ART. XXVIII.—*On the Quartzite, Limestone and associated rocks of the vicinity of Great Barrington, Berkshire Co., Mass.;* by JAMES D. DANA.

[Continued from page 91, vol. v.] *

3. *From the Housatonic Valley eastward.*

THE region about to be described is within the same half a dozen square miles of area that have afforded the facts mentioned in the preceding parts of this memoir. It lies to the south and southeast of Monument Mountain, and is within three miles of it. And yet it is independent in the flexures of its rocks, and exhibits alternations of quartzite, mica schist or gneiss, and limestone beyond what has been elsewhere observed.

It will be remembered that Monument Mountain † crosses the north and south Housatonic region obliquely from northwest to southeast, and that the section along the course of the mountain included on the west a low anticlinal of limestone (l) beneath mica schist (s^1), and then, eastward, in the mountain, a succession of strata of quartzite, (q^1, q^2) and gneiss (s^2, in part

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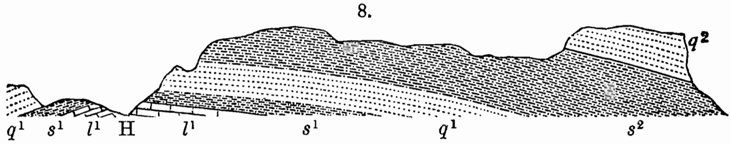

Section across Housatonic Valley and Monument Mountain.

mica schist), dipping 20° to 25° to the southeastward, as represented in the annexed section (fig. 8). At the east end there is no change to a westward dip, so as to make the whole a gentle

* The preceding parts of this Memoir are in vol. iv of this Journal, pp. 362, 450, and vol. v, pp. 47, 84.

† See this Journal, III, iv, 450.

synclinal; instead, the slope continues on and terminates in a fault, as explained beyond.*

While this is the position of the rocks in this Monument Mountain section, there are, but a mile north of the position of the mountain—as shown in the Glendale section—two steep and small synclinals (V^1, V^2, fig. 9) of the same schist and

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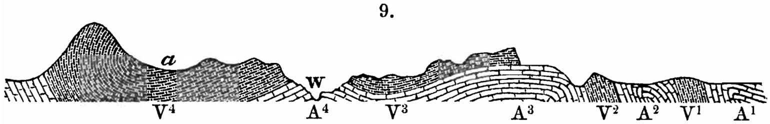

Section from Glendale westward.

limestone, with intervening anticlinals, the limestone being the prevailing and underlying rock, between whose jaws the schist was pinched up; and, further, these two small synclinals narrow out within a mile to the south against Monument Mt.†—each trough where widest being too narrow to take in much of the overlying schist, and including less and less as it extends southward.

Now in the section through Great Barrington,—three miles south of the east end of Monument Mountain and four miles of the west end (and separated from it by open meadow land)—the position of the rocks is still different; and the rocks themselves, although equivalents, are also to some extent different. There is a fault, as in the Monument Mountain section; but instead of a fault at the *east* end of the section, it is near the Housatonic River toward the *west* end (see fig. 10), and east of the fault there extends for three miles a single low synclinal of gneiss, with overlying quartzite at the west end and underlying quartzite at the east; and at the east end there is next—instead of a fault—the beginning of a low anticlinal, whose middle part is occupied by the southern continuation of Muddy Brook Valley, and whose eastern side is a bluff of quartzite overlaid by gneiss, and underlaid by alternations of limestone, gneiss or mica schist and quartzite.

The following are the details with regard to this Great Barrington section.

In my last paper on this subject, in volume v, of this Journal, I give, on page 88 and beyond, some account of the section *west* of Great Barrington, continued eastward through the village to the mountain (East Mountain) bounding the valley on the east, and illustrate it by the following cut (fig. 10). Here the low portion is the position of Great Barrington village, underlaid

* Page 265. The rocks of Monument Mountain owe their preservation as a prominent feature in the region to the cap of hard upper quartzite.

† This Journ., III, v, 48.

by steeply-dipping limestone; the low ridge on the left (west) consists of mica schist (and gneiss) with some intercalated quartzite (*q*), and, on the west side as well as at top, of the

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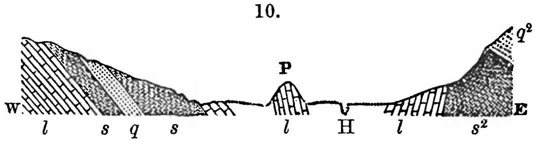

Section across the Housatonic Valley through Great Barrington.

Stockbridge limestone—all conformable to the Great Barrington limestone; the elevation on the east—East Mountain—is made of very firm fine-grained gneiss *unconformable* to the limestone adjoining, with a bed of quartzite at top 100 feet thick. H is the position of the Housatonic River.

Speaking in my former paper of the Great Barrington limestone, I observed that I had been unable to find evidence of its being a continuation, in a fold, of that to the west, and that I therefore supposed it to be a second independent stratum. The importance of settling this point has led to the delay in the publication of this continuation of my memoir. Having been recently over the ground again, I have finally arrived at the conclusion that the ridge of schist west of Great Barrington is actually the course of a synclinal, and that therefore the Great Barrington limestone stratum dips under it and is nothing but the Stockbridge stratum, or the same that covers the great plains of Egremont, Sheffield, Stockbridge, etc. The ridge of schist fades out half a mile south of the center of the village, and has low meadows south of it connecting with those of the river on the east and the limestone plains on the west; and the ridges which rise just south and continue the line southward are all limestone; so that there is no outcropping schist found to the south of it. Again, the connection of the quartzite of this ridge with that of the south end of Tom Ball, explained on pages 87, 88, of vol. v, and the fact that Tom Ball is itself the course of a synclinal, sustains the above conclusion. Hence I now believe that there is in the region no second or upper limestone stratum.

I pass now to the region east of Great Barrington.

The ridge begun in East Mountain (at the east or right end of the preceding section, fig. 10) continues for three miles (with a partial interruption at one place), to Muddy Brook Valley, where stands "Three-mile Ridge" as its terminus. This Three-mile Ridge is in the same line with Monument Mountain and is connected to it by a low ridge, and the whole together forms the west side of the open Muddy Brook Valley, while the much higher Beartown Mountain Ridge forms the east side.

(The map, in volume v, may be consulted for the positions of these points.) The south end of Beartown Mountain stands on a high plateau, 150 feet or more above the level of Muddy Brook; and where this plateau faces Muddy Brook Valley with a bluff front is Devany's hearthstone quarry (D Q on the map), an important geological locality referred to below. Three-mile Ridge stands directly opposite, on the west side of the valley (as represented in fig. 11).*

Along the high region from East Mountain near Great Barrington to Three-mile Ridge on Muddy Brook Valley, the rocks, gneiss and quartzite, form a very shallow synclinal. The dip at the west end of the section (right end of fig. 10) have at first a high dip, or 50°; but it changes in the course of 30 yards to 40°; and then a mile beyond becomes nearly horizontal; and in Three-mile Ridge, the low anticlinal which spans Muddy Brook Valley is already begun, its rocks dipping 10° to 15° to the northwestward. The quartzite at the top of East Mountain—a stratified and rather soft quartzite, in some places gneissoid—disappears to the eastward. In Three-mile Ridge the rock above (see fig. 11, left end) is the hard gneiss that prevails to the westward; but the lower part is a very hard, well-characterized quartzite, finely exhibited in the bluff front constituting its foot, but rising to a higher level to the southward. The fact that the formation of quartzite in preference to gneiss, or the reverse, depends only on very small changes in currents or levels is beautifully shown in the bluff; for near the middle of the hard and pure quartzite there is a layer of mica schist ten inches wide which to the southward commences to have a thin center of quartzite, and then, in the course of a hundred feet, is changed wholly to hard quartzite, while in the opposite direction (northward) it retains its mica schist character, but narrows gradually to six inches before passing under cover of the soil.

The rocks in the low synclinal between Three-mile Ridge and Great Barrington are then (1) the lower quartzite, q^1, of Monument Mountain (fig. 8), at the bottom of the front of Three-mile Ridge (fig. 11); (2) the gneiss, s^2 (of the same section), overlying this quartzite and making the mass of the high land; and (3) the upper quartzite, q^2, at the top of East Mountain at the west end of the section.

Three-mile Ridge, as I have said, and as the section in fig. 11 shows,† fronts on the limestone valley of Muddy Brook; and across, and directly opposite, is Devany's quartzite bluff, Q.

* Muddy Brook has its head just north of this point; but the broad valley continues on southward, and becomes the valley of the Konkapot, and at the same time expands eastward, over the lake region of Monterey.

† The diagram here given, to be true to nature, should have the dotted line representing the meadow land of the valley doubled in length.

In this bluff, and in the fields adjoining the road (R in figure) just south and southeast of it, there occur the alternations of limestone, quartzite and mica schist or gneiss, already alluded

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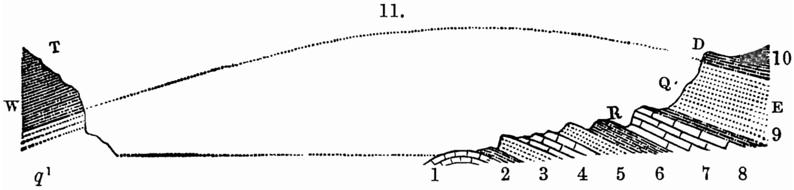

to. This interesting place—about four miles east of Great Barrington village—was made known to the writer by Mr. R. P. Stevens, of New York, who, many years since, studied the alternations of the rocks and made a section of the region.

The succession is as follows, commencing below, or in the field to the south of the road (R).

1. White granular limestone—that of the valley.
2. Mica schist, a thin bed.
3. Hard jointed QUARTZITE, 30 feet.
4. Same, limestone, 60 feet.
5. QUARTZITE, like the lower, 20 feet.
6. Gneiss, 30 feet.
7. (North of the road, R) bluish granular limestone, crumbling.
8. Mica schist, 6 to 8 feet.
9. QUARTZITE, 100 feet (Devany's quarry).
10. Gneiss (overlying the quartzite at the quarry).

The dip of the beds south of the road (R) is 30° to 35° to the eastward, the strike being N. 10°–30° E. But at the quarry, which is two hundred yards to the eastward, the dip is 20° to 30° to the northeastward. The change of strike and other facts, including the northwestward dip in Three-mile Ridge, show that the low anticlinal opens widely to the south:—the axis being inclined to the northward.

The alternations of quartzite and schist evince the little genetic importance of the distinction between quartzite and schist in Berkshire; and the intercalations of beds of limestone indicate that the conditions for sand or mud accumulations intermitted with those favorable for the shells or corals, or other material, fitted for limestone-making; and hence, that the area of sand depositions changed easily to an area of mud depositions, or of clear waters and abundant life. The lower of the quartzite beds (No. 3 in the section above) has but little lateral extent; for only a hundred yards off in the direction of the strike there is nothing but limestone. The old seas were hence much like modern ones in the irregularities of the bottom and in the outlining of sand-banks.

The thickness of the beds of quartzite and gneiss (or mica schist) between the lower schist (No. 2) and the upper (No. 10) taken together, is very near that of the lower quartzite (q^1) at the west end of the Monument Mountain section (fig. 8), and corresponds to it. Thus that quartzite which is there all quartzite, and in other places all mica schist or mica slate, here consists of alternations of the two, with only the upper half all quartzite; and, moreover, instead of including near its base merely a bed of calcareous quartzite, as in the west side of the ridge between Van Deusenville and Williamsville* there are three thin beds of the ordinary granular limestone.

Devany's Bluff has been stated to be the front of the plateau on which the south end of Bear Mountain stands. Going eastward a mile and a half, and then rising by a rough and steep road to the top of this plateau, the dip of the upper gneiss becomes northwestward, and the limestone formation outcrops on the plateau from beneath it and is the surface rock to the eastward over a large region.

Turning northwestward toward Beartown Mountain, the overlying gneiss is again reached; and the very small dip, 10° to 20°, and that to the northward, together with other observations in the region adjoining, show that the rocks in the southern end of Beartown Mountain, which are all nearly horizontal in position, constitute a shallow synclinal. Hence, east of the low anticlinal spanning Muddy Brook Valley, a little to the north of its line, there is a shallow synclinal like that west of it.

But Beartown Mountain, while having nearly horizontal rocks at its south end, has its beds very steeply upturned to the north, and hence in that direction it is a *deep* synclinal. It is hence like Tom Ball* in being a shallow synclinal at one end and a deep at the other, but the shallow is at the opposite extremity—the south.

The rocks of the mountain all overlie the Stockbridge limestone. They are mainly varieties of firm and well characterized gneiss. Fissile dark-gray gneiss, approaching mica schist, and a firm less schistose variety of similar color, are common. But these vary on one side to a white feldspathic gneiss containing a little black mica, in short interrupted lines; and on the other side to a quartzose variety, which on weathering becomes at surface in appearance a curiously pitted quartzite. Again, the gray gneiss at the north end is an exceedingly firm gnarled rock, owing to the contortions experienced in the period of bold upturning and metamorphism. South of the railroad half a mile west of South Lee, immense blocks of this gnarled gneiss lie like ruins on the slope of the adjoining ridge.

* This Journ., III, v, 85.

In some places in Beartown Mountain there are hornblendic layers; and at one ascent of the mountain made from the west side, about midway between the north and south extremities, I found, near the top, a dark-gray, fine-grained layer, exceedingly tough, consisting largely of quartz and massive garnet. In a spur just east of the south end I observed in the gray gneiss a seam three-fourths of an inch wide of magnetite.*

I have stated that the rocks of Beartown Mountain overlie the Stockbridge limestone. Precisely the same kinds of gray, white, and quartzitic gneiss I found constituting the first ridge south of the road that leads up the valley to Washington from near Lenox Furnace. The Stockbridge limestone makes the base of the ridge and outcrops at its western foot; and the marble quarries of Lee are the same stratum two miles to the southwest.

Leaving now the region of the preceding section and Beartown Mountain, we may go west to the low north-northwest and south-southeast ridge that extends from Three-mile Ridge north to the south end of Monument Mountain, and follow the ridge northward.

First, at the notch where the road from Great Barrington passes through Three-mile Ridge, the gneiss is nearly horizontal, with a slight dip, where distinct, to the westward, as in Three-mile Ridge just to the south.

A mile and a half to the north of the notch, a rocky bluff faces Muddy Brook Valley, the rock of which, a hard gneiss, dips westward 10° to 15°. For the rest of the way north to Monument Mountain the ridge is mostly under soil; and along the western slope all is earth-covered. Toward the base of the western slope there are immense numbers of quartzite masses which seem to indicate the presence of a layer of quartzite beneath. As the few dips observed correspond with that in Three-mile Mountain, the ridge is probably, like that, the course of a shallow synclinal, but a narrow one.

Reaching the notch along which the Stockbridge road passes the south end of Monument Mountain (near the east or right end

* I speak, p. 262, of "rising by a rough and steep road to the top of this plateau." Near the point there reached, in the limestone area north and west of the road, I found a loose mass of white limestone consisting mainly of what appears to be rhodophyllite (rose-colored pyrosclerite), but containing also yellow chondrodite in grains; and, later, another smaller loose mass consisting of quartz and dark-green crystallized chlorite, along with large imperfect crystals of a remarkably beautiful rose-colored sphene. Since the first discovery I have been twice over the region in order to find the original site of these specimens, but without success. They suggest the suspicion that there may be an outcrop of Archæan (Laurentian) rocks in the vicinity. But in three ascents of Beartown Mountain, and an excursion along its whole western side, no evidence of any was met with. They may be of drift transportation. Until the minerals are found there in place, I forbear to draw the conclusion—seemingly the most probable—that they are from the rocks of the region.

of the annexed section, fig. 13), there is an exhibition of quartzite under its various contradictory phases. In the first place, on the Monument Mountain side of the road, stands out in some

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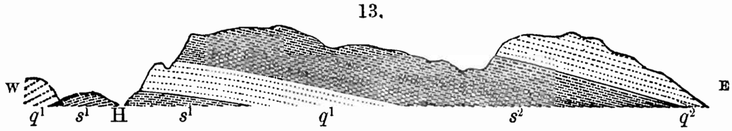


Section across Housatonic Valley and Monument Mountain.

places the intensely hard and enduring quartzite of the mountain, having joints, as usual, but only fallacious signs of stratification. On the opposite side, the rock, when any in place is seen, is also quartzite; but, unlike the mountain kind near by, it is, in the first place, very distinctly stratified; and, in the second, part is so soft or unenduring that much of it has fallen to loose dirty sand. Thin layers of a hard cellular quartzite often stick out from the sand, showing that there are strange alternations in the rock. What is stranger yet, there are also isolated portions, some 10 to 20 feet across, that are intensely hard quartzite, without a trace of lamination, except in some parts of the contour—the layers of which they originally consisted having been locally solidified into the hard massive structureless rock. But for evidences of transition in some parts of their contour these masses might be taken for transported boulders. The dip of the layers of this soft quartzite is 30° to 35° to the eastward, and the strike N. 5° to 20° E.

At one place, 200 yards to the north of the other outcrops, this soft quartzite occurs on the *west* side of the road with the dip reversed or to the westward, the amount 15° to 20°, and with the strike N. 20° W.; and here also there are immense boulder-like masses lying alongside of the crumbling kind, or seemingly imbedded in the soft quartzite. Such a quartzite easily changes to earth and thus makes a region of pseudo-boulders; and this suggests the true explanation, as I think, for the boulders on the west side of the ridge south of Monument Mountain, and shows that all quartzite boulders elsewhere are not drift boulders.

This soft, bedded, rotting quartzite at one place is exposed within forty feet of the massive enduring Monument Mountain quartzite, and with nearly the same dip, the latter not relenting in the slightest as it approaches the former. Are the two, notwithstanding the abrupt transition in texture, parts of the same layer? This is possible. Along the path descending northward from the eastern quartzite summit of Monument Mountain, the quartzite, elsewhere of extreme hardness, is for some yards thin bedded and rather fragile; showing a rapid falling off toward the soft variety. Again, on the south and west parts of the mountain, the same bedded variety in some places occurs. Still, in each of these cases the passage is rather gradual and not absolutely abrupt, as here on the Stockbridge road.

In view of all the facts, it seems most probable that the soft quartzite at this place is really that of the lower quartzite stratum (q^1), and therefore that there is a fault near this east side of the mountain, along which the lower quartzite is brought up to a level with the upper quartzite (q^2). This conclusion is favored by the fact that a mile farther to the north, if not here, a fault actually exists east of the vertical eastern front of Monument Mountain; for the limestone of Muddy Brook Valley outcropping within 200 yards of the foot of the precipice (at *q*, on the map in vol. v), has a nearly vertical dip (75° to 80° to the eastward), although the eastward dip of the beds of the mountain is only 15° to 25°—the strike being N. 15° W. Moreover the stratification of the limestone is mostly indistinct owing to the soldering together of the layers in consequence of the lateral pressure attending metamorphism. The evidence proves at least that there exists here either a fault or a very abrupt synclinal.

The limestone at this outcrop is the Stockbridge stratum; it outcrops at several points along the way to Stockbridge and Glendale; and it is consequently the same stratum that is seen descending under Monument Mountain at its west end near Housatonic village.

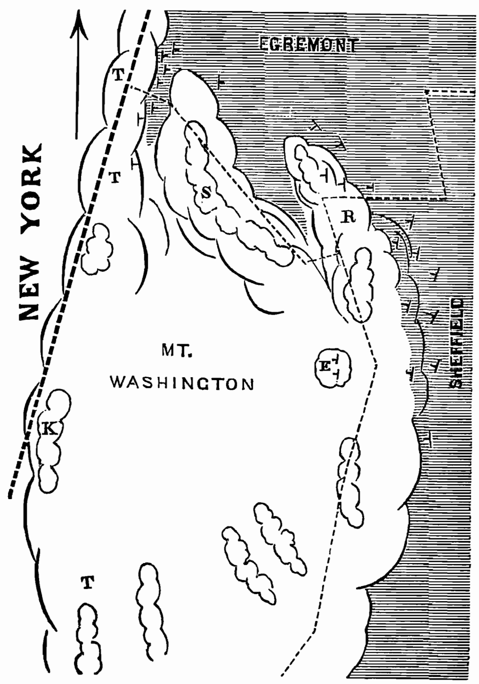
The porosity of many of the hard layers in the soft quartzite is probably owing to the former presence of disseminated carbonate of lime; and the ready disintegration of the other layers may be due to the same fact. Yet the soft quartzite crumbles in other localities without such a cause. The thin-bedded porous quartzite often has on its surfaces minute brown tourmalines.

4. *Observations outside of the Great Barrington Region.*

a. *Mt. Washington and Western Sheffield.*

Mount Washington is a mountain plateau, situated in Southeastern Massachusetts, with its western side in New York and southern in Connecticut. It is about 2,000 feet in elevation above tide level, and four to five miles across at top. Its western side stands in the line of the Taconic Range; but the mass of it projects to the eastward, and is almost wholly within the State of Massachusetts. Mount Everett, the highest point, —2,634 feet high, according to the Massachusetts triangulation,—is on the eastern border. It has the limestone plains of Sheffield on the east, and those of Egremont on the north.

This projection of the mass from the east side of the Taconic Range is shown in the accompanying outline map of the region. T T is the course of the Taconic Mountains, situated along the boundary between N. York and Massachusetts; while E, more than three miles east of the boundary, is the position of Mount Everett. The part lined over is the limestone region lying to the north and east and covering a portion of the eastern foot of the mountain.



R and S are two ridges extending from the plateau northward into Egremont. The limestone reaches into the intermediate valleys, even into the narrow western, between S and T (the one by which the carriage road leads to the summit of the plateau on the way to Mt. Everett, or to Copake).

The rock of the mountain, and also of the ridges R, S, T, is a fine-grained mica slate approaching (if not really) hydromica slate, and much of it is chloritic. It is the same that constitutes Tom Ball near Williamsville, west of Housatonic, and various ridges of the Taconic Range; at the summit of Mt. Everett it is much seamed with quartz.

Mount Washington is a synclinal with limestone below and slate above. In the plains of Sheffield, near the eastern foot of the mountain, there are two parallel north-and-south roads nearly a mile apart. Along the more eastern the limestone has its usual easterly dip—the amount 35° to 45°. But along the western—the under-mountain road—the dip is *to the west* 25° to 30°, with the strike N. to N. 25° E. (compass course). The limestone extends up the slope of the mountain for 100 to 120 feet above the road (by estimate, 700 feet above the sea level), and retains throughout its westerly dip; and then there follows the overlying slate of the mountain, with the same dip. This plunge of the limestone westward under the slates of Mount Washington may be traced along for four to five miles, even to the north extremity of the ridge R; and it characterizes also the high eastern summit, Mt. Everett, where the westward dip is 35° to 60°. East of the extremity of the ridge R, the strike of the limestone has some westing, becoming first N. 15° W., and then N. 30° W., and the last is the strike just north of it.

The limestone thus dipping under the mountain does not emerge short of the region of Copake in New York, and consequently the Copake and Sheffield limestones are the same stratum—both, the Stockbridge limestone; and the limestone stratum, therefore, makes a synclinal.

But the slates of the ridge S, and also those of the Taconic Range, T T, dip *eastward* 45° to 70°.

Moreover, the limestone of Egremont west of the ridge R takes the steep easterly dip of the ridge S, and the same also is the dip of the extension of it up the valley between S and T, where there are fine exhibitions of the conformability of the slate and limestone—the dip being there 60° to 70° and the strike nearly north and south.

We find thus evidence of a very broad synclinal across the center of Mount Washington. But just north, in Egremont, the structure is totally different; the ridges S and T are the courses of very steep and comparatively narrow independent synclinals, with the axial plane inclined eastward.

We learn then that the trough or synclinal, in the formation of which was involved the making of the mass of Mount Washington, commenced three times farther east than that for the Taconic Range to the north of it; and that thus the mass of enclosed slate is more than three times as wide, and hence it happened that the mountain there made was a lofty one. The lateral pressure, from the eastward, beginning the downward trend a mile east of the foot of Mount Washington, made a trough whose bottom on the east inclines westward at a comparatively small angle, as shown not only in the slates seen near the eastern foot but also in those of Mt. Everett; but over the corresponding region just north, in Egremont, the displacements were small and no mountain synclinal was begun until near the site of the Taconic Mountains; and there the whole force acted on a relatively narrow trough, making it of great depth, and pressing it over until its axial plane, like all the slate rocks enclosed, dipped eastward 50° to 70°. Then, quite near Mount Washington, the second synclinal, S, was made with the same steep inclination. The synclinals S and T become merged in one mass, in Mount Washington; and as the limestone does not appear at the summit, the intermediate anticlinal in the mountain was only an anticlinal of slate. In other words, the synclinal of limestone beneath the mass of the mountain was one great trough with breaks and incipient flexures; while to the north these incipient flexures became two defined synclinals, with the intermediate anticlinal — the synclinals being the courses of the ridges S and T, and the anticlinal that of the limestone outcropping between; and then, farther north there was formed the Taconic synclinal T alone. West of Southern Alford the Taconic slate and limestone have the same steep eastward dip.*

It is to be noted that a limestone as soon as made is as hard and unyielding as at any time afterward. It is hence far more resistant to flexure than the slates. This will account for changes in the flexures within short distances. The limestone of Sheffield and Egremont generally dips eastward at an angle as high as 35°, showing universal displacements; but where are its faults and folds it is for the most part difficult to discover.

The Taconic Mountains hence consist of no older rocks than Monument Mountain, or Tom Ball, and the multitudes of other heights in Berkshire, which are made of strata overlying the Stockbridge limestone. Further, the gray, white and quartzitic gneiss of Beartown Mountain, and the mica schist and quartzite of Monument Mountain, are strict equivalents of the chloritic mica slate of Tom Ball, Mount Washington, and the Taconic Range. It will be remembered that Tom Ball is only two miles from Monument Mountain, and but one from a ridge of the quartzite.

If then the Stockbridge limestone is of the age of the Chazy and Trenton, the *Taconic slates* may be reasonably set down as of the Hudson River or Cincinnati group.

To the eastward of Mount Washington, and half to three quarters of a mile west of the village of Sheffield, there are two narrow ridges of mica schist, each about half a mile long, standing surrounded by limestone. The western, called Bear's Den Ridge (from a deep gorge in its west side), is about 150 feet high, above the plain around; and the other, Barnard's Ridge (so named after President and General Barnard, whose paternal residence is near by), about 120 feet. The schist at Bear's Den and the limestone adjoining dip 60° to the eastward. The western side of the ridge is limestone, and the wearing away of the limestone at the junction has made the gorge, while the tumbling of great masses of the schist has contributed greatly to the wildness and beauty of the place. Each of these ridges is a local synclinal of limestone and schist; the trough of limestone was small, and hence it pinched in but little of the overlying schist. The layer of the schist folded together in the synclinal was probably not over 80 yards thick,

* This Journal, III, v, 86, 91.

making the whole thickness of the schist between the jaws of limestone about 160 yards. The schist involved in the synclinal is but a very small part of the great formation that overlay the whole limestone region when the folding began; for the thickness in Mt. Washington, between the top of Mt. Everett and the underlying limestone, is not far from 1000 yards, and this is what is left after ages of denudation.

The mica schist of Bear's Den is a coarse kind, full of translucent garnets a tenth of an inch in diameter, and *some layers abound in dark brown slightly translucent crystals of staurolite.* The staurolite crystals have the planes O, I, $1\text{-}\bar{i}$, and the garnets are dodecahedrons with the edges deeply truncated.

In the limestone of West Sheffield, two miles east of Mt. Washington, an opening has been made by Mr. Ralph Little of Sheffield, which has afforded some copper pyrites, with traces of galena and blende, and also rutile in crystals one to two or three inches long and an eighth to a fourth of an inch broad.

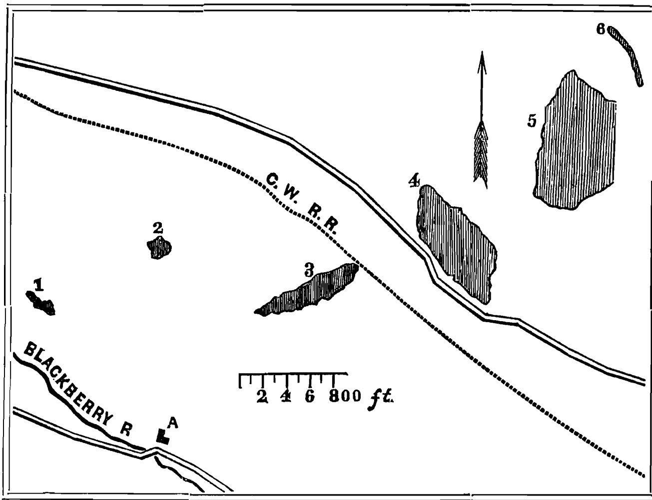
b. *Canaan, Connecticut.*

From the region of Great Barrington, the mica schist (or gneiss) and quartzite extend southward to Sheffield, and thence through East Sheffield to Canaan, the hard quartzite constituting long ridges the latter part of the way. At the same time, the great limestone formation of Great Barrington and Egremont stretches south to the same town, with undiminished breadth; there is hence no doubt that Canaan and Great Barrington are within the same geological region.

The patches of quartzite at Canaan, taken by themselves, or even with outcrops of some other localities, suggest strongly and enforce the conclusion presented in my former paper;* for the isolation of the areas with limestone around, the absence of stratification, and the apparent uncomformability and independence, are as I have stated. But, in view of the later observations—that the hard jointed quartzite may pass in the course of a few rods into soft friable quartzite; that it may graduate almost as abruptly into mica schist or mica slate, either firm or decomposable; that the hardest and most massive kind may directly overlie the crystalline limestone, or even be interstratified with it, as well as with the mica schist or gneiss, and the latter not participate in the system of joints that pervade the other; that small beds of quartzite may lie isolated in the upper part of the limestone formation; that consequently, the qualities, thick or thin, of wide or narrow extent, mean nothing, as applied to the hard quartzite—the facts are not at all adverse to the views gathered from the Great Barrington region.

* This Journal, III, iii, 179.

The only place in the outcrops of quartzite near Canaan, where the stratification is distinct, is in the northeastern of the patches, Nos. 5 and 6. (I reproduce here the map of the region, prepared for me by Mr. Adam.) I still find, on a re-exam-



ination of the region, the uncomformability of strike between the quartzite of No. 6 and the limestone outcrops but a few rods distant strongly marked; and, moreover, directly in its line of strike, but a hundred yards off, there is nothing but limestone. Still, there is much variation in the strike of the quartzite itself, the angle being N. 60°–65° W. at the northwest end, N. 45° W. at the middle, and N. 30° W. at the south end; and much also in that of the limestone at its parallel outcrops 20 to 25 yards to the westward, that to the northwestward being N. 80° W. and N. 70° W.; while only 12 yards west of the southeast end of the quartzite, the dip of the limestone is N. 35° W. Now, noting, in connection, that limestone uplifts are very irregular in their strikes, and also the fact that to the eye, from a little distance, without the use of an instrument, there is apparently a general conformity in the dip of the quartzite and limestone, we may conclude that the limestone does dip conformably beneath the quartzite (No. 6). The fact that there is only limestone to the northwest, in the line of the strike of the quartzite, is proof that the bed is one of small lateral extent, like one observed near Devany's quarry,* or that there is a fault. Seventy-five yards farther to the northeast, the limestone outcrops again, with the strike N. 53° W., and dip to the northeastward as in the other

* No. 3, page 261.

cases, as if it were a bed overlying quartzite No. 6; and this it is, unless there is a fault between the two. The quartzite of patches Nos. 5 and 6, having the dip in opposite directions, may be parts of one bent layer; for the thinness of the bed No. 6 may be only the thinness of the *hard part* of the bed, a soft upper portion having been removed. Hence, while my previous deductions are sustained by Canaan facts, they are wrong only because facts elsewhere observed have proved that the quartzite has no fixed qualities, and is hence the most deceptive of rocks.

Rattlesnake Hill, just north of Canaan, while consisting mainly of a decomposable arenaceous mica schist, has below a stratum of soft quartzite over the limestone. Canaan Mountain, a very prominent feature in the topography of the town of Canaan, rises from the plain half a mile or so south of the above quartzite outcrops, and *stands on a high base of limestone*, outcrops of which are best displayed on the southwest side. The rock of the mountain, over the limestone, four hundred feet or more in thickness, is mainly coarse and fine mica schist, passing into gneiss. I have not found any quartzite stratum, but it is possible that the soft kind may be concealed beneath the high grassy slope of the north side. *Canaanite*, or white augite rock,* occurs in many places in the upper part of the underlying limestone.†

c. *South Canaan and Falls Village.*

The village of South Canaan is situated to the south of Canaan Mountain, and two miles east of the Housatonic River, where is Falls Village and the railroad station. A few rods to the southeast of the South Canaan Church, there stands what may be called a spur of Canaan Mountain, named Cobble Hill. This hill consists below, to the west, of quartzite, dipping southeastward 40° (strike about northeast). Above the quartzite, 20 to 25 feet of which are exposed above the road, there is a stratum of mica schist and thin-layered gneiss, containing scales of both black and white mica; and above this, and constituting the body of the hill, there is a whitish granite-like gneiss, great blocks of which lie at the foot of the bluff adjoining the road. The quartzite is mostly the soft

* Both tremolite and white augite occur in the Canaan region. The Canaanite is a massive form of the latter, as first observed by Prof. C. U. Shepard, in his Report on the Geological Survey of Connecticut, 8vo, 1837, p. 135.

† In the observations on the rocks at Poughquag (this Journal, III, iii, 255) it is stated that the quartzite and the limestone at outcrops 200 yards apart are unconformable. It is quite possible that within this 200 yards, where the rocks were concealed from view, there is a bend in the limestone, bringing it into conformity of dip with the nearly horizontal quartzite, and that thus it may pass conformably beneath the latter rock; and facts elsewhere observed render this most probable.

bedded kind, and in its upper part it contains, at intervals, some streaks of black and white mica, thus showing its relations to the overlying schist. The dip of the rocks conform to that of the limestone not far distant, and there is no reason to doubt that the quartzite, with the other crystalline rocks, overlie conformably the limestone.

At Falls Village, the limestone outcrops above the river at the falls and over the plains adjoining. Just above the falls, on the west side, there is an outcrop of well characterized mica schist; and half a mile to the northwest the schist forms a ridge, with limestone outcropping in its lower slopes from beneath the schist, both rocks having a dip of but 15° to 20°. The mica schist contains small garnets, and some of its layers *abound in crystals of staurolite.* This locality of staurolite was mentioned to me by Dr. Stephen Reed, of Pittsfield, as well as that at Bear's Den in Sheffield.

d. *Rutland, Vermont, and Graylock in Northwestern Massachusetts.*

Vicinity of Rutland.—I have not attempted to give the Rutland region a careful study, but have made some observations of interest bearing on the relations of the same to that of Great Barrington.

On the eastern border of the Rutland limestone, just east of the road from Rutland to Mendon, there is a portion of that long Vermont range of quartzite, which is marked on the geological map of Vermont as extending from the Massachusetts boundary to a point just north of Mendon, sixty miles, and thence, after a brief interruption, to Rockville, nearly forty miles beyond. This so-called "quartzite" ridge consists, near Rutland, of chlorite slate containing magnetite, and hydromica slate (the so-called talcose slate or talcoid schist), along with quartzite; and, as has been stated (this Journal, III, iv, 69), the hydromica slate graduates laterally by rather abrupt transitions into the quartzite, the same bed being quartzite in one place and hydromica slate 100 yards off. Part of the quartzite looks like gneiss, owing to streaks of silvery mica (hydrous mica?) in largish scales. Another part is a coarse conglomerate.

The rocks in the Rutland ridge, excepting the massive quartzite, are well stratified, and have a dip to the eastward corresponding with that of the Rutland limestone and apparently lying over it. I found no vertical section of quartzite and limestone near Rutland, showing positively that the quartzite with the hydromica and chlorite slates were uppermost. But the dip of the rocks at the nearest outcrops was the same with the limestone; and at one outcrop of the limestone, the upper layer was covered above with a coating of quartzite, confirming the conclusion that the quartzite is the superior rock.

It will be observed that the variations from hard to softer quartzite, and from quartzite to metamorphic schists, are similar to those observed in Berkshire. East of Brandon, a mile or two beyond the limonite, lignite and kaolin bed of "Forestdale," I visited another part of this Vermont quartzite range. There the rock is of the hard jointed kind. But the bedding is in some places distinct, and in a few layers there are slaty portions.*

Graylock.—Graylock, standing between South Adams and Williamstown, in Northwestern Massachusetts, 3600 feet above tide level, while Taconic in system and in the character of its rocks, belongs to a parallel line of elevations about six miles east of the Taconic Ridge. In structure and origin it is closely like Mt. Washington. This is shown as far as relates to the existence of the synclinal, in the section of it published by Prof. Emmons, at page 19 of his American Geology (8vo, 1853), the general truth of which I have verified.

This section commences at South Adams, and terminates at the entrance to the great funnel-shaped valley called the Hopper, where the limestone stratum dips *eastward* under the mountain. The dip of the slates at the summit of Graylock and to the west of it is steep to the eastward.

At the narrow north end of the Graylock range of elevations, abreast of North Adams ($5\frac{1}{2}$ miles north of South Adams), the limestone and slate *both dip eastward*, just as with the Taconic ridge in Egremont north of Mt. Washington; and the explanation is, I believe, the same: that the broad synclinal which holds the broad and lofty mountain, is, at this place pressed to a steep and narrow synclinal with the axial plane inclined eastward. The very large and deep mountain-girt depression called the Hopper, north and south in trend, suggests strongly the view that two synclinals with an intermediate anticlinal exist in the slates of the broader part of the mountain mass, and that the existence of the Hopper was determined by the position of the anticlinal; while the limestone synclinal may have been a nearly simple one beneath the slates. My own observations over the region have been too limited to make this more than a suggestion.

* The Geological Report of Vermont makes the quartzite east of Brandon to extend west over two miles of country which is without outcropping rock and deep in earth, to the bed of limonite and kaolin at "Forestdale." But the kaolin has come from the decomposition of feldspar; and it is probable that a decomposable mica or hydromica schist underlies the earth-covered interval referred to, and that its feldspar was the origin of the kaolin.

CONCLUSIONS.

I close with the following conclusions as a sequel to those mentioned on former pages of this memoir.

XIII. *Lithological evidence as a test of Geological age.*—It is above shown that the mica schist overlying the Canaan limestone is in Sheffield and Canaan *staurolitic. The mineral staurolite exists, therefore, in rocks younger than the Stockbridge limestone.*

But the facts which have been presented, besides opposing the idea that staurolite is a satisfactory mark of age, also show that lithological evidence should be used with extreme caution even within a district of a few square miles. For in a distance of three miles or less, a stratum of quartzite has been found to become one of mica schist, or of gneiss, or of mica slate, garnetiferous or not, or of hydromica slate, or of chloritic mica slate, or chlorite slate containing magnetite or not; and in another locality, in the course of two miles, the quartzite stratum changes to a coarse staurolitic mica schist, full of garnets; and in another, mica schist is replaced by a granitoid gneiss. Had I known these facts when I commenced my investigations in Green Mountain geology, I should have had much less difficulty in reaching right conclusions. It is hence evident that, in the present state of the science, we should beware of all conclusions as to the age of metamorphic rocks that rest on lithological evidence alone, whether they relate to præ-Silurian or subsequent time. When every square mile of New England has been investigated *stratigraphically* with thoroughness, we shall begin to know something of its geology.

It should be understood that tracing a formation along from mile to mile by means of the rocks, *after an understanding of their characters and transitions*, is a very different thing from deducing the age of rocks on the principle that a particular kind belongs to a particular age in geological history.

It follows from the facts reviewed, as stated in an early part of this memoir, *that there is not strictly any quartzite formation in the Green Mountains; the formation being made up of various rocks, and quartzite being not always the predominant one.*

XIV. *Age of the Stockbridge Limestone.*—This mass of limestone, as I know from personal study, extends continuously from Pittsfield to Canaan.* Beyond Canaan it stretches on, as shown by Percival, to a point south of Pawling in Dutchess Co., New York—making for the total from Pittsfield southward a length for the formation of 70 miles. To the north of Pittsfield, I have examined the limestone only at isolated points. At these I have found no reason to doubt the conclusions of the geologists of Massachusetts, Vermont and Canada, that the

* The one interval not examined when page 52 of volume v was printed, I have recently been over.

rock, all the way to Rutland 80 miles from Pittsfield, and 20 miles beyond, is the same limestone. The evidence consists not only in the apparent continuation and similarity of the limestone throughout, but in the fact that with very small interruptions the quartzite continues to accompany the limestone, especially along its eastern border, just as in Berkshire, and that it undergoes the same transitions to mica schist, mica slate or hydromica slate, along its course; and, further, that the mica slate accompanying the limestone, especially along its western border, is very similar throughout. That the evidence should be conclusive, the actual continuation of the limestone through, from Pittsfield northward, should be ascertained, and also the stratigraphical relations of the quartzite to the adjoining limestone. What is now known is sufficient to render the conclusion exceedingly probable. If so, the age of the limestone at Rutland and other parts of Vermont is approximately that of the rock in Berkshire and farther south.

I have referred to the facts with regard to Chazy fossils found in the Rutland limestone by the Rev. A. Wing. As the facts are of the highest importance, the paragraphs may be here cited. (This Journal, vol. iv, 133, 1872.) Mr. Billings says—

I received last summer some fossils from Rev. A. Wing, and made the following note upon them before I sent them back.

15th June, 1871, from the Rev. A. Wing, twenty specimens with the following ticket: "Encrinites and obscure fossils, supposed to be Trenton, collected May, 1870, at the marble quarries, West Rutland, not one hundred yards northwest of an abandoned marble quarry,—the most northern one worked on the southwest side of the valley, say one hundred and fifty rods southwest from Barns' hotel, West Rutland."

This is the description of the locality given by Mr. Wing. My note on the fossils in the book I keep for such purpose is—

"These consist of numerous obscurely preserved forms like *Pleurotomaria staminea*, small *encrinal joints*, and a single plate of *Palæocystites tenuiradiatus*. I think this collection is Chazy. The rock is a gray fragile limestone with white crystalline seams in it."

If Hitchcock's Eolian is Stockbridge limestone, then the latter includes the Chazy. The plate of the Cystidean, *P. tenuiradiatus* Hall, is a never-failing guide to the Chazy; at least it is so on the west side of Lake Champlain.

That all the facts may be before the reader, I quote a page (pp. 418, 419) from the Vermont Geological Report on other fossils from the same limestone.

Although the Eolian limestone is largely distributed in our country, no fossils have been found in it, except the few which occur in Vermont. We have found the following genera, to which specific names cannot yet be attached: *Euomphalus*, *Zaphrentis*, *Stromatopora*, *Chætetes* and *Stictopora.* Two kinds of encrinal plates have also been discovered. These genera were determined by Prof. James Hall.

Euomphalus. This is a genus of univalve mollusks, somewhat resembling Maclurea and Ophileta. It is most common in the Devonian and Carboniferous rocks, though not wanting in the Lower Silurian. This genus has been collected from the Eolian limestone in Whiting and Sudbury. A shell of the same genus is found in the Hudson River limestone in Orwell, which is quite near the locality in Sudbury. There are two species of Euomphalus in the Eolian limestone.

Zaphrentis. The three other genera are of corals. *Zaphrentis* belongs to the family of *Cyathophyllidæ*, and there is no instance in this country where this genus has been found below the horizon of *Atrypa reticularis*, which is an Upper Silurian and Devonian species. The two are found together in great abundance in the semi-crystalline limestone connected with clay slate upon Lake Memphremagog near talcose schist. We cannot ourselves distinguish between the specimens of *Zaphrentis* from Lake Memphremagog and the Eolian limestone. This genus occurs in a dark colored slaty limestone in Sudbury and Cornwall, associated with Euomphalus and Chætetes.

Stromatopora. This is the most common of all the fossils in the Eolian limestone, and it is a genus whose lower limit is in the Niagara group of Upper Silurian rocks. It has been found in Sudbury, Orwell, Cornwall, East Middlebury, Brandon, New Haven and Williston. The specimens from East Middlebury and Williston are referred to this genus with a query. There are probably two species of Stromatopora in the Eolian limestone.

Chætetes. This genus is both an early and late one—that is, it is found from the Lower Silurian to the Carboniferous rocks. Both branching and oval forms of this genus occur in the Eolian limestone of Vermont, and there are two distinct species of it. It has been found in Sudbury, Benson, on M. C. Rice's farm, Cornwall and Williston. A supposed fossil of this genus is quite common at Peck's quarry in Cornwall, and on Dea. Casey's farm; at New Haven on the railroad north of New Haven railroad bridge, and in a loose block of limestone at Middlebury village.

Stictopora. In Sudbury were also collected specimens of the genus *Stictopora.* This genus was remarkably well defined. Prof. Hall did not venture to pronounce upon the species. An obscure coralline form, distinct from any of the others described, has been found in the limestone above Sheldon & Slason's marble quarry, in West Rutland.

Encrinal stems. The large encrinal stems from Sudbury and Cornwall are interesting, because the only cases where encrinal rings of such dimensions have been found in this country are in Devonian rocks. The fragments of small encrinal stems that have been discovered in the Eolian limestone, were found at the marble quarries in East Dorset, upon Mt. Eolus, and in West Rutland, Sudbury and Cornwall.

One will be struck with the fact that all these fossils have an Upper Silurian or Devonian character, wherever they are of value in identifying strata. * * * *

We incline to the opinion that they must probably be placed as high as that formation, or as low as the Lower Silurian: to which last position Mr. T. S. Hunt assigns them.

With regard to the Vermont quartzite, we have the following facts from page 356, of the same report.

Several species of fossils occur in the quartz rock. They are a species of *Lingula*, a mollusk resembling the *Modiolopsis*, a straight chambered shell (?), a few crinoidal columns, the *Scolithus linearis* (Hall), a few fucoids, and some indeterminable forms which are evidently organic.

The Lingula is from the north part of the principal range of quartz rock in Starksboro, near Rockville, at the house of Mr. Hill. The locality was discovered by Henry Miles, of Monkton. The specimens contain scores of fossils, but none of them are very distinct. Prof. James Hall has examined them, and regards them as a new species of Lingula, related to a species contained in the Medina sandstone.

The "Modiolopsis," chambered shell, and encrinal remains are found in hyaline quartz on the west side of Lake Dunmore. The first and last were referred to the same authority by Prof. Adams.

From the above statements it would appear that the limestone is either later Lower Silurian, or younger. But species of Zaphrentis have been described by Billings from the Lower Silurian (Hudson River group, one of them three inches long and an inch and a half in diameter at top); and it has been inferred by Hall, Billings, Hunt and others that the beds are probably Lower Silurian. The encrinal stems, as I learned from Prof. C. H. Hitchcock, were not over three-eighths of an inch in diameter. Putting the facts together, the evidence is strong that the limestone is not older than the Chazy, and that the Trenton limestone is included with it, its deposition having followed that of the Chazy, as in most regions of Chazy rocks. Excepting the *Scolithus*, there is nothing in the quartzite that suggests a Potsdam origin, or anything older than the Hudson River group; and the Scolithus is of no particular age.

The results thus take us back to the old idea of the Professors Rogers, that the limestone is mainly Trenton, and therefore that *the slates of the Taconic Range are of the Hudson River group.* The two make up the true original Taconic system of Emmons.

Before leaving this topic I make one remark of a personal nature. Through the early part of the Taconic controversy—in which the principal contestants were Prof. Emmons on one side, and Prof. James Hall and the Profs. Rogers on the other — I took no part, as I had given the facts no investigation in the field.

At the same time I inclined toward the views of Profs. Rogers and Prof. Hall because of my confidence in them as geological observers. When, thirteen years since, Sir Wm. Logan, after investigations in the Green Mountains of Vermont and Massachusetts, as well as in Canada, brought out his view that the Taconic rocks—those of Taconic mountains and the associated limestone—were identical with the Quebec group,* (an opinion then participated in, I believe, by Prof. Hall,) I gave it acceptance and adopted it in my Manual of Geology. Within the past half a dozen years I have looked to the rocks themselves in order to obtain ground for an independent judgment; and the result is that above presented. It makes the Taconic rocks and the associated limestone one in formation, as held by Logan; and it differs from his view as to the age of the beds—on the basis partly of the older examination of fossils by Hall, and especially on the recent, by Billings; and diverges also as regards the relations of the quartzite.

The conclusion I have presented relates to the *original Taconic* as presented by Emmons in his New York Geological Report published (in quarto) in 1842, and not to the unfortunate additions to it made in his later publications†—unfortunate because they drew off attention from the real Taconic, and became the chief subjects of controversy and prolific sources of error.

XV. *The condition of the Green Mountain region in Berkshire during the formation of the rocks.*—The occurrence of the quartzite along the limestone region, and its passage occasionally into conglomerate, testify to the existence in the Green Mountain seas, during the later part of the Lower Silurian, of great exposed sand flats, such as are made in the face of the waves; and the frequent transition in the quartzite stratum to mica schist, or gneiss, or mica slate, and the like, are good proof that in the shallow waters about the great sand banks, the bottom was of mud. The fact that the quartzite prevails most along the eastern border of the limestone shows that in that portion of the region the water was most shallow, or that there lay the largest amount of emerged land. Whatever the depth of water in which the limestones were made, the depth appears to have diminished in the Berkshire region toward the end of the Lower Silurian era; and this was a prelude to the time of upturning and metamorphism which appears to have closed that era in Western New England.

It is a remarkable fact that the conglomerate accompanying the quartzite contains no pebbles of gneiss or of any of the older crystalline rocks. The pebbles are all of quartz or quartzite.

* The views of Logan are to be found in this Journal, II, xxxi, 210, 1861; and also, with additional conclusions, by T. Sterry Hunt, at page 392 of the same volume, in an article entitled "On some points in American Geology."

† See this Journal, III, iii, 468.