# THE GEOLOGY OF NEW HAMPSHIRE.

CONTENTS.



THE first public notice of the importance of examining the mineral resources of New Hampshire is contained in a message of Governor Levi Woodbury to the legislature in 1823. He recommended the institution of an agricultural survey with a view to chemical analyses of the various kinds of soils. Had this recommendation been adopted, New Hampshire would have been the first of the United States to inaugurate a scientific survey of her mineral resources.

*The First Geological Survey.*—In 1839, after earlier suggestions from the executive, the legislature passed an act to provide for the geological and mineralogical survey of the state, appropriating for the purpose the sum of two thousand dollars annually for three years. Dr. C. T. Jackson, of Boston, received the appointment of geologist, and with several assistants conducted the work of the survey, and published the following reports:

First Annual Report on the Geology of the State of New Hampshire, 8vo, 164 pp., 1841.

Second Annual Report on the Geology of the State of New Hampshire, 8vo, 8 pp., 1842.

Final Report on the Geology and Mineralogy of the State of New Hampshire, with contributions toward the improvement of Agriculture and Metallurgy, 4to, 378 pp., 11 plates, 1844.

Views and Map of the Final Report, reprinted, 4to, 20 pp., 8 plates, 1845.

The character of this final report may be summarized as follows: 44 per cent. of the pages is occupied with a description of the method of procedure and notes upon the geological and mineralogical results in the form of an itinerary; 20 per cent. relates to economic geology; 22 per cent. to agricultural geology and chemistry, and the remaining 16 per cent. is devoted to such miscellaneous topics as barometrical tables, the official documents relating to the survey, glossary and index. One of the assistants, was Professor J. D. Whitney, of Cambridge; Dr. E. E. Hale, of Boston, aided in the exploration of the White Mountains.

The method of exploration or reconnaissance adopted by Dr. Jackson was based partly upon the structure. Knowing that the strata pursue a general northeast course, it was proposed to cross them several times at right angles to their outcrops, and also along the lines of strike. These lines divided the territory into triangular areas whose outside boundaries became known, and the various excursions for study were planned across several tracts, depending somewhat upon roads and settlements. Four cross sections are described and figured, viz., from Portsmouth through Concord to Claremont; from Concord to Wakefield; from Concord to Winchester; from Winchester to Haverhill. There is also a longitudinal section along the Connecticut River from the Massachusetts line to Haverhill; and from Haverhill to the extreme northern part of the state. Six distinctions are made: (1) Granite, syenite and gneiss; (2) mica slate; (3) hornblende rock; (4) argillaceous slate; (5) drift; (6) alluvium. Symbols indicate the location of twenty kinds of ores and minerals, quarries, dips of strata and anticlines.

The nature of the work was mineralogical. Scarcely any assistance was acquired from these reports for the later geological studies. The general view of age and structure presented was that of the older authors, all granite being regarded as "Primary," and the dips of the strata outward in every direction from an igneous center. This conclusion is best shown in an ideal section across northern New England. At the White

Mountains granite prevails, having mica slate and gneiss dipping to the east in Maine; similar rocks occur on the west side, together with "Cambrian," all inclined towards Lake Champlain. The Green Mountains are made out to be an immense mass of quartz rock. There seems to be an important element of truth in this representation, while the details cannot be relied upon. In the neighborhood of the White Mountains the older rocks make their appearance, but granite does not constitute the central axis of the White Mountains; the strata are not uniformly regular in their dips outward from the axis, and the Green Mountains are not made of quartzite.

It is difficult to find accurate reports of the cost of Jackson's survey, but it would appear probable that the explorations and studies cost less than $10,000, and the expense of publication was met by other appropriations. Owing to the wish to reduce the size of the last item of expenditure, the map has no coloration, so that it is difficult to pronounce upon its value.

*The Second Geological Survey.*—In 1868 the legislature passed an act providing anew for the geological and mineralogical survey of the state, for which the sum of $3500 was annually appropriated. It was stipulated that brief annual reports showing the progress of the survey should be made, and "when the survey shall be completed, a report of the same, accompanied by such maps and drawings as may be necessary to elucidate and exemplify the same, shall be published under the direction of said state geologist."

On the eighth of September 1868 the writer was appointed state geologist by Governor Walter Harriman. The work was prosecuted for ten fiscal years, the time used for exploration being somewhat less than would appear from the records. So far as the survey had a connection with the state government, its enabling act carried two favorable provisions: (1) It was not necessary to go before the legislature every year with a request for a new appropriation. If this had been the case, probably the life of the survey would not have extended beyond three years. (2) Only brief reports of progress were expected annually.

I have taken great pains to determine exactly the cost of every part of this survey to the state, including the explorations, printing the annual and final reports, but not the cost of distribution.

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| Expenses of exploration and study, - - | $32,199.27 |
| Annual reports (1500 copies), - - - | 1,459.80 |
| Final report (1000 copies), - - - - | 33,959.17 |
| Relief map and cases for museum, - - | 500.00 |
| | $68,118.24 |

The following titles express the official reports to the state:

First Annual Report upon the Geology and Mineralogy of the State of New Hampshire, by C. H. Hitchcock, state geologist, 12mo, 36 pp., 1 map.

Second Annual Report upon the Geology and Mineralogy of the State of New Hampshire, by C. H. Hitchcock, state geologist, 8vo, 37 pp., 1 map.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1870, by C. H. Hitchcock, state geologist, 8vo, 82 pp.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1871, by C. H. Hitchcock, state geologist, 8vo, 56 pp., 1 map.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1872, by C. H. Hitchcock, state geologist, 8vo, 15 pp., 1 map.

The Geology of New Hampshire. A report comprising the results of explorations ordered by the legislature, by C. H. Hitchcock, state geologist, J. H. Huntington, principal assistant. Part I. Physical Geography, Royal 8vo, 680 pp., 49 plates, 1874.

The Geology of New Hampshire, etc., by C. H. Hitchcock, state geologist, J. H. Huntington, Warren Upham, G. W. Hawes, assistants. Part II., Stratigraphical Geology, Royal 8vo, 696 pp., 40 plates, 1877.

The Geology of New Hampshire, etc., by C. H. Hitchcock, state geologist, J. H. Huntington, Warren Upham, G. W. Hawes, assistants. Part III., Surface Geology. Part IV., Mineralogy and Lithology. Part V., Economic Geology. Royal 8vo, 760 pp., 30 plates, 1878.

Atlas accompanying the report on the Geology of New Hampshire, by C. H. Hitchcock, state geologist, 1878. Folio containing seventeen maps and profiles.

*Peculiarities of this survey.*—Geological surveys may be classified in groups. Those prosecuted in the same decade will be found to be very much alike. The surveys more or less coeval with that of New Hampshire, 1868 to 1878, were the following: Canada, where the directorship was transferred from Sir W. E. Logan to A. R. C. Selwyn in 1870; the geographical and geological work in the territories under F. V. Hayden extending from 1867 to 1878; the fortieth parallel survey under Clarence King, 1867 to 1880; the Wisconsin survey, T. C. Chamberlin, 1873 to 1879; the Michigan survey, 1869 to 1876, under Rominger, Brooks and Pumpelly, and the Ohio survey under Newberry, 1869 to 1878. The second geological survey of Pennsylvania began in 1874, and that of Minnesota in 1872. It was an honor to any geologist to have been a contemporary worker with the gentlemen who directed these several surveys. But the style of work in vogue then should not be expected to equal that which is being executed in the nineties, with the multitudinous facilities of the later period.

The new methods of petrographic study were first exemplified in these surveys by the report of Ferdinand Zirkel upon Microscopical Petrography for the Fortieth Parallel organization in 1876, and by Dr. G. W. Hawes upon the Mineralogy and Lithology of New Hampshire in 1878. Both of these treatises were models in their way, and were carefully studied by workers in this field for many years. Mineralogists not connected with surveys engaged in corresponding studies even earlier. Dr. Hawes continued his investigations into some of the New Hampshire rocks after the publication of his report, as is evidenced by his descriptions of the contact phenomena between the Albany granite and mica schist upon Mount Willard, and upon the dissimilar dikes found at Campton. His early death cut short a most promising career.

The progress of the New Hampshire survey was much retarded by the presence of a dense forest covering an area of 2000 square miles in the northern portion of the state, and by the difficulties of transportation. All this mountainous forest had to be traversed on foot mostly without paths or guides. From the summit of Mount Washington a sea of mountains is visible. Every one of them was visited by some member of the survey, observations made and specimens preserved for study. At the present time railroads thread three-fourths of this forest country, and by excavations and the removal of the forests, facilities for exploration have been greatly increased. Had the survey of this region commenced fifteen years later, the information acquired could have been gathered in a fourth part of the time actually taken.

*Connection with work in adjoining territory.*— The geology of New Hampshire is intimately connected with that of Vermont and Canada. The writer had fortunately been connected with the survey of the former as principal assistant, and was familiar with what had been published for both adjoining districts, and had taken pains to revisit typical and extra-limital areas during the progress of the explorations. The published New Hampshire map covers fully a third part of eastern Vermont and an important section of Canada, for which information was based upon a manuscript left by Sir W. E. Logan, interpreted in the light of later studies. The chief support of our stratigraphical conclusions lay in the anticlinal structure of the Green Mountains. My advisers, Professor James Hall, Sir W. E. Logan, and Professor J. D. Dana, taught me that this structure was synclinal. After measuring thirteen general sections across this range, it became clear that my guides were in error. Their great anxiety to maintain the synclinal notion had been exerted in order to sustain the doctrines of the metamorphism of the crystalline rocks and their Palæozoic age. With the determination of the anticlinal attitude quite a different interpretation of age resulted, as well as less respect for the theories that had led my masters astray.

A word in reference to the determination of this structure. C. B. Adams in his Annual Reports (1846–8) states the questions at issue in respect to the age of the crystallines, without endorsing either view. Having noted the existence of quartzite and limestone in Plymouth upon the east side of the range, he queries whether these rocks may not be repetitions of the granular quartz and Stockbridge limestone. Other facts show that Adams favored the metamorphic view—and it is supposed influenced his successor Zadock Thompson to draw up an elaborate section along the Winooski River between Burlington and Waterbury, exhibiting a fan-shaped stratification. After taking charge of the Vermont survey, my father commissioned me to measure and protract on paper the thirteen general sections across the state. From these plans he drew various conclusions, including the anticlinal attitude of the Green Mountains, without referring either to his theoretical Hoosac section of 1847, or to the Canadian belief in a synclinal, or to its importance in the development of the more eastern terranes. Since 1861[1] I have several times insisted upon the fact and its importance, maintaining at first that Logan's description of Sutton Mountain favored the anticlinal view. Selwyn corrected Logan's error in 1877. Professor Dana acquiesced in this view in 1882. Of late it has been confirmed by Professor Pumpelly[2] for the Hoosac Mountain, and by Mr. C. L. Whittle[3] for the range at Mt. Holly. At my first visit to Montreal (1857) Sir W. E. Logan referred the chief part of Canada adjoining Vermont to the Oneida conglomerate. After 1860 he devised the "Quebec group," subdivided into the Levis, Lauzon, and Sillery formations, supposed to be allied to the Calciferous and Chazy. It was his coloration of the maps next the international boundary, classified into these three divisions, that I copied on my map of New Hampshire as part of the Huronian, or the hydro-mica schists. In my first two annual reports I used the name of Quebec for these rocks, changing later at the instance of Dr. Hunt, who claimed them to be partly, at least, older than Cambrian, or equivalent to the Huronian of Ontario. Our use of terms was dependent upon the terminology employed by our Canadian neighbors, as they were the originators of the various expressions employed. Still another modification of the nomenclature will be presently alluded to.

*Topographical results.*—The map in our atlas was drawn upon

[1] Geological sections across New Hampshire and Vermont, Bull. Am. Mus., N. Y., Vol. I., 1884.

[2] Geology of the Green Mountains in Massachusetts. Monograph XXIII. of the U. S. G. S.

[3] JOURNAL OF GEOLOGY, Vol. II., p. 296.

the scale of two and one-half miles to the inch, to match the Massachusetts work of Simeon Borden in 1842, adding to his delineations approximate contours for every hundred feet. It was based upon the United States government map of the international boundary (1842), special triangulation under our direction, the early and late determinations of the United States coast and geodetic survey, combined with detailed compilations from the county odometer road surveys. Without pretense to special merit, it has been pleasant to us to compare the best parts of this map in the White Mountains and the southeast part of the state with the beautiful sheets of the United States geological survey, when enlarged to their scale. That experts should at first have placed higher value upon this map than it deserved is not the fault of its compilers.

## DETERMINATION OF THE ORDER OF THE GROUPS OF SCHISTS.

In establishing the New Hampshire stratigraphical column the attempt was first made to construct it independently of the existence of similar rocks elsewhere. Certain principles were accepted as well established. One of them was that crystalline schists constitute stratified formations, capable of being identified in different districts by their mineral composition. Among the groups capable of ready recognition were the following: gneiss, ordinarily consisting of the three constituent minerals, quartz, feldspar and mica, with no accessories; and this was termed *common*, or from a locality, *Lake Winnipisoegee* gneiss. This for convenience was shortened to *Lake* gneiss, and seemed to be equivalent to the lower part of the Green Mountain series. In another area mica was replaced by chlorite, giving rise to chloritic gneiss, protogene or locally *Bethlehem* gneiss. Another peculiar variety was termed *Porphyritic*, corresponding to the *Augengneiss* of Central Europe. The occurrence of large crystals of feldspar seemed to be more noticeable than the presence of black spots with the white, producing a resemblance to eyes. It was also found that sometimes this porphyritic rock was devoid of foliation—the crystals were disposed at random instead of being arranged in lines—and our observations were never extended so far as to be able to declare that these differences were of importance.

Of the mica schists one range abounded in *fibrolite*, a second in *andalusite*, and a third in *staurolite*. No two of these minerals were combined in the same set of schists, while all the bands are related to one another. The *hydro-mica-schist* group contained associated bands of chlorite schist, quartzites, bedded diorites, diabases and protogenes; and had before our time been known as "talcose slate." No local term was applied to this complex, as it was supposed to represent the *Huronian* group of Canada, with which it had strong points of resemblance. *Hornblende-schist* proved to be common, and, with some misgiving, was relegated to the base of the hydro-mica groups. These several groups of schists were believed to belong to as many distinct periods of growth, each with its peculiar conditions.

Inasmuch as the formations possessed northerly trends, sections in east and west lines would most economically represent their structure, and hence the Dartmouth museum has a special large case prepared upon which fifteen sections are arranged in geographical order extending from Maine to New York across New Hampshire and Vermont. This collection contains about 3000 specimens, which are still further elucidated by geologically colored profiles and a large relief map.

A second principle employed was the discovery that the crystalline schists of New England tended to assume ovoidal shapes exhibiting a banded structure. Reference was made to the groups of Percival in Connecticut, $K_1$, $K_2$ and $K_3$, as well as to the $B$ of the Eastern Primary. The center of the oval seems to be the oldest part. Dr. A. C. Lawson[1] describes similar areas in the Rainy Lake district north of Lake Superior, as does Professor A. Winchell[2] in Minnesota and Professor B. K. Emerson[3] in western Massachusetts.

As there is no readily recognizable base to the New Hampshire rocks, it was found necessary to fix upon some convenient

[1] Ann. Rept. Geol. Can., 1887.

[2] Bull. Geol. Soc. Amer., Vol. I., p. 361.

[3] *Ibid.*, p. 559.

starting point where the succession seemed obvious. The horizon selected was the superposition of hornblende-schist upon gneiss. My first work of a stratigraphical nature had been the study of a low anticline of this nature at Shelburne Falls, Mass.[1] At the base was a well defined gneiss, capped in succession by hornblende-schist, mica-schist and the same with interbedded limestones.[2] The first two rocks occupied quite a small area, and were exposed only through denudation. On proceeding northerly similar relations of gneiss and hornblende-schist were seen upon several of our sections. Hence the generalization, hornblende-schist overlies gneiss. The next point was to follow out the distribution of these two rocks. The gneiss of the Halifax-Hartland range proved to be a well-defined geanticlinal sixty miles long, dipping westerly to reappear in the Green Mountain gneissic area, and dipping easterly to reappear in the gneisses of Cheshire, Sullivan and Grafton counties, traceable for over one hundred miles with a westerly dip. On traversing the country to the east still other gneisses appear. Hence the second generalization, there exist several parallel anticlines of gneiss, connecting the Green Mountain and Lake areas. But two of these ranges cover an area of porphyritic gneiss, between Jaffrey and Groton, sixty miles in length, thirteen miles in its greatest breadth, following the height of land between the Connecticut and Merrimack rivers. Its stratification is obscure, while the representation of the dips upon the six revised sections crossing it, conform to the notion of its inferior position. Nothing has been found underlying this rock, so that it must be considered as the base of the crystalline succession for New England. More than twenty patches of this basal gneiss occur in the state, a few carrying fibrolite schist and one contains fragments of a dark gneiss—possibly an older layer.

The place of the chloritic (Bethlehem) gneiss is not so readily determined. It occurs only on the east slope of the Connecticut

[1] Proc. Boston Soc. Nat. Hist., Vol. VI., p. 330.

[2] Upon the Hawley sheet Professor Emerson describes the same succession, using the local names, Becket gneiss, Hawley amphibolite, Goshen schist and Conway schist.

Valley in six or eight isolated areas, interspersed over a distance of a hundred and twenty-five miles, and covered by hornblende-schist occasionally. It has been located between the porphyritic and lake gneisses. The hornblende schist does not guide us satisfactorily to the upper formations; and hence other considerations must be taken into account in the further attempts at classification. Most of the remaining rocks are some form of mica schist. They are plainly above the gneisses, for wherever any of them come in contact with the feldspathic rocks they are superincumbent. They have been distinguished as the *Montalban*, or mica schists carrying some feldspar with fibrolite or andalusite; the group of *hydromica schists; Rockingham mica schists; Merrimack group* and *Ferruginous slates*. After detailed studies our conclusion was that the Montalban preceded the hydromica schist which were closely related to the Kearsarge and Merrimack schists and the Ferruginous slates of Hillsborough county. The Rockingham schists simulated the Montalban.

The hydro-mica schists are arranged primarily in two divergent lines, which are assumed to represent one grand formation, whatever its place in the scale may be. The best known is that which starts in western Massachusetts under the old name of talcose schist, passes through central Vermont east of the Green Mountains and continues past Quebec parallel to the St. Lawrence River. Both the Vermont and Canada surveys recognized a similar (third) belt on the west side of the Green Mountains, extending as far south as Middlebury. The eastern line begins at Bellows Falls and is nearly continuous along the Connecticut to the mouth of the Passumpsic River, and thus expands to as great a width as that of the central belt, and it continues through the western edge of Maine into the Gaspè peninsula. Ranges of gneiss flank both these hydro-mica belts, viz., the Green Mountain gneiss upon the west and the Connecticut band of lake gneiss on the east, and with the same synclinal disposition. Inside of the hydro-mica schists are belts of argillite, which seem to follow the same synclinal law of distribution. There is left between the argillites an immense area which has been designated the Calciferous mica schist, and it naturally completes the filling of the basin. This is the formation that was described in my Shelburne Falls section in 1858, with the same two divisions. There is a great development of rocks related to the lower division along the Connecticut Valley that were presumed to represent the lower part of the Calciferous, and they received the name of Coös group, consisting of a basal quartzite, mica-schists, hornblende-schists, staurolite-mica-schists and slates, several thousand feet in thickness. The early Canadian reports regarded the Calciferous schists as of Niagara age. Our report regards all these schists as the most modern of the stratigraphical column, but does not insist upon their identity with the beds carrying fossils.

An important chapter would relate to the discovery of fossils in New Hampshire. They were found at Littleton in 1873 and referred to the Lower Helderberg by E. Billings, palæontologist to the Canadian survey. Later discoveries have proved the Niagara age of the enclosing rock, because of the presence of *Halysites* or chain coral and *Pentamerus nysius*. The rocks connected with the fossils are limestones, slates and sandstones, more like the Coös bands than the Calciferous. They have been followed down the Connecticut to connect with the fossiliferous limestone and sandstone of Bernardston, Massachusetts, belonging to the Devonian. Niagara fossils are also known from the west shore of Lake Memphremagog.

The column thus established from structural evidence consists at the base of the porphyritic or *Augengneiss* followed by the Bethlehem or chlorite gneiss, and the ordinary lake gneisses, amounting to at least 28,000 feet in thickness, if foliæ are to be esteemed capable of measurement. In the view of the report, the immediately ensuing 12,000 feet of gneissic-mica schists or Montalban occupied an intermediate place between the gneisses and the hydro-mica-schists. These last were subdivided in the Connecticut belt into the Libson chlorite schist, the Lyman argillitic (*Urthonschiefer*) schist and the auriferous conglomerate, in all 12,000 feet thick. In the central belt the triple classification of Logan into the Levis, Lauzon and Sillery was recognized. In the central and southern part of the state was a great development of mica-schists of about the same thickness, called locally the Rockingham, Kearsarge and Merrimack groups. The well recognized Palæozoic rock of the northern parts of the state foot up about 16,000 feet, and were named the Cambrian slates, Coös group, Calciferous mica schist and the Lower Helderberg.

*Correlation with recognized standards.*—Having established an order of succession, our next effort was directed to their correlation, with the generally recognized sequence elsewhere. In Canada the order was that of Laurentian, Labrador, Huronian and Cambrian; in southern New England no satisfactory determinations were available. The porphyritic gneiss naturally allied itself to the *Augengneiss* of the Laurentian of Canada and elsewhere. The Bethlehem gneiss had more affinities with the same group than any other; and we were fortified in our conclusions by the independent and unsolicited opinions of Professor J. D. Dana and Dr. T. Sterry Hunt. It was difficult to know where to place the lake gneiss, if not in the same general group. The Manchester and Berlin ranges rendered this reference easy because of their saccharoidal character. Other areas contained beds of magnetite, limestone and plumbago, but none of the Adirondack pyroxenic rocks occurred in any of them. Hence, the three schistose groups would seem to correspond in general with the Ottawa and Grenville divisions of the Canadian Laurentian. While referring the gabbros to the Labrador system, it was expressly stated that they could be regarded only as an igneous rock, and hence not properly a stratified system.

If these gabbros represented an igneous action occurring in the later Laurentian of Canada, then the schists penetrated by them in New Hampshire must have been equally ancient or Archæan. Hence the origination of the term *Montalban*, representing a terrane younger than the Laurentian and older than the Huronian.[1]

[1] This does not correspond to the signification attached to this word later by Dr. T. Sterry Hunt.

As thus defined the New Hampshire Montalban is like the *Coutchiching* division of Ontario, proposed by Professor A. C. Lawson for a system that occupies just this horizon.

The hydro-mic-aschists and associated diabases, etc., corresponded well petrographically to the Huronian complex, and were so referred. At first it was thought that our White Mountain porphyries might be referred to the lower Huronian or Arvonian of Dr. Hunt, but the reasons demanding the removal of the gabbro from the stratified systems prevailed equally well as applied to the porphyries.

As to the various mica-schists and related rocks, called locally Kearsarge, Merrimack and Rockingham, no satisfactory reference could be made; and hence they were called Palæozoic in general, their alliance being obviously Huronian or Cambrian. The argillites were all referred to the Cambrian, having in mind the fact that this seemed to be the place for rocks of this class, whether in Vermont (Georgia), Massachusetts (Braintree), or Nova Scotia. The Coös quartzites, schists and slates, also the Calciferous mica schists all received an assignment to horizons superior to the Cambrian.

*An improved classification.*—The question now arises, How can our early classification be improved? It is eighteen years since the New Hampshire report was published, and there are many new workers in the field, all placing great reliance upon petrographical principles, such as were inaugurated in Dr. Hawes' report. Some are advocates of extreme metamorphism, and hence the conclusions are not harmonious. It seems to us that our early views may be modified by the following principles: (1) The mineral characters of crystalline rocks are not a sure guide to geological age. (2) Protogenes, diabases and diorites more or less interstratified with hydro-micas are of true igneous origin. (3) The Archæan gneisses and protogenes may also be of igneous origin, and their apparent stratification has no connection with sedimentary or chemical deposition. (4) The Huronian[1] era may properly represent the beginning of sedi-

[1] There seems to be no need of introducing a new term—Algonkian—to replace

mentation. The first sediments must have been accompanied by a greater flow of eruptives than those formed later. (5) Much of the hornblende-schist is igneous, related in origin to laccolites. (6) Serpentine and steatite are alterations of material originally igneous.

Applying such principles to the classification of the rocks of northern New England, we may improve on the report in several particulars. (1) Archæan rocks are not eliminated from our list. They exist as oval areas, such as have been indicated, in the Stamford gneiss and south of Mt. Killington, Vermont, in the Hinsdale, Massachusetts, area, the Hoosac Mountain, and elsewhere. I recognize the porphyritic gneiss in the Stamford rock and in the Hoosac tunnel as Archæan. (2) Our hesitancy about the place of the Bethlehem gneiss is met by recent observations. They are batholites, containing inclusions of the adjacent mica schists. It does not follow that all these protogene areas are of the same character; each one must be studied by itself. Some may be altered gneisses, and others sandstones where feldspar grains prevail. (3) Later observers are not agreed as to the nature of the upper part of the Green Mountain gneisses. What is apparently the same material is called "Cambrian gneiss" on Hoosac Mountain by Professor R. Pumpelly[1] and "Algonkian" by Mr. C. L. Whittle[2] near Rutland, Vermont, Professor Emerson in adopting Pumpelly's view finds a series of anticlinals of the same material further east, which probably correspond to the similar folds referred above to the lake gneisses. (4) Later conclusions respecting the age of the rocks entering Vermont and New Hampshire are entertained by the Canadian Geological Survey.[3] There are three areas of pre-Cambrian, viz., the axis of the Green Mountains; the Sherbrooke belt, reaching Lake Memphremagog, and along the international

Huronian. Better amend the latter so as to exclude the Cambrian, rather than cumber literature with a term harder to write, less euphonious, and with practically no difference of signification.

[1] Monograph XXIII., U. S. Geol. Survey.

[2] This JOURNAL, Vol. II., p. 396.

[3] Bull. Geol. Soc. Amer., Vol. I., p. 453.

boundary of New Hampshire and Maine. Associated with these older rocks are slates, sandstones and conglomerates believed to be Lower Cambrian. The continuations of the Calciferous mica-schists are termed Cambro-Silurian, because Trenton-Utica graptolites occur in them. Various limited outlying patches of Upper Silurian fossiliferous rocks rest upon the mica-schists. It is easy to connect these belts with their more southern developments. Some portions of what we have called Huronian are Pre-Cambrian, in the two diverging areas specified above, page 54. The two bands of argillite supposed to overlie the hydro-micas, the one reaching to Barnard and the other to North Hartland, are identical with the Cambrian of Ells, and there is complete agreement as to the order of succession of all the formations named between the two surveys. This argillite underlies the Calciferous mica-schist. (5) In this connection it is proper to say that recent studies enable me to trace the argillite of Bernardston, Mass., past Bellows Falls to East Hanover and Orford, and it is to be distinguished from the two ranges just named in Vermont, for it overlies the Calciferous, and is associated with the latest rocks of the Connecticut Valley, being perhaps Devonian. I have recently explored a mass of it in Littleton, N. H., which appears to overlie the Niagara. It was called Cambrian in part in the New Hampshire report, because it seemed to be the same with the slates of that age further west, while other portions carrying incipient staurolites and small garnets were denominated Coös slate. (6) A study of several areas of hornblende-schist proves that they are igneous. (7) The area of the Montalban about the Presidential range among the White Mountains proves to be less in amount than has been stated. Mts. Adams, Jefferson and even the top of Mt. Washington are composed of mica-schists like those occurring along the carriage road rather than the true gneisses. On Mt. Clinton the mica-schists carry fragments of other rocks as if they were an igneous paste carrying inclusions.

SURFACE GEOLOGY.

Few of the early state reports have discussed glacial phenomena so fully as that of New Hampshire. The glacial theory of Agassiz, and Dana's doctrines as to the origin of the modified drift in connection with the flooding of river valleys through the melting of ice were accepted to explain the facts obtained. Measurements of striæ were taken everywhere, whether upon the tops of mountains, scant forest exposures, or in valleys, their number much exceeding those taken by any other organization.[1] The most important conclusion derived, for which the territory is best adapted because of the great elevation of the land, is that during the maximum ice development the motion came from the northwest and was directed over the mountains southeasterly; or, in other words, from the St. Lawrence Valley up the northward slopes of the White and Green Mountains, and over them towards the Atlantic.[2] Striæ were noted upon the summits of nearly all the highest mountains, and where these were wanting transported erratics abounded. Later observations have shown some form of glacial work upon every summit and every col of the White Mountains. By way of confirmation of this doctrine, our latest unpublished observations show that remnants of the accompanying terminal moraines[3] had a northeast-southwest course, being at right angles to the normal direction of the ice-sheet. In other parts of the state, notably upon the seaward slope, the striæ appear to have been deflected by the topography; and still later evidence is presented to suggest the presence of local glaciers radiating in every direction from the higher mountains, pushing northerly and northeasterly into Canada as well as to the south. A few suggestions as to the diversity of the Ice Age were made, such as would now confirm the theory of Geikie. They consist in the advocacy of interglacial deposits in the valley of Lake Winnipiseogee and about Portland, Me., and in the existence of an

[1] Seventh Annual Report of the U. S. Survey, p. 157.

[2] Bulletin Geol. Soc. Am., Vol. V., p. 35.

[3] Proc. Amer. A. A., Sci., Vol. XLI., p. 173.

abnormally compact lower till under the ordinary ground moraine.

The writer can find no reference to the drumlins earlier than his own descriptions of Prospect Hill[1] in Andover, Mass., in 1867. It represented something accumulated by ice, but not an ordinary moraine. These hills received much attention in the report, hundreds of them having been mapped in the atlas. Their longer diameters were found to coincide with the direction of the ice movement; being generally southeasterly in Rockingham county, southerly west of Merrimack River, and west of south in the Connecticut Valley on the edge of Massachusetts. Mr. Warren Upham devoted himself to the exploration of these lenticular hills, and in searching for them beyond the limits of New Hampshire, became interested in the terminal moraines of Cape Cod and Long Island.[2]

Special attention was given to the modified drift in the report by Mr. Upham. The terraces of the Connecticut and Merrimack Valleys were carefully mapped and leveled, with the intention of testing the application of the marine or fluviatile theory of their origin. It would appear that the highest terraces and deltas of tributaries represent the remnants of the ancient flood plain where the river had its greatest volume. These remnants are quite uniformly nearly two hundred feet above the Connecticut River—whether at the state line on the south or at the mouth of the Passumpsic. Very commonly a tributary increases the height of the flood plain for a short distance. If the terraces had been made in a series of lakes, or at successive heights of the ocean, they should have been arranged in a series of steps from the sea upwards.

Eskers had been described in Maine, but it remained for Mr. Upham to bring them to light in all the principal New Hampshire valleys, especially in the Connecticut from Windsor, Vt. to Lyme, N. H., a distance of thirty miles. The main river cuts its way across this gravel ridge seven times, and it is quite concealed by terrace deposits in a part of its course.

[1] Proc. Essex Inst. Nat. Hist., Vol. V., p. 159.

[2] Geol. New Hampshire, Part III., p. 300.

The writer in accepting the diversity of the Ice Age, believes the Champlain to have been one of the glacial epochs. The name was originally given by him to the sands and clays bearing marine mollusca, with the accompanying deltas and terraces; and that includes terraces in the Champlain Valley, the south-flowing rivers and along the New England coast. The fossils indicated a glacial climate as far south as Massachusetts Bay, and a cooler climate in Nantucket. It was a time of differential depression, amounting to more than one foot to the mile in proceeding northward, so that sediments filled up rivers and compelled the renewed streams of today to find new channels for themselves over ledges. With a submergence of perhaps a thousand feet in the lower St. Lawrence and an arctic climate, glaciers would form on the Laurentides, Green and White Mountains, moving towards each other and discharging icebergs into the inter-island area. Mr. Upham[1] suggests that all the drumlins in the country were formed at this time. It was certainly true of those near Boston, as they contain not less than fifty-five specimens of marine temperate mollusca, which must have been transported as erratics to their present locations. Hence the climate of New England must have had an arctic character in the Champlain epoch.

As elsewhere suggested,[2] the writer believes the adoption of the view that the Champlain was a glacial epoch with the land much depressed, and a sea full of icebergs moving southwesterly from the Gulf of St. Lawrence, will enable the advocates of the glacier and iceberg theories to harmonize their conflicting opinions.

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[1–2] Bull. Geol. Soc. Amer., Vol. VII