REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1931-1932

EIGHTEENTH OF THIS SERIES

GEORGE H. PERKINS
State Geologist

FREE PRESS PRINTING CO., BURLINGTON, VT.

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STATE OF VERMONT

OFFICE OF STATE GEOLOGIST

BURLINGTON

To His Excellency,

Stanley C. Wilson, Governor of Vermont:

Sir:—In accordance with Act 405 of the General Laws of Vermont I herewith present my Eighteenth Report as State Geologist.

Hoping that the following articles may be interesting and useful to the citizens of the State as well as to others outside of Vermont, this Report is very respectfully presented.

GEORGE H. PERKINS,
State Geologist.

JANUARY 5, 1933.

THE MARBLE INDUSTRY OF VERMONT

George H. Perkins

State Geologist

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INTRODUCTION

Nearly twenty years have passed since in the Report of the Vermont State Geologist an account of the marble industry of Vermont was published. All copies of this volume were called for and sent out not long after it was ready for distribution. During the intervening years there has been frequent demand from far and wide for information such as is attempted in the following pages; moreover there have been many changes, some of them important, since the volume above mentioned was issued. For these and other reasons, the writer considers a restatement of the facts given in the former volume desirable. While he would not claim that this account is entirely complete, it is certainly the most so that has hitherto been issued.

It has not been possible to collect an absolutely complete statement of all that may be desired concerning this industry. It may, however, be truly said that it has been the desire of the writer to make the following discussion of all that pertains to the marble industry satisfactory to all who are interested in it. It has been the aim of the State Geologist to present in a simple and untechnical form such phases of marble quarrying and finishing as he could learn from observation and from marble workers. He has had in mind not only the many readers who are especially interested in the business, but as well those not so directly connected with it, all the citizens of Vermont, for directly or indirectly, every Vermonter is interested in this, one of our most important assets.

In course of following pages it has been necessary to refer to many of the minerals and rocks associated with the marble and those who wish fuller information as to these are referred to articles by the writer on "The Minerals of Vermont" in the Reports of the State Geologist for 1928 and "The Rocks of Vermont" in that of 1930. In some respects the following pages are to be regarded as a compilation rather than original, it being far more the desire of the writer to present a full and accurate account of the marble industry than to write an essay about it.

As the reader will soon find, there are extensive quotations from various writers, who the writer of this considered good authorities, as also many other statements which are taken from interviews with those who were actively engaged in the business. It may be well to notice that, unless stated otherwise, what is here given refers only to the marble work in Vermont, yet much is

applicable to any other marble-producing region, wherever it may be.

The marble companies of Vermont, manufacturers of marble-working machinery, and others especially interested in the subject, have been most cordial and generous in rendering aid in the preparation of the following pages. Especially helpful have been the following, as will be understood later.

To the Vermont Marble Company I owe especial thanks not only for much information, but also for the loan of a large part of the illustrations, without which much of the value of this account would be lost. To Mr. F. C. Partridge, Mr. David C. Gale, Mr. Nathaniel C. Peterson and others of this company, Mr. F. R. Patch of the Patch-Wegener Company, Mr. Major Jenks from whose thesis on "Marble Quarrying in Vermont" I have taken much, Mr. Ernest H. West from whose report to the Vermont Marble Company on the Dorset area much has been quoted, Mr. R. W. Reynolds, Colonial Marble Company, Mr. E. J. Raverty, New Albany Machine Manufacturing Company for illustrations, Mr. S. A. King, Sullivan Machinery Company, Mr. Newman C. Chaffee, Mr. W. C. Cash, Ingersoll-Rand Co.

Further reference to some of these gentlemen will be made in what follows.

The author of these pages wishes it understood by the reader that, while he has quoted freely from various writers he does not necessarily endorse all the opinions expressed. There are many as yet unsettled points in the discussion of Vermont geology and some of these come into the considerations of the marble regions. As to these disputed points the writer simply presents them and does not wish to be held responsible for all ideas here presented.

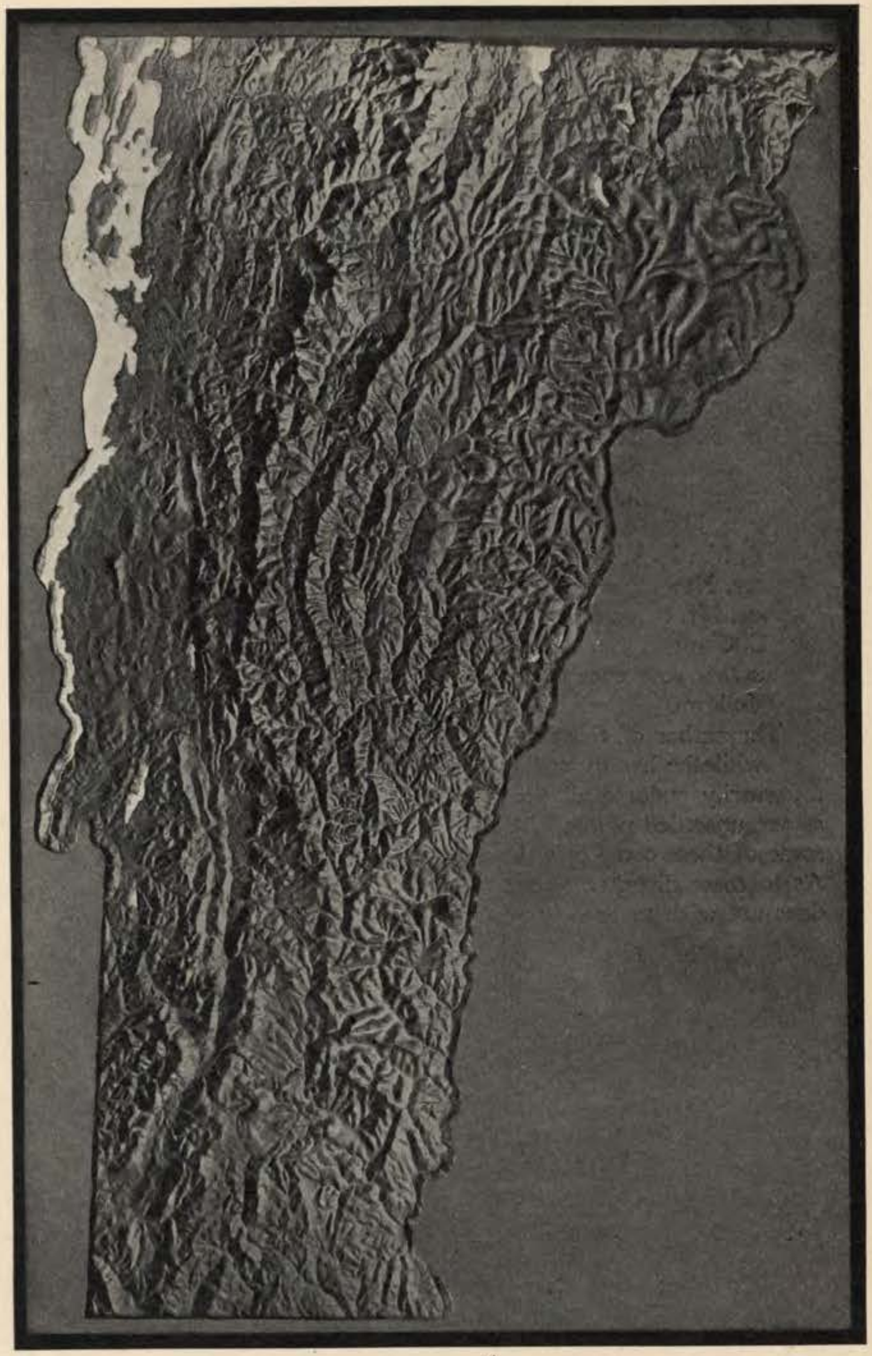

FIG. 1. Relief map of Vermont. (Courtesy of Vermont Commission on Country Life.)

PHYSIOGRAPHY OF VERMONT

Only as related to marble deposits can this subject find place in the discussions that follow. One who is at all familiar with the more prominent physical features of this State must be impressed by the charm of the scenery. He must also realize the lack of large level spaces. Elevations from low hills to the higher mountains are never far away. No one can fail to be pleased, if not delighted, as he looks about him almost anywhere in the State. But while this will surely be true, many will not think of the economic value of the ever-present irregularities of the surface. The origin and development of marble will be considered later. It is sufficient to call attention now to the fact, and a very certain fact it is, that had Vermont not had the geologic history that is written everywhere it could not have become the great producer of marble that it has been for so many years. I do not mean to say that all that has taken place in past geological times has had much to do with the making of marble, but I do mean to say that had not some of the geological forces and changes which were active, at what may be called an epoch, in the building of hills and mountains, been so active no marble would have been formed and a very important part of the industries of Vermont would not have existed. The great marble areas of the world, in this country and everywhere, are in mountainous regions, Carrara, Pentelicus, etc. It requires only a brief study of the map (Figure 1) to show how uneven and disturbed is the surface of the State, as now seen, and it is not difficult to understand that not all but some of the forces and processes that have made the State what it is have made the marble what it is. Of the map as shown here let me add that in the original, which is in the Museum of the University of Vermont, the utmost accuracy is obtained by using the Topographic Maps of Vermont made in cooperation with the United States Topographical Survey and the employment of skilled workmen in construction. The model from which the photograph is taken is eighty-five inches long and fifty-four inches in greatest width. No representation of the surface features of Vermont has ever been made, or at present can be made, which so accurately shows these features as does the original model, which necessarily suffers much from its reduced photograph as here shown. The reader, who may be interested in what has just been written, will find on pages 17 and 40 in this volume a much more complete account of the formation of marble. In the Report of the Geologist for 1930 will be found an extended discussion of "The Physiography of Vermont" to which the reader is referred. This volume may be found in most libraries in the State.

DURABILITY OF MARBLE

Enquiries sometimes come to this office as to the ability of marble to endure the effect of long exposure to climatic conditions. Many suppose that a hard stone of any sort is less affected by weathering than a softer variety. Hard stone, very hard, may be very resistant to destructive agencies, as many ancient obelisks and statues prove, but many are not. It all depends upon the composition. Dikes are usually of very hard stone as some varieties of trap, but in many cases the hard stone of a dike decomposes faster than the much softer and apparently less durable limestone or marble through which it has made its way to the surface. Many examples of this may be seen on some of the shores of Lake Champlain where one can row a boat for several feet inland between walls of limestone because the hard stone of the dike has been so acted upon by atmospheric acids, etc., that it has decomposed and, therefore, fallen away, while the limestone stands out into the lake. Of course, this is limited in its application—the softer stone must not be too soft, but it is far less the hardness of a rock than its chemical composition that determines its resistant power. A basalt dike may be decomposed and to a greater or lesser extent be washed out leaving a sharply defined channel into which one may row his boat, as mentioned, or when a dike is of different composition, the stone on either side may be most easily decomposed and then the stone of the dike projects into the lake—it may be for several feet. But there is abundant proof other than this that limestone and marble are able to endure when variously exposed. Except where glaciation is still evident, as it is in places in Vermont, we are not able to look back very far in this country, but when we turn our investigations to the east and look at some parts of Europe or Asia or Northern Africa we can follow the history of marble, and other kinds of stone, though to a far less extent, through many centuries. An English writer has well said, "We are indebted to incised marble for most of our early records." He should also have said that had marble been less durable these valuable records would not have been available. It may also be noticed that the very wide distribution of marble and much the same may be said of limestone, many of the records would have been lost or never been carved. Still

standing exposed, as for centuries they have been, we may now see many of the ancient monuments of Greece, Rome and older nations, as Egypt, some of them still even in their ruins in far from ruined condition. Others buried in the slime of rivers, the sands of the adjacent sea or the soil of the farmer are continually coming to the light of day to add to our knowledge of the long past.

But some may say, "These remains are of stone, and have been exposed to climate, of a different sort than we experience in Vermont or anywhere in this land." As to the marble, much of it is nearly or quite the same, and as to climatic effect let us see. Of course, one cannot go back to a time before the early settle-

FIG. 2. Old headstone in Bennington churchyard. Vermont marble, erected 1768.

ment of the State nor until the settlement became established and we must deal with what evidence is possible and here all the evidence which can be found as far as it goes adds to what has been written. In Figure 2 is an example.

There are many gravestones in and near Vermont which have stood for more than a century and are still in good condition.

But occasionally still more astonishing evidence of age is found. On the top of what is known as High Street quarry in Brandon, a surface of a marble deposit was uncovered and plainly seen there were glacier scratches completely covering the otherwise smooth surface, yet for what may be called ages these had remained clearly distinct as Figure 3 shows. Nor is this the only example of the kind in the Vermont quarries.

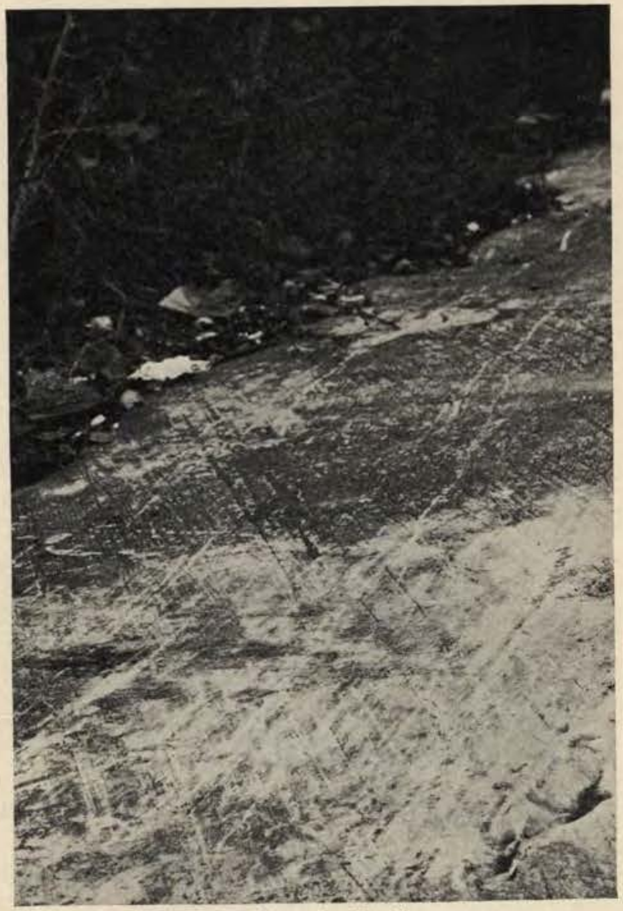

FIG. 3. Glacial marks, Brandon quarry.

Examples of many buildings in which Vermont marble appears show its value.

It is hardly necessary to add that all the most ancient relics of early man are such as could be used as weapons or implements, for these were what man must have if he lived. Only hard material was useful for these early weapons and tools and such stone as flints or quartzite would answer the purpose. Therefore, it was not until man had developed sufficiently in civilization that

not only the need for ornamental objects, even the thought of them, arose, and then softer stone could be used. Hence, no one expects to find marble nor stone like it in any of the older deposits of human remains. But even in some of the very ancient accumulations of humanly made objects, not the oldest, but old, a few objects of marble have been found. Many years later, when men were at least half civilized, do buildings of any sort appear and, of course, as a convenient and very suitable stone in constructing even rude huts and shelters marble began to be used. When this was no one knows or even guesses. It was very long ago. In Vermont, as has been noticed, the use of marble could not begin, even in the simplest manner, for hearth stones, and in other structural work in the early homes of the early settlers, even for gravestones, etc., until other and more necessary objects had been attended to. Surely the conspicuous outcrops of light marble here and there, especially in the western part of Vermont, must have attracted the notice of the first settlers. When, as they probably soon did, they found that out of these ledges of pretty stone pieces might be split that could without very great labor be extracted from the larger mass, the value of such material and its utility for many purposes became apparent. When it was found that by heating a mass of this stone and when it was hot dashing cold water over it and with some sort of chisel it could be rudely wrought into slabs suitable for head stones, the beginning of its present uses came. But there is abundant evidence that Vermont marble was used in more prosaic ways, as Figure 4 shows. Here we have the lower part of a chimney taken from one of the oldest houses in which the fire-place and borders of oven doors were marble.

FIG. 4. Old Vermont chimney, after the house of wood has fallen away. Built 150 years ago and faced with marble slabs from Dorset quarries.

It is obvious that no one who uses good Vermont marble for any purpose need fear lest it shall not last as long as he is likely to want it, and much longer. It may be well to remember that what is here written does not apply to every variety of the stone. Some of the very charmingly shaded or colored marbles are disappointing when used in outside work because of the fading after a time. These are for inside work, where they do not fade. But most of these marbles do not fade indoors or outside and the dealer can inform the buyer as to this.

It may be well to notice in this connection that these old stones were, as compared with modern monuments, very rudely finished and for this reason less fitted to withstand weathering than modern stones of identical composition. Also the older slabs were split from poorer stone than that now used, as in most quarries the stone at or near the surface is thrown aside and only that deeper down in the beds is considered suitable for use.

"The old cemetery in Bennington contains over a hundred headstones made from slabs set up before 1800. These are mostly, if not all, of Dorset marble," Zephine Humphrey states in "The Story of Dorset." "Isaac Underhill opened a quarry for marble to be used for fire jambs, chimney backs, hearths and lintels; this was in 1785." Before this a stone slab was set up at the grave of John Pratt in the cemetery in Bennington in or about 1768. This was also undoubtedly Dorset marble.

RESISTANCE TO FIRE

Vermont marble has been found, when tested to withstand damage from fire, much better than many other building stones. In a publication issued by the Vermont Marble Company there is the following statement, "Vermont marble will stand a heat of 1,200° Fahrenheit without injury. The Security Savings Bank, San Francisco, a Vermont marble structure, was in the path of the great fire (of 1906). Adjoining buildings of brick and stone were ruined by the intense heat, but the Security Bank remained intact. Several other cases of this kind could be cited." When heated, marble does not crack as do many building stones.

ABSORPTION OF WATER

The absorption of water from the atmosphere or ground is in some cases an important item in the durability of a stone. As to this it is found by tests of the United States Bureau of Standards that the Vermont marbles absorb very little when tested. The report of the Bureau of Standards is as given below:

100 pounds of	*Absorbs*
Troy white granite	0.269 lbs. of water
Silver gray Georgia marble	0.131 lbs. of water
Gray Vermont marble	0.122 lbs. of water
Brandon marble	0.116 lbs. of water
Pittsford Italian marble	0.108 lbs. of water
Pittsford Valley marble	0.106 lbs. of water
Riverside marble	0.103 lbs. of water
Danby marble	0.102 lbs. of water

The above table shows that ordinary Vermont marble is less absorbent than any of the ordinarily used building or monumental stones.

"In the flood of 1913, the Vermont marble interior of the City National Bank of Dayton, Ohio, was subjected to an unusual water test. Although it was submerged for three days, all that was needed to restore it to its original condition was a little cleaning."

CRUSHING STRENGTH

I am often asked by prospective builders to give the "compressive strength" of this or that Vermont building stone. As to this I can do no better than to quote from a published statement of the Vermont Marble Company: "The importance of crushing strength is greatly overestimated. There are few stones on the market that will not support ten times as much weight as is ever required of them. In case of cemetery memorials particularly, this has no real significance. Some rocks which test unusually high in compressive strength are far less durable than others of lower test. It means little to the average person to say that such a stone will stand so many thousand pounds to the square inch. It is much simpler to say that the marbles we recommend for exterior building work and cemetery memorials could be used in the base of a tower two and a half to three miles high before failure from compression would result."

WHAT IS MARBLE?

Anyone looking over a considerable variety of pieces of "marble" is likely to find very great difference in the samples, not only in color, but in the very evident variety in texture, composition, etc., of the stone. He soon realizes that some of the samples of "marble" are not at all the same sort of stone as others. In short, not all that is called marble in trade is marble in the scientific use of the term. In the following pages the writer will often follow the popular use, but before going further it will be well to ask what really and truly is marble. This is not to find fault with popular custom, even when it goes so far as to call nearly all stone, not granite, marble if it can be carved or polished. Here in Vermont we find marble often enclosed or surrounded by wholly unlike rock, schist, quartzite, limestone. Evidently none of these have close relation to marble and yet in some cases they seemingly, at least, merge into each other. A geologist will declare that some of the schist is of similar formation to marble. (For fuller account of the rocks mentioned, see Sixteenth Report.) Both schist and marble are more or less crystalline, but in texture and many other respects they are very different. In the briefest statement marble is metamorphosed limestone. But what is limestone? As the name implies, limestone always contains a large proportion of lime, as every limekiln burner knows. To begin at the beginning in answering the question we go back of limestone to water, usually sea water. Living in all seas, as all know, there is a multitudinous life of almost infinitely varied species, and also lime-producing plants. Disregarding many animals, as fishes, it may be said that in corals, shells and, to a lesser degree, other animals, incalculable amount of lime carbonate is always present and as in ancient seas, so now is this true. Sea water is full of lime carbonate, as well as many other minerals. From this water the animals and corallines take the lime, die and leave the lime in the sea from which it came. Of course, originally it came from the solid materials of the land. For age upon age this interchange has been going on. The animals have in course of generations come and gone, taken the lime from the sea, and have deposited it in the form of limestone on the sea floor, the shells, corals, and all the rest, being broken into small bits or more or less dissolved or entire, and all stages between. This may be illustrated by a bit of the coquina stone common in southern Florida. As all familiar with this stone know, it may be made up entirely of shell sand, it may be made up of shell sand, or larger bits, or entire shells. Finally the coquina, subjected to the various conditions about it, becomes solid stone, limestone. In taking up the geology of marble further discussion of this matter will be read. Here it is sufficient to notice that in time coquina becomes limestone, and limestone under geological conditions to be mentioned becomes more or less completely changed into marble (see page 13). This should show what is meant when it is said that true marble is metamorphosed limestone. All the marbles of the Marble Belt of western Vermont are true marble; the so-called marble of Roxbury is not, as are not the Champlain "marbles" of Swanton or Malletts Bay or the "black marble" of Isle La Motte which is unchanged limestone. However, as already said, for common use the common name is well enough. Scientifically, only the metamorphic stone is called marble. Further definitions are as

follow: The Century Dictionary gives a very good general definition, "Marble is a metamorphic limestone in which the particles and fragments of organic origin have been converted into crystalline or crystalline-granular condition." In Chamberlain and Salisbury's "Introduction to Geology," "In pure limestones and dolomites little chemical change takes place, but the molecules are rearranged into larger crystals, making marble."

Scott's "Introduction to Geology" tells us, "Marble is metamorphic limestone in which the particles and fragments of organic origin have been converted into crystalline calcite. Magnesian limestone yields dolomites which are likewise included under marble." Also, "In the processes of reconstruction the fossils and even the bedding planes are usually entirely obliterated. The grain of the rock varies from the fine, dense, loaf-sugarlike statuary marble to a very coarse texture of very large crystals. Pure limestone gives rise to a white marble but the presence of organic matter is betrayed by veins of graphite, which may indicate the lines of mashing and flow, along which the rock yielded to the compressing force. . . . But not all crystalline limestone may be called marble for the crystallization may be the work of surface waters at ordinary temperatures. Such non-metamorphic limestones differ from marbles in being less hard and in retaining the fossils and the stratification planes which they originally had. Other crystalline limestone, like stalagmite and stalactite and travertine were deposited from water. Marble is an exceptional case of a completely crystalline rock derived from sediments by dynamic metamorphism, which is not foliated nor schistose. This I believe to be due to the capacity of calcite after crushing and mashing." Schuchert and Pirsson, "Textbook of Geology," "This (marble) is the metamorphic condition of sedimentary rocks formed by lime deposits, such as limestone and chalk. Generally the marks of bedding, fossils, etc., are obliterated and the material converted into crystalline grains of calcite. It is, therefore, harder, more compact, with purer colors, and takes a good polish. Marble is massive and shows no cleavage even when found in regions where its association with schists shows that it must have been subjected to enormous pressure, mashing and shearing stresses."

METAMORPHISM

As the term metamorphism has been often used, and will be in what follows, it may add to the reader's understanding of the subject if it is explained just what geologists mean by metamorphism.

As to this I cannot do better than to quote from the work mentioned above, showing the change in limestone as it becomes marble. Textbook of Geology, Part I, page 317. "The outer part of the earth may be divided into different zones according to various geological activities going on at different levels. Below the layer of soil the bedrock is full of fractures and as far down as the surface of ground water it is exposed to atmospheric agencies, the moisture, carbonic acid, etc., which tend to cause decay and convert the rock into soil. It is a zone of rock destruction. Below this belt comes the zone in which the rocks are full of cavities and fractures filled with water. The upper limit is the surface of the ground water, the lower that where openings cease, the zone of fracture if we disregard the upper limit. In this the action of water is most important, it performs chemical work aided by the carbonic and other acids it may carry. Substances are taken into solution and added to by those leached downward from the belt of weathering, are deposited in the pores and fissures of the rocks. From this cementing and filling of the cavities it may be termed the belt of cementation. Below this comes the zone where the pressure of the superincumbent masses is greater than the elastic limit of the strength of rocks; they crush under it and are to be regarded as being in a relatively plastic condition. As a result all openings and fractures are closed, and this must mark the limit downward of the percolation of ground water. The upper limit of this zone is variable and depends upon geological conditions in times of quiet it may be fifteen miles below the surface; in times of compression and mountain making it may be at a much less depth. Where its lower level may be, we do not know. In this zone the enormous pressure and increasing heat of the earth are the chief agencies; liquids and gases are less important, and tend to be squeezed out. . . . It is chiefly in the lower part of the belt of cementation, or zone of fracture, and in the upper part of the zone of rock flowage that the work of producing metamorphic rocks, as we know them, is done." It is evident from the above that a metamorphic rock is often very unlike that from which it has been formed. In color, hardness, texture, chemical composition, perhaps in other respects, it may be very unlike its source. I have dwelt upon metamorphism more than I should if it were not very common in Vermont. Indeed, the larger part of Vermont rocks are metamorphic. All the rocks of the Green and also the Taconic Mountains are of this kind, as are most of the schists and slates that lie along the mountain borders. Hence, anyone who wishes to understand Vermont geology must be in some measure familiar with metamorphic processes. In different parts of the State the degree of change is not the same. In some, as the Roxbury serpentine, or the Green Mountain gneiss, it is very complete, so that in some cases it is difficult to discover by examination of the rock from what it originally came and from this complete metamorphism there are all sorts from rocks that are only changed to a small extent, though the latter are not common. In many parts of the State geologists are reasonably certain in their estimate of the age, origin and general character of Vermont rocks, but all doubt has not been removed and if one geologist is certain, his companion does not always agree with him. It is not many years, as geological history is reckoned, since the age of the great marble masses of western Vermont was known and settled. It is an interesting fact, that, after geologists of the best sort had explored the State for many years and reached no, or few results that are now accepted, the most important discovery was made by a country minister in Whiting to whom allusion has been more than once made in previous Reports. The Rev. Augustus Wing (see Life of A. Wing, Third Report Vermont Geologist, page 22), by most patient investigation, first in Addison County and later elsewhere, first in the sixties found fossils, without which geologists are usually perplexed, by means of which he found a satisfactory clue, which being carried on by others, determined the age of the western marble belt and more or less surely the age of the Green Mountains, thus opening a trail which has led to very important results and ultimately will settle most of the mooted questions in Vermont Geology. One point should be mentioned to be exact. This is that it is possible to form metamorphic rocks from those of igneous origin, though not usual. It may be noted in passing that besides sedimentary and metamorphic rocks we have igneous rocks in our granite and dikes.

In this discussion it will sometimes be necessary to refer to calcite marble and dolomite marble. Both varieties are true marble, or may be. Both may occur in the same quarry, or in separate quarries, as will be seen when special quarries are taken up. In some cases there is little difference in appearance. The calcite marble usually effervesces much more strongly when exposed to acids, is less hard, often less compact in texture, less complex chemically. Any of the West Rutland marbles are good examples of calcite marble; Dorset marble is somewhat dolomitic; "Champlain marble" is more dolomitic.

The total area in Vermont in which marble of any kind is found is not large, yet within this comparatively small area a very considerable variety not only in appearance, but in chemical composition, may occur. Sometimes in a single quarry, as in the old Eastman quarry at West Rutland, many varieties have been found (see pages 90 and 91). Calcite marble and dolomite marble have been mentioned. Between these two kinds there are numerous grades. Before going further it may be well to make as plain as possible the difference in chemical composition which some of the Vermont marbles present.

Calcite is pure carbonate of lime. Dolomite always contains more or less magnesia in addition to the usual composition of the calcite marble. It must, therefore, always be more complex. The following records (page 17) of actual analyses show the chemical difference found in calcite marble, dolomite marble and unaltered limestone. The composition here given is not necessarily that of every piece of the stone in hand. In most, or at least in many sorts called in general by any one of the above names, there are other materials than those that are predominant, of which there is more to be said.

Calcite is, when pure, crystallized carbonate of lime. It is not only forms the main component of calcite marble, the most common form of this stone, but it is everywhere, in all limestone and in many other rocks, though not as large a component. As a mineral, it may often be clear and transparent as in Iceland spar, or it may be milk white, or of many shades. In many samples it closely resembles quartz in appearance, but is easily distinguished from it by its softness, being readily scratched, and the shape of its crystals, as by its brisk effervescence when acid is applied. Other differences may easily be noticed, and some have already been. Dolomite, besides lime, contains always a considerable amount of magnesia, while limestone is largely carbonate of lime, but it is not in any way metamorphic, as is invariably true of the other two. Expressed chemically, calcite is $CaCo_2$; dolomite, MgCa ($CaCo_2$), and limestone, $CaCo_2$. This is the simple mineral, but many other elements are generally present and, as elsewhere noticed, materially affect the color and character of the stone. As one would suppose, there are endless varieties in the marbles of different quarries, but in a general way they are as stated above. By comparing the analyses here given, the essential character of each may be understood. The first list is an average of calcite marble from West Rutland, as given by Dale.

$CaMg(Co_3)_2$

ANALYSIS OF CALCITE MARBLE, WEST RUTLAND, LIGHT COLORED

Carbon dioxide, CO_2	43.66
Lime, CaO_2	55.15
Magnesia, $MgCO_3$	.15
Alumina and iron oxide, Al and FeO	20.
Alumina silicate, AlOSiO	trace
Insoluble	.40
	99.56

ANALYSIS OF DOLOMITE MARBLE. DORSET

Carbon dioxide, CO_2	41.46
Silica, SiO_2	8.16
Alumina, Al_2O_3	1.16
Iron oxide, 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	.05
Water in combination	.42
	100.00

ANALYSIS OF LIMESTONE (BLACK MARBLE). ISLE LAMOTTE

Calcium carbonate, limestone, $CaOCo_3$	87.34
Magnesium carbonate, MgCO	4.56
Alumina and iron, Al_2FeO_3	26.60
Silica, SiO_2	4.80
Water, H_2O and loss	.10
Manganese oxide, Mn_2O_3	trace
	123.40

The difference between calcite and dolomite, as well as the close resemblance between calcite and limestone, is evident from the above analyses. Calcite is pure carbonate of lime, dolomite is carbonate of lime and magnesia, limestone is carbonate of lime, but not metamorphosed as it is in marble. Then, too, in dolomite limestone and marble there are usually several other substances in addition to those named above. In the formation of these rocks the amount of magnesium varies very greatly, so that there is pure marble and dolomitic marble, and all grades from pure calcite to many kinds of dolomitic marble and to essentially pure dolomite. As to the origin of these stones, somewhat has already been given, and it is not necessary to add much more. It may be of interest to some of my readers if I quote somewhat from what Mr. Dale has written on this subject (Bulletin 526, U. S. G. S.). Mr. Dale writes of the difference between calcite and marble and dolomite as between limestone and marble as follows: "If a chemical precipitate of carbonate of lime is examined microscopically it will be found to be composed of infinitesimal irregular 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 the microscope is seen to be an aggregate of transparent crystalline plates, generally of irregular outline, of calcite or dolomite, with the rhombohedral cleavage characteristic of these minerals and also crossed by twinning planes. These twinning planes, which are so conspicuous in a 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 the marble is the plane along which the two crystals meet. But as the 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. The difference between these semi-granular limestones and a true marble appears in polishing. . . . The microscopic appearance of many of the Vermont marbles affords much of value and interest, but as few of those who read this account will have the equipment needed for such examination of specimens, those who are especially interested in so studying our marbles are referred to Dale's investigations given in United States Geological Survey Bulletin 526, where a considerable number of microscopic sections are figured and described. These are also reproduced in the reprint of this Bulletin in the Ninth Report of the Vermont State Geologist, which though long since out of print, may be found in many libraries. The cuts of microscopic sections of various varieties are scattered through the above-named bulletin but may be easily found by looking over the "List of Figures" in either the Bulletin or the reprint in the Vermont Report.

Mr. Dale writes as to the microscopic features of the calcite marbles as follows: "The grains of calcite in the calcite marble

never show crystalline 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 denticular outlines. . . . In beds which have suffered much compression the grains are very perceptibly elongated in, at least, one of their directions and probably in two. . . . The effect is to give a degree of schistosity to the marble so that it breaks more readily along the bedding plane. . . . 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 in diameter than the calcite, but of more regular outline and here and there of crystallographic form (rhombohedron). The marbles of the Clarendon Valley, Landon and Hollister quarries show this feature."

As has been stated, limestone is usually formed in sea water, but not always. It may be, and sometimes is, formed in fresh water and rarely chemically. Until comparatively recent times geologists believed it to be a deep-water formation, and undoubtedly it is sometimes formed in deep water, but it is far more often formed in comparatively shallow water; this is water less than 100 fathoms deep (600 feet). The whole story of the formation of dolomite has not yet been told, but it seems pretty certain that in part it is formed from limestone by chemical action by which a part of the calcium is replaced by magnesium, but the manner of substitution cannot be stated. As has been already stated many of the commercially valuable marbles of Vermont are more or less dolomitic, that is, they contain variable quantities of carbonate of magnesia. It may be said that there are many opinions offered by many geologists as to the real origin of dolomite, but none have been unqualifiedly adopted by geologists in general. Very probably several theories may be correct, that is that dolomite may have been formed in different ways in different localities and under different conditions. According to Dale, two varieties of dolomite marble are to be found, what may be called coarse grain and fine grain. Both are harder than most calcite marbles. Each may best be distinguished by the microscopic structure. Both are brilliant marbles and take a fine polish, though more difficult to polish and, generally, to work than the calcite marbles. Dale says that "the lower 680 feet of the Vermont calcareous belt consists mainly of dolomite. . . . As appears from detailed sections and from the stratigraphic succession the marble beds are interbedded with dolomite." By way of showing how interbedded and mixed up the marble beds are, Dale mentions the following: "At the unused Sutherland Falls, now Proctor, quarry, the calcite marble beds, roughly estimated at 100 feet thick, but in part doubled over so as to measure apparently 200 feet, are overlaid on the west by dolomite and on the east by another dolomite. The dolomite on the west side, which is followed farther west by calcite marble, consists of dolomite granules, surely rhombs, having an average grain diameter of 0.4 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."

Also of the True Blue quarry: "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 an inch and an eighth inch to 16 feet thick, alternating with beds of calcite marble. The whole series measures 280 feet 7 inches thick, out of which the dolomite beds measure 73 feet 9 inches."

A drill core in 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. In this section they seem to consist of graphitic dolomite. Analysis of the dolomite in one of the Dorset quarries is given on page 17. Showing how the two kinds of marble are sometimes mixed in the Proctor area, Dale says, "On the west side of Pine Hill in the upper part of the marble series, close to its contact with the overlying schist, a mile and a half southeast of Proctor is a bed of gray and white mottled calcite marble containing roundish and angular fragments of dolomite which, being less soluble by atmospheric acid than the rest of the rock, project on the weathered surface. . . . This association of dolomite and calcite appears to be due to the brecciation of small, alternating beds of dolomite and calcite marble."

"The calcite marble of Florence number two in Pittsford is of very light bluish gray color with dark gray mottlings which form minute projections on the polished surface which can be scratched with a knife. In thin sections this is seen to be a medium-textured marble."

MARBLE BELT OF WESTERN VERMONT

The commercially valuable marbles of Vermont are all limited to a long and narrow area between the Green Mountains and Lake Champlain. Other stone, in trade, marble, as the dolomite Champlain marbles, the serpentine of Roxbury, the black marble of Isle La Motte and Swanton Dove are not true marbles as will be noticed later. In Vermont the most northern of the true marbles is found in the north part of Shelburne, just west of Shelburne Pond. The quarry, for many years disused, is described more fully on page 143. From this point south as far as, and beyond the Massachusetts line, marble is found. As most of the marble quarries now worked are located in this area it is important that its location be well understood and to this end I can do no better than to quote freely from Mr. Dale's account as given in the U. S. Bulletin and also in the Ninth Vermont Geological Report. . . . "Beginning in latitude 44° 15′ or about fifteen miles south of Burlington, the west flank of the Green Mountain range lies near longitude 73° 5′ and extends thence southward with minor deviations for thirty-six miles to Coxe Mountain a little north of Pittsford village. From this point the range curves eastward forming an embayment that is six miles wide near Rutland, where it reaches longitude 73° 7′. This embayment extends forty-three miles from Gore Mountain south gradually curving westward to the Manchester-Sunderland line. . . . From that line it gradually curves west for eight and a half miles and reaches longitude 73° 9′ near the Salisbury-Glastenbury line. The length of the flank here considered is therefore eighty-seven and a half miles. West of the Green Mountain range and three miles southwest of Brandon village is the north end of the Taconic range which extends with a course more or less parallel with 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 two miles wide near Manchester, but in places between East Dorset and Danby only one-fourth of a mile. This narrowing is due to the fact that for six miles between Manchester and Dorset line on the latitude 44° 20′ the Taconic range widens out eastward for five miles on 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, and extends twenty-three miles south to Danby Hill, a little north of Dorset Mountain. The width of this range is from one and a half to two and a half miles. North of the Taconic range the surface between the Green Mountain range and Lake Champlain presents only minor irregularities, but between Middlebury and Monkton 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 the 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 is eighty miles.

"Within the Taconic range itself there is another marble belt west of Rutland, six 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 there are small marble areas which will be considered more fully beyond. The boundary line between the marble and the schist in the towns of Dorset and Manchester runs at a considerable elevation, being in places 2,000 feet and in others 2,500 feet contour.

"The intricate course of this boundary 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 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 between Dorset, Equinox and Red Mountain. The triangular 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 area four miles northwest of it.

"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 the schist and the lower part next the underlying dolomite. At the present time (1912) the most productive are next the schist. Finally where two formations which do not follow each other in natural order of superposition are brought together at the surface 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 in 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." Dale, Ninth Report Vermont Geologist, page 57. Two other faults do, however, occur here and by these the marble beds are affected.

GEOLOGIC AGE OF VERMONT MARBLES

For many years early study of Vermont geology in the days of Adams in 1846 until A. Wing, to whom allusion has been made on preceding pages, in 1870 and the years immediately following, began and continued to a solution. By Mr. Wing's researches and discoveries a long step was taken towards the settling of the age of the Vermont marble beds and of the Green Mountains. Much has been written of the value of Mr. Wing's work, and this need not be repeated here, except in the way of résumé and incidentally. After reading the manner in which the calcite marbles of Vermont have been brought into their final state, no one can wonder that nearly all traces of their original condition has been obliterated. Fossils in most cases, as need not be noticed, are the only sure witness to the age of a bed of rock, so that where these are wanting, as in the marbles, the geologist is perplexed as he studies the age of non-fossiliferous beds. The almost entire absence of fossils from any true marble is usual, but fortunately in a very few quarries in this State, fossils and distinct ones have been found. Fortunately, too, the best preserved fossils are characteristic of only one geological period. The illustration (Figure 5) shows a slab of marble which came from the quarry known as the Dove Blue Rutland. The illustration shows part of a slab reduced to about one-fourth natural size. Slabs of this sort have been found only in the deep beds. No other distinct fossils have been found here, but the white fragments, some at least, are probably bits of other fossils. The Maclurites is found in many localities in western Vermont and Isle La Motte, sometimes in abundance in beds of the Chazy limestone and is a fossil by which that period is well known. By this fossil and other indications the age is surely fixed as of Chazy age, and this period is placed in the lower part of the Ordovician age, the succession being Precambrian, Cambrian, Ordovician and then follows a long list of the geological series until the present.

FIG. 5. Fossils, Maclurites magnus, Chazy period.

It is enough to add that not only the beds in the quarry from which this slab, and others like it, was taken but that all the marble beds of western Vermont are of the Chazy age and therefore of one of the older geological ages. As to this, geologists are fully agreed, as far as most of western Vermont is concerned

and the Green Mountains as well. Let me remind the reader that this determination of age refers only to the calcite marbles of the western marble belt. As will be seen later, there are some dolomite marbles that are undoubtedly older.

While no traces of fossils nor other proofs of age have as yet been found in the marble beds east of the Green Mountains, there is great probability that these are also Ordovician. As will be shown later, all the commercially valuable marble of Vermont is obtained west of the Green Mountains. Though the beds east of the Green Mountains, many of them, are very similar to those west of these mountains, yet there was evidently sufficient difference in the geological conditions east and west to produce different results, at least in some respects, as will be seen. In many respects, not only in the marble beds, but in other features shown in the two sides of the Green Mountains, the geology of each side is somewhat unlike that of the other, though in many features similar. Doctor Richardson in his discussion of several of the towns east of the Green Mountains, see page 325, evidently considers the marbles of this region as older than the Ordovician, though he furnishes no convincing proof. While the writer does not wish to write positively, yet he is inclined to place most of the eastern beds in the Ordovician. In any case this is more an expression of opinion than a positive statement. The proof as yet waits to be found.

STRATIGRAPHIC LOCATION OF VERMONT MARBLE

Geologists will be interested in studying the position of our marble beds in relation to those adjoining them. Here, as often before, I quote largely from Mr. Dale: "Next in importance to determining the boundaries of the marble area and of the contiguous formations is to ascertain the probable thickness of these formations and to refer them to their proper geological 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 measurement of the latter on Bald Mountain amounts to 1,600 feet, and it is all of Lower Cambrian age. The thickness of the overlying dolomite is still uncertain. It cannot be less than 500 feet and in places it may be much more. The discovery of Lower Cambrian fossils by Wolff and Foerste in 1890 on the east side of the Intermediate range about a mile and a half above Rutland, near East Creek opposite the Baxter farm, in dolomite 500 feet east of the quartzite fixed the age of the

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lower 300 feet of the dolomite. Measurements made by the writer in 1891 near Chippenhook in Clarendon along the axis and on the west side of the Intermediate range showed that the marble and dolomite together measure there about 1,200 feet, of which at least the lower 450 feet is dolomite and of the Lower Cambrian age. 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. 470

"One estimate 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 near North Adams, Massachusetts, between the north ~~and south~~ 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 masure 900 feet for the marble. Another estimate made between the top of the Cambrian quartzite at the foot of Danby Hill and the base of the schist on the northeast shoulder of Dorset Mountain, give 1,400 feet for the entire thickness of both, divided equally between the dolomite and the marble. Hitchcock and Hagar estimated the thickness of both on Green Peak as 1,970 feet, of which they assigned 707 feet to the marble and 1,263 feet to the dolomite, but as the actual vertical distance between the valley floor and East Dorset and the base of the schist cap should be assigned to the dolomite, and that figure should be reduced to allow for the folding in the Vermont Valley. The marble has been shown by the investigations of Wing and others to be beds of the Chazy age, and probably some of the Trenton age above them, and possibly some of the Beekmantown below them." Dale, Ninth Report Vermont Geologist, page 58.

The same authority gives the following table from which one can understand the arrangement of the marble beds and areas and also can mentally picture a geological map of the region. The table is substantially as Dale has published it, but now and then there has been some condensation.

TABLE SHOWING THE STRATIGRAPHY OF THE MARBLE BEDS OF WESTERN VERMONT AND IMMEDIATELY ADJACENT FORMATIONS

Formation	Rock Characteristics	Geologic Age	Thickness feet
Berkshire schist	This schist is usually greenish (chloritic) purplish (hematitic) black (graphitic) fibrous muscovite (sericitic) schist with quartz, soda feldspar (albite) pyrite, magnetite, pyrophyllite, in places speckled with actinolite. Much quartz in lenses and blades, containing chlorite, and siderite more or less altered to limonite. This schist is interbedded with quartzite (much chloritic) in small beds (in a few places with chalcocite) siderite, (pyrophyllite). These quartzite beds are from ten to thirty feet thick. Within them or separate are beds of conglomerate one to two feet thick, with pebbles of blue quartz, three-fourths of an inch or less in diameter. The schist is also interbedded here and there with small beds of 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 schist is generally graphitic.	Ordovician mainly Chazy	2,000 to 2,500
Calcite marble	Alternating beds of calcite marble of various grade of texture, white, gray (graphitic) greenish banded (muscovitic) actinolithic interbedded with bluish or grayish untwinned dolomite and with muscovite schist in small beds in places graphitic and forty 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.	Trenton, Chazy, possibly, Beekmantown	200 to 300
Dolomite	Thin bedded, untwinned, crystalline dolomite, fine grained and generally more or less quartzose, white, grayish, dove, cream, or ivory colored with many intersectioning microscopic joints, or quartz veins, along which the surface weathers in grooves. The pink and cream colored beds have a brownish weathered surface. Small beds and films of fibromuscovite schist are common in these dolomite beds. Some of the dolomites, such as the light gray bed under the marble at Proctor,	Beekmantown, Lower Cambrian	500 to 800

500 to 9?? should be in ( )

TABLE SHOWING THE STRATIGRAPHY OF THE MARBLE BEDS OF WESTERN VERMONT AND IMMEDIATELY ADJACENT FORMATIONS—*concluded*

Formation	Rock Characteristics	Geologic Age	Thickness feet
	consists of dolomite plates, some of which are twinned, crowded with dark granules lying in a matrix of smaller untwinned clear dolomite grains. A black and gray dolomite in Proctor consists of dolomite plates and graphite in minute bands. Near the top of the dolomite and exposed for one-fourth of a mile on the west side of the intermediate range in West Clarendon, half a mile east of Tinmouth River bridge is a twenty-five foot bed of dark-gray graphitic dolomite filled with Hyolithes and oolitic nodules. Each nodule has a fossil as nucleus. On a polished surface the fossils (Hyolithes) appear as triangles and circles (in section). 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 calcite marble, a few feet. Some of these beds are pyritiferous and some were evidently derived from a mixture of calcareous, quartzose and argilaceous material. Some of the lower dolomite beds in Sugar Hollow, Brandon, carry pebbles of purplish potash feldspar and of quartz, and two miles south of Silver Lake the lower beds contain a little metallic and red hematite, the latter in small lenses of concretionary or organic origin.		
Quartzite and schist	Largely quartzite (metamorphic sandstone) more or less feldspathic and micaceous with some beds of conglomerate with pebbles of blue quartz and gneiss in places attaining large dimensions. Interbedded and possibly interfolded with these quartzites are schists and in a few places beds of dolomite. Some of these schists are coarse biotite quartz schist, others are muscovite-chlorite schist with abundant magnetite, others are very fine grained dark biotite sericite, banded with minute dark quartz and feldspar grayish beds. Generally the dark schist is biotitic, whereas the dark schist of the Ordovician is graphitic." Ninth Report Vermont Geology, page 59, 1914.	Lower Cambrian	1,600

As to the age of the calcite marble beds it seems probable that, as given in the above table, they are all Ordovician, though, as stated in the table, the lowest portions may possibly be older (speaking only of the calcite marble). As far as the writer has learned, no proof of any beds lower than the lower Ordovician have been found and as the fossils found in the True Blue quarry were in the lowest layers of that quarry and none have been found lower than these it seems to the writer most likely that none of the calcite marbles of the west side of the State are older. Probably the smaller beds east of the Green Mountains are of the same age, though there are some indications that in eastern Vermont there were more or less different conditions from those that prevailed west of the mountains. As a single proof that there were differences in the action of the forces that operated in the making of ancient Vermont the presence of the great granite masses which are found along the eastern part of the State, while not one is found west of the Green Mountains may be cited. Just what these differences were is not fully known, nor is the present paper the place to discuss the matter.

In the above table the thickness of the true calcite marble, as given by Dale, is from 500 to 900 feet. This figure he has derived from records of borings, outcrops, etc., but it is not to be considered as more than approximate, though probably not excessive. The schist which overlies the marble may be of the same Ordovician age, but very likely it is most of it somewhat more recent than the marble, that is, middle and upper Ordovician. The superincumbent schist Dale puts at from 2,000 to 2,500 feet. Very likely, at least in some places, it was originally more, for evidently it has been greatly eroded in some portions by glacial action. In some places, aside from glacial erosion, the schist must have suffered weathering from the time it was formed, during the ages between the Ordovician and glacial time.

As has been mentioned, and as will often be noticed by careful observers, most of the marble beds, as also the schists, quartzites and whatever other rocks may be found in or near the marble, are more or less disturbed, sometimes not greatly, sometimes very much so. Of course when disturbed they are not in their original position. Let the reader recall how marble is formed and he must see that disturbance, misplacement, etc., must always attend marble making, as only by great transformation can original limestone beds become marble. Usually this must also be true of rocks in the immediate vicinity, though they do not form marble, but schists, etc.

The present position as well as character of all the rocks gives a clue to what has been going on during geological time. Mr. Dale has written so good an account of this that I can do no better than to quote his words, "In consequence of a powerful crustal contraction at the close of Ordovician time, operating mostly in a west north western to east southeast direction, the sediments not only became crystalline, but were intensely folded and in some places faulted. . . . In the southern part of the marble belt, Arlington, Sunderland and Manchester, the Vermont Valley and the axis of the folds (strike) have a general north northeast trend; that on the Danby, Dorset, Tinmouth and Clarendon—West Rutland line their trend is 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 end of the Taconic range in Brandon; and that from there it is again nearly north.

SECTIONS OF A PART OF THE MARBLE BELT

"Mr. Dale gives three sections in this area which will be of interest to geologists, if not to those who are not concerned with the geology of the region.

SECTION 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. The section crosses Otter Creek Valley, which here corresponds to a complex anticline, the dolomite appearing in the center, with dolomite on both sides. The schist ridge between the West Rutland Valley and Center Rutland-Proctor 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 area east of Biddle Knob and one and a half miles west of Florence. 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 not far below the marble floor of the West Rutland Valley.

SECTION II

"Made by F. B. Moffit, begins at the east foot of Clark Mountain in Tinmouth and 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 and quartzite 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 one and a half miles south of the top of Tinmouth Mountain and along its strike between Harrington Hill and Dutch Hill in Danby and also by a small area of dolomite, probably belonging in the marble at the west foot of The Purchase.

SECTION III

"Section III begins on the Green Mountain range near the head of Downer Glen on the Manchester-Winhall township line and runs about west northwest through Manchester village and the top of Equinox Mountain, ending at Manchester-Sandgate town line. At the east end of the section crop out the Precambrian gneisses of the Green Mountain range, whose unconformable relations to the overlying Lower Cambrian are finely exposed in the bottom of Downer Glen. This locality affords evidence of a crustal movement and erosion of the region prior to Cambrian time. In Section III the foliation of the Precambrian gneiss is therefore represented as not parallel to the bedding of the overlying Cambrian and also as eroded prior to 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 then crosses the entire quartzite and schist formation which flanks the range. In the lower part of Lye Brook this formation lies in a syncline which the lower beds of the dolomite have preserved from erosion. On this brook near the Manchester-Sunderland town line about two and a half miles south of Section III a loose rectangular block of coarse micaceous quartzite, probably from a nearby 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 Battenkill the quartzite forms an anticline. The Vermont Valley, from the Battenkill to a point about three miles west of the Equinox House is occupied by the dolomite and consists of a syncline made up of minor folds. The steep eastern slope of Equinox Mountain up to elevations of 2,300 or 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 Dyer quarry two and a half 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 Taconic Mountains, which are, as a rule, more or less complex synclines." Dale, page 62, Ninth Vermont Report.

STRUCTURAL NOTES

Equinox and Bear Mountains.—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.—There is an unusual change in the strike on both sides of the valley near South Dorset and extending to Owls Head, a change from north to northeast of 40-45.°

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 and the marble generally from the 1,600-foot level to the 2,000-foot level. The mountain is deeply furrowed by erosion and the marble is exposed on three sides. 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 overlaid by schist which from that point constitutes the steeper upper 1,600 feet of the mountain. There is a marked southerly pitch in this part of the mass.

West Rutland Anticline.—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 clearly dips 30° east, striking in some places north 10°-20° east, in others north 25° west. The bedding, shown by plicated quartz veins, strikes north 25° west 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 schist range a mile west northwest of the West Rutland station the slip cleavage dips 10°-20° east, but the bedding strikes north 30° west and dips steeply 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. . . . In the western schist range at a point about 200 feet above the north-south highway, and north 47° west of the red schoolhouse above the West Rutland quarries, there is a cliff of schist forty feet high. The bedding shown by calcareous beds three inches thick, dips alternately east and west in minor undulations, with a general horizontal course crossed by eastward-dipping slip cleavage. The exposure is sixty feet long. . . .

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

That the West Rutland anticline is made up of minor folds is indicated by the small schist tongues which overlie the marble at the north end and near the True Blue quarry.

Schist Ridge West of Proctor and Florence.—The complex structure is indicated by the lenses of marble or dolomite, which are probably the tops of minor anticlines about midway between the West Rutland and Proctor belts of marble. The problem as to the dip in 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 Florence. Where the quarry railroad cuts the schist nearly west of the north end of the pond, cleavage strokes north 5°-10° east and dips 60°-65° east, but the bedding, shown by the plicated quartz veins and lenses, dips at a low angle to the west.

At a point south 85° east of the tower on the Proctor school the schist has a cleavage strike of north 10° east and dips 55° east, but with a magnifying glass traces of westward dipping, plicated bedding can be made out 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° east and the bedding dips at a low angle to the west or is horizontal. At a point one and three-quarters south of Florence, marble and schist occur in contact. Some large glacial boulders rest on the marble nearby. The marble strikes north 15° west 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 plication is crossed by an eastward dipping slip cleavage. The boundary here turns to a northwest course and at a point northwest a fourth of a mile the two rocks are within a foot of each other, but both strike north 21° west, a dip 40° east, owing probably to a minor fold in the schist mass. Opposite the road corner near it, two and a half miles south of the Proctor line, the schist shows cleavage dipping 40° east, but plicated bedding dipping west.

Structure North and South of Center Rutland.—The narrowing of the belt, Proctor to Pittsford, southwest of Center Rutland 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 are just the opposite of those implied in the disappearance of the West Rutland anticline both at north and south under the overlying schist.

Notes on the conditions and character of the marble beds, quarried in the western part of Vermont from which all the commercially important marbles are, and always have been, quarried, will not be without interest to some of those who read this account. The following detailed statements are largely taken, with some abbreviation from the investigations made by Mr. Dale as given in the Bulletin often noticed. (Also quoted in Ninth Report Vermont Geologist, 1914, p. 79.) Mr. Dale made careful and very complete measurements of many different beds. Beginning at the quarry known as the Gilson quarry "and the probable line of contact between the marble and the schist," Mr. Dale found the following succession of beds. At the time the measurements were made the schist contact was 248 feet east of "the red schoolhouse on the brow of the ridge."

East Wall of the Gilson Quarry

	Feet	Inches
White marble	11	6
Graphitic marble, includes fossiliferous beds	135	6
Light marble	2	
Graphitic marble (east of schoolhouse)	73	
White marble, dolomite lenses	25	
Covered, probably graphitic marble with interbedded dolomite	58	
	305	

These measurements generalized and added to those from core drill records and other measurements made by the Vermont Marble Company, give the following succession for the east side of the Vermont anticline, beginning at the schist.

Section of Marble Beds on East Side of West Rutland Anticline

	Feet
Covered area	58
White marble, with dolomite lenses	25
Graphite marble, including white two feet	220
White marble	31
White finely banded with gray	90
White graphitic and muscovitic marble	140
Dolomite	40
Mainly graphitic marble, but with 18 feet, 6 inches of white, 34 feet muscovitic, 73 feet, 9 inches dolomite	250
Muscovite green marble	12
Graphitic marble	34
	900

The reader should notice in this as in other tables that since they were written quarrying has taken place in many places and therefore the same localities might differ in measurement from the figures given above. The fact that many of the quarries in western Vermont are continuously working and therefore continually changing in a greater or lesser extent has already been mentioned and should always be kept in mind.

In the U. S. G. S. Bulletin so freely used in the preparation of this paper Mr. Dale gives the beds in two other quarries, but the above is sufficient with others given here below to show the varied beds in this area.

In the gravel pits north of the Catholic Church 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 north 25° 30′ west dip on the east 30° and on the west 60°-70° west. The nearest schist outcrop and the probable boundary between marble and schist is about 400 feet west of the graphitic marble. If the space between the two rocks is all marble and the dip is 60° west the thickness of the marble would be 320 feet. If the graphitic beds in and west of the old 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 above 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, WEST SIDE OF WEST RUTLAND ANTICLINE

	Feet	Inches
Graphitic marble, with possibly some interbedded dolomite	300	
Cream colored, white, green, muscovitic, Eastman quarry	73	6
Gray dolomite—core drill, east of quarry	3	
Graphitic marble—core drill, east of quarry	3	6
White marble—core drill, east of quarry	13	6
	393	6

That the marble of the above-named quarry (now of the Colonial Marble Company) does not correspond bed for bed to that on the east side of the anticline is probably due 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 muscovite green marble and an almost white one.

Proctor.—The marble beds of the Proctor and of the old Columbian quarries and of a disused quarry between these belong apparently to the base of the marble series, as do also those of the Riverside quarry two 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 to the west. At the disused quarry on the knoll one-third of a mile to the south marble about 185 feet is exposed. At the Riverside quarry marble 85 feet thick is in sight and 170 more have apparently been crossed by core drilling westward, giving a total of about 250 feet. As the dolomite series and the marble overlying 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.

The dips range from 35° to 75° east. The conspicuous knoll half a mile south of Proctor and north of the Columbian quarry presents an interesting problem. Its west side is pretty clearly an anticline with an almost vertical west limb and a nearly vertical 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 two miles north of Proctor. Although the marble of this knoll belongs to the Proctor line of beds, yet its strike is in line with 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 twenty feet wide cut off by dolomite on the south which is in line with the disused quarry in the village and of the Proctor quarry. There may be a 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 twenty feet of marble may be a small bed in the basal dolomite. If there is such dislocation the intermediate dolomite which lies west of the Proctor quarry passes west of the marble knoll and is covered by the drift.

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, in the upper part of the marble beds well exposed in the disused Shangrow quarry and other neighboring quarries and at several points in the village.

This marble is graphitic and is finely banded in places. The distance between the dolomite at the pond and the schist boundary on the west is roughly 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 greatest thickness exposed at any one quarry of the graphitic beds is 135 feet.

These graphitic marbles extend to the schist ridge, where they dip west under the schist, the plicated bedding also dips west, although crossed by a more eastward dipping conspicuous dip cleavage. The presence of at least one anticline in the basal dolomite at Proctor is shown by the fifty westward dip of the dolomite back of the Y. M. C. A. building and the town hall.

Pittsford.—In Pittsford the marble belt widens to seven-tenths of a mile west of Florence and to nine-tenths 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 beds and that its structure consists of minor folds. . . . At the Florentine quarry where the contact between the 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 about 127 feet west of the west wall of the quarry, counting eastward and downward, the following section has been made out:

MARBLE BEDS AT HOLLISTER QUARRY

	Feet	Inches
Marble, mostly light bluish gray, about	90	
Clouded marble	16	
Bluish marble	14	
Marble, white and muscovitic	15	
West edge of quarry		
Light bluish gray marble	12	6
Inferior	7	
Marble, light bluish gray, mottled	20	6
East edge of quarry		
Marble, white or light bluish gray	47	10
	222	10

LIST OF MARBLE BEDS OF WESTERN VERMONT

	West Rutland Anticline East side	West Rutland Anticline West side	Proctor	Pittsford	Dorset Mountain Owls Head Green Peak
	feet	feet	feet	feet	feet
Upper graphitic marble, including dolomite and exceptionally schist	190-203	300	150	150	20-100
Average					Mostly dolomite
White, graphitic and dolomitic marbles, alternating	180-222	93 Rest not reached	Absent	Absent	
Average	201				100-175
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	165-242
Dolomite Total	715-842		554-678	778	335-617

Among the most striking features in the above table is the disparity of the thickness of the intermediate dolomite in the West Rutland and Dorset Mountain sections and the Proctor-Pittsford belt on the other. The absence in the Proctor section of both the assorted marbles and the clouded light gray Pittsford 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 the Proctor quarries has been pointed out, and the Pine Hill fault is only two miles distant east. The upper clouded marbles and the white muscovitic which normally occur above the intermediate dolomite are shut out by an overthrust fault which brings the dolomite next to the 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 undoubtedly 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 more exact determination which further quarrying, core drilling, and geologic exploration will make possible. It is a tentative list of all the marble beds.

VOLCANIC MATERIAL IN THE MARBLE BEDS

In a number of the marble quarries and in unworked beds dikes, bands of volcanic rock are found. These are of very different widths, from a few inches to twenty-five feet wide. They are usually dark in color and thus often conspicuous as they cut through the lighter marble. They are always harder than the marble and very unlike it in appearance as they are in all characters. They are believed to be masses of molten rock that have come up from beneath the marble beds. Appearing as they do through the marble beds through fissures caused by the breaking of the folds of the beds, they are at right angles to the beds and have caused more or less shattering of the stone. Hence in the quarries they must usually be avoided because the stone adjacent is more or less unsound. Of course the geological age of the dikes is later than the marble and very probably they are not all of the same age. They appear to represent the last of the disturbances which affected western Vermont.

ELASTICITY IN MARBLE BEDS

In speaking of the several qualities that a good commercial marble must possess, it almost goes without saying that it must be, in all respects, perfectly sound, that is for the best grades. Building marble may not require to be so perfect, but for inside work it cannot be too good. That it may be of the best grade for carving, etc., it must have very careful examination and even so the best expert is sometimes deceived because the stone is sometimes, as seen in the quarry, perfectly sound but all the time be full of little cracks that are not visible until polishing brings them out. The writer remembers visiting one of the quarries on Dorset Mountain some years ago in which was what seemed a wholly sound and good-grained light marble. The quarry was abandoned apparently without reason, but inquiry brought out the reason. This quarry had been opened and one or two layers taken out and some blocks taken down the east side of the mountain to a mill in East Dorset and blocks sawed into slabs, all involving considerable expense and not until some slabs had been polished did multitudes of minute flaws and cracks appear which made the stone unsalable. These imperfections which rendered the stone of little value were caused by the stress of folding, by which the beds were cracked. Men, who had worked in this quarry, said that after the pressure of the upper layers had been relieved by removal, the lower layers so held the drills and all tools used that it was not possible to work them. That is, the elasticity of the layers, as they were somewhat released, so far retained its gripping power that they could not be worked, but held the tools and so prevented their use in loosening the blocks. Hence, either of these conditions, both from the same cause, rendered the deposit practically of no value. Fortunately these conditions do not often occur, but sometimes they do. It seems impossible that so inelastic a material as marble, or any other stone, could have remained, no one knows how many thousands (or is it millions?) of years, ready to spring to its position before folding occurred as soon as some of the superficial material was removed, but so it is.

GEOLOGICAL HISTORY OF WESTERN VERMONT

Although a considerable portion of what follows in the next few pages has already been noticed, it will certainly not be without interest if a condensed statement be given here before going

on to a more detailed description of the marble quarries and special varieties of marble. While each geologist probably has his own interpretation of the marble beds and adjacent region, most, if not all, are in substantial agreement as to the main history of the region. Let us attempt to answer the question, why have the marble beds come to be as we now find them? The conditions before Cambrian times are uncertain and will not be considered here. No doubt that there were rocks before this Cambrian in Vermont. In the Vermont Valley and very likely in the axis of the Green Mountains there were many such beds and the region we are studying was certainly undergoing many and great changes for ages, some of which there is abundant evidence; for our present purpose it is quite sufficient that we begin with those beds that immediately underlie the marble beds. Of these there is abundant record. West of the marble belts are the Adirondacks, a great mass of metamorphic and crystalline hard rocks older than any we find in Vermont. Against the foothills of the Adirondacks dashed the waves of the great ocean which coming north from what is now New York bay extended north at least to the present St. Lawrence Valley, joining the sea as it turned eastward and again became a part of the ancient ocean. Where New England now lies, if there was any land, were only islands, to which during subsequent ages additions were made until all became in time an entire land mass, although New England is still a great island, surrounded by the Atlantic, St. Lawrence, Sorel, Lake Champlain, and the Hudson River. Great quantities of sand and other material was eroded from the old Adirondacks and washed over the land of what is now western Vermont. Lake Champlain, not as now, existed and there seems to have been a cañon where is now the deepest channel. During the ages following, the rocks of western Vermont, at one time thousands of feet thick, were mostly washed away, leaving "Cambrian remnants." Doctor Walcott, who published reports of several thorough explorations of this region, found that at least 10,000 feet of sandstone, shale, limestone and red sandstone, anciently covered the east side of the Champlain Valley. The "remnants" now seen are Snake Mountain, Mount Philo, Hogback and lesser elevations along the lake, as Mallett Head, Red Rocks, etc. Now the highest of these elevations is only a little more than 1,000 feet above sea level (Hogback, in Monkton, is somewhat higher than any other "remnant," 1,650 feet at one point), no other is 1,000 feet. This example gives us some conception of the vast changes which have occurred in past time. Of course, all this must have taken place before the marble beds were begun, long before. As time is estimated historically and geologically, it must have required some time to form and then remove such a mass of rock. The Green Mountains as well as the Taconics did not exist as they are now, but partially at least they may have commenced in elevation. Ancient Lake Champlain was certainly in evidence, but not as now. (For history of Lake Champlain see Volume VIII, page 43; Volume XVII, page 40.)

After the Cambrian and the period of erosion following it, came the Ordovician. In the Champlain sea, then salt, were living many forms of animal and plant life, and limestone, not abundant in the times before this, was deposited in abundance. Dolomite is mentioned in a former page. It may here be noticed that during these early times there was probably a periodic or continual rising and sinking of the land areas. That is, that the ocean bottom now rose, now sank and also this became a great limestone-forming age. From this limestone, as has been shown, came the marble. Also by some different combination of material, or some change in ingredients, came the dolomite, schist, and other rocks by means of metamorphism during or more probably soon after the close of the Ordovician. How much of the metamorphism occurred near the close of the Ordovician, or whether it all came after, cannot be positively told.

After the Adirondacks came a long period of deposition when first the Cambrian beds were laid down and then the limestones which later, in some places, became dolomite and marble beds. Apparently some of the dolomite is older than the marble, but some of it evidently was contemporaneous with it. In the seas of the Cambrian, and perhaps earlier, animal and plant life was more or less abundant, but when the Ordovician followed, the life of this region seems to have been very abundant. As has been noticed, in writing of the origin of marble and dolomite, much calcareous, as well as some other, material was added to the deposits of the Ordovician (see page 17). From this mostly, if not entirely, came the material from which the marble was made. As already noticed, numerous other mineral substances were added to these Ordovician deposits, or perhaps in some cases formed by changes which accompanied marble making. Probably, too, there was during this time slow subsidence of the sea floor.

At some time after the above deposits had become thick disturbances began to affect them. That is, marble forming began. The calcite, which formed partly from the beginning, greatly increased, while the dolomite decreased and calcite was the most abundant and important material. As we have seen, this calcite was very largely of organic origin. Of what sort the fossils of the Ordovician tell us. Of course, there may have been some calcite chemically formed, but probably not much. As the various analyses show, there is more or less dolomite in many of the calcite marbles. The coloring of the fancy marbles is mainly due to various minerals. Mr. Dale thinks that in the graphitic and dark marbles the color is due to vegetable matter, sea weeds.

In the time of depositing what became the marble beds, and probably much more at sometimes than at others, a considerable amount of sand, clay and other material was brought into the region by such streams as were wearing down the rocks of the period and carrying it to the sea. Some of this very probably was added to the calcareous sediments, but most was finally consolidated and became the schist so abundant among the marble beds and adjacent to them. If, as is probable, the land which then existed was more or less widely raised, the streams would, of course, be more rapid and erode more extensively. So, too, the bottom of the sea subsided and great quantities of material of various kinds thus accumulated, the more calcareous finally becoming marble, the rest schist.

The appearance of the rocks plainly shows that during the Ordovician there was to some extent rising, folding, crushing metamorphism of the various beds and towards the close of this time and immediately after dynamic activity was very greatly increased. Not only were the sedimentary beds folded faulted, raised or lowered, but great metamorphosis went on for a very long time (see page 13). Changes were going on during all the time, at least from the beginning of the Cambrian through the Ordovician, but at the close of the Ordovician there appears to have been an enormous increase of dynamic activity and at this time, it may have continued long, it must have been so as it undoubtedly was in general, not violent, but gradual, though mighty, in producing the results we now study. It was especially at this time, following the Ordovician that the schist, marbles and some of the dolomites were formed, as we now find them. At this time everything was changed. The Green Mountains and others as the Taconics were gradually raised and to a greater altitude and mass than we now have seen. During this long age, long as we estimate time, not only was much marble made by the metamorphic forces, chemical, mechanical, etc., but a part of it was broken, shattered so that it was ruined, commercially, and must be removed as useless when sound stone is obtained. Many good marble beds were thus ruined. What happened in this region during the immense interval between the close of the Ordovician and the beginning of the Great Ice Age, the Pleistocene, we can conjecture, but it will not be considered here. Probably there was something going on much of the time, erosion at any rate, parts of the region were raised, other parts lowered, especially the mountains, but we must pass all this.

How long the period or periods just noticed one can hardly guess, but, as has been stated, the time must have been very long. At some time during this long interval, probably, as geological time must be reckoned, not very long after the completion of the formation of marble, schist, etc., in the eastern part of Vermont, great activity took place by which the numerous granite masses, Millstone Hill, areas at Calais, Woodbury, Kirby, Newport, Derby and their neighborhood were raised under the already formed schists. As we shall learn, all the granite of the State is east of the Green Mountains, but not all the marble beds. Of these there are a goodly number in eastern Vermont, but no extensive beds, rather patches scattered here and there through a long, though narrow, area from the southern line of Vermont nearly to the northern border. None of these deposits have been profitably quarried and by far the greater number not at all. Both the western and the eastern deposits will be taken up in somewhat of detail in following pages. Thus all the commercially valuable marble is and always has been quarried west of the Green Mountains, all of the granite east of the mountains. It is certain that the granite is geologically later than the marble because it has evidently come up from beneath the schists, etc., and at first was covered by them, they having been eroded, thereby exposing the granites since they were thrust up through them.

At last, in what is geologically recent time, came the great change in climate that brought on the Pleistocene or Glacial Period. As most readers will know, this is the geological age immediately preceding the present. Its record is very plainly and abundantly seen in Vermont. The sand and gravel beds, the clay banks, the boulders, the grooving and scratches on many ledges, and not a few other results of glacial activity are everywhere in evidence. Even the highest summits of our mountains have been ground away, no one can tell how much, by the great ice sheet which came from the north and covered the whole of New England and the northern part of the United States. It would certainly be of great interest if we could see a large photograph, or

several, of the Vermont as it was immediately before the Ice Age and now. Certainly we should appreciate the changes in the landscape caused by the great ice sheet which covered the State. Figure 3 shows some of the marble beds rubbed smooth and scratched by the movement over it of the glacier and the stones and gravel carried in the bottom of the ice sheet as it moved over the ledge. Of what may be called minor geological changes, though some of them were by no means small, which occurred during glacial time there is no place here to speak. The reader, who is interested, may be referred to Physiography of Vermont in Volume XVII of this series of Reports, first article, for further account. By the activity of the great glacier and also by the streams, which by its melting were caused, some marble beds were badly broken and thus injured, some were covered by the sands, gravel or clay, others uncovered finally.

At this time most of the great activities known in geological time appear to have taken place, not necessarily at the same time but in course of the period, probably a long period. Just when, just how long, this time of activity was no one can tell, but at any rate much disturbance certainly occurred in the beds that had been deposited before this. It seems certain, however, that none of the true calcite marbles were formed until after these disturbances had taken place. The "Champlain marbles," and perhaps some on the eastern part of the State, were evidently formed in the Cambrian, for in some of the beds of the Champlain marbles unquestioned Cambrian fossils are found. Not only the Champlain Valley but the whole Appalachian border of the United States was greatly affected and much metamorphosis, transformation, resulted. Most of the Green Mountain mass was raised during this convulsive period. As is usually the case when such activity is found in any large region, it is very probable that only a part of the changes that have been produced are now indicated by the effects remaining till the present time, for in geological processes change often destroys all traces of previous change. Changes of various sort may and often do act again and perhaps again at different times and each new change obliterates the evidence of what has gone on in times before that observed. However this may be in Vermont it is certain that the destruction and construction, of which there are so abundant proofs, was to be in long future times of very great commercial advantage to Vermont. As has been already mentioned in discussing the formation of calcite marble, the transformation through which the limestone beds have passed has in most of the marble beds entirely erased all evidences of the life that existed before and during the deposition of the Ordovician limestones, but not absolutely all fossils have been destroyed. As has been noticed in some of the marble beds deep in some of the quarries, distinct fossils occur and to the geologist these in any bed of stone are a sure proof of the time when (in general at any rate) the beds of sedimentary material became stone. By the above fossils, the time of these beds, and, therefore, of those adjacent, is fixed at the lower part of the Ordovician (Chazy). Very probably some of the beds, nearer the present surface, may be somewhat later in the Ordovician than the Chazy, and as will be noticed later, several of the well-known "marbles," as the Champlain marbles, etc., are Cambrian, but by far the greater part of the marble that is sold in Vermont is of lower Ordovician Age.

At the close of this age, and immediately after, there evidently was a period of long duration that was especially characterized by the unusual activity of vast dynamic forces by which the universal folding, faulting, and chemical transformation was produced. Probably at this time, that is during the disturbances, the foundations of Vermont were fixed. The limestone beds seen at or near the shores of Lake Champlain are now the only rock beds above the Cambrian which afford the geologist any abundance of fossils, though in a few localities a few fossils are found, or have been. The great metamorphosis of the rock beds seems to have been greatest and most complete in and near the mountains and going west to the lake the activity and, therefore, the effects decreased, the limestone of the western belt being less transformed in the marbles, and along the shores of the present lake, changed little or in most cases not at all. Metamorphic activity apparently was in many parts of this region greater east of the Green Mountains than west of them; so also the dynamic activity, which is believed by most geologists to have come considerably later, probably in the Devonian, by which the granite masses, so valuable to the State commercially, were pushed up from below.

We may truly say that during the Ordovician Vermont was roughly blocked out, but that during the ages following great changes were all the time, more at some time less at other, and, indeed, through all time greater or lesser changes have been going on. The ages before the Cambrian we must leave, though there are beds in the State which are considered older than any of the Cambrian. Starting with the Cambrian, the oldest rocks of whose history we are quite sure, and which certainly were

the oldest of any great extent, we find as already shown the great beds which became the red sandrock and in which are the more or less metamorphosed beds now called the Champlain marbles. These will be more fully treated in following pages.

By the above showing we find in Vermont: First, the more or less imperfectly known pre-Cambrian. Second, the period between this and the close of the Ordovician, the period of great geological disturbance when large limestone beds were deposited; many of these being the foundation of the great marble beds. Thirdly, a period, probably long, of especial manifestation of great dynamic forces and metamorphism, folding, faulting when the marble beds were made from metamorphosed limestone. Fourth, a very long time when, as far as we can judge, no great and violent action occurred in western Vermont, more east of the Green Mountains, where are the Granite Hills, from which all our granite comes. Also the abundant schist, gneiss, etc., were formed about this time. Fifth, the great Ice Age, Pleistocene. Sixth, the present.

Some geologists would assign several more periods to the formation of the rocks of the State. The above is not intended to be as complete a summary as might be given, but in general and briefly, the past geological history of the State is as above. From the above one sees that all Vermont marble is not of recent origin, but, even geologically, is an old rock and that going back to its origin from marine animals, through the limestone phase, that of change from limestone to marble and, one might add, through the eroding and planing of the Ice Age and subsequent covering of sand, gravel and clay, by which in many cases the marble mass was protected from atmospheric or other decomposing and eroding agencies, all the marble masses have gone through many experiences. Undoubtedly because of these varied modes of formation and transformation a far greater variety in our marbles has been produced and probably the value commercially has been increased in most varieties. As to the folding of the western Vermont marble beds Mr. Dale says, "The western Vermont marble region is one of folding so that horizontal beds are exceptional. They are only to be expected at the bottom of the troughs or the tops of the arches of the folds, and, therefore, cannot 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 epitomize the large ones. The folding of the strata is the fundamental character of the region, and the primary factor in controlling the vertical and horizontal distribution of the marble. If a series of folds plunges in at one point it should emerge at another for it is part of a fold, and for the same reason if a series of beds emerges at one point unless it is 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.

"The folds are rarely symmetrical, that is inclined equally, and the angles of a symmetrical fold may vary from a few degrees away from the horizontal to the vertical (*l.c.*, page 72). 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 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 the pitch is generally small, 5° to 20°, but it may be more. The practical effect of the pitch is that working along the strike of a series of beds the same bed will be found at a greater or lesser depth. A syncline at the Albertson quarry pitches alternately north and south. The termination of the West Rutland anticline both north and south is presumably due to pitch, the marble fold pitching under the schist mass. The low southerly dips in the southern part of the Dorset Mountain mass are evidently due to pitch.

"The weight of half a mile of superincumbent schist upon the calcareous sediments at the time of folding and the intensity of the compressing force which produced the folds were both so great that the calcareous folds became effectually plastic. Had this compression occurred with less overhanging weight, the beds would have been simply folded or possibly brecciated or granulated. The result of the plasticity is seen in the elongation and thinning of the beds along the folds and their thickening at the ends. To this process the variation in the thickness of the 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 and such structures as that of the bottle-shaped folds near Brandon and that near Owl's Head can be explained in no other way. As the flowage of marble under compression has been demonstrated experimentally the probability that the crystallization of the limestone beds into marble occurred at an early stage in the process of folding does not involve any theoretical difficulties."

Mr. Dale mentions a peculiar exposure at the True Blue quarry at West Rutland: "A 15-foot of alternating graphitic dolomite and calcite marble stops abruptly along an eastward bedding plane, but a three-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 which continue in the direction of the original dip of the bed and have been found in the tunnel below on the right. The first of these lenses is three by two feet. It is more probable that this change of a stratum into a series of lenses is the result of elongation and pinching out of the bed than of diminished sedimentation or of dolomitization." 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 that may be very helpful in solving certain stratigraphic problems.

RELATION OF THE MARBLE TO THE SCHIST

"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 on 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." "Slip cleavage is generally, though not invariably, in straight or slightly undulating planes; bedding is in minute or small plications, in places even of microscopic size and is generally crossed by the cleavage at various angles. Bedding is determinable by the course of small calcareous or quartzite 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 of the localities where these phenomena may be studied in the Taconic region is opposite the eastern West Rutland quarries. The marble which crops out on the line of the strike south of West Rutland, about the Colonial and adjacent quarries, is here covered by meadows. A line of conspicuous schist ledges forms the base of the hill west of the highway (Taconic Range) and the schist appears to dip east and thus to underlie any marble that might be concealed by the meadows, but closer inspection reveals low western calcareous beds in the schist crossing the deceptive eastward dipping cleavage and indicating that the marble of the meadows dips under the schist with that dip. As this eastward cleavage in parts of these ledges is plicated, the usual criterion as to bedding fails here. At a point one and a quarter miles northwest of Proctor station similar relations exist between the marble and the schist. The schist has a cleavage dipping 65° east but its bedding is horizontal or at a low angle to the west. On the other hand at a point a mile and a half southwest of Pittsford station marble and schist are in contact, both dipping 40° east and the cleavage and bedding of the schist being parallel."—Dale, *l.c.*

CLEAVAGE IN THE 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 True Blue and Albertson quarries, are planes of slip cleavage. (See page 112, Ninth Report.) As graphite is here hardly a secondary mineral its abundance along the cleavage planes is to be accounted for by transfer under compression and its accompanying metamorphism. The planes dipping 30° east crossing the 80° west plicated beds at the Landon quarry at Pittsford are probably planes of slip cleavage also. But there are other parallel close fractures crossing the marble beds at many points and known as reeds by the quarrymen, which are not as 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. At the abandoned quarry about half a mile south of Proctor quarry the marble beds dip 70° east but the reeds 20°.

FAULTS

It has been noticed that faults are not uncommon in the marble beds. Of course, when these are exposed they demand the attention of the quarrymen. They must first find the position of the

fault and the amount of the displacement, up and down, or if there are other displacements, as is likely, though not certain, these must be investigated, until the faulted beds are located. In the marble beds this is usually, though not always, not difficult to be discovered.

FOLDED STRATA

The upheavals, distortion, folding, crumpling, faulting and other changes in position and composition of the material of the marble beds has been noticed on past pages and will be noticed in pages to follow. As to folding, all the regularly deposited and horizontally placed show at present more or less displacement, some are completely overturned, many much inclined, many raised in folds and those who operate a marble quarry must examine and be governed in the working by all these changes that have so long ago happened.

Unless close attention is given to all the present conditions of the quarries there will inevitably be greater or less loss in attempting to get the utmost financial profit from the mass of stone. Most of the many conditions which the quarryman finds must be studied if the stone is to be taken out in the most satisfactory manner. Of course, the locality of the marble mass, the convenience of transportation, the disposal of the great amount of unsalable stone, the waste, always a very important item, must be considered as well as the quarry conditions; all these and more determine the profitableness or unprofitableness of a marble quarry. I find many persons who seem to think that it is enough to own a good marble quarry, or what can be made such. Not only the mass of sound stone is needed, but one must ask and find a satisfactory answer to the question, can it be easily and profitably worked?

GLACIATION

It is needless to call attention to the fact obvious to one who has any knowledge of geology that every part of Vermont was, in the Pleistocene, covered by one or more ice sheets. Even the highest of our mountain summits were covered and eroded. If this is true, no marble bed could escape the universal (in this State) action of great glacial action. The results of the movement of glacial streams over the then exposed beds of marble are not at all the same in all. In one respect there was the general erosion and moving away from its original location of great quantities of marble, which, of course, was an entire loss. The tops of folds were, in many cases, worn off, beds elsewhere were crushed, worn down and left exposed if they had previously been covered by schist or other material, but elsewhere they were covered by masses of sand and gravel and thus protected from atmospheric erosion. Very few marble beds can be found in the State that are sound and salable from the top. More or less surface material must be removed, and

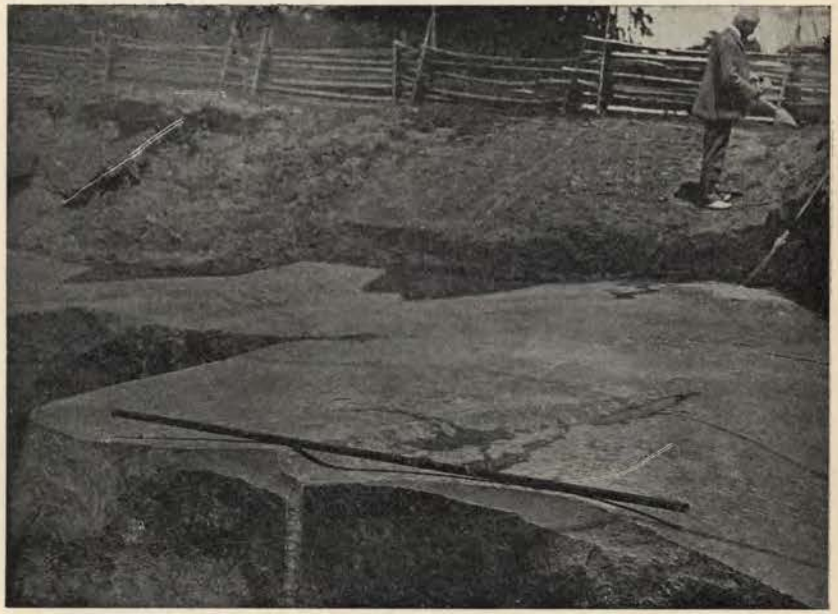

FIG. 6. Glaciated surface, old Fisk quarry, Isle La Motte.

then usually the upper marble beds moved away before salable marble is found. Had not the glacial material covering some of the marble beds been left to protect the marble, much more unsound stone would trouble the quarryman. The fine clay made by the glaciers is the most effective covering, as would be expected. Where this clay covered the stone it can be used from very near the surface. (See Figure 6, also Figure 3.)

HISTORY OF THE VERMONT MARBLE INDUSTRY

Before going forward to a detailed account of the quarries and marbles of Vermont it will not be without interest to read a concise history of the marble industry in this State. Necessarily somewhat of this has already appeared on previous pages, but a more complete account will not, I am sure, be unwelcome to many of my readers. It is very fortunate that in undertaking this I have the very valuable assistance of Mr. F. R. Patch, president of the Patch-Wegener Company of Rutland, Vermont. Mr. Patch has not only been interested in marble-working machinery for many years, but also has had much personal experience in marble quarries and mills, so that he can not only say with truth this I know and have seen but "a part of it I was." I know of no one who is able to tell us more intelligently or authoritatively about this industry than Mr. Patch. He has sent me a copy of an address made in Rutland in 1931 and most of this is repeated in the following quotations. First, the following is taken from a personal letter: "In my early marble days when I first became interested in marble working, some sixty-five years ago, there was very little metal used other than in the saw blades and crankshafts of the gang saws. There were no quarry machines and only the very rudest of the hoisting machinery. The only machine used was the Wardwell Chaneller. This was at Sutherland Falls (Proctor). In those days no wire rope was used, and the derricks could carry only a load of ten tons. The hoisting power was oxen walking around a sweep."

When in following pages the machinery now in use is described, there will be further quotations from Mr. Patch. As to the early history of this industry, Mr. Patch says in the Rutland address as follows: "Probably the first reference to marble in the State of Vermont was in a letter written by Nathaniel Chipman to Gen. Philip Schuyler of New York. This letter was dated Rutland, January 25, 1792. There are also in this part of the country numerous quarries of marble, some of them of superior quality. Machinery may easily be erected for sawing into slabs by water and in that state it might become an important article of commerce."

Several outlines of the History of the Marble Industry in Vermont have been published and from them the facts, as nearly as can be ascertained, together with hitherto unpublished material, have been compiled. Vermont is not a very old state, and, of course, no marble was thought of, still less used, before the region was occupied by some of the early settlers. Apparently marble has been quarried in this State for 150 years, though not to any great extent during the earlier years. Conspicuous as are some of the marble ledges in western Vermont they must have attracted some notice from any explorer who came into this part of the region, but even after, when considerable numbers of home seekers came and for years after their coming, they had full need of occupying themselves with more immediately practical duties than those necessary in getting out marble for even household purposes. So far as the writer can discover the first mill in which marble was worked was built, according to Mr. Patch, in Middletown by "Marcus Stoddard," who built a small mill. "His marble came from a quarry in the north part of Tinmouth. There was also about this time a marble sawing mill at Chippenhook in Clarendon, owned by Peleg Semans." This may have been the first mill, but marble was quarried and worked by hand before this.

About all of the headstones standing in the cemeteries from Bennington to Burlington, dating from 1785 to 1830, came from this quarry and are most of them in good condition. They were worked before sawing was done and tooled by hand. "The quarry was 150 feet long, 128 feet wide and 16 feet deep." I find that this was not the only quarry opened, or at least used, in 1785, and it is not improbable that other small quarries were opened about this time. While probably marble was mostly used for gravestones, yet it was also used, as shown in Figure 4, about chimneys, fireplaces, walks and such uses as required little hand work in its preparation after it came from the quarry. The early history of some of the later valuable marble land was, like that of coal lands and other land, at first worthless, but later valuable. I do not vouch for the entire truth of the story but it is told as true that the original owner of some of the land in West Rutland, where now there are several large quarries, after trying in vain to make profitable agricultural fields on the rocky soil, was glad to trade his then worthless property for an old horse. The stone which the barren fields afforded was then of no value for any purpose. It was many years before there was any demand for marble or any machinery by means of which it could be made useful. In a number of the *American Stone Trade* I find the following: "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 this country."

At first, for reasons explained in early pages of this article, the demand for marble increased very slowly, that is, between 1785 and 1850, but there was a constant increase, at any rate, in the demand for Vermont marble, until the industry was greater in volume than it was in any other state. A more rapid growth began in 1860 and continued until the general business depression.

In Professor Seely's article in The Marble Border of Vermont, page 42, we find: "It is an interesting scene to behold 200 workmen ranged in rows each with his drill cutting deeper the groves that are destined to sunder the fetters that bind these valuable blocks to their parent bed. The musical ring of the quarryman's drill that reverberates to the ear from the deep-vaulted quarry as he looks down into it is pleasing to the spectator." It is a long time since one visiting a marble quarry would find any such scene as the above describes. The channeling and the gadding machines, driven by steam, or later by electricity, have wholly displaced hand drilling, except in special cases. In 1863 the first channeling machine was introduced in the Sutherland Falls quarry at Proctor, using steam as its motive power. This channeling machine was used for twenty years, when it was replaced by a more modern form driven by electricity.

When the first marble mill was built in Vermont, I cannot be sure as the early records that I am able to find are somewhat uncertain, but the earliest trustworthy account that I can find is the following, sent by Mr. Patch: "In 1821 Gen. Jonas Clark operated a quarry and mill of two gangs and one single blade saw in the south part of Tinmouth. The machinery was driven by an overshot water wheel 27 feet in diameter. This mill was operated for about thirty years. The marble was hauled by horses a distance of 30 miles to Comstock where it was loaded onto canal boats. The marble for the Conant house in Brandon was sawed at a mill that stood on the south side of the Neshobe River, just below the grist mill, about 1831. Between the years 1825 and 1845 there was in use a marble mill called 'The Taylor Mill,' the ruins of which can be seen today beside the highway about a half mile north of Clarendon Springs. Mr. John Sheldon told me about sending marble to Castleton, Fair Haven and Poultney from quarries in West Rutland by ox team."

"The first Sheldon mill was built in West Rutland in 1844. In the same year, 1844, the old Ripley mill was built. This mill was rebuilt and afterwards, 1889, was burned. Where the Vermont Marble Company's blacksmith shop in Center Rutland now stands, near the highway bridge, there were four pendulum gangs of saws for sawing marble in what was called the Porter mill. These saws were driven by water wheels in the basement of the mill.

"In 1845 William Kittridge, Alonzo Allan and Joseph Adams built a mill in Fair Haven about where the railroad crosses the river at the State line. The mill was equipped with eight old-style pendulum gangs and was built by Hiram Shaw, of Hampton, and in 1851 was changed by adding four gangs, the pendulums being replaced by the new modern and improved machinery of pulleys and belts. Up to the opening of the Rutland and Whitehall Railroad in the fall of 1849, the marble was drawn from the quarries in West Rutland to the mill by ox teams and, after sawing, again by teams taken to the canal at Whitehall."

As has been noticed, this industry developed slowly for many years, though quite a number of mills and marble companies were started. In 1840 there were sixteen marble companies in business in the State, not only finishing but also working quarries, but the business does not appear to have been very prosperous. Nevertheless it thrived sufficiently to cause the formation and activities of thirty-three companies by 1860. From this time on, though the demand for marble seems to have considerably increased, the number of companies decreased, not, however, because the marble business had decreased, but because many of the smaller companies had united with, or sold out to, a few larger companies. As the result of this the Vermont Marble Company, which started as the successor of the Sutherland Falls Company, had bought other plants and become thereby much the largest of all. In the year 1900 there were only sixteen manufacturing and quarrying companies and at the present time there are only the Vermont Marble Company, the Colonial Marble Company, the Green Mountain Marble Corporation, and the Venetian Marble Company. The main office of the Vermont Marble Company is at Proctor with several branch offices elsewhere. The office of the Colonial Company is in Rutland and the office of the Green Mountain Company is in West Rutland. I need not say that the three companies mentioned are all quarrying and manufacturing many varieties of Vermont marble and that the numerous smaller concerns, scattered all over the State, are not included in this account."

A brief statement concerning each of these companies may not be out of place here as not only showing what each is doing, but also showing the great development in the marble business since the early beginning, when the first mills were started. Before going on to the above, it will be well to take up a little more that belongs to the History of the Marble Industry. I find it impossible to take up this general subject separately, under distinct headings, as I should wish. As it seems to me, some of the subjects included in this account are so interwoven that they cannot be separated by hard and fast lines. Hence it may appear to some readers that in some cases there is too much of a mixup. But this seems unavoidable.

This is especially true in what follows. The history of the marble industry and the history of the development of the Vermont Marble Company are so completely interwoven that one cannot be properly treated without the other.

I wish here to quote somewhat extensively from a very excellent summary of mainly a history of the establishment and growth of the Vermont Marble Company, as it is surely an account that I feel certain will interest all who are interested in the marble industry in this State. I quote, with some abbreviations and omissions from a thesis, meeting the partial requirements for the degree of Master of Arts in the University of Vermont, on Marble Quarrying in Vermont, 1932. As will be seen, this history is mostly that of the West Rutland area, but it is also a history in great measure of marble in Vermont by Major B. Jenks.

"Beginning with the opening of the West Rutland deposit, 1844, in this and the following year important openings were made. Sheldon and Slason made one of the most important of these, in 1844, which proved highly successful and formed the basis for one of the most substantial and prosperous of the early companies. William F. Barnes, a retired minister, was responsible for opening, in 1844 and 1845, a quarry that became the property of the Rutland Marble Company. The marble in this quarry was said to be inexhaustible by C. B. Adams, in his first report as State Geologist in 1845. In that same year two men made the third important opening in the West Rutland field. Joseph F. Adams and Ira Allen of Fair Haven leased three acres from Ebenezer Goodrich for a marble quarry in March, 1845, and made a beginning there. In 1860 they were employing 100 men at the quarry but in 1868 they sold out to E. P. Gilson and John P. Woodfin, under the name of Gilson and Woodfin. This company did not work the quarry, but had an unusual agreement with the Sullivan Machine Company of Clarement, New Hampshire, manufacturers of marble machinery, by which this company agreed to cut the marble for a number of years. The mill contained eight gangs of saws, about thirty men being employed in mill, quarry and office. This company produced annually about 240,000 feet in 1873. W. E. Barnes, besides making some of the earliest openings, soon became interested in the manufacturing side. He joined William Y. Ripley in building a mill for sawing marble. The business was soon carried on by Mr. Ripley's sons. They soon, however, divided their holdings, Ripley taking the mill at Center Rutland, Barnes the quarry at West Rutland. An agreement was made that Barnes was to supply, forever, a certain number of cubic feet of marble and that Ripley was to saw and sell this and divide the proceeds as he collected them. (Gale, A Marble Town, see Bibliography.) In 1844 a mill of six gangs was built and in 1852 another mill of eight gangs of saws was built. In 1873 this mill was running night and day, with a working force of twenty-three men, putting out about 150,000 feet annually, mostly monumental stock. These mills were the first to adopt the automatic sand feed, an invention of W. T. Ripley, grandson of W. Y. Ripley, founder of the concern. . . . General Baxter managed to secure some measure of success from the Barnes holdings (after Mr. Barnes' death). In a few years he sold the property to the Rutland Marble Company, a corporation largely owned by bankers in New York City. In 1860 this company was employing 125 men in the quarry, selling the marble in the rough to W. Y. Ripley and son through the agreement above mentioned. Charles Clement had early begun a mill at Center Rutland and later W. C. and Percival Clement, his sons, were associated with him. Beginning in 1868 Clement and Sons operated a quarry in West Rutland. The quarry was not owned by them but leased from the Rutland Marble Company. In 1860 the company was operating twelve gangs of saws and producing about 150,000 feet annually. This had increased by 1873 so that, with a force of seventy-five to a hundred men, a mill of sixteen gangs was producing about 250,000 feet annually. This company was purchased a few years later by the Rutland Marble Company."

"Previous to this purchase in 1873 the Rutland Company owned a mill with twenty-four gangs of saws running night and day, besides supplying other companies with marble on contract. This company operated another mill of eight gangs, the Baxter Manufacturing Company, at Salem, New York. By 1880 the Rutland Marble Company had become a large unit of the marble business. It owned four quarries in West Rutland, and was the largest in this area. It also had twenty-four gangs of saws in West Rutland, twenty-eight in Center Rutland and eight in Salem, New York, a total of sixty gangs. This company failed to grow as it might because it paid out the profits as dividends instead of investing it in the business. . . . Another important organization was Sheldon and Slason, who made one of the original openings. About 1860 their excavations had reached a depth of 160 feet, which insured a fine type of marble. This company was employing 200 men in the quarry and steam mill. The mill operated nineteen gangs, sawing 500,000 feet of marble annually, which was sold mostly in the slab. After the first quarry they opened three others in this locality. These quarries became quite deep, one reaching 185 feet below the surface, and the cutting was done by hand as late as 1873. In May of 1873 the company shipped 110 carloads of marble. The mill was located at the quarry and contained 24 gangs of saws, which ran night and day. A new mill was built in 1873 which added eight more gangs. The company employed 225 men and produced 360,000 to 400,000 feet of marble annually. The sales for 1873 were $80,000." (Redington, see Bibliography.) (Here it should be noticed that as there is discrepancy in some of the dates, Mr. Jenks has adopted that which appeared most likely to be correct. G. H. P.) "In 1860 Smith Sherman and Moses Jackman of Castleton made an opening in West Rutland. (Smith and Rann, see Bibliography.) Later this quarry was purchased by the Dorset Marble Company. In 1860 the firm was known as the Sherman, Holley and Adams Company. They obtained an excellent marble which they shipped by rail to Castleton and Fair Haven. In that year, 1860, they turned out 200,000 feet of marble. (Note: Here it may be noticed that there never were quarries at either Castleton or Fair Haven, but this company had mills for sawing marble in both these towns.) By 1875 this company had increased so that in that year they produced 300,000 feet and employed 120 men."

"A group of men, Horace and Norman Clark, Soloman Giddings and J. H. Post, organized as the American Marble Company and opened a quarry in 1866. They built a four-gang mill at the quarry, but after six years they went out of business. David Morgan opened a quarry the same year. This quarry was abandoned in 1873 because of the unsoundness of the marble.

Later in 1885 it was reopened by the West Rutland Marble Company."

As the story of not only West Rutland, but also that of neighboring towns, involves the story of quite a number, not only of the marble interests of these towns, but as well the story of a number of marble companies, in order to understand the history of the marble industry in Vermont, it will be necessary to consider as briefly as possible, leaving details to the discussion of each town for consideration on other pages of this article. Here again I shall make free use of Mr. Jenks' thesis. What Mr. Jenks says of a part of the marble industry may as well apply to the whole: "The story of the early years is one of constant ups and downs, with greater emphasis on the downside, a situation which would discourage any but the optimistic and resourceful Yankee business man of young America." In 1884 the town of Sutherland Falls was renamed and incorporated as the town of Proctor and to a consideration of marble interests here we digress from West Rutland for a little. Indeed, the history of marble in Proctor, West Rutland, Pittsford, Dorset and Danby is really one. Taking up first Proctor, or Sutherland Falls as it was at first, we find that the first marble was quarried in the Humphrey quarry, later owned by the Columbian Marble Company, in 1836. . . . The Humphrey Brothers became associated with Edgar J. Ormsbee and in the winter of 1836-37 erected a mill with four gangs of saws. . . . The quarry known as the Sutherland Falls Quarry was begun in 1838. The financial panic of 1836-37 was too much for the enterprising quarrymen, who were obliged to give up the unequal struggle and turn the business over to the creditors, who appointed Francis Slayton of Rutland to run the business. . . . After 1845 the business was practically dead. In 1854 the North River Mining Company decided that conditions were more favorable, since the coming of the railroad, and opened new quarries at Sutherland Falls. The mill was rebuilt and although the marble was harder than that at West Rutland and well adapted to outdoor work, the business did not grow rapidly enough to save the company from disaster and it went to the wall in 1887. A reorganization was effected in that year and the Sutherland Falls Company was formed. . . . In 1860 thirty men were employed in the quarry and the mill was cutting about 75,000 feet annually. Six more gangs of saws were added in 1860 as a result of increased business, due to the durability and excellent polish of the marble. A lease was made with S. M. Dorr and J. J. Myers by which they were to do the sawing and selling for the Sutherland Company and receive land and water privileges at the falls. They built an eight-gang mill and made other improvements. . . . Dorr and Myers fell into disagreement, disrupting the partnership, and a receiver was appointed to carry out the contract. (Redfield Proctor was appointed receiver. This was Mr. Proctor's first connection with the marble business, it was in 1869.) Sutherland Falls was admirably situated for such a business and Colonel Proctor was quick to see it. Here existed in close proximity a fine deposit of marble, abundant waterpower (Otter Creek drops 120 feet here), a good supply of sand for sawing, and a railroad. All these features needed to be united, and in November, 1870, Mr. Proctor organized the Sutherland Falls Marble Company, a Vermont corporation, that took over the whole business. Mr. Proctor invested all the money he had and all he could borrow and became treasurer and manager. The new company prospered by dint of hard work and good management. . . . By 1880 the Sutherland Falls Company was a solvent substantial concern, operating sixty-four gangs of saws and a real success in Vermont marble business." (This appears to have been the beginning of the great Vermont Marble Company. G. H. P.)

"In 1868 the Rutland Marble Company resumed work on the quarry at Humphrey's Cove, a mile south of Sutherland Falls, opened by Moses Humphrey and Edgar J. Ormsbee and idle since 1838. The property was sold in 1871 to the Columbian Marble Company, whose mill was located in Rutland on the Central Vermont and Delaware and Hudson Railroads. The mill contained nine gangs which were run by steam. In 1873 this company employed seventy men in quarry and mill, producing 150,000 feet of marble annually. In 1875 the use of fixed tools in turning marble was introduced. In 1860 the Rutland district was, by all odds, the most important marble region in the State. Its importance was felt from its opening in 1844 and as early as 1850 it was probably the largest single field in Vermont. After this time it continued to grow rapidly so that by 1880 it was the dominating factor in the marble industry of Vermont."

"The early period (of the marble industry) was one of exploration, slow development, and little commercial importance; the middle period is one of machinery, railroads and rapid exploitations; the third period is one of consolidation, rapidly widening markets and commercial importance. In this account of the recent period of the industry, possibly the easiest way to secure a connected picture is to follow the fortunes of the company which has come to symbolize the marble industry in Vermont in the Rutland district, and by this is meant Rutland, Center Rutland, West Rutland, and Proctor. The companies in the West Rutland field in 1880 were Sheldon and Slason, operating three quarries and a mill with forty-eight gangs; the Rutland Marble Company, operating the largest quarry holdings in West Rutland and a mill with sixty gangs; Gilson and Woodfin, operating one quarry and eight gangs in the mill; Ripley and Sons, one of the oldest firms in the county, with a sixteen-gang mill; the Columbian Marble Company, with quarries south of Proctor and a thirteen-gang mill in the town of Rutland; and the Sutherland Falls Marble Company, with quarries and mills containing sixty-four gangs of saws in Proctor. Several companies were incorporated and further rapid advance took place in the Rutland district in the next few years but the most important advance came in 1880. Then Colonel Proctor, while in the office of a friend, met Elisha Riggs, president of the Rutland Marble Company, and was offered the management of that company. In order to give Colonel Proctor a free hand in managing the company offered to resign the presidency in favor of Colonel Proctor. Thus unexpectedly placed in control of these two marble companies, Colonel Proctor soon saw the advantages that might ensue from a union of the two companies. Such an undertaking, however, was not without great risk, as he was taking a company free from debt in which he and his friends had controlling interest, built up as it was by more than a decade of hard work to a successful position and joining it to a company with considerable debt and somewhat unsuccessful in which he would be a minority stockholder. . . . In September of 1880 the Vermont Marble Company, a New York Corporation, took over the properties of the Sutherland Falls Marble Company and formed the Rutland Marble Company with Colonel Proctor as its first president. The phenomenal success of Colonel Proctor in the marble business must have encouraged others to embark upon investments in this field in the years from 1880-85. Col. Benjamin F. Baker of New York purchased an old farm in West Rutland and discovered a bed of marble on it. He made an opening and formed the Center Rutland Marble Company, composed of some of his New York friends. He took up his residence on the farm and personally superintended the work. The marble was a beautiful dark color and an eight-gang mill was built. This quarry was found on working to contain a large amount of unsound marble and was abandoned for this

reason. By sawing marble from the Albion quarry and others and by opening a new quarry on the farm the company succeeded in continuing and even increasing their business. By 1884 about fifty men were employed and the mill had twenty gangs. The Dorset Marble Company, with its office in West Rutland, was organized in 1881 with a capital of $300,000. This company purchased two quarries and a mill in East Dorset, a quarry and mill in West Rutland, and a mill in Hydeville, a village in Castleton. The West Rutland quarries produced white clouded and blue marble, the Dorset Italian or white monumental stone. This company, in 1865, ran thirty-two gangs of saws and employed 100 men with annual sales of about $125,000. In the fall of 1881 the West Rutland Marble Company was chartered, operating the Green Mountain Marble Company, originally opened by David Morgan in 1865. The capital was mostly held by Massachusetts men, $250,000. The company owned mills in West Rutland and Salem, New York, with a capacity of 250,000 feet annually for its twelve gangs. The company grew steadily and was employing fifty men in 1885. A new quarry was opened in 1883 by the Esperanza Marble Company in Whipple Hollow in the north end of the West Rutland deposit. It was a blue marble capable of fine polish. An eight-gang mill was erected and started to saw the marble. Adjoining the quarries of this company were those of the Valido Marble Company of West Rutland, organized in 1884 with a capital of $300,000 chiefly owned by G. H. and J. B. Reynolds and W. H. Johnson. The mills were run by water power at Fair Haven. The company employed about 100 men and produced a beautiful and exceedingly sound marble. The Standard Marble Company was organized in 1883, operating a quarry started in 1830 by William Barnes and Francis Slayton. The light clouded and blue marble was sawed at the mill of the American Marble Company, which was leased by the Standard Company."

"The most important company formed at this time was the True Blue Marble Company in 1884, with a quarry and mill at West Rutland, and offices in Rutland and West Rutland. Their capital was $200,000 and the moving spirit was George E. Royce. The company was started only after careful prospecting of the deposit and because of the great demand for blue marble, that sold as fast as it could be produced and commanded a high price. This company built an eight-gang mill, which was run night and day. Besides the formation of these seven new companies in a very brief period, the five companies already in the field were expanding rapidly. In October of 1881 Charles Slason retired from the business and it became Sheldon and Sons. A twenty-gang mill was added giving a capacity of sixty-eight gangs in all, run day and night. A finishing mill was built in 1879-80 which employed 120 men. All varieties of Rutland marble were handled, the value of which was, in 1885, $450,000 annually. In the early eighties the company contracted to furnish 245,000 lettered headstones to the Government for soldiers' graves costing $864,000. This was possible by the use of the sand blast in lettering the stones. Marble for the gold room in the United States treasury building and the old Parker House, Boston, came from this company." (Seeley, see Bibliography.)

"Gilson and Woodfin owned a quarry in the heart of the marble belt which produced white and blue marble. This mill contained twenty-one gangs and employed 100 men. Ripley and Sons did not quarry marble but sawed marble. They had a contract with the Rutland Marble Company for an unlimited time. The Ripleys were to saw and sell the marble and divide the proceeds. One mill was turned into a finishing shop in 1877 and a new twenty-gang mill built in 1881. In 1882 a new contract was made with the Vermont Marble Company by which the Ripley Company received blue marble from West Rutland and dark variegated from Proctor. (Smith and Rann, see Bibliography.) The Columbian Marble Company, the only company in this area besides the Vermont Marble Company, employed 150 men. They also handled the marble of the Bardillo Company of Brandon. The Vermont Marble Company operated four quarries in West Rutland besides owning considerable undeveloped quarry land in Proctor. In West Rutland they owned about half a mile of the marble belt, including seven quarries of which three or four were operated at a time. They also purchased some undeveloped property in Clarendon. In the Proctor mills were seventy-four gangs of saws, a twelve-gang mill having been added in 1876 and a thirty-gang mill in 1880. A fourteen-gang mill was built in Center Rutland in 1882, making 128 gangs in all. By 1886 their annual sales were $800,000 and 900 to 1,000 men were employed."

"The rapid expansion of existing companies and the addition of seven new companies tended to create unfortunate conditions. Many of the companies were large and were tempted to cut prices thus making the business unprofitable for everyone. Before their consolidation into the Vermont Marble Company, the Rutland Marble Company had actually held auctions of their marble, a condition certainly calculated to demoralize the market. In order to prevent cut-throat competition and to help standardize prices, Colonel Proctor organized and planned the Producers Marble Company on January 1, 1883. Each of the members ceased to sell marble directly but sold their entire output to this new company, they reselling to the trade, collected for it and controlled all branches and agents. The members were allotted a certain quota of the company and furnished marble as near as possible to that percent. The five largest companies in the field held the following percentages: Vermont Marble Company, 54.72; Sheldon and Sons, 23; Dorset Marble Company, 5.88; Ripley and Sons, 7.25; Gilson and Woodfin, 7.03. (David Gale, see Bibliography.) The pool controlled such a large amount of the business that they controlled the price. They handled all the best varieties, shipping, in 1884, 6,000 carloads to all parts of this country and to foreign countries. This agreement was to continue five years and ended December 31, 1887."

"Immediately after the breakup of this pool the Vermont Marble Company began to acquire other companies rapidly. The Dorset Marble Company had gone into receivership. . . . On January 1, 1889, they purchased all the property of Gilson and Woodfin. Later in the year they bought the Ripley mill at Center Rutland. In 1881 they acquired the Sheldon property, by first leasing it for thirty years, then buying the capital stock and merging it in the Vermont Marble Company. The Sherman Company, formerly worked by the Dorset Marble Company, was bought and a railroad was built to unite the properties, work on the Clarendon and Pittsford properties beginning in 1886 and continuing three years, thus connecting Center Rutland, West Rutland, and Proctor. The Vermont Marble Company possessed by 1891 most of the West Rutland marble deposit and had absorbed all of the companies that formed the Producers Marble Company. In 1889 Redfield Proctor was appointed secretary of war by President Harrison. This closed his active connection with the Vermont Marble Company, and he was followed in the presidency of the company by his son, Fletcher D. Proctor, who continued in that position till his death in 1911. The Vermont Marble Company, after it was firmly established as the dominant interest in the West Rutland field, began to extend its influence over the State; in 1889 this company bought the quarry of the Esperanza, before this the Albertson quarry, in the northern end of the West Rutland marble range."

"Several of the companies which were consolidated with the Vermont Marble Company, though doing business in Vermont, were New York or Massachusetts corporations, but now, 1880, the corporation became a Vermont concern. Though the old name of the Barney Marble Company of Swanton, in 1901, was kept, the management of the quarries and mills was under the greater company. The old Morgan quarry in West Rutland was reopened by the Vermont Marble Company in or about 1912, soon after taking over the 'Winooski Marble,' the name being changed to Champlain marble. The Roxbury 'Marble,' a serpentine or verde antique, to be discussed on a following page, was controlled by the Vermont Marble Company; also a new quarry of this stone was opened in Rochester, Vermont. In Danby this company bought quarries in 1905. This purchase included all the most desirable marble land in Danby. In 1909 the Vermont Marble Company bought the large Brandon Italian quarry at Brandon. In 1901 the Rutland-Florence Marble Company was formed. They also purchased the property of the True Blue, the Central Vermont, the Tennien, the Newbury estate, and several other quarries, mills and lands in adjoining towns. Later in 1911 all these were purchased by the Vermont Marble Company. In possession of all these properties the Vermont Marble Company practically controlled the marble interests of western Vermont. This company in addition, in 1913, became owners of the Dorset property which had been carried on by the Norcross-West Company. Thus it will be understood how, by the consolidation of many companies, one very large company was formed, though, as will be seen, this company did not acquire all the valuable marble beds in the State."

It has been necessary to allude to the "Marble Belt" several times already. By this is usually meant the marble region of western Vermont, in which are located all the commercially profitable quarries in the State. This belt, as has been stated, is a narrow area extending from Shelburne on the north to the southern part of Dorset on the south, and between the Green Mountains and Lake Champlain, though nowhere as far west as the lake shore. The marble passes south across Massachusetts into Connecticut, but in Vermont all the commercially valuable marble has been quarried north of the south town line of Dorset.

As will be found, several varieties of "marble" are obtained outside of this border. These are fine "marbles" but none is true calcite marble. Only that part of the "Marble Belt" which is in Vermont will be discussed. The belt extends, however, south of the southern border of this state as far as Danbury in Connecticut where it is known as "The Stockbridge Limestone."

In the belt south of Vermont some marble, beginning in early times, has been quarried, but by far the most important marble industry has always been carried on in Vermont. This belt must not be thought of as continuous, for there are many breaks between workable marble beds in the entire area. For many years, as now, the principal marble quarries have been in the towns of Danby, Dorset, West Rutland, Proctor, Clarendon, Florence, Pittsford, Brandon, and Middlebury. For several years no calcite marble has been quarried north of Middlebury, not much north of Brandon, nor south of Danby, though in former years Dorset and some few other localities produced more or less marble. A word respecting the rocks adjacent to the marble beds. The most commonly seen rocks are mica and sometimes other schists; less commonly there is quartzite, gneiss and occasionally other kinds.

In starting a marble quarry some important features must be sought and carefully considered. More will be written as to this later. It will be enough to allude to only a few of these features here. All marble is found to be in layers or beds, which, as already noticed, usually are not horizontal, but the incline in it may be in one direction, may be in another, sometimes almost vertically. Prospecting in one way or another is the first requirement. More or less guesswork is sometimes unavoidable and formerly, much more than latterly, was so; but now, with machines to be mentioned, this always unfortunate necessity is reduced to a minimum. As would be expected, new processes in getting out of the quarry and preparing for sale the marble have been adopted from time to time and the entire work is now very different from what it was in the earliest days of the marble industry. Some reference to the early days of getting out and finishing marble in addition to what has been said may not be without interest. In some respects the early history is indefinite and fragmentary, but not all is of this nature.

In a letter written by Mr. G. E. Royce of Rutland I find the following: "I would say without any doubt that 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 in a small way for about fifty years. The record shows that in the beginning it was described as a stone quarry, so-called marble, and in 1795 it was sold for 400 pounds, about $2,000. In 1812 our member of Congress, Ezra Meech, took a contract,

Fig. 7. The Danby quarries as viewed from across the valley.

to supply for a Government building in Charleston, South Carolina, 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 from 1878 to 1830 came from this quarry, and are almost all in good condition. They were worked before sawing was done and tooled by hand. This quarry was 150 feet long, 125 feet wide and 16 feet deep." This letter was written some twenty-five years ago and the property is now owned by the Vermont Marble Company.

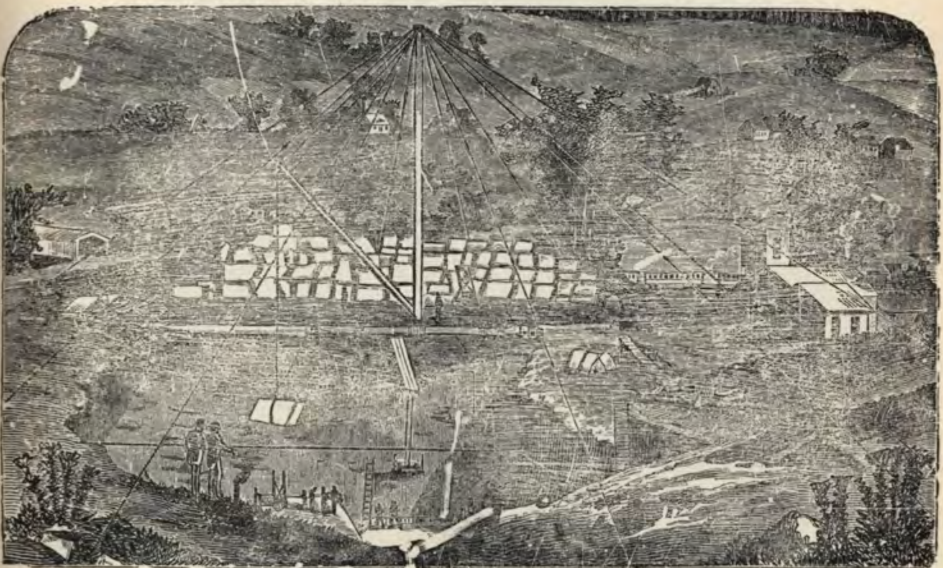

FIG. 8. Old woodcut; illustrating early days of marble quarrying.

ACTIVE MARBLE COMPANIES IN VERMONT IN 1932

The introduction of channelers and other machinery, formerly used only in marble quarries has made these other quarries more and more appear like them. But, until lately, the orderly and regular appearance of a marble quarry was in very noticeable contrast with the ordinary stone quarry. In the various methods, from the very rude used at first, through divers improvements to such as are used now, there has been a succession of changes. This will be readily seen in the reading of the following quotations from the writing of Mr. Patch and Mr. Royce. Before giving these it may be noticed that before marble can be quarried a bed of the stone must be found. Sometimes this is very conspicuous, often more or less covered. Figure 7 shows a part of the hillside in Danby where the marble outcrop is very conspicuous. Because of this need for care, which has been noticed, the expense of opening a marble quarry is often considerable. One of the officials of the Vermont Marble Company once told the writer that in opening many of the quarries afterwards worked, the cost had been from twenty-five to fifty thousand dollars, even more in some recent quarries—this before any good marble was obtained. As has been mentioned, a few quarries, as the River-

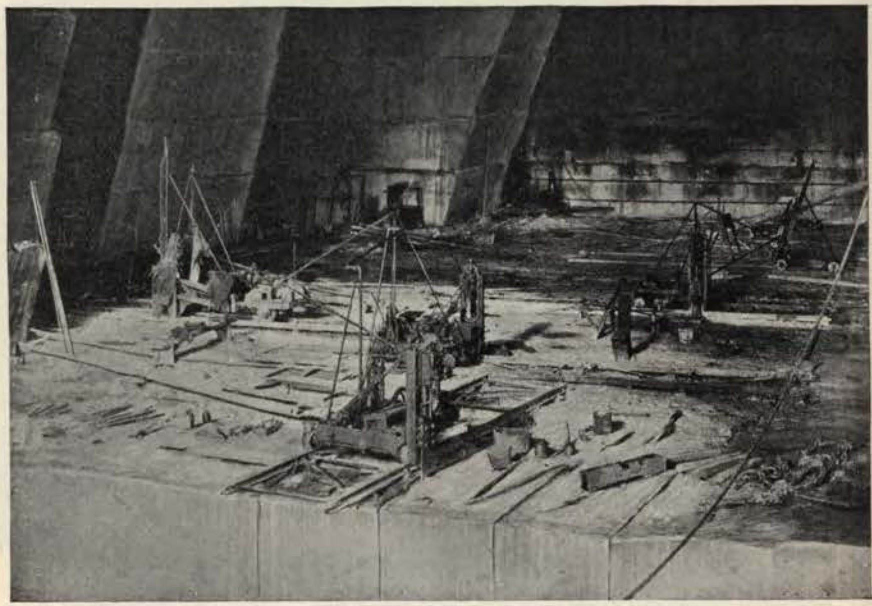

FIG. 9. Covered quarry, showing diamond channelers and Sullivan channelers.

side, could be operated from the surface, but this is not the common rule. As the following illustrations show, there is considerable difference in the quarries in different localities; some are deep, as most of the West Rutland quarries, going down from 100 to over 300 feet below the surface. Some are open, others only partially open to the surface, while some are entirely underground, and then a more or less inclined tunnel is necessary as shown in Figures 8, 9, and 10.

After a quarry is located and stripping off the useless material which may very probably be on top, then the channelers are

used and the valuable marble taken off, layer after layer and block by block. Figure 8 shows one of such quarries that has been worked for some time.

Of course, loose material can be easily removed, but the valueless stone must be carefully removed. All blasting that is not very necessary is avoided, lest it injure good stone beneath, for marble, even if good in quality, if cracked is of little worth. And, therefore, none of the salable marble can be subject to blasting if this is not absolutely necessary. It may be noticed here

FIG. 10. Opening a new floor in the underground marble quarries.

that methods long employed solely in marble quarries are more and more being adopted in other stone quarries and the unwanted material taken out by various kinds of machinery.

As has more than once been stated, all the commercially valuable marbles sold in Vermont are found west of the Green Mountains and this has always been true. As will be shown, a few kinds of stone, which in trade, are called "marble," have been obtained east of the Green Mountains, but as compared with the product of the western quarries, that of the eastern does not amount to very much. The areas from which marbles have been and are being taken are, beginning at the south, as follows: No marble appears, as far as records show, to have been in any way quarried before that of Dorset, though, as will be seen, in the Rutland area marble was taken out at about the same time, 1785. The individual quarries will be considered later, but there are some general features that are found in all or most of the Vermont quarries that may be taken up before treating each quarry by itself. The areas in which, for 150 years in some quarries, in most for many years, marble in great variety has been obtained and sold are the Dorset quarries, the Danby quarries, the Wallingford quarries, the Clarendon quarries, the West Rutland quarries, the Proctor quarries, the Pittsford quarries, the Brandon quarries, and the Middlebury quarries. These are all of importance, a few others from which small quantities of stone have been taken will not be noticed in course of this discussion.

The reader will soon see that it is quite impossible to keep wholly separate a discussion of quarries and the varieties of marble which are taken from them or which may be taken if needed. At least this is true in a sketch such as this is intended to be. In following pages we shall take up the more important varieties. Many of these are always on hand, many others are in various quarries and can be obtained if wanted. The varieties here mentioned are those of a more or less standard sort. There are very great differences in different quarries and not seldom in different parts of the same quarry. This is true not only as regards color but shade, veining, clouding, arrangement of these, coarseness or fineness of grain, sometimes chemical composition, etc. Hence if one were to attempt to collect every possible variety, there is scarcely any limit to the number. In not a few quarries, especially the light shades, it is often more difficult to exactly match two slabs than to find a piece more or less unlike the one in hand. Then in addition to the variety in slabs sawed in the identical way more varieties can usually be brought out by sawing a block in different directions, always if there is an elaborate pattern in the arrangement of veins, shades, etc. As all must know, in some of the lighter beds marble of the purest white is found, at least in some beds, and of course here variety of any sort is not seen. It should also be noticed that in many of the colored marbles it is very difficult to describe the lesser characteristics in such fashion that an accurate picture of the coloring, shading, etc., may be gained. Some marbles are readily understood from a good description, in some, when one attempts to picture the stone in words, only an imperfect result can be reached. To really see the marble one must have before him an actual specimen, and sometimes the piece seen, to be appreciated, must be of considerable size. In studying different quarries they will be taken up in the main in geographical order, beginning at the most southern. There are some marble beds south of Dorset, but none, as far as the writer knows, have been operated in this State.

In addition to what Mr. Patch has written in the quotations from his addresses we may quote the following: "The first quarrying was done with an extremely long and heavy drill and coarse blasting powder. A hole about four inches in diameter was started on the surface of a vein and a scaffolding built above it. Then a 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 rhythmically 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 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 hilltop, there to await the explosion and the shower of earth and marble. This method of getting marble was employed for years. After the earth's surface is sufficiently stirred by blasting to get at the marble the quarrymen proceeded very much as do their brother workmen today, that is, the marble was split and wedged 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 split out from the rest of the deposit. The feathering process was superseded by another, much more tedious for the workmen but better because less marble was wasted. The stone cutter under the new régime worked at a single block of marble with a long drill at 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 readily be seen that this method of starting blocks from the original bed, that is, the blasting part of it, was exceedingly destructive as much good stone was spoiled."

Apparently during this same year, 1785, one or more small quarries were opened in Dorset, as has been noticed on another page. Which of these places was prior to the other is uncertain, but the time when both were in operation to some extent must have been about the same in each case. Most of the headstones now in cemeteries from these quarries were made before 1830 because those of later date were taken from a larger number of quarries which were then used. Anyone who desires can readily find and examine these old headstones and thus the carving and lettering which they have received and judge thus as to the durability of Vermont marble.

After the great deposits in West Rutland with their varied kinds and colors were opened, naturally the demand for the stone from the older quarries decreased. During the years between the earliest opening of Vermont quarries and 1850 the marble business with slow increase constantly went on. Yet in 1850, according to the United States Census report, there were only sixty men employed in all the stone quarries in the State, marble, granite and slate. To this number should be added 265 employed in the finishing works. Three times this number were employed in various mines in Vermont. Now, and for some years, no mines are operated in the State and in the quarries and mills several thousand. For fifty years or thereabout this State has led the country in production of marble and at first was the only state that sold this stone. Soon, however, other states began to open quarries and sell marble. At present marble is quarried and sold by at least nine of the states in considerable amount and in as many more in greater or lesser quantity. Vermont still sells nearly five times as much marble as does any other state. Especially after 1860 the marble business began more rapid development. Some of the many and very important changes, not only in quarrying but still more in manufacturing, or rather finishing this stone, have been adopted until, as will be more fully related later, about anything that can be fashioned in wood can be produced in marble.

In former times a much larger amount of marble than in later days was quarried in the two states south of this, but as the years went by the Vermont marbles overtook and passed the southern varieties and ere long exceeded the output of the whole

country and Vermont became known far and wide as the great marble-producing area of the United States. The growth of the marble industry in this State was for a time remarkable. Not until 1860 did the real boom in marble begin in Vermont. At any rate, this business did not become very important before that time and after this it rapidly increased. In 1860 there were fifteen companies operating fifty quarries and employing 550 men. As nearly as I can discover, the value of marble sold was at least $500,000. During the following twenty years the value increased to $1,340,000. During the next ten years it increased to $2,284,000. In 1900 the value of marble sold was not less than $3,562,000 and in 1920 to $5,000,000. The amount sold in 1930 I am not able to give, except that it was somewhat less than it had been and, as has been the case with most other business, it did not increase but rather decreased during the last few years. It has never been possible to state exact figures as to the sales of either marble or granite in this State. This is for the same reason in each of these industries. In each a very considerable amount of stone is sent in blocks as quarried to cutters all over the country and by them finished and sold. A larger value is finished in the State and sold as completed. Of course all the stone must be first brought from the various quarries and its value can be ascertained, so the value of finished stone can readily be found. The difficulty is to discover how much should be added to the value reported from quarries to properly indicate the value of the labor expended on the finished stone, shipped not as stone blocks, but as mausoleums, monuments, etc.

Many of the Vermont quarries are started as would be a cellar for some building so that the walls are nearly or quite vertical, but others must follow the inclination of the marble beds, others as in the illustrations in Figures 9 and 10 have to be opened in cave fashion and as quarried form cave-like openings. Evidently the slope, or dip, of the marble beds must be followed, whatever these may be. In many cases the quarries are located singly, elsewhere they are in groups or near each other in lines. The most important of such groups is the West Rutland area, and probably more marble has been and will be quarried from this region than from any other Vermont locality. There is also the region of Danby Mountain and the Dorset region, where the marble beds are more scattered over a considerable area, as also the Pittsford area and the Brandon area. The numerous quarries of these areas will be taken up in some detail on following pages. Active quarrying

FIG. 11. Section of storage yard for quarried blocks at Proctor.

has been carried on in all of the regions named, but some are now idle or supply only a small part of the stone sold. In addition to what has been said of the West Rutland area it is said in "Book of Marble" that "in recent years from 400,000 to 600,000 cubic feet of marble have been removed each year, and there still appears to be an unlimited quantity available." At one time the West Rutland quarries, on both sides of the valley which extends northward from the railroad station between not very lofty ridges on the east and west sides, were owned and operated by several companies, but now the whole range of quarries on the east side is owned and worked by the Vermont Marble Company, while the Colonial and the Green Mountain Marble Companies operate on the west side. The Taconic Mountains are west of this valley and what is called the Intermediate range forms the east side. Proctor, with its great mills and quarries, is just over this ridge. This village is regarded by many as the greatest marble center of the world.

As already explained, no blasting that can by any possibility be avoided can be allowed in a marble quarry, but the stone must be detached from the bed with the utmost care by channelers and gadders, which will be described later when we come to a study of marble-working machinery. Blocks of such size as are wanted immediately may be detached, and the greater number, in one or two standard sizes, usually 6′ x 4′ x 4′, larger if ordered for any especial use. Figure 11 shows how the blocks of common size are stored in the yard of large works. This or a like supply is kept on hand continually, 20,000 or more, at West Rutland. (See also Figure 22.) As these blocks weigh from 40,000 pounds, some less, some more, they must be handled by derricks. If larger pieces are wanted than these blocks can furnish, they are taken from the quarry in such size as is needed. The rough block or shaft is then taken to the mill, put on a powerful lathe, and if a column, turned to the desired form. Figure 12 shows one of two monolithic columns made for a bank in Bridgeport, Connecticut, supplied by the Vermont Marble Company. These columns weighed fifty-five and fifty-two tons. The piece of marble from which the Scott memorial fountain in Detroit was made by this company weighed sixty-three tons. (See Figure 13.)

Figure 15 is an illustration of the Arlington Memorial.

The main portion of the Arlington Monument in memory of the unknown soldier is here shown (Figure 14) though the block was quarried at the Vermont Marble Company's Colorado

Fig. 12. Marble column for Bridgeport Savings Bank, Bridgeport, Conn., ready to leave Proctor yards. These columns weigh over fifty tons each.

Yule quarry. Aside from its historical interest, it is appropriately introduced here because it was largely finished by the Vermont company.

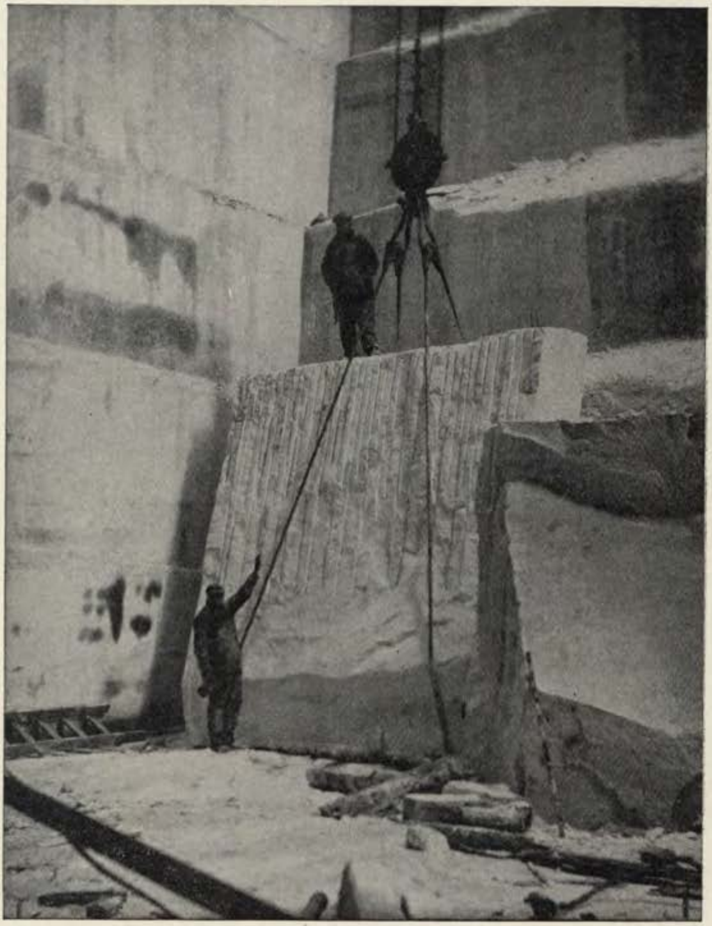

FIG. 13. Sixty-three ton marble block for bowl of Scott Memorial Fountain, Detroit, Mich.

The block from which this was finished weighed fifty-six tons. The marble company were obliged to have special machinery to help in getting the block down the mountainside from the quarry. From the foot of the mountain it was transported to the Proctor mills and nearly finished, it then went to Washington,

Fig. 14. Cutters outside Proctor Shops at work on fifty-six ton block for Tomb of Unknown Soldier.

where some final finishing was done, and finally to Arlington. The usual method of detaching blocks from the beds in a quarry is well stated in the "Book of Marble" as follows:

"In quarrying marble, blasting cannot be resorted to on account of the danger of shattering the blocks. The electric channeling machine, running on movable tracks on the floor of the quarry, first makes a series of vertical cuts or channels to the required depth. The first strips of blocks, known as key blocks,

FIG. 15. Arlington Memorial, National Cemetery, Arlington, Va. Marble from Danby quarries.

must be cut on all four sides. After these are wedged out and removed the remaining strips are channeled on two parallel sides only. (See Fig. 15a.) A drill, placed in the keyway, drills horizontal holes between the layers and at the bottom of the cut. The blocks are then broken off by wedges. All quarrying machinery is operated by electricity, and the tunnels are lighted by powerful electric lights."

As has been shown, the numerous marble companies of past years are now represented by few. There has been during fifty years or more a steady reduction in the number of companies quarrying and manufacturing marble and a constant or nearly constant increase in the amount of marble quarried and sold. Mr. Peterson sends the following list of companies now active:

MARBLE PRODUCERS IN VERMONT, 1932

Colonial Marble Company.
Two quarries (Eastman) at West Rutland.
Finishing plant at Rutland.

Dorset Mountain Marble Company (inactive).
Quarries (Owls Head) at Dorset.

Green Mountain Marble Corp.
Quarries at Clarendon and West Rutland.
Finishing plant at Clarendon and West Rutland.

Manchester Marble Company (inactive).
Quarry (Freedley) at East Dorset.

Venetian Marble Company.
Quarry (Raleigh) at Pittsford.

Vermont Marble Company.
Quarries at Brandon, Pittsford, Proctor, West Rutland, Danby, Dorset, Isle La Motte, Swanton, St. Albans, Roxbury, Rochester and Moretown.
Finishing plants at Proctor, West Rutland, Center Rutland, Pittsford, Middlebury and Swanton.

The above-named companies will be taken up in the course of the following pages and the main facts concerning them stated.

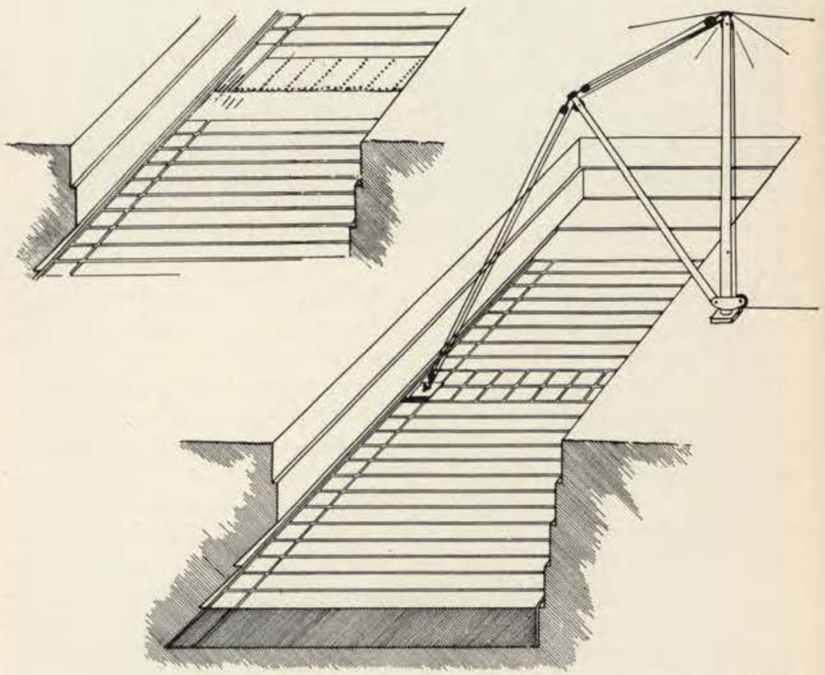

Fig. 15A. Diagram showing how floor of quarry is cut by channeling machines and how key-block is removed. Upper diagram shows initial row of blocks removed.

THE VERMONT MARBLE COMPANY

This company has already been mentioned more than once in the course of our study of the marble industry and will be mentioned in following pages. Indeed the story of this industry is, at least from the early eighties, so interwoven with the whole story that I find it impossible to write otherwise than the reader finds in the immediately following pages. For more than fifty years this company has greatly dominated the marble business in Vermont, and I think after a study of more than a few years the State owes to this company, and its management, very much of the wide reputation over the world as a producer of good marble. Certainly the writer does not wish in any way to lessen the value of what other companies, past and present, have done, but while not forgetting what others have done, the writer of these pages has tried to give the Vermont Marble Company what notice is their just due. It is surely evident from the findings of past history that had there been during the past fifty years or so no such company, the marble industry could not by any means be what it now is. As will be made evident, the Vermont Marble Company has little by little consolidated many other marble enterprises. In writing of this company it is difficult to determine just when to begin the account, but rather arbitrarily taking as a starting point Col. Redfield Proctor's visit to the office of the president of the Rutland Marble Company, Elisha Riggs, in 1880, or about that date. Apparently from this time on, when Colonel Proctor accepted the management of the Rutland Marble Company, the development of the Vermont Marble Company, as elsewhere related, began. It will not be possible to write here much more as to the development of this enterprise. However, a few facts as to the present equipment of this company may be given. These show something of the growth of the company from the small beginning in the early eighties to the present, 1932. The following gives a list of the quarries belonging to this company as furnished by Mr. Peterson:

Active Quarries in Vermont

Operated by the Vermont Marble Company

Brandon
Brandon Italian (two openings).
Pittsford
Pittsford Valley (Hollister) (five openings).
Pittsford Italian (two openings).
Florentine Blue.

Fig. 16. Distant view of Vermont Marble Company's Proctor Plant.

Proctor
    Sutherland Falls.
West Rutland
    White Quarries (three openings).
    West Blue Quarries (three openings).
    Westland.
Danby
    Imperial.
    Brook (White Stone) (two openings).
Roxbury
    Verde Antique.
Rochester
    Verde Antique.
Moretown
    Verde Antique.
Isle La Motte
    Black (Fisk).
    Grey (Goodsell).
St. Albans
    Red.
Swanton
    Red and colored (three openings).
    Also quarries in Alaska, Colorado and Montana.

Inactive Quarries in Vermont

Brandon
    High Street, Seldon, Thayer, Corona, Prime, Peck and Bardillo.
Pittsford
    Landon (or Eureka), Florence (or Hogback), North Pittsford, Valley, Smith and Brainard, and Highland.
Proctor
    Mountain Dark (or Shangrow), Riverside and Columbian.
West Rutland
    True Blue, Esperanza (or Albertson) and Sherman.
Danby
    New York.
Dorset
    Plateau, Valley (or Norcross) and East Dorset.

The Vermont Marble Company claims, and can make the claim good, that in amount of marble quarried, number of quarries, number of men usually employed, number and equipment of mills, varieties and quality of stone, no other company in this or any other country is its equal. This company not only have mills and quarries in Vermont, where these are mostly located, but also in Alaska, Colorado and Montana. The main offices of the Vermont Marble Company are at Proctor, but as there are quarries and mills elsewhere so it is necessary that branch offices be located elsewhere as at West Rutland, Center Rutland, Middlebury, Swanton, Boston, New York, Philadelphia, Cleveland, Chicago, St. Louis, San Francisco and Tacoma. The number of employees varies more or less according as business

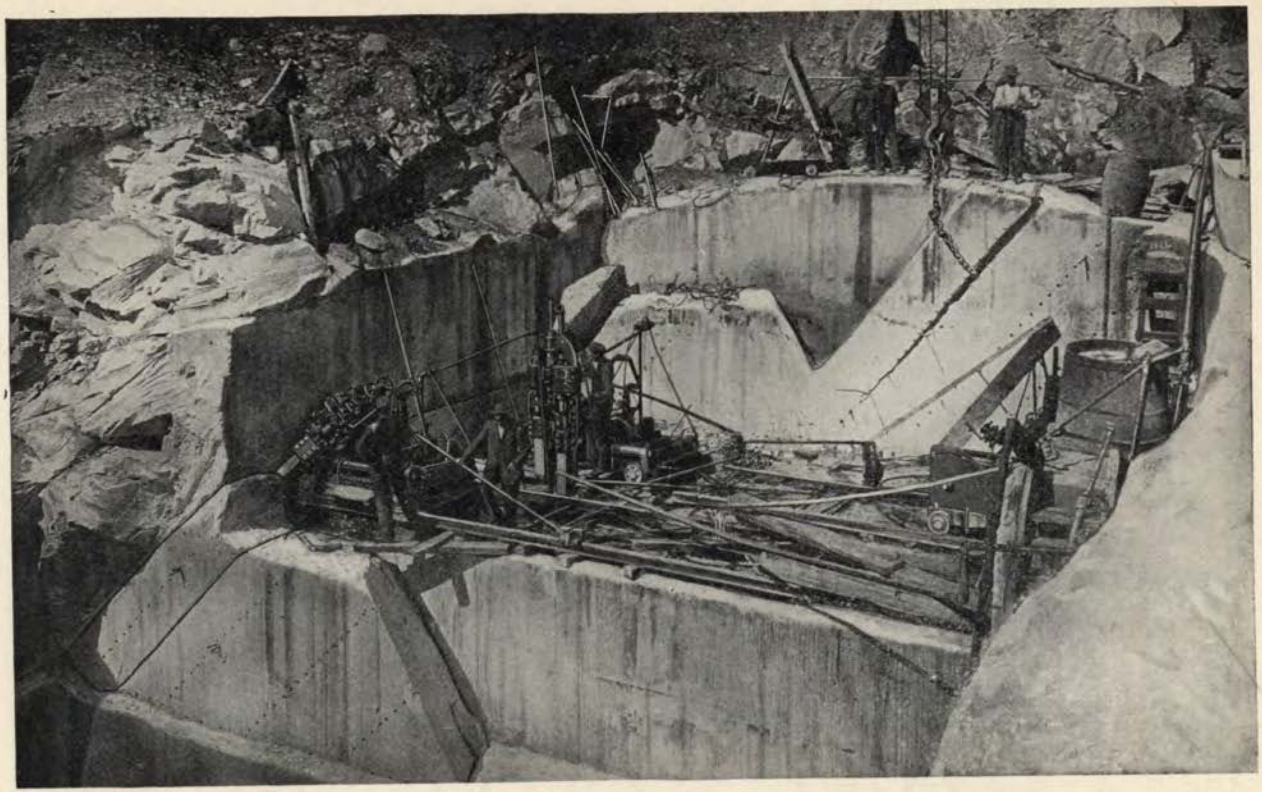

Fig. 17. A corner of the Clarendon quarry, showing method of opening. Sullivan corner cutter in foreground, cutting a transverse into a tunnel cut made with the Sullivan duplex channeler to the right of it. In the rear, Sullivan gadder, and derrick lifting out a block.

is good or only fair, but it has not of late years been less than several thousand and has been as many as seven thousand. Many nationalities are at work in office and mill. This company own 28,000 acres of quarry and forest land.

Why does a marble company need to own and use forest land? Because all wrought stone must be carefully packed; for that reason all companies that sell cut stone must use lumber. The Vermont Marble Company have used in a single year 6,500,000 feet and usually need several million feet. This company owns seventy-five quarries, not all of which are carried on; some are not worked, others only occasionally, as the kind they supply is demanded; others constantly. In one of the numerous bulletins published by them from time to time we find the following bit of history: "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 quarry and the blocks were placed on a car and lowered into the mill by a cable. A yoke of oxen furnished the motive power needed to get the empty car back to the quarry."

As to equipment of the various marble companies such information as could be obtained is given. Something as to this is to be formed in the discussion of marble machinery. Mr. Peterson of the Vermont Marble Company reports as to that company the following:

GANG SAWS

In various mills there are now in use:

Swanton	24
Middlebury	23
Florence	43
"New Mill," Center Rutland	28
Ripley Mill, Center Rutland	21
West Rutland Mill	48
Albertson Mill	24
	211

"The old finishing mill at Center Rutland has been closed and a new mill erected there in 1930. We do not have any gangs for sawing at Proctor now. The old north mill and the stone mill have been rased and a new monumental and exterior finishing shop erected on the site. The gangs in the old south mill have been removed and the building remodeled for finishing interior work. In regard to channeling machines which the company operates, there are ninety-six Ingersol electric, six or eight steam

4

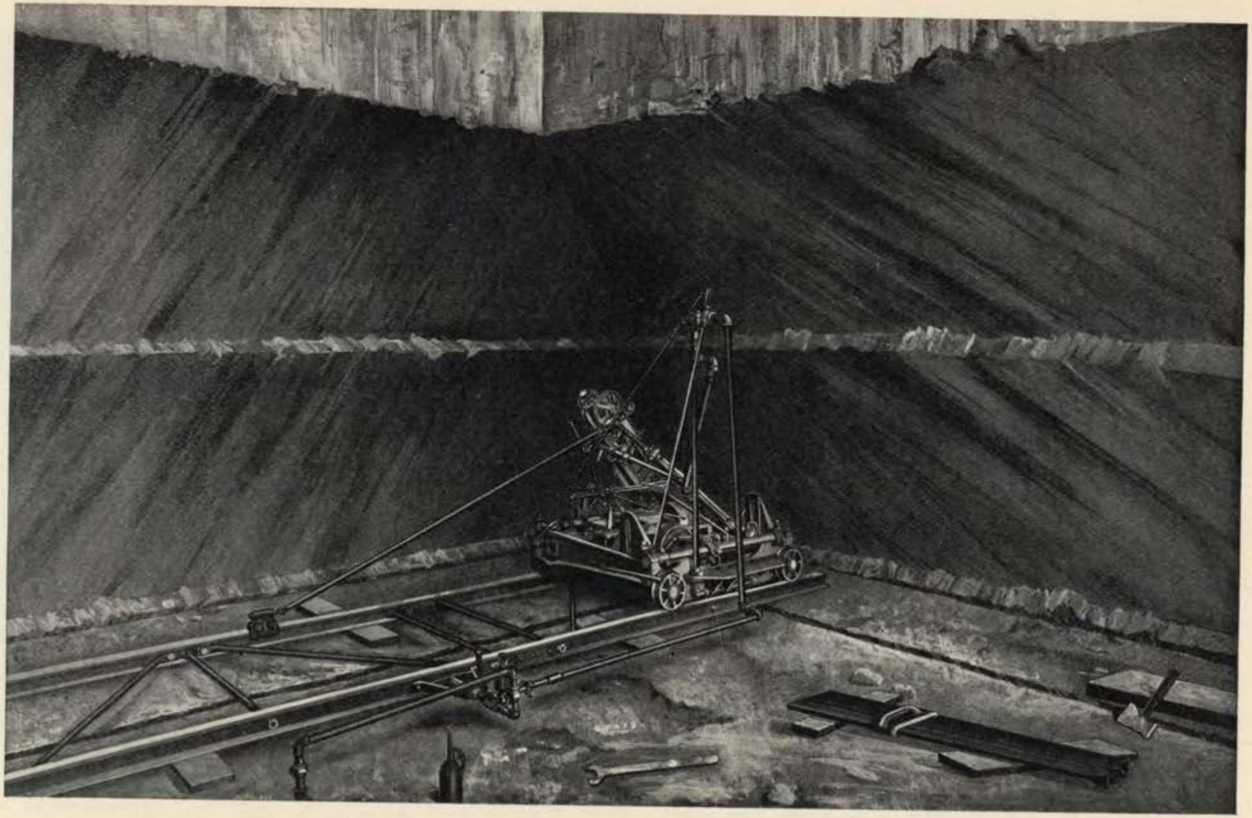

Fig. 17a. Sketch showing Sullivan corner channeler cutting out a corner in a quarry. The right wall slopes at an angle of 45 degrees, the left wall at 15 degrees.

Sullivan, which at present are not in use, and twelve electric Wardwells." Other and quite extensive improvements have been made by this company.

On the following pages is a list of the varieties of marble quarried and sold by this company at the present time, 1932. As with other active companies more detailed account of these marbles will be found farther on. The company has classified the marbles according to the uses for which the different varieties are especially recommended, though many of them are not limited to the group in which they are placed but are equally useful in any of several groups:

MARBLES QUARRIED BY THE VERMONT MARBLE COMPANY, 1932

Interior Marbles

American Pavanazzo
Avenatto
Best Light Cloud
Brocadillo
Champlain Black
Extra White Rutland
Florence
French Gray
Grand Isle Fleuri
Imperial
Jasper
Light Cloud
Light Vein
Listavena
Livido
Lyonaise
Mountain White
Metawee
Neshobe Gray
Northern Ivory
Northern Pearl
Northern White
Olive
Olivo
Olympian White
Oriental
Pittsford Italian
Royal Antique
Rubio
Second Statuary
Silvestre
St. Albans Red
Standard Green
Standard White
Striped Brocadillo
Talcose Veined
Venoso
Verdoso
Verde Antique
Westland Cippolino
Westland Cream
Westland Cream Vein
Westland Green Cream Vein
Westland Siena
Westland Verde Verde

Grouped Together

Royal Antique (two grades)
West Rutland Italian (three grades)

Sold Under Another Name

Special Rutland Building
Special Rutland Italian
White Rutland Building
Danby (various grades)
Dorset Plateau
Fisk Black or Champlain Black

Exterior Marbles

Mountain White
Imperial
Highland
Corona
Eureka
Florence
Pittsford Italian
Plateau
Gray Vermont
Rutland White A
Rutland White B
Rutland White C

Monumental Marbles

Pittsford Valley	Dark Vein Blue
Brandon Italian	Rutland White
Pittsford Italian	Rutland Statuary
Sutherland Falls—Light	Rutland Italian
Sutherland Falls—Dark	Rutland Sylvert
Mourning Vein	Rutland Cippolino
Castle Gray	Danby Riverside
Standard Gray	Danby Montclair

Not Now Quarried

Aeolian	Extra Dark True Blue
Albertson Extra Dark	Highland Blue
Blane Clair	Light Green Cloud
Brandon Statuary	Moss Vein
Dark Vein True Blue	Ruvaro
Dorset A	Swanton Dove
Dorset Green Bed	True Blue
Esperanza	White Pavonazzo

THE COLONIAL MARBLE COMPANY

The Colonial Marble Company now own and operate the quarry that has been known as the Eastman quarry and also a second quarry not far south of this. Both produce an unusual number of varieties of stone, as the section below shows. The former Eastman names have been changed to those given below.

Marbles Produced by the Colonial Company

Colonial Antique	Colonial Verdas
Colonial Colmareo	Colonial Cipolin Fleuri
Colonial Gray	Colonial Cream Fleuri
Colonial Green	Colonial Cream Statuary
Colonial Green Vein Cream	Colonial I J Cream
Colonial Ivorvein	Colonial K Cipolin Fleuri
Colonial Pavonazzo	Colonial M N White Vein
Colonial Sienna	Colonial Quaker Gray

The old names as far as they correspond with the above are given on a following page.

Section of Marble Beds in the Colonial (Eastman) Quarry

	Feet	Inches
Graphitic gray marble	57	
Graphitic	6	
Graphitic gray marble	22	
West edge of quarry		
Graphitic gray marble	11	
Graphitic gray with white bands	3	
Cream marble	4	
Green marble, bands of cream in coarse	7	
Purplish gray marble	1	6

	Feet	Inches
Green marble, muscovitic	2	
Dolomite and marble mixed	2	10
Cream marble, green and yellow bands	4	6
Muscovitic, green solid	11	
Pure white marble	4	
Cream marble with green bands	4	6
Muscovitic marble	3	
Muscovitic, plicated	4	6
Cream marble	4	6
White marble	5	
Muscovitic green marble	4	6
White marble	5	6
White marble greenish beds	5	
Edge of quarry (east)		
Gray dolomite	3	
Graphite marble	3	6
White marble	13	6

The quarries of this company are at the south end of the western side of the West Rutland group of quarries. Not far north is a quarry of the Vermont Marble Company. There appears to be in the area occupied by these quarries an unusual variety of coloring and shades, often very delicate and attractive, due undoubtedly to an unusual number of mineral substances in the limestone from which these marbles were formed. For some account of the most valuable of these marbles see page 175. Some of these delicately tinted marbles are not found elsewhere in the marble belt.

THE GREEN MOUNTAIN MARBLE CORPORATION

This company some years ago took on the property and rights of the old Columbian Marble Company and in 1927 bought out the Clarendon Marble Company. They produce a number of varieties of marble and own a number of quarries in West Rutland, Proctor, Pittsford, and Florence. They have also much marble land at Brandon, North Middlebury, and New Haven, with mills in Rutland. This corporation is a consolidation of the Clarendon Marble Company and some other marble companies located at West Rutland. This company is operating quarries and plant at Clarendon and also a plant at West Rutland (the old Baronial quarry) and a new quarry (the Well Hole) in a meadow south of the West Rutland railroad station.

Mr. E. B. Fleming, of this corporation, writes as follows:

"This corporation owns extensive marble properties. At the present time we have developed three different quarries, two at West Rutland, Vermont, and one at Clarendon Springs, Vermont.

"The quarry at Clarendon Springs produces a high grade of light variegated marble, which is suitable for exterior, interior and monumental work. This quarry also produces a very dark blue marble which is sold in large quantities for monumental work.

"Our Mine quarry at West Rutland, Vermont, produces several different grades of marble. These grades run from a white statuary, white with green veins, cream with green veins, and a solid green. All grades are suitable for exterior, interior, and monumental work.

FIG. 18. General view of one of the Clarendon Marble Company's quarries.

"Our Baronial quarry, which is also located in West Rutland, Vermont, produces several grades of marble also. The marking in this marble is somewhat different from the marking in the marble procured from our mine quarry. The grades procured run about as follows: Dark cream, light cream, cream with light green veins, cream with heavy green veins, and blue. All grades are suitable for interior decorative work.

"In addition to our quarry developments, we operate an eleven-gang sawmill and finishing plant at Clarendon Springs, Vermont,

and an eight-gang sawmill and finishing plant at West Rutland, Vermont."

It may be noticed that this company is entirely different from the old Green Mountain Company and is not to be confused with it. This company reports that they produce the following varieties of marble:

Meadow White	Clarendon Medium Cloud
Venato	Clarendon Gray
Verte Monte	Clarendon Light Exterior
Vermont G M Exterior	Baronial Antique
Clarendon Quarry	Baronial Verde
Clarendon Light Cloud	Baronial Cipolin
Clarendon X	

THE VENETIAN MARBLE COMPANY

This company is operating a quarry in Pittsford. It is the quarry formerly known as the Raleigh quarry. The marble is sold as quarried or taken to a mill in Brandon to be sawed.

The following is a discussion of the marble areas of the State, including those that are now idle, some temporarily, others probably permanently.

For the sake of making the account historically useful all quarries, active or idle, that have been of importance in past years, will be at least mentioned.

As the reader will soon discover, the various areas with the quarries are arranged from south to north, beginning at the southern end of the marble belt.

THE DORSET AREA

As noticed in the History of the Vermont Marble Industry (page 52), it is quite definitely determined that the first marble taken out of a quarry was obtained in Dorset, and for some time after this Dorset was the source of most of this stone. Hence, the evidence of very early, we can scarcely call it quarrying, but getting marble from some ledge or bed in this town is an interesting beginning for the study of marble quarrying in Vermont. The Dorset area, as here defined, includes South Dorset, East Dorset, Dorset Village, Dorset Mountain (including the Danby quarries which, though in the town of Danby, are on the north end of Dorset Mountain, as also are the peaks of the long mountain, which extends in a somewhat irregular fashion for several miles through the eastern part of Dorset north into Danby. As outliers or spurs we have Green Peak and Owl's Head in the south and the Danby quarries in the north, Dorset Peak being the highest northern point.

The first marble quarried in Vermont appears to have been taken from land belonging to one Reuben Bloomer by Isaac Underhill in 1785, as noticed on page 67. It is said that customers from many points came to buy from Mr. Underhill slabs of marble rudely split out after the fashion of those days, some coming seventy-five miles. Ere long several other quarries or openings were started near the first one. Probably the earliest headstones in Dorset and other cemeteries came from this quarry, and many, as heretofore stated, are still in good condition. (See Figure 2.)

Not until forty or fifty years later was any marble sawed in this region. "After 1840 seven mills were built in Dorset and four in Manchester, all sawing Dorset marble," sawing annually 750,000 feet, "two feet thick and employing over 200 quarrymen and sawyers." (West, see Bibliography.) In 1855 eight quarries were in operation in Dorset. Mr. West gives the following list of these early quarries, *viz.*:

Wilson, McDonald and Freedley.
McDonald and Freedley.
Holley, Field and Kents Vermont Italian.
Gray, Wilson and Sanford.
M. and G. B. Holley.
Fulsom and Barnard.
Bloomer.
Holley, Field and Kents extra white.

These companies employed in each quarry from six to twenty-five men, in all 143. As far as records show, the marble business was at this time fairly good (1840-60), but later it was less satisfactory and during the next twenty years it declined and some quarries were closed. The Kent and Hollister quarries were prosperous. After this, by 1897, many quarries were closed. Marble from the quarries of Rutland County had scarcely begun. After this the stone from the more northern quarries was found more desirable for monumental, interior, and ornamental work, though not for building, and being softer were less expensive to work. The Rutland and other beds, moreover, lay in the quarry in a way that made quarrying less expensive and in these quarries, as will be shown on following pages, far greater variety in color is found. The Dorset quarries appear to have been idle until 1902 when the business revived under new management. Mr. West writes: "Dorset marble having been selected as the building material for the New York Public Library, a building requiring half a million cubic feet of cut stone, and Mr. O. W. Norcross of Worcester, Massachusetts, having purchased a part of the quarry where Isaac Underhill first worked, he in company with S. H. West of Dorset organized the Norcross-West Marble Company. Operations were rapidly pushed and in place of the hammers of Underhill and Manley was heard the roar of twenty Sullivan channelers and a half dozen gadders. A standard gauge railroad was built connecting the quarries with the Rutland Railroad at Manchester and at the latter place was erected a splendid sixteen-gang mill, well equipped for handling a building job. Much block marble was also shipped to a new mill erected at Mount Morris, New York. During this period Dorset marble was furnished for a number of large buildings, but after ten years building operations began to decline and once again the lack of monumental marble brought this industry to a low ebb."

In 1913 this entire property came into the hands of the Vermont Marble Company. This company operated for a few years, but for several years the quarries have been closed. As a prediction, Mr. West says, "While the immediate future does not look promising, there is much fine marble locked up in Mount Aeolus and in the valley below that it is safe to predict that history will repeat itself, and that after a period of idleness Dorset will again forge to the front as a marble center." Mr. West further writes: "In order to show the extent of quarrying operations in Dorset I have made a fairly close approximation to the total amount taken out of the principal quarries."

MARBLE TAKEN FROM THE SOUTH DORSET QUARRIES

	Cubic feet
Freedley's	4,250,000
Norcross-West	3,300,000
Sanford	2,500,000
Blue Ledge	2,000,000
Prince and Company	1,500,000
Kent and Root	1,000,000
Fulson	775,000
T. D. Manley	250,000
	15,575,000

The total number of quarries is thirty-five, besides a considerable number of more or less worked openings. As has been intimated, the story of the Dorset quarries is important in any complete account of the marble industry of Vermont, and as the above statement shows, it has been, if not now, of commercial value. In general, the Dorset marbles are of the light shades, differing more or less in different quarries, but light in all. An analysis of Dorset marble is, in general, as follows:

ANALYSIS OF A SAMPLE OF SOUTH DORSET MARBLE

Calcium carbonate, $CaCo_3$	98.43
Magnesium carbonate, $MgCo_3$	2.28
Iron oxide, FeO	0.38
Moisture, H_2O	0.44
Loss and undetermined	0.42

Many samples contain silica and all the quarries produce a harder stone than the Rutland and Pittsford quarries. Because of this harder and more evidently crystalline structure, these marbles are more difficult to bring into such shapes as may be desired, harder to polish, but more brilliant when polished, and, as has been stated, are more useful and therefore more in demand as building stone than as ornamental or monumental stone.

As the reader has noticed, much has been quoted from Mr. E. H. West's report recently made for the Vermont Marble Company and much more will follow. As far as the writer is aware no one is more competent or been more closely connected with the marble business than Mr. West. Through the courtesy of Hon. Redfield Proctor I am allowed to use freely this report, and in the following pages, quoting from the report, I am able to give a very complete history of the Dorset region from its beginning to the present time. Probably no region has been more completely explored, nor as long used as this. Consequently it adds greatly to the value of such an article as this that it is possible to present a pretty full account of this always important marble region.

The entire area of the township is stated as only 28,756 acres, about 45 square miles, and yet, Mr. West states, that aside from prospect openings there have been not less than thirty-five quarries operated at some time in this town. Historically, as well as commercially, Dorset must always be considered a marble town, at least, as a producer of quarried marble. In general, in addition to what has been said above, that all the varieties of marble produced are light in color, some entirely white, more veined or clouded by darker colors. As will be seen, many large buildings in all parts of the country have been built of Dorset marble. As given by Mr. West, the following is a complete list of the quarries that have been actually operated in the town of Dorset:

LIST OF QUARRIES WHICH HAVE BEEN OPERATED IN DORSET
(This list is arranged to show the time when opened)

Norcross-West Quarry
Freedly Quarry
Cave Quarry
Deaf Joe Quarry
Mud Hole Quarry
Blue Ledge Quarry
Middle Quarry
Sanford Quarry
Manley Quarry
Bennington Marble Company Quarry
Mills Quarry
Dorset Mountain Marble Co.
Upper Quarry
Green Peak Marble Co.
Kent and Root Quarry
East Dorset Italian Quarry
Lower Quarry
Kent Quarry
Manchester Breccia Quarry
Edson Quarry
Klondike Quarry
Plateau Quarry
Jack Warren Prospect
McDeavitt Quarry
Buskirk Prospect
Paddock Prospect
Imperial Quarry
Cullen Quarry
Fulsom Quarry
Grady Quarry
Adair Quarry
Stafford Quarry
Halpin Quarry
Westfield Company
Cody Quarry
White Stone Brook Quarry

As briefly as possible, each of these quarries will be considered in the pages immediately following. As a matter of historical interest, the names by which each quarry has been commonly known, at least for a time, are given.

As stated on a previous page, these are arranged according to time of opening. All are now idle.

THE NORCROSS-WEST QUARRIES

The main quarry used by the Norcross-West Company has been called the Bloomer quarry, the Valley quarry, and the Main quarry. With some intervals of idleness, this quarry has been operated for 150 years. It was operated from 1903 to 1913 by the above-named company. Several varieties of marble are found in this quarry. As before stated, this appears to be that opened by Isaac Underhill in 1785. Good examples of marble from this quarry are seen in the New York Public Library, in which building over half a million feet were used. In the exhibition room of the library there are twenty-five large columns of this marble. The stone is light, streaked and clouded by green of many shades, and in various parts showing the coloring in very different proportions, from a ground which is mainly white to portions in which the coloring is mainly green.

For a short time this quarry was operated by the Vermont Marble Company to which it now belongs. Mr. Dale remarks as to quarries of this area as follows: "The marbles of South

Dorset not only differ from those already described (the marbles of West Rutland and north), being generally coarser and containing actinolitic beds, but they appear to be 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. If such horizontal or low-dipping folds have been produced by extreme lateral compression and a subsequent erection of the folded series so as to give the beds a general dip across the folds of 80° south and 45° west, 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 of the former Norcross-West quarries and the core records of the company indicate the folding succession beginning at the top.

THE FREEDLY QUARRIES

"These quarries have been long quarried and consequently have been known by a succession of names, *viz.:* Sykes quarry, Chapman and Underhill quarry, Wilson, McDonald and Underhill quarry, McDonald and Freedly quarry, Freedly, Prince and Wilson quarry, J. K. Freedly and Sons quarry, and Manchester Marble Company. The quarries are located high up on Green Peak (a spur of Dorset Mountain), 2,040 feet above sea level or 1,160 feet above the village of East Dorset. This quarry was opened by Elijah Sykes in 1808. "The deposit is in the form of a bold cliff and the early operators worked on the face of this ledge. In 1859 the first tunnel was started. The strata lie in a nearly horizontal position, dipping slightly into the mountain. The mountain rises very steeply so that by going into the hill only a short distance there is a great protective covering over the marble. The tunnel extends for several hundred feet in a north and south direction, and is 160 feet east and west at the north end. There is a succession of pillars and openings leading into one great room. On the north side the tunnel leads into the 'open quarry' 110 feet deep. The total depth of the marble must be at least 165 feet; 90 feet are shown in the open quarry and, as shown by coring operations, there is a depth of 65 feet below the present working area. Beginning about 1907, the property was leased by Edwin Shuttleworth, who formed the Manchester Marble Company and under his energetic management

for several years was worked. In 1909 Mr. Shuttleworth opened the Sweeney quarry and in 1910 the Scotchman's quarry, both proving failures.

"The Sweeney quarry is near the open quarry and the Scotchman's quarry half a mile north. Mr. Shuttleworth operated for several years when he gave up his lease and the property was idle for a period, after which a lease, with option to buy, was taken by Pearly Eaton and others and for several years they operated the tunnel with several periods of idleness. In addition to the quarry he is now running a mill. They are now working just over the 'mahogany' layer, which is the best in the quarry. . . . The total excavation on the property, including the stripping, is 2,250,000 cubic feet. In spite of this great output, no very great structures have been built of this marble." (West, see bibliography.) Perhaps the most accessible example of this stone is in the soldiers and sailors monument, New York City, Drexel Building, and entrance to the Plaza Hotel. Mr. West says further, respecting the Freedly marble: 'While there is no specially fine marble in this quarry, judged by Rutland standards, there is considerable good building stone and some that seems to do for monumental trade.' A dike occurs on the west side of the deposit. There is also an inclined railway descending from the Freedly quarry to the railroad track, a mile distant, by which the marble is readily sent down for shipment. The great piles of waste from this quarry are plainly visible on the side west of the Rutland track as one passes by near East Dorset station. The following quotation from Prof. H. M. Seeley of Middlebury is of value here as showing something of the geological character of this location:

"The quarries in this town (Dorset) are situated mostly up the sides of Dorset Mountain. It is stated, with much truth, that the mountain is a mountain of marble. But it must not be inferred that it stands out as a mountain of pure marble and can be cut into anywhere and remuneratively quarried. Many of the strata are siliceous and of too hard a texture to be worked, others are slaty and fragile, others magnesian, and some are ferruginous while in some places the layers are quartzite, and in others of slate seams here and there through it." "Comparatively but a small part of the mountain furnishes merchantable stone, but this small portion is in the aggregate immense. As one ascends the mountain he finds most of the rock obscured by débris making it difficult to observe the real sequence of the strata. He will pass beds of variable character, reach the compact and fine-grained marble, higher he will find the beautiful white and more coarsely crystalline stone, still higher the gray interbanding with the white, then the gray carrying many crystals of pyrite and mica slate, then he will miss the limestone altogether which disappears under a mass of comminuted rock over which have fallen many blocks of slate. Higher still are many masses of slate, seamed in many places by milky quartz, and by this slate the top of the mountain is covered." This cap of slate Hitchcock estimates at 498 feet thick, and the limestone with the marble below at 1,970 feet, the whole a total of 1,970 feet. The gray lime rock beneath the slate, impure with crystals of iron pyrites and grains of quartz together with interbedded lines of hydromica schist, call to mind the blue stone of Great Barrington, though this rock is more slaty in character. "The pyrite and hydromica accompanying this stone favor the conjecture that to the decomposition of this rock and the slates are due the deposits of iron ore a kaolin which so generally border the slate belt and attend the deposits of marble. Lower down, after passing the white and gray, is reached the seamy, easily quarried, coarsely grained marble, crystalline and white. Flag-like layers here afford slabs suitable in thickness for headstones, and the early supply here came from such strata. Deeds for such property date back more than a century."

Dale gives the following section of the marble beds at the Freedly quarries:

Section of the Marble Beds at the Freedly Quarries

	Feet
Covered, probably dolomite	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
Dolomite	44
	360-370

An old record gives the following series of rock:

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

Upper quarry	
Bluish dolomite	10
Light gray marble (Manchester Blue)	26
White marble	4
White marble (mahogany bed)	110

10

Though all varieties of this marble have, or have had, each its own special name, they are often all called Dorset marble. Aside from the less important quarries, which will not be mentioned, in some cases the name of the quarry from which it was taken is given, sometimes a name for which neither reason nor appropriateness can be imagined. A few of these varieties may be given, though the name is of little use at present.

THE CAVE QUARRY

According to Mr. West, this quarry is on the mountain 2,400 feet above sea level, 1,742 feet above the village. It is a small opening operated for some eight years by Martin Beardsley. The marble here seems to be in the main hard and coarse. Evidently the deposit has not been thoroughly explored. From this quarry a "magnificent view to the south may be enjoyed."

"Many of the old quarry slabs are piled about the opening. The cave is probably the old bed of a river and can be penetrated for several hundred feet. The walls are of white marble." The existence of an extensive cave is indicated by a strong current of air that used to blow from the unexplored portion of the cave. This air current is not now in evidence, but is noted by Hitchcock, Hagar and other reliable observers. (See Geology of Vermont, 1861, page 759.) In the report of this quarry, West quotes the following account of the cave: "Dorset cave—an aperture 10 feet square opens into a spacious room 9 rods by 4. At one end of this apartment are two openings 2 feet by 4 about 30 feet apart. The right, 3 feet from the floor, 20 inches by 6 feet, leading to an apartment 20 feet long, 12 feet wide and 12 feet high from which is an opening sufficient to admit a man for about 20 feet when it opens into a large hall 80 feet long by 36 feet wide. The left is about as large as a common door and leads to an apartment 12 feet square, out of which is a passage into another considerable room in which is a spring of water. This cavern is said to have been explored for 40 or 50 rods without arriving at the end."—*Vermont Historical Magazine.*

THE DEAF JOE QUARRY

"This is a small opening made in 1817 by Joseph French. Rumor has it that he operated this place for many years. In 1829 he sold half the quarrying rights to Zadock Hanley and John Higgins, but reserved a block of marble four rods front and six rods back on the east end of the largest ledge of white marble. This is the site of the quarry. Manley and Higgins did some work on the upper ledge some 400 feet above the Deaf Joe quarry. The marble dips rather steeply northwest. Between the upper opening and the quarry there is an outcrop of what is probably the intermediate dolomite. This deposit has never been cored. The natural expectation would be, from all surface indications, that a large body of white marble is here available."—West Report.

THE MUD HOLE QUARRY

"First called the Gray and Briggs quarry, then Way and Eggleston, now the property of the Vermont Marble Company, this North Dorset quarry has not been operated for a long time (eighty years). Mr. West says: 'This property consists of about ten acres of land, located just south of the Freedley quarries. The opening is on the west side of the property. The first operation was begun by Lyman Gray and others. Because of numerous riving seams it was profitably worked during the period when men were looking for deposits with divided strata. One opening is about 100 feet long, 40 feet wide and 30 feet deep at the west wall. There is another small opening east of the Mud Hole quarry. Shortly after my purchase of the property I gave Edwin Shuttleworth of New York a lease of the option to buy. He bored the lower opening to a depth of fifty-two feet. The marble was largely white and gray, banded by occasional muscovite strips. There was also a small amount of clear white. Mr. Shuttleworth also cored the Mud Hole quarry to a depth of seventy-two feet. I saw only the last six feet of this core which was like the best Freedley tunnel layers. Those who took out this core thought it the best core ever taken out on this side of the mountain.'"

THE BLUE LEDGE QUARRY

"Like most of the Dorset quarries, this has been known by several names, as Vermont Italian Company, Holley, Field and Kent quarry, Hollister, Tyrel and Company quarry, Blue quarry, and Dorset Marble Company quarry. West says: "The deposit

was opened in 1825 by Chester Kent and Sam Fulson. It is 1,265 feet above East Dorset station, or 1,943 feet above sea level. The opening is 350 feet north and south and 100 feet east and west, with walls seventy feet high. Marble from this quarry resembled much of the Italian marble. . . ."

This quarry was opened about 1823 and was known as the Kent quarry. It is not only an old quarry, but one from which a large amount of marble has been taken. It is located about one mile from the village of East Dorset. It was last operated by the Norcross-West Company but has not been active for several years. "The marble exposed here consists of sixty feet of mottled marble overlain by twenty-five feet of dolomite, but the 1861 Report (Vermont Geology) states that the dolomite bed measures 100 feet ten rods west of the quarry. As there is marble above the dolomite, this may be an intermediate dolomite." The marble is better known as "Dorset Mountain." The stone is white, with a tinge of blue, in the main. This is mottled by light gray clouds or spots which are scattered through it. It contains quartz. Now and then, though not abundantly, bits of pyrite, rarely little scales of light mica (muscovite) dolomite and a few other minerals in small amount. The beds of calcite marble are often separated by thin beds of dolomite but none are nearly as large as the calcite crystals which make up most of the ground of the stone. The mottled appearance seems to be especially due to dolomite patches which are harder than the calcite, so that if weathered these latter are worn more readily than the dolomite and thus an uneven surface is caused. This marble, in some of the beds, is not valuable even as a building stone, since there are between the better marble bands, sometimes an inch thick, of what appears to be a calcite marble, but containing dolomite, pyrite, mica, and quartz, and these bands when exposed to weathering turn brown and thus disfigure the stone.

"This marble was greatly in demand; in fact, the demand exceeded the supply in the sixties. It was sawed at East Dorset in a steam mill of ten gangs. At one time the company employed 150 men. This property and part of the Fulsom was purchased in 1881 by the Dorset Marble Company. The company operated an eight-gang mill in West Rutland, twelve gangs in East Dorset, and twelve gangs in Hydeville. While there is no possibility of getting more good marble from the old opening, it would be possible to strip a block west of the quarry and get a better marble. After Mr. Norcross purchased this property we cored with the following results: One hole near the entrance was put down twenty-five feet, but we found the marble badly cut up. A second core was started a considerable distance inside the opening. We got forty feet of marble of inferior grade and a gray-banded stone not suitable for either building or monumental work. At this time Mr. Norcross had a contract in Springfield, Massachusetts, which required the use of an Italian marble to match work already completed in Carrara. He induced the architect to use marble from this quarry and the finished job was satisfactory to all concerned. However, the layer which furnished this grade of stone is quarried out, being but eighteen inches thick. The total excavation in this quarry is two million cubic feet. It was operated for sixty years, much of the time very profitably. The aggregate thickness of the good marble was forty-six feet. There is about thirty feet of limestone on top of the marble in the west wall."

THE MIDDLE QUARRY

This quarry, also called Manley quarry and Holley, Field and Kent, extra white, was opened by Edward Manley in 1836. "For about 400 feet the thin layers of marble have followed the edge of the cliff. The marble is overlaid by several feet of limestone and limestone and marble mixed. The thickest bed of marble quarried was twelve feet, and this is apparently underlaid by dolomite. Some of the marble is white and fairly sound, but a good part of it was gray and white banded. In the northwest corner of the quarry the back wall is forty feet high."—West, *l.c.*

THE SANFORD QUARRY

West says of this quarry: "This quarry was opened in 1840 by Martin and George Manley. Other names are Martin Manley quarry, Way, Wilson, Sanford and Company, National Marble Company, and Continental Marble Company. In looking at this quarry one is impressed by the evidence of the great amount of overburden that was removed, there being fifteen feet of earth and gravel and ten feet of solid limestone over much of the area, while over the remainder there is twenty feet of limestone. The total excavation is 2,800,000 cubic feet. The mystery is how the operators could have afforded to remove so much waste to obtain marble in such quantity and of such quality, yet the quarry was worked thirty-six years by men who had no capital to start with. Because of the protecting covering the white marble was comparatively sound. The marble removed by the Continental Company was all light gray but was rather hard because of "cat teeth." As far as soundness goes, the gray marble leaves little to be desired. The business not profitable, it was closed in 1899, although coring operations were carried on for two years afterward. One core put down fifty feet in the bottom of the quarry showed a large deposit of marble like the plateau or a little lighter in color, but throughout the entire deposit were found in greater or lesser abundance particles of white flint which make the marble hard to saw and cut. Several hundred feet south of this quarry a second core was put down fifty-two feet. This showed twenty-five feet of white marble before reaching the gray. The cores, however, were short, indicating the presence of "reeds."

THE T. D. MANLEY QUARRY

This quarry was opened by William Soper and T. D. Manley in 1841. Closed in 1875. Formerly called Mud Hole quarry, and M. and G. B. Holley quarry. At one time 850 men were at work in this quarry. West reports of this quarry: "On the west side of the quarry the beds dip steeply to the west. The opening is about 400 feet long, 50 feet wide and 40 feet deep. The marble as exhibited in many Philadelphia buildings shows well, being a sound, commercial white stone with blue spots attractively distributed. All the men who worked in this quarry claimed that it was the best in Dorset in its day, but with the inadequate pumps of that day they found it impossible to keep the opening dry. This deposit has never been cored and should be investigated. . . . The fact that the beds dip so steeply is a favorable feature in this locality."

THE BENNINGTON MARBLE COMPANY

"On the site of the present quarry a small opening was made by Robert Bloomer in 1846. The property was purchased by S. H. West in 1891. In 1905 E. W. Ely and George Newman with S. H. West formed the Bennington Marble Company. In 1906 Michael Cowan of New York was taken into the company. The quarry was equipped with two channelers, derrick, etc., and during 1906 and 1907 considerable marble was quarried. Considering the fact that the blocks quarried came from so near the surface the marble turned out well. The stock proved to be fairly sound and was largely used in New York for treads, base and wainscotting. Three cores were taken out, one in the quarry, one a short distance to the south, and one a few rods west. After a depth of sixty feet limestone was reached. The stone was all more or less of a light blue variegated. There is a little white marble in the deposit."

THE MILLS QUARRY

"The beds in this quarry were worked in 1846 by the Manleys and others. At the time of letting the contract for the New York Public Library one of the lowest bids was submitted by Carlin and Company. . . . Carlin and Company were planning to use marble from this quarry (if they got the contract). They put down several cores, one fifty feet deep, but got only limestone. However, on the hill just south of this quarry eighty feet of promising-looking stone was found. . . . The marble was like the plateau and very sound. On the death of Mr. Mills the writer purchased the property and put down a core south of the opening to the depth of 108 feet with the following result: Sixty feet of light-gray marble, ten feet of white marble, eighteen feet of white and blue mixed. The cores averaged four or five feet long, one sixteen feet long. The beds dip gently into the hills. This is one of the best prospects in Dorset for building stone." —*l.c.*

THE FULSOM QUARRY

This quarry, formerly called Clark and Fulsom quarry and Hollister quarry, was begun in 1864. It is on the south slope of Green Peak, 1,850 feet above sea level. West writes: "This quarry is about 125 feet square, with walls 50 feet high, and is on the same ledge as the Blue quarry about a fourth of a mile south. It produced much monumental marble during the time it was operated. The stone was also much used in wainscotting because of the uniform appearance of the sawed slabs. It was cored by Edwin Shuttleworth to a depth of sixty feet from the bottom of the quarry. I only saw a few feet of the first part of the core which was like the East Dorset Italian. After coring thirty feet an inferior marble is reached, and marble and limestone mixed." On the west side of the Fulsom quarry is a dike, from one to eight feet wide. As is usually true, the marble near this dike is much cracked and therefore useless.

THE DORSET MOUNTAIN MARBLE COMPANY

West writes: "That portion of the property on the west side of town consists of 200 acres of mountain land, on which are

six quarries; one-third of the Hodge lot; all of the school lot; and a six-gang mill. On the east side of the town this company owns a ten-gang mill and property with houses in East Dorset; a six-rod quarry; three-quarters of the thirty-six rod quarry; a quarter of the Fulsom quarry; one-half of the nine-acre lot; three-eighths of the Pitch quarry; half of the Harwood lot containing 100 acres; half of the Harwood spring; half of the Wetherbee farm. The quarries on the west side are known locally as the Upper quarry, the Middle quarry, the Lower quarry, the Klondike quarry, the Edson opening, and the Kent opening.

THE UPPER QUARRY

"Also called the Prince quarry, the Holly Hill quarry, and the Gettysburg quarry. Some early work was done in this quarry by Abram Underhill, but the deposit was really worked by D. L. Kent in 1856. Shortly after it was bought by C. F. Prince and operated most of the time until 1894, when it came into the possession of the Dorset Mountain Marble Company, which operated spasmodically till 1897. This quarry is 1,607 feet above sea level, and on a steep slope of Owls Head. The eastern wall is ninety feet high and shows the marble to be capped by a fifty-foot layer of limestone. Below the limestone is a forty-foot layer of marble, then comes a thin layer of limestone. When this quarry was operated the marble was carried by team down a steep road to a mill of six gangs below. The marble company started a tunnel in the above-mentioned forty-foot layer and obtained excellent marble. The beds dip into the mountain gently and there is evidence that a large deposit of excellent stone is to be found in the tunnel driven in a northeast direction. . . . These are the beds that are shown so strikingly in the ledge on the Hanley property, a quarter of a mile north, but are more promising because of the steep hill east and the excellent opportunity for driving a tunnel. Much of this marble was shipped to Philadelphia. The marble is white banded with gray, or sky blue, which, as usual in the Dorset beds, comes in without regularity. No cores were taken out in the quarry, but two were taken a short distance south as follows: A core 102 feet deep was taken out near the Klondike quarry which showed a large body of good building stone. The marble was largely a commercial white, white with gray bands, a little was blue variegated and some sky blue. About half a mile further south and near the Cody line another promising core was put down. The depth was around

100 feet. One singular fact is that in this last core about ten feet of blue marble was found, similar to Pittsford marble. It had not been supposed that any marble like this could be found in this region. The few white cores that I saw were equal to the best Dorset white."

THE GREEN PEAK MARBLE COMPANY
(ÆOLIAN)

West writes: "In 1870 the Green Peak Marble Company was organized. It was never worked much and was sold for taxes in 1881. This deposit has not been cored. There is no outcropping on the lot but there can be no question that the marble belts of the 1,900-foot level pass through the property."

Considerable marble has been taken from this quarry within the last thirty or forty years, first by the Norcross-West Company, later by the Vermont Marble Company. It is one of the veined marbles, the main background being white or very light tint while running in every direction through the mass are numerous green veins of greater or lesser width, some being mere lines, others wider, others more bands than lines. In some pieces these are almost a tangle of numerous and confused veins. Good specimens of this are to be seen in the Massachusetts Mutual Life Insurance building, Springfield, Massachusetts. Much more than in most Vermont marbles, though not exclusively in this, the green veins run in every direction, not merely in one as is usual in many varieties. Sawing a block in different directions will also give different appearance to the coloring. Sawed in any way, through a block, the result is sure to be pleasing for almost any interior work. It is or may be used for outside work. As the Æolian is distinctly peculiar in markings and very attractive and apparently abundant in the quarry, it is in the opinion of the writer very likely to be again on the market. The shades of green in this marble vary from dark to light, and in some pieces a yellowish tint is seen.

KENT AND ROOT QUARRY

"This quarry was opened by Tyrel and Kent in 1877. It has been called Tyrel and Kent quarry, National Marble Company quarry, Continental Marble Company quarry, Imperial Marble Company quarry, and McCormick quarry. This quarry was operated till 1891, reopened in 1916 and operated since. The beds dip northwest about 45°. The quarry was worked quite profitably a number of years by Kent and Root Marble Company. An eight-gang mill, well equipped with machinery for carrying on monumental business, was installed. Water power was used. In 1894 the property was sold. At this time 100 men were employed, and according to records which I have, the average monthly profit for several years previous to the sale was $1,750. The marble was largely sold for monumental work south and west.

"In 1916 Pat McCormick bought the property from F. M. Weeks and opened northeast of the old quarry. The best marble is largely blue variegated which takes a fairly good polish. McCormick got about twenty feet of the blue variegated on top; below this he went down through forty feet of poor stock, hoping to find good beds locally called 'buttermilk.' One trouble with this deposit is that occasional masses of limestone roll in without regularity."

EAST DORSET ITALIAN

West says of this: "Located between the Blue Ledge and the Folsom, about 200 feet south of the former, this is a small opening made by D. F. Kent in 1878. It was operated in a small way for four years. About forty feet of marble is seen in the quarry wall. It is of the same grade and quality as the marble of the Blue Ledge quarried some years before. We put down a core sixty feet near the center of the opening. It showed marble very similar to that of the Blue Ledge in color and texture, but at the depth of forty feet we found marble and limestone mixed and doubtless reached the basal dolomite. This core was not nearly as good as the one taken from the Fulsom quarry."

THE LOWER QUARRY

"This was opened by S. F. Prince in 1876. Closed in 1881. This opening is forty by sixty feet and forty-five feet deep. It is 425 feet above the valley. After about twenty feet of marble about twenty feet of limestone was reached. This was so broken up that it was easily removed. Below this there was a little inferior marble. The deposit was never cored."

THE EDSON QUARRY

"This deposit was opened by S. F. Prince about 1850 and closed 1893. The color and quality of this marble encouraged Prince to continue development in hope of finding good marble, but this hope was never realized. The internal strain was very pronounced. This venture was decidedly a failure."

THE GRADY QUARRY

"Located several hundred feet south of the Prince upper quarry and on the same beds. It is only a small stripping of the face of a very step ledge, made in 1895 by the Dorset Mountain Marble Company. Only a few blocks were ever quarried."

THE PLATEAU QUARRY

"Opened in 1905 by the Norcross-West Company. The first opening produced a great deal of reedy white marble, but in developing south the marble turned to a light gray color and was remarkably sound. During the next several years there was a fine run of this marble, but little waste and many very sound blocks were quarried. Specimens of this marble may be seen in the Montreal Art Association Building, New York Public Library cornice, Harvard Medical Buildings, monoliths of the Daughters of the American Revolution Building, Washington and elsewhere. Whereas in most quarries each layer has its own peculiar characteristics as regards color, markings, texture, etc., this did not occur in this quarry. The marble may change abruptly from a soft, light-colored plateau to hard, dark marble. This is a decided drawback. During the years we were getting out stone for the United States Rubber Building in New York and the Tremont Building in Boston the waste was very small."

THE JACK WARREN QUARRY

This quarry was only worked about a year. Coring showed a depth of sixty feet of poor to fairly good light-blue variegated marble, beside white and gray banded.

THE CODY QUARRY

This quarry was opened by the Norcross-West Company in 1907. "Four floors were taken out, some exceptionally good plateau stock obtained. In the last floor there was much trouble from internal strain (see page 40). Also some quartz was met In the second floor we got some monoliths that were twenty-two feet long without any trouble. We took out several cores near this opening. The one in the northwest corner was a 128 feet deep and showed a great body of plateau stock, but the last three feet were limestone. Only a short distance north the marble bed was not as thick by twenty feet. The best core was at the present opening. We got three cores twenty-one feet long and each of these was broken by driving an iron rod beside the core. Most

of this core showed good stone with small amount of quartz. The internal strain is a serious problem here."

THE KENT OPENING

This small quarry is located just west of the Klondike and was made in the early sixties by D. L. Kent. The marble was largely white, but somewhat "reedy."

THE McDEVITT QUARRY

This quarry is located about fifty feet above the valley level and fifty rods southeast of the McDevitt store. In 1907 the owner, W. M. McDevitt, put down a core near the present opening and some of the coring looked very good. Several white pieces looked very well after being polished. In 1912 McDevitt, with Potter and McCormick, worked on a small area. They called the firm the Dorset Valley Company. Operations ceased about 1914 and the next year Mr. Benniker operated the quarry for about six months. In 1916 Perley Eaton operated it for two months, since which time the quarry has been closed. A core in this quarry was put down eighty-two feet and two more cores east of the opening were put down, one to a depth of eighty-five feet, the other 132 feet. The prevailing color was white or blue variegated. As far as operated these quarries did not turn out as well as would have been expected from inspection of the cores. The principal trouble seems to be that considerable patches of dark material, probably mica schist, comes in without any regularity. It was found that the core at the depth of ten feet showed clear white, while the marble only a few inches away was very inferior and dark colored. The beds pitch northeast. The prospects for good marble would be better if the pitch was east into the mountain. It is possible that the stone may improve at a greater depth and be all that the core indicated, but as far as operated this quarry has been a failure."

THE BUSKIRK, MANCHESTER

"This is only a prospect and was purchased from Martin Buskirk in 1906 by the writer. It is located near his residence and at the foothills of Equinox Mountain. We put down a core to the depth of eighty feet and the marble was largely blue and green variegated, although bordered on a "plateau." There was one piece of the core five feet long very white and of fine crystallization. This ledge can be traced for half a mile south with one large outcropping near the southern limits. I do not think that this deposit is promising enough to warrant development."

THE PADDOCK PROSPECT

"The John Paddock pasture north of the highway, it is possible to find in the stone walls small blocks of marble resembling skyros. A few of these blocks sawed at our Manchester mill turned out fine samples. We put down three cores, the deepest being sixty feet. The first part of the core showed marble like the Skyros, but after reaching a depth of twenty feet a beautiful yellow and pinkish stone was reached. However, the deposit proving unsound, nothing further was done. The openings described are all that are worth while in the town of Dorset and also Manchester."

THE DANBY AREA

Mr. West has extended his report to the next town north of Dorset, Danby. Indeed, as previously stated, much of the marble quarried in Danby is often called "Dorset marble." The long, somewhat irregular mass of Dorset Mountain crosses the north town line of Dorset into Danby in which town are located the quarries to be mentioned, hence the marble is often called "Danby marble." Mr. West writes: "Quarries were opened in Danby in 1840, though before this date James Lincoln and others had hewn out grave stones. That the business flourished is shown by the fact that seven mills for sawing marble were built on Mill Brook within a few years. The first was at the Borough, built by William, Alfred and Albert Kelley. In 1841 we find that Aaron Rogers, Elisha Rogers and Seth Griffith built a mill that was considered an improvement upon two that had been built. In 1845 George Griffith, John T. and Gardner Griffith built a fourth mill. Later two more mills were built and after the completion of the Rutland Railroad a seventh mill was built on this brook, so appropriately named. The total number of gangs was at this time thirty. Mr. George F. Kelley operated the Kelley quarry which is the most western of the old quarries. A short distance from the Kelley quarry is the area operated by Thomas Symington of Baltimore, the product being largely shipped to that city. This quarry is now known as the Tunnel. The eastern opening was formerly the Griffith quarry and is now called the Imperial quarry. In 1862 the Western Vermont Marble Company was formed and control of most of the quarries obtained. This company continued for six years, when the property was leased

by L. S. Waldo. In 1860 the business began to decline it appears from the records. Until 1869 the said L. S. Waldo was the only one engaged in the industry. Soon every plant was closed. Then came a long period of idleness for the Danby quarries. Even the old-timers came to the conclusion that the industry was of the past. In 1902 Pat McCormick, Clark Potter and William McDevitt leased the property with option to buy. . . . Shortly after beginning operations they took into partnership John Cullen of New York City, but he left after three years a $70,000 winner because of his venture in the abandoned Griffith and Tunnel properties. The first blocks taken from the Griffith quarry proved to be sound white marble, then much in demand. A small front near the Public Library on Forty-second Street was built of this marble and created much favorable comment. In March, 1899, the Danby Marble Company was formed. The latter part of this year the Vermont Marble Company bought all of the property of the Danby Marble Company and developed it very greatly. The quarries worth mention in this area are the Imperial, the Kelley, the White Stone Brook, the Cullen, and the Grady."

THE IMPERIAL QUARRY

"Like so many of the Dorset and Danby quarries, this quarry is 1,690 feet above sea level, 700 above Danby railroad station. The first opening was made in 1842 or near that date. It has been known as the Warner, Imperial, Danby Marble Company quarry, idle from about 1868 to 1902, sold to the Vermont Marble Company in 1905. During its activity much white or light marble was taken out. The quarry is on the east side of the northern part of Dorset Mountain, in Danby. This quarry furnishes a light marble in some variety, yellowish white, bluish (a light tint) mottled clouded, gray. Between various marble beds are often thin veins of micaceous schist. In some of the schist beds are calcite crystals of large size, for marble, some an inch in diameter. Quartz grains are sometimes found in the marble. Dale writes of this quarry: "The marble beds here, as exposed by quarrying and core drilling measuring from the roof of the tunnel down, and making allowance for the inclination of the bed, are about 292 feet."

THE KELLEK QUARRY

According to West, this quarry was opened in 1859 and operated till 1867, when it was idle till 1907, when it was reopened by the Vermont Marble Company.

THE CULLEN QUARRY

"This is better known as the Symington, Tunnel, New York, Poli quarry. The quarry was opened in 1855, operated until 1869, after which it was idle until 1904, when the Vermont Marble Company revived it. Like the Imperial quarry, this is a tunnel quarry. In the beds of this quarry there is first a bed of dolomite, above the main tunnel. Below this is a bed of white marble, then below this of bluish, yellow (light) gray with some beds of dolomite. At the north side of the north tunnel there is a dike of augite-camptonite five and a half feet wide. For a space of eighty feet west of the dike the marble is crossed by many joints, parallel with the dike, and these are crossed by another set. The marble on this side is of no value, while that opposite is sound. Fifty feet northwest of the north tunnel is a second dike. This is only a few inches wide but the marble is badly cracked."

THE KLONDIKE QUARRY

Three-fourths of a mile north of the Cullen quarry is located a quarry opened by Grady of Danby. West writes: "In connection with Dan Leary of Dorset we took an option on this quarry and put down a core fifty-two feet. We thought we should recognize the Tunnel layers, but they were considerably thinner than in the Grady quarry. The core was fairly good, but not good enough to warrant further development."

WHITE STONE BROOK QUARRY

West writes of this quarry: "A general history of the Danby district would be incomplete without mention of the above quarry. In December, 1902, Potter, McDevitt and McCormick leased all the quarry, the property containing sixty-five acres. A few days later Mr. Norcross and the writer became interested in the quarry. Mr. Norcross worked the quarry hoping to get marble for the New York Public Library and, while we met many disappointments, the quarry did produce some good marble. The deposit was only a prospect when we took it, no development being done. It was one of the most promising ledges of white marble I ever saw, but as usual, the prospect of getting good white marble near the surface proved a delusion." Dale gives the following list of beds in this quarry:

	Feet
Dolomite	10
Gray marble	10
White marble*	68
Gray marble	13
White marble	933
Branded white and gray marble.	

* In beds five to ten feet thick separated by two or three inches of schist.

The beds of marble mostly alternate with beds of slickensided pyritiferous mica schist a few inches thick, the pyrite crystals elongated in the direction of the slickensiding. The schist consists of calcite and vein quartz in lenses or beds alternating with fibrous muscovite containing chlorite and lenses, probably of some carbonate. In parts also quartz and sericite occur mingled. The marble, White Stone Brook, is a coarse calcite marble, faintly cream tinted, somewhat translucent, with fine yellow greenish streaks and spots, hardly transparent in the rough but showing on a polished surface, and of very irregular texture.

THE WALLINGFORD AREA

I presume that many persons in the State have not thought of Wallingford as a marble town, and of late years it has not been, but in former times no little stone was obtained here. In the 1861 Report on Vermont Geology, page 760, there is this:

"The Otter Creek Valley runs parallel to that of Furnace Brook and, like it, has extensive beds of marble on the western side. These beds are brought to the surface by undulations or folds in the strata; and in many places by extensive erosion, large portions of the marble beds have been removed and the remaining portions show their edges on the hillside. The most southern quarry worked is at South Wallingford, owned by J. Adair and Brother. At the time of our visit (1857) the proprietors were engaged in filling a government order in furnishing marble for a custom house to be erected at Charleston, South Carolina. About seventy-five men were employed in quarrying and finishing the blocks ready to be placed in the building. The marble has not the fineness of that at West Rutland and in the more northern quarries but it is of fair quality." A pot hole is mentioned 'twenty feet in diameter,' probably like one in one of the Proctor quarries described later. Half a mile north of this quarry is another owned by Anson Warner and a mile north of South Wallingford village another owned by Robinson Hall. From the account of the region marble outcrops were found to be abundant.

The quarries named above were actively used, others had been worked and considerable marble taken out. Before the quarries just noted, quarries were in Wallingford, or near the town, as early as 1848. At the Adair quarry there was also a mill with six gangs of saws. Apparently, this Wallingford marble, though considered good marble, could not compete with other marbles and there has been no quarrying at this locality since 1869. All the Wallingford marble was light in color and as far as I have discovered, used only for building.

"We acquired half of the quarry rights on the entire farm of 200 acres. About this time the other partners sold their rights to Norcross and West. There was a pile of old blocks at the quarry which we shipped to Manchester and sawed for the interior of the New York Public Library. These blocks were so good that the architect of the Library urged us to open the deposit as he thought the stone superior to both Dorset and Danby.

A quarry plant was moved to Wallingford and an area opened near the old quarry. After the purchase by Mr. Norcross and myself we put down two forty-foot cores, both east of the quarry opening. We found sound marble but much of the stone bordered on gray. There was a little white and white with green bands. Much of the best and whitest of the marble is on the west side of the vein which is wide and is exposed for at least a hundred rods north. Near the northern limits of the Stafford property we moved a small amount of overburden, uncovering a strip for 150 feet and the showing was impressive. On the land north of the Stafford farm, now owned by G. M. Moxham, the outcrop appeared well. A short distance further north the rocks dip in every direction and the marble beds disappear."

A brief account of the Wallingford quarries, though none have been active for many years, will at least make this article more complete and will be of interest and value historically. Most of what follows is from Mr. West's report.

THE KELLEY QUARRY

According to West, this quarry was opened in 1840, by J. H. Lippitt, who operated it in a small way for a few years. W. W. Kelley bought it in 1866 and worked it and six years later built an eight-gang mill and continued till 1890. The Norcross-West Company leased this property for two years. They put down a core sixty-two feet a little east of the old quarry. The marble was white with green stripes and a fair building marble. A little quarrying was carried on in 1916. Like all the Wallingford marble beds these pitch steeply west.

THE ADAIR QUARRY

"This quarry was opened by J. A. Adair and Brother in 1857. Shortly after beginning operations this company secured a contract for the custom house at Charleston, South Carolina. A six-gang mill was built on a nearby stream and at one time the company employed seventy-five men. After a few years the quarry was closed but was opened again by Loren Waldo in 1867. He operated just one season."—West.

THE STAFFORD QUARRY

"This quarry was formerly called the General Hall and later the Norcross quarry. This deposit is located on the land of George Stafford, a mile north of South Wallingford. The quarry was opened by General Hall in 1855. Meeting financial reverses General Hall closed the quarry after two or three seasons. Frank Post operated the quarry in 1859. It was then idle till 1867, when it was worked two years by Loren Waldo. In 1905 it was reopened by E. W. Norcross and E. West and operated one year. Pat McCormick rediscovered this locality and in company with Potter, McDevitt and myself took out a lease on two acres. We all thought this a good prospect and began coring in high hope. The first core, put down in the bottom of the old quarry, did not meet our expectations. . . . The following year we acquired the quarry rights on half the property.

"The Danby, and to some extent the Wallingford, marble have a general and often close resemblance and structure. There either were two periods of metamorphism or in some way the conditions were more or less different in this southern portion of Vermont from those that prevailed in the Rutland and Pittsford area. The marble we have been considering is in most, if not all, the southern quarries harder, more coarsely crystallized, and more brilliant. Though some of the marbles of the more northern quarries are used in the construction of buildings, they have from the first been more extensively used in monuments, inside ornament and such work, while the marbles of the southern quarries have been very much more generally used as building stone, though many monuments stand as silent witnesses of the adaptability of these marbles, some of them, to other than building purposes."

THE CLARENDON AREA

North from the Wallingford district quarries is the Clarendon area. During the past few years several quarries of light-colored marble have been opened and operated in this town. Clarendon, West Rutland, Proctor and Pittsford are practically in the same area and all produce a more purely calcite and somewhat softer stone than the quarries south. The Clarendon marble is mainly a building stone. In the New York Educational Building at Albany 72,000 feet of Clarendon marble were used, including twenty-three columns each sixty-two feet high and forty-seven inches in diameter, forming a most stately row in the front of the building. The following is given as showing the chemical constitution:

Carbonate of lime	97.85
Carbonate of iron	0.06
Carbonate of magnesia	0.56
Sulphate of lime	traces
Silica, alumina, alkalies, organic matter and undetermined	1.53
	100.00

There are two main quarries of this marble, the Valley and the Clarendon. Both quarries are operated by the Green Mountain Marble Company of West Rutland.

THE VALLEY QUARRY

Otter Creek flows through Clarendon and in the valley of this stream is located the Valley quarry, producing the "Valley Gray" marble. This, like the more southern quarries, produces only light-colored marble. "The marble beds exposed here consist of at least seventy feet of calcite marble."—Dale. The marble, "Clarendon Valley Gray," is a calcite marble of very light bluish color and acutely plicated dark gray dolomite beds. Graphite abounds in the dolomite beds and also sparsely through the calcite marble as does also quartz. There are rare grains of feldspar (orthoclase, plagioclase, 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. 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. This schist is finely plicated and crossed by slip cleavage and is veined by quartz, calcite and pyrite. This is the typical schist of the basal formation of the Taconic range. 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 seven feet in thickness and a little farther west measures thirty feet and boulders and sand."—Dale, *l.c.*

THE CLARENDON QUARRY

This quarry is north of that named above and therefore near the West Rutland deposits. Two views of the Clarendon quarry are shown in Figures 17 and 18. These views are of the same quarry but taken from different points. This quarry is older than the Valley quarry. As the list below shows, there is considerable variety in shade in the marble of this quarry, although all is more or less light. The different beds are as follows:

MARBLE BEDS OF THE CLARENDON QUARRY AS GIVEN BY DALE

	Feet
Graphitic marble	50
Graphitic schist	7
Graphitic banded marble	19
White marble, ~~banded~~ slightly	17
White marble, mottled and banded	34
Mixed mottled marble	99
Dolomite	20
Graphitic variegated marble	81
	327

The marble is varied in texture, some grains being rather large, others much finer. "The white parts contain minute grains of quartz and of pyrite. . . . The gray spots and bands are graphitic. The marble takes a high polish. The graphitic marble of the third bed is a graphitic calcite in some beds almost black, alternating with dark bluish gray bands from .05 to .2 inch wide, without plications, but in other beds of light gray calcite marble alternating with similar bands of light gray shade. The variegated stone of the lowest bed is a graphitic calcite marble of a very dark bluish gray color, mottled or banded with very light bluish gray almost bluish white. 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 is seven feet in thickness and a little farther west measures thirty feet and contains boulders and sand."

The dark banded marble of the nineteen-foot bed is a graphitic calcite marble, in some beds almost black, alternating with dark bluish gray bands, but in other beds with light gray calcite marble, alternating with similar bands of dark gray shade. . . . The variegated bed rock of the lowest bed is a graphitic calcite marble of very dark bluish gray color, mottled or irregularly banded with bluish gray, almost bluish white. This is probably much older than that mentioned above, and nearer the Taconic Mountains, a little west. At this quarry glaciation is well preserved by a layer of clay which originally covered it.

Marble quarrying must have begun in Clarendon many years ago, for Hitchcock in his report written before 1860 speaks of an "abandoned quarry, southwest from the Springs." When or how long this quarry on the land of Abner Colvin was used there seems to be no record.

THE WEST RUTLAND AREA

Rutland city and West Rutland village are often confused and easily so in considering marble, for in many phases of the business the two are very closely connected. For many years no marble has been quarried in Rutland, but all quarries are at West

FIG. 19. East quarries at West Rutland.

Rutland. This latter town was formerly a part of Rutland, but in 1886 part of the older town was set off as a separate town. On all sides except the east of Rutland city there are marble quarries. From West Rutland quarries a very large amount of marble has been sold during the past thirty years and not a little before that time. More than any other locality, West Rutland has for years been the center of the marble industry of Vermont. Most of the so-called "Rutland marbles" have long been quarried at West Rutland. As will be seen later, the Vermont Marble Company have openings on the east side and several more on the west side. Besides these on the west side there are the quarries of the Green Mountain Corporation and the Colonial Marble Company. Several of the quarries on the east side have been cleared until they are confluent and some contain an electric track by which marble may be conveyed to any one of several openings from which it may be hoisted to the surface. In some of these quarries the marble beds are not very unlike each other. In some there is a very remarkable variety of shade, color, and veining as is shown on other pages. I do not pretend to be familiar with all the marble quarries of the world, but as far as I do know and can learn there is no locality anywhere that is able to supply such a large variety of marbles as does the West Rutland area, at least any area of equal size. The brief descriptions of different marbles given on pages 175-205 are my warrant for saying this. It is needless to add that the West Rutland area is in many respects the marble center, not only of Vermont, but of the United States, although other of the areas herein mentioned have done much to give Vermont marble the fame it has long enjoyed throughout the world. Figure 20 shows something of the appearance of some of the united quarries noticed above.

As has been related, some of the former quarries have in course of quarrying been united, and most will not be singly considered here. What originally was one separate quarry is, in several cases, now a part of a larger. There are two ridges here and some of the quarries are on the western ridge, more on, or in, the eastern. Naturally a valley runs in a northerly and southerly direction between the ridges. These two localities are on each side of an anticlinal valley "along the west foot of the synclinal ridge which intervenes between the Taconic range proper and the intermediate range."—Dale, *l.c.* Several (Covered quarry, New Opening, and Upper Gilson quarry) in an eastern upper series of beds, and eight (Gilson, Ripley, Baxter, Clement, Foster, Sherman, and Old) in an adjoining western and lower series

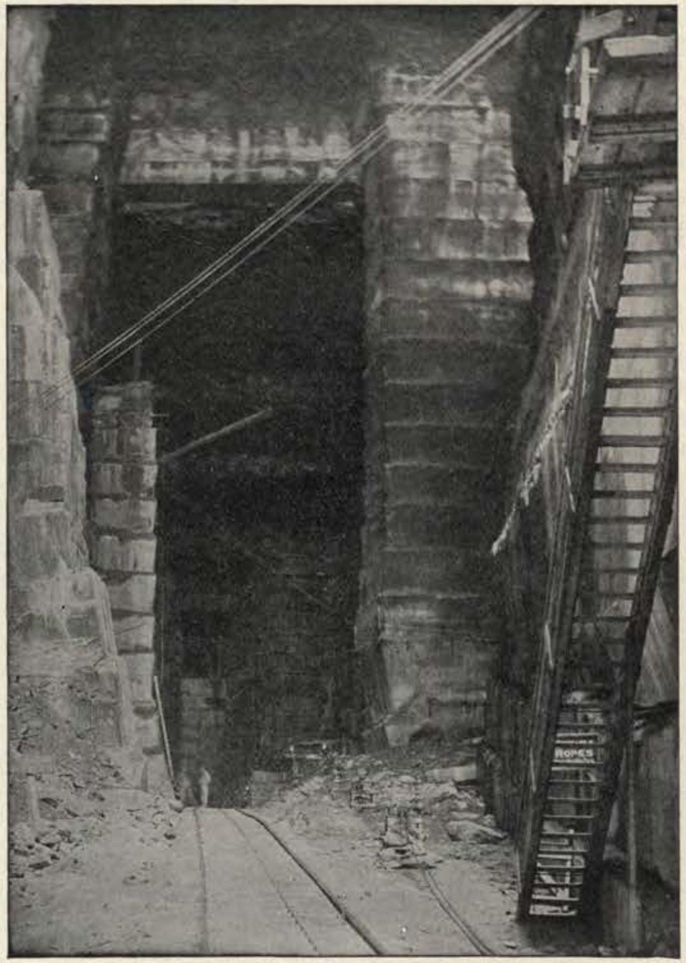

FIG. 20. Looking down into the tunnels, underground marble quarries of West Rutland.

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 four-tenths of a mile north northwest of the West Rutland station, extends eight-tenths of a mile north northwest. . . . The quarries are narrow openings along the strike and follow the dip of the beds more or less closely, with foot and head walls dipping 35°-45° east. In some places the supporting head walls between the quarries have been excavated below, leaving narrow rock bridges at the top, Figure 21. As the beds turn eastward in anticlinal 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

FIG. 21. Looking out from underground tunnels, West Rutland quarry.

as to admit of a continuous electric mine railroad 1,500 feet long. In the Ripley quarry at a depth of 225 feet tunneling has been done 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 beds in generalized form is as below:

Fig. 22. Storage yard for quarried marble blocks at West Rutland.

SECTION BETWEEN THE MARBLE BEDS AND SCHIST CONTACT, GILSON QUARRY

as on p. 35

	Feet	Inches
East wall of Gilson Quarry		
White marble	11	6
Graphitic marble, including fossil beds	135	6
Light marble	2	
Graphitic marble	73	
White marble with small lenses of dolomite	25	
Covered interval, probably graphitic marble with interbedded dolomite schist	58	
	305	

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

SECTION ON THE EAST SIDE OF THE WEST RUTLAND ANTICLINE

as on p. 35

	Feet
Covered area, probably graphitic marble with interbedded dolomite	58
White marble with dolomitic lenses	25
Graphitic (blue) marble, including 2 feet of white	210
White marble, 11 feet 6 inches of this is east of east wall of Gilson quarry	31
White marble finely banded with gray	90
White graphitic (blue) and muscovitic (green) marble in alternating beds	140
Dolomite	40
Mainly graphitic marble, but with 18 feet 6 inches of white, 34 feet of muscovitic (green) and 73 feet 8 inches of dolomite in beds of 1.8 inches to 16 feet thick	250
Muscovitic (green) marble	12
Graphitic marble	34
	890

In what is called True Blue quarry the sequence is as follows: Dale 521 Pg 87

SECTION OF TRUE BLUE QUARRY

	Feet	
Graphitic marble	10	30
Graphitic dolomite and marble	15–20	
Graphitic marble of various shades, average	62	
Graphitic schist	40	

SECTION OF MARBLE BEDS AT ESPERANZA QUARRY

	Feet	
Graphitic marble above floor of tunnel	105	
Graphitic marble below floor of tunnel	20	
Dolomite	22	23
	147	Incomplete

Marble, some greenish — 19

Dolomite — 22

101

At the quarries of the Vermont Marble Company at West Rutland the following beds are found. As will be seen, there is here no such variety found in the coloring of the marble as in the quarry. In fact, as great a number of different colors and shades is not often found as in the first named quarry. In the West Rutland section, though the number of layers is less than in the Eastman quarry, the entire thickness is more, the Eastman quarry showing a thickness of 196.4 feet made up of twenty-four beds while the Vermont Marble Company's quarry shows a thickness of 220 to 262 feet and twenty beds. These figures are those given by Dale in Bulletin 521, United States Geological Survey.

SECTION OF MARBLE BEDS OF THE WEST RUTLAND QUARRIES OF THE VERMONT MARBLE COMPANY

	Feet
White marble (top white) about	50
Graphite marble	222
White and graphitic (includes olivo)	50
White (includes second statuary)	3
Muscovitic, banded	4– 5
White and graphitic	6
White (Rutland statuary)	7– 11
Muscovitic (dark greenish) average	4
White	3– 4
Muscovitic, fine banded, light Brocatillo, Pavonazzo	5– 6
White (best light cloud)	6– 10
Muscovite, banded (Listavena)	4
Muscovite, banded (dark greenish), Verdoso	2– 4
White	1– 2
Dolomite	1– 4
Muscovite, banded	2– 3
White (Rutland and Italian)	3– 6
Graphitic, abundant Maclurites, Lividoec	8– 25
Dolomite	40
	220–262

One more section may suffice here. All of the sections have been quoted from Dale, *l.c.*

SECTION OF MARBLE BEDS IN THE ALBERTSON QUARRY

	Feet
Graphitic beds above floor of tunnel	105
Graphitic beds below floor of tunnel	20
Dolomite	23
Marble, some of it greenish	19
Dolomite	22
	189

(This quarry is also known as the Esperanza.)

"As the east boundary of the schist 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 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 the sedimentation in the space of a mile along the strike. The open syncline in the Albertson quarry is probably a continuation of one of the minor folds of the True Blue quarry, but lower down. It will be noticed that the graphitic beds of the True Blue and the Albertson quarries belong to the upper graphitic series in the West Rutland section." Dale, *l.c.*

It should be here noticed that all that has thus far been written in regard to the "Rutland quarries" refers only to the west side of the West Rutland anticline. That which follows refers to the opposite side (west) of the anticline. This is largely quoted from Dale's report of his observations in this locality. Dale writes as follows:

"The most complete exposure on the west side of the West Rutland anticline is at the Eastman quarry, about one and a half miles south of the West Rutland station, where, however, owing to a minor overturned westward fold in the western half of the anticline the beds dip east at the surface. 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. A little more clay sediment in the sea at one point or another would make the difference between a green muscovite marble and an almost white one."

THE PROCTOR AREA

As has been noticed in 1884, Sutherland Falls became the township to be henceforth known as Proctor. The falls, which gave the old town its name, very early after some of the areas south, attracted marble workers to its locality as able to supply an excellent water power for the machinery needed in new marble mills. At this locality Otter Creek dashes over cliffs 120 feet high and has proved, when properly harnessed, an important factor in the development of the Vermont marble industry. For years used for its water power, these falls are now the chief motive force, not only at Proctor, but carried by wires they supply mills and, to some extent, quarries at West Rutland and mills at other accessible points. Book of Marble tells us that "The Otter Creek provides power for by far the larger part of the machinery in the shops, mills and quarries of the Vermont Marble Company. Power houses at several of the falls of the river feed into a general circuit, with a combined force of 13,000 horse power." The main fall is at Proctor, shown in Figure 24, but the reader will under-

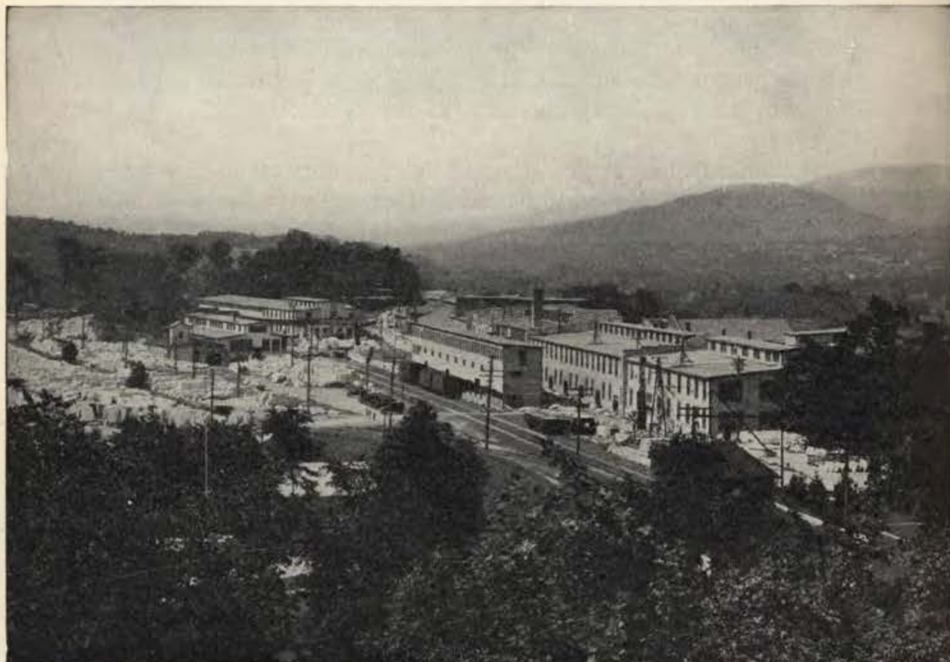

FIG. 23. The Vermont Marble Company's Proctor Plant. Two new shops have been built since this photograph was taken.

stand that this fall is only one of several falls which are utilized. As in all our streams, the amount of water in Otter Creek varies considerably at different seasons, and the illustration shows the falls at Proctor at high water, but there is at all times water sufficient for all the needs of the mills.

As it is not necessary to tell Vermonters, Proctor is the marble center of not only the marble industry of Vermont, but of the United States, and without much, if any, exaggeration, of the world. More mills are found elsewhere, as noted on other pages, but nowhere else is there so large a plant in which all the many

processes by which marble is transformed from the quarry block to the carved or polished piece as here. Not much quarrying is done here, but from the many quarries of the company all kinds of jobs are sent to the Proctor mills to be finished, as in the large stone quarried in Colorado and with much difficulty and expense, sent to Proctor to be finished, as here appliances not to be found elsewhere are available. (See Figure 15.)

As to the geological conditions in and about Proctor, Mr. Dale states the following:

"The main features are the schist ridge on the west (of Proctor), under which the marble dips, and the dolomite on the

FIG. 24. Falls of the Otter Creek at Proctor.

easting dipping under the marble as shown in the Sutherland Falls quarry. The marble beds of the Proctor (Sutherland Falls) quarry and the Columbian and of a disused quarry between these two apparently belong to the base of the marble series, as do also the beds of the Riverside quarry two 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 to the west. At the disused quarry on the knoll, one-third of a mile south, marble 185 feet thick is exposed. At the Riverside quarry marble

85 feet thick is exposed and 170 feet more have apparently been crossed in core drilling westward. 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 overhanging mass of dolomite 840 feet wide, which extends to the pond. . . . The dips range from 35° to 75° east. . . . The conspicuous marble knoll half a mile south of Proctor . . . . presents an interesting problem. . . . Its west side is clearly an anticline with an almost vertical west limb and a narrow horizontal or nearly top and core followed on the east by a compressed syncline overturned on the west, the upper beds of the dolomite overlying the marble with an easterly dip, as at the Proctor quarry. In this dolomite a test pit has exposed a graphitic dolomite like that of the Prospect two miles north of Proctor; although the marble of this knoll belongs to the Proctor quarry line of beds, yet its strike is in line with the Shangrow quarry beds 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 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 knoll is covered by vegetation, it is uncertain whether the intermediate dolomite is represented in the synclinal part of the knoll. . . . The entire thickness of the marble beds here is 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 disused Shangrow quarry and other neighboring quarries and at several points in the village. This marble is 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. 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° east on the east side and 25° to 45° west on the west their thickness can hardly exceed 150 feet. The greatest thickness of the graphitic beds exposed at any one quarry is 135 feet. . . . 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 back of the Y. M. C. A. building and the town hall. This dip becomes 75° to 80° west a few hundred feet farther south back of the post office, whereas the prevalent dip west of these points is 70° east. The marble of the entire Proctor section thus appears to consist of the following members, so far as the data obtained indicate, beginning at the west and on top:

Section of the Marble Beds at Proctor

	Feet
Graphitic marble of Shangrow and other neighboring quarries with some interbedded dolomite	156
Dolomite, knoll west of Proctor quarry	264
Marble, bluish white, clouded	172–264
Dolomite	586–678"

—Dale, *l.c.*

In the town of Proctor itself, while much marble has been and is at present prepared for market, as has been noticed, relatively not much quarrying is done here. There are now several idle quarries such as the old Sutherland Falls quarry which was long worked, and may be considered as a good typical example of a Vermont marble quarry, yet it is not now used, having been idle since 1907. This quarry was for a long time actively worked and finally reached a depth of nearly 200 feet. "The marble beds form the eastern limb of a syncline about 150 feet in depth, but instead of curving directly over on the east to form an anticline they dip sharply to form a dip at a low angle to the east for a space of 50 feet and then turn again to resume the direction of the anticlinal limb. The effect of this minor fold in the anticlinal part of the fold is to double over some of the beds in the eastern part of the quarry and reduce the apparent thickness." (Dale, see Bibliography.) The only other quarry in Proctor that ever became important is the Shangrow quarry.

THE SHANGROW QUARRY

This quarry was given up as impracticable in the early 1900's. It produced a dark gray-colored marble of various shades which appeared in stripes or bands. It was not operated for a long time and did not produce any better than second-rate marble.

There have been several openings in the town, but none have been much worked.

About half a mile south of the Shangrow quarry is that of the Columbian Company now idle. The same mottled marble appears in an outcrop on the farm owned by L. O. Chapin, a short distance north of the Columbian. The level area on which the Proctor offices and mills are placed is on the east side of the ridge in West Rutland on which and in which is the great line of quarries carried on by the Vermont Marble Company.

As has been stated the power used in mills and quarries at West Rutland, changed from water power at the falls to electric power, is from Proctor. Dale writes: "The main features (of the Proctor area) are the schist ridge on the west, under which the marble dips, and the dolomite on the east dipping under the marble, as shown in the Proctor (Sutherland Falls) quarry. The marble belt thus bounded is here from 1,600 to 2,200 feet wide. The marble beds of the Columbian and the Proctor quarries and of a disused quarry between these belong apparently to the bottom of the marble series, as do the beds of the Riverside quarry two miles south of Proctor. At the Riverside quarry marble measuring 88 feet is in sight and 170 feet more have been crossed by core drilling west, giving a total of about 250 feet." Quarries formerly operated in Proctor, but now idle, are Mountain Dark or Shangrow, Riverside, and Columbian.

THE PITTSFORD AREA

The history of marble quarrying in Pittsford is quite complicated and can be treated only briefly here. In course of the years a considerable amount of good marble was and still is taken

out of the quarries here and those of Florence, which is a part of Pittsford. It seems somewhat uncertain just when quarrying began in this immediate region, but probably it was early. According to Caverly, quarries were opened in this town by Jeremiah Sheldon in 1785 and from that time on at intervals more or less quarrying was carried on in this town. But it was not very extensively or profitably quarried until in 1901 when the Rutland-Florence Marble Company was formed, though at this time the Vermont Marble Company held considerable property at Pittsford.

The Rutland-Florence Company started with a capital of $1,000,000, built a very finely equipped mill, one of the best in the whole country. The name of this part of Pittsford became Fowler and every indication of a large business appeared, but in 1911 the entire property was bought by the Vermont Marble Company, and the name of the locality was changed back to Florence. With this large addition to their property the Vermont Marble Company controlled the Pittsford area, except one quarry held by F. R. Patch and Co., which will be fully treated later.

The Pittsford marble is varied in color, veining, etc., but is all light in shade. The tables here given indicate the general character of the stone. In the descriptions on following pages additional characters will be found. In some, though not many, good evidence of glaciation is found in one of the Pittsford quarries.

As anyone would suppose most of the Vermont marble quarries are located in the midst of attractive and often inspiring scenery. At almost any of our quarries the visitor looks out over beautiful, or at least fine, landscape. The Pittsford area is not the least of these fine outlooks. Figure 25 gives an imperfect idea, as all pictures must, of the location of the Pittsford quarries.

Dale, writing of this region, says, "In Pittsford the marble belt widens out to nearly a mile east of the Florence quarries. 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 of obtaining satisfactory estimates of thickness in this locality is great. At the Florentine quarry, where the contact between the 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 127 feet west of the west wall of the quarry and counting east and down the following section has been made out:

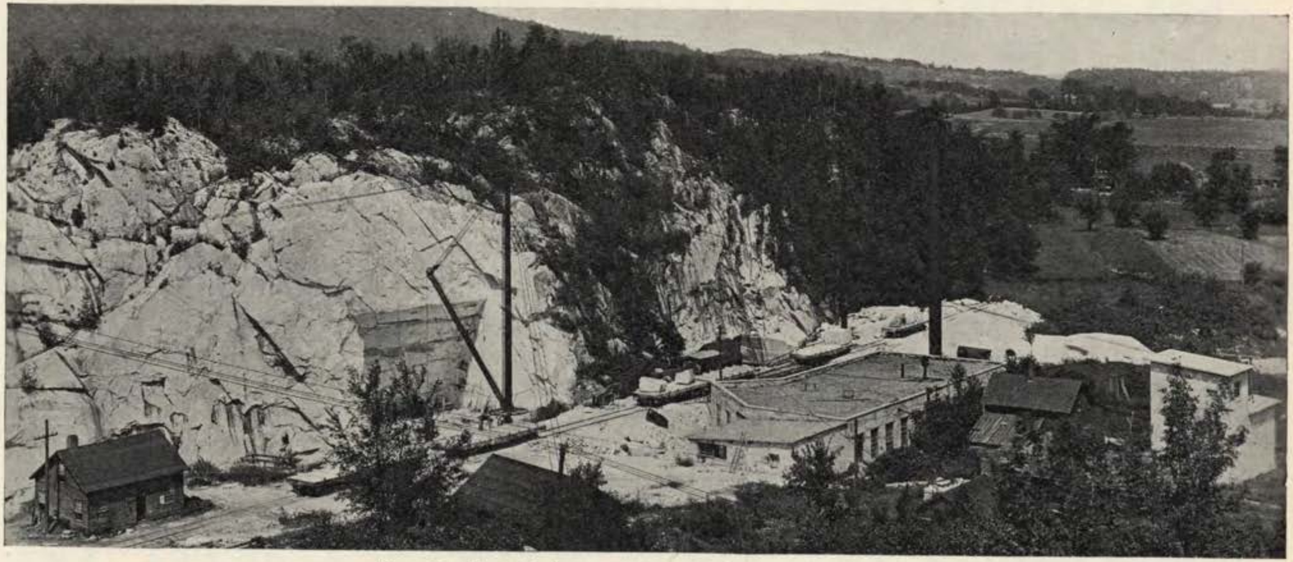

FIG. 25. General view of Pittsford Valley marble quarries.

Section of Beds in Hollister Quarry, Pittsford

	Feet	Inches
Light bluish gray marble	90	
Clouded marble	16	
Bluish marble	14	
Alternating muscovite and light bluish gray	102	
White and muscovitic marble	15	
West edge of quarry:		
Light bluish gray marble	12	6
Inferior marble	7	
Light bluish gray marble	20	6
East edge of quarry:		
White or light bluish gray marble	47	10
	324	10

"Among the striking features (of this region) is the disparity of the intermediate dolomite in the West Rutland and Dorset Mountain sections on the one hand and the Proctor-Pittsford on the other. The absence in the Proctor section of both the West Rutland assorted marbles and the Pittsford clouded gray 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 knoll between the Columbian and the Proctor quarries is noted elsewhere, and the Pine Hill overthrust fault is only two miles east. The upper clouded marbles and the muscovitic marbles, which normally occur above the intermediate dolomite, are shut out by an overthrust fault, which brings the 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 mentioned. Some of these differences are evidently due to local changes in the character of the sediments in which the marble beds originated." Dale, *l.c.* As to these sections, some of which are given in following pages, Mr. Dale calls attention to the fact that they are rather provisional than final. That "they may afford a basis for the more exact determinations which further quarrying, core drilling, and geologic exploration will make possible."

At the Florence No. 1, or Hogback quarry, besides the 112 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 the white near the dolomite. The succession here beginning on the west as follows:

MARBLE BEDS IN NO. 1 QUARRY, FLORENCE

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

Another estimate of the Pittsford section, lower part of the marble, was obtained at the Pittsford Italian and Florence quarries No. 2. At the Florence No. 2 quarry there are 42 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:

45

SECTION OF FLORENCE NO. 2 AND PITTSFORD ITALIAN QUARRIES

	Feet
Florence No. 2 quarry and light gray clouded marble and beds east of it 215 feet at 76 dip (average, 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 70 feet at 75	65
Outcrops on either side of quarry 150 feet at 75	142
	667

657

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

The following quarries, formerly worked in Pittsford but now closed, are the Landon or Eureka, Florence or Hogback, North Pittsford, Valley, Smith and Brainerd, and Highland.

At present the only quarry in Pittsford is owned and operated by F. R. Patch and others. This quarry, the Venetian, has no mill but sells blocks as they come from the quarry. Formerly it was called the Raleigh quarry, now as stated.

THE VENETIAN QUARRY

Though this quarry has been known and passed through several ownerships it has not been worked much till recently, that is, within a few years since the Venetian Company took hold of it.

"From 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 THE PITTSFORD MARBLE BEDS

	Feet
Graphitic marble, with interbedded dolomite	150
Florence No. 2 and Hollister beds, average	230
Intermediate dolomite, average	247
'Pittsford Italian' marble, light	151
Dolomite	778"

OK

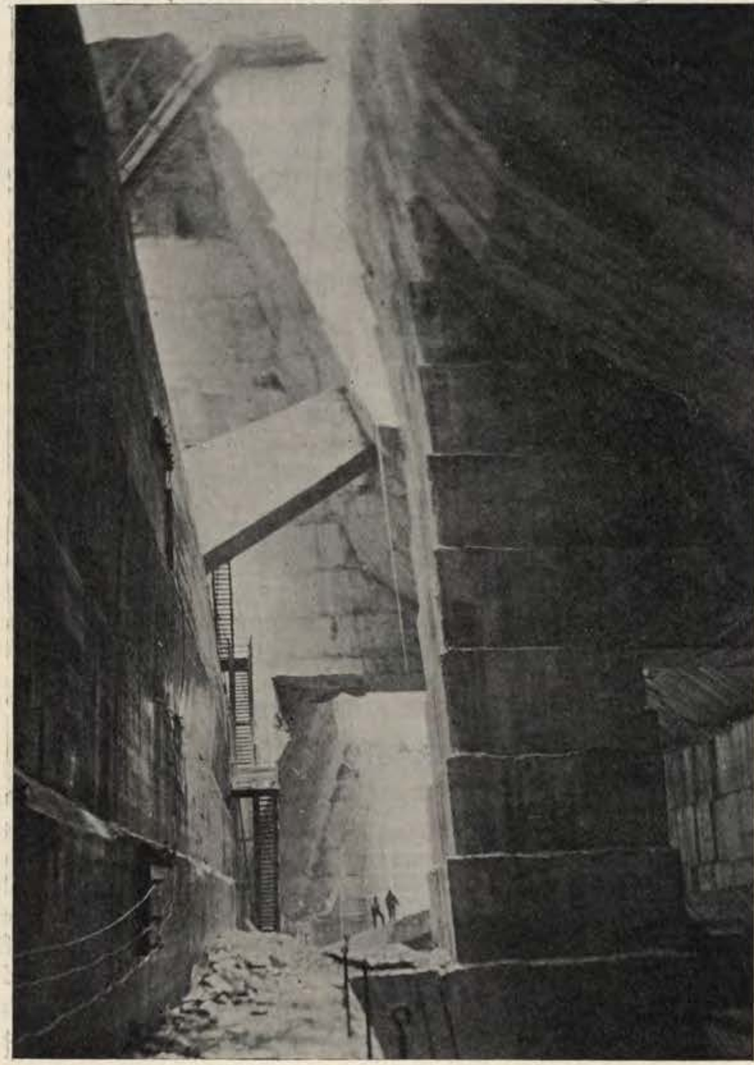

FIG. 26. Pittsford Valley marble quarry, Pittsford. Over 300 feet in depth.

By abridging and arranging the West Rutland, Proctor, Pittsford, Dorset Mountain and Green Peak estimates in one table we get 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 cannot well be tabulated with the others as their position either with reference to the base and top of the marble cannot yet be determined.

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Marble Beds in Western Vermont

	West Rutland Anticline East side	West Rutland Anticline West side	Proctor	Pittsford	Dorset Mountain Owls Head Green Peak
	feet	feet	feet	feet	feet
Upper graphitic marble...	199-293	300	150	150	20-100
Average................	246				
White, graphitic and muscovitic, alternating	180-222	93 Rest not reached	Absent	Absent	
Average................	201	Probably absent	Absent	230	100-175
Upper clouded light gray..	Absent				
Intermediate dolomite	40	Not reached	264	247	50-100
Lower clouded white	Absent	Not reached	172-264	Absent	165-242
Lower graphitic marble...	296	Not reached	Absent	Absent	165-242
Dolomite					
Total..................	715-821		554-678	778	335-617
Average................	783		616		476

Should be 151

851

THE BRANDON AREA

North from Pittsford we come to Brandon. Indeed the marble beds of Brandon are apparently a continuation of those of Pittsford, though, as is true of each area considered, each has some peculiar features. As far as records show, mills were built and operated in Brandon some years before quarries were opened. Some of the Pittsford was sawed in Brandon as early as 1828, when one Justus Hyatt began to saw Pittsford marble for building purposes. Somewhat later another mill was built here. The water power available probably explains this. The earliest record I have found declares that in 1840, or about that time, a quarry,

the Boston quarry, was opened by several Boston men. They operated it for a few years then selling out to men who operated it for several years. It was then sold to different persons. At some time before 1880 the Boston quarry was closed and about that time much or most of the dozen or so quarries at Brandon were given up. A few continued till later and the Brandon Italian quarry is still active as will be seen later. The latest opening as far as the writer has discovered, is an unnamed quarry a mile north of the Landon quarry at Pittsford. This quarry produced a very pure white marble, as did several of the Brandon quarries. There were also beds of clouded and some veined stone. The largest and longest operated quarry in Brandon is the Brandon Italian quarry.

THE BRANDON ITALIAN QUARRY

This quarry, now owned and operated by the Vermont Marble Company, is a deep excavation near the railroad track and plainly visible as the train goes south from the Brandon station. It is on the west side of the track and about half a mile south of the station. The quarry is open entirely below the level of the track. The name indicates the appearance of the stone, fine in grain, light in color, veined with dark shades, described on page 178. The quarry is like a huge cellar, 600 feet from north to south, 60 or more feet wide and at least 75 feet deep, and, as it is actively worked, growing larger as work goes on. Let me repeat the caution as to descriptions of active quarries and remind the reader that all active quarries are constantly changing as work goes on. The descriptions are accurate at the time of writing, but as this reaches any reader they are not exact.

Since 1909 this great quarry has been the property of the Vermont Marble Company as stated above. This company has been active in Brandon for thirty years, opening prospects, working small quarries, etc., but have done more satisfactory work in this quarry than elsewhere in town. Until a few years this company worked the High Street quarry, but have now abandoned it. The principal quarries that have been active in Brandon are briefly mentioned below. From some of these in past years considerable marble has been taken and sold, and at times the purity of the white marble caused a very satisfactory price. But in some cases, though the marble was very satisfactory, it was in too thin beds or too unsound, or for one reason or another not permanently marketable.

THE HIGH STREET QUARRY

This quarry is a short distance north and east of the Brandon Italian and, therefore, nearer the business part of the town. "The marble beds consist of 107 feet of light bluish gray marble situated very near the underlying dolomite. The marble closely resembles that of the Brandon Italian quarry." Dale, *l.c.* Located very near the main road from Brandon to Proctor. Not now open.

VERMONT ITALIAN MARBLE COMPANY

This quarry produces stone essentially like that of the Brandon Italian quarry, though over three miles north.

THE GOODELL QUARRY

This quarry is no longer operated. Like all the Brandon marbles it is of the lighter varieties. It is located two miles southwest of the station. The marble here is in too small a bed to be profitably quarried and was not quarried long. The stone is of very clear white, fine grained, and receives a fine polish. The main difficulty seems to be the small quantity that can be obtained.

THE CONNELL QUARRY

This quarry was operated by the Brandon Marble Company for a time but is now idle. Its location is not far, less than half a mile northeast of the Goodell quarry, about four miles from the village. There are two openings here both furnishing light-colored marble. The bed of marble is not far from 30 feet thick. Above and below the marble is a bed of dolomite.

According to Dale, "The marble bed is here made up of 7 feet of fine white statuary, 13 feet of mottled, and 10 feet of gray marble."

THE ROYCE QUARRY

Northwest of the station at Brandon is an old quarry, not used for many years, formerly known as the Royce quarry. There is here a bed of marble fully 70 feet thick, capped by dolomite. Dale writes: "The marble here 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. . . . It contains some small quartz grains and some pyrite. . . . The other is a calcite of a milk white color with little grayish micaceous dolomitic beds.

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Somewhat more than two miles north of the station at Brandon some years ago an outcrop of marble was formerly quarried; a marble rather coarser than that of the Royce quarry, but similar in color, white or gray with a bluish tint. It is located a little east of the main road to Leicester. Next east of the marble comes the rock which Dale refers to as "basal dolomite." Both marble and dolomite dip 35° east. This marble, as some others of this region, contains a little quartz and pyrite.

The Brandon quarries named, only two of which have been recently in operation, mentions only a part of the prospects that have been really worked mostly in passed years. In this area there are many outcrops that have not been more than very superficially tested or not at all, as there seemed, from such examination as was made, too little prospect of finding beds of marble that would be commercially profitable.

Within the past twenty-five years the following quarries, formerly worked in Brandon, have been closed. These are: High Street, Seldon, Thayer, Corona, Prime, Peck, and Bardillo. Some of these, as the Bardillo, were carried on for some years, others had only a short life.

THE MIDDLEBURY AREA

Marble was discovered in Middlebury somewhat later than in towns south as it does not appear to have been quarried before 1802, though it must have been recognized by early settlers before this time, for the white outcrops are seen here and there in the region. All through the marble belt there are more or less conspicuous white or light-colored outcrops of the underlying marble and they must have been observed by the earliest settlers. If they had been, the attention of the home makers was undoubtedly needed in many directions other than to these surface exposures of stone, besides they had no use for marble in those pioneer days and no means of cutting or hammering it into desired shapes if they had known all about it. According to Professor Seely, marble was first sawed in Middlebury by one Dr. Ebenezer Judd in 1805. The marble was quarried on the west bank of the Otter Creek not far below the falls. The stone was sawed here until 1837, from 5,000 to 10,000 feet being produced. The greater part, if not the whole output was in slabs two inches thick. "Some of the blocks sawed were taken from the bed of the river at low water." Seely.

"One of the oldest quarries with its mill was known as the Spaulding or Phelps. It has since been known as North Middlebury, old Middlebury, and Cutter quarry, and has been in operation for many years, until recent years when it has been closed." Professor Seely continues: "Other quarries have been designated as the White or Foot Street quarry, the Vermont, and the Addison County. In all these expensive excavations have been made, but they have failed to be remunerative. In most cases a beautiful white marble has been obtained, but the amount free from flaws and wholly sound was so small that the proprietors have not felt encouraged to continue the work." (Seely, Marble Border of Western New England, page 48.)

The Vermont Marble Company have a large mill in Middlebury which for some years has been actively employed in finishing marble brought from some of the quarries of the company not far south, but this is now idle, perhaps only temporarily.

At East Middlebury the quarry most recently worked has been until recently in active operation. Here the stone was chiefly white or light, but some beds afforded a very pretty pink marble. The stone is of fine grain and apparently sound.

West writes: "About three miles northeast of Middlebury station, near a small stream called Muddy Branch, is located the Halpin quarry, formerly known as the Spaulding quarry, the Phelps quarry, the old Middlebury quarry, and the Cutter quarry. There are two quarries, one at the north end and the other near the southern limits of the property. The north and larger quarry is approximately 100 feet long and 100 feet broad in the widest part. The opening is full of water, but the south wall well displays the beds. The marble vein is about 125 feet wide and dips east about 30°. The color is light clouded with white, the predominating color. While some of the marble is of excellent quality, it is very unsound and many reeds, heads and irregular fractures are in evidence. The south quarry is only a small opening full of water. On the western limit of the Halpin property is a narrow gorge through which a small stream flows. This water power was utilized by the Cutter Marble Company to run an eight-gang mill. The following buildings were furnished with this marble: Part of the post office, Portland, Maine, Catholic Church, Middlebury, and a small part of the custom house, Boston, Mass."

The pioneer in this business seems to have been Dr. E. W. Judd of whose work in beginning the sawing of marble more will be mentioned. During the life of Doctor Judd the marble business at Middlebury seems to have been more active than

since then. Quarries and mills were operated, but after his death in 1837 no one appears to have filled his place and the business grew less and less. The main activity for many years has been in the large mill of the Vermont Marble Company and the quarry of the Middlebury Marble Company, which were located at East Middlebury.

Besides the Halpin quarry there have been at different times, longer or shorter, a number of quarries in Middlebury, as the Addison County Company, the Foot Street quarry, the Toledo Marble Company, and the Middlebury Marble Company. None of these quarries are now at work. The marble from some of these quarries has been highly praised and by competent judges, but on the whole, while as already mentioned, the marble does not appear to be sufficiently sound, especially when large blocks are needed. Nevertheless, so eminent and experienced a judge as Richard S. Greenough could write of marble which he had used from the Addison County quarry thus: "I have no hesitation in assuring you that I prefer it to any marble I have ever used, and as I have always worked in the best marble of Carrara and Serraveza, I cannot say more in its praise." (Quoted from Smith, History of Addison County.) But it is quite certain that blocks like that used by Mr. Greenough have never been common. As far as statuary marble is concerned, the chief difficulty here and at Brandon has been that it was not possible to get sound pieces of pure white large enough. The best is beautifully clear white but the beds are too thin to provide the necessary blocks.

THE SHELBURNE QUARRY

In years now long past sundry attempts have been made in Shelburne to find good marble but with small success. A short distance west of Shelburne Pond, nearly 75 years ago, Messrs. Tasker, Taylor and Company opened a quarry and worked it for a time, but it did not prove a success. No other has been opened in this region. The deposit here is the northern border of the great marble belt of western Vermont. The marble is pure white and of good quality, but, as noted, it was never a success.

In preparing the account of various quarries from those of Dorset to this of Shelburne a few insignificant attempts at opening quarries and a few mills erected where there was no quarry have been omitted, but it is hoped that all facts of any importance have been included. As has been noted, the dates may not all be exact, but they are as nearly so as it was possible to fix them from more or less incomplete records. The writer will welcome any corrections that may be found.

THE DAY QUARRY

This is located in the town of Ira, a little more than three miles from West Rutland. "The marble belongs either to the upper graphitic beds close to the base of the schist formation, or else within the schist." I have not seen any specimen of this marble, but Dale writes of it as follows: "The marble is a graphitic calcite marble with fine black and grayish bands and of very uneven texture. . . . It contains quartz and feldspar grains and much graphite in bands. In places it abounds in sections of a large gasteropod resembling Maclurea. The marble area is about 300 feet east to west and 800 feet north to south and is surrounded by the Berkshire schist. It either protrudes through the overlying schist 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 and west and the dip 10° to 20° south. The strike of the schist mass east of the marble is North 30° east and the dip 20° north 60° west. 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 near the marble is slickensided, the grooves running north 5° west and dipping 45° east. The marble is much jointed, fractured and veined with calcite and quartz. Vertical joints strike north 20° east and are coated with felty asbestos and mountain leather, indicating metamorphism subsequent to jointing."

STONE NOT CALCITE MARBLE—IN TRADE CALLED MARBLE

Some of the finest and most attractive of the Vermont marbles are, scientifically speaking, not marbles, though no one will object to the trade name. Most of these are not marbles either in chemical composition or geological age as the true marbles, others are much like the marbles in many of their characters, but they differ in structure and to some extent in composition from the true metamorphic, calcite marbles. These are the limestones of Isle La Motte, Swanton, etc., the breccias of Plymouth and Equinox, the dolomites of Swanton, Malletts Bay and Monkton, the Serpentine, Verde Antique of Roxbury, and perhaps a few others. All of these can be cut, polished and sold as marble, and are regarded popularly as such. As was told in past pages, a true marble, scientifically, is a metamorphosed limestone of crystalline structure.

CHAZY LIMESTONE OF ISLE LA MOTTE

This is in trade a black marble. Long before any marble was quarried in this country stone was taken from the old Fisk quarry and used by the French in building Fort St. Ann on Isle La Motte. The stone appears to have been at first used for making quick lime in 1664 and later as a building stone. Mr. N. W. Fisk writes in 1920: "My grandfather, father and myself quarried marble from it and all kinds of building stone for more than 110 years."

All sufficient evidence shows that this was the oldest quarry opened in Vermont, though not at first for marble. Just when this stone was first used as marble does not seem to be certain, but it certainly was long ago. Very probably the honor of first stone used as marble belongs, as before stated, to Dorset, surely if we are strict in our definition of marble. However, it seems to be proved that the Fisk quarry has been continuously worked longer than any other in Vermont. For many years, if not at first, this stone has been sawed at the old Barney mill in Swanton, the Missisquoi River furnishing the water power. The piers which supported the old Victoria Bridge at Montreal came from this quarry, 500,000 feet of the stone are said to have been used.

This quarry is in extent not in depth, the largest in the State. The quarry is most conveniently situated for the transportation of the stone.

The limestone at the Fisk quarry is all Lower Ordovician, Chazy, as is shown by the fossils in some of the beds, *Maclurites magnus, Stromatocerium rugosum,* etc. The quarry is not deep, tracks for a small railroad running directly from the back wall to the dock on the shore of Lake Champlain. The top covering is not thick and the top stratum of rock is finely glaciated. Some of the strata are black, others gray. This stone is used in tile floors, mantels and wherever black marble is wanted. It has also been used extensively as a building stone in Montreal and elsewhere. For three generations operated by the Fisk family, the quarry is now owned by the Vermont Marble Company. The trade name is Champlain black. The quarry is, as before stated, not deep, not over 25 feet. Nowhere is there metamorphosis in the stone, but everywhere it is unchanged limestone. The floor of the quarry is little above the level of Lake Champlain and the strata dip at only a small angle.

THE HILL QUARRY

The stone in this quarry is much the same as that of the Fisk quarry and is used for the same purposes. This quarry is north and east of the Fisk quarry.

THE SHOREHAM QUARRY

On the shore of Lake Champlain just south of Larrabee's Point, is an old quarry in the Black River limestone. The stone is jet black and fine grained. However, it was not extensively quarried or sold, the reason why does not appear. It was used more extensively, apparently, by the iron works at Port Henry across the lake as a flux for smelting.

GRAND ISLE FLEURI

This is another "marble" quarried by the Vermont Marble Company, which is an unchanged limestone of Chazy age. It is similar to some of the beds in the old Fisk quarry and of much the same composition and character. In color it may be black or gray.

PLYMOUTH MARBLE

There are in Vermont a number of dolomitic beds which have been used to a greater or lesser extent as sources of various kinds of "marble." Though these are all dolomites, they differ greatly in many respects. All of these deposits are outside of the marble belt and none are true marbles in the scientific use of the term, but in trade they are classed with other marbles. At Plymouth, "about 250 feet above Plymouth Pond or what is now called Lake Amherst," in schist are beds of a dolomite unlike any other stone found in the State. The quarry in this was opened about 1830 and worked for a time and though the stone was used for many years as material for burning into quicklime, as marble it was little used. An analysis of the stone, made many years ago, is as follows:

Calcium carbonate	53.9
Magnesium carbonate	44.7
Iron and alumina oxides	1.3
	99.9

The "marble" is mainly a very dark, almost black when polished, though really it is dark gray-blue in which are included light gray or nearly white fragments, making a very conspicuously brecciated stone. The light inclusions are usually one or two inches long and half an inch wide but many are three or four inches long and a few may be six inches long. These light fragments are dolomite.

According to E. L. Perry, speaking of this dolomite breccia as used for marble, "The particular bed used for this purpose is metamorphosed intraformational conglomerate (or breccia) composed of rounded or subangular phenoclasts of white dolomite in a matrix of carbonaceous, dark gray dolomite. The bed is about a yard thick and is interstratified between beds of white dolomite. It is strongly jointed and consequently the proportion of waste in quarrying was too great."

As has been noticed, the deposit from which the "marble" was taken has for many years been a source of lime much more than of marble and there are a number of other beds of stone from which lime could be burned in various parts of Plymouth; but, as far as the writer has learned, from none except the Scott quarry has any marble been taken.

Elsewhere in the State limestone, generally used for burning into lime, has also been more or less finished and made into hearths, flagstones, etc., or when polished, into mantels, wainscotting, etc., for interior finish. Many of these have been abandoned for many years. Many have been used now and then as mortar was needed in the neighborhood for supplying lime. In fact, in the long ago lime in this State appears to have usually been obtained from the nearest bed of limestone and stone burned to lime by each individual builder, for what remains of old lime kilns are very numerous in western Vermont.

In an article in the Vermont Report for 1827-28, Doctor Perry writes: "Much of the dolomite beds of Plymouth and Bridgewater have at some time been used as a source of quicklime. Abandoned kilns are numerous in the vicinity of the dolomite outcrops and at least two kilns have been of recent use (1925). . . . Much of the dolomite is too impure for making lime without preliminary hand-picking to remove quartz or micaceous layers. . . . The most troublesome impurity is quartz, present both as small veinlets and as small grains in the sand phases of the formations. This quartz acts as a flux and causes sintering of the charge during the roasting process. . . . The dolomite from the small quarry near the head of Lake Amherst in southern Plymouth was used to a limited extent as a fancy marble for interior construction. The particular bed used for this purpose is a metamorphosed intraformational conglomerate (or breccia) composed of rounded or subangular phenoclasts of white dolomite in a matrix of carbonaceous dark gray dolomite. The bed is about a yard thick and is interstratified between beds of white dolomite. It is strongly jointed and consequently the proportion of waste in quarrying was too great for practical operation."

Dale writes: "The marbles of Plymouth are dolomite and dolomite breccia, occurring either as lenses either in a very quartzose mica schist 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 following analysis of a mixture of dark and light parts was made by T. S. Hunt:

	Feet	Inches
Calcium carbonate, $CaCo_2$	53	9
Magnesium carbonate, $MgCo_2$	44	7
Iron oxide and alumina, FeO_2 and AlO_2	1	3
	99	7

A section of the rocks east of Lake Amherst is as follows:

	Feet	Inches
Muscovite schist	26	
Dolomite, quartzose, cream color	2	3
Quartzite	4	
Dolomite, quartzose, some marble	5	6
Quartzite	2	6
Dolomite		6
Quartzite	5	6

THE SWANTON DOVE QUARRY

A very neatly tinted marble of a gray or rather dove color, described on page 203, is another variety of the unmetamorphosed limestones which at different times during the last century have been used as marble. The quarry operated by father and son of the Rich family for many years, generally for making quicklime, has been at times made into slabs or other pieces and when polished used for mantels and other interior work. The quarry, not far east of the village of Swanton, was opened about 1848 by Charles W. Rich and has been carried on ever since with some small interruptions. As a producer of lime this quarry seems to have been a success, and, especially in early times, considerable marble

was manufactured. The stone, however, was not sufficiently sound to be a success when used as marble, joints are too abundant so that it has not been possible to quarry large, sound blocks. Many thousands of barrels of lime have been produced here and the kilns are still going.

THE CHAMPLAIN MARBLE QUARRIES

Scattered from the south end of Hogback Mountain in Monkton north nearly to the Canadian line, but with wide intervals in the series, are a number of not very large quarries of the very elegant "marbles," called, by the Vermont Marble Company, by whom they are now quarried and finished, the Champlain marbles. These marbles are entirely unlike the true marble of the marble belt as they are only slightly calcareous, are not metamorphic and are older than the ordinary Vermont marble. Called at first "Winooski marble," "Calico marble." The later name as given above, is now generally used for the whole group. As more fully described on page 153, these marbles are of several varieties, all attractive, some very elegant when polished. They are of Lower Cambrian age, being phases of the dolomitic red sandrock of western Vermont. The varieties all exhibit more or less red of different shades, mingled with white, olive greenish, and sometimes other colors. They are nowhere found south of Hogback Mountain in Monkton, and nowhere except in a narrow strip between Lake Champlain and the Green Mountains, and occupy only small areas in the red sandrock formation. A comparison of the microscopic section of the Champlain marble and the true calcite marbles will show something of the difference in structure. Also the analysis as given below still more clearly shows the difference. Other analyses of these marbles are given on another page.

Analysis of Champlain Marble

Lime carbonate, $CaCo_2$	35.31
Magnesia carbonate, $MgCo_2$	42.23
Silica, SiO_2	10.30
Alumina and iron	12.25
	100.09

This analysis gives perhaps a fair average composition, but the relative proportions vary somewhat in different samples. As shown above, there is much more silica in these marbles than in any of those quarried in the marble belt. Not many chemical analyses of the Champlain marbles have been made, but from simple optical examination of various samples there appears to be considerable variation in composition, especially in the relative amount of silica and lime, some varieties having more silica and less lime, some the reverse.

As would be expected from the quantity of silica in these marbles, they are surer to keep in good condition than softer stone. There is more variation in chemical composition than in most of the true marbles. The variation in the relative proportions of calcium and silica is especially noticeable. In the red sandrock, which, as has been stated, is the chief rock of the Lower Cambrian in western Vermont, silica forms a much greater portion than in the modified phase of the Champlain marbles and a smaller portion of lime, but the amount of lime in the "marbles" is always considerably greater and there is less silica or quartz. Analyses, believed to be correct, are as follows:

ANALYSES OF CHAMPLAIN MARBLES

Silica, SiO_2	19.30	Silica, SiO_2	10.13
Alumina, AlO_2	12.25	Alumina, AlO_2	12.25
Iron, FeO	....	Iron, FeO	....
Lime, CaO_2	36.30	Lime, CaO_2	33.30
Magnesia, MnO	42.25	Magnesia, MnO	42.25
	110.10		97.93

It is interesting to compare the "marble" with the unchanged red sandrock in western Vermont:

ANALYSIS OF COMMON RED SANDROCK

Silica, SiO	83.80
Alumina and iron	8.70
Lime, $CaCo_2$	1.12
Magnesia, MgO_2	~~10.00~~
Potash, KO_2	4,59
Soda, NaO_2	~~45.00~~
Loss	~~80.00~~
	~~233.21~~ 77.

The above is that given by Hitchcock in Geology of Vermont, 1861.

Some beds of the red sandrock are mostly quartzite and, therefore, nearly 99 percent silica; others are more composite and in a lesser degree this is true of the various beds of the Champlain "marbles." The change, it can hardly be called metamorphosis, which made the more common beds of the Cambrian into the "marble," appears to have varied somewhat in different beds.

In no case was it great metamorphosis, such as occurred in the region of the marble belt.

The reader, comparing the above with an analysis of Rutland marble on page 17, will at once notice the difference in composition of that marble and this. Just what change took place in the sandrock is uncertain, but there was a great diminution in the amount of silica and increase in the lime. In an average specimen of the sandrock there was found, on analysis, silica 83.80 percent while in the lime of the sandrock there was found lime 1.12 percent.

As will be seen, the greatest difference, chemically, between the true marble is in the amount of silica, over 19 percent in the Champlain, while most of the true marbles are either wholly free from this mineral, or at most, as in some of the Dorset marble show on analysis, only a very small percent.

The calcite marbles are, many of them, 98 to 99 percent lime carbonate while, as just shown, there may be not over 1 or 2 percent in the Champlain stone. Thus this stone is much harder and more difficult to work than the softer stone of the marble belt. The prevalent red shades found in nearly all the varieties are due to the iron oxide present. As will be mentioned, some varieties are almost or entirely red or pompeiian shade, others more pink and more or less white, and so on.

For some time after this marble began to be used it was found difficult to get a good polish, or as fine as was desired; but lately new methods have been used and a very brilliant polish is produced. While used for counters, columns, panels and other interior work, this marble is largely used in connection with white or light stone in floor tiling and may often be seen in many parts of the country. In addition to the materials mentioned in the analysis, in some varieties, though far more rarely than the other ingredients, grains of feldspar, muscovite, chlorite, and occasionally other substances occur so that a complete analysis of some specimens gives a much more complex composition than that here given. Fossils are rarely, but sometimes found, the most clearly defined being Salterella. Various white or light-colored bodies occur in abundance in some varieties and some of these, as Dale, Walcott, and others have thought, may be of organic origin, corals, sponges, etc., but the writer has never seen sure proof of this. Many are dolomite lenses. These light bodies are from a small fraction of an inch long to several inches. The presence of these light bodies gives to the stone the characteristics of breccia.

(Walcott writes as to this in the Tenth Annual Report, United States Geological Survey, pages 587 and 588.)

Very diligent study of many pieces have failed to show, in the sections examined, distinct coral structure. That many of them are of organic origin seems to be certain, but I doubt this in many cases. Dale writes as to these dolomites: "These marbles are mainly magnetitic, quartzose dolomites, partly of sedimentary and partly of organic origin. The magnetite may have been deposited originally as 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 the result of an interesting series of processes—sedimentation both mechanical and organic, if not also chemical; dolomitization; metamorphism, accompanied by siliceous infiltration; brecciation; and underground oxidation. The marbles of Swanton are very sonorous and, of course, harder than the calcite marbles, or even twinned dolomite marbles."

A number of quarries have been opened during the past 100 years in exposures of the Champlain marbles, but most have been given up after a longer or shorter time. The greatest difficulty has been the great hardness and consequent expense in dressing and polishing the stone, for while the marble phases of the red sandrock contain much less silica than the general mass of the rock, it nevertheless is usually more than 10 percent, and thus the stone is too hard to be economically sawed unless water power can be used and this is only possible at the Swanton quarries, where it is now sawed, the other quarries that have been tested being too far from running streams.

Beginning at the southern quarries, those at Monkton in the rock beds of Hogback Mountain and going north, we have several quarries as noted beyond. This mountain is wholly composed of the Lower Cambrian sandstone and extends from south to north along the foot of the Green Mountains. While the stone, which is sufficiently calcareous to be used as marble, is not of large extent, yet in all it amounts to considerable. According to Dale: "The rock has fine beds or films of fibrous muscovite at short intervals. In a thin section one of these, one to two millimeters thick is seen to consist of minutely plicated sericite, with many grains of magnetite; next and parallel to it runs a quarter-inch vein of quartz with calcite, dolomite, sericite and magnetite. The dolomite marble of Monkton then is 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 from the oxidation of 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 fibrous muscovite was formed during metamorphism; vein quartz was deposited by siliceous waters at the same time. The dolomite marble of Monkton is attractive because of its very delicate color, but this color is not durable under outdoor exposures and the stone can be utilized only for indoor decoration."

THE VERMONT MARBLE COMPANY'S QUARRY

The Vermont Marble Company opened a small quarry on the west side of Hogback Mountain in Monkton. The stone did not prove satisfactory and after a short time the quarry was abandoned. The marble is described on page 155.

THE SWANTON QUARRIES

Much more successful have been the quarries, first opened by Mr. George Barney, in Swanton on the banks of the Missisquoi River about seventy years ago. First Mr. Barney opened a single quarry, then several, and for many years at mills in Swanton, where there was abundance of water power, he built mills and sawed and finished the stone. It was then called "Winooski marble." In 1901 the Vermont Marble Company bought the mill and quarries. For a more detailed description of these marbles see page 156.

As has been noticed, the varieties of these Swanton marbles are almost unlimited. While the prevailing colors and shades are red in various shades, white, now and then green, yellow, gray, etc., the arrangement in the different blocks of these shades is endlessly varied, there being in some of the beds hardly two blocks exactly alike, though they may be similar. Mr. Barney had in the market a dozen varieties and he might, had he wished, have named as many more, but the Vermont Marble Company list only half as many in their trade list, and describing the varieties, I have followed the listing of this company as it alone offers them for sale.

Some of the Swanton marbles are breccia, wholly or in part, as the variety called by Mr. Barney "mosaic." Other varieties as "olivo," "royal red," etc., do not show this feature. The Vermont Marble Company list in their enumeration of Vermont marbles the following as "Champlain marbles," all quarried and finished in Swanton: Jasper, Lyonaise, Olive, Oriental, and Royal Red. These are described on pages 156-159. As stated in that place, imperfectly, for the writer is fully aware of the utter impossibility of adequately describing so varied characters as are seen in these Swanton marbles.

Dale gives the following sections made at the Swanton quarries or near them:

1. At the top of the hill, strike north 30° east, dip 10° south 60° east. Beginning at the top 17 feet of mottled white and red dolomite marble, 3 feet of bluish gray dolomite, 2 feet of plain red marble, "Royal Red"; 16 feet of mottled red and white. A jointed face is coated with salmon-colored calcite. The bluish dolomite has a marked argillaceous odor and weathers light ochre 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 grains.

2. At the next quarry down, 12 feet of mixed dolomite beds measuring 7 feet of hematitic and magnetic dolomites with purplish spots (oriental). Some joints strike north 35° east, stand vertical and are spaced 5 to 18 feet; others strike north 50° west, are vertical to steep, and are spaced 5 to 20 feet. Some diagonal fractures are coated with chlorite and salmon-colored calcite. At a disused quarry next below, beginning at the top, 8 feet of mixed dolomite marbles, 2 feet of plain red, 8 feet or 10 feet with white lenses or corals, discolored, and 2 to 3 feet of plain red. On some of the weathered surfaces the red argillaceous cement projects above the white lenses. The brecciation of the lenses is distinct. Below the disused quarry and near the gateway, strike north 50° east, dip 10° to 15° south 40° east. Beginning at the top 10 feet of hematitic dolomite with light lense and corals, rather short and mostly parallel to bed, 3 feet of plain red (royal red) and 10 feet of hematitic dolomite (Jasper) with long narrow white corals on bright reddish ground, the corals at all angles, some vertical but most parallel to the bed.

At the west foot of the hill near the river and 60 feet above it, lower than section four, the following series dips 15° about

southeast, beginning at the top: Uncertain lenses 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. These marbles are used for counters, wainscotting, and other interior work, especially for floor tiling, for which their hardness especially fits them. Their bright colors and brilliant polish, when this is desired, make the stone very effective wherever placed.

A short distance from the Vermont Marble Company's quarry a small quarry, in the same red and white stone, was opened by the Columbian Marble Company, but was carried on for only a short time. In neither quarry the stone was, for various reasons, profitable and the region was abandoned. Although the red sandrock formation is found through nearly the entire length of the State, abundantly in western Vermont, forming very conspicuous features in the landscape, and originally covered a considerable area in extent and was hundreds if not thousands of feet thick, leaving now only remnants of its ancient massive sheets, yet those more calcareous phases which form this "Champlain marble" are only a very small part of the whole great deposit.

Mountains like Snake Mountain, Philo, and Hogback, and headlands like many near the shore of Lake Champlain, as well as many ledges in western Vermont, show what has been soon after the close of Lower Cambrian times, shales; limestone, quartzite and the familiar red sandrock make up by far the greater part of the beds. North from Monkton there is no more "marble" until Malletts Bay is reached, a distance of about twenty-five miles. At Malletts Bay and at several localities in Colchester large masses of this marble are seen. But not until 1850 was the stone quarried. At that time David Reed opened a quarry and gave the stone its name, "Winooski marble," by which it was known until the Vermont Marble Company bought quarries and mills at Swanton and called it by its present name, "Champlain marble," in 1901. Malletts Bay, it may be noted, is bordering the lake shore in the town of Colchester, six miles north of Burlington. There are here large masses of "marble" very near the shore and also on "Marble Island" in the Bay. The other quarries mentioned as in Colchester were farther inland. Being on the lake shore, the location of the quarries was very convenient for transportation, also several varieties are obtained here that are not found elsewhere, though bearing a general resemblance. But in spite of all advantages, the hardness of the stone made the cost of sawing so great that, in the absence of water power, Mr. Reed ceased to quarry. After being idle for some years, this locality was taken up by the Wakefield Marble Company. Quarries were opened anew, a large brick mill built and for a time things looked flourishing. This was in 1880. After working for several years, this company in turn abandoned the enterprise mainly because it was not possible, using so hard a stone and being compelled to use steam power, to compete with water power elsewhere. North of Malletts Bay the marble phase is not found until near St. Albans, it is quarried, as Royal Red by the Vermont Marble Company. A few miles farther north at Swanton Junction, several years ago, Messrs. Fisk and Bradley opened a small quarry, but it was not successful.

A few miles north of St. Albans on the banks of the Missisquoi River Mr. George Barney, who had been in the marble business for several years and had sawed much of the Isle La Motte and Swanton Dove Stone, opened the above-named quarries in 1860 or thereabout and later in 1870 opened other and better quarries which are still operating. All the mill and quarry property in Swanton was bought by the Vermont Marble Company in 1890. From the Swanton quarries most, if not all, the Champlain marble seen in many buildings over the country has come. More details as to these "Champlain marbles" will be found on pages following. That these marble beds are a phase of the Lower Cambrian red sandrock is evident from fossils found in the marble itself to some extent, and abundantly in the associated limestone, *Iphiddea labradorica, Kutorgina cingulata, Olenellus thompsoni,* and other fossils. In the marble itself at one or two localities the marble is filled with *Salterella pulchella,* which are very distinct and numerous imperfect fossils, not identifiable, but almost certainly organic. However, while abundant in a few localities, confined to not large areas, as a rule fossils are scarce everywhere in Vermont in this formation.

The best known localities for fossils in this formation are Parker's ledge, Georgia, Vermont, limestone near the Swanton-St. Albans line, east of the cement road from St. Albans to Swanton, several ledges in Colchester (especially for *Ptychoparia*), and a few other localities in the western border of the State. The prevailing colors in the several varieties of the Champlain marbles are red, white, pink, and olive of different shades as will be again noticed when the separate varieties are mentioned (see page 189).

MANCHESTER BRECCIA

Of this, not marble but typical breccia, Mr. West writes: "A few miles south of Manchester on the farm of D. H. Dyer, and on the foothills of Equinox, there is a large deposit of breccia of pinkish, reddish and bluish gray marble, cemented by brick red material. In 1888 Spencer Trask of New York City became interested in the property and worked it for two years. The quarry plant consisted of two channelers and was otherwise well equipped. None of this breccia was sold in the market. All that was fit to be used was sent to decorate 'Yeddo,' the residence of the owner. Two cores were put down near the quarry, one to the depth of 105 feet, and even then it did not reach the bottom of the deposit. For a breccia, the stone is not very unsound but a difficulty was that the sawed blocks usually showed large patches of a bluish gray which ruined the ornamental value. There is great lack of uniformity in the sawed slabs so that the stone probably will never become of economic importance. So far as I know this is the largest and the only important deposit of breccia in Vermont."

THE QUARRIES AT LEICESTER JUNCTION

There are two quite large quarries at Leicester Junction. Neither of these is marble and the product is mainly used in lime kilns for making quicklime. As far as the writer knows there has never been any attempt to use this limestone for marble. The Huntley quarry is located about 800 feet west of the railroad station. Dale calls this stone "marble," and it is useful as showing certain geological features not seen elsewhere in the State and it is closely associated with the marble belt of the region, though, properly speaking, the Leicester Junction stone does not belong in an account of Vermont marbles. Still, if one wanted to do so, much of the stone could be cut and polished as marble, but this has not been done to any extent.

About a mile, or somewhat less, east of the Huntley quarry is the quarry of the Leicester Marble-Lime Company. In the immediate neighborhood there are several other quarries in the limestone, long ago abandoned, though at some time a large quantity of stone has been taken from them. The stone here is not precisely like that at the Huntley quarry. Here all the limestone is hard, dark gray with veins of satin spar in some parts. Even more do we see in this quarry plain evidence of severe upheaving, folding, and fracture. In some places the rock is folded in an unusual manner as Figure 27 shows, especially in the long log-like rolls or folds, best shown in that figured, but seen also in two other differential folds elsewhere in the quarry. As the figure shows, these rolls are made up of thin, shaly layers of the limestone which appears to be compressed and harder than that in the quarry as a whole. Though, as has been noticed, there is disturbance of the limestone beds in every part of this quarry, there appears to have been greater folding, etc., in the west part of the quarry than elsewhere, and instead of being merely

FIG. 27. Roll of limestone, Leicester quarry.

crumpled or folded together, the thin layers were in a measure, by differential folding, rolled up. The roll shown in Figure 27 is nearly 100 feet long and at the end shown, it is about seven and a half feet in diameter. The roll is near the top of the limestone mass and is covered by a few feet of drift, but the other rolls in the quarry are lower down and covered by 15 or 20 feet of rock. The outside layers in the folds are harder than that of the quarry in general and apparently contain more silica. As Dale notices: "The structure in 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 Owls Head in Dorset."

While little true marble is found east of the marble belt, there are several masses of more or less silicious limestone as already noted in the case of the dove limestone of Swanton which are a supply for limekilns, but from none has any noticeable quantity been used as marble. Those that have been mentioned are introduced because they are near the marble belt and also because they give or suggest some idea of the geology of the area considered. Writing of the limestone here, Dale notes: "The marble, more than 20 feet thick, is exposed in beds which are doubled over on themselves two or three times. The marble is of translucent but dull aspect, light buff pinkish in color and uneven, parallel, elongate texture with alternate tiers of large and small grains. The strike of the beds is north 15° east. Beginning on the east there are within 60 feet three synclines, two anticlines, and part of a third. . . . From the manner in which the rock breaks from the mass it is evidently still under compression or tensional strain." This quarry is in a much-tilted and disturbed lime rock. The rock in the quarry is somewhat variable, varying from a rather hard grayish stone to a light buff or pink and softer stone.

THE SERPENTINE, VERDE ANTIQUE, QUARRIES

This, while in no sense a true marble, is yet by dealers classed and sold as one of the Vermont marbles and so let it be in trade. It is surely, for interior finishing, one of the most elegant and dignified in appearance of "marbles." It is interesting to a Vermonter to learn that this very fine stone was quarried in Cavendish in 1835 and this was the first of its kind in this country. The quarry was opened by the Black River Marble and Soapstone Company. This was certainly a bold venture for that time, for even now with all modern appliances serpentine is probably the most difficult stone to quarry, cut and polish that is found in Vermont. It is no wonder that this enterprise failed. When the Vermont Marble Company began to quarry this stone, they chose a new locality and opened a quarry at Roxbury, which they have worked ever since.

The polish which can be given to a good slab or column is superb in a clear light. If any of the Vermont marbles merit the term royal it is certainly this. The stone is not in any way related in location or composition or color to the marbles of the marble border. It resembles the verde antique of European and other localities in this country. It is, however, darker in some veinings and richer than most from other places. The general color is green in various shades, from very light to almost or quite black, but the predominating shades are dark. White streaks,

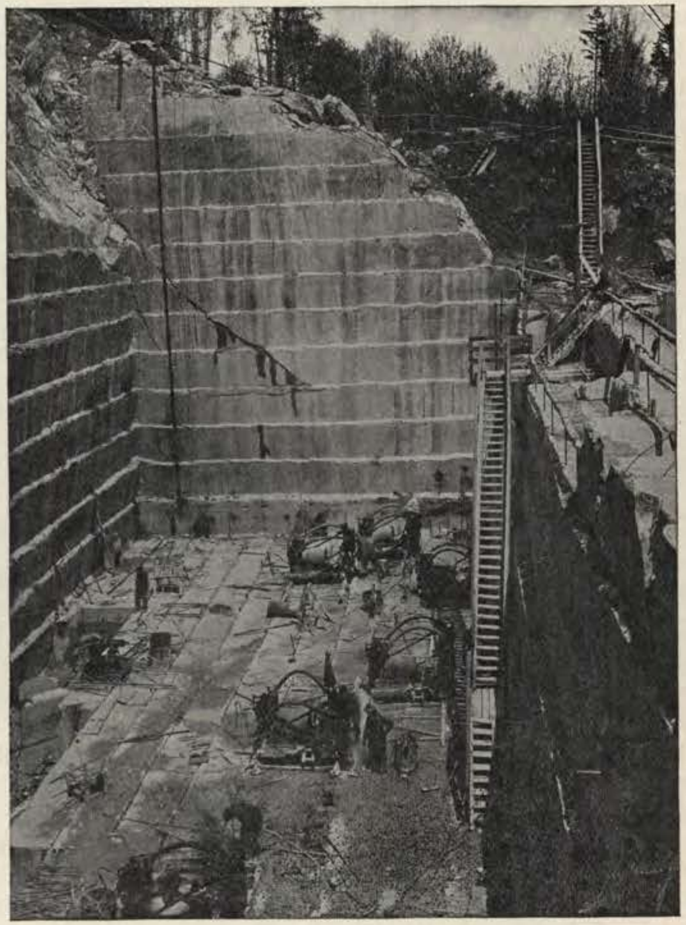

FIG. 28. Roxbury verde antique. Channelers at work.

spots, etc., are more or less numerous and add much to the fine effect of the highly polished surface. The composition, though varying somewhat in different blocks, is in all complex. An analysis as given by Professor Jacobs is the following:

Vt 10th Ser
Pg 256

Silica

SiO_2	42.06	
AlO	3.25	Al_2O_3
Fe_2O_3	1.60	
FeO	3.40	
MnO	30.00	0,30
MgO	38.44	
H_2O+F	10.94	
H_2O	29.00	0.29
	158.69	100.2

Evidently there was no calcium in the specimen which Professor Jacobs analyzed, but in some parts of the ledge this has been found, though in small amount. The above analysis was made from Roxbury material.

"This verde antique consists of a great mass of serpentine veined in every direction with dolomite, chrysotile and picrolite." Jacobs, *l.c.* Calcite is often found and occasionally other minerals as chlorite, iron, and nickel, though only a trace of the latter. "On the horizontal joint planes, particularly in the floor of the quarry, there are large tabular masses of crystallized dolomite, including beautiful green foliated talc and masses of soft, fine-fibered, greenish gray picrolite which in places becomes nearly chrysotile (asbestos). The dolomite is often beautifully slickensided, showing clearly the shearing to which it has been subjected, and it includes the shear fiber. This fact and the evidence of thin sections of the stone show conclusively that the verde owes its existence to the infiltering of the carbonates to the cracks and crevices which are so characteristic of serpentine. Regarding the carbonate which has filtered into the cracks and crystallized out, quite a number of writers, including Edward Hitchcock in the Geology of Vermont, page 778, 1861, describe this as magnesite— Vt 10th Ser Pg 251
but the following analysis of the Roxbury mineral shows it to be an average dolomite, *viz.*:

CaO	CaO_2	30.63	CaO
	MgO	21.20	
Fe_3O_4	Fe_2O_3	1.43	Fe_3O_4
		53.26	

"It thus appears that the verde antique, picrolite, talc and grit have been derived either from the serpentine itself or from the rock giving rise to the serpentine; the picrolite where shearing has taken place; the talc where metamorphic processes have attacked the parent rock; the grit and verde where carbonate solutions have filtered in," *l.c.* page 251. The reader interested in this verde antique is referred to the article from which the above quotations are taken, "The Vermont Verde Antique Deposits," E. C. Jacobs, Tenth Report Vermont Geologist, page 246, 1916.

Serpentine is found in small amounts, and in some places in large, in many localities in Vermont, but it is much of it unfit to be used as marble. The Vermont Marble Company are at this time spending considerable in prospecting for other deposits. Thus far the larger part of the verde antique sold by the Vermont Marble Company has been from the Roxbury quarry. The same company has also quarried it in Rochester.

From a study of the microscopic sections of verde antique from several localities in Vermont and some from adjoining localities, Jacobs reaches the following conclusions: "A study of these sections (microscopic) suggests that the serpentine beds of this region may be divided into two phases—a very basic dunite phase, possibly a continuation of the western Massachusetts dunite; and perhaps a pyrogenetic phase, extending from Lowell northward into Quebec, identical with the Broughton phase described by Dresser. . . . Magnetite is present in every section, and in most cases if not in all, since it includes antigorite and carbonate. It has evidently been derived from the olivine, or other ferromagnesian mineral, which was the parent of the serpentine. Chromite when present is a primary mineral. Dolomite or calcite is always secondary to the parent minerals since it includes the alteration product antigorite. The carbonate both includes and is included in the magnetite, but it is more often secondary to the magnetic oxide," *l.c.* page 261. Professor Jacobs gives the average analysis of the serpentines as follows:

AVERAGE ANALYSIS OF THE SERPENTINES

SiO_2	41.37
Al_2O_3	2.33
Fe_2O_3	1.96
FeO	4.77
MnO	.24
CaO	.56
MgO	32.62
H_2O	11.47
	95.32

"Since all evidence of primary minerals is missing in the serpentine between Cavendish and Lowell the conclusion as to the origin of the serpentine must rest, in this region, on chemical analysis. The evidence points to dunite." A fine display of Roxbury Verde Antique may be seen in the bases of many of the cases in the Fleming Museum, University of Vermont.

As has been stated elsewhere, the first quarry of serpentine, not only in Vermont, but in America, was opened and operated for a time in Cavendish, but was of short life. Lately, 1932, the Cavendish Serpentine, or Verde Antique, is again quarried by Messrs. McCormack and Moriglioni. Of this Mr. McCormack writes, giving the name of the company as

THE PROCTORSVILLE MARBLE COMPANY

"We are now producing a considerable quantity of marble of a Breche nature. The color is dark green with light greeen irregular veining and the material seems to be free from talc and takes an extremely high polish." The large sample that was sent me fully bears out the above.

In the 1861 Report the verde antique from this locality appears to be darker in shade of green than that from Roxbury and judging from the analysis given by Hitchcock is less elaborate in composition and with little or no lime. It seems rather strange that there should be as much difference in the analyses of this stone from Cavendish and Roxbury as the tables show. I quote that given of the Cavendish locality:

CAVENDISH VERDE ANTIQUE

Silica	43.34
Magnesia	39.53
Protoxide of iron	5.32
Water	11.79
Carbonate of lime	00.00

Hitchcock thinks that one cause of failure in the Cavendish quarry was caused by the use of gunpowder which so shattered the stone that sound blocks could not be obtained. Also the expense of finishing such hard stone. Even in many of the marble quarries, as long ago as 1860, gunpowder was taboo in them.

Among the most anciently used ornamental stone we find Verde Antique; on the whole in the old-world quarries this stone was somewhat lighter in shades of green and generally contained more or less lime.

As has been noted it is not the intention of the writer to attempt to give an account of nearly every opening, large or small, that has been made in hope of finding salable marble, though some of very little importance have been intentionally omitted as of not even historical interest, but a few mentioned in the older histories of the State, though long since abandoned, may be briefly noticed. One of these is of interest because, as far as the writer has ascertained, the extreme southern point at which marble has been at any time quarried in Vermont, though the days when marble was quarried in the town are long gone by. Several quarries were opened here in North Shaftsbury in time long past, the exact date I have not been able to find, but as all were closed before 1857 they must have been opened before then. I find that Hitchcock, in his Geology of Vermont, published in 1861, calls the quarry opened by Samuel Cranston an "old quarry." "It has been abandoned several years." The marble was found to be cracked and not durable. Good blocks could not be taken out. North of Shaftsbury is Arlington. Here were several quarries and here a mill was built. At this point Hitchcock says quarries and mill were working, about 1860 or 1861. Hitchcock says: "The marble is not of fine quality but is good for building stone. West and Canfield not only had two quarries here, but also a four-gang mill." Much marble has been taken from these quarries. "Cases are common in marble taken from this quarry where the end of a white stripe abuts against and is firmly cemented to a dark one. Another quarry, a mile and a half west of the village, known as the McKee quarry, opened about 1810, was worked for a time. All of these are south of Dorset village. None of the quarries here produced good marble, though some of it was usable as building stone. All was hard and could not be well polished.

As noted all the companies that at one time or another have tried to succeed in the marble business are not even named, and if named would add little to the story the writer is trying to tell, they are, therefore, omitted.

The Vermont marbles do not fade appreciably under ordinary conditions. As quarries which are active must necessarily change more or less when extensively worked it is obvious that some of the varieties which have been formed in small beds are worked out and for this reason can no longer be supplied. As has been noticed above, such formerly obtainable varieties, but not now to be had, are not included in the list. It may be well to call the readers' attention to the fact that this list does not indicate the number of different quarries, but only the trade names of marbles sufficiently diverse in appearance to be readily distinguished from each other. The quarries vary greatly in the coloring seen in different parts of a quarry and in the manner in

which they have been cut or sawed. In some quarries the stone good enough to be used may be of much the same texture and coloration and veining, while in an adjoining bed, or perhaps the same, marked differences will be seen. For example, in one of the Colonial quarries at West Rutland the following condition occurs:

SECTION OF MARBLE BEDS AT THE COLONIAL QUARRY

	Feet	Inches
Graphitic gray marble	57	
Graphitic	6	
Graphitic gray marble	22	
West edge of quarry:		
Graphitic gray marble	14	
Same but with white bands	3	
Cream-colored marble	4	
Muscovite (green) with beds of cream-colored marble with coarse folds or undulations	7	
Purplish gray marble	1	6
Muscovite, plicated, slip cleavage	2	
Dolomite and marble mixed	2	10
Cream-colored marble with faint green and yellow bands	4	6
Solid green marble	11	
Pure white marble	4	
Muscovite marble	3	
Muscovite plicated marble	4	6
Cream-colored marble	4	6
White marble	5	
Muscovite (green) marble	4	6
White marble	5	6
White marble with small green beds	5	
East side of quarry:		
Gray dolomite	3	
Graphitic marble	3	6
White marble	13	6
	190	10

CLASSIFICATION—BASED ON COMPOSITION

Another classification of the Vermont marbles is based upon the constituent composition. He groups them as follows: Graphitic calcite marble, clouded calcite marble, muscovite calcite marble, actinolitic calcite marble, dolomitic marble, graphitic marble.

In this connection Mr. Dale writes: "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 (like much of the stone from Clarendon). A microscopical examination of such marble, in thin section, brings out the presence of very small black bodies scattered through the calcite. These black bits are found to be specks of graphite. This is found in quite a number of the varieties of West Rutland and Clarendon marbles."

Dale adds: "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 life, but the abundance of graphite in the planes of slip cleavage would have to be explained by transfers of graphite from the adjacent calcite grains during metamorphism."

CLOUDED CALCITE MARBLE

"In the clouded calcite marble of Vermont, the clouds generally follow the bedding plans 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 surface and are, therefore, harder than calcite. As they are softer than quartz they can be scratched with a knife. This is corroborated by a microscopic examination of thin sections which shows that the cloudy parts consist mainly of dolomite. Associated with the dolomite are plentiful minute particles of graphite, which account for the dark shade, also some quartz, pyrite and rarely, muscovite. Where the small clouded beds are plicated, a slab sawed in the direction of the stripe will intersect the tops of small meandering anticlines, but if sawed in the direction of the dip it will intersect a superimposed 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."

MUSCOVITE CALCITE MARBLE

"Many of the banded marbles of western Vermont owe their bandings to fibers and scales of muscovite (white mica) mingled in varying amounts with calcite and forming little beds which alternate with beds of calcite grains alone. The marble has a grayish or greenish of varying intensity. The whole series of beds is generally more or less intricately plicated. . . . In rare cases in thin sections the fibrous muscovite is found associated with quartz grains, rarely one of the plagioclase feldspars, also with epidote and chlorite, which emphasize the green tint given

by the muscovite. In some beds the muscovite, epidote and chlorite are distributed through the calcite so uniformly as to produce a bright greenish marble. Along with these minerals are usually small dark lenses of uncertain character, minute opaque specks, and a little pyrite. The fibrous muscovite of these marbles must have originated in clayey sediment (feldspathic quartzose) of which the few plagioclase grains are remnants, unaltered, and most of the quartz also, possibly. 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 . . . . into muscovite calcite marbles containing small quantities of accessory minerals. About one and a half miles southwest of Brandon . . . . is a knoll, rising about 120 feet above the flood plain of Otter Creek, consisting of rusty weathering impure bluish marble that illustrates well the effect of weathering on a mass of calcareous, sandy, and clayey marine sediments. In some places the rock is a medium-grained calcite marble. In others it is a fine-grained dolomite, including lenses of calcite and quartz. In still others it is graphitic, pyritiferous sericite schist. The whole is intricately plicated and crossed by planes of slip cleavage. It combines some of the features of a marble, some of a quartzite, some of dolomite, some of a muscovite 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 muscovite mica these marbles do not take a perfect polish."

ACTINOLITIC CALCITE MARBLE

"Several of the Dorset marbles differ somewhat from most of the other calcite marbles. In these Dorset marbles there is usually more or less green veining which may be distinct or indistinct or wanting. There is in all the Dorset varieties, and as shown elsewhere, there are several varieties, a little silica and the crystallization is more pronounced, hence these marbles are somewhat harder and receive a more brilliant polish than other varieties. They are all light in shade, so that they may pass as varieties of white marbles, though none are really white. Quoting from Dale: "Some beds are 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."

Dale regards the actinolite as due to metamorphism of material of sedimentary origin containing magnesia, iron and silica combined with lime from the calcareous sediments. Enlarged figures of each of the just named varieties (from Dale's account) are given in Ninth Report, Vermont State Geologist, 1914, pages 34 and 35. They are also to be found in Bulletin 520, United States Geological Survey. Anyone who is especially interested in the microscopic structure of these marbles is referred to these works.

On the following pages it is proposed to give, not by any means all the characteristics of each marble considered, as that would necessitate too much space and might well be tiresome to the reader, but the intention is to present the most obvious and important characteristics. In many ways it is, of course, better, if possible, as in the show room of the Vermont Marble Company at Center Rutland, to see the stone in large slabs. This is especially true of some varieties, as royal antique for a single example, and the veining is on a large scale. Naturally, when the veining is fine and delicate or when there is little or no veining smaller pieces give a fair idea of the stone.

All that the writer wishes to claim for the following which may be called an annotated list of our Vermont marbles, is that from it, if one can do no better, he may have some general idea of any given stone and be able to call into mind some picture of that about which he is seeking to know.

It is often very difficult, if not impossible, so to describe some varieties, and these are some of the finest and most attractive, as to give more than a quite general view of the stone which is considered. In many, or at least in some considerable number, any two pieces of the polished marble are unlike in the veining and more rarely in distribution of color. So, too, as has already been suggested, as quarrying proceeded, new and more or less different styles are brought to view. This, of course, cannot be true of all or perhaps the major part of the varieties, but it certainly is true of a goodly number.

The reader of these pages is again reminded that, as in so many other matters, it is quite impossible so to describe some of the varieties of Vermont marble that the full appearance of the stone is clearly brought before the mind of the reader, and moreover in some of the finest varieties it is difficult to find two pieces which

are exactly alike. In many of the varieties, too, it is necessary to see a large area of the surface if one is to see the real character and full beauty of the stone. At least the following notes may be able to call attention to the great variety and usually to the attractiveness of the Vermont marbles. The list of marbles, as will be seen, contains all important varieties, now or at any time quarried in the "Marble Belt" of western Vermont, though in some cases the trade name has been changed and the name here given may not readily be recognized by older readers, but it has been thought better to give the names now current. Besides the varieties quarried in the marble belt and mingled with them, are a few, as stated in future pages, not found in the same localities and, in most cases, of different geological formation, but for convenience placed with the other "marbles." So, too, a few varieties not now quarried for geological or other reasons, or historical value. Some of these varieties not now quarried may be again brought into market, some will probably not be quarried again, some may have disappeared in the old quarries. In Dale's bulletin often quoted many of the varieties there mentioned are given, many others were not when that bulletin was published found or at least were not then on the market.

Because, as has been said, the writer has quoted liberally from some of the publications which in past years have been issued because these facts or theories are not accessible to readers except where access to the larger libraries can be gained. It is believed that most of the important writings on Vermont marble are included in the Bibliography, given later, and most of these can be consulted, but it may not be easy to find a few. For the convenience of those who simply wish to know in general what varieties of marble are or have been found in Vermont, the first list is given, while those desiring further information may find it in the anotated list.

Mr. Dale gives the following "scientific classification" of Vermont marbles, with examples of each kind:

Calcite Marbles:
- Statuary Rutland.
- Light Rutland Italian.
- Middlebury.

Graphitic Calcite Marbles:
- True blue.
- Florentine.
- Dark blue Rutland.

Muscovitic Calcite Marble:
- Brocadillo.
- Solid green.

Chloritic and Muscovitic Calcite Marbles:
- American pavonazzo.
- Dark cipolin.

Actinolitic Calcite Marbles:
- Dorset green bed.

Calcite Marbles with Minute Dolomitic Lenses and Beds; Usually Graphitic:
- Hollister.
- Pittsford Italian.
- Brandon Italian.

Brecciated Calcite and Dolomite Marble with Hematite Cement:
Manchester.
Carbonaceous, Slightly Dolomitic, Unmetamorphic Calcite Marble:
Champlain black.
Graphitic Dolomite ~~Marble~~:
Parker and Pinchey prospect.
Hematitic Untwinned Dolomite with Quartz Grains:
Champlain marbles.
Serpentine:
Vermont verde antique.

In the following list of the marbles of Vermont it is intended to include all varieties now on sale as well as some, though not all, that are not now quarried, and a number of marbles in trade, but not true marble, geologically speaking. That is, they are not calcite mainly, nor metamorphic, or if calcitic, not metamorphic. Some varieties are not now called for, some have disappeared from the bed which supplied them, some can be supplied if wanted.

LIST OF WESTERN VERMONT MARBLES

CALCITIC AND NON-CALCITIC

Varieties not now quarried marked *.

Æolian*
Africano
Albertson*
American pavonazzo
American sienna
American yellow pavonazzo
Avenatto
Baronial antique
Baronial cipolin
Baronial verde
Best light cloud Rutland
Brandon High Street*
Brandon Italian
Brandon statuary
Brocadillo
Champlain black
Cipolino
Cipolino fleuri
Clarendon dark cloud
Clarendon gray
Clarendon light exterior
Clarendon medium cloud
Clarendon X
Colonial antique
Colonial Colmaro
Colonial cream statuary
Colonial gray
Colonial green
Colonial green vein cream
Colonial ivorvein
Colonial I. J. cream
Colonial M. E. white vein
Colonial pavonazzo
Colonial Quaker gray
Colonial sienna
Colonial verdas
Dark cipolino
Dark ivory green
Dark vein blue
Dove blue Rutland
Electric blue
Extra dark royal blue
Extra white Rutland
Florence
Florentine blue
French gray
Grand Isle Fleury
Gray building
Green vein statuary
Highland
Highland blue*
Holland average blue
Holland blue
Holland electric blue
Holland mottled blue
Imperial
Italio
Jasper
Light cloud cipolino
Light cloud Italian
Light cloud Rutland
Light Columbian building*
Light vein Rutland
Listavena
Livido
Lyonnaise

Manchester blue*
Metawee
Mountain white
Neshobe gray
Northern gray
Northern ivory
Northern pearl
Northern white
Olive
Olivo
Olympian white
Oriental
Pink Listavena
Pittsford Italian
Pittsford Valley
Plateau
Riverside, Danby
Riverside, Proctor*
Royal antique
Royal red
Rubio
Rutland building
Rutland Italian
Ruvaro
Silvestre
St. Albans red
Standard blue
Standard green
Standard white
Statuary Rutland
Striped broccadillo
Sutherland Falls
Swanton dove
True blue*
Talicose
Veined blue
Venoso
Verdoso
Verde antique
Vert de mer
Westland cipolin
Westland cream
Westland cream vein
Westland green cream vein
Westland verde verde
White Rutland

Elsewhere most of the varieties named in this list have been or will be noticed, but it may not be without interest to some of those who read these pages to discover what a variety of marbles are not only quarried in Vermont but to remember that all these, and more not now quarried, for one reason or another, are found in a comparatively small part of a small State. Not all, but most of those given here are obtained within the boundaries of Rutland County.

As is seen, only the names of varieties are given. Immediately following the list above most of them are repeated with notes on color, location and such other facts as may seem to the writer of importance. As will be seen by the reader, all the Vermont marbles as named in trade are given, including a few, and some of them not excelled in attractiveness, elegance and other desirable qualities, by any true calcite marble which are not now quarried. The names in this list are some of them such as have for various reasons been recently adopted by the companies using them. Older names used for the same variety, will usually be given in the annotated list following this.

Most of the marbles included in the first list are largely composed of calcite combined, as is shown by analyses, with numerous other materials in less amount. Therefore, they effervesce vigorously in acids, especially hydrochloric. But there are a few other "marbles" which are not at all "marbles" in the proper use of the term. Using the word "marble" as a trade name, however, does no harm and is perhaps convenient, but, as already intimated, it should be well understood that the use is not scientifically correct. Some of these, indeed most, have little calcite in their composition and effervesce not at all or only feebly in acid.

COLORS OF MARBLE

In the display of marbles in the show room of the Vermont Marble Company, at Center Rutland, the varieties from a single quarry, the Westland quarry, there is a series of slabs, arranged in the order they had in the quarry, which show excellently what is sometimes found within a few feet in a marble deposit. Other quarries exhibit this tendency to variety, while most show much greater uniformity and some produce only a single color or shade. The Westland, as also the Colonial and a few other quarries, afford more or less variety in color and shade.

In the Westland quarry are, or were, found the following varieties as exhibited. Beginning at the west side the marble is creamy white, veined by wavy veins of a not very abundant nor very distinct light brown shade, a band of about five feet wide of this, then immediately following, the veins suddenly change to green, the main ground being at first like that before it; but it too soon changes to olive green, light and dark shades being intermingled. Bands of very light and others of brown, rather sparsely mixed, also appear. Next we have a surface of light shade. This piece is nearly nine feet long. Here the veins are less distinct and more of a smoke color. Next this the veins are more distinct and veins and blotches of a soft green replace the light brown and the ground becomes a salmon pink which grows deeper as one goes on eastward and the green of the veins becomes brown or yellowish.

Still farther east in this quarry the colors of the second variety are very nearly repeated, but here the shades are deeper and more distinct. Next east of this we find a salmon ground crossed by more or less confluent green veins, some of them distinct, some less evident. Then follows a much lighter ground sometimes almost white and crossed by indistinct veins of a smoky brown shade, which a few feet farther on change to green. Another very light area follows the last with numerous green veins and also veins of pure white. Then comes a light cream-colored ground and besides the abundant green veins which are very distinct are numerous, though delicate, brown or dusky veins. Thus in this quarry we find easily a dozen varieties of marble, each of them more or less distinct from others, and each plainly recognizable.

All of these were varieties taken from one floor in what would be classed as one of the smaller quarries. Not only does the color scheme vary thus in some layers, but the quality and texture as well, though this does not apply to the Westland quarry.

As has been noticed in some quarries, some of the largest, the whole body of the stone is substantially of uniform shade and color. If the reader recalls what has been said of metamorphism and the processes involved, such variety instead of being the exception would be expected more generally than it is. Of course, the obvious explanation of the difference in the marbles is seen in the constant changes in different localities, though these may be near each other, in the metamorphic processes. And then we find evident faulting in some of the slabs.

The question "Which is the most beautiful of the Vermont marbles?" is not infrequently asked. To this no very definite reply can be given, certainly the writer would not willingly reply, because so much, indeed everything, depends upon the use to which the marble is to be put, the lighting it will receive, the size of the piece used, to say nothing of the individual taste of the user. Advice from the company supplying the marble should, in cases of any importance, be asked. Some varieties are much more attractive in certain conditions than in those that are different, some in a bright light, some in a softer, some inside, others outside a building, some anywhere are fine and so on through a long list of conditions of environment, location, etc. In one of the many publications of the Vermont Marble Company, "The Book of Vermont Marble," there are many very valuable suggestions and much good advice as to the selection of the variety of marble to be used in various kinds of work and in various places in a building. The descriptions following on pages 175-205 in this article, are intended to be of use to intentional purchasers. But no one can realize more fully than the writer how far from adequate some of these descriptions are and how much more useful than any description actual inspection of the stone must be in most varieties.

As has been stated, the many colors and shades of the Vermont marbles render them adaptable to any situation. In many cases the cause of this great variety, and in most marble localities not equalled, can be and has been discovered, but in some examples the cause of the delicate shading is not so readily explained. As analyses show, and as would be expected, a very considerable number of mineral substances enter into the composition of these marbles and, of course, whatever tints are found must be produced by combinations of a greater or lesser number of these materials. The more commonly found materials are carbon, actinolite, manganese, graphite, chlorite. Oxides of iron play an important part in giving color to some of the varieties. Muscovite (white mica) is responsible for some shades of greenish marble and chlorite deeper and brighter shades of green.

We may safely consider that nearly, if not quite all the tints found are due to the minerals named, or some combination of them. The list of Vermont marbles given on page 170 shows how numerous and varied are these colors. Of the many colors, purple and yellow appear to be least common. Pure white that can be used, as some has been, for statuary is not common but it does occur, as for one example, the large statue of Ethan Allen at the State House in Montpelier well proves.

In Vermont, light marbles are perhaps less common than darker shades. I do not know that anyone has counted the number of colors, shades or tints which can be obtained from the Vermont quarries, but in one lot of samples I counted over sixty and there are certainly a considerable number which were not among those I saw and counted.

A difference, and sometimes a great difference, in the appearance of a slab of marble is seen in the pattern of heavily veined marble as it is sawed out of the large block in one direction or another. Very elegant effects are produced in some of the veined stone by setting slabs, taken from the large block side by side, set up edge to edge thus making one large pattern, as in royal antique, when slabs of considerable size are well matched.

LIST OF ALL STONE QUARRIED IN VERMONT AND SOLD AS MARBLE

For convenience of reference all stones called marble in trade are included in the list here given. Most are true calcite marbles, but as already noted, a few, and among them are some of our most elegant and attractive varieties, are put in place with the rest, that is arranged alphabetically, as a more convenient arrangement than if grouped in a separate list. None of these are quarried in "The Marble Belt" and as will be seen, they vary greatly in composition and appearance, also in the geological age in which they were formed. These are the Champlain marbles, quarried at Swanton and St. Albans, of which there are five varieties

recognized in trade, although, if a dealer wished to make out as many varieties as possible, many more could easily be counted. Then very unlike these are several varieties of limestone, used as marble, quarried on Isle La Motte and Swanton. The elegant verde antique quarried at several localities. The peculiar and practically useless Manchester breccia. As in case of the true marbles more detailed accounts of these will be found elsewhere in this article. All of these "marbles" are quarried and sold by the Vermont Marble Company, except the verde antique.

In reading the annotated list which follows let it be remembered that active marble quarries are continually changing and that all that can be done in a brief description of the stone produced is to take it as at the time when the description was written, not forgetting that some quarries may produce at any time new varieties and fail to produce old ones. Because of this possibility of change what is written and true today may need revision a few months hence. This perhaps is especially true of the colors of marble, and of some quarries.

ANNOTATED LIST OF THE CALCITE MARBLES

ÆOLIAN

Æolian is the trade name of a marble, not at present quarried, but as the stone is apparently good and for many purposes attractive it may be used again. For some time it was quarried by the Norcross-West Company. However, for one reason or another, the quarry has been unworked for several years. Through a ground of white many green veins extend in every direction. In some parts of the stone these veins are more or less confluent and thus form bands. In shade of color the whole range is found in different parts of a large piece, from very dark to olive. There are or may be blotches of white. The effect of all this renders the marble unlike other varieties.

As Mr. Dale has noticed: "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 conform but not so in this. I have spoken of the prevalence of white but usually this white is not clear white, but more or less cream in color. Moreover, though not abundantly, there are areas of several square inches extent which are solid green and there are also areas of solid white."

This quarry is in Dorset and is owned there, though not now worked, by the Vermont Marble Company. Mr. Dale cites as examples of this marble, those in the Massachusetts Life Insurance Building, Springfield, Mass.

AFRICANO

As the name indicates, this is a dark marble. In most cases it is not quite black, but rather a dark gray, which is of several shades of intensity. There are not infrequently areas of decided black in some specimens. I have seen no other of the Vermont marbles so black as this, except Fisk black, quarried on Isle La Motte, to be mentioned later. Quarried by the Green Mountain Corporation at West Rutland.

ALBERTSON

This marble, formerly named "Esperanza," is a very dark stone, being gray, or rather bluish gray, veined more or less profusely in different pieces with fine or coarse darker lines, some almost black. Quarried at West Rutland by the Vermont Marble Company for a long time, but not quarried at present.

This marble, unless so placed as to receive a good light, is rather somber, but in such a light it is an elegant stone. The main ground is gray, usually of a slightly blue shade. The dark shades, for the frays are more or less variable, are relieved by white spots or blotches which vary in abundance in different specimens. Running through the dark ground and even darker are numerous lines often black and of very variable breadth. Sometimes these are crossed by other veins or bands. These darker veins, etc., are much more abundant in some of the marble than in other pieces. This marble is quarried by the Vermont Marble Company in West Rutland.

AMERICAN PAVONAZZO

This is mostly used for interior work and it is, when carefully selected, a very charming stone. The ground is less completely covered than that of many varieties and is often beautifully shaded, the colors being light yellow or nearly white. Through this ground run many veins which may be very light, or they may be very dark, or both mingled, but always green of some shade. In some samples these are less numerous, but, however, they may be the effect is usually exceedingly pretty. This stone is quarried in West Rutland by the Vermont Marble Company.

AMERICAN YELLOW PAVONAZZO

As the name indicates, this marble is in some respects similar to that just mentioned, but it is considered sufficiently distinct to be given another name. It is, in the opinion of many, a most attractive ornamental marble. Certainly there are few more beautifully colored marbles known that are more attractive than the yellow pavonazzo. Usually this variety is somewhat darker than the pavonazzo. In this variety the ground is like the foregoing, yellow, but while that may properly be called very light or lemon yellow, this, at any rate the best specimens, is rather a salmon yellow. This shade is, in many pieces, beautifully shaded from lighter to darker and through the main color there are green or greenish veins and sometimes bands which form a very charming addition to the general effect. Generally the green veins do not occupy the greater part of the area and the general effect is given by the yellow parts. The yellow pavonazzo is quarried in West Rutland by the Vermont Marble Company.

AVENATTO

This, although one of the lighter marbles, as the ground is light, is so very abundantly veined by various shades of brown that there is little clear white. Of this marble, Mr. Dale notices: "The effect is 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 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 double coloration, one which is distinct and readily seen 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 whatever, which are only slightly tinted and form a sort of undertone so little pronounced that the stone must be well finished to bring them out but in many cases to be closely examined. Yet in many varieties these half-hidden tints do affect the appearance of a fine slab." Formerly quarried at West Rutland by the Vermont Marble Company. Not now quarried.

BARONIAL ANTIQUE

The baronial quarry, operated by the Green Mountain Marble Corporation, which is not to be confused with the defunct Green Mountain Marble Company, has several quarries, three of which are now active. Three varieties are produced and sold from this quarry, namely, Baronial Antique, Baronial Verde Verde, Baronial Cipolin. This quarry was opened about 1926.

BEST LIGHT CLOUD RUTLAND

This is one of the lightest of the Vermont marbles, and often it is nearly pure white. In such pieces it must be examined when polished to be sure it is not white, but like many other similar marbles it varies considerably in different pieces, the fine veins in some being distinct while in others they are more or less indistinct. It is quarried at West Rutland by the Vermont Marble Company. Renamed gray building, and which will be taken up under the latter title.

BRANDON ITALIAN

Most travelers on the Rutland Railroad have seen something of the large quarry on the west side of the track and very near to it, a short distance south of Brandon station. Unlike some smaller quarries this very large quarry has for many years furnished a large quantity of fairly uniformly colored stone. As the name implies this marble quite closely resembles the more ordinary, veined imported stone. Through a pure or nearly so white ground and in variable abundance extend dark blue or black bands or narrow veins so that the usual effect is a sort of blue gray, darker in some, lighter in other samples. Though a large quantity of stone has during the passing years been taken out of this quarry, there seems to be a large amount remaining. The quarry is longer by much than it is wide, being over 600 feet long and over 60 feet wide, while it is towards 100 feet deep. It extends nearly north and south. "North 20° west 25°, and on the east side the beds 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." The quarry has been idle most of the time for some years. Owned by the Vermont Marble Company.

BRANDON ITALIAN HIGH STREET QUARRY

This quarry has been very little worked for some years. It is now known as the Pittsford Valley marble and will be noted on a subsequent page.

BRANDON STATUARY MARBLE

This is a beautiful marble in small pieces, but is not used because only small pieces can be obtained. No Vermont stone

that I have seen is so clear a white, but it is of little value because of the small blocks. This would be a very valuable quarry if only good-sized blocks could be found in or near it.

BROCADILLO

More than any variety thus far mentioned, this is a green stone. The ground is lighter than most of the surface which is seen, but there are darker veins running through the ground that give tone to the stone. Though darker than the ground, these veins are not usually very dark, but though rather seldom quite dark veins, etc., occur. This marble is quarried at West Rutland by the Vermont Marble Company.

CIPOLINO

In one of the beds of the Westland quarry of the Vermont Marble Company at West Rutland is a very pretty marble which bears the above name. In different specimens, or blocks, it varies more or less in color, but it is fine for decorative inside work in all its varieties. The general ground is green or greenish yellow, or yellowish green. The general effect is, however, all of a greenish cast. The various tints are undulating or waved in what may be called clouded masses and through these there are often streaks or bands of a different shade. Several varieties are especially noticeable, *viz.*, light, cipolino, medium cipolino and dark cipolino. Perhaps the names sufficiently define these varieties for in this case the coloring justifies the name.

CLARENDON DARK CLOUD

As has been stated on a previous page, the Clarendon quarries have been opened for some time. Not all are now operated. As in the case of the above, the Green Mountain Marble Corporation produces several varieties as shown below.

CLARENDON GRAY

This marble is perhaps sufficiently characterized by its name. As may be supposed the varieties here mentioned are mainly due to varying proportions of the white background and the dark veins.

CLARENDON LIGHT CLOUD

Though, as the name indicates, this marble is lighter in shade than the variety named above, through a white ground run numerous dark veins, though not enough to make the general effect very dark, the white background giving tone to the whole. Different layers in the quarry give more or less of the white.

CLARENDON LIGHT EXTERIOR

As the name indicates, this is especially a building stone, all shades being light in general effect. These Clarendon marbles are all bright and desirable for outside work. They are rather harder and often brighter than most of the Vermont marbles. There is a general likeness in most of the Clarendon marbles and it is difficult to describe them so particularly as to convey a clear idea of their distinct appearance. This is true of other varieties sold by the Green Mountain Corporation, as Clarendon medium cloud, Clarendon X. An excellent example of the Clarendon marble may be seen in the columns in the front of the New York Educational Building at Albany, New York.

CLARENDON X

As I have not examined any sample of this marble, I cannot speak specifically of it except that as it is a Clarendon marble it is light in shade and a good calcite marble.

COLONIAL ANTIQUE

This may be considered one of the several varieties of blue marble which have been or are quarried in the Rutland area. It is noticeable that while marbles of various sorts are and have long been quarried in the area about the township of Rutland none have been quarried for many years in the limits of the city. I suppose that there is nowhere an area of equal dimension that has for more than 100 years produced as great a variety of fine and very handsome marbles as this including Center Rutland, West Rutland, Proctor (formerly named Sutherland Falls), Pittsford, Florence and Clarendon might also be included. The stone is usually a dark marble, but occasionally white blotches are so abundant that they give to the entire block or slab a light tone.

The older name is that last given above, but later the first name is used. Viewed in a good light this is an attractive marble.

Two varieties are sold by the Colonial Marble Company, one lighter than the other. The lighter variety is "Colonial gray," the dark variety is "Colonial antique." This marble formerly was called "Oxford fleuri."

COLONIAL COLMARCO

This marble formerly was called "light cipolin." It is another of the Eastman marbles, green in general color, but lighter than the foregoing. Dale calls attention to the close resemblance of this marble to the ivory green but says that it is distinguished by the entire absence of the yellow tint found in the latter. He also notices that when unpolished "it has almost a gray color, as the green is less in evidence than when polished."

According to Dale this is a "muscovitic calcite marble . . . . in which the muscovite occurs in many close, fine, broadly plicated beds." Quarried at West Rutland by the Colonial Marble Company.

COLONIAL CREAM STATUARY

This marble, quarried at West Rutland by the Colonial Marble Company, is a very pretty and delicately tinted stone, in coloration a yellowish, cream or salmon tint; that is, there is a mixture of white, yellow and pink veins also.

COLONIAL GRAY

This is what was formerly named as a light variety of what was called "Oxford fleuri" while the darker variety was also called "Oxford fleuri"; but the Colonial Company prefer to call the two varieties by different names. Quarried by the Colonial Marble Company at West Rutland.

COLONIAL GREEN VEINED CREAM

As a "fancy marble" used especially in inside work, this is a very beautifully colored and shaded marble. The coloring, often delicate and dainty, is more variegated than in most varieties, but the various combination and shadings are without exception pleasing. Sometime the shades or colors are quite clear and distinct, or they may blend into each other and finally disappear. As has been noticed, the colors are always rather delicate and often blend in a very charming fashion. The main ground is more prominent in the color than it is in most of our marbles. This is light, white or with a light-blue tint with now and then a dash of pink. Harmonizing finely with these tints are frequent bands, veins, etc., of various shades of green, brown or yellowish brown, which are more or less undulating or irregular. In a large surface of the marble sufficient to show the full combination of the colors and shades mentioned, as may be easily imagined, the well-polished stone is often very beautiful, and always attractive, as are few marbles. In the Fourth National Bank of New York City, at Dodd, Mead and Company, and elsewhere, this marble may be seen, if their location has not been changed within a few years. The marble is quarried by the Colonial Marble Company at West Rutland. Known formerly as Colonial green.

COLONIAL I. J. CREAM FLEURI

This marble, formerly called "blanc clair," is a purely white stone in many parts but not always, for irregularly scattered over the surface are patches, small or large, of light gray and sometimes nearly black. There may be many patches of clear white which nearly or entirely cover the surface, but generally and with more or less distinctness, the faintly cloudy gray areas are shown, or it may be that these are quite distinct. Quarried at West Rutland by the Colonial Marble Company.

COLONIAL IVORVEIN

This is what may be classed with "fancy marbles," formerly Rosaro. Mr. Dale compares Rosaro to oriental alabaster in appearance and, as it is much harder and more durable than any alabaster, it is by so much preferable. In general, Rosaro is a charmingly tinted, rather strongly colored marble. Mr. Dale writes of this as follows: "The general shade of Rosaro is a light yellow suffused by a salmon tone. . . . At a distance the whole surface seems of a uniform or only slightly shaded tint but close inspection reveals softly indistinct and often exquisite veins of darker yellow or light olive tints." These veins are always more or less indistinct, though sometimes they show more plainly. Because of more evident veins, some varieties have been called veined Rosaro. It is a finer grain than many Vermont marbles. Quarried by the Colonial Marble Company at West Rutland.

COLONIAL K. CIPOLIN FLEURI

This rather unique marble, formerly named "Heidelberg green," is one of the darker shades of green, quite different from other varieties.

COLONIAL M. N. WHITE VEIN

This is a new variety. In this the ground is white, with rather large veins of color.

COLONIAL PAVONAZZO

The Colonial pavonazzo is another variety which has not been on the market until recently. In this marble the main ground is light cream. Scattered upon this background are spots and clouds of green. The texture of this variety is very fine.

COLONIAL SIENNA

This is one of the lighter marbles as it is generally of a light yellow shade, often very light. In the darker pieces the brown veins give tone to the whole. This is a fine-grained marble and is capable of a very bright polish. In the estimation of many it is one of the most elegant of the Vermont marbles. It is especially useful and beautiful in interior decoration. The older name given to this stone was "American sienna." Quarried by the Colonial Marble Company at West Rutland.

COLONIAL VERDAS

This marble, formerly called "Dark Cipolin" by the Eastman Company, is a very elegant marble. Mr. Dale says of this marble: "This is perhaps the most striking of the Eastman marbles," and this is pretty strong testimony considering the character of others of this group of marbles. The coloring of this marble is unusual. The ground is green and over this distinct surface there are many veins, unusually numerous, in some cases nearly hiding the ground. These veins are not at all regular but sinuous, waved, undulating, like waves in a turbulent sea. In color the lines or veins are very variable, shading from light to dark, more light than dark. It is not necessary to say that a large slab or block of this marble, well polished and viewed in a strong light, is exceedingly handsome, and out of the ordinary. Quarried at West Rutland by the Colonial Marble Company. Its value is increased by the fact that like many of the fancy and more beautiful varieties it cannot be found in as large quantities as can many of the lighter marbles. Nevertheless, enough for ordinary calls for inside ornamental work can be obtained

DARK FLORENCE

In spite of its name this marble is not one of the darker marbles. Some pieces are properly placed in the list of dark marbles, some should be classed with the light. Its name correctly indicates its coloring, for while in many respects it is like the Florence it is distinguished from that marble by the constant difference in that its colors are darker and more distinct. On a rather dark bluish ground there are seen numerous still darker veins and sometimes spots or clouds of the same darker shade. This stone is quarried by the Vermont Marble Company at Florence.

DARK IVORY GREEN

This marble is not, as the name might imply, a dark variety of what is named light ivory green, noticed later. The ground, not much of which shows, is chiefly a grayish color and a little white. There are a multitude of dark green veins. Apparently this marble is the same as what used to be known as white Stone Brook marble, quarried on the north side of Dorset Mountain, a short distance south of the Dorset-Danby town line. It is not now used. The quarry afforded white marble in some layers and gray in others. The marble is a coarse calcite marble of a 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. There are also, as usual in the Dorset marbles, grains of silica. Owned by the Vermont Marble Company.

DOVE BLUE RUTLAND

The above name defines this marble briefly. It is well named "dove blue" for many pieces are just that shade and the coloration is less varied than in most marbles. In some pieces it shows decided blue, in others it is more drab than blue, but it is always a neat, attractive, though by no means a showy marble. In many specimens the shade is not uniform, as it may be in others, but there are numerous veins which are darker than the main body, and also often there are white spots, usually of small size. In Mr. Dale's account this is called "dark blue Rutland," but generally this stone is not dark, and the name above given is more appropriate.

Quite a number of years ago there was not a little discussion as to the age of the marbles of the Rutland area, and it was left finally not to a trained geologist, but to a geologically minded minister, Rev. Augustus Wing of Shoreham, who studied the rocks of Rutland County and adjacent country with great thoroughness and success, to discover unmistakable proofs of the correct age by finding certain characteristic fossils in several localities. This was in the later sixties and early seventies. In fixing the age of the limestones and other rocks of the ex-

plored region Mr. Wing opened the way as had never been done to fixing the age of the marble beds of the studied area. More than twenty years later distinct fossils (Maclurites magna, see Figure 5, page 24) were found deep in this quarry. The Maclurites is found only in beds of the Chazy formation, one of the early Ordovician periods. As Mr. Wing had assigned the limestones of the region to the Lower Silurian age (now called Ordovician) this discovery put Mr. Wing's determinations beyond doubt. It is doubtful if all the Vermont marbles are of the Chazy period but it seems beyond doubt that those of West Rutland are. Of course, it necessarily follows that if, as none may question, all true marble is metamorphic limestone it would not be supposed possible that any of the fossils, by which the age of limestone beds can be certainly ascertained, could be recognizable after the metamorphic changes had changed the limestones into marble, and very rarely can they be identified. However, the Maclurites are large strong fossils, several inches across the coiled shell, and in those which appear in the Rutland blue are easily identified, notwithstanding metamorphism. This marble is quarried at West Rutland by the Vermont Marble Company.

DARK VEIN TRUE BLUE

This stone is without doubt dark in all cases. Like other varieties of the West Rutland quarries it has more or less resemblance to other varieties quarried nearby, but it need not be difficult to distinguish it from them, at any rate in typical specimens. Except the true Albertson or Esperanza, it is the darkest of these marbles. Very dark, not seldom black veins, as well as dark blue ones, are abundant, coursing irregularly through the dark, but lighter ground, which also exhibits often numerous spots of white. Quarried by the Vermont Marble Company at West Rutland.

ELECTRIC BLUE

This term is used for a group of marbles not much quarried and used mainly for electric switch boards.

EXTRA DARK ROYAL BLUE

This is another of the dark marbles. As it comes from the quarry it may be very dark, but usually it is not as dark as some of the other dark marbles. It is not unlike the preceding in general appearance. The ground coloring is similar, and so is the veining. As Mr. Dale notices, the darker blue or black veins "are greatly broken and nowhere extend far and as they are much confused they afford a mosslike effect which is very handsome." As far as I know this marble, which was formerly taken out by the defunct Raleigh Marble Company at Pittsford, has not been quarried for some years.

EXTRA DARK TRUE BLUE

As Mr. Dale notes, several of these dark Rutland marbles, and the same may be said of some others already mentioned, that any of them might be called gray or blue, for in all the gray is touched with blue and the blue with gray. Several may be selected from blocks taken from the same quarry though usually from different beds. The essential difference is seen in the shade of the stone. This the names sufficiently signify. Especially is this true of the Esperanza already noticed; and what has been called mottled true blue, extra dark, is from the same quarry at West Rutland owned by the Vermont Marble Company.

FLORENCE

There are several varieties, now called Pittsford Valley marble which are quarried at Florence (formerly Fowler). These have been named Florence W, Florence X, light Florence, dark Florence. For consideration of these see Pittsford Valley on a following page.

FLORENTINE BLUE

This is a dark, or it may be lighter, veined stone. It is in most pieces rather a bluish drab shade than clear blue. It is difficult so to describe this marble as to make it distinct from several already mentioned. Perhaps the general effect as this stone is placed in a good light is less of the blue and more of the drab than is shown in other varieties. Still there does not appear to be much to distinguish several of the so-called dark blue marbles from each other. Quarried by the Vermont Marble Company at Pittsford.

FRENCH GRAY

This is a dark stone, quarried on Isle La Motte by the Vermont Marble Company. Sand-finished it is a definite dark gray, but when polished it is almost black in some pieces. In a strong light, however, it is usually a distinct gray. For certain positions it is an elegant marble. Really French gray is an unchanged "Chazy" limestone. The dark appearance of this stone is somewhat lightened by numerous indistinct whitish spots.

GRAND ISLE FLEURI

This is an unchanged limestone, but when polished it makes a very unusual marble and of unique appearance. In some parts it is brecciated. These parts are much lighter gray than the rest, which is dark gray. There are also very black portions of no great size, but adding to the appearance of the whole mass. This stone acquires a good polish and placed in a strong light would be very effective. Quarried by the Vermont Marble Company at Isle La Motte.

GRAY BUILDING

As has been noticed this marble has been named Blue Building. It is one of the varieties mentioned above that may be called either blue or gray, or, and perhaps, more accurately, gray blue. As the name suggests, this marble has been used mainly for outside work, and for building it has always been in demand. In the walls of a building it is sometimes bluish, sometimes gray as the light may fall upon its surface. As indicated, the general surface may be gray or blue and beside this there are white blotches and dark lines and veins. It is quarried at West Rutland by the Vermont Marble Company.

GREEN VEIN STATUARY

This is one of the light marbles, the main ground being milky white veins of varied tints, but in all specimens delicate, gracefully waved and often broken. There are clouds or bands where the veins have. These colorings are at times distinct, at times quite faint, fading into the white ground. The veins or color may be abundant or may be so few that the stone is almost white. The effect is often very charming, sometimes like a patch of moss. Quarried at West Rutland.

HIGHLAND MARBLE

This is one of the products of a Danby quarry. A part of the deposit in this quarry differs more or less from the rest. The main ground is described as of a pearl shade very thickly traversed by gray streaks, clouds and more rarely veins. All these are wavy as if windswept and render the marble a very distinct character. The beauty of the stone is much increased by the variety in shade of the color, some being dark, some light brown. Quarried by the Vermont Marble Company.

HIGHLAND BLUE

While different blocks differ considerably in shade, all are dark, the lighter toned surfaces being more abundantly spotted or blotched with white and also white veins of usually no great width. Different varieties of these dark marbles differ, sometimes greatly in the surface whether it is simply finished by hammering or more completely finished by polishing, also the difference in fineness of grain. The fine grain, especially if there is silica in the composition, as in the Dorset marbles, can be much more brilliantly polished than those which contain only a larger amount of calcite and the hammered surface in these is not so much lighter than is the polished, but in some of the darker marbles, of which this is a conspicuous example, are usually lighter and in this variety very much lighter than the polished. In the lighter marble this contrast does not, of course, appear. Hence carving, lettering, etc., done on most dark varieties is far more conspicuous than if done on lighter stone. Inasmuch as in most respects this marble closely resembles the variety known as True Blue, though the quarry is differently located, being at Brandon, the demand for such marble is met by the true blue and the quarry from which this is taken is competent to supply the need, and the Highland blue is not at present quarried.

HOLLAND BLUE

The writer agrees with Mr. Dale when he writes: "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 occur in a number of quarries." Still the varieties named by different companies are quite distinguishable and deserving of separate names for trade purposes. In the Holland blue the chief effect is a fairly dark blue with a gray tint. Narrow bands and veins of still darker shades run abundantly and in every direction across the ground, and variously shaped white bands, veins, spots in many blocks, though not in all. In some blocks there are lines or veins which are clear black. Where the white veins, etc., are numerous, naturally the appearance of a surface is not the same that it is when, as in some pieces is the case, there is no white and the stone is evenly dark blue. Originally this was quarried by the Green Mountain Marble Company at Florence.

IMPERIAL

Like all or most of the marble quarried in the Danby region the variety named imperial is a light-colored stone. Much of the stone is clear white or very light cream. Not at all prominently and not very abundantly, in the samples I have seen, are delicate clouds of light yellow or pinkish. This marble is usually recommended for exterior work, but its delicacy in shading and brightness fit it extremely well for interior finish. It is one of the harder marbles and, therefore, receives a fine polish. It is obtained at the imperial quarry in Danby by the Vermont Marble Company.

ITALIO

This is a light marble quarried at West Rutland. Though a light marble it has a bluish tint over the surface. Scattered over the surface are many spots, dashes, etc., of different shapes and sizes, of a darker shade. These darker spots are sometimes quite dark, sometimes faint and all shades between.

Perhaps it is unnecessary to add to the general account already given of the Champlain marbles. The nomenclature now in use by the Vermont Marble Company is much shorter than that used by Mr. Barney and others and is here followed. Really, the grouping of these marbles is largely a matter of individual opinion, for there is so much diversity in some varieties that one could adopt almost any list that he chose. This may be said of any group of these dolomites. That is, the beds at Monkton, those at Malletts Bay, those at Swanton and from a few other localities are all different in color, shade, and pattern as far as there is any pattern. But, as noticed, the Vermont Marble Company, which at present alone supplies these marbles, has adopted the simple list which is here followed. These are the only names now given to the public.

JASPER

The above name was given to this stone many years ago, but it has little appropriateness. Like most of the Champlain marbles the colors, mainly red of various shades and white, have no special resemblance to the mineral jasper, except that as red jasper is red, so this color predominates in this in many specimens, but also white or very light red is common and in some there is more white than red. Indeed, it is often a sort of breccia, white pieces, sometimes several inches long, imbedded in a red matrix. All the included pieces are not white, but some are pink or deeper red. The included fragments are usually calcite and quartz, sometimes the latter only, but usually this is in smaller bits than the calcite. Still, as stated, there is always quartz enough in all these marbles to make them very hard and difficult in working. As this stone is thus hard it is probable that the failure of attempts to manufacture it is due to the location, as all the machinery needed in preparing it for market has been used where steam power alone was available, except at Swanton, where there is plenty of water power. Steam power is too costly. Occasionally this and the allied marbles have been used for outside trimming but far more often as tile flooring, where the contrast with white or gray stone is marked and the hardness of the stone adds much to its durability. Though on the whole the stone must be called light, there is generally enough white to give considerable light effect, and one far from gloomy.

The variety named Jasper is also a quartzose hematitic dolomite, as indeed are all the Champlain marbles. The very distinctly red color is caused, mainly, at least, by the contained hematite. This color is often of lighter shades in some parts. White or light red irregular bodies of many sizes from a fraction of an inch to seven or even more inches long, and usually less in width are abundant and form a breccia. The light bodies are mainly dolomite, but in some cases have a sort of nucleus of quartz. Dale and some others consider them as "distorted corals" and this may be true, but at least in many specimens it is very uncertain what they are, if organic of any sort.

Besides the little Salterella, which are unquestioned fossils, found epecially in the beds of "Jasper," also to a less extent in that called "mosaic," there are in some parts of a slab numerous white or light or pink bodies like fragments of broken stone. Some of these may possibly be fossils (sponges or corals), others bits of broken stone, making the marble a breccia. Some of the leading Cambrian geologists have thought that some of these, at least, were veritable fossils, others do not agree to this. They are, as has been noticed, found usually in the jasper and mosaic varieties. Whatever these may be they evidently have not been to any extent exposed to erosion, as the corners and edges are not all rounded.

LIGHT CLOUD

Like the other light Rutland marbles this offers a bluish ground veined by darker color. In most cases the veins are less distinct than in most veined marbles and at a little distance a block appears white or nearly so. Besides the veins there are blotches, clouds, etc., usually of a light bluish white shade. These lines, clouds, etc., are not conspicuous, even in the highly polished surface. They are more or less waved and irregular. They are

usually irregular. This variety often fades into one or another of the light Rutland marbles and several which are known by different trade names are obviously varieties of essentially the same marble. The coloring and veining in all these is nearly or quite the same and they can easily be blended into each other. However, when one or another variety is called for it can easily, in most cases, be selected from the stock and, of course, supplied. It will scarcely be expected that all these varieties can be so described that they can be readily distinguished. To be properly differentiated they must be seen, then the varieties can be selected. Several of this group of marbles are quarried by the Vermont Marble Company at West Rutland.

LIGHT CLOUD ITALIAN

It is not necessary to say much about this marble as it is perhaps enough to say that it is little else than somewhat darker and more distinctly marked in veining cloud, etc., than that just mentioned. It is quarried by the Vermont Marble Company at West Rutland.

LIGHT COLUMBIAN BUILDING

This marble, though not now quarried, is worthy of notice. It is a bluish white, and when finished as a building marble, the dark veins do not distinctly appear. This stone has been quarried at the Columbian quarry at Proctor.

LIGHT IVORY GREEN

Dark ivory green has been noticed on a former page. The two, light and dark, seem to be varieties of the same marble. Yellowish white, green and yellow are seen but these colors and shades of color are, however, plainly unlike in different samples. The ingredients which make up these two varieties appear to be the same, but they are evidently in very different proportions. When the yellow tones are most evident, especially in the veins, etc., the marble is classed as light, but when the green markings are most obvious, the marble is classed as dark. Both are very pretty marbles, each in its place. Like the dark, this is quarried at West Rutland by the Colonial Marble Company.

LIGHT MOSS VEINED

This is a variety, because of its lighter shade than that of the moss vein, mainly because the white, always in some measure and very greatly in most pieces, predominates over the black and necessarily this gives a very different appearance to the polished slab. This and the moss vein are not taken from the same quarry, this coming from West Rutland, that from Dorset.

LIGHT SUTHERLAND FALLS

In some respects similar to the preceding this marble is from a different locality and is easily separated from it by its bluish veins, usually dark, but of various shades. Like the preceding, the ground is white, or nearly so and this light ground is sufficiently pronounced to give the stone a light tone, though it is veined with dark bluish lines, bands, etc. These are more distinct than those of many varieties quarried at Proctor by the Vermont Marble Company. In some blocks, though not commonly, the black or bluish veins have a green tint.

LIGHT VEIN RUTLAND

Not very unlike the light Sutherland Falls is the light vein Rutland. It is not as hard, the first named stone being harder than most of the marbles of this area. Also it is usually a much greener marble than that. The green veins are very numerous so that they give the whole surface a green shade in many specimens, though in some there is so much white that the surface appears much lighter than where there is more green, but different parts of a block are likely to differ in shade. Whatever the color of the veining, it is quite prominent. Quarried by the Vermont Marble Company at West Rutland.

LISTAVENA

Another of the Rutland light-shaded marbles is the Listavena. White, green or olive in various shades are found in this marble and, though more rarely, there is a suggestion in some of the white bands of pink. The white bands as well as the colored are much more regularly arranged than is usually the case in the light marbles and alternate instead of intermingling with each other. This stone is quarried at West Rutland by the Vermont Marble Company.

LIVIDO

Although the shade varies in different slabs of this marble it is usually rather dark, but in some slabs the color is light. The

ground is gray with a blue shading and the bands or veins are the same color but darker, often very much darker, even to black sometimes. Whether the slab is lighter or darker depends upon the frequency of dark veins and this varies considerably in different samples. Dale says that the darker parts are dolomite in this marble, while the white is calcite. In addition to the veinings named, there should be noticed small spots of white which are distributed not very abundantly through the whole. There is also some graphite in the darkest parts of this marble. This marble is quarried by the Vermont Marble Company at West Rutland.

LYONAISE

This is one of the "Champlain" marbles but very different in appearance from the Jasper. The colors are very similar in all this group, but the arrangement is very different in that the appearance is that of a very much mixed and stirred material when not hardened or before the mass became rigid. It is decidedly darker than the preceding, the red portions in some specimens being almost black. There are no veins in the jasper, but, though exceedingly irregular, they are nowhere true veins, but as if veins had once been present and after formation stirred, broken and disturbed in every way. White spots are abundant and quite variable in size. Though all are dark, the shades of red are numerous. For many kinds of interior work this is a fine marble. Quarried and sold by the Vermont Marble Company at Swanton.

MAHOGANY

Notwithstanding its name, this is a white stone. I find little to say about it more than to speak of its very white color and rather coarse grain and greater hardness than is usual in the Rutland marbles quarried north of the Rutland area. It is not quarried at the present time. It can be finely polished and when polished makes a very nice appearance. The quarry is on the east side of Dorset Mountain at the formerly called Freedly quarry, later owned by the Manchester Marble Company. Being a coarsely crystalline stone it is bright and lively.

MANCHESTER BLUE

This marble was quarried by the Manchester Marble Company when that company was doing business.

MARINE VENOSO

The veining in the marine venoso is more conspicuous than in most Vermont marble and this makes it resemble some of the marble of Georgia. The bold and therefore prominent green or white bands are often more or less confluent. There are also more narrow veins or lines of brown and blotches of dark green. These are parallel with the bedding, but it is easy to see that as may be the case, when a block is sawed in some other direction, quite different effects must be produced. By placing two or more large slabs side by side, as suggested by the colored or white portions, very striking effects are obtained. For some kinds of interior work, as the railroad station in Burlington, this marble gives very elegant results. The stone takes an excellent polish and is altogether a very fine variety. It is quarried by the Vermont Marble Company at West Rutland.

MOSS VEIN

A few years ago the Norcross-West Company quarried this stone, but the quarry is at present idle and owned by the Vermont Marble Company. I suppose that it is not now on the market. This marble presents only two colors, gray and white. These colors are so peculiarly intermingled that either may be considered the ground and the other veins very thickly traversing the other. The title is very correct, for it is in truth moss veined and the effect produced is very attractive. The two colors are arranged in a moss-like pattern and there are no large areas of either, that is, generally, but patches and blotches of white do occasionally appear.

METAWEE

This is one of the Dorset marbles, quarried at the Imperial quarry by the Vermont Marble Company. Like all Dorset marbles it is light in shade and resembles some of the Pittsford stone, but it is harder. The main ground is white or bluish white and is clouded by dark, often with a purplish tint, especially where, as is often the case, the darker colors are faint. It is a very attractive marble and takes a brilliant polish.

MINE QUARRY

About 1929 the Green Mountain Marble Corporation opened a new quarry which they named the Mine quarry. From this they produce four varieties of marble. The varieties are named

Meadow White, Venato, Vert Mont, and Vermont G. M. exterior. These are all at West Rutland.

MOUNTAIN WHITE

This is a Danby marble and its appearance is suggested by its name. In this there is mostly pure white, but usually not very distinct veins and clouds of light green or, in some pieces, light brown. Also, some of the narrow wavy clouds are darker and brownish in tint. Like most of the Danby marbles this is a bright, sparkling stone when well polished.

As Mr. Dale has written: "The metamorphism of the original limestone from which the marbles (the Danby marbles) are made appears to have been somewhat different in the two regions (Danby and West Rutland) and most if not all of the Danby and Dorset marbles are harder and more coarsely crystalline than those farther north (West Rutland, etc.) and for this reason these marbles are unusually good for building stone." It may be added that these marbles are also generally brighter in appearance. The Danby marble is always light, white or only moderately veined. Used in many fine buildings, this marble has proved an excellent building stone. Quarried at Danby by the Vermont Marble Company.

NESHOBE GRAY

This is a West Rutland marble, where it is quarried by the Vermont Marble Company. This marble is a soft, rather dark gray as a whole, though there are many signs of gray and rarely small white blotches. Some pieces resemble the Swanton dove, though of different texture, as would necessarily be true, the former being metamorphic, while the dove is unchanged limestone. Wherever a gray marble is called for this should be satisfactory.

NORTHERN IVORY

This marble is obtained from the Pittsford Italian quarry, but is quite like some of the Danby stone. It is a very delicately colored marble. On a ground of pure white are rather sparsely distributed, when distinct, almost black streaks and clouds, most of which are not prominently seen. It resembles closely some of the Italian marbles. In fact, those who named the quarry from which this stone comes seem to have recognized the resemblance when the quarry was named. Quarried by the Vermont Marble Company.

NORTHERN PEARL

This is quarried by the Vermont Marble Company at the Pittsford Valley quarries. It is a beautiful marble, where a light variety is required, for either inside or outside use.

OLIVE

This is one of the dolomite marbles quarried at Swanton by the Vermont Marble Company. It is usually largely drab or olive, mingled with which there is usually much red of varied shades, often these are light. Different pieces of this stone are or may be quite different in appearance, but in all there are reds, usually not very dark, olive, light or dark, pink and white. Like all the Champlain marbles this may be very finely polished.

OLIVO

This is very much more unlike the preceding than the name indicates. It is one of the West Rutland marbles and therefore a calcite marble. It resembles the stone named Brocadillo, but while the color is much the same, various shades of olive green mingled with white, the bands or veins of color, now mixed with the white, again less conspicuous, making the general effect lighter or darker, but always attractive. The effect of the mingled colors is best shown in columns, as then the undulating veins are most prominent. Quarried by the Vermont Marble Company at West Rutland.

OLYMPIAN WHITE

A Danby marble practically pure white, though careful examination will often reveal faint clouds. However, it is regarded as the whitest of the Danby marbles. For further particulars about the Danby marbles see page 112.

ORIENTAL

Oriental has the same dark red ground, which is sometimes almost brown in tint. Enclosed in this ground are very irregularly shaped spaces of banded purplish or purple-gray shades. There are also very irregular blotches of white, mainly calcite, with a nucleus of quartz. "The dark purplish-gray spots 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."—Dale, *l.c.*

All of the Champlain marble might well be named oriental, for the colors of oriental fabrics are suggested by most pieces. But it seems that to the marble company this exhibits the oriental characteristics more than other varieties of this sort. It is difficult to so describe these red mottled marbles in any way that conveys to the reader an adequate idea of the stone. Like most varieties of marble they must be seen to be appreciated, and this is more true in this case than in most others. The arrangement of colors and shades is so very variable in different parts of the same slab, or block, that only in general can one speak of any of the varieties. The colors named are found in all of the varieties, but the arrangement or pattern is exceedingly varied. All of these marbles are fine and all receive a splendid polish. Which of the varieties is most beautiful must always be a matter of taste.

PINK LISTAVENA

This marble, as the name implies, resembles the Listavena, mentioned above, but it has an individuality of its own. Of course individual taste differs much, but to the writer this stone is equalled for dainty interior finish by few Vermont marbles or for that matter from any other part of the world. In fine specimens the delicate pink ground is often exquisite in tint or shade which varies somewhat in different slabs or other pieces, and running across or through this charming background are veins, also very delicate, of green shades. In addition to this beauty of tint and color there are white veins more or less thickly mingled with the green. The veins, sometimes bands, are usually quite irregular, but more infrequently they are straighter. Pink listavena is obtained at West Rutland by the Vermont Marble Company.

PITTSFORD ITALIAN

The variety named Pittsford Italian, or it is better to say varieties, for this marble is very variable and scarcely any two slabs are exactly alike in all particulars, but in a general list of their marbles held in stock, only this one name is given. The stone is light in all varieties. Some varieties are much darker than others because of more dark veins. The usual colors are white, light yellow, with veins of gray, which may be very dark, sometimes they have a touch of blue. No regular rule is found governing the very greatly confused and intermingled arrangement of these veins. The dark veins are not anywhere numerous, else the marble would not be light in tone. Quarried at Pittsford by the Vermont Marble Company.

FLORENCE OR PITTSFORD VALLEY

This marble, in several varieties, seems identical with what has been called Florence. At present the name in use is that first given above. Often some of the varieties are specifically designated by letters as A, B, C, etc. Light Florence is another name that has been used. This marble is much like some of the foreign marbles in color and veining. The white has generally a bluish tone and through this are very numerous dark veins, blotches, clouds, etc., also often there are dark lines. The more prominent bands or veins are very variable in width. Some are more or less wide bands rather than veins, while from these wider bands the dark coloring may be found in all widths to simple lines. The veins, etc., vary greatly in distribution. Some slabs are very thickly covered, others show areas of white or light shade. Hardly does any of our marbles vary more in markings and dark shades or those which are lighter than this. Thus as it is difficult to find two slabs of any size unless it be very small that exactly match in shade or veining, great variety is produced, though all is in general similar. So, too, as in most strongly veined marble, the way in which a block is sawed often makes great difference in the appearance of the surface. Hence in this way varieties that differ very much are obtained. In fact, the difference caused by sawing a large block in the direction of the bedding or across it may be quite as great as that between two entirely different varieties. By this means, as well as by "matching" slabs strongly marked in veining or banding, many fine effects are produced. All the varieties of Florence marble are quarried by the Vermont Marble Company at Florence.

PLATEAU

This is a Dorset marble, better for building than for interior or ornamental work. It does not take as good a polish as most of the Vermont marbles, though it is capable of a fair gloss. The ground is a light pearl, abundantly veined and clouded by somewhat darker shades. There are also much wider and more conspicuous pure white veins. The darker shades are not so evident as to place this outside of the group of light marbles.

RIVERSIDE (Danby)

This is a stone closely resembling the imperial and is from the same quarry. It differs from the marble named Riverside (Proctor) in the color of the clouds which are bluish rather than yellowish or, more rarely, pinkish.

RIVERSIDE (Proctor)

This is a very light, in some blocks nearly white, marble. None of the numerous quarries that I have seen is more interesting to a geologist than this, since very unusual and conspicuous evidence of glaciation is, or was, plainly seen before much stone had been taken from the quarry. In working this quarry, which is plainly seen not far from the track of the Rutland Railroad on the west side, as one goes from Proctor to Rutland, about two miles from Proctor. The surface marble in this quarry was not more than a few feet below the surface of the earth which covered the bed of marble. As the surface was removed to uncover the bed of marble the surface of the bed was found to be very deeply glaciated, deeply and widely grooved in undulations, some several feet wide, and potholes ten to fifteen feet deep and six to ten feet across the top, were brought to light. A splendid example of a pothole was sent to the museum of the University of Vermont by the Marble Company, through the courtesy of Mr. Mortimer Proctor. This specimen in two pieces weighing eighteen tons, illustrates not only the lesson taught by the marble potholes but by all wherever found. One large piece of the marble shows the wear of the glacial stream, which did the work and the other, a large cubical block, contains the pothole, forty-two inches of it. In the bottom are some of the boulders by which the hole was made. This hole is forty-two to ninety inches in diameter across top. Altogether this is a most interesting geological specimen. It also shows well this Riverside marble. Weight of both pieces, eighteen tons. Cube, sixty by forty-six inches. Top piece, ninety by eighty by sixty-four inches high. The marble from this quarry is rather coarsely crystalline, which structure gives it when polished a brilliant surface. As noticed above, it is almost pure white, usually of a tint of blue, darkened by gray or sometimes black blotches, which do not materially change the light aspect of the stone. Until recently this quarry has been operated, but at present appears to be idle. Owned by the Vermont Marble Company.

ROYAL ANTIQUE

This is a conspicuously and richly veined and shaded marble. It is one of the varieties most frequently used in matched pairs of slabs or panels, as shown, where the curious figures of the block are made still more impressive and bold by pairing consecutive slabs from a block. The figures, as will be readily seen if the slabs are examined, are dark, sometimes almost black, more often dark olive or green of many shades, which move through a gray, white, white touched by shades of blue, in often fantastic and often grotesque fashion. A slab of considerable size is always dignified and often elegant, in slab or column. All in all it is always a very striking marble, and is especially valuable for interior work in large buildings. As might be expected in such a marble, there are many varieties to be obtained. In fact, no two would be likely to present exactly the same appearance. However, the Vermont Marble Company, by whom it is quarried at Florence, also some varieties at High Street quarry at Brandon, list only three or four varieties, or at any rate only a few.

ROYAL RED

"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; (b) interstitial reddish brown hematitic (kaolin), in places more abundant, forming streaks along the bedding; (c) plentiful angular quartz grains; (d) a few opaque particles magnetite, and (e) rare muscovite plates. The dolomite plates have minute reddish specks. The quartz grains have cavities with moving vacuoles."—Dale, *l.c.* Especially when wet, a distinct clay odor can be perceived. When properly treated it, like all the Champlain marbles, takes a very brilliant polish.

This was formerly named Pompeian Red and this name well fits it, as the entire surface is usually of a deep red without veins or any other color. There is, however, some variation in the shade of red in different pieces, though not very much. Of course by selection from a large lot exact matching can be easily effected. In places where such a marble is wanted, this is very desirable, as even when different shades are present in a slab or block they are so blended as to be very handsome. Whatever the shades present may be, they are always rich and dark. As a consequence the stone should always be placed in a strong light. Quarried at Swanton by the Vermont Marble Company.

RUBIO

Another of the Champlain varieties and an exceedingly pretty one. It would not be likely to be used except as a decorative marble in interiors. It is to be classed as a light shaded marble. Like most of our Vermont stones, it is not what would be called self-colored, though it has one predominating shade, a salmon pink of usually a very light shade, an uncommon color in our Vermont marble. Not as prominent as in many marbles, but fairly distinct, distinct enough to give charming contrast, are veins of light green shade.

RUTLAND BUILDING

As the name indicates, this is one of the building marbles. Practically, it is a white marble, as this is its usual appearance and the never very prominent dark veining does not appear on the unpolished piece, but when thus finished, rather indistinct veins may be seen. Of course, as a building stone it would not be polished but only hammered and then would seem white. Quarried at West Rutland by the Vermont Marble Company.

RUVARO

In each of the several localities in which the Champlain marbles are obtained a different arrangement of colors is found. The colors are in all localities about the same, but there is a difference in proportion, shade and, if it can be called so, pattern at each quarry. The Ruvaro is quarried by the Vermont Marble Company as are all the rest of these marbles, but not at Swanton, fifty miles north. As before stated, the quarries at Hogback Mountain are not now operated. The Ruvaro is more fully treated on page 189.

ST. ALBANS RED

This is one of the marbles like those mentioned above, which belong to the Lower Cambrian red sandrock. It is, therefore, a dolomite. The general color is a pompeian red abundantly blotched by lighter clouds of various distinctness and shading from dark red to white. Like all the Champlain marbles this is a harder stones than the marbles of the "marble belt" and takes a fine polish. Quarried by the Vermont Marble Company at St. Albans.

SILVESTRE

This, like most of the Pittsford marbles, is a clear pure calcite stone of light appearance. It has a decided character of its own when carefully examined. The white ground occupies the larger part of the ground, but dark veins or clouds are in some parts of a slab very conspicuous, especially when very dark. From these darker clouds the coloring grows less and less until it is hardly perceptible.

STANDARD BLUE

As the name implies, this is a marble of blue or bluish color. It is very much like several varieties already mentioned. Aside from blotches of darker blue, this is not a dark stone. Over the not very dark ground there are scattered spots of lighter shade or even white. Naturally the general effect of this marble varies considerably as the dark veins and spots are more or less numerous and thus varieties appear. So, too, the direction in which sawing slabs from a block is taken makes great difference in the appearance of the stone.

STANDARD GREEN

This marble, while always the general tone, is more or less green, varies very greatly in different blocks. Various shades or tints of green, pink, light blue and spots of white, or at least whitish, are seen. These shades are often much mixed and confused or clouded. Generally the marble is light in shade. The Vermont Marble Company quarry this at West Rutland.

STANDARD WHITE

This is quite like the metawee and is from the same quarry in Dorset. It is also much like some of the Pittsford Valley marbles. However, in the samples I have seen it is lighter than most of the light marbles. The ground is white with a light cream shade, not very abundantly clouded or striped by clouds and streaks of dark material, which may be quite distinct or may appear to fade into the background. Quarried by the Vermont Marble Company at the imperial quarry in Dorset.

STATUARY RUTLAND

While statuary marble is not always white and unveined, the best usually is clear white, of the whitest found, and this sells at a much higher price than any other of the standard varieties, here or anywhere. In Vermont the best statuary marble is found and has been long quarried, it is nowhere in the State found in large quantities. As has been noticed on a foregoing page, fine statuary marble is found in one of the Brandon quarries, but while the

quality is all that is desired, no blocks of any commercial size, or very few, can be obtained. It is good statuary marble, as a stone, but pieces of sufficient size for statues are wanting. Hence the quarry has never been worked except in a small way. However, in several quarries good statuary marble has been obtained, but not in large quantity. Most of this has come from West Rutland quarries owned by the Vermont Marble Company.

STRIPED BROCADILLO

This is a very pretty stone which would be classed as a light marble. It is very evidently striped, either across the white ground or longitudinally, as the quarry block is sawed. The stripes, or in some cases elongated clouds, are of a moderately light green, more rarely a dark green. These lines or clouds are waved or irregular. The effect on the whole is quite different from that of most Vermont marbles. Quarried at West Rutland by the Vermont Marble Company.

SWANTON DOVE

This is not a true marble, scientifically speaking, but a good limestone. It is quite different from the Rutland marbles in color, being a quiet drab or, hence the name, dove or bluish gray. It takes a good polish and is often very pleasing when used for interior work, as mantels, etc. The quarry has been worked for many years. I have seen in several of the oldest houses in the State mantels made from this stone, also hearthstones, steps, etc. On the gray ground there are often white or very light drab clouds or spots, usually not very conspicuous. The quarry, just east of the village of Swanton, is owned by Mr. John P. Rich, and the stone is mostly used in the burning for lime. As a marble quarry this is operated by the Vermont Marble Company.

TRUE BLUE

The marble sometimes sold as true blue is little more than a dark variety of standard blue already mentioned. However, it may properly enough be regarded as a variety. Often it is dark enough to have a gray tint or more accurately a blue gray. Quarried at West Rutland by the Vermont Marble Company.

VERDE ANTIQUE

This very elegant stone is a serpentine and has been considered on page 159, perhaps as fully as need be for the present article and the reader is referred to this page for further information.

VERDOSO

The marble which has been called verdoso is in many respects like others of the green marbles found in West Rutland, but is sufficiently distinct to have a special name. There is not as much white in this as in other green marbles, though it is not wholly absent. Green, however, is far more conspicuous. The green in verdoso is usually darker than in most green marbles, but there are different shades and a few veins are nearly black. In a few cases there are small veins which are reddish yellow or salmon. In all specimens the veins are rather narrow, sometimes mere lines, which in great profusion cover the surface. This is eminently a green stone. Quarried by the Vermont Marble Company at West Rutland.

VERDURA

This is a green marble, different parts of the bed giving dark or lighter shades. In fact all shades from almost black to nearly white are seen. With the decidedly green shades and tints are white blotches and light olive clouds.

VERT DE MER

This also is a green or greenish marble and a beautiful variety. In many respects it is unlike other marbles. It is distinctly a green marble but not dark in tone. Abundantly scattered among the green shades are white spots so arranged that they (or is it from the green?) give a very peculiar appearance to the polished surface. There are also many inconspicuous dark veins. A peculiarity of this marble is found in multitudes of little cracks, which while not being sufficient to in any way injure the stone, add to its charming appearance. Quarried by the Green Mountain Marble Company at West Rutland.

WESTLAND CREAM

The Westland Cream resembles more than most of our varieties, some of the oriental alabasters, and is their equal in charm as well as their superior by far in endurance. Several varieties of Westland Cream are listed by the Vermont Marble Company as Westland Cream D. E.; Westland Cream Vein D. E.; Westland Cream Green; Cream Vein E. F. G. These are all very charming marbles for interior work. Green veins are sometimes thickly distributed through the pink, again few and less apparent. Always occupying comparatively small spaces, though, in less common specimens, they are more than usually abundant and

therefore give a greenish tone to the whole. In general, however, the red shades prevail. This is, as may well be supposed, one of our most attractive marbles for interior work. Quarried by the Vermont Marble Company at West Rutland.

WESTLAND CREAM VEIN

This is one of the varieties quarried by the Vermont Marble Company and recommended as especially good for interior decoration. It is a light shaded marble, veined by darker shades.

WESTLAND GREEN CREAM VEIN

Quarried at the Westland quarry at West Rutland. As the name indicates, this marble is much like the preceding. As the name also indicates many of the numerous veins are green. It is a very pretty stone, especially when placed in a good light.

WESTLAND VERDE VERDE

The general effect of this marble is that of a rather light green, and a very pretty effect it is. There are light, not very distinct, wavy lines of dark green. So thickly mingled with these are lighter green clouds of very variable tints of green, usually not very dark. So abundant are these that they practically cover the ground. Here and there, not abundantly, are pure white streaks and much wider than any of the colored streaks or clouds. Altogether this marble differs from other Vermont marbles. I have not seen this variety in place, but it would seem certain that for many sorts of interior finish it would be very satisfactory. Quarried by the Vermont Marble Company at Westland quarry, West Rutland.

WHITE RUTLAND

This is a fine, very light or often white marble suitable for both exterior and interior work, anywhere that requires a marble as light in shade. It takes an excellent polish, and is altogether a desirable marble. Quarried by the Vermont Marble Company at West Rutland.

MARBLES OF EASTERN VERMONT

Although they appear to be of little or no commercial value, the various outcrops of marble and so-called marble east of the Green Mountains are of considerable geological interest and for that reason are considered in some detail. Many attempts during the past hundred years have been made to obtain good commercially valuable marble east of the mountains, but all have failed to be remunerative, some very soon after opening, some after more or less money and labor had been expended. Nevertheless, this account would not be complete were these eastern marble and limestone beds omitted. As will be seen by the reader, many have been useful in furnishing material for limekilns and some are still used, though many have long ago ceased to be of any value. As has been mentioned, there are three areas, or belts, in Vermont in which quarrying has been carried on, and if, as properly may be done, granite is included, four may be mentioned. These are the Marble Belt of western Vermont, which has been fully discussed in the preceding part of this article; the Slate Belt of western Vermont; the Marble Belt of eastern Vermont, and the Granite Belt of eastern Vermont. I need only to call attention to the very great importance of marble, slate and granite to this State for years gone by as well as at present and for many a year to come. For convenience we may speak of the Marble Belt of eastern Vermont—it is hardly to be called a belt, but rather scattered outcrops of no great extent as compared with the western beds.

No one has so thoroughly studied the marble outcrops which lie east of the Green Mountains as has Mr. Dale and, as heretofore, quotations in this Bulletin, United States Geological Survey, No. 589 (reprinted, Ninth Report, Vermont State Geologist, 1914) are given: "The rocks of the Green Mountain Range on the east include various gneisses and schists 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. The formation 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 by more or less quartzose beds. This extends along the valleys and underlies the belt of calcite marble. To this formation belong the dolomite marbles of Pittsford and East Mountain described in the former Bulletin of this series number 526. Then follows the marble belt proper consisting of beds of calcite marble alternating with beds of dolomite, and in places of graphitic mica schist."—Dale, Bulletin 589, United States Geological Survey, reprinted, page 56, Report Vermont State Geologist, 1914.

As to the limestones of eastern Vermont, Mr. Dale writes: "The calcite marbles and dolomites of eastern Vermont differ from those of the western part of the State not only by their inconsiderable thickness but by their sporadic distribution. Instead of marble and dolomite beds 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." As those who have read the preceding pages, in the early part of this article, will have noticed, especially if the stone found in the east side of the Green Mountains is compared with that of the "Marble Belt" of the west side, very different conditions are present in the two areas. The true marbles, which as has been noticed, are metamorphic are found east of the main mountain range only in small deposits. These, too, vary greatly in many respects from each other. The present writer has not studied the localities and the adjacent rocks in eastern Vermont as he has those of the western part and very much work must be done in the eastern part of the State before the detailed geological features can be positively stated. The rock beds or deposits of eastern Vermont are for the most part wholly destitute of fossils by means of which the age can be determined, many of the outcrops are quite destitute of any of those characteristics by which geologists determine age and as a consequence it is not possible to speak with confidence as to the age to which many of the rock masses of eastern Vermont belong. Dr. C. H. Richardson, of Syracuse University, who has for over twenty-five years worked in connection with the Vermont Geological Survey, and has during these years studied the rocks of eastern Vermont thoroughly, has found in many of the shales of the region several species of graptolites, which Dr. R. Ruedemann has determined as Ordovician. While the writer does not wish to speak positively, it is his conviction that most of the rocks east of the Green Mountains are of later age than those west of these mountains. The great granite beds near Barre, Woodbury, and elsewhere in eastern Vermont, are certainly of later age than many beds west of the mountains. The adjacent and formerly overlying schists are probably Ordovician, some smaller beds may be older, but not many. There are apparently in Vermont, and beyond its borders as well, beds offering an irregularly distributed succession of rock formations, beginning with Cambrian near, and bordering, the eastern shore of Lake Champlain and interrupted by occasional pre-Cambrian beds. Next above these older rocks we find near the lake unaltered Ordovician beds, and externally at least, in the Taconic and Green Mountains, Ordovician and on to the east Ordovician in the mountains much metamorphosed and not improbably, but not surely, pre-Cambrian rocks in the inner parts of the mountains, what we may call the core. Then the granite hills, which are Devonian or later, between the mountains and the Connecticut Valley. Thus passing from west to east we have in the Adirondacks of eastern New York, mostly pre-Cambrian, across the beds under the lake, mostly Ordovician to the Ordovician beds of the eastern part of the Champlain Valley and including the marble belt and across the Green Mountains, over Ordovician and generally greatly altered rocks east of the mountains to the granite uplifts, which have been pushed up through the schists, etc., to the Connecticut River. This in rough outline gives the general features of Vermont geology.

In the bulletin above mentioned Mr. Dale gives twenty varieties of "Calcite and Dolomite Marbles." As has been said, very few of these have ever been quarried for marble but only as limestone which could be and in most cases had been burned for quicklime.

Mr. Dale writes: "This bulletin is based on a reconnaisance of the deposits of dolomite and marble of Windham and Windsor Counties made by the writer in execution of a plan to determine the relations of the calcareous beds east of the Green Mountain axis and those of the west of it . . . . those of Orange County . . . . and on a visit to those of Franklin, Lamoille and Washington and Addison Counties and those of the eastern part of Rutland County and the western part of Windsor County. . . . 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 none of it been geologically mapped on an adequate topographic base map, much of the geology has yet to be unravelled."

"Although the structural observations recorded in this bulletin are likely to be of service when the final geologic mapping is done, they are insufficient in themselves to determine the exact place in the geologic column to which many of the marble and dolomite beds should be assigned. Such indications, however, as the data afford of their age will be found in the section on the geologic age." I have thought that it might be convenient to any readers who may wish to know as to this question of geologic age, if it was discussed at this time. Mr. Dale writes as to this: "All but one of these deposits (Marble of eastern Vermont) 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 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 ('Geology of Ascutney Mountain,' Bulletin 106, United States Geological Survey)."

"If the interfolding took place prior to the deposition of the Cambrian beds, the interbedded marbles are also pre-Cambrian, 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 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 Townshend and Athens at least, possibly some of these at 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 at 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 during 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 the writer found schist up to seventy-five feet thick, some of it biotitic, associated with Lower Cambrian quartzite. This schist occurs also at several other points on that side of the range as well as on the intermediate ridge on the 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 are conformably overlain by schist of sedimentary origin and may, for the same reason, belong to the Lower Cambrian. The Berkshire schist which overlies the marbles of the Vermont Valley, includes here and there in Vermont and in Massachusetts small areas of marble, and in Vermont some thick beds of quartzite. . . . From the foregoing facts and the occurrence of Lower Cambrian schists west of the Green Mountain axis it follows that the schist that underlies, overlies or encloses calcite dolomite marbles in Richford, Waterville, Johnson, Stratton, Dover, Wilmington, Whitingham, and Readsboro may belong to the Lower Cambrian or to the Berkshire schist (Ordovician)." Bulletin 589, United States Geological Survey.

"The quartzose marbles of Topsham and Washington, described by C. H. Richardson, belong to a formation as the Waits River limestone, which is regarded by him on paleontological evidence as of Ordovician age. The dikes associated with the marble differ greatly in age.

"The diabasic dike in Cavendish may be of Triassic age. The pegmatite and biotite granite dikes of Washington and Topsham probably belong to the close of, or to, 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."

Perhaps the most important scientific feature of these deposits is the prevalence of a coarse-textured, manganese-bearing, rose-colored marble, alternating with very small beds of dolomite fine textured and white. In thin sections the demarcation between the calcite and the dolomite is usually sharp. The small percentage of manganese oxide is one and its absence in the other set of beds points to different beds of sedimentation rather than to an intermittent process of dolomitization affecting only the beds without the manganese. The interval of time represented by each little bed must have been short. Some very recent chemical investigations by Bertrand and Medicgreceanus show that both are calcareous and soft parts of marine mollusks Ostrea, Pecten and Mytillus, contain manganese, averaging 0.5 percent.

"May not the manganese, to which the rose color of these marbles is largely due, have been extracted from the sea water by the organisms whose remains produced the calcite sediments? Does not also the absence of manganese from the intervening dolomite beds point to the possible inorganic deposition of dolomitic under conditions not yet perfectly understood?

"As the thickness of the calcite and dolomite beds together scarcely exceed 150 feet at any of the localities visited, whereas in the western part of the State they measure several hundred feet, it is evident that conditions favorable to calcareous sedimentation were of much shorter duration 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 pressure on the dolomite having been more intense on the east of the Green Mountain axis or to some more obscure cause is uncertain.

"Some of the rose-colored marbles are 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 to combine 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 dolomite of Swanton, except that the ground in the former is graphitic and in the latter hematitic and that the breccia of Plymouth, so far as explored, is without corals. The brecciation of the little monographitic beds must be attributed to their having been of rigidity greater than that of the intervening graphitic parts. In thin sections the only perceptible difference between them is that the white beds contain a few quartz grains.

". . . . It may be well to note in this connection there is very little resemblance seen in the Plymouth and the Swanton marbles, the former as heretofore described, being black or gray ground with white or light gray inclusions, while the latter usually has red ground with light red, white, greenish, brown fragments. (G. H. P.)

"The quartzose, graphitic, calcite marble of Orleans County owes its peculiarity to contemporaneous, calcareous and mechanical quartzose sedimentation, so that 25 percent 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 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 gneiss involves either the deposition of calcareous sediment upon denuded intrusive granite and the alteration of these rocks by metamorphism, respectively, into marble and gneiss followed by interfolding or else metamorphism in pre-

Cambrian time of a granite intrusion into gneiss, the deposition thereon in Cambrian time of calcareous sediments followed by metamorphism into marble and the interfolding of both marble and gneiss in late Cambrian or late Ordovician time. The history of marbles enclosed by schist begins with a period of clayey or sandy sedimentation from the erosion of the granite rocks on the neighboring land masses, followed by a period of clear water and organic sedimentation, possibly followed 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 calciferous sediments into calcite and dolomitic marble."

"At this time also the beds were folded into close overturned anticline and syncline. Later movements elevated and modified them. Erosion during the long period since the close of Ordovician time has produced the present surface features and exposed the edges of the marble beds.

"At several points along the contact of the 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 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, the marble is associated on one side with a mass of calcareous epidote, hornblende, and schist. In Mount Holly the dolomite marble and garnetiferous sericite-biotite schist are separated by about five 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, the dolomite at its contact with muscovite 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 marble and dolomite of Swanton and Ira; also the rim of scapolite and garnet surrounding a large 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. Of scientific interest is a ten-foot lens mostly of albite secondary in the marble at Johnson,

described on page 227. Albite feldspars occur throughout the Taconic Range, though in varying amounts and were also found in the schists associated with the marbles and dolomites at Waterbury, Plymouth, Weathersfield, Jamaica, Stratton, Dover, Wilmington, Whitingham, Searsboro, and Readsboro. In thin sections, 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 exceedingly minute and opaque (graphite). Rurile is 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 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 chlorite-albite-muscovite-quartz schist contains a half-inch bed of marble plicated with it. The general inference from the facts here is that the argillaceous sediment under metamorphism passed into a very albitic schist, just as the organic calcareous sediments passed into marble. The impregnation of the marble of Richford 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 marbles of Athens and Townshend should be mentioned here. Inasmuch as the minerals of the humite group are usually found in rocks of the pre-Cambrian age this occurrence affords an indication of the age of the marble. This indication is corroborated by the presence of granite gneiss and the unusual reaction 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 the Cambrian and Ordovician time.

"Of special structural interest is the marble outlier at Johnson. Here are illustrated, in miniature, principles governing the structure of large mountain masses in a region of folding. An intensely folded marble synclinorium, 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 structures of the Green Mountain region. One general feature 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 and of the vast amount of erosion that 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 both, are quite unsuitable for monumental work, but the banded variety described on page 232, Ninth Report, might be used for inside 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 marbles, finely interbedded with fine-grained white dolomite which is also twinned and, therefore, polishable, is a very attractive stone well suited to internal decoration, but owing to the non-durability of its color (when exposed to outside conditions) is unsuitable for outside work.

As stated in the preceding descriptions, some of the marble and especially 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, though 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.

Many of the localities named below have also been more or less fully investigated by Professor Richardson, the writer and assistants, but I give here mainly Dale's notes.

However, it does not now appear to be at all likely that any commercial success will attend exploiting the marble deposits located east of the Green Mountains, still the unexpected may happen. I give the following list for whatever of value it may be to any who may be interested.

THE MARBLE BEDS OF EASTERN VERMONT

Amsden—Calcite, grayish in color interbedded with white twinning to dolomite.
Bethel—Calcite, bluish black, containing graphite, muscovite, probably siderite and much quartz.
Cavendish—Calcite, interbedded with twinned white dolomite.
Dover—Calcite, rose to cream in color, not much white dolomite.
Hancock—Dolomite, cream colored.
Jamaica—Calcite interbedded with white dolomite, some rose calcite, some twinned purplish lenses and grains.
Ludlow—Dolomite, white, granular.
Mendon—Dolomite, white, few twinned grains.
Moretown—Cream white calcite mottled with gray.
Mount Holly—Rose to cream calcite, little interbedded dolomite.
Mount Tabor—Cream dolomite, granular, some twinned grains.
Plymouth—White twinned dolomite with purplish spots. In Ward prospect brecciated white and gray dolomite.
Readsboro—Calcite with large scales of graphite and mica.
Richford—White to pink calcite, light and dark green bands.
Rochester—Calcite and granular dolomite thinly interbedded with schist.
Stratton—White calcite interbedded with twinned dolomite.
Topsham—Calcite, interbedded with fine light and gray plicated beds.
Townshend—Coarse light pinkish and greenish calcite marble.
Washington—Grayish, dark with graphite, muscovite pyrite, much quartz.
Waterville—White calcite.
Weathersfield—Calcite, coarse, rose pink and green actinolitic marble.
Whitingham—Calcite, whitish, large scales of mica and graphite.
Wilmington—Interbedded rose, interbedded with white calcite and twinned dolomite. Some white.

It should be noticed that whenever the marble is overlaid or underlaid by granite gneiss, as it is sometimes, the marble is folded on itself so that the real thickness is only half of the apparent.

In discussing the marbles of eastern Vermont, we are considering outcrops rather than tested masses as is usual in western Vermont. As has been noticed, thus far all the commercially valuable marbles of the State have been found west of the Green Mountains, between the mountains and Lake Champlain. And here it may be noticed that the following pages will necessarily be of little interest to readers who care little about the general geology of the State, but it is all important to those who care to know what is actually found in all parts of the State. As will be shown, there are various deposits of marble to be found east of the Green Mountains, and also many varieties which are dolomite and some which are unchanged limestone, but which are often called marble. As has been noticed, the stone of eastern Vermont, for various reasons, has never been profitable when put onto the market, and all that has been quarried and sold when compared with the sales of western Vermont do not amount to very much. As a rule the stone of the eastern part of the State is coarser in texture, some varieties very coarse. Even in the calcite, and still more in dolomite varieties, there is more or less silica, so also graphite, hematite, actinolite, manganese, siderite. Evidently the varied tints mentioned in following pages are chiefly due to the presence of these minerals, as the colors of the stone in the western marble belt are also caused by their mineral content. Other minerals in addition to those named are found in small amount in some varieties, but the species named are most common, the others very seldom occur. In some cases the eastern marble is badly cracked and broken, so that if otherwise good, they are of little value. The small beds in some cases and the very thin beds in others, preclude the possibility of getting out useful blocks.

Future and more extensive quarrying may possibly reveal more valuable deposits in eastern Vermont than have yet been brought to light, but at present the chances of finding commercially valuable marble in eastern Vermont seem very poor. More definite and specific characters of the eastern marbles follow. For convenience the varieties are arranged alphabetically.

I have spoken of the eastern Vermont marbles, but with these should be grouped five varieties which are more like those mentioned as eastern than they are like the western varieties. In all there are at least twenty, probably a few more, varieties clearly east of the mountains and at least five more which do not in any way belong to the "Marble Belt."

DESCRIPTION OF THE MARBLES AND MARBLE LOCALITIES OF EASTERN VERMONT

By eastern Vermont is here meant that part of the State lying east of the Green Mountains.

AMSDEN

The reader is asked to recall what has been written by way of definition of marble. Many of the so-called marbles of eastern Vermont are, as has been repeatedly noticed, not like those of western Vermont and the stone quarried at Amsden is of this sort.

It is much better suited to burning to make lime used by masons than as an ornamental stone and it has always been used and valued as producing lime, and as far as the writer has known, it has never been attempted to use it as marble. Before the stone is thrown into the kiln it is, of course, broken up and then it is carefully looked over and those pieces, more or less abundant, unfit for burning, on account of impurities, are thrown out. The main impurities are silica and mica. Although the writer has visited the quarries several times, the statements of Mr. Greefull that the following account is very largely a quotation from his account.

Before taking up the definite locality it may be noticed that the immediate region is interesting geologically. As Mr. Dale says, the region between Perkinsville and Upper Falls on the Hawks Mountain ridge includes several outcrops of marble. The enclosing rock is a coarse muscovitic-biotite schist which includes large crystals and lenses of feldspar and beds of quartzite. A few hundred feet south the schist is intruded by a mass about 300 feet square of coarse pegmatite, containing feldspar up to six inches across. Pegmatite dikes as much as three feet thick run parallel to the foliation of the schist. The marble consists of alternating beds plicated, one or two inches thick, of rose-colored and light greenish actinolitic calcite marble, extra coarse. The bunches of actinolite prisms are as much as half an inch long. The rose color is as elsewhere due to a small amount of manganese oxide and the green to actinolite. Biotite quartz, a little feldspar, plagioclase, apatite, and once in a while zircon are found. This is a very attractive marble, but only a few feet are exposed at any outcrop. It has not been tested enough to show whether or not blocks of large size could be quarried. Coming nearer Amsden we find quarries east of the brook that flows into the Black River south of the store at Amsden about three-fourths of a mile east of Perkinsville. Here is a quarry at which about 45 feet of marble is exposed that has a wavy dip. The beds are in places plicated somewhat. There are two dikes here about 100 feet, or a little more, from each other. One of the dikes sends off branches into the marble. This has joint faces on which, owing, as Mr. Dale says, to solution by underground water, so that the more quartzose and micaceous beds project above the softer calcareous bands. The marble is more or less variegated by bands, light, bluish or greenish gray, pure white, or buff in color, from a tenth of an inch to an inch wide. The marble is variable in texture from fine to coarse, in some parts very coarse. These finer bands are dolomite while the coarse are calcite. In some places these two kinds of bands are somewhat mixed. The varied colors are caused by muscovite, mica, hematite, limonite. There are little strips of mica (biotite). There may be other minerals in very small quantities. All the specimens of this stone which I have seen contain more or less silica, often considerable. According to Mr. Dale, this marble is calcite and twinned dolomite, these two minerals are in "small alternating beds" and these beds are very irregular. Occasionally the marble is pink or rose color, due to the presence of manganese oxide. The following analysis, furnished by the Amsden Company, shows the general composition of the material which is burned for lime.

The lime made here is not as white as in many localities, but it is considered very strong and durable. Four quarries have been worked for some years by the Amsden Lime Company; indeed, it is said that the oldest quarry has been open for a hundred years. This and at least one other quarry have not been worked much for some time. Lime from the quarries now in operation can be cast in blocks like cement and, in any case, it is said that it needs no reinforcement when very strong mortar is required. As has been noticed, the lime is dark, about the color of Portland cement. Mr. L. C. White, some years ago, gave the writer a copy of an analysis of the Amsden limestone as used for lime burning, which is as follows (three samples being used):

H_2O	.04	.085	.10
P	.085	.013	.065
Fe_2O_3	1.43	.83	.77
MnO	.60	.84	.61
Al_2O	1.35	.42	.37
CaO	38.94	52.78	50.00
MgO	11.32	1.60	1.66
CO_2	42.74	42.74	40.00

ATHENS

As the writer has not made a detailed study of the geology of Athens he quotes from the reports of others who have made a more thorough study of the area of that town. Mr. T. N. Dale writes in Bulletin 589, United States Geological Survey: "Marble occurs in the western part of the township just west of the west-northwesterly part of the Townshend line, on the east side of the road from Townshend to Athenson, at the Guilds farm. Here are several old openings and the remains of a kiln. The marble outcrops cover a width of over 200 feet and are bordered on both sides by biotite granite gneiss. Some of the gneiss on the west side is finely banded; some of that on the west side 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 ten feet thick. The width of 200 feet probably includes some minor folds and repetitions of the same beds. At one of the openings the marble is interbedded with a few feet of dark yellowish green schist, which consists of a ground of diopside containing hornblende crystals and which is in contact with an epidotic calcitic biotite gneiss. The marble varies considerably. Some of it is very light-pinkish and light-greenish calcite marble in alternating bands. The pink tint is probably due to manganese oxide and the green to actinolite. Some of the bands contain a brownish mica (phlogobite). The tints are more distinct in some of these beds than in others. In some there are a few streaks of black biotite. This marble would finish in slabs that would be very pretty if sufficiently sound and large blocks could be quarried, but it has never been cored or otherwise explored to reveal either the depth or character of the beds enough to show.

Apparently the beds in Athens have never been used as marble, but only as material for making lime. Writing of the Waits River limestone in Report of the Vermont Geologist, 1923-1924, Professor Richardson says: "The Waits River limestones traverse Bethel in two belts, separated from each other by a rather broad belt of phyllite. In Randolph, north of Bethel, there are three belts of limestone, separated by belts of phyllite. The eastern end of the two limestone belts in Bethel occupies a limited area in the northeast corner of the township. The village of East Bethel is situated upon this limestone. The terrane extends in a southerly direction into Royalton. It does not exceed one mile in width even in the widest part.

The eastern belt belongs to the Waits River phase, which is lighter gray than the Washington phase and often closely plicated. Some of the beds are sufficiently massive and recrystallized to receive a handsome polish, and are, therefore, a marble. For further details of this marble see page 235 (in the account of Washington). In structure some of the beds are massive while others are shaly. In texture it is fine to medium grain. Its essential mineral composition is calcite and silica. The western belt of the Waits River limestone in Bethel occupies the north part of the White River Valley. Its color is normally a dark gray without the lighter bands of the Waits River phase.

On page 219, of this volume, Professor Richardson says of the Athens marble: "Marble occurs in the western part of Athens on the Eugene Bemis farm. It is furthermore located on the east side of the road from Athens to Townshend, within twenty-five rods of the road and only a few rods north of the Athens-Townshend town line. The marble outcrops over a width of about 150 feet and is flanked on either side by a biotite granite gneiss. . . . The beds are narrow and interfolded with actinolite and chlorite schist. . . . The marble varies widely in color. Some samples are white, some a light pink, others a light green hue. The pink color is due to manganese, the green to actinolite, and in some cases the color is intensified by epidote. One sample from the Bemis quarry is pink to pinkish-white, coarse-grained marble, with a few irregular streaks and bands of actinolite. Calcite constitutes about 95 percent of the rock. It carries many small crystals of clinozoisite. In ordinary light these crystals are of a clear greenish-yellow color. There are also a few well-defined crystals of dolomite and grains of titanite. The clinozoisite is regarded as the mineral considered by Dale as of the hematite group." Professor Richardson evidently places this marble in the Cambrian.

BETHEL

As to the marble of Bethel, Richardson writes: "The Waits River limestone, Ordovician, which includes the quartzose marble of Topsham and Washington, ... extends southward into Windsor County and crops out along a small brook, tributary to White River, two miles northeast of Bethel, half a mile west of East Bethel. The marble is in beds one to five feet thick in graphitic sericite schist. It was at one time burned for lime. A specimen from a ledge about 1,000 feet south, ten feet west, of the crossroads is a dark bluish-black, weathering brownish, quartzose, muscovitic and graphitic calcite marble. The calcite greatly exceeds the quartz, which in turn is more plentiful than the muscovite. The interbedded sericite schist is very quartzose, graphitic, garnetiferous and magnetitic and contains 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 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 to see any economic possibilities in this marble at this locality."

CAVENDISH

The ledges in Cavendish are mostly hard crystalline metamorphic but there are three belts of a sort of marble, one in Cavendish Gorge, one in the northern part of the town, and a third nearer the town line and that of Weathersfield. Three miles northeast of Cavendish village a calcite marble was quarried and burned for lime years ago. About three miles north of the village the road forks and on each side of the western branch marble outcrops. Near the fork in the road there is schist containing garnets, below the marble. East of the east fork of the road the marble is overlaid by granite gneiss. A short distance, perhaps half a mile south of Cavendish station, is an outcrop where there is an old quarry long unused, and a limekiln. This is a short distance east of where the railroad track makes a turn from due east at the north to south and west and continues south to Bellows Falls. Here there is a bed of white dolomite of no great thickness, about twelve feet average. Below it is a bed of granite gneiss which is made up of quartzite, feldspar, mica (biotite and muscovite). The dolomite dips under the gneiss, which is foliated. This gneiss appears to dip under the dolomite. Through the gneiss are intruded pegmatite dikes, so that at some time there has been considerable activity here. The dolomite is very white and encloses lenses of calcite, usually of a pink shade, and also veins of smoky quartz, which are slender and light in shade, also mica. The dolomite is very fine in grain, while the grain of the calcite is much coarser. About a mile south of the old kiln is another outcrop of the dolomite in a thicker bed. Apparently the dolomite is surrounded by gneiss. The geology all about this locality is quite complicated, especially in Cavendish Gorge, through which the Black River flows. Here the marble is, in places, much thicker than in the localities just mentioned, being over seventy feet. It is dolomite like the rest, but encloses beds of actinolitic calcite and mica schist, while above and below it is schist or granite gneiss. This outcrop is near the town line of Baltimore, perhaps half a mile west of the line. Of this gorge Mr. Dale says: "As the gorge meanders in the direction of the strike, which ranges from north 35° east to north 15° west, and as the gorge is crossed by a diabase dike and by a fault the distinction between its metamorphic igneous and metamorphic sedimentary rocks is not clear. About three miles north of the north end of Cavendish Gorge and a quarter of a mile south of the road fork at School 6, west of the road, the following section was observed:

	Feet
Garnetiferous mica schist	15
Granite gneiss	15
Pink and white dolomite	15
Granite gneiss	5
Covered space	
Garnetiferous mica schist	40
(On both sides of the road)	

"The whole series strikes north 10° east and dips 20° west."

Although not a marble, mineralogically, the verde antique of Cavendish should be noticed in this connection. It is many years since the quarries of this stone were abandoned, as other localities in the State have been used and as the stone is always called in trade a marble and as such is extensively used by the Vermont Marble Company. Historically the Cavendish verde antique is of interest as the first quarries of this stone in America were those of Cavendish. The Verde Antique of Cavendish is harder and more difficult to work than that of Roxbury or some other localities. It contains no carbonate of lime, more silica than the Roxbury stone. Because of the expense incurred in preparing this stone for market it did not prove profitable to quarry it, probably, the quarry was, as noticed above, abandoned many years ago. Nevertheless, it is, when properly treated, a very elegant "marble," as is the Roxbury Verde Antique which it closely resembles in color and brilliant polish.

DOVER

There are two marble beds in the northwestern part of the township of Dover, about a third of a mile north of Mount Pisgah. This stone was burned for lime many years ago and has never been used, or very seldom, as marble. Muscovite (mica) schist is associated with the marble. This schist also contains considerable graphite. Also in the immediate neighborhood is a feldspathic mica schist which seems to be below the marble. The marble is a coarse-grained variety, pinkish or rose, variegated by green streaks or bands not very distinct and by white streaks of dolomite, with lines of pyrite.

Another marble locality is on Mount Pisgah, near Somerset town line. "North of Mount Pisgah there is a saddle at the 2,700-foot line level, which was formerly utilized as a road that ran from Dover to the sawmill 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 into Chase Pond in Somerset. . . . On the 3,000-foot level, and about 500 feet from the Somerset

line, this brook crosses beds of white dolomite, about fifty feet thick. Small quantities of quartz mica and probably pyrite are also present in some of the rock. The calcite part of the stone is coarse grained with a little quartz. It appears to be very doubtful as to the commercial value of the Dover marble, but it has not as yet had sufficiently thorough examination to enable one to give a certain report."

HANCOCK

Hancock is in both the east and west areas. Limestone was burned for lime many years ago at a locality on the west side of the White River Valley, or more properly the western branch of White River. The locality is near the Rochester town line. The town of Hancock is really on both slopes of the Green Mountains, but the localities here considered are on the eastern slope. White River and, of course, its tributaries flow into the Connecticut at White River Junction. Hence the marble of the eastern part belongs with other deposits east of the mountains, though nearer the divide than any other deposit here mentioned. The rock at this locality is a yellowish or buff color and, as is true in several of the eastern localities, is found between a muscovite granite gneiss at the top and "a finely plicated chlorite muscovite quartz schist below. This dolomite is fine grained and includes some quartz, a very little zircon and limonite stains from siderite."—Dale.

JAMAICA

All the marble outcrops in the township of Jamaica are to be found in the east part of the area, on or near the eastern foot of Ball Mountain.

As the writer has not carefully investigated this area the statements here given are largely taken from Mr. Dale's account. There are several beds of calcite and dolomite marble in the area. Whetstone Brook enters West River two and a half to three miles southeast of Jamaica village. At a bend in the brook on its north bank, about 2.6 miles southeast of the village, on the Prouty farm, ten to twenty feet, possibly more, of marble . . . . dips 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. The marble beds are faulted with displacements of from one to six inches and the fault planes are filled with quartz. The marble consists of beds of rose-colored calcite marble an inch or so in thickness alternating with beds of white twinned dolomite from three-tenths to one inch thick. The calcite is coarse. The dolomite very fine. Both marbles contain grains of quartz and microcline and a little muscovite. About forty feet above the marble, the overlying schist contains two beds of dolomite, one and two feet thick, separated by a little schist, showing that dolomitic and argillaceous sedimentation were intimately connected.

Southeast of Jamaica village and probably less than 500 feet southeast of the road corner . . . . a white dolomite marble crops out here and there over a width of 125 feet. . . . At the west bank of West River this dolomite crops out again for a length of sixty 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 one and one-half inches thick of pink calcite marble. At a point one and three-quarters miles southeast of Jamaica, on the road crossing, and north of the covered bridge over West River, is a railroad cut through a series of beds of schist, granite, gneiss and marble. . . . The beds occur in the following order:

SECTION IN RAILROAD CUT SOUTHWEST OF JAMAICA, VERMONT

	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	8
Calcite and dolomite marble thinly interbedded	15
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 and west road, the schist that overlies the highest member of the section is finely exposed. . . . It is a garnetiferous muscovite hornblende chlorite schist, containing a little black tourmaline graphite and pyrite. Its thickness is probably considerable.

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 bed of contorted 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 also crop out 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 one to five and a half inches thick, possibly thicker, alternating with beds of like thickness of twinned white dolomite marble. Streaks of mica occur at many of the junctions of the beds or form with quartz little darker beds here and there. . . . The calcite, with minute specks, presumably of manganese . . . . is coarse grained. The dolomite is 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 to internal decoration on account of the pleasing contrast between the rose-colored and the white bands, but the rose color would not be durable under outdoor exposure.

Nearer the station at Jamaica and near a bridge over West River, some of the same beds as those mentioned above are well exposed in the railroad cuts. Northeast of the village, south of Adam Pond, there are several indications of marble but no tempting outcrops, as the calcareous streaks which occur are very thin, schist being far more in evidence than marble.

Dale writes: "Ball and Shatterack Mountains originally formed a continuous schist mass but have been cut down 1,000 feet by West River in its meandering course. East of Ball Mountain the river follows the strike and separates that mass from Turkey Mountain. Marble crops out in this vicinity at three points—along the east foot of Ball Mountain, 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.

"At the above locality, in a pasture and over 100 feet above the river, and on the west side of it, there is a bed of dolomite. On the west the dolomite is underlaid by a bed of quartzite, and it also includes several little beds of the same mineral. Under the dolomite and considerably higher is a bed of muscovite biotite schist. This schist is on the east slope of Ball Mountain, near the foot. The schist also contains garnets and feldspar. This same schist appears to cover the dolomite. This dolomite is very white in some parts, cream colored elsewhere. It is fine in texture and contains grains of quartz, feldspar, microcline muscovite in small amounts, and at one outcrop it includes small bits of coarse calcite. Going northwest to the river there are outcrops of mica schist cutting the dolomite, and continuing downstream for several hundred feet. Following down the river marble is found on the south bank. This outcrop shows marble for nearly 100 feet.

Dale says that this is probably underlaid by "a micaceous quartzite or gneiss." It is overlaid by epidotic biotite gneiss. The marble is rose calcite mixed with white dolomite which in some places is bluish tint or gray bluish.

At a point known as the "Ox Bow," on the west side of Turkey Mountain, near the base, where West River turns from flowing south to west, there is a marble outcrop, extending several hundred feet along the railroad. This marble is close-grained dolomite enclosing a little of the rose calcite. There is also a little mica. The bed does not seem to be very thick.

Above the dolomite at the north there are several feet of quartzite, perhaps ten feet, and above this is schist. In the river are large boulders, outcrops of muscovite quartzite, in which there are little beds of dolomite of not over three feet in thickness, though the real marble beds are above all of these.

Dale writes: "Turkey Mountain is the long little incised ridge east of Ball and Shatterack Mountains. . . . On the west side of this ridge, about 550 feet above the river, is a longitudinal bench, or hollow, about 600 feet wide from east to west, caused by the partial erosion of the dolomite between the harder rocks below and above. At a point about a mile and a quarter south of the Windham Township line this dolomite was burned for lime as shown by a kiln and several small quarries. Its thickness is at least 125 feet and possibly greater. The dolomite from the southern opening is of light cream color with grayish streaks. It contains some quartz and muscovite. The dolomite from the northern opening is of light bluish-gray tint, in some places whitish with light to very dark purplish plicated streaks, also with some faintly pinkish calcite lenses and a little muscovite here and there. . . ."

There is very little reason to think that these just mentioned dolomites can be of commercial value because of the frequent joints in the beds by which sound blocks of marble are spoiled. The "bench" mentioned by Mr. Dale is confined between cliffs of muscovite schist on the east and gneissoid rocks on the west. The schist of the eastern side contains garnets and black tourmaline.

Dale writes: "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."

In the Report on the Geology of Vermont, 1861, Dr. Charles Hitchcock, on page 556, volume I, writes of beds of limestone

in South Windham which Dale thinks may be "a continuation of those on Turkey Mountain."

JOHNSON

Limekilns were used in Johnson many years ago, but as far as is known, none of it has ever been used as marble. A bed of limestone, which Dale calls "marble," was long ago burned for lime, is found north of the village. Like many of the limestone beds in Vermont, especially east of the Green Mountains, this is between the more abundant beds of schist. Mingled in the limestone is often dolomite and less abundantly feldspar. The marble is white calcite with streaks of chlorite. This deposit has not been carefully explored but there is little probability that the quantity of usable marbles is very great. Dale writes of this: "In passing from the above-named locality (Bradford) north-northeastward onto the ridge, small masses of marble are found in the schist band. Just over the crest on the Butler farm is a larger outcrop of marble, commonly quarried, and the remains of a kiln farther down near the brook flowing southwestward. The marble is seventy feet thick but not more than 100 feet long and is bordered by sericite schist on both sides. The marble is a whitish calcite marble with fine black bands (graphitic). . . . About fifteen feet west of this marble mass, and separated from it by schist, is a small marble outlier about ten feet wide and fifteen feet long surrounded by schist and containing some lenses of schist and dolomite. The marble also contains some lenses of schist and of dolomite. It is strongly plicated. The schist has deep glacial striæ. The course of the plications in 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 this on the larger marble outcrops is important for it shows that these folds are not anticlinal projecting through the schist but synclines underlain by the schist and, therefore, contain but a very small amount of marble."

LUDLOW

Many years ago there was a quarry and near it a kiln, where the rock from the quarry was converted into lime, but it has not been used for a long time. This rock is dolomite and is probably of no value as marble as it is badly broken by numerous joints so that blocks of stone are very hard to get out. There is also a good deal of quartz in the dolomite. Moreover, there is only, apparently, a small quantity of the marble as the bed is not thick nor long. Schist, micaceous quartzite, surround the dolomite which may very probably be of the same age as that of Plymouth. This dolomite is light in shade, being usually a shade of gray, sometimes with a not very distinct blue shade and also there are little bands of yellow, or yellowish, calcite.

MENDON

Northeast of Rutland and about 1,000 feet higher than the city a dolomite was quarried thirty years ago. The stone, because of its content of magnesia, was used by a paper mill at Bellows Falls. This stone is white or in some parts of the beds slightly rose pink. There are several quarries east of the main road from Mendon to North Sherburne. As far as appears this stone has not been used as marble.

MORETOWN

In this town, which is next north from Montpelier, some of the ledges were tested for marble nearly seventy years ago. A quarry was opened and operated for several years without much success. There is marble here on the road a mile or more south of Waterbury on land owned by Henry Carpenter, on the west slope of Moretown Hill. The stone quarried here is calcite, very light in shade. Schist appears to enclose the marble.

Of geological interest is the following from Dale, who writes: "Farther down Duxbury Brook there are large outcrops of schist similar to those in contact with the marble. . . . 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."

MOUNT HOLLY

At a locality in the southeastern part of the town of Mount Holly there was a limekiln seventy years ago which has been used at times since. The marble crops out in several places on the Edgerton farm. It is really in the midst of the Green Mountains, having Mount Tabor on one side and Mount Terrible on the other (east). Northwest of the Edgerton house marble crops out from a bed over twenty feet thick which lies on a mass of schist

containing quartz, biotite, sericite, epidote, garnet, and some magnetite. Immediately under the marble and between it and the sericite schist is a bed of schist in which is considerable actinolite. On the opposite side of the road, several hundred feet southeast of the house, is a bed of marble twenty feet thick in the thickest part, less elsewhere to about fifteen feet. All the marble is coarse grained and very light in shade.

MOUNT TABOR

I have not visited this locality and will quote Dale's account, *l.c.*, p. 237: "A trifle over five and a quarter miles east of the Danby station on the Rutland Railroad, and 1,540 feet above it, on the Green Mountain range at the 2,200-foot level, ... at the divide which separates the drainage basin of the Connecticut River from that of Lake Champlain, a little below the road from Danby to Weston, is an eastward facing overhang cliff known as Devils Den, fifty to seventy-five 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 the undermining of the lower part. At the foot of this talus begins a brook which finally empties into the West River, nine miles to the southeast near Londonderry. The cliff consists of banded garnetiferous biotite muscovite granite gneiss with a little chlorite. . . . A few hundred feet east of this locality, on the northeast side of the road, is a cliff forty feet high, exposing the following series, beginning at the top: Muscovite quartzite with magnetite, twenty feet; slightly muscovitic quartzite with a few rounded grains of zircon, ten feet; dolomite, twenty feet; all striking the same way. . . . 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, and rarely a grain of zircon and minute black dots. About 350 feet further east there is an outcrop of similar dolomite. . . . A little east of this is an old kiln where the dolomite from these localities was burned many years ago. The gneiss of the Devils Den is pre-Cambrian age and the dolomite and quartzite are presumably of Cambrian age, as are also large outcrops of quartzite cut by Big Branch on the lower part of its course within a mile and a half of the village of Mount Tabor, in the west flank of the range on the road to Devils Den."

PLYMOUTH

The marbles found at Plymouth are much better known than most of those mentioned from eastern Vermont. Like so many other outcrops of limestone of this region, these are dolomites and occur as lenses in mica schist or associated with underlying quartzite and finally passing into quartzite. On the east side of Lake Amherst and considerably higher than the lake is a quarry, formerly worked, from which considerable stone was once taken, but which has been closed for many years. Here the marble is dark gray with, in some lights, a bluish cast. Included in this as a background are numerous light-colored bodies, sometimes nearly white, sometimes light gray, in strong contrast with the very much darker mass, thus the marble is a breccia. The inclusions are little rounded and of very variable size, though mostly between four and six inches long and usually not more than half an inch thick. The dolomite contains more or less graphite and muscovite, usually very little muscovite. On the north side of the road to Plymouth Five Corners, not a long distance (perhaps half a mile) south of Plymouth Church, there was long ago a limekiln and small quarry, furnishing stone similar to that just named.

East of Lake Amherst, towards Tyson, Dale reports the following section—*l.c.*, p. 242: On the west slope of Mount Solitudus there is a bed of cream-colored dolomite, over which is a bed of schist, which contains white bits of feldspar, which are scattered through it. At one time there was a limekiln not far north of Plymouth Union. At this place there were several places where rock had been taken out. The dolomite here is light pink. Still farther north of Plymouth Union there was another limekiln and outcrops of dolomite of considerable size. The white dolomite here is spotted by little purplish patches.

There appears to be a large amount of dolomite here and very sound but there is need of more extensive investigation of the beds before one can be sure. Another dolomite bed is to be seen at what is known as the narrows between Black Pond and a reservoir. Here, east of the road, there is a fairly thick bed, twenty-five or thirty feet, of dolomite and there are more beds of dolomite which have not, apparently, been prospected.

For other notice of Plymouth see page 229.

PUTNEY

On page 333 of this report, Professor Richardson writes, as a result of recent investigation: "The Waits River limestones, or quartzose marbles, do not occur in Athens or Brookline. In Westminster they form a more or less continuous bed stretching north and south across the township and extending south into Putney. They range in color from a medium to a dark gray.

A few are slightly banded. The only essential minerals are quartz and calcite. The quartz grains are usually small and well rounded, but sometimes they appear elongated by the pressure to which the rock has been subjected. In the outcrop two miles south of Saxtons River both the quartz and the calcite have been drawn out in the direction of the schistosity. Small flakes of sericite are abundant and scattered uniformly throughout the rock. Magnetite in small grains and powder is well distributed. There are a few small grains of titanite present and much limonite stain. In the southern part of the township the quartzose marbles are finer grain, less banded and richer in calcite. On Windmill Hill in Westminster the marble shows a slight schistose texture and contains approximately 60 percent of calcite and 40 percent of quartz."

Richardson writes of Putney: "The quartzose marble is medium grained and massive. It contains approximately 75 percent of calcite and 25 percent of quartz. The calcite is perfectly recrystallized. . . . There are a few flakes of sericite and grains of titanite in the marble. The beds are interstratified more or less with the phyllites and appear to be in a synclinal trough in the phyllites.

READSBORO

In Readsboro there is a stone, years ago quarried and burned for lime, as far as I have ascertained it was never used as marble. A very short distance north of this is a cliff of schist which is in small folds, plications. This schist is full of biotite and feldspar. Farther up on the cliff the rock contains muscovite (light-colored mica) and incloses a second marble bed of no great size, the entire mass is apparently a metamorphic and sedimentary rock. The schist continues as one goes up the hill to a height of nearly 300 feet. The marble is calcite, coarse, with numerous scales of phlogopite (light-colored mica), quartz grains, graphite, and sometimes green actinolite. But in some parts these latter minerals are wanting. Near its base this cliff or ledge is more filled with biotite (black or dark mica) and as noticed above, the mica is lighter muscovite.

RICHFORD

A marble in thick beds was quarried two miles northeast of the village of Richford more than fifty years ago and a limekiln built and used. This is a calcite marble. In the thickest bed it is over 100 feet; other beds are less. White, green or greenish, pinkish, often in streaks or bands. About the marble is schist, much like that adjoining some of the other marble beds and common in many localities in the State. In many parts of the marble beds there is chalcopyrite and for a time it was thought that a copper mine could be found here, but this never materialized. This sulphide of copper has been mined in Fairlee, Corinth, Strafford and some other localities and at some of the mines as that Vershire and Corinth a good deal of ore has been taken out but all mines are now deserted.

ROCHESTER

About three miles south of Rochester village, in the valley of White River, there were limekilns and quarries many years ago. At the base of the rock is schist and no marble appears until about 200 feet above the valley it is found dipping beneath the schist. Considerably higher there is a coarse marble streaked with schist. Dale writes of this locality: "The thin bedded rock of the lowest outcrop consists of streaks of white calcite marble merging or alternating with dolomite without twinning . . . . both containing some muscovite, quartz, plagioclase, epidote and magnetite and alternating with laminæ of closely plicated bluish or greenish gray sericite schist with minute yellowish green epidote lying transverse to the strike of the plications. The rock also contains a greenish biotite. In the little calcite beds, the thickest three-tenths of an inch thick, alternate with greenish gray dolomitic beds containing much epidote and a little muscovite. The coarser rock higher up is a mixture of medium-grained, cream-colored calcite marble, and clouded cream-colored dolomite, mostly granular, in part twinned, both containing quartz, muscovite, greenish biotite, epidote, apatite and magnetite. The rock itself is veined with smoky quartz and at intervals has micaceous streaks."—*l.c.*, p. 240.

SEARSBURG

In Searsburg we find marbles much like those of neighboring parts of Bennington County, especially those found in Wilmington. There is in Searsburg calcite marble and dolomite, the former rose in tint, the latter pure white; alternating in thin beds. They are found in small outcrops on each side of a ravine or valley, through which flows a small brook, which soon empties into the Deerfield River, north. There is here considerable thickness, 200 feet, of dolomite and calcite. West of the marble beds

is a mass of schist, biotite, albite, quartz, lime carbonate, pyrite and zircon, as determined by Dale. On or near the east side of the brook mentioned above, other outcrops of dolomite appear, and as usual plenty of schist. The schist contains a variety of miners, sometimes it is garnetiferous, sometimes feldspathic. As in the other beds in this locality, the marble is partly calcite, partly dolomite. As noticed above, the calcite is often more or less pinkish, the dolomite pure white or nearly so.

SOMERSET

East of Mount Pisgah, in Somerset, is an outcrop on East Brook of calcite marble of a yellowish white shade and rather coarse in grain. In several other localities in Somerset, other outcrops of marble have been reported but the writer has not examined them. In past years there have been several limekilns used in this town.

STRATTON

In Stratton there is an outcrop of marble nearly a mile west of the town line of Wardsboro. Lime was burned from limestone in the southwest corner of Stratton, in what was Somerset, but now Stratton, there are two beds of dolomite. This locality is near a house occupied by A. J. Pike. There are here about sixty feet of marble, beneath which, and under as well, is mica schist, containing small quantities of other minerals. This marble is a calcite marble, white or bluish white. There are also alternating beds of dolomite, of fine texture, while the calcite part is coarse. In the northwest part of this quarry the calcite marble is pink in tint. There are thin bands of quartz and also light and dark mica (muscovite and biotite), mostly in the lower part of the marble. In some places there are a number of other minerals such as feldspar, apatite, zircon, tourmaline, and epidote. As to the extent of the marble all that now can be said is that it needs more thorough exploration.

TINMOUTH

In some parts of Tinmouth there were, long ago, quarries operated for a time and considerable marble taken out. The beds of marble are reported as of some thickness, but the stone was imperfect and so much so that it had no commercial value, and has never been used to any extent.

TOPSHAM

There are several localities in Topsham where marble has been sought. Three have been more or less extensively worked. The marble found in Topsham is evidently very similar to that found in the town of Washington, although this is rather lighter in shade. Obviously it is what is called in the Reports of the Vermont State Geologist "Waits River Limestone" or "the Washington phase of the Waits River Limestone," named by Professor Richardson, and found quite extensively in central Vermont, east of the Green Mountains. As it was first described in the town of Washington, this stone will be more fully discussed under the marble of that town. It is of a dark gray shade, varying more or less in different specimens. Perhaps the largest opening of this stone is about a mile east of the Waits River church on the road toward Bradford. Here it is a compact, well-banded stone. The bed is several feet thick and contains lenses of quartz which contain mica and pyrite. When well finished it takes a pretty good polish but is rather dark and hard for many purposes.

In Washington the limestone lies in horizontal position upon the crest of the anticline. In Derby the fold becomes quite sharp. After passing over this anticline in a westerly direction the dip is uniformly to the west. It is in this limestone that the broad, U-shaped valleys of the Barton and Black Rivers have been cut. In this limestone a zone of crushed graptolite has been discovered. In this limestone many Devonian granites of great economic importance appear. . . . The third member is darker than the other two, more carboniferous, sometimes shaly and never susceptible of a polish. It traverses Irasburg, Coventry and Newport and dips uniformly in a westerly direction. Lying as it does at the foot of the western slope of the anticline, it is the youngest phase of the limestone series.—Fourth Report, Vermont State Geologist, p. 274, 1908.

This limestone, in its various phases extends from Canada, where it is about forty miles wide, south through Northfield and still farther to Hartford, where it is divided by the intrusion of the Bradford schist. The western member terminates in Cavendish. The eastern member crosses Windsor and Windham Counties. It continues south through Woodstock, Springfield, Rockingham, Brattleboro, and probably through the southern line of the State. In most of this marble there is some pyrite and when exposed to weather this oxidizes and stains the stone rust color, as is seen

on gravestones in the Washington cemetery. This marble is not likely under any conditions to be useful, as it contains pyrite and other injurious minerals which are easily affected by weathering. It is also too hard to be readily used. The marble in Topsham is Richardson's Waits River formation. There are not very significant outcrops of this marble in the town.

TOWNSHEND

A few outcrops appear in different parts of Townshend. These are not in most respects like the Waits River stone. They are calcite marbles of a pinkish shade mingled with dolomite, usually alternating, with one of white or nearly white color, also there are very light beds of green tint. The grain is not very fine and some of it is very coarse. Other beds are more gray with a greenish tint. Some seventy-five years ago there was a kiln for burning lime a mile or so east of the village and sundry outcrops of marble near the main road, south of the Horace Gale farm.

On page 329 Professor Richardson writes as to the marble of Townshend as follows: "Marble occurs on the farm of Stanley B. Martin in Townshend. The outcrops are about a mile southeast of Townshend village and 500 feet above the valley. The marble beds appear less than 100 feet in width and are flanked on either side by a finely foliated biotite gneiss. The purest specimen collected is a white saccharoidal marble. Under the microscope it shows an interlocking mosaic of pure calcite crystals, some of which show well-developed cleavage, others broad twinning bands. There are a very few flakes of chlorite and biotite in this marble."

WASHINGTON

Attention was first called to the "Washington Limestone" in 1802 in the Third Report of the Vermont State Geologist, by Dr. C. H. Richardson; and in numerous notices in several subsequent reports by the same author, there is given an extended account of "The Washington Limestone," at first called "Waits River Limestone," but this name, being preoccupied, was changed to that given above. Most of the Vermont marbles and limestones are not very complex in composition, but, according to Doctor Richardson, this is much more complex than most rocks of its kind. As it will be interesting to some geologist, the following analysis of the Washington limestone is given, quoted from Third Report, Vermont State Geologist, p. 66, 1902:

"I know of no marble or limestone in Vermont that is composed of as many substances as the limestone of Washington. As Richardson's analysis shows, the stone is mainly composed of a few substances only, the more numerous components occurring only in small amounts. Richardson recognizes two phases, *viz.*, the Waits River and the Washington. In both phases it is a hard stone and while it varies much in shade, it is always gray, from light gray to very dark. This stone is quite widely distributed throughout the State. The shade of gray is much lighter in the northern parts of the State than in the southern. Diversity of shade in many localities causes the variety in appearance and adds much to its appearance. It has sometimes been advertised as "Imperial Variegated Granite" which, of course, is only a trade name. First and last, since this stone was first quarried in 1893 a considerable quantity has been taken out. Richardson reported thirty years ago that "within five years more than twenty-five quarries were opened by different parties" (in Washington).

According to Richardson: "The Waits River limestone . . . . falls into three distinct phases. The first of these, the beautifully banded variety, resembling the Columbian marble of Rutland, occurs at Willoughby Lake in Westmore. The typical locality is more than seventy-five miles south in the town of Topsham, Orange County. The dark steel gray Washington phase appears in Derby, Brownington, Newport and Coventry."

WATERVILLE

In the days of fifty or seventy-five years ago many farmers, who discovered any form of limestone on their farm, apparently built a more or less rude kiln and burned what lime they needed. As is seen in the accounts of various and numerous towns, especially in those east of the Green Mountains, old limekilns are scattered far and near over the State. But of late years most of these have long been abandoned, since it was better to buy lime manufactured in larger and modern kilns than to use an usually inferior article.

As is noticed, most of the lime or marble deposits were never used, except, possibly very seldom, for anything else than as material for making lime, and fortunately for the owners in most cases no attempt was made to use the stone for marble. All this seems to be true of the Waterville stone. Beds of calcite, light-colored marble are found in several parts of this town, but none of them have been thoroughly investigated.

WEATHERSFIELD

I have not explored the region in and about Weathersfield. Dale says: "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 which lies east of the tributary of Black River upon which Felchville and Amsden are situated; and a central belt on Pine Hill."

In "Geology of Vermont," 1861, vol. II, p. 749, it is stated that: "Formerly much lime was manufactured in Weathersfield." This was before the building of railroads, but since then less has been made. The Weathersfield lime had the disadvantage of dark color, but on the other hand it proved to be very strong and durable, and nearly equal to cement. It was in demand for railroad culverts and other such work very successfully.

WHITINGHAM

Like many of the towns here mentioned, Whitingham was years ago dotted with limekilns. These have long since been abandoned like many others in the State. Not far from some of the old kilns are deposits of calcite marble, white or light gray, rather coarse in texture.

WILMINGTON

In the town of Wilmington there are several beds of marble near Haystack Pond and another near Mud Pond, not far south. Calcite and dolomite marble is found east of the main road north and south and somewhat more than a mile northeast of the village. The marble in the northern part of the town, near the ponds named, is pinkish in some parts, light yellow in other parts. The marble for several miles is both calcite and dolomite in alternate layers. The dolomite is white, the calcite is more or less pink. Both are coarse in grain. No exploration has been made at any of these localities and there seems to be doubt as to quantity and soundness of the stone. Except near the southern locality it has not been used for making lime as far as I have been able to discover. Adams, in his first report on Vermont geology, writes of serpentine as occurring in Roxbury, Cavendish, Lowell, etc.

The frequent beds of marble in Vermont are noticed in the first report of Vermont geology by C. B. Adams, and several pages are given to this subject.

Though in those early days, 1845, the marble interests were very small as compared with recent times, there was even then no little work in quarrying and working marble, especially near Rutland, Brandon, and Pittsford.

The black limestone, now quarried only on the south end of Isle La Motte, was then quarried at Benson, South Hero and several quarries on Isle La Motte, all of which have long since been discontinued, except the old Fisk quarry on Isle La Motte, described on page 145.

Adams' second report mentions a number of additional quarries and gives additional details concerning all then in operation.

After Professor Adams' death, in 1853, very little was published about the marble interests of the State, until Hitchcock's report in 1861, and after this until the present series the first of which was issued by the present State Geologist in 1898.

Especially in discussing the rocks of eastern Vermont, the statements of Mr. T. N. Dale, as given in the bulletins of the United States Geological Survey, are often quoted, not necessarily because the writer is in full agreement with these, though in most respects he accepts them, but because Mr. Dale has much more carefully and thoroughly investigated the localities mentioned than any other authority and his views are by so much entitled to consideration by geologists and others who may study the areas involved. And also, as intimated previously, because as an accumulation of facts and conditions in many Vermont areas, Dale's observations are of no little value in not only a study of the marbles of the State, but of the general geology as well.

Dale calls attention to the difference found between the east and west side of the Green Mountains in that there is found on the eastern side a "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 demarcation between the calcite and the dolomite is usually sharp. The small percentage (0.23 to 0.49) of manganese oxid in one and its absence in the other set of beds point to different kinds of sediment rather than to an intermittent process of dolomitization affecting only the beds without the manganese. The interval of time between the two beds must have been short.

Some recent observations by Bertrand and Medigreceanu show that both are calcareous and soft parts of marine mollusks (Ostrea, Pecten and Myttillus) contain manganese in percentages ranging from 0.15 to 0.91 and averaging about 0.5. May not the manganese, to which the rose color of these marbles is due, largely, have been extracted from sea water by the organisms whose remains produced the calcite sediments? Does not also the manganese coloration from the intervening dolomite point to the possible inorganic deposition of the dolomitic sediments under conditions not yet completely understood? "So, too," Mr. Dale asks, "since the calcite and dolomitic beds on the western side of Vermont are several hundreds of feet thick while the combined beds in the east are far less, whether the agencies which favored deposition of calcite beds were not much shorter in duration on the east than on the west. The dolomite as found east of the Green Mountains are generally twinned while those on the western side are usually granular, as shown by microscopic sections. Why these conditions were unlike on each side of the mountains it is not easy to say, except that more or less geological forces were active to a different degree on the east and west sides of the mountains and this is evident from the different varieties of metamorphic rocks on the two sides."

Writing of these rocks of eastern Vermont, Dale says: "The history of those marble beds which are interfolded with pre-Cambrian granites-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, following by interfolding or else the metamorphism in pre-Cambrian time of a granite intrusive into gneiss, the deposition thereupon in Cambrian time of calcareous sediments followed by 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 the schist begins with a period of clayey and sandy sedimentation from the erosion of granite rocks on the adjacent land masses, followed by a period of clear water and organic sedimentation, possibly accompanied by or alternating with chemical dolomitic precipitation, 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 overturning anticlines and synclines. Later movements elevated and modified them.

"Erosion during the long period since the close of Ordovician time has produced the present surface features and exposed the edges of the marble beds.

"At several points along the contact of the marble dolomite and granite gneiss chemical reactions between silicates and carbonates have taken place under regional metamorphism resulting in a few inches or feet of actinolite or diopside schist or in the growth of actinolite or tremolite within the calcareous beds.

"The most interesting example of this is in Athens, where, page 218, the calcite marble is sharply interfolded with biotite gneiss and between them are a few feet of diopside schist containing disseminated hornblende crystals half an inch in diameter. In Cavendish, page 159, the marble is associated with, on one side, a mass of calcareous epidote-hornblende schist. In Mount Holly, page 228, the dolomite marble, garnetiferous schist and biotite schist are separated by five feet of actinolite schist and a little epidote and biotite. The marbles are filled with fibrous actinolite. In Weathersfield, on Pine Hill, half a mile east of Perkinsville, page 237, 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, also the rim of scapolite and garnet surrounding the large autoclastic block of hornblende granite-gneiss within the pre-Cambrian calcite marble of Fort Ann in Washington County, New York. Of scientific interest is the occurrence of a ten-foot lens mostly of secondary albite in the marble of Johnson described on page 227. Albite feldspars occur throughout the schist of the Taconic Range, though in varying amounts, and were also found in the schists associated with the marbles and dolomites of Waterville, Plymouth, Weathersfield, Jamaica, Stratton, Dover, Wilmington, Whitingham, Searsburg, and Readsboro. In thin sections the albites of this lens many of them simply twinned, measure up to two-hundredths of an inch in diameter and contain minute objects in stratified 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 exceedingly minute and opaque (graphite). Rutile needles are present. . . . There can be no question as to these feldspars being entirely secondary and not altered pebbles of another feldspar.

"The impregnation of the marble at Richford, page 231, with chalcopyrite is unique in the white marbles of the State. As the ore occurs in some of the dip joints, impregnation may not have occurred until long after the first metamorphosis 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 to occur in rocks of the pre-Cambrian age, this occurrence affords an indication of the age of the marble; and this 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 times. Of special structural interest is the marble outlier in Johnson, described on page 227. Here are illustrated in miniature principles governing the structure of mountain masses in a region of folding. An intensely folded marble synclinorium having a pitching axis has been folded transversely and in the direction of the pitch, while the underlying and surrounding 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 tilting 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 folds 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 suffered this minor effect is not surprising."

As has been previously stated, this detailed description of many of the outcrops and deposits of eastern Vermont is here presented less because of their value, present or future, as economically valuable marbles as because by presenting them and their surroundings some knowledge of the geology of many localities east of the Green Mountains is necessarily brought out.

As has been shown, schists of various kinds, gneiss, some granite and in small amounts other rocks and many species of minerals may appear to one who carefully examines the deposits of eastern Vermont. It is possible that when some of the beds of marble are more thoroughly studied and perhaps also new methods of quarrying the stone are discovered, a few of the marble beds may be profitably worked, but in most of the localities mentioned it is quite certain that they can never be profitably operated. This appears to be the unanimous opinion of all geologists who have examined the region.

In many of the outcrops the stone, as far as examined, is much cracked or jointed so that large sound pieces are not to be quarried, elsewhere the beds are too thin to be commercially useful, or the marble contains too large an amount of silica and is too hard to work easily. Some beds contain pyrite which readily decomposes to oxide or iron and stains the dressed stone. Some beds while very attractive when freshly quarried soon fade and lose their beauty. Some are very badly located and so on.

For these and other reasons, there is in most localities in eastern Vermont no prospect that commercial demand can ever be considerable and profitable. As is plainly seen from a study of the east and west side of the State, there has been during geological movements a great difference between the two sides of the mountains by which the various rock beds have been formed.

As has been repeatedly noted, all the marbles of commercial value, with a few unimportant exceptions, have come from western Vermont. As the following pages will show, beds of marble, more or less important, are numerous east of the Green Mountains, but for reasons of different kinds, none of them have been satisfactorily operated. In fact, as has been shown, nearly all the marble beds that have yielded even fair returns within the past fifty years have been located in the Rutland area, and this is true even from early times.

As to the Vermont marbles east of the Green Mountains, Dale writes: "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 metamorphosis consisted of sandstone and shales that in turn were originally deposits of sandstone and clay.

"This formation of quartzite and schists 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 by quartzitic beds. This extends along the valleys and immediately underlies the belt of calcite marble. To this formation belongs the dolomite marble of Pittsford and East Monkton. Then follows the marble belt proper consisting of beds of calcite marble alternating with beds of dolomite and in some places of graphitic mica schist. 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 soda feldspar (albite), graphite, chlorite, pyrite, etc. It includes here and there small beds of quartzite, originally sandstone, of fine quartz conglomerate, and more or less crystalline limestone and is generally veined with quartz and contains many quartz lenses. The 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 calciferous sediments of the underlying series were metamorphosed into marble these clays passed into mica schists.

FINISHING MARBLE

After the blocks, or whatever shape is wanted, have been separated from a layer in the quarry and sawed, or otherwise cut into a desired shape and size or sizes, they are finished over the surface as is wanted. Obviously, a block can be sawed in the direction parallel to the bed in the quarry or transversely or in any direction chosen. If the marble is in any way colored by clouds, veins, blotches, etc., of course, the different directions in which it is sawed give different varieties, sometimes very unlike one another, and it is in this way that some of the varieties are obtained. Usually the most common method of sawing is in the general direction of the quarry bed, but not by any means always. When in such manner as is needed a large block is sawed it goes to the storage yard or the finishing mill. By this time it has been decided whether it is needed to fill some order or that it waits for an order to come.

If the slabs are to be cut, nowadays the cutting is usually done by diamond or carborundum saws, which are wholly unlike the gang saws used to cut up the larger blocks. These are often circular, the teeth alone being diamonds, black diamonds (or bort, chemically diamonds), but useless as ornaments. Small bits of bort are set in the teeth of these saws and are exceedingly efficient, or a carborundum wheel is used. Usually the first work done on a portion of a piece of marble, slab or thicker as may be, is effected by the rubbing bed. (See Figure 47.) As the figure shows, the rubbing bed is a large iron circular plate placed horizontally and freely supplied with sand and water. If the marble is to be used on exterior work, of course, only that portion which is to be exposed needs to be finished, and is used as the saw leaves it; but those parts that are not to be exposed are still further rubbed, ground and finally polished. Naturally all interior work is smoothed and most is polished by machinery or by hand. If the stone is for outside work it is finished in several different ways. The most common are sand, axed or tooled.

A better sand finish is obtained by rubbing the marble with fine sand, using a block of iron held in the hand. Tooled finish is done by hand, the worker using a broad flat tool, while axed finish is caused by a number of small chisels held in a clamp, or a planer may be used. Moldings are largely cut by a planer. Carborundum is used and after several discs, each finer than its predecessor, discs using fine hone stone are used and at last the marble is made very smooth. This only leaves a dull though smooth surface. If the marble is to be polished, discs using felt filled with some sort of polishing powder are used. More or less polishing, especially of narrow pieces, is still done by hand. Naturally, different kinds of stone require different material in effecting a good polish. If there is carved work it must generally be done by hand. Marble workers say that while the carborundum machine works much faster than the hand drill, even if this is worked by compressed air, yet in many cases, as when only a few pieces of each of several different patterns are needed, the pneumatic tools can be most profitably used. Where very fine carved work is to be done, nothing as yet invented can equal the hand of a skilful workman. Of course, where it is possible, machine work is used rather than handwork. Figure 29 shows the finish of white marble caps for columns at the Arlington Memorial Amphitheater.

A few examples of work done at the Proctor shops (Figures 29, 30, 31, 32, 33, 34, 35, 36, 37, 38) by courtesy of the Vermont Marble Company are here illustrated.

AN ACCOUNT OF SOME OF THE MACHINES COMMONLY USED IN THE MANUFACTURE OF VERMONT MARBLE

Until comparatively recent days the cost of marble used in decorating the interior of a building or even in constructing the outer walls has been considered prohibitive in most cases and the reason for this is plain to anyone at all familiar with the material. It was quite a different proposition in the older days when in preparing a block or slab of marble for a place in some fine building, all the work, from start to finish, must be done by hand, to the present when in many pieces most, or even all, the work is done by machinery. Now comparatively little of this finishing work is done by hand in the larger establishments. To the unaccustomed observer, it seems almost miraculous to see what can be and is accomplished in this way. Far more rapidly and often more accurately is the work, even elaborate work, accomplished by the aid of one or probably several machines than

FIG. 29. Marble carvers in Proctor shops at work on column caps for Arlington Memorial.

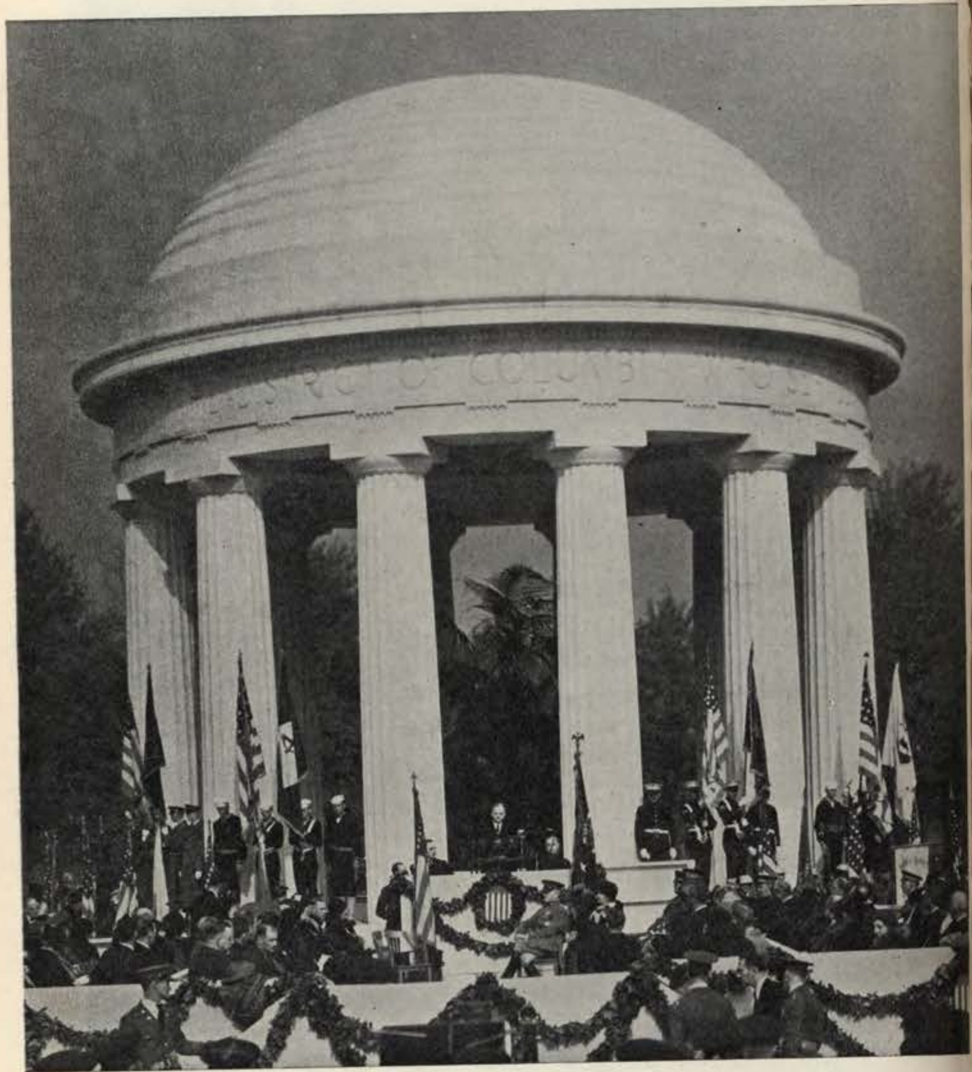

FIG. 30. President Hoover speaking at dedication of District of Columbia War Memorial, Washington, D. C. (Photo by Harris & Ewing.)

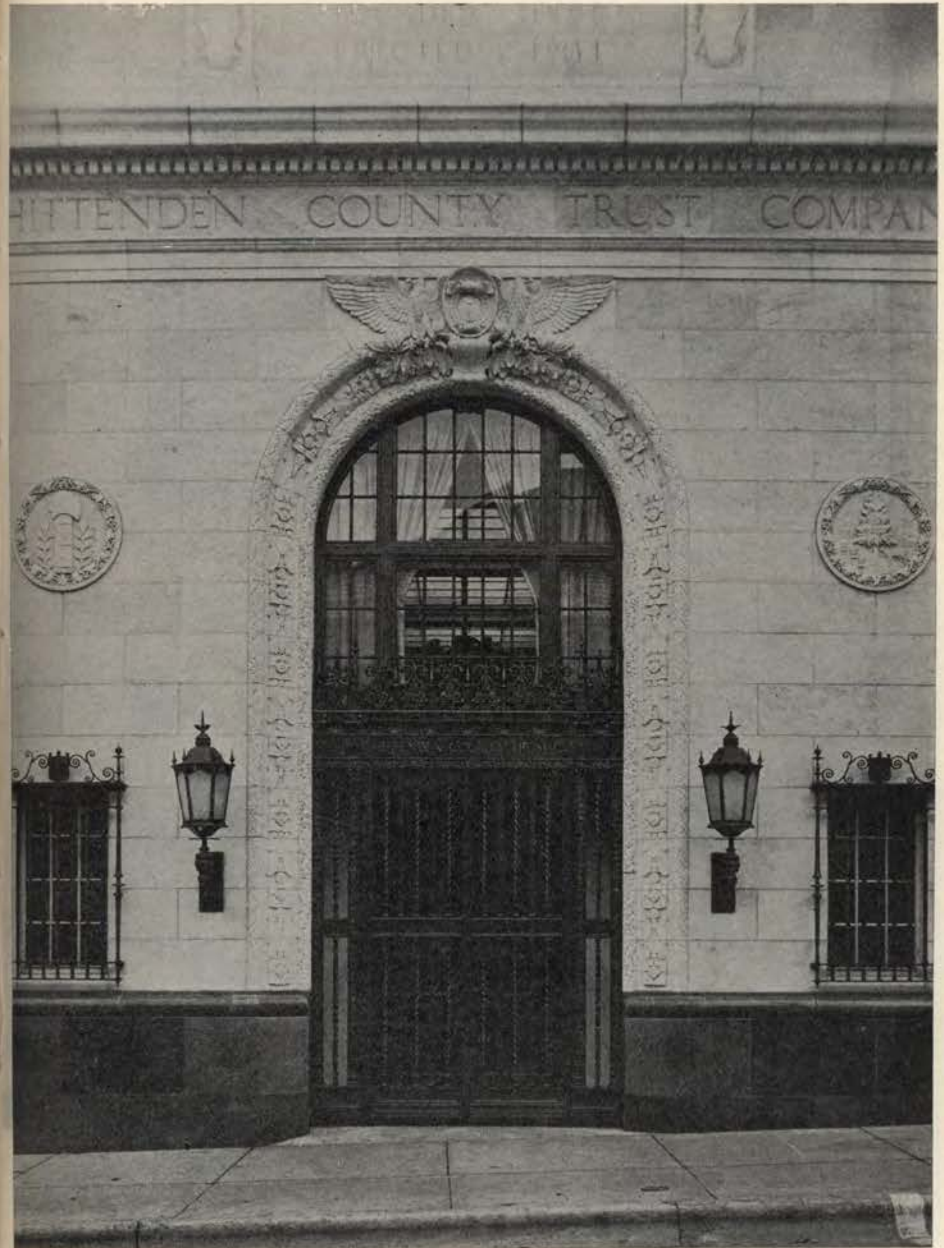

FIG. 31. Chittenden County Trust Company, Burlington Vt. Marble from Danby quarries.

FIG. 32. Carved clock frame for interior of West Virginia Capitol, Charleston, W. Va. Marble from Danby quarries.

FIG. 33. Staircase in King County Courthouse, Seattle, Wash.

FIG. 34. Museum of Arts, Montreal, Canada. Marble from Dorset quarries.

FIG. 35. Sectional view of monumental marble shop at Proctor.

FIG. 36. Hinde Memorial, Toledo, Ohio. Marble from West Rutland quarries.

FIG. 37. Porter Mausoleum, Woodlawn Cemetery, Woodlawn, N. J. Marble from Danby quarries.

Fig. 38. First Trust & Savings Bank, Chicago, Ill. Marble from West Rutland and Roxbury quarries.

by hand. In some kinds of shaping marble into a desired form no machine has yet been invented that can equal the hand of a skilful workman, but more and more machines are replacing the hand. It is now almost literally true that any work that can be accomplished by wood-working tools and machines can be better and much more speedily wrought by marble-working machines.

As has been noticed, machinery of all sorts is more extensively used in this country than in Europe or anywhere. It necessarily follows that where labor is cheap and orders not frequent nor large it does not pay to install costly machinery and no other country at present uses so great an amount of marble as does the United States. Therefore, our marble men can well afford to equip the marble mills with the varied appliances in common use in this country. The fact alluded to on a preceding page, that a great deal of marble-working machinery has during the past few years been sent abroad to all parts of the world, is sufficient proof that these machines, many of them not only made but invented in Vermont, are increasingly coming into use and are now often used abroad. More slowly, as one would suppose, than if softer material is the work done as the rough block than from its many years' location in ledge or quarry, carried to the mill, sawed into desired shape, carved, smoothed or polished. It may be rubbed and polished, turned in a lathe, or shaped in many ways by curiously contrived machines. Most of these have been mentioned by Mr. Patch but it has seemed to the writer that it might be interesting to some of his readers to say somewhat more as to the more commonly used machines and as far as possible to illustrate them. This latter I am able to do by reason of the courtesy of the Vermont Marble Company and the Patch-Wegner Company; most of the illustrations having been supplied by these companies, especially the first mentioned, though other companies mentioned on an early page have also furnished illustrations of machines which they manufacture, as acknowledged on an early page of this article.

In the pages preceding this much of the space has been used in considering the kinds of marble available in the deposits of the State, the quarries from which marble is or has been taken, and the uses to which marble may be given. Of course, the deposit of marble must be discovered, then the character of the stone as to its availability and accessibility; its texture and hardness and, therefore, its workable possibilities, its adaptability to various uses. Finally we take up the various processes of manufacture, that is, the transformation of the rough stone as taken from

European and Oriental countries, especially the latter, marble was the quarry to the finished piece.

As has been noticed, at first, many centuries ago in the European and Oriental countries, especially the latter, marble was used in some cases largely, and must have been wrought by hand, and when it began in comparatively modern times to be used in Vermont, everything done was effected by handwork, and often as little of that as could make a presentable piece in whatever location it was fitted for. Now very little marble is in its original condition as it was taken from the quarry. From the plainest sort of a slab, when thin bedded stone was sought and used after very little work had been expended upon it, to the most elaborate piece of modern architecture, the steps may be many and may require much artistic ability and time. When this is considered, it is no wonder that the main cost of a monument or other piece of work is not in the stone block or slab but in the work required to bring it to its final form. It is very noticeable to those who have visited foreign countries, especially in northern India and European palaces and public buildings, or some Greek or Roman ruins, how much more lavishly marble was used and how much more elegantly it was fashioned, than could be seen in this country. In some of the Mogul buildings of northern India, one may see in every part of every room, large rooms they are, nothing but marble, often very elaborately carved. But within the last fifty years and especially during the last twenty-five, in our new buildings marble of many colors has been used and now many of the large buildings are very extensively decorated by the abundant exhibition of marble. It is true that very much of this freer use of stone is due to great advance in the invention and adoption of machinery in working marble and other stone. While there is often not a little hand work executed on marble now, almost everything can be in some way effected by machinery, if so desired.

I think that few persons, who are unfamiliar with the inside of a marble mill, have any idea as to how much efficient, satisfactory work can now be accomplished by machinery and how much more easily and in how short a comparative time by modern methods. By this means it is obvious that the cost of such work has been reduced. At the same time the cost of building has greatly increased—I mean the amount that builders have been able and willing to expend in building. Because of this change, as well as the general interest in such work, the writer adds to what has been stated something descriptive of the processes by which a block or slab of marble passes from the simple roughly quarried block to the elaborately cut and carved top of a column, or whatever it may become.

Not only have the methods of working marble been greatly improved, but, in most kinds, it is now possible to finish polished pieces as was not possible in former times. This, naturally, is especially true of the hard varieties, those containing more silica than most. Some of the varieties, as verde antique, not true marbles, can now, within a few years, be polished more brilliantly than any others, though not very long since it was difficult to find the right sort of material to bring out the finest characters. Since the invention of carborundum and the use of "bort," and other very hard materials, by which an edge is given to stone-working machines, the work of the marble cutter has been greatly changed.

PREPARING QUARRIED BLOCKS FOR MARKET

As everyone would suppose the block of marble as taken from the layer in the quarry must receive much treatment before it can be used in any of the varied positions in which it may be placed. In old times when in Vermont the stone was used only in a few places. It was impossible to use the quarried stone and the innumerable methods now employed to shape the rough stone into such form as is desired had not come into the imagination of the marble worker. Hundreds, yes thousands, of years before marble was wrought into desired shapes in America anywhere, long before there was any such place known as America, as the ruins of ancient cities in the old world abundantly prove, marble was cut, carved, or otherwise shaped, but the early settlers of this country had other and more important matters to attend to than such work as stone cutting.

In Vermont, and, I suppose, elsewhere in what is now this country, the first employment of stone was such that very simple and easily available tools could accomplish all that was needed or desired, hammers, chisels and the like. Foundations to buildings, and after these were built, hearth stones, chimneys, flagstones, etc., were needed. Consequently only stone which in the quarry was naturally nearly in the shape wanted and, therefore, required little dressing, was sought and used. Stone in thick layers, except for bridges and foundations, could not be used. In Vermont there were deposits of stone in comparatively thin layers and quarries which afforded such stone were, of course, first used. Aside from building material, I suppose that slabs, hearthstones, gravestones, and flagstones were most in demand and, therefore, the first quarries opened and worked were those which supplied the need and some of the Vermont marble quarries did supply this need.

When and where stone of any sort was first used in Vermont does not appear to be anywhere recorded but as far as this State is concerned it seems to have been about 1780.

As has been already stated, the "Marble Belt" extends south of Vermont into Massachusetts and formerly, more than of late years the southern quarries were active. Still farther south into Connecticut what may be called the "Marble Belt" extends, though marble of any commercial value has not been quarried throughout its entire length, but only here and there at intervals.

Surely there has been marked advance from the time when blocks were split from the quarry mass by building a row of fires in a suitable part of a quarry and when the stone was heated sufficiently, water was thrown on the heated parts and more or less irregular blocks thus cracked off so that they could be removed and worked; from such treatment by the slow increase of mechanical devices until in many cases, especially in this country, the completed work was finished by machinery. Yet even here and now, the finest work may need the effort of the human hands. In many cases no handwork can produce as satisfactory results as some of the machines, but in other work elsewhere, no machine has yet been devised that can produce effects equal to those accomplished by hand. If we may judge from many reports, there can be no doubt that America has produced machinery that is able to accomplish more varied and satisfactorily finished marble than any other country. And probably this is true especially of Vermont.

The president of the Patch-Wegner Company of Rutland writes that that company has furnished marble-working machines to not only everyone of the United States but also to Russia, Japan, Australia, New Zealand, Sweden, Norway, Germany, England, Central America, Cuba, Porto Rico, Mexico, South America, Canada, etc. Thus Vermont apparently leads the world not only in variety and quantity of marble but as well in machines to help in preparing the stone for markets. An English writer accounts for this in part at least by the fact not only of the great amount of marble in the United States, but in addition to this wages are much higher here than elsewhere and consequently handwork is more costly and because the demand for the finished marble

is much larger in this country than abroad. Therefore, it is profitable to install and use in our marble mills abundant and complicated machines to take the place of handwork, whereas the lower wages and smaller production in most foreign countries finds handwork on the whole cheaper than machine work. According to all accounts much less machinery has been invented or used abroad than here. Elsewhere a small amount of marble work is done by machinery, here a comparatively small amount is done without machinery.

Notwithstanding the great amount of marble quarried in this country, a large amount of foreign marble is imported.

MACHINERY USED IN FINISHING MARBLE

Some of those who find a more or less promising outcrop of marble on their land do not think far enough to see that finding even a good marble ledge is only the beginning and the necessary work which follows before the best marble can be sold is usually the most expensive and difficult part of the successful operation of any quarry. In all quarrying as well as all mining it must be remembered that a great deal of money has been lost in the business as a great deal has been gained. This has been shown very plainly by the history of the industry. What the future shall reveal the writer will not attempt to foretell, but as things now are it seems certain that in most, if not in all, quarrying and mining, there is little probability that any small company, still less single individuals, can hope to make money. Large capital, the best and most intelligent advice, the most patient endeavor, are absolutely necessary if there is to be anything but loss in the undertaking.

Not in any way to discourage, I have at least hinted this in previous pages and in much that follows there should be seen that after a ledge is discovered and blocks taken out there is more or less work needed. There is always risk of losing in opening a quarry, however promising it may be. Not to hinder any who so desire from opening new quarries, but earnestly to warn against hasty action is the above written. Vermont never could have the world-wide reputation which prevails had no one been ready to risk, "to take a chance," but before one does this he should consider the matter and decide that he can afford the risk.

It is the intention of the writer to discuss the various processes by which, under present conditions, marble is prepared for sale.

Some quarries do not finish their stone but sell in blocks directly from the quarry, but most have connected with the quarry a mill in which the stone is wrought as may be desired. How this is accomplished and the machines by which it is accomplished is to be the topic before us. Before taking up special kinds of machines it will be well to speak of finishing marble in a general way.

EXTERIOR FINISH

One of the publications of the Vermont Marble Company gives the following as to the finish of exterior marble:

"*Sand Finish.*—This finish is the one most commonly specified. It brings out to the greatest degree the veining of the marble. It is put on by rubbing the stone by hand, using coarse sea sand.

"*Tooled Finish.*—Where a rougher finish is desired, tooling is often specified. The work is done by hand or by a special tool used in the planer. In either case the effect is that of a slightly corrugated surface. The lines are continuous and are regularly spaced. All the plain surfaces are tooled vertically. Moldings are tooled longitudinally lengthwise of the molding. Very small moldings as well as all top surfaces and washes are sand rubbed instead of being tooled.

"*Axed Finish.*—This is also known as hammered finish. It is the usual granite finish. It is distinguished from tooled finish by the fact that the lines are finer, nearer together and somewhat irregular.

"*Chisel Finish.*—This is a special finish put on with the pneumatic tool. Designed as it is for monumental work it is not adapted to large structures. It is recommended, however, for mausoleums or other memorial work.

"*Rock Face.*—This, as the name implies, is a very rough finish. After the block is sawed the surface is split off by hand, leaving the stone with its natural surface. The work is done in such a way as to leave the stone somewhat thicker in the center than on the edges."—"Book of Marble," p. 31.

INTERIOR FINISH

"*Polished.*—This is the standard finish for interior work, not exposed to wear. The marble has a mirror-like surface.

"*Hone Finish.*—Marble that is honed presents a perfectly smooth surface, but is not glossed.

"*Fine Sand Finish.*—This is the standard finish for floors and stair treads. It is put on by the rubbing bed."

As one would suppose, a very much greater variety of marble is suitable for interior work than for exterior. At first all varieties, whatever may be the final destination, must pass through the same processes, that is, the quarried blocks must be sawed into slabs or whatever pieces are to be needed, and usually all must go to the rubbing bed. If for interior work the smoothed pieces go from this to the finishing shop. By this time most pieces have been worked into the final shape and size. From the rubbing beds the marble passes to the final treatment, carving, polishing, or whatever may be called for.

The polishing machine, Figure 48, usually used at present, as shown in this figure, is made up of several parts. There is an arm readily moved about in various directions, to the lower end of which is attached a disc, of which various patterns are used. The under side of the disc is coated with some abrasive powder, finer or coarser. The first contact of the marble with the under surface of the disc, carborundum in powder is used.

MACHINES USED IN PREPARING MARBLE FOR MARKET

On previous pages the use of machinery instead of handwork has incidentally been mentioned. We now come to such account as space allows to consider the principal machines that from time to time have been invented to, at least, help in the often slow and laborious work of preparing rough blocks as taken from the quarry for whatever use they may be designed. Many years ago, as there was no machinery, necessity required all the work to be done by hand; now nearly all is accomplished by machinery, as anyone visiting a large marble mill will soon discover; done usually more speedily, more easily, more efficiently and more cheaply. No account of the marble industry in Vermont, or anywhere, would be at all complete were there no discussion of the methods by which the recently quarried block of marble was wrought into some of the beautiful forms now produced As to the more recent developments in this part of the industry the reader will find some accounts in later pages. Anyone reading of the older methods of detaching from the original bed and laboriously fashioning the stone by mallet and chisel, as may be desired, and then understanding present methods, soon sees how great the change from ancient to recent work. In all things demand is likely to produce some sort of supply, and as the development of this industry has gone on through the centuries supply has met the demand. This is especially true in this country and in Vermont.

It is gratifying to a loyal Vermonter to learn how much of the great advance in the invention and use of machinery has, directly or indirectly, been due to Vermont. Many of the important machines now in use everywhere in what may be called the manufacture of marble have originated and many manufactured in this State. The Patch-Wegner Company, the Lincoln Iron Works of Rutland, the Lane Works of Montpelier, as most Vermonters well know, are large manufacturers of stone-working machinery. The president of the first named company writes: "We believe there are machines of our manufacture in everyone of our forty-eight states of America, as well as in Russia, Japan, Central America, Cuba, Mexico, Canada, England, Norway, Australia, New Zealand, Porto Rico, South America, Germany, and many other countries." From the same source we learn that many of the finest memorials, such as the Lincoln Memorial, Washington Monument, McKinley Monument in Buffalo, Denver Post Office and many of the finest memorials and buildings in the country, have been constructed by aid of machinery manufactured by this company.

Any reader who recalls what has been written on previous pages as to the very early treatment of marble for the very limited uses for which it was demanded will appreciate the immense advance in the handling of this stone that the passing years have brought. Probably in the management of none of the industries has there been greater advance in methods of work than in this, and by far the most important advance has been effected during the last fifty years. Not only have new machines been invented, but new materials, such as carborundum, add much to the efficacy of many machines, as we shall find later on.

It is somewhat of an interpolation here, but a word may not be out of place as to a question often arising. What is the prospect, considering the greatly increased demand for marble, that the Vermont supply will last? In reply I can best repeat what is declared to be the fact by those best qualified to judge as to this. While the location of many a Vermont quarry may be changed, as has been true in the past, yet it seems certain that for many years at any rate, the supply will not fail. As one explores our marble areas he will notice many abandoned quarries which give emphasis to the question. While I think no one would wish to prophesy with absolute confidence as to a supply as yet undeveloped, he will see enough to convince him that for a long

time to come there will be plenty of marble, and that in all probability it will be a very long time before it comes to pass that there is no more Vermont marble. Old quarries there are and abandoned quarries there will be, but new quarries there also will be. That there is a very large quantity of as yet untouched marble in Vermont is certain as far as all appearances go, but there is much to be done before anyone can be sure.

As has been noticed, it is not enough that a mass of marble exists, for there are numerous other conditions to be taken into account. No quarry can be accurately appraised until it has been considerably worked. There can be, however, no reasonable doubt that there is in Vermont a large amount of unworked and valuable marble. Mr. Dale, who has more than once been quoted, says of this: "The unworked profitable portions of the boundaries probably aggregate forty-four linear miles." Further he says: "The breadth of the marble is not estimated but whatever it may be the total amount cannot be other than very large." Probably no one has made a more thorough study of our marble areas than Mr. Dale.

THE CORING MACHINE

Let us now take up with as much of detail as space permits the principal machines now used in Vermont to extract and prepare for market the marble which is found in the State as indicated. After clearing away whatever surface material there may be—sand, clay, poor and useless marble—the first move which the prudent prospector will usually wish to ascertain is the character and extent of the marble bed. He, therefore, uses a "coring machine" if such a machine is available. By the aid of this machine, the uncertainty as to the value of the deposit is very much reduced, though by no means wholly. By the use of this machine, and by careful examination of the cores taken out very much can be learned about the deeper layers of the deposit, and by several cores, of the extent of the beds. Even when several cores are taken in a given locality, there is still much risk for as will be understood, though the coring machine is a very valuable help, it cannot tell more than a very partial story and must leave much yet to be ascertained.

The coring machine (Figure 51) consists, usually, of a diamond drill which cuts out of the marble, or whatever it may be a "core" which can be taken out and examined. This core varies in size in different drills from one or two to several inches in diameter.

Obviously a core may show a few or many feet of rock as it goes more or less into the beds of stone. A drawback to the use of this machine is that it is expensive, or the black diamonds are. Its utility and value are certainly great.

After the marble beds in a quarry are uncovered, and usually fifteen or twenty feet of unsalable marble is removed, the channelers are brought on. The old way, before channelers were invented, has been noticed as have some varieties of channelers from the old days when only the Wardwell channeler was used. As those familiar with the older days have told us, the stone was loosed from its bed by hand labor of the hardest sort. Even slabs to be used as gravestones were, by tediously used chisels, worked into slabs from thin layers. Inasmuch as there is no sure evidence, in most marble deposits as to the amount of usable stone at a given locality, visible on the surface, its quality, uniform color, etc., there is always some risk attending a new opening, therefore, it is always worth while, before expending much in starting a new quarry, to thoroughly test the marble mass. This is readily done by means of a diamond drill which can give a core of the marble large enough to give a good sample of the stone at different depths. By using such a drill, by no means all, but a great deal of risk is avoided, how much, of course, depends upon the thoroughness of the drill examination. This coring is rather costly, but is certainly a great help in deciding whether or not still further outlay is advisable. Should there be sufficient indications of a supply of good marble then after clearing the surface of the deposit of whatever waste material, as sand, gravel, clay, poor stone, whatever, then the channeler is brought on.

THE CHANNELER

It is not difficult to understand that the earlier methods of getting out marble were exceedingly wasteful, but for many years, and even now in the far east in some quarries they are still used. These early methods as practiced in Vermont have been described elsewhere. The first channeling machine was invented by George Wardwell of Rutland in 1862 and was first tried in 1865 in the Sutherland Falls quarry. Although involving some repetition of what has been previously stated, a quotation from Mr. Patch is as follows: "Once on a time, the channel cutting was done entirely by hand as was also the drilling and I distinctly remember visiting the West Rutland quarries and seeing 100 or more men sitting in rows on benches, each man having about three or four feet of space, cutting channels by hand, using a

cutting tool called a tunner—a round iron bar about seven-eighths of an inch in diameter by six to nine feet long, according to the depth of the cut, each end of the bar carrying a steel chisel. Marks of hand channeling are to be seen on the walls of the quarries in West Rutland."

Blasting in marble quarries was for obvious reasons abandoned in all our quarries except when in removing waste material, as in opening a new quarry, or similar work was needed, and after the introduction of channelers, there was little need of blasting.

Until 1863, or about that time, the exact date does not appear to be known, all marble was obtained in the somewhat wastful and laborious manner previously described. About 1863 the first satisfactory machine for quarrying marble was invented by Mr. George Wardwell. This machine, which was destined to add very great efficiency to all quarrying, was built for the Sutherland Falls quarry and used there constantly for over twenty years. The first channelers were large clumsy machines moved by steam, the large boiler necessary being a part of the whole. At a distance this channeler resembled a small locomotive. A great trouble in this machine was soon found to be in the smoke and steam which in dull weather filled a quarry of any considerable depth. As the days went on these channelers were simplified and they were no longer moved by steam, but by and by when water power could be used to move a dynamo, in most places electricity replaced steam. Figures 39 and 42 show the later channelers and the great advantage in lightness and simplicity over the earlier machines is apparent while the benefit in the quarries to the workmen cannot be shown but may be easily imagined.

Nearly twenty years after the Wardwell came into use and was for a time the only channeler used, the Sullivan channeler came into use. Figure 39 shows this form of the machine. This machine used five steel-pointed drills clamped together, like the fingers in the open hand. The two end drills and the center drill had chisel points across the cut, at right angles with the channeler, while on the drills each side of the center drill the chisel points stood at opposite angles. This was in order to prevent the bottom of the channeler being lumpy, like teeth in a saw. The same number of drills stood in the same form and are used today in all rock channeling machines, except in cases where the single drill is used, drilling holes near together, near enough so that a broaching tool can break down the partition, thus forming a channel. This form of channeling is used in granite work and hard stone.

After the Wardwell channeler came the diamond drill, built by the Sullivan Machinery Company. This was first used in the form of a single drill, used for drilling single holes, for raising the marble from its natural bed in the quarries and also for breaking the layers into blocks. (See Figure 40.)

Next after the single drill came the two-spindle drill and this was used for channeling. The first of these machines bored holes near together and the rock between the holes broken out.

FIG. 39. Sullivan channeler.

"Channel cutting by hand was considered quite an art and a man who could cut out a left-hand corner of the quarry was in demand as late as 1890. I believe Michael Benson, one of the best left-hand cutters that I ever knew, was also about the last one to do that kind of work.

"Work now done by channelers and gadders in the West Rutland quarries was, in the beginning, done by blasting with black powder. John Barnes, son of William Barnes, the first to quarry marble in West Rutland, attempted to open a quarry with black powder. He drilled a deep hole of large diameter,

working many days with a churn drill. The hole can still be seen just south of the Gilson and Woodfin quarry. I do not remember the number of fifty-pound kegs of powder used by Barnes in loading the hole. Gen. Edward Ripley once told me about it and said that a great many people, himself included, gathered on the side of the hill across the swamp, nearly a mile away, expecting that when the blast was fired to see the whole side of the marble hill go up into the air, but, when the blast was finally discharged, there was almost no sound, there was no

FIG. 40. Drilling in the marble quarry preparatory to wedging and splitting apart of the marble blocks.

earthquake, in fact nothing to indicate to the people a mile away that the blast had been fired excepting the cloud of smoke arising from the burned powder.

"The first machine to be put in the marble quarry was a channeler invented and built by George Wardwell. This machine was used in the quarry in Proctor in the early sixties (1863, I believe). I first saw it in 1865. The quarrymen had named it "the Posey." The channeling machine proper was mounted on a wooden frame which slid along a track made of straps of iron laid on wooden beams. It was propelled along the track by a rack and pinion, reversing by a ratchet and pawl. A leather string attached to the pall or dog made it more convenient for the operator to reverse the machine. The gang of drills much the same as are used today was operated by a lever and cam copied from the old-fashion trip hammer. The wooden lever was attached to the drill clamps by leather straps, one attached to the top clamp and one to the lower clamp. As the cut was made deeper, it was necessary to stop the machine letting out on the straps leading to the lower clamp and tightening up on the straps leading to the upper clamp, thus letting the drills down two or three inches."—F. E. Patch.

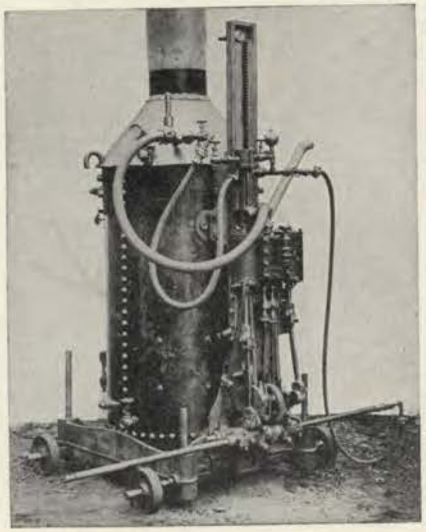

FIG. 41. Diamond gadder.

As the writer recalls these machines they were rather ungainly and awkward in appearance, somewhat like a small old-fashioned locomotive (Figure 41), and the quarry was often unpleasantly full of escaped steam, but they were an immense improvement over handwork. Of course, where, as in most marble quarries, electricity has replaced steam, the nuisance of steam and smoke is done away with. As may be seen by comparing Figures 39 and 41 the new form of the channeler is quite different in appearance from the old. As in all machines which have displaced handwork, these machines accomplish several times as much as can be produced by the best workman. It is easily understood that in all

quarries, wherever located, a very great advance in getting out the blocks which are to be sawed, or otherwise worked, has been made since Mr. Wardwell invented his channeler. At present several other forms of channelers are used in different quarries. All of these work in very much the same manner, though sufficiently unlike to have each its own patent. The necessity of getting rid of the earth, bad or imperfect material at the surface, has been alluded to.

"There was a second single-lever channeling machine called the 'Monitor' made practically like the first one, then they began building them with two sets of drills, one on each side called double levers. The machines were all named. Some of the names I remember as follows: 'The Wideawake,' 'The Beat 'Em Alive,' 'The Emerson.'

"The first channeling machines in West Rutland were used in the Manhattan quarry, a hole long since abandoned and filled up, about east of the present lime plant. They attempted to run the machines nights, but were forced to give it up, owing to the fact that the opponents of the machines would come to the bank of the deep quarry and throw stones at the channeler operators.

There was great opposition to this channeling machine and fear among the handcutters that their jobs would soon be gone. One day packing blew out of one of the valves about the boiler, the steam escaping with a hiss; the workmen all rushed up the ladder out of the quarry. Meanwhile, Mr. Wardwell repaired the trouble and in a very few minutes had the machine running again. The workmen came back to the bank of the quarry, looking down to see the machine again in operation and one of them shook his fist at the machine saying, "Bad cess to ye, ye blame old steam engine, cheating a man out of his honest day's labor, but be-jabers ye can't vote."

As has been stated, the Wardwell channeler was a very great improvement over the older hand method, aided often by the wire saw, but during the years since Mr. Wardwell invented his form of channeler there have been not only great improvements in this channeler, but several other machines are now on the market, and the old machine has given place to the newer forms invented by others.

At present the Ingersoll-Rand channeler (Figure 42) is most commonly in use in all the Vermont quarries. So, too, wherever possible the former use of steam power is abandoned and compressed air, electricity or a combination of both are used. The Vermont Marble Company report that "in our Vermont quarries the electric air type is used mainly, the older lever type has practically gone out of use."

The Sullivan "chopper" (Figure 43) as the marble men nicknamed it, must have an expensive steam plant to move it, supplemented by air compressors as well as the diamond drills. The cost of operating this channeler seems to have increased and, as seen above, went to a great extent out of use. It is said that in Vermont other channelers have largely gone out of use, but in the south in limestone, sandstone, etc., many are still in use. The Ingersoll-Rand channeler, as Figure 42 shows, is quite a different looking machine from the others named. It is reported that

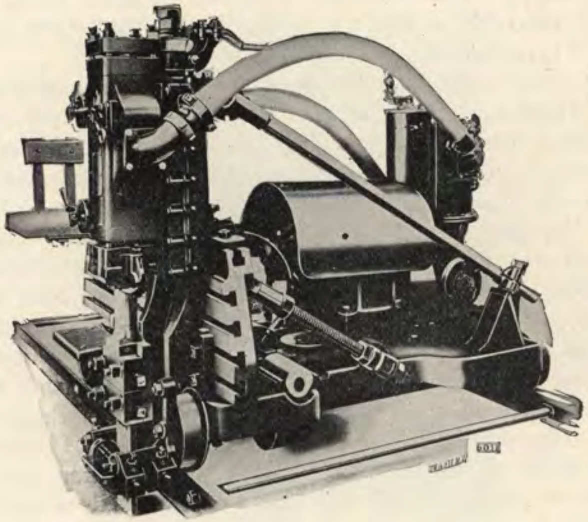

FIG. 42. Latest form of Ingersoll-Rand channeler.

the Vermont Marble Company alone uses seventy-five—all run primarily by electricity, to the air compressors, thence wherever wanted by the aid of hose compressed air at the channelers.

Very soon after Wardwell had made a success of his machine, Mr. Lamson made, in Windsor, a double-lever channeling machine, all built in connection with the boiler and engine as one machine, making it in many respects superior to the Wardwell machine. This was proved to be an infringement on Wardwell's patent and after quite some litigation the use of the Lamson machine was discontinued. The machines were set up on the banks of the quarries where they stood during the life of the Wardwell

patent. After Wardwell's patent had expired, some of the Lamson machines were put back to work and the Sheldon Marble Company were using one or two of these machines in 1890.

The top layer of good marble having been laid open, the channeler is brought on. Bars of iron or steel are placed upon the marble wherever it is thought best to detach blocks. These make a small track, a temporary railroad, on which by its own power, steam, compressed air or electricity, the machine moves back and forth on the marble bed. As the illustrations well show, the machines driven by compressed air or electricity are beyond comparison superior in every way to the older steam-driven machine, and are now almost exclusively used everywhere.

In answer to an inquiry, Hon. Redfield Proctor writes of the Wardwell channeler: "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 the quarry 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 blocks thus cut on four sides is then broken out by means of wedges or any way possible, usually with the assistance of a Lewis hole in the center of the top which assists at least a portion of the 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 have been removed, usually four, so as to allow the use of a power drill or gadder the rest of the blocks in the two key way courses are thus removed.

"The first channeler was never sold, but used on contract work in Vermont quarries and for a time on red sandstone at Portland, Connecticut. The channeling price was $1.25 but afterwards was seventy-five cents per square foot. The second was sold to the Columbian Company and used in its quarries nearby. The third was sold to the owners of the old Prime quarry at Brandon, Vermont. In 1871 the six-spindle machine was superseded by the two- or three-spindle channeler, which remained in use for many years until the high price of black diamonds proved prohibitive. The thousands of semi-circular holes on the walls of stone and marble quarries in Vermont and other states attest the extensive use of the diamond channeling machines made by the Sullivan Machine Company. The drills sank into the marble at the astonishing rate of eight to ten feet a minute when run at the usual speed of 800 to 1,000 revolutions. A depth of one inch to a hundred revolutions could be depended upon in average marble."

The Sullivan Channeler.—The idea, as far as we know, of the at present indispensable channeler was first in the mind of Mr. George Wardwell. After some years others caught something of the same idea and several forms of the channeler at different times appeared and, as we shall see, the original Wardwell channeler disappeared and was followed by newer and much better Wardwell machines and the Sullivan and Ingersoll-Rand channelers. The Sullivan channeler (Figure 39) can perhaps be better understood from the figure than from any description.

In a magazine published by the Sullivan Machinery Company is the following description of the Sullivan channeler: "The first diamond channeler completed in August, 1868, was a six-spindle, variable speed, core drill, movable on a track with a gauging device driven to space the holes and operating at any angle. It was soon found that cores caused difficulty by breaking and jamming in the rods and an obtuse angled, conical solid head was substituted for the annular head, at first there were four, afterwards two for the escape of the water to clear the detritus. Black diamonds were then cheap, costing $3.50 per carat. They now cost $100. About twelve diamonds were set in each head. They averaged about three-sixteenths inch in diameter, nine-tenths of each diamond being imbedded in the steel. This channeler was made to cut at any angle, which no other machine was capable of doing."

These channelers were so far in advance of all other machines that they became indispensable and elicited the highest praise from many of the best known quarrymen. As the figure shows, the Sullivan channeler is comparatively simple and not in any way clumsy. Figure 43 shows the Sullivan "chopper" or double channeler.

Not long after the Sullivan channeler was introduced, came a gadder (Figure 41) which worked with diamond drills and was very satisfactory. As the writer understands this case, it went out of use because the cost of the necessary black diamonds rose to such a degree that it was too costly in operation.

As far as I can find out, the Sullivan channeler is not now much used in our Vermont quarries. It is still manufactured, the rights having been sold by the Sullivan Company to the New

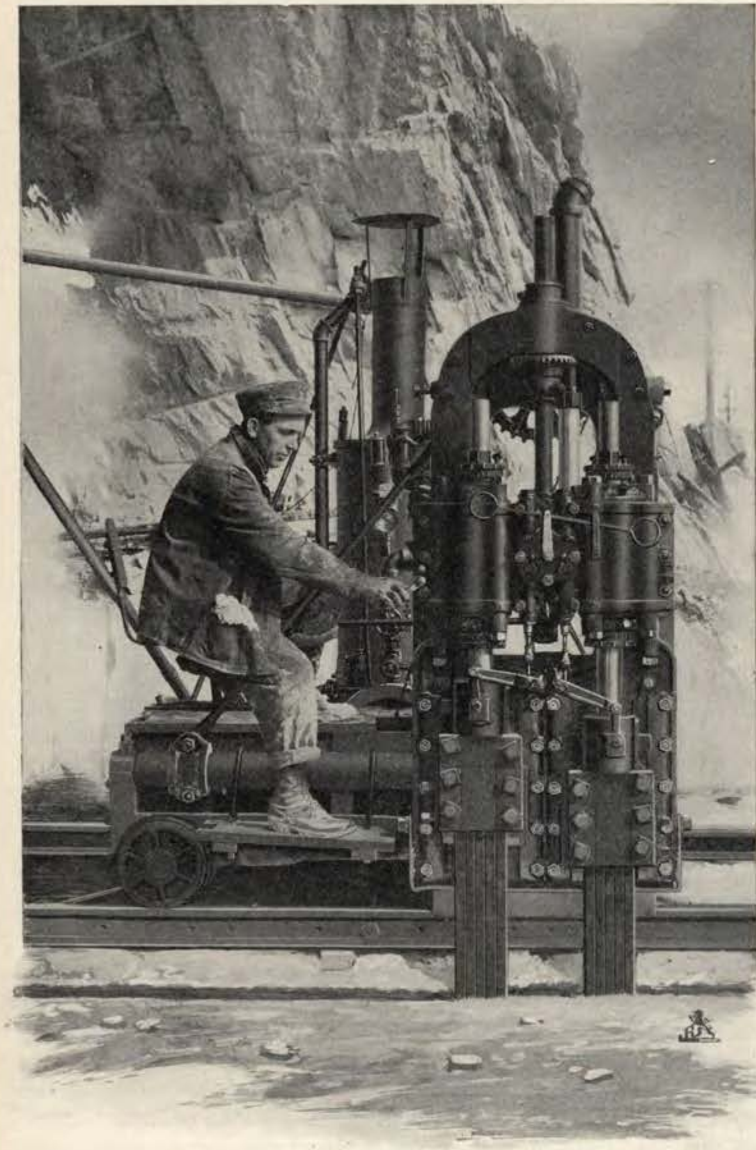

FIG. 43. Sullivan "double chopper" channeling machine.

Albany, Indiana, Company. The channelers are, apparently, still on the market, but are nowhere largely used, mainly because of the greater expense, as compared with other channelers, though they are very efficient.

It will be of interest to some of my readers if a few words are written as to the peculiar form of drill used in all channelers. The reason of this unusual form of the arrangement of the drills is given by Mr. Patch as follows: "The first gadding machine, about 1869, used a diamond bit and was successful from the start. These were built by the Sullivan Machinery Company and were very nice little machines, an upright boiler with a double cylinder engine attached. From this diamond gadder grew the diamond channeling machine, a two-spindle affair, also a very successful machine, as well as economical, when black diamonds could be purchased as in those days for $4.50 per karat. In fact, in 1890, the Sheldon Marble Company were running several diamond bores, paying $11.50 per karat.

"In a three-bit gang the diagonal bit should be set back from one-sixteenth to one-fourth inch from a line drawn across the chisels, according to the hardness of the rock. In a five-bit gang, the two outside chisels should be square with the edge of the steels; the center chisel bit is advanced from one-eighth to one-fourth inch, according to the rock, and the two diagonal bits are a little back of a line across the center and outside bits.

"Mr. Ball, of the Sullivan Machinery Company, a very skilful mechanical engineer, designed a much lighter channeling machine which he called a 'chopper.' This machine had an independent feed engine similar to the feed on the unsuccessful Green machine and was a huge success. The drills would stick the same as the other machines, but the feed engine was not strong enough to break the drills, but was sufficiently strong to move the machine back and forward a very little which worked the drills loose in the cut.

"Very many of these machines were in use until the Ingersoll-Rand Company came out with their electric pneumatic channeler (Figure 42). The pneumatic portion of this channeler is a copy of the first pneumatic hammer ever invented and used; the patent papers are, no doubt, today in the vault of the Vermont Marble Company's office (patented by F. R. Patch). This pneumatic hammer was first tried out in the basement of the old carpenter shop at Proctor, after which two of them were used in cutting, tracing, and lettering marble in the finishing shop, which was destroyed by fire along about 1885. Many of us foresaw the uses to which

this pneumatic machine has been put. These first machines would strike only about 1,000 blows per minute.

"While they were in use, a little machine was invented to be used by dentists in hammering gold in filling teeth. A visitor to the marble shop saw these first machines in operation and adapted the dental plugger to do the same work. The dental plugger rebuilt for use on marble would strike some 3,000 blows per minute and very quickly knocked out my pneumatic machines but not until they were destroyed in the fire above referred to.

"The first gang of drills had the chisel points at right angles with the cut and they simply made pockets for themselves in the marble like saw teeth. The workmen called them lumps so that in spite of the ratchet feed on the machine, the drills would strike the top of these lumps and slide back into the hollow cutting almost nothing.

"A hand cutter named Martin McDonough has the credit of suggesting to Mr. Wardwell the setting of two of his drill bits at an angle of 45 degrees, stating that when he, cutting by hand, found the bottom of his cut in that condition, he cut the high lumps off by turning his runner at an angle. This one change made the machine a success."

The center chisel cuts both going and coming, as do the two chisels beside it as it moves forward and the two on the other side as it moves back, reversing. It was found by experience that the cutting went on better if two of the chisels were sharpened so as to cut diagonally, the other three transversely. As far as possible the machine is automatic in action; that is, when it has reached the end of the channel it immediately reverses without stopping. The channels are longer or shorter as may be required, and also the depth depends upon the thickness of the layer of stone; the width, of course, is determined by that of the chisels, usually one inch or one and one-eighth inches. The gang of chisels is raised and dropped at the rate of 150 a minute. At each stroke the cutters are moved forward an inch or more.

One of these channelers is expected to make a channel from forty to eighty square feet daily; a two-gang machine twice as much; depending, of course, on the quality, hard or soft, of the marble; that is, a channel one foot deep and forty to eighty feet long; while, if done by hand, it is supposed that a good workman can channel about a tenth as much or at most an eighth as much. The smaller channeler requires two men to attend it, the larger three.

As a Vermont invention and as a great help in quarry working, the Wardwell channeling machine will always be highly esteemed by Vermonters.

Since the introduction of this machine several others have been invented and are now widely used. These are the Ingersoll, the Sullivan, and the Saunders. The five cutters composing this drill are somewhat differently arranged from those in the Wardwell machine. The stroke of the drill is operated directly from the engine. The blows of the gang of drills give 200 blows a minute, the feed average about one inch per stroke. Several improvements are claimed for this machine. Both the Ingersoll and the Saunders machines are made by the Ingersoll Rock Drill Company, New York City. This machine is more compact and works more rapidly than others, it is claimed.

THE INGERSOLL-RAND CHANNELER

As has been mentioned this channeler is the form most used in the Vermont quarries. Several kinds of this machine are on the market, but that which is the latest and best and, therefore, most generally used is "The Electric-Air Channeler." For which it is claimed, and the claim appears to be true, that "the work is done rapidly, which requires a machine that can be easily moved and set up and one which delivers a large number of the right kind of blows per minute. The work must be done economically, that is using a minimum amount of power per square foot of rock cut. The machine is built to withstand the severe work it performs. The cut stone, especially in marble quarrying, must not be marred or stained. The conditions should be as convenient and comfortable as possible for the operator." Adapted from a circular issued by the manufacturers: "It is guaranteed to do as much work, if not more, per unit of time using only a small portion of the power of any other machine for similar purpose now on the market." Indeed, the Ingersoll-Rand Company give the following guarantee: "The electric-air channeler is guaranteed to be equal in cutting capacity to any steam- or air-driven channeler of standard size operating at 100 pounds pressure. In doing this work it will use not more than half the power required by a steam-driven channeler and one-quarter the power required by an air-driven channeler. As will be noticed in the illustration the Ingersoll-Rand channeler runs on a regular railroad track instead of the strap-shaped piece used in other machines of this sort. (Figure 42.)

Anyone who has seen a quarry equipped with the old Wardwell steam-driven machines and the modern machines mentioned above can easily recognize the vast improvement that has come about. And yet it is scarcely too much to say that the older machine was a greater advance beyond the older methods than has subsequently been attained.

Perhaps enough has already been written explaining the action of the channeler and little more need be added. Partially by way of review this may be added: Whether moving on straps, as in the old machines, or on rails, like small railroad rails, it is, of course, necessary that the drills may be moved as desired to other parts of the marble layers. The channeler placed on the track moves back and forth as the track is located and proceeds with the work of loosening the marble in blocks of a desired size. By the machine grooves, "channels" are cut of a depth desired. Of course, the first set of channels must run across the bed, parallel to each other, then the channeler is moved as the size of the blocks may determine, and cut across the first set. There often, in a large quarry, will be several machines at work at the same time.

The next step is, when the blocks are cut out on all sides, to loosen them below. This is usually accomplished by a gadder or "broken out in any way possible by means of wedges, usually with the assistance of a Lewis hole in the center of the top which assists in removing at least a portion of the block."

After one block is removed, sometimes easily, sometimes with more or less difficulty, and in several pieces, holes are drilled either by hand or with a small air drill at the bottom of the blocks. The first few blocks, usually four, are called "key blocks." When key blocks have been removed, so that a gadder can be used, the rest of the series of blocks are loosened and removed. The holes however drilled are made as near the floor below the one first to be lifted as possible and they are placed as determined by the character of the stone in hand. They may be a few inches or a foot apart. So also these holes may need to be deep, or shallow holes are sufficient, as the character of the marble may indicate. The small half-round steel wedges are then driven into the drill holes. Wherever a crack is wanted that a block may be taken out it is in general effected in this manner. By the above methods the entire floor of a quarry is cleared of one course of blocks and left ready for a repetition of the process. Thus in a marble quarry, as may be seen in the illustration, the stone is taken out in unbroken blocks, tier by tier, layer by layer. Of course, in any quarry it is essential that in some way the marble must be loosened on all sides of the quarry. In many channelers the cutting chisels are arranged on both sides of the machine, that is, two channels can be cut at the same time or only one as may be wanted. The machinery that moves the drills or chisels, the reversing, etc., are automatic, so that the workmen have only a few points to keep watch of.

Of course, after the blocks of marble are detached from the bed, the next move is to take them by some means to the sawing machines. This has been accomplished in various ways and with various degrees of efficiency. Necessarily first come the derricks.

Quoting from Mr. Patch, we see how this was done in early times: "In those days there was no wire rope used, the derricks were very light, in fact ten tons was a heavy load. The hoisting power was oxen walking around a sweep. I spent many hours and strong arguments for speeding up the method of hoisting blocks out of the quarry and the method of putting the stock under the gang saws, in fact I used to roll blocks myself. I have hanging in my office a photograph showing one of the early mills at Proctor (then Sutherland Falls) where I was foreman in 1873 and wherein I was personally handling the rollers engaged in rolling the blocks into the mill to put under the gang saws. . . . In 1871 I worked with my father in building a wooden trestle at Sutherland Falls for the first railroad from the quarry to the mills. I worked for the Vermont Marble Company till 1890, the last few years as general superintendent; I went from there to the Sheldon Marble Company at West Rutland, having the same position there. While at Sheldon's I introduced a new method of tunneling. Previous to the change it took quite a gang of men all winter to drive a tunnel thirty feet deep and about a hundred feet wide. It was all done by blasting, which not only left a very unsafe roof, but necessitated the removal of large quantities of waste material. I changed this method to channeling and had the Sullivan Machine Company make a special machine for cutting off the ends. This method has been used for about forty years and must have been a great saving in cost of tunneling."

Continuing the account of the channelers, in order that the action of this important machine may be fully understood, the following explanation is added: The cutting and, therefore, the important part of a channeler, varies somewhat in different machines. Usually the cutters are in bunches, that is, one in the

middle is longer than the rest, two on each side are arranged like steps, the whole forming one large cutting instrument, which is constantly raised and lowered, making a very effective cutting tool with a wedge-shaped end. Each bar is from seven to fourteen feet long and as the whole weighs several hundred pounds, it falls upon the stone with considerable force cutting more or less of the channel as the stone is harder or softer.

The workmen declare that when the cutting bars are arranged so that two of them have the cutting edges diagonally placed and three transversely the machine does more and better work.

As far as possible all the various movements are automatic, and the work is carried on without stopping to change direction. There is some variation as the stone cut is more or less variable. What may be considered a normal or average cut or channel is four to six feet deep and an inch and an eighth wide. As has been stated one channeler can accomplish from forty to eighty feet in length a day while a good workman with a good drill cannot do more, usually, than an eighth as much, this, of course, depending upon the character of the marble. Completing the work of the channeler is that of the gadder. This by far is a less noticeable and smaller machine, but a very necessary one. Like all the other machines this is driven by compressed air or electricity, or very rarely by steam when it seems most available. It is a drilling machine and, like the channeler, replaces a lot of handwork. Wherever holes are required, as under a channeled block, etc., the gadder is useful and may do the work of twenty men, when several drills are set in action.

Somewhat allied to the channeler and gadder is the corer. The work of the coring machine, as has been mentioned, is mainly preliminary, that of prospecting a new ledge, and as such it may be of very great value, as it enables the owner of a ledge to ascertain, as can in no other way, the character of a ledge and enables him to know with much certainty whether or not it is best to commence and carry out work on that particular deposit.

The channeler, as we have seen, is an indispensable machine in a marble quarry, but though the newer machine can work at an angle, as shown in Figure 39, yet most of the work of channelers is to cut vertical grooves, or more rarely, holes, close together down to the bottom of a layer and then cutting with a gadder horizontal holes between the layer drilled and that next below it. The gadder is a much simpler machine than the channeler, but hardly less important.

THE GADDER

Channeling separates a block from the rest of the layer to which it belongs while the gadder works its way in from the outside of the bed and bores a series of holes beneath the block, separating it from the layer below.

Gadders are essentially drills by which a series of holes are bored, as near together as convenient, on the lower side of a block. Usually the gadder is a power drill, but, of course, a hand drill may be used. Diamond drills can be used and often are in this undercutting. The next step in the process is driving some sort of wedge into the bored holes and splitting the block from its bed. (See Figure 40.)

The larger gadders carry several drills and are, of course, very efficient tools, though they are very much less conspicuous in a working quarry than the larger channeling machines, though just as necessary in detaching the stone. More or less extensively, diamond drills are now used in "gadding." The blocks as separated from the bed in the quarry are of such sizes as are needed at the time they are taken out, but if no especial size is called for at the time, the usual dimensions are followed. Of course, much larger dimensions are supplied when called for.

"Very soon after the diamond gadder, the Ingersoll Rock Drill Company brought out a steam drill which was very successful and it soon replaced the diamond gadder. Many attempts were made to channel with the gadder. Mr. Namhan Green attempted to make a channeling machine using three Ingersoll gadders mounted on one side of a car which was driven along the track by an independent engine. This was a failure owing to the fact that the drills would stick in the cut and the feed being independent would force the machine along the track, breaking off the drills."

With a gadder the holes are drilled as nearly 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 a crack is effected. The same method is used after all the blocks in the two keyway courses are removed to get at the other course for the entire floor of the quarry and in most instances the same method is used to insure 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 the marble should be cut free 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 the 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 keyway being loosened by drill holes and wedges. The blocks in the other courses in the quarry can all be removed from the floor and can be broken apart in each course by drill holes and wedges, though it is necessary to have a channel cut at the two wall ends of each course or strip. Something has been said as to the machine itself, but it has not all been described. Running like a small locomotive on the track laid for it, the channeling machine carries, in the smaller sizes, one set of chisels on the side, in the larger, a set on each side. This is the effective part. It consists of a set of chisels, each from seven to fourteen feet long. Five of these cutters firmly clamped together, the whole weighing several hundred pounds so that when raised and then dropped on the marble it has much force. The five chisels or cutters are arranged so that the middle one is longer than those on each side, which are each shorter than that nearest the center, thus forming a step-like group on each side. Thus the set forms a practically single broad flat drill which as it passes to and fro over the stone, continually rising and falling, cuts a channel.

Thus by means of the channeler and the gadder, and, if necessary, wedges below, a block of the marble is detached from its bed and can be hoisted out. The Sullivan Machinery Company appear to have produced the first gadder, about 1869, and since then various kinds have come into universal use.

In *Mine and Quarry,* a publication of the Sullivan Machinery Company, we find the following account of working one of the Clarendon quarries, illustrated by the accompanying diagram. It should be noticed that this is only one method, applied when it appears best to the foreman.

"The pit was sunk with straight walls to the depth of two channel cuts. With a fresh floor leveled off two channel cuts were put in at an angle of 45° with a Sullivan duplex channeler. These cuts were carried twelve to fourteen feet deep on the angle. A double row of key blocks was then channeled across the middle of the quarry floor the depth of the cuts and their distance apart depending somewhat on the size of blocks wanted. This work has been done largely by the Sullivan 'Z' swivel plate channelers, of which three are in operation. The floor cuts are at right angles to the tunnel cuts and are carried under the roof as far as the machines will work. The remainder of the cut under the roof, known as a transverse cut, and all corner channeling is done by a Sullivan 6½ channeler equipped with a corner-cutting mechanism. The first key blocks are wedged out and pulled from the tunnel side of the quarry, as shown in the illustration. The floor is then cut in both directions, the bottom holes for raising, as well as the breaking holes being drilled with two Sullivan steel gadders. This process is shown on the left-hand diagram."

HOISTING MACHINES

It is readily understood that so heavy a weight as the ordinary block of marble cannot be moved easily except by aid of suitable hoisting apparatus after it is completely detached from the quarry bed. It must be moved from the quarry to the mill where it is first to be sawed and then wrought as need requires.

First, then, the block is conveyed from the quarry to the mill and the usual manner of accomplishing this is by means of some sort of derrick, by which the block can be moved from the quarry and finally set in place under the gang saw. Mr. Patch tells of this as follows:

"In 1865, at Sutherland Falls, the derrick stood on the east bank of the quarry; the hoisting rope was two inches in diameter manila having a five-part lift with wooden tackle blocks and iron sheaves. The change had just been made from a sweeping hoisting power to a steam hoisting power having a vertical boiler. This hoisting power stood in the southeast corner of the blacksmith shop which was on the south side of the quarry.

"The only man in the neighborhood at that time who knew how to splice a rope was Peter Kivelin, known as 'Peter the Sailor.' Peter lived in one of the long tenement houses that stood on the hill south of the quarry, and the rope to be spliced had to be taken to his house, the large coils being left outside with the ends to be spliced taken in the house, the door shut as closely as possible and the shades drawn so that no one would 'steal the trade.'

"The quarries in West Rutland, however, were still being operated by the same style of derrick, using two-inch manila rope and five part lift with wooden tackle blocks, but the hoisting power was a vertical drum power set in the ground, turned by a pair of oxen attached to about a fifteen-foot sweep. The lifting speed was about one foot per minute, a little more or a little less, depending upon the pace of the oxen.

"A little later, the West Rutland derricks were changed to a single wire rope lift with geared hoisting powers having a grooved drum but still operated by oxen walking around the sweep. No change in speed.

"The next step was to replace the oxen by driving the hoisting powers with the steam power from the saw mills by underground shafts and belts. This increased the lifting speed to about five feet per minute, but it was a uniform speed which could only be changed by loosening setscrews with a wrench and sliding two pinions, to a faster speed for handling light loads, such as boxes of waste from out of the quarry; the fastest speed being fifteen feet per minute and could only lift four or five tons.

"Soon after Colonel Proctor became president of the Rutland Marble Company we improved upon the hoisting powers by attaching friction clutches to the hubs of the pinion gears which could be operated by a hand lever. It took several years to convince the quarry foremen, and even the quarry superintendents, that any faster hoisting machines would be safe. For instance, the Sheldon 'covered quarry.' There were two derricks on the west bank of the quarry and two corresponding derricks on the floor of the quarry, a gang of three men to each derrick, and when we suggested to the quarry superintendent that one derrick with a hoisting power speeded up to fifty feet per minute would do more work with one-fourth the help, he replied, 'We have to have the help anyway and we might as well keep the four derricks.'

"About the year 1867-68 the Sutherland Falls Marble Company built an overhead traveling crane to store blocks at the quarry. It was a very heavy clumsy affair operated by hand and very slow. Both craneway and bridge were of wood. The entire craneway was housed in and roofed over.

"At about the same time there was a hand power overhead traveling crane at West Rutland, the craneway extended from one of the east quarries long since abandoned, along the north side. Neither of these cranes were much used and were soon abandoned."

SAWING MARBLE

Unless the entire block as taken from the quarry is wanted, the first process undertaken is to saw the large block into slabs,

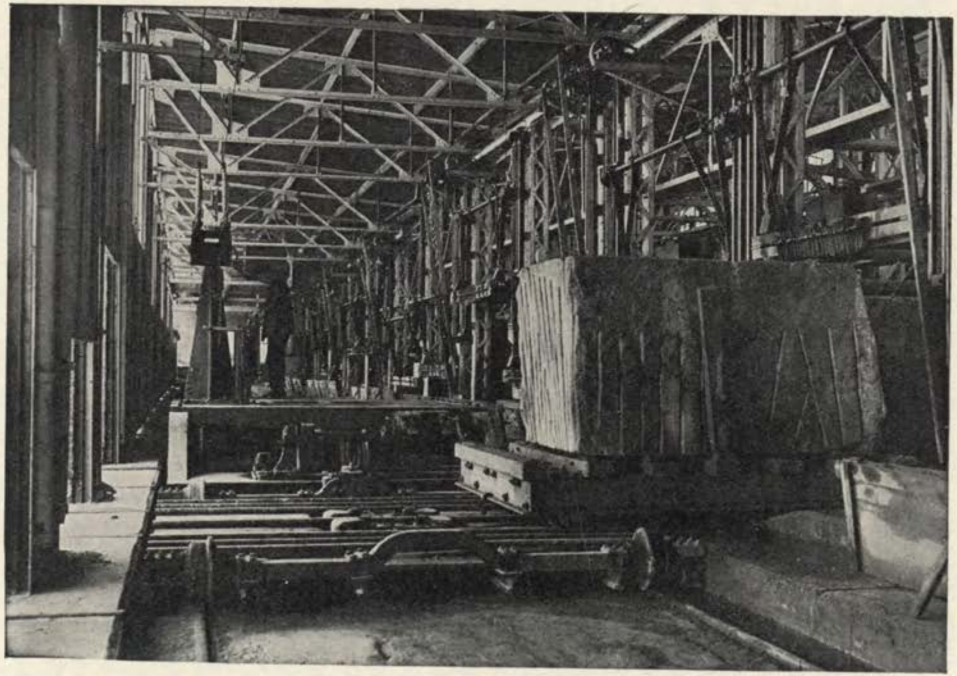

FIG. 44. Interior of a marble mill showing steel framework and electric transfer track for loading and unloading marble into gang saws at right.

or whatever may be wanted. In order to bring a piece of marble to the form or size originally needed, as we have seen, the task was slowly and laboriously done by hammer and chisel, and necessarily it was very crudely done. As will be shown from the most ancient working of marble until the present the development of machines by which the cutting the stone into such form as desired has gone on. In the history of such development we are aided by the investigations of Mr. Patch as follows:

"The oldest record which I have been able to find of sawing stone is in First Kings, seventh chapter, ninth verse, describing the building of Solomon's house. 'All these were of costly stones according to the measure of hewed stones, sawed with saws within and without, even from the foundation unto the coping and so on the outside to the great court.'

"Ezra Brainerd, in his 'Marble Border,' says:

1. Hand saws without teeth fed by hand with sand and water were used 350 B. C.
2. Saw mills for sawing stone driven by water power were in use on Little River Rorea, Germany, fourth century, Christian Era.
3. Long toothless saws as long as twenty feet were used in the Pyrenees quarries before 1700 A. D.
4. Saws driven by water power were used in Ireland in 1730. Polishing and boring was done in the same place.
5. Sawing and polishing by water power at Devonshire, England, 1748.
6. Automatic feeding distributing sand and water used by Filo, Tomlinson, Marble Head, Conn.
7. Marble sawed by water power in Middlebury, 1803. E. W. Judd, owner.

"In *Scribner's Magazine,* Volume XVII, page 342, is a print of a marble-sawing machine having two plain blades or saws, designed by Leonarda Da Vinci about the year 1480.

"Probably the first reference to marble in the State of Vermont was in a letter written by Nathaniel Chipman to Gen. Philip Schuyler, of New York. The letter was dated Rutland, January 25, 1792, and contains this statement: 'There are also in this part of the country numerous quarries of marble some of them of superior quality. Machinery may easily be erected for sawing into slabs by water and in that State it might become an important article of commerce.'"

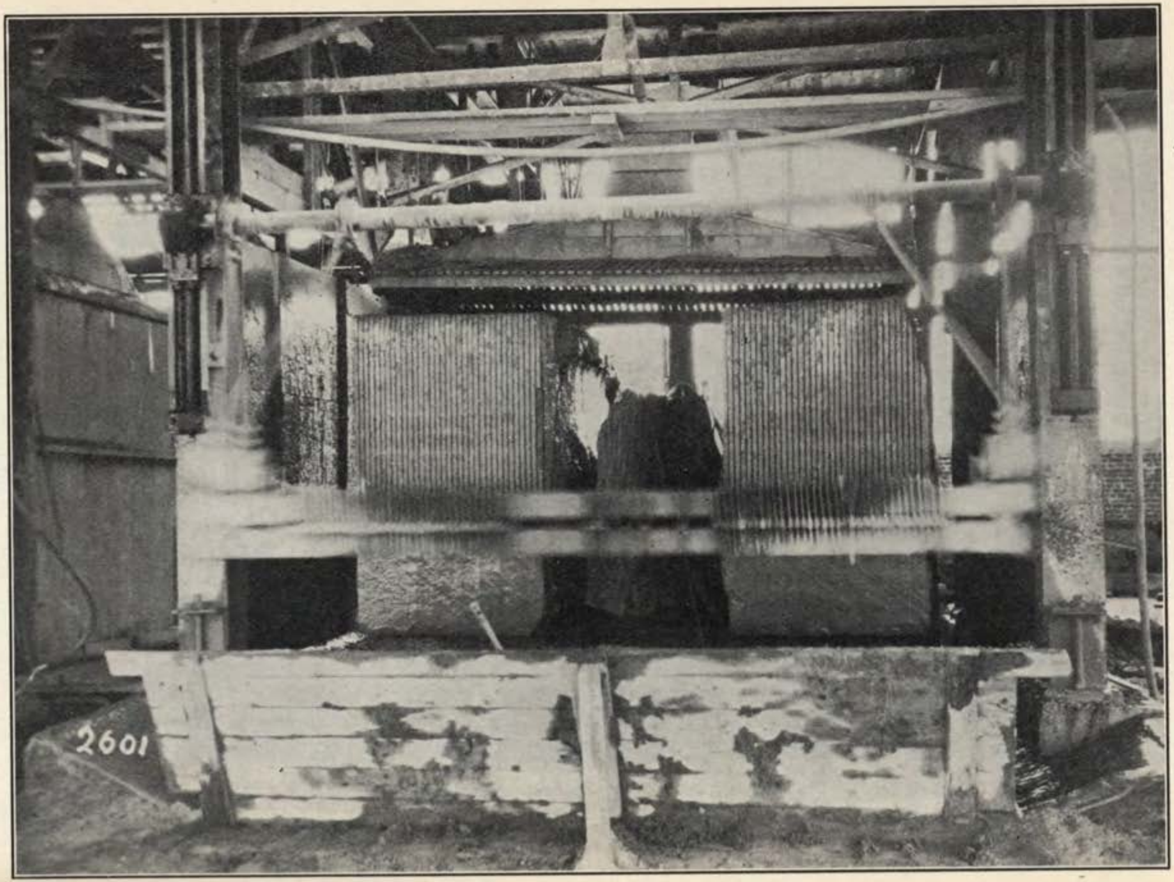

FIG. 45. Large gang saws cutting blocks into seventy-five slabs.

Figure 45 shows one of the largest gang saws built by the Patch-Wegener Company. Here we have two large blocks of marble, the two containing about seventy-five slabs. The saws have finished cutting through about two-third of the blocks.

"Where the Vermont Marble Company's blacksmith shop now stands, near the highway bridge, at Center Rutland, there were four pendulum gangs of saws for sawing marble in what was called the Porter Mill. They were driven by water wheels in the basement of the mill. A crank on the end of the water wheel shaft was connected by a short pitman to the lower end of a long beam; the upper end hanging to the ridge of the mill building. These beams were called pendulums and there was a long, vertical slot cut through each pendulum. Through this slot passed a yoke from the gang head-block, similar to the present noddle-pin. As the gang lowered, its stroke lengthened and as it was raised the stroke shortened, so that the longer the pendulum, the less variation in the length of stroke.

"The gang frames and sashes, including the headblocks, were of wood; however, the headblocks had an iron strap about five-eighths inch by two inches, one on each side of the slot, to prevent the keys of the saw dogs cutting into the wood.

"The gangs were suspended by four, about one inch in diameter, manila ropes, one attached to each corner of the sash, passing up over a wood roller, one at each end of the gang, to a central roller on which the ropes wound. On the end of this center roll was a flanged wooden wheel about four feet in diameter. Around this wooden wheel was another rope running down to a hand power attached to one of the gang posts. In this manner the gang was raised and lowered. A wooden pin stuck into a hole in the gang post prevented the crank from turning backward and the gang running down.

"To feed the gang down, the sawyer took hold of the crank, pulled out the safety pin, let off one turn of the crank, put the pin back, until in his opinion the saws had freed themselves sufficiently to stand another turn of the crank.

"The long ropes hanging the gangs from the roller above made the saws drag on the stone nearly the whole length of the stroke, especially when the gang was low.

"At such time, unless the sawyer was working 'be th' da,' he would put a hard hack pole from post to post behind the suspension ropes, to make the gang lift and take more sand and water under the blade. This hard hack pole was the father of the sway bar and the beginning of the suspension rod.

"The next advance step was the sway bar from post to post in wooden grooves, with suspension rod attached. About three-fourths inch round iron suspension rods, about six feet long, with a stirrup forged on each end.

"The manner of feeding down the gang remained much the same, until about 1863 when A. T. Merriman invented the screw gang. Mr. Merriman was foreman of the lower mill and he put in two small gangs to saw about four feet wide by nine or ten feet long. They were of very light construction and run about 110 or 115 r.p.m. The workmen called them the 'pony gangs.' The other gangs ran about 70 to 75 r.p.m. and we boys used to stand up on the pitman and ride when the gang was running. I have seen more than one boy take off his coat and put it on again while riding standing on a gang pitman in the old lower mill. In fact, I have done the same trick many a time.

"About this time came the cast-iron head block; but it was not until after 1870 that L. B. Clogston invented the steel sash while working for the Sheldon Marble Company. His first sash was of four-inch standard pipe and twelve-inch channel iron head-blocks. The workmen called it a 'horse fiddle.' Later, while working for A. N. Adams, at his marble mill in Fair Haven, Clogston built several gangs for use in Mr. Adams' mill, using wire instead of hemp rope, and iron bars instead of wood grooves to guide the sway bar. He also patented a clutch to grip the iron bar guide and prevent the gang from jumping. In 1877 twelve gangs of this type were put in the mill now called, I believe, the Patterson mill. These gangs had five-inch pipe sides, twelve-inch thirty-pound headblocks, the balance wheels weighed about 1,000 pounds. They also had a hand power to raise and lower the sash and an arrangement to feed down by power. In 1876-77 Milo Lyman built for Clement & Page the Continental mill at Center Rutland using a modified type of Clogston gang, very much heavier and stronger.

"In those days the hurst frames were of wood although about this time there were some gangs running in Burlington with cast-iron standards instead of the wooden hurst.

"David Shortsleeve made, I think, the first three-bearing cast-iron bell crank shaft. It was six inches in diameter and had a two-inch core all through it. After he went out of business the Patch Company bought the patterns and continued the making of cast-iron, three-bearing bell crank shafts. However, they soon discovered that the three bearings caused the shafts to break so they left off one, relocated the balance wheel and pulley, made cast-iron standards mounted on a cast-iron base. This led to the one-piece hurst and the steel crank shaft.

"The round sway bar rocking in boxes on the guide housing was first used by Volkening in New York City. I don't know who invented or first used the saw blade, but I do know that for marble the same old three inches wide, No. 11 gauge, soft-iron blade, has been used as long as I can remember.

"The very best method of feeding sand and water or other abrasive to the saw gang is a long-handled shovel in the hands of an intelligent, able-bodied man interested in his work. This is also the most expensive.

"The first automatic or power sand feed to be used in sawing marble in this part of the country was in the mill of the Barney Mill Company at Swanton. In planning the addition to the Clement mill at Center Rutland we considered the power sand feed. Mr. N. P. Simonds, then superintendent, took me with him to Swanton to see and learn what we could about the automatic feed. We spent one day in Swanton noting the marble sawing done by each gang and arranged with Mr. Barney to use the device in our new mill. The device consisted of cast-iron buckets, so made as to interlock one with the other to form an endless chain, thus making a cast-iron bucket elevator.

"We installed this feeding apparatus in the new extension on the west end of the Clement mill and this was the first sand-feeding apparatus used in Rutland County, although at the same time in the old Ripley grist mill, which stood across the river opposite the present Ripley marble mill, young William Ripley was experimenting with a sand-feeding apparatus operated by compressed air, which device was afterwards used for a time in several marble mills.

"I well remember starting the first gang saw with the sand feed. As usual, in starting a new machine of any kind there were many interested spectators. Mr. Simonds told many times afterwards of hearing one sawyer say to another while the saw gang was running successfully at about 100 r.p.m. with plenty of fresh sand and water: 'You know what that gang bees saying? "No Irish need apply—no Irish need apply."'

"The bucket sand feed worked very well but cast-iron buckets wore out rapidly and we experimented with rubber belting carrying steel buckets. There were many devices offered following this first installation, pumps of various kinds were tried, but, I believe, the first real successful feed was the rotary pump equipped by Hawley with chilled iron linings. Frenier, with his scroll pump, came at about the same time, in fact, it is hard for me to remember which came first.

"Until about the year 1880, the gang sash was guided and kept in place by wear irons attached to the gang side and running against hard-wood guide boards attached to the gang posts. Barney, of Swanton, invented the end bracing which replaced the wear iron and wear board. The early suspension rod was of round iron with a stirrup forged on each end, later the suspension rods, still of round iron, were threaded at each end and screwed into cast-iron boxes. These often broke in the thread causing much damage. We changed to flat suspension rods about 1904 and I have yet to see the first broken one.

"The Dorr mill, built by Dorr & Meyers in 1868-69, was built to be filled by trucks. A railroad ran from the derrick along in front of the mill and there was a wooden turntable in front of each mill door, from each turntable ran a track through the mill alleyway and a turntable between each two gangs. Although this mill was completed including tracks and cars or trucks, to the best of my recollection, none of the truck or car equipment was ever used. Although at this time, or it may be a year or two later, there was a truck mill in successful operation in Pittsford a few rods southwest of the Wheaton quarry.

"In 1872-73 Mr. Kelley built, at South Wallingford, a well-arranged eight-gang truck mill. The sash hung on chains were power fed, held down by a break clutch that had to be released before the sash could be raised. This mill was in operation until about 1890 and was destroyed by fire some ten years later.

"When the thirty-gang mill was being built about 1881, filling with trucks was considered and the building arranged for a door opposite each gang to run the truck through. We, for a time, used trucks under one gang.

"While planning the Clement mill we took time to keep tabs on all the gangs then in use in Proctor. We kept the record for several months and found that the most sawing was being done by a gang in the north section of the lower mill that in 1873 had been built over from the old-fashioned manila rope heavy style to a Merriman screw type. The speed was about ninety per minute. The crank was eleven inches throw and the suspension rods were forty-eight inches long. We built the gangs for the Clement mill with forty-eight-inch suspension rods, ten-inch crank and ran them 100 r.p.m. These proved to be the best cutting gangs we had and I believe so continued until they were destroyed by fire when the mill was about twenty years old.

"In the first Merriman gangs the screw had no step bearing, the entire weight of the gang being carried on the pedestals at the top of the posts. The step bearing was suggested to us by Wm. Graham, the foreman machinist at West Rutland.

"The timbers used in wooden hurst frames were ten inches by fourteen inches, either birch or maple. The gang sills were spruce eight inches by nine inches, the gang posts eight inches by eight inches, wooden pitmans were three inches by eight inches, all spruce. The sides of the sash were eight inches by eight inches spruce. The sash headblocks, if of wood, were either maple or birch, but in case of the narrower or block gangs, the headblocks were of cast iron.

"The gang frame itself was practically a part of the mill building, depending upon the line shaft timbers and mill roof for steadiness, and was not uncommon in mills having twelve or more gangs to feel the roof of the mill sway back and forth when the gangs, as frequently happened for a few minutes at a time, were running in beat.

"The change from wood to iron and steel was slow. The first change was in the sash from wood sides and wooden or cast-iron headblocks to pipe sides and iron headblocks. For many years this construction was very light, beginning with five-inch pipe, then six-inch standard pipe, then six-inch extra strong pipe, then seven-inch extra strong and now the steel H-beam. The change in headblocks began with twelve-inch, thirty-pound channel iron, using cast-iron corner irons slowly advancing in weight and width to fifteen-inch, fifty-five-pound channels, then to fifteen-inch, seventy-pound channels, then fifteen-inch, ninety-pound channels, either double or reinforced. I believe in some instances we use channels eighteen inches in width for headblocks.

"The True Blue mill, West Rutland, was destroyed by fire in 1891. It was rebuilt of steel using single steel channels for gang posts. The steel gang posts formed part of the building and helped support the roof in the same manner as had been the custom in wooden buildings.

"The burned mill had but twelve gangs, but when rebuilt was equipped with sixteen gangs, all fed by one Hawley sand pump.

"It is said that we move in circles and this must be so, for I notice the bucket elevator as an aid to feed sand and other abrasives to gang saws is again being tried. My experience with the first automatic outfit was sufficient to last me my lifetime. There were too many joints and bearings to withstand the constant wear of the abrasive.

"At Sutherland Falls, when the thirty-gang mill was being built, about 1881, filling with trucks was considered and the building arranged for a door opposite each gang to run the truck through. We, for a time, used trucks under one gang. I planned and had charge of building this mill and was anxious to see it filled by trucks. I had handled eight inches by four feet birch rolls in rolling blocks long enough to know that it was hard work. The block boat or drag was made of two three inches by fourteen inches by eight feet birch planks placed about eight inches apart and held together by four inches by eight inches hardwood crosspieces pinned together with wooden pins, having a strong draw iron at each end of the boat. By the way, I should add the boat planks were so sawn as to make the first two feet in length turn about two inches. This was done to make the boat catch and ride the roll placed on the ground in front.

"In loading, the boat was placed on the eight-inch rolls under the derrick and the block put on the boat on top of four iron rolls about three inches in diameter, if the block was right side up when put on the boat. This was done to assist in rolling the block into the gang, but if the block when put on the boat lay on its side, it would be so placed as to easily tip up when dumped into the gang, and you may rest assured it took an expert to do this. It usually took two pairs of oxen to pull this kind of a load. The head man placed the rolls in front of the boat, one man in the rear picked up the rolls as the boat left them, catching them by one end and tossing them forward to a middle man, who in turn handed them to a head man, who usually was an expert in turning corners, keeping the team going and so guiding the load as to have the block dump itself into the gang.

"In 1901-02 the Fowler mill was built, a steel building with twenty gangs filled by trucks, and to handle these trucks the F. R. Patch Manufacturing Company designed and built two special electric locomotives arranged to have a steel transfer attached, one to each end of the locomotive. The engines were provided with powerful hauling drums by means of which the block cars were not only put into, but pulled out of the gangs.

"In the block-rolling method above described, it required five men and two pair of oxen to keep eight gangs going part time, this in a mill not equipped with trucks. At the present time, three men with one of these special electric engines keep a forty-eight-gang truck mill so well filled that it is an exception to find one idle. This does not include, however, loading and unloading the gang trucks, this being done by men outside the mill.

"In 1902 I built for Volkenning's mill at Mill Street, Astoria, Long Island, New York, twenty-two gangs. Mr. Volkenning was quite a genius and suggested the round sway bar rocking in boxes attached to the saddles on the guide. This method allowed clamping the suspension rod to the sway bar, the method now universally adopted.

"Mr. Volkenning had two gangs attached to one crank shaft, the cranks, one on either end of the shaft, set on the quarter claiming a saving of one-half the power over the individual drive. I wanted to ask him, why not couple on two more gangs and save all the power, but I was more anxious for the business than to save him power.

"The so-called 'gravity gang' was for many years, and may be still, in use in the Sandstone mills about Cleveland and Borea, Ohio.

"The Columbian Marble Company had in their mill in Rutland thirteen gangs when they sold out in 1898 to J. F. Manning and in 1899 we changed the thirteen gangs and mill building so that the gangs could be filled by trucks, making this the first truck mill in the Rutland district. This change dispensed with twelve horses and after using the mill one year, Mr. Manning wrote me that their output was increased 33⅓ percent and the cost of operation cut down 25 percent.

"Soon after changing the old mill we built for the same company a seven-gang mill, then a fourteen-gang mill and later a twelve-gang mill, all truck filled. These were in operation when their quarry failed. The Vermont Marble Company leased it for a time.

"When I went to Sutherland Falls, March 1, 1865, the Sutherland Falls Marble Company had ten gangs and in 1869 they added ten more.

"In 1868 Dorr & Meyers built at Sutherland Falls an eight-gang mill which was not used until Redfield Proctor went there as receiver.

"In 1871 Redfield Proctor became superintendent for the Sutherland Falls Company and in 1876 built a twelve-gang mill adjoining the Dorr & Meyers mill and in 1880 built a thirty-gang mill and formed the Vermont Marble Company, then a twelve-gang mill, so that when I left there May 1, 1890, the Vermont Marble Company had 106 gangs running in Proctor. (The name of the village was changed in 1885 from Sutherland Falls to Proctor, at the same time dividing the town of Rutland into three towns, Rutland, West Rutland and Proctor.)

"In 1867-68 my father built for Wyman Flint, at the Double Crossing, a twelve-gang mill. I became fifteen years of age in October, 1868, but I had helped build the mill from the beginning to its finish, doing a man's work as carpenter and millwright.

"The year 1868 there was a strike of all the quarrymen in West Rutland, known by the older men of West Rutland as 'the big turn out.'

"Up to this time (1868) the workmen in West Rutland were all Irish, but when they 'turned out' the employers went to Canada and brought in a couple of cars of Frenchmen. This caused almost as much bloodshed as did the World War.

"On the west deposit in West Rutland, the West Rutland Marble Company opened a quarry and built a four-gang mill but shut down in 1885. This job sported the first electric lights to be used in quarry or mill, one arc lamp in the mill and two in the quarry but is more noted for the stolen bank funds concealed in their office safe, however, than for its lighting system. The quarry is now owned by the Vermont Marble Company.

"Clark Brothers operated the quarry which we know as the Eastman quarry and operated a four-gang mill there in 1870.

"In 1885 my father built the Baker mill at Rutland Valley for Mr. Baker. Baker's quarry turned out worthless and the mill was leased for a time to, and operated by, the Vermont Marble Company.

"W. H. Johnson and John B. Page organized the Valido Marble Company and built a twelve-gang mill in 1883 at the State line in Fair Haven. Their quarry in Whipple Hollow near West Rutland failed and the mill in Fair Haven burned about the year 1896.

"The first Clement mill, eight gangs, was built about the year 1845. A few years later four gangs were added to the east end. The line shaft was in a trench under the hurst frames which were of wood and bridged over the line shaft trench. When I built the fourteen-gang addition on the west end I took the line shaft out of its trench under the old mill, and put it overhead. In the first eight-gang mill, the front gang posts, that is, the post next to the alleyway were cut off about seven feet above the floor and the sash was guided by slides passing on two sides of the back posts. The front posts were cut away in order to make it easier to get blocks in under the sash.

"At the time of building the Clement fourteen-gang addition in 1885, the first power used to pull loads into and out of the mill was tried out in the thirty-gang mill at Proctor and met with plenty of opposition and it was only the foreman's fear of losing his job that helped the hauling power to win out, which it did, and within four weeks the very foreman that had fought against it asked to have a power installed in each alleyway of his mill.

"The hauling power was designed to relieve the horses that had but recently taken the place of oxen. In the days of ox teams the only way horses were used about the mill was singly, attached to a small light boat, although occasionally on a heavier load they were used tandem, but when the underhung steel for two horses came, with the single draw chain instead of the four leather thugs with heavy wooden evener and whiffletrees dragging behind, the two-horse team replaced the slow ox team. This took place in about the year 1883, although the Sheldon Marble Company continued using oxen until 1890.

"In 1877 I made the drawings for the first all-steel truck to be made of used T-rails. The truck was made in the machine shop of the Sutherland Falls Marble Company by Henry W. Taylor, who for the past fifty years nearly, has been engineer of the Heating and Ventilating Departments, House of Representatives, Washington, D. C. This first steel car was made of used T-rails so bent at each end that they rested on top of the axles and then dropped down to very near the ground lengthwise of the car. The cross pieces were made of about one and one-fourth inch by six inch iron bars and were so placed as to support rolls on top of which the block boat with its load was placed.

"The railroad truck ran from the derrick about 250 feet along the front of the mill and the steel car drawn by oxen moved on this truck to a point opposite the mill door, where the block boat and its load was drawn off the steel car onto rollers into the alleyway and gang, a great saving from the old method of rolling the block a long distance and turning a sharp corner into the mill.

"About the year 1887 D. Shortsleeve & Company made gang crank shafts of cast iron. They were about six inches in diameter made for three bearings. The crank was of the so-called bell type and there was a two-inch core hole through the center. Soon after the Shortsleeve shop closed we bought their pattern and used it in place of the thin common type of about four and one-half inch round iron shaft with cast-iron crank wheel.

"The balance wheel had by 1910 increased to from 1,200 pounds to 1,500 pounds in weight and the belt pulley from thirty-six inches in diameter by nine inches face for an eight-inch, four-ply rubber belt, to forty-two inches in diameter by eleven inches face, using a ten-inch, five-ply rubber or in some instances a ten-inch double leather belt.

"The cast-iron crank shafts broke, we thought, owing to the three bearings, so we discarded one bearing. Then we had them made of steel castings without changing the dimensions. Then we changed to steel forgings and this is the shaft that is in almost universal use today, although the balance wheels and pulleys are much larger.

"We made our first cast-iron hurst frame in 1898 for the three-bearing crank shaft, three cast-iron stands set in cement. Four gangs of this type were erected in Norcross Brothers' Charles River plant in Cambridge, Massachusetts.

"Our next step was a cast-iron base plate for the three stands. We for a time, after adopting the two-bearing crank shaft, continued to use a base plate until we adopted the plan of making the complete frame in one piece, and this too is the common practice today.

"You will note that this story begins with the crude, pendulum construction gang saw (which by the way was a better piece of timber work than we see nowadays). We have followed along through all the so-called improvements, from water power with water wheels twenty-seven feet in diameter, to steam-driven mills and now to electric drives, and from direct connection to the water wheel, to and through the line shaft and belt drive, until the present popular method is the electric motor unit drive, twelve or more V-belt drives and 4,000-pound balance wheel."

In this country it was used in mills in Connecticut in the early years of 1800 and also, though probably, a few years later in Middlebury, where as has been noticed there were several marble mills. It may very likely have been sawed in mills at Dorset though as to this and also as to Pittsford, there are no unquestioned records. In a pamphlet, "Statistical Accounts of Middlebury," by Prof. Frederick Hall, published in 1821, is found the following: "The marble in this village, which is now wrought on a large scale, and extensively diffused over the country, was discovered by Eben W. Judd, the present principal proprietor as early as 1802. A building was constructed and machinery for sawing the marble was then first put into operation. In 1806 a new and commodious building two stories high and destined to comprise sixty saws to be moved by water was erected. In 1808 this enlarged establishment went into operation and has continued until the present day (1821)."

"The saws are made of soft iron without teeth and are similar to those used in Europe in sawing marble by hand." Quoted from "Marble Border of Vermont," page 65.

Professor Hall evidently found Mr. Judd's mill in active operation and this proves conclusively that saws were used to cut marble some time before his visit.

Some of the early writers, speaking of Middlebury, declare that the saws used in the marble mills there were invented by a Middlebury boy. How this may be cannot be determined. So, too, Professor Hall evidently thought, for he says in the account from which the above is quoted, in speaking of the saws at work on the stone: "The idea of which had its origin in the inventive mind of the proprietor."

The "saws" had no teeth, as similar ones still used do not have. The "saws" are bars of soft iron arranged in a suitable frame and propelled back and forth through the block of stone, at the same time being plentifully supplied with fine sand and water. The sand supplies teeth to the saws. Probably the most ancient marble saws, except in unimportant details, did not differ very greatly from those still in use.

Now, a "gang of saws" is made up of a greater or lesser number of "saws" in a steel frame. The hand has long since given place to water power, now this is displaced in up-to-date mills by electricity produced by water power, though steam is used when water power cannot be obtained. The following item gives the cost of these saws and may be of interest to some of those who read this:

"In 1888 the Vermont Marble Company shipped by water around Cape Horn to San Francisco two double Pitman gangs complete. They were made by Willard in the old Shortsleeve shop on Strongs Avenue, Rutland. They cost the Vermont Marble Company $450 each.

"On August 18, 1892, the Vermont Marble Company bought of the Patch Manufacturing Company eight single Pitman gangs complete for $3,600. All of the above-mentioned gangs were of the Merriman type and weighed about 10,000 pounds each.

"Each gang consisted of all of the iron work and bolts necessary to attach same to wood posts and wooden hurst frames.

"The Patch Manufacturing Company a few days ago shipped two of their latest model gangs. They weighed 31,400 pounds each and eight of them would sell for $20,000. They have one-piece cast-iron patented hurst frames, seven-inch steel pipes, fifteen-inch, seventy-pound channel steel headblocks, cast-steel corner irons, ten inch by eight inch 'H' steel posts."

Although saws of some sort have been used for centuries in Europe and Asia and appear to have been independently invented in this country more than a century ago, comparatively a very short time, nothing has been as yet found to take the place of the gang saw machine, though, as has just been related, the machine for sawing has been improved, still it is essentially the same.

In the early days a mill meant little else than some arrangement of saws, all the variety of machines for finishing marble have been developed long since the saw and, as we have seen, much has been invented and is manufactured here in Vermont. For finishing marble there are many machines, but for sawing it from large blocks nothing is equal to the gang saw, even now. Much larger saws are now used when needed. The frames are steel, the necessary sand is more automatically supplied, nearly all parts of the old machine have been improved, but it is still the gang saw. A more complete description of this contrivance will not be amiss.

"The gang consists of a steel frame suspended from above with an arm reaching back to machinery in the rear which gives the swinging motion. The frame is so arranged that saw blades . . . . can be tightly stretched from front to rear. There is a car under each gang which carries the block or slab which is being sawed. (See Figure 44.) As soon as the block is sawed down it is pulled out by power and another car carrying a new block is rolled under the gang. The sawed slabs go directly to the finishing shops or if there are no orders for the particular grade, to storage yards. Many blocks produce marble of several different grades." —Vermont Marble Company.

In carrying on the above process an astonishing amount of water and sand is needed. Of course, if water power is used in driving the machinery of the mill, an abundance of water is at hand, at any rate it must be supplied, as must plenty of sand. Hence, an ample supply of sand is essential. One of the Vermont Marble Company's officials, speaking of the Proctor works, gives the following account:

"Years ago, when the quarries were young, a big sand hill stood beside the mills. Little by little this was carried down to take its turn with the grinding steel. Later a short aerial tramway was stretched across the river to another sand deposit. Finally when this was cleared away, the tramway was extended more than two miles over a mountain to a supply which has made all other small. For more than twenty years the buckets have been in endless chain eating into the heart of that gigantic sand bank. They arrive in Proctor, each with its load of 500 pounds, at the rate of one every twenty-eight seconds. Millions of tons have been moved down into the valley and the end is not yet in sight."—"The Book of Vermont Marble," page 13.

During a working day of twenty-four hours this means a lot of sand. It must be remembered that in gang saws there are no teeth, they do not saw as wood is sawed, the sand or other abrasive does the sawing, the bars of iron or steel or the wire cable, of which a description is soon to be given, are only carriers, moving to and fro endlessly bearing mixed sand and water and the sand is used over and over again—it is these that do the sawing.

We are told that in the harder marbles an amount of sand equal to the amount of stone sawed is necessary. Without an abundance of sand and water the gang saw is useless. Hence, if Vermont did not provide plenty of sand and water it could not lead in the marble industry as it long has done. Not everywhere in the State is sand as conveniently located as it is at Proctor, but if the sand is not at hand it must be drawn there, and the Proctor sand bed not only supplies the need at Proctor, but also at other plants.

A word may tell us where all this sand of which we have been speaking came from. It came from the mountains. In geological times (to go no farther back than the formation of our mountains, else the story would be too long for our present purpose) we find that all elevations, large or small, were, in Vermont, finally composed of very hard stone. Had they been made of soft stone Vermont would have no, or at best, little sand of any value to the marble industry.

CIRCULAR SAWS

While quarry blocks must be sawed by the methods mentioned, slabs and all small pieces are cut to whatever size is wanted by circular saws, actually sawed as wood is sawed by toothed saws, though, of course, more slowly. The steel teeth of wood saws are in the marble saws reinforced effectively by diamond teeth and more recently by carborundum, or the entire saw may be of carborundum. Thus all work may be greatly speeded. In the diamond saws the black diamonds are imbedded in small pieces of steel (about an inch square) and these are so placed that they

FIG. 46. Circular saw.

form the teeth of the saw. Figure 46 shows one of the smallest of the circular saws.

WIRE SAWS

The wire saw is little used in the marble quarries of this country, but in the old world it has for a long time been extensively in use. For the requirements of our quarries the common gang saw is found to be much more ordinarily useful than the wire saw. Nevertheless, in some cases this saw is sometimes used in Vermont. The huge block used in the tomb of the unknown soldier at Arlington was sawed at Proctor by one of these machines, the great block being too large for any of the gang saw machines.

As in the gang saw, the sawing is done by sand. The wire saw, really a wire cable saw, is made usually of three strands of wire twisted to form the cable. This cable is endless and is carried over two or more wheels or pulleys. It is usually arranged so that the whole machine is portable and can be readily moved about. The pulleys are of various sizes as may be decided by the special work to be done.

According to English writers, for most purposes a driving wheel four feet in diameter is best for ordinary use, but other sizes are in use varying from not more than six inches to several feet in diameter.

"The wire saw serves two purposes. First, it is employed for cutting the stone from the quarry bed and second for cutting the stone so obtained to the required dimensions. Where the formation is suitable dimension stone can be quarried direct; in other cases huge blocks are extracted, these being afterwards cut to size."

The inventor of the wire saw writes: "In a word, I claim essentially as the basis of my invention, the employment, as sawing instrument, of one or several wires or metal cords or chains, acting in a continuous or rotary motion driven by hand or machine with the property of flexibility and linear reduction, to bite at the same instance the block along all imaginable outlines which may be needed for sculpture or statuary, mosaic or other artistic and industrial objects."—"Marble and Marble Working," page 32, W. G. Renwick, London, England, 1909.

This sort of a saw for detaching blocks from the marble beds as well as reducing too large blocks is declared by foreign writers on marble quarrying to be cheaper when only small quantities of stone are needed.

Mr. Renwick writes: "The channeling system is more costly in adoption than the wire saw and much less portable." The wire saw can be stationary in a mill, but often it is moved from place to place, as the gang saw cannot be. On the other hand, a channeler can do very much more work in a given time but it needs a more intelligent operator and more power. The wire saw may be, and often is, used in other countries in the quarry to detach the stone, as well as to saw the blocks into slabs.

According to European authorities the wire saw is more economical in localities where the demand for marble is not very great.

Mr. Gale, of the Vermont Marble Company, writes: "Our experience with wire saws, so far as work in the quarry is concerned, has not been satisfactory. Thus far we have found drilling and channeling machines much more effective. We occasionally use a wire saw outside of the quarry when a block is too large for the mill, but with the present capacity of the larger mills, such occasions are very rare."

As in gang saws, the saw is not the wire but the sand and water are the essential parts of the machine. It has been found by experience that the best sizes of wire are those of three- or four-sixteenths of an inch in diameter, making, when three are twisted in a rope, one of nine- to twelve-sixteenths inches in diameter. In a pamphlet issued by the United States Bureau of Mines, *Bulletin 469,* is an excellent account of the wire saw. This saw is operated far more extensively in slate quarries than in marble.

In many ways the great ice sheet, or possibly more than one, though there is not certain proof of more than one in Vermont, vastly benefited the region, though at the time it existed it seemed terrible desolation.

At present when one travels over a sandy waste or through a cut in a sandbank, it is not regarded as of much value to the State, but the time may come when its value becomes important, and its use as an aid in cutting the marble into serviceable pieces is not the least of these. Other uses of sand may not be even noticed here, but some will occur to any reader. Of course, the chief work of the glacial ice, was, in various ways, to prepare the region for agricultural uses, but if we remember that the only source of sand is from what were originally rock masses and that most of our sand is broken and ground from the mountains and that nothing less than glacial action and running water could have produced most of the sand we now find, we realize what the ice has done for the future of the State.

If we want to think of the former greatness of the Green Mountains and all our elevations, we must see them as much higher than now, most of the present sand being added to the present mountains. It is not forgotten that the lakes and rivers have done their part, but only a small part, relatively. Probably Vermont would have been a marble state had no, or little, sand been produced, but it could not have produced what it has and what it can produce for long. Some idea of the amount of sand needed can be better imagined if we know that the Vermont Marble Company have dug and brought over the hill by their tramway from a not far distant sand area and lowered over seven acres a total of sixty feet.

As may be imagined there was always more or less difficulty in bringing in the heavy blocks of marble from quarry to mill where it could be sawed and the methods practiced were developed as were the other contrivances for preparing marble for sale. I glean from accounts given by several who have had experience in this part of the business.

At first all marble mills were necessarily near some water power, but the quarries were usually at some distance from the mills, hence the necessity of getting the blocks as channeled out from the quarry to mill. And this was sometimes a problem not easily solved. The heavy blocks must be placed under the several sawing machines. At first and for years the stone boat or "drag" was drawn by slow moving oxen and thus drawn to the gang, from which they were slowly and laboriously moved under the saws, using a series of wooden and iron rollers, until it was properly placed. Usually two yoke of oxen were needed to accomplish

this. In the later sixties, instead of the stone boat a sort of low-wheeled cart was sometimes used and, later, generally, tracks on which cars could run from quarry to mill were used, but the cars or trucks came into use only gradually. After a time horses were used in place of oxen, but oxen were used by some companies till as late as 1890.

Yet in many mills better methods were in use before this date. Mr. Patch, to whom reference has often been made, in 1887 invented an all-steel truck by means of which this work was more easily done. In some of the Proctor mills, as early as 1885, the trucks were drawn from quarry to mill by steam. At last in the then most modern mill, electric power was adopted. A unique sort of locomotive was invented by Mr. Patch, driven by electric power.

The aerial tramway by which, at Proctor, sand was brought has already been mentioned. It is difficult to think of a more effective method of moving the indispensable sand than this. Of course, in quarries selling marble only in blocks to be finished elsewhere, all this difficulty in transportation is avoided. In a few cases branch railroads have been constructed for transporting the marble from point to point. Thus by various methods according to varied conditions the transportation problem is solved.

THE RUBBING BED

After a block is sawed into slabs the next step, if it is to be completely finished, is to smooth and then polish the surface. The precise method employed varies more or less according to the kind and hardness of the stone.

Mr. Patch says: "The first rubbing bed installed at Sutherland Falls, and almost the first rubbing bed in the State, was an unfinished cast-iron plate eleven inches in diameter. The machine was erected out of doors. The rough top of the marble was smoothed somewhat by placing on the plate large pieces of grindstone."

Plenty of sand and water was first used as a piece of marble was applied to this surface and by these, the disc of iron being rapidly revolved, the marble was made comparatively smooth. This small plate soon developed into a larger and more efficient machine, until now a well made iron wheel, sometimes twelve or fourteen feet in diameter, is used. If to be used as building marble this treatment is all that is needed, though even in a building a more finely finished stone may be desired, and usually for interior

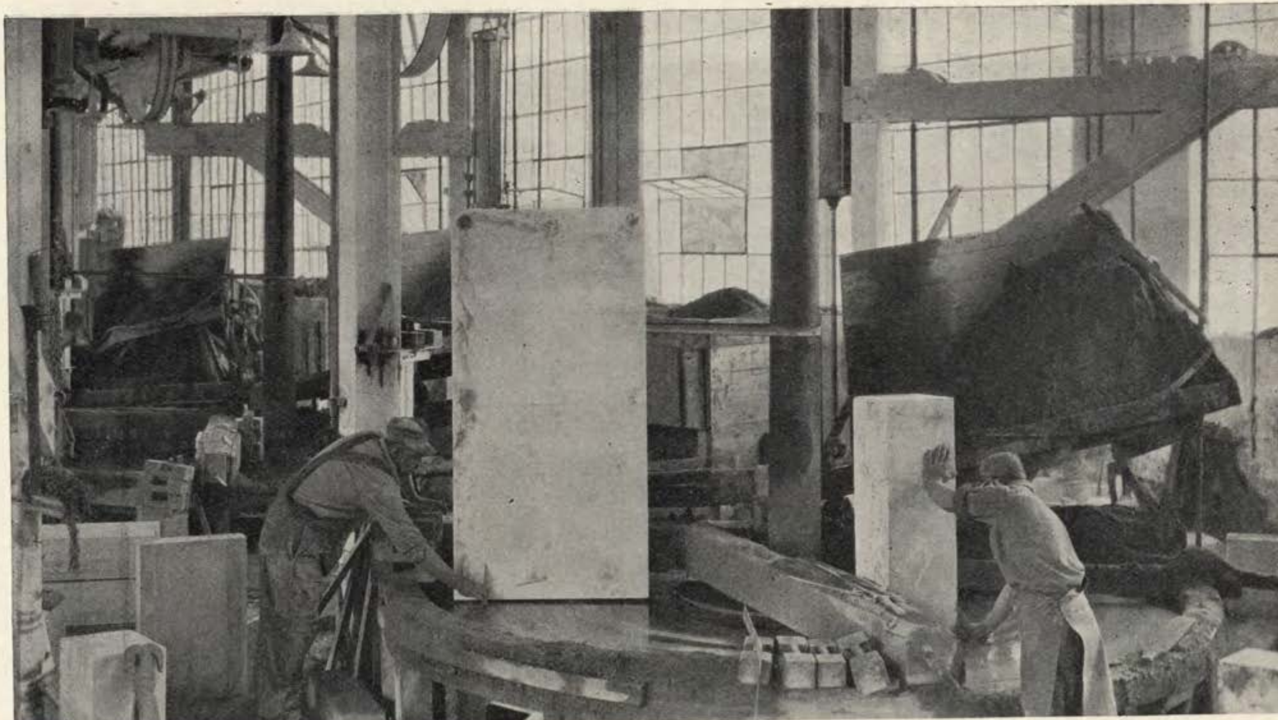

FIG. 47. Marble rubbing beds.

work, mantels, wainscoting, etc. The rubbing beds are large or small as determined by the size of the stone to be rubbed. Figure 47 shows a modern rubbing bed.

After the marble has been sufficiently smoothed on the rubbing bed, if it is to be polished, it goes to

THE POLISHING BED

The construction of this machine varies somewhat, but in general, as is shown in Figure 48, as a whole, and some of the numerous discs used are shown in Figure 49.

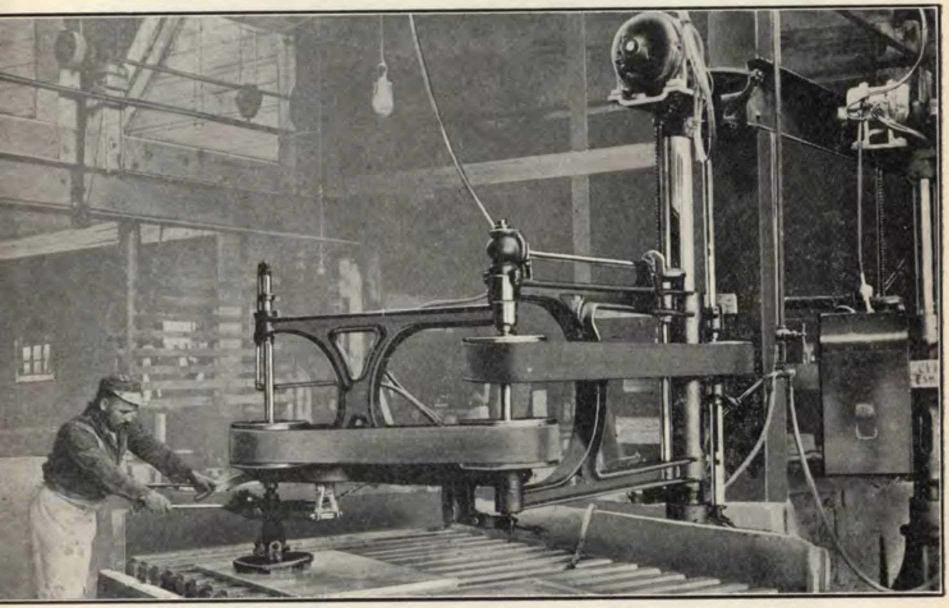

FIG. 48. Polishing machine in operation

As shown, these discs are more varied and much smaller than those used if the stone is to be only smoothed. The polishing wheel is usually small, covered with felt, supplied with polishing powder of some sort. The polishing wheel or bed is not large like the disc of the rubbing bed. The polishing machine usually employed is that shown in Figure 48. This rather queer-looking machine may be easily understood after a little examination. No water is used by this machine, but polishing powder placed on the rubbing disc. As may be seen from the figure, the arm of

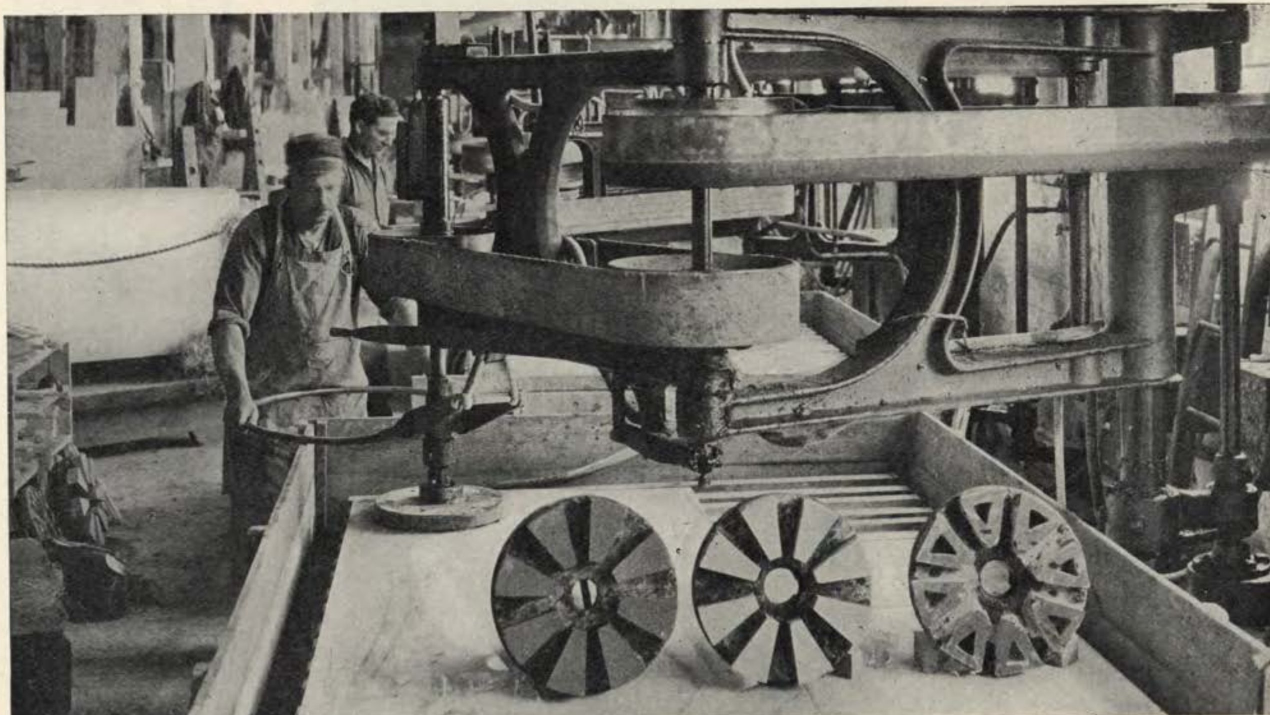

FIG. 49. Polishing machine, showing three polishing discs.

the machine is so hung that the discs, a variety being used, can be moved in any direction over the stone.

As the disc is rapidly revolved over the marble it soon brings the luster to its surface. Various discs and kinds of powder are used on various sorts of stone. In most cases the entire work can be done by this machine, but in some the best result can be attained only by hand. In using the polishing machine the workman holds the movable ring at his right and by this guides the parts which control the disc. The installment of the polishing disc has made possible not only a great saving of time and labor, but it is able to obtain a finer polish in some marbles than had been produced before, though this is not true of all varieties.

The stone is placed below the revolving disc. This disc is covered with felt on which some kind of polishing powder is spread. Different kinds of stone require different materials, as a finer or less fine polish is needed. For instance, if only a very smooth surface is desired, carborundum powder is used; then if a more polished surface is to be made a material called aloxite is used on some other disc; then if a fine polish is wanted a disc faced with a fine hone is necessary. Other methods are used in other cases, and if a very fine polish is given the piece of marble the disc is covered with felt and this covered with some polishing powder.

The reader will readily see that all this applies only to plane surfaces. A very irregular surface must be polished, now as always, by hand. It is easily seen how greatly the use of machinery has lessened the work of former days, when all this must be done by hand. Here we have a great saving of time as well as of labor and thereby great lessening of expense.

FINISHING COLUMNS IN LARGE PIECES

As was long ago mentioned, marble may now be, it is hardly too much to say manufactured, in many cases in much the same manner as wood, though less rapidly as large columns, such as that shown in Figure 12, which are no longer laboriously worked out by hand, but turned in great lathes as wood is turned. For the most part now hammer and chisel are out of date, the machines do the needed work and better, but, nevertheless, in many jobs nothing but the hand can accomplish the desired result.

What has already been accomplished in invention of machinery is wonderful, as we compare modern methods with those of long ago, but all has not yet been done. It is scarcely possible, even

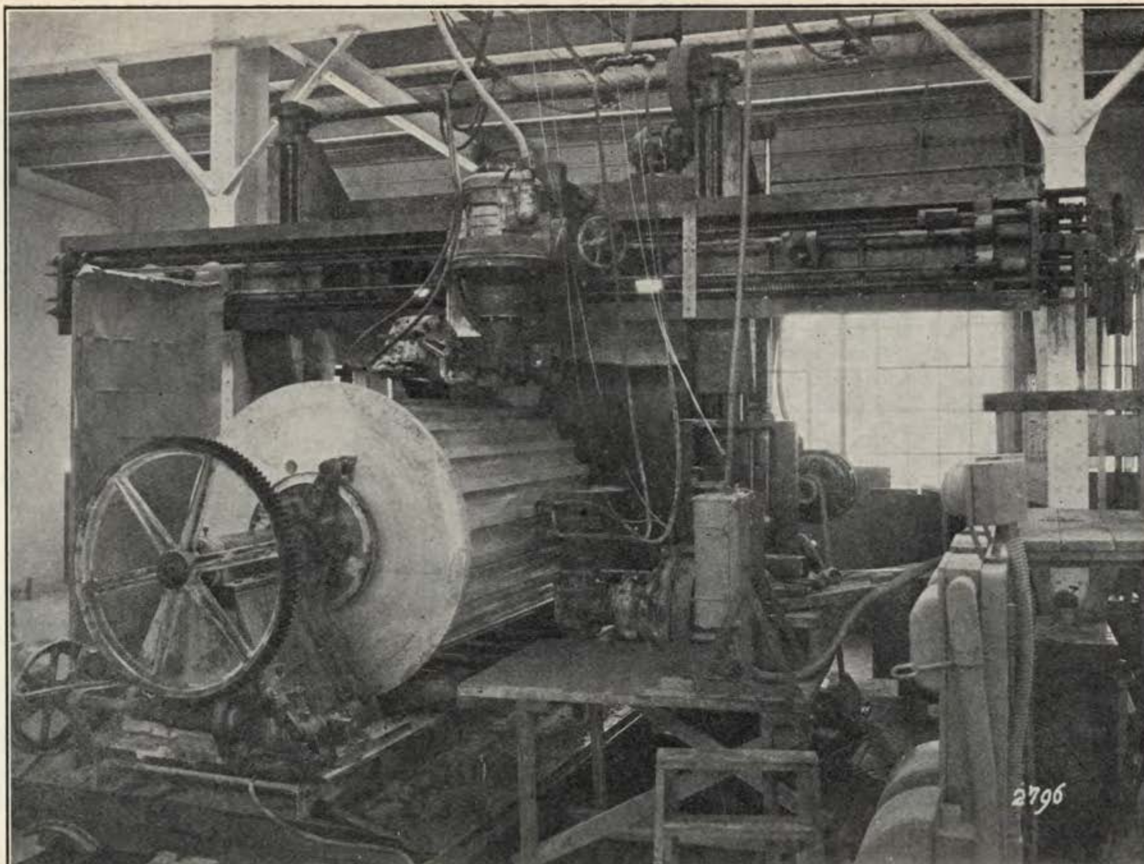

Fig 50. Fluting a large column.

if aided by abundant illustration, to present in a clearly understandable manner the way some of the more complicated machines do their work. Seeing them work is far better than any description can be. But in an article such as this, not what is most desired, but what is possible, must be presented. Although it can at best be only a very imperfect and unsatisfactory attempt, yet it is better than nothing, at least, to mention some of the more complicated machines now in use. That most, if not all of the marble-working machinery is very useful is well proved by the wide use of machinery put upon the markets of the world by our Vermont companies.

COPING AND FLUTING MACHINES

A machine which very obviously saves much time and labor is shown in Figure 50. It is easily seen at a glance how this machine, furnished with numerous carborundum wheels, as need determines, is able to accomplish many of the operations formerly done by hand and chisel. Columns finished in a smooth surface can usually best be turned on a lathe, but when, as often, fluting of some sort is demanded, this, formerly and not very long since, done only by hand, can much more cheaply be done by machine. Few, if any, columns would now be laboriously cut by hand, and there are many examples of the machine fluted columns in our public buildings. The machine can easily be adapted to very large or to small columns as desired.

The machine figured has a platform or table on which the block to be cut is placed. This table is rotary and is marked by a scale to be used to set the machine for whatever grooves or flutings are wanted. Of course such arrangements as are needed to secure the block in place during the operation are provided. As seen in Figure 50, there is an upright pillar on each side which holds necessary attachments and, most important, a circular saw, usually carborundum, but, if preferred, diamond. By automatic adjustment the column may be uniform in diameter or tapered. Of course, by such a machine long columns cannot be fluted, but in drums.

As described by a marble worker, "The manner of operation depends upon the size and depth, also shape of the fluting desired. When the fluting is deep, so that considerable marble must be cut away, a number of diamond saws may be used. These are always circular, but of different sizes as may be needed, and a number can be used at once. These may be set an inch or so apart, making what may be called a battery. Feeding these saws through once, cuts the stone, groove or flute into thin partitions which can be easily removed."

After the stone has been cut by diamond saws, these are removed and carborundum wheels are substituted, which finish the groove. The carborundum wheels are shaped to make the fluting as desired, then flat edged carborundum wheels are used on the portion between the grooves. By appropriate changes in the cutting parts, larger pieces are worked into desired forms, such as are needed in bases, capitals, etc., and when needed for such work various turning tools are used. As large drums as seven feet in diameter and six feet long can be worked out on this machine.

It may occur to the reader that to well understand such a machine it must be seen when at work, not merely read a description. Only when seen actually at its task can the speed and efficiency of these newer machines be appreciated. There still is some delicate or intricate carving, and nothing can replace a skilful workman, but the manner of cutting, carving, molding marble now, as compared with the only known methods of past years, and not so many either, is very impressive.

Other similar machines are used in turning out small balusters and work of that kind. After the marble is worked, usually by saws like that shown in Figure 46, or otherwise worked into shape suitable to the purpose, they may be finished by a somewhat complicated machine and in a few minutes completed, while if shaped and finished by hand the work might require hours. Not only is much time saved by the use of these machines, but the work is done more accurately and in the separate pieces, as in a row of balusters, each piece must be exactly like every other. Of course in some cases it happens that only hand work can accomplish the desired result, but this does not often occur.

PLANING MACHINES

Especially in the larger marble works it often occurs that planing a slab or other piece of marble is the most rapid and satisfactory method of finishing it.

Before going to the planer the marble is usually "set in" by the cutter, which means that the mold is cut by hand for about an inch at each end of the piece. Shop lists or diagrams of each piece are provided by the drafting department so that the cutter may know the dimensions and finish. In the case of molded sections it is the custom to furnish metal patterns for the guidance of the cutters. Turned work is brought to form in a lathe in much the same way that wood or metal is fashioned. If a column is to be fluted it is done on a planer or carborundum machine after it has been turned. All this applies to outside work; on interior work these same processes are often carried farther.

DRILLS

Drills of many kinds are constantly needed in all marble work from quarrying to finish. Consequently we find in all the catalogs of stone-working machinery the omnipresent drill of some kind. The number and variety of the drills is much too large to find space here and new and, it is claimed, improved forms are every now and then brought out. Not only when a quarry is opened, but before, it is now very important or rather so considered, it of course was always important that the marble beds be tested as much as possible, by coring drills, and thus often prevent costly work with only hope as guide. Figure 51 shows one very effectual method of this testing.

In most cases when the drill of whatever sort can be used it is worked by some other power than the human hand, most commonly by electrically produced compressed air. In fact, compressed air is now used very generally in all forms of marble work.

Mr. Gale, of the Vermont Marble Company, writes of this: "The new machinery introduced into the quarries since 1914 consists mainly in air compressors and pneumatic drills of the jack-hammer types. Many of these drills are fitted with pneumatic feeds in place of the older screw feed for advancing the drill into the marble. These pneumatic drills, with suitable attachments, are now being used for channeling, especially where the cuts are flat or at considerable slope, as in driving tunnels. The channeling operation consists in boring a series of holes near together and breaking out the partition between the holes with a flat steel broach.

"The use of compressed air in marble mills, as well as in all other stone-working mills, and elsewhere, has in a way revolutionized several branches of work. Limiting ourselves here to our special line of work, it may be said that in many phases of marble working, and many kinds of work until comparatively recent times, carried on entirely by hand and, therefore, laboriously and in some cases very expensively; now by the application of compressed air to various tools and machines the same or better work is done easily and cheaply. Still further has marble-working machinery been greatly improved by a combination of electricity as motive power in the first instance in the main source of motive

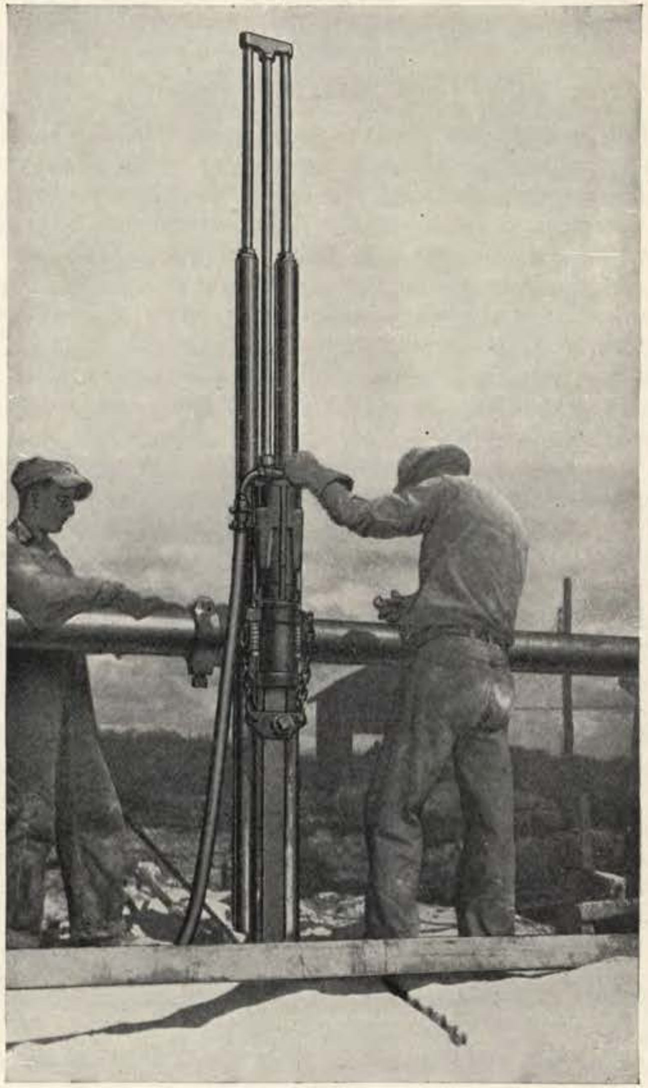

FIG. 51. Testing marble by use of a drill which removes a circular piece or core of the material.

power, and moving the tools, large and small, by use of compressed air. This is common in many marble quarries and mills as they are now equipped. Compactness in many tools, simplicity in all efficiency have been thus obtained. What are called 'jackhammers,' which are made in great variety of sizes, and to some of form are, perhaps, the most prominent examples of this present kind of tools. Perhaps in no branch of the stone business, especially in numerous kinds of marble work, are the pneumatic tools of greater value than the 'jackhammer drills,' chisels, etc. It would seem that in no way other than this has the work in quarries, ledges, and mines, wherever stone is worked, been so changed and speeded up from the former hand-cutting methods. As is usually true the value of such machinery is much greater in large mills, or wherever there is much work to be done, than in smaller establishments, because of the often expensive machinery necessary."

So important has the use of compressed air become that in all but very small stone-working establishments some form of air compressor, of which there are many available, is at hand. Not only are large and permanently fixed compressors in use, but smaller, portable compressors are easily obtained. It is not too much to say that, as has been intimated, the introduction of machinery powered by compressed air has revolutionized all marble mills, and in thus reducing the cost of marble has been a prominent factor in the greatly increased use of marble, especially in building operations.

CARBORUNDUM

Of comparatively recent use, at least in its many applications, is the invention and greatly multiplied use of carborundum. It is especially fortunate that this is true now that the formerly much used black diamonds have so greatly increased in cost as to be almost prohibitive as an aid in stone working.

The use of carborundum is an example showing how one invention may lead to another, for until it was found how an electrical furnace could be made, and thus greater heat be produced, this most necessary material could not be made, except on a small scale and that expensively. As it can now be cheaply produced, is harder than any other material obtainable, except costly stone like the diamond, it can be molded into many forms as needed. Carborundum is made in an electrically-heated furnace by melting together a few simple and inexpensive materials.

Carborundum is a silicon carbide (chemically $SiO_2 + C_2 = SiC + 2CO$), good sand, charcoal.

All the cutting and molding machines are supplied with carborundum wheels or other appliances and much of the labor-saving work could not be accomplished were this material not available. Figure 52 shows a carborundum machine in operation.

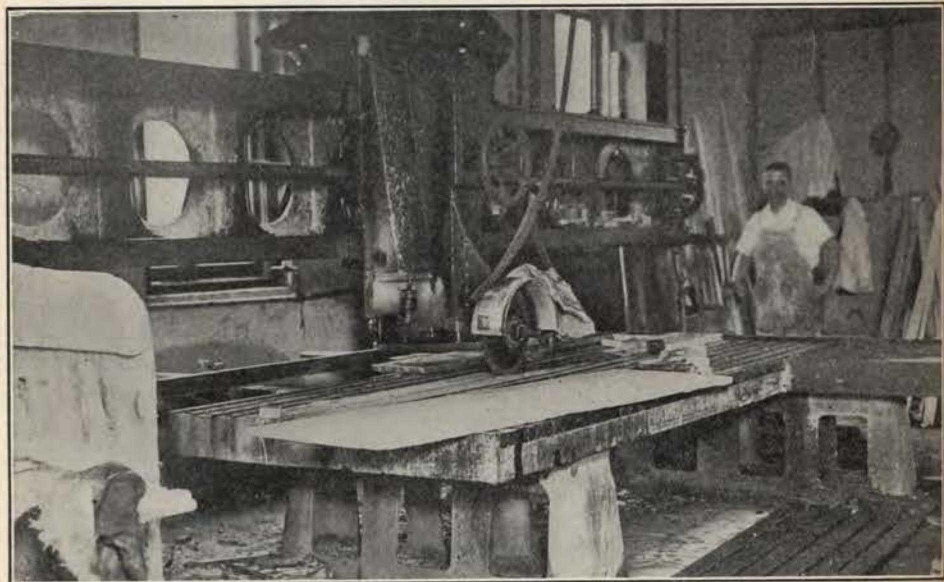

Fig. 52. Carborundum machine in operation.

Writing of marble machinery, Mr. Gale says: "The new machinery for finishing marble has been limited largely to machines equipped with carborundum wheels and saws, also with diamond saws. All kinds of molding, countersinking, fluting, checking, etc., are done with these machines."

GLOSSARY

This Glossary is only intended to serve as an abbreviated dictionary of technical terms used in the foregoing pages.

Actinolite—A green mineral, often in long prismatic crystals of glassy appearance. Often makes green clouds or streaks in Vermont marble. Usually very hard in crystals.

Anticline—Where rock beds are forced up forming a ridge-like mass or fold.

Bed—Of rock, one or more layers of sedimentary deposit.

Biotite—One of the mica group, usually black or brown, easily splitting in thin laminæ.

Breccia—A rock consisting of cementing material in which are enclosed angular pieces of different stone.

Calcite—A very common mineral which is wholly lime carbonate. Of many forms and colors. It makes up the larger part of many of the best marbles.

Cambrian—One of the oldest formations in the geological scale. Sometimes contains many fossils, sometimes none. Common in western Vermont.

Chlorite—A soft green mineral, usually foliated. A silicate of alumina.

Cleavage—A mineral cleavage is the cause of the mass splitting more easily and evenly in certain directions than in others. A slaty rock always shows evident cleavage.

Conformable—When one layer of rock is parallel to the next as situated in the bed.

Crystalline—When the material of a rock is so arranged that it breaks most readily in some regular, geometric form it is said to be crystalline.

Dike—When volcanic rock is pushed up through a ledge, usually in the form of a band, it is called a dike.

Dip—When as often, the layers of sedimentary rock are forced from the original horizontal position and tilted at some angle they have dip.

Drift—Any movable sand or rock carried from its original locality to some other and there deposited. Usually by glacial action.

Epidote—A usually green mineral found in some marbles.

Erosion—Wearing away rock by running water, wind, or chemical action.

Fault—When in a mass of rock beds one side of a break is raised, or lowered, so that the strata are no longer continuous, this is called a fault.

Formation—A group of strata, containing like fossils, or other evidence of deposition about the same time and in orderly succession.

Galenite—A common ore of lead. It is found sparingly in marble.

Gneiss—A rock often much resembling granite, but is of different origin and usually in more or less distinct layers or strata. It is a metamorphic rock.

Hematite—Red oxide of iron. Dark in color but red when scratched.

Limonite—Brown oxide of iron. Dark yellow or brown when scratched.

Maclurites—A coiled shell, one to several inches in diameter (see page 24). Found in some marble.

Magnetite—A black oxide of iron. Often magnetic. The streak is black.

Metamorphic—(See page 13.)

Muscovite—A light colored mica. Often seen in marble.

Ordovician—One of the older geologic ages. Next above the Cambrian.

Pitch—In a mass of rock layers, the angle of inclination.

Porphyritic—A rock enclosing crystals of another kind of rock.

PYRITE—A yellow mineral, iron and sulphur. It is very hard and glossy and often mistaken for gold, but is usually harder and brighter.

QUARTZITE—A metamorphic quartz sandstone. Generally light in color, but sometimes dark.

SCHIST—A rock usually in laminæ, crystalline, metamorphic. Very common in Vermont. Often closely associated with marble.

SEDIMENTARY—Rock usually in layers which has been deposited, usually under water.

SERICITE—A schist of silky appearance, usually distinctly laminated.

SERPENTINE—A metamorphic rock, of a generally green color, often very dark in Vermont, very hard, often variegated with streaks of white, black or yellow.

STRIKE—The strike of a bed of rock is the direction at right angles to the dip, or inclination of the beds.

SYNCLINE—When rock beds are folded, the lower or trough-like part of the mass is called a syncline, the reverse of an anticline.

UNCONFORMABLE—When in a ledge of rock the upper layers are not parallel to those beneath.

Other technical terms are explained by the context.

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The Vermont Marble Company have published from time to time very instructive and interesting accounts of their work and equipment. Some of these can be obtained by applying to the main office at Proctor, Vermont.

REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1931-1932

EIGHTEENTH OF THIS SERIES

GEORGE H. PERKINS
State Geologist

FREE PRESS PRINTING CO., BURLINGTON, VT.

CONTENTS

LIST OF FIGURES

THE GEOLOGY AND PETROGRAPHY OF ATHENS, BROOKLINE AND WEST-MINSTER, VERMONT

CHARLES H. RICHARDSON AND JAMES E. MAYNARD

Syracuse University, Syracuse, N. Y.

INTRODUCTION

The report upon the geology and petrography of Athens, Brookline and Westminster, Vermont, is of necessity brief. The time available for detailed field work and the petrographic study in the laboratory at Syracuse University has been altogether too limited to bring out all that might be desired as to structure and the original composition of the terranes involved. Some important discoveries that bear upon the mineralogical composition and probable age of some of the terranes involved have been made. It is hoped that the results will be presented clearly of this new study of field relations and petrographic evidence in a field hitherto undescribed, yet closely folded, faulted and invaded by both acid and basic intrusives. The môde of origin cannot be ascertained with certainty in some instances even with a most careful petrographic study. The metasomatic changes have been so complete that scarcely a trace of an original mineral remains. An excellent example of this pronounced alteration can be seen in a dike on Windmill Hill in Westminster which is now a limestone that cuts across the known sedimentaries nearly at right angles. The original dike appears to have been a diabase.

The high percentage of microcline showing the characteristic grating structure in rocks that are coarsely laminated is a strong argument in favor of an igneous origin. Such rocks in this report are listed as granite gneisses, even though such terranes have always been listed as sedimentaries. It is difficult to determine the actual age of some of the terranes involved because no fossils have yet been found in the pre-Ordovician formations of eastern Vermont. The heavy burden of glacial drift that covers the area renders the correct interpretation of structure exceedingly difficult. In road cuts and river beds the best evidences of the structure are obtainable.

The area involved in this report lies between north latitude 43° 00′ and 43° 10′. It also falls between meridians 72° 25′ and 72° 40′ west of Greenwich. The extreme eastern port is in

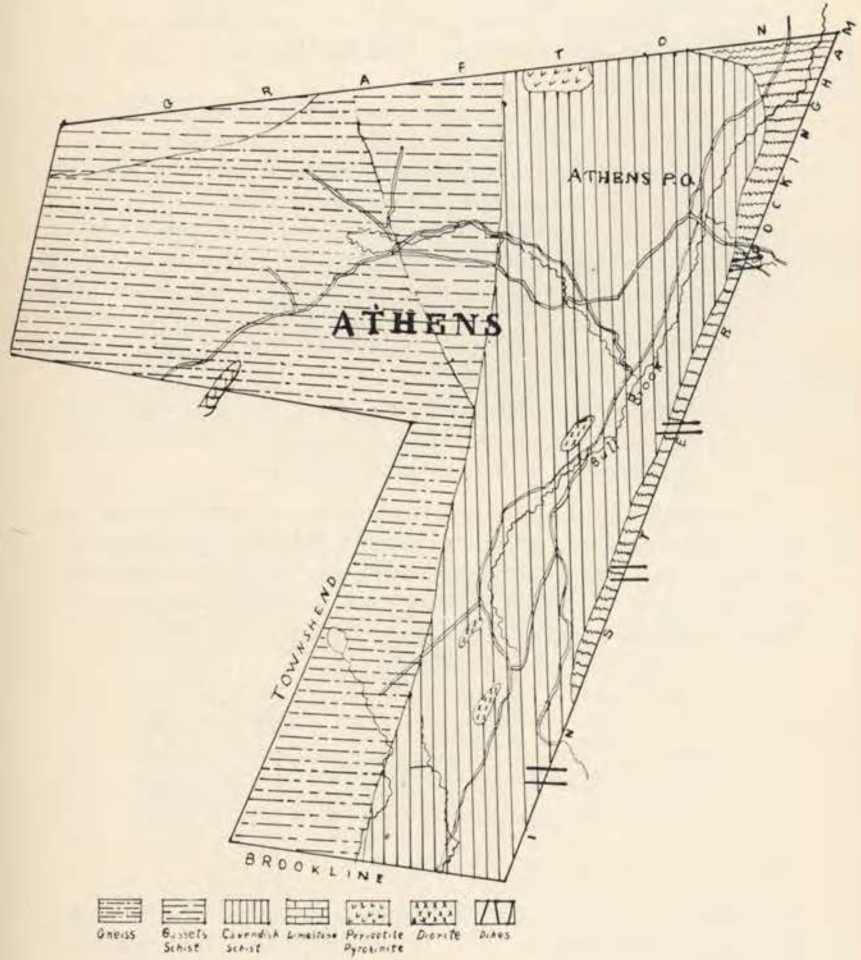

FIG. 53. Areal map of Athens, Vt.

the Bellows Falls Quadrangle and the remainder of the area is in the Saxtons River Quadrangle.

There are six definite reasons for the selection of Athens, Brookline and Westminster for field work:

1. Athens lies directly south of Grafton whose geology and petrography was published in the Biennial Report of the State Geologist for 1929-1930. Brookline lies directly south of Athens and Westminster directly south of Rockingham whose geology and petrography was also published in the last Biennial Report of the State Geologist.
2. They make the work continuous in the eastern half of the state southward toward the Massachusetts line.
3. They carry the field work eastward to the Connecticut River for the second time in recent years.
4. Westminster falls in line with the erosional unconformity between the Ordovician and the pre-Ordovician, probably Cambrian, on the eastern side of the Green Mountains.
5. The presence of both acid and basic intrusives whose mineral composition has never been worked out and published.
6. The fact that no detailed field work has ever been done and no petrographic study ever made of either the sedimentaries or their associated intrusives.

The detailed field work was essentially done during the summer of 1931 but some field work was done in Athens and Westminster in 1930. Furthermore some field work was done in both Newfane and Putney to the south of Brookline and Westminster to the Brattleboro Quadrangle north line.

FIG. 54. Cross-section of Athens, Vt.

The field relations of the different terranes in Athens, Brookline and Westminster are difficult to determine. The three townships are hilly, glaciated and in fact densely wooded. With a heavy glacial till and a dense growth of underbrush actual contacts between the different terranes are extremely difficult to find. However, actual contacts were found on Windmill Hill in Westminster and on Putney Mountain.

Three areal maps showing the distribution of the different terranes accompany this report as Figures 53, 55, 57. A cross-

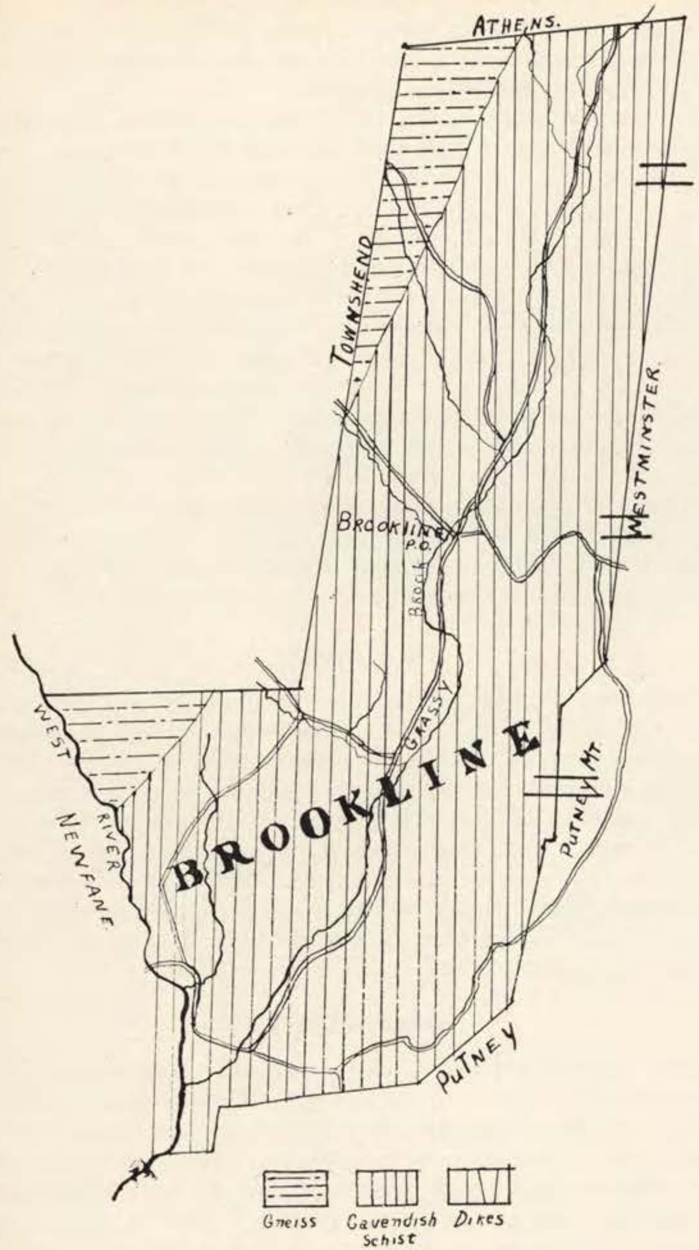

FIG. 55. Areal map of Brookline, Vt.

section of the terranes in Athens appears as Figure 54, the cross-section of Brookline as Figure 56 and the cross-section of the terranes in Westminster as Figure 58.

The area involved in this report has always been mapped in as purely sedimentary but both acid and basic intrusives have been discovered and so far as possible their location will be shown on the areal maps. It is interesting to note that some of the rocks considered by earlier geologists as highly metamorphosed sediments are now definitely proved to be granite gneisses. The presence of a large amount of microcline in the microscopic slides substantiates this view.

Fig. 56. Cross-section of Brookline Vt.

Approximately 100 samples of rocks have been collected from which microscopic slides have been made for a detailed petrographic study. Without this type of detailed work it is impossible to correctly translate the results of field investigations.

DRAINAGE

The chief drainage of the area involved in this report is effected by three rivers. The northernmost of these is Saxtons River which empties into the Connecticut River at Bellows Falls. The easternmost is the Connecticut River itself. The southernmost is the West River which empties into the Connecticut River at Brattleboro. Each of these three rivers receives several small tributaries some of which have only local names and need not be mentioned. Grassy Brook flowing south through Brookline and Sacketts Brook flowing south through Westminster are the largest and most important of these smaller streams.

TOPOGRAPHY

There are three broad U-shaped valleys traversing the area covered by this report. These are the valleys of Saxtons River on the north, the Connecticut River on the east and Grassy Brook on the west. These are pre-glacial valleys. The numerous transverse valleys are in part pre-glacial and in part post-glacial (Figure 59).

Certain altitudes that may be of interest are given below. Some of them were taken with an aneroid barometer while doing

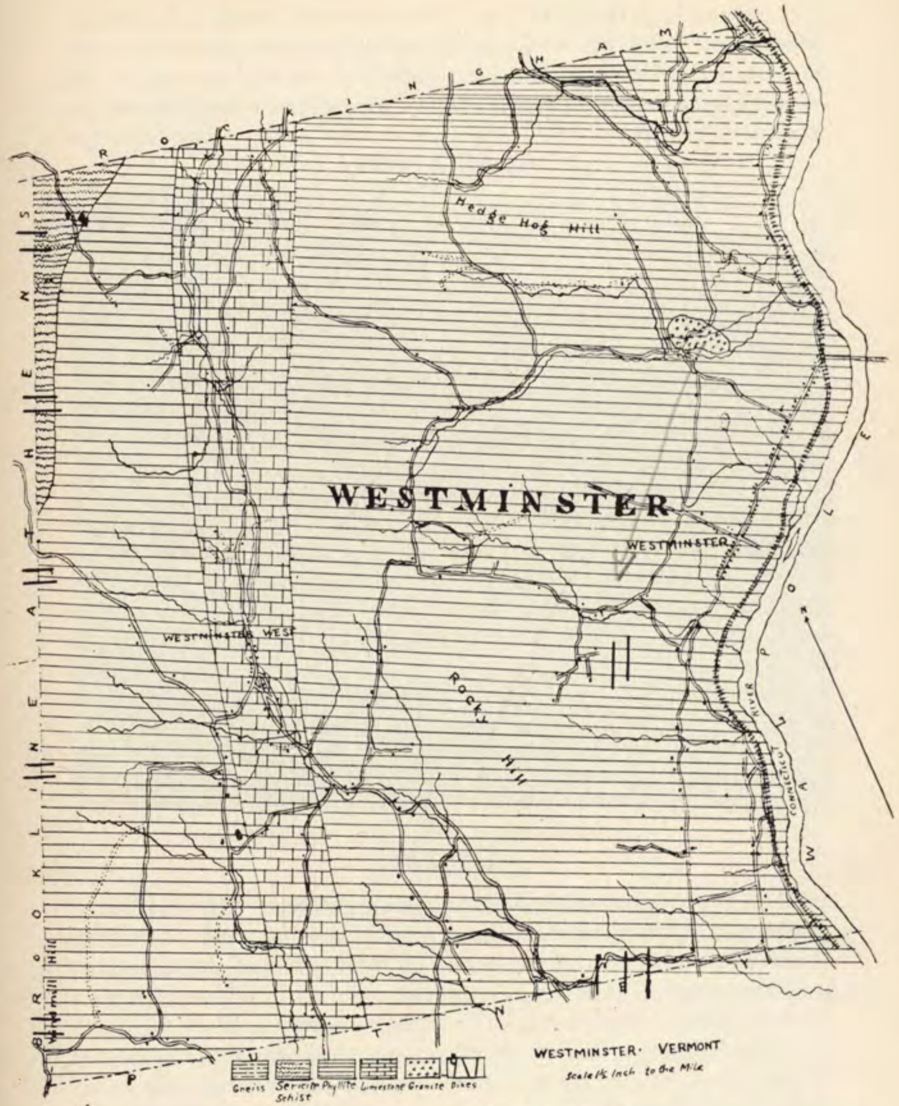

Fig. 57. Areal map of Westminster, Vt.

the field work. Others were taken from contour maps of the area involved. The lowest altitude in the eastern part of Westminster is 238 feet, Westminster Station is 256 feet. The altitude of the village of Westminster is 314 feet, Hedgehog Hill 1,140 feet, Pinnacle Hill 1,300 feet, Windmill Hill 1,600 feet, Putney Mountain 1,740 feet, the western part of Athens 1,780 feet, Crane Mountain 1,700 feet. The topography of Athens, Brookline and Westminster is rugged and may be regarded as in the stage of late maturity.

GLACIATION

Evidences of glaciation are found in the thick mantle of glacial till that covers the entire area involved in this report together

FIG. 58. Cross-section of Westminster, Vt.

with the wide distribution of glacial boulders. The direction of the ice movement is found in the striations still remaining upon the more resistant rocks. Well-exposed outcrops of nearly pure white vein quartz are particularly prone to furnish this evidence. The outcrops of Cambrian quartzite as they appear on some of the higher altitudes and the more resistant beds of the Brattleboro phyllite have furnished many good examples. The direction of movement corresponds with those recorded in the more northern township, *viz.,* due south, south 20 degrees east and south 20 degrees west.

LAKES

There are two small lakes or ponds in Athens. One is situated in the northwestern part of the township and is known as Athens Pond. It is also on the north side of the main road from Athens to Townshend. The other is situated in the southwestern part of Athens and is known as Lilly Pond. There is also one small pond in the eastern part of Westminster about one-half mile west of the Connecticut River. It furnishes ice for the village of Westminster but the pond and its environs carries thousands of tons of peat.

GEOLOGY AND PETROGRAPHY

The geology of Athens, Brookline and Westminster is intricate and complex. The sedimentaries consist of highly folded and

faulted metamorphics that are often invaded by intrusives of more than one period of introduction. The sediments range from quartzose marbles to feldspathic quartzites or gneisses with no trace of a fossil content, and from phyllite to highly chloritic and epidotic mica schists. In fact some of the rocks listed as sedi-

FIG. 59. Modern alluvial fan, Athens, Vt.

ments in this report are so highly metamorphosed that it is extremely difficult to prove that they were not of igneous origin. This holds especially true of some of the rocks now listed as hornblende schists. The intrusives range from soda granites through diorites and diabases to the ultra-basic rock peridotite. In the petrographic laboratory under polarized light the microscope tells us what the individual constituents in both the sedimentary and igneous rocks now are, but it does not always reveal with certainty the mineral composition of the original rock. In some instances what constituents have been subtracted and what added and under what condition various solutions were introduced we do not know. The question naturally arises were solutions rich in iron, aluminum, calcium, magnesium and titanium introduced to form the hornblende, zoisite, epidote and rutile now so abundant?

The sediments vary in age from the Cambrian to Ordovician. There is no positive evidence of any pre-Cambrian or even Lower Cambrian sediments in the area covered by this report, nor is there any evidence of any sedimentary rock younger than Middle Ordovician. The intrusives range in age from the Cambrian to the Carboniferous and possibly the Triassic. There is strong evidence that some of the diabase dikes are as late as the known diabase in the Connecticut Valley in Massachusetts.

Approximately 100 chips for microscopic slides were collected in the field. Slides have been made from all of these for petrographic study. The great majority of the slides were made from the rocks in Athens, Brookline and Westminster but a number have been prepared from rocks in the adjacent townships in Vermont and a few from the igneous rocks in New Hampshire to ascertain their relation to the Bellows Falls gneiss.

A detailed study of these slides has brought out several interesting facts which may be listed as follows:

1. A large decrease in the percentage of magnetite in the pre-Ordovician terranes.
2. A large increase in the percentage of rutile and titanite in the same formations.
3. A rapid increase in the albite content of the sericite schists and sericitic quartzites.
4. A rapidly increasing biotite content in the sericite schists so that many outcrops are biotitic sericite schists and some are biotite schists.
5. The albitization of the feldspars in some of the igneous rocks. It has not been proved that the original feldspar was albite.
6. The granites are soda granites like that of Black Mountain in Dummerston rather than potash granites like those in Barre and Woodbury.
7. The feldspar in the pegmatite veins is mostly microcline and microperthite. In some slides there is a little orthoclase and albite-oligoclase.
8. The abundance of microcline in the gneisses of wide distribution. This is regarded as one of the most important petrographic discoveries in the study of the highly metamorphic rocks in eastern Vermont in recent years for microcline is usually a pyrogenitic mineral rather than one of sedimentary origin.

ALGONKIAN

The Algonkian, or pre-Cambrian terranes, do not occur in Athens, Brookline and Westminster. However, they do occur in Sherburne, Plymouth, Ludlow, Andover, Windham and southward to the Massachusetts line. Now that contour maps are available as an aid in detailed field work along the line of the Green Mountains it would be a valuable piece of work to follow the break in the geologic history on the east side of the Green Mountains northward to the international boundary. The northernmost point where this break has been definitely located is in the southwest corner of Rochester.

CAMBRIAN

The term Cambrian as here used denotes a 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. The Cambrian formations consist of a series of highly folded feldspathic mica schists, often sufficiently coarse textured to be listed as a gneiss, feldspathic quartzites, chlorite schists, hornblende schists, biotite schists, sericite schists and sericitic quartzites that were derived from the erosion of the Algonkian land mass on the west during Cambrian times.

That these terranes listed as Cambrian are post-Algonkian and pre-Ordovician in age is proved by three facts:

1. They all overlie the Algonkian gneiss that flanks them on the west.
2. They all underlie the Irasburg and Northfield conglomerates which are definitely proved by fossil content to be of Ordovician age.
3. The lowest member of the group of Cambrian sediments is the Sherburne conglomerate.

LOWER CAMBRIAN

The Lower Cambrian terranes consist of a series of highly folded and faulted metamorphics of widely varied mineralogical composition. These formations are the Sherburne conglomerate, Plymouth conglomerate, Plymouth dolomite, Albitic mica schist, Pinney Hollow schist and the Ottauquechee schist. None of these terranes occur in Athens, Brookline and Westminster.

If the conglomerate found by the first named author of this report in 1928 at Windham Four Corners, two miles north of Windham, is a true conglomerate, then it marks the base of the Upper Cambrian and the above-named formations would all be Lower Cambrian. That this conglomerate lies at the base of the Bethel schists there can be no doubt but it may be interformational.

UPPER CAMBRIAN

The terranes listed in this report as Upper Cambrian comprise a series of highly folded and faulted sedimentary rocks that have been invaded by both acid and basic intrusives. The schistose rocks may be listed as chlorite schists, biotite schists, muscovite schists, sericite schists and hornblende schists. However, not all of the schistose, hornblendic rocks belong with the sedimentaries.

Before taking up the general discussion of the above-named terranes several significant questions may be raised:

1. Was deposition of sediments continuous on the eastern side of the Green Mountains throughout Cambrian times?
2. Did deposition begin with the Sherburne conglomerate in Lower Cambrian time and cease with the Middle Cambrian?
3. Did deposition begin with the Upper Cambrian and cease with the uplift that came at the close of the Cambrian?
4. Is the Middle Cambrian entirely wanting east of the Green Mountains?

The field evidence is that deposition began in Lower Cambrian time with the Sherburne conglomerate as the oldest member of the series. The presence of an apparent conglomerate in the lower portions of the Bethel schist would imply that sedimentation was not continuous during Cambrian time. If this conjecture can be proved in subsequent field work in Windham and Townshend then it seems rational to assume that the break in the continuity came in Middle Cambrian time. It is indeed unfortunate that no fossil content has yet been found in the terranes listed as Cambrian on the east side of the Green Mountains. The rocks are highly metamorphosed, closely folded and faulted which may account for the absence of a fossil content.

BETHEL SCHIST

The Bethel schists are fine grained, greenish, schistose and highly metamorphic sedimentary rocks which are more or less intimately associated with chlorite and epidote. They are particularly characterized by numerous eyes, or lenses, and stringers of granular quartz. These schists are abundant in Windham and Jamaica. They may appear in the extreme western part of Townshend, but they do not extend far enough to the east to appear in Athens and Brookline.

CHLORITE SCHIST

The chlorite schists are fine grained, green, schistose and highly metamorphic rocks. The mineral chlorite, or some related species of the chlorite group, is their determinant mineral. Epidote and magnetite are invariably present. Quartz grains and plagioclase feldspars are either wanting or sparingly present.

These chloritic rocks occur in narrow beds whose strike and dip conform with the strike and dip of the associated sedimentaries. In such cases it is rational to assume that these chlorite schists are also of sedimentary origin. Narrow beds of chlorite schist occur in the Cambrian in Grafton, Athens and Brookline but in beds too narrow to appear on the areal map. There are a few outcrops of chlorite schist in Athens and Brookline that are alteration products of basic igneous rocks.

CAVENDISH SCHIST

The Cavendish schist is a dark gray, fine to medium grained, highly metamorphosed sedimentary rock. In Cavendish, the site of its discovery, the essential mineral composition is quartz and biotite. It is often hornblendic and the hornblende sometimes replaces nearly all of the biotite. Among the accessory minerals epidote is very abundant. A plagioclase feldspar is invariably present but usually in small amounts. Garnet, tourmaline, apatite, chlorite and magnetite are common. Zoisite, zircon, rutile or titanite are found in many slides.

In stratigraphic position the Cavendish schist unquestionably underlies the Gassetts schist which belongs to the Missisquoi group. Actual contact between these two formations can be seen in the road cut a few rods north of Gassetts station.

The Cavendish schist occupies a large area in the northern part of Athens and extends northward through Grafton. It may extend southward through Athens and Brookline. If this formation is the Cavendish schist, then practically all of the biotite has been replaced by hornblende. It seems better to leave this hornblende schist for the time being as a phase of the Cavendish schist rather than to make it an additional formation. It forms an extensive area on either side of the north-south valley in both Athens and Brookline. It is uncertain how much of the horn-

Fig. 60. Gneiss dipping east, Brookline, Vt.

blende schist in Athens and Brookline belongs to the Cavendish schist.

The strike of the Cavendish schist varies from due north to north 30 degrees east. The dip on the east side is invariably to the east, varying from 45 to 60 degrees. On the west side in

Chester the dip is to the west varying from 35 to 45 degrees (Figure 60).

CAMBRIAN MARBLE

Marble occurs in the western part of Athens on the Eugene Bemis farm. It is furthermore located on the east side of the road from Athens to Townshend, within 25 rods of the road and only a few rods north of the Athens-Townshend town line.

The marble outcrops cover a width of about 150 feet and are flanked on either side by a biotite granite gneiss whose strike is north 60 degrees east and whose dip is 45 degrees to the northwest. The beds are narrow and interfolded with actinolite and chlorite schist. Many samples were collected for petrographic work and several of these can be listed as actinolitic marbles.

The marble varies widely in color. Some samples are white, some are a light pink, others are of light green hue. The pink color is due to manganese and the green color to actinolite and in some cases it is intensified by epidote.

One sample from the Bemis Mine is a pink to a pinkish white coarse-grained marble, with a few irregular streaks and bands of actinolite. Calcite constitutes about 95 percent of the rock. The rock is a mosaic of calcite crystals. It carries many small crystals of clinozoisite. In ordinary light these crystals are of a clear greenish yellow color. They show good cleavage which is parallel to the elongation, with the axial plane at right angles to the cleavage. The interference colors are high. Basal cleavage flakes show the almost perpendicular emergence of the optic axis. The axial angle is very large but gives a distinct negative sign. There are also a few well-defined crystals of dolomite and grains of titanite. The clinozoisite is regarded as the mineral considered by T. Nelson Dale as belonging to the humite group.

The actinolite marbles are characterized by varying amounts of coarse-grained, pink calcite and green actinolite. Biotite is sometimes present, giving a mottled appearance to the rock. A little diopside appears in some of the slides.

No evidence could be found that these marbles are older than the Cambrian. The metamorphism of the calcareous sediments into marble and the interfolding of both marble and gneiss may have taken place in late Cambrian time.

Marble also occurs on the Stanley B. Martin farm in Townshend. These outcrops are about 1 mile southeast of Townshend village and 500 feet above the valley. The marble beds appear less than 100 feet in width and are flanked on either side by a finely foliated biotite gneiss.

The purest sample collected is a white saccharoidal marble. Under the microscope it shows an interlocking mosaic of pure calcite crystals, some of which show well-developed cleavage, others broad twinning bands. There are a very few flakes of chlorite and biotite in this marble.

One slide examined was an actinolite diopside marble. About 90 percent of the rock is made up of a mosaic of calcite which is pinkish white in color. There are many elongated crystals of actinolite and grains of diopside which have resulted from the recrystallization of the impurities in the original calcareous rock. There are a few flakes of sericite and chlorite, and a few grains of pyrite and magnetite present. The Townshend marble is of the same age as the marble in Athens.

MISSISQUOI GROUP

The Missisquoi group of terranes comprises highly garnetiferous muscovite schists, sericite schists, sericitic quartzites, chlorite schists that are not the Bethel schist, hornblende schists and gneisses that may not be of sedimentary origin. This group of terranes has been followed southward from the international boundary on the north into Windham County, a distance of nearly 150 miles. The mineralogical content of the sericite schists and sericitic quartzites in the northern half of the State was fairly constant but in Bethel biotite began to replace the sericite and in Windham County the rock becomes a biotite schist in some of its outcrops. These beds are often too narrow to appear on the areal map.

GASSETTS SCHIST

In the type locality just north of Gassetts railroad station this schist is essentially a highly garnetiferous mica schist. The texture is scaly for the muscovite is arranged in parallel plates and is by far the most abundant constituent. The quartz grains are somewhat angular. The garnets vary in size up to nearly two inches. The magnetite is drawn out into parallel lines. Staurolites and tourmalines are fairly abundant. There are a few plates of biotite and few grains of apatite.

In the western half of Grafton these schists were very abundant. In the southern extension into Athens the mineralogical composition of the Gassetts schist is materially changed. Quartz has become more abundant. Plagioclase feldspars are sometimes

the most abundant constituents. Staurolites and tourmalines have disappeared and the rock suggest a para-gneiss. This type of rock is abundant in the western part of Athens and extends southward into Townshend. Its strike is from north 20 to 30 degrees to the east and its dip, sometimes as high as 80 degrees, is to the west.

SERICITE SCHIST

In structure the sericite schists are finely laminated, schistose and granular. In texture they are fine to medium grained. In color they range from a silvery white to a slightly greenish tint. In some instances the green color is due to the chloritization of biotite and in others to the chloritization of hornblende. In both instances the greenish tint is intensified by grains of epidote which result from the interaction of the feldspars and the ferromagnesian minerals. The only essential minerals in the sericite schists and the sericitic quartzites are muscovite, var, sericite, and quartz. If the sericite is in excess of the quartz the rock is listed as a sericite schist, but if the quartz is in excess of the mica the rock is listed as a sericitic quartzite. The normal accessory minerals are biotite, albite, garnet, magnetite, pyrite and apatite. The secondary minerals are epidote and chlorite.

This formation is practically limited in the townships covered by this report to a very narrow belt in the eastern part of Athens and Brookline and the western part of Westminster. That it extends southward into Putney is proved by an outcrop on Putney Mountain. This rock is a medium grained, definitely banded schistose rock that is greenish white in color.

The chief constituent of the rock is fine to medium granular quartz with much sericite and a little biotite more or less altered to chlorite and orientated in one direction. Irregular shaped metacrysts of garnet are abundant and also grains of magnetite.

The strike of this formation is north 25 to 30 degrees east and the dip is invariably to the east, at an angle from 70 to 80 degrees.

The sericite schist carries small beds of sericitic quartzite that are toc narrow for mapable areas and, therefore, no attempt is made to differentiate the true sericite schist from the sericitic quartzite.

CHLORITE SCHIST

There are thin beds of chlorite schist in the Missisquoi group and the underlying Cavendish schist that conform in dip and strike to the enclosing sedimentaries. Such beds are regarded as of sedimentary origin for the following reasons:

1. The extreme narrowness of the beds.
2. Their conformity in dip and strike to beds of unquestioned sedimentary origin.
3. The presence of an appreciable amount of more or less rounded quartz grains.
4. The absence of any alteration by igneous intrusions in the walls of the enclosing sediments.
5. The absence of any plagioclase feldspars that could not have been derived from sediments.

If the above interpretation is correct then the age of these chlorite schists would be the same as the age of the enclosing sedimentaries. These beds of chlorite schist do not occur in the Ordovician although there are some beds in the Ordovician that are chloritic from the chloritization of biotite.

The chlorite schists that cut across the strike of the sedimentaries are regarded as of igneous origin and belong to the discussion under the caption of intrusives.

HORNBLENDE SCHIST

There are lenticular beds of hornblende schist in Athens and Brookline that may represent hornblendized sediments. The arguments in favor of a sedimentary origin may be listed as follows:

1. The gradation from outcrops particularly rich in hornblende to rocks in which hornblende crystals are only sparingly present.
2. The occasional alternation of narrow bands particularly rich in hornblende with equally narrow bands extremely low in hornblende.
3. The bifurcation of long crystals of hornblende that appear fresh and of later generation than the main mass of the rock.
4. The presence of many well-developed crystals of hornblende whose longer axis is across the schistosity of the rock.
5. The absence of any visible contact with rocks of unquestioned igneous origin.

The arguments in favor of an igneous origin of many of the lenticular outcrops of rocks now listed as hornblende schist or hornblende gneiss may be listed as follows:

1. The lenticular character of the hornblende outcrops.
2. The massiveness of the rock in some of its outcrops.
3. The definite rectangular jointing into small blocks from an inch to six inches in length as if formed by contraction during rapid cooling.
4. The presence of crystals of tourmaline which, however, are not found in all the outcrops.
5. The presence of much rutile or titanite in several of the outcrops.
6. Apparent apophyses of a basic igneous rock in the enclosing schists and gneisses.
7. A close folding of the hornblende schist with the associated schist or gneiss.
8. A border zone of either quartz or pegmatite sometimes tourmalinized that bears a striking contrast in color and mineral composition with the enclosing sediments.
9. The great abundance of plagioclase feldspars in certain layers so that the rock now appears as a hornblende gneiss, for rocks highly feldspathic are more apt to be of igneous than of sedimentary origin.
10. The wedging apart of beds of unquestioned sedimentary origin so that the same narrow beds pass around the hornblendic rocks. A condition that could not be obtained in sedimentation.

ORDOVICIAN

The term Ordovician as here used embraces the series of sedimentary rocks that lie unconformably upon the east flank of the Cambrian terranes. They consist essentially of limestones, slates and phyllites. They do not appear in Athens and Brookline, but they occupy all of Westminster save the extreme western border of the township.

The structure of the phyllite can be seen in a section due west from Westminster for the road over the hills to the west cuts through many outcrops in the phyllite. The dip near the Connecticut River is to the east but west of the crest of the ridge the dip is at a high angle to the west. The structure is, therefore, that of an anticline.

WAITS RIVER LIMESTONE

The Waits River limestones, or quartzose marbles, do not occur in Athens and Brookline. In Westminster they form a more or less continuous bed stretching north and south across the township and extending southward into Putney. They range in color from a medium to a dark gray. A few are slightly banded. The only essential minerals are calcite and quartz. The quartz grains are usually small and well rounded but sometimes they appear elongated by the pressure to which the rock has been subjected. In the outcrop two miles south of Saxtons River both the quartz and the calcite have been drawn out in the direction of the schistosity. Small flakes of sericite are abundant and uniformly scattered throughout the rock. Magnetite in fine grains and powder is well distributed. There are a few small grains of titanite present and much limonite stain.

In the southern part of the township the quartzose marbles are a little finer grained, less banded and richer in calcite. On Windmill Hill in the extreme western part of Westminster the quartzose marble shows a slight schistose texture and contains approximately 60 percent calcite and 40 percent quartz. In the northwest part of Putney the quartzose marble is medium grained and massive. It contains approximately 75 percent calcite and 25 percent quartz. The calcite is perfectly recrystallized, and, therefore, it must be listed as a marble. There are a few flakes of sericite and grains of titanite in this marble.

The general strike of these quartzose marble beds is north to north 20 degrees east. Their dip on the east side is to the west and on the west side the dip is invariably to the east. They are interstratified more or less with the phyllites and appear to lie in a synclinal trough in the phyllite.

MEMPHREMAGOG GROUP

The Memphremagog Group consists of slates, phyllites and quartzites. In the northern half of the State the slate has appeared as a continuous belt from Northfield to the international boundary on the north. On the eastern side of the Ordovician the belt has been more or less broken, but beds of slate have appeared in nearly every township southward from Waterford to the Massachusetts State line.

SLATE

The Memphremagog slate does not occur in Athens and Brookline for these two townships are west of the Ordovician terranes. In Westminster commercial slates appear to be absent. Such slates occur in four distinct areas in Rockingham which township

lies directly north of Westminster. Slate belts also occur in Putney, Dummerston, Brattleboro and Guilford to the south. The line through Westminster in which one might expect to find slate is occupied by a quartzite.

QUARTZITE

The belt of quartzite in Westminster lies about one mile west of the Connecticut River and extends in a southerly direction for approximately four miles. The northernmost outcrop is on Bare Hill southwest of Gageville and the southernmost is south of Fullam Brook. The belt is narrow.

In the outcrop south of Fullam Brook the rock is of light gray color, dense and shows no indication of bedding. In the field the outcrops strongly suggest a basic igneous rock.

The texture of the rock is finely granular. Its essential minerals are quartz with numerous small flakes of biotite. There are several partially formed crystals of garnet and hornblende with numerous grains of magnetite and titanite. Calcite is also present. In the numerous outcrops on Bare Hill to the southwest of Gageville the rock is very fine grained and suggests a fine-grained basic igneous rock. It consists of a granular aggregate of quartz with biotite elongated in one direction thereby giving indication of crystallization under stress. Small feldspar grains are subordinate. There are numerous small grains of garnet and flakes of sericite. The rock has been derived from an impure, fine-grained sand and is highly metamorphosed. Intrusives on the northern end of the hill may have been responsible in part for this metamorphism.

BRATTLEBORO PHYLLITE

The term Brattleboro phyllite has been applied to all the phyllites that flank the Cambrian terranes on the east in Chester, Rockingham, Athens, Brookline and Newfane. They extend southward through Brattleboro, Guilford and Vernon into Massachusetts. They flank the Connecticut River on the west in Vermont but extend across the river into New Hampshire in Charlestown and Walpole. Nearly all of the township of Westminster is covered with the phyllites and the interbedded Waits River limestone.

The strike of these phyllites varies from due north to north 30 degrees east. The dip of the planes of fissility varies widely. Near the Connecticut River the dip is to the east. Near the Kurn Hattin home it is nearly horizontal. From the crest of the divide to Westminster West it is from 75 to 85 degrees west. In the extreme western part of the township the dip is again to the east. In the eastern half of the township the structure is that of an anticline and in the western part a syncline (Figure 61).

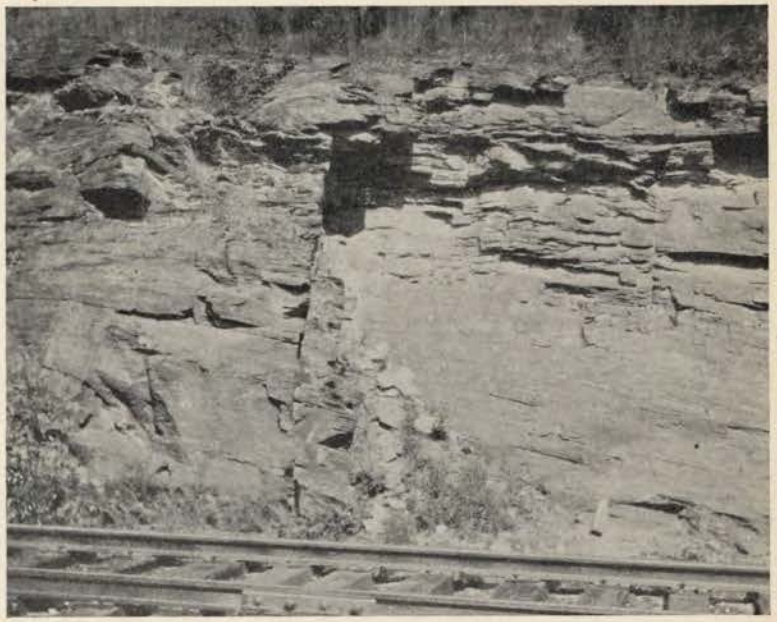

FIG. 61. Phyllite in nearly horizontal position, Westminster, Vt.

Two miles west of Westminster the rock is fine grained, bluish gray and lustrous. It is composed of very fine confused aggregates of sericite with some biotite and fine-grained quartz which appears to be segregated into separate layers. There is evidence of a few flakes of biotite that have been altered to chlorite and iron oxides. There is much magnetite in both large and small grains with some of the larger ones showing alteration to limonite.

There are three areas easy of access in the Brattleboro phyllite that are highly staurolitic and intensely interesting:

1. This exposure is at the falls on Saxtons River at Gageville. The strike varies widely from north 40 east to north 25 degrees west. The strike in one section is a curve. The dip varies from 45 degrees west to northwest. Staurolites are abundant on the beds under the falls (Figure 62).

2. By the large storage barn on the property of the Connecticut Valley Orchard Company owned by George A. Dascomb with J. W. Collins, superintendent, the phyllite is in nearly horizontal position. The outcrop is covered with staurolites that are twinned both at right angles and the saw-horse type. Many crystals are from three

FIG. 62. Twin Falls on Saxtons River, Gageville, Vt.

to four inches in length and one inch or more in diameter. It is the best exposure of the staurolitic phyllite found in the southern half of Vermont.

3. The third area is east of the easternmost north-south road of Westminster West, and about one mile to the south. The outcrop is some 50 rods east of this road and on the western slope of the hill. Some planes of the phyllite are completely covered with staurolites from one to two inches in length and varying in width from a fraction of an inch to one inch. Good saw-horse twins are numerous. The dip here is at a high angle to the west.

ACID INTRUSIVES

The acid intrusives in Athens, Brookline and Westminster consist of granites, granite gneisses, and pegmatites of more than one period of introduction. The gneisses are by far the most abundant of these intrusives.

GRANITE

Granite outcrops do not occur in Athens and Brookline, although there are granite gneisses in each township. In Westminster, on Wellington Hill some two miles west of the Connecticut River, there is a medium-grained gray granite. While the texture of the rock is granitic the constituents have been crushed to a considerable extent but not orientated into parallel lines to produce a gneissoid structure.

The essential minerals in this granite are quartz, oligoclase, orthoclase and biotite. Oligoclase is by far the most abundant constituent. Biotite is the chief ferromagnesian mineral and it shows all stages of alteration to chlorite. The accessory minerals are a few crystals of hornblende, apatite and ilmenite. The ilmenite shows alterations to titanite. The secondary minerals are calcite, sericite, chlorite and kaolinite. This granite has been quarried and shows some commercial significance.

GNEISS

Gneisses occur in both Athens and Brookline in extensive areas. They represent more than one period of introduction and possibly more than one mode of origin. Their texture, structure and mineral composition are widely different. Perhaps the discussion of some of the gneisses should have been included with the sedimentaries.

BELLOWS FALLS GNEISS

The Bellows Falls gneiss underlies the village of Bellows Falls. It extends south into Westminster and east across the Connecticut River into Walpole, New Hampshire. It was also found in the extreme southwestern corner of Charlestown, New Hampshire. In Westminster, at the bridge over Saxtons River, there are new rock exposures which give fresh chips for microscopic slides. Saxtons River near its mouth is flanked on either side by this gneiss.

In texture this gneiss varies from medium to coarse and in places it becomes porphyritic. In color it varies from a light

gray to a very dark gray. The darker colors are largely due to a higher percentage of biotite in the rock. The structure is gneissoid, but south of the plant of the New England Power System there was little if any of the gneissoid structure in the rock. In the sample collected for petrographic study at the south end of the bridge over Saxtons River the gneiss is of coarse texture, dark gray color and slightly banded. The feldspars are so arranged that the gneiss has a spotted appearance. The texture of the rock is granitoid with the micas all elongated and flattened in the same direction.

In mineral composition albiclase is the most abundant constituent. Much of it shows polysynthetic twinning, curved twinning bands and shadowy extinction. Biotite is very abundant and shows many inclusions of zircon. Quartz is less abundant than the albite and biotite.

The accessory minerals are small grains of epidote, magnetite and a few small grains of pyrite. The secondary minerals are epidote, paragonite and calcite. The calcite is present in a very small amount.

This gneiss carries zenoliths of both the sedimentary and igneous rocks which it cuts. Three of these zenoliths were sampled for microscopic slides. Some of the zenoliths of the sedimentary rock are 10 feet in length and several feet in width. The zenoliths that are intrusives are of smaller dimensions. Some of them are rectangular while others are more or less rounded.

The three zenoliths from which the samples were taken for petrographic study are syenites.

1. This is a fine-grained, gray, crystalline rock with a granitic texture that has suffered some shattering. It consists of microperthitic intergrowths of microcline and albite which constitute over 50 percent of the rock. Biotite is far in excess of the muscovite. Zircon is very abundant. There are a few fine grains of magnetite. Tourmaline is present and quartz is absent.
2. This zenolith is a medium-grained quartz syenite. Its essential minerals are albite to albite-oligoclase and biotite. There is also present a small amount of myrmekite, which is a worm-like aggregation of quartz and albite. The accessory minerals are apatite, zircon, titanite, magnetite and sericite.
3. This zenolith shows abundant albite to albite-oligoclase. There is also some microperthite and myrmekite. Biotite

is far more abundant than muscovite. The accessory minerals are apatite, zircon, titanite, pyrite, magnetite, ilmenite and garnet. There is some clear quartz in this zenolith (Figure 63).

FIG. 63. Zenolith in Bellows Falls gneiss, Gageville, Vt.

BULL HILL GNEISS

The Bull Hill gneiss embraces only those gneisses that are pronouncedly porphyritic. In the type locality on Bull Hill, which is east to northeast of the village of Grafton, the phenocrysts of feldspar vary from 1 to 3 inches in length but some were measured that were 4 inches in length. On Whitney Hill in the southern part of Athens the feldspars vary from 1 to 3 inches in length. The phenocrysts of feldspar elongated in the direction of the gneissoid structure of the rock with the biotite completely encircling the phenocrysts of feldspar so as to suggest an augen gneiss. The Bull Hill gneiss appears to be an orthogneiss.

READING GNEISS

Reading gneiss received its name from the township of Reading where this gneissoid rock is particularly rich in microcline

which shows the characteristic grating structure. Such a gneiss appears in Athens and Brookline and it does not seem necessary to introduce a new name for the formation.

This gneiss occurs abundantly in the southwestern part of Athens. It is light gray in color, fine grained, well banded and shows the biotite, feldspars and quartz arranged in definite layers. The banded texture does not show so well under the microscope but rather the rock has the appearance of a fine-grained mosaic.

The essential minerals are quartz, which shows undulatory extinction, abundant intergrowths of microcline and albite, oligoclase and a small amount of orthoclase. The only ferromagnesian mineral present is biotite and this is not very abundant. The accessory minerals are magnetite, pyrite and apatite. The secondary minerals are epidote, zoisite, muscovite and limonite. This gneiss extends southward into Townshend with the same structure and the same mineral composition.

There is in Brookline, near the base of Putney Mountain, an outcrop of epidotic muscovite granite gneiss. The rock is fine grained in texture, light gray in color and slightly banded. It is a highly crushed almost mylonitic aggregate of quartz and feldspar. The feldspar is hard to determine but it appears to be a soda lime feldspar rather than a potash feldspar. This conclusion can be drawn from the great abundance of epidote in the rock. The muscovite is very abundant but the biotite is rare and much altered to chlorite. Calcite is present, also a few grains of pyrite partially altered to hematite. Magnetite is also present. This gneiss carries zenoliths of the Cavendish schist and is unquestionably an orthogneiss.

In the northwestern part of Athens there is a large area of white, coarsely laminated, muscovite, albite gneiss. Albite is by far the most abundant constituent. Much of it does not show polysynthetic twinning. It carries inclusions of clear quartz. Granulated and strained quartz is much less prevalent than the albite. Large flakes of muscovite are very abundant. Biotite is rare. This rock may be a paragneiss and represent a highly feldspathic phase of the Gassetts schist.

BASIC INTRUSIVES

Basic intrusives occur in Athens, Brookline and Westminster. They are associated with both the Cambrian and Ordovician terranes. They may be listed as diorites, diorite gneisses, gabbros, diabases, pyroxenites and peridotites.

DIORITE AND DIORITE GNEISS

The diorites are granitoid igneous rocks whose chief feldspar is usually the plagioclase, andesine, and whose chief ferromagnesian mineral is hornblende. In eastern Vermont the feldspar is often richer in sodium than andesine through albitization and the hornblende is often chloritized.

Augite may be present in an appreciable amount and then the rock becomes an augite diorite. The presence of a considerable amount of quartz constitutes a quartz diorite. The presence of biotite in sufficient amount gives rise to a mica diorite. The shearing of the diorite so that the ferromagnesian minerals are arranged in parallel lines gives rise to a diorite gneiss. The gneissoid structure is present in many of these rocks in Athens, Brookline and Westminster.

In texture the diorites vary from fine to medium and granular. The crystals of hornblende vary from fine to coarse and many of them are drawn out into parallel lines. Under transmitted light the hornblende is greenish to greenish blue. The quartz and feldspars are fine grained. Calcite is present in some of the slides examined. It has been derived from the soda-lime feldspars. In some slides a little biotite is present partially altered to chlorite. The percentage of hornblende varies widely. The center of an outcrop is often richer in hornblende than the borders which will suggest to some investigators hornblendized sediments. The strike of some of the diorites will parallel the sedimentary rocks while others cut directly across the strike of the sedimentaries. Such diorites must be of igneous origin.

In the southeastern corner of Westminster there occurs a medium-grained, dark gray, massive rock that is over 50 percent hornblende. The texture is hypidiomorphic in which euhedral crystals of hornblende are surrounded by anhedral andesine. The hornblendes are wholly or partially altered to chlorite. The andesines are partially altered to a confused aggregate of calcite, paragonite and kaolmite. There is much magnetite and many wedges and grains of titanite. There is present also a small amount of clear secondary quartz.

On Windmill Hill, in the extreme western part of Westminster, there occurs a massive and dark green diorite gneiss. The texture is hypidiomorphic in which euhedral crystals of hornblende are surrounded by anhedral feldspar. The hornblende constitutes about 60 percent of the rock. The interstices among the hornblendes are filled with a granular aggregate that is principally albite and subordinate epidote. There are a few highly altered andesines present. Titanite and ilmenite are abundant. Grains and stringers of calcite are rare (Figure 64).

FIG. 64. Dike cutting Ordovician sediments, Windmill Hill, Westminster, Vt.

GABBRO

The gabbros constitute a group of rocks that are intermediate in composition between the diorites and diabases. They occur on both sides of the east-west road in the southeastern corner of Westminster and extend southward into Putney. The rock is green, massive, hornblendic, in which only a very little feldspar can be distinguished. Hornblende constitutes about 80 percent of the rock. The hornblendes are large, irregular anhedrons in which there are many inclusions of albite. The hornblende is secondary after augite and partially altered to chlorite. The spaces between the hornblendes is filled with highly altered basic plagioclase, fresh albite, epidote and calcite. Grains and large aggregates of titanite are very abundant. There are a few flakes of biotite, much altered magnetite and ilmenite, some pyrite and zircon and a very little clear secondary quartz.

On Pinnacle Hill, in the northwestern part of Westminster, there occurs a coarse-grained, green gabbro in which much feldspar can be distinguished. The texture is hypidimorphic in which there are many irregular aggregates and euhedrons of hornblende surrounded by a granular aggregate of albite and zoisite. The hornblendes are secondary after augite and the albite and zoisite have resulted from the alterations of a basic feldspar. There is a small amount of biotite and clear secondary quartz present. Rutile, titanite and magnetite are abundant.

DIABASE

At Bellows Falls there is a variolitic, fine-grained, porphyritic, diabase dike that cuts the Bellows Falls gneiss and extends in a westerly direction into Vermont. The ground mass of the rock is hypocrystalline and consists of fresh lath-shaped skeleton crystals of andesine, granular and skeleton crystals of augite completely altered to calcite in a brown to grayish yellow base which is densely charged with skeleton crystals of magnetite. Radiate aggregates of feldspar microlites occur which are similar to the spherulites in acid rocks. The phenocrysts are not abundant and consist of embayed crystals of augite largely altered to calcite. A few narrow dikes of diabase were found on the high altitudes in the extreme western part of Westminster and the eastern part of Athens. A new diabase dike was discovered in the summer of 1931 a few rods west of Gassetts railroad station. This dike is fine grained, greenish black and aphanitic. The texture is ophitic. The lath-shaped crystals of labradorite constitute over 60 percent of the rock. The interstices between the labradorites are filled with calcite, leaving practically no indication of the original augite. Magnetite is abundant. The ilmenite shows all stages of alteration to lencoxine. Chlorite is quite abundant and quartz is rare (Figure 65).

PYROXENITE AND PERIDOTITE

The belt of pyroxenites and peridotites that traverses Vermont in a north and south direction appears in Athens but not in Westminster. The pyroxenites are now altered to talc and steatite and the peridotites to serpentine.

Talc or soapstone occurs in the extreme northern part of Athens on the southwest slope of Bear Mountain. The Athens-Grafton town lines traverse the quarry. The old quarry is situated about three miles north of the old Post Office of Athens and about three miles south of the village of Grafton. The stone at

one time was extensively quarried, and cut at Cambridgeport. This steatite or soapstone is of good grade, for in samples collected around the old quarry and along the brook at the junction

FIG. 65. Dike of diabase cutting granite gneiss, Bellows Falls, Vt.

of the soapstone road with the Saxtons River Road there is but little change in color during the many years of exposure to the corrosive agents of the atmosphere. Soapstone has also been quarried on the J. L. Perham farm in the southern part of Athens.

The age of the introduction of the pyroxenites and peridotites into Vermont terranes is regarded as Cambrian for they abound in the terranes of Cambrian age and nowhere have been found to cut the Ordovician formations.

PALEONTOLOGY

As yet no fossils have been found in the pre-Ordovician terranes on the eastern side of the Green Mountains. The relative age, therefore, of these formations must be determined by their stratigraphic position, continuity and lithological characteristics. The pre-Ordovician terranes as they appear in Athens and Brookline are unquestionably post-Algonkian, for the base of the Cambrian series is the Sherburne conglomerate which overlies the Algonkian. They underlie the Irasburg, Albany and Northfield conglomerates which form the base of the Ordovician in eastern Vermont. If the conjecture is correct that the Bethel schist carries a conglomerate bed in Windham then the Cambrian terranes as they appear in Athens and Brookline are Upper Cambrian for they overlie the Bethel schist.

The Ordovician terranes unquestionably overlie the Upper Cambrian with an erosional unconformity separating the two groups of formations in the northern half of Vermont. No new beds of graptolites were found in Westminster and, therefore, there is no new evidence to present as to age.

The Paleontological evidence was given so fully in the Biennial Report of the Vermont State Geologist, 1927-1928, that it need not be reproduced here.

ECONOMICS

There are no known commercial metallic minerals in Athens, Brookline and Westminster, or in their immediate environs. However, there are some non-metallic mineral products of commercial significance. The steatite or soapstone deposits in the extreme northern part of Athens was worked for several years and much good stone was marketed. The quarry was abandoned many years ago, but the supply of stone was not exhausted. Soapstone has also been quarried on the farm of J. L. Perham in the southern part of Athens near Lilly Pond.

The granite of Westminster is susceptible of a good polish and can be used locally for monumental or constructional work. It was quarried many years ago but the quarry has been abandoned. The Bellows Falls gneiss, which extends southward into

Westminster, makes a good building stone. It has been quite extensively used in foundation work and in walls. The granite gneisses of Athens and Brookline can be used for foundation work. The hornblendic rocks of all three townships can be used in the construction of permanent roads. In some of these rocks the resistance to abrasion is high and the cementing power is good.

The small pond in Westminster one-half mile west of the Connecticut River carries thousands of tons of peat that can be used as a fertilizer or dried and used as a fuel.

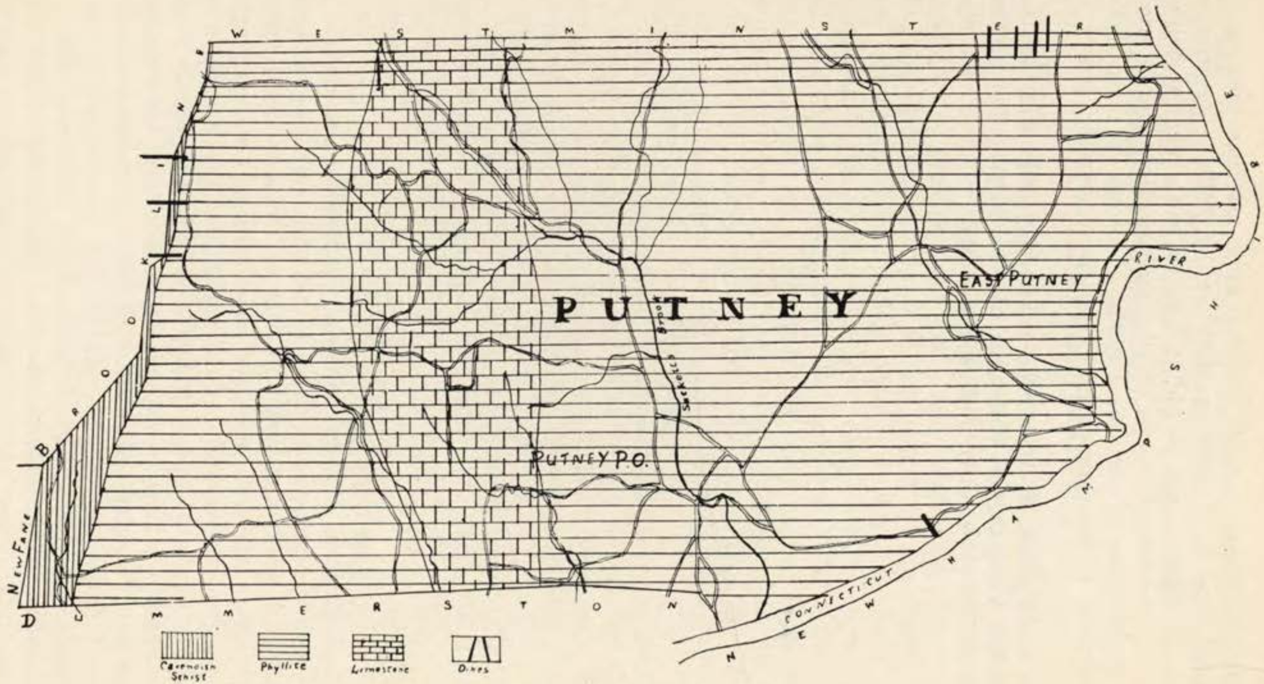

FIG. 66. Areal map of Putney, Vt.

THE AREAL AND STRUCTURAL GEOLOGY OF PUTNEY, VERMONT

CHARLES H. RICHARDSON

Syracuse University, Syracuse, New York

INTRODUCTION

The report upon the areal and structural geology of Putney, Vermont, is of necessity brief. The time that could be given to field work this summer was limited, and the time available for detailed petrographic study in the laboratory too limited to bring out all that might be desired as to structure and the original composition of the terranes involved. The exposed rocks are closely folded, faulted and invaded by intrusives. The whole area is heavily drift covered and much of it is wooded.

The author recognizes his indebtedness to Dr. James E. Maynard for drawing the areal map and for his assistance in the petrographic study, to Carl H. Almfelt and E. Kermit Handley for their aid in the field work. The field work was essentially done during the summer of 1932 but some work was done during the summer of 1931. Some work was also done in Dummerston on the south of Putney and Newfane on the west, but not in sufficient detail to warrant these townships being included in the present report.

The area involved in this report lies between north latitude 42° 57′ and 43° 2′. It also falls between meridians 72° 25′ and 72° 38′ west of Greenwich. The northern half of the township is in the Saxtons River Quadrangle. The extreme northeastern corner is in the Keene, New Hampshire, Quadrangle and the southern half is in the Brattleboro Quadrangle. Furthermore Putney lies directly south of Westminster whose geology and petrography appear in the Bulletin of the Vermont Geological Survey for 1931-32.

An areal map showing the distribution of the different terranes accompanies this report as Figure 66. A cross-section appears as Figure 67.

Several samples of rocks were collected from which microscopic slides have been made for a detailed petrographic study. Without this type of detailed work it is impossible to correctly translate the results of field investigations.

DRAINAGE

The drainage of Putney is all in a southerly or southeasterly direction. The Connecticut River is on the east and into it there flows several small streams that rise in Westminster. Sacketts Brook that empties into the Connecticut River near the village of Putney is the largest of these streams. In origin these smaller streams are in part pre-glacial and in part post-glacial.

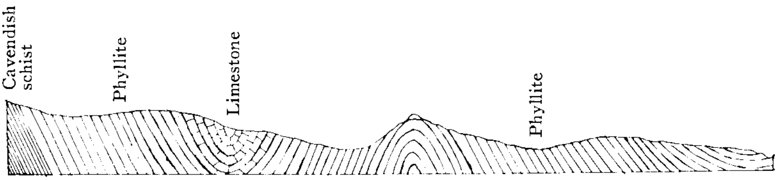

FIG. 67. Cross-section of Putney, Vt.

TOPOGRAPHY

Certain altitudes that may be of interest are given below. The lowest altitude in the eastern part of Putney is 240 feet. The railway station at Putney is 251 feet. Bare Hill is 1,150 feet. Putney Mountain in the extreme western part of the township is 1,740 feet. The topography of Putney is rugged and may be regarded as in the stage of late maturity.

GLACIATION

Evidences of glaciation are found in the thick mantle of glacial till that covers Putney, in the wide distribution of glacial boulders and in the striæ that remains on the more resistant rocks. Excellent exposures of these striations are found on Bare Hill in the northern part of Putney and on an abandoned farm at the end of an abandoned road in the extreme southwestern part of the township. On this farm two distinct sets of striations were found, one south 15° west and the other south 40° east. This last direction is unusual in eastern Vermont.

GEOLOGY

The geology of Putney is intricate and complex. The sedimentaries consist of highly folded and faulted metamorphics that in places have been invaded by basic intrusives. The sediments embrace quartzose marbles, phyllites, hornblendic and chloritic mica schists. As will be seen on the areal map the quartzose marbles and phyllites occupy nearly all of Putney while the hornblendic and chloritic mica schists are confined to the extreme western border of the township. The intrusives are mostly gabbroic rocks in the northeastern part of Putney and in the extreme western part on Putney Mountain.

The sedimentary rocks are nearly all Ordovician in age. The hornblendic and chloritic rocks of the extreme western border of Putney are Cambrian. The age of the intrusives is not definitely known. There are no known granites in Putney but Black Mountain in West Dummerston is all granite. Such granites in eastern Vermont have long been regarded as Devonian. The gabbro dikes may be carboniferous in age while the diabase dike on Putney Mountain may be as late as the triassic.

CAMBRIAN

The oldest known rocks in Putney are regarded as Cambrian. They consist of hornblendic and chloritic mica schists together with an unmappable outcrop of a micaceous quartzite and sericite schist on the western slope of Putney Mountain. These terranes overlie the Algonkian gneiss that flanks them far to the west and underlie the Irasburg and Northfield conglomerates on the east. The dip of the Cambrian sediments is at a high angle to the east as will be seen in the cross-section of Putney.

CAVENDISH SCHIST

The Cavendish schist is a fine to medium grained, dark gray, highly metamorphosed sedimentary rock. In Cavendish, the site of its discovery, the essential mineral composition is quartz and biotite. In Athens and Brookline the biotite is largely replaced by hornblende. In Putney the hornblende gives way to biotite which is largely altered to chlorite. Among the accessory minerals epidote is very abundant. A plagioclase feldspar is invariably present but usually in small amounts. Garnet, tourmaline, apatite, chlorite and magnetite are common. Zoisite, zircon, rutile and titanite are found in many slides.

The Cavendish schist occupies only a very narrow belt in the extreme western part of Putney. Its strike varies from due north to north 30° east, and its dip is at a high angle to the east.

ORDOVICIAN

The term Ordovician as here used embraces the series of sedimentary rocks that lie unconformably on the east flank of the

Cambrian terranes. Actual contact between the Cambrian and Ordovician formations can be seen on Putney Mountain in the extreme western part of the township. The Ordovician sedimentaries consist of limestones, slates and phyllites. The phyllites are by far the most abundant.

The structure of the phyllite along the Connecticut River is quite varied. An excellent section can be seen between the village of Putney and the river. It is best observed in following up Sacketts Brook westward from the river for about one mile. Back of the old mill on the brook bank an excellent syncline can be observed. Between this and the cement bridge in Putney there is an anticline for at the bridge the phyllite is dipping to the west 80° to 85°.

The eastern part of a cross-section drawn through the village of Putney would be markedly different from one drawn along the north boundary of the Brattleboro Quadrangle where the cross-section in this report was drawn.

On Bare Hill in the northern part of Putney there is a distinct anticline. West from Bare Hill to the Newfane line the structure is that of a broad syncline as will be seen in the cross-section of Putney.

WAITS RIVER LIMESTONE

The Waits River limestones or quartzose marbles form a more or less continuous belt that stretches across the township of Putney in a north and south direction. It extends northward through Westminster and southward into Dummerston. It lies in a synclinal trough in the phyllite and in itself is more or less interstratified with small beds of phyllite.

The only essential minerals are calcite and quartz. The quartz grains are usually small and well rounded but sometimes they appear elongated by the pressure to which the rock has been subjected. In some of the outcrops there are a few flakes of sericite, a few grains of magnetite and titanite are present.

The purest quartzose marble found in Putney occurs in the northwestern part of the township. The marble is medium grained, massive and contains about 75 percent calcite and 25 percent of quartz. The calcite is perfectly recrystallized and some of it is twinned. This marble is susceptible of a good polish and could be used for decorative interior work.

In the western part of the village of Putney there is a thin bed of limestone or quartzose marble that shows a much finer texture with the calcite drawn out somewhat into parallel lines. Some of the quartz grains appear elongated and show shadowy extinction. This slide is 65 percent calcite and about 35 percent quartz. There are a very few plates of sericite, a few grains of magnetite and some uncombined carbon. A shearing has occurred in the rock so that perfectly smooth surfaces like slickensides have been produced.

The strike of these quartzose marble beds varies from due north to north 30° east. The dip on the east side is to the west and on the west side it is invariably to the east. The beds lie in a synclinal trough in the phyllite.

MEMPHREMAGOG GROUP

The Memphremagog group consists of slates, phyllites and quartzites. The quartzites do not occur in a mappable area in Putney.

SLATE

The Memphremagog slate occurs in a merchantable bed in the eastern part of Putney. It has been quarried for roofing and flagging purposes. On the Austin farm the strike of the slate belt is north 20° east and the dip is vertical. On the west slope of Bare Hill slate was quarried many years ago for flagging purposes. The dip here is at a high angle to the west.

BRATTLEBORO PHYLLITE

The term Brattleboro phyllite has been applied to all the phyllites in the southeastern part of the State. They extend southward from Putney into Massachusetts. In Putney with the associated limestones and quartzose marbles they cover nearly all of the township. The belt is constantly widening to the southward and at the Massachusetts boundary it is three townships in width.

The strike of these phyllites varies from due north to north 40° east. The dip of the planes of fissility varies widely. In some of the outcrops as in the northern part of the township the phyllites are so contorted and injected with quartz that strikes and dips in all directions can be recorded.

On the south end of Bare Hill the phyllite shows much contortion in the microscopic slide. The rock is a fine aggregate of quartz and sericite with much magnetite scattered throughout the entire slide (Figures 68 and 69).

ACID INTRUSIVES

Acid intrusives have occurred in every township south of the international boundary to Putney but in Putney none were found. They do occur in Dummerston, the first township to the south of Putney. The well-known Black Mountain granite is at West Dummerston.

FIG. 68. Phyllite dipping east and injected with quartz, Putney, Vt.

BASIC INTRUSIVES

A few basic intrusives occur in Putney. They are associated with both the Cambrian and Ordovician terranes. They may be listed as diorites, gabbros and diabases. The pyroxenites and peridotites do not occur in Putney.

DIORITES

A diorite occurs in the eastern part of Putney where the north-south road comes close to the railroad. It crosses both the highway and the railroad. The essential mineral composition is hornblende and andesine. The hornblende is partially altered to chlorite. Rutile and titanite, partially altered to leucoxene, is

sparingly present. There are a few small grains of magnetite in the slide and quartz is absent.

FIG. 69. Phyllite dipping west, Putney, Vt.

In the northeastern part of Putney, south of the east-west road, there occurs a diorite that is approximately 60 percent hornblende. The texture is hypidiomorphic in which euhedral crystals of hornblende are surrounded by anhedral andesine. The hornblendes are partially altered to chlorite. The andesines are partially altered to a confused aggregate of calcite, paragonite and kaolinite. There is much magnetite present and many wedges and grains of titanite. There is also present a few sporadic grains of secondary quartz.

GABBROS

Several gabbros occur in the northeastern part of Putney along the east-west crossroad. They all extend north into the south-eastern corner of Westminster. They are green, massive and hornblendic with only a very little plagioclase feldspar that can be distinguished. The hornblendes constitute from 80 to 85 percent of the rock and some of these contain small inclusions of albite. Much of the hornblende is secondary after augite and partially altered to chlorite. The interstices amongst the hornblende crystals are filled with highly altered basic plagioclase, fresh albite, epidote and chlorite. Grains and large aggregates of titanite are very abundant. Biotite, magnetite, ilmenite, pyrite, zircon and a few grains of clear secondary quartz are also present.

In the extreme western part of the township on Putney Mountain there are dikes of gabbro that cut both the Cambrian and Ordovician formations. They strike in a northeasterly direction and their width is approximately twenty feet.

These gabbros are coarse-grained, massive, hornblendic rocks in which there is a small amount of plagioclase feldspar between the hornblendes. The texture of the rock is slightly gneissoid. About 85 percent of the rock is a large irregular aggregate of secondary hornblende in which there are many inclusions of small albiclase crystals. Surrounding the hornblendes there is a granular aggregate of albiclase which comprises about 14 percent of the rock. The remaining 1 percent includes a small amount of calcite, zoisite, titanite, ilmenite and magnetite.

DIABASE

Only one dike of diabase was found in Putney. This dike occurs on the west slope of Putney Mountain. It is narrow and strikes in a northeasterly direction.

PALEONTOLOGY

No fossils have as yet been found in the Cambrian terranes in eastern Vermont and no new beds of graptolites were found in Putney. Therefore, there is no new evidence to present as to age. The paleontological evidence was given so fully in the Biennial Report of the Vermont State Geologist for 1927-28 that it need not be reproduced here.

Several suggestive samples from the limestones and slates in Putney were sent to Dr. Rudolf Ruedemann, state paleontologist, Albany, New York, who writes that "none of the samples are distinct enough that it would be safe to suggest their organic origin."

ECONOMICS

The quartzose marbles in the northwestern part of Putney are susceptible of a good polish and can be used for decorative interior work. They can also be used as foundation stone.

The slate in the eastern part of the township can be used for roofing and flagging purposes.

The clay beds along the Connecticut River make good building brick. It is necessary to dry and screen the clay to remove the sand-lime concretions, or else to grind the clay before mixing to reduce the concretions to a fine powder. The concretions are neither abundant nor large (Figure 70).

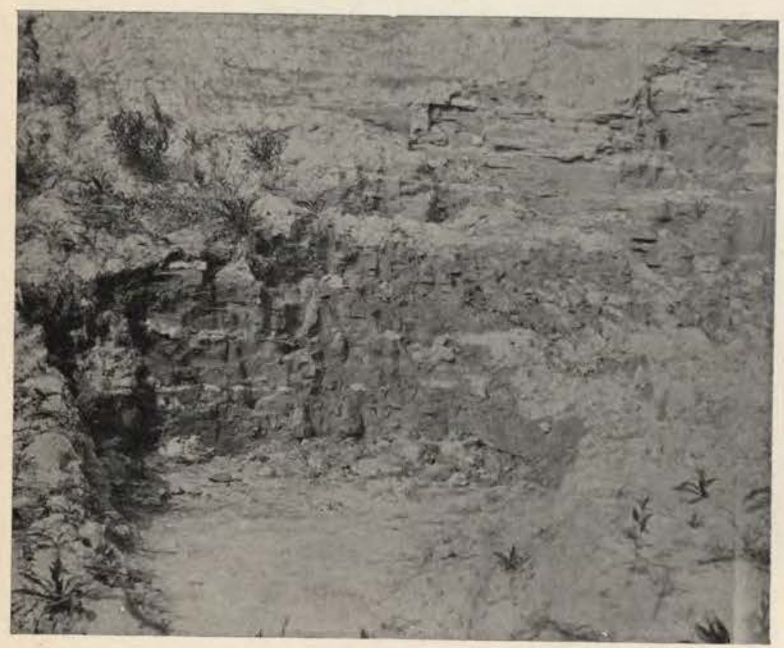

FIG. 70. Varved clay, Putney, Vt.

FIG. 71. Areal map of the Stowe Valleys.

THE LAST LAKE OF THE STOWE VALLEYS

EDWIN L. BIGELOW

Brief studies have been made of physiographic features of the Stowe Valleys indicative of ancient lake levels, but the data referred to have been limited to the east side of the main north and south valley, and none of the investigators, Hitchcock, Merwin or Fairchild, seems to have made any observations on the west side of that valley, or to have investigated the valley of the West Branch River which enters the main valley from the west, or the small north and south Barrows Brook Valley east of Luce Hill.

Two lake levels have been noted. One is at an altitude of 1,000 to 1,100 feet, which Hitchcock believes (5th Rept., Vt. State Geol., p. 248) to be the level of a body of water which he named Glacial Lake Memphremagog which existed when the waters of the present Lake Memphremagog basin were discharged into the Lamoille Valley through an outlet at Elligo Pond. The Lamoille Basin, because of a barrier at the west, was drained through Stowe to the Winooski Valley. Fairchild concurs in this view (10th Rept., Vt. State Geol., p. 39).

The second level is found at about 800 feet (6th Rept., Vt. State Geol., p. 129) representing a body of water which Merwin called Glacial Lake Mansfield which, he believed, owed its existence to the fact that an ice barrier prevented the waters of the Winooski basin from finding their present outlet into the Champlain Valley. Instead they flowed out the Hollow Brook channel in Hinesburg which maintained a water level high enough to cover the divide between the Lamoille and Winooski Basins near the Morristown-Stowe town line and make a lake of the present Stowe Valleys.

Fairchild believes (10th Rept., Vt. State Geol., pp. 29, 37, 38) that the penetration of these valleys by the waters of Lake Champlain at its so-called marine stage when it existed as a strait between the Hudson and St. Lawrence Valleys (10th Rept., Vt. State Geol., p. 4) accounts for a similar level, the deposits of which may be easily confused or even coincident with those of the glacial lake levels described by Merwin (10th Rept., Vt. State Geol., p. 38).

The writer wishes to call attention to certain physiographic features overlooked by other investigators which might account for a local lake in the Stowe Valleys at about the levels held by the waters considered by Merwin and Fairchild as confluent with the glacial or marine waters of the Winooski and Lamoille Valleys. The area described is shown on the Montpelier sheet of the United States Geological Survey topographical maps in the section bounded by the 25′ parallel and the 40′ meridian.

It seems entirely possible, and indeed probable, that the preglacial drainage from the basins of the present East and West Branches of the Waterbury River, which join to make the latter stream a little above the covered bridge in Stowe village, was south from the valley of the West Branch through the north-south valley east of Luce Hill now occupied by the small Barrows Brook and its tributaries.

The truth of such an hypothesis is indicated by the following data:

1. The direction of the Barrows Valley. This makes it appear to be a continuation of the Waterbury River Valley from a point a little north of the latter's junction with Miller Brook. The Waterbury River, in its present course west from Moscow to where it turns south at its junction with the Barrows Valley, seems to be occupying a side valley.
2. The size of the Barrows Valley. Making allowance for the glacial drift now partially filling it, the size of this valley indicates the erosive work of a considerable stream of water.
3. The depth of the Barrows Valley. Ledge at the edge of the present brook about halfway down the valley is nearly 100 feet lower than the present level of the West Branch Valley, and at least 75 feet lower than the next highest point in the rim of the East and West Branch basins near the village, and this ledge does not appear beneath the brook which would indicate that the stream has not yet worn its channel to the rock bottom of the valley.

The valley of the West Branch is filled to its present level of about 750 feet by glacial deposits of unknown depth. At no point in its course below the Barrows Valley does the stream uncover the ledges which one would assume underlie the valley between the

opposite points of their outcropping on its north and south sides. Terraces and deposits in this valley correlating with those of the main north and south valley present ample evidence of standing water in both valleys.

Glacial deposits also fill the Barrows Valley, the most conspicuous of which is a broad sandy terrace, faced with clay on its north side, which occupies the opening of the Barrows Valley, at its junction with the valley of the West Branch. This deposit would have proved an effective barrier to stream drainage from the West Branch Valley which is about 40 feet lower. A swamp occupies the divide between the two valleys near the southwest corner of the E. B. Gale farm, and there is evidence of a former stream channel through the terrace barrier south from the swamp at a level between 760 and 780 feet, which probably at some time was an outlet for water which stood in the West Branch Valley after its normal outlet had been closed by the terrace barrier at its level of 800 feet.

Two miles to the east, Stowe village is located on a ridge (which may be an old barrier beach) extending from the ledges of Sunset Hill on the east to those of Cady Hill on the west at a level of 723 feet, and it was here at the lower end near Cady Hill that the impounded waters of the East and West Branch Valleys found the lowest point in the rim of the lake, and gradually wore a new channel through which the Waterbury River now finds its way to the Winooski via the Lower Village and Moscow.

When the water stood in these valleys at a level high enough to outlet through the 760- to 780-foot channel in the Barrows Valley drift barrier, it was high enough to have covered the divide between the Winooski and Lamoille Basins near the Morristown-Stowe town line at an altitude of 745 feet, which makes it possible to assume that Merwin's glacial Lake Lamoille and glacial Lake Mansfield were confluent through the Stowe Valley after the Lake Winooski water had found its present outlet to Champlain. This would mean that the barrier at the mouth of the Winooski Valley was removed some time previous to that at the mouth of the Lamoille, which if that barrier were ice—as others have assumed—might be reasonably believed from the fact that the mouth of the former is some twenty miles south from that of the latter.

The 760- to 780-foot channel could not have been used for any great length of time nor used by a large volume of water, or else it would have been worn deep enough to have completely drained the West Branch Valley, and the drainage of both the East and West Branch Valleys would have resumed its old pre-glacial course through the Barrows Valley. This channel may have carried water only at flood times when the new channel being cut at the village was unable to take care of the total overflow. It is probable, too, that water also flowed at times between the 800-foot terrace and the hill east of it, as the lowest point of the divide here is about 780 feet, and that section of the Barrows Brook directly south of the terrace occupies a deep ravine between the terrace and the hill, the depth of which implies the work of a larger stream than has occupied it for some time.

Thus it would seem that a body of water responsible for the lower level lake phenomena of the Stowe Valleys might have been due to the blocking, by the glacial drift terrace at the 800-foot level, of a former drainage channel through the valley now followed by Barrows Brook.

METAMORPHISM NEAR RUTLAND, VERMONT

Edward J. Foyles

INTRODUCTION

The geological history of the rocks of the Green Mountains is so complicated that it is with hesitancy that one attempts to solve the difficult problems contained in them. It is hoped that some of the conclusions in this paper, which may be regarded as a preliminary survey of the many problems implied in the text, will lead to the true facts. The present knowledge of the significance of petrologic data forbids confident conclusions in many cases, but this method of approach may help.

For their helpful suggestions and assistance during the course of this study I am grateful to Dr. Harold L. Alling and Dr. Quentin D. Singewald of the University of Rochester.

The data for this study were collected from the rocks of the townships of Sherburne, Chittenden, Mendon, Shrewsbury, Pittsford, Rutland, Clarendon, Proctor, West Rutland, Castleton, and the townships extending eastward from Shoreham.

GENERAL NATURE OF THE ROCKS AND MINERALS

The rocks are intensely folded and faulted and have a secondary cleavage independent of the bedding. They exhibit banding, foliation, and augen. The minerals comprising the rocks show parallelism and interlocking of mineral grains, distorted crystals, granoblastic structure, undulatory extinction, and bent cleavage. This paper deals almost exclusively with rocks composed chiefly of quartz, feldspar, mica, sericite, and chlorite, excepting only those which are referred to the Champlain Valley.

THE LAKE CHAMPLAIN-GOSHEN SECTION

As one goes eastward from Lake Champlain one finds a gradual disappearance of fossils, a gradually increasing complexity of structure and gradually increasing abundance of igneous phenomena.

At Larrabee Point fossils are abundant in the rocks of the lake shore. Going eastward across the township of Shoreham fossils are less abundant. In Whiting and in Leicester fossils are rare, having been found only in the eastern part of the townships. No fossils have been found in Goshen or Rochester. The fossils near Lake Champlain are in a good state of preservation, but in addition to the decrease in the abundance of fossils from Lake Champlain eastward, the specimens themselves are poorer the farther east they are found.

The Cambrian quartzite of Shoreham does not yield fossils, but the Cambrian quartzites east of Lake Dunmore and Fern Lake have yielded molds of *Hyolithes communis* (Billings) and *Nothozoe vermontana* (Whitfield). Although quartzites occur farther east in Goshen, no fossils have been found in them. The Beekmantown formation of Shoreham has furnished abundant *Cryptozoon, Holopea, Ophileta,* and *Leperditia.* No fossils have been found in the crumpled Ordovician shales and limestones of Whiting and Leicester. The uplifted lime rocks of the Green Mountain front contain no fossils. The Chazy rocks of Shoreham have yielded many trilobites, cephalopods, gastropods, and brachiopods. No known Chazy fossils are found east of Shoreham. The Trenton beds of Shoreham contain an abundance of fossils. In Whiting the only fossils of probable Trenton age are a bryozoan which resembles *Prasopora,* and the eye of trilobite. These are the last Trenton fossils found to the east.

It is seen that there is a rapid diminution of fossils as we go east from the lake shore, but still enough to prove that the rocks are of Cambrian and Orodovician age. In Shoreham, Whiting, and Leicester there is no marked evidence of regional igneous metamorphism. In Goshen and Rochester the schistose sediments furnish tourmalines and feldspars which indicate the proximity of post-Ordovician acid magma. Igneous rock indeed appears at the summit of Mount Horrid as a granite and, like most of the igneous rocks of Vermont, is probably Devonian. The low levels of the valley, while they do not exhibit evidences of igneous intrusion are, nevertheless, sheared and folded, due to pressure from the east which was probably in large part accompanied by the igneous intrusions which are elsewhere evident at the junction of the valley and the Green Mountain front.

The structure of the rocks becomes more complex as we go eastward and the surface profile rises to higher levels. The available views of vertical sections of the rock, such as the walls of the quarries at Leicester Junction, reveal close folds with steep to vertical axial planes.

A study of thin slices of the section from Lake Champlain eastward reveals a gradation from rocks somewhat metamorphosed by stress to rocks considerably metamorphosed by stress, and these in turn to rocks metamorphosed by stress, heat, gases, and actual contact with the igneous matters.[1] The conclusion derived indicates that there is a continuation of the valley rocks of known ages into the schists of the Green Mountains, but that the latter carry in addition a number of minerals produced by igneous activity.

EVIDENCE OF VERTICAL FAULTING PRODUCING RELATIVELY HIGH AND LOW AREAS

On the west side of Nickwaket Mountain, southeast of Brandon, a series of step faults, the time of occurrence of which is not known, illustrate in part the manner in which the topography has been attained. The Cambrian quartzites and dolomites are found at higher and higher levels on a mountain side which is part of the Green Mountain front. A figure by Gordon[2] implies that the quartzites become schistose as one goes eastward.

The synclinal valley between the Green Mountains and the Taconic range in the latitude of Rutland is partly the result of upthrow of the rocks on both sides of the present valley rocks. Field evidence described below supports my theory of vertical displacement, which was preceded by horizontal displacement.

On the west flank of East Mountain several instances of vertical faulting with the upthrow side to the east indicate the forces which have helped to raise East Mountain to its present level.[3] As viewed from the north, the mountain has the appearance of a block fault which form is due to thrusting from the east and upthrow.

In section C-D, Figure 36,[3] a vertical scarp shows the dip of the fault. The schistosity of the rock dips 40° to the east. In the fine sediments the schistosity is usually at an angle to the beds. I believe that the schistosity of the metamorphosed shaly sandstones and conglomerates of East Mountain follows the direction of the bedding planes because these rocks are more resistant to the development of schistosity than shales. This is shown in the strata exposed in section B-A, Figure 35,[3] which illustrates the excellent exposure on the highway east of Mendon. Throughout all sections on East Mountain, the direction of the dip of the schistosity is east.

[1] Foyles, E. J., Rock Correlation Studies in West-Central Vermont, Rpt. Vt. State Geol., XVI, 1929, pp. 282-284.
[2] Gordon, C. E., Studies in the Geology of Western Vermont, Rpt. Vt. State Geol., XII, 1921, p. 192, Fig. 16.
[3] Foyles, E. J., Rpt. Vt. State Geol., XVII, 1929-30, pp. 242-243, Figs. 36-38.

West of Rutland a structural break is shown, with Pine Hill on the upthrown side. The uplifted Cambrian quartzite is exposed in a quarry west of the city and at a high elevation west of Rocky Pond. The west and north sides of Pine Hill show exposures of a schist. The schist is separated from the quartzite by a small valley northwest of Rocky Pond. The valley may represent a fault or it may be weathering along the contact of the quartzite and schist. There is only slight indication in the quartzite of igneous activity.

On the summit of Pine Hill a few large boulders of greatly weathered dolomite indicate by their localization and condition that they may be residual. They may be glacial erratics, but if so, they are the only ones of their kind in the vicinity. According to J. E. Wolff,[1] "the facts . . . prove that the limestone of the Rutland Valley is of lower Cambrian age, that in Pine Hill it overlies conformably a mass of quartzite with associated beds of metamorphic conglomerate . . . and that the Pine Hill quartzite must, therefore, be of *Olenellus* age."

In a series of laboratory experiments Cloos[2] has demonstrated the formation of a graben when the borders of the graben area are uplifted. The movement of the clay used in such an experiment was recorded in motion picture by Ernst Cloos and shown at the annual meeting of the Geological Society of America in 1931. It illustrates very well the resultant faults and folds in the walls of the valley. The faults form in directions extending downward and away from the valley. With respect to the folding, the experiment exhibits a down-turning or slumping of the strata of the eastern wall as the clay, as a whole, on that side is forced upward. This reaction along the edge of the wall is of important significance because it might easily be assumed, when this structure is seen in the field, that the rocks have been overturned by a thrust from the east. This may be the explanation of the structure seen on the southwestern side of Mt. Moosalamoo. These occurrences are independent of westward movement of the Green and Taconic Mountains which does not entirely explain the presence of the valleys.

THE MENDON SERIES

The Mendon series has been discussed so many times that the only excuse for referring to it again would be new information

[1] Wolff, J. E., Bull. G. S. A., Vol. XI, p. 336, 1891.
[2] Cloos, Hans, Zur experimentellen Tektonik. Naturwissenschaften, 18, H. 34, 1930; 19, H. 11, 1931; Geol. Rundschau, 21, H. 6, 1930.
Fliessen und Brechen in der Erdkruste, Plastische Massen, 1, 1931.

on that series of rocks. It is my opinion that the establishment of the "Mendon series" has hampered a clear understanding of geologic history of the western side of the Green Mountains for many years. It has never been proven to be pre-Cambrian in age, and yet its records have often been used by authors as an infallible classic; many series of a somewhat similar nature, but in no way exactly comparable, have been correlated with it. For several years I have been unable to reconcile the Mendon series as such with the formations of the region. An excursion was made to the type locality in the summer of 1931. Making side trips from the beaten path, nothing unusual was encountered until the well-known dolomite outcrop of the type section was reached at 1,240 feet above sea level. The dolomite is a large block fifteen feet long by ten feet wide, surrounded with glacial till. No bedding planes are recognizable in the dolomite. North and south along what would be the strike of the rock no dolomite was found. Instead, 150 yards north of the dolomite, there is found a quartzite schist dipping steeply to the east. Schist also occurs east and west of this outcrop. It is concluded that the occurrence of the "Mendon dolomite" is really the Rutland dolomite which arrived in its present position through faulting or by glaciation.

Although Whittle[1] thought that the "Mendon series" in Blue Ridge Mountain was completely overturned, there is no sign of field evidence to prove this fact. Thin sections of the rocks show very close folding and shearing, and it is evident that the geographical sequence in no way represents the stratigraphic sequence which may never be determined. Likewise the indicated thicknesses of the rocks do not represent the true thicknesses, but rather the generally overestimated geographical extent of the several rock types across the strike.

In a study of the region covered in this paper Pumpelly[2] stated: "The Green Mountain range is composed of crystalline schists, which our results show to be of Cambrian and Lower Silurian age, resting on pre-Cambrian rocks, and it was long ago shown by Edward Hitchcock to be of anticlinal structure. The western edge of this axial range is for long stretches marked by a lofty brow of quartzite, and for this reason the mountains present a very steep flank to the west." According to Dr. T. N. Dale,[3] "The (Cambrian) age of the conglomerate pebbles is fixed by contained fossils." The "Mendon series" may eventually be proved to be Paleozoic rock.

[1] Whittle, C. L., Journal of Geology, Vol. II, 1894, pp. 396-429.
[2] Monograph U. S. G. S., XXXII, 1905.
[3] Dale, T. N., Cambrian Conglomerate of Ripton, Amer. Jour. Sci., 1910.

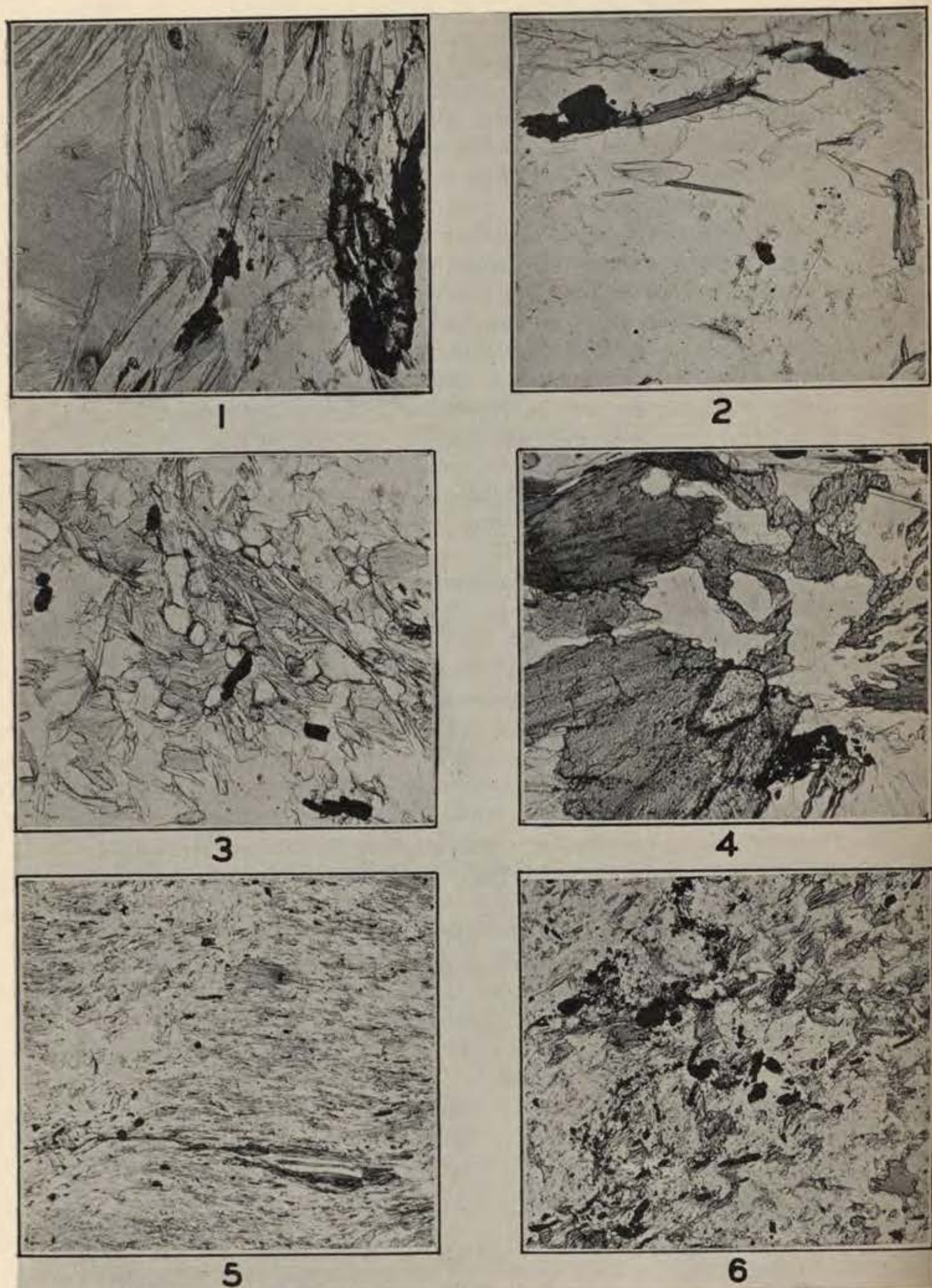

FIG. 72. For description see opposite page.

IGNEOUS ACTIVITY CAUSING METAMORPHISM OF THE SEDIMENTS

The flood of 1927 exposed granite and pegmatite at the north end of the dam at Mendon village. The pegmatite cut through the chloritic schist, Figure 73, 4, in which it formed numerous crystals of magnetite. Granite occurs at intervals in the schist for a distance of 200 feet east of this outcrop.

Along the road east of Mendon a long ledge of rock affords numerous evidences of igneous injection. Many specimens taken from the west flank of East Mountain show saturation in igneous matter.[1]

The numerous instances of the discovery of igneous material in the rocks of the area studied are sufficient to show that a body of igneous rock must underlie the sediments under study. No account seems to have been taken of the influence of the rising magma on the Paleozoic sediments through which it passed and its ability to change them. Indeed, it is not surprising that Whittle, in 1894, should have assigned the schists and gneisses of his "Mendon series" to the Proterozoic. They were markedly different from the neighboring Paleozoic rocks, and they occurred at much higher elevations. The mica-quartz-actinolite schist of the type section contains injected forms of vein quartz.

At an elevation of 1,190 feet in the type section of the Mendon series at Mendon the rock, Figure 74, 3, contains quartz dominantly, plagioclase, orthoclase, muscovite, magnetite which appears to have been present before hydrothermal alteration, hematite, zircon, epidote, and apatite. One hundred and fifty yards north of the so-called Mendon dolomite, which is probably not *in situ*, the

[1] Foyles, E. J., Rpt. Vt. State Geol., 1929-30, pp. 235-251.

FIG. 72

A series of thin sections showing the relation of the minerals from Mt. Pico in the Green Mountains on the east to the Taconic metamorphic rocks of Castleton on the west. Magnification eighty-five times.

1. (3606) Top of Mt. Pico.
   Minerals: Quartz, feldspar, magnetite, titanite, leucoxene, hematite, muscovite, biotite, chlorite, apatite, zoisite, epidote, zircon.
2. (3657) Blue Ridge Mountain, 150 yards north of "Mendon dolomite."
   Minerals: Quartz, magnetite, leucoxene, hematite, muscovite, chlorite, zircon, epidote.
3. (3671) North end of Blueberry Hill.
   Minerals: Quartz, feldspar, magnetite, leucoxene, hematite, muscovite, sericite, biotite.
4. (3668) Foot of Pine Hill at Rutland-Pittsford town line.
   Minerals: Quartz, magnetite, leucoxene, hematite, hornblende, muscovite, biotite, chlorite, zircon, rutile, epidote.
5. (3784) Whipple Hollow, West Rutland.
   Minerals: Quartz, feldspar, titanite, hematite, muscovite, sericite, biotite, chlorite, tourmaline, zircon, epidote.
6. (3782) North Brittain Brook, Castleton.
   Minerals: Quartz, feldspar, magnetite, leucoxene, hematite, muscovite, sericite, chlorite.

FIG. 73. For description see opposite page.

rock exhibits quartz in abundance, chlorite, muscovite, magnetite, hematite, leucoxene, zircon, and epidote. Another outcrop in the Mendon series yields quartz, feldspar, muscovite close folded, biotite, magnetite, hematite, leucoxene, tourmaline, zircon, epidote, and apatite. The aggregation of minerals in the rocks of the Mendon series on the flank of Blue Ridge Mountain, when considered with regard to the region as a whole, suggests that there has been igneous activity in this locality.

In attempting to follow the schist across the Rutland Valley, it is necessary to go to Blueberry Hill, an outlying knob, where outcrops may be found on the north end of the hill. This rock, Figure 72, 3, contains quartz dominantly, sericite in abundance, feldspar, muscovite, biotite which in places is altering to sericite, magnetite, and hematite. The next step takes us to the Rutland-Pittsford town line where it crosses the west road. Here a greatly injected rock, Figure 72, 4, contains quartz in abundance, muscovite, hornblende in abundance, magnetite in abundance, a small amount of biotite, hematite, leucoxene, chlorite, zircon, epidote, and rutile. Above, on the top of the north end of Pine Hill, Figure 74, 4, the rock contains quartz dominantly, muscovite, magnetite in abundance, hematite, and leucoxene.

The beds of quartzite on Pine Hill dip east. The uppermost third of the exposed vertical section of rock is massive quartzite; the middle third is thick-bedded quartzite separated by thin layers of quartz schist exhibiting slickensides and pyrite crystals; the lowest third is comparatively thin-bedded quartzite separated by equally thin beds of impure quartzite and quartz schist. At the south end of the quarry on Pine Hill a large vein of glassy quartz shows a sharp contact with the quartzite. At the contact and in

FIG. 73

Illustrations of thin sections suggesting igneous intrusion in the area studied. Direct and indirect evidence of igneous influences were found in nearly all parts of the region. Magnification eight-five times.

1. (15) One hundred yards west of bridge which is east of Mendon.
   A metamorphosed argillaceous sediment containing tourmaline, biotite, graphite, zircon, quartz, ilmenite, titanite, potash feldspar, muscovite.
2. (24a) Upper dam, Mendon.
   A granite containing tourmaline, zircon, quartz, apatite, plagioclase, microcline, muscovite.
3. (23) Mendon dam.
   A pegmatite containing quartz, orthoclase, plagioclase, muscovite.
4. (21) Mendon dam.
   A schist in contact with pegmatite (23). The minerals are quartz, magnetite, feldspar, epidote, muscovite, biotite, chlorite.
5. (3640) McLaughlin Falls, Mendon.
   A granitized schist containing tourmaline, zircon, quartz, lime carbonate, apatite, titanite, feldspar, plagioclase, muscovite, chlorite.
6. (3780) North Brittain Brook, Castleton.
   A chloritic schist containing tourmaline, hematite, magnetite, titanite, feldspar, muscovite, biotite, chlorite.

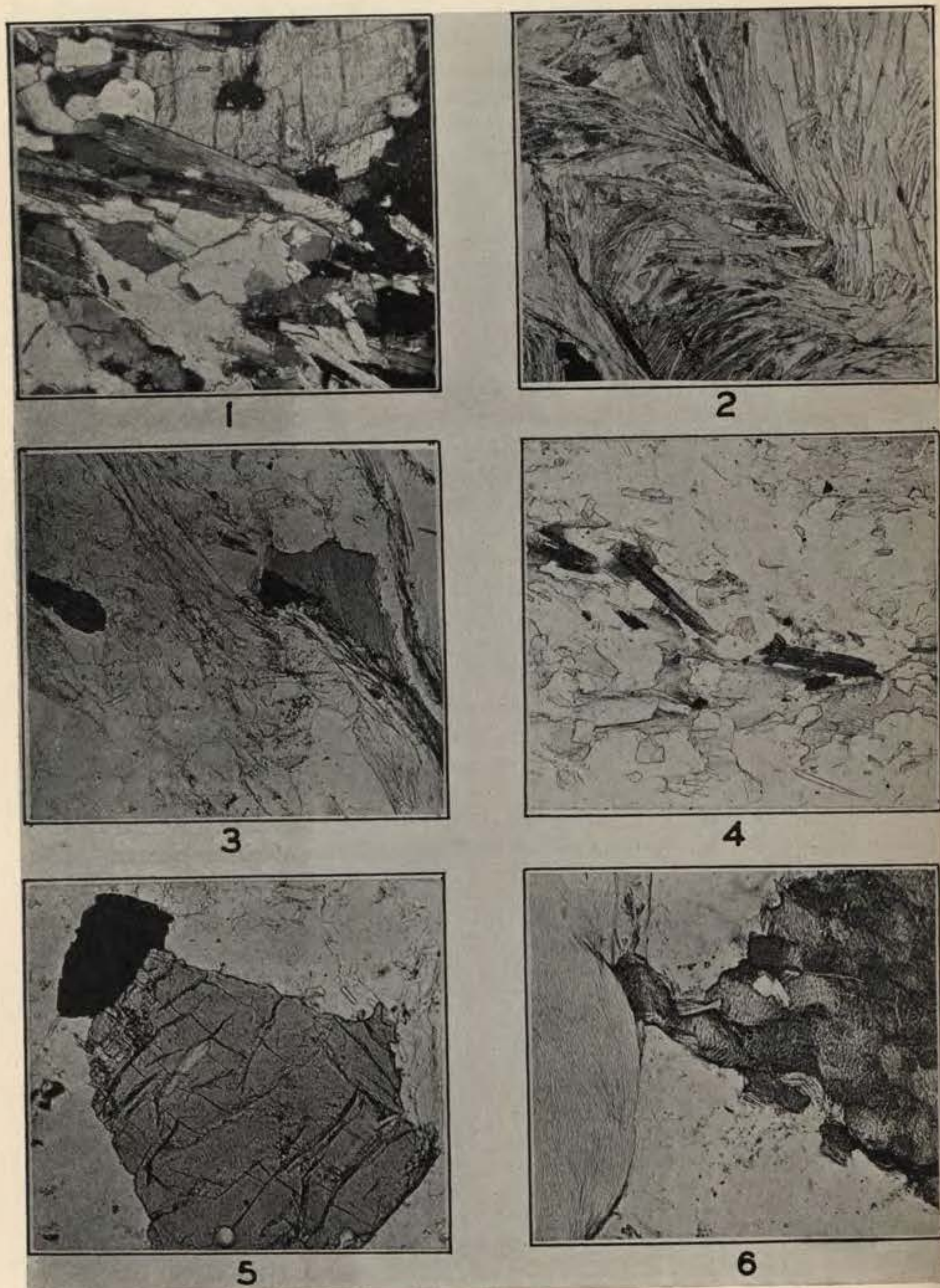

FIG. 74. For description see opposite page.

the glassy quartz there are hundreds of cavities showing the crystal faces of a mineral. Some cavities contain a powdery hematite and others limonite, which may be derived from magnetite or pyrite. Other minerals were probably present. The glassy quartz may represent hydrothermal injection which has caused the growth of the minerals noted.

On the Rutland-West Rutland town line, near the Gateway road, the rock, Figure 74, 5, contains quartz in abundance, muscovite, biotite, biotite altering to chlorite, chlorite, magnetite in abundance, hematite, leucoxene, tourmaline, hornblende, epidote, and zircon. At West Rutland, one-fourth mile north on the Whipple Hollow road, the Stiles phyllite, Figure 12, 5, yields quartz, feldspar, muscovite, sericite, chlorite, tourmaline, biotite, hematite, leucoxene, epidote, and zircon. The rock is fine-grained but otherwise has many of the characters of the Green Mountain rocks. At Castleton rocks, Figure 74, 6, collected for three miles along the North Brittain Brook road contain quartz, feldspar in fine-grained areas, muscovite, sericite, chlorite in abundance, tourmaline, biotite, magnetite, hematite, leucoxene, and in one place large dolomite crystals.

It is apparent that there is a large body of igneous rock underlying the region. Its effect as a magma was to alter the Cambrian and Ordovician rocks in such a manner as to make them difficult to recognize as Paleozoic sediments. The rocks of the Taconic Mountains contain more chlorite than those of the Green Mountains. The mineral composition of the rocks of the two mountain areas and the schists lying between them is essentially the same; the varying amounts of the minerals is probably of no significance

FIG. 74

Illustrations of thin sections showing special mineral and structural features from Sherburne Pass to Castleton. Magnification eighty-five times.

1. (28) Deer's Leap, Sherburne Pass.
   A schist containing a large crystal of lime carbonate together with graphite, quartz, apatite, feldspar, muscovite. Limestone is found opposite Deer's Leap on the side of Mt. Pico.
2. (3660) Mendon series, Blue Ridge Mountain.
   The section illustrates the intense folding and shearing undergone by the rocks of the "Mendon series." The minerals are hematite, zircon, quartz, magnetite, leucoxene, apatite, tourmaline, feldspar, epidote, muscovite, biotite.
3. (3651) Mendon series, elevation 1,190 feet.
   An argillaceous sediment containing hematite, zircon, quartz, magnetite, apatite, feldspar, plagioclase, epidote, muscovite.
4. (3677) North end of Pine Hill, Rutland.
   An uplifted metamorphic sediment containing hematite, quartz, magnetite, leucoxene, muscovite.
5. (3785) Gateway road, Rutland-West Rutland town line.
   Large crystals of hornblende and magnetite in a finer groundmass of hematite, zircon, quartz, epidote, muscovite, biotite, chlorite.
6. (3791) North Brittain Brook, Castleton.
   A large mass of ultra-blue chlorite in schist composed of hematite, quartz, magnetite, dolomite, oligoclase, muscovite, chlorite.

in regard to the ages of the rocks. In conclusion, the sediments forming the western flank of the Green Mountains at Rutland were deposited at the same time as the sediments of the Taconic rocks studied at West Rutland and Castleton. They are of Cambrian and Ordovician age and were all injected by igneous matters after they had been indurated. This injection may have taken place in Devonian time.

ANALYSIS OF THE MENDON ROAD SECTION

The outcrop begins at the first bridge east of Mendon village and extends along the south side of the road for a distance of 3,000 feet. Thin sections were made from eight typical rocks in the section and were studied by the Rosiwal method of micrometric analysis. The following data were obtained from this study:

	Quartz	Feldspar	Biotite	Muscovite	Chlorite	Tourmaline	Magnetite	Leucoxene	Hematite	Yellow iron oxide	Apatite	Carbonate	Epidote
No. 13, bridge	40.2	32.4	.4	26.9	..	..	..	..	..	..	..	..	..
No. 14, bridge	36.5	43.4	1.3	16.8	..	..	..	..	..	..	..	..	..
No. 15, 300 feet...	36.2	4.2	.8	11.1	..	42.7	2.6	.3	2.1	..	..	..	..
No. 16, 1,000 feet..	58.7	13.3	5.3	20.3	.6	..	.1	..	..	.4	.8	.1	..
No. 17, 1,300 feet..	85.6	1.4	..	11.	..	..	..	..	..	..	..	..	1.9
No. 18, 1,300 feet..	31.5	..	18.9	36.9	..	..	..	..	..	..	..	8.3	4.5
No. 19, 3,000 feet..	56.	12.6	1.9	27.9	.9	..	..	..	..	..	..	1.6	..
No. 20, 3,000 feet..	54.8	9.8	9.	26.3	.6	..	..	..	..	..	..	..	..
	49.9	11.1	3.6	22.2	3.8	5.3	.3	.04	.26	.05	.1	1.2	.8

No. 13. A gneissoid rock which was originally a quartz conglomerate. Its present form is due to injection and stress.
No. 14. An injected quartzite which was originally a sandstone.
No. 15. A tourmalinized mica schist which was originally an argillaceous sandstone.
No. 16. A fine quartzite containing large feldspar crystals. It was originally an argillaceous sandstone. Igneous injection is evident.
No. 17. A quartzite with two sizes of mosaic quartz. Originally an argillaceous sandstone.
No. 18. A closely folded argillaceous sediment.
No. 19. An argillaceous sediment.
No. 20. An argillaceous sediment.

A visual demonstration may be obtained of the contents of the rocks east of Mendon village if the data in the table are plotted in graphic form. The quartz increases in abundance until a point half way along the exposure is reached. At this point it drops off very sharply and then increases in abundance to the western end of the exposure. At the eastern end of the exposure the minerals produced by igneous action command attention, perhaps at the expense of the other minerals. As the quartz increases the feldspars increase, and in the western end the lime decreases. Quartz and muscovite are obviously the dominant minerals, while the feldspars and biotite are much less abundant and tend to decrease in amount as the quartz and muscovite increase. Chlorite is scarce compared to its abundance in the Taconic Mountains.

Throughout the slides studied, the minerals as listed in the order of abundance indicate quartz 49.9 percent, muscovite 22.2 percent, feldspar 11.1 percent, biotite 3.6 percent, and other minerals 1.3 percent.

In appearance some of the thin sections are so similar to those from the Taconic sequence that there is temptation to state that the Green Mountain and the Taconic Mountain rocks are of the same kind and, in consideration of the general history of the region, the same age. Empirically, this is thought to be true, but proof is not available.

The presence of abundant sericite and some chlorite, and the general appearance of the West Rutland and Castleton rocks indicate that they have undergone less metamorphism than the Green Mountain rocks, which are more abundant in muscovite and biotite.

TYPES OF METAMORPHISM

In order to clarify the meaning of the following text the terms used for the three zones of metamorphism may be explained. The epizone corresponds to the upper two-thirds of the belt of cementation and the catazone is equivalent to the lower two-thirds of the zone of anamorphism. The mesozone refers to the lower third of the belt of cementation and the upper third of the zone of anamorphism. Since the criteria described below were studied with reference to three zones it is found expedient to use the terms epizone, mesozone, and catazone.

By comparing the rocks of the Green Mountain front and the eastern edge of the Taconics with tables furnished by Grubenmann-Niggli,[1] it is seen that the Green Mountain rocks as they now

[1] Grubenmann-Niggli, Die Gesteinsmetamorphose, 1924.

occur were formed principally in the mesozone with possible grading into the epizone and catazone; the Taconic rocks were formed in the same zones. In general, the rocks were all formed principally on the borderline between the epizone and the mesozone. This conclusion is further supported by the nature of the thermal contact metamorphosis which indicates remote injection. The rocks are normally metamorphic. Undoubtedly mineral changes have been effected by exposure to the weathering zone.

The evidence obtained from the thin sections of rocks from the Mendon area indicates that the region has been influenced by magmatic injection although pure igneous rock is seen only at the dam in Mendon.

CATACLASTIC METAMORPHISM

Cataclastic metamorphism throughout the area studied is shown by several effects in the thin sections of the rocks. Strain shadows are shown abundantly in the quartz. The feldspars often exhibit patchy and irregular twinning, with microcline structure occasionally developed in the orthoclase. The micas are often arranged in curved crystals, are often interrupted by cracks, and show lamellar twinning. Irregular birefringence is common. Many crystals are cracked along parallel lines, parts of the same crystal sometimes being separated by other minerals. Some fractures cross several crystals. Evidence is shown that some quartz crystals have been fractured and healed by deposits of quartz which were later broken. Granulation of the borders of crystals is sometimes seen.

RECRYSTALLIZATION

Recrystallization of the schists is demonstrated in several ways. The minerals indicating this phenomenon are chlorite, tourmaline, magnetite, rutile, epidote, mica, hornblende, and sericite. The quartz shows phantom veinlets and a dovetailing of crystals which sometimes approaches sutured structure indicating the zone of metamorphism. Mica is seen to feather out against adjacent crystals, and several quartz crystals may be bounded by biotite. Inclusions in some large crystals of feldspar are largely quartz. Some minerals in unweathered rocks have bleached edges. Chlorite in the granitic gneiss of Great Roaring Brook indicates recrystallization. Many thin sections contain large dense crystals, as well as irregular masses of lime carbonate. Mosaic and porphyroblastic structures are common, while foliated and banded

structures may be seen everywhere. An oriented slide contains minerals at sharp angles to the trend of the groundmass in which the minerals are segregated into bands. Other indications of recrystallization are the deformations of the rocks as seen in the field and the results of the influence of the pegmatite outcrops at Mendon.

METASOMATIC REPLACEMENT

The minerals of the region often exhibit metasomatism or simultaneous solution and deposition through submicroscopic openings. The feldspars demonstrate this phenomenon to a great extent. Diffusion banding is quite common. Faceted crystals intersect original structures and grains or the schistosity of the rock; outside the area studied pyrite is visible in shale and garnet in the schists. The micas in the Great Roaring Brook granitic gneiss contain quartz and other minute minerals. Many veins in the quartz, whose sides do not match, are filled with mica or mosaic quartz which are oriented as in the walls. The minerals of the rocks in thin section show a great variety of size and form; this contrast is quite striking in some slides. Minerals penetrate as blades along the cleavage or fracture plane of other minerals. Thirteen hundred feet west of Mendon bridge clear crystals are shown strikingly in a dusty rock. Inclusions occasionally exhibit dendritic structures. The common minerals of replacement in the rocks of the area are sericite, quartz, carbonate, uralite, and epidote.

CONVERGENCE TO TYPE IN METAMORPHISM

The rocks of the region appear to be arranged into areas according to type of metamorphism, based on the dominant mineral content. In Castleton the rocks are marked by the dominance of chlorite which in some samples is an alteration from biotite. The east side of the north end of Pine Hill is abundant in hornblende. Sericite characterizes the rock of Blueberry Hill north of Rutland; some crystals show altering of biotite to sericite. The rocks of the mountains east of Rutland are composed principally of quartz and muscovite. Due to dynamic stress nearly all of the rocks, with the exception of the quartzites and dolomites, are schists and, in a few instances, gneiss.

CONTACT METAMORPHISM

Contact metamorphism is seen at the Mendon dam where a pegmatite has intruded the sedimentary rock. Since the wall rock is siliceous the acid intrusion has not notably affected it. However, several features in the specimens studied are indicative of this type of metamorphism. With the possible exception of chalcopyrite, magnetite is the only ore mineral and it occurs in great abundance not only in thin section but in crystals exposed on the surface of the rock.

Gangue minerals along the edge of the wall rock are epidote, mica, apatite, quartz, and feldspar. Crystals of quartz are often sutured. The rock has a greenish, flaky appearance due to the chlorite and mica. The quartz and small feldspars along the contact are dusty. Replacement has taken place along cleavage planes and intergranular spaces. Oriented inclusions occur in metacrysts, many of which have diffusion banding.

HYDROTHERMAL ACTION

A few evidences suggest hydrothermal alteration having taken place in the mesozone and catazone, such action probably being on either side of the vague border between the two zones.

Mesothermal alteration is distinguished from epithermal change by the presence of apatite and orthoclase. No minerals eliminate the presence of the catazone in which hydrothermal action occurs. The minerals are often fine grained and fibrous. Alteration which is widespread includes carbonation, sericitization, silicification and, to a small extent, dolomitization. Other suggestive characteristics are the presence of chlorite and fibrous biotite.

High temperature hydrothermal alteration is indicated by several minerals such as tourmaline, amphibole, and garnet outside the area studied. Magnetite alone represents the ore minerals of this zone. Interlocking grains, crude banding, fluid inclusions, irregular fissure walls, schistosity, and low porosity are significant characteristics. Alteration of the wall rock near a pegmatite intrusion is not extensive. The narrow veins carry no commercial deposits.

The balance of evidence does not seem to be in favor of the alteration having taken place principally in either the hypothermal zone or the mesothermal zone. There is no evidence to indicate that alteration has taken place in the epithermal zone.

ORIGIN OF THE METAMORPHIC ROCK

Although the determination of the original nature of some metamorphic rocks would require unusual petrographic skill, the condition of the rocks of the region studied is not difficult to

ascertain and with one or two exceptions may be obvious upon brief examination of the thin sections or the field evidence.

Sedimentary origin is indicated by the gradation of the schist into the quartzite of Pine Hill. Sedimentary structures like bedding, stratification, and conglomerates may be seen in many places. There is abrupt change in structure and composition across the bands of minerals not only in the thin sections but in the megascopic structures in the field. Recrystallization is much more common than augen.

In mineral composition there is a preponderance of quartz and a variety of plagioclase feldspars. Talc schist is dominant in places outside the area studied, as well as slates and phyllites. Rutile and abraided accessories are noticeable.

INTENSITY OF THE METAMORPHISM

Assuming that the original rocks consisted of sandstones, shales, and limestones, it is found that they are altered to quartzites, slates, phyllites, mica schists, and marble. If we postulate a scale of slight, moderate, strong, and extreme metamorphism, the rocks of the area are moderately to strongly metamorphosed.

A considerable change from the original composition of the rock is indicated by the addition of many minerals to the original rock, by the large proportion of recrystallized minerals, and by the surface luster of the rocks. Granulation is not carried to any marked degree, but the deformation of original structures and textures is very noticeable in some thin sections. Practically all of the rocks have a cleavage which is independent of the original structure.

STRUCTURES AND TEXTURES OF THE ROCKS

Observations on the thin sections of the rocks of the area covered in the present study reveal a variety of structures and textures which are severally characteristic of the three zones of metamorphism. The prevailing structures of the three zones may first be described. Cataclastic structure is partially developed in the Great Roaring Brook granitic gneiss (slide No. 3664). Cracked crystals are adjacent to finely ground masses. Porphyroblastic structure is seen in many slides which exhibit large crystals formed in a finer matrix of schist. Metasomatic structure is obvious in specimens from all parts of the area. These structures are found in the epizone and suggest that part of the metamorphism occurred when the rocks were in that zone. Several features

GEOGRAPHICAL MINERAL DISTRIBUTION

Slide number	Locality	Graphite	Pyrrhotite	Hematite	Zircon	Rutile	Quartz	Magnetite	Leucoxene	Ilmenite	Lime carbonate	Dolomite	Apatite	Augite	Hornblende	Titanite	Tourmaline	Garnet	Feldspar	Potash feldspar	Plagioclase	Microcline	Perthite	Oligoclase	Andesine	Zoisite	Epidote	Muscovite	Sericite	Biotite	Chlorite
13	Bridge, Mendon	.	.	.	*	.	*	.	.	.	.	.	*	.	*	.	.	*	.	*	*	*	*	.	.	.	.	*	.	*	.
14	Bridge, Mendon	.	.	.	.	*	*	*	.	.	*	.	.	*	.	.	.	.	.	.	*	*	.	*	.	.	.	*	.	*	.
15	100 yds. west of bridge......	*	.	.	*	.	*	.	.	*	.	.	.	.	.	*	*	.	.	*	.	.	.	.	.	.	.	*	.	*	*
16	1,000 ft. west of bridge......	.	.	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	.	*	*
17	1,300 ft. west of bridge......	.	.	.	.	.	*	.	.	.	*	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	*	*	.	.	.
18	1,300 ft. west of bridge......	.	.	.	.	.	*	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	*	*
19	3,000 ft. west of bridge......	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.	.	.	*	.	*	*
20	3,000 ft. west of bridge......	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	*	.	*	.
21	Mendon dam schist..........	.	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	*	*	.	*	*
23	Pegmatite, Mendon dam.....	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.	.	.	*	.	.	.
24	Upper dam, Mendon.........	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*
24a	Upper dam, granite..........	.	.	.	*	.	*	.	.	.	.	.	*	.	.	.	*	.	.	.	*	*	.	.	.	.	.	*	.	.	.
25	"Notch" road (½), Rutland..	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	*	.	*	.
26	"Notch" road (¾), Rutland..	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.
27	"Notch" road, top, Rutland..	*	.	.	.	.	*	.	.	.	.	.	.	*	.	.	.	.	*	.	*	.	.	.	.	.	.	*	.	.	*
28	Deer's Leap, Mendon........	*	.	.	.	.	*	.	.	.	*	.	*	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	.	.	.
29	Killington Peak	*	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	.	.	.	.	.	*	.	*	*

33	Quartzite above Mendon series	.	.	.	.	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	*	.	.	*
34	Above quartzite of 33	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	.	.	.
3606	Top of Mt. Pico	.	*	*	.	*	*	*	.	.	.	*	.	.	*	.	.	*	.	.	.	.	.	.	*	*	*	.	*	*
3622	McLaughlin Falls (below)	.	.	.	.	*	.	.	.	*	.	.	.	.	.	*	.	*	.	*	.	.	.	.	.	.	*	.	*	.
3640	McLaughlin Falls	.	.	*	.	*	.	.	.	*	.	*	.	.	*	*	.	*	.	*	.	.	.	.	.	.	*	.	.	*
3651	Mendon series, elev. 1,190 ft.	.	*	*	.	*	*	.	.	.	.	*	.	.	.	.	.	*	.	*	.	.	.	.	.	*	*	.	.	.
3657	150 yds. north "Mendon dol."	.	*	*	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.	*
3660	Mendon series	.	*	*	.	*	*	*	.	.	.	*	.	.	.	*	.	*	.	.	.	.	.	.	.	*	*	.	*	.
3661	North Shrewsbury, 1,290 ft.	.	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	*	*	.	*	*
3668	Rutland-Pittsford town line	.	*	*	*	*	*	*	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	*	.	*	*
3671	Blueberry Hill	.	*	.	.	*	*	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	*	*	.
3677	Pine Hill	.	*	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.
3780	Castleton, North Brittain Bk.	.	*	.	.	*	*	.	.	.	.	.	.	.	*	*	.	*	.	.	.	.	.	.	.	.	*	.	*	*
3781	Castleton, North Brittain Bk.	.	*	.	.	*	*	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	.	.	*
3782	Castleton, North Brittain Bk.	.	*	.	.	*	*	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	*	.	*
3783	Rutland-West Rutland town line	.	*	.	.	*	*	*	.	.	.	.	.	*	.	*	.	.	.	.	.	.	.	.	.	*	.	.	*	*
3784	Whipple Hollow	.	*	*	.	*	.	.	.	.	.	.	.	.	*	*	.	*	.	.	.	.	.	.	.	*	*	*	*	*
3785	Rutland-West Rutland town line	.	*	*	.	*	*	*	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	*	*	.	*	*
4010	Mendon series	.	.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	*	.	.	*
4012	Mendon series	.	*	*	.	*	*	.	.	.	.	*	.	.	.	*	.	.	.	.	.	.	*	.	.	.	*	.	*	.
4013	Mendon series	*	.	.	.	*	.	.	.	*	*	.	.	.	.	*	.	*	.	.	.	.	.	*	.	.	*	.	.	.
3664	Great Roaring Bk. granite	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	.	.	*

indicate metamorphism in the mesozone. Porphyroblastic structure is already mentioned. The interlocking grains of the homöoblastic structure are found in the quartz groundmasses. Metasomatic structure has been mentioned. Metamorphism in the catazone is suggested by homöoblastic structure among quartz grains which are principally granoblastic.

Torsion texture is sometimes seen in the injections in the schists. Zigzag texture is quite common. These textures of the epizone may be compared with those of the zone below. The mesozone is represented by crystalline schists of scaly, linear, lenticular, and banded forms. Banded texture which has been folded is also present. Textures characteristic of the catazone are seen in injected bands and ptygmatic folds.

It is evident that the structural and textural features of the rocks indicate metamorphism in three zones. The difficulties of distinguishing the times and areal extent of these events are too great for inclusion in this paper. It can only be suggested that a series of magmatic intrusions altered the rocks at intervals during the time they were approaching surficial exposure. Finally we find that metamorphic rocks of the deeper zones include phenomena of dynamic stress near the surface.

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