THE GEOLOGY OF LITTLETON, NEW HAMPSHIRE, WITH AN ARTICLE ON A TRILOBITE FROM LITTLETON, AND NOTES ON OTHER FOSSILS FROM THE SAME LOCALITY

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C. H. HITCHCOCK & AVERY E. LAMBERT

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THE GEOLOGY OF LITTLETON.

By C. H. Hitchcock, Ph.D., LL.D.

SUNDRY facts relating to the geology of Littleton have appeared in C. T. Jackson's State Report, 1844; in the Geology of the State of Vermont, 1861; in the Annual and Final Reports of the State Survey, 1868–1878; a Paper upon the Helderberg of New Hampshire, etc., in the American Journal of Science, 1874; an Atlas of the State of New Hampshire, by Comstock and Kline, 1877; Geological Sections across New Hampshire and Vermont, in the State Agricultural Report for 1884; and lastly, a notice of the Discovery of Trilobites, by T. Nelson Dale, in a Canadian publication.

The present sketch is based upon the facts contained in these publications, supplemented by several visits made subsequently for the purpose of gaining more precise information. New facts have been discovered at each visit, and the rapid progress of the science necessitates a rearrangement of the conclusions not anticipated. It is to be regretted that our knowledge is still so incomplete.

The township is traversed by two rivers, — the Connecticut and the Ammonoosuc. The first constitutes the boundary on the northwest side, more than thirteen miles long. The principal portion of the "Fifteen Miles Falls" is situated within the limits of Littleton. The head is in Dalton, to the north, 830 feet above the sea, and the foot in Monroe, near the mouth of the Passumpsic, 460 feet above the sea, the total fall being 370 feet. Of this amount, 300 feet lie within the town limits. With such a great descent, the river is narrow and the shores rocky, with an absence of the intervales so abundant in both the upper and lower sections of the river. These features result from the geological conformation. A range of mountains has been cut across by the river. It is the Gardner Mountain range, 2000 feet high, coming northerly through Bath, Lyman, and Monroe, and falling rapidly to the water level in West Littleton, to rise again in Waterford, Vt. The second valley lies parallel to the first, and may owe its inception to the presence of softer rocks, which have been excavated along their trend, while in the first instance the cutting has been effected directly across the strata. These facts may suggest at some period the drainage of the northern Connecticut through the Ammonoosuc valley.[1]

Between these two valleys the land is mountainous the whole length of the township. A gap near the village separates the mass into two sections. That to the south is the Blueberry Mountain; that to the north occupies the width nearly of the whole township, and the names upon the old county map are for the western line, — Wheeler Hill, Palmer Hill, Morse Hill, and Mount Misery. This map gives only Mann's Hill upon the eastern side, to which should be added Palmer Hill. Mr. Gile's map combines Mann's Hill and Morse Hill into Black Mountains, with a course somewhat north of west, and attaining the altitude of 2000 feet above tide water. The other mountains named reach, in many cases, the altitude of 1900 feet. The mountains in the northern section constituted a broad plateau originally, from which the drainage now flows in every direction.

Upon the older geological maps the rocks were represented as granitic and Archean. Fortunately, well-defined fossils have since been discovered, which convey exact information of the age of the associated strata. The history of the discovery is interesting. The writer had been examining the limestones near the sites of the old kilns on Parker Brook and Burnham Hill, and detected the presence of crinoidal stems and coralline bunches. Aware of the importance of the discovery, he at once telegraphed this message to the Dartmouth Scientific Association, Hanover: "No longer call New Hampshire Azoic. Silurian Fossils discovered to-day, Sept. 28, 1870." The fossils found in 1870 were submitted to E. Billings, Paleontologist of the Canada Geological Survey. He found among them *Favosites basaltica*, *Zaphrentis*, and crinoidal fragments, but nothing enabling him to localize the horizon more definitely than by the general term of *Helderberg*, Devono-Silurian. The Devonian part of the Helderberg was known to Mr. Billings at Memphremagog Lake, fifty-five miles distant; and that knowledge evidently biassed his opinion at that time.

The next important discovery came three years later. In answer to inquiries about the existence of limestone, Mr. A. R. Burton had told us of the existence of that rock upon the farm of Mr. E. Fitch; and a party of us, including J. H. Huntington and A. S.

[1] See Geology of Vermont, Vol. I. p. 116.

Batchellor, set out for its exploration, September 22, 1873. Mr. Huntington had the honor of first recognizing the outlines of a shell, and soon we all had more specimens of well-defined brachiopods and corals than we could carry away.

These additional fossils did not cause Mr. Billings to be more precise in the recognition of the horizon. Later, we found large masses of *Halysites*, or chain coral. On submitting these, with the others, to Prof. R. P. Whitfield, of New York, it was perceived that the horizon was distinctly that of the Niagara limestone, as determined by the presence of the chain coral and the brachiopod, which proved to be the *Pentamerus Nysius*, and both species are specifically characteristic of the Niagara. Later, Mr. T. Nelson Dale visited the locality, and discovered the trilobite known as the *Dalmania limulurus*, also a Niagara species. Hence the existence of a Niagara horizon is well established. As will appear later, other horizons may be represented as well; and that there is still opportunity for the discovery of Helderberg species. In my State Reports I have used the name "Helderberg," but in later publications have changed to "Niagara," because there is certainty in respect to the existence of the earlier terrane on Fitch Hill. The term "Helderberg" may be useful when speaking of the related rocks.

The rocks of Littleton may be classed as, *first*, granitic; *second*, schistose; *third*, the fossiliferous Niagara and associated slates and sandstones. It will be convenient to describe them in this order, without reference to their exact succession.

The granitic rocks occupy three areas, and have been described in the State Report as the *Porphyritic gneiss* or *granite*, *Protogene* or *Bethlehem gneiss* or *granite*, and *ordinary gneiss*, believed to be the *Atlantic* or *Winnipiseogee series*. Such were the terms used in 1877. Since then the study of crystalline rocks has made great progress, and it will be best to modify the earlier opinions with reference to structure and origin.

It was necessary for the New Hampshire Geological Survey to enter upon the study of crystalline rocks, making use of the new methods in the employment of the compound microscope and polarized light. The services of the late Dr. G. W. Hawes were called into requisition, and the report he prepared for the State upon Lithology and Mineralogy opened the way for the study of related crystalline rocks by others. The conclusions of Dr. Hawes have been fortified and supplemented by the later workers.

The peculiarity of such of these rocks as occur in Littleton is that they are traversed by lines of mineral arrangement called *foliation*, and the material may be cleaved readily by the application of blows with steel utensils, hammers, or chisels. Such rocks are termed *schists*, because of their easy splitting, and the arrangement can be called a crystalline lamination. Most schists possess banding that is unmistakable. These granitic masses in Littleton are imperfectly foliated, — so much so that different geologists will call them granite or gneiss, according to their predilections. Now granite has tendencies to cleave where the foliation cannot be perceived to exist by the eye, but may be present, so that some hesitation in deciding upon the presence or absence of foliation is pardonable. My present belief is that all these rocks are true granites rather than schists.

When this tendency to split was observed by the geologist of twenty-five years ago, he had before him the conclusions of his instructors that schists occupied the place of strata. Alternating bands of strata would have varying composition. The action of thermal influences with water would cause the molecules to rearrange themselves according to their affinities, and thus to form crystals, which would be as different in respect to coloration as were the original strata. The earlier geologists saw no way in which these crystalline laminæ could have been formed except through the metamorphism of sediments, and hence foliation was said to be identical with stratification, only that sometimes one set of planes might cut across others. On studying the phenomena of cleavage, it became apparent that lines of structure perfectly comparable with strata could be superinduced. It is the result of pressure. Suppose this admitted fact be applied a little further. Let us take a mass of granite just formed, still somewhat plastic. The constituent minerals lie in every conceivable position, perhaps well expressed by the statement that no two of the flat minerals lie in the same plane. Now let pressure be applied to this plastic bunch. All the flat minerals will be made to lie at right angles to the force exerted, and consequently parallel to one another. When an attempt is made to break the rock, splitting will follow the lines of arrangement of the flat minerals. If the pressure has been free to act for a long time, genuine foliation will be the result. Hence it is possible to understand the origin of schists possessing no trace of sedimentary origin. It will be easier to believe the granitic rocks of Littleton originated in this way than from the alteration of sediments. If the foliation is distinct, however, the rock is a gneiss rather than granite.

In entering upon the descriptions of these granitic areas it is assumed that they are all of igneous origin, and that their foliation has been induced by pressure; that they are not altered sediments, although metamorphism has acted vigorously upon clastic rocks in other parts of the town, — in fact in districts adjacent to these granites, because the source of the heat is thus understandable. Pains have been taken to record the positions occupied by the foliation, partly because of the habit acquired when these were supposed to represent sedimentation, and partly because they give information as to the direction of pressure.

PORPHYRITIC GRANITE. — Studies of the crystallines show a grouping of material in concentric rings around a nucleus. The porphyritic granite of Littleton may constitute the nucleus around which a finer-grained granite is enwrapped. The chief part of the area is towards the north, outside of the town limits. The interior core is an oval-shaped area of about four square miles in the adjacent corners of Littleton, Whitefield, Bethlehem, and Dalton. The rock is of medium grain, filled with crystals, up to two inches in length, of potash feldspar (orthoclase), whence the significance of the term "porphyritic" or "spotted." The feldspars are often twinned, the plane of twinning corresponding with that of the foliation of the mica. The reversal of one-half of the twin changes the position of the cleavage planes, so that one part is clearly, and the other indifferently, reflected, and thus the crystals are conspicuous. Part of the rock is foliated, in which case the large crystals are disposed along the foliation planes; other portions show no arrangement of any of the minerals. The ground mass is made up of the three usual mineral constituents of granite, — quartz, feldspar, and mica. The mica is commonly the black variety, called *biotite;* but in Littleton there is more than the usual supply of the white variety known as *muscovite*. Oligloclase may be present as well as orthoclase for the feldspar. The quartz is always amorphous, so far as I have observed. Where the large crystals of feldspar are badly formed, they may be somewhat lenticular in shape, and the attendant mica disposed like eyebrows, so that one may imagine a ledge filled with staring eyes. Noticing this peculiarity, the Germans call this rock the *Augen, — eye gneiss.* There is often, also, a considerable iron in the rock, whose decay imparts a rusty color to the ledges.

In Europe and Canada the augen gneiss has been ranked as Archean. For that reason I called this rock Laurentian (=Archean) in my report, and represented that the thirty areas of it known to exist in New Hampshire might have been the primitive land areas of the continent. With a changed view of its origin, it may still be regarded as thus ancient in some localities, for igneous rocks constituted the whole of the Archean terranes. This rock has also been erupted in post-Archean times, so that by the mineral character alone we are not warranted in deciding upon the age.

At Alder Brook, in company with the late Dr. T. Sterry Hunt, I made an attempt to determine the possible disposal of the minerals in certain planes, which might be termed strata. We found, first, nearly horizontal masses with no variation of mineral composition; second, an alternation of coarse gneisses; third, fine feldspathic layers, more irregular than the others. The predominating dip of these several sheets was 75° S. 40° E. It seemed at the time as if this arrangement might correspond to stratification; and if so, it would represent a downward dip reappearing on the north flank of Mount Lafayette, thus constituting a synclinal axis; and it was so figured in the report (Vol. II., Plate VI., Fig. 7).

At this same locality the rock has been much decomposed, so that when a ledge has been cut through it is found to be made up of loose blocks, as the softening and removal of the granite adjacent to the joints has separated the fragments from union with one another. To the west of Alder Brook is a precipitous hill of the porphyritic granite, very conspicuous as seen from the village of Bethlehem. It is known as Bald Hill, and is immediately adjacent to Mann's Hill. The foliation at the back of Bald has the dip of 70° N. 75° W., making an anticlinal with that at Alder Brook, and nearly parallel with the position of the adjacent mica schist. In the low ground towards Round Pond the boulders of this rock are extremely numerous.

Granitic Gneiss. — The porphyritic granite is encircled by a granitic gneiss, which represents the southwest terminus of a large terrane reaching as far as Milan. A band of mica schist interrupts the direct continuity of this gneiss from Mann's Hill; but it is supposed to exist beneath the schist. The most important portion of this rock underlies the village of Littleton north of the Ammonoosuc, extending west as far as to the cemetery. The dip of the foliation is greater on Mann's Hill than upon Oak Hill or in the village, it being 75° in a general northwesterly direction in the former, and about 40° in the latter locality. At the reservoir on Palmer Brook there is a ledge with the high dip, also along the railroad near Apthorp. Hornblendic layers occur on Mann's Hill; and both there and in the village pieces of mica schist appear included in the gneiss. Hence the granite is probably of later origin than the adjacent Coös mica schists, from which the frag-