valley in its southward extension crosses these abnormal strikes while in

PLATE LV.

ELIGO VALLEY LOOKING SOUTH FROM TOP OF ESKER. HARDWICK LAKE IN BACKGROUND.

Calais it becomes normal again. The origin of the valley is pre-glacial and in part its course is determined by the ready solubility of the limestones which form the present bed of the valley. It has been carried westward somewhat on the limestones and is flanked now on the west by a narrow belt of slate as will be seen on the areal map.

About four miles south of the village of Hardwick this valley divides. The cause of the division is in part a resistant belt of phyllite schist. In part it has been determined by glacial erosion. The eastern portion extends a little to the southeast through the villages of Woodbury and South Woodbury into Calais. The western branch extends somewhat southwesterly through Woodbury into Calais.

Two transverse valleys appear in the southern part of Woodbury. They are deep, incisional and V-shaped. They are largely of post-glacial origin. The northernmost of the two valleys extends from the western branch of the pre-glacial valley across the divide between the two valleys and terminates at South Woodbury. The southernmost of the two valleys is situated about one-half mile north of the Calais town line. It traverses the same divide as the preceding transverse valley. Its western extremity begins in the low and level area of southern Woodbury. It terminates in Woodbury Lake in Woodbury and Calais. Nelson Pond and Cranberry Pond lie in this valley.

In the northwestern part of Hardwick there is a very interesting, transverse and hanging valley. Through it Cascade Creek flows in an easterly direction. In it there are three reaches and three small ponds. Each section of the whole valley hangs at its eastern terminus. It is of post-glacial origin. Its falls are determined by difference in the resistance to erosion in the rocks over which Cascade Creek flows. At Tuckerville there are granite intrusions in the Cambrian schists that have been in part responsible for the falls. At the eastern terminus of the valley the water falls in cascades for 125 feet into the Eligo valley which has been carved in limestones.

Two hanging valleys appear in Woodbury, one on the north and the other on the south side of Woodbury Mountain. These are both of post-glacial origin. The cascades that appear near the eastern terminus of the more northern valley are determined by a comparatively narrow belt of granite over which the water falls for more than 100 feet. The southernmost of these hanging valleys stretches in a westerly direction from a broad pre-glacial valley across the Cambrian hills to Slayton Pond in the southwestern part of Woodbury.

The lowest altitude recorded in Hardwick was in the Lamoille valley near the Wolcott town line. It was 756 feet. The highest altitude was found on West Hill approximately 1,500 feet. The altitudes where the cross section traverses Hardwick are as follows, viz.:

| | | |
|---|---|---|
| Walden town line | 1,300 | feet. |
| Lamoille valley | 850 | " |
| Hill north of Hardwick | 1,300 | " |
| Eligo valley | 840 | " |
| West Hill | 1,500 | " |
| Wolcott town line | 1,300 | " |

The section across Woodbury shows altitudes as follows, viz.:

| | | |
|---|---|---|
| Cabot town line | 1,300 | feet. |
| Robeson Mountain | 1,800 | " |
| Woodbury Gulf | 950 | " |
| Woodbury Mountain | 2,800 | " |
| Elmore town line | 1,500 | " |

As the St. Johnsbury and Lake Champlain Railroad crosses the area involved in this report the altitudes of the different station, or the tracks in front of the station, will prove interesting to some readers.

| | | |
|---|---|---|
| St. Johnsbury | 556 | feet. |
| Danville | 1,341 | " |
| Dow | 1,411 | " |
| Walden | 1,656 | " |
| Greensboro Bend | 1,146 | " |
| East Hardwick | 1,031 | " |
| Hardwick | 861 | " |
| Wolcott | 690 | " |
| Hyde Park | 576 | " |
| Cambridge Junction | 461 | " |

## GLACIATION.

The townships traversed for this report are mantled with morainic material to such an extent that the geologist is seriously hampered in the study of field relations of the different terranes. This condition holds especially true in the northern part of Hardwick where the glacial till is heavy, in the Lamoille valley where lake and river terraces cover the sedimentaries and in Woodbury where remnants of a terminal moraine of recession appears.

Each ravine and wooded slope has been traversed to find the various rock exposures that warrant the present mapping of the different geological formations. The post-glacial valleys have often been a prolific source of the desired outcrops. The densely wooded areas have concealed many exposures that might have been studied had there been more time available for the work.

Evidences of glaciation and the general direction of the ice movement are the striations still remaining on the more resistant rocks of the region. The well exposed outcrops of nearly pure



white, secondary, vein quartz show striations upon their smoothed and polished surfaces. The resistant phyllites are perhaps the best preservers of this evidence although the Cambrian quartzites on the west slope of Woodbury Mountain show most excellent striations.

The general trend of the ice is well known to have been in a southeasterly direction but there were other movements, perhaps somewhat local, in a southwesterly direction. On the phyllites of Barr Hill in Greensboro striations were recorded south 40 degrees east and south 10 degrees east. On the resistant phyllites near the south end of Robeson Mountain in Woodbury striations were recorded south 30 degrees east, due south, and south 30 degrees west. Each ice movement then in a distance of some 20 miles has moved 10 degrees to the west. These varying directions imply more than one ice movement. The first named direction appears to be the oldest and the last direction the youngest for the last striations cut all of the others.

Another evidence of glaciation is the boulder strewn fields, pastures and woodlots. Their size and angularity determine in some measure the distance they have been transported from their original habitat. Some of these boulders will weigh between 50 and 100 tons. One of these larger boulders of granite may be seen in a pasture about one-half mile northwest of the village of Woodbury. Plate LVI shows a boulder strewn pasture, looking east from Robeson Mountain, Woodbury, Vermont.

Remnants of a terminal moraine of recession are found in Woodbury. The rock material carried by the glacier as medial, lateral, ground moraine and englacial drift was dropped by the ice during its retreat where the end of the ice sheet remained stationary for some period of time. This line of debris stretches in an easterly direction across Vermont through Lyndon and appears again in New Hampshire.

Near the village of South Woodbury this material appears as a kettle moraine. The morainic material is here studded with several symmetrical kettle-like depressions, or holes, that at one time were filled with water, although in none of them was water found standing at the present time. They vary from 50 to 100 feet in diameter and are from 25 to 50 feet in depth. One of these kettle-holes which is about 75 feet in diameter is perfectly symmetrical. It is situated in a transverse valley about one mile northwest of the village of South Woodbury.

Small drumloid hills which are also ice-laid appear in Greensboro, Hardwick and Woodbury. The vast number of glacial ponds scattered throughout Woodbury testify still further as to the effects of glaciation. Plate LVII shows a glacial pond and drumloid hills in the northeastern corner of Woodbury.

In the Eligo valley in Hardwick there appears an esker. It is a low winding ridge of sand and gravel elongated in the direction of the ice movement. It was formed by the accumulations in a sub-glacial stream which, at the time of the formation of the esker, would have its sides and roof of ice. The esker is some two to three miles in length. The coarser gravel is found in the more northern portions of the esker and the finer sand in the more southern portions. Plate LVIII shows a bed of gravel near the north end of the esker in Eligo valley, Hardwick, Vermont.

Another proof of glaciation lies in the evidence of the existence in this part of Vermont of the extinct, glacial, Lake Vermont. Several terraces consisting of flat deposits of stratified lake sand appear at as high an altitude as 1,250 feet. As the valley divide that separates the head waters of the Black River which flows into Lake Memphramagog at Newport from the source of Alder Creek which empties into the Lamoille River one mile west of the village of Hardwick is approximately 850 feet, there must have been a confluence of the waters of Lake Memphramagog and the Lamoille River at some period in the history of these two bodies of water.

As the altitude in the divide in Woodbury Gulf that separates the waters flowing north into the Lamoille River from those flowing south into the Winooski River is approximately 1,000 feet, there must also have been a confluence of the waters of the Lamoille and Winooski Rivers. The altitude of the divide in Williamstown Gulf in Orange County is not sufficiently high to have precluded an outlet for Lake Vermont into the White River and Connecticut River valleys.

Fragments of the highest terrace, 1,250 feet, appear in three places; one mile northeast of East Hardwick, on the east side of Eligo valley near the Poorhouse farm and near the west line of Hardwick on West Hill. These levels vary slightly but this variation is due to slight diastrophic movements or to erosion. The lowest terrace found here is 810 feet and this level has the terrace form because the Lamoille River has cut down through the old lake bottom deposits. Between the highest and lowest levels other fragmentary terraces were recorded at 825, 880, 940, 1,050, 1,100 and 1,140 feet. The first four of these levels are well marked on Buffalo Mountain southwest of the Woodbury Granite Company's sheds. The 1,100 foot terrace is found on the eastern side of Woodbury Gulf two miles south of Hardwick village. This level also appears near East Hardwick. Only one level at 1,140 feet was found and this is near the east line of Hardwick village. These fragmentary terraces record the ancient water levels of glacial Lake Vermont.

## LAKES.

But one lake appears in Hardwick. This is situated on the Lamoille River about one mile from the village of Hardwick. It

PLATE LVI.

WOODBURY, BOULDER STREWN FIELD.

receives from the north the waters of Alder Creek. It is about two miles in length and one-half mile in width at its widest point. It is of artificial origin and was constructed to provide a reserve supply of water and power for the electric light plant on the Lamoille River in Wolcott.

Two small ponds appear in the northeastern part of Hardwick and furnish the head waters for two small streams that flow in a southerly direction into the Lamoille River. Three small ponds appear in the northwestern part of Hardwick on Cascade Creek. Their volume has been increased somewhat to furnish a greater water-power for mill purposes.

There are thirty-two lakes and ponds in the township of Woodbury. More than twenty of these appear on the areal map. Space in this article will permit of a description of only the larger and more interesting of these bodies of water. They are distinctly of glacial origin and indicate a youthful topography. The longer axis of each lies in the direction of the moving ice during the glacial epoch and indication points to some of the valleys having been deepened by ice erosion. In the main, however, glacial debris has been thrown across some ancient valley and the empounded waters have sought an outlet over the lowest altitude around their shores.

Only two of the larger lakes have an outlet to the north. These are East Long Pond and Nichols Pond. Two small ponds, one to the southeast and the other to the southwest of East Long Pond, furnish the head waters for that pond. East Long Pond itself is one and one-half miles long and more than a half mile in width. It lies partly in beds of granite on its western side while the center and eastern half is in limestones and their associated or interfolded phyllite schists. Its outlet is to north through a small stream that flows into Nichols Pond. An artificial dam has been constructed at its outlet by the Woodbury Granite Company to provide a reserve volume of water for their power plant near the small village of Mackville in the township of Hardwick.

Nichols Pond in the northeastern part of Woodbury is also situated at the foothills of Nichols Ledge, from which a most beautiful panoramic view of the mountains of Woodbury and the subdued hills to the southeast can be obtained. The length of this pond is about 200 rods and its width about 150 rods. Unlike East Long Pond its bed lies entirely in granite, or if limestone patches appear they are inclusions within the large granite area surrounding Woodbury Mountain. The outlet of this pond is through Nichols Pond Brook which flows in a northwesterly direction into the Lamoille River near the village of Hardwick.

Buck Lake is situated within the same large granite area. The sedimentaries may approach the water's edge on the northeastern side of the lake. Its length is about 250 rods and its width 100 rods. It is surrounded by a thickly wooded area and therefore concealed from view from long distances. It is also environed with granite hills, some of which have been opened up for the commercial granite they contain. Somewhat unexpectedly its outlet is to the south through Buck Lake Brook that empties into Woodbury Lake. There are some evidences that here we have another case of reversed drainage for the deep incisional valleys to the northwest of the lake are much lower in altitude than the granitic floor over which Buck Lake Brook now flows.

Greenwood Lake is situated about one and one-half miles northwest of the village of Woodbury. It is about 300 rods in length and 150 rods in width at the widest point. Its shores are very irregular, often deeply indented. There are two small islands within the lake. Its bed lies entirely in limestones and the interstratified phyllites. Its outlet is through a small brook that flows into or through five small ponds before it finally enters Woodbury Lake. Plate LIX shows Woodbury Mountain from Greenwood Lake, Woodbury, Vt.

Valley Lake is situated about one-half mile to the south of Greenwood Lake. Their altitude is approximately the same and they are separated from each other by low mounds of morainic material. This lake is 250 rods in length and 175 rods in width at the widest point. Its shores are deeply indented and therefore very irregular. The long narrow bay on the northeastern coast is known as the Hart's Tongue from its general shape. This lake lies partly in limestone and partly in a narrow belt of very fissile slate. Its outlet is through several small ponds whose waters flow in a southeasterly direction through the northernmost of the two larger transverse valleys mentioned in this report and empty into Woodbury Lake only a few rods to the west of the inflow of the waters from Greenwood and Buck Lakes.

Woodbury Lake is situated in the southeastern part of Woodbury and is on the road leading from South Woodbury to North Calais. It is approximately 400 rods in length and 200 rods in width at the widest point. A part of the lake lies in Woodbury and a part in the township of Calais. It was formerly known as Sabine Pond but its name was changed by an act of the State Legislature. Its outlet is to the south through Calais into the Winooski River. Its bed is in the limestones and interstratified phyllites. (It may be of interest to note here also that the former name of Greenwood Lake was West Long Pond and that of Valley Lake was Dog Pond and that these earlier names were changed also by an act of the State Legislature).

Nelson Pond is situated in the extreme southern part of the township of Woodbury. In fact a part of the pond like Woodbury Lake lies in the northern part of the township of Calais. It is about 300 rods in length and about 250 rods in width at its

PLATE LVII.

GLACIER POND, DRUMLIN HILLS, WOODBURY.

widest point. Its shores are far more regular than any of the other lakes or ponds herein described whose waters flow into the Winooski River except Buck Lake. The outlet of this pond as already intimated is to the south into the Winooski River. The bed of the pond is in the limestones and their interstratified phyllites. This pond also receives the waters that flow from two small ponds in a southeasterly direction through the southernmost of the two larger transverse valleys mentioned in this report. The larger of the two ponds is known as Cranberry Meadow Pond. Many of these smaller ponds are rapidly disappearing by the abundant growth of vegetable matter and the infilling of mineral matter. Several of the swamps about these small ponds contain peat deposits of unknown depth.

There is only one pond in the township of Woodbury that is situated on the western slope of the Cambrian hills. This is known as Slayton Pond. It lies in the southwestern part of the township and is surrounded by sericite schists and quartzites of Cambrian age. It is about 100 rods in length and some 50 rods in width. Its outlet is to the west into Elmore and through Worcester Branch into the Winooski River.

## GEOLOGY.

The geology of Hardwick and Woodbury is intricate and complex. The terranes consists largely of a series of highly crumpled, folded and faulted metamorphic rocks, dipping always at high angles and often cut by intrusive masses of both acidic and basic character. The sedimentaries as well as the intrusives differ widely in age as well as in their mineral constituents. A careful study of their field relations has been absolutely necessary to avoid the introduction of errors in their interpretation. To aid in this work, as stated in the introduction, more than 100 microscopic slides have been prepared. This step has been rendered necessary by the nature of some of the more basic intrusives. In the western part of the area covered by this report stratigraphy must be determined by field relations, and even then there is a wide chance for error with the limited time at our disposal. In the central part of the field it has been the good fortune of our party to discover this summer new beds of limestone and slate carrying marked evidence of crushed graptolites. This new feature will be discussed under the caption of Paleontology. It is believed that here lies the true diagnostic feature of age and the question of the age of the limestones and interstratified phyllites should be settled.

### ALGONKIAN.

The introduction of the term Algonkian in this report is made only to show the relation of the sedimentaries in Hardwick and Woodbury to the oldest geological formations within the State. In Algonkian time there appears to have been an area of sedimentation to the west of the central meridian of the State. This was followed by the introduction of granitic rocks into the sedimentary beds. These granites are the present gneisses of the Green Mountain range. At the close of Algonkian time there occurred a crustal movement which metamorphosed these earliest sediments in Vermont into schists and the earliest granites into gneisses. This movement was accompanied by folding and elevation. The earlier mountain system of the State was thus formed. These rocks comprise the major anticline of the Green Mountains which stretches southward from the international boundary on the north to Massachusetts. The Green Mountain gneiss is flanked upon either side by a series of highly metamorphic schists. It is only the schists on the eastern side of the Green Mountains with which this report can be in any measure concerned. Even then a wide belt of altered sedimentary rocks must be traversed before the crest of the main anticline has been reached.

In the summer of 1908 the first named author of this report, accompanied by Burton W. Clark, then a graduate student of Syracuse University, ran a section westward for a distance of more than five miles over these metamorphics to the summit of Jay Peak which is 4,018 feet above sea level. In the summer of 1910 the same author accompanied by J. A. Dresser of the Canadian Geological Survey traversed the area westward in the valley of the Missisquoi River to the highly feldspathic core of the Green Mountains. There appears to be no evidence available that the westernmost sedimentaries of Hardwick and Woodbury are as old as the Algonkian.

## CAMBRIAN.

The term Cambrian as here used signifies an undivided group of highly metamorphosed sedimentary rocks which lie between the eastern foothills of the Green Mountains and the erosional unconformity that separates the pre-Ordovician terranes from the Ordovician formations. These Cambrian rocks consist of pyritiferous mica schists, sericite schists, chlorite schists, quartzites and slates. These formations are all of sedimentary origin.

In early Paleozoic time a submergence of a large area of Algonkian rocks occurred. From the erosion of these Algonkian land masses sediments were derived and deposited upon the submerged Algonkian terranes. At the close of the Cambrian a crustal movement occurred which metamorphosed these sediments into schists, quartzites and slates. This was accompanied by the intrusion of a few granite masses, some of which have been subsequently converted into gneiss. The eastern foothills of the Green Mountains, especially in the more northern part of the

PLATE LVIII.

BED OF GRAVEL NEAR NORTH END OF ESKER, ELLIGO VALLEY, HARDWICK.

State, were thus formed. A proof of the introduction of pre-Ordovician granitic masses into these Cambrian schists is the fact that boulders of granite nearly a foot in diameter are found in the Irasburg conglomerate which is the lowest known member of the Ordovician rocks in eastern Vermont.

The general strike of the Cambrian terranes in Hardwick and Woodbury is north 40 degrees east, but there are local variations from north 30 degrees east to north 60 degrees east and in some places on Woodbury Mountain an east and west strike has been recorded. The dip varies from 85 degrees west on the east to 80 degrees east on the west side of the townships. In certain sections there are two synclinal troughs and one anticlinal axis not comparable to the major axis of the Green Mountains.

In the Lamoille valley in Hardwick the strike of these rocks varies from north 40 degrees east near Hardwick Lake to north 10 degrees east near the Wolcott town line. The dip on this section is 70 degrees east on the east and 45 degrees east some two miles west of the village of Hardwick and 60 degrees east near Wolcott line.

In a section passing over the Cambrian terranes on the Buffalo Hill road the sericite schist on the east had a strike of north 40 degrees east and a dip from 85 to 90 degrees east, or vertical. The quartzite about 1,000 feet to the west had the same strike and dip as the sericite schist. The dip of the biotite-quartz schist near the crest of the mountain is also very high. In the edge of Elmore to the west of Woodbury Mountain the strike of the quartzite is north 60 degrees east and the dip 60 to 75 degrees east.

A few miles south of Woodbury Mountain the dip of the sericite schist which forms the easternmost member of the Cambrian group of terranes is to the west. This terrane has dipped on the eastern side towards the west all of the way south from the international boundary to Hardwick and Woodbury where it unexpectedly is to the east. Perhaps Woodbury Mountain has been overturned. The folding of the rocks that compose the mountain has been more intense than it has in the same formations to the northward.

### A. PYRITIFEROUS MICA SCHIST.

The pyritiferous mica schist that appears so abundantly in Troy and has been followed southward to the southern side of Lowell Mountain does not appear in Hardwick and Woodbury. In its southern extension it should appear in Wolcott and Elmore. It is recognized by an abundance of quartz and black, or greenish-black hydrated mica in which large crystals of pyrite occur. Many square cavities appear in the decomposing schists. These cavities are formed by the oxidation of the pyrite and the leaching out of the secondary minerals formed during this oxidation.

### B. SERICITE SCHIST.

This terrane has been continuous from the international boundary on the north to the south as far as our work has been carried. It everywhere flanks the Ordovician formations on the west and is therefore the easternmost member of the Cambrian group of rocks. It is fine grained and even textured as a rule. In a few instances, as in North Troy, it becomes as fissile as slate and is equally fine grained with slate. Its chief mineral constituents are quartz and muscovite (sericite). The muscovite of the original schist has been altered to sericite. The secondary minerals are quartz, pyrite, magnetite, garnet, and in a few instances, hornblende. Biotite is of common occurrence. Garnets in well crystallized rhombic dodecahedrons stud the exposed surface of several outcrops. Some microscopic slides from Woodbury have shown one-half of the area of the slide filled with magnetite. The pyrites are often visible to the naked eye, but sometimes they are only microscopic.

This formation passes by insensible gradations into the quartzite. In some instances it becomes a quartz conglomerate and the pebbles are nearly one-half inch in diameter. This condition is found to the north of Hardwick and Woodbury. It is well pronounced in the western part of Craftsbury. In the section from Hardwick westward through the Lamoille valley to the Wolcott line the rocks might all be cataloged as sericite schist. Plate LX shows an outcrop of crumpled sericite schist one mile west of the village of Hardwick, Vermont.

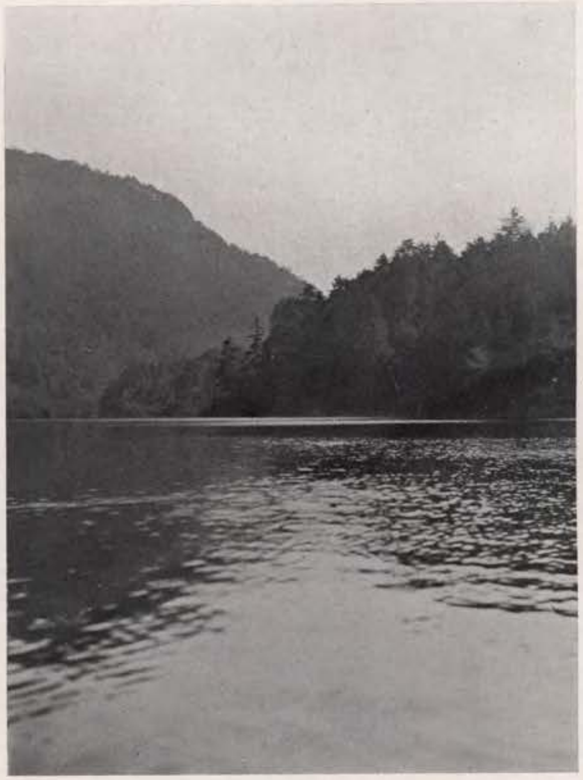
### C. QUARTZITE.

The Cambrian quartzite has been continuous from the international boundary on the north as far southward as our work has been carried. It flanks the sericite schist upon the west. In the townships traversed for this report it extends westward to their west town lines, especially on the higher altitudes.

This quartzite is usually from fine to medium grained but sometimes becomes conglomeratic. In many instances what has been described as a quartzite might equally well be cataloged as a quartz schist. In this terrane quartz is in large predominance over the muscovite (sericite). Biotite has been present in some microscopic slides and absent in others. Magnetite is far less abundant than it is in the sericite schists. Pyrites when present are small. Zoisite is sometimes present.

The first mentioned author of this report has traversed this formation in its northern extension all of the way from Woodbury on the south to the Canadian line on the north, and from thence northward to where Upper Cambrian fossils appear in Canadian territory. In this entire distance of more than 100 miles this formation has not lost its lithological characteristics.

PLATE LIX.



WOODBURY MOUNTAIN FROM GREENWOOD LAKE, WOODBURY.

It is from this fact that these highly metamorphic sedimentaries are cataloged as Cambrian.

### D. SLATE.

There are no true slates in the Cambrian formations of Hardwick and Woodbury. There is however a belt of fairly fissile Cambrian material that occurs in considerable abundance in the vicinity of Slayton Pond in Woodbury that has a slaty ring. It has often been mentioned by people in both Hardwick and Woodbury as a slate deposit of large commercial possibilities. Samples collected for the State museum are thickly studded with garnets which would prevent its use as roofing material provided outcrops could be found that were sufficiently fissile for roofing purposes.

The strike of these slaty outcrops is north 40 degrees east and the dip is from 80 to 85 degrees to the west. They stand from 25 to 50 feet in height above the surrounding depressions which separate each belt by about 200 feet. The outcrops themselves are from 50 to 100 feet in width. There are 8 of them and the central one is the highest and the thickest.

## ORDOVICIAN.

The term Ordovician as here used embraces a group of metamorphosed sediments that lie to the east of the Cambrian terranes already described. These two groups are separated from each other by an erosional unconformity. This unconformity has been followed southward from the international boundary as far as our work has been carried, which is a distance of approximately 50 miles. The Ordovician terranes consist of a basal conglomerate, limestones, marbles, quartzites, schists and slates.

In Ordovician time there occurred a submergence of a large area of Cambrian rocks and the deposition thereon of sediments resulting from the erosion of the Cambrian land masses, together with calcareous sediments largely of organic origin. If the total thickness of these beds is 6,000 feet as Prof. C. H. Hitchcock has often figured them, then sedimentation should have been begun fairly early in Ordovician time.

At the close of the Ordovician a crustal movement accompanied with elevation and complex folding took place which metamorphosed the Ordovician sediments into limestones, marbles, quartzites, schists and slates. Some of these sedimentaries encircle a part of the granites of Hardwick and Woodbury, while a part of these intrusives are found in the Cambrian terranes.

### A. IRASBURG CONGLOMERATE.

This basal conglomerate was discovered by the first named author of this report in 1904 near the village of Irasburg, Vermont, and designated by him at that time the Irasburg conglomerate. It has now been traced southward for over 30 miles. How much farther to the south it can be found is a matter of conjecture. In it there are pebbles of diabase, granite, porphyrite, quartzite, sericite schist and a sericitic marble. In the type locality there are boulders from one to three feet in diameter in the conglomerate but to the north and the south of Irasburg these rock fragments diminished in size and in number. In certain of the more southerly exposures the pebbles are small and well water worn.

Its general strike has been north 40 degrees east but the strike sometimes changes 90 degrees within 10 feet. It has been powerfully folded into sharp anticlines and synclines and these folds dip in all possible directions. Its general dip has been to the west but in the northern part of Hardwick in the Eligo valley there is a dip of 85 degrees to the east. Several of these sharp anticlines make the finest of museum specimens and some of them can be seen in the museum at Syracuse University.

The southern extension of this conglomerate into Hardwick and Woodbury is proven by the presence of a few small pebbles and the intense folding to which it has been subjected. It unquestionably is a basal conglomerate at the base of the Ordovician terranes in the eastern half of Vermont. Plate LXA shows this conglomerate greatly folded.

### B. WAITS RIVER LIMESTONE.

The Waits River limestone is by far the most extensive single geological formation in Hardwick and Woodbury. Including the granites which it encircles, it comprises about three-fourths of the rocks of these two townships. It includes several beds of a quartzose marble, one bed of calcareous quartzite and many beds of phyllite schist that are not mapable areas but everywhere interstratified with the limestones. Where these calcareous sediments predominate the areal map shows only limestones. Where the non-calcareous sediments predominate the area has been mapped either as phyllite schists or slates according to the degree of metamorphism to which these sedimentaries have been subjected.

The Washington phase of this limestone which is dark steel-gray and compact is the most abundant. The Waits River phase which is banded, variegated or even of light gray color is largely confined to the eastern part of the townships and to those localities where erosion has been the least pronounced. An illustration of this phase can be seen at Wonderland Junction within a few rods of the white quarry of the Woodbury Granite Company. The outcrop here is very small. It is surrounded upon three sides, if not upon the fourth, by granite. Many small acicular crystals of hornblends are present as a product of contact meta-

PLATE LX

CRUMPLED CAMBRIAN SERICITE SCHIST, ONE MILE WEST OF VILLAGE OF HARDWICK.

PLATE LXA.

FOLDED AND CRUMPLED CONGLOMERATE, HARDWICK.

morphism. It lies in nearly a horizontal position which is in striking contrast to the high angles generally observed. It may be elevated and underlaid by granite.

The Waits River phase of the limestone appears also in several places in the southeast corner of Hardwick in school district No. 10. Here the banded appearance is pronounced. It is also cut by granite dikes. When the limestone is not affected by intrusives it dips at an angle of about 30 degrees to the west.

In the eastern part of Woodbury about three miles southeast of the village of Woodbury and to the east of the W. C. Daniels farm there is a ledge of the Waits River phase of the limestone in which the lime content is sufficiently low to permit the outcrop to be cataloged a calcareous quartzite. The ledge is in a wooded pasture owned by the Morse Manufacturing Company of Hyde Park, Vermont. This property was formerly owned by J. A. Wing of Montpelier. The ledge is about 500 feet in length, 100 feet in height and rises more than 200 feet above the valley on the western side. Its crest is level with a small plateau upon the east.

In the museum at Montpelier there are said to be samples of this rock collected many years ago and cataloged as "Sand rock, Woodbury, Vermont." A considerable amount of the original lime has been leached out by percolating waters. The sand grains are now loose and the exposed surfaces so friable that the stone crumbles easily in the hand. Under the hammer it reduces to a white powder. This fact has suggested to several people in Woodbury its possible use as an abrasive. It is impossible without the use of explosives to blast away the exposed and weathered surfaces to state whether the lower portions of the ledge would be well adapted for abrasive materials or not.

Under the microscope the sand grains are small, well water worn and in excess of the calcium carbonate. Only an occasional small crystal of mica was found in the slides studied. The stone effervesces freely with cold dilute HCl. Its quantitative analysis has not been made.

Below the Falls at the village of East Hardwick the Washington phase of the Waits River limestone strikes north 40 degrees east and its dip is from 20 to 30 degrees to the west. About one mile north of the village the limestone appears to be in a horizontal position. The upper portion of the outcrop is thick bedded and massive. The lower portion is thin bedded and shaly. Plate LXI shows the horizontal position of the limestone and the character of the bedding one-half mile north of the village of East Hardwick.

The powerful folding to which this limestone has been subjected is best seen on the western side of the terrane near its contact with the sericite schists. In the village of Hardwick in the bed of the Lamoille River there is exposed during low water a very sharp anticline and syncline. In fact the whole western part of this limestone and its interstratified phyllites is closely folded and the dip is therefore nearly vertical. In the railroad cut just west of the village of Hardwick there is an easterly dip of the limestone. Plate LXII shows the limestone with dip to the east near the crest of an anticline, Hardwick, Vermont.

The more massive portions of this limestone are susceptible of a high polish and may therefore be cataloged as quartzose marbles. Microscopic slides of these marbles show well developed crystals of calcite with their perfect cleavage. The sand grains are small and well rounded. Three micas have been observed; muscovite, the white mica; biotite, the black mica; phlogopite, the amber mica. Microscopic, and sometimes macroscopic pyrites are present. Uncombined carbon serves as a pigment.

A few of the many abnormal strikes and dips of the limestones and marble beds are here cited as evidences of the powerful folding to which these terranes have been subjected. The normal strike of the area to the north as well as on the south of these two townships is north 40 degrees east and the normal dip is to the west.

One mile west of the village of Hardwick the strike is north 10 degrees east and the dip is 10 degrees east. Near the southeastern corner of the town the strikes recorded were north 40 degrees west, dip 50 degrees east, and east and west strike with dip to the north. Near the western border of the limestone in Hardwick a strike was recorded north 40 degrees west with dip 44 degrees to the north.

Along the railroad of the Woodbury Granite Company leading to their quarries in Woodbury the following abnormal strikes were found; east 30 degrees south, north 80 degrees east, east 10 degrees south, east 30 degrees south, east 50 degrees south, north 60 degrees east and north 70 degrees west. South of the boarding house on Robeson Mountain a north and south strike was recorded.

One mile west of the Cabot line the strike is north 75 degrees east and changes to east and west. On the Cabot line and to the southeast of Robeson Mountain the strike is north 85 degrees east with a dip of 45 degrees to the north; also strike north 60 degrees east with a dip of 22 degrees to the north; again strike north 30 degrees east with a dip of 30 degrees to the north.

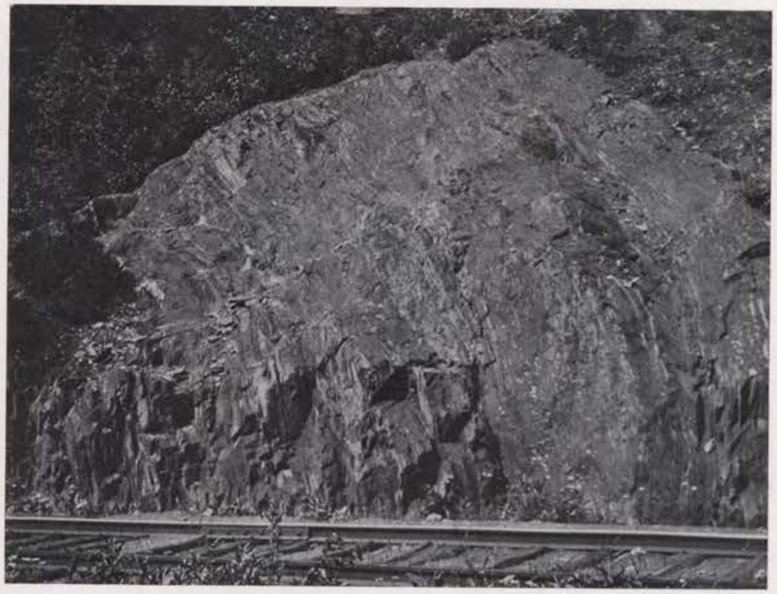
One mile south of Woodbury the strike is north 75 degrees east. One and one-half miles south of Woodbury the strike is north 70 degrees east and the dip 48 degrees north. Two miles south of Woodbury in a recently burned area the strike is east 20 degrees south and the dip varies from 35 to 40 degrees to the northeast.

These abnormal strikes and unexpected dips may be explained by a more intense folding of the sedimentaries in Wood-

PLATE LXI.

HORIZONTAL BEDS OF LIMESTONE—UPPER BEDS MASSIVE, LOWER SHALY—ONE-HALF MILE NORTH OF EAST HARDWICK.

PLATE LXII.



LIMESTONE DIP EAST NEAR CREST OF ANTICLINE, HARDWICK.

bury than has been observed in any other township in the eastern half of the State. This powerful folding is not confined to the Ordovician sediments alone for it extends westward over Woodbury Mountain into the Cambrian terranes. On the west side of West Hill in Hardwick a strike in the sericite schist was recorded north 55 degrees east and a dip of 55 degrees east, and in the southern part of Woodbury and Elmore the strike was north 60 degrees east and the dip 75 degrees east. Near the contact between the sedimentaries and the granite on Buffalo Hill the strike is north 40 degrees east and the dip from 85 to 90 degrees east. Near the contact between the sedimentaries and basic intrusives at South Woodbury the strike is north 40 degrees east and the dip 75 degrees west. In addition to the more intense folding the abnormal strikes may be influenced by the introduction of both large and small masses of granitic rocks. The amount of basic intrusives present is too small to have effected a change in the strike over such extensive areas.

### C. PHYLLITE SCHIST.

The two parallel belts of mica schist that have been somewhat responsible for the high ridges in the Ordovician terranes in the more northern townships covered in the previous reports are not continuous in Hardwick and Woodbury. These noncalcareous rocks as they appear in Greensboro are not persistent in Hardwick. They appear in these two townships as isolated outcrops of rather small dimensions. Many of them cannot be mapped in without including the calcareous members which are all mapped as quartzose limestones and marbles.

These schists vary from fine to medium in texture save where they come in contact with intrusives and become rather coarse grained. Mineralogically considered they are biotite-muscovite-quartz schists. They are studded with lenticular plates of ottrelite set transverse to the planes of foliation. T. N. Dale considers these crystals as biotite. A quantitative chemical analysis made from several isolated spangles from the same schists several years ago approximated to the formula for ottrelite. These crystals vary in size from 0.1 millimeter to 1 millimeter. They bear both magnetite and pyrite. Magnetite sometimes forms the nucleus of the ottrelite spangles. Pyrite appears both in small lenses and in isolated small cubes. When pyrites are invisible to the naked eye they often appear in the microscopic slides. Garnets are common in the more highly metamorphosed outcrops. Acicular crystals of hornblende have often been observed near the contact with intrusives. These crystals are of secondary origin, a product of contact metamorphism. Occasionally these schists are epidotic where they are in contact with intrusives.

The highly altered, garnetiferous, phyllite schist outcrops in the pasture one-half mile west of the village of Woodbury. The garnets are rhombic dodecahedrons and fairly perfect in form. Their broken surfaces show a fresh fracture and therefore they have suffered but little if any oxidation. This is in striking contrast to the condition of some of the garnetiferous rocks in the more northern part of the State. The rock is here closely folded into a rather sharp anticline. The strike is nearly east and west.

A second outcrop of this schist that is highly garnetiferous appears on the east side of the State road leading from Woodbury to South Woodbury. A strike was recorded here of north 70 degrees east and a dip from 45 to 50 degrees to the north. The schist is traversed by three basic dikes that will be described under the caption of basic intrusives. The schist is phyllitic, garnetiferous, hornblendic, ottrelitic or biotitic. It possesses the same characteristics on both sides of the supposed dikes. The garnets appear in the schists for more than 100 feet on each side of the supposed dikes. The limestones that flank the schists on the north are also garnetiferous. The limestones immediately to the south of the schists are drift covered and therefore their characteristics could not be observed. Plate LXIII shows an outcrop of these schists cut by dikes and dipping to the northwest one-half mile north of the village of South Woodbury.

A mapable area of phyllite schist appears on the west side of the Gulf road leading from Hardwick to Woodbury. Its general strike is nearly east and west and its dip is always at a high angle. It is responsible in part for the low ridge to the north and east of Greenwood Lake.

This schist appears again in an intensely folded and crumpled form to the west of the village of Hardwick near the contact of the Ordovician rocks with the sericite schist of Cambrian age. It has been so powerfully folded and crumpled that its strike is difficult to determine. It dips in all possible directions. Plate LXV shows an outcrop of this highly folded and crumpled schist, Hardwick, Vermont.

On Robeson Mountain in Woodbury the original capping of the granite mass contained both calcareous and non-calcareous beds of sediments. The calcareous outcrops now predominate and therefore no phyllites appear in this area on the areal map. The contact between the granite and the biotite-muscovite-quartz schist is well exposed on the northwest side of Robeson Mountain along the railroad of the Woodbury Granite Company. The strike of this outcrop is north 70 degrees west while the axis of the mountain is north 70 degrees east. The plane of contact between the granites and the phyllites is here nearly parallel with the strike of the sedimentaries. The pitch of the strike is about 30 degrees north. The schists interbedded with the limestones

PLATE LXIII.

PHYLLITE SCHIST DIPPING WEST, CUT BY THREE DIKES, A HALF MILE NORTH OF WOODBURY.

also appear on the southwest side of the mountain. A strike of north 67 degrees east was recorded with a dip of 55 degrees to the northwest. By plotting all the dips and strikes of the sedimentaries about the mountain the original structure was synclinal. Schists appear also to the east of Buck Lake but they are encircled by granite. Many small outcrops of mica schist as well as limestone which are surrounded by granite are included in the granite area as drawn in the areal map.

Inclusions of the sedimentaries often appear within the granites. This is especially true of the quarries on Robeson Mountain. These inclusions vary from a few inches in length up to 30 feet and in width from a few inches up to 15 feet. Excellent illustrations can be found at the white quarries of the Woodbury Granite Company. Smaller inclusions can be seen in the prospect openings and abandoned quarries between the Woodbury white and gray quarries.

### D. SLATE.

In the Vermont report of 1861 by Edward Hitchcock and others a belt of slate is represented as flanking on the east the older sedimentaries now cataloged as Ordovician. In the subsequent maps by C. H. Hitchcock this belt is represented as continuous through Hardwick and Woodbury with no limestones to the west of the belt. The latter condition holds true of Woodbury but not of Hardwick. This belt of slate enters Hardwick from the north on the east side of Little Eligo Pond and therefore it lies on the east side of Eligo valley. Eligo valley is cut in the limestones and conglomerate that flank the slate belt on the west. Limestones in Hardwick lie unquestionably to the west of the slate belt. The belt of slate is only a few rods in width and extends southward on the eastern side of Eligo valley almost to the northern end of Hardwick Lake. Here it has been completely removed by erosion.

About three miles further to the south and in Hardwick this slate belt reappears and is continuous in a southwesterly direction into Calais. In Woodbury there are no limestones to the west of the slate. The northern end of this belt in Hardwick to the south of the Lamoille River is very narrow. It widens continuously to the southward where near the south town line of Woodbury it is approximately 100 rods in width. This belt forms somewhat of a semicircle around the eastern side of Woodbury Mountain. The strike of the belt is about north 40 degrees east on the south, north 70 degrees east in the northern part of Woodbury and about north 20 degrees east in the northern part of Hardwick. In its southern extermity the dip of the cleavage planes is at a high angle to the west. In the central portion the dip is at a similar high angle to the east. In the extreme northern part of Hardwick and in Greensboro the dip is to the west. This suggests an overturn of the slate in the southern part of Hardwick and the northern part of Woodbury. From the northern part of Hardwick northward to the international boundary wherever this slate belt has appeared the dip has been to the west.

This slate belt was continuous from Lake Memphramagog on the north in its southern extension through Newport, Coventry, Irasburg into Craftsbury except where it has been cut out by the Irasburg granite. In Craftsbury the belt was broken because erosion was carried below the level of the lower beds of slate. The belt reappears in Greensboro and is again broken in Hardwick for a distance of about three miles. Such evidence lends to the conclusion that this slate is the youngest member of the Ordovician rocks in eastern Vermont. With the uplift at the close of Ordovician time the Ordovician sea was driven out of eastern Vermont to the northward.

This slate represents the western member of the Memphramagog slates described in previous reports. In Newport there are three distinct belts of this slate. In some of the intervening townships the two more eastern belts have been metamorphosed into phyllites. Some of the phyllites of Woodbury are remnants of these belts. If so, in the southern part of Woodbury and the northern part of Calais these more eastern belts should appear again as slates. In Woodbury this condition holds true. Calais remains for future work. The second of these slate belts in Woodbury appears on the eastern side of Valley Lake. The character of this slate is well seen on the outcrops directly east of Valley Lake and on the road from the village of Woodbury to Valley Lake.

The third belt appears on the higher altitudes about one mile further to the east. It is only a few rods in width and is traversed by granitic dikes. This belt of slate as well as the one to the east of Valley Lake belongs to the Memphramagog slates. In them the work this summer has revealed the presence of crushed graptolites which will be mentioned again under the caption of Paleontology as further evidence that these slates are of Ordovician age.

These slates vary from bluish-gray to black in color. They are fairly fissile and trim easily to specimens 3 by 4 inches on the tire of a wagon wheel. They possess the characteristic slaty ring and are sufficiently strong to permit the head of a hammer to be driven through small sheets without splitting the slate. Therefore they could be nailed to a roof without splitting. They are carbonaceous and magnetitic. Pyrites are usually visible on the sawn edge and grains of pyrite are sometimes seen in the microscopic slides. A few garnets are present in the more highly metamorphosed areas and in a few instances small staurolites



were observed. The slate in the more western portion does not effervesce in cold dilute HCl but the central belt that is more or less interstratified with the limestones shows some effervescence.

## ACID INTRUSIVES.

### GRANITES.

The uplift that occurred at the close of the Ordovician caused sedimentation to cease in northeastern Vermont and atmospheric erosion to begin. At the close of the Devonian another crustal movement occurred which was accompanied by the intrusion into the sericite schists, quartzites, phyllite schists, limestones, marbles and slates granitic material in a state of fusion with superheated water. These intrusions induced further changes in many of the sedimentaries and in places injected them with dikes of pegmatite. Inclusions of these sedimentaries as already noted occur in the granite masses. Acicular crystals of hornblende appear in the phyllite schists, limestones and marbles as products of contact metamorphism. Epidote is occasionally found in the limestones and marbles. Zoisite is present in the Cambrian sericite schist and quartzite of the same age.

Soon after the crystallization of the granites they were traversed by dikes of pegmatite and aplite. T. N. Dale in his Bulletin on "The Granites of Vermont" suggests that these granite masses may have been introduced as late as the Carboniferous time. In Quebec where the same types of granite occur in terranes of the same age as those in Hardwick and Woodbury the granites are considered as Devonian. In all of the earlier reports by the first named author of this report, whether written alone or in conjunction with some graduate student, these acid intrusives have been cataloged as Devonian.

#### HARDWICK.

The areal map of Hardwick, Plate LXIV, represents three rather extensive granite areas within the township. One of these is situated in the northwestern part of the township, one in the southeastern part and one in southern part of Hardwick.

The granite district in the northwestern part of the township of Hardwick appears near the summit of West Hill and extends to the north for more than two miles. Its width at the widest point exceeds one-half mile. It embraces all of the abandoned quarries on West Hill and at Tuckerville. It lies entirely in the Cambrian terranes.

The product of these quarries has found only local use. The granites are generally gray in color and of uniform medium texture. The rift and grain are good for the stone splits easily and uniformly into paving blocks. Some of these blocks may now be seen around the abandoned Brodie quarry at Tuckerville. Here there are two openings. One was a boulder quarry situated about 100 rods to the south of the road through Tuckerville. The other was situated about 150 rods south of the same road. The strike of the outcrop was north 40 degrees west. In the same belt another strike of the granite outcrop was north and south.

On the farm of C. W. Alexander in the wooded pasture about 100 rods south of the same road through Tuckerville there is a granite of pink or red color entirely different from any other granite in the State. The strike of this granite is north and south. Samples from these outcrops were necessarily taken from near the surface for no openings have ever been made in this new variety. Some ledges were found in which the feldspars appeared but little kaolinized and the discoloration through the oxidation of iron was slight. The stone appears of finer grain than the Newark red granite. Microscopic slides of this granite have been prepared but the time available for their petrographic study in detail has been too limited for this report. The extent of the area is unknown. The owner purposes to open a prospect at this site this autumn and have samples below the surface polished to ascertain their susceptibility to a polish and the color of the stone below all possible oxidation. As this locality represents an entirely new discovery made by our party this summer the results are awaited with much interest.

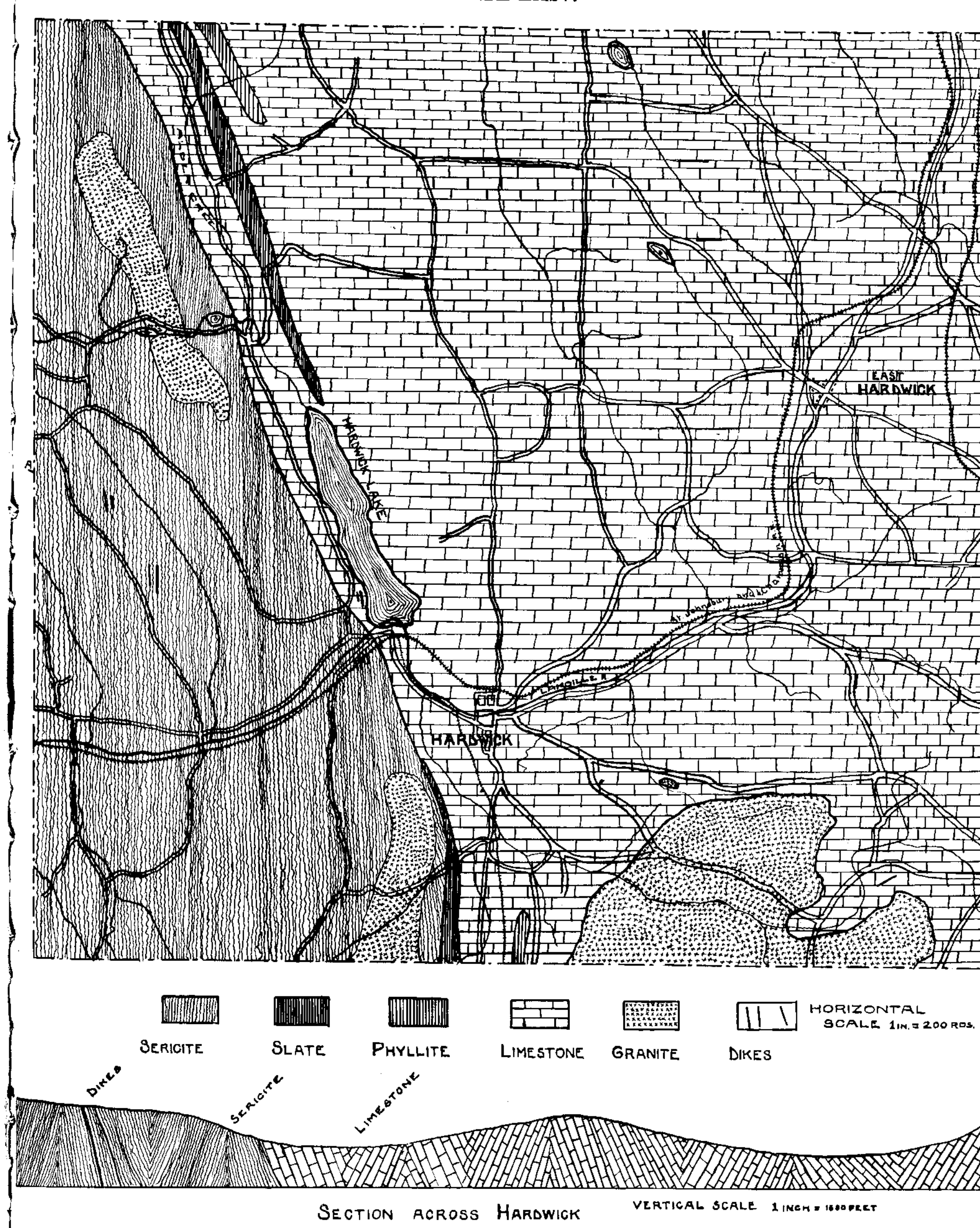
The granite areas in the southeastern part of the Township fall within the Robeson Mountain district as given on the areal map. The area between the abandoned R. H. Carter quarries and the Nichols Ledge and Buck Lake quarries is heavily covered with glacial debris. A careful study of the area has led to the conclusion that the entire field should be mapped as a unit. Numerous outcrops of granite are observed by the careful student in the field. Where the schists appear at the surface they are often intersected by granite dikes.

The abandoned quarries at Mackville still have their derricks standing. The granite is of dark gray color and medium texture. It receives an excellent polish and is well suited for monumental work. It is a biotite granite bearing only a few scales of muscovite. Microscopic slides of this granite have also been prepared for further study.

About 100 rods to the northeast of the Mackville quarries there is now in active operation a boulder quarry. It is a biotite granite of lighter hue than that at the old Mackville quarry.

On the W. A. Scott farm one-half mile to the north of the Mackville quarries George H. Bailey of Hardwick is quarrying granite from another new opening. A few men only are quarrying the stone and a few men are manufacturing monuments at the small stone sheds at the quarry. It is a biotite granite of

PLATE LXIV.




MAP OF HARDWICK

East town line is N. 40° E.

lighter gray color than that at Mackville now owned by the R. H. Carter estate. Although the opening is about 150 feet in length and 100 feet in width it is called a boulder quarry. There is no granite outcrop to the north from which a granite boulder more than 100 feet in length and breadth could have been derived. It is neither impossible nor improbable that true bed rock will be encountered at no considerable depth. The chief difficulty in operating the quarry lies in the fact that the quarry is situated in a valley which entails a greater expense in the disposal of grout. The distance from Hardwick and the easy haul by teams does not preclude continued operations of the quarry.

The third granite belt in Hardwick of commercial significance has its northern terminus about one mile southwest of the village of Hardwick. The general strike of the belt is in Hardwick, north 40 degrees east, but in its southern extension into Woodbury it becomes north 70 degrees east. The entire belt is more than three and one-half miles in length and is about 200 rods wide on the southern Hardwick line. It includes the Brush quarries in the edge of Woodbury, the abandoned H. R. Mack quarries on Buffalo Hill and the quarries now operated by Clarence Hamilton on the north side of the road to Elmore over Buffalo Hill.

The quarry long known as the Buffalo Hill quarry was opened up in 1887. It was operated for a considerable period of time by the Hardwick Granite Company, Hardwick, Vermont. A derrick still stands but the property has been abandoned. The opening is about 30 feet deep and shows no signs of a sheeted structure. The course of the rift which is vertical is north 50 degrees east, while the course of the grain is north 30 degrees west with a dip of 35 degrees to the west. It is in contact on the west with a medium grained biotite quartz schist containing zoisite. The position of the schist is nearly vertical and the quarry opening has been carried westward to the contact face.

The color of this granite is a dark gray. Commercially it has been known as the "Dark Blue Hardwick granite." Its texture is medium. It takes a good polish and hammers light. The stone bears a marked contrast therefore between the hammered and polished faces. This granite bears a little pyrite and magnetite in smaller percentage than the pyrite. The zone of oxidation on surface blocks extends about six inches into the rock. It effervesces feebly with dilute HCl, showing the presence of calcium carbonate.

T. N. Dale in his Bulletin entitled "The Granites of Vermont" characterizes this granite as a quartz monzonite of dark gray shade, a little darker than dark Barre and a trifle lighter than dark Quincy granite. Dale gives its mineral composition in descending order as smoky quartz with hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase to oligoclase-andesine), much kaolinized, somewhat micasized and epidotized, and containing calcite; in about equal amount with this feldspar a clear to bluish-white potash feldspar (microcline with a little orthoclase), some of it kaolinized, some of it inclosing particles of all the other constituents; olive colored biotite with a little muscovite or bleached biotite. The accessary minerals are pyrite, magnetite, apatite, zircon and allanite. The secondary minerals are kaolin, a white mica, epidote and calcite.

The Clarence Hamilton quarries are situated about 100 rods to the northeast of the old Mack quarries and within the same granite belt. This granite is being actively quarried at the present time by a few men only. The granite is not of quite so dark a gray color as the Buffalo Hill. It is of medium texture with good rift and grain. Its close proximity to the preceding granite, and in fact connected with it in a drift covered area, would suggest that this stone is also a quartz monzonite.

Further study of our microscopic slides is necessary to establish this point, either for, or against.

## WOODBURY.

There are five mapable granite areas in the township of Woodbury as will be seen on the areal map, Plate LIII. One of these is situated in the northwestern part of Woodbury, one in the northern and northeastern part, two small isolated areas lying between Woodbury Gulf and the hill road from Hardwick to Woodbury and one small area about one mile to the northeast of South Woodbury.

The first mentioned area forms the southern end of the last belt described in Hardwick. The length of this belt in Woodbury is approximately two miles. It lies on the eastern slope of Woodbury Mountain and everywhere to the west of the long narrow belt of Ordovician slate. This granite belt is about one-half mile in width on the north town line of Woodbury. It also lies in a section that is everywhere heavily wooded and on the steep slopes of Woodbury Mountain range. It was with great difficulty that this outcrop was traversed along the line of its strike and cross sections run over its eastern bluffs which sometimes rise abruptly for nearly 200 feet. It contains the old Brush quarry now abandoned. The granite is of medium texture, with good rift and grain. It is of light gray color and may be used for either monumental work or building purposes.

The Robeson Mountain district comprises a vast area whose southern end is about one mile to the northeast of the village of Woodbury. Robeson Mountain proper attains an altitude of approximately 2,000 feet. It is about 1,100 feet above the village of Hardwick and about 700 feet above the village of Woodbury. It rises also some 400 feet above the depression upon either the

PLATE LXV.

HIGHLY FOLDED AND CRUMPLED PHYLLITE SCHIST, HARDWICK VILLAGE, ON R. R. NORTH OF WOODBURY GRANITE CAR SHEDS.

east or the west side of the mountain. It forms a ridge whose strike varies from north 70 degrees east to north 80 degrees east and is about one mile in length.

The entire district with its northern extension into Hardwick is about four and one-half miles in length and about two and one-half miles in width. It embraces an area therefore of more than ten square miles. The Buck Lake quarries, the Nichols Ledge quarries and the Mackville quarries in Hardwick are all within this area mapped as granite.

The Fletcher quarries are situated near the extreme southern end of Robeson Mountain and on the southeastern side. The quarry opening is being carried in a northwesterly direction across the axis of the mountain. Work has now been extended to the very crest of this axis. The quarry is about 300 feet in length and about equal width and 50 feet in depth. The structure is double-sheeted. The position of the sheets on the crest of the mountain is horizontal. They curve gradually on the eastern side until the dip of the beds reaches an angle of 30 degrees, which determines somewhat the slope of the eastern side of the mountain. They curve also on the western side of the mountain gradually up to 30 degrees which determines the slope of the mountain on its western side. This condition is well illustrated at the new quarry of A. B. Thomas on the southwestern corner of the mountain.

A second set of sheets at the Fletcher quarry possesses a dip of south 10 degrees west 70 degrees. The sheets on the northwest end of the mountain dip to the northwest. There is therefore a dome-like structure in the granites of the mountain. The double sheeted structure so far as known to the writers of this report has never before been observed in granite quarries.

T. N. Dale explains this structure by the existence at some time of a secondary compressive strain operating differently from that which produced the primary sheet structure to which the ridge owes its form, and giving rise to a nearly horizontal set of joints or sheet partings.

The sheets vary in thickness from 2 to 30 feet. Some of the thicker sheets are seen near the surface and the southern end of the quarry. The quarries are owned and operated by E. R. Fletcher, Hardwick, Vermont. The stock is well suited for monumental work and constructional purposes. The average number of men employed at the quarries during the year 1913 was 50 and at the manufacturing end 50 more men, making a total average on the payroll of 100 men. The stone is transported to Hardwick over the railroad owned and operated by the Woodbury Granite Company.

T. N. Dale in his Bulletin on "The Granites of Vermont" characterizes this granite as a biotite granite of light gray shade (between light Barre and the granite of Hallowell, Me.) and of medium texture with feldspars up to 0.3 inch and mica to 0.1 inch. Its mineral composition in descending order is orthoclase clear to translucent, some of it minutely intergrown with plagioclase and microcline; smoky quartz with hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase-albite) much kaolinized, somewhat micacized, epidotized and with calcite; black mica, biotite, some of it chloritized; and a little muscovite or bleached biotite.

The accessory minerals are pyrite, titanite, zircon, apatite and rutile. The secondary minerals are kaolin, a white mica, epidote, zoisite, calcite and limonite.

The Woodbury gray quarries owned and operated by the Woodbury Granite Company of Hardwick, Vermont, are situated about 1,500 feet north 80 degrees east from the Fletcher quarries. They are therefore on the eastern slope of Woodbury Mountain. A sheeted structure was also here observed. The different sheets in descending the quarry face are: (1) 15 feet, (2) 10 feet, (3) 15 feet, (4) 25 feet, (5) 50 feet in thickness, making a total depth of the present working face 115 feet. The sheets as already noticed dip to the east from 15 to 30 degrees depending upon how far down they are on the eastern slope of the mountain. The length of the quarry is about 2,000 feet with a breadth of 500 feet. The average number working at the quarries in June was 150 and the average number at the manufacturing end in Hardwick was 430, making an average payroll for the month of 600 men. On January 10, 1914, there were 1,373 men on the payroll. The largest payroll in 1913 at any one time carried by this company was 1,789 men. Plate LXVI, A, shows the thickness of a single sheet of granite, Woodbury Gray Quarry, Robeson Mountain, Woodbury, Vt.

The Woodbury gray granite is a biotite granite of medium gray color and medium texture. The feldspar crystals reach 0.3 inch in diameter and the biotite 0.1 inch. To the naked eye the stone closely resembles the granite from the Fletcher quarry. It is in reality a finer stone, for the quartz particles are not as large, or as numerous, or as smoky as they are in the Fletcher quarry. The mineral contrasts on the rough blocks is not quite so strong as in the Fletcher quarry but contrasts on the polished face are very strong. The stone receives a good polish as seen on the discs submitted to the writers of this report. It is a good stone for monumental work or constructional purposes.

T. N. Dale gives the mineralogical composition of this granite as clear to translucent potash feldspar (microcline and orthoclase) somewhat kaolinized; light smoky quartz with hairlike crystals of rutile; milk-white soda-lime feldspar (ologiclase) considerably kaolinized; biotite and a little muscovite or bleached biotite. The accessory minerals are pyrite, apatite, zircon and rutile. The secondary minerals are kaolin and zoisite.

PLATE LXVI.

A. WOODBURY GRANITE CO.'S GRAY QUARRY, SHOWING THICKNESS OF A SINGLE SHEET, ROBSON MT., WOODBURY.

B. CONTACT BETWEEN PHYLLITE AND GRANITE, WOODBURY GRANITE CO.'S WHITE QUARRIES, WOODBURY, BUCK LAKE DISTRICT.

The Woodbury Bashaw quarries owned and operated by the Woodbury Granite Company from the northern extension of the Woodbury gray quarries. They are therefore nearer to the northeast corner of Woodbury Mountain. This quarry also possesses a sheeted structure with a dip of the beds nearly horizontal on the top and more towards the northeast on this slope of the mountain. The thickness of the different sheets approximate to those in the Woodbury gray quarry. Seven different joint courses were found in this quarry. They are either head seams well defined or what the quarrymen call tight shut seams. (1) North 30 degrees east, called a dead head seam; (2) north 20 degrees west, called a tight shut seam; (3) north 20 degres east; (4) north 40 degrees west; (5) north 15 degrees west; (6) north 60 degrees west; (7) north 50 degrees west.

The Woodbury Bashaw granite is a biotite granite of medium gray shade that somewhat resembles the biotite granite of Concord, N. H., but its contrasts are stronger. It varies from fine to medium in texture with feldspars up to 0.2 inch and biotite to 0.1 inch in diameter. The feldspars are less kaolinized than they are in the Woodbury gray granite and therefore the mineral contrasts are not quite so marked on either the rough or polished surfaces. This granite effervesces slightly with cold dilute HCl showing the presence of calcite. It is chiefly a monumental granite but it may also be used for building purposes. The average of three compression tests made at the United States Arsenal at Watertown, Mass., of the Woodbury gray granite was 20,806 pounds per cubic inch.

The Vermont white quarries of the Woodbury Granite Company are situated near the crest of a ridge about one-half mile north of Robeson Mountain, and about 100 rods north of Wonderland Junction on the railroad of the Woodbury Granite Company. These quarries are owned and operated by the Woodbury Granite Company. The quarry is about 1,000 feet across it and about equal length. It is 40 feet in depth. The sheeted structure is not as pronounced as on Robeson Mountain and the sheets vary in thickness from 2 to 23 feet.

Large inclusions of limestone and phyllite schists can be seen at these quarries. The largest ones measuring up to 30 feet in length and 15 feet in width. In a smaller opening on the right of the spur of the railroad leading into the quarry the contact between the granite and nearly vertical wall of the sedimentary rocks is plainly visible. Plate LXVI, B, shows the contact between the phyllite schist and the granite in the Woodbury white quarries, near Buck Lake district, Woodbury, Vermont.

The direction of the joint courses for this quarry was not worked out on account of a lack of time available for the work. Other and unexpected matters took our attention. On one of the major head seams there is a zone of crushed granite that resulted from compressive stresses operating subsequently to those that developed the jointing of the granite. This crushed zone has been impregnated with iron minerals whose oxidation has produced a red or yellowish red coloration to the entire crushed mass. The intensity of the color depends upon the amount of hydration the resulting oxides of iron have undergone. Within a few feet of this crushed zone of granite there is a dike of amygdaloidal basalt that was introduced into the granite probably in Triassic time. This dike appears to be responsible in part for the impregnation of the granite with iron compounds. Plate LXVII, A, shows this crushed zone of granite near dike of amygdaloidal basalt, Woodbury, Vt.

There is a striking contrast between the very light and cream-tinted gray granite of this quarry and the reddish color of this limonitized and crushed zone. The granite assumes a normal color only a short distance from this zone and upon either side of it.

This granite as already intimated is a very light, slightly buff or cream-tinted gray shade of color. It is of medium texture for the feldspars measure up to 0.3 inch in diameter and the biotite to 0.15 inch. Its quartz is pale smoky. The biotite is present sparsely which is responsible for the whiteness of the granite. Kaolinization of the feldspars may also be responsible for this whiteness. The stone is not as white as the Bethel granite. The stone takes a good polish and the mica furnishes a strong contrast with the quartz and the feldspars. Microscopic slides of this granite have been prepared but their mineral composition has not yet been determined. The stone is one of the most desirable of construction products and one of the largest contracts ever given a Vermont Granite Company was filled from this quarry. More than 500,000 dollars worth of stone is said to have been removed from this one quarry.

A few hundred feet to the east of this quarry there is a small quarry of fine dark gray granite. It is a biotite granite of dark bluish-gray shade and fine texture. The feldspars measure up to 0.2 inch in diameter and the biotite to 0.1 inch. It is darker than any granite on Robeson Mountain but not quite so dark as the Woodbury imperial blue granite. It is about the same shade as the dark granite of Barre, Vt. It is a monumental stone rather than constructional. It receives a high polish. The sheets appear to dip under the sheets of the Vermont white granite.

The imperial blue quarries of the Woodbury Granite Company are situated about 1,000 feet to the southeast of Buck Lake. The quarry opening is about 600 feet in length and 500 feet in width and 30 feet in depth. The stone is of dark bluish-gray color and medium texture with feldspars up to 0.3 inch in diameter and biotite 0.1 inch. This granite receives a very handsome polish and is a fine monumental stone. It may be used also in construction. Microscopic slides have been prepared from these

PLATE LXVII.

A. SHOWING CRUSHED ZONE OF GRANITE NEAR DIKE OF AMYGDALOIDAL BASALT, BUCK LAKE DISTRICT.

B. WOODBURY GRANITE COMPANY'S BLUE QUARRY, SHOWING HEAD SEAMS, BUCK LAKE DISTRICT, WOODBURY.

quarries but the mineral composition has not yet been worked out for lack of time. The granite is darker in color than any of the granites on Robeson Mountain. Plate LXVII, B, shows the Woodbury imperial blue quarries with characteristic head seams, Buck Lake district, Woodbury, Vermont.

About 20 rods to the south of the imperial blue quarry there is an extremely fine grained biotite granite of grayish color that has not yet been opened up. The glacial debris that overlies this granite to a depth varying from 2 to 4 feet has been cross-cut for a distance of 125 feet north and south without finding the ends of this fine grained granite. It has also been cross-cut in an east and west direction for 75 feet with the same result. The granite is owned by the Woodbury Granite Company whose intention is to open quarries on this site at once. The granite is much finer grained than any other granite found in either Hardwick or Woodbury except a new discovery made by our party a little to the northwest of Buck Lake.

About 40 rods to the southwest of the imperial blue quarries on the slope of Round Mountain there is another granite area now being opened by the Woodbury Granite Company. This is a prospect of biotite granite of medium texture and dark bluish-gray color that closely resembles the imperial blue granite.

There are a considerable number of prospects and small quarries, some now being operated and others abandoned, around Buck Lake and between the Woodbury Vermont white granite and the Woodbury Bashaw granite quarries.

The abandoned Carson quarry is situated on the northeast foot of Robeson Mountain in Woodbury. The granite is a biotite granite a little finer than that of the Fletcher quarry and quite similar to the Woodbury gray.

The old Ainsworth quarries are about 1,000 feet northeast of the railroad of the Woodbury Granite Company and also to the northeast of Robeson Mountain. These are both biotite granites quite similar to that of the Woodbury gray quarry. One quarry has an opening 50 feet in length, 35 feet in width and 20 feet in depth. The other quarry has an opening some 50 feet in length, 20 feet in width and about 15 feet in depth.

The abandoned Miller quarry is about 500 feet to the southwest of the Ainsworth quarry. It is a biotite granite with about the same texture as the Ainsworth quarries.

The Webber quarries are situated to the north of Woodbury white quarries on a ridge that is continuous with the one on the southeast side of Buck Lake. Two types of granite appear in these quarries. One is a fine grained, bluish-gray biotite granite and the other a medium grained light bluish-gray biotite granite. These granites are best suited for monumental purposes.

The Robie quarry is situated near the south end of Buck Lake. It is a biotite granite, of medium texture and gray color. It quite closely resembles the Woodbury gray.

The Ashley Smith quarry is situated a little to the west of the outlet to Buck Lake. It is a biotite granite of bluish-gray color and medium texture. The Fryatt and Ainsworth quarry is situated to the east of Buck Lake outlet. It is a biotite granite and somewhat resembles the Ashley Smith granite.

The Kimball quarries are situated to the south of Buck Lake. There are two different types of granite in these quarries. They are both biotite granites of medium texture. One is of bluish-gray color and the other is pinkish or slightly reddish.

In this immediate neighborhood there are several abandoned quarry openings and the name of the original or present owners is not known to the writers of this report. Their presence tends to confirm the large distribution of this granite mass as shown on the areal map.

Nichols Ledge is situated within the same large granite area as given on the areal map. It is furthermore in the northeastern corner of Woodbury. The old R. H. Carter quarry is on the northeast side of this ledge. The granite is a biotite granite of light to medium bluish-gray color and of fine to very fine texture. It is further characterized by large porphyritic feldspar crystals formed about the other minerals. This porphyritic aspect of the granites is seen in some of the smaller openings around Buck Lake.

The Fisher quarry is situated on the north side of Nichols Ledge and the granite possesses the same general features as the Carter quarry which has later been known as the McLeod quarry.

The S. Judd quarry is situated in the northernmost of the two isolated granite outcrops west of the hill road that leads from Buck Lake to Mackville. The opening is on the northeast end of the granite mass and three-fourths of a mile south of the Hardwick line. The quarry opening is 150 feet in length, 100 feet in width and 35 feet in depth. The granite is of grayish color and medium texture. It is a biotite granite. The quarry has been abandoned.

At a higher altitude on this ridge and to the south of the Judd quarry a few hundred feet there is another very small and shallow opening of the same type of granite. This appears to be the abandoned Hopkins quarry.

In the southernmost of these isolated granite masses about two miles to the south of the Hardwick line the granite has a surface exposure for about one-fourth of a mile and for several hundred feet in width. The western face is about vertical and approximately 100 feet high. The granite is an extremely fine grained biotite granite of a bluish-gray color. The sheets appear to be above the average thickness around Buck Lake. No openings were found in this mass which lies in a very thick tangle of second growth timber and underbrush.



In the southeastern part of Woodbury and to the south of Robeson Mountain there is another granite area about one mile in length and 100 rods in width. It is a biotite granite. In this area no quarry openings could be found. Difficulty in access and distance from the railroad of the Woodbury Granite Company practically preclude the opening of quarries at this place.

## GRANITE MANUFACTURERS.

The Granite Manufacturers' Association of Hardwick comprises the firms now actively engaged in the manufacture of granite in Hardwick and those firms that are quarrying granite and shipping the same in the rough stock. The list as far as could be ascertained is given below.

American Granite Company with John Walsh as manager employs an average of 25 men. The company uses stock from the Fletcher quarry and from Barre. The work is all monumental.

Albertini and Company employs 3 men. The stock used is Woodbury and the work monumental.

George Anairo, Greensboro Bend, employs 6 men. The stock is from Woodbury and Barre. The work is monumental.

Calderwood and Merriam employ 3 men. The stock is Woodbury and Barre. The work is monumental.

Crystal Brook Granite Company employs 20 men. Stock is Woodbury and Barre. The work is all monumental.

Eureka Granite Company employs 3 men. Stock is Woodbury. The work is monumental and mausoleum.

E. R. Fletcher employs 100 men. The quarries are on the southeast side of Robeson Mountain in Woodbury. The work has been both monumental and constructional.

Hardwick Polishing Company, Frank Dupaw, manager, employs a few men and executes all kinds of polished work desired.

John Hay employs on an average 8 men. The stock is Woodbury. The work all monumental.

Howard and Martin employ 25 men. The stock is Woodbury. The work is monumental, mausoleum and building.

James Granite Company employs 3 men. The stock is Woodbury and Barre. The work all monumental.

E. R. Murch employs 20 men. The stock is any New England granite. The work is monumental, mausoleum and building.

F. A. Purdy employs 40 men. The stock is Woodbury and Bethel. The work is building, carving, architectural and sculptoring.

Ashley Smith averages to employ 35 men. The stock is Woodbury, Barre and Scotch granites. The work is building and monumental.

Frank Vavala employs 13 men. The stock is Woodbury. The work is building and monumental.

Woodbury Granite Company now employs 600 men. January 10, 1914, there were 1,373 men on their payroll. The stock is from their own quarries on Robeson Mountain, from the Buck Lake quarries, and from their own quarries in Bethel, Vermont, where they obtain the Bethel white granite, the whitest granite known.

A. B. Thomas employs a few men in quarrying granite at a new opening on the southwest corner of Robeson Mountain in Woodbury.

George H. Bailey employs a few men in quarrying and manufacturing granite at a new quarry about one-half mile east of Mackville, in Hardwick.

Clarence Hamilton employs a few men in quarrying granite at a new quarry north of the H. R. Mack quarry on Buffalo Hill, Hardwick.

Fadden Granite Works employ 3 men. The stock is Mackville and is quarried in the Wheatley pasture in the town of Hardwick near Mackville.

R. H. Carter estate is the owner of the old quarries at Mackville, now idle.

Henry R. Mack is the owner of the quarries on Buffalo Hill, now idle.

The West End Granite Company employs 6 men. The stock is Woodbury and Barre. The work is all monumental.

## ACID DIKES.

On West Hill in Hardwick, two miles southwest of Tuckerville and one mile from the west town line, there is a light colored aplitic dike with a strike similar to that of the sedimentaries north 50 degrees east. It is several hundred feet in length and 10 feet in width.

Another aplitic dike is exposed between Hardwick Lake and the Alder Creek road to Craftsbury. It is about 15 rods north of the dam at the outlet of Hardwick Lake. This dike is from 12 to 15 inches in width and has a strike of north 40 degrees east.

Four parallel dikes cut the sericite schists 20 rods south of the dam at the outlet of Hardwick Lake. These dikes have a strike of north 40 degrees east and vary from 6 inches to 2 feet in width and from 50 feet to several hundred feet in length.

On the town line between Hardwick and Woodbury and on the eastern side of the Gulf road there is an aplite dike 5 feet in width which has a north and south strike and cuts the Ordovician terranes at an angle of about 50 degrees.

A granitic dike several hundred feet in length and from 10 to 20 feet in width with a strike almost east and west is situated in the southeastern part of Hardwick. It is about one-half mile north of the Woodbury town line and about one-half mile west of the Walden town line.



Directly to the west of Woodbury Mountain there is a large granitic dike several hundred feet in length and from 15 to 40 feet in width. Its strike is nearly east and west.

A very similar dike both in size and texture is found on the Cabot line two miles south of the Hardwick town line. The strike is north 30 degrees east.

Another granitic dike cuts the limestones just south of the Hardwick line in Woodbury and a few rods to the east of the Hill road to Buck Lake.

Four dikes cut across the Gulf road within a mile north of the village of Woodbury. They are in part granitic, in part pegmatitic and vary from 2 to 15 feet in width. One of these dikes forms a natural dam across the outlet of a very small pond close to the Gulf road. The northernmost of these dikes has a strike of north 70 degrees east. The others have a strike nearly east and west.

A small aplitic dike occurs at the first switchback on the railroad of the Woodbury Granite Company. It is furthermore located under and to the west of Robeson Mountain.

One mile southeast of Valley Lake and on the road to South Woodbury there is a large aplitic dike several hundred feet in length and 10 feet in width which forms the center of a ridge whose strike is north 40 degrees east.

Southeast of Robeson Mountain the limestones and their interstratified phyllites are traversed in almost every direction by a number of dikes which occur on both sides of the road for a distance of about 2 miles. Seventeen of these dikes were cataloged and their strike recorded. Most of them are aplitic, although some of the larger ones are granitic. The strike of these dikes varies from north and south to east and west. It is probable that there are several other smaller dikes that escaped notice as the country is rough and bush-covered.

In the limestones and schists in close proximity to the granite mass on Robeson Mountain there are many pegmatite and aplite dikes. They vary in width from a few inches to several feet. Three of these dikes may be seen on the east side of the spur of the railroad of the Woodbury Granite Company that extends from Wonderland Junction to the white quarry.

An excellent illustration of a true pegmatite dike may be seen upon the floor of the Woodbury white quarry. It varies from 3 to 4 feet in width. The large plates of mica reach 4 inches in diameter. This dike, like several others, was injected into the granite mass soon after the crystallization of the granite took place.

## BASIC INTRUSIVES.

The basic intrusives in Hardwick and Woodbury appear in the form of dikes. These dikes are post-Devonian in age for they cut the granites and may be as late as the Triassic. The freshness of the broken surface and the narrow limit of disintegration on the surface of some of these dikes substantiates this late age.

On West Hill in Hardwick, two miles southwest of Tuckerville and one mile east of the Wolcott town line, there is a diabase dike several feet in width. Its strike is north 50 degrees east. It is within 20 rods of an aplite dike and parallel with it.

One mile to the south of this dike and to the east of the road over Lovejoy Hill there are two basic dikes some 10 feet apart with strike north 30 degrees east and dip of 60 degrees to the west. These dikes are of high specific gravity and the exterior is of almost black color on account of the rapid oxidation of a large iron content. They are several hundred feet in length and about 3 feet in width. Their blackened weathered surface renders them conspicuous objects for a considerable distance away.

On the Walden town line to the southeast of East Hardwick there is an amphibolite dike with strike almost north and south and width about 10 feet. It can be seen in the railroad cut along the town line between Hardwick and Walden.

A diorite dike more than 100 feet in length and 12 feet in width appears just west of Hardwick Lake and about 20 rods north of the outlet of the lake. The rock forms the core of a small hill and extends down to the water's edge. This intrusive is granitoid in texture and of dark gray color. The strike is north 40 degrees east and the dip is 70 degrees east.

About 25 rods to the east of the outlet of Hardwick Lake and south of the road to the village of Hardwick there appears a dike of diabase about 50 feet in length and 12 feet in width. This rock has a dark olive-green color. The strike is north 40 degrees east and the dip is at a high angle to the east. Acicular needles of secondary hornblende appear in the Ordovician sediments which this dike cuts. These crystals were developed by contact metamorphism.

A dike of basalt somewhat serpentinized cuts through the granite on the southwest corner of Robeson Mountain in Woodbury at the A. B. Thomas quarry. This dike is about 18 inches wide at its southernmost exposure and narrows somewhat towards the northeast. The strike is north 80 degrees east and the dip is at a high angle to the south. The dike material is a dark colored compact basalt. In places it shows bright yellowish-green patches of serpentine.

Near the northeast corner of the Woodbury Vermont white granite quarry there is a prominent dike of amygdaloidal basalt. It varies from 1 to 2 feet in width and is faulted. Its strike is north 80 degrees east and its dip varies from 80 degrees to 85 degrees south. This dike material is somewhat serpentinized and falls to pieces rapidly on exposure to the atmosphere. This condition is well illustrated at the exposed end of the dike amidst the unremoved blocks of granite already quarried. The amygdaloidal cavities are filled with secondary quartz, or calcite, or both. Some cavities still remain unfilled, or filled only in part, or else there has been a solution of calcite from an original filling.



One and one-half miles south of the village of Woodbury and on the east side of the road leading to South Woodbury there are three dikes of amphibolite or else they represent most highly altered sediments that present all the facial appearances of dikes. The northernmost of the three dikes has a strike of east 20 degrees south and a dip of 40 degrees to the northeast. It is about 100 feet in length and varies from 2 to 4 feet in thickness. The central dike has a strike of east 25 degrees south and a dip to the northeast. It is exposed for a much shorter distance than either of the other two dikes.

The southernmost of these three dikes has a strike of east 20 degrees north and a dip to the southeast. It is over 100 feet in length and is about 6 feet in width at the widest point.

Arguments in favor of this material being dikes may be summed up as follows: (1) They cut across the strike of the sedimentaries. (2) They do not conform with the cleavage planes of the schists and slates which they traverse. (3) They make an angle of 15 degrees with the planes of schistosity in the sedimentaries. (4) They are without definite rift and grain. (5) They are jointed like many basic rocks. (6) Their specific gravity is much higher than that of the adjacent sedimentaries. (7) The exposed surface weathers differently from that of the adjacent sedimentaries. (8) The rock bears phenocrysts of hornblende somewhat resembling those found in camptonite. (9) The rock is highly garnetiferous, more so than the adjacent sediments. (10) The adjacent sediments are studded with garnets that appear to be developed through contact metamorphism and there is no other contiguous intrusive to which this influence can be attributed.

Microscopic slides have been prepared of all of these basic dikes but the time available for their optical study has been inadequate. These slides await the identification of all minerals they contain which may lead to a change in the definition given the contents of some of these dikes. It is desired therefore that these names be held as tentative, being determined only by field relations and macroscopic study in several cases. The results of the later investigations will be of interest in connection with the next report. Some of these dikes are too rare in Vermont for a hasty interpretation.

## PALEONTOLOGY.

T. Nelson Dale in his Bulletin entitled "The Granites of Vermont" on page 85 as printed in the Annual Report of the Vermont State Geologist, 1910, says: "Great difficulties have been experienced on the west side of the Green Mountain range in distinguishing slates and schists of Cambrian, Trenton and upper Silurian age, because of their petrographical identity in places and also because of the unexpected unconformity between the Cambrian and Ordovician, and the frequency of faults, as well as the general obscuration of original structure by cleavage. In view of that it will be well to proceed cautiously in discussing the age of slate and schist belts on the east side of that range. This is the more important because of the uncertainty of geological mapping, owing to the want of contour maps. In such a territory paleontological evidence should be confirmed by carefully established areal and structural relationships in order to obtain final age determinations." Dale regards all age determinations thus far obtained in eastern Vermont as provisional.

The erosional unconformity that exists between the Cambrian and the Ordovician terranes was discovered by the first named author of this report in 1904 in Irasburg, Vermont, and the true basal conglomerate revealing the existence of this erosional unconformity was named by him the Irasburg Conglomerate. This conglomerate has now been traced several miles to the north of Irasburg and to the south through Irasburg, Albany, Craftsbury, Greensboro, Hardwick and Woodbury.

The sericite schists, sericitic slates, sericitic marbles, sericitic quartz schists and quartzites cataloged as Cambrian all lie to the west of this unconformity. Furthermore the quartzite has been followed northward with the same general lithological characteristics into Canada where upper Cambrian fossils have been obtained.

In 1897 the first named author of this report visited the typical graptolite beds at Castle Brook, Magog, Quebec. He collected hundreds of specimens of rock and made a careful study of the different graptolites they contained. In 1898 and 1899 while at work on the eastern side of Lake Memphramagog in Canada in the black slates and limestones he found graptolites well preserved in the slates that dip under Lake Memphramagog and reappear in Newport and Coventry. These slates in their extension into Vermont where named by him Memphramagog slates. This name has been retained for the black or bluish-black slates in their southern extension in Vermont.

In 1907 the same author also found crushed graptolites in Coventry in the limestones, and in 1908 in Brownington in the limestones at a point about 5 miles east of the first named locality. These graptolites or other carbonaceous forms have been recognized by Dr. Rudolf Ruedemann, State Paleontologist, Albany, N. Y., as genuine graptolites of Ordovician age. Prof. J. A. Dresser, then of McGill University, from several samples submitted to him from each locality wrote "Your graptolite will no doubt prove genuine."



In 1909 a few crushed forms were found in Irasburg and in 1910 in Albany. These added no new evidence. In 1911 a new area of considerable promise was found in Craftsbury. In 1912 a far better area was found on Graptolite Hill in Greensboro to the north of Caspian Lake, and another smaller and less important area to the east of the cemetery near the village of Craftsbury and also another small area in the extreme northeastern part of the township.

In 1913 a few forms were obtained in the work in Hardwick and Woodbury. In 1914 the best locality yet discovered was found during the closing days of our work in the field on the east side of Valley Lake in Woodbury and to the south of the bay called the Hart's tongue. Graptolites were obtained here in both the limestones and the interstratified slates. Some of these forms have been sent to Dr. Rudolf Ruedemann, from six of the towns mentioned above, and in his opinion they are all graptolites, although in several cases the genera is uncertain.

Dr. Ruedemann in his letter of September 26, 1914, writes concerning the specimens submitted from Graptolite Hill in Greensboro and the Valley Lake discovery in Woodbury, "These are quite certainly graptolites, probably branches of Dichograptus and Didymograptus." Concerning the sample from Craftsbury he says, "These suggest Phyllograptus and Diplograptus."

Ruedemann has previously recognized other genera in samples submitted to him from both Coventry and Brownington. It is expected that the work another summer around Valley Lake in Woodbury will reveal forms better preserved than any specimens yet obtained, for this discovery was only made during the last hours of the work in the field this summer, and because here the planes of cleavage more nearly coincide with the planes of bedding than in any other locality in eastern Vermont where evidences of crushed graptolites have been discovered.

As all of the terranes classified as Ordovician in the eastern half of Vermont lie to the east of the erosional unconformity already mentioned between the Cambrian and Ordovician sedimentaries, and as crushed graptolites have been found within the area of approximately 50 miles in length and 5 miles in width in all townships, it would appear from the evidence submitted that these Waits River limestones and Memphramagog slates are Ordovician where they were placed by C. H. Richardson in 1895 and that their stratigraphic position need no longer be considered as provisional.

The granites are regarded as having been introduced into the sedimentaries at the close of the Devonian. There is evidence in the mineralogical composition of these granites, in their microscopic structure and in their quarry structures that they have been subjected to a pronounced crustal movement. Such a folding accompanied by uplift came at the close of Carboniferous time.

The basic dikes which are definitely known to be younger than the granites, for they often cut the granites, are regarded as having been introduced as late as the Carboniferous and possibly as late as Triassic time.

## ECONOMICS.

The Cambrian schists and quartzites in Hardwick and Woodbury appear to be of little commercial value. They are traversed here and there by veins of quartz bearing traces of gold but nowhere is the gold found in commercial quantities. The sericitic slate near Slayton Pond in Woodbury is quite far removed from all railway transportation and is difficult of access. It is furthermore highly garnetiferous and lacks the perfect fissility of true slate.

The Memphramagog slates are sometimes pyritiferous and often quite fissile. It is possible in Woodbury to the east of Valley Lake in some of the isolated areas of slate outcrops and on the eastern slope of Woodbury range to the west of the road west of Valley Lake that a fair roofing slate might be obtained. The slate however is often used in the construction of permanent roads and cellar walls.

The limestones and quartzose marbles have been used in the construction of permanent roads, in abutments and guards of bridges, in culverts, in foundations for barns and houses. In nearly every town in this section of the State the limestones have been burned at some time in the manufacture of lime. These limestones often possess good rift and grain and work easily into regular rectangular blocks. The beds of quartzose marble are susceptible of a high polish and there is a strong contrast between the hammered and polished faces but no attempt has been made as yet to utilize them as marbles.

Peat deposits of large distribution and depth unknown are numerous especially in Woodbury. They are of considerable value in agriculture, and may be cut, dried and used as a fuel whenever the available wood from the present well-timbered area becomes exhausted.

The basic intrusives as seen to the south and west of the outlet of Hardwick Lake would make most excellent road metal but the quantity is very limited that is easy of access.

The large granite industry of Hardwick, with the most of its quarries in Woodbury, has long been established and is well known not only in Vermont but throughout the country. The employment at one time by the various companies manufacturing granite in Hardwick of more than 2,000 men and a shipment in 1913 from Hardwick over the St. Johnsbury and Lake Champlain railroad of more than 500,000 cubic feet of granite testifies to the magnitude of this industry. At one time in 1913 the Woodbury Granite Company alone had upon its payroll 1,789 men.



As a monumental center Hardwick may be second to Barre. The fine and medium textured dark gray and dark bluish-gray granites are excellent monumental stone. There are large areas of dark granite of bluish-gray color that have never been opened. Some of these discovered this summer can produce a monumental stone that can successfully compete in the marts of trade with the well known popular monumental stone of both Vermont and other States. The large number of firms listed in this report manufacturing monumental stone testifies to the magnitude of this phase of the granite industry in Hardwick.

As a building granite center it stands first in Vermont, if not in the world. In 1903 the contract for the Pennsylvania State Capitol came into the open market. It called for 400,000 cubic feet of granite to be furnished in the brief space of two years. The contract went to the Woodbury Granite Company. The work was shipped complete during the twenty-second month with two months yet to spare. The feat was unprecedented.

In 1910 the Hardwick plant of the Woodbury Granite Company furnished stone for 24 office buildings, 14 post-offices, 18 banks, 3 city halls, 2 hospitals, 1 State Capitol, 1 stock exchange and a score of lesser constructions.

The Northwesterin Mutual Life Insurance Building more recently completed at Milwaukee, Wisconsin, was built of Vermont white granite from the white quarries to the north of Robeson Mountain furnished by the Woodbury Granite Company, Hardwick, Vermont.

The building contains 11,000 pieces of granite, with a total of 200,000 cubic feet. This means an average cube in each of approximately 18 cubic feet. This appears to be the record in heavy construction yet attained in this country.

The ten Corinthian columns in the front of the building are 71 feet and 5 inches from base to cap, so that if the separate blocks were placed end to end they would extend one and three-fifths miles.

The columns are surmounted by richly carved capitols 11 feet square, which set on the column shafts 100 feet above the sidewalk. The fact that these were placed without damage to either stone or equipment is a technical triumph of which Vermont may be justly proud.

The shafts to the columns were constructed in drums each 6 feet and 5 inches in rise, with 10 drums to the column. The diameter of the columns is 7 feet and the bases are 10 feet square.

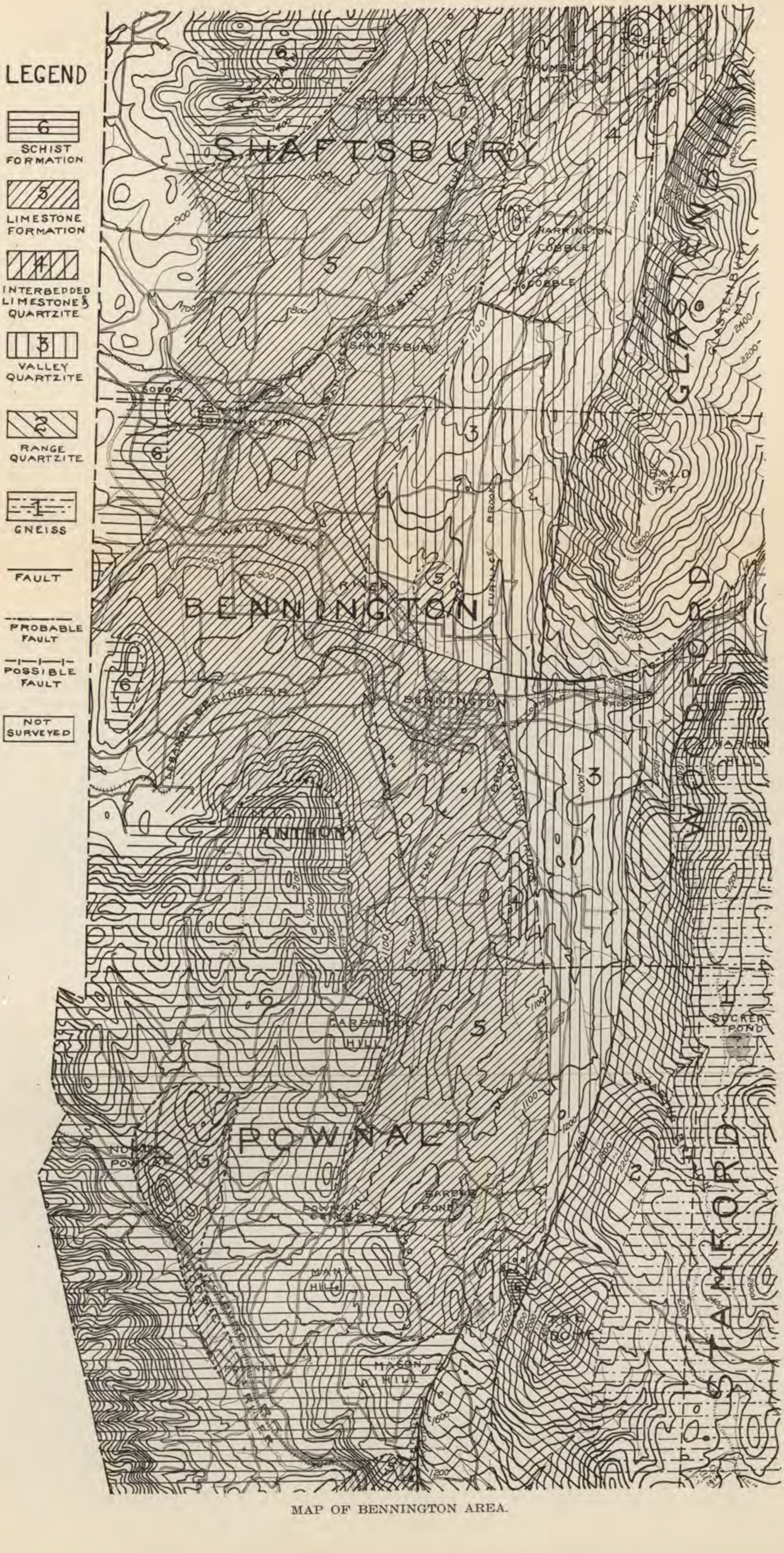
Around the building the principal ornament is a series of fluted pilasters attached to the wall. The flutes extend the full height of the columns. Altogether there are seven and three-fourths miles of flutes. Each flute averages 4 inches deep and 8 inches wide.

The granite tonnage for this one building approximated 17,000 tons all quarried, cut, carved, delivered and set under a single contract.

A clearer understanding of the achievement of the granite contractors may be had when it is understood that when the contract was taken the ledge from which the Vermont white granite was quarried was covered with forests, and outside of test borings that had been made upon the quarry site, no development work or quarrying had been done. The problem, therefore, was to strip the ledges, erect derricks and electric hoists, build a five mile power transmission line to carry electric current, install air compressors and quarrying machinery, and then quarry 11,000 pieces of granite averaging not less than 18 cubic feet apiece. The column sections alone weighed over 40 tons each in the rough and the finished columns in place at the building represent 80 pieces of granite. Each piece represented a carload shipment. This contract was also completed well within schedule time.

The untimely death in June, 1914, of George H. Bickford, the scholarly, polished, congenial and efficient president and general manager of the Woodbury Granite Company is an irreparable loss not only to the granite industry of Hardwick and Woodbury but to the entire State of Vermont.

PLATE LXVIII.




MAP OF BENNINGTON AREA.

# NOTES ON THE GEOLOGY IN THE VICINITY OF BENNINGTON, VERMONT.

C. E. GORDON.

## TABLE OF CONTENTS.



## INTRODUCTION.

In the summer of 1912 the writer spent two and one-half weeks in the study of the geology in the vicinity of Bennington, Vt. Though the work speedily involved a detailed inspection from outcrop to outcrop, it was purposely carried out as a reconnaissance. It was expected that another season's work would bring out the broader structural relations among the different formations and lead to more positive conclusions with which to return to the task of mapping the Bennington region.

It has proved inadvisable to carry out the original plan. In view of the brief period spent in the field and the intricate nature of the problem only such notes as were collected and such suggestions as they seem to afford can be offered in this report.

Attention was chiefly given to the hard rock formations. So far as observed, the surface deposits offer no special features of interest.

A map is offered herewith to show the outcrops which were examined. The boundaries of the different formations are drawn in on the basis of these observations. Certain probable structural relations are involved which are also exhibited on the map and discussed in the report.

## LOCATION.

The area discussed in this paper is situated in the extreme southwestern part of Vermont and forms approximately the western third of the Bennington quadrangle. The southern boundary of the Bennington sheet is on the west less than one-half a mile, and on the east somewhat more than a mile from the Massachusetts line. The western part of the map includes a strip of the Hoosick quadrangle, varying in width from a mile and a half to two miles, which separates the western margin of the Bennington sheet from the New York State boundary.

The Bennington quadrangle lies between parallels 42° 45′ and 43° north latitude and meridians 73° and 73° 30′ west longitude. The particular parts of the quadrangles discussed in this paper embrace the townships of Pownal and Bennington, the major part of Shaftsbury and small strips on the west of Stamford, Woodford and Glastenbury.

## TOPOGRAPHY.

The area includes the southern portion of the great limestone "valley of Vermont." Within the Bennington quadrangle the valley is hemmed in on the east by the steep western slope of the Green Mountain Plateau, which extends as a rugged wilderness through the towns of Stamford, Woodford and Glastenbury. East of Bennington the plateau is cut by the northeast-southwest valley of Walloomsac Brook. North of this stream are the especially rugged masses of Bald and Glastenbury mountains.

The plateau has a high average elevation. "The Dome" in the eastern part of the town of Pownal is 2,750 feet high, while other knobs farther east in Stamford reach an elevation of 3,000 feet or more. Bald Mountain northeast of Bennington is 2,865 feet high; other peaks in Glastenbury Range from this altitude to 3,764 feet in Glastenbury Mountain.

From the western edge of the Green Mountain Plateau the descent to the valley is very steep throughout most of the area. This abrupt topographic break is a striking feature of the landscape.

East of Bennington the western margin of the plateau has been offset to the west a distance of two miles. This east-west break is marked by the course of Walloomsac Brook. Both north and south of this fault the western margin of the plateau has practically the same general trend to the north-northeast.



By this same offset the valley is shifted to the east at Bennington. South of Bennington the valley extends in a somewhat southerly direction, gradually narrowing up, and ending abruptly at the northern end of Mason Hill in the town of Pownal.

The valley which comes down from the north through the towns of Manchester, Sunderland, Arlington and Shaftsbury is bounded on the west by a high range which terminates west of Shaftsbury Center in West Mountain with an elevation of 2,000 feet. The valley widens out as it enters the quadrangle, its western margin bending west around the southern end of West Mountain. Northwest and west of Bennington is a wide-open valley area which extends west beyond the limits of the map.

The valley south of Bennington is bounded on the west by the Mount Anthony ridge. This ridge begins two miles west of Bennington. Its eastern margin follows a southerly course as far as Pownal Center. Here the ridge bends to the southeast, cutting off the valley of Bennington, and bringing up abruptly in Mason Hill against the Green Mountain Range. Mount Anthony, southwest of Bennington, is 2,345 feet high. The elevation falls off southward to 986 feet at Pownal Center and rises again through 1,500 feet in Mann Hill to 1,660 feet in Mason Hill. The North Adams-Bennington electric railway rises from the 549 feet contour at Pownal village to an altitude of 986 feet at Pownal Center, a vertical distance of 437 feet in about three miles, through the lowest pass in this mass which cuts off the valley of Bennington at the south.

Although there are numerous altitudes in the valley south of Bennington higher than this pass, the essential ridge-like character of the whole stretch from Mount Anthony to Mason Hill is reasonably apparent, its former relatively higher altitude at Pownal Center being obscured by the erosion of the mass between Pownal Center and the bed of the Hoosick. The Mount Anthony portion of the ridge is at the northern end of a southwardly pitching syncline. This fact perhaps in connection with the favor shown by the forces of erosion may account for its present relatively higher altitude.

An inspection of the map will show that in correspondence with the eastward extension of the valley west of Bennington the northern end of the Mount Anthony ridge lies farther east than does the boundary of the valley as formed by West Mountain in Shaftsbury. And the southeastward bend of the Mount Anthony ridge through Mann and Mason hills finds a parallel in the great eastward sweep of the valley region of Williamstown and North Adams around the southern end of Clarksburg Mountain to the Hoosick Range.

## DRAINAGE.

In southern Vermont and northern Massachusetts the Green Mountain Range is the divide between the drainage of the Hudson and the Connecticut rivers.

Hoosick River, which rises on the western slope of the Green Mountains in Massachusetts, flows north to North Adams, then westward past Williamstown, and then crosses in a northwesterly direction the extreme southwestern corner of the state of Vermont. Five miles northwest of Hoosick Falls it turns west to join the Hudson.

Near Hoosick Junction, N. Y., the Hoosick receives the waters of Walloomsac River which drains the larger part of the area discussed in this paper. The Walloomsac gathers its headwaters in the Green Mountain Range, five miles east of Bennington, from two large brooks, one of which forks and drains the southern slope of Glastenbury Mountain, while the other forks in a similar manner and drains the northern slopes of Stamford Mountain in its northern extension in the town of Woodford. The sources of these terminal, tributary streams come close to the headwaters of the tributaries of the Deerfield River.

North of Bennington, Furnace Brook and Paran Creek head on a low divide which parts the drainage of the Walloomsac from that of the Batten Kill. They flow south to join the Walloomsac. South of Bennington, South Stream and Jewett Brook flow north from Pownal, the former receiving the drainage of the western slope of Stamford Mountain, and the latter that of the eastern slope of Mount Anthony. South Stream and Jewett Brook join near Bennington and flow into the Walloomsac in the eastern part of the town.

The western slope of the Mount Anthony ridge drains to the Hoosick.

In general, the Walloomsac has an east-west direction across the gneiss, quartzite, limestone and schist. Probably its course was primarily determined by certain important structural features of the region.

## GENERAL GEOLOGY.

The core of the Green Mountain Range is made up of gneiss of pre-Cambrian age.

Time did not allow a careful examination of the gneisses within the area. It was extremely difficult to accomplish much on the mountains of the range. The country is still mostly a heavily-wooded wilderness crossed by only two roads and a few overgrown trails. Glastenbury Mountain, which is the most inaccessible, is especially disappointing in outcrops. Seemingly any separation of the elements of its pre-Cambrian core would prove



very difficult under present conditions. Nevertheless, the writer had hoped to make some study of these rocks.

It would seem that an important line of investigation supplementary to the researches of various workers in the pre-Cambrian rocks of the Green Mountain belt is still open.[1] The difficulty in drawing always a sharp line between the Cambrian and the pre-Cambrian was expressed by Professor Pumpelly.[2]

Professor Wolff argued for the presence in the Cambrian ("Vermont Formation") of the Hoosick Range of coarse gneisses, finer-grained banded gneisses, slightly micaceous gneiss, metamorphic gneiss conglomerate and ordinary quartzite conglomerate, these rocks or phases passing into one another along the strike.[3] Later Van Hise[4] made the white gneiss of Hoosick Mountain pre-Cambrian and maintained that there is no transition between the pre-Cambrian igneous and the Cambrian sedimentary.

Keith[5] describes as a result of recent studies in Vermont a great thickness of schist, dolomite, graywacke, quartzite and conglomerate overlain unconformably by the Cambrian quartzite which transgresses the whole of the lower series. This series is classed as Algonkian.

Resting against the gneiss all along the western front of the range within the area is a lofty brow of quartzite which slopes steeply, often precipitously, to the valley on the west. This quartzite is a conspicuous feature for many miles northward in Vermont along the western margin of the Green Mountain Range.

The Woodford-Stamford gneissic core of the Green Mountain Range extends down for a short distance into Massachusetts and terminates in Clarksburg Mountain directly northwest of North Adams. The quartzite formation extends from the town of Pownal southward on the western face of the range and eastward around the southern slope of Clarksburg Mountain. It lies unconformably on the pre-Cambrian (Stamford) gneiss.

In the quartzite formation "east of Bennington," and also on the western slope of Clarksburg Mountain, Dr. C. D. Walcott[6] discovered fossils (Olenellus) which definitely proved the quartzite to be of Lower Cambrian age.

On the east of Clarksburg and Stamford mountains, north from North Adams, the quartzite extends some distance north of the village of Stamford through Hartwellville towards Woodford. Its further northern extension was not followed.

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[1] C. P. Berkey, Structural and Stratigraphic Features of the Basal Gneisses of the Highlands, Bull. N. Y. State Mus. 107, 1907.
A. Keith, A pre-Cambrian Unconformity in Vermont, Bull. Geol. Soc. Amer., Vol. 25, p. 39.
[2] Mon. U. S. G. S., XXIII, p. 25.
[3] Idem, pp. 35-118.
[4] Bull. U. S. G. S., No. 360, p. 588.
[5] Loc. cit.
[6] The Taconic System of Emmens, Amer. Jour. Sci., Series 3, Vol. XXXV, 1888, pp. 235-236.

In the southern part of the area, as shown on the map of this report, the quartzite on the western slope of the range lies against the schist of Mason Hill, and north of Mason Hill against limestone and schist, and then for the rest of the distance south of Bennington against the quartzite formation of the valley. Southeast of Bennington the floor along the eastern edge of the valley is quartzite. It extends south of the fault along Walloomsac Brook, between the range and the limestone which borders it on the west, and wedges out to the south against the edge of the plateau. The western margin of the range cuts somewhat diagonally northeastward across the general trend of the formations of the valley, south of Bennington.

The valley quartzite south of Bennington is bordered by a broad limestone band which extends south from Bennington and which narrows up and ends somewhat abruptly at the south against Mason Hill. The limestone gives place at the west and south to the schist of the Mount Anthony ridge. At numerous places along the eastern slope of this ridge, north of Pownal Center, the limestone is seen to dip westward beneath the schist. It appears again dipping east along the northwestern slope of Mount Anthony. It forms the high hill just east of the village of North Pownal. It lies on the schist on the west side of the Hoosick, two and a half miles south of North Pownal, and outcrops again on the southwestern slope of Mason Hill along the Williamstown-Pownal road about two miles southeast of Pownal.

East-northeast of Bennington, as described in the topography, the plateau has suffered an offset to the west so that east of Bennington, south of Walloomsac Brook, the quartzite of the valley forms a recess eastward, while north of the stream is the steep southern slope of Bald Mountain and the western quartzite slope of the range lies two miles farther west. Northeast of Bennington from the Walloomsac northward to Buck's Cobble the quartzite was traced as a well-defined band about two miles wide along the east side of the big valley and east and north of Buck's Cobble it was followed somewhat indistinctly as far north as Maple Hill.

The same sharp topographic break which marks the ascent from the valley quartzite to that which fronts the range south of Bennington also distinguishes the relations of Glastenbury Mountain to the valley on the west. North from Buck's Cobble the quartzite is replaced by sharply-folded interbedded limestones and quartzite. West from the margin of the valley quartzite and the westernmost scarps of the hills of interbedded limestones and quartzites, so far as it is possible to learn about this heavily drift-covered region, the valley is underlain by limestone which extends to the eastern foot of West Mountain and around its southern end and south through South Shaftsbury and North Bennington to the northern end of Mount Anthony. West of North Bennington the limestone is mixed somewhat with the schist, but in general bounds the schist formation at the west much as shown on the map.



The quartzite, limestone and schist which have been mentioned form the eastern members of the great Taconic belt of rocks which extends from northern Vermont southward along and near the boundary of New England and New York.

As early as 1872 it had been established through the investigations of the Rev. Augustus Wing that the limestones (Eolian) lying west of the Green Mountain Range contained strata, as shown by fossils, ranging from the Upper Potsdam or Lower Calciferous to the Trenton.[1] From Wing's investigations the term "Calciferous-Chazy-Trenton" was applied to the limestone in general as it outcropped in and west and north of Rutland.

Later studies in the limestones of Dutchess County, New York, by Professors Dana and Dwight showed the presence there of the Georgian, Potsdam, Calciferous and Trenton in rocks having field relations similar to those in northern Vermont and to be regarded as essentially the southwestward continuation of the Stockbridge and Eolian limestone formations of Massachusetts and Vermont.[2]

In 1887, Dr. Walcott carried his studies into the region around Bennington and southward into Massachusetts, and found fossils in the limestone which he assigned to the Chazy-Trenton.[3]

By these and other researches the age of much of the limestone of the Taconic region was shown to be of Ordovician age.

In 1890, Professor Wolff studied the area around Rutland, Vt.[4] He found the limestone (Eolian) of the main Rutland valley to lie conformably along the west side of the valley on the quartzite of Pine Hill. Pine Hill is a ridge just west of Rutland which divides the main limestone valley of Rutland from a smaller limestone valley in Center Rutland. Wolff found the quartzite forming the eastern slope of Pine Hill to bend to the eastward north of Rutland and join the quartzite of the main range. At Pine Hill the quartzite passes upward into limestone through beds of "calcareous quartzite." Cambrian fossils were found in the limestone above the contact with the quartzite. Associated with the quartzite of Pine Hill was a series similar or identical with that associated with the quartzite east of the valley, in each case older than the limestone. The limestone of the Center Rutland valley, just west of Pine Hill, as shown by fossils is of Ordovician age. The general significance of these relations will be appreciated. Part of the Eolian limestone near Rutland was thus indicated to be of probably Lower Cambrian age.

[1] Amer. Jour. Sci., Series 3, Vol. IV, 1872; Vol. XIII, 1877.
[2] Papers by W. B. Dwight, Amer. Jour. Sci., 1879-1889.
[3] Amer. Jour. Sci., Series 3, Vol. XXXV, 1888, p. 238.
[4] Bull. Geol. Soc. Amer., 1891, pp. 331-337.

The schists which lie to the west of the limestone of the Vermont valley, extending north from West Mountain in Shaftsbury through East Poultney and beyond, were colored Cambrian by Walcott[1] in a map accompanying his discussion of The Taconic System of Emmons, while the Mount Anthony ridge and the schists to the west of it and around Hoosick Falls, together with certain schist outliers in the limestone of the valley between Shaftsbury and Rutland, were shown as belonging to the Hudson terrane.

In Pownal, at what appears from the description and the map to be on the southwestern side of the Mason Hill mass, Walcott discovered fossils which he described as Trenton, and again on the east side of Mount Anthony, about three miles south of Bennington Center, in the limestone beneath the schist, he found parts of crinoids allied to a form found in the Trenton limestone of New York. Near Hoosick Falls, in limestone about 200 feet below the "shales," he found fossils of the genera Maclurea and Murchisonia and assigned the limestone to the Chazy-Trenton. On the basis of these discoveries, the schist of Mount Anthony and the region about Hoosick Falls was placed in the Hudson terrane and considered to be of Ordovician age.

The terrigenous sediments, described above as colored on Walcott's map as Georgian, were so designated on the basis of fossils of Lower (then called Middle) Cambrian age, contained in thin interbedded limestones. These fossils were "distributed at various horizons throughout the 14,000 feet or more of strata referred to this terrane." These slaty, or phyllitic rocks Walcott regarded as the off-shore equivalent of the quartzite of the Green Mountain Range. Two belts of the Cambrian slates are shown with a belt of the Hudson terrane faulted in between them.

Probably most of the eastern portion of Walcott's eastern Georgian belt, including West Mountain, is of Ordovician age.

## GENERAL RELATIONS OF GEOLOGY AND TOPOGRAPHY.

The whole region is mountainous in structure. Viewing it as a whole, we find that the mountain folds have been truncated, exposing the older rocks along the anticlinal axes, while in the synclinoria the younger strata were folded down and thereby preserved. In the valleys certain strata, which primarily belonged to faulted upthrust blocks, have been dropped back by normal adjustment faulting and are now exposed by erosion in abnormal relation to adjacent strata.

Professor Davis[2] early described the region as a worn-down mountain area peneplaned by sub-aerial agencies. The higher

[1] Amer. Jour. Sci., Series 3, Vol. XXXV, 1888.
[2] Mon. Nat. Geogr. Soc., Vol. 1, 1895, pp. 279-284.



eminences were interpreted as monadnocks. Professor Dale[1] later questioned the peneplaned character of the Taconic physiography on the ground that the peneplain theory would require for the region, as shown by its history, an elevation of from 1,500 to 2,000 feet at the beginning of the Tertiary and that subsequent time was seemingly not long enough to carve to its present condition a dissected peneplain, if, as seemed likely, such sculpture involved the removal of at least half of the Taconic topographic belt since its post-Ordovician elevation.

Recently Professor Barrell[2] has come forward with the view that much of the Piedmont belt of southern New England and New Jersey, which is generally regarded as part of a great peneplaned region, could be explained as the result of marine planation at right angles to the lines of drainage. In western Massachusetts and Connecticut and extending into New York and southward, he has described a more or less clearly recognizable series of wave-cut terraces at different levels, showing the former presence of the sea, at the time of its maximum transgression, a long distance inland from the margin of the present coastal plain. He correlates the terraces with definite formations of the present coastal plain and recognizes in the planes of disconformity among the deposits of the present plain the record of the uplifts that successively elevated the different terraces, assuming, of course, that the oscillitary movement reached the coastal plain.

*Condensed Table of Hard Rock Formations.*

| Age. | Formation. | Members. |
|---|---|---|
| Cambro-Ordovician. | Schist. | Shales.<br>Slates.<br>Grits, Phyllites.<br>Calcareous Schists.<br>Sericite Schist. |
| | Limestone. | Marbles.<br>Compact and granular crystalline limestones.<br>Limestones and calcareous quartzites with interbedded quartzite.<br>Quartzite.<br>Quartzitic schist. |
| Basal Cambrian. | "Vermont Formation." | Schistose quartzite.<br>Dense compact quartzite.<br>"Granular quartz rock."<br>Conglomerate. |
| | Unconformity. | |
| Pre-Cambrian. | | Gneiss of Stamford Mountain and Harmon Hill. |

[1] Bull. U. S. G. Sur. No. 272, p. 33.
[2] Bull. Geol. Soc. Amer., Vol. 24, pp. 688-690.

At the time of its farthest advance the sea is believed to have reached the south side of the Adirondacks and the southeastern side of the Green Mountains in Massachusetts, there cutting the oldest, or "Becket terrace" in middle Cretaceous time. Later terraces range from this epoch into the Pleistocene.

The absence of unconsolidated marine deposits far inland from the margin of the present coastal plain is held not to invalidate the claims of this later view of the Piedmont region, since such deposits might well have been almost completely if not quite removed by erosion.

The approximate elevation of the inner margin of the oldest, or Becket terrace, is now 2,400 feet, but the region is known to have undergone progressive warping.

## THE GNEISS AND ASSOCIATED QUARTZITE.

### GENERAL DESCRIPTION.

The gneiss was examined on the western slope of "The Dome" and on the western and northern slopes and summit of Harmon Hill. The western boundary of the gneiss, where shown, is drawn in somewhat arbitrarily. The boundary was not touched on Bald or Glastenbury mountains.

On the southwestern side of "The Dome" the quartzite rests unconformably on the gneiss. West-southwest of this eminence, lower down the slope and about on the 1,700-foot contour, in a valley recess southeast of the pond, the gneiss is exposed in a wet-weather gulley. The rock is in place, but the strike and dip of the foliation could not be satisfactorily determined. Northward from this outcrop along the steep slope east of the pond, gneiss talus boulders were common with some admixture of quartzite northward.

At a point due east from the pond, well up the very steep slope at this point, limestone and interbedded calcareous quartzite, quite like that which will presently be described as commonly occurring apparently at no great distance above the quartzite of the valley south and north of Bennington, forms the slope with strike N. 17° E. and dip 25° easterly. This limestone at a short distance to the northeastward passes upward into black, shiny, graphitic-looking schist, or phyllite, which forms the summit of the sharp spur that sticks out northeastward from the range in the direction of Barber's Pond. Descending this spur towards its apex, the phyllite, which seems to be conformable, gives place to limestone and interbedded quartzitic layers like those described above. The phyllite is less gritty than the schist of Mason and Mann hills, and differs somewhat from any which I have elsewhere observed in the area. I have not elsewhere found it associated with these particular limestone beds as shown in this spur. The relations are peculiar and difficult of explanation. The phyllite apparently lies in a syncline of limestone closed northwestward and pitching towards the range. Northwest of the log cabin the limestone beds stand at high angle.



I have drawn a fault, from the outcrop of gneiss mentioned above, north-northeastward where this spur abuts against the range to show the prevailing tendency of the older rocks to appear against the younger by reverse faulting. To what extent the older rocks moved upward will be discussed later on. This spur is mentioned in connection with the gneiss as it helps to develop the writer's interpretation of the structural relations along the western margin of the range.

Northeast of this spur is another sharp recess, on the eastern edge of which ascends the road that crosses the range to Stamford. Along this road just before it makes the abrupt turn up the steeper slope of the mountain limestone outcrops in the road. Definite readings could not be made. The limestone is not succeeded by any outcrop along the road for a long distance. Near the summit thin-bedded quartzite with irregular, rusty parting surfaces outcrops in the road and woods with low westerly dip.

North of the mountain road to Stamford the western slope of the range is quartzite above the lower drift-covered portion. It was observed at places, in the woods, dipping gently westward and in some places lying nearly flat. Near the summit the thin-bedded quartzite was observed passing upward into gritty schist which, in some places showed great similarity to certain lower members of the schist formation overlying the limestone in Mount Anthony.

The valley occupied by the pond northwest of the gneiss outcrop, which was described above, is apparently underlain by limestone, but south of this recess the quartzite of the range extends a half mile or more west of the outcrops of gneiss and along Reservoir Brook abuts against the schist of Mason Hill. The quartzite stands as a fairly high scarp above the brook about one mile north of the Williamstown reservoir. At this place it is a thick-bedded, compact white rock. Higher up the brook it becomes more thinly-bedded and the scarp in consequence diminishes in abruptness to the northward. Where the scarp is composed of the compact heavy quartzite, we have exposed lower beds of that formation. The dip is flat, or slightly easterly. The general relations are shown in figure 27.

Along the mountain road east of Reservoir Brook and between the brook and road are frequent low-lying ledges of the thin-bedded quartzite, having a notably flattish position. The quartzite is often rather a quartzite-schist with well-developed micaceous bands. Ledges are often "flaggy" and under the hammer break into irregular chips with rusty parting planes. Along the brook east of the mountain road, at the base of the steeper slope on the west of the southward extension of "The Dome," it changes to a fine-grained quartz-pebble conglomerate. Along the mountain road just before it leaves the woods at the north, just east of the source of Reservoir Brook, the thin-bedded quartzite is badly crumbled and frequently carries veinlets of quartz. East of these outcrops is the thin-bedded, flaggy quartzite which prevails over most of this flat hill lying southwest of "The Dome."

Along the higher portion of the western slope of the range the quartzite, as far as the physical difficulties made it possible, was traced from Roaring Branch to the southern end of Harmon Hill. On the western slope of this hill the gneiss comes down close to the base and stands in ledges from 30 to 40 feet above the quartzite. The contact is clearly a faulted one. Here the upthrust brought the gneiss against the quartzite, as now exposed. The quartzite dips slightly to the westward and passes by gradual slope into the valley west of the hill.

The actual contact of gneiss and quartzite was not observed, but ledges of the two formations are less than 100 feet apart. The quartzite strikes nearly north, or slightly west of north, while the strike of the foliation of gneiss is east of north. The relations here described are best observed in the pasture about one-half mile northeast of Woodward's Corner.

The fault between the gneiss and quartzite I have represented as dying away southward in the quartzite, its place being taken by another break farther west which faulted the quartzite of the range against that of the valley.

From its outcrops near the quartzite along the fault, the gneiss continues up the slope to the summit of the hill. A reading at the summit gave the strike of the foliation as N. 60° E. and the dip 80° NW.

The relatively ancient character of the foliation of the gneiss is impressive. It seemingly antedates the deposition of the quartzite, as shown by the discordance in strike and dip, and belongs to a pre-Cambrian mountain-building time. The gneiss had acquired practically its present foliated condition before the deposition of the quartzite.

East of Bennington, in the valley along the Woodford road which skirts the northern end of Harmon Hill, the quartzite outcrops in frequent ledges. Less than a mile east of the trestle bridge across the Walloomsac the road has been blasted through a heavy ledge of quartzite which rises abruptly from the bed of the brook. This ledge is nearly along the northward projection of the quartzite just west of the fault at Harmon Hill. It also probably lies south of the cross fault, which is represented on the map as cutting off the Bald Mountain mass at the south.

Numerous ledges of the quartzite outcrop along the road to the eastward. This formation was traced from the fork in the road, along Walloomsac Brook to the junction of Bickford Hollow and Bolles brooks, and also beyond the forks along City Stream for three-fourths of a mile. Along the upper reaches of the Walloomsac the quartzite is the rusty, flaggy rock which has been described.



A mile from the fork, along the Woodford road, the gneiss of Harmon Hill outcrops in the road, showing the foliation strike as N. 50° E. and the dip 70° E. The quartzite was not traced farther east.

It seems likely that a great irregular fault cuts off the gneiss of Harmon Hill at the northern end, and that this formation rests with faulted contact against the quartzite in the valley north of the hill.

### PETROGRAPHY OF THE HARMON HILL GNEISS.

The gneiss as it appears along the Woodford road is a rather fine-grained biotite gneiss without pronounced foliation. The biotite appears in fine flakes uniformly distributed in the rock both across and with the foliation. The thin section shows a granitoid texture with prominent anhydrons of feldspar and quartz of allotriomorphic type with biotite of igneous habit and distribution, usually enclosed in the feldspars. The feldspars are somewhat decomposed and are partly clouded with kaolinite and other decomposition products.

The gneiss at times carries coarser bands of quartz and feldspar which roughly alternate with micaceous bands of a texture similar to the finer-grained gneiss described above. Where freshest the feldspars appear to be chiefly plagioclase. Zircon occurs as an accessory. There appear to be no pronounced strain effects. While there is usually a decided wavy extinction of the quartz, the twinning lamellae of the feldspars are not broken perceptibly and show uniform width along their entire lengths.

The rock at the top of the hill is essentially the same as that along the Woodford road, although it is more prominently gneissic. It has the same general texture in thin section and the same mineralogy, with the addition of some microcline.

The rock near the contact with the quartzite along the western slope of the hill clearly shows the effect of shearing. In the hand specimen it appears crushed and when hit by the hammer breaks along smoothed surfaces. In thin section the quartz appear shattered. The fragments have recrystallized and healed without extensive migration. Where before were large quartz crystals are now patchworks of small grains with independent extinction. The plagioclase shows badly bent and pinched out lamellae and the biotites are broken into numerous fragments and dustings.

### INTERPRETATION.

So far as I have observed, there is little evidence of folding in the gneiss and not much of shearing, except in the zone of faulting.

From the gentle dip of the quartzite and its frequent almost flat position we may suppose that this formation, as a general rule was not violently folded. At places accommodation was effected in the gneiss by shearing, but over large areas, so far as observed, even shearing is inconspicuous. The quartzite was folded somewhat in the general movement of elevation and in some places buckled into small folds, as, for example, along lines on which the gneiss was shoved up on the quartzite, the break often dying away along the line into a fold in the quartzite.

The breaks were primarily initiated by the crystalline gneissic substratum refusing to fold. The tendency to rupture was doubtless augmented by the covering of heavy quartzite which was also reluctant to fold.

The release of the highly crystalline substratum was apparently effected by numerous breaks along the strike. At some places, for some reason, the rupture occurred earlier than at others and at some places farther west, so to speak, than at others, the effect being a sort of echelon of faults along the western margin of the range.

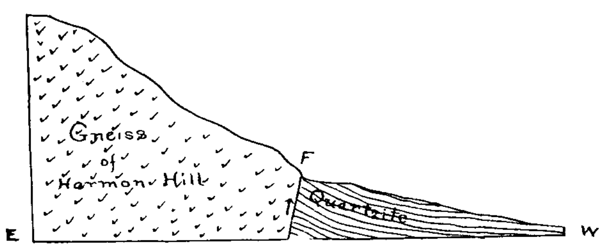



FIGURE 26.—Generalized section to show reversed fault between the gneiss and quartzite on the west of Harmon Hill.

The fault on the west of Harmon Hill, figure 26, is represented as dying away southward in the quartzite. Its place is taken by another break farther west by which the quartzite rests against younger quartzite at the west. The latter fault is represented as dying away northward in the quartzite west of Harmon Hill. Southward it is drawn near the base of the slope as far south as the latitude of Barber's Pond. It then probably merges with a break that bounds the valley quartzite south of Bennington on the west or passes directly into the fault shown along the western slope of "The Dome."

The fault on the west of "The Dome" dies away southward, its place being taken by another break farther west by which the quartzite was thrown against the schist of Mason Hill along



Reservoir Brook. My interpretation of the probable relations at Mason Hill are shown in figure 27. The famous "Sand Springs,"

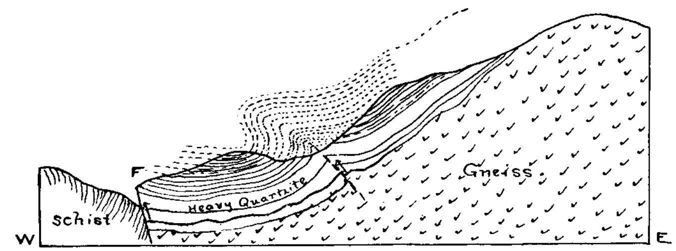



FIGURE 27.—Generalized section to show the interpretation of the relations at Mason Hill.

a resort two miles northwest of Williamstown, lies along or close to the southward extension of the Mason Hill fault along Reservoir Brook. This spring issues from clear white sand and in winter and summer, as well as in dry and wet seasons, gives an average flow of 400 gallons a minute. The temperature of the water in winter and summer is about 76° Fah. Its freedom from organic contamination and its remarkable mineral content have given the water a wide reputation for medicinal purposes, both for drinking and bathing. The water is now extensively used for the manufacture of "soft drinks," and the excess flow is utilized for a swimming pool. The following analysis was made by Leverett H. Mears, Professor of Chemistry at Williams College.

| | Parts per 100,000. |
|---|---|
| Lithium chloride | 0.0353 |
| Sodium chloride | .0768 |
| Acid calcium carbonate | 3.2249 |
| Acid magnesium carbonate | 2.6479 |
| Calcium sulphate | .7262 |
| Aluminium sesquioxide | .0325 |
| Iron sesquioxide | .0075 |
| Silica | .7026 |
| Sodium carbonate | .4641 |
| | 7.9178 |

The spring issues from the drift, but its constancy, temperature and mineral content suggest a deep-seated source and argue for the great depth of the fault along which it comes.

The fault shown on the map as bordering the quartzite of the range on the west of the low hill just southwest of Harmon Hill is marked by a rugged talus slope across the edge of the quartzite beds just within the edge of the woods southwest of Woodward Corner and Harmon Hill. This scarp and talus was distinctly followed southward for two miles.

There would have been a tendency to break across the strike on the north of this hill, but it seems more likely that the fault on the west dies away northward owing to compensation by the fault at the east on the west of Harmon Hill.

Southwest of "The Dome," however, there may be a cross fracture for here the quartzite passes northward into limestone. This limestone may, however, be of Cambrian age as discussed beyond.

The "valley quartzite" is represented as probably wedging out to the southward against the range. The quartzite of the range cuts somewhat diagonally across the general trend of the formations in the valley.

The presence of the quartzite formation high up on the slopes of the range and its eastward extension along Walloomsac Brook in themselves strongly argue for the former extension of this formation over the range toward Woodford. The quartzite, as noted in the discussion of the general geology, extends northward from the southern end of Clarksburg Mountain for a long distance toward Woodford on the east of Stamford Mountain. The presence of the quartzite formation along the headwaters of the Walloomsac and in City Stream may be explained by down-faulting.

## THE VALLEY QUARTZITE SOUTH OF BENNINGTON.

By this term may be understood the quartzite formation as it outcrops in the valley west of the prominent gneiss or quartzite scarps and slopes of the range.

East of Bennington outcrops are concealed by modified drift as far east as the foot of Harmon Hill and the outcrop along the Woodford road a mile east of the bridge across the Walloomsac.

South of Walloomsac Brook the only outcrop observed between the range and South Stream was two and a half miles south of the brook, so effectually are outcrops concealed by the heavy surface deposits over this area. Near the south road to Sucker Pond, about half way between the foot of the range and the old lumber mill along South Stream, where this road makes its sharp bend southward, are outcrops of quartzite.

Drift conceals this formation between these outcrops and South Stream. In the bed of the latter, near the bridge, a fourth of a mile north of the old lumber mill, the quartzite gives a strike of N. 42° E. and a dip of 17° SE. From the bed of the stream the topography eastward rises by gentle slope to the foot of the range. Near the old lumber mill the limestone is interbedded with calcareous quartzite at the dam and in and west of the road just above the stream. Similar beds outcrop along the stream at the gentle rapids five or six hundred yards south of the dam. All the beds along the stream have a notably flattish position.

The valley quartzite and its associated interbedded series were not traced farther south, but probably continue under the drift for a distance of three or more miles southward to the foot of the range, seemingly wedging out where the limestone extends down into the recess southeast of Barber's Pond.



Northward along the road that follows South Stream to Bennington, about three-fourths of a mile north of the old lumber mill, the interbedded calcareous quartzite and limestone outcrop in the bed of the stream and on each bank. The beds vary from two to four to six inches in thickness and dip gently eastward; a stratum of limestone beds alternating with a stratum of calcareous quartzite. The road to Bennington forks just north of these outcrops. At the fork a ledge of quartzite was blasted to make way for the road. The quartzite in this ledge is sheared vertically, apparently at right angles to the bedding, which, however, is obliterated, and along the shearing planes are numerous crystals of pyrite which have stained the sheared surfaces a rusty brown. The five feet of vertical exposure here is all dense steel-blue quartzite. Two or three outcrops of the quartzite were noted farther north along the east road from this fork.

The data are meager for forming definite conclusions, but from the sheared quartzite just described and the general flat position of the beds, I imagine the valley quartzite to have buckled very little, but on the contrary, to have faulted against the rocks farther west. In the course of adjustments following reverse faulting it would probably have dropped back again by normal faulting along earlier thrust planes so that its present position would be misleading as to its real history. The valley quartzite east of Bennington would have folded with that of the range until the great breaks along its eastern and northern margin occurred when it would have slumped somewhat. The amount of displacement of the valley quartzite along its western margin would have been less than that which occurred in the quartzite and gneiss of the range on the principle that the reverse faulting would tend to die away westward.

## THE VALLEY QUARTZITE AND INTERBEDDED LIMESTONES AND QUARTZITE NORTH OF BENNINGTON.

Northwest of Bennington on the south bank of the Walloomsac, at the edge of the golf links of the Mount Anthony Golf Club, near the covered bridge, quartzite is interstratified with limestone, the whole forming a gentle arch. At this place there is no shearing and the outcrop is considered to lie east of the probable western boundary of the valley quartzite in its occurrence north of Bennington.

A mile and a half north of the outcrops at the golf links along the road to South Shaftsbury, the quartzite outcrops in the road. North of this outcrop two roads leave the South Shaftsbury road, one going west, the other east. On the latter, close to the main road and south and north of it, ascending the slope to the eastward, are numerous ledges of the quartzite lying nearly flat, or dipping gently eastward. This road is locally known as the "Stony Hill road."

An almost continuous outcrop of the quartzite was traced northward through the woods along the edge of the hill, one-fourth of a mile east of the South Shaftsbury road, for nearly a mile. Westward the quartzite descends by gentle slope to the South Shaftsbury road, but the slope is across the edges of the quartzite beds. Eastward the formation passes under drift.

North of the next crossroad, the quartzite forms a high hill just northwest of Wait's Corner. Well up the rather steep eastern slope of this hill are great patches of white granular quartzite dipping easterly. The southern end of this hill is a berry pasture. North of the pasture are thick woods with some clearings. Through this wood the quartzite was followed nearly to the next crossroad running from South Shaftsbury to the Madison school. The northernmost outcrop of the quartzite, as thus followed from Bennington northward was noted near Buck's Corner. North of the South Shaftsbury crossroad begins the southern limestone slope of Buck's Cobble. The limestone continues northward through Harrington Cobble and across the next road and then passes under a gentle west slope, lying between Harrington Cobble and the crossroad which skirts Trumbull Mountain on the south.

East of the north-south road on the east of Buck's Cobble, everything is concealed by drift as far north as Maple Hill. The quartzite forms the eastern slope of Maple Hill and outcrops a mile eastward at the apex of the loop formed by the road that runs to the base of the range, east of Maple Hill. At the latter place, within a space of 50 feet, the structure exhibited in figure 28 was shown. The quartzite is thin-bedded and lies

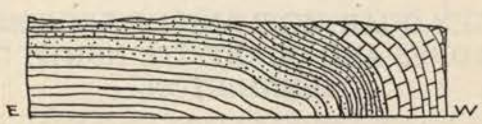



FIGURE 28.—Structure in limestone and quartzite east of Maple Hill.

quite flat. At the west it bends downward and passes beneath limestone which is folded down at a rather sharp angle.

North of Maple Hill, south of the loop road, in the thick woods on the north side of a deep gully, the quartzite in vertical section shows the structure exhibited in figure 29. The folding of the quartzite here, as contrasted with its flat position farther south, is in line with the relations exhibited in the "Cobbles" west of Maple Hill, which will be described presently.

Along the road leading to the old abandoned hamlet of Fayville (see Equinox sheet; not shown on the map of this report)

PLATE LXIX.

*A.* BUCK'S COBBLE, A VIEW LOOKING NORTH.

*B.* FOLD IN INTERBEDDED QUARTZITE ON TRUMBULL MT. ON THE CREST OF AN OVERTURNED ANTICLINE.

quartzite outcrops in the bed of the brook. It is a heavy, compact rock in beds from 2 to 5 feet thick and strikes N. 25° W. with a dip about 12° S. W.

It will thus be seen that a band of quartzite 2 miles wide extends north from Bennington as far as the crossroad from South Shaftsbury to the Madison School. So far as observed, there is no limestone overlying or interbedded with the quartzite, within this distance, except at the south near Bennington. Along the road leading northeast from the covered bridge at the Mount Anthony Golf Club links, a half mile north of the railroad, limestone outcrops in the road and in the fields east of it are numerous ledges. A reading gave the strike as N. 13° W. and a dip 9° westerly. Because of their apparent superjacent conformity to the quartzite and because of the resemblance to other limestone, which the writer has elsewhere observed in the Taconic belt, lying a little way above the quartzite, the rock was closely searched for Lower Cambrian fossils, but without success. How extensive this limestone is north and east of these outcrops it was not possible to tell on account of the drift. Southward from them there are no outcrops in Bennington north of Main St., so far as observed. These ledges probably represent an outlier resting on the quartzite and conformable with it.

The sudden transition from quartzite, east of Buck's Corner on the South Shaftsbury crossroad to the limestone of Buck's Cobble on the north of it suggests a cross fault between them. The high scarp on the west of the Cobble suggests a strike fault here, which extends north on the left of Harrington Cobble, beyond which it apparently shortly dies out. Harrington Cobble has much the same structural outlines as Buck's Cobble (see Plate LXIX, A) but its western slope is less precipitous and merges gradually into the eastern slope of Hale Mountain at the west. The western slope of Hale Mountain is, however, decidedly steep and scarp-like. The limestone on the east slope of Buck's and Harrington Cobbles dips eastward at a rather high angle. On Hale Mountain a reading on the eastern slope at the southern end gave strike N. 19° E., dip 40° E., and on the northern slope, strike N. 46° E., dip 23° E.

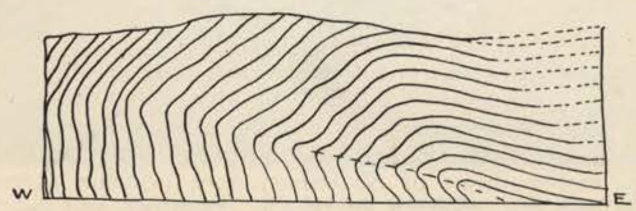



FIGURE 29.—Quartzite north of Maple Hill.

As contrasted with the hills at the north, now to be described, the limestones of Buck's and Harrington Cobbles and of

Hale Mountain, so far as observed, show no associated quartzite.

At Maple Hill, the limestone which forms the summit and western slopes exhibits in cross section a close folding and slight overturning which are features in line with the folding of the quartzite (as shown in figure 29) at the northeastern end of the hill. Near the base of the western slope the rock is a slightly banded, rusty, medium-grained "buckwheat" marble. It dips eastward at a high angle.

The hill just west across the road from Maple Hill is limestone. On the eastern slope the beds dip eastward. In this hill there is no associated quartzite. Its western slope is steep and suggests a break as also does the slope on the west of Maple Hill. (See Plate LXIX, B).

The next hill to the west shows quartzite on the eastern slope dipping eastward, but at the summit the dip is westward, indicating overturning. My notes indicate that it is interbedded with limestone and calcareous quartzite.

The next hill on the west is Trumbull Mountain. At the south end of this hill, which rises very steeply from the road which skirts it on the south, the quartzite forms the eastern slope, dipping east. Near the top of the hill, but 300 or 400 yards east from the summit of the western slope, quartzite shows a structure seen in Plate LXX, A, which is a view looking north. It will be observed that the bed of quartzite dips east on the right of the photograph and west on the left. Associated limestone beds outcrop near by at the south on the southern pitch of the hill, also dipping slightly west. A little farther west they stand nearly vertical and on the western slope dip to the east, forming an overturned anticline.

Similar relations were shown in the hill east of Shaftsbury one mile north. (See Equinox sheet). Quartzite which forms the eastern slope of this hill outcrops at the western base of the next hill to the east with strike N. 25° E. and dip of 24° easterly.

FIGURE 30.—Structure seen in hill near Shaftsbury, interbedded limestone and quartzite.

A wide swampy track borders the steep western scarp of Trumbull Mountain. West of the northward extension of this swamp, east-southeast of Shaftsbury (see Equinox sheet), is another high hill, showing interbedded limestone and quartzite, standing at high angles on the summit. At one place the structure was similar to the accompanying figure 30. On the top of



*A.* LOOKING NORTH FROM HARRINGTON COBBLE. TRUMBULL MOUNTAIN ON THE LEFT. MAPLE HILL ON THE RIGHT.

*B.* MINOR COMPRESSED FOLDS IN LIMESTONE OVERTURNED TO THE WEST, ONE-HALF MILE NORTH OF HARRINGTON COBBLE.

the hill the limestone was folded down in a minor synclinal. The structure was interpreted as that of an anticline, but with one or more infoldings along its crest.

South of the transverse series of hills beginning with Maple Hill on the east and ending with Trumbull Mountain, between them and Harrington Cobble and Hale Mountain at the south, is a gentle westward slope of low relief. Plate LXX, A, is a view looking north from the summit of Harrington Cobble across this slope. The scarp-like character of the western slopes of the hills in the distance is brought out in the photograph. The 100-foot contours of the map of this report do not bring out these hills as sharply as do the 20-foot contours of the United States topographic sheet. In the foreground of the plate is the gentle, northern drift-covered slope of Harrington Cobble. The northern slope of Hale Mountain is more abrupt. In the southern portion of the gentle western slope, north of the crossroad on the north of Harrington Cobble, are numerous ledges of limestone. In the brook that crosses this portion of the slope the limestone dips gently westward. Plate LXX, B, gives a view of a portion of a limestone ledge 500 or 600 yards south of the brook. This ledge was interpreted as connecting under the drift with Harrington Cobble and as genetically a part of it, thus revealing the close overturned folding that caused the Cobble.

The general flat position of the quartzite in the broad band north of Bennington indicates that it was not folded much. It buckled a little. In its southern portion a downward fold caught and preserved the limestone outlier north of Bennington. At the northern end an upward bulge formed the long high hill of quartzite south of Buck's Cobble.

All the different hills that have been described in the eastern part of Shaftsbury are of similar genetic type, including the hill of quartzite south of Buck's Cobble. They form long camel-hump arches along the strike with anticlinal structure and all are overturned. Probably all have suffered some overthrusting or developed a strong tendency in that direction. It may be that Buck's and Harrington Cobbles and Hale Mountain had a quartzite member of the interbedded series at one time covering them, but not being so violently folded as the hills farther north, there was no infolding of the quartzite along their crests. It is also possible that the limestone of these Cobbles belongs to a higher horizon than the interbedded limestones and quartzites farther north and that the latter did not reach the surface in Buck's and Harrington Cobbles. The former view, however, seems more likely because the limestone outlier north of Bennington would seem to suggest that the quartzite was succeeded by a certain thickness of limestone before the deposition of the interbedded series and the occurrence of the quartzite at the surface at the south points to diminishing reversed faulting northward so that

Buck's and Harrington Cobbles with Hale Mountain take an intermediate position with respect to the quartzite south of them and the interbedded series at the north. The exact relation of the broad quartzite band to the adjacent limestone on the west could not be positively determined, but I believe it is a faulted one. An intersecting cross fault south of Buck's Cobble dies away eastward. North of this break folding was more violent, the tendency towards which is recorded in the quartzite at the high hill just south of Buck's Cobble. The tendency to folding increased northward and inversely as the tendency to upthrust of the lower beds diminished.

If there is a reversed fault on the west of the broad band of quartzite it becomes a question how far north it should be drawn. The interbedded series appear to be at no great distance above the basal quartzite, whether we reason from the surface succession northward from Bennington or eastward from the range through Maple Hill, and I have drawn a probable break northward to the limit of the map to show the probable close age relation of all the rocks of this broad band on the east of the valley north of Bennington with intervening probable strike faults between this major break and the foot of the range.

In view of the heavy drift covering in the central and western part of Shaftsbury the probable stratigraphical relations of the east and west portions of the valley in this town are hard to work out. If there is a reversed fault all along the western edge of the quartzite and the series of "Cobbles" north of it, it would mean that the interbedded series underwent some folding before the break occurred and were caught at whatever stage of folding they had attained when the heavy quartzite basal member broke.

South of Bennington the interbedded series lies flat for the most part. The high hill just west of the brook that joins South Stream three-fourths of a mile northwest of the old lumber mill shows interbedded calcareous quartzite and limestone like those in the hills of Shaftsbury and obeys a similar arching tendency along the strike. A reading on the steep eastern slope of this hill gave the strike as N. 35° E. and the dip 80° E. At the northern end of the hill a reading gave strike N. 33° E. and dip 70° W.

Placing this hill with the valley quartzite formation the western boundary of the latter should perhaps be drawn through or on the west of this hill and southward so as to include the spur sticking out northwest from the range towards Barber's Pond. The limestone of the base of this spur in its lithology recalls the limestone of the outlier north of Bennington and underlies the interbedded upper series of the spur.

Possibly the western margin should be drawn even farther west to include certain outcrops south of Meyer's house on the



extreme northeastern slope of Mason Hill which are lithologically similar to the limestones just mentioned.

The calcareous quartzites of the interbedded series so strongly resemble the quartzite that one must always carefully examine them to be sure. They weather to look like the quartzite although frequently showing a pitted surface. These siliceous limestones, as they may be equally well designated, effervesce rather strongly with cold dilute acid and under the microscope show an approximately equivalent amount of calcite and quartz distributed in grains over the section in such manner as to indicate detrital origin for both and free admixture during deposition. The siliceous elements of the thin section show some microcline and other feldspar but are predominately quartz.

## THE LIMESTONE FORMATION IN AND SOUTH OF BENNINGTON.

On Hillside street in Bennington, near the house of J. T. Remington, the limestone as blasted in the road shows the structure as exhibited in figure 31. The section indicates close folding, overturning and reversed faulting.

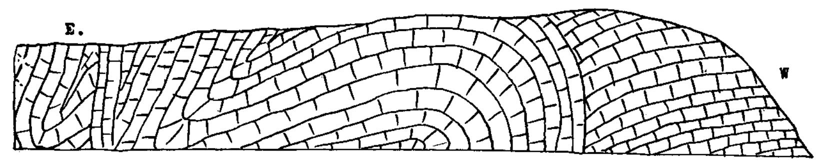



FIGURE 31.—Limestone on Hillside Street, Bennington, near J. T. Remington's.

Just south of Main street under the west bank of the cemetery the limestone dips easterly at 54° and strikes N. 31° E. One mile south of Main street, along the road leaving the latter west of Jewett Brook, near "Camp corner," in the quarry beside the road, the limestone dips 60-65° easterly, the strike in the quarry varying in a distance of 50 feet from N. 45° W. to N. 7° W. One-half mile directly south of this quarry, on the northern slope of the hill, the limestone lies quite flat. This outcrop is on the extreme northwestern slope of the hill which a mile to the southeast shows interbedded limestone and calcareous quartzite as described above, dipping 80° E. on the eastern slope and 70° W. on the northern slope.

In Bennington on Main street near the mill pond the limestone dips eastward at a low angle and shows shearing structure dipping eastward at a high angle.

South of Bennington, between South street and Dunham avenue and the Pownal road, the limestone is dove-colored, carrying many wavy bands of a chamois color, reminding the writer very strongly of certain portions of the calciferous of Dutchess

County, N. Y. The rock has every appearance of having undergone shearing whch has developed an eastward dip so that it proved very difficult to distinguish between shearing and bedding. Near the Pownal road the dove and buff seem to be clearly interbedded, dipping east so that the shearing is with the bedding, but 200 yards to the southwest the dip is 19° W. with the strike of N. 27° W. Weathered surfaces were searched for fossils without success. It was not possible from the surface exposures to determine to what extent the shearing and dip approximately coincided.

In Bennington, three-fourths of a mile west of South street, in the Lebanon Springs R. R. cut the limestone dips east with shearing joints across the bedding.

In the field north of Dunham avenue, between it and the next road north, a greatly brecciated limestone appears in numerous small and large ledges over an area several acres in extent. Plate LXXI shows the vertical face of one of these ledges. The brecciation is often coarser than that shown in the plate, but is also rather fine, the two passing into one another. The fragments range from the size of a marble to that of a man's head. The brecciation is clearly apparent on the lichen-covered surface outcrops but is most conspicuous on comparatively fresh surfaces.

Just west of the Pownal road, a few hundred yards northwest of these brecciated outcrops, the limestone strikes N. 81° W. and dips 24° southerly.

Both east and west of the Pownal road, south of Robinson's crossroads, and one mile north-northeast of Carpenter Hill, the limestone generally dips westward. One reading one-half mile south of the crossroads gave the strike N. 30° W. and dipped 48° westerly. At this place there is confusion; another reading gave a dip clearly to the southeast. The limestone is frequently brecciated, breaking into many irregular pieces under the hammer. Westward up the hill the dip is eastward.

Along the mountain road, running west of Carpenter Hill, about a mile and a fourth from Robinson's crossroad, and just beneath the eastern edge of the Mount Anthony schist, which rises very steeply here, the structure shown is exhibited in the composite section of figure 32. One-fourth of a mile northeast of this outcrop, just west of the road, the limestone shows pronounced shearing. It is the gray or dove-colored rock seen so frequently farther north, to the east of the Pownal road, and carries the same chamois-colored wavy patches and streaks.

Just south of the ledge, whose structure is shown in figure 32, the limestone of Carpenter Hill gives place to schist. On the summit of this hill the eastern margin of the schist is one-half mile farther east than along the mountain road. In both places the schist dips to the west.

PLATE LXXI.

A LEDGE OF COARSELY BRECCIATED LIMESTONE WEST OF DUNHAM AVENUE IN BENNINGTON.

Existing maps show the limestone passing over the mountain west of Carpenter Hill to join the limestone in the valley of the Hoosick. My observations find the schist intervening and contradict this connection across the mountain.

The limestone east of Carpenter Hill and southward, west of the Pownal road along the foot of the mountain to Pownal Center, so far as observed, dips westward beneath the schist. Where Jewett Brook crosses the road, and in the electric railway cut just east, the dip is apparently eastward.

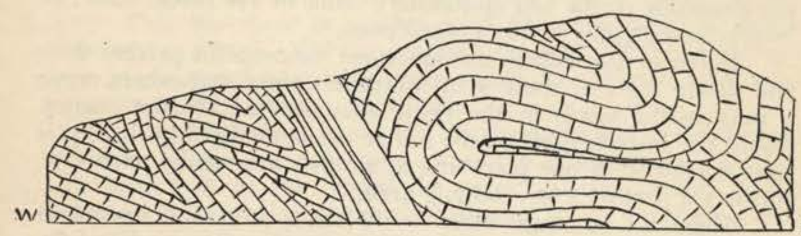



FIGURE 32.—10'-12' Limestone and schist on east side of Mount Anthony, near Carpenter Hill. Composite section.

Only a few non-committal outcrops occur southeastward on the hills as far south as the road going east from Pownal Center. On the northeastern slope of the hill lying in the angle between this road and the one going south from "Irish corner" the limestone and schist are mixed in great confusion, outcrops of one passing within short distances into those of the other, the whole side hill presenting the aspect of limestone overthrust or overfolded and resting on the schist.

Around Barber Pond and northward for a distance of three miles or more the drift conceals the limestone, leaving the structure over this broad area wholly in the dark.

It is a problem how to interpret the structure of the limestone south of Bennington, but the observations which have been noted show close folding, overturning, overthrusting, extreme and violent brecciation and shearing. I believe the limestones south of Bennington to be mainly older than those which pass beneath the schist of Mount Anthony. Studies which the writer has elsewhere made in the Taconic rocks have shown great blocks of limestone to move upward as a mass by reverse faulting against younger strata, at the same time suffering extreme folding and minor breaks within the block.

I would hesitate to assert that this is what has happened south of Bennington, but in view of the tendency to reverse faulting and the structural features observed in the field such a history does not appear improbable.

## LIMESTONE AND SCHIST NORTHWEST OF BENNINGTON.

Limestone outcrops in the road and along the Walloomsac in Papermill Village and in Paran Creek along the trolley road toward North Bennington. Outcrops in Papermill Village show some minor folding westward. In the quarry east of the lumber mill on Paran Creek and a few hundred yards south of it the strike is N. 80° E. and the dip 11° S. SE. The flat position of the limestone in the bed and eastern bank of the creek, south of North Bennington, is very conspicuous.

North of the village the limestone outcrops in patches here and there. One of these is at Mattison corner and others occur a mile to the north in the fields southeast of Horton corner. Along the eastern slope of the hill at the latter locality the dip is west-northwest at one place and at another apparently northeast, forming a part of a low doming arch.

Abundant outcrops occur in the fields west and northwest of Horton's corner near "Cold Spring." A reading of the dip gave 14° NW. North of Clark's corner another reading gave the apparent dip southeast at a high angle, but at this place the rock was greatly sheared and distinction between dip and shearing was not easily made. A patch of the limestone north of "Cold Spring" showed many gray patches resembling fossils on the weathered surface. Nothing positively distinct was found and the rock was too tough to break.

The limestone formation over much of the area north of Bennington shows the same gray rock which streaks and patches of buff as described for so much of the area south of Bennington, and likewise showed evidence of much shearing.

On the west slope of the hill at Taper's corner, one and a half miles south of Shaftsbury Center, the limestone dips to the north. In the Rutland R. R. cut a mile northeast of South Shaftsbury the dip is to the south. Southeast of South Shaftsbury the dip is south or southeast.

On the southeastern slope of West Mountain the schist comes down to within a half mile of the Shaftsbury road. The southernmost outcrops of limestone just north of the road running west of Shaftsbury Center dip to the south. Along the base of the eastern slope of the mountain one-half mile farther north the dip could not be made out.

There is seen to be considerable apparent variation in the strike and dip of the limestone formation north of North Bennington. In some cases the dip may have been that of shearing structure, but in general the limestone appears to lie in gentle undulating folds and to have suffered shearing which has produced an apparent eastward dip in many cases.



North of the road at the base of the southern slope of West Mountain the schist formation succeeds the limestone dipping to the east-southeast.

In North Bennington village, one-half mile northwest of the post office, near the railroad track, slate or phyllite outcrops dipping west with eastward cleavage. A few hundred yards west are outcrops of limestone. Westward in the direction of Sodom the limestone gives place to slates.

The eastern and southern slopes of the low hill southwest of Bennington are underlain by limestone dipping to the southeast. This limestone is farther west than the slate in North Bennington village. On the western slope of the hill the limestone is succeeded by papery slates which are the southward continuation of the outcrops at Sodom.

On the south slope of the hill the limestone comes down close to Henry Bridge and continues across the Walloomsac. A half-mile southwest of the bridge the papery slates outcrop in the brook on the west side of the road dipping to the southwest with strike N. 55° W. The limestone occurs a few yards east on the east side of the road. On the east slope of the hill to the southwest of these outcrops the limestone rests on the slate.

The high hill southeast of the "ore pit" is capped by slates and flanked by limestone on the east.

The schist was thus traced along an irregular line beginning two miles west of the northern end of Mount Anthony, as shown on the map, as far north as Sodom. Another trip was planned to trace the boundary north from Sodom. There are reasons for thinking that the Vermont Report has the boundary substantially correct in representing the limestone as entirely cut off in the west by the slate just east of the state boundary.

The apparent dip of the schist up the south slope and at the summit of West Mountain is eastward. The rock at the summit is a sericite schist which does not differ essentially from that of Mann Hill both in the hand specimen and in thin section.

The country immediately southeast, east and northeast of North Bennington and northward through South Shaftsbury and Shaftsbury Center is so largely drift covered that outcrops are few and to a great extent non-committal. Limestone outcrops on the west slope, southeast of South Shaftsbury, below the slope that truncates the beds of the quartzite, with strike N. 40° E. and dip of 18° E. The limestone outcrops at a few places in the Rutland R. R. cut north of South Shaftsbury.

The outcrops on the whole through this drift-covered area suggest that the limestone is not greatly folded, as is also the case around North Bennington.

The western portion of this broad valley area northwest of Bennington is much sheared and the field observations indicate that the limestone has been pushed against and over the schist at the west. The map shows that this limestone area has suffered at offset to the west corresponding with that in the valley quartzite north of Bennington and also with that of the Bald Mountain mass.

Throughout this broad area no marbles were found corresponding with those that pass beneath Mount Anthony and the formation was considered to belong to an older terrane than the Mount Anthony limestone.

It was hardly possible to make out the structural relations on the south and east of West Mountain. The schist of West Mountain is regarded as younger than the limestone and so also is that which the valley limestone rests against or upon at the west.

It is not possible to assert how far west the great fault that bounds Bald Mountain on the south extends in the limestone northwest of Bennington and so it is represented as dying away west of Bennington.

## LIMESTONE AND SCHIST OF MT. ANTHONY SOUTHWEST AND WEST OF BENNINGTON.

Beginning at a point about three miles south of Bennington Center near the base of the eastern slope of Mt. Anthony and proceeding northward along the slope, the limestone was found dipping westward into the mountain beneath the schist. The formation is sometimes thinly bedded, but consists mainly of beds of white or clouded marble ranging from two to three or more feet in thickness. The dip is as low as 5° in some places and always at a low or moderate angle. Towards the northern end of the mountain the dip changes to the southwest and at the northern end to due south. Southwest of Dunham's corner the limestone shows much confusion of strike and dip, the latter changing from easterly dip through a vertical position to the characteristic southwest dip. The schist near here is two or three hundred feet below its normal contour. A small normal fault has dropped the schist and disturbed the limestone.

In quarry excavations just southeast of the Edward H. Everett mansion the strike of the limestone was N. 29° W. with dip 28° S. W. Along the wood road following up the brook west of the mansion the slaty schist appears showing eastward dipping cleavage. The limestone outcrops a few yards north on nearly the same contour. Farther up the mountain in the woods at an old quarry the schist rests conformably on blue limestone which strikes N. 80° W. and dips 47° southerly.

Along the edge of the woods northwest of the Everett mansion the limestone varies in strike between due east and west and N. 48° W. Along the northwestern slope a short distance up from the base the rock is a thick-bedded marble. Along the northern slope just below the woods these heavy beds dip south-

PLATE LXXII.

*A.* BLUE CRYSTALLINE LIMESTONE BENEATH MT. ANTHONY SCHIST AT COLGATE'S QUARRY. THE ROCK IS USED FOR ROAD METAL.

*B.* CONFORMABLE SCHIST AND LIMESTONE JUST SOUTH OF OUTCROP IN PLATE VI.

ward and this same dip appears along the Pownal road from Bennington Center just west of the brecciated ledges which were described above and also along the road running east and west through Bennington Center.

A private road ascends the northwest slope of Mount Anthony on the estate of James C. Colgate. Along this road the limestone gives place to the schist which strikes N. 50° E. and dips 20° easterly. In some slaty beds in this schist some distance up the road a crushed crinoid stem was found.

Along the road to North Pownal, which branches from the Bennington-Hoosick road on the west side of Mount Anthony, the dip of the limestone is southerly. In a quarry used for road metal, about a mile south of the Bennington-Hoosick road, a blue limestone with the same southerly dip conformably underlies the schist (see Plates LXXII, A, and LXXII, B). The conditions are similar to those in the quarry in the woods west of the Everett mansion.

In Bennington Center, three-fourths of a mile northwest of the monument, the limestone was observed with the same southerly dip.

Along the North Pownal road, from the quarry south of Colgate, only the schist formation outcrops to within a mile of North Pownal village. The western slope of Mount Anthony is schist and this was followed over the ridge to Carpenter Hill. If, as seems likely, there is a fault on the northwest of Mount Anthony it dies away southward.

Mount Anthony is a synclinal pitching southward and capped by the schist formation which is conformably underlain by blue crystalline limestone and heavy-bedded marble which outcrop on the northwest, north, northeast and a part of the east slopes of the mountain.

## THE LIMESTONE AND SCHIST IN NORTH POWNAL AND POWNAL VILLAGES.

Northeast and east of North Pownal village is a large inlier of limestone, as shown on the map. It extends east of North Pownal as far as the road running south from Arnold's (school house) corner along which it is mixed with the slate as far as the next corner south. This inlier is surrounded by the slate or schist on the west, north and east and at the south extends along the valley of the Hoosick as far as Pownal. South of Pownal it seems to be cut off by the schist from the limestone northwest of Williamstown.

At the northern end of this inlier, east of the road from Bennington Center to North Pownal, the limestone forms a conspicuous hill. A reading here gave the strike N. 35° E. and the dip 23° SE. Across the road at the "Wash Tubs" (see plate

LXXIII) the limestone arches gently as shown in figure 33. At this place the stream has cut into the gently arching limestone and made a series of large pot-holes locally known as the "Wash Tubs."

In the old quarry at Whipple's corner in North Pownal village the limestone is rather massive. In the north wall a small overturned fold was observed, the axial plane lying flat. In the south wall the dip appeared to be gently westward, but dynamic movement has largely effaced distinct bedding.

East of Main street in the village the limestone forms a high scarp to a point one-half mile south of the railway station. At the quarry at North Pownal station the limestone shows folding on large and small scales with severe jamming. In the railroad bank just under the highway, southwest of the quarry, is the slate which is greatly jammed and crushed. Just across the river opposite the quarry the slate or phyllite forms a knoll between the river and the road near the Dean place. Here the slate shows severe crumpling which dips eastward.

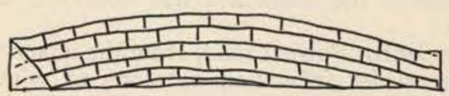



FIGURE 33.—Limestone structure at Wash Tubs.

Southward along the west bank of the stream a thick drift covering conceals the rock near the river, but schist outcrops up the slope of the hill to the west. A mile south from the Greylock Mills, on the west side of the stream, a knoll of limestone lies close to the river clearly resting on or against the slates. South of this outcrop past the abandoned Service farmhouse all is slate nearly to Daniel Gardner's house.

Along the road south from the Service house, just after it makes its turn west of Gardner's house, the slate outcrops in the road and the brook with limestone in close proximity. The actual contact was not seen but the two are less than eight feet apart. Limestone outcrops south of the road and elsewhere partly surrounding the slate, indicating that the limestone has been pushed over on the slate.

At the bridge in Pownal limestone outcrops in the bed of the river.

Along the road west of the Hoosick, south of Pownal, the drift hides the underlying rock, but near the quadrangle boundary, a half mile east of the road, near the railroad bridge, the schist outcrops in numerous ledges dipping west into the hill. Westward the schist passes beneath the drift of an immense drumlin. It forms the west bank of the river south of the railroad bridge, but east of the river is succeeded by limestone.

PLATE LXXIII.

THE WASH TUBS, NORTH POWNAL.

In thin section this schist shows a felt work of sericite with quartz and some magnetite as accessory and numerous flakes of chlorite rather uniformly distributed in the section. In correspondence with the presence of the latter the hand specimen shows a greenish color, although the parting planes show the same silvery luster exhibited by the schist of Mann Hill.

On the map, between the railroad bridge and Pownal, the schist of Mason Hill is made continuous with that west of the river. The schist was traced along the Pownal road east of the Hoosick to and through the village of Pownal to a point about one mile south of North Pownal station, where it is succeeded by the high scarp of limestone along the road. At this point the boundary turns northeastward and passes west of the brook to the mixed outcrops of schist and limestone that have been described.

All along the Pownal road at the base of the westerly slope of Mason and Mann hills, the dip of the schist is eastward, while west of the river, so far as observed, it is normally westward.

The eastern margin of the limestone hill east of North Pownal shows pronounced shearing, especially about one mile north of Wright Bridge corner, just west of the brook. It is here a gray rock with chamois-colored stringers and patches like that so common north and south of Bennington. Although the limestone in the quarries in North Pownal is somewhat different, in the surface outcrops near by, it weathers in a similar way. I have not found in this inlier any heavy beds of marble like those on the east and north slopes of Mount Anthony.

I look upon this limestone at North Pownal as a faulted inlier which is thrust against or on the slates at the west and which pinches out southward in Pownal village.

## SCHIST OF MANN HILL.

Through the fields and along the road from North Pownal northeastward to Carpenter Hill and eastward to Pownal Center are numerous outcrops of the schist dipping east. Along the eastern margin of the Mount Anthony ridge north of Pownal Center the dip is westward into the hill. There is, therefore, within a mile going south, a change in dip from west to east. All the schist south of the road from Pownal Center to North Pownal and along the road, as described above, from Pownal to North Pownal, and on the west slope and summit of Mann Hill dips east. On the east slope of Mann Hill the schist also dips east and passes beneath the limestone which is mixed with the schist in great confusion south of "Irish corner" as described above.

The schist of Mann Hill has been overturned, and the limestone east of it has been either thrust or overturned on it.

The rock at the summit of Mann Hill is a silvery sericite schist. In thin section it shows a felt work of sericite with quartz and without apparent accessories.

## THE SCHIST AND LIMESTONE OF MASON HILL.

The summit and western slope of Mason Hill are underlain by schist similar to that of Mann Hill. Along the road over the summit it is noticeably crumpled.

The modified drift is piled high against the southwestern slope of Mason Hill above the Hoosick River. Limestone outcrops from beneath the drift along the Williamstown-Pownal road a hundred yards southeast of the railroad bridge.

A road ascends the hill one-fourth of a mile south of this outcrop. Four or five hundred yards north of this road just above the gravel pits limestone lies on the sericite schist as shown in figure 34. The limestone continues up the hill northward

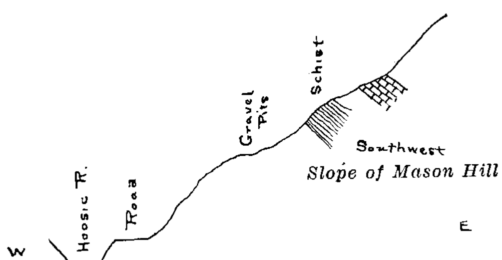


FIGURE 34.—Limestone and schist.

along the slope and is succeeded by the schist, both dipping easterly. Here again the limestone rests on the schist.

East of the road over Mason Hill the schist outcrops under the west bank of Reservoir Brook and just across the brook less than 50 feet away rises the high scarp of compact, white quartzite. The schist along Reservoir Brook is greatly shattered. This broken schist was also found east of Meyer's house along the road and at this place lies close to the northward extension of the fault along Reservoir Brook.

Along the Pownal road towards Williamstown the limestone outcrops along the east side of the road with southeasterly dip and strike N. 18° E., and southward joins the limestone area of Williamstown.

The Hoosick between the Massachusetts line and North Pownal has apparently availed itself of a great line of rupture. Along this break the limestone has come to the surface, as now exposed, except in the interval between Pownal and the railroad bridge two miles southeast of the village along which the schist of Mason Hill apparently joins that west of the river.



## GENERAL RELATIONS.

It is difficult to represent on the map the probable intricate structural relations of the rocks of the area. The writer hoped by another season's work to get some light on the relative ages of the rocks which in so many cases apparently lie in faulted positions against each other.

It is possible that the major flexures which ultimately were to find expression in the Green Mountain elevation began early in the Cambrian period and that folding went on slowly enough to allow for continuous deposition from Lower Cambrian to Ordovician. The writer has elsewhere suggested that faulting and erosion may possibly account for the apparent absence of portions of the Cambrian.

The thick masses of sediments which accumulated in the great troughs of the older rocks underwent profound folding as the basement crystalline floor slowly closed in on them. They were often greatly jammed, overturned and sheared. It would seem that after a time the pre-Cambrian floor reached the limit of strain and broke into blocks which were thrust upward into the younger rocks, but not in all cases reaching the surface, as now exposed. The folded younger rocks were caught at whatever stage of folding they had reached when the gneissic floor broke.

Later adjustment faulting would have probably caused some slumps along the planes of earlier reverse faulting.

Similar relations obtain in other portions of the Taconic belt; as at Rutland, Vermont, and in Dutchess County, N. Y. at Stissing Mountain, near Stissing Junction, at East and Schaghticoke mountains near Dover Plains, at Corbin Hill near Pawling, in the Fishkill Mountains and also at "Pine Island" near Patterson, in Putnam County.

The great abyssmal swell of the pre-Cambrian floor caused it to break at numerous places, often pushing the gneiss up into much younger strata, the gneiss often carrying the quartzite with it. Movements of lesser violence would have caused similar breaks between younger rocks which would not be so apparent as where the movement was violent enough to carry the pre-Cambrian against the Ordovician limestone and schist.

## THE PLEISTOCENE.

Only incidental attention was given to the surface deposits.

Typical kame moraine topography prevails over the area around Barber Pond and two miles north of it. (See Plate LXXIV, A). Barber Pond is very shallow and is surrounded and formed by kames. A tongue of ice probably projected down the valley from Bennington and the drainage from this tongue was impounded in a shallow basin formed by Mann and Mason hills on the south and the ice on the north. In this basin the kames were built. They are the marginal moraine deposits of the ice in the valley.

Northeast of Barber Pond a long serpentine ridge rises gradually from the flat ground just west of Brown's corner and extends one-fourth mile up the hill in a northeasterly direction towards the range. It has the form of a typical esker and was probably formed when the ice rested on the lower slope at the foot of the range. (See Plate LXXIV, B).

There is evidence of border drainage along the eastern edge of the valley southeast of Bennington.

East of Bennington the Walloomsac has cut through a thick bench of gravel and sand which the stream built out towards the ice margin as it receded from the range. This delta terrace extends for two miles southward west of Harmon Hill. At the time it was forming the drainage of the Walloomsac may for a time have passed as a marginal stream along the eastern edge of the ice and around its southern end to find exit at the pass at Pownal Center.

On the southern flank of Mason Hill the modified drift, which is piled high above the river, consists of thick deposits of well-sorted sands and gravels and probably represents deposits from glacial streams into a lake at the south during a halt of the ice in its retreat northwest along the Hoosick Valley.

North of Bennington the typical knob and basin topography is lacking. One or two kames were noted on the southern end of West Mountain.

PLATE LXXIV.

*A.* KAME MORAINE TOPOGRAPHY TWO MILES NORTH OF BARBER'S POND.

*B.* ESKER NORTHEAST OF BARBER'S POND.

# THE TOPOGRAPHICAL MAPS OF VERMONT.

G. H. PERKINS.

The importance and character of the maps prepared by the United States Geological Survey does not seem to be as fully understood by all as they should be, hence some account for explaining these maps, their purpose and the steps necessary to their completion will not be out of place.

It is more than twenty years since these maps were first made by the Government and during this time many thousands of square miles largely in the west, have been surveyed and the maps made and published. During the last ten years much work of this sort has been carried on in the Eastern States, and Vermont has not been wholly neglected. Indeed every state has been more or less mapped and some have been completely covered. At first, in 1882 and for some years thereafter, only the General Government through the Geological Survey was concerned with the Surveys, but later the different states began to cooperate to the extent of contributing a portion of the expense of the field work, the most frequent arrangement being that the state appropriated a certain fixed sum, for example $5,000 and the U. S. Survey $5,000 and this entire sum was used for the expense of the surveying. After this was done the Government paid for preparing, printing and publishing the maps, which are sold to anyone at about cost price. By this arrangement any cooperating state gets maps such as are made in no other way for about a third of the total cost of making them.

It is not to the credit of Vermont that it is behind most of the states in taking advantage of the very great opportunity thus presented. It was not until by Act number 285 of the Legislature of 1912 that this State entered the list of those cooperating, although opportunity was offered to Vermont some years ago, but it was rejected by the Committee to which it was referred. Through the generosity of the General Government, as well as that of New York and Massachusetts, about a third of Vermont had been mapped at no cost whatever to this State. New York for a number of years made large appropriations to this work and as the maps are made by "Quadrangles" instead of towns, when the surveyors in New York reached the eastern border they completed whatever quadrangle they were surveying wherever it carried them and in this way a large area of western Vermont was surveyed. Thus all the islands in Lake Champlain and the western border of most of the lake towns were included in the New York survey. This was mostly done in 1894 and the maps were available in the following year. So too, all of the quadrangles in the northern border of Massachusetts overlapped, though to a much less extent, and took in narrow portions of the southern tier of Vermont towns.

Through the influence of Senator Morrill the Strafford Quadrangle was completed in 1894 and the map issued a year or two later.

Several years before this in 1886 the Hawley Quadrangle was completed by the National Survey in cooperation with Massachusetts and this included a narrow strip of the southern parts of Readsboro, Whitingham and Halifax and this was perhaps the first surveying done in Vermont by the U. S. Survey.

No work appears to have been done in Vermont until 1888-1891, when the Rutland and Castleton quadrangles were surveyed. During the five years following a little work was done each summer, then for six years nothing was done anywhere in the state until 1910 the Woodstock Quadrangle was finished and the map is now published.

During the last few years the number of states willing and even very desirous to cooperate and ready to appropriate money for the purpose had so increased that it became evident that no further surveys would be made in a state which was unwilling to do its part in assisting the Government to the extent required.

In 1912 a vigorous effort to secure cooperation on the part of Vermont was made by the Green Mountain Club, the Automobile Club and the State Geological Survey. This resulted in the passage of the Act mentioned above, whereby the State appropriates $2,000 annually to the Topographic work. It is earnestly hoped by all who understand the great value of these maps to the State that this appropriation may be continued by future Legislatures until the entire area of Vermont has been mapped. As a result of cooperation the quadrangle immediately north of Burlington was completed in 1913 and during 1914 the region still further north, including St. Albans, has been surveyed, this making a complete tier through western Vermont as it continues former work. As to the maps themselves, it may be assumed that many have seen and used them and these need no explanation of their nature and value. There may be others who are less familiar with them.

It seems absurd that anyone can confound the topographic maps with the old fashioned county maps familiar to us all, but I have actually heard apparently intelligent men declare that they could not see enough difference to make the new maps worth while. It is to be hoped that such men are not numerous. To those who have seen the topographic maps it is unnecessary to say that they are not like any maps that have ever been made of any part of Vermont, but are beyond comparison more accurate and give clearly many details not usually found on any maps. The sheets are all of equal size, but the engraved surface varies a little. In the Vermont sheets they are usually a little less than thirteen inches in width by seventeen in length. The area covered also varies somewhat, but is usually not far from 220 square miles. On the back of each sheet is printed an explanation of the map and of the various symbols used to indicate different conditions of the surface, swamps, forests, roads, quarries, etc. Perhaps the most important and economically useful feature is the marking of contours whereby all changes in level are plainly indicated. Every twenty feet these little brown lines mark a change in elevation and every hundred feet a heavier line is drawn. All water, streams, lakes, etc., are represented in blue, while roads, boundary lines, names, etc., are in black. The use of these colors for different classes of objects greatly adds to the clearness of the maps.



Three scales are used on the maps throughout the country, but those of Vermont are nearly all on the same scale—1:62,500 or nearly one inch to a mile so that it is easy to find two places and measure the distance between them, also by means of the contour lines it can be at once seen whether the space is level or hilly and the height of the elevations if there are any. A very few of the Vermont maps are drawn to cover a much larger area and these are made on a scale only half as large, 1:125,000, but in this case the same areas are also given on the usual scale.

The cost of the preliminary surveys must obviously depend largely on the nature of the country to be covered, a level region being less expensive than a hilly one. The cost of mapping the whole of Massachusetts averaged $12.90 per square mile, while that of Connecticut was $9.79 and Rhode Island still less. The use of the maps is thus stated in one of the Reports of the U. S. Geological Survey.

"1. Educational.—By promoting an exact knowledge of the country; by serving teachers and pupils in geographic studies.

2. Practical.—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts, sewage plants may be laid out on them and the cost of preliminary surveys saved. Areas of catchment for water supply, sites for reservoirs and routes for canals may be ascertained from these maps.

3. Political.—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

4. Administrative and military.—In all questions relating to Federal or State administration of public works as canals, reservations, parks, highways, and as military base maps.

5. Statistical.—As base maps for the graphic representation of all facts relating to population, industries, products or other statistical information.

6. Economic.—As a means for showing the location, extent, and accessibility of lands, waters, forests and valuable minerals. In this respect these maps are indispensable to State and Federal bureaus and to owners, investors and corporations."

As the work of the Survey progresses, bench marks, monuments, etc., are established and these are ready for any future surveys.

When the maps are completed they are sold to any applicant for about cost, 10 cents for a single or small number and $5 for a hundred which need not be all the same map.

Inquiries from many sources are frequent asking if one or another of our towns have been mapped and these have suggested the usefulness of some list to which reference can be made showing just what has been done by the map makers. In the pages immediately following, what may be called an annotated list, is given and the main facts in this are summarized in as compact form as possible in the second list.

Beginning on the north and west we have the NEW YORK-ROUSES POINT sheet. This is carried east across Lake Champlain to include almost the whole of Alburg and North Hero, all of Isle La Motte and the northern tip of Grand Isle.

South of this comes the PLATTSBURG sheet which takes in the rest of Grand Isle, Colchester Point and some of the region south including the last few miles of the Winooski River.

The next sheet, WILLSBORO, has in it most of Shelburne Point and a strip of the lake shore south as far as Ferrisburg and a little of that town.

The PORT HENRY sheet though a New York sheet, covers more of Vermont than of New York. This sheet takes in much of Addison County from Lewis Creek to Bridport.

The TICONDEROGA sheet also includes more of Vermont than of New York, viz.: the whole of Bridport, a bit of Cornwall, most of Shoreham, and Orwell, with a little of the north border of Benson, just taking in Sunset Lake.

The WHITEHALL sheet has most of Benson, all of West Haven, and the west third of Fair Haven. This completes the western tier of quadrangles and makes a continuous strip through western Vermont.

Next east there is at the north, the uncompleted quadrangle which has been surveyed this season. This will include Swanton, St. Albans, the north portion of Georgia and parts of the towns adjoining on the east.



Then the map just issued, the MILTON sheet, includes the southern part of Georgia, all of Milton, most of Colchester, the northwest corner of Burlington, a large part of Fairfax, more than half, west, of Westford, and a large area in Essex.

On the BURLINGTON sheet is nearly all of Burlington, the rest of Essex, about a third of Jericho, all of Williston, Shelburne, Hinesburg, Charlotte, much of Richmond, a strip of West Huntington, the northern border of Ferrisburg, and Monkton, and quite a bit of Starksboro.

Then comes the MIDDLEBURY sheet on which are the eastern half of Ferrisburg, Waltham, New Haven, Weybridge, Bristol, the west part of Starksboro including a large part of the town, a smaller part of Lincoln, most of Ripton and Middlebury and a little of Cornwall.

Next is the BRANDON sheet, on which are the greater part of Cornwall, the southern part of Middlebury, all of Sudbury, Leicester and Brandon, considerable of Ripton and Goshen, a small part of Chittenden and Pittsford, a bit of Hubbardton, the eastern edge of Shoreham and Orwell and the northeastern corner of Benson.

South of the BRANDON sheet comes the CASTLETON, on which are found most of Hubbardton, and Pittsford, all of Castleton, Proctor and West Rutland, most of Poultney and Ira, the west part of Rutland, northwest of Clarendon, the north part of Middletown, and a little of western Benson and Fair Haven.

The PAWLET sheet contains the southern part of Poultney, most of Middletown, a bit of the extreme south of Ira and Clarendon, the whole of Wells and Tinmouth, nearly all of Pawlet, Danby and Rupert, the north half of Dorset and just a bit of Wallingford.

Next south is the EQUINOX sheet. In this there are the following towns: the southern part of Rupert and Dorset, practically the whole of Sandgate, Manchester, Arlington and Sunderland; the northern border of Shaftsbury and Glastenbury.

South of the EQUINOX sheet is the BENNINGTON. This covers a large part of Shaftsbury, Glastenbury and Bennington, the whole of Woodford, nearly all of Pownal, and Stamford, with a narrow strip of the western border of Somerset, Searsburg and Readsboro.

The northern MASSACHUSETTS sheets overlap to include a strip of southern Vermont. That immediately south of the BENNINGTON sheet is called GREYLOCK and this includes a narrow strip of the southern border of Pownal and Stamford with a little corner of Readsboro.

West is the BERLIN sheet which takes in a very little of Pownal, while the HAWLEY and GREENFIELD sheets take in a wider strip of southern Readsboro, Whitingham, Halifax, Guilford and Vernon.

As yet none of the tier north of Rutland has been surveyed, but the RUTLAND sheet has been finished several years. This contains the larger part of Chittenden, the southwest part of Stockbridge and the southeastern part of Pittsford, about half of the town of Rutland, including the city, the whole of Mendon, most of Sherburne and Shrewsbury, a strip of western Plymouth and about half of Clarendon.

The WALLINGFORD sheet follows Rutland on the south and contains southern Clarendon and Shrewsbury, the whole of Wallingford, Mount Holly, Mount Tabor, and Weston, much of Peru, the northern part of Landgrove, a corner of Ludlow and a strip the entire length of Andover.

Next is the LONDONDERRY sheet. This covers the southern corner of Dorset, the southern half of Peru and Landgrove, nearly all of Londonderry, Winhall, Stratton and Jamaica, the northeast corner of Somerset and the northern half of Wardsboro. In this tier the last quadrangle is the WILMINGTON. At the north of this is most of Somerset, a southern bit of Stratton, and Wardsboro, the whole of Dover and Wilmington, most of Searsburg and Readsboro and Whitingham, a small area in Newfane, and large areas in Marlsboro and Halifax.

Comparatively little mapping has been done east of the Green Mountains, but there are a few areas mapped.

The HANOVER sheet is more largely occupied with Vermont than New Hampshire and embraces in its eastern portion a bit of Sharon, the southeastern corner, much of Norwich and Pomfret, the whole of Hartford, nearly all of Hartland, the northern part of Windsor and West Windsor and the northeastern corner of Woodstock.

The BRATTLEBORO sheet covers most of Newfane and Putney, the whole of Dummerston and Brattleboro and most of Guilford and considerable areas in Marlboro, Halifax and Vernon.

Adjoining the RUTLAND sheet on the east is the WOODSTOCK, recently issued. This contains southeastern Stockbridge, the southern two-thirds of Barnard, the western half of Pomfret, the eastern half of Sherburne, the whole of Bridgewater, most of Woodstock, the northern half of Plymouth, about half of Reading and a little of West Windsor and Hartland.

Quite by itself is the STRAFFORD sheet. On this are more than a third of Chelsea, a small area of southern Corinth, almost all of Vershire, all of Strafford, more than half of Tunbridge, a corner of Royalton, most of Sharon, a large area of Norwich, Thetford and West Fairlee.

On the NEW YORK sheet named CAMBRIDGE there is a narrow strip of the western border of Rupert, Sandgate, Arlington, and Shaftsbury.

On the HOOSICK sheet is a little more of western Shaftsbury, Bennington and a bit of Pownal.



In addition to what has been stated as to the various sheets and the towns mapped it will be convenient for reference if the whole is given in a condensed form. By reference to the following list one can at once see whether a given town has been mapped and approximately how much. It is also shown in which of the sheets the town is found and as has already been noticed, by writing to the Director of the U. S. Geological Survey any map can be obtained. As will readily be seen some of the towns are all mapped on one sheet, others are partly on one sheet and partly on another or in a few cases on several. Already 122 of the 256 towns of the state are more or less mapped, and of these 82 have been wholly, or nearly all mapped, 24 are more than half mapped, 16 less than half.

| Name of Town. | Topographic Sheet. | Extent Given on Map. |
|---|---|---|
| Addison | Port Henry | All of the town. |
| Alburg | Rouses Point | Nearly all. |
| Andover | Wallingford | A narrow strip of the west part. |
| Arlington | Equinox | Nearly all. There is a narrow strip on the west on the Cambridge sheet. |
| Barnard | Woodstock | More than half, southern part. |
| Bennington | Bennington | Nearly all. |
| | Hoosick | Quite a strip of the west side. |
| Benson | Ticonderoga | North border, narrow strip. |
| | Whitehall | Nearly all. |
| Brandon | Brandon | All. |
| Brattleboro | Brattleboro | All. |
| Bridgewater | Woodstock | All. |
| Bridport | Port Henry | North part. |
| | Ticonderoga | Southern two-thirds. |
| Bristol | Middlebury | All. |
| Burlington | Burlington | All. |
| Castleton | Castleton | All. |
| Charlotte | Burlington | Nearly all. |
| | Willsboro | Quite an area of lake border. |
| Chelsea | Strafford | Southeast half. |
| Chittenden | Brandon | Eastern border. |
| | Rutland | Nearly all. |
| Clarendon | Rutland | Most of the town. |
| | Pawlet | A very little of the south border. |
| Colchester | Burlington | Southeast part. |
| | Milton | A large part. |
| | Plattsburg | A small part, west. |

| Name of Town. | Topographic Sheet. | Extent Given on Map. |
|---|---|---|
| Concord | Whitefield | A little of southeast corner. |
| Corinth | Strafford | Small part of the south part. |
| Cornwall | Brandon | A large part. |
| | Middlebury | A strip on the north. |
| | Ticonderoga | A strip on the west. |
| Danby | Pawlet | Nearly all. |
| Dorset | Equinox | Southern half. |
| | Pawlet | Northern half. |
| | Londonderry | A little of the southeast. |
| Dover | Wilmington | All. |
| Dummerston | Brattleboro | All. |
| Essex | Burlington | Southern third. |
| | Milton | Nearly all. |
| Fairfax | Milton | Southwestern part. |
| Fairhaven | Whitehall | Nearly all. |
| Fairlee | Strafford | About a fourth. |
| Ferrisburg | Burlington | North border. |
| | Port Henry | A large part. |
| Georgia | Milton | All except the north border. |
| Glastenbury | Equinox | North third. |
| | Bennington | Southern two-thirds. |
| Goshen | Brandon | A large strip on the west. |
| Grand Isle | Plattsburg | Nearly all. |
| | Rouses Point | North end. |
| Guilford | Brattleboro | North two-thirds. |
| | Greenfield | South border. |
| Guildhall | Whitefield | A little of the southeast. |
| Halifax | Brattleboro | Northeastern two-thirds. |
| | Greenfield | Southern border. |
| | Hawley | Southwestern border. |
| | Wilmington | Northwestern part. |
| Hartford | Hanover | All. |
| Hartland | Hanover | Nearly all. |
| | Woodstock | Southwestern corner. |
| Hinesburg | Burlington | All. |
| Hubbardton | Castleton | Nearly all. |
| Huntington | Burlington | Western part. |
| Ira | Castleton | Nearly all. |
| | Pawlet | South end. |
| Isle La Motte | Rouses Point | All. |
| Jamaica | Londonderry | All except a little southeast. |
| Jericho | Burlington | Southwest third. |



| Name of Town. | Topographic Sheet. | Extent Given on Map. |
|---|---|---|
| Landgrove | Londonderry | Small strip on the south. |
| | Wallingford | Nearly all. |
| Leicester | Brandon | All. |
| Lincoln | Middlebury | Western third. |
| Londonderry | Londonderry | All except a little on the north. |
| Ludlow | Wallingford | Southwest corner. |
| Lunenburg | Whitefield | A considerable part. |
| Manchester | Equinox | All. |
| Marlboro | Brattleboro | Eastern two-thirds. |
| | Wilmington | Western third. |
| Mendon | Rutland | All. |
| Middlebury | Brandon | South half. |
| | Middlebury | North half. |
| Middletown | Castleton | North third. |
| | Pawlet | Southern two-thirds. |
| Milton | Milton | All. |
| Monkton | Burlington | Considerable of the north part. |
| | Middlebury | Two-thirds of the town. |
| Mount Holly | Wallingford | All except the extreme northeast. |
| Mount Tabor | Wallingford | All. |
| Newfane | Brattleboro | More than half. |
| | Wilmington | A strip on the west. |
| New Haven | Middlebury | All. |
| North Hero | Rouses Point | Nearly all. |
| Norwich | Hanover | Southern half. |
| | Strafford | Northern half. |
| Orwell | Ticonderoga | Nearly all. |
| | Brandon | Eastern border. |
| Panton | Port Henry | All. |
| Pawlet | Pawlet | Nearly all. |
| Peru | Londonderry | Southern half. |
| | Wallingford | Northern half. |
| Pittsfield | Rutland | Southern part. |
| Pittsford | Castleton | More than half southwest. |
| | Rutland | A large area southeast. |
| Plymouth | Rutland | West border. |
| | Woodstock | Northeast half. |
| Pomfret | Hanover | East half. |
| | Woodstock | West half. |
| Poultney | Castleton | Northern two-thirds. |
| | Pawlet | Southern third. |
| Pownal | Bennington | Nearly all. |
| | Berlin | Small part, southwest. |
| | Greylock | A little of south border. |

| Name of Town. | Topographic Sheet. | Extent Given on Map. |
|---|---|---|
| Proctor | Castleton | All. |
| Putney | Brattleboro | Southern part. |
| | Keene | Southeast corner. |
| Reading | Woodstock | North half. |
| Readsboro | Bennington | Narrow strip on the west. |
| | Greylock | Southwest corner. |
| | Hawley | Southern strip. |
| | Wilmington | Eastern part. |
| Richmond | Burlington | Western half. |
| Ripton | Brandon | A large part. |
| | Middlebury | Northern part. |
| Royalton | Strafford | Northeast corner. |
| Rupert | Equinox | Southeast half. |
| | Pawlet | Northeast half. |
| | Cambridge | Southwest corner. |
| Rutland | Castleton | West border. |
| | Rutland | Eastern part including the city. |
| Salisbury | Brandon | All. |
| Sandgate | Equinox | Nearly all. |
| | Cambridge | A little of the western border. |
| Searsburg | Wilmington | Nearly all. |
| Shaftsbury | Bennington | Southwestern third. |
| | Cambridge | A little in the northwest. |
| | Equinox | Northern border. |
| | Hoosick | Western border. |
| Sharon | Hanover | Southeast corner. |
| | Strafford | Nearly all. |
| Shelburne | Burlington | Nearly all. |
| | Willsboro | Western part. |
| Sherburne | Rutland | Nearly all. |
| | Woodstock | Eastern part. |
| Shoreham | Brandon | Eastern border. |
| | Ticonderoga | Nearly all. |
| Shrewsbury | Rutland | A large part. |
| | Wallingford | Southern border. |
| Somerset | Londonderry | Northeastern corner. |
| | Wilmington | A large part. |
| Stamford | Bennington | Nearly all. |
| | Greylock | Southern border. |
| Starksboro | Burlington | Northwest, a considerable part. |
| | Middlebury | A larger part on the southwest. |
| Stockbridge | Rutland | Southwest part. |
| | Woodstock | Northwest part. |
| Strafford | Strafford | All. |
| Stratton | Londonderry | Nearly all. |



| Name of Town. | Topographic Sheet. | Extent Given on Map. |
|---|---|---|
| Thetford | Strafford | More than half. |
| Tinmouth | Pawlet | All. |
| Tunbridge | Strafford | More than half. |
| Vernon | Brattleboro | Northern two-thirds. |
| | Greenfield | Southwestern corner. |
| | Warwick | A little, southeastern corner. |
| Vershire | Strafford | Nearly all. |
| Wallingford | Wallingford | Nearly all. |
| Waltham | Port Henry | West border. |
| | Middlebury | Eastern half. |
| Wardsboro | Londonderry | Most of the north half. |
| | Wilmington | Southern strip. |
| Wells | Pawlet | Nearly all. |
| Westford | Milton | Western half. |
| West Haven | Whitehall | All. |
| Weston | Londonderry | Southeastern corner. |
| | Wallingford | Nearly all. |
| West Rutland | Castleton | All. |
| West Windsor | Hawley | Northeastern corner. |
| | Woodstock | Northwestern corner. |
| Weybridge | Port Henry | West part, a considerable area. |
| Whiting | Brandon | All. |
| Whitingham | Hawley | Southern strip. |
| | Wilmington | Nearly all. |
| Williston | Burlington | All. |
| Wilmington | Wilmington | All. |
| Windham | Londonderry | Western border. |
| Windsor | Hanover | Northern border. |
| Winhall | Londonderry | Nearly all. |
| Woodford | Bennington | All. |
| Woodstock | Hanover | Northeastern corner. |
| | Woodstock | Nearly all. |

# TALC, AND THE TALC DEPOSITS OF VERMONT.

BY ELBRIDGE CHURCHILL JACOBS.

## CONTENTS.



## INTRODUCTION.

The purpose of this report is to present, for the information of those engaged in the talc industry, the mineralogical properties and the commercial uses of talc, its occurrence, statistics of production, and other useful knowledge. Furthermore, it has been attempted to describe in detail the talc deposits (but not the soapstone deposits) of the State in their geologic and economic relations and, by means of field studies, chemical analyses, and the microscopic study of many thin sections, to determine as far as possible the origin of these deposits.

The writer wishes here to acknowledge his indebtedness to the officers of the various talc companies in the State for much valuable information and for many courtesies; to the State Geologist for his encouragement and assistance; to Professors J. F. Kemp, A. W. Grabau, and C. P. Berkey, of Columbia University, for their advice; and to Mr. Max Roesler, of New York City, for his aid in the study of several of the thin sections.

The problem of the origin of the talc is admittedly a difficult one and its complete solution has by no means been reached. The writer expects to continue his studies and hopes, in a subsequent report, to reach a final conclusion.

University of Vermont, November, 1914.



## THE MINERAL TALC.

The mineral talc, is described by Dana[1] as an acid metasilicate of magnesium, whose formula may be written $H_2Mg_3Si_4O_{12}$, or $H_2O$, 3 MgO, 4 $SiO_2$. The theoretical chemical composition calls for 63.5% of silica, 31.7% of magnesia, and 4.8% of water. Talc is a very stable chemical compound, being practically insoluble in hydrochloric acid and giving up its water only at a red heat. It is uncertain whether the mineral crystallizes in the orthorhombic or the monoclinic system. It has perfect basal cleavage, is sectile, flexible but not elastic, has a greasy feel, and a pearly luster on cleavage surfaces. Its hardness in the mineralogical scale is from 1 to 1.5, while its specific gravity is from 2.7 to 2.8. The color of the massive and fibrous varieties varies from pure white to gray to greenish-gray or to dark green, while the foliated varieties afford beautiful sea-green tints. The foliated varieties are translucent while the massive forms are subtranslucent.

## VARIETIES.

Foliated talc consists of thin, easily separable laminae. It is ground with difficulty and has no commercial use, but affords beautiful mineralogical specimens. Fibrous talc is pseudomorphous after the anhydrous enstatite or tremolite and, when pure, consists of a network of fine white fibres which gives it a particular value in paper-making. It is, as far as known, restricted in occurrence to St. Lawrence County, New York, where it is known as agalite.[2]

Regarding the third variety, massive talc, much looseness of nomenclature is found. Steatite, soapstone, potstone and, in Vermont at least, freestone, have been used as synonyms indiscriminately. The last named, while it correctly describes the ease with which talc may be cut, has long been in use as a "quarryman's name for those sandstones that submit readily to tool treatment,"[3] and so should not be applied to the mineral under discussion. By soapstone we mean that greenish-gray to dark green, massive form of talc whose interlacing fibrous structure enables it to withstand high temperatures without cracking. It is the variety used for stoves, furnace linings, foot-warmers, and griddles. The other important variety of the mineral, for which the name "massive talc" might well be restricted, has little or no fibrous structure, is white or gray in color (except where stained by impurities) and is either a homogeneous, structureless mass or else has a more or less laminated structure. Associated with the talc is another substance, to which the term "grit" has been

[1] A System of Mineralogy, Dana.
[2] Genesis of the Talc Deposits of St. Lawrence County, N. Y., C. H. Smythe, School of Mines Quarterly, July, 1896.
[3] A Handbook of Rocks, J. F. Kemp.

applied. It will be shown later that this is a mixture of talc and dolomite.

Under the name talc we have therefore to distinguish:

1. Foliated talc.
2. Agalite.
3. Steatite or soapstone.
4. Massive talc.

"French chalk" is a very fine grained, milk-white variety of massive talc used by tailors. "Indurated talc" is an impure, slaty variety, harder than the ordinary. "Talcose slate" is a dark, slaty, argillaceous rock, whose greasy feel is due to the presence of more or less talc.

Commercial talc is also known by various trade names: asbestine, talc clay, verdolite, albarene, etc.—names which of course have no scientific value.

## HISTORICAL NOTE.

It is natural that a substance as resistant to heat and so easily wrought should long have been in use by mankind and that references to it should be found in the classic literature.[1] Theophrastus writes of "magnetis" as a stone of silvery lustre, occurring in large masses and easily cut or wrought. From this we get the word magnesia, or oxide of magnesium. Agricola gives as the German synonym for magnetis, "Talck." He mentions its resistance to fire and speaks of it as "lapis scissilis." Other writers derive the word talc from the Arabic "talk," while Androvandus (1648) states that it is of Moorish origin. Caesius ("De Mineralibus," 1636) writes the word in Latin, "talchus," while most other writers of this time write it "talcum." The word "steatitis" occurs in Pliny as the name of a stone resembling fat.

## USES.

We may distinguish:

(1) Sawed or manufactured talc (soapstone).
(2) Ground talc.

### (1) MANUFACTURED TALC.

The North American Indians early recognized the useful properties of talc and fashioned it into cooking utensils, pipes, and ornaments. In the modern industries the heat and acid resistant properties as well as the toughness of the mineral were first made use of in the manufacture of stoves, griddles, furnace linings, mantels, sinks for chemical laboratories, wash tubs, fireless cookers, etc. Soapstone has great dielectric strength, 30,000 to 40,000 volts being required to pierce a half-inch slab. Since

[1] Dana, A System of Mineralogy.



in the variety of the mineral known as steatite or soapstone these properties find their best expression, soapstone quarries were worked before uses for the "massive talc" were found. However, this "massive talc" near the surface appears tougher and harder than deeper down in the earth and the deposits of this variety at Rochester and Moretown were first worked fifty or sixty years ago for foot-warmers, while near Cambridge several houses have fireplaces built of blocks of impure massive talc. The very compact massive talc is also being manufactured into slate pencils, gas tips, insulators, etc.

### (2) GROUND TALC.

Mr. J. S. Diller, in the "Mineral Resources of the United States" writes that the most important use of ground talc (meaning generally the non-steatitic varieties) is in the manufacture of paper, in which a white mineral filler has been found necessary in order to render the paper opaque. In the past the mineral kaolin (China clay) has been extensively used but experiments have shown that talc possesses decided advantages over this mineral and it is gradually replacing the clay in the paper industry. In an article[1] compiled by Heinrich Rosenberg, the advantages resulting from the use of talc as a filler are set forth and it is noted that 89% of French talc, 85% of American, and 90 to 95% of the Syrian talc, respectively, are retained by the paper pulp, while only about 35% of kaolin is held. For the best grades of paper the fibrous variety of talc known as "agalite," which, as mentioned before, is confined to St. Lawrence County, New York, is used almost exclusively. The purity and fibrous quality of this variety of talc lends not only whiteness to the product but also much strength and therefore durability. For newspaper, wrapping paper, wall paper, mortar and plaster, etc., the finely ground "massive talc" and "grit talc" are extensively used, while the more coarsely ground material is finding application in various grades of roofing papers.

Ground talc is also being used in the rubber industry, both as a filler and as a dressing for the surface to prevent the material sticking to the moulds.

Many of the cheap grades of cotton cloth are still being filled with talc, the product being of course a sham, easily discovered on washing the fabric. The whitest grades are used extensively in cotton bleacheries. In the past a good deal of the best grades of the mineral has found an unworthy use as a food adulterant, but it is the belief of the authorities at Washington that this practice has almost wholly ceased.

In the modern "talcum powders" the best grades of the American talc are used to some extent but the superior qualities

[1] Translation made by the U. S. Geological Survey. See "Mineral Resources" for 1912.

(whiteness and freedom from grit) of the French and Italian mineral lead to its importation for this purpose and for use in certain medicinal preparations.

Powdered talc is used in the manufacture of paints, especially those waterproof preparations for protecting iron ship bottoms. It is used, further, in electrical insulating material, in dynamite manufacture, in lubricants, in dressing skins, and for boiler and steam-pipe covering. The rather coarsely ground mineral is used in some soap preparations to give them a mildly scouring property.

The American Soapstone Finish Company of Chester Depot manufacture a wall finish preparation which is used for skim coating.

## OCCURRENCE AND PRODUCTION.

Talc is a mineral of common occurrence and is mined to a greater or less extent in many parts of the world. The following table, taken from the "Mineral Resources of the United States" for 1912 shows the principal producing countries and the amount, in short tons, produced by each.

| | 1904. | 1906. | 1908. | 1910. | 1912. | 1913. |
|---|---|---|---|---|---|---|
| United States* .... | 91,189 | 120,644 | 117,644 | 150,716 | 159,270 | 175,833 |
| France‡ .......... | 23,206 | 29,061 | 37,053 | 42,316 | ¶ | ¶ |
| Italy† ............ | 7,716 | 9,624 | 12,048 | 13,727 | 13,580 | ¶ |
| Austria† .......... | ..... | ...... | ...... | ...... | ¶ | ¶ |
| Canada† .......... | 840 | 1,234 | 1,016 | 7,112 | 8,270 | 12,250 |
| German Empire† (Bavaria) .... | 1,884 | 2,113 | 2,424 | 3,398 | 3,551 | ¶ |
| India§ ............ | 19 | 11 | 856 | 274 | ¶ | ¶ |
| Spain† ........... | 5,693 | 3,978 | 5,214 | ¶ | ¶ | ¶ |

*Talc and soapstone.
†Talc.
‡Talc, soapstone, and asbestos.
§Soapstone.
¶Statistics not available.

To this list may be added Brazil, China, Japan, Australia, New Zealand, Mexico and Norway.

It will be seen that the United States is far and away the largest producer and that, after her, come France, Italy, Austria, and Canada. The United States imports considerable amounts of talc from these four sources and the growth of the imports is shown by the fact that in 1900 but 79 tons were received, while in 1912, 10,989 tons were admitted. The imports have fluctuated widely, showing:

In 1908 .................. 7,429 short tons.
1909 .................. 4,417 " "
1910 .................. 8,378 " "
1911 .................. 7,113 " "
1912 ..................10,989 " "



This fluctuation is probably due to the varying supply and demand and also to tariff legislation. The imports from Europe are wholly of the finest grades of massive talc, which are probably superior to any that are mined in this country.

The following brief notes[1] on foreign occurrence may be of interest.

FRANCE: The principal deposits are in the French Pyrenees, in the Department of Ariege. The deposits at Luzech, about midway between Bordeaux and Marseilles are among the most valuable. "The deposits are large, of excellent quality, free from mica, and of a bluish-white color much appreciated by consumers." The beds are situated in contact with the St. Barthelemy granite and the old schist, about 4½ miles from Luzech. The deposits are operated as quarries. The French production of talc in 1911 was 46,312 tons.

ITALY: The deposits in this country are located in the Italian Alps, at Pinerolo, near Turin. Talc has also been mined in the valley of the Chisone and in the high valleys of Susa and Lauzo. The Italian talc is probably the finest in the world for color and freedom from grit. It brings the highest prices and is mainly used for toilet powders and medicinal purposes. In 1911 Italy produced 15,620 tons, the crude product being valued at the mines at $7.13 per metric ton, while the finished product had a value of about $12.00 per metric ton.

AUSTRIA: The mineral comes chiefly from the Province of Styria. Only a limited amount is exported to the United States. The production in 1911 was 13,800 metric tons.

Of the total imports of talc into the United States in 1912, 38% came from Italy, nearly 36% from France, 18% from Canada, and 7% from Austria-Hungary.

While the average value of imported talc is given by the United States Geological Survey as $10.54 per short ton in 1897, $13.50 in 1900, $13.07 in 1908, $12.71 in 1910, and $12.38 in 1911, very much higher prices have been paid for the best grades. To illustrate, an American firm contracted in 1906 for a thousand tons at $40.00 per ton. Talc varies so greatly from its best to its poorest grades that average figures are of small significance.

## TALC PRODUCTION IN THE UNITED STATES.

The talc produced in the United States comes mainly from the belt of old metamorphosed rocks which extends from the Gaspe Peninsula of Canada down through the States of Vermont, Massachusetts, Connecticut, New York, New Jersey, Maryland, Pennsylvania, Virginia, and North Carolina, to Georgia. Talc has also been produced to some extent in California and Arkansas,

[1] The Mineral Industry.

while deposits are known in Texas. The following table[1] will show the increase in production since 1880. As stated before, the fibrous talc of New York (agalite) is unique. Hence the production in "all other states" will show the variation in production of the varieties of the mineral with which this report is concerned. The figures represent short tons.

| | New York. | Value. | All other States. | Value. | Total tons. |
|---|---|---|---|---|---|
| 1880 | 4,210 | $ 54,730 | 8,441 | $ 66,665 | 12,651 |
| 1885 | 10,000 | 110,000 | 10,000 | 200,000 | 20,000 |
| 1890 | 41,384 | 389,196 | 13,670 | 252,309 | 55,024 |
| 1895 | 39,240 | 370,897 | 21,495 | 266,495 | 60,735 |
| 1900 | 63,500 | 499,500 | 27,943 | 383,541 | 91,443 |
| 1902 | 71,100 | 615,350 | 26,854 | 525,057 | 97,954 |
| 1904 | 64,005 | 507,400 | 40,134 | 637,062 | 104,139 |
| 1906 | 61,672 | 557,200 | 58,972 | 874,356 | 120,644 |
| 1908 | 70,739 | 697,380 | 46,615 | 703,832 | 117,354 |
| 1910 | 71,714 | 728,180 | 79,006 | 864,213 | 150,720 |
| 1911 | 62,030 | 613,286 | 81,521 | 1,032,732 | 143,551 |
| 1912 | 66,867 | ...... | 92,403 | ...... | 159,270 |

It will be noted that the total production of talc has increased very rapidly and that the increase of the non-fibrous grades has been considerably greater than that of the fibrous agalite. This is due in part to the increasing number of uses found for the mineral. The average price obtained for the non-fibrous grades was about $19.00 per ton in 1902 and has since declined to $11.00 or $12.00 per ton. The increased production and consequent sharp competition have been largely responsible for the decline in price. In 1902 the 26,854 tons brought on an average $19.50 per ton. In 1903 the duty on ground talc was increased to 1c per pound. In 1904 the 40,134 tons of non-fibrous mineral averaged $15.90 per ton, the increased duty having apparently stimulated supply above demand. It is unfortunate for the industry that competition has been so keen, for many of the mills are selling their product at a very small margin of profit.

The present tariff law (Schedule 69, Act of 1913) provides for a duty of fifteen percent, *ad valorem,* on "ground talc, steatite, French chalk, cut, powdered, washed, or pulverized," while "crude and unground talc" are admitted free. Former Acts (1897 and 1909) levied a duty of one cent per pound on "French chalk" and thirty-five percent, *ad valorem,* on "steatite blanks" and "soapstone." The looseness of terms caused much confusion and led to many decisions being handed down, one of them gravely asserting that "French chalk" was not talc at all. The present law is very clear.

[1] Mineral Resources of the United States, U. S. G. S. publication.



## PRODUCTION IN THE DIFFERENT STATES.

In 1911 and 1912 the talc producing states, in their order of importance, were:[1] New York, Vermont, Virginia, New Jersey and Pennsylvania, Massachusetts, North Carolina, California and "Other States." The following table shows the marketed production in short tons and the value.

| | 1912. Quantity. | 1912. Value. | 1913. Quantity. | 1913. Value. | Increase (+) Decrease (—) |
|---|---|---|---|---|---|
| New York | 66,867 | $656,270 | 81,705 | $788,500 | +14,838 |
| Vermont | 42,413 | 275,679 | 45,547 | 327,375 | + 3,134 |
| Virginia | 25,313 | 576,473 | 26,487 | 615,558 | + 1,174 |
| New Jersey and Pennsylvania | 10,400 | 50,519 | 11,308 | 80,780 | + 908 |
| Massachusetts | † | † | ..... | ...... | ....... |
| North Carolina | 3,542 | 63,304 | 4,676 | 48,817 | + 1,134 |
| California | 1,169 | 15,653 | 952 | 6,000 | — 217 |
| Other States* | 9,566 | 69,065 | 5,158 | 41,067 | — 4,408 |
| Total | 159,270 | $1,706,963 | 175,833 | $1,908,097 | +16,563 |

*Includes California, Georgia, Maryland, and Rhode Island, in 1911; Georgia, Maryland, Massachusetts and Rhode Island, in 1912.
†Included in other states.

Analyzing the above figures, we see that New York is far and away the largest producer. As mentioned before, her product is the fibrous agalite, which is ground and largely used for paper-making. Vermont stands second in production. The average price received per short ton of mineral is as follows:

| | 1911. | 1912. |
|---|---|---|
| New York | $ 9.88 | $ 9.81 |
| Vermont | 6.78 | 6.49 |
| Virginia | 24.70 | 22.37 |
| North Carolina | 16.09 | 17.87 |
| Other States | 12.00 | 7.21 |

It may be noted that the Virginia product is almost wholly soapstone, which is sawed into slabs and sold for laundry tubs, sinks, etc. The North Carolina mineral is a very compact, massive variety which is used for the manufacture of pencils, gas tips, etc., and brings a high price. It is claimed that this variety is as good as the best imported talc.

As already stated, not too much value can be placed on average prices, since talc varies so much from its best to its poorest grades. A good deal of the Vermont mineral brings much more than the average prices shown above. On the other hand, so many new uses have been found for the poorer grades that much of this material, formerly discarded, is now being ground and sold, thus bringing the average down.

[1] Mineral Resources of the United States, 1912.

## TALC PRODUCTION IN VERMONT.

In this report the terms, "steatite" or "soapstone," will be restricted to those greenish-gray to dark green varieties, with interlacing, fibrous structure, which are sawed into slabs, etc., while the term "massive talc" will be applied to the light colored, non-fibrous varieties which are ground.

With this distinction, it may be stated that the soapstone deposits of the State were worked long before uses were developed for the massive forms. Thus the soapstone deposits at Athens were worked eighty years ago; the deposits at Perkinsville were quarried and sawed as early as 1850; the old Pilgrim Talc Company worked the soapstone deposit near Stockbridge from 1870 to 1875; the soapstone deposits near Chester Depot have been worked to some extent for the last twenty-five years. In some places the massive variety, rendered harder and more resistant to heat by impurities near the surface, has been worked to a slight extent for foot warmers, as at Rochester and at Moretown on the Deavitt farm. It is stated that the Rochester deposit was worked in 1865 and 1866.

Activity in the mining and grinding of massive talc in Vermont seems to date back to about 1902, when the United States Talc Corporation commenced operations on the Rochester deposits. In 1903 two companies were active in Windsor County, while in 1904 three were at work.

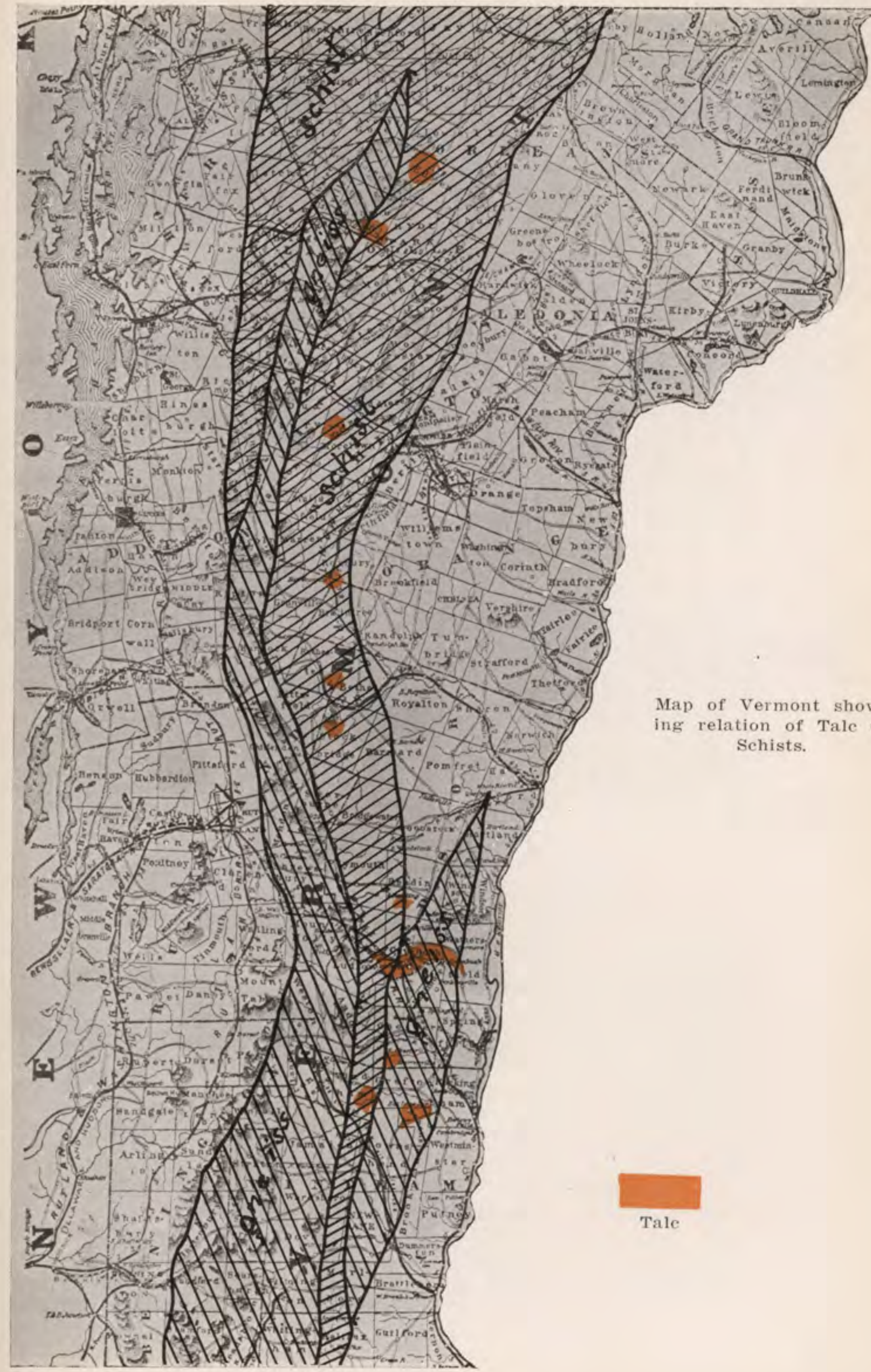
The "Mineral Resources of the United States" gives the production and value of the talc deposits (including all grades) of Vermont, as a separate state, since 1905 as follows:

| 1. | Short tons. | Value. | (Average per ton). |
|---|---|---|---|
| 1905 .............. | 8,978 | $ 65,525 | $7.29 |
| 1906 .............. | 10,413 | 101,057 | 9.70 |
| 1907 .............. | 16,200 | 82,500 | 5.09 |
| 1908 .............. | 10,755 | 99,741 | 9.27 |
| 1909 .............. | 23,626 | 120,329 | 5.09 |
| 1910 .............. | 25,975 | 136,674 | 5.26 |
| 1911 .............. | 29,488 | 200,015 | 6.78 |
| 1912 .............. | 42,413 | 275,679 | 6.49 |
| 1913 .............. | 45,547 | 327,375 | 7.18 |

It will be noted that with the exception of 1908 there has been a steady increase in production, with an exceptionally great increase in 1912. The average price, if the figures be correct, has fluctuated widely. Keen competition, tariff changes, and periods of financial depression have all contributed to this variation. As before stated the low average price is due to the increasing amounts of low grade (grit) talc that are coming on to the market.

It has not been possible to classify the production among the different varieties, but it may be said that the deposits of soap-





Map of Vermont showing relation of Talc to Schists.

Talc

stone are being exhausted, at least one mill finding it necessary to import soapstone from Virginia, and that a very large part of the present production is from the massive talc deposits. These deposits are thought to be very widespread and there seems every reason to believe that Vermont will rank as one of the leading producers for many years to come.

## GEOLOGICAL CONSIDERATIONS.

The chief structural feature of Vermont is the Green Mountain Range, which has its origin in the Gaspe Peninsula of Canada. The highlands are here known as the Shickshock Mountains. In the southern part of the Province of Quebec they are called the Notre Dame Hills and are the northwestward extension of the Green and White Mountains. The formation crosses Vermont in a generally north-and-south direction and, extending into Massachusetts, forms the Taconic Mountains. This system of crystalline rocks, therefore, constitutes the northern portions of the Appalachian Mountains which, generally following the coast, find their southern extremity in Georgia and Alabama.

The Green Mountain Range, which is about one hundred and fifty miles long, constitutes a great anticline, the axis of which appears as a broken chain of ridges of gneiss, rising to its greatest elevation at Mount Mansfield (4,453 feet) and to lesser heights at Killington Peak, Camel's Hump, and Jay Peak. The position of this gneissic backbone is outlined on the accompanying map. It may be noted here that a smaller area of gneiss occurs in the southeastern part of the State. Lying upon the flanks of the range are beds of metamorphic rocks: marbles, slates, schists, and phyllite.

### THE FORMATIONS.

A comprehensive geological survey of the State was undertaken by Edward Hitchcock and his associates. The results of their work were published in 1861 in two volumes, entitled "Report on the Geology of Vermont." By means of thirteen cross-sections, the first near the Massachusetts State line and the last a few miles south of the international boundary, the formations of the State were studied and mapped. Hitchcock's map shows the following sequence from east to west: (1) a belt of "talcose schist" which constitutes a narrow strip following the Connecticut River till near the town of Waterford, where it widens out into a broader area; (2) a bed of "clay slate," extending for three-fourths of the length of the State with an extreme width of about four miles; (3) an area of "calciferous-mica-schist" which extends the whole length of the State. In this formation are located most of the granite areas. Professor C. H. Richardson has studied this area[1]

[1] The Terranes of Orange County, Vt. Report of the Vermont State Geologist, 1901-1902.

and divided it into a limestone member on the west, which he called the Washington limestone (later changing the name to Waits River limestone), and a schist area on the east, which he named the Bradford schist (later changing this designation to Vershire schist). He states: "The widest part of the limestone belt is in Canada. Its greatest breadth in Vermont is in the northern part of the State, where it approximates forty miles. It narrows towards the south and in the town of Hartford it is divided by the intervention of the Bradford (Vershire) schist. The western member terminates suddenly in the southern part of Windsor County, in Cavendish, while the eastern member crosses Massachusetts and is known as the "Conway schist." (4) A second belt of "clay slate" which forms the western boundary of the "calciferous-mica-schist." It is known in Canada and extends to about the middle of Vermont, where it dies out. It follows a sinuous course and is about three or four miles wide at the maximum. Richardson has named this formation the Memphremagog slates. (5) A great central area of "talcose schist" (shown on the accompanying map, Plate LXXV) which is nearly divided into two parts by the "gneissic backbone." The formation extends the entire length of the State, narrowing to two and a half miles in width at the Massachusetts boundary. All the talc deposits of the State are found in this great "talcose-schist" area. All but one or two are found on the eastern side of the "gneissic backbone." (6) An area of "talcose-conglomerate" bounds the western part of the "talcose schist" belt and is succeeded by the "Georgia slates." (7) The marble area, which lies in a great syncline, west of the central gneiss belt. (8) The commercial slate area of the State, which lies in the southwestern part. There are other minor areas which do not concern the present discussion. It may be stated that most of these rock names have been discarded. The "clay slates" are probably shales, the "calciferous-mica-schist" has been called by Daly an ottrelite schist, while in the present article, "talcose schist" has been renamed quartz-sericite-schist.

## SECTION BETWEEN WALLINGFORD AND PLYMOUTH.

In the southern part of the State, on opposite sides of the mountain range, lie the towns of Wallingford and Plymouth, about ten miles apart. Hitchcock studied the section[1] and showed the following relationships. (Fig. 35).

"The base of the section is the sea level and the heights are laid off from the same scale as the horizontal distance. This makes the Green Mountains (1,390 feet above the ocean at Mount Holly) appear of very diminutive height. . . . In the section, *ab* is the present surface, 'a' being at Wallingford, 'b' at Plymouth.

[1] Report on the Geology of Vermont, Vol. I, p. 37.



AB is 'talcose conglomerate';[1] BC, mainly gneiss with some schist and at least three beds of limestone; CD is gneiss with several trap dikes at 'H,' the summit level of the railroad; DE is gneiss, with

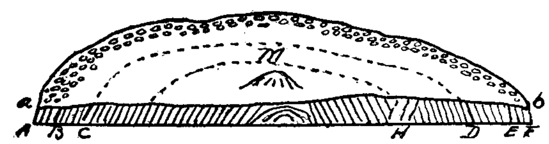



FIGURE 35.

'talcose schist,' and with at least two beds of limestone and several thin beds of quartz; EF, 'talcose conglomerate'; M, the relative height of Mount Mansfield." From the general correspondence of the beds and of the dips, Hitchcock concluded: (1) That the gneiss of the Green Mountains forms a great anticlinal fold; (2) that gneiss underlies the "talcose schist," the limestone, the quartz, and the conglomerate; (3) that these latter rocks once extended over the gneiss but have been eroded; (4) that the amount of erosion at Mount Holly cannot have been less than eight thousand feet, or nearly six times the present height of the mountain at the summit level of the railroad.

Dr. J. E. Wolff has studied the formations in the limestone area of the west-central part of the State,[2] his section extending from the Green Mountain gneiss westward through the Rutland, Center Rutland, and West Rutland valleys to the Taconic Range. (Fig. 36). He states: "In the high, abrupt, frontal range of the Green Mountains there occur crystalline schists, often gneissic, which pass eastward into the gneissic rocks proper of the Green


FIGURE 36.

Mountains. These schists contain beds of true conglomerate, with a metamorphosed crystalline cement (presumably Hitchcock's 'talcose conglomerate'), and pass westward, on the slope, into the quartzite of Vermont, which the discoveries of C. D. Walcott prove to be of lower Cambrian age (Olenellus zone). This is succeeded by a broad belt of limestone occupying the Rutland Valley; next, in Pine Hill, we find a partial repetition of the 'frontal' range, namely, massive quartzite underlain by a transitional gneissic series; then, on the west crest of the hill, a band of black schist in contact with a band of crystalline limestone

[1] Defined as "a coarse conglomerate, cemented with talcose grit."
[2] Bulletin of the Geological Society of America, 1891, p. 331.

which occupies the second, or Center Rutland Valley. The narrow ridge west of this valley is again formed by black schists, succeeded by a third band of crystalline limestone in the West Rutland Valley and finally, black and greenish schists form the slopes of the Taconic Range."

Wolff showed that, at its western edge, the limestone lies conformably in a trough of the quartzite, which dies out northward. The quartzite is about one thousand feet thick. Wolff and Foerste have shown that this limestone at its base is of lower Cambrian age. It is probable that all three beds represent the same formation, having been separated by folding. Augustus Wing showed that the beds of the West Rutland Valley were of Lower Ordovician age and Wolff and Foerste showed that the limestones of the Center Rutland and Tinmouth Valleys should be attributed to the same horizon. The limestones, about one thousand feet thick, are better known as the Stockbridge limestones. It is thus seen that we have in this section about a thousand feet of quartzite separated from the underlying schists by a conglomerate bed, and passing up, conformably, into a limestone of Lower Cambrian age. This passes up, disconformably, into the Lower Ordovician horizon. We have here, therefore, a hiatus, the Middle Cambrian being cut out by erosion.

Brainerd and Seeley have worked on the stratigraphy of Shoreham and have found there Beekmantown limestone (Ordovician) resting conformably on the Pottsdam sandstone (Upper Cambrian). They report 1,151 feet of the sandstone, of which only the upper 251 feet are fossiliferous. This would indicate that the sands were accumulated at an earlier period and that the advancing Pottsdam sea reworked only the upper portion.

The most complete section thus far discovered in Vermont is in Georgia and in Highgate Springs, Franklin County. The stratigraphy here, as everywhere else in the State, has been much obscured by faulting and has been much disputed by early writers on geology: Emmons, Barrande, and Logan. Dr. C. D. Walcott has given the Georgia formation close study.[1] He shows that the schists and quartzites of the southern part of the State are not exposed here. The formation "consists, as seen at the base, of a great thickness of limestones that passes, in its upper portions, into an arenaceous, magnesian limestone, which is overlain by a belt of arenaceo-argillaceous shales (the Georgia 'slates'), and this, by a great thickness of purer argillaceous shale that, higher up, carries a brecciated limestone conglomerate and lenticular masses of sandstone and limestone." This Georgia formation contains fossils of Lower Cambrian and Middle Cambrian age. The formation is overlain, conformably, on the west, near the lake shore, by the Hudson River series, of Ordovician age.

[1] Bulletin of the U. S. G. S. Nos. 24-30, 1885-86.



## OTHER STRATIGRAPHIC RELATIONSHIPS.

In the northern part of the State, in the adjoining towns of Eden (Lamoille Co.) and Lowell (Orleans Co.), is an important area of chrysotile (commonly called asbestos) which lies in the belt of "talcose schist." The deposit is undoubtedly a continuation of the Thetford chrysotile formation of Canada, the schists of which are assigned by the Canadian Geological Survey to the Cambrian. It is not unlikely that they belong to the Lower Cambrian, equivalent therefore to the schists of the southern part of Vermont.

Mr. M. F. Marsters has reported on the Vermont chrysotile deposits.[1]

Prof. B. K. Emerson[2] has studied the schists of Windham County, Vermont, and Old Hampshire County, Massachusetts, and considers them Ordovician (in the modern terminology) or possibly Cambrian in age.

Prof. C. H. Hitchcock, formerly of Dartmouth College, and Prof. C. H. Richardson,[3] of Syracuse University, have studied the formations in Irasburg and Craftsbury which lie in the slate and "talcose schist" areas in the northern part of the State. Prof. Hitchcock considers the formations to be pre-Cambrian, while Richardson states that the "finding in this series of undivided metamorphics of many beds of Upper Cambrian quartzite has led the author to place this group definitely as Cambrian." In the Waits River limestone, which it will be recalled forms the western part of the "calciferous-mica-schist" belt, Richardson has found crushed graptolites (diplograptus and climacograptus) which fix the age of the limestone as Ordovician.

Regarding the slates of this area (which are really shales and not the metamorphic roofing slates of southwestern Vermont), which Richardson has named Memphremagog, Richardson states that they are more or less interstratified with the limestone. They would thus appear to be of the same age as the limestone. Furthermore, the Memphremagog slates are in all probability the southern extension of the graptolitic slates of Canada.

Richardson states that there is an erosional unconformity between this Ordovician series (Lower Trenton) of limestones and slates and the adjoining "talcose schists." This would argue a Cambrian age for the schists. Furthermore, these schists extend, with like lithographic character, into Canada, where Upper Cambrian fossils establish their age.

Dr. T. Nelson Dale has discussed very exhaustively the granite areas of Vermont[4] which lie almost wholly in the belt of "calciferous-mica-schist." In the granite areas of Barre, Dr.

[1] Petrography of Asbestos Deposits of Belvidere Mt., G. S. A., Vol. 16.
[2] Mon. XXIV, U. S. G. S., pp. 115, 116.
[3] Report Vermont State Geologist, 1911-12.
[4] Bulletin 313, U. S. G. S., 1907.

Dale brings out several points of interest. He notes that the schists contain beds of quartzite limestone, which clearly show their sedimentary origin. He notes the difficulties in accurately fixing the age of the formations and is inclined to ascribe, provisionally, the schists and slates of central and eastern Vermont to the Ordovician. He notes the frequent inclusions of schist in the granite, thus showing the later age of the intrusive.

Prof. R. A. Daly has worked on the geology of Ascutney Mountain,[1] which lies in the towns of Windsor and East Windsor, in the "calciferous-mica-schist" belt. Basing his opinion on Richardson's results and inferences regarding this belt elsewhere, Daly regards the schists of this region as of Trenton or pre-Trenton age, while the intrusives are of much later (post-Carbonic or pre-Cretaceous) age.

Regarding later formations, Dr. G. H. Perkins states[2] that "there is a very small area in the extreme southern part of the State, in Vernon, which has been usually regarded as Silurian and another larger area near Owls Head, in Canada, which is Devonian. That there are other Devonian areas wholly within the State is very probable. Indeed, if Dr. Hitchcock's conclusions are correct, we have in Springfield and Charleston considerable areas of altered Devonian strata. No undoubted Devonian fossils have been found within the limits of Vermont."

The small isolated area of Tertiary represented by the Brandon lignites has been fully described by Dr. Perkins.[3]

From the above summary it is seen that there is general agreement that the metamorphic areas of the State, with very few exceptions, are of not later than Ordovician age, but that there is much uncertainty regarding their exact age. When it is remembered that these areas are for the most part covered with accumulations of glacial drift, that much folding and faulting have taken place, and that metamorphism has practically wholly obliterated all traces of organic life from a great part of the schist areas, this uncertainty is not to be wondered at. As Dr. Dale has shown for the schist areas around Barre, this report will point out that the "talcose schist" areas of the State are of undoubted sedimentary origin. It must be postulated that these enormous deposits of sediment were derived from the old land mass, called Appalachia, without which it is impossible to explain the sedimentary deposits of the Palaeozoic which extend over the eastern portions of the continent. It is generally agreed that the folding which resulted in the formation of the Green Mountain Range came at the close of the Ordovician and that this folding was repeated by the Palaeozoic revolution. Other periods of folding may also have taken place. From Hitchcock's cross sections it is

[1] Bulletin 209, U. S. G. S., 1903.
[2] Report of Vermont State Geologist, 1912-13.
[3] Report of Vermont State Geologist, 1903-04 and 1905-06.



seen that the Vermont sediments were folded into a series of generally north-and-south-running anticlines and synclines, though, owing to the lack of "competence" of the strata, many departures from an orderly sequence are seen. Prof. C. H. Hitchcock has attempted to map these "principal axial lines in New Hampshire and Vermont."[1]

As one goes about the State one is impressed with the irregularity of the gneissic and schistose structure of the hills and ridges. The rocks are bent and twisted, with many lenticular inclusions of quartz, and present an appearance of having been highly compressed while in a plastic condition. It has been noted that an enormous time interval of erosion has elapsed since Vermont land emerged from the sea—an erosion so great that Hitchcock calculated that Mt. Holly has been reduced from a height of at least 8,000 feet to its present elevation of 1,400 feet. We have, therefore, to deal with a formation that was once buried under many thousand feet of strata. According to modern theories of metamorphism, as enunciated by Van Hise, this present land surface was metamorphosed deep down in what he calls the "zone of flowage," where, under the influence of heat and pressure and probably only a small amount of water, the (probably arkose) sediments were subjected to a recrystallizing process. This, dissolving the particles of minerals under strain, and depositing them anew where the strain was lessened, or recombining the elements into other mineralogic species, produced the laminated rocks which we call schists and gneisses.

In these areas of so-called "talcose schist," talc was produced by some metamorphic process acting upon either some igneously intruded rock or upon a sedimentary deposit. The problem is, therefore, by studying these talc deposits, to determine their origin.

## THE "TALCOSE SCHIST."

As stated before, the talc deposits of the State lie wholly in a belt of metamorphosed schistose or gneissoid rocks to which Hitchcock gave the name "talcose schists." He realized that this was a misnomer, for analyses by G. F. Barker[2] showed from a trace to 1.98% magnesia. Still, as the great belt of schist extending from Canada to Alabama was at that time known as the "talcose schists," he retained the name in order to avoid confusion.

Dr. T. Sterry Hunt was among the first to study these rocks as they occurred in Canada, and to decide that they were derived from slates. He also brought out the fact that the adjective, talcose, was unwarranted, his analysis of a sample from Saint Marie, Quebec, showing the following:

[1] Geology of New Hampshire, Vol. II, p. 672.
[2] Report on the Geology of Vermont, Vol. 2, p. 503.

| | |
|---|---|
| Silica | 66.70% |
| Alumina | 16.20 |
| Peroxide of iron | 6.90 |
| Lime | .67 |
| Magnesia | 2.75 |
| Alkalies (by difference) | 3.68 |
| Water | 3.10 |
| | 100.00 |

For the present investigation, a sample of the schist from Rochester, Windsor County, was analyzed. The sample was taken just east of the Williams mine, the largest talc working in the State.

The analysis gave the following results:

| | |
|---|---|
| Silica | 63.60% |
| Alumina | 16.54 |
| Ferric oxide | 3.01 |
| Ferrous oxide | 3.88 |
| Magnesia | 2.05 |
| Lime | trace |
| Potassium oxide | 5.52 |
| Sodium oxide | .48 |
| Manganese oxide | .21 |
| Titanium oxide | .61 |
| Sulphur trioxide | .58 |
| Loss on ignition | 3.73 |
| | 99.21 |

The analysis agrees very well with Dr. Hunt's, the greatest difference being in the greater amount of alkalies. It is seen that the schists maintain their chemical character very closely.

A microscopic examination of the schist shows unaltered orthoclase, and quartz (the latter largely in excess), sericite, biotite, magnetite, graphite, titanite and pyrite (in small amounts) and considerable chlorite. There are no "soda minerals" and the sodium must therefore be considered a replacement of potash. No manganese-containing minerals are discernible, but the schists all over the State invariably give a reaction for manganese, which is thought to represent the remains of ferro-magnesium minerals. All the titanium is present as titanite (CaO, $TiO_2$, $SiO_2$), hence the determination of the lime is in error. The amount necessary to combine with the .61% of titanium oxide is .427, and therefore the analysis may be corrected by this amount. The "loss on ignition" of course represents not only the water but also the graphite present in the sample.

With so many mineral constituents containing common ingredients a natural recasting of the analysis to represent percents of the constituents would be impossible, while a calculation to certain types or "norms" would add nothing of value to the problem. The chemical composition points clearly to the sedimentary origin of the schist, a conclusion which is strengthened by the finding of primary calcite in the "calciferous-mica-schist" of Barre, as already noted.



Since the material is available, it may be of interest to compare these figures with the analysis of a sample of the Manhattan schists of New York City. This sample is described as a "gray gneissoid variety from Shaft No. 18, of the Catskill aqueduct tunnel." The analysis was made by Dr. Charles R. Fettke, of the Carnegie Technical School, Pittsburg.

| | |
|---|---|
| Silica | 68.51% |
| Alumina | 15.68 |
| Ferric oxide | .71 |
| Ferrous oxide | 2.32 |
| Magnesia | 1.42 |
| Lime | 3.83 |
| Potassium oxide | 2.49 |
| Sodium oxide | 4.62 |
| Titanium oxide | .58 |
| Water | .58 |
| | 100.73 |

The chief points of difference between this analysis and that of the Rochester schist is in the smaller amount of iron oxide and the larger content of lime. Unfortunately the microscopic analysis of the Manhattan schist is not available. It may be stated, however, that the Manhattan schists are considered to be of sedimentary origin.

Schists have been examined from Waterville, Lamoille County, in the northern part of the State, to Windham, Windham County, in the southern portion. The talc deposits at Zoar, Mass., have also been visited and the country rock investigated.

The typical "talcose schists" are brownish-gray, lusterless, much folded and contorted, laminated rocks, which present the same general appearance throughout the schist belt. They are generally iron stained. In places they present the slaty appearance of a phyllite, while again they are more or less graphitic. That their acid constituent is in excess is shown by the frequent lenticular quartz inclusions and by the numerous quartz outcrops.

## MICROSCOPIC EXAMINATION.

Thin sections were prepared representing the schists, from north to south, at Waterville, Cambridge, Johnson, Moretown, Waitsfield, Rochester, Perkinsville, and Windham, Vermont; and Zoar, Massachusetts. The Perkinsville sample was taken from the vicinity of the soapstone deposits, which lie, not in the belt of "talcose schist," but in the area of "calciferous-mica-schist" and gneiss, in the southeastern part of the State. Since this investigation was not concerned primarily with the schists, only a single slide was ground from each locality, as a rule, and so the results of the microscopic examination will give chiefly an idea of the schists as a whole. (Plate LXXVI, A).

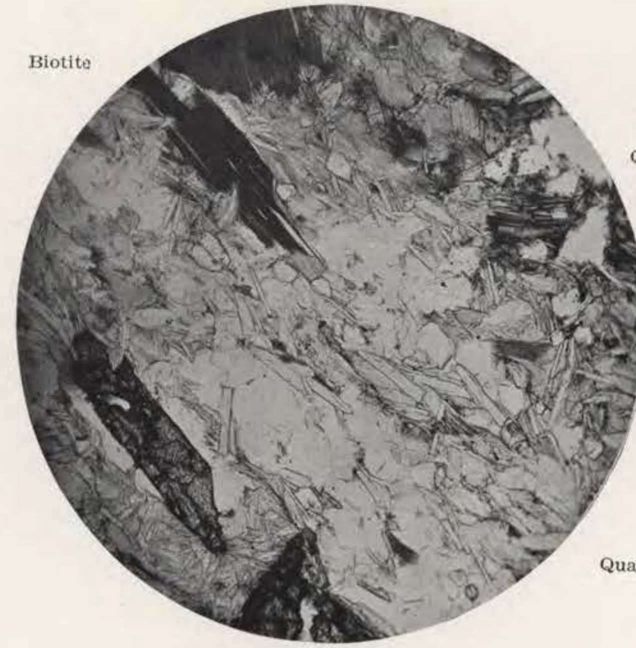
Microscopically, the rocks are seen to consist of grains of orthoclase and quartz, of varying size and irregular outline, with the quartz largely in excess of the orthoclase. The remarkable feature of the feldspar is its freshness, no alternation to kaolin or sericite being apparent on the surfaces of the grains. But in places, between the grains, are seen single rods of secondary muscovite (sericite); while in other parts of the sections there have been developed considerable areas of sericite which have almost entirely replaced the quartz and feldspar grains. By polarized light the sericite presents a brilliant appearance of yellow, red, and purplish rods, fibres and flakes; some straight, some curved, but all showing a general elongation in the direction of the schistosity. The graphite is seen in generally parallel streaks conforming to the general direction. In some of the slides there are only one or two such streaks, while in others, notably those from Moretown, the grains present a banded appearance and are associated with talc. The Moretown slides in which this talc is best shown represent a contact between the schist and the so-called "black-wall," which will be described later. Talc is also seen in a similar contact at Rochester. The slides disclose, further, small amounts of magnetite, varying quantities of biotite, and now and then a stray crystal of tourmaline. Titanite is generally present in small amount and is seen in its typically wedge-shaped, stubby rods, conforming to the direction of the schistosity. Patches of chlorite in all the slides from the "talcose schist" belt, testify to the former presence of a ferro-magnesian mineral. A good deal of iron stain is seen in all the slides and in many cases, where the little rods of sericite are lacking, it forms a cement between the grains of quartz and feldspar. In the section from Windham an intergrowth of garnet and quartz is noted, while in one or two slides a few fine needles of apatite are in evidence.

In the slide of the Perkinsville schist, outside of the "talcose schist" belt, there is a larger development of the constituent minerals, and a considerable amount of microcline is seen. The muscovite forms relatively large, well-cleaved patches and the biotite is present in larger flakes. Crystal terminations are, however, wanting and there is no evidence of a sequence of crystallization. Very little titanite and only a few specks of magnetite are to be found, while there is no graphite and no chlorite.

At Zoar we meet, for the first time, a hornblende schist, whose constituents are hornblende, augite, quartz, orthoclase, and a little magnetite.

Judging as much as may be from one or two sections at each locality, we may say that orthoclase occurs in largest amount in the Waterville region and at Perkinsville; that graphitic schists seem to be most prominent at Waterville, Johnson, Moretown,

PLATE LXXVI.




X 45
*A.* QUARTZ-SERICITE SCHIST.


X 45 (Polarized light)
*B.* EAST JOHNSON SERPENTINE AND TALC.

and Waitsfield (field observations bear out this fact); that biotite, titanite, and sericite appear in largest development at Rochester; and that there is much less evidence of a former ferro-magnesian mineral in the gneiss area at Perkinsville than in the "talcose schist" belt.

### CONCLUSIONS REGARDING THE ORIGIN OF THE "TALCOSE SCHISTS."

If we take into account the tremendous amount of erosion to which the state has been subjected, the discovery of primary calcite in the schists at Barre, the chemical composition (high silica, and alumina, low magnesia and lower lime), and the observation that titanite is a common constituent of sediments, the conclusion at present seems warranted that the gneiss or schist of the great belt in which the talc occurs has been derived from an arkose sediment, by a process of regional metamorphism deep down in the zone of flowage. Since the rocks present more the appearance of a schist than of a gneiss, the adjective, "talcose," will be dropped and the rocks will be called "quartz-sericite-schist" in the following discussion.

## THE TALC DEPOSITS.

In the belt of sericite-schist, talc deposits are known from Canada to Massachusetts. Some prospects have also been discovered in Connecticut.

In Canada[1] numerous deposits are found associated with the so-called "Serpentine Belt" from the Vermont boundary northwards to the Chaudiere River.

In Vermont, from north to south, deposits are known in the following towns. Those marked "*" have been worked but are now idle, while those marked "**" are being actively mined.

North Troy,
Berkshire Center,
Berkshire, southwest part,
Enosburg, southeast corner,
Belvidere, northwest part, lenses in the serpentine,[2]
Waterville, northern part,*
Cambridge, northeast part in the gneiss area,
Stowe, near Sterling Pond,
Johnson, southwest part,**
East Johnson,**
Moretown, northwest corner ** associated with serpentine,
Moretown, near its junction with Fayston and Waitsfield,*
Warren, north and south center,
Roxbury,
East Granville,**
Braintree, several prospects,
Rochester, several deposits,**

[1] Communication from Dr. R. W. Brock.
[2] Marsters, Asbestos Deposits of Belvidere Mountain, p. 428.

Bethel,
Pittsfield,*
Stockbridge, northwest part,*
Plymouth, southeast part,
Reading, southwest corner,*
Cavendish, western part,
Gassetts,
Chester, southwest part,**
Chester, northwest part,**
Andover,
Windham, central part,**
Windham, farther south,
Marlboro, northern part.

Prospects have also recently been reported around Randolph. In Massachusetts there are several deposits in the town of Rowe. The deposit of the Foliated Talc Company is being actively worked, while that of the Massachusetts Talc Company is idle. These deposits are in line with the Vermont beds and no doubt belong to the same formation.

It may be mentioned here that the deposits of steatite or soapstone occur in the southeastern part of the State at Perkinsville, Athens, and Grafton, and seem to lie in the small area of gneiss seen on the map. A continuation of this soapstone belt is found at Francestown, N. H. It is therefore seen that the formations of soapstone and massive talc are quite distinct.

## GENERAL FIELD RELATIONSHIPS.

The talc deposits consist of irregular, lenticular masses, of widely varying length and breadth and of unknown depth, except in the case of the Johnson lens. The strike of these lenses is generally north and south and the dip is 60 or 70 degrees, sometimes to the east, sometimes to the west. Generally speaking these deposits form a chain running north and south through the schist belt. At times they overlap, while at others the outcrops are some miles apart and lie off the main line, as though faulted. The deposits lie almost wholly in the great central belt of sericite schist.

Where typically developed, the talc deposits consist of three parts: (1) A relatively wide central core of a mineral aggregate which is locally called "grit." This material is harder than the talc and has less "slip." It is white to gray in color and has a crystalline habit, often resembling dolomite. It merges gradually into the talc.

(2) A relatively narrow band of talc lying on either side of the "grit." This varies much in structure and quality. Near the surface it is at times very compact and impure, so that it may be cut into blocks and used for foot-warmers, fire-place linings, etc. This massive variety becomes purer with increasing depth and forms the most desirable quality of commercial talc. In other places the mineral is white and foliated, while again it is present



as the beautiful green foliated talc, more valuable in mineralogical cabinets than for commercial purposes. Both the talc and the grit contain more or less disseminated pyrite or pyrrhotite, while in the southcentral part of the State considerable chalcopyrite is developed. In places the talc contains a good deal of actinolite and in the mines whose mineral is ground and "bolted" the presence of this needle-like substance renders the talc unfit for milling, since it destroys the silk bolting cloth. In some of the deposits quite a little chrysotile is developed, generally near the outer edge of the talc.

(3) A narrow border of chloritic schist, which is known as "black wall." The talc lies against this schist but easily cleaves away from it. There is often seen a good deal of "slickensides"[1] between the talc and the black wall. This black wall varies much in thickness, in some places merging in a distance of only a few inches into the country rock, while in others it is found in considerable thickness and is studded with pyrite crystals, hornblende, etc.

## SPECIAL LOCALITY RELATIONSHIPS.

### QUEBEC.

"In Canada numerous talc deposits are found associated with the 'Serpentine Belt,' from the Vermont boundary northwards to the Chaudiere River. 'The Highlands' of Notre Dame Hills consist of three parallel, anticlinal ridges running in a northeasterly direction, with two broad intervening basins, each of which has a width of about 25 miles. The ridges are usually distinguished as the Sutton, Sherbrooke or Stoke, and Lake Megantic anticlines. . . . Closely bordering the southeast side of the Sutton ridge is a series of basic intrusive rocks. These rocks constitute the serpentine belt and contain the deposits of asbestos and chrome iron ore. They extend from the Vermont boundary line with little interruption northeasterly to the vicinity of the Chaudiere River. Representatives of this series of rocks appear at frequent intervals from Georgia to Newfoundland. In Quebec they consist of peridotite and serpentine, pyroxenite, gabbro, diabase, porphyrite, hornblende, granite, and aplite, all of which are regarded as differentiates of a single magma. . . . . In the Thetford series, serpentine forms the country rock of all the mines and, with less altered peridotite, makes up many of the larger hills in the mining district. . . . . . The rocks of the Thetford series are obviously intrusive in their relations to the enclosing sediments. . . The alteration of the sediments is sometimes shown by a hardening of a band near the contact, producing a hornstone rim. . . . . The peridotite, pyroxenite, gabbro and diabase form a continuous

[1] More or less polished surfaces produced by the rubbing of two surfaces upon each other. They are caused by faulting, fracturing, etc.

series, passing by gradual transition from one variety to another in the order named. . . . In general, peridotite, or the serpentine derived from it, and diabase form the larger portion of a rock mass. At the other edge, the diabase, in places, passes into a hornblende porphyrite, and this occasionally into a hornblende granite, or aplite. . . The minerals of economic importance that have been found in the serpentine belt are asbestos, chrome iron ore, talc, antimony, copper, and platinum. . . . . It is difficult, and often impossible to distinglish peridotite and serpentine in hand specimens. In the field and in mining operations they are collectively called serpentine. The peridotite is composed of olivine, a small amount of pyroxene, and a little chromite and magnetite. The serpentine is merely an altered phase of the peridotite. The mineral serpentine is derived from olivine by hydration accompanied by loss of the iron content. Pyroxene may also alter to serpentine, but it changes less readily than olivine, having originally more silica in its composition, and more frequently alters to soapstone or talc. The olivine is sometimes completely altered to serpentine."[1]

The largest talc deposit in Quebec is situated in Bolton Township. It is said to be a hundred feet long, about 20 feet wide at one end, and 60 feet at the other. Several other prospects are also mentioned.

### BELVIDERE.

In Vermont, talc is found in the serpentine area which lies on Mount Belvidere, in the adjoining townships of Eden, Lamoille County, and Lowell, Orleans County. This area lies in the belt of sericitic schist. Mr. Vernon Freeman Marsters has studied the petrography of this area[2] and found that the associated rocks are schist, amphibolite, and serpentine. The main part of the serpentine deposit was found to be a fine-grained light grayish-green rock, sometimes exhibiting a tendency to become talcose. A number of talc-bearing lenses were found in which the talc was moderately pure. Marsters believed that the igneous contact found between the amphibolite and the serpentine furnished unmistakable proof of the intrusive origin of the rock from which the serpentine had been derived. The metamorphism of this primary rock had been so complete, however, that little idea of its character could be obtained.

### WATERVILLE.

On the Curtis farm at North Waterville, Lamoille County, a deposit was worked for some years by the American Mineral Co. The marketing of the talc involved a haulage of eight or

[1] Robert Harvie's summary of J. A. Dresser's reports in the Canadian Geological Survey for 1907, 1909, and 1910.

[2] Bull. G. S. A. 16, pp. 419-446.



nine miles to the North Cambridge Railroad Station and the venture did not prove successful. The mine was full of water when visited, so that only a superficial examination was possible. The deposit was mined partly by an open cut and partly by a shaft. The strike of the deposit is a little east of north and the dip is easterly. Its length is over 200 feet while its width between walls is about 75 feet. The talc at the surface is compact and impure and has been sawed into blocks. The material found around the grinding machines indicates both talc and grit of good quality. Large masses of actinolite and some chrysotile were found on the dump.

### JOHNSON.

The American Mineral Company, on abandoning its mine at Waterville, moved to Johnson and opened up a small talc deposit there in 1906. The deposit is at the base of French Hill within a stone's throw of the St. Johnsbury and Lake Champlain Railroad, so that the marketing of the product is very cheap. The deposit is a lens of mineral whose strike is approximately northeast and whose dip is about 65 degrees westerly. The length of the lens is 100 feet on the surface, its depth, measured on the foot wall, is about 200 feet, while the maximum width is about 60 feet. The lens has narrowed along both axes with increasing depth, till at the south end the east wall is said to bend under the deposit and form the west wall. At the north end of the mine, however, the bottom of the lens was not reached, the mine having been abandoned when the deposit became too narrow to permit profitable operations. The mine when recently visited was full of water, so that further examination was impossible. No other outcrops of talc have been found in the immediate vicinity but it is quite possible that other lenses may occur at depth, either beside the exhausted deposit or below it.

The country rock is the typical schist of the talc belt, though it contains rather an unusual amount of graphite. The talc lens is typically developed, consisting of a wide core of grit, bounded on either side by narrower zones of talc, which in turn are bounded by black wall. The grit is very white and "sparry" in appearance and has not much "slip." Actinolite seems to be wholly absent. The talc is of excellent color and more laminated in structure than is the case in the deposits further south. No masses of green, foliated talc are found here but some of the talc suggests by its color the presence of some of this form of the mineral. The talc is about four feet thick on the west wall and one foot thick on the east, although pockets occur in which there are much wider areas. The black wall is a soft, dark gray, laminated rock, of undetermined thickness, which merges into the country rock on the one hand and cleaves away from the talc on the other. The contact between the talc and black wall is often a slickensided surface.

**EAST JOHNSON.**

In 1913 the American Mineral Company bought the Homer, Fox, Wood, and Fullington farms in East Johnson, about four miles northeast of the old mine, and on them has opened up extensive talc deposits. On the surface there appear to be two deposits, perhaps half a mile apart. Number one mine is being developed on the more southerly, number two on the more northerly. The strike of both deposits is approximately north, 30 degrees east, which puts them in line with the Johnson lens. Southwest of the shaft of number one mine there is an outcropping of serpentine rock, the microscopic character of which will be discussed on page 418. The southerly deposit is several hundred feet in length while the outcroppings of the black wall indicate a width of 250 feet. The deposit is therefore very large. The mine has been opened on the east (foot) wall by a vertical shaft, from which a forty-foot and an eighty-foot level have been driven for distances of 215 and 260 feet, respectively. The east wall is nearly vertical at the surface but soon dips to the west, the angle reaching 55 degrees. Beginning at the surface, where it touches the east wall, and extending vertically downward to an unknown depth, there is a great pillar of so-called "cinder," three or four feet wide and of undetermined length. This substance looks like serpentine. It will be discussed microscopically later (see p. 418). Talc or grit is found on either side of this pillar. The invariable black walls bound the deposit and merge into the country schist. There are lesser zones of "cinder" enclosed in the talc and grit in other parts of the mine. This deposit is also remarkable for the evidences of extensive faulting that it contains, the talc in one place being clearly sheared for a distance of several feet. The black wall is much slickensided. The talc and grit at the 80 foot level show a thickness of 36 feet. No attempt has yet been made at cross-cutting to reach the west wall. The mine is being worked chiefly for grit, which is of excellent quality and color.

The northerly deposit, on which number two mine is being opened up, has been traced 300 or 400 feet on the strike and is 30 or 40 feet in width. A shaft has been sunk 25 feet on the east wall which is vertical and has been polished by slickensiding to the smoothness of window glass. The talc which lies on this wall is three to four feet wide and, as regards color, slip, and massiveness of structure, is by far the best mineral yet found in this part of the state.

Both of these deposits look very promising.



**MORETOWN.**

About two miles from Waterbury village, in the northwest corner of Moretown, Addison County, there is a large talc deposit located on the Deavitt farm. This deposit has been known for many years, being one of those from whose outcrop foot warmers and fire place linings were cut in the old days. It is described by Hitchcock in his Report.[1]

The property was acquired by the Magnesia Talc Co., of Burlington, in 1912. This company has opened up the deposit and constructed a modern mill, which has been running since July, 1913.

The deposit appears, not far from the Winooski River, as a bed of foliated talc. From here, following a strike of south, about 20 degrees east, the outcrop runs up a hill covered with glacial drift and river sand. The following sketch (Fig. 37) is taken from Hitchcock's Report.

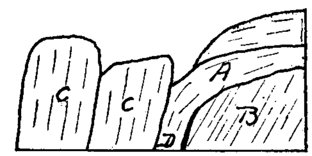



FIGURE 37.

The west black wall is shown heavily shaded. The east wall, as far as can be determined, is about 125 feet away. The dip of the deposit is very steep, being about 75 degrees easterly. The talc is shown at A. It is bounded on the west by the black wall, which merges into the country schist, B. On the east it is bounded by great masses of serpentine, C, which seem to make up the great part of the material between the walls. A tunnel has been driven southward into the hill, at D (which is about 270 feet above the Winooski River), for a distance of 500 feet, following the talc. This tunnel is driven at a four per cent grade and its inner extremity is about 120 feet below the surface. Farther down the hill, near the mill site, a second tunnel has been driven for a distance of 300 feet. A vertical line from its inner extremity would reach the surface at a distance of 80 feet from, and at a point considerably north and below the mouth of the first tunnel. The talc vein varies in width from eight to thirty feet and follows a sinuous course, narrowing in places and again widening out into pockets. The development work so far accomplished has disclosed, therefore, a body of talc at least 1,000 feet long, 200 feet deep, and from eight to thirty feet wide, all on the foot wall. No effort has yet been made to discover talc on the east, or hanging, wall. The great central mass of the deposit,

[1] Vol. I, p. 541.

where one would expect to find grit, is apparently composed of serpentine rock, dark green in color and very hard. Furthermore, "cobblestones" of serpentine, varying from fist size to that of a bushel basket, have been found in the talc. The deposit is unique in its great serpentine development and in its small amount of grit. The conclusion that the talc has been derived from the serpentine is borne out by microscopic study (see p. 416). The mining is done by tunneling and overhead stoping. The talc cars run by gravity to the mill.

Five or six miles south of Waterbury in the valley of the Mad River, a tributary of the Winooski, at the junction of the towns of Moretown, Fayston and Waitsfield, there is a large deposit of talc on the farm of Mr. J. C. Bissbee. This deposit was opened up by the International Mining Company, whose mining operations, however, were confined to the immediate vicinity. A large mill of doubtful utility was erected and preparations were made to operate on a large scale. The affairs of the company are said to be in litigation and work is at a standstill. The deposit has been opened up by quarrying methods and consists of talc of good color and slip, though of rather foliated character. The strike varies, as the deposit curves from north to northeast. The walls converge, the talc and grit lying in the trough formed by them. The deposit is seen to consist of a central core of grit, with talc lying on either side and terminated by the black walls.

### EAST GRANVILLE.

Continuing up the long, north-and-south-running valley of the Mad River, and crossing the "divide" in Warren, one comes to the next talc deposit, in the northeast corner of Granville. This deposit is some fifteen miles south of the International Company's mine, and lies in the hills just east of the Central Vermont Railroad's tracks. It consists of a chain of lenses varying from 50 to 400 feet in length and from 15 to 50 feet in width. Some of these lenses abut upon one another, while others are separated by distances of from 100 to 150 feet. Most of them are in line, but several are offset by considerable distances, in one case by 400 feet. The country rock is the typical schist. The talc is both foliated and massive but of a gritty variety. Black walls bound the deposit. No serpentine is seen about the mine but it is very likely that its presence in the talc would be shown on microscopic examination. The deposit is opened by two tunnels, one above the other, from which the mineral is carried by aerial tram to the mill beside the railroad tracks. This mine is one of a number operated by the Eastern Talc Company.

### ROCHESTER.

South of the "divide" at Warren, the White River rises. It flows southeasterly through the towns of Granville and Rochester,



into the town of Stockbridge, where it turns to the northeast and joins the Third Branch at Bethel. Rochester Mountain, a low, north-and-south-running ridge, separates the valley of the Third Branch from that of the White River proper. At the foot of this ridge, at an elevation of 1,175 feet above the river, the country becomes a broad plain, sloping to the west for two and a quarter miles, when it descends precipitously about 500 feet to the river. West of the river the land rises again to irregular ridges which to the south contain intrusions of the Liberty Hill granite. The topography of the country is very rough and bears many evidences of glacial activity. The physiographic old age of the river is shown by the terraces along its valley and by its meandering course. The following sketch (Fig. 38) shows the general topography.

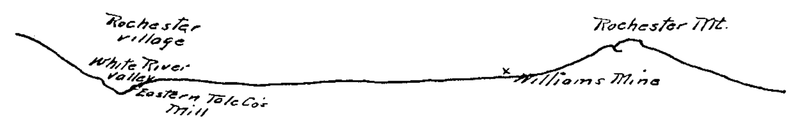



FIGURE 38.

At X, which is somewhat west of the base of the mountain, there is a series of talc lenses strung out over a distance of two miles or more. These lenses have the following relative positions (Fig. 39). Other outcrops of talc have been noted to the south. This Rochester district contains more of the mineral than any so far discovered in the State. The whole group of deposits is controlled by the Eastern Talc Company, of Boston.

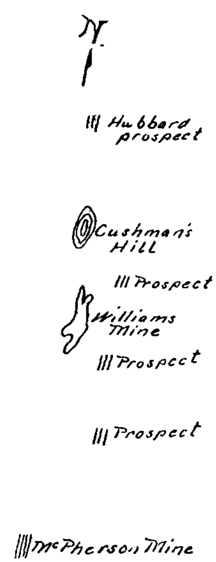



FIGURE 39

The talc occurs in irregular, lenticular masses whose long axes lie about north and south, corresponding to the direction of the schistosity of the country rock, which is a quartz-sericite schist. The Williams mine, which forms the center of interest, lies about four miles southeast of Rochester village, measured over the roads. Both it and the McPherson mine are now connected with the company's two mills in lower Rochester by a narrow gauge railroad, which was completed in 1913. The Williams deposit was described in some detail by Hitchcock, in 1861, as the Williams steatite bed, it having been worked superficially to some extent for soapstone purposes.

Some five hundred yards north of this deposit (Fig. 39) there is a small, dome-shaped hill, perhaps 400 feet long, two hundred feet wide, and a hundred feet in elevation. The long axis lies practically north and south. This hillock is shown petrographically to be the result of an extrusion of igneous rock through the country schists. The outcrops show it to be made of a great mass of serpentine, dark green, very hard—in fact just like the Moretown rock. Near the summit of the hill the serpentine is crossed by several dikes, from one to four feet wide, studded with octahedra of magnetite. So promising did this material seem to local experts that a tunnel was driven into the west base of the hill in the expectation of disclosing a considerable iron ore body. The tunnel at least had the merit of opening up the hill for study. Specimens from both the tunnel and the surface, examined microscopically, show the great mass of the extrusion to be made up of serpentine (or, more correctly speaking, antigorite), with small amounts of magnetite and either calcite or dolomite.

It may be noted here that serpentine is not an original mineral, but the decomposition product of the non-aluminous magnesian silicates: olivine, the orthorhombic pyroxenes, augite, and hornblende.

The dike material is seen, microscopically, to consist of chlorite studded with magnetite. Chlorite is a decomposition product of the igneous material of which the dikes were originally composed. Since these dikes cut across the serpentine, they must be younger in age.

On the east and west sides of the hillock there is some development of talc.

This whole igneous extrusion will be considered later in its probable bearing on the origin of the talc.

## THE WILLIAMS MINE.

This is the largest deposit thus far developed in the State. The following plan of the fourth level (Fig. 40) and the profile of the mine at the shaft (Fig. 41), made from surveys kindly loaned by Mr. C. B. Hollis, Superintendent of the Eastern Talc Company, show the general relations.

The profile shows the cross section on the shortest axis of a great lens of mineral, dipping to the eastward at an angle of about seventy degrees and extending downward to a vertical depth of over 300 feet. The first level is a hundred feet below the surface, while the succeeding levels are driven at 50 foot intervals. At the surface the lens is probably 60 feet wide, at the second level, it is 65 feet, at the third, 55 feet, at the fourth, 58 feet, while at the fifth it narrows to about 10 feet, only to widen again below, where development work is in progress.

The plan of the fourth level, where the maximum development is found, shows the irregular charâcter of the mineral lens on its longest axis. The strike is practically north and south. The total length is 432 feet. The thickness of the lens at the



shaft is 55 feet, at the northern end, 18 feet, and in the southern part, 70 feet. The shaft is shown on the hanging wall.

The country rock, as already stated, is a quartz-sericite-schist and the talc lens lies in the plane of its schistosity, in no place cutting across it—indeed, this may be said of all the talc deposits

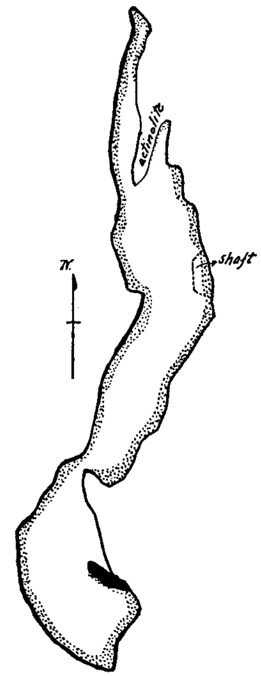



FIGURE 40.

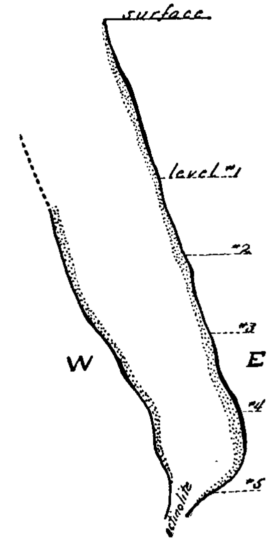



FIGURE 41.

of the State. In both plan and profile the central, unstippled area of the lens represents grit; the stippled zone, talc; and the heavily shaded borders, black wall.

The grit, which makes up the great mass of the deposit, is a gray, highly crystalline mass having the appearance of dolomite. That this mineral is a constituent of the grit is shown by its effervescence only in hot or concentrated acid. The grit also contains a good deal of talc and, when ground, possesses a good "slip." Quite a little pyrrhotite is disseminated through it. The ground grit finds a ready market. As indicated in the plan, the grit in the north end of the mine is highly impregnated with needles of actinolite, which render it worthless for grinding purposes. Again, in the fifth level, the grit becomes greatly contracted in width and is finally almost wholly replaced by a mass of actinolite, as shown in the profile. This mass continues downward for a distance of thirty feet, when it apparently gives way, in turn, to another lens of very pure talc. We have here, therefore, evidence of the deep lying source of the deposit.

The grit, on either side, merges gradually into talc, which varies greatly in thickness and in places almost entirely disappears. It is about two and one-half feet thick on the east wall and six and one quarter feet on the west wall, but there are pockets where it is much thicker. The lower lens shows talc ten feet in thickness. The mineral is generally massive in structure but includes small areas of foliated talc accompanied by rhombs of dolomite. The talc increases in purity with depth and is of excellent color and "slip." It contains some disseminated pyrrhotite. Both talc and grit contain some small amounts of included "cinder" which, microscopically, is seen to consist of the same chloritic schist which composes the black wall. No masses of serpentine have been found in the mine but the presence of this mineral in the talc will be shown microscopically and chemically, later (p. 422). The talc lies against the bordering black wall, from which it cleaves easily, and along which it has moved to some extent, as shown by the slickensiding.

The black wall is in appearance a chloritic schist, dark, compact, more or less lustrous, and laminated. It seems to vary much in thickness, but not many measurements have been possible. In the southern part of the fourth level it is shown (Fig. 40) some ten feet in thickness, but for the most part it is much thinner and merges rapidly into the country schist. The east wall is rarely clean, being covered with a layer of actinolite two or three inches in thickness. In places the actinolite contains small quantities of fine white asbestos—or rather, chrysotile. The lateral pressure to which the deposit has been subjected is shown in the fifth level, where the black wall has been compressed into great, north-and-south-lying rolls. In the third level a similar roll of actinolite is seen.

The talc and grit are very compact and impermeable to water, but the black walls are wet, their smooth surfaces enabling water to percolate. There is no doubt that percolating water or aqueous solutions have been instrumental in producing the talc.

The amount of grit in the mine is enormous and will furnish an ample supply for many years to come. Mining is done by overhand stoping.

### OTHER DEPOSITS.

The prospects shown northeast and southeast of the Williams mine are being developed and appear to be independent lenses. No other outcrops are seen between this group of deposits and Cushman's Hill but there may very well be buried lenses present. The presence of this hill of altered igneous rock suggests the probability of a connection between it and the talc lenses. The Hubbard prospect, lying to the north, has not yet received attention.



### THE McPHERSON MINE.

About one mile south of the Williams mine, and perhaps faulted a quarter of a mile to the westward, is the McPherson mine, which has been in operation for about a year. This mine is opened by a tunnel, 150 feet long, and by a shaft. It is being worked chiefly for talc, which is of excellent quality and color. The field relations of this deposit have not been studied.

### STOCKBRIDGE.

The next important deposit is found about five miles south of the Williams mine, on the other side of the river, in the northeast corner of Stockbridge. This deposit is known as the Greeley mine and is also owned by the Eastern Talc Company. The deposit lies near the base of the high land that rises above the valley, just south of the river. It has a north-and-south strike and the walls are very irregular, so that a great vaulted chamber has been opened up between them. The roof of this chamber has been blown off, facilitating the mining. The deposit consists essentially of grit, there being only a narrow band of talc between it and the black wall. In the grit, however, there are masses of green, foliated talc, intergrown with large crystals of dolomite. Chalcopyrite also occurs in the grit, in places as large as one's fist. The discovery of this copper mineral, not many miles away from the worked-out chalcopyrite deposits of Strafford and Vershire, occasioned no little excitement at the time. The chalcopyrite, however, seems to have no commercial possibilities. The deposit has been opened up by two tunnels, one above the other, the lower of which has penetrated the hill for 700 feet. As the work progressed, more and more serpentine, mixed with dolomite, was encountered, the grit diminishing correspondingly. It seems probably that the great mass of the rock is made up of this mixture of minerals, which approaches the composition of verd antique (or ophicalcite). Time has not permitted a more careful study of this formation but the occurrence together of talc and serpentine is to be noted, in connection with similar relationships, elsewhere in the talc belt.

The company has discontinued work on this mine, since it has ample reserves at its other deposits, which can be much more economically mined and milled. In the past the mineral from this mine has been shipped to the company's mill in Lower Rochester, over the White River Railroad.

### CHESTER.

At the Carlton quarry, two and a half miles from Chester village, there is a peculiar deposit of talcose material, which is being worked by the American Soapstone Finish Company. The deposit has been known for twenty-five years or more but has been worked only since 1904. The quarry lies on a hillside. Its strike is about north, 15 degrees west, while the dip is 70 degrees west. The open cut is at present 100 feet long, 80 feet wide, and 64 feet in maximum depth. The country rock in the west wall of the quarry is gneiss, similar in appearance to that found at the Davis soapstone quarry, some ten miles away. The talcose material narrows at the north end of the quarry and merges into a hard, serpentinous rock. The east wall of the deposit has not been located but probably lies somewhere below the sandy surface soil, on which the road to the open cut is built. The deposit has a peculiar black wall which separates it from the gneissic country rock on the west. This black wall is a large green, very lustrous, highly foliated, chloritic schist. It is very soft and at times hangs down from the face of the gneiss like the leaves of an open book. Moreover, it is found studded with pyrite crystals (simple cubes and combination forms of cube and octahedron) sometimes an inch on the edge. Hornblende crystals have also been found. It may be noted that this black wall is identical in appearance with that in which the soapstone lenses occur at the Davis quarry.

The deposit itself consists mainly of a mixture of fine scales of foliated talc, and dolomite. (The presence of dolomite is proved by the fact that cold hydrochloritic acid produces no effect on the powdered mineral, while hot acid causes a lively effervescence of carbonic acid). This peculiar, scaly material has not been noted elsewhere in the talc belt. There is some development of large sheets of foliated talc.

### WINDHAM.

The deposit here is worked by the Vermont Talc Company, which was formerly known as the Vermont Talc and Soapstone Company. The deposit is on the A. L. Stone farm, about nine and one-half miles southwest of Chester, at an altitude of 1,900 feet above sea level. As in other Vermont deposits, the gritty outcroppings were first worked for soapstone, but were found to be deficient in strength and fire resisting qualities. Later the deposit was worked as a source of ground talc and has yielded a very good product.

The deposit was first mined by open cutting. The cut is in the shape of a hollow rectangle, opening to the north, about 95 feet long by 47 feet wide. The east wall of the cut dips 65 degrees westward and is composed of a gritty talcose material containing dolomite, not at all like the usual black wall. Forty feet east of the cut there is a thick surface-showing of chloritic schist which is probably the true east wall. Beyond this appears the country schist. The west wall of the cut is nearly vertical and is made up of a hard, talcose grit, capped at the top with soft, iron-stained talc. About thirty feet west of this wall is the old quarry, where large blocks of hard, gritty talc, containing carbonate, have been cut, in the attempt to use the material for soapstone purposes. The quarry is about twenty feet wide. West of it, the land slopes down to a swamp.



In this deposit there appears to be an unusual relationship. We have first the east black wall, then forty feet of grit, followed by about forty-seven feet of talc and fifty feet more of grit. It is reasonable to suppose that there is a west wall somewhere and that, lying against it, there is another zone of talc, as yet undiscovered. It is at present impossible to determine the maximum width of the deposit, though it has been put from 110 to 242 feet. On the surface the outcrop has been traced southward to the adjoining farm of Mr. Madison, a quarter of a mile away. Northward no outcroppings have been noted beyond the open cut.

In order to obtain a better grade of talc, which always comes with increasing depth, the company has sunk a vertical shaft in the middle of the open cut to a depth of 70 feet and driven a level 56 feet southward and 95 feet in a northerly direction. In this level, the east, or hanging wall, of grit, dips 65 degrees to the eastward (the same wall in the open cut dips at the same angle westward) which shows that the wall has curved considerably. The strike of the deposit is, in the south level, north, 45 degrees east; in the north level, north, 20 degrees east. The talc is very compact and massive. In the north level it has squeezed out, but in the south working it is from 7 to 56 feet in width—an enormous thickness. As stated before, no grit core has been found in the talc and it is probable that the west wall of the talc deposit marks the beginning of this zone. If this theory be true, a cross cut driven westward might discover another talc belt, with the country rock beyond.

The south level is being driven forward and it is proposed to sink the shaft deeper in order to start a second level. The daily output of the mine is about thirty tons of talc. No grit is being mined.

Prospects of talc are known on the neighboring Graves farm, and Warren Rhodes farm. The writer has visited the Graves prospect, which seems to indicate an enormous deposit.

## INACTIVE DEPOSITS.

There are in the State a number of mines and mills which for one reason or another (insufficient capital, ignorance of proper mining and milling methods, remoteness from railroads, etc.) have suspended operations, probably permanently.

### WATERVILLE.

At North Waterville the American Mineral Company developed a mine and constructed a mill on the A. M. Howes farm, several years ago. The talc is of excellent quality, but it is said that the teaming charges were too great to make the enterprise successful. Operations ceased about seven years ago.

### MORETOWN AND FAYSTON.

There is a large deposit of talc on the J. C. Bisbee farm, located in these towns. About eight years ago the International Mining Company, incorporated under Maine laws for one and one-half million dollars, built a very elaborate plant and started mining and milling. Owing it is said to litigation, operations soon ceased and the plant has lain idle for years. The long haul to Middlesex station, some nine miles away, may have been a factor in stopping operations. The talc seems to be of good quality.

### PITTSFIELD.

Mineral Resources of the United States for 1905 contains the fullest information available concerning the deposit here. Talc and soapstone are used as synonyms though it is probable that the mineral is really talc. The deposit seems to be a large one. It was sold to the New England Talc Co. in 1897. This company operated the mine until 1905, shipping the mineral to its mill at Arlington, Mass. The reasons for suspending operations are not given. It is understood that the Eastern Talc Co. has recently bought the mine.

### STOCKBRIDGE.

One mile west of the village, according to Mineral Resources for 1905, there is a deposit of soapstone, so poor in quality and with so much included talc, that it has been used mainly for grinding purposes. This deposit was first worked for soapstone between 1870 and 1875. Between 1895 and 1904 it was mined for talc intermittently. Since then the mine has lain idle. The property belongs to the Pilgrim Talc Co., of Boston.

### READING.

The Reading Talc and Asbestos Company, of which Mr. J. E. Gay is president and manager, has a deposit in Hammondville, a hamlet in the town of Reading. A shaft has been sunk 65 feet, revealing a large deposit of mineral of excellent quality. A mill has been erected and some grinding has been done. In order to provide more working capital, the company has recently been reorganized; and it hopes soon to start operations anew.

## MICROSCOPIC AND CHEMICAL EXAMINATION.

In problems of paragenesis, by which is meant the association of minerals with special reference to their occurrence and origin, the microscopic study of prepared thin sections of the substances



under examination and their chemical analysis are of the greatest aid. The microscopic study reveals the presence of the constituent minerals, often invisible to the naked eye, frequently shows the sequence in which these minerals crystallized from a cooling magma, may disclose the formation of one mineral from another by an invading solution, and in many other ways may throw much light on the problem at hand.

Chemical analysis shows us the proportions in which the component elements are present. By comparing the analysis of a rock with the analyses of many other rocks, igneous or sedimentary, we can draw reasonable conclusions regarding the igneous or sedimentary origin of this rock, as was done in the case of the sericite schists. Or, again, we can rule out certain rocks or minerals as possible sources of a mineral under investigation. Finally, by combining chemical and microscopic analyses, we can compute the percentages of the minerals which make up a rock or a mixture of minerals.

In this investigation many mineral sections were studied and several chemical analyses were made. The discussion of these studies follows.

### EAST JOHNSON.

It was stated on page 406 that southwest of mine No. 1 there was an outcropping of serpentine rock. A photomicrograph of a small portion of a section of this rock appears on Plate LXXVI-B. The dark areas are serpentine (antigorite); the light, talc. The photomicrograph does not accurately show the relative proportions of these two minerals, for in reality, the ground-mass is mainly antigorite while the talc occurs either in dense patches or else in filaments crossing the antigorite. Scattered through the section (not seen in the plate) and always associated with the talc are small amounts of pyrrhotite and magnetite, which in places have been oxidized to limonite. There are a few small areas of dolomite, with its characteristic rhombohedral cleavage. The boundaries of the dolomite are invaded by flakes of talc and antigorite, which also appear in the cleavage cracks and on the surface of the carbonate mineral. Furthermore the antigorite, which in places appears in larger, columnar sections, also shows flakes of talc in its corroded outlines and in its cleavage cracks. No trace of a primary mineral is seen. Whether the talc has been derived from the serpentine, or whether both minerals owe their origin to the action of some invading solution on the dolomite, is an open question. There is evidence for both theories.

It was further noted, on page 406, that the East Johnson mine contains great pillars of so-called cinder and that zones or cores of this substance occur in the talc and grit. A thin section of this cinder shows a ground-mass of chlorite with many minute grains of an isotropic mineral and fine flakes of talc. But chloritic schist is the substance which composes the black walls of all the deposits and we therefore see that this same substance also penetrates the talc and grit. In other deposits it occurs in these minerals in much smaller amounts.

### MORETOWN.

It was noted on page 407 that in this deposit large masses of serpentine make up the core of the formation, that the talc lies against this serpentine, in the two tunnels which have been driven, that "cobblestones" of serpentine occur in the talc zone, that a relatively small proportion of grit has been encountered, and that the chloritic, black wall substance occurs to a small extent in the talc.

The serpentine has been examined microscopically both near the talc and remote from it.

Sections of the serpentine remote from the tunnels show a ground-mass of serpentine (antigorite) made up of fine fibres often crossing at right angles and giving a meshed appearance to the mineral. No trace of a primary mineral is to be found, however. In some of the sections no talc is seen, while in others a few flakes appear. All the slides show either pyrrhotite or magnetite and there are rusty streaks, due to the oxidation of these minerals. No carbonate mineral is seen in these sections. It appears, therefore, that in this part of the deposit we have simply unaltered serpentine.

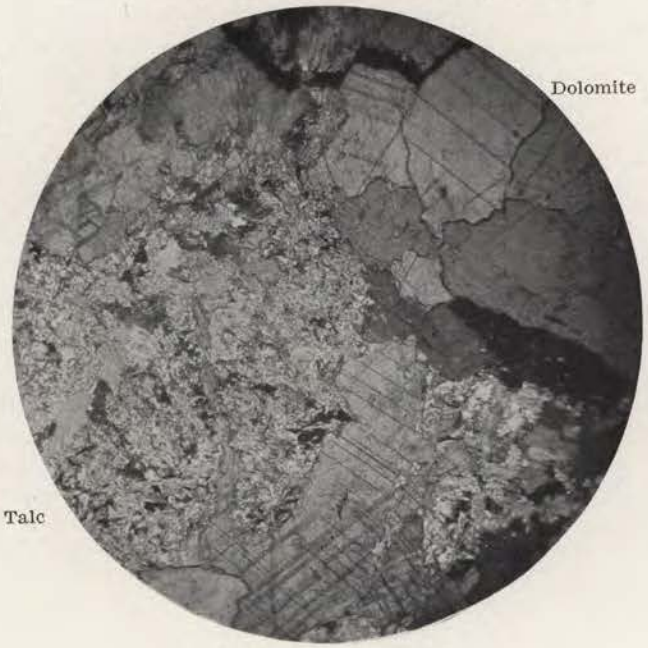
But in the serpentine sections nearer the tunnels and in the serpentine forming the tunnel wall, there is a different condition. Here the antigorite appears not only in fine fibres but also in larger, prismatic sections. Mixed with these fibres, corroding the edges of the sections, and appearing in the cracks, are seen the fine flaked, brilliantly polarizing talc. It has obviously been derived from the serpentine. Pyrrhotite occurs chiefly in the talc, as though the invading solution which altered the serpentine to talc had also brought in the iron sulphide. No carbonate mineral, or at best, only a very small amount, is to be seen.

The photomicrograph, Plate LXXVII A, is taken from a section of the serpentine in contact with the talc in the lower tunnel. It shows how completely the talc (the light mineral) has replaced the antigorite (the dark mineral).

The section of the so-called "cobblestone" was cut at the contact between the serpentine core and the thin talc covering. On one side of the contact is seen antigorite thickly sprinkled with fine talc flakes; on the other, a mass of talc flakes containing a few fibres of antigorite. Pyrrhotite is disseminated through the slide and there seems to be some showing of sericite. No car-

PLATE LXXVII.
Serpentine.


X 45 (Polarized light)
*A.* MORETOWN SERPENTINE AND TALC.




X 45 (Polarized light)
*B.* WILLIAMS GRIT.

bonate is seen. This section points to talc derived from serpentine.

No section of the grit was prepared but this material looks just like the Rochester grit, which will be described later.

The grit occurs as isolated masses in the talc, just as the "cobblestones" of serpentine do, and might represent a carbonation of the magnesian minerals.

The chloritic material of which the black walls are composed also occurs in the talc but in much smaller amounts than in East Johnson.

No section of the talc itself was made but a chemical analysis gave the following results:

| | |
|---|---|
| $SiO_2$ | 60.06% |
| $Al_2O_3$ | 1.37 |
| Fe | 3.39 |
| S (calculated for $Fe_7S_8$) | 1.85 |
| MgO | 28.80 |
| $H_2O$ | 4.78 |
| | 100.25 |

Recasting the analysis on the assumption that all the magnesia is present in the form of talc, we get for the mineralogical composition of the talc:

| | |
|---|---|
| Talc | 90.72% |
| Quartz | 2.46 |
| Pyrrhotite | 5.25 |
| Alumina in some form | 1.37 |
| | 99.80 |

It is clear that the Moretown talc has been derived from serpentine and that the alteration of the latter substance has been so complete that probably no trace of the parent mineral remains.

## ROCHESTER.

As stated before, page 409, Cushman's Hill seems to be made up of a great mass of serpentine, crossed near its summit by one or more dikes of an igneous rock which has been altered to chlorite and contains crystallized magnetite. Sections of the serpentine from the surface of the hill and also from the tunnel in the hill reveal ground-masses of serpentine (antigorite) with a few small areas of dolomite and scattered flakes of talc. Magnetite also appears in the sections. In one of the slides there is a crystal section, with reaction rims, of calcite or dolomite, pseudomorphous after an orthorhombic mineral, possibly olivine. This is the only trace of a primary mineral that has been found.

It seems clear that this hill has resulted from the extrusion of a mass of igneous rock through the country schists, in the planes of their schistosity. It is probable that if this igneous mass could be followed to the south, a connection between it and the Williams deposit would be found. It has been noted that in the Williams mine and elsewhere in the talc belt a good deal of slickensiding has taken place between the talc and the black walls, and a question as to the cause of this movement arises. The hill appears as a small monadnock above the surrounding country and the further question arises as to whether it has maintained itself because of its greater ability to resist erosion or for some other cause.

Prof. W. O. Crosby[1] has recently studied the serpentine highland of Staten Islands in an effort to account for its ability to maintain itself above the surrounding Cretaceous peneplain. He finds a sufficient explanation in the increase of volume due to the serpentinization of some massive, basic and highly magnesian igneous rock, such as a peridotite. This voluminal increase, according to Van Hise,[2] may amount to from 15 to 40 per cent. Crosby states that under the conditions surrounding an approximately vertical plug or stock, at great depth, this increase in volume would be manifested in an upward direction, giving rise to topographical relief and slickensiding. For this type of serpentine reliefs Crosby has coined the name, *statenlith.*

This theory may serve as a possible explanation for the observed conditions at Cushman's Hill.

## THE WILLIAMS DEPOSIT.

### THE GRIT.

The Williams grit has been described (page 410) as a gray, highly crystalline mass of talc and dolomite. A thin section of this substance shows dolomite or calcite (effervescence only in strong acid fixes it as dolomite), talc, antigorite, and pyrrhotite. The photomicrograph (Plate LXXVII, B) reveals large areas of dolomite, showing rhombohedral cleavage and twinning striae, with their fretted outlines filled partly with talc flakes. The section shows that antigorite also abuts on the dolomite. The pyrrhotite is disseminated through the talc and antigorite. The most plausible explanation seems to be that a silicate solution has invaded the carbonate mineral, changing it partly to antigorite, partly to talc, and bringing in the iron sulphide. Antigorite is a unisilicate; talc, a bisilicate. The formation of one or the other mineral would depend upon the abundance of the silicate solution, an excess producing talc; a dearth, antigorite. No trace of a ferromagnesian mineral could be found but it is to be noted that all the talc and grit in the State give strong reactions for manganese.

A chemical analysis of the grit gave the following results:

[1] Journal of Geology, XXII, 6, p. 582.
[2] U. S. G. S. Monograph 47.



| | |
|---|---|
| $SiO_2$ | 23.53% |
| $Al_2O_3$ | 2.45 |
| FeO | 5.26 |
| MgO | 28.14 |
| CaO | 10.26 |
| $H_2O$, by Penfield tube | 1.40 |
| Loss on ignition, excluding water | 29.04 |
| | 100.08 |

Recasting the analysis in terms of the constituent minerals, we find:

| | |
|---|---|
| Talc | 36.88% |
| Pyrrhotite | 6.76 |
| Alumina, in some form | 2.45 |
| Residue of dolomite | 53.91 |
| | 100.00 |

It is concluded that the grit is essentially a mixture of talc and dolomite, in which the talc has been derived from the carbonate mineral. This conclusion, taken by itself, argues a sedimentary origin for the talc.

### THE TALC.

About a dozen sections of talc from different parts of the mine have been prepared and examined. Disseminated pyrrhotite is observed in all the slides. In the sections representing the east wall and the north workings of the mine, talc and actinolite are found associated, but there is no apparent genetic relationship. The actinolite, in basal sections and prismatic rods, is well bounded, and often separated from the surrounding talc by shrinkage spaces, showing that the mineral has crystallized independently.

In the sections taken near the grit core, a small amount of calcite or dolomite scattered through the talc is observable, but in those parts of the talc more remote from the core, practically no carbonate mineral is seen. The talc itself presents a varied appearance. In some of the slides a good deal of crushing is noted; in others the talc plates are in places large and show considerable cleavage. Shreds of these large plates continue through the slides, surrounded by the typical minute flakes of talc which seem to have been derived from them—in fact, it was at first thought that the large plates represented tremolite which had altered to talc. This was found however not to be the case. In some of the slides there are shredded remains of some former mineral or minerals which, unfortunately, have been almost entirely destroyed by alteration. In quite a number of the slides there are small areas of a mineral which resembles antigorite. The optical properties of several of these magnesian minerals have so much in common that a diagnosis, based wholly on microscopic examination, is exceedingly difficult; but, as will be seen, there seems good reason for believing that antigorite is present. No quartz could be found in the sections.

The chemical analysis of a sample of talc, taken near the grit, showed the following results:

| | |
|---|---|
| $SiO_2$ | 53.68% |
| $Al_2O_3$ | 2.02 |
| Fe | 4.26 |
| S, calculated to form $Fe_7S_8$ | 2.78 |
| MnO | .76 |
| MgO | 28.98 |
| CaO | 1.54 |
| $CO_2$, calculated for $CaCO_3$ | 1.21 |
| $H_2O$, by Penfield tube | 5.59 |
| | 100.82 |

The minerals present are talc, calcite or dolomite, pyrrhotite, and probably antigorite. If the analysis is recalculated on the basis that all the silica is in the talc, we find that there is an excess of magnesia over the requirements of the talc. Effervescence in cold dilute hydrochloric acid shows that the carbonate mineral is calcite, so that the excess magnesia must be present in the silicate form. Therefore the probability of there being antigorite in the talc is strengthened. Since the talc and antigorite both contain the same molecules, it is impossible to recast these on a percentage basis.

From the above microscopic and chemical examination, there seem good reasons for believing that the talc, antigorite and calcite have been derived from the grit.

### THE BLACK WALLS.

Thin sections show the material of the black walls to be a chloritic schist, containing members of the chloritoid group, probably peninite. Some of the sections show talc in close association with the chlorite. Minute crystals of rutile or zircon are also seen. It has been noted that, in the southern part of the State, large crystals of pyrite occur in the black wall in considerable quantity, while hornblende crystals have also been found.

A partial chemical analysis of the black wall gave:

| | |
|---|---|
| MgO | 25.98% |
| FeO | 13.85 |

The high magnesia and iron content of this black wall shows it to belong to the mineral or group of minerals from which the talc and grit were derived.

### THE SCHIST.

This has already been considered. We may merely state here that the low magnesia and iron content precludes the possibility of the talc, grit, or black wall being derived from it.



No microscopic or chemical examinations of the other talc deposits have been attempted, since it is thought that they would add nothing new to the problem.

## SUMMARY AND CONCLUSIONS AS TO ORIGIN.

It has been shown that the talc deposits of Vermont consist of mineral lenses which extend in a broken chain probably throughout the length of the State, with their longest axes lying generally north and south. It has been noted that, with one exception (the Moretown deposit), these mineral lenses consist of a core, composed of a mixture of talc and dolomite, surrounded on either side by relatively thin zones of talc (though in some places the talc is entirely lacking), which, in turn, are bounded by generally very thin bands of a chloritic schist, called black wall. This black wall material also occurs in the talc and grit, in at least one instance (at East Johnson) reaching large proportions. In the Moretown deposit great masses of serpentine form the core. Pyrrhotite has been found disseminated throughout the talc belt. Slickensiding has been generally noted between the black wall and the talc, and the smooth surfaces have offered ascending or descending solutions access to the deposits. The country rock has been shown to be a quartz-sericite schist of a very low magnesia content—probably of sedimentary origin. Evidences of the intrusion into the schists of basic, igneous magmas are found in the asbestos deposits on Mount Belvidere, at East Johnson, at Moretown, and in Cushman's Hill, in Rochester. Furthermore, the topography of the valley at Rochester suggests that faulting may have afforded opportunity for these intrusions.

Outside the State, it has been seen that the serpentine belt of Quebec, which is in line with the Vermont chain of deposits, has resulted from the alteration of a series of basic, intrusive rocks—peridotites, gabbros, diabases, etc. On Staten Island and in Hoboken, stocks of serpentine testify to the intrusive activity of igneous magmas, while other outcrops of a similar character, forming a series of isolated lenses, follow the Appalachian Mountain chain to Alabama.[1]

It remains to formulate a satisfactory theory to account for the chain of Vermont deposits with their grit, serpentine, talc, and black wall members.

Since the country schists are far too poor in magnesia to have been the source of the material of these members, it follows that this source must have been within the mineral lenses themselves. These lenses must therefore represent altered igneous intrusions or else altered sedimentary carbonates.

[1] North Carolina Geological Survey, Vol. I, plate 4.

If we were to leave out of consideration for the moment those lenses whose cores are composed of dolomite, we should at once reach the conclusion that the deposits had resulted from the alteration of serpentine, which in turn had been formed from a basic, igneous rock, containing silicates of magnesium, iron, calcium, etc. On this theory, the chloritic schists would be explained as segregations of the iron and some of the magnesia along the borders of and in the mineral lenses.

But the occurrence of great masses of dolomite in the core of the deposits at East Johnson, Granville, Rochester, Windham, etc., and the evidence of Plate LXXVII B, that talc has been derived from dolomite, cast a doubt on this igneous origin. Dolomite may indeed result from the carbonation of serpentine, and many of the serpentine slides examined show the presence of small amounts of this mineral, but one is hardly prepared for such extensive and nearly complete carbonation.

The alternative hypothesis is that of the alteration of a magnesian sediment, in part to dolomite and in part to talc, perhaps through the intermediate formation of pyroxenes. Such an hypothesis Smythe[1] has found best to fit the conditions at Gouverneur, New York. Here there are areas of crystalline limestone (presumably Grenville) forming large, irregular belts, separated by gneiss. Smythe states that "the talc occurs in beds, lying wholly within the schist of the limestone formation. The beds range in thickness from a few feet to thirty feet and sometimes 'pinch out.' They conform in dip and strike to the rest of the formation and have schist for both the foot and hanging wall, with an intervening thin layer composed largely of quartz."

In attempting to apply this theory to our problem, we find it difficult to imagine a magnesian sediment confined so closely within our narrow chain of deposits, situated about in line, but separated by intervals of many miles (though of course future prospecting may serve to connect many of these links). Furthermore, the significance of the black wall, which always borders the talc, is difficult to appreciate on the theory of a metamorphosed sediment. Finally, no pyroxenic mineral can be found in the talc, while there is good reason to believe that serpentine is present.

On account of the great preponderance of evidence for an igneous origin, the tentative theory is advanced that the Vermont talc deposits owe their origin to a series of basic, magmatic intrusions into the sedimentary country schists and that metamorphic processes have produced the serpentine, grit, talc, and chlorite members of the mineral lenses.

* * * * * *

There is one location that has not been examined. In Roxbury, which lies just north of East Granville, the Barney Marble

[1] Loc. cit.



Co. has for many years worked a series of lenticular deposits of verd antique. This material, more properly called ophicalcite, consists of irregular or rounded masses of serpentine, embedded in calcite or dolomite. Correspondence with the company elicits the facts that these lenticular deposits have a general strike of north, to north thirty degrees east, that they vary from 100 to 300 feet in length and from 30 to 100 feet in width, and that the greatest depth reached is 160 feet. Furthermore, the verd antique appears to occupy the position of the grit in the neighboring talc deposits, being bounded by zones of talc on either side. The lenses are spread out over a territory three miles long and one mile wide.

In a section of a drill core from one of these deposits there have been found undoubted primary minerals, which show the igneous origin of the serpentine at least.

Time has not permitted a further study of these deposits which apparently are intermediate in their structure between the Moretown or Williams formations. They appear to be rich in possibilities and will be further investigated.

## ECONOMIC NOTES.

### JOHNSON.

The deposit here is worked by the American Mineral Company of Boston. Mr. E. P. Jose, of Johnson, is president and general manager. The present company has been in operation since 1910. The mill is located beside the Central Vermont Railroad tracks, within a stone's throw of the shaft, from which the mineral is conveyed by an aerial tram. The grinding machinery, driven by a crude oil engine, consists of coarse jaw and rotary crushers and, for the fine grinding, buhrstones and Abbey mills. The products are ground talc, screened through silk bolting cloth, and ground grit, screened through wire mesh. The production is about thirty tons per day.

The mineral from the new mines at East Johnson is hauled to the mill by teams.

The Johnson deposits are remarkable for their white color and low content of iron.

### MORETOWN.

The Moretown deposit, some two miles from Waterbury village, is operated by the Magnesia Talc Company, of Burlington. The officers are: President, Elias Lyman; vice-president, G. H. Holden; secretary and treasurer, J. S. Patrick.

The mine is on the D. P. Deavitt farm and is one of the oldest known deposits in the State. It was acquired by the Magnesia Talc Co. in 1912 and production began in July, 1913.

The mining and milling represent one of the most economical practices to be found in the State. This is due largely to the possibility of opening the mine by tunnels and to the location of the mill in a place where full advantage can be taken of the force of gravity. By driving the tunnel at the proper grade, it has been possible to have the cars, loaded at the tunnel heading, run by gravity to the storage bins of the mill, which is about 100 feet below. The mill is equipped with what is probably the best machinery yet devised for grinding talc, the Raymond Impact Pulverizer, used in conjunction with the Cyclone Separator. The mill is simple in operation, the fine material being "winnowed out" by adjustable air currents (thus avoiding the use of bolting cloths). The resulting product is remarkably free from grit. The newer mills of the State have been equipped with either this or the Sturtevant system, which is similar to it in essential details. The so-called "flow sheet" of these mills is as follows:

Storage bins,
Steam or air dryer,
Jaw crusher,
Rotary crusher,
Raymond or Sturtevant mill,
Cyclone separator, giving finest flume talc, caught in vertical textile bags, and fine grade talc which is bagged.

The coarser material is elevated and reground or else is screened, to extract a coarser product fit for roofing papers, and then reground. The capacity of these mills is from 1½ to 2 tons per hour, depending upon the fineness of products desired. The finest, or "flume," talc is rather insignificant in amount. In some mills this is allowed to go to waste.

The Magnesia Company finds only a small amount of grit in its deposit, and so makes but one product. The capacity is at present 29 to 30 tons per day, but the mill may be easily expanded to yield two or three times this amount. There is also a buhrstone equipment, not at present used. The mill is driven by electric power.

## EAST GRANVILLE.

The Eastern Talc Co., of Boston, by far the largest talc mining concern in the State, has been at work on the deposit here since 1906. The officers of the company are: President, Freeland Jewett, of Boston; mining superintendent, C. B. Hollis, of Randolph.

The company also operates several mines at Rochester and Stockbridge.

The mill is located near the railroad station, just east of the track. The mine is in the hills, several hundred feet above the mill, and is opened by tunnels, as at Moretown. The mineral, which as stated before is a rather low grade of talc, is carried to the mill by an aerial tram, some 1,500 feet long.



Arriving at the mill the mineral is ground by the Sturtevant system of crushers and grinders, while the sizing is done by cyclone separators and New Eygo screens. The capacity of the mill is 25 to 30 tons per day. The product is used for filling paper pulp, rubber goods, etc.

## ROCHESTER.

The Williams mine is the oldest in this region, having been worked superficially for soapstone purposes many years ago. Of late years this mine and the Greeley mine, five miles to the south, in Stockbridge, have been operated by the United States Talc Corporation and later, by the Standard Talc Company. The two mines were bought by the Eastern Talc Co. in 1911. Besides working these two properties, the Eastern Talc Co. has developed the McPherson prospect, which lies about one mile southeast of the Williams deposit, into a producing mine. Undeveloped prospects in the vicinity of the Williams mine promise an abundant supply of talc and grit for many years to come.

The company's old mill (No. 2) is located in Lower Rochester (now called Talcville), on the river, about west of and 1,175 feet below the Williams shaft house. Until about a year ago, the talc and grit from the Williams mine were teamed over the roads, about four miles, to the mill. This mill is driven by a crude oil engine and is equipped with buhrstones and Holmes-Blanchard pulverizers, while the sizing is done by screens and cyclone separators. A water-power, developed by damming the river, supplements the oil engine.

In 1913 the Eastern Company greatly increased its output and effected important economies in operation by completing a new mill (mill No. 3) about half a mile south of mill No. 2, and connecting it by a narrow gauge railroad with the Williams and McPherson mines. The road is four miles long and has an average grade of five per cent. The loaded cars are drawn by a locomotive to the lower terminus of the road, which is located on the top of an old river terrace. About 250 feet below, at the bottom of the terrace, stands the mill. The cars are lowered singly, by means of an inclined gravity railroad, to a lower track, along which they are pushed to the storage bins. The mill building is about two hundred feet long and is so arranged as to take full advantage of gravitational force, the raw material being received on the up-hill side and the final product being bagged and loaded onto cars at the level of the White River Railroad.

The mill is driven by steam power and is equipped with Sturtevant and Raymond pulverizers. It runs night and day and has a capacity, at present, of between 80 and 90 tons per twenty-four hours. Since the company finds a ready market for its ground grit as well as for its talc, it is able advantageously to run one mill on each product. The material for mill No. 2 is teamed from the supply bins of mill No. 1.

The mining and milling force of the company is made up of trained engineers and the whole organization is a splendid example of a large enterprise, scientifically managed.

## STOCKBRIDGE.

As before noted, the Greeley mine is a deposit of grit, containing considerable masses of green, foliated talc, calcite and some small amount of chalcopyrite. The mine has been worked by the Eastern Talc Co. up to within a short time, the mineral being brought to the company's No. 2 mill by the White River Railroad, which runs from Rochester down the valley to Bethel. With the advance of the tunnel into the mountain, the proportion of calcite to grit has increased until there has resulted a stone resembling verd antique. The company has discontinued grinding this material, since the supply of mineral from the Rochester region is ample.

## CHESTER.

The Carlton quarry, about three miles from Chester Depot, has been worked for the past eight years by the American Soapstone Finish Co. Mr. C. P. Dodge, of Amherst, N. H., is the proprietor, and Mr. E. E. Holt, of Chester Depot, is the superintendent. The mineral, a low grade talc, is hauled in teams to the mill, which is located alongside of the Rutland Railroad tracks at Chester Depot. Here, by means of the usual coarse crushers and an emery mill, the material is ground to the requisite fineness to be bolted through brass and silk mesh. The mill is operated by electric power. The company also buys and grinds the waste material from the Union Soapstone Co., whose mill adjoins.

The capacity of the plant is about 30 tons per day. The products are used for filling roofing paper, plaster board, and also for several special purposes, developed by the company. One of these is a patent soapstone finish, said to be superior in many respects to ordinary plaster. Another is an artificial slate for blackboards.

## WINDHAM.

The Vermont Talc and Soapstone Company, which has operated the Windham mine for a dozen years or more, has recently changed its name to the Vermont Talc Company, which more accurately describes its operations.

The president of the company is Mr. Nathan P. Avery, of Holyoke, Mass.; the general manager is Mr. T. P. Dean; and the mill superintendent is Mr. B. J. Monier.



The old mill was located near the mine, fuel and supplies being teamed from Chester, 10 miles over the roads, and the ground talc being drawn back to the railroad. In order to effect economies, a new mill was built at Chester, alongside of the Rutland Railroad tracks. It has been in operation since the fall of 1912. The new mill is a wooden structure, 300 feet long, with storage capacity of 3,000 tons, in order to provide reserves of mineral for the winter's grinding. The mineral is drawn by teams over the roads and the haulage charge is a heavy handicap. The company is considering the use of motor trucks as a substitute for horse haulage.

The talc is air dried, coarsely crushed in a jaw crusher and a Sturtevant mill, and then fed automatically to a Raymond roller mill. The resulting fine material is air lifted by a Cyclone separator. The product is of good color and "slip" and finds a use as a filler for paper and rubber goods. The mill is driven by electric power and is economically run, only three men being needed. The capacity is 20 tons per twelve hour shift.

# MINERAL RESOURCES.

G. H. PERKINS.

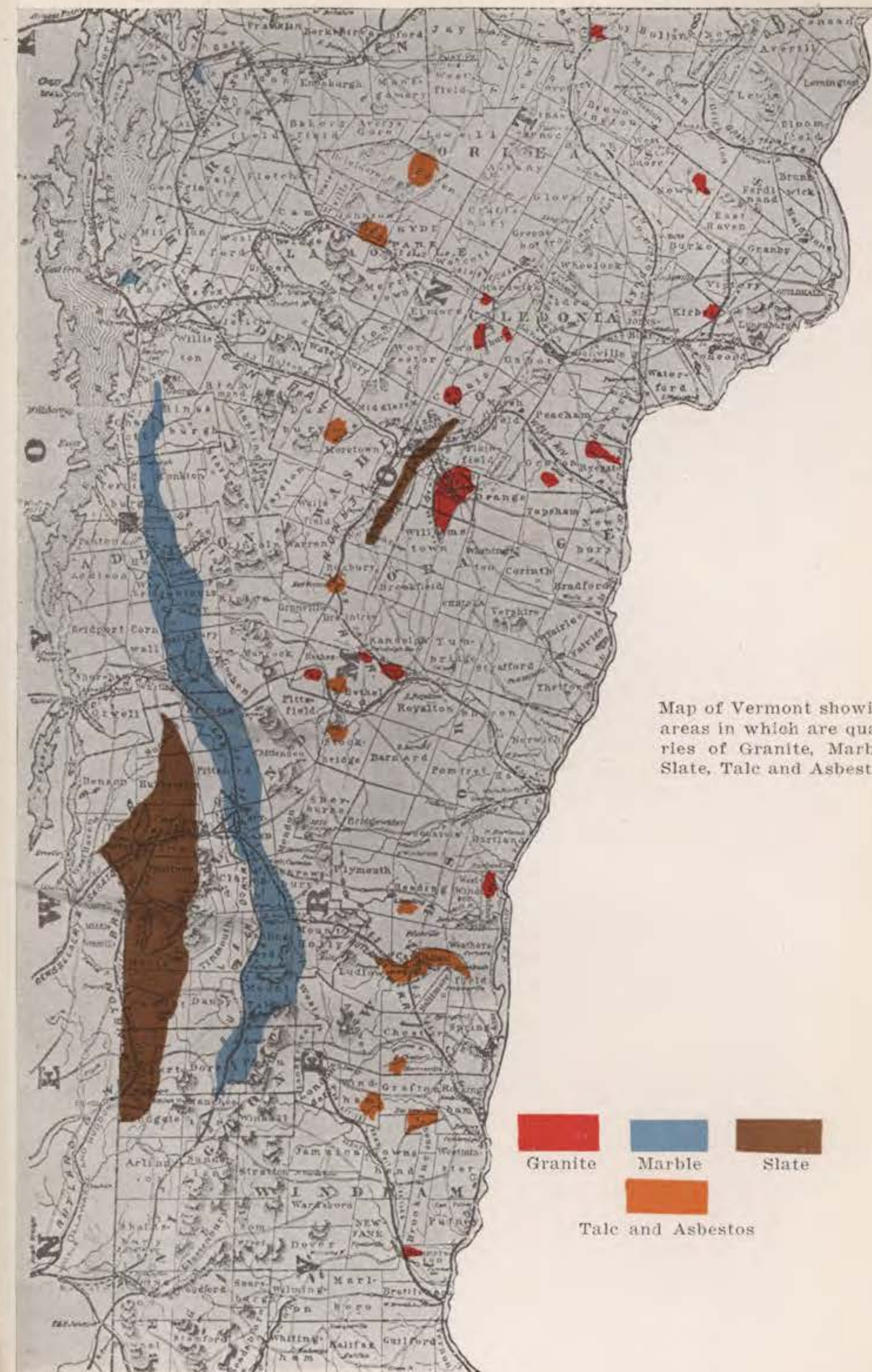
Since the publication of the last Biennial Report there has been no very notable change in the development of those industries which come properly under the above title. There has, however, been steady progress in nearly all of them and consequent increase in the amount of stone and similar products sold in the State.

It it unnecessary to note that the important rock products of this State are granite, marble and slate and this must always be so although there is now and may be more in the future, a considerable revenue from what may be called minor products.

The mountains and hills of Vermont will not for centuries to come refuse to furnish ample supplies of granite and marble. I think that no geologist who examines the deposits of these materials can fail to appreciate the practically unlimited quantity of these valuable building and monumental stones. It may be well to note here that the abandonment of a quarry here and there does not, as some seem to fear, indicate the exhaustion of the general supply. Either because the particular sort of stone is not at the time called for, or because the quarry has actually given out it is no longer profitable to work it, but there are plenty of other quarries that take the place of the one disused and the trade is not affected.

It would be instructive if accurate figures showing the magnitude of the stone industry in Vermont could be obtained, but this does not appear to be possible. Of course the simplest way would be to go to the last volume of the Census Reports or to Mineral Resources, but neither of these is entirely correct. The only absolutely accurate figures would be those obtained from the addition of all given by each of the active companies and such figures are not available. It is not at all from a wish to exaggerate the actual amount of stone produced in Vermont in order to boom the State that I question the Government estimates, but only that the exact amount may be known. I have alluded to this in previous reports and do not care to dwell upon it here, but when the total amount given for the value of granite from the whole State is over a million of dollars less than the amount paid






Map of Vermont showing areas in which are quarries of Granite, Marble, Slate, Talc and Asbestos.

in wages for the same time in Barre alone it is very plain that there must be error somewhere. For this reason the amounts given in this Report for the production of different kinds of stone are not the same as those found in the Government publications.

About 97% of the sales of mineral products in the State are of the three materials mentioned, granite, marble, and slate and lime and limestone make up a goodly portion of what is left.

There are at present quarried or mined in Vermont the following besides these that have been named: Talc, Soapstone, Clays, Ocher, Asbestos, Scythestones. Some of these are produced in considerable quantity, others only in small amount.

It will be noticed that the list contains no metal. For many years only chalcopyrite has been mined though formerly gold, manganese and iron were mined and sold. The chalcopyrite for the copper has been mined more or less until within a very few years and at some of the mines work may again be started, but at present all mines are idle. Notwithstanding the increasing demand for copper for electrical uses the Vermont ores are too poor in this metal to make profitable mining possible.

According to the last Census Report there are now 137 companies operating mines or quarries in the State. In the offices and works nearly 10,000 men are employed so far as I have been able to ascertain, the following figures are more accurate than those of the Census:

| | |
|---|---|
| Granite | $6,000,000 |
| Marble | 4,000,000 |
| Slate | 1,800,000 |
| Limestone | 12,000 |
| Clays | 100,000 |
| Ocher, etc. | 10,000 |
| | $11,922,000 |

From the above it will be seen that Vermont annually sells these products to the value of nearly $12,000,000 and the whole amount, if it could be gotten at, is very probably above rather than below this sum. In the last Bradstreet the amount is given as the same as that above.

Everywhere Vermont is usually regarded as an agricultural state and so it is, but few recognize the fact that the products of the Vermont stone deposits amount to but little less than half as much as do all farm products, for according to late statistics these latter for 1913 amounted to $27,446,000.

But the above does not tell by any means the whole story. As has been noticed before, the farm products all of them represent a profit on an investment. In addition to such agricultural machinery and appliances as are necessary, there must be a large expense for fertilizers before much can be expected by way of crops. All the farm products involve more or less loss in material taken from the State, although of course, there is a much greater gain. The rock products, however, involve no loss and as a result of their removal nothing need be replaced. It costs not a little to take the granite and marble and slate from the ground, but their taking involves no loss to the State. There are rocks enough left. All these conditions being considered, the difference between the mineral and the agricultural products is much less than at first appears in net value to the State.

The same relation is made evident when the value of the investment of capital in these two products is noted. There is invested in farm property in Vermont not far from $145,000,000 and in the stone industry $68,000,000.

## MARBLE.

In the first part of this Report the Marble Industry has been so fully discussed that there is no need for extended treatment in this place, therefore only a few statements will be added to what has been said.

The business has never been better than during the last two years and though this, like all other business, must suffer somewhat on account of the war, there does not appear to be any reason to fear a permanent decline.

For several years as the country has grown in wealth and has adopted higher ideals as to architectural excellence the use of marble for building and especially for interior work has steadily increased and it may be expected that this will not only continue, but increase. Whatever may be thought as to the kind of stone most suitable for the outside of a building, there can be little difference of opinion as to the value of marble for interior finish for most buildings.

The marble work done in Vermont has been for a long time gradually falling into the hands of fewer companies until now only two are engaged in both quarrying and manufacturing, though there are several others that quarry the stone and sell it in the rough.

The Vermont Marble Company of Proctor. In the History of Marble in Vermont in the early part of this Report a pretty full account of the Vermont Marble Company was written and to that the reader is referred. Probably there is nowhere in the world so large a company as this and it supplies more than half of all the finer grades of marble used in the whole country. They regularly offer fifty varieties of marble, but can easily furnish many others if they are called for. The list given on pages 183-184 mentions the more important sorts.

The Green Mountain Marble Company of Rutland replaces the older and well known Columbian. This company have a very



extensive and up to date plant and appear to be carrying on a thriving business. They have a number of excellent quarries and also work and sell stone from other quarries. The price list of this company includes twenty-six varieties and several fine varieties seen in their yard are not on the list.

Of those who do not manufacture marble, but sell it from the quarry, the principal dealer is Mr. G. P. Eastman who has a remarkable quarry at West Rutland from which over twenty varieties are taken. As the list shows some of these are very choice and beautiful.

The Clarendon Marble Company quarry and sell several grades and varieties of light marble from the quarry at Clarendon. These are mostly used in building.

The Manchester Marble Company is successor to the old Freedley Company and has furnished considerable stone from the quarries at East Dorset on Dorset Mountain, but of late has not done much business.

The Norcross-West Marble Company of Dorset with a large mill at Manchester has been bought by the Vermont Marble Company and the various marbles formerly sold by this company are listed under the name of the latter.

## GRANITE.

As has been shown in previous Reports the granite industry in Vermont has had a remarkable growth during the last twenty and especially ten years so that from one of the small producers the State has become not only first of the United States, but the granite center of the world.

The following list, which has been revised for this Report with the assistance of Mr. Charles Wishart, Secretary of the Barre Manufacturers' Association, Mr. George James of the Woodbury Granite Company and others, shows the number of granite producers in the State. The letters Q. C. refer to quarry or cutting plant. It should perhaps be noted that there are scattered over the State a considerable number of monument dealers who in all do a business of some magnitude, but are not included in the list, which is intended to include only the larger firms which take the stone directly from the near-by quarries or quarry their own stone.

## LIST OF GRANITE COMPANIES IN VERMONT.

BARRE AND VICINITY.

Adie & Milne, Barre, C.
Art Granite Co., Barre, C.
Barclay Brothers, Barre, Q. C.
Barre Granite Co., Barre, Q. C.
Barre Granite Turning Works, Barre.
Barre Medium Granite Co., C.
Barre Monumental Yard, Barre, C.
Barre White Granite Co., Barre, Q.
Barre Granite Quarry Co., Barre, Q.
Barton, Chas. H. C.
Beck & Beck, Barre, C.
Bianchi, Charles & Son, Barre, C.
Bond, Geo. E. & Co., Barre, Q. C.
Boutwell-Milne-Varnum Co., Barre, Q. C.
Brown, Carroll & Co., Barre.
Brown, John & Co., Barre, C.
Brusa Brothers, Barre, C.
Bugbee, E. A. & Co., Barre, C.
Burke Brothers, Barre, C.
Canton Brothers, Barre, Q. C.
Carroll & McNulty, Barre, C.
Carswell-Wetmore Co., Barre.
Carusi, E. A., Barre, C.
Central Granite Co., Barre, C.
Chiold Brothers, Barre, C.
Cole, W. & Sons, Barre, C.
Comolli & Co., Barre, C.
Consolidated Quarry Co., Barre, Q. C.
Corskie, J. P. & Son, Barre, C.
Davis Brothers, West Berlin, C.
DeBlois, L. G., Granite, C.
Dessureau & Co., East Barre, C.
Dewey Column and Monumental Works, Barre, C.
Freeman & Wasgatt, Barre, C.
Gasparello Brothers, Barre, C.
Gerrard-Barclay Granite Co., C.
Goodwin & Milne, Barre, C.
Glysson, E., Barre, C.
Grearson & Lane, Barre, C.
Guidici Brothers & Co., Barre, C.
Harrison Granite Co., Barre, C.
Herbert & Ladrie, Barre, C.
Hoyt & Lebourveau, Barre, C.
Indum, G. E., C.
Johnson & Gustafson, Barre, C.
Jones Brothers' Co., Barre, Q. C.
Jones, A. S., Barre, C.
Jones, W. B., C.
LaClair & McNulty, Barre, C.
Libersont, George, Websterville, C.
Littlejohn, Odgers & Milne, Barre, C.
Lucia Granite Co., East Barre, C.
McCall, John, Barre, C.
McDonnell & Sons, Barre, C.
McMillan, C. & Son, Barre, C.
Malnati Brothers, Barre, C.
Manufacturers' Quarrying Co., Barre, Q.
Marr & Gordon, Barre, C.
Marrion & O'Leary, Barre, C.
Martell, S. B., C.
Martinson Estate Co., Barre, C.
Melcher & Hadley, Barre, C.
Milne, Alex, Barre, C.
Milne, Geo. P., Barre, C.
Newcombe, T. J., Barre, C.
North Barre Granite Co., Barre, C.
Novelli & Calcagni, Barre, C.
Oliver & Co., Barre, C.
O'Herrin, Robert & Co., Westerville, C.
Palaora Brothers, Barre.
Paradis & DeRegibus Granite Co.
Parry & Jones, Barre, C.
Parnigoni Bros., Barre, C.
Passera Bros., Williamstown.
Peerless Granite Co., Barre, C.
Pirie, J. K., Graniteville, Q.
Presbrey-Coykendall Co., Barre, C.
Provost, S. & Son, West Berlin, C.
Pruneau, John, Websterville, Q.
Rizzi, L. G., Barre, C.
Rizzi, L. G., Barre, C.
Robertson, J. C., Barre, C.
Robins Brothers, Barre, C.
Ross & Ralph, Barre, C.
Ross & Cassellini, Barre, C.
Roux Granite Co., Barre, C.
Sassi & Co., Barre.
Scandia Granite Co., Barre, C.
Scott Brothers, Barre, C.
Sector, James & Co., Barre, C.
Sibson Quarry Co., Barre, Q.
Smith, E. L. & Co., Barre, Q. C.
Smith Brothers Granite Co., Barre, C.
Standard Granite Co., Barre, Q.
Star Granite Co., Barre, C.
Stevens, H. D., Barre, C.
Straiton, George, Barre, C.
Sunnyside Granite Co., Barre, Q.
Sullivan Eugene, Barre, C.
Tosi, Sanguinetti & Co., Barre, C.
Valz Granite Co., Barre, C.
Vanetti Granite Co.



Wells-Lamson Quarry Co., Barre, Q.
Wells & Barney, Websterville, C.
Woodcock Bros., Barre, C.
World Granite Co., East Barre, C.
Young Brothers Co., Barre, C.

MONTPELIER.

Airoli, G. & Co., Montpelier, C.
Aja Granite Co., Montpelier, C.
American Granite Co., Montpelier, C.
Bianchi, G. R., Granite Co., Montpelier, C.
Bonazzi & Bonazzi, Montpelier, C.
Bowers, R. C., Granite Co., Montpelier.
Columbian Granite Co., Montpelier, C.
DeColaines, R. J., Granite Co., Inc., Montpelier, C.
Doucette Brothers, Montpelier, C.
Excelsior Granite Co., Montpelier, C.
Fernandez, P., Montpelier, C.
Fraser, R. M., Montpelier, C.
Gill, C. P. & Co., Montpelier, C.
Globe Granite Co., Montpelier, C.
————, Montpelier, C.
Jurras Granite Co., Montpelier, C.
Lillie Granite Co., Montpelier, C.
Lowe-Mercer Co., Montpelier, C.
McGovern Granite Co., Montpelier, C.
Maloney, M. G., Montpelier, C.
Mills & Co., Montpelier, C.
National Granite Co., Montpelier, C.
Patch & Co., Montpelier, Quarry at Adamant.
Pecu Brothers, Montpelier, C.
Pioneer Granite Co., Montpelier, C.
Poulin, J., Granite Co., Montpelier, C.
Sheridan & Poole, Montpelier, C.
Sibley, Clark E., Montpelier, Q.
Vermont Granite & Polishing Co., Barre.
Wetmore & Morse Granite Co., Montpelier, Q.

NORTHFIELD AND BETHEL.

Cross Brothers Co., Northfield, C.
Empire Granite & Quarry Co., Northfield, C.
Northfield Granite Co., Northfield, C.
Osgood Granite Co., Northfield.
Pelaggi, N. & Co., Northfield, C.
Phillips & Slack, Northfield, C.
Woodbury Granite Co., Bethel and Northfield, Q. C.

WATERBURY.

Carr, W. L. & Co., C.
Drew, Daniels Granite Co., Q. C. Quarry at Adamant.
Oclair & Anair, Waterbury, C.
Perry Granite Co., Waterbury.
Union Granite Co., Waterbury, C.

HARDWICK AND WOODBURY.

American Granite Co., Hardwick, C.
Bailey Bros., Woodbury, Q.
Calderwood & Merriam, Hardwick, C.
Crystal Brook Granite Co., Hardwick, C.
Donald, Wm. B., Hardwick, C.
Emerson & Bond, Hardwick, C.
Eureka Granite Co., Hardwick, C.
Fletcher, E. R., Woodbury, Q.
Hardwick Polishing Co., Hardwick.
Hay, John, Hardwick, C.
James Granite Co., Hardwick, C.
Murch, E. R., Hardwick, C.
Purdy, F. A., Hardwick, C.
Smith, Ashley, Hardwick, C.
Thomas, A. B., Woodbury, Q.
Vermont Quarries Corporation, Woodbury, Q.
West End Granite Co., Hardwick, C.
Woodbury Granite Co., Hardwick. Quarries at Woodbury, Buck Lake and Bethel. Works at Hardwick, Northfield and Bethel.

GROTON AND RYEGATE.

Augustini, Ryegate.
Anderson, Axel, South Ryegate, C.
Beaton, James, Ryegate, C.
Beaton, A. T., Ryegate, C.
Benzie & Company, Groton, C.
Blue Mountain Granite Works, Ryegate, C.
Brock, S. E., Ryegate, C.
Cerutti, C. F., S. Ryegate.
Checchi, A., Groton, C.
Craigie, James, Ryegate, C.
Eliason, C. E., S. Ryegate, C.
Hartz, L., S. Ryegate, C.
Hendry, C. H., Groton, C.

Hosmer Brothers, Groton, C.
Nicolo, T., Ryegate.
Leonard, G., S. Ryegate, C.
McDonald, M. F., Ryegate, C.
Rosa Brothers, Ryegate, Q. C.
Ryegate Granite Works, Ryegate, Q. C.
Samuelson, H., S. Ryegate, C.
Zambelli, S. Ryegate, C.
Zambion, Peter, S. Ryegate, C.

BARTON.

Barton Granite Co., Q.
Ray, E. F., C.
Ward & Company, C.

OTHER PARTS OF THE STATE.

Ayer, E. S., West Danville, C.
Calais Granite Co., Calais, Q.
Chapman, W. J., West Concord, C.
Clark, James, West Dummerston.
Daniels, J. C., West Concord, C.
Goss A. J., West Danville, C.
Grant, C. H., Granite Co., Dummerston, Q. C.
Grout Granite Quarry, West Concord, Q.
Haselton, Charles, Beebe Plain, Q.
Kearney Hill Granite Co., West Concord, Q.
Lake Shore Granite Quarry, Adamant Q.
Newport Granite Co., Albany, N. Y. Quarry at Derby.
Norton, S. B., Beebe Plain, Q.
Stanstead Granite Quarries Co., Beebe Plain, Q.
Tillcrop Granite Co., West Concord, C.
Union Granite Co., Calais, Q.
Union Granite Co., Morrisville, C.
Welch, Joseph, West Concord, C.
Williamson, Harry W., Concord, C.

Granite also occurs in Albany, Newark, Cabot, Lowell, Randolph and some other towns, but is not quarried in these places.

According to the latest figures given in Mineral Resources, 1913, the output of granite from the whole State was valued at $2,829,522. This is obviously in need of explanation in the light of the figures given before of the wages paid, for according to the best available authorities in Barre and Hardwick the annual payrolls amount to $4,725,000 and if we could add to this the total of all the numerous lesser centers and only the largest of the Hardwick companies, certainly several hundreds of thousands of dollars are not included and so far as I can reach a reasonable estimate it seems pretty certain that little less than $6,000,000 are annually paid out in wages by the different granite firms doing business in Vermont. If this be so, then it follows necessarily that the amount of granite sold must be more than $6,000,000 for nearly all the companies report that business was never better and is satisfactory.

A partial explanation is found in the reply to enquiries made at Washington as to the published figures.

The Statistician in charge wrote as follows:—"I have noted what you say as to your belief that the value of the stone production of Vermont is understated, particularly the granite. An explanation of this lies in the fact that the values reported to this office cover the output of stone reported by quarrymen and not by stone cutters. These values do not include the value of any stone dressed by the various granite manufacturers * * * * * who do not quarry their stone, but buy from the quarrymen. If you take the stone sold in the rough, deduct from it say 10% for waste in cutting and value the cut stone at the average price at which dressed stone is sold by the quarrymen, the value of granite produced in Vermont in 1912 would exceed $6,000,000. This presupposes that all of the granite was dressed in the State, but a considerable quantity of Barre stone is shipped in the rough or partly finished state to various granite cutting shops all over the United States. Therefore the industry in the State of Vermont will probably amount to not quite $6,000,000."



As the above list shows there are in the State 210 quarrying companies that cut and finish granite. In and about Barre alone there are now 14 quarrying firms, some of them working a number of quarries, and 75 cutting plants. In these there are nearly 5,000 men employed and the annual payroll in Barre is, according to the Secretary of the Granite Manufacturers' Association, $3,725,000, and in 1913 the output was 261,776 tons, including all sold both in the rough and finished. Besides the above, 600 car loads of paving blocks and a large amount of crushed stone were sent out from Barre. The first named output in cubic feet would be 81,156,760.

Barre claims to be the largest producer of granite in the world and the above figures seem to prove the claim. As the list shows, many of the cutting sheds, as all the works are locally called, are in Montpelier, which adjoins Barre on the west.

Next to Barre, the towns of Hardwick and Woodbury, which must be considered here as one, for they form a single granite center, should be named. Most of the quarries are in Woodbury and most of the cutting plants in Hardwick which is on the railroad. Dr. Richardson has given the main facts as to this region in the article on the Geology and Mineralogy of Hardwick and Woodbury that the reader is referred to that for further information. Probably the plant of the Woodbury Granite Company at Hardwick is the largest anywhere. Certainly this is true if to the Hardwick plant of this company there is added their plants at Northfield and Bethel, both of which are very large. The payroll of this company alone is over $1,000,000 annually. The white granite which has been used during the past few years in some of the finest public buildings is quarried by this company at Bethel. The main business of the company is in supplying stone for building, though they do monumental and other work.

At Ryegate and Groton there are a number of quarries and cutting sheds.

In addition to the localities given, granite is quarried and worked in Derby, Burke, Barton, Adamant, Concord, Rochester, Kirby, Dummerston, Topsham, Windsor, and there are deposits that could be worked in Williamstown and Windsor,

This applies to 1912 and it is I think on this basis safe to estimate the output as above, i. e., over $6,000,000 for 1913-1914, and is much nearer the truth than the statement given in Mineral Resources.

Why granite is estimated differently from other stone does not appear evident to the writer.

## SLATE.

A very large part of the slate sold in Vermont is in the form of roofing material. Formerly there was quite a large business done in what is called mill stock, i. e., slate sold in slabs or blocks for table tops, stair treads, wainscoting, switchboards, etc., and this business has not entirely ceased by any means, but in 1907 there was a serious strike in the mills producing mill stock and in course of time much of the old business went to the Pennsylvania mills or elsewhere and much of it has never returned to Vermont. The roofing slate business has been very good for the last two years. There are reported as active forty-five slate companies in the State. These produce several varieties as sea green, unfading green purple and some intermediate grades.

The sales of slate during 1913 amounted to nearly $2,000,000.

The following is a list of such slate companies as are at present doing business.

### LIST OF VERMONT SLATE COMPANIES.

CASTLETON.

Criterion Slate Company, Hydeville.
Hayes Slate Company, Hydeville.
Hinchey Brothers, Hydeville.
Hinchey, O. & Company, Castleton.
John J. Jones Slate Company, Castleton.
Minogue Brothers & Quinn, Hydeville.
Metalo Slate Company, Hydeville.
Penryn Slate Company, Hydeville.

FAIRHAVEN.

Bedford & Ryan Slate Co., Fair Haven.
Durick & Flannagan, Fair Haven.
Durick & Keenan, Fair Haven.
Durick, Keenan & Flannagan, Fair Haven.
Fair Haven Marbelized Slate Company, Fair Haven.
Jones & Francis, Fair Haven.
McNamara Brothers, Fair Haven.
Mahar Brothers, Fair Haven.
Vermont Unfading Green Slate Company, Fair Haven.
Victor Slate Company, Fair Haven.
Young, A. B., Fair Haven.

POULTNEY.

Auld & Conger, Poultney.
Eastern Slate Company, Poultney.
Eureka Slate Co., North Poultney.
Frasier Slate Company, Poultney.
Green Mountain Slate Co., Poultney.
Griffith & Nathanael, Poultney.
Hughes-Snyder Slate Co., Poultney.
Johnson, E. J. Slate Co., Poultney.
Roberts & Rowland, Poultney.
Matthews Slate Company, Poultney.
Parry, Jones & Owens, Poultney.
Poultney Consolidated Slate Company, Poultney.
Rice Brothers, South Poultney.

PAWLET AND WELLS.

Layden & Burdick, West Pawlet.
Hughes, W. H. Slate Company, West Pawlet.
Nelson Bros. & Morow, West Pawlet.
O'Brien Brothers, Wells.



Phoenix Slate Company, West Pawlet.
Rising & Nelson, West Pawlet.
Roberts, G. T., West Pawlet.
Williams, R. Scott, Slate Company, Wells.

GRANVILLE, NEW YORK, QUARRIES IN VERMONT.

Norton Brothers, Granville, N. Y.
Owens, O. W. Sons, Granville, N. Y.
Sheldon, F. C., Granville, N. Y.
Vermont Slate Co., Granville, N. Y.

## SOAPSTONE AND TALC.

These materials have been so fully treated by Professor Jacobs on preceding pages that no further discussion is needed here.

The production of talc and soapstone for 1912 is given in Mineral Resources as $275,679, but Professor Jacobs, who has visited all the mines in the State gives the amount for 1913 as $327,675.

## CLAYS.

At present there are the following active companies in the State, viz.:

Horn-Crockett Company, Brandon works at Forestdale.
American Paper Clay Company, Rutland.
Rutland Fire Clay Company, Rutland.
E. L. Sibley, Bennington.
E. F. Rockwood, Bennington.
S. C. Lyon Brothers, Bennington.

The first two and last named produce white clay, the Rutland Fire Clay Company sell a variety of products obtained from several different kinds of clay which they dig. Messrs. Sibley and Rockwood produce yellow clay, ocher.

In all over $100,000 worth of clay is annually sold. This is exclusive of bricks which are made in a number of localities.

# INDEX.

PLATE I


**GEOLOGIC MAP OF MARBLE BELTS OF WESTERN VERMONT, SOUTH OF SALISBURY**

Topography by U. S. Geological Survey

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 40 feet.

Geology by T. Nelson Dale and F. H. Moffit, at intervals during 1888-1904