

ART. XXV.—*Geology of the New Fossiliferous Horizon and the Underlying Rocks, in Littleton, New Hampshire*; by FREDERIC H. LAHEE.

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Introduction.

IN August, 1912, the writer published a notice of the discovery of a new fossiliferous horizon near Littleton, New Hampshire.* Further field work and subsequent laboratory study have furnished material for a more complete description of the geology of this region.†

The town of Littleton is 23 miles nearly due west from Mt. Washington, and is situated on the terraces of the Ammonoosuc River, about 22 miles from the point where this stream unites with the Connecticut River at Woodsville.

Two miles west of Littleton the land rises westward 1000 to 1200 feet above the Ammonoosuc River to a ridge known in its northern part as Blueberry Mountain and in its southern as Bald Hill. Blueberry Mountain has its northeastern end in a valley in which two brooks flow, one northwest to the Connecticut River, and the other southeast to the Ammonoosuc River (see fig. 1). A relatively small crest (not shown by the contours) at the northern end of Blueberry Mt. is known as Fitch Hill. This hill is just south of Locality 7, as shown in fig. 2.

* A New Fossiliferous Horizon on Blueberry Mt., in Littleton, New Hampshire, *Science*, N. S., xxxvi, p. 275, 1912.

† This geological investigation was undertaken with the aid of a fund provided through the generosity of Mr. R. W. Sayles, of the Harvard Geological Department.

The area to be described (fig. 2) is a strip $1\frac{1}{4}$ miles wide and $7\frac{1}{2}$ miles long, including Fitch Hill, Blueberry Mt., Bald Hill, and the country for four miles southwest of Bald Hill.

Blueberry Mt. and its vicinity should be of peculiar interest to the geologist because the rocks there are less metamorphosed than those anywhere else between the Connecticut River and the Franconia range of the White Mountains, and because most of the fossils obtained in northern New Hampshire have come from this locality.

In presenting the results of our field work we shall describe (1) the petrology, structure, and stratigraphic sequence of the

FIG. 1.

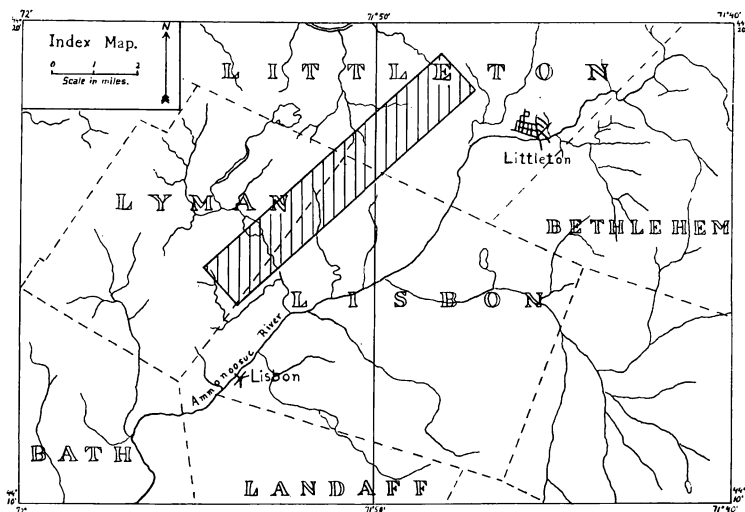


FIG. 1. Outline map of the Ammonoosuc district in New Hampshire, showing the position of the area (shaded) included in fig. 2.

rocks on and near Fitch Hill; (2) the southwestward distribution of these rocks; and (3) the new fossiliferous horizon of Blueberry Mt.

Summary.

Following is a summary of the essential facts set forth in this paper:

1. A metamorphic igneous rock, herein called the 'Fitch Hill granite gneiss,' outcropping in the township of Littleton, N. H., displays certain variations in mineral composition, which are possibly consequent upon original magmatic differentiation.

FIG. 2.

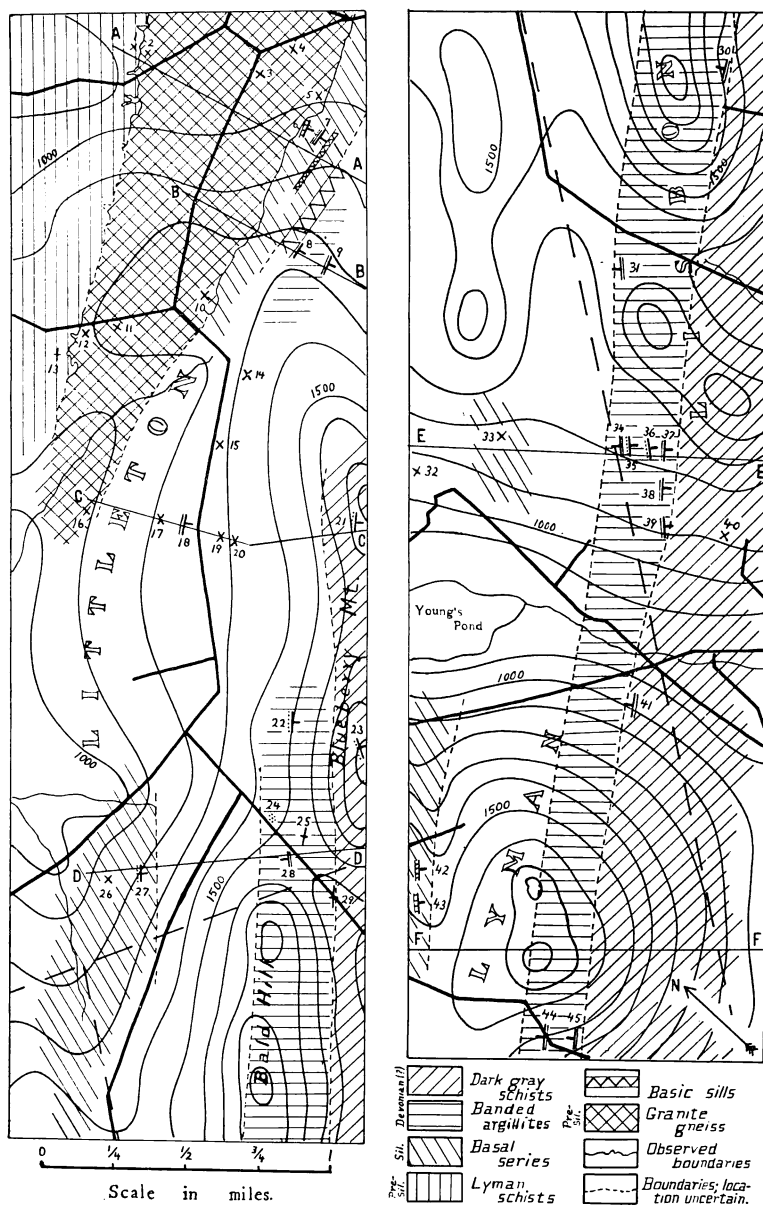


FIG. 2. Map of the area described in this report. The lower edge of the map on the left is the upper edge of that on the right. The positions of the cross-sections drawn in figs. 3 and 4 are marked by lines lettered A-A, B-B, etc.

2. The Fitch Hill granite gneiss is intrusive into the Lyman schists, but unconformably underlies the Niagaran sediments of Fitch Hill, Littleton, thus demonstrating the presence of a regional unconformity beneath the Upper Silurian strata of the Ammonoosuc district in New Hampshire.

3. The limestone near the base of this Upper Silurian formation is, at least in part, a conglomerate composed of roundish pebbles of crinoidal limestone, together with a very few pebbles of granite, in a highly calcareous, argillaceous, coral-bearing paste.

4. Marine fossils of Devonian age—presumably Lower Devonian—have been discovered in fine-grained elastics ('banded argillites') about 3000 feet above the base of the Upper Silurian in this region. These Devonian strata may be followed for seven or eight miles along their strike, but they grow finer and more metamorphosed southwestward. Fossils have been found in them at four localities within a distance of five miles along the strike. These fossils confirm the belief, long ago stated, of a seaway situated near the Connecticut River valley in Devonian times.

Geology of the Fitch Hill Section.

In fig. 3 is shown a vertical section drawn nearly north and south across the strikes of the Fitch Hill rocks. Its position is indicated in fig. 2 by the line A-A. Its southern end cuts through Fitch Hill. The rocks appearing in this section are the Lyman schists, the Fitch Hill granite gneiss, and a group of strata which may be called the Blueberry Mountain series.

The Lyman schists.—The terms 'Lyman schists' and 'Lyman group' were applied by Professor Hitchcock to a body of 'hydro-mica and chlorite schists' which in his earlier report* he assigned to the Huronian. Writing 30 years later,† he referred the group to the Cambrian or Ordovician, but not with complete assurance, for the structural relations of the formation are obscure and all possible evidence of fossils has been destroyed by metamorphism.

These Lyman schists outcrop in the northern corner of the map (fig. 2). They are highly metamorphosed fine-grained sandstones and mudstones, with a few beds of fine conglomerate in which the pebbles, all angular and mashed, are hardly distinguishable from the paste. Some of the finer schists are thinly banded, and these strata bear evidence of great contortion. In one place a zone of crush-conglomerate was seen.

* Hitchcock, C. H.: *Geology of New Hampshire*, vol. ii, p. 50, etc., 1877. *Ibid.*, *Geology of Northern New England*, p. 12, 1874.

† *Geology of Littleton, New Hampshire*, reprint from the *History of Littleton*, pp. 11 and 29, 1905.

The series as a whole is drab or greenish gray in color. Weathered surfaces are much lighter, sometimes almost white.

The Fitch Hill granite gneiss: Earlier references.—While this rock has been mentioned several times in previous writings on the Littleton district, it has never received very thorough consideration, nor have its relations to the adjoining formations been described. In Hitchcock's works it is called 'chlorite,'* 'chlorite rock,'† 'chloritic foliated granite,'‡ and 'protogene,'§ a name given to it by Hawes. Lambert refers to it as a "stratum of igneous rock,"|| and also merely as "igneous rock."¶

Distribution.—The Fitch Hill granite gneiss outcrops in a belt which trends N.E.—S.W., to the south of the Lyman schists. It is widest (3/4 mile) at the northeastern edge of the map, and can be traced thence for two miles southwestward, beyond which no exposures were seen. The rock is essentially a valley-maker, although it rises half-way up some of the adjacent hills, Fitch Hill being one of these (Sec. A, fig. 3). In the field the gneiss can be followed northeastward for more than a mile beyond the border of the map.

In passing across this belt, one finds that the rock gradually changes from a dark, hornblende-bearing, northern facies to a lighter, hornblende-free, southern facies. The petrology of these two phases will be described separately.

Northern phase.—In its northern outcrops the Fitch Hill granite gneiss is a fine-grained (average size of grain, 1/16 inch or less), dark gray or greenish gray rock, composed essentially of quartz, feldspar, and hornblende. The hornblende crystals are black, are more than twice as long as they are wide, and are without definite orientation. The feldspar is of a dirty pale greenish color. Sometimes a few very indistinct phenocrysts of this mineral are present, and rarely these are pinkish. The quartz is inconspicuous because its grains are small and transparent. Fine chlorite and sericite may be observed, particularly in those outcrops where there has been a little shearing.

In thin sections the microscope reveals evidence of crushing. The quartz, which is more or less granulated, has wavy extinction. Among the feldspars, orthoclase, microperthite, microcline, and plagioclase, ranging from albite to oligoclase, were

* Geology of Northern New England, p. 15. Geology of New Hampshire, vol. ii, p. 327, 1877. † Ibid.

‡ New Studies in the Ammonoosuc District of New Hampshire, Bull. Geol. Soc. Am., xv, p. 465, 1904.

§ Ibid., p. 465. Also, by the same author, Geology of Littleton, p. 13.

|| Lambert, A. E.: In New Studies of the Ammonoosuc District of New Hampshire, p. 480.

¶ Geology of Littleton, p. 34.

recognized; but they are nearly always much decomposed. Epidote and sericite, disseminated through the decaying minerals, are most abundant as alteration products. A little calcite,

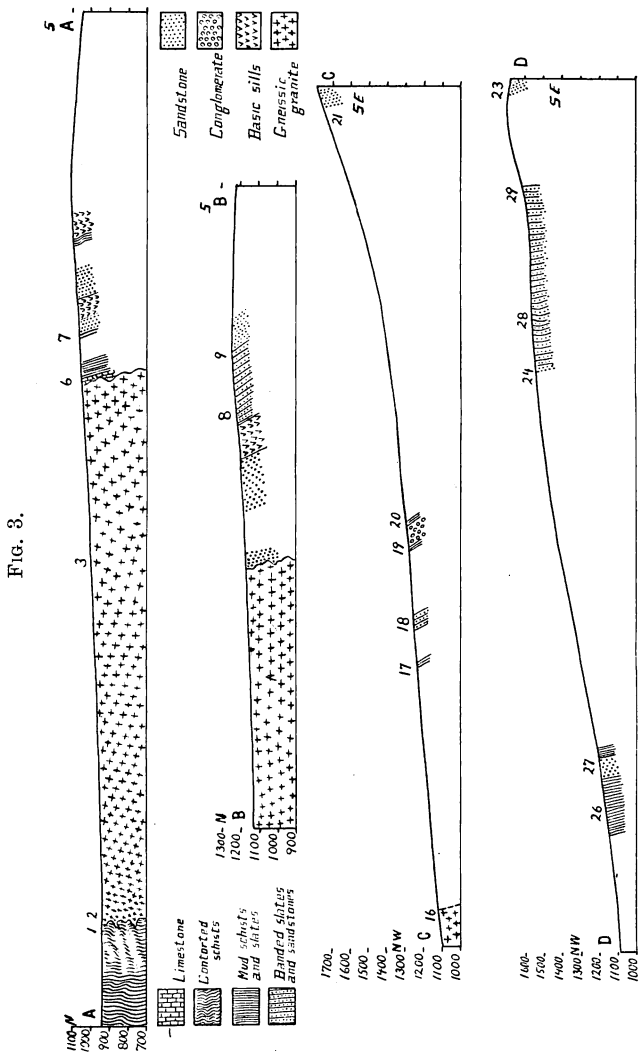


Fig. 3. Sections A-A, B-B, C-C, and D-D, the positions of which are indicated on the map (fig. 2). The horizontal scale is the same as that given in fig. 4.

which has crystallized between the grains of the rock, may have been derived from the lime-bearing feldspars. Having no sign of decay nor of distortion, and being moulded against or around the quartz and feldspar particles, the hornblende is

FIG. 4.

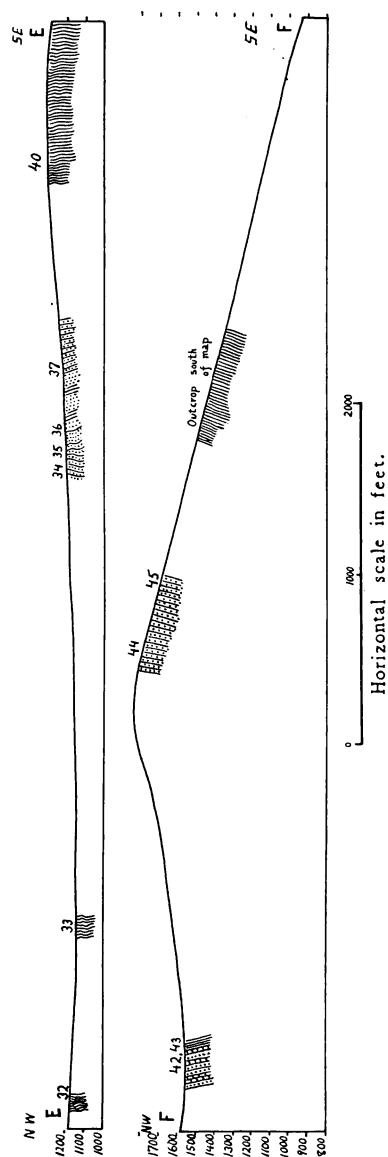


FIG. 4. Sections E-E and F-F. The legend for these sections is the same as that in fig. 3.

probably of metamorphic origin. It is often twinned in multiple fashion. The remains of decomposed biotite flakes ap-

pear as bent and twisted shreds of colorless micaceous material, associated with minute grains of quartz and epidote.

Southern phase.—The southern phase of the Fitch Hill granite gneiss is of rather coarse grain and is of a medium grayish tone, with light pink or flesh-colored crystals of feldspar. It is lighter in color and coarser than the northern type. Here, too, the quartz is not conspicuous. Frequently the structure is indistinctly porphyritic, and then the pink feldspars become phenocrysts with blurred edges. Many are twinned according to the Carlsbad law. Chlorite is always present, not as clear-cut individual flakes, but as irregular patches formed by many minute flakes. In some specimens chlorite occurs, together with sericite, as small, separate flakes, both micas being metamorphic in origin; and in such cases the chlorite is more abundant the greater has been the shearing. No hornblende was seen in the southern phase.

Many of the features observed in thin sections of the northern phase are characteristic of the southern. The quartz shows crushing and straining. The feldspars—orthoclase, microperthite, plagioclase, and a little microcline—are much altered. Of these the plagioclase preceded the others in time of development. Chlorite is in aggregates, accompanied by quartz, calcite, and epidote. Its form suggests derivation from biotite rather than from hornblende.

Variations in Mineral composition.—Five specimens of the gneiss were selected from as many different localities. Specimen 106 came from Loc. 10 (see fig. 2). Sp. 302 came from Loc. 5. Sp. 245 was taken from an outcrop not represented on the map. It belongs to the southern facies. Sp. 447 was obtained a few feet south of Loc. 2; and sp. 448, belonging to the northern phase, came from an outcrop northeast of Loc. 2, just off the map. Thin sections of these specimens were examined and the percentage of the constituents was estimated by thorough measurements according to the Rosiwal method.

To be sure, this kind of analysis, when applied to rocks of low metamorphism, and, therefore, of incomplete recrystallization, introduces errors which are large compared with chemical analysis; but it does bring out the relative abundance of the minerals clearly enough for general purposes.

The feldspars are not here classified by species. They are so much decayed that an attempt to distinguish them specifically, for quantity determinations, would be fruitless.

The results of the analysis are tabulated below:

	Per cent quartz.	Per cent feldspar.	Per cent calcite.	Per cent iron-bearing silicates.	Per cent total iron silicates.	Total.
Southern phase.						
Sp. 106	27.08	52.93	0	Chlorite : 19.97	19.97	99.98
Sp. 302	18.42	61.79	0	Chlorite : 19.59 Epidote : 0.18	19.77	99.98
Sp. 245	26.20	46.20	7.05	Chlorite : 20.54	20.54	99.99
Northern phase.						
Sp. 448	21.16	57.44	.36	Chlorite : 1.89 Epidote : 4.84 Hornblende: 14.30	21.03	99.99
Sp. 447	14.98	61.07	.17	Chlorite : 3.11 Epidote : 3.99 Hornblende: 16.66	23.76	99.98
Average for southern phase :						
	23.9	53.64	2.35	Chlorite : 20.02 Epidote : .06	20.09	99.98
Average for northern phase:						
	18.07	59.25	.26	Chlorite : 2.50 Epidote : 4.41 Hornblende: 15.48	22.39	99.97

The above table shows that the northern phase has a lower percentage of free quartz than the southern phase, a higher percentage of feldspar, and a slightly greater percentage of iron-bearing silicates, although hornblende comprises the larger proportion of these silicates in the northern type, and chlorite in the southern. Hornblende is quite wanting in the southern facies. These facts suggest a certain amount of magmatic differentiation in the original granite magma, either by an increase in acidity toward the southern boundary or by an increase in basicity toward the northern boundary.

Intrusive contact with the Lyman schists.—We can discover in the literature no mention of the relation of the Fitch Hill granite gneiss to the Lyman schists. Although the contact is actually exposed in many places, it is so obscure on account of metamorphism and weathering that its study requires more detailed search than was possible under the conditions of the earlier geological surveys.

When carefully examined, this contact is seen to be very irregular. The granite gneiss projects into the schists in the form of blunt apophyses or as short, narrow dikes. Most of these intrusive tongues are of fine grain; but a few are pegmatitic, sometimes with quartz and feldspar crystals an inch or two across. Angular fragments of the schist are occasionally seen entirely included within the gneiss. Add to these statements the fact that the gneiss usually grows finer toward the

schists, and there can be no doubt that this Fitch Hill granite gneiss is intrusive into, and therefore younger than, the Lyman schist group.

Unconformable contact with Blueberry Mountain Series.

—At the southern contact the conditions are very different from those on the north. Here the gneiss rests against a body of sedimentary rocks which are much less metamorphosed than the Lyman schists. The lower members of this sedimentary series are known to be of Niagaran (Upper Silurian) age.* They were formerly called Helderbergian.

While the southern contact region does receive some mention in the geological literature, the references are vague. Lambert wrote that the granite gneiss “broke through” the sediments.† Hitchcock in one place‡ says it “cuts off” the “Helderberg.” Elsewhere he says it “may be followed to close contact with the limestone” (Niagaran);§ and again, “Below and in contact with the fossils on Fitch Hill the rock is a chloritic foliated granite.”|| On the same page|| we read, the “synclinal in Littleton rests on igneous materials”; and here, too, we find the suggestion of an unconformity in the words “basal limestones,” meaning the Niagaran limestone.

We made as minute an examination of this contact as we did of the northern one. No dikes nor apophyses of any sort pass from the gneiss into the sediments, and, while the contact has several broad and often deep jogs or indentations, it is essentially straight. The granite gneiss sometimes remains coarse quite up to the sediments. More often, however, it grades into a somewhat finer rock. In one place where the gneiss adjoined this finer rock, the former seemed to pass into the latter by concentric layers about a roundish projection of fresh gneiss (see fig. 5). There were several such boulder-like masses of fresh gneiss partly or wholly wrapped in layers of the same material, more and more weathered outward. From these facts and from a microscopic inspection of the ‘finer rock,’ we have been led to infer that this contact is an unconformity; that the granite gneiss, preceding the deposition of the Niagaran, broke down, by disintegration without much decomposition, into a feldspathic gravel or coarse sand, now an arkose (the ‘finer rock’); and that in some places we have the original spheroidal weathering preserved and bevelled across by the present land surface (fig. 4). Further support of

* See Hitchcock’s *Geology of Littleton*, pp. 4–6, and his *New Studies in the Ammonoosuc District*, p. 462.

† Lambert, A. E.: A Trilobite from Littleton, etc., in Hitchcock’s *Geology of Littleton*, p. 34.

‡ *Geology of Northern New England*, p. 15.

§ *Geology of Littleton*, p. 17.

|| *New Studies in the Ammonoosuc District*, p. 465.

these conclusions depends on certain characters of the overlying (to the south) Blueberry Mt. sediments, which we shall describe below.

Since the northern contact of the Fitch Hill granite gneiss is intrusive in its nature and the southern contact is an unconformity, (1) the original differentiation must have been one of increasing basicity toward the margin (northward), and (2) the age of this granite gneiss must be intermediate between that

FIG. 5.

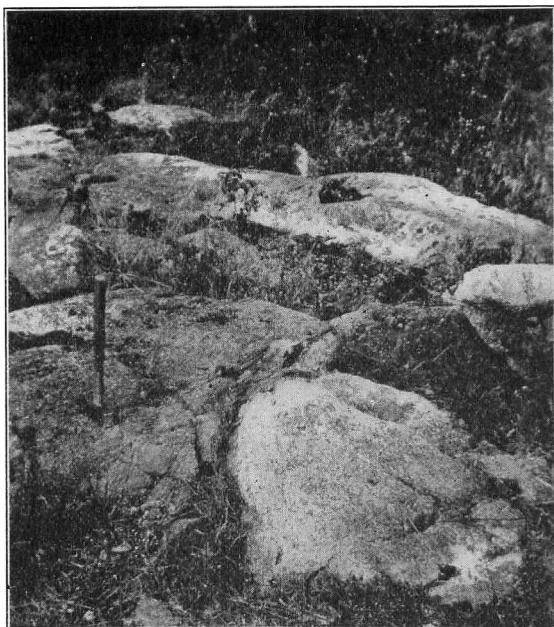


FIG. 5. Fossil concentric weathering. The rock in the right foreground is the Fitch Hill granite gneiss. It is partly surrounded by layers of the disintegrated gneiss, which have been reconsolidated since the time when the weathering was in process. The hammer stands on arkose which was formed from the completely disintegrated products of the gneiss. Photo by F. H. L.

of the Lyman schists and that of the Niagaran sediments on the south.

The Blueberry Mountain Series on Fitch Hill.—Blueberry Mt. is regarded as a synclinal ridge.* The base of the

* Hitchcock : *Geology of Littleton*, p. 15.

sedimentary series which forms the fold appears in the region above described, where the lower strata rest unconformably on the Fitch Hill granite gneiss. It is interesting to notice that Hitchcock mentions an unconformity on the southeastern side of the syncline about seven miles southwest of Fitch Hill, northwest of the town of Lisbon, where the Blueberry Mt. argillites meet the Swift Water series, a formation supposed to be equivalent to the Lyman schists and associated rocks on the northwest side of the syncline.*

In passing southward from the Fitch Hill granite gneiss, crossing the strikes of the strata, one encounters in succession (going upward, stratigraphically) (1) the basal arkose already mentioned, which may grade locally into quartzite beds (2–80 feet thick); (2) limestone carrying fossils of Niagaran age (30–40 feet);† (3) calcareous slate, also with fossils of Niagaran age (6–10 feet); (4) non-fossiliferous limestone and slate (150 feet)*; (5) basic sill (thickness uncertain; not great); (6) thick mass of arkose forming Fitch Hill and therefore called the Fitch Hill arkose to distinguish it from the basal arkose (200–300 feet); (7) basic sill (200 feet); (8) banded argillites (450–500 feet); (9) dark gray sandstone with dark shale layers (to the crest of Blueberry Mt.).‡ The first four and the sixth members we have called the ‘basal series.’ Our measurements for the thickness of the basal series, exclusive of the sixth member, amounted to between 150 and 250 feet.

Further proof of the unconformity beneath these sediments is presented in the character of the basal arkose. This is a hard, compact, gritty rock, usually without the least indication of stratification. In one or two outcrops, however, a faint streaky appearance, striking and dipping parallel to the strata on the south, suggests that there was a very slight tendency toward sorting of the disintegration products of the granite gneiss in the encroaching Niagaran sea. The feldspar grains, ranging in size up to $3/16''$ or $1/4''$ in the longest dimension, are so conspicuous on account of their white color that they often give the arkose a porphyritic look. They are of the same kind as the feldspars in the Fitch Hill granite gneiss (orthoclase, microperthite, plagioclase, and some microcline). The quartz, together with a very little chlorite, constitutes a dark background for the feldspar. In thin sections the quartz is seen to be cracked and strained. Secondary calcite occurs as veinlets and fillings between the other minerals.

As a rule the feldspar in the basal arkose is nearly as abundant as the quartz; but in a few places the latter becomes rela-

* Hitchcock: *New Studies in the Ammonoosuc District*, p. 478, and fig. 8 on plate 42.

† Hitchcock's figures.

‡ Called ‘dark gray schists’ on the map.

tively so much more plentiful that the rock must be called a quartzite. It is then very hard and white. Ordinarily such quartzite beds are not more than five or six feet thick and do not extend more than twenty or thirty feet along the strike. They are purely local.

Above the quartzite or the arkose, as the case may be, and sometimes very near to the granite gneiss, is the limestone that carries fossils of Niagaran age. This limestone is of a bluish gray color and is crystalline. Since we found that it had certain peculiarities which marked it as different from other limestones with which we had been familiar, we studied it carefully. In an outcrop just east of the upper right corner of the map (fig. 2), two types of limestone were observed, one fine-grained and faintly banded and the other coarse-grained. These two kinds occurred as separate, pebble-like bunches, apparently lying in all attitudes (banding), and enclosed in a thin paste of fossiliferous calcareous shale. So small in quantity was the paste and so similar the colors of the two types that, with three or four exceptions, the outcrop as a whole seemed to be composed of uniform limestone. These exceptions were rounded pebbles of granite, contained, as the limestone 'bunches,' in the fossiliferous shaly paste. The granite of these pebbles looked strikingly like the Fitch Hill granite gneiss. Many of the limestone 'bunches' held crinoid stems, but no other fossils. In the shale paste, however, were numerous remains resembling *Stromatopora*, *Syringopora*, and *Favosites*.

On Fitch Hill, where Section A is drawn, the conglomeratic nature of the limestone is not so evident; but there are indications of it. In this connection it is interesting to note that there are occasional scattered, lenticular hollows, elongate parallel to the strike of the formation, in the basal arkose, even as much as ten feet below its upper limit. These little hollows (average: 8" long, 2" wide, 5" deep) are isolated pieces of limestone, weathered several inches below the surface of the outcrop. They are identical with the 'bunches' in the eastern outcrop just described.

Now, these observations, if correct, point to limestones of two geologic ages in the Ammonoosuc district. Indeed, our investigations in other parts of the region have led us to believe that some of the limestones hitherto mapped as "Mid-Upper Silurian"* contain crinoid stems, but no fossils distinctly of Niagaran age. This matter will bear more thorough study.

The fossiliferous slate (third member) is dark gray and calcareous. It has no particular importance for us, and will not be described at greater length.

Overlying this slate are the non-fossiliferous limestone and

* Hitchcock: *New Studies*, etc., plate 43.

shale beds, concealed for the most part by the vegetation. And stratigraphically above them is the second great mass of arkose, the 'Fitch Hill arkose.' Just what structural relations this rock has to those underlying, we cannot say. Contacts are not exposed. It appears to be in conformity. It is very like the basal arkose,—hard, dense, and spotted with white grains of feldspar which compose about half of the rock. It is more uniform in texture than the basal arkose, its grain averaging $1/15$." No signs of bedding nor of limestone inclusions were seen. Microscopically, also, it is similar to the lower arkose.

Both of the sills are composed of a coarse, massive, unsheared rock, formerly consisting of hornblende and plagioclase. The hornblende has been replaced by zoisite, calcite, and chlorite. These intrusions grow much finer toward their upper and lower contacts. In spots they have metamorphosed the sediments.

The Fitch Hill arkose is overlain by a thick body of nicely banded mudstones or argillites. The bands, of lighter and darker gray, are from $1/2$ inch to 3 inches wide, and may be traced for many yards. The lighter bands are fine argillaceous sandstone, and the darker, medium to fine-grained mudstone. They are very regular, but sometimes show local crumpling on a small scale. Neither this formation nor the overlying dark gray sandstone are of immediate concern for us. Their importance will be explained later.

*Geology of the Blueberry Mountain Series Southwest of
Fitch Hill.*

Distribution.—We have previously stated that the Lyman schists pass off the map (fig. 2) and that the Fitch Hill granite gneiss narrows and finally disappears southwestward.

On the northern side of Fitch Hill the limestone is a valley-maker (not shown by the contours). Without entering into great detail of description, we may say that this limestone is thought to underlie the valley which is just northwest of Blueberry Mt., Bald Hill, and the hill in the extreme western corner of the map. This valley contains Young's Pond. Associated with the limestone are the other members of the basal series; but there are exceedingly few outcrops of these rocks. Locality 26 (sec. D, fig. 3) is an outcrop of coarse feldspathic grit resembling the Fitch Hill arkose. Half a mile southwest of this a large glacial boulder of conglomerate, with ten or twelve limestone pebbles in it, was found; and calcareous schist is exposed a few hundred feet away. Limestone and calcareous grits outcrop at Locs. 42 and 43. Here the lime-

stone is in thin, long lenses between thin calcareous shale layers. The limestone has been dissolved down several inches below the level of the shale (fig. 6).

The sills of Fitch Hill soon disappear and can be traced no farther.

The banded argillite of Locs. 8 and 9 cannot be definitely followed. A similar rock outcrops at 17 and 18, and also at Locs. 25, 28, 29, 30, 31, etc. Locs. 14 and 15 are dark gray slate. Locs. 19 and 20 are coarse conglomerate, traced 200 or 300 yards along the strike, but no farther.

FIG. 6.

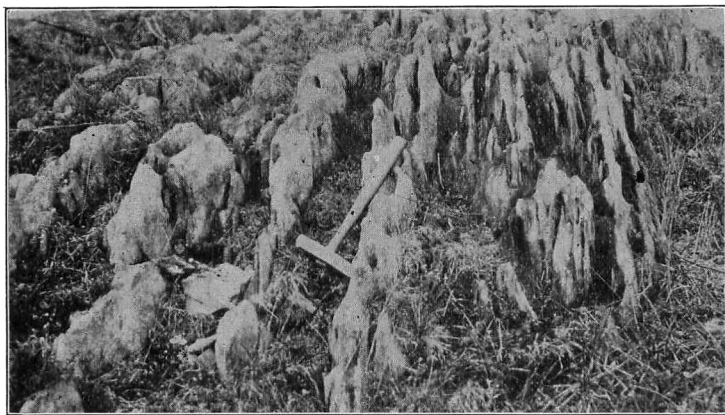


FIG. 6. Differential weathering. The limestone layers have been dissolved out, leaving the argillaceous layers projecting as ridges. Photo by Mr. R. W. Sayles.

The banded argillites of Locs. 25 and 28 are easily followed southwestward in a belt which runs, parallel to the strikes, along the crest of Bald Hill, to the east of Young's Pond, and over the hill in the southwest portion of the map. In the northeastern localities this rock is like that in the Fitch Hill section, although perhaps a little coarser. It is similar, too, at Locs. 34-39. At 41, and to a more marked degree at 44 and 45, it is finer; and southwestward beyond the border of the map it becomes very fine. Accompanying this change of texture is also an increase in metamorphism. The more northern specimens are hard, but are scarcely sheared. Southwestward the content of secondary mica increases until, in the southwest, just off the map, the rock is a fine sericite schist or phyllite. The entire Blueberry Mt. series of sediments dis-

plays, although not always so obviously, the same southwestward advance in metamorphism.

Structure and correlation.—That Blueberry Mt. is thought to be synclinal in structure has been stated before. This conclusion is based, not so much upon an inverse succession of well-marked strata, as upon the exposure of pre-Niagaran rocks which are nearly identical on opposite flanks of the ridge. We are unable at present to locate the axial region of this fold. For some reasons it seems to be in or near the long belt of banded argillites. Dips (which have been omitted from the map) are usually steep, so steep, indeed, that variations in direction within the area mapped are probably due to local contortion rather than to actual synclinal or anticlinal folding on a small scale. Below are listed the dips for those localities where the attitude of the bedding could be obtained :

Locality	Dip	Locality	Dip
6	80° southward.	34	80° northward.
7	75° “	35	70° southward.
8	70° “	36	60° “
9	60° “	37	75° “
18	60° “	38	78° “
21	80° “	39	75° “
22	70° “	41	60° northward.
23	85° “	42	80° southward.
27	85° “	43	80° “
28	70° northward.	44	80° northward.
30	75° “	45	80° “
31	72° “		

As regards the relations of the Fitch Hill exposures of banded argillite, we cannot now say whether they are continuous with the outcrops at Locs. 17 and 18 or with the belt including Locs. 25 and 28. Various conjectures might be made. A fault might have caused an offset. Overlap might explain the increasing thickness of the Blueberry Mt. series southwestward. Or the exposures at 17 and 18 might be at the same horizon as those of 25 and 28, but on the opposite limb of a fold. This paper is not concerned with the full discussion of the geological structure of the region. We shall leave these matters to future investigators for settlement.

One significant point we do wish to emphasize, however. Cross-bedding in the sandstone of Loc. 22 and contemporaneous erosion at Loc. 27 show that relatively higher beds, stratigraphically, are in each case to the south, and that, consequently, all the strata from the valley up to Loc. 27 belong to the same limb of a fold.

Devonian fossiliferous horizon.—The sediments of Blueberry Mt. are less metamorphosed than anywhere else in the Ammonoosuc district. With this fact in mind, the writer was constantly on the lookout for fossils during his field work in this part of the country. In 1911 he chanced upon some poorly preserved brachiopod impressions in talus at the foot of the 'Craggs,' a precipice in the dark gray sandstone above the banded argillites south of Fitch Hill. The outcrop does not come within the bounds of the map. This is probably on the south side of the syncline.

The most important discovery was made last summer (August, 1912) at Loc. 25 (Sec. D). Here, in a layer of fine sandstone not more than two inches thick—one of the light gray layers of the banded argillites—were found fifty or sixty impressions representing eight or nine species of brachiopods and possibly one pelecypod. This harvest was so encouraging that careful search was made in the vicinity for more fossiliferous beds, but with no success. Even the one layer that contained these impressions was barren except within a length of about four feet. Subsequently, the banded argillites yielded more brachiopod remains at Loc. 39, near Young's Pond, almost three miles southwest of Loc. 25. Some very obscure impressions of the same nature were found at Loc. 21, on the crest of Blueberry Mt.

If, as we believe, the exposure at Loc. 25 is stratigraphically directly above the strata of Locs. 26 and 27, and if these latter rocks belong to the basal series, allowing for the slope of the hill and for the dip, the thickness of the beds between Locs. 26 and 25 is about 2900 feet.* It is unfortunate that the structure is so doubtful; but even if Loc. 25 were on the south limb of a fold, it would still be more than 3000 feet above the basal member on the south. This is demonstrated by the nearly vertical dips on the southeast slope of Blueberry Mt. We are forced to conclude, then, that these fossils come from a horizon many hundred feet higher than any of the fossiliferous beds hitherto known in the Ammonoosuc district.

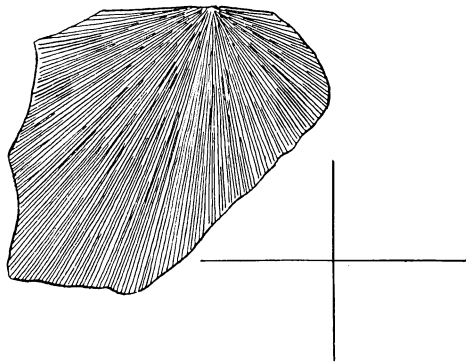
The layer containing the fossils is a hard, tough, medium gray, fine-grained sandstone in which a little secondary mica has developed, yet not enough to give the rock a cleavage. With a hand-lens it is seen to be pitted with small holes, probably the casts of some soluble mineral, such as calcite.

*In our notice printed in *Science* (N. S., xxxvi, p. 275, 1912), we said that the fossiliferous horizon of Loc. 25 was "stratigraphically 700' or more above the Fitch Hill" Niagaran limestone. This estimate was made before we had investigated the geology of the hillside below Loc. 25. It was obtained by adding the thickness of the basal series of Fitch Hill to the thickness of the banded argillites below Loc. 25. It was obviously very conservative.

Embedded in the sandstone, sometimes partly in a fossil and partly outside, are occasional large cubes of pyrite (up to $1/4$ " across). Most of the fossils are external impressions, although a few internal ones have been found. All of them are slightly distorted. (See figs. 7 to 9.) There is not a vestige of the original shell substance left.

While the characters of the impressions indicate eight or nine species, none of the fossils is perfect enough actually to determine its species. With the assistance of Professor Shimer, to whom we are glad to express our thanks, we made an attempt to name some of the genera. These are described below:

FIG. 7.

Fig. 7. *Stropheodonta* sp.?

(1) *Stropheodonta* sp.? (fig. 7): Only a part of one valve was found, including about 18^{mm} of the hinge-line. The impression is nearly flat. Its original size must have been at least 36^{mm} by 33^{mm} . It is marked by fine radial striae, all of equal height, of which 180 or 200 must have reached the outer margin of the shell when entire. Few run the whole length. These striae are crossed by still finer concentric wrinkles, or growth lines, which, however, are not well preserved. The hinge-line is straight and has on it indistinct vertical ridges. In general aspect this specimen is like *S. perplana*.

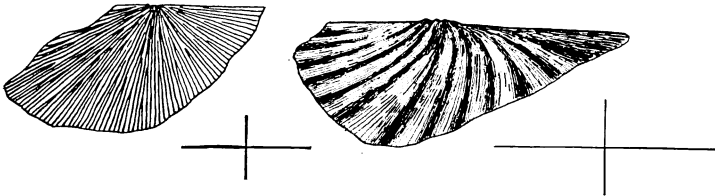
(2) *Chonetes* sp.? (fig. 8, actual size shown by cross): We have several incomplete specimens. The shell is about 20^{mm} wide and 12^{mm} long. It is nearly flat, slightly convex. Its surface is marked by fine, almost straight, equal, radial striae, about 100 in number. They are crossed by three or four low, indistinct concentric folds. The hinge-line is straight and forms the greatest diameter of the shell. Since the hinge area

is not well preserved in any specimen, we cannot tell whether or not spines were present.

(3) *Spirifer* sp.? (fig. 9). This is the most abundant species. We have portions of six brachial valves and of one pedicle valve. In no case were the two valves found together. The shell is 30 or 40^{mm} wide and 15 or 20^{mm} long. The brachial valve is characterized by a large unstriated median fold and, on each side of it, six or seven strong, rounded, radial plications that become narrower and lower near the hinge-line. There are no radial striæ. Very fine, thread-like, concentric

FIG. 8.

FIG. 9.

FIG. 8. *Chonetes* sp.?FIG. 9. *Spirifer* sp.?

growth lines may be seen in some specimens. The hinge-line is straight and the beak is small.

The pedicle valve resembles the brachial valve except that it has a median sinus instead of a median fold.

Both valves are moderately convex.

(4) *Spirifer* sp.?: All the best specimens seem to be brachial valves. The impression is broadly convex. There are in all about twenty-four radial ribs, a dozen on each side of a rather inconspicuous median fold. No concentric growth lines are visible. The hinge-line is poorly preserved, but seems to have been straight. The beak is more prominent than in the preceding species.

There are several other species and genera among the specimens, but they are too fragmentary even for generic determination. One looks like a *Spirifer* of the type of *S. Murchisoni*. Another appears to be a *Spirifer* with very few and very distinct ribs. We shall postpone the description of these more doubtful forms until more satisfactory samples have been obtained.

The writer's examination of these fossils led him to believe that they were unmistakably of Devonian age. He, therefore, sent them to Dr. John M. Clarke, who kindly consented to look them over. In a letter to the author he wrote, "I should hesitate to identify any single species among these, though they are to me conclusively early Devonian."

In this fossiliferous horizon, then, we have evidence of marine deposition during early Devonian times. Unless the Fitch Hill arkose and the conglomerate of Locs. 19 and 20 represent a short cessation in deposition, sediments were being laid down continuously from Niagaran times up into the early Devonian, and this may have continued much longer. With the possible exception of a few hundred feet, post-Carboniferous erosion has removed all rocks higher than the Blueberry Mt. Devonian.

In the present connection we may quote the following remark of Professor Hitchcock: "The fossils characterize only the basal limestones,* which are middle Upper Silurian. There is certainly enough thickness of strata in the sandstone, slates, and conglomerate superposed on the limestones to suggest at least the residue of the Upper Silurian, and perhaps the Devonian."†

At Bernardston, Mass., in the Connecticut valley about 150 miles south of Littleton, is a section showing limestone overlain by quartzite. Fossils in these rocks prove them to be of Devonian age, the limestone Helderbergian and the quartzite Oriskanian.‡ Emerson assigns both limestone and quartzite to the Upper Devonian.§

The Littleton Devonian may be taken as additional evidence confirmatory of the Connecticut valley trough in which the marine Devonian strata of Bernardston have long been thought to have been deposited.

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* On Fitch Hill.

† New Studies in the Ammonoosuc District, p. 465.

‡ Clarke, J. M.: Early Devonian History of New York and Eastern North America. N. Y. State Museum, Memoir 9, vol. 1, p. 156, 1908-1909.

§ Emerson, B. K.: Geology of Old Hampshire County, Mass., U. S. G. S., Monog. xxix, p. 258, 1898.