REPORT

OF THE

STATE GEOLOGIST

ON THE

GEOLOGY AND MINERAL INDUSTRIES

OF

VERMONT

1945-1946

TWENTY-FIFTH OF THIS SERIES

Centennial Issue

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F.G.S.A.
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STATE OF VERMONT
OFFICE OF THE STATE GEOLOGIST
BURLINGTON

To the Conservation Board,
Department of Natural Resources,
Montpelier, Vermont,

Gentlemen: I present herewith my biennial report, as state geologist, for 1946-1947. Like many other efforts the report is late in publication due to uncontrollable conditions.

The State Geological Survey was begun somewhat over a century ago. It has seemed fitting therefore to write a history of the survey and its accomplishments. In this story one can trace something of the progress of geologic thought, from the credulous acceptance of dogmatic explanations of phenomena to scientific interpretations.

The carefully prepared index which follows the history will enable the student quickly to find references to the subjects which he seeks.

In the following paper Professor James E. Maynard, of Syracuse University, contributes a very important technical study of the granites of Derby, Vermont.

The mineral industries of the state reached new levels of production during the war years, with a total output exceeding $20,000,000. These industries are considered in the fourth paper of this report.

Following the increased appropriations by the 1945 legislature, the geologist planned the beginning of a detailed geologic examination of the state, beginning with the most northerly tier of topographic quadrangles, in order to take advantage of the known Quebec formations which extend into Vermont.

Professor Charles G. Doll, of the University of Vermont department of geology, has finished his work on the Memphremagog quadrangle, and mapped it, but the pressure of his teaching duties has prevented the completion of his paper in time for this report.

During the 1946 field season Professor Doll and Professor Verne H. Booth of Brooklyn College, nearly completed the Jay Peak quadrangle. It is expected that the papers on the Memphremagog and Jay Peak quadrangles will be ready for the 1947-1948 report.

The considerable correspondence, interviews, laboratory and field examinations have been attended to; visits to the mineral companies have been made.

Respectfully submitted,

ELBRIDGE C. JACOBS,
State Geologist.

Fleming Museum,
University of Vermont,
December, 1946.

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1844-1946

Elbridge C. Jacobs

Following the war of 1812 the United States entered upon a period of external peace and increasing prosperity. Her population and wealth were growing, new states were added to the Union, the balance of trade was slowly turning in favor of the young republic, and the national debt was nearly paid. Channing, in his *History of the United States*, states that: "The energy of the American people was absorbed by an amazing internal expansion."

In the North the Champlain-Hudson Canal, completed in 1823, opened up the great valley between the Green and Adirondack mountains to traffic in lumber, iron ore, and other commodities; while the Erie Canal, opened in 1825, provided cheap transportation between the seaboard and the interior of the continent. In the South, the National Road (also called the National Pike) had been projected as early as 1802 and was slowly making its way across the Alleghanies with the Mississippi River, which it never quite reached, as its ultimate objective. Before the coming of the railroads, the Pike afforded the chief means of transportation between the Chesapeake region and the interior plains.

Railroads were built, the screw propeller revolutionized steam propulsion, reaping machines slowly replaced manual labor in the fields, and many other inventions were developed.

Naturally all these activities called for iron and other metals, as well as for non-metallic substances, from the great storehouse of nature. It followed, of course, that the several states should take steps to find out what mineral riches lay within their borders and about the geology which contained them; therefore geological surveys were gradually established.

Geology was gradually, very gradually, outgrowing the grotesque theories that had so long hampered it. Its development was greatly aided by the establishment of scientific societies. The Royal Society of London, dating back to 1662, served the American colonies down to the Revolution. In the new world The Boston Philosophical Society was founded by Increase Mather in 1683; The American Philosophical Society by Benjamin Franklin in 1743; The American Academy of Arts and Sciences in Boston in 1780; The American Mineralogical Society in 1798; The American Journal of Science by Benjamin Silliman in 1802; and many others. In regard to Silliman (1779-1864), Merrill[1] states that "he did more to advance the science of geology than any other man of his day."

[1] Merrill, George P., The First Hundred Years of American Geology: Yale University Press, 1924.

Of the early geologists Parker Cleveland had written his *Treatise* on mineralogy and geology in 1816. Amos Eaton had surveyed Rensselaer County, N. Y., and the route of the Erie Canal; further he had written his *Index* of the geology of the northern states and had traveled many thousand miles on foot through New York and New England delivering short courses of lectures in many towns, to the students of Williams College, and before the New York legislature—lectures which Merrill states resulted in the establishment of the New York geological survey in 1836.

Among other contributions were those of William Maclure: *Observations on the Geology of the United States* (1909); Benjamin De Witt on the *Origin of the Drift;* William Bertram on his *Travels in North America;* Count C. F. Volney's work on the *Geology and Physiography of the United States;* J. F. and S. L. Davis' *Geology and Mineralogy of Boston;* S. L. Mitchell's *Observations on the Geology of North America;* Edward Hitchcock's *Early Geological Papers;* Major S. H. Long's *Expedition to the Rocky Mountains;* Long and Keating's *Survey of the Great Lakes Region;* H. H. Hayden's *Geological Essays;* Ebenezer Emmons' *Manual of Mineralogy and Geology;* and Elisha Mitchell's work in North Carolina.

Louis Agassiz had published his *Études sur les Glaciers* in 1840 and, coming to America in 1846, had continued his studies in the Lake Superior region, and done much to increase interest in glaciology. Geology was evidently on the march.

STATE GEOLOGICAL SURVEYS

North Carolina was the first state in the Union to provide a geological survey, in 1823, and she was followed by South Carolina in 1824. Both of these undertakings were short-lived.

Massachusetts established her survey in 1830; she was the first state to complete a survey. Her state geologist, Edward Hitchcock, published his reports in 1830, 1833, and 1841. This work was followed in New England by the Connecticut survey under J. G. Percival in 1835; the Maine survey, under C. T. Jackson in 1836; the New Hampshire survey, under C. T. Jackson in 1839 and under C. H. Hitchcock in 1868; the Rhode Island survey, also under Jackson, in 1839; and the Vermont survey in 1844.

In contiguous regions New York provided for her survey in 1836 and the Canadian survey, under Sir William E. Logan, was inaugurated in 1842. At present all the states except Delaware and Utah have geological surveys or their equivalents.

THE VERMONT SURVEY

Agitation for a geological survey goes back to October, 1836, when the following resolution was adopted by the legislature: "Resolved that the committee on education be instructed to enquire into the expedience of providing for a general and critical geological and topographical survey of the State and to report by bill or otherwise." Acting on this the senate in the same year

"Resolved that the Governor be requested to procure an estimate of the probable expense of a geological and topographical survey and report to the next Generaly Assembly." In response Governor S. H. Jennison sent to the Assembly in 1837 a message in which the project was fully discussed and an estimate presented of the probable cost: $12,500 for the topographical and $10,800 for the geological survey. The time was evidently not ripe for such an expenditure and the bill for the creation of a survey was laid on the table. Further debate on the bill took place in the 1839 session in which the bearing of a survey on the agricultural and manufacturing interests was stressed, but the financial condition of the treasury was such that postponement of the measure was deemed advisable. In the 1840 session the bill again appeared. It was read twice, tabled, taken from the table and referred to the committee on agriculture—and once more tabled.

Finally a bill (No. 12 of the Acts of 1844) entitled an act to provide for the geological survey of the state was passed by the legislature and became law. For implementing the act the sum of $2,000 annually for the term of three years was appropriated. It provided as follows:

"Sec. 1. The Governor is hereby authorized and directed to appoint a state geologist, who shall have a competent knowledge of scientific and practical geology and mineralogy, and shall be subject to the orders of the Governor for the time being, and removable at his pleasure.

"Sec. 2. The state geologist, with the approbation of the Governor, shall, from time to time, appoint all proper and necessary assistants, fix their compensations, direct them in their labors and remove them and appoint others whenever it shall be found necessary or expedient.

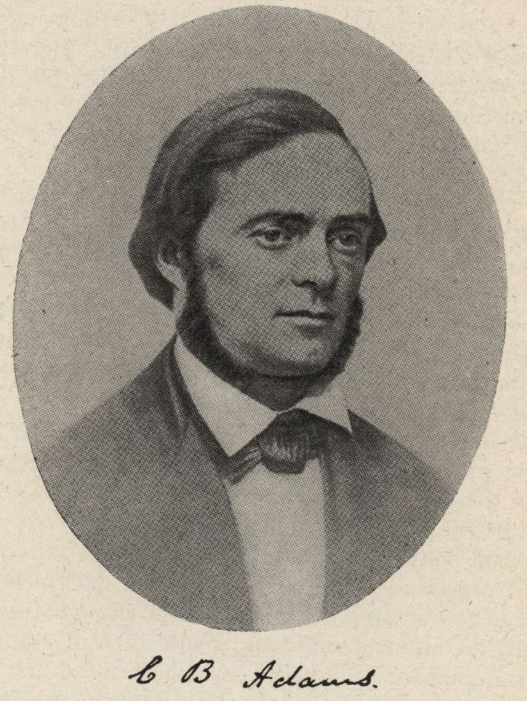
"Sec. 3. It shall be the duty of the state geologist, as soon as practicable, to commence and prosecute a thorough geological and mineralogical survey of the state, embracing therein a full and scientific examination and description of its rocks, soils, metals, and minerals; make careful and complete assays and analyses of the same, and annually, on or before the first day of October, to report to the Governor the progress of the work, the most efficient and economical manner of conducting it, and an estimate of the expense for the ensuing year.

"Sec. 4. For the purpose of carrying into effect the provisions of this act, the sum of two thousand dollars, annually, for the term of three years, is hereby appropriated.

"Sec. 5. All claims under the provisions of this act, shall be presented to the auditor of accounts, for allowance, who shall draw orders on the treasurer of the state for the amount he shall find due, equal to, but not exceeding in any year, the annual appropriation. Approved, October 28, 1844."

Professor Charles Baker Adams was appointed by Governor William Slade as state geologist. He selected as his head assistant Zadock Thompson of Burlington; Denison Olmsted, Jr. and T. Sterry Hunt had charge of mineralogy and chemistry, while Rev. S. R. Hall had the agricultural part of the survey.

It may be noted that the legislative enactment was largely economic in its provisions: the state wanted to know what of value lay hidden in "them thar hills" and was not interested in the other branches of geology—if indeed the solons knew anything about such matters. It seems to have been thought that three years and $6,000 could see the end of the work—and a hundred years later we see no end in sight!



CHARLES BAKER ADAMS

Charles Baker Adams,[1] a scion of a famous Boston family, was born in Dorchester, January 11, 1814. He was educated at Phillips Andover Academy, at Yale University, and at Amherst College where he graduated in the class of 1834. Like so many other geologically-interested men, he studied theology for a while. After this he was a tutor at Amherst under President the Rev. Edward Hitchcock and in 1838 occupied the roomy chair of chemistry and natural science at Middlebury College. During this incumbency he became state geologist of Vermont.

As state geologist Professor Adams produced four reports of a rather fragmentary nature: the first, a pamphlet of 92 pages in 1845; the second,

[1] A very beautiful appreciation of Professor Adams, by Professor Henry M. Seely, of Middlebury College, is to be found in the 4th Rpt. of the Vt. State Geol. (1903-1904).

a much more ambitious work of 267 pages, in 1846; the third, a small pamphlet of 32 pages in 1847; and the fourth, a small pamphlet of eight pages which proved to be his last, for in 1848 the legislature failed to continue the geological appropriation—probably because those legislators who had backed the original bill had given way to members who had no interest in geology.

Professor Adams accepted a professorship at his alma mater in 1847 and turned his scientific interests to zoology, especially the *Mollusca* in which he had long been interested. He died of yellow fever in 1853 in St. Thomas, W. I., while on a collecting trip.

A final report of his Vermont studies was to have been written by him and might have been prepared by others from his accumulated notes had not these notes been written in a "peculiar shorthand which could be read by no one but himself."

Only a few of Adams' reports are extant and in these the third and fourth have been incorporated in the second. The resulting two volumes may be found at the state library in Montpelier and perhaps in some of the New England universities and colleges.

ADAMS' REPORTS

Professor Adams gives the number of minerals in the earth's crust as 434, of which he describes the nine most common. (We now know about a thousand species.) Rocks he divides into stratified and unstratified, the latter including lavas and granite, which are "of igneous origin erupted from beneath the stratified." He describes serpentine as "an aqueous rock altered by fusion." Then he notes that most Vermont rocks are "of that intermediate character which has ever been most perplexing to geologist." These, of course, make up a third class of rocks, the metamorphics about which he has nothing further to say. (Serpentine belongs in this class.) But his assistant, Mr. Hall, in his agricultural work east of the Green Mountains frequently alludes to the metamorphics.

At this time the production of cast iron and some wrought iron was the leading mineral industry in Vermont and there was a considerable number of small stone furnaces in the state. Among them were the Tyson furnace in Plymouth obtaining its ore from nearby beds; the Granger furnace in Pittsford supplied with ore from the Mitchell bed of Chittenden (the remains of this furnace are still standing); the Conant furnace in Brandon fed from local deposits; and the Blake and Hammond furnace in Forestdale, the source of whose ore is not known. This stack is the best preserved of all the furnaces in the state and is well worth a visit.[1]

It may be noted here that the ore bed at Monkton was a large source of iron ore in colonial days.

There were two iron furnaces in East Bennington; their ruins are still standing. The ore was obtained from shallow deposits along the Walloomsac River.

[1] A picture of it is shown in the 24th Rpt. of the State Geol. (1943-1944).

In Troy, Orleans County, titaniferous magnetite had been discovered in the serpentine range east of the Missisquoi River. In 1814, 600 tons of pig and castings was produced by a blast furnace there. Titaniferous magnetite is a difficult ore to smelt, especially with the cold blasts which were used in those ancient furnaces; this was probably the reason for the short life of the enterprise. There are said to have been iron furnaces in St. Johnsbury and at East Middlebury. All told there were in the state in 1810 eight blast furnaces and 25 forges, the output of which amounted to $235,640.

The ore used by most of these furnaces was limonite (brown iron ore, bog ore), hematite and some magnetite, which seem to have occurred in thinly bedded deposits, often associated with manganese minerals.

These ore deposits are briefly described by Adams, while Denison Olmsted made the analyses in Professor Silliman's laboratory at Yale College. After Mr. Olmsted's death, Mr. T. Sterry Hunt (1826-1892), who was much in evidence in the geology and chemistry of the time, became chemist to the survey.

The copper pyrite (chalcopyrite) deposits of South Strafford and Corinth are rather briefly mentioned—the copper pyrite is stated to be "dispersed" in iron pyrite instead of in pyrrhotite. No mention is made of the most famous of the copper deposits, those at Vershire, where the Ely mine was in operation as early as 1821. On the other hand the Strafford deposit is stated by Adams to "have no equal in the world"—a very hazardous statement to make.

It may be added that the pyrrhotite (not the pyrite) of South Strafford came from an open cut and was mined as early as 1793 for the manufacture of copperas, which is a hydrous ferrous sulphate containing no copper, as the word would imply. This was shipped by team to Boston and Whitehall to be used as a disinfectant. The importance of copper in the deposit and the development of a copper mine came in 1830 but Adams makes no mention of them.

Various small deposits of lead and zinc are recorded; they have never had any commercial significance.

Among non-metallic minerals the kaolin deposits of East Bennington are very briefly treated. Fire bricks were made from this clay by first firing it and pulverizing the resulting sinter, and then mixing this with fresh clay and firing the mixture. No real fireclay, as far as is known, occurs in the state. Practically no mention is made of the Bennington pottery works, conducted by Norton and Fenton, works which endured for a hundred years from about 1793.

Serpentine deposits are noted in Coventry, Lowell, Westfield, Troy and Jay but no mention is made of the verd antique of Roxbury although this ornamental stone was famous from Egyptian times; this variety of serpentine is found in many places in Vermont.

In Kelleyvale, "a word which was changed to the less poetic name of Lowell," the serpentine was found to be covered with a coating of delicate

amianthus (the finely fibrous form of asbestos). This was probably the first indication of asbestos, deposits of which, discovered on Mt. Belvidere in about 1900, were to give Vermont first place in the United States in the production of this strategic mineral.

"Soapstone" deposits are noted in many places, north to south, in the Green Mountain area, throughout the state. These are for the most part talc, a mineral which seems to be unknown to Adams, although almost all greasy-feeling rocks were called talcose-slates or talcose-schists. There were at that time several deposits of soapstone (steatite) in Perkinsville and Grafton but they are now practically exhausted.

Very brief mention is made of the roofing slates of Fair Haven but nothing is said of the other slate deposits; perhaps they were unknown at that time.

Limestone deposits and marl and muck beds are described and analyzed but the great occurrences of limestone in the Champlain Valley were yet to be discovered.

For building stones, marble is defined as "any limestone that will take a good polish" (really it is metamorphosed limestone). Marble deposits are described in considerable detail from Rutland, Pittsford, Brandon, Plymouth, Sudbury, Middlebury, and Isle La Motte. The Rutland, Brandon, and Isle La Motte stones were chemically analyzed by Olmsted.

Scant attention is paid to granite which "forms a line of eruptions extending from Lake Memphremagog to Dummerston" and which Adams "is convinced has great value as a building stone." He notes that Essex County is practically all granite and gneiss. Gneiss he defines as "a stratified rock composed of quartz, feldspar, and mica." (Of course it is a metamorphic.)

Hall's work on agricultural geology of the region east of the Green Mountains includes a collection of 60 soils, properly apportioned over the area covered, as well as descriptions of the character of the subsoils and underlying rocks, the marl and muck beds, crops produced, and the general topography and geography. The soils of 84 townships are examined and chemically analyzed and suggestions given for increasing their productivity. He is much interested in the high fertilizer value of animal urine and deplores the fact that it is allowed to go to waste. This section of the reports is very well done and must have been of much value to the farmers—if they read it!

In his second report Adams finds it expedient to instruct his readers in the elements of geology—"not the scientist but primarily those at whose expense the survey is conducted." Accordingly he devotes 82 pages to the subject, going extensively into the matter of volcanoes, with vivid descriptions of Etna, Vesuvius, the Hawaiian Islands and even Tomboro and its most destructive recorded eruptions of 1815. Earthquakes are to him (and to his times) closely associated with volcanoes. He notes the great temblor at Lisbon in 1755, the West Indian 'quakes, and those on the coast of Chile. He seems to accept the ancient conception of volcanic "fires" and of an earth whose interior is in a state of fusion, within a crust 35 or 40 miles thick (which is about right). The heavings of this molten interior, occasioned by steam or chemical action, produce earthquakes while volcanoes act as safety valves. Another of his theories has it "that there are within the earth immense reservoirs of lava, and subterranean channels, whose action is the source of eruptions and earthquakes—which in a way suggests Idding's petrographical provinces.

All this is interesting, though smacking more of the middle ages than 1846, and is largely erroneous; it is hardly germane to Vermont geology.

In his first report Adams has a woodcut of an ideal section of the crust of the earth, a cut which Merrill in his "One Hundred Years" reproduces as an illustration of the "rough method of picture making with which the early workers had to content themselves." The section shows a mountainous region of "primary" and paleozoic rocks much disturbed and broken, and intruded by great batholiths of granite and dikes of porphyry. The sea is near at hand and fissures are shown by which its waters gain admission to the lava below causing a coastal volcano. The remarkable feature is that the whole crust is underlain by *lava*. The obvious question as to why the crust would not have foundered in the lava apparently did not occur to the maker of the diagram.

There follows a discussion of other geological agencies, a short treatise on the animal kingdom including man, all of whose remains are found subsequent to the "drift" (glacial accumulations), "in accordance with the sacred scriptures which assumes a period of about 6000 years for the past existence of man and the animals associated with him." He also considers the introduction of species, their duration and extinction in the light of the then existing theories. (Darwin's works did not appear till the 1850's.)

In his observations on what we now call stratigraphy (which means the description, order, and relative position of stratified rocks), Adams notes that: "The convulsions of ancient times, which many geologists believe to have been far more violent than those which have occurred during periods of human history, have more or less tilted up the layers of the stratified rocks, so that few of them now lie in their original positions. They are more or less inclined and are often nearly or quite perpendicular." The believers in convulsions of nature were numerous and their doctrine held for centuries; they came to be known as catastrophists. Their opponents, beginning with Sir Charles Lyell (1797-1875), maintained that there was no reason to suppose that "the degree of activity of geological agents has ever seriously differed from what it has been within human experience"; these were called uniformatarians and they ultimately prevailed. Adams spent much time in the explorations of the geological boundaries of many formations in the state and must have encountered many inclined strata but seems to be careful not to commit himself to the "convulsion" theory. His stratigraphy was to have been shown on a colored geological map of the state but it probably never appeared.

HISTORY OF THE EARTH

Under this ambitious title Professor Adams briefly sketches the different "systems" in the geological history of the earth. He presents the New York

system which Ebenezer Emmons introduced into the New York survey about 1840; it is shown in the following diagram.

TABULAR VIEW

Order	*Group*	*Divisions*	*Formations*	*Found in*
Older Paleozoic	New York System: Upper Silurian	Erie Division	Chemung Group Portage Group Genesee Slate Tully Limestone Hamilton Group Marcellus Slate	Western States New York Great Britain
	New York System	Helderberg Series	Corniferous Limestone Onondaga Limestone Schoharie Grit Cauda Galli Grit Oriskany Sandstone Upper Pentamerous Limestone Encrinal Limestone Delthyris Shaly Limestone Pentamerous Limestone Water Lime Group Onondaga Salt Group	
	New York System	Ontario Division	Niagara Group Clinton Group Medina Sandstone Oneida Conglomerate	
	Lower Silurian (Ordovician)	Champlain Division	Red Sandrock* Hudson River Group Utica Slate Trenton Limestone Isle La Motte Marble Birdseye Limestone Calciferous Sandrock Potsdam Sandstone	Vermont New York
Pre-Cambrian				

* Really belongs here.

In modern usage we should substitute Geologic Time Table for "Tabular View," era for "Order," and period for "Group."

The "Lower Silurian" was renamed the Ordovician by Lapworth in 1879; the "Upper Silurian," or Silurian proper, was later divided into lower, middle, and upper members. The "Champlain Division" is of immediate importance to Vermont geologists. In it the Red Sandrock (Adams' coinage) is seen at the top and remained there for many years, to the confusion of geologists. The Potsdam sandstone is seen at the bottom of the Lower Silurian (Ordovician). It was found resting upon the crystallines (Pre-Cambrian) in Essex County, N. Y., and was supposed for many years to be the lowest of all fossiliferous rocks. Ebenezer Emmons was quite right in showing that there were fossiliferous rocks older than the Potsdam, but wholly wrong in claiming an independent Taconic System. (See below.)

When Sedgwick's Cambrian System (1835) was introduced into American geology and divided into lower, middle, and upper members it was found that the Red sandrock (now divided into Monkton quartzite, the Winooski dolomite, and the Mallett dolomite) lay at the base of the Lower Cambrian, and the Potsdam sandstone at the base of the Upper Cambrian.

Adams shows a section of Snake Mountain, Weybridge, in which the Red sandrock lies apparently conformably on the Hudson River shales; and so he places it at the top of the Champlain Division. But it really lies upon the shales through thrust faulting, a phenomenon unknown at that time. Professor Adams appreciates that the Champlain rocks have been disturbed and "appear for the most part to have been uplifted on one side of a fracture"; but it remained for Sir William Logan to show that Adams' disturbance was due to the Great Fault, which we know as the Champlain thrust. This extends along the St. Lawrence River from Gaspé to Quebec and then, turning southward, runs along or near the Vermont shore of Lake Champlain, crossing the upper part of Snake Mountain—a great thrust block in which the Lower Cambrian red sandrock has been carried over the "Lower Silurian" (Ordovician) shales.

Edward Hitchcock was to make the same mistake in his Georgia section (see p. 28).

Adams briefly discusses the Taconic System, proposed by Emmons in 1842, a system which gave rise to the Taconic question and which raged for half a century. He remarks that some geologists regard it as only a part of the New York System, while others believe it to be a distinct and older system. Adams' own opinion is reserved for his final report—which never appeared.

Professor Adams gives some attention to the Primary Strata (not shown in the "Tabular View") which lie below the oldest fossiliferous rocks. They are gneiss, "mica slate" (probably mica-schist), and limestones which have been intensely heated (metamorphosed) and much disturbed from their original position. The history of these rocks in "enveloped in obscurity and all sources of knowledge fail the geologists whose lot is cast in such a region; such is most of Vermont."

Sir William Logan's work on the Pre-Cambrian of Canada did not appear till 1863.

THE DRIFT PERIOD (OUR PLEISTOCENE)

That the drift or glacial deposits loomed large in the minds of geologists of that time is shown by the attention that Adams gives it. He knows that this drift covers North America to about the fortieth parallel of latitude and that drift deposits are found in northern Europe as well as in the Falkland Islands and in Patagonia. Then he adds curiously enough, that "it appears to be wanting within the tropics"—as though he thinks that it *might* occur there.

He gives the material of the drift as sand, gravel, hardpan, pebbles and boulders. He knows that enormous boulders (erratics we call them), sometimes weighing many tons, have been carried up steep "acclivities" and always towards the south. Scratches (striae in modern parlance), and furrows, some a foot wide and two inches deep, are found on mountain tops, Jay Peak among them—on this mountain he found scratches within eight inches of the summit, trending N. 40° E. Rock surfaces are rounded and polished. The direction of the drift movement is generally from northwest to southeast. In Vermont the greatest accumulation of the drift is in the narrow mountain valleys and over the lower parts of the Green Mountains.

To account for the drift he presents various theories current at that time: The Iceberg Theory which called for the submergence of the mountain tops beneath a *universal ocean,* "not long before the drift agency" and the rafting southward of the drift material by icebergs—but just where in a universal ocean the bergs picked up their loads of drift is not suggested—the scouring and striating of rock surfaces by rock-shod icebergs, and the final dropping of the drift material when the bergs melted. But why these bergs drifted so constantly in one direction that the resulting striae were often, but not always, parallel is not considered. He notes almost immediately that the climate was colder at that time (although in another place he finds no evidence of it) and that glaciers must have descended from the mountains of New England, although there was general submergence.

The Glacio-aqueous theory was based on a cold climate at the beginning of the drift period, "whereby," quoting "Hk," (?) all organic life was destroyed and in high latitudes at least, glaciers were formed on mountains of moderate height; indeed that vast sheets of ice were spread over almost the entire surface extending south as far as the phenomena of the drift have been observed. The northern regions, especially around the poles, were supposed to have formed one vast *mer de glace* which sent out its enormous glaciers in a southerly direction by the force of expansion. The advance and retreat of these glaciers accumulated the moraines and produced the striated and embossed appearance on the rocks. When the temperature was raised, the melting of the immense sheets of ice produced vast currents of water which would lift up and bear along huge icebergs loaded with detritus, and thus scatter boulders over wide areas. Whoever "Hk" was, he was getting on towards a tenable theory. Adams objects to this theory because "such a refrigeration of climate is without any known parallel in the history of the earth" and would call for a "great derangement of the solar system"; and further, that "glacial action is peculiar to the highly inclined valleys of very lofty mountains," and so on. It is evident that Adams at that time had no clear idea of continental glaciation. Another and most fantastic hypothesis had it that, "in the great centers from which the drift emanated there were violent earthquakes, oft repeated through a succession of ages, whose shocks threw down over the northern portions of the globe enormous earthquake waves, and water-waves of translation, bearing along the immense icebergs of the polar regions with great violence, and strewing the pre-existing loose materials of the surface far to the south of their former position, and that immense masses of such materials were moved along in the same manner as glaciers, producing similar results." Adams is not wholly hostile to this theory.

A fourth theory of that time was that polar currents flowed southward over a *submerged* North America, while other currents moved northward from the tropics; they met in Lake Champlain!

One more wild idea may be given: As the waters of the universal ocean receded from the North American continent, great lakes were impounded by mountain ranges and other high lands. The dams ultimately burst, permitting vast floods to rush across the land, carrying with them the materials of the drift, which were deposited as the currents slackened.

The idea of a universal ocean harks back to the Noachian deluge of the book of Genesis in which we read that: "The waters prevailed exceedingly and all the high hills that were under the whole heaven were covered." Back in the 18th century Bishop Clayton declared that the deluge "could not be literally true save in respect to that part where Noah lived before the flood." We know that a universal deluge would be physically impossible, since the volume of water on the earth is practically constant and, if part of the water were evaporated to furnish the rain for "40 days and 40 nights," the level of the oceans would be correspondingly lowered—it would be akin to trying to fill a bucket of water with water drawn from that bucket.

No doubt there was an inundation in the Tigris-Euphrates valley; Chaldean and Assyrian legends follow quite closely the Mosaic account. Adams was probably the first American geologist to state what others had no doubt thought, that "Geology gives us no evidence of a universal deluge since the beginning of the historic period, nor any other deluge which was universal, and throws great doubt on any such theory." And he wisely adds: "The design of the Bible is not to teach science but the religious truth that there is one God, the Creator of all things."

In his third report, 1848, Adams writes that "he hastened to fulfill an appointment with Professor Agassiz and M. Desor in Burlington and vicinity" (Agassiz had come to America in 1846 and had accepted the chair of zoology and geology at Harvard University the following year). In studying the stoss (windward) and lee sides of hills, they agreed that a mass of drift material, impelled by waves of translation, could not account for the observed phenomena, but that a solid agency would be needed; that is, a glacial sheet. This may well have been the beginning of Adams' conversion to Agassiz's glacial theory; at any rate Merrill[1] states that at the New Haven meeting of the American Association for the Advancement of Science, in August, 1850, Adams suggested an ice sheet 5000 feet thick, in a "great elevation of the land in the northern regions," as the cause of the drift phenomena.

Agassiz's glacial theory, 1840, based on observations in the Alps and the Juras, conceived that, "at a period geologically very recent the entire eastern hemisphere north of the thirty-fifth and thirty-sixth parallels was covered by a sheet of ice possessing all the characteristics of existing glaciers in the Swiss Alps. Through this agency he would account for the loose beds of sand and gravel, the bowlder clays, erratics, and all the various phenomena within the region described, which had heretofore been variously ascribed to the Noachian deluge, the bursting of dams, the sudden melting of the polar ice cap, or even to cometary collisions with the earth."[2]

[1] *Op. cit.*, p. 631.

From his studies in North America Agassiz found that his theory held there. We now know that the Pleistocene ice sheet covered over 1,000,000 square miles of this continent and Greenland, northward from latitude about 40 degrees, extending practically from coast to coast, and that it was, at maximum, of the order of 10,000 feet in thickness.[3]

STRATIGRAPHY

Following the drift or Pleistocene epoch, Professor Adams very briefly discusses the remaining "systems" and "formations" as they occur in the United States and Europe. This discussion includes some account of the occurring fossils, especially those of the reptiles of the Mesozoic among which he includes the famous dinosaur footprints of the Connecticut Valley, footprints which were popularly called turkey tracks.

The New York System embraced all the fossiliferous rocks extending from the Primary to and including the old red sandstone of the Devonian. The system included the British Cambrian of Sedgwick, the Lower Silurian of Murchison (which Lapworth later renamed the Ordovician, 1871), the Upper Silurian of Murchison, and the Devonian of Phillips. The Champlain Division included the following formations which occur wholly or partly in Vermont: the Potsdam sandstone (now known to be Upper Cambrian), the Calciferous sandrock (now the Beekmantown), Isle La Motte marble (Ordovician; name no longer used), Trenton limestone (Ordovician), and the Red sandrock (now the Monkton quartzite).

"GEOLOGY OF VERMONT"

Under this caption Adams devotes some twenty pages to the drift, which has already been discussed. "Younger than the drift" is described an Older Pleistocene and a Younger Pleistocene, both of which are now included under the recent Epoch. The Older Pleistocene includes (1) blue clays and (2) brown clays, fine sand, loose gravel. The blue clays, which contain "no evidence of marine origin" are really the glacial clays of the drift period; they are "insulated beds" scattered over the state, often overlain by beds of muck or marl, or both. They are now used in brick making. The "brown clays, fine sand, and loose gravel" are divided into marine and fresh water deposits. The marine clays are limited to the Champlain Valley and "to an elevation not exceeding 300 feet above the lake level." These include our Pleistocene fossils: *Mya, Leda, Saxicava,* and other genera.

The Newer Pleistocene contains "the remains of mastodons and other *mammalia*." In Adams' time they had not been found in this state, but the

[2] Merrill, *Op. cit.*, 211.
[3] For further information see text books on geology, or the 23d Rpt. of the Vt. State Geol., p. 27 (1941-1942).

task of a mastodon was later discovered in Richmond, another in Brattleboro (in 1865), a tooth of *Elephas americanum* was unearthed in Mt. Holly, the antlers of a deer, in Grand Isle, and most impressive of all, the skeleton of a small whale (*Delphinapterus vermontanus*[1]) was discovered in Vergennes in 1849.

In his discussion of the Champlain Division in Vermont, Professor Adams notes very sketchily that: "These rocks occupy a portion of the valley of Lake Champlain adjacent to the lake, usually extending from two to eight miles to the east. In Addison County they are exhibited as low, successive uplifts with a moderate northerly dip. Elsewhere they appear in uplifts, and rarely in plications which trend a few degrees east of north." For his work at Snake Mountain, see page 10.

Adams made numerous investigations in the Green Mountains, believed that Taconic rocks existed in Plymouth, east of the mountains, noted that "an interrupted band of granite extends from Lake Memphremagog southward through the State and that this granite is probably the great source of the igneous agency to which the metamorphic character of the azoic rocks is due." This is a decided advance from his earlier statement that azoic rocks are "enveloped in obscurity." He speaks of the "theory of plications" in the Green Mountains but leaves us in the dark in regard to this theory.

The remainder of the report is taken up with an extended discussion of concretions which Merrill calls "abstruse," and with letters from President Hitchcock, Zadock Thompson, and "Mr. Benjamin Silliman, Jr., professor of chemistry in Yale College" in regard to chemical analyses.

The reports are written somewhat in the formal style of the time in which "courteous gentlemen" remain "Your obedient servant," and so on.

It is to be stressed that Adams' reports were only preliminary to a final report for which he had accumulated a vast amount of material. He estimated that this concluding work would require three years time and $3,750 to prepare. Without this final report he believed that his work would be a failure.

But Professor Adams' work was far from being a failure. He and his associates brought to light a great deal of important geology in which the observations were accurate and the conclusions were generally well grounded. He boldly stated his position on theological dogma and took no stock in a universal ocean and drift-carrying icebergs—in this he was a man in his generation.

His theory of a ice sheet 5000 feet thick and an elevation of the polar region during the Pleistocene were probably his most significant contributions.

It is regrettable that he spent so much time on his treatise on geology and had so little left for the real objectives of the survey—and that he left illegible notebooks.

In 1848 a special committee of the legislature having reported that "it does not recommend the completion of the survey," the legislature repealed the act establishing it, evidently believing that Professor Adams had had quite time enough to finish the job.

[1] 6th Rpt. of Vt. State Geol. (1907-1908). These fossils are to be found in the state cabinet at Montpelier or in the University of Vermont geological museum.

In 1849 the legislature directed that the specimens collected by Adams, together with his reports, be brought together by a "suitable person to be appointed by the governor" and deposited in the state house under the care of the state librarian. Zadock Thompson, who had been Adams' assistant and whose voluminous writings on the natural history of the state had made him the obvious choice, was appointed.

This was the beginning of the state cabinet. Unfortunately the exhibits were destroyed in the state house fire of January 6, 1857. A second cabinet began to take form during Edward Hitchcock's tenure as state geologist (1856-1864).

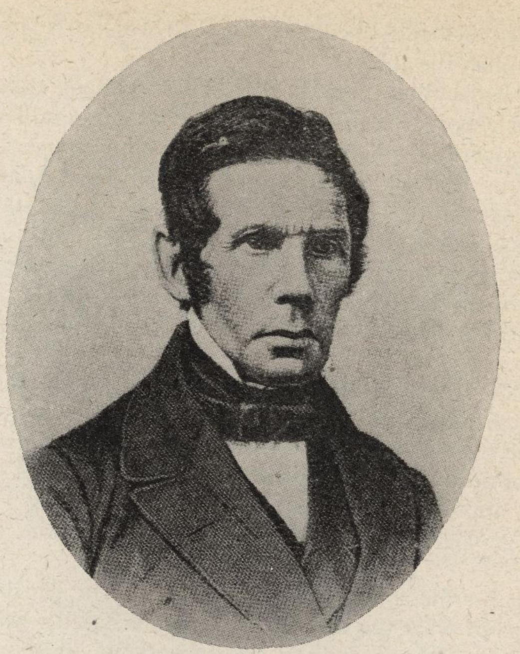
The matter of reestablishing the survey dragged on through succeeding sessions of the legislature until October, 1853, when the "persistent discussions of friends of the survey at last bore fruit" and a bill providing for its *completion*, and appropriating $1,000 a year for the work, was enacted. Zadock Thompson was appointed state naturalist, thus becoming in fact the second Vermont state geologist. Thompson continued his duties as curator of the cabinet.

In providing for the *completion* of the survey, the legislature showed that it had scant ideas of what the task involved; we are still working at it and, the legislature providing the necessary appropriations, must continue so to do for many years to come.

ZADOCK THOMPSON

Zadock Thompson, the son of Barnabas Thompson who was one of the first settlers of Windsor County, was born in Bridgewater, Vermont, May 23, 1796. Little is known of his early schooling but he granduated from the University of Vermont in 1823 and during the next year published his *Gazetteer of Vermont,* a work of 200 octavo pages.

Like so many of the early geologists he had a decided theological bent and was ordained a deacon in the Episcopal Church in 1836 but, on account of a heart ailment which followed him through life, he never held a parish although he did considerable preaching in Burlington, where he passed the most of his life, and in the neighboring towns. But Thompson was essentially a writer of books and he produced lots of them: *Gentleman's Almanac,* in 1820; *A Farmer's Almanac,* 1827; *The Green Mountain Repository,* 1828; *The Youth's Assistant in Theoretical and Practical Arithmetic,* also in 1828; *History of the State of Vermont,* from its earliest settlement to the close of the year 1832; *Geography and History of Lower Canada,* 1835; *Geography and Geology of Vermont,* 1848; and many others. But his enduring work was *Thompson's Vermont, Natural, Civil and Statistical,* an octavo volume of some 650 pages published with the financial aid of his old friend and neighbor, Mr. Chauncy Goodrich who was a publisher and printer in Burlington. The legislature of the state ordered one hundred copies for the use of the state library and voted



Zadock Thompson

$500 to the author in token of the popular appreciation of what he had done. This book is a comprehensive work and is still found in many Vermont homes and libraries where its wealth of information on a myriad of subjects delights young and old alike.

During his tenure as assistant to Professor Adams, Thompson and his associate explored one hundred and ten of the townships of the state. His field specimens and notes, as well as those of his chief, were added to the state cabinet.

Mr. Thompson was elected professor of natural history at the University of Vermont in 1851.

Thompson had long been a student of Vermont geology; in the section on geology and mineralogy of his "Vermont," he really gives us a better summary of the physical features of the state than we get from Adams' reports. He gives a section from Lake Champlain eastward to about the crest of the Green Mountains; in this section he finds the following systems of rocks: "1. Old Red sandstone, in an interrupted range. 2. Graywacke. 3. Transition of metalliferous limestone, alternating to transition argillite. 4. Transition or calciferous sandstone. 5. Transition argillite. 6. Primitive argillite. 7. Sparry limestone. 8. Granular limestone. 9. Granular quartz. 10. Hornblende rock. 11. Gneiss with alternating layers of granite. 12. Mica-schist, constituting the middle ridge of the Green Mountains and extending down the eastern side." He further notes that "most of these ranges of rocks extend the whole length of the State" and that, "on the east side of the mountains the geological features are not so well defined nor so well known."

It may be explained that the "Old Red sandstone in an interrupted range" is not the famous "Old Red" of the Scottish Devonian but our Red sandrock which is definitely of Lower Cambrian age. Furthermore, the "graywacke" was probably our Georgia slate; the "granular limestone," marble; "granular quartz," the Cheshire quartzite; the "alternating layers of granite" are sills; "metalliferous limestone" is—what?

In his appendix Thompson tells us of the fossil whale which was discovered in Charlotte in 1849 while excavations were being made for the Rutland and Burlington Railroad. Thompson collected and studied the scattered bones and, with the aid of Cuvier's "Osse Foss," decided that the fossil resembled *Beluga (Delphinapterus) leucas,* or northern white whale. Professor Thompson took the bones, which represented about four-fifths of the whole skeleton, to Professor Agassiz at Harvard College who confirmed Thompson's tentative conclusion.

For many years this famous fossil (which is some 14 feet long) has been on exhibition in the state cabinet at Montpelier. The titles of the numerous articles which have been written about it appear in the index to this article.

Professor George H. Perkins, in his sketch of Thompson's life, writes: "Into the execution of his work as state naturalist Thompson entered with enthusiasm, as it afforded him the opportunity he had long eagerly desired: to complete his study of the natural history of the state. He had been preparing himself from childhood for just this task and his whole soul went into it. He at once planned an extensive work and wrote out the title pages of the three volumes of which it was to consist. Each volume was to be entitled *Natural History of Vermont;* the first was to be given to geology, the second to botany, the third to zoology." "The work never went far beyond the plan indicated, for the shadow of death, which for years had hovered over his life, at last fell and, in 1856, he died at his home in Burlington."

And so Professor Thompson never published a state geologist's report.

AUGUSTUS YOUNG

Soon after Thompson's death Governor Ryland Fletcher appointed Judge Augustus Young to the office. Judge Young prepared a preliminary report of 88 pages but, as far as the writer can learn, it was never published. He died within the year of his appointment.

Under these sinister conditions President Edward Hitchcock (then 63 years old), of Amherst College, was invited to take charge of the survey; he thus became the fourth Vermont state geologist, serving from 1856 to his death in 1864.

Edward Hitchcock

EDWARD HITCHCOCK

Edward Hitchcock, who was of English ancestry, was born in Deerfield, Mass., May 5, 1793.

Nothing seems to be known of his early education. He had intended to enter Harvard College but poor eyesight and illness prevented. Through his friendship with Amos Eaton he became interested in botany and mineralogy and later studied chemistry under Benjamin Silliman of Yale College. Of strong religious leanings he entered the New Hampshire Theological Seminary, graduated there in 1820, was ordained in 1821, and became pastor of the Congregational Church in Conway, Mass. On account of poor health he gave up his pastorate and accepted a professorship of chemistry and natural history in Amherst College. Twenty years later he became president of Amherst and professor of natural history and geology but after ten years he resigned as president in order to devote himself wholly to these subjects.

In 1830, through his efforts, the Massachusetts Geological Survey was established and he was appointed its head. This was the first American geological survey to be carried to completion. After three years' work Hitchcock published his report on the geology, mineralogy, botany, and zoology of Massachusetts. For this work he states that he traveled 4,550 miles and collected at least 5,000 specimens.

When the geological survey of New York was established in 1836, Hitchcock was appointed geologist of the first district which comprised the southeastern section of that state, but he soon resigned in order to revise his Geology of Massachusetts which was completed in 1841.

Professor Hitchcock, in 1840, was appointed chairman of the Association of American Geologists and Naturalists which, in 1847, became the American Association for the Advancement of Science. In 1856, still continuing his connection with Amherst College, he accepted Governor Ryland Fletcher's invitation and became state geologist of Vermont.

Merrill[1] says of him: "As a prolific writer Hitchcock was without an equal. He wrote five volumes and thirty-seven pamphlets and tracts on religious subjects, including the religion of geology and its connected sciences (1851); three volumes and as many tracts on temperance; fourteen volumes, five tracts, and some seventy-five papers on botanical, mineralogical, geological, and physical subjects, and twenty-seven others. His *Elementary Geology*, published in 1840, ran through thirty editions and then was rewritten."

Another biographer describes him as: "A man of religion, a man of science; in both a docile student and an expert teacher . . . . in both shackled by traditions which he feared and hated to break, yet rigorously holding up his shackles and keeping abreast, and in some instances, ahead of the advancing age," and so on.

That he was a "catastrophist" is shown by his statement that: "Geology (1) furnishes evidence of direct and repeated acts of creative power, (2) proof both of a general superintending providence of God over our globe and also of special interference from time to time with the usual order of things upon its surface, but catastrophies are never permitted to pass certain limits, and (3) furnishes numerous illustration of Divine benevolence: soil from the rocks, disruption of strata to uncover coal beds, existence of valleys from this disruption, modified however by erosion, ore deposits, and volcanoes which He employs as Penal inflictions"(!) Furthermore, "Geology and revelation agree in representing the surface of our globe as swept over by a general deluge, at a period not very remote." But later[2] he sees "No geological evidence of a deluge contemporaneous with the Mosaic deluge but geologists do not deny the account of this deluge." All of this shows his religious bias, a bias which runs through his *Geology of Vermont*.

Vermont geology was no new territory for Professor Hitchcock; his letters to C. B. Adams in 1845 and 1846 show that he was well acquainted with many of the mineral deposits of the state while, in structural geology, he had raised the "sublime question whether the almost entire ranges of the Green and Appalachian mountains have been folded together like the crumpling of paper and then thrown over."

He was also impressed with the deep interest manifested by Vermont citizens in geology, "which certainly indicates a high degree of intelligence and

[1] *Op. cit.*, p. 152.
[2] Geology of Massachusetts, p. 141 (1883).

just appreciation of scientific pursuits." And he is "bold to say that a parallel example cannot be found in any state in the Union"—the professor evidently knew something of the art of the diplomat.

REPORT ON THE GEOLOGY OF VERMONT

DESCRIPTIVE, THEORETICAL, ECONOMICAL

1861

This report, in two quarto volumes, comprising 988 pages, one colored geological map of the state and several others showing terraces and beaches, illustrated by many plates and woodcuts of scenic features, was the most comprehensive geological work on Vermont ever written—and probably ever will be written. In this undertaking Professor Hitchcock was assisted by his son, Edward Hitchcock, Jr., who wrote the section on Vermont minerals; another son, Charles H. Hitchcock (for many years professor of geology in Dartmouth College and the author of the *Geology of New Hampshire*) who was the chemist of the survey; and Albert D. Hager who was responsible for the economic geology, physical geography and scenic features. The paleontological work was done by James Hall of the New York survey, and the paleobotanical by Leo Lesquereux, a Swiss who came to America in 1848. Hitchcock and his associates embarked upon an ambitious programme which included the following objectives:

1. "To gain such a knowledge of the solid rocks of the State as to be able to delineate them upon maps and sections, according to the (then) established systems of geological science."
2. "To study the loose deposits lying upon the solid rocks, and trace out the astonishing changes which the surface of the State has undergone."
3. "To collect, arrange and name specimens of rocks, minerals and fossils from every part of the State for the state cabinet." (It will be remembered that Adams' collections had been destroyed or rendered worthless by the state house fire in 1857.)
4. "To obtain a full collection for the same Cabinet of specimens valuable in an economical point of view."
5. "To identify the metamorphosed rocks of the State with those that have not been changed. This last point has been the most difficult of all." He adds that: "To carry out such a plan over an area of more than 10,000 square miles everyone must see to be a gigantic work for less than three years; and we fear that it will be thought only imperfectly performed"—in the year of grace 1946 we are still working on it!

MINERALS

Whereas Adams in his first report (1845) states that "there are in the crust of the earth 434 simple minerals, of which he lists only quartz, feldspar, limestone (calcite?), hornblende, mica, talc, chlorite, serpentine, and gypsum, Edward Hitchcock, Jr., enumerates about 60 mineral species, which are represented in the state cabinet, although varieties of these minerals swell the list to 370. Localities are given and the minerals are also listed by townships. This is the fullest mineral list that we have in the reports and it is still valuable although it needs revision.

In another part of the report Hitchcock states that the principal authorities used are Dana's System of Mineralogy and Shepard's Treatise on Mineralogy, which he cites as the most complete works on American minerals extant.

He also gives the names then in use for the six systems of crystallography as follows: Monometric, which we now call Isometric; Dimetric, which we know as Tetragonal; Trimetric, or Orthorhombic; Monoclinic, Triclinic, and Hexagonal.

ROCKS

Professor Hitchcock states that the rocks of Vermont are the most difficult with which he ever attempted to grapple. In this statement he probably had in mind the metamorphics in which, until the period of extensive chemical analyses (C. H. Hitchcock's analyses were almost wholly confined to sedimentary rocks and ores), and the petrographic study of thin sections (about 1870), but little progress could be made.

He believes that "the interior of the earth is now in a molten state, and that at an early date it was entirely melted." "This interior is sourrounded by a crustal envelope which cannot be more than a hundred miles thick." Modern seismology points to a crustal thickness of about thirty-six miles and is uncertain as to whether the earth's core is a solid, a liquid, or a gas.

Hitchcock divides the rocks of the earth's crust into unstratified (the igneous rocks) and stratified rocks; the latter, into fossiliferous and unfossiliferous rocks—we should call them igneous and sedimentary rocks; the sedimentaries may be fossiliferous or not. Then he goes into a consideration of metamorphism—which of course gives us a third class, the metamorphics.

Metamorphism he defines as "the transfer of one kind of rock into another." This definition would include oxidation, hydration, carbonation, silication, etc.—agencies which are no longer included under the subject. His agents of metamorphism are "heat, water, and *galvanism*"; "pressure" should be used instead of this ungeological term.

With these vague definitions Hitchcock believes that "almost any rock can be transformed into any other rock" and raises the rhetorical question: "What can granite be but metamorphism carried to its utmost limit"? His final conclusions are that: "A great wave of metamorphism has swept over North America" and that: "The entire crust of the globe has undergone metamorphism and is not now in the condition in which it was created." In the light of modern knowledge this paragraph is wholly wrong. Metamorphism was evidently in swaddling clothes!

THE DRIFT

On the subject of the drift Hitchcock was a Neptunist[1]; he never wholly emerged from the ocean although he did make concessions to mountain glaciers —but never to a continental ice sheet.

In his reports on the Geology of Massachusetts (1830, 1833, 1841) he accepts the Mosaic account of creation and states that: "Nearly all geologists agree that their science exhibits no evidence against the occurrence of the deluge, as Moses described it." This is of course decidedly negative evidence; it would be more correct to say, as Adams did, that geology gives no evidence for the occurrence of the deluge. Further: "Geologists agree in representing the continents as having been submerged beneath the ocean." In support of this he quotes the 104th Psalm: "Thou coverest the earth with the deep, as with a garment; the waters stood above the mountains." We now know that the waters which many times covered many parts of the earth were shallow epicontinental seas, and not the deep ocean.

Not content with one deluge, Hitchcock believes that numerous extensive, if not universal, deluges have occurred since creation. "The last deluge, in Massachusetts, was universal and comparatively recent." Furthermore, he believes that a *"former continent"* once existed on the site of North America.

In his field work in Vermont Dr. Hitchcock and his associates give the trends of over 200 glacial striae in various parts of Vermont, and show that they vary, at maxima, from N. 45° E. to N. 70° W.; at minima, from N. 5° E. to N. 5° W. The prevailing trend is to the southeast. The striae are ascribed to the action of icebergs, their bottoms shod with englaciated rocks, being swept over the rock surfaces on which they were being grounded.

Hitchcock also locates many of the large erratics in the state, the largest, called the Vermont Giant, on a hill in the western part of Whitingham: 40 by 36 feet and weighing about 34 tons.

Professor Hitchcock's assistant, A. D. Hagar, describes the (schist) erratics near the summit of Mount Mansfield according to the oceanic theory: "Two bowlders of about 30 or 40 feet in circuit lie nearby, reposing against a firm barrier that doubtless wrenched them from their icy matrix as they were recording the history of the iceberg epoch upon these tablets of stone, which record was to reveal to man the fact that even Mansfield's lofty summit was once beneath the ocean, and icebergs sailed majestically over it." In a universal ocean one wonders where the icebergs picked up the boulders.

In similar vein Hagar believes that what we know to be a glacial trough in which Lake Willoughby lies, up in Orleans County, north of St. Johnsbury, was eroded by "powerful northern currents which, during the drift period, rushed with impetuous force through this deep gorge." We know that the gorge did not exist until it was formed by the erosive action of the Pleistocene continental ice sheet. Just what caused these impetuous currents in a universal ocean is not suggested.

[1] The term, neptunist was used ironically for those who believed in a once universal ocean.

The inability of geologists of the early, and even later, times critically to examine the theories they employed led to the general acceptance of many futile ideas and was, of course, inimical to the progress of the science.

Dr. Hitchcock devotes many pages to the drift phenomena: boulders or erratics, gravel, sand, and "loam." Topographic glacial forms, such as kames, eskers, drumlins, and others were not recognized at that time.

He regards the agencies of the drift to have been icebergs, ice floes, and shore ice, acting while the country was slowly sinking beneath the ocean; the ocean was refrigerated by polar currents. But: "We have no doubt that a part of what we call drift phenomena in New England was produced by mountain glaciers, such as we have described as once connected with the Green Mountain range." It may be noted that there is no evidence of mountain glaciation in these mountains.

Elsewhere Hitchcock needs a rising continent on which to ground his bergs. Again he speaks of a former continent which once existed on the site of North America, but has now disappeared—like the lost Atlantis! And so Dr. Hitchcock requires a rising, sinking, and pre-existing continent to account for all his glaciology.

In a paper read before the American Association of Geologists in 1842,[1] Hitchcock had discussed glacial phenomena and the theories of several European geologists on the subject. Among them was the theory of Lyell (1797-1875) to the effect that the results observed by him in North America were produced by floating icebergs derived from glaciers formed on the mountains as the content slowly emerged from the ocean. Hitchcock objects to this theory; first, because it fails to account for the lower temperature which would be necessary; second, because there is no evidence that the glaciers descended from the mountains (compare above); third, because the deposits of vegetable matter derived from land plants show that the continent must have been above sea level long before the drift period. The theory of De la Beche (1796-1855), which supposed the contents of the northern (universal) ocean to have been precipitated over the countries farther south by the elevation of the polar regions, Hitchcock thinks possibly applicable to the low countries of Europe but not to New England, since it would require too great a rise of the ocean to carry the drift over the summits of the mountains. Nor, indeed, can he understand how such a result could be obtained when the land was rising from the ocean and the water was therefore retreating, as it must have been to account for the observed phenomena—such phenomena as would call for the occurrence of water loaded with ice and detritus.

"To Agassiz's theory, which supposed an immense accumulation of ice and snow around the poles during the glacial period and a consequent sending out of enormous glaciers in a southern direction, followed by floods of water and transportation of icebergs on return of a warmer period, he likewise takes exception, since he was unable to conceive how such effects could operate when

[1] Merrill, *op. cit.*, p. 625.

land was rising from the ocean and the waters were consequent retreating," and so on.

After considering the phenomena and weighing all the theories advanced, he asks: "Is it not possible that the phenomena of the drift may have resulted from all the causes advanced in the theories under consideration"—"I feel . . . that the proximate cause of the phenomena of the drift has at last been determined, namely, the joint action of water and ice." This was practically the *glacio-aqueous* agency, given by Adams (p. 11).

The old conception of a universal ocean with submerging and emerging continents, and the failure to distinguish between mountain glaciers and a vast continental ice sheet were the stumbling blocks.

GLACIERS

In the present work Hitchcock describes (mountain) glaciers as "vast rivers of ice which, starting from the snow-capped summits of lofty mountains, move slowly down the valley as far as the heat of summer will permit them. Slowly advancing, their great thickness and the weight of the superincumbent snow cause them to grate hard upon the rocky surface beneath; and they do, in fact, produce all the phenomena of striation, planishing, and embossment, which have resulted from the drift," and so on.

He naturally looks to the White Mountains for such phenomena "but the explorations there have not had much success. The Green Mountain range has afforded more satisfactory results." He then gives many examples, in Vermont, of what he considers to be evidences of mountain glaciation.

He notes that "some able geologists (presumably Agassiz) regard all the phenomena of drift as produced by (continental?) glaciers. "Such, of course, make no distinction between the different varieties as we do. The difficulties in the way of referring all the drift phenomena in our country to (continental?) glaciers seem to us insuperable and we therefore resort to icebergs for common drift, and refer such cases as have the following characteristics to (mountain?) glaciers: 1. Glacial striae often differ widely in direction from drift striae. 2. Glacial striae occur only in valleys, radiating outward from the crests of mountains, while drift striae overtop the mountains. 3. Glacial striae generally descend from higher to lower levels. Drift striae frequently ascend mountains. 4. Drift is spread promiscuously over the surface; glacial detritus more or less blocks up the valley."

In criticism of the above it may be briefly said that: 1. The White Mountain region shows abundant evidences of both mountain and continental glaciation. 2. Glaciation in Vermont was due wholly to continental glaciation.[1] 3. Universal oceans, submerged and emerging continents, drift-laden icebergs (except on a small scale), and other absurdities are things of the past.

Thus, from 1848 to 1861, Vermont state geologists had made no real progress on the subject of glaciology; this in spite of Agassiz's glacial theory of

[1] Goldthwait, J. W., Evidence for and against the former existence of local (mountain) glaciers in Vermont: 10th Rept. Vt. State Geol. (1915-1916).

1840 and his later work in America. Hitchcock was still "shackeled" by the tradition of Noah's deluge and so was incapable of critically examining the astonishing theories which he and others had advanced.

But in the next article on Vermont glaciology[1] the drift theories had been abandoned and Agassiz's theory accepted.

RIVER VALLEYS, GORGES, TERRACES, ETC.

Vermont has very many lake and river terraces which were mainly due to the gradual and interrupted rise of the land following the recession of the Pleistocene ice sheet. In the case of rivers this rise of the land rejuvenated the old streams and made them cut more deeply, forming inner gorges and leaving terraces along their courses.

But to Hitchcock, steeped in his neptunist theory, they were due to the submergence of the continent and its gradual reappearance above the ocean. Dr. Hitchcock states very wisely that, "in the present age scientific men are too apt to *speculate in the absence of facts*" whereas he proposes to give "views of common, plain phenomena." But then he writes: "If the ocean once covered the tops of Jay Peak and Mansfield Mountain, as shown by the striae upon them, surely the whole of Vermont might justly be called the bed of a former ocean."[2] He sees evidences of this sea bottom in the "many gravelly and sandy plains and low ridges," and he "draws a distinction between sea bottoms and the drift; according to him, the drift accumulations were collected together by the joint action of water and ice; the oceanic deposits were the finer material of the drift sorted out and transported, or else the drift modified subsequently by aqueous agency." But there is no valid evidence that the ocean ever covered Vermont; much of this fine sand and gravel belongs to the Recent Epoch. And so, Hitchcock's premise being wrong his conclusions were bound to be in error.

After its long submergence Hitchcock sees "the continent slowly emerging from the ocean, rivers commencing their wearing action on the islands, waves and oceanic currents comminuting, sorting, and arranging the same, in the shape of beaches and terraces; while it may be that icebergs and glaciers modified the whole."

Under "Erosion of the Surface" Dr. Hitchcock gives the principal agents of erosion but thinks that the "greatest part of the work has been done by waves, tides, currents and ice floes of the ocean, as the land has sunk and risen again and again. The drainage of the land, also by rivers, accomplished again and again by these vertical movements, has worn out gorges and valleys of great depth, and the work has not yet ceased." Where rivers have sought new channels, Hitchcock believes that, "during the sojourn of the continent beneath the ocean at the drift period, gravel accumulated in valleys which, on a *previous continent,* were the beds of rivers, so that when the continent rose,

[1] Hitchcock, C. H.: Geology of the Green Mountain Range: 4th Rpt. Vt. State Geol. (1903-1904).

[2] He might have added the fossil whale, already referred to, in seeming support of his erroneous premise.

the rivers had to seek new channels." With these neptunist tenets in mind he proceeds to explain the existence of various gorges: Bellows Falls, Brattleboro, Cavendish, and others. Another novel explanation has it that, as the continent was rising and a mountain ridge, having a depression in its crest, slowly emerged, the winds, the tides and the currents would cause the water *to rush forward and backward through the opening,* thus enlargening it. With further emergence rivers might form and wear out valleys of great extent. "These processes, repeated several times over, might have accomplished the mighty work of ploughing out at length Vermont's deepest valleys." Thus he would explain the Winooski, Lamoille, and Missisquoi valleys. These trans-state river valleys, affording easy communication between the eastern and western parts, and also other natural routes of travel, Hitchcock attributes to the "design of the Creator." This may be so but He chose perfecty natural methods in bringing them about; peneplaned mountains and superimposed streams are relatively modern conceptions and were not dreamed of in Dr. Hitchcock's philosophy. Hutton had written his great work on rivers about a century before and many other writers had probably added their investigations but Hitchcock seems not to have benefitted by them any more than he had by Agassiz's glacial theory.

STRATIGRAPHY

Here Dr. Hitchcock is on surer ground. As the result of his work on the aereal geology of the state he produces the first colored geological map of Vermont in its entirety. For this work Hitchcock and his associates ran thirteen sections across the state and many sub-sections, a tremendous job with no good maps to aid them and with the most primitive means of transportation.

Section	I	crosses the state from Guilford to Pownal.
	II	crosses the state from Brattleboro to Bennington.
	III	crosses the state from Dummerston to Shaftsbury.
	IV	crosses the state from Rockingham to Rupert.
	V	crosses the state from Windsor to Wells.
	VI	crosses the state from Waterford to West Haven.
	VII	crosses the state from Thetford to Orwell.
	VIII	crosses the state from Newbury to Bridport.
	IX	crosses the state from Newbury to Colchester.
	X	crosses the state from Waterford to Charlotte.
	X-A	crosses the state from Lunenburg to Colchester.
	XI	crosses the state from Guildhall to Grand Isle.
	XII	crosses the state from Brunswick to Isle La Motte.
	XIII	crosses the state from Canaan to Alburg.

These sections follow river valleys only to a very limited extent. Sections XII and XIII cross Essex County which is a wilderness of granite rocks crossed by no roads.

From the study of his thirteen sections, and sub-sections, Dr. Hitchcock is able to present the first colored geologic map of the state of Vermont. Naturally this is now largely obsolete. It may be noted here that the 1861 report is practically out of print and is to be found in only a few libraries. A very limited number of copies, much damaged by the 1927 flood, can be purchased from the state librarian at Montpelier.

DISCUSSION

Dr. Hitchcock makes use of the Champlain Division ("Lower Silurian") of the New York System (see p. 9), the formations of which may be repeated ascending, as follows: Potsdam sandstone, calciferous sandrock, birdseye limestone, Ise La Motte marble, Trenton limestone, Utica slate, Hudson River group and Red sandrock.

In his discussion of Hypozoic and Paleozoic rocks, Hitchcock states that "so far as has been ascertained, these rocks, with one or two unimportant exceptions, occur only in that part of the state west of the Green Mountains. We find there a succession of formations whose order of superposition is settled in other parts of the country and, in some cases, in Vermont; but often, in consequence of *inversion,* faults, and metamorphism, it is obscure and undetermined." By "inversion" we understand thrust-faults which were the great stumbling blocks of the early geologists.

Hitchcock knows the "Cambrian period" but uses the expression only once or twice. He knows, further, that the Potsdam sandstone in New York rests unconformably upon the Hypozoic (Pre-Cambrian) crystalline rocks of Logan's Laurentian System. "The areas of the Laurentian rocks in Vermont are very limited. They are found projecting from the great nucleus in northern New York as a narrow spur, entering the town of West Haven and extending three or four miles to the north."

No formations are listed under Cambrian, but the Potsdam sandstone, given as Lower Silurian, is found in small exposures in West Haven, Orwell, and eastern Shoreham. Keith[1] found a small area in Shoreham, just west of the Champlain faul. Cady[2] makes no mention of it.

Ultimately the Potsdam was found to be the basal member of the Upper Cambrian period.

Under the caption, Quartz Rock, Hitchcock describes "the great range of quartz, or quartzite, which extends along the west foot of the Green Mountains." It really extends south into Massachusetts and north at least into Milton. Hitchcock describes it in great detail and gives its occurrence in many townships. It is no doubt the Cheshire quartzite of Lower Cambrian age which B. K. Emerson named in 1892.

THE RED SANDROCK

This is a famous Vermont formation whose age has been one of the most disputed in the state.

As formerly accepted it comprised a great belt of quartzite and dolomites extending from Quebec, at or some distance from the lake shore, southward into Addison County. It makes up low mountains (Eagle, Pease, Philo, Shell-

1 Keith, Arthur: Amr. Jour. of Science, vol. 5 (February, 1923).
2 Cady, W. M.: Bull. Geol. Amr., vol. 56 (May, 1945).

house, Buck, and Snake), promontories (Malletts Head, Lone Rock Point [once called Sharp Shins]), and headlands (Red Rocks in Burlington). Structurally it is made up of a number of enormous thrust blocks presenting steep escarpments to the west. Of these thrust blocks the most impressive is at Lone Rock Point, just north of Burlington harbor, where the sandrock (here the dolomite member) is seen resting by thrust upon the Orodivician (Trenton) shaly limestone and perhaps the Canajoharie shale, with a dip of about 15° easterly. Thrust faults were unknown in those days and "inverted dips" were used to explain them.

In some localities (Snake Mountain and Georgia) the Red sandrock is seen to lie, apparently conformably, upon the shales beneath and hence the age of the sandrock became a moot question in Vermont geology and engaged the studies of many geologists.

From its general appearance (lithologic similarity) Amos Eaton believed the Red sandrock to be the Old Red sandstone of Devonian age. Jules Marcou correlated it with the Potsdam. It has already been noted that C. B. Adams (p. 10), at Snake Mountain, believed it to lie in natural sequence upon the Hudson River Group and so placed it at the top of the Champlain Division (p. 9). Ebenezer Emmons, working on his Taconic System, stated that there is a fracture at the base of Snake Mountain, "one of the most interesting in all geologic phenomena." This is no doubt the Great Fault of Logan (1862); it is now known as the Champlain thrust—but it occurs higher up the mountain, where the Red sandrock lies apparently conformably upon the Hudson River Group. He considered the sandrock to be "conformably superjacent" to his Taconic slate and correlated it with the Medina sandstone, which is of Silurian (properly so-called) age. Later Emmons regarded the Red sandrock sometimes as equivalent to the Calciferous sandrock (which is now known as Beekmantown) and again as the Potsdam sandstone.

Dr. Hitchcock, working at Snake Mountain, notes that "without exception the Red sandrock rests upon the Hudson River Group and is Medina or Oneida in age." But Elkanah Billings of the Canada Survey in 1861 assigned the sandrock on paleontological evidence to the Potsdam group.

As will be shown the solution of this vexed problem was found by C. D. Walcott in the Georgia group.

In later times the Red sandrock has been divided into the Monkton quartzite (Keith, 1923) and the Winooski dolomite of much earlier coinage. In 1945 Cady[1] named the western member of the Winooski the Dunham dolomite. It is now known that the Red sandrock is of Lower Cambrian age.

The Calciferous sandrock, which was later renamed the Beekmantown, is stated by Hitchcock to form a narrow belt on the western border of Vermont, in the towns of West Haven, Benson, Orwell, and southern Shoreham.

The Chazy limestone Hitchcock finds to be the most extensive limestone of the Lower Silurian (Ordovician) of Vermont. He finds it on Isle La Motte, Providence Island, South Hero, Ferrisburg, Panton, Addison, Bridport, and Shoreham. Sections are shown across Isle La Motte, and Larrabee's Point. Many strikes and dips and characteristic fossils with illustrations are given.

[1] *Loc. cit.*

Birdseye limestone "is very rarely found in Vermont." Professor Adams collected specimens with characteristic fossils at South Hero, Ferrisburg, and Crown Point. Fossils of this formation are described.

The Black River limestone of New York Adams and Hitchcock designate, in Vermont, as the Isle La Motte marble. It occurs in a small area on the eastern shore of Isle La Motte, the northwest part of Ferrisburg, at Larrabee's Point in Shoreham, and in the northwest part of Benson.

On the colored geological map the Chazy, Birdseye, and Isle La Motte are shown in the same color.

The Trenton limestone is represented in Vermont by three ranges.

"The principal range enters the State in West Haven, crosses Rutland and Addison counties into Charlotte; thence through Benson, Orwell, Shoreham, Bridport, Addison, Waltham and Ferrisburg. It reappears on Grand Isle, South Hero, and Isle La Motte."

The second range is found upon the west flank of the anti-clinal in the Chazy limestone upon the lake shore in Bridport, Addison, and Panton. The third range is found in Vermont only at Highgate. These are all thoroughly treated. The Trenton is rich in fossils and many are described and illustrated.

THE UTICA SLATE

The black slates or shales of North Hero, Grand Isle, Isle La Motte, Colchester, Juniper Island, Rock Dunder, Colchester Point, Appletree Point, Lone Rock Point, Charlotte, and Shoreham are called by Hitchcock Utica slate, and they were so regarded by later geologists. Later investigations have disproved this. Dr. Rousseau Flower[1] of the New York survey states that the Utica does not extend east of Little Falls, N. Y. Dr. Marshall Kay of Columbia University, in a letter to the writer, states that "the shales for several hundred feet above the Glens Falls (Shoreham), limestone are Canajoharie." It is probable that all of Hitchcock's Utica is also Canajoharie.

THE HUDSON RIVER SLATES

This is an obsolete term. The formation thus named by Hitchcock is probably Canajoharie or Lorraine.

THE GEORGIA GROUP

This name was proposed by Edward Hitchcock in 1861. He includes in it "two (and perhaps three) terrains in Vermont" which are identified by their organic remains: *Barrandia* (*Olenellus*) *thompsoni* and others. "The most northern terrain is found in Franklin and Chittenden counties, originating probably in Quebec. The second terrain is first seen in Cornwall in Addison County. From thence it gradually enlarges, is several miles wide as it

[1] Personal communication.

leaves Rutland County, and passes into New York. The third terrain, in which no fossils have been found, extends from Milton to Starksboro. The name is from Georgia where the group is developed in full proportions and where the most interesting fossils have been found."

His second terrain is no longer classified with the Georgia Group, but is called the Taconic slate.

The Georgia group was involved in Ebenezer Emmons' Taconic System (1842) which first included an area of unfossiliferous rocks lying between the Hoosac Mountains and the Hudson River; this, the author claimed (and rightly), was older than the Potsdam sandstone of New York which rested upon the Pre-Cambrian crystallines.

In Vermont[1] it extended from Richmond, Chittenden County, to the Hudson River shales, and in Franklin County, from the Green Mountains, across St. Albans and Georgia to the Hudson River shales. The controversy concerning the Taconic System, which Schuchert[2] called "that great irritant of unacknowledged ignorance," lasted for some fifty years and was shared in by many American and some European geologists. The Taconic System was proved to be no system at all but a mixture of Lower Cambrian and Ordovician rocks.

To come back to northern Vermont: Hitchcock gives a section, some ten miles wide, west to east through St. Albans township showing easterly-dipping strata of his Hudson River shales, upon which lie, apparently conformably, the Red Sandrock (the Winooski dolomite or Dunham member), followed by beds of the Georgia slate, and these by the crystallines of the Green Mountains. Hitchcock did not see the great thrust fault by which the Red sandrock is carried over onto the Hudson River shales—a thrust which Sir William Logan first recognized in 1863 and which he followed from Quebec to Burlington. It was later traced from the Gaspé Peninsula along the course of the St. Lawrence River, and then south along or near the eastern shore of Lake Champlain and into New York. This is Logan's Line or the Champlain Fault. But, as has already been noted, Hitchcock had no patience with faults; he wrote: "There may be faults. The great difficulty arising in this view is, that one fault will not satisfy the opponent of this view. The theorist's desire for faults in speculating upon these rocks is no more readily satiated than the miser's desire for gold—the more he obtains the more he wants. One instinctively shrinks back from a theory involving numerous faults." This was a fatal frame of mind for a worker in western Vermont geology.

To return to Hitchcock's section: "The Hudson River group is Lower Silurian (Ordovician). The Red sandrock (apparently resting conformably upon it) is of the age of the Oneida conglomerate or Medina sandstone (true Lower Silurian), and the Georgia slate is still newer and therefore Middle Silurian."

[1] Geol. of Vt., p. 436
[2] Schuchert, Charles: Geol. Soc. Amr., Vol. 48, No. 7, p. 1005 (1937).

This pronouncement called forth another great controversy, in which Elkanah Billings of the Canadian survey; James Hall of the New York survey; Joachim Barrande of Bohemia; C. D. Walcott of the U. S. Geological Survey; Arthur Keith, also of the U. S. G. S.; Charles Schuchert of Yale University; and others participated. A trilobite from Noah Parker's farm in Georgia (Parkers Cobble) was sent to Hall for identification; he named it *Olenellus thompsoni* (in honor of Zadock Thompson) and placed it in the Hudson River group (Ordovician) whereas it was really Lower Cambrian, thus adding to the confusion. Walcott[1] finally showed that the Georgia group consisted of Lower Cambrian and Upper Cambrian strata. Schuchert suggested that "the highest Upper Cambrian, which is unfossiliferous, might be Lower Ordovician."

EOLIAN LIMESTONE

Dr. Hitchcock's esthetic sense is outraged by the "low associations" of some Vermont mountains: Tug, Hog Back, Snake, Rattlesnake, Camels Hump (or Rump) and others, against which good taste *reluctates*. He suggests Mt. Ophis for Snake Mountain, Mt. Crotalus for Rattlesnake, Mt. Leo for Camels Rump (Champlain improved on this by calling it *Le Lion Couchant*, the couching lion), and others. In this vein he and his students while on a visit to Dorset Mountain decided to rechristen it Mt. Eolus, hence the Eolian limestone. This was unfortunate because the name connotes wind-blown deposits which this is not—nor is it limestone but highly crystalline marble. The belt is shown on Hitchcock's map extending from Bennington to Colchester. In the southern part it includes the Marble Belt of Brandon, Pittsford, Proctor and West Rutland. In the ninth report of the state geologist, T. N. Dale describes and maps the marble belt and places it in the Ordovician. Cady[2] places the marble deposits from Pittsford northward to Burlington in the Shelburne marble formation of doubtful Ordovician age.

THE GREEN MOUNTAIN ROCKS

Hitchcock shows the Green Mountains on his map as consisting of a single range whereas, from Rutland northward, there are several diverging ranges. He gives their extension into Massachusetts as the Hoosac Mountains, and notes that they continue "far north into Canada" (as the Notre Dame or Sutton mountains). He describes the composition of the mountains as Green Mountain gneiss, bordered east and west by "talcose schist," which is largely sericite schists containing no talc. The names, talcose schist and talcose gneiss, appear to have been given to any smooth, somewhat greasy metamorphic. Later investigations have shown that the Green Mountains are also made up of various schists, gneisses, quartzites, amphibolites, granular quartz, and lenses of marble and dolomite, intruded by granite and basic eruptives

[1] Walcott, C. D., Am. Jour. Science, Vol. 35 (1888).
[2] *Op. cit.*

A roughly parallel belt of the Green Mountain gneiss, separated from the main belt by "talcose schist" extends in the southeast part of the state, from Halifax to Hartford.

SLATE

Hitchcock calls this clay slate but the "clay" is superfluous. His map shows four slate belts as follows:

a. The famous roofing slate belt extending in the southwest part of the state from Cornwall to Sandgate. This Hitchcock calls the Georgia slate though it has but little lithologic resemblance to the slate of Georgia, which is largely shale. This belt was mapped and described by T. N. Dale (see the Index). The centers of the slate industry are at Fair Haven, Castleton, Poultney, and Wells.

b. A narrow band of slate extending from Troy, Orleans County, southwest to Moretown and again through Stockbridge, Sherburne, and Bridgewater.

c. A wider belt extending from Newport, Orleans County, southward through Orleans, Washington, and Orange counties. This was named the Memphremagog slate by C. H. Richardson (1908). In Montpelier and Northfield it is of roofing quality and was quarried in the early part of this century.

d. The Connecticut River belt which extends from Burke, Caledonia County, southward along or near to river to the Massachusetts border. A good deal of the rock in the northern part of the belt is phyllite but excellent roofing slate is quarried at Guilford.

CALCIFEROUS MICA SCHIST

This is the largest formation in Vermont. It extends from the Green Mountains eastward to the Connecticut River and from Canada to Massachusetts. The name is unfortunate because it suggests an intimate association of the lime with the schist, whereas a large part of the formation is better described as limestone (which is crystalline to a considerable degree) with intercalated beds of schist and phyllite. Hitchcock finds no fossils in it but, on stratigraphic grounds he thinks it is probably of Silurian age.

In 1902 Charles H. Richardson, whose name runs through the index at the end of this article, divided the calciferous mica schist into a Washington limestone phase and a Bradford schist member, from type localities in Washington township and Bradford, respectively. Later, in 1906, "Washington" having been preoccupied, he changed the name to the Waits River limestone, and as such it has been known ever since. Richardson's discovery of supposed graptolites in the formation led him to place it in the Trenton. In 1943 Charles G. Doll[1] found a brachiopod mold in the mica schist of Whitcomb Hill, Strafford quadrangle, a fossil which he believed was *Spirifer murchisoni* and indicated a Devonian age for the strata in which it was found; but probably a large part of the formation is Ordovician.

[1] A Brachiopod from Mica Schist, South Strafford, Vt.; Amr. Jour. Science, vol. 241, pp. 676-679 (November, 1943).

SACCHAROID AZOIC LIMESTONE

Mostly within the Green Mountain gneiss belt, and especially in the southern part of the state, Hitchcock shows many small areas and one larger area of limestone. The largest is in Plymouth township. Some, notably in Weathersfield, have been worked for agricultural lime. These deposits have been investigated by T. N. Dale[1]; he believes them to be "presumably of Pre-Cambrian age." They are not saccharoidal but crystalline.

ECONOMIC MINERAL DEPOSITS

Commercial mineral deposits of granite, marble, kaolin, slate, talc (for which he uses the word steatite), verd antique, gold, and other minerals are either plotted on his map or described in the text. Dr. Hitchcock is over enthusiastic in his plotting of "gold in alluvium" for he shows this along many of the streams in and west of the Green Mountain region, giving the impression of a veritable Eldorado which is not borne out by the facts. Although gold in Bridgewater once gave some promise of being economically valuable, gold in commercial quantity has never been found in Vermont.

STRUCTURES

Dr. Hitchcock pays rather scant attention to the lithology of the mountains of the state but is much impressed and uplifted by the beauty of the landscape as seen from their summits.

He gives a section across the Green Mountains, from Wallingford to Plymouth, showing a great anticline made up of his "talcose conglomerate" and other metamorphics, resting upon the Green Mountain gneiss. The steeper, westerly dips indicate that the anticline is somewhat overturned to the west. By projecting the dips across the section he gains an idea of the amount of erosion that has taken place: about 8000 feet at Mt. Holly.

Some of the sections (I to XVIII) show the anticlinal nature of Mt. Mansfield, Camel's Hump, Jay Peak and others. But the Mansfield section shows the steeper dips to the east, which is incorrect.

As a result of his thirteen sections Hitchcock is able to establish the fact that the Green Mountains "consist of a large number of anticlinals and synclinals" (in modern parlance, an anticlinorium). One anticlinal runs along the crests of the mountains; another is found in the eastern part of the state, in Windham and Orange counties, and so on. These structures he attributes to "a crumpling force coming from the southeast which has folded the strata together and actually thrown them over, so as to produce inverted dips." . . . "Since the time of disturbance and plication, the tops of the folds have been worn away, so as to leave only the outcropping edges of the strata in sight."

[1] Dale, T. N., The Calcite Marble and Dolomite of Eastern Vermont: 9th Rpt. Vt. State Geol. (1913-1914), pp. 224-276.

FAULTS

Dr. Hitchcock's contempt for faults has already been cited (p. 30); for the structure which we call thrust-faults he uses "inverted dips"—that is, folds that have been overturned so that after erosion has taken place the older strata overlie the younger.

But in his section of Long Rock Point, just north of Burlington harbor, the reddish Winooski (later called the Dunham) dolomite rests by thrust upon a shale and no amount of "inverted dip" would explain it. This thrust is plainly shown in Section X. Also in Section XIII the thrust fault by which the Red sandrock lies upon the Hudson River group is plainly seen but is not appreciated by Hitchcock. This thrust, it will be remembered, led to the confusion regarding the age of the Georgia Group.

Dr. Hitchcock visited most of the mountains of the state. His esthetic sense is uplifted by the panoramas afforded from their summits but he has nothing to say of the rocks and structures upon which he stands.

CHEMICAL ANALYSES

A few chemical analyses of ores, kaolin, marble, and limestone are found in Adams' second report (1846); they were made by Denison Olmsted, Jr. But by 1861 such work had evidently come to the fore for Hitchcock gives many analyses (made by Charles H. Hitchcock) not only of ores and other minerals but also of rocks: verd antique, talcose, schists, granite, porphyry, dikes and the Red sandrock. T. Sterry Hunt of the Canadian Survey had shown that "talcose schist" was a misnomer since it "was almost destitute of magnesia, alumina being present in a large percent in its stead." These early analyses were often faulty, being too high in alumina and too low in magnesia owing to the inaccurate separation of these two compounds.

Dr. Hitchcock is interested in all sorts of things and phenomena: beaches and terraces (over 60 pages), frogs and the frozen well at Brandon (16 pages), ancient sea beaches and the fossil whale of Vergennes, lake ramparts arts, purgatories, caverns ("This continent has been again and again beneath the ocean"), clay stones, the law of concretions, lakes, falls, railroads, and other topics. The work is profusely illustrated with small cuts and large wood engravings of the principal scenic features of the state.

The style is verbose, the subject matter poorly arranged and rather inadequately indexed. Although a good deal of the work is now obsolete it still contains much useful material to the discriminating reader.

Dr. Hitchcock's admiration and affection for Vermont is shown in his concluding remark to his preliminary report of October 1, 1859: "I cannot, therefore, but look upon Vermont as a giant whose full proportions and strength are as yet in a great measure undeveloped; and in this, which is probably my last literary labor, I cannot but pray that God would continue to prosper and bless a State so strong by nature and so rich in noble institutions."

THE STATE CABINET

In 1848 the legislature passed a joint resolution which provided: "That all collections of minerals, field notes, and all preparations amassed by the State Geologist for a final report be brought together by some suitable person, to be appointed by the Governor, and be deposited in the State House, that nothing be lost and that the State may have the benefit of these collections whenever the State shall deem it expedient to prosecute the Survey to completion."

As already noted, Professor Zadock Thompson was given charge of this work and partly accomplished it but he died before it was finished. For the reception of the collections room No. 14 in the state house was set apart. The state house fire in 1857 destroyed the collections.

Another room was provided in the present state house and in it Professor Edward Hitchcock arranged the new collections of minerals, rocks, and fossils, which he and his associates had accumulated. The rocks from the thirteen sections were arranged and placed upon the shelves in the exact order of their occurrence in the state. Besides the geological exhibits, specimens representing the mineral resources of the state—granite, marble, slate, talc, and others—exhibits of mammals, birds, reptiles, and Indian implements were added from time to time. The fossil whale from Charlotte, the only one of its kind ever discovered in this country, was, of course, outstanding.

Albert D. Hagar was appointed curator of the cabinet in 1859 and so continued till 1870 when he left the state. Since his time Vermont state geologists have also been curators of the cabinet.

When the state house annex was erected in 1918 the state cabinet was given very inadequate quarters in one end of the Historical Society room and in the narrow hall leading to it. There was no opportunity properly to display the rock collections and so they were discarded. Professor George H. Perkins arranged the exhibits to the best advantage under the circumstances. The present state geologist has added material from time to time, both from within and outside of the state.

The cabinet is fairly representative of the state and is attracting the attention of visitors to the capitol and especially of the school children.

In the seventh report (1909-1910) Professor Perkins has an illustrated article of 75 pages on the state cabinet and its exhibits.

ALBERT D. HAGAR

Professor Hitchcock died in 1864 and Albert D. Hagar was appointed state geologist and curator in the fall of that year. The bill providing for the resumption of the survey had the following clause: "Providing however that in no case and under no circumstances shall said geologist charge or receive from the State anything for expenses, but in accepting such office it is understood that he looks to his employers (?) for any compensation that he may reasonably deserve to have for professional services by him so rendered."

It is evident that the legislature considered that the survey had been completed and that the title of state geologist was *honoris causa*.

Hagar, as has been noted, continued with his work on the cabinet. He also republished that part of the 1861 report which he had contributed: Economic Geology and Physical Geology and Scenery; but he published no new report—how could he, save at his own expense? It is not surprising that he left Vermont to accept a position on the Iowa survey.

In his state geologist's report for 1921-22 Professor G. H. Perkins states: "At this time, and for several years after, the title (of state geologist and curator) was only a name. All that the Geologist was expected to do, or was paid anything to do, was to care for the State Cabinet."

H. A. CUTTING

Dr. H. A. Cutting was appointed in 1870 to succeed Hagar. In his report for 1875 and 1876 Dr. Cutting states: "As there is no appropriation by the legislature to enable me to examine the mining sections of the State, or even to collect statistics of the same, I am of course unable to give a definite report." He notes "the hard times" of that period (following the panic of 1873) but states that the marble industry is on the increase. Further, he stresses the excellence of Vermont granite and mentions the quarries of Blue Mountain, Ryegate, Barre, Craftsbury, Brownington, Newport, Kirby, Victory, and Brunswick. Most of these are no longer active. In the state cabinet, he is able to note an increase in the number of specimens. He enumerates a good many mounted birds which have been added to the cabinet, as well as birds eggs, shells, and skeletons of Vermont mammals. Under entomology Cutting goes extensively into the ravages of insects in the state, including potato beetles, squash beetles, tent caterpillars and many others. For many of these insects he gives the life histories and proper insecticides.

The writer has not been able to learn why Dr. Cutting left the survey but can hazard a shrewd guess!

GEORGE W. PERRY

The Rev. George W. Perry succeeded Dr. Cutting in 1886 and continued in office till 1898 when, on account of ill health, he retired.

Mr. Perry made two reports. In the first, 1888, he notes that "An examination of the statute by which this office was created and under which it is maintained, makes it evident that the intent of the act was the development of the mineral resources of the State rather than the advancement of science." With this in mind he visits the centers of the state's mineral industries—slate, granite, marble, copper, iron, soapstone—and gathers data of production. In 1888 these substances had a value of $2,448,437. Forty-five companies reported to him an aggregate capital of $5,234,500, employed 4,045 men, and paid out in wages $1,550,517—an everage of $383 per man per year!

In regard to the iron industry, Perry states that: "The low price of iron produced where fuel is more plentiful long ago put out all the furnace fires in Vermont and now the abandoned shafts are found with difficulty. There is no hope that the mining of ordinary iron ore will ever again pay in this State." He notes that in the new process of steel-making (the open-hearth process), manganese is in great demand and that the old deposits in South Wallingford, which carry a good deal of manganese, have been reopened and worked at a profit. (This was later called the Kinny-Cobble mine which was worked by the Carnegie Steel Company for several years in the early 90s.) He speaks of aluminum, "a comparatively new and strange metal which is destined to revolutionize the metal world," and thinks that the Vermont green slate may be used as a source of this metal—a vain hope.

In regard to the state cabinet, he states that there is the beginning of a fine collection but that the appropriation for it—two hundred dollars a year—is hardly sufficient to keep it in order. Furthermore, that there should be complete sets of specimens of the granites and marbles of the state. These were later added.

In his report of 1889 Mr. Perry again gives statistics for marble, granite, slate, limestone, brick, and soapstone. The companies producing these materials have a capital of $7,330,710, employ 5,324 men, and expend for wages, $1,781,955. The total value of the output is $4,275,851. Comparing these data with those for the preceding year, one notes an increase of about 42 percent in dollar output but an average wage of only $335 per man per year. What the "take home" wage was we have no means of estimating.

In writing of the cabinet Mr. Perry states that "the collection of Vermont birds has been greatly enriched by a large number of specimens many of them very rare. The cabinet contains at least one specimen of every species of birds of prey found in the State."

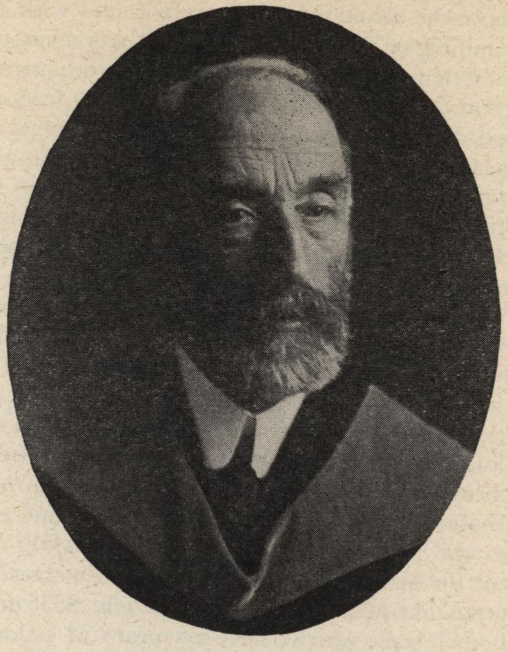
Finally he makes the surprising statement that "nearly all the larger animals found wild in Vermont have been added to the collection"! This suggests a "zoo" rather than a cabinet.

In regard to stipend, Mr. Perry says that "Not one dollar is appropriated for this office, and provision is not made for even postage and stationery. Under such circumstances how much ought to be expected in results?" And still he continued in office till his poor health forced him to resign—truly a labor of love and devotion.

The survey had sunk to a very low ebb when, for reasons unknown to the writer, the legislature decided to rehabilitate it. A new law to this end was enacted and Governor E. C Smith, or others in authority, invited George H. Perkins, professor of geology in the University of Vermont, to assume the office. He was appointed state geologist and curator of the cabinet in 1898 and continued in office till his death in September 12, 1933, a tenure of 35 years.

GEORGE HENRY PERKINS

Mr. Perkins was born in Cambridge, Massachusetts, on May 25, 1844. He was of New England ancestry with a long and honored line of descent through



George H. Perkins

both father and mother. His father, Frederick Trenck Perkins (1811-1893) was a graduate of Yale College and a Congregational minister. His mother was Harriet Thomson Olmsted, a niece of Professor Denison Olmsted who was associated with Charles B. Adams, the first Vermont state geologist.

After two years residence at Knox College, Illinois, Mr. Perkins entered Yale College where he was fortunate in studying under J. D. Dana, the famous geologist; Willard Gibbs, the eminent physicist; and others. He was graduated with honors in 1867 and received his doctorate two years later.

Perkins came at once to the University and taught botany and zoology till 1881 when he became Howard professor of geology and was appointed dean of the department of natural sciences. In 1907 he became vice-president of the University. He was acting president during 1917-1919. For 56 years he was curator of the university museum and brought to it many valuable specimens from his extensive travels.

The university conferred on him the degree of LL.D. in 1911, while Knox College gave him its Litt.D. in 1912.

Professor Perkins became a fellow of the Geological Society of America in 1902 and was also a member of other learned societies. To these he contributed many papers on botany, zoology, entomology, anthropology, archaeology, and geology.

As state geologist Professor Perkins entered upon his duties with great zeal. He inaugurated the publication of biennial reports, which is still being continued.

Perkins' tenure might be called a golden age in Vermont geology. During this time a special appropriation for printing state reports enabled him to publish, not pamphlets but sizable octavo volumes which contain, besides his own articles, papers by eminent geologists from other states who were attracted to Vermont by her varied and intricate geology. These contributing geologists include T. Nelson Dale and Arthur Keith of the U. S. Geological Survey; H. L. Fairchild of the University of Rochester; C. H. Hitchcock and J. W. Goldthwait of Dartmouth College; B. F. Howell of Princeton University; P. E. Raymond, J. B. Woodworth, and J. E. Wolff of Harvard University; and others. The index at the end of this article records the titles of their papers.

Professor Perkins' biennial reports cover the years from 1897-98 to 1931-32, inclusive, eighteen volumes in all.

The subjects treated include mineral deposits and their origins, which run through all the reports; preliminary areal mapping, mostly reconnaissances; structural geology, physiography, petrology, metamorphism and hydrology. Most of the work has been done in the lowlands; the Green Mountains and their metamorphic rocks were anathema to the early geologists and received scant attention.

Among the outstanding papers are those of G. H. Perkins on the Brandon lignites and the fossil whale (*Delphinapterus vermontanus*); C. H. Hitchcock and J. W. Goldthwait on glaciology; T. N. Dale on the granites and marbles; H. E. Merwin on the post-glacial shorelines of northwestern Vermont; J. W. Eggleston on the eruptive rocks of Cuttingsville; P. E. Raymond, H. M. Seely, and E. J. Foyles on paleontology; Arthur Keith on the division of the northwestern fault-blocks into sequences; Robert Balk on the structures of the granite in Bethel, Barre, and Woodbury; B. F. Howell on the Cambrian fish-plate and other fossils; G. W. Bain on history of the Green Mountain front; and J. E. Wolff on Mount Monadnock, Vermont.

ELBRIDGE C. JACOBS

The present state geologist took office in September, 1933; he has published six reports including that for 1945-46.

The 1932 legislature provided that state officials include the cost of publishing their reports in their budgets which, in the case of the state geologist, had also to bear his per diem remuneration, cost of travel, subsistence, and even his postage and telephone calls. The total budget of the geologist was $1,200 a year. This necessitated the publishing of pamphlets, the largest of 155 pages and left no funds for the employment of assistants. A few articles by other geologists were contributed without charge or purchased for nominal sums. In spite of this handicap it is believed that valuable contributions to the geology and mineral industries of the state have been made.

Of course the position is a part-time job, as it has always been. It has been held mainly by college and university professors whose chief income has been gained by their academic duties.

On account of the lateness of his appointment the present geologist's report for 1933-34 is wholly devoted to a survey of the state's mineral resources and production. This mineral production exceeds that of all the other New England states and information concerning it is in much demand.

In the report for 1935-36, besides "mineral production," an article entitled "An Account of Vermont Geology" is given. This paper, written as far as possible in non-technical language, endeavors to present briefly the common minerals and rocks of the state and the structures, physiography and chief geologic formations, with their geologic ages. It was written especially for the school children and for the general reader.

At about this time small collections of minerals and rocks, supplemented by an explanatory pamphlet, were prepared for distribution to the schools. It is regrettable that the educational authorities have not seen fit to cooperate with the geologist in providing suitable receptacles for these collections and, furthermore, that in this state, so wonderfully rich in its geology, greater attention is not paid in the schools to this fundamental subject.

In this report Professor C. G. Doll has a most interesting account of a glacial pothole far up on Burnt Rock Mountain in Fayston.

In the twenty-first report (1937-38) a technical article on the geology of the Green Mountains of northern Vermont is found. It treats of the physiography (better called geomorphology), stratigraphy, structure and metamorphism of the mountain rocks together with chemical analyses and petrologic studies. This paper is, of course, in the nature of a reconnaissance and will later be supplemented by detailed areal mapping.

In this report, also, Professor Doll has a study of the structure of Clay Point in Colchester, a most interesting bit of geology. Professor Howell of Princeton University presents a study of the Rugg Brook formation of Franklin County. The final article by the late Professor C. H. Richardson, entitled "The Geology of Vernon, Guilford, and Halifax," appears posthumously.

The 1939-40 report is devoted to a full account of Vermont's economic minerals and rocks, including data of production, dollar value of the products, and number of men employed.

The report for 1941-42 is largely concerned with glaciology: "The Great Ice Age in Vermont," and Prof. D. H. Chapman's "Glacial History of Lake Champlain. Professor Doll contributes an article on an abandoned stream valley in West Charleston.

The reopening of the Vermont copper mines in 1942 was an outstanding event in the state's mineral history. A review of the copper industry going back to 1793 is given.

In the 1943-44 report the geology of the Elizabeth mine, which is now in active production, is considered and the present practise in mining and milling is presented. As the state's contribution to the Vermont Copper Company, Professor Doll spent a long field season in studying the Strafford quadrangle and produced an areal map, with accompanying descriptions, which appears in this report.

In studying the long series of reports dating from 1898, the writer finds that while a great deal of geologic information has been published, detailed and systematic mapping has been lacking—this on account of very inadequate appropriations. Of all the forty-six states carrying on some kind of geologic surveys, none has appropriated so little as Vermont. But on the geologist's earnest representations to the 1945 legislature, appropriations of $2,000 for 1945 and $4,000 for 1946 were granted. These grants have made possible the continuation of areal mapping begun by Professor Doll.

Professor Doll has completed the mapping of the Memphremagog quadrangle which will appear in the 1945-46 report. He and Professor V. H. Booth, of Brooklyn College, have nearly completed the Jay Peak quadrangle and will finish it during a part of the 1947 field season.

In this quadrangle a large body of serpentine was discovered; it may contain soapstone, talc, or asbestos, although this has not yet been proved.

The present plan is to complete the northern tier of quadrangles: St. Albans, Enosburg Falls, Irasburg, Island Pond, and possibly Averill, and then continue southward. This approach to the mapping was chosen because the known formations of southern Quebec, mapped by Professor T. H. Clark, of the Canadian Survey, continue into Vermont and so furnish stepping stones to the complex and unfossiliferous rocks of our state.

Dr. L. W. Currier of the U. S. Geological Survey has mapped a part of the Barre quadrangle and Dr. W. M. Cady of the same survey is at work on the Montpelier quadrangle. Furthermore, Dr. Cady has done an impressive work in mapping parts of the Milton, Burlington, Middlebury-Port Henry, Brandon-Ticonderoga, and Castleton-Whitehall quadrangles; so that a very good beginning in the state-wide mapping has been made.

If liberal appropriations by the legislature continue, as it is devoutly to be hoped that they will, we shall eventually have the whole state mapped, further economic minerals discovered, if they exist, and data for an accurate geologic map of Vermont obtained. A state of Vermont's geologic importance should surely have such a map; Hitchcock's map of 1861 is, of course, long out of date and, moreover, is no longer obtainable.

CHARLES H. RICHARDSON'S WORK

No account of geological investigations in Vermont would be at all complete without a statement of the work done by Dr. Richardson.

Born in Topsham, Orange County, Vt., September 26, 1862, Richardson won his undergraduate degree and doctorate at Dartmouth College and was for many years professor of mineralogy at Syracuse University. He was devoted to the geology of his native state and spent most of his summers from 1901 to 1937 in studying a belt of rocks east of the Green Mountains and extending from Quebec to Massachusetts. He died in 1935.

In Irasburg Dr. Richardson believed that he had discovered the basal conglomerate which formed the geological boundary between the Cambrian rocks to the west, and the Ordovician rocks to the east. This he named the Irasburg conglomerate. The belt he followed was included in Hitchcock's "calciferous mica-schist" which the 1861 map showed to be the largest formation in the state, extending from the Green Mountains to the Connecticut River and the entire length of the state. Richardson separated this old formation into the Waits River limestone and the Bradford schist, but the latter name being preoccupied, was changed by him to the Vershire schist. In the northern part of his Waits River limestone he named the included slate the Waterford slate and the Montpelier slate. Again, the latter name being already in use, Richardson changed it to the Memphremagog slate.

Professor Richardson established his Missisquoi group of rocks which he stated formed the most easterly members of the Cambrain. They consist of impure limestone, sericite schists and sericitic quartzite, chlorite, hornblende and muscovite schist, and some gneiss. He followed them from Quebec to the latitude of Athens, a distance of some 150 miles, and considered them to be of lower to middle Ordovician in age.

Richardson's studies took him across the townships of Troy, Newport, Irasburg, Craftsbury, Greensboro, Hardwick, Woodbury, Calais, East Montpelier, Montpelier, Plainfield, Orange, Northfield, Roxbury, Braintree, Washington, Randolph, Bethel, Barnard, Pomfret, Woodstock, Reading, Cavendish, Baltimore, Chester, Springfield, Grafton, Rockingham, Athens, Westminster, Brookline, Putney, Halifax, Guilford, and Athens—a very large area. In this work he named a large number of minor formations, and located many acid and basic intrusives.

The designation of the Waits River formation, the largest in the state, as Ordovician (lower Trenton) was based on his discovery of crushed graptolites whose authenticity has been seriously questioned though Ruederman, of the New York survey, thought that some of them were authentic. At any rate the formation was generally believed to be of Ordovician age.

Doubts of the validity of the Irasburg conglomerate have been cast by the work of Currier and Jahns of the U. S. Geological Survey[1] who believe that this conglomerate is not basal but intraformational within the Waits River limestone. The late Arthur Keith also doubted the basal nature of this conglomerate. The writer thinks that the true nature of this conglomerate is still in doubt.

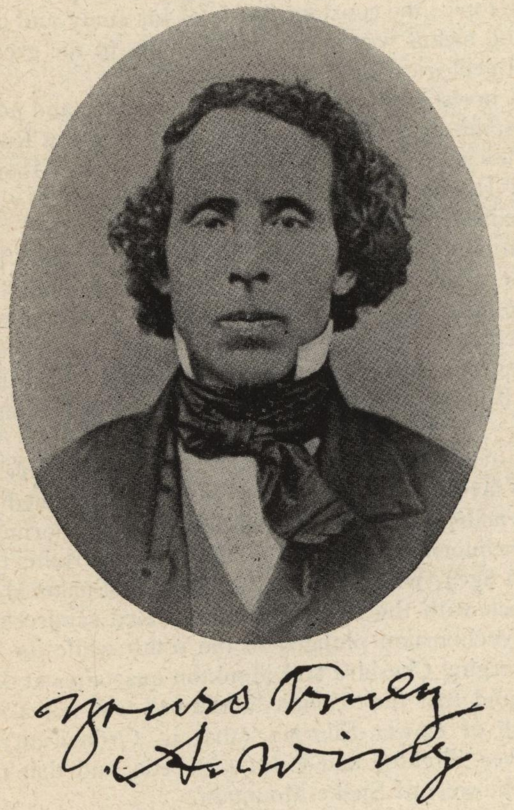
In any case Professor Richardson's far-extended reconnaissance work deserves a great deal of credit. It is hoped that detailed areal mapping of the state will ultimately settle many problems in Vermont geology. Some years ago Professor Doll, working on the Waits River formation in Westmore, Orleans County, discovered fossil crinoids, cystoid calyces, and two gastropods,

[1] Ordovician Stratigraphy of Central Vermont: Geol. Soc. Amr., vol. 52, p. 1487 (1941).

which showed that this formation is "at least as young as Middle Silurian and very possibly of Lower Devonian age."[1]

The same author in his mapping of the Strafford quadrangle (1942-1943) found in the crystalline schists of Whitcomb Hill, immediately east of the Memphremagog formation, "a single determinable brachiopod, probably *Spirifer murchisoni*, of Lower Devonian (Oriskanian) age."[2]

Further fossil discoveries will be eagerly awaited.



REV. AUGUSTUS WING

Although Mr. Wing had no official connection with the Vermont survey, his geological work was so important and so fundamental that space should be given it in this report.

Augustus Wing was born in Rochester, Vermont, November 19, 1808. He prepared for college at Burr and Burton Seminary, Manchester, gradu-

[1] Doll, C. G., A Paleozoic Revision in Vermont: Amr. Jour. of Science, vol. 241, pp. 57-64 (January, 1943).

[2] Doll, C. G., A brachiopod from Mica Schist, South Strafford, Vt.: Amr. Jour. Science, vol. 241, pp. 676-679 (November, 1943).

ated from Amherst College in the class of 1839, and studied at the Andover Theological Seminary from 1840 to 1842. But he soon turned to teaching and was principal of several academies and high schools. Professor Seely[1] wrote that: "His pupils never forgot his impressive ways of instruction. Thought stimulated, investigation undertaken, individual judgment exercised were, in Mr. Wing's estimation, of far greater value to the pupil than the acquisition of many facts from printed pages."

His avocation was geology "which became first the prominent and later the all absorbing topic; the constant theme of his study and investigation. All available time and means were made contributors to the great object of solving self-imposed geological problems."

Wing's chief investigation concerned the structure and geologic age of the crystalline limestones of the Otter Creek Valley, between Rutland and Monkton and from the Green Mountain quartzites to Snake Mountain. This area was included in Hitchcock's Eolian limestone (see p. 31) of which Hitchcock "quite despaired of fixing the age."

Mr. Wing worked on the problem for ten years (1865-1875), traversing the state on either side of the Green Mountains and extending his investigations into adjoining states. He found that "the rocks of the area were so folded and broken that their true position was uncertain; while the fossils, in the partly metamorphosed rocks, were so obscure that identification was difficult." Elkanah Billings of the Canadian survey helped Wing in their identification.

As the result of his ten-year research Mr. Wing was able to state that the rocks of his area lay within a great syncline which contained also subordinate anticlines and synclines—in modern parlance, a synclinorium. On the east he found the synclinorium bordered by ridges of quartzite (the Cheshire of Lower Cambrian age), while on the west lay the Snake Mountain (Champlain) thrust block with the Lower Cambrian Red sandrock on top. Wing found that the synclinorium plunged to the south while its "nose" was outlined by the converging Cheshire and Monkton quartzites at Monkton.

Wing discovered that the "Eolian limestone" was not a single formation but was made up of Lower Silurian (that is, Ordovician) Beekmantown, Chazy, Black River, Trenton and Utica (?) beds, and that these formations occurred also to the west of Snake Mountain.

Seely[2] wrote: "It was a rare day to Mr. Wing when he secured the promise of Professor Dana to look into the facts, the basis of his (Wing's) theory. . . . It was the climax of his life when Mr. Wing met Professor Dana and a party of geologists at Great Barrington, Mass., and there began to unfold his theory, verifying each position as they traveled through the Berkshire hills and Hoosac Valley, and made their way north, traveling the entire length of his native state, crossing and recrossing the Green Mountain range, by which time his theory had given place to a deep conviction that it was correct."

[1] Seely, H. M., Sketch of the life and work of Augustus Wing: 3d. rpt. Vt. St. Geologist (1903-1904).

[2] *Op. cit.*

Mr. Wing died in January, 1876. He never published his work but Professor Dana[1] did so, with accompanying map and cross-sections. He remarked that "Mr. Wing, by the use of his spare time amid the duties of teaching, accomplished vastly more for the elucidation of Vermont rocks than had been done by the Vermont Geological Survey."

Of course this was written in 1877!

THE TOPOGRAPHICAL SURVEY

For many years the U. S. Geological Survey and the state of Vermont have cooperated in surveying the state topographically, each party contributing $2,000 a year.

The resulting "quadrangles" cover 15 minutes in latitude and 15 minutes in longitude; the scale is approximately one mile to the inch. The Rutland and Wallingford quadrangles were first published (1893) while the most recent are the Lyndonville and St. Johnsbury sheets. The quadrangles are now complete with the exception of Corinth and Burke. When these are finished it will be in order to resurvey some of the older quadrangles which contain considerable errors.

Of late years the survey has been publishing "7½ minute" maps in which two miles equals one inch. This, of course, makes the features much larger and more adapted to surveying or geological work. The 7½ minute maps now available are those covering East Middlebury, Cornwall, and Lake Bomoseen. Presumably future maps will be made to this scale.

Topographical maps can be purchased of the U. S. Geological Survey in Washington and in some of the larger book stores. The names of the quadrangles can be found in the 1939-40 report.

[1] Dana, J. D., An account of the discoveries in Vermont geology of the Rev. Augustus Wing: Amr. Jour. Science, Vol. 13, pp. 332-347, and Vol. 14, pp. 36, 37 (1877).

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Note: Many glacial data are found in the Geology of Vermont (1861).

A Contribution to the Petrography of the Quartz-bearing Plutonites of Derby, Vermont

J. E. Maynard
Syracuse University

INTRODUCTION

The Township of Derby, the southern portion of which was formerly known as Salem, is situated in the north central part of the State of Vermont. It is bounded on the west by Lake Memphremagog and on the north by the international boundary line. Quartz-bearing plutonites have long been known to occur in this district.[1] With very few exceptions,[2] however, and upon megascopic examination only these rocks were simply designated as granites. The few recorded petrographic descriptions were qualitative rather than quantitative for no modal analyses were found in the literature. The purpose of this paper is to make available quantitative petrographic descriptions of those rocks that have received only megascopic examination; to re-examine those that were studied only from the qualitative viewpoint so that the results could be recast as quantitative modal analyses; and to give, where necessary, a more detailed mineralogical and textural description of them.

This study was made possible through the kindness of the late Dr. Charles H. Richardson whose large collection of Vermont rocks was made available to the author.

PETROGRAPHY

For convenience and comparison the modes of the various rocks are grouped together in Table 1. They represent the volume percentages of the

TABLE 1. Modes of Quartz-bearing Plutonites

	1	2	3	4	5	6	7	8	9	10
Quartz	23.64	18.26	20.18	21.40	22.68	19.00	22.18	13.01	11.78	41.48
Microcline	3.42	4.49	13.82	17.12	12.89	8.51	13.21	17.50	25.50	13.50
Oligoclase	68.46	69.20	52.10	45.72	55.20	65.98	57.80	57.42	49.21	39.67
Muscovite	×	0.75	1.95	4.94	4.73	0.43	×	1.01	0.51	×
Apatite	×	×	×	×	×	×	×	×	×	×
Biotite	4.06	6.88	11.70	9.88	4.50	6.06	6.13	11.26	13.00	4.96
Zircon	×	×	×	×	×	×	×	×	×	×
Sphene	..	×	×	..	×	×	..	×	..	..
Orthite	..	..	..	×	..	..	..	..	..	×
Epidote	×	0.50	..	0.36	×	..	×	×	..	×
Chlorite	..	..	..	×	×	..	..	×	×	..
Calcite	×	..	..	..	..	×	..	×	..	..
Kaolinite	×	×	×	×	×	×	×	×	×	×
Secondary mica	×	×	×	×	×	×	×	×	×	×
Garnet	..	..	..	..	..	..	..	..	..	×
Rutile	?	?	?	?	?	?	?	?	?	?

× The mineral is present.
? May be present but not certain of the identification.

various minerals in the rocks as determined by the Rosewal method. Using the modal determinations the rocks were assigned to the various families, orders and classes in accordance with Johannsen's[3] classification. With further study a few of the assigned names may be changed, especially where the plagioclase-potash feldspar ratio is close to the dividing line between two families, as in No. 2, in which an increase of less than one per cent in the microcline content would change the rock from a tonalite to a granodiorite; likewise where the biopyriboles ratio is near the boundary between two classes, as in Nos. 5 and 10, a small increase in the biotite content would indicate a granodiorite rather than a leucogranodiorite.

1. Leucotonalite, Johannsen (P. 128). This specimen was called a "light gray, coarse-grained granite from the La Casse Granite Company's quarries."

The hand specimens show flakes of biotite rather sparingly distributed throughout a ground of slightly smoky quartz and milk-white feldspar, giving the rock as a whole a very light gray, almost white, appearance.

The microscope shows the texture of this rock to be hypautomorphic-granular. This is due to the partial automorphism of the oligoclase and biotite. The rock is medium grained tending towards the upper limit. Oligoclase is by far the most abundant constituent. Many of the individuals show twinning, both pericline and polysynthetic on the albite law, and in addition they may be exceptionally well zoned. Alteration of the oligoclase has only occurred to a minor extent, flakes and shreds of white mica being the most abundant product, with kaolinite, epidote and calcite in very subordinate amounts. It contains many hair-like inclusions: some apatite, others muscovite or perhaps rutile. Grains and automorphic apatites and zircons are also sparingly present in it. Occasionally the outer borders of the oligoclase are altered into a deuteric intergrowth of vermicular quartz and albite, called "myrmekite" by Sederholm.[4] Grout.[5] Xenomorphic quartz, rarely showing shadowy extinction, and containing innumerable gas and liquid inclusions in sheets with often cracks parallel to them, fills most of the interstices between the oligoclases. Hair-like inclusions of apatite, with perhaps some rutile, occur sparingly in the quartz. Microcline showing the typical grating texture is fresh and unaltered. It was the last mineral to crystallize as shown by its automorphism when in contact with the quartz. Brown biotite is only sparingly present. It shows the characteristic "bird's-eye maple" effect, and occurs as irregular flakes, or as irregularly terminated laths that grade out on the ends into fine-shredded muscovite. Often the biotites are segregrated into knots. An occasional brown zircon, surrounded by the customary pleochroic halo is enclosed in the biotite. A few small automorphic muscovite crystals are also enclosed in it indicating that the muscovite crystallized at least simultaneously with the biotite or perhaps even before it.

2. Biotite Tonalite, Johannsen (P. 228). This specimen was obtained from just south of the La Casse Granite Company's quarry. It was simply designated as a "relatively coarse phase of the granite present in the vicinity of the quarry." The biotite content is such that the rock is very close to the dividing line between the leucotonalites and the biotite tonalites. Further, it is also very close to being a granodiorite as it contains 4.49 per cent of microcline.

In hand specimens the rock is massive, light gray, and varies from almost coarse to medium grained. The mica individuals appear as spots in a white ground rather than as part of an intimate mixture of oligoclase and quartz. The quartz grains have a tinge of color which detracts somewhat from the clean appearance of the stone.

In thin section the texture of the rock is seen to be hypautomorphic-granular and in mineralogical composition and degree of alteration it resembles No. 1 very closely. The oligoclase, however, only rarely shows twinning on the albite law. Small automorphic needles of apatite are more abundant as inclusions, especially in the oligoclase and they tend to be more numerous in localized areas. The individual laths and knots of biotite are very similar to those of No. 1, except that they have associated with them more and larger grains of apatite and epidote. There are, also, occasional aggregates of brown sphene enclosed in the biotite that were not present at all in No. 1. Of particular note is the paucity of zircon inclusions in the biotite. Those that do occur, however, show the characteristic pleochroic haloes.

3. Biotite Granodiorite, Johannsen (P. 227). This specimen was obtained from the Newport Granite Company's quarry near the center of the town of Derby and is the rock that they designate as "Derby gray." Richardson[6] says the rock "is mainly a biotite granite and the uniform arrangement of the black scales of mica with white quartz and feldspar makes the stone 'a thing of beauty.' " According to Dale[7] this rock

"is a quartz monzonite, with both biotite and muscovite, of light bluish-gray color and even grained, medium inclined to fine texture, with feldspars up to 0.25 and 0.3 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are light smoky quartz with hair-like crystals of rutile, fluidal and other cavities in sheets with cracks parallel to and in places coinciding with them; clear to bluish-white striated soda-lime feldspar (oligoclase), mostly much kaolinized and somewhat micacised, also intergrown in places with quartz in vermicular structure; clear to translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized; biotite (black mica); and muscovite (white mica). Accessory: Apatite, titanite, allanite, rutile. No magnetite or pyrite was detected. Secondary: Kaolin, a white mica, and calcite from chemical test."

The rock is of a bluish gray color and resembles quite closely the "medium bluish-gray" rock that is quarried so extensively at Barre. Megascopically, biotite, slightly smoky quartz and milk-white feldspar can easily be identified.

The microscope shows a medium grained hypautomorphic texture. Zoned oligoclase, rarely twinned on the albite law but quite often on the carlsbad law, makes up a little better than 50 per cent of the rock. In general it is surprisingly fresh, the chief alteration products being a small amount of kaolinite, white mica, and more rarely calcite. An occasional oligoclase, however, is more or less completely altered to fine-shredded white mica. Apatite, either as grains, needles, or hair-like individuals, is quite abundantly enclosed in the oligoclase; zircons, however, are rare. Xenomorphic quartz and microcline fill the interstices between the feldspars and micas. The former shows slightly wavy extinction and is filled with gas and other cavities that appear to be arranged in planes. Needles and hair-like inclusions, mostly apatite, with perhaps some of the individuals being rutile, are very numerous in the quartz. Slightly kaolinized microcline, showing the typical grating texture and containing many inclusions of apatite, was the last mineral to crystallize, as at times quartz is automorphic against it. Brown biotite occurs as small laths and flakes which may be grouped into irregular aggregates, arranged in more or less irregular lines, or just simply as separate individuals. Laths of muscovite are occasionally found making up a part of the biotite aggregates.

Thin sections from several specimens taken from this quarry were examined and in no case was any orthoclase found.

4. Biotite Granodiorite, Johannsen (P. 227). This specimen was obtained from the Parameter quarry which is situated near the Canada line about one mile east of Lake Memphremagog. This rock was first described megascopically by Dale.[8] He states the rock "is either a biotite granite or a biotite quartz-monzonite of very light gray color and even grained medium texture, with feldspars up to 0.3 inch and mica to 0.2 inch. Its constituents are slightly bluish milk-white feldspar, light smoky quartz, and biotite (black mica)."

Under the microscope this rock shows a hypautomorphic-granular texture, the grains averaging 1.3 millimeters in cross section. The most abundant constituent is zoned and striated oligoclase. There were, however, oligoclase individuals that did not show polysynthetic twinning and which on casual examination could be very easily mistaken for orthoclase. The larger oligoclases contained many inclusions of poorly terminated laths of muscovite and biotite, grains of sphene, and more rarely automorphic needles of apatite and short stout prisms of zircon. They are more or less altered to kaolinite, white mica or rarely epidote. Occasionally the margins of the oligoclase are replaced by myrmekite. Microcline is entirely xenomorphic and invariably shows the characteristic grating texture. It is rarely altered and, with the exception of minute hair-like crystallites, there is a pacity of inclusions. Quartz is the second most abundant constituent. It contains many very fine hair-like inclusions on which no satisfactory determinations could be made. They may be rutile. Knots of biotite are very evenly distributed throughout the rock. They are made up of broad laths that have no particular orientation; sometimes a lath of muscovite will be in parallel intergrowth with the biotite and more rarely elongated sphenes will have the same relationship. The biotite shows all stages of alteration through chlorite to epidote. One flake may show just a slight amount of chloritization, another may be partly chloritized and just starting to alter to epidote; again there may be no traces left of the original biotite, the secondary chlorite from it being nearly completely changed over into epidote; finally the biotite may be completely changed

over into epidote. In changing from biotite to chlorite the alteration starts at the margin and works toward the center, whereas the change from chlorite to epidote commences at the center and works toward the margins. The epidote, in general, begins to form before the biotite has been completely chloritized. Cross sections and prisms of apatite are the most prevalent inclusions in the biotite, although small zircons, not always showing pleochroic haloes, can be seen. Only one grain of orthite was found.

5. Leucogranodiorite, Johannsen (P. 127). This rock crops out near Beebe Plains in the northern part of Derby township. Richardson[9] very briefly states that "the granite near Beebe Plains is a very light gray color and of even medium texture. It is darker, however, than the Bethel stone. It bears biotite uniformly distributed throughout the stone."

The microscope shows the rock to be of medium grain and hypautomorphic-granular texture. Mineralogically the rock is very similar to No. 4, except that biotite is only about half as abundant and microcline about two-thirds as abundant. The chief constituent in the rock is oligoclase. It is often zoned, only occasionally shows polysynthetic twinning, and minor alteration to kaolinite and white mica. Sometimes the outer margins of the oligoclase are altered to myrmekite. Microcline, showing the typical grating texture and enclosing small needles of apatite, and with little indication of kaolinization, was the last mineral to form. Quartz is very similar to that in previously described specimens. It shows undulatory extinction, is fractured, and contains in planes and zones numerous gas and other inclusions, together with an occasional apatite and very few hair-like individuals that could not be determined. Biotite and muscovite, often in parallel intergrowth or in knots that are made up of these haphazardly orientated, are in about equal abundance. Zircons are relatively rare, being in general indicated only by the pleochroic haloes in the biotite. There is a paucity of inclusions of any kind in the muscovite. Sometimes the biotite shows alteration to chlorite or epidote, or has associated with it aggregates made up of grains of sphene. The alteration to epidote is not so well developed as in No. 4.

6. Biotite-granodiorite, Johannsen (P. 227). This rock is found in the vicinity of Derby Line, near the Quebec boundary. The potash feldspar makes up only about 8 per cent of the rock so that it is not far from being a tonalite. In addition biotite is only about 6 per cent so that it is rather close to the leucogranodiorites.

The rock, megascopically, very closely resembles No. 2. The base, very light gray feldspar and quartz, is speckled with knots of biotite, so that the general appearance is black spots in a white ground, rather than a uniform mixture of the base and biotite.

Under the microscope the close resemblance to No. 2 is even more noticeable, textures, minerals and degree of secondary alteration being just about the same. There is a marked difference, however, in the percentages of the various minerals present. The oligoclase is often twinned on the albite law so that in this respect it is more like that in No. 1. Secondary muscovite is quite abundant as irregularly shredded patches, fan-like aggregates and sheaves, which are quite common as alteration products in the oligoclase. Occasionally the oligoclase is partially altered to calcite. Biotite laths grading out on the ends into finely shredded white mica are relatively common. Brown sphene, acutely terminated, is abundant. Epidote appears to be entirely absent from this rock.

7. Biotite-granodiorite, Johannsen (P. 227). This specimen was designated "light gray granite from Salem Mountain which is situated about the center of the old township of Salem, now included in the southern half of Derby."

In hand specimens the rock very closely resembles No. 5. The base of the rock is very light gray milk-white feldspar and slightly smoky quartz. Distributed throughout it are flakes and patches of biotite, the combined effect producing a rock of very pleasing light gray color.

Microscopic examination shows the rock to be of medium grain and hypautomorphic-granular texture. Its general appearance, mineralogical composition, and degree of alteration, are practically the same as that shown and described in detail under No. 5. Biotite is only a little more abundant and in contrast does not show any alteration to chlorite, but does enclose many more automorphic zircons. Of especial note is the absence of flakes and laths of muscovite. The paucity of apatite is also rather noteworthy, only a few small grains being enclosed in the biotite and relatively larger ones in the oligoclase.

8. Biotite-granodiorite, Johannsen (P. 227). This specimen was obtained from the southern side of Salem Mountain about one-half mile from No. 7. It was called a gray biotite granite.

Megascopically and microscopically this rock is very similar to the other darker colored granodiorites of the township. In texture, mineralogical composition, and degree of alteration it very closely resembles No. 6. The oligoclase is very rarely twinned on the albite law and on casual examination could quite easily be mistaken for orthoclase. In places its margins are replaced by a vermicular intergrowth of quartz and albite. Alteration products of note are chlorite, epidote and calcite.

9. Biotite-granodiorite, Johannsen (P. 227). This specimen was called a "dark gray biotite granite from along the Clyde river, Salem, Vermont." It thus came from along the eastern margin of the exposures in the east central part of the old township of Salem. It differs principally from the other biotite-granodiorites studied in having a higher percentage of biotite with also a much higher percentage of microcline. Secondary minerals: white mica, kaolin, and chlorite, are at a minimum. Apatite is worth mentioning. It is most abundant as inclusions in the oligoclase, to a lesser extent in biotite and only rarely in the microcline and quartz. It occurs as irregularly shaped colorless individuals, as small, short, automorphic crystals, as long slender needles showing prominent basal parting, and as minute hair-like crystallites.

In a few cases the larger apatites enclose small zircons, in others they are full of minute indeterminable inclusions. At times the automorphic needles are bunched together into more or less radiating aggregates.

10. Leucogranodiorite, Johannsen (P. 127). This rock was designated "light gray granite from the west side of the exposures in the center of Salem township." From the high percentage of quartz it appears that the specimen was taken from near the contact of the intrusive and country rock. The presence of garnet in this rock and not in any of the others also points towards this conclusion. The amount of biotite is so close to the dividing line between the leucogranodiorites and the granodiorites that the rock might just as well be placed with the latter. In texture and mineralogical composition the rock is quite similar to the other granodiorites of the district. A few points with respect to the inclusions are worth mentioning. Oligoclase is often found enclosing small, very perfect, six-sided pseudo-hexagonal red to brown biotites and occasionally short automorphic needles and prisms of apatite that are of a pale bluish color. Furthermore most of the rhombic dodecahedrons of garnet are enclosed in the oligoclase, a very few are in the quartz. Gas and other inclusions are very abundant in the quartz. They are much larger than those noted in any of the other rocks examined.

GENERAL DISCUSSION

According to Jacobs[10] the quartz-bearing plutonic rocks of this part of the State must be at least post-Ordovician in age because they are found intruding strata of that period. This conclusion is further substantiated by the present petrographic study, for none of the rocks examined showed any evidence of having suffered dynamical metamorphism such as might have been brought about by the Taconic disturbance had they been formed during the Ordovician or previous to that time. Field evidence just across the boundary in Quebec indicates that similar rocks are pre-Devonian in age for it is thought that they intersect Devonian strata. Jacobs[11] further states that some geologists even go so far as to put the time of intrusion as post-Carboniferous. So far no evidence has been found to show that they could or could not have been intruded at this time.

A study of Table 1 shows that orthoclase does not occur in any of the rocks that were examined. This absence of orthoclase, however, is not characteristic of this area of Vermont alone for practically none was found by the author[12] in many of the quartz-bearing plutonic rocks that he studied from widely scattered areas throughout the State. Furthermore, examination of many thin sections of these post-Devonian plutonic rocks from the Appalachian system, even as far south as Georgia, shows the same remarkable phenomenon.

Another notable fact is the relatively low percentage of potash feldspar as represented by microcline, the lowest amount being 3.42 per cent, the highest 25.5 per cent, with an average for the ten rocks of 13.0 per cent; this in contrast to the relatively high percentage of oligoclase, the lowest amount being

39.67 per cent, the highest 69.20 per cent, with an average of 56.0 per cent. These figures and the general petrographic study suggest that the township of Derby is underlain by a granodiorite batholith of which the potash feldspar-plagioclase ratio is such as to yield differentiates, the majority of which have compositions that tend toward the tonalites rather than toward the quartz monzonites. This fact expresses itself locally in the actual occurrence of tonalites as differentiates from the main granodiorite magma. The great mass of this batholith has yet to be exposed by erosion, the present exposures being stocks or bosses that are connected with the main mass.

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The Mineral Industries

ELBRIDGE C. JACOBS

The principal mineral industries of Vermont have to do with asbestos, copper (with associated silver and gold), granite, limestone, marble, slate, talc, bricks, sand and gravel. During the past few years there has been a notable increase in the amounts and values of these substances as is shown by the following table.

Dollar values:

1944	1945	6 mos. 1946	Cf. 1940
$13,244,191	$17,005,817	$10,629,000	$12,283,886

The figures for the separate products are:

	1944	1945	6 mos. 1946	Cf. 1940
Granite	$ 7,516,449	$10,805,607	$ 6,389,013	$ 7,304,356
Lime products	1,243,256	1,276,866	631,460	463,451
Slate	1,231,549[1]	1,916,976[2]	no data	no data
Talc	799,125	841,012	381,917	230,137

With the exception of slate these figures are based on returns made to the writer. Figures for asbestos, copper, and marble are withheld since only one company is producing asbestos and one company copper. Presumably the Green Mountain Marble Company is in business but letters remain unanswered.

ASBESTOS

THE VERMONT ASBESTOS MINES
Division of the Ruberoid Company

Postoffice address: Hyde Park, Vt.

Officers: President, W. B. Harris, 500 Fifth Avenue, New York City; vice-president, L. C. Rugen; assistant to the president, F. E. Byrnes; treasurer, S. D. Van Vliet, all of New York City; resident manager, M. J. Messel, Hyde Park.

Products: In the past: asbestos cement, asbestos paper, asbestos shingles, brake linings, clutch facings, molded products, paints, plastics, mill board, and perhaps other products. Because of the present demands for shingle fiber, paper stock, and cement fiber, the entire output is being converted to these grades.

Chrysotile asbestos, occurring as slip fiber and cross fiber in the serpentine rock of Belvidere Mountain, is being quarried. This mountain lies in Lowell and Eden townships, Lamoille and Orleans counties. It is shown on the Jay Peak topographical quadrangle.

Some years ago the company abandoned its old quarry on the south side of the mountain and moved its operations to the southeast side where it had

1 Includes Maine.
2 Includes New York.

developed a very large body of asbestos-bearing rock, about equally divided between cross fiber and slip fiber. The New England Mining Company had operated in this locality as early as 1901; later the Lowell Lumber and Asbestos Company, under W. G. Gallagher, worked the deposit.

The Vermont Asbestos Mines retained its mill on its old site and installed an aerial tramway to transport the rock from the new workings. This tramway is over 5000 feet long and its terminus near the mill is about 1000 feet greater elevation than the quarry. The tramway has proved to be very efficient and economical in operation.

The Gallagher quarry, as it is called, is at present about 550 feet long, 350 feet wide and 1000 feet deep. The rock is yielding about five percent in fiber. In the cross fiber section of the deposit there are many veins which might be classified as "No. 2 crude" and could therefore be utilized as high-grade milled spinning fiber as pilot plant tests have shown. Operations at the new quarry began in April 1944. Core drilling operations have proved an adequate supply of asbestos-bearing rock for many years to come.

The demand for the asbestos is much greater than the supply. Approximately 150 men are employed; they work three eight-hour shifts six days a week.

It is expected that in 1947, 400,000 tons of asbestos-bearing rock will be produced.

MINERALS

The Gallagher quarry has proved to be a new and important mineral locality. A perfect crystal of idocrase (vesuvianite) was sent to the writer some time ago and is now displayed in the Fleming Museum. In May, 1941, Professor Clifford Frondel of Harvard University visited the quarry and found besides idocrase, calcite, brucite and abundant crusts of the rare minerals, pyroaurite and artinite, as well as grussularite, malachite, diopside, prehnite, clinochlore, leuchtenburgite, and other minerals.

COPPER

THE VERMONT COPPER COMPANY, INCORPORATED

Postoffice address: South Strafford, Orange County, Vt.

Officers: Chairman of the Board, George Adams Ellis, Bennington, Vt.; president, Frederick W. Snow, South Strafford, Vt.; vice-president and general counsel, Stanley C. Wilson, Chelsea, Vt.; vice-president, E. A. de Villermont, South Strafford; treasurer, Clarence B. Benson, South Strafford.

Operating Organization: General manager, Frederick W. Snow; geologist, H. M. Kingsbury; mine superintendent, J. C. Wangaard; assistant superintendent, C. F. Banker; mill superintendent, H. A. Johnson; office manager, C. B. Benson; public relations, G. E. Northrup.

Product: Copper concentrates, silver, and gold.

In the REPORT OF THE STATE GEOLOGIST for 1941-42 an article was presented entitled "Reopening of the Vermont Copper Mines." This article gave a brief history of the mines at Corinth, Vershire, and South Strafford. It was followed, in the report for 1943-44, by "The Vermont Copper Company."

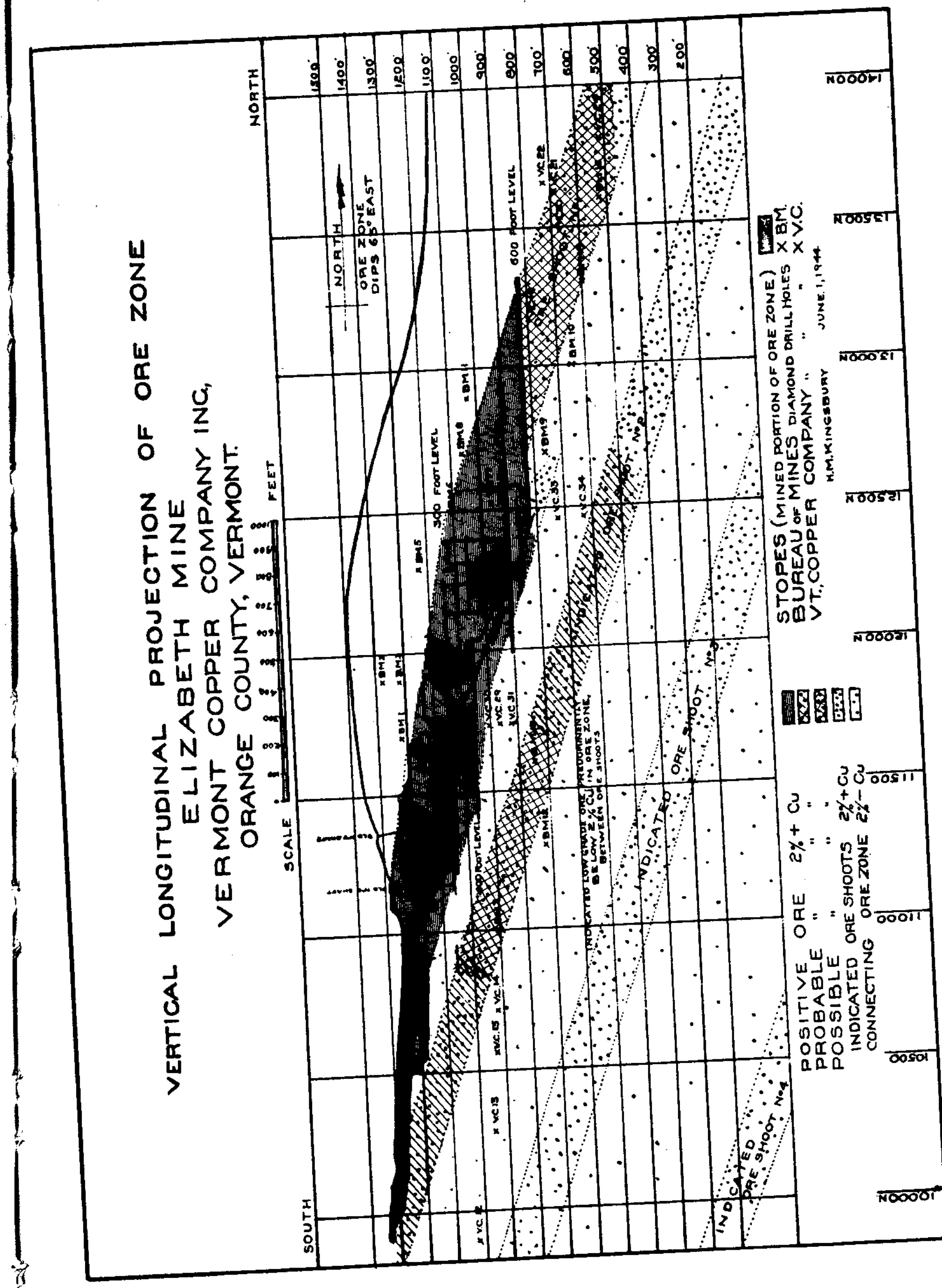


PLATE I

In this article the geology of the Elizabeth ore body was considered, together with a cross-section of the mine and a flow-sheet of milling operations.

Professor Charles G. Doll of the Vermont Geological survey made an areal survey of the Strafford Quadrangle in order to bring out the geological features of the region.

The Vermont Copper Company began operations on the Elizabeth mine in 1942 and has proceeded with the development of the mine and the production of copper. The company is now operating from the second to the sixth level, inclusive, and is finding much rich ore, some of it running as high as five percent in copper.

A new two-compartment shaft, ten by seven feet, is being sunk from the sixth level (Plate I), following the dip (63° easterly) to cut the lower ore shoots. From this shaft levels will be driven at 725 and 850 feet, respectively, below the surface.

The U. S. Bureau of Mines geophysical prospecting operations have shown several promising anomalies.

The copper concentrates are shipped to the Phelps Dodge Company, Laurel Hill, Long Island, N. Y., for smelting and refining into electrolytic copper.

PRODUCTION

	Copper (pounds)	Silver (ounces)	Gold (ounces)
In 1944	3,758,512	18,759	99
In 1945	3,806,508	19,998	101
In 1946 (Jan.-June)	3,290,000	10,000	90

Number of men employed, 150.

EXPERIMENTAL WORK

The ore carries a great deal of pyrrhotite (a sulphide of iron) which, in the past, has been a waste product. Experimental work for the recovery of the iron and sulphur, electrolytically, is being carried on.

GRANITE

Vermont has for many years stood first in the production of granite. Her granite is used almost wholly for monumental purposes although some finds use in structural work. During times of "easy money" the cemeteries are well remembered; this has been true in the war years when the companies have been put to it to fill their orders. The table (p. 87) shows rather impressively the increased business of the granite companies.

In the Barre district there has been a further consolidation of the old companies, the Rock of Ages Corporation now controlling the E. L. Smith and the Wetmore and Morse companies, but the corporate existence of each is maintained.

ACTIVE GRANITE QUARRYING COMPANIES IN THE BARRE DISTRICT

ROCK OF AGES CORPORATION

NOTE: This corporation is the consolidation of the following old companies: Boutwell, Milne and Varnum, which operated quarries in the town of Barre, and the following manufacturing plants: Barclay Brothers, Canton Brothers, E. A. Chase Granite Company, Eureka Granite Company, Grearson and Lane, Lawrence Granite Company, William Milne Granite Co., Perry Granite Corporation, Phillips & Slack, and George Stratton Granite Co. The consolidation was effected in 1930.

Main office: 206 Bank St., Burlington, Vt.

Officers: President, Roy L. Patrick; executive vice-president, Joseph T. Smith; vice-president and general manager, Alex. D. Straiton; treasurer, Athol R. Bell; clerk, Warren R. Austin.

Quarries in Graniteville.

Fabricating plants at Barre, Montpelier, Northfield, Waterbury.

Products: Mostly dark Barre granite; some light Barre.

E. L. SMITH COMPANY

Main office: Barre.

Officers: President, Donald W. Smith; vice-president, J. Wendell Smith; treasurer, Maurice W. Dewey; assistant treasurer, Bernard V. Funk.

Quarries in Graniteville and Websterville.

Fabricating plant: None. The company simply quarries granite.

Products: Light and dark Barre granite.

WETMORE AND MORSE GRANITE COMPANY

Main office: Barre.

Officers: President, Fred A. Howland; vice-president, Maurice W. Dewey; secretary-treasurer, Herbert R. Pierce; assistant secretary-treasurer, William H. Duthie; general manager, John P. Davis.

Quarries in Websterville.

Fabricating plant: None. The company simply quarries granite.

Product: Light and medium Barre granite.

WELLS-LAMSON QUARRY COMPANY

Main office: Barre.

Officers: President, Marshall J. England; treasurer, H. Brandon Jones.

Quarries at Websterville.

Fabricating plant: None. The company simply quarries granite.

Product: Light Barre granite.

JONES BROTHERS COMPANY, INCORPORATED

Main office: 10 High Street, Boston, Massachusetts.

Branch office: 700 Main Street, Barre, Vt.

Officers: President, M. Walker Jones; vice-president, Marshall J. England; treasurer, Seward W. Jones.

Quarry in Graniteville, not active at present.

Fabricating plant: 700 Main Street, Barre.

Products: Monuments and mausoleums, granite machinery, rolls for paper companies and chocolate grinding, ornamental sundials, garden seats, etc.

J. K. PIRIE ESTATE

Main office: Barre.

Trustees and managers: James G. and Fred F. Pirie.

Quarries in Williamstown.

Cutting plant: None. This company simply quarries granite.

Products: Mostly dark Barre granite; some light Barre.

EMPLOYMENT

In 1946 1,475 men were employed in the granite industry. There is still a serious shortage of labor. Strikes have been settled and nothing but the labor shortage stands in the way of increased production.

MEMBERS OF THE BARRE GRANITE ASSOCIATION, INC. JULY 15, 1946

BARRE
- Acme Granite Co.
- Adams Granite Co.
- American Granite Co.
- Anderson-Friberg Co.
- Anderson & Johnson
- Barre Blue Granite Co.
- Barre Hickey Mill
- Batchelder Co., E. J.
- Beck & Beck
- Bilodeau & Co., J. O.
- Burke Brothers
- Buttura & Sons
- Caccavo Granite Co.
- Celente & Bianchi
- Cerasoli & Cerasoli
- Chioldi Granite Co.
- Comolli & Co.
- Cook, Watkins & Patch
- Dessureau & Co.
- Giudici Brothers & Co.
- Granite Memorial Shop
- Grearson & Lane
- Green Valley Granite Co.
- Hebert & Ladrie
- Hinman Co., H. P.
- Hoyt & Milne, Inc.
- Initial Granite Co.
- Johnson & Gustafson
- Jones Brothers Co.
- Jones Brothers Dark Quarry
- Lawson Granite Co.
- Letter Granite Co.
- Marr & Gordon, Inc.
- Mascitti, Paul
- McDonnell & Sons
- Milne Granite Co., Alex.
- Modern Granite Co.
- Morlote Granite Co., S.
- Nativi Granite Co.

BARRE
- North Barre Granite Co.
- Novelli & Calcagni
- Peerless Granite Co.
- Pirie Estate, J. K.
- Revilla Granite Co., J.
- Rock of Ages Corporation
- Roux Granite Co.
- Saporiti & Co., William
- Shield Co., Waldron
- Sierra Granite Co.
- Smith & Co., E. L.
- South Barre Granite Co.
- South End Polishing Co.
- Thurber Granite Co.
- Union Granite Co.
- Usle & Perojo Granite Co.
- Valz Granite Co.
- Wells Lamson Quarry Co.
- Wetmore & Morse Granite Co.
- White Granite Co.
- Zampieri & Buttura

MONTPELIER
- Bonazzi & Bonazzi
- Capitol Granite Co.
- Desilets Granite Co.
- Everlasting Memorial Works
- Excelsior Granite Co.
- Jurras Granite Co.
- Montpelier Granite Works
- Sheridan & Poole
- United Granite Co.

NORTHFIELD
- Cross Brothers Co., Inc.
- Duprey Granite Co.

WATERBURY
- O'Clair Granite Works, C. L.

OUTSIDE THE BARRE DISTRICT

HALL, GRANITE

Proprietor: John B. Hall.
Postoffice address: Hardwick, Vt.
Products: Imperial blue and Woodbury gray granites. Both monumental and structural granite are produced.
Number of men employed: 20.

THE ANAIR GRANITE COMPANY

Proprietor: Larry Anair.
Postoffice address: Hardwick, Vt.
Products: Monumental and building granite.
Number of men employed: 8 to 10.

LIMESTONE

Vermont limestone is used for a variety of purposes: agricultural lime for soil "sweetening"; crushed limestone for building mortar, blast furnace and open-hearth flux, concrete aggregate, paper mills, glass manufacture, calcium carbide manufacture; in the finely divided condition for pharmaceutical preparations; in the hydrated form for building, chemical and agricultural purposes (see the Vermarco Lime Company); in the extremely finely divided state, for chemicals, pigments and fillers (see the White Pigment Corporation).

The total value of these products was given on page 87. The increases over 1940 are impressive.

THE OPERATING COMPANIES

THE CHAMPLAIN VALLEY LIME COMPANY

Postoffice address: Box 107, Burlington, Vt.
Officers: President and treasurer, H. D. Brewer; vice-president, C. B. Swett; clerk, E. A. Brewer.
Nature of the products: Manufacturing and processing lime and limestone.
Number of men employed: 20.

THE GREEN MOUNTAIN LIME COMPANY

Postoffice address: Box 107, Burlington, Vt.
Officers of the Company: Same as for the Champlain Valley Company.
Nature of the products: Same as for the Champlain Valley Company.
Number of men employed: 8.

THE SWANTON LIME WORKS

Postoffice address: Swanton, Vt.
Officers: President, Davis Rich, 2nd*; vice president, John P. Rich, Jr.; secretary and treasurer, Charles Rich.
Nature of the products: Lime and limestone products, sulphite lime, fluxing stone, agricultural "soilsweet," highway stone, concrete stone, rip-rap.
Number of men employed: 39.

THE VERMARCO LIME COMPANY

Postoffice address: West Rutland, Vt.
Officers: President, Redfield Proctor; treasurer, Howard V. Smith; secretary, Wallace M. Fay; general manager, Chester C. Thomas.
Nature of the product: Hydrated lime.
Number of men employed: 18.

THE VERMONT ASSOCIATED LIME INDUSTRIES, INC.

Postoffice address: Leicester Junction, Vt.
Officers of the Company: President and secretary, John M. Dalglish; treasurer, Thomas C. Pollock.
Nature of the products: Lime and limestone.
Number of men employed: 25.

* Deceased.

THE WHITE PIGMENT CORPORATION

Postoffice address: Proctor, Vt.
Officers: President, Redfield Proctor; treasurer, Howard V. Smith; secretary, Benjamin Williams; general manager, C. L. Montgomery.
Number of men employed: 60.
Nature of the products: Pigments and fillers.

The following companies and persons produce ground limestone for soil-sweetening: The Brandon Rock Products Company; L. A. Garrow, East Charlotte; Paul Robinson, Pawlet; Shelburne Lime Company, and Farrell and Webster, Shelburne; and Edward Vivie, Plymouth-Union.

Marl is produced by Will Busino and J. A. Jamieson of Williamstown; Frank Lathrop and Percy Lathrop, Arlington; and E. A. Lawson, Lyndonville.

MARBLE

THE VERMONT MARBLE COMPANY

Postoffice address: Proctor, Vt.
Officers of the Company: President, Redfield Proctor; treasurer, Howard V. Smith; secretary, Wallace M. Fay.
Nature of the product: Marble.
Number of men employed: 1,247.

During the war years the marble business, owing to the dearth of building operations, was much restricted and the Vermont Marble Company went extensively into war production. About 80 percent of the company's sales was for metal working, wood products, mica processing, radio condensers and radar cable assemblies. So outstanding was the conversion of men and machines to this work that the company was awarded the Army-Navy "E" four times.

Upon the termination of hostilities it was decided to continue in the metal-working field. About 170 men were thus employed in the fall of 1946.

Reconversion to marble work has of late been pushed rapidly. Quarries, mills and shops are again active, limited only by the available labor supply.

THE GREEN MOUNTAIN MARBLE COMPANY

No information has been received from this company.

TALC

For many years Vermont has ranked second in talc production, being exceeded only by California.

In Vermont the talc business has been good during the war years, handicapped however by the prevailing labor shortage. The labor situation is improving and there is an active demand for the mineral. The Minerals Year Book for 1945 places Vermont's production at 737,181 short tons.

OPERATING COMPANIES

THE EASTERN-MAGNESIA TALC COMPANY, INCORPORATED

Postoffice address: Burlington, Vt.
Officers: President, Joseph T. Smith; vice-president and general manager, Eugene W. Magnus; treasurer, Roy L. Patrick; clerk, John H. Patrick; assistant treasurer, Robert F. Patrick.
Products: Ground talc, floated talc, mill workers crayons.

THE VERMONT MINERAL PRODUCTS COMPANY, INCORPORATED

Postoffice address: Chester, Vt.
Officers: President and director, Harry F. Douglas; treasurer, Stanley C. Dorand; director, Roger G. Guild.
Products: Ground talc and soapstone.
Number of men employed: 14.

THE VERMONT TALC COMPANY

Postoffice address: Chester, Vt.
Officers: President, N. P. Avery, Holyoke, Mass.; vice-president and secretary, Giles Blague, Springfield, Mass.; treasurer and manager, T. A. Yager, Rutland, Vt.
Product: Ground talc.
Number of men employed: 10.

The talc deposits of the Eastern-Magnesia Company at Johnson and at Moretown have been mapped by M. P. Billings, A. H. Chidester, and A. E. J. Engel, working under the auspices of the U. S. Geological Survey. These maps may be examined at the office of the state geologist, Fleming Museum, Burlington.

SLATE

Vermont slate is largely used for roofing, either solid or in the form of slate granules set in an asphalt base. It is sold in "squares" which cover 100 square feet of roof surface exposed three inches to the weather. Other uses are electrical switchboards, lavatories, floor tile, grave vaults, billiard table tops, blackboards, and ornamental flagging. Ground slate is used for surfacing tennis courts and playgrounds. Slate flour finds use as a filler for paints, road asphalt mixtures, and the like.

The slate industry has felt the effect of renewed building and is now operating at about 50 percent of normal—two years ago it was less than five percent. The demand for slate is now exceeding production. Vermont stands second to Pennsylvania in output.

OPERATING COMPANIES

CASTLETON

The large quarries and mill of the Staso Milling Company are located in Castleton, just south of the village. Headquarters are at Poultney.

HYDEVILLE

THE HINCHEY CONSOLIDATED SLATE COMPANY

This company is a consolidation of the P. F. Hinchey Slate Company, the G. R. and J. F. Hinchey Slate Company, and the General Slate Company.
Main office at Hydeville.
Officers: President, James Hinchey; treasurer, M. H. Fain.
Quarries at North Poultney and Fair Haven.
Fabricating plants at Hydeville, North Poultney and Fair Haven.
Products: Unfading-green, unfading-mottled-purple, and green slate, sold as roofing slate and mill stock (electrical panels, billiard slabs, flooring, flagging, etc.).

FAIR HAVEN

HARVEY BUSH SLATE COMPANY

Office at Fair Haven.
Partners: Joel Griffith, Mrs. Joel Griffith, John R. Griffith.
Quarries at Scotch Hill, Fair Haven.
Products: Unfading-green, mottled, purple, and gray, sold as roofing slate.

THE FAIR HAVEN MARBLEIZED SLATE AND VERMONT STRUCTURAL SLATE COMPANY

Office at Fair Haven.
Officers: President, D. L. Carpenter; treasurer, M. A. Owens; manager, E. S. Carpenter.
Quarries at Castleton, Fair Haven, and Poultney.
Products: All unfading colors, except red, made into roofing and structural slate (flooring, electrical slate, etc.); also marbleized slate.
This company is the oldest slate company in Vermont.

MAHAR BROTHERS SLATE COMPANY, INCORPORATED

Office at Fair Haven.
Officers: President, George M. Mahar; vice-president and general manager, Thomas Mahar; secretary-treasurer, Edward F. Mahar.
Quarries at Poultney and Castleton.
Fabricating plants: Roofing slate mill at Poultney; electrical and structural slate mill at Hydeville.
Products: Unfading-purple, unfading-mottled-green, and purple-slate, sold mostly as roofing slate, but also for electrical and structural purposes.
This company also leases the Minogue Brothers and Quinn mill at Hydeville.

PEDRO BROTHERS PARTNERSHIP

Office at Fair Haven.
Partners: Joseph Pedro, Rivese Pedro, Tony Pedro, John Foote, Dominic Sbardella.
Quarry at Scotch Hll.
Products: Unfading-green, mottled-green, purple, and gray slate, sold for roofing slate and flagging.

W. H. PELKEY, INCORPORATED

Product: Roofing slate.

C. R. BEACH

Office at Fair Haven.

POULTNEY

THE CAMBRIAN SLATE COMPANY

Office at Granville, N. Y.
Officers: President, David O. Roberts; secretary-treasurer, Iola San.
Quarry at Poultney.
Products: Sea-green and variegated roofing slate.

FRED GRAVES

Product: Roofing slate.

LANDSCAPE SLATE AND ROOFING COMPANY

Office at Poultney.
Officers: President, D. O'Brien; vice-president, W. H. Williams; treasurer, R. I. Williams; sales manager, G. W. Sutter.
Quarries at Poultney.
Products: Roofing and flagging.

H. A. MATOT

Product: Roofing slate.

THE STASO MILLING COMPANY

Office at Poultney.
Officers: President, John W. Powers; secretary-treasurer, W. F. Krohn; general manager, Charles T. Kett.
Quarries at Castleton and Poultney.
Processing plants at Castleton and Poultney.
Products: Slate granules (green, red, and other artificial colors).
The company also has quarries and mills in Maryland, Georgia, Missouri, and Michigan.

THE UNITED SLATE COMPANY

Product: Roofing slate.

INTERNATIONAL SLATE COMPANY

Office at South Poultney.

THE VERMONT SLATE FLOORING CORPORATION

PAWLET

OWEN W. OWENS' SONS, INCORPORATED

Office at Granville, N. Y.
Officers: President, D. O. Owens; vice-president, W. R. Owens; secretary, D. O. Owens, Jr.
Quarries and mill at Pawlet.
Product: Roofing slates.
Note—The Progressive Slate Company of Granville has been merged with this corporation.

THE O'BRIEN SLATE COMPANY, INCORPORATED

Office at Granville, N. Y.
Officers: President and secretary-treasurer, James O'Brien.
Quarries at Pawlet.
Product: Roofing slate.

WEST PAWLET

RISING AND NELSON SLATE COMPANY

Office at West Pawlet.
Partners: S. M. Rising, T. S. Nelson, A. H. Morrill.
Quarries and mills at West Pawlet, Poultney, Fair Haven, and in Maine.
Products: Roofing, flagging, flooring, etc.

OWEN L. WILLIAMS AND SON

Postoffice address: Granville, N. Y.
Office and quarry at Wells, Vt.
Products: Roofing slate and flagging.
Dealers in all slate products.

About 400 men are employed in the slate industry.

SAND, GRAVEL AND CRUSHED STONE

VERMONT DEALERS IN SAND AND GRAVEL

H. G. Calkins	Lyndonville
R. J. Cone	Woodford
Dailey Crusher	Shaftsbury
R. W. Overocker	Burlington
Rutland Sand & Gravel Co.	Rutland
Vermont Stone Products Co.	Burlington & Morrisville

DEALERS IN CRUSHED STONE

Barton Construction Co.	Barton
Alfred Perotta, red quartzite	Burlington
Fonda Junction Lime Company, limestone	Fonda Junction
H. B. Huntley, limestone	Leicester Junction
Rutland City Quarry	Rutland
St. Albans City Quarry	St. Albans
Swanton Lime Works, limestone	Swanton
Vergennes City Quarry, dolomite	Vergennes
Vermont Stone Products Co.	Burlington & Morrisville
Wells-Lamson Granite Co., granite	Barre

SOAPSTONE

THE VERMONT SOAPSTONE COMPANY

Office and mill at Perkinsville.
Proprietor: John H. Hicks.
Products: Soapstone sinks, wash tubs, griddles, laboratory fittings, etc.

The company obtains its soapstone from the Holden quarry, near Chester, and from Virginia.

BRICKS

As far as is known, only two companies are making bricks in the state.

THE DRURY BRICK COMPANY

Postoffice address: Essex Junction, Vt.
Officers: President, H. K. Drury; treasurer, M. W. Drury.
Product: Sand-struck bricks.
Output in 1946: 4,500,000 bricks.
Number of men employed: 45.

THE BENNINGTON BRICK COMPANY

Proprietor: Peter Lemieure.
No further information has been received.

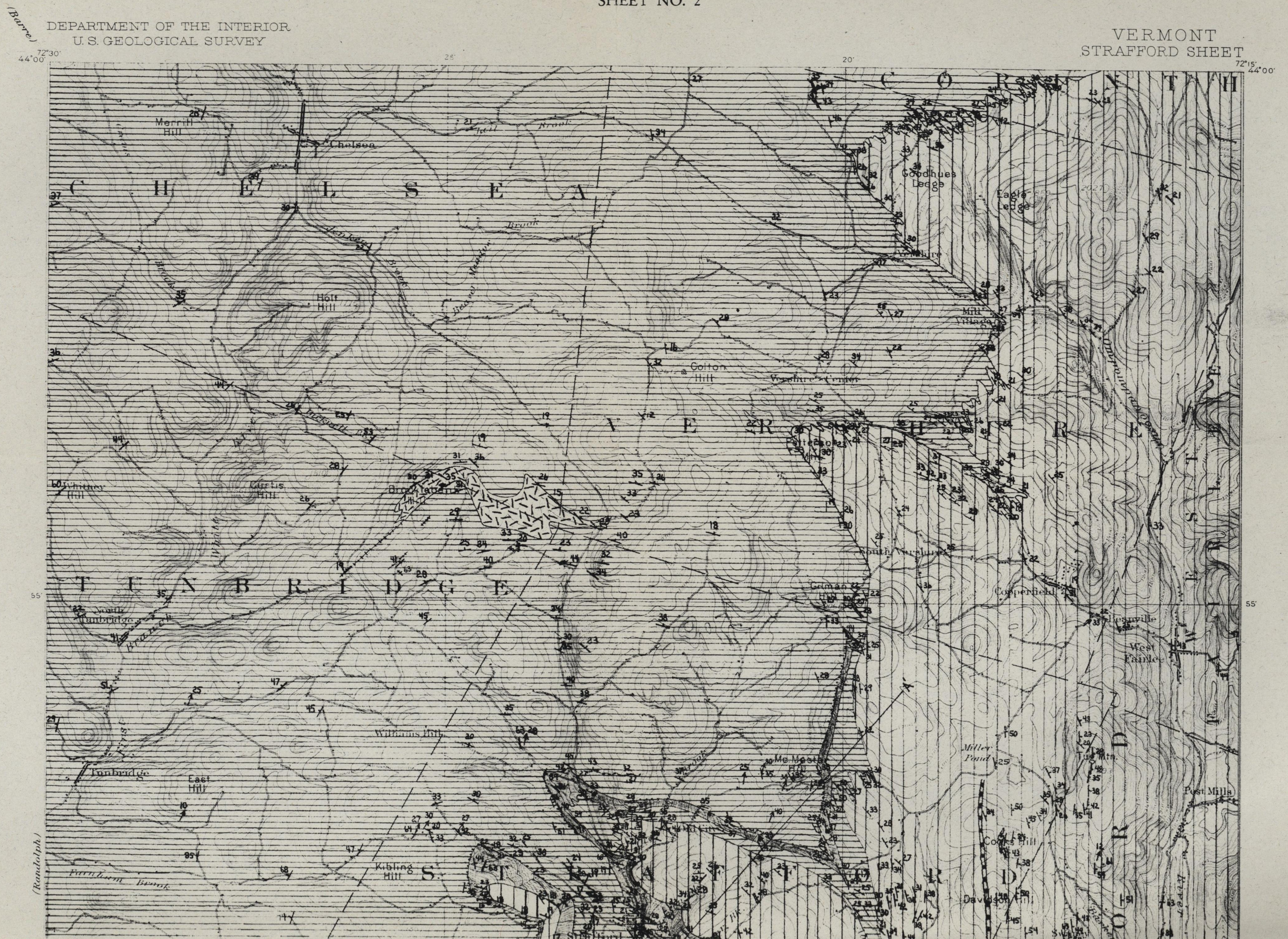
NUMBER OF MEN EMPLOYED IN THE MINERAL INDUSTRIES, 1946

Asbestos	150
Copper	150
Granite	1,475
Lime	170
Marble	1,247
Talc	103
Slate, about	400
Others	45
	3,740

In 1940, 4,062 were employed.

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE STRAFFORD QUADRANGLE, VERMONT

SHEET NO. 2



43°45' 72°30' (Woodstock)

ENGRAVED OCT. 1896 BY U.S.G.S.

25' (Hanover) 20'

72°15' 43°45' (Mascoma)

Henry Gannett, Chief Topographer.
H. M. Wilson, Chief Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by G. E. Hyde and Jas. McCormick.
Surveyed in 1894.

Hyde | J.McC.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 20 feet
Datum is mean Sea level

Edition Dec. 1896, reprinted 1937

Polyconic projection. North American datum

This area surveyed by reconnaissance methods. Maps of adjacent areas surveyed by modern methods may not join this sheet exactly

VT.
STRAFFORD

Geology by Charles G. Doll, 1942, 1943, 1944

Middle Si
Probabl
Lower Dev

Memphremagog formation

Arenaceous, micaceous, dolomitic limestones and mica schists.
SPa, Standing Pond amphibolite (needle amphibolite conspicuous)
gs, coarse garnet schist occurring with amphibolite

Contacts

Special Symbols

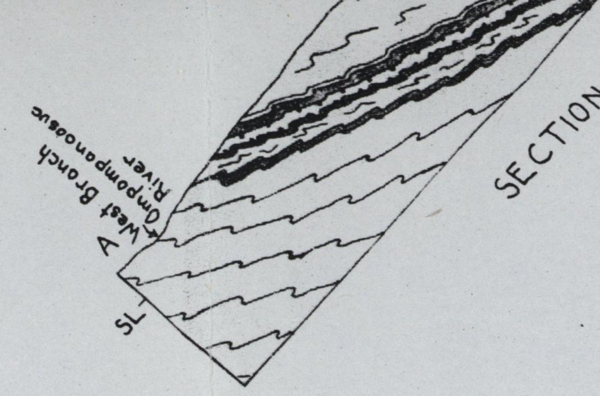
60
Dip and strike of bedding and schistosity including inverted beds

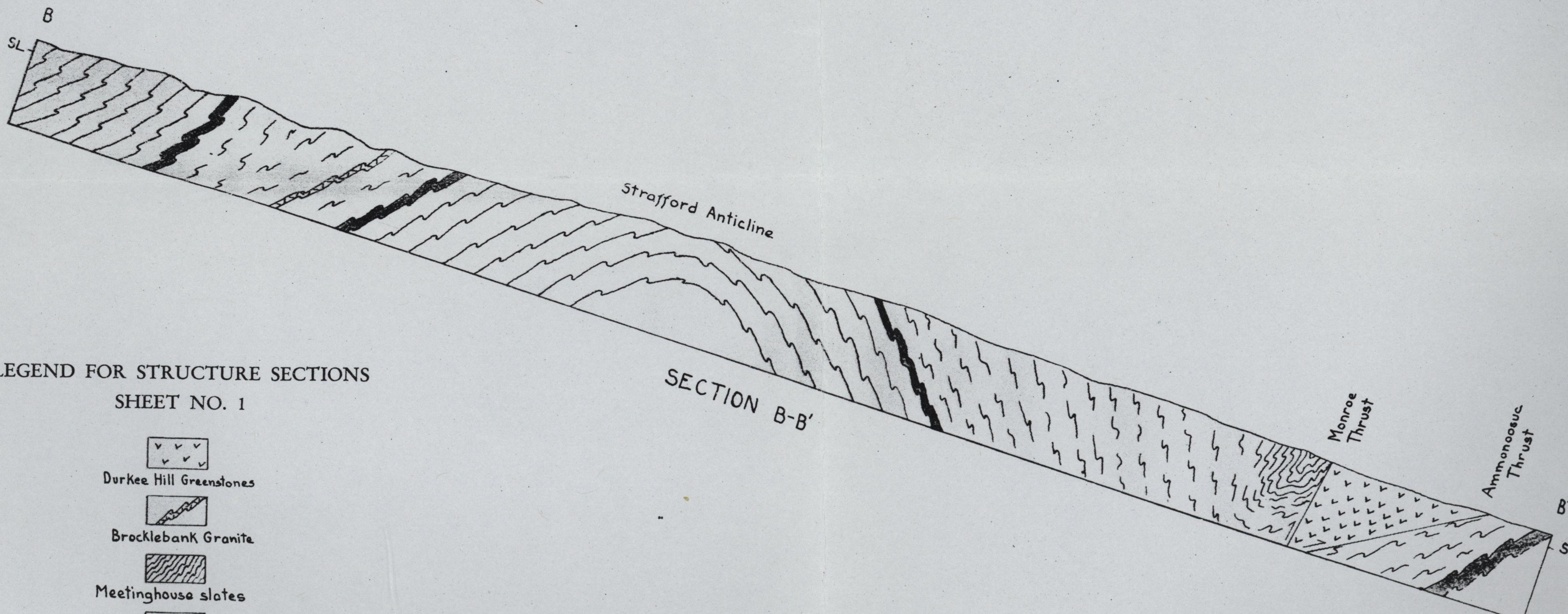
Strike of vertical beds

20
Plunge and trend of fold axes

Overthrust side of thrust faults

Mines, prospects, and quarries





LEGEND FOR STRUCTURE SECTIONS
SHEET NO. 1

Durkee Hill Greenstones

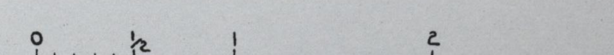
Brocklebank Granite

Meetinghouse slates

Gile Mountain schists

Memphremagog formation

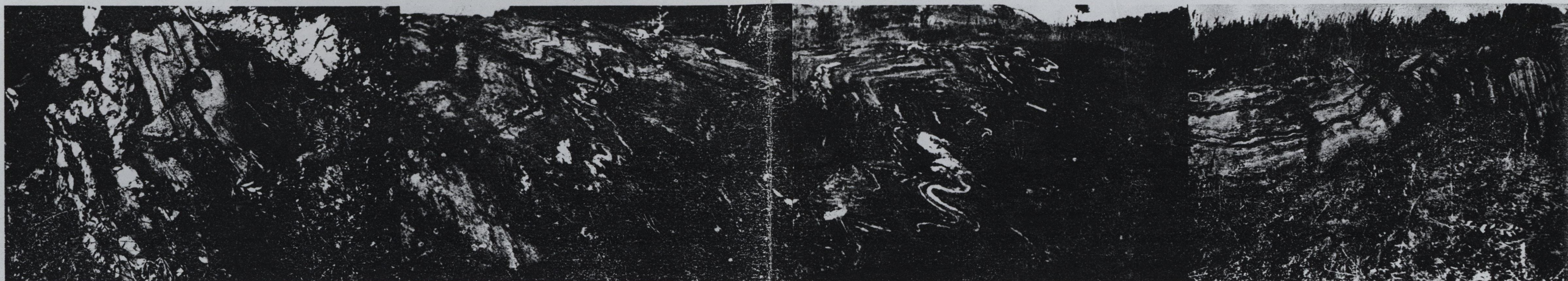
Relationship of Structure Sections to Geologic Map is shown by placing Sheet No. 1 over Sheet No. 2. (See A - A', B - B'.)



Scale in Miles

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE STRAFFORD QUADRANGLE, VERMONT

SHEET NO. 1



Figures 1 - 4, Showing Bedding—Schistosity Relationships

LEGEND FOR GEOLOGIC MAP
SHEET NO. 2

Post-Devonian

Basic diKes and sills

Late or Post-Devonian

DurKee Hill Greenstones

BrocKlebanK granite and associated diKes and sills

Lower Devonian

—Mhs
—ca

Gile Mountain schists

Mica schist, quartz-mica schist, garnet-mica schist, biotite schist graphitic schist, arenaceous schist, quartzite, some staurolite, kyanite, and sillimanite schists. ca, coarse amphibolite. Mhs, Meetinghouse slate, gray to black.

Middle Silurian Probably Lower Devonian

-gs
-SPa

Memphremagog formation

Arenaceous, micaceous, dolomitic limestones and mica schists. SPa, Standing Pond amphibolite (needle amphibolite conspicuous) gs, coarse garnet schist occurring with amphibolite