ART. XXVIII.—*On the relations of the Geology of Vermont to that of Berkshire*; by JAMES D. DANA.

[Continued from page 140.]

CONCLUSIONS AS TO THE RELATIONS OF VERMONT AND BERKSHIRE GEOLOGY.

THE conclusions, which flow from the fact, illustrated in the two preceding numbers of this Journal, that the limestone areas of Vermont and Berkshire are geologically one, may be presented under the following heads:

1. Chronological conclusions: or the equivalence and age of the formations.
2. Lithological conclusions.
3. Orographic conclusions.

And, as a sequel to this discussion, I propose, next, to present stratigraphical facts bearing on the geological relations between the area which has been under consideration and the country lying to the southward and eastward of it, in Connecticut and New York.

I. CHRONOLOGICAL CONCLUSIONS: OR THE EQUIVALENCE AND AGE OF THE FORMATIONS.

1. *Age of the Limestone series as a whole.*—From the facts brought forward it is manifest that the limestone, schists and quartzite, making up the limestone series of Vermont and Berkshire, are *continuous* formations, and that they are *conformable* throughout. Hence we have proof that the conclusions deduced for Vermont, from Mr. Wing's discoveries, are true also for Berkshire: namely, that—

(1.) The limestone series is *made up wholly of Lower Silurian formations*; that is, of formations not older than the Primordial or Cambrian, nor newer than the Cincinnati or Hudson River group.

(2.) All these formations were upturned and metamorphosed together at one mountain-making epoch, no epoch of disturbance having intervened; and that upturning occurred after the laying down of the most recent of the formations in the series.

2. *Age of the Taconic slates, and of the limestone immediately adjoining.*—The Taconic mountains of western Berkshire are a direct continuation of the "Great central slate-belt" of Vermont. The two make one range and one rock-formation, and consist of the same kinds of rocks similarly upturned. They are alike also in dividing off a western band of limestone from the main limestone area—that extending through West Cornwall in Vermont, and that of Hillsdale, Copake and Millerton, in New

York. In Vermont the Taconic slates (those of the central slate-belt) *overlie* the adjoining limestone in one or more synclinals, as plainly shown in Mount Dorset, Danby Mountain, Equinox Mountain, Spruce Peak in Arlington, and Mount Anthony in Bennington; and in Berkshire they have the same position, as observed in Graylock and Mount Washington. Hence in both States *the Taconic slates overlie, or are younger than, the adjoining limestone.*

In Vermont, as Mr. Wing has shown, the limestone nearest the slate contains, in several places, Trenton fossils (*Trinucleus*, etc.), and at West Rutland, Chazy fossils (*Maclurea*, etc.) if not also Trenton; and the slates are, therefore, as has been already stated, *younger* than the Trenton limestone of that region and belong probably to the Hudson River or Cincinnati group. If this be true in Vermont, the Taconic range in Berkshire, since it is part of the same slate-belt, consists of rocks younger than the Trenton, and is therefore either of the *Upper Trenton* or of the *Hudson River* or *Cincinnati* group.

It may be questioned whether the Graylock Spur should be included with the Taconic range, since it stands to the east of it. But the resemblance in its rocks to those of the Taconic range, coupled with its position stratigraphically *above the adjoining limestone*, just as in Mount Anthony, Equinox Mountain, Mount Eolus and other peaks in the slate-belt of Vermont, make it almost certain that the age of one is the age of the other, as first observed by Emmons.

The Berkshire *limestone* of the band adjoining the Taconic range is mostly, if not wholly, non-magnesian, like that of Vermont. Hence its constitution, as well as its position, makes it altogether probable, that it is Trenton or Chazy, as in Vermont. The limestone *west* of the Taconic range in Hillsdale, Copake and farther south, must also be Trenton or Chazy since this is true for that similarly situated in Vermont; and, moreover, it is the west side of one and the same synclinal flexure, the limestone on the east side of the Taconic range passing beneath and coming up again on the west side.

3. *The Limestones and Schists of the Eastern half of the limestone area.*—Like the Taconic slates to the westward, these more eastern rocks in Berkshire are a continuation of those north of them in Vermont. The quartzite is not all in one range in either State; but, whether in one or several ranges, it is alike from north to south in belonging especially to the more eastern part of the limestone area. Hence whatever is true of the age of the quartzite in one State is almost certainly true in the other.

Further, whatever the range of age in the more eastern of the limestones of Vermont, the same is the probable range of that in Berkshire and farther south. Like the Vermont limestone

then, the Berkshire limestone of the middle and eastern half of the area may include the Calciferous, Quebec, Chazy and Trenton formations, and perhaps also the Primordial; but, since there are no fossils to fix the precise age, the areas of these different formations in Berkshire cannot be separately distinguished.

4. *The age of the Quartzite formation, and its relation in position to the adjoining limestone.*—The quartzite formation includes, as has been explained, strata of quartzite and schists—sometimes one, and sometimes the other, predominating. The special age of the formation is in doubt, equally with that of the eastern limestones. There may be quartzites of different periods of the Lower Silurian; and so with the schists. The question of age can be positively answered only by the discovery of decisive fossils in the quartzites of Vermont; and so many imperfect forms have already been brought to light (besides the unsatisfactory worm-burrows, and Fucoids or worm-tracks) that we may feel sure the future will clear away the doubts. A word is added beyond (p. 207) on two of the forms thus far discovered.

One important point—the position of the quartzite with reference to the associated limestone—is well illustrated in Berkshire. Mr. Wing, in his explanations of the Vermont sections (pp. 410, 411 of the last volume of this Journal), makes this limestone to *overlie* the quartzite, and to be the equivalent of the “subcrystalline limestone” which overlies the Red Sand-rock on the west side of the limestone area—the quartzite being in his view the same rock with the Red Sand-rock. It is to be noted, however, that the sections themselves do not indicate whether the limestone is overlying or underlying, and may be explained as well on one supposition as the other.

In Berkshire, beyond all reasonable doubt, the eastern quartzite formation overlies the adjoining limestone.

The most distinct and positive proof of the superposition of the quartzite over limestone that I have observed is that

afforded by sections either side of Konkapt Valley—a locality brought to my attention, as I state in my memoir of 1872–3, by Dr. R. P. Stevens. The figures of the sections of Devany's

Bluff and Three-mile Ridge, which face one another on opposite sides of the valley, are here repeated from page 45 of this volume. In each of the sections, quartzite strata and overlying schists of great thickness rest on the limestone which outcrops in the valley. The dip is small (8° – 25° , p. 46). The limestone is plainly at the bottom; and *it is stratigraphically* so, unless there has been a flexing of the strata and an overturned fold at the place. Nothing in the region suggests that there has been such an overthrow: the facts, on the contrary, prove the flexure which the strata have undergone to be a gentle one. As has been stated, the two ridges stand opposite one another, not quite a mile apart. In the eastern, the dip is 20° – 25° to the northeastward; in the western, about the same to the northwestward. The series of rocks from below upward, limestone, quartzite, schist, of one side, is repeated in the other, and the schist of the west side has a thickness of several hundred feet like that of the east. All the conditions are those of a low anticlinal spanning the valley; and one whose axis dips gently northward, and whose sides flare southward or southward and eastward. The valley south of Devau's Bluff widens much to the eastward and has its lakes with limestone about them.

Besides this, the rocks of the gentle anticlinal are continued in the high land either side in a broad shallow synclinal—the high land synclinals and the anticlinal valley between covering a breadth from east to west of ten miles. (a) In the synclinal to the *west* (between the Konkaput valley and Great Barrington), the schist has first a dip northwestward of 8° to 25° , but, after three-fourths of a mile, the dip is eastward 20° to 25° , and finally 40° to 50° , just east of Great Barrington. (b) In that to the *east*, the dip is 5° to 25° to the northeastward, over the high land and mountainous region all the way east from Devau's bluff to the village of Monterey; but on the northeastern side of this high land, at the village of Tyringham, and at South Lee, it is to the southwestward. A section between Monterey and Tyringham, east of north in course, shows the change of dip. The limestone about Monterey dips 25° to the northwest; along the highest part of the road, the gneiss and mica schist of the hills outcrop and have the same dip and strike; descending to Tyringham, five miles to the north, the dip diminishes, and for the last mile is reversed, being to the southwestward; finally, at Tyringham, the limestone comes into view again overlaid by the same kinds of gneiss and mica schist, with a dip of 15° to 25° .

Thus, both *east* and *west* of the Konkaput anticlinal there is as gentle a synclinal; and hence the idea of an overturn cannot be reasonably entertained. It appears to be a general rule, for the eastern or quartzite part of the limestone area as well as the western, that *the valleys are eroded anticlinals, and the ridges*

or areas of high land are *synclinals*, a rule exemplified extensively in the continuation of the Appalachians from Pennsylvania to Alabama, where the facts are little obscured by metamorphism. The position of the limestone *beneath* the quartzite and schists along the Koukaput is then the original position.

This underlying of the thick quartzite and schists by limestone appears to be a fact in many other parts of the Berkshire region, as in Monument Mountain, in quartzite ridges east of Tom Ball, and elsewhere, though these examples are not as free as the above mentioned from other supposable explanations. The evidence is complete with or without them, that *the quartzite and the associated schists in some prominent cases in Berkshire, if not all, overlies limestone*. In such cases, accordingly, the limestone is the older formation of the two; and this is as true for Vermont as for Berkshire. And where so in either State the quartzite and the associated schists constitute *synclinals or monoclinals—not anticlinals*.

There is another argument favoring the view that the quartzite is in *synclinals*. It may be questioned whether lofty anticlinals of quartzite are a possibility. The quartzite was originally a deposit of sand, or a sandstone, of great thickness. Now such a sand-bed or sandstone, raised into a close and lofty anticlinal flexure so as to have, as in Vermont, and in some parts of Berkshire, a dip of 40° or 50° , would be sure to have been very profoundly broken by the strain; and thus broken, it would have been exposed to erosion and destruction, and even to removal so as to leave a valley in its place, as has been the usual fact in the Appalachians; while, if bent up into a synclinal, whether shallow or deep, the pressure would tend to promote compactness, consolidation, and preservation. Hence the existence of the quartzite formation in lofty ridges is strongly against its being in anticlinals.

If then the quartzite ridges are not anticlinals, *the limestone is the inferior stratum*.

Again: if the quartzite is Primordial, the underlying limestone is inferior Primordial. Consequently, the quartzite formation should be elsewhere found separating this inferior Primordial limestone from the limestones of the Calciferous, Quebec, Chazy and Trenton periods. But the fact is that this limestone which underlies the quartzite is in many places in Vermont continuous with the rest of the limestone formation, one area of limestone stretching from the quartzite quite to the Taconic slate-belt where are Trenton and Chazy fossils in it. We naturally inquire—how under these circumstances can it be that the quartzite formation belongs any where between the Trenton and that inferior limestone? Is it not necessarily superior to all the continuous Lower Silurian limestone formation? But if thus superior, the quartzite is not Primordial; it is not the

equivalent of the Red Sandrock; it is even related in age to the Taconic slates; these overlying a western portion of the limestone and the quartzite formation an eastern. If so, *the eastern quartzite formation is of the age of the later Trenton, or the Cincinnati group, both in Vermont, Berkshire and Connecticut.*

It will be remembered that the axis of the iron-ore belt is situated in the vicinity of the quartzite in Vermont, but in the vicinity of the Taconic range in Berkshire; and even west of the Taconic range for the region south of the latitude of middle Berkshire (this vol., p. 133). Thus the quartzite and the Taconic slates have the same geological relation to the iron ore belt; and this again suggests the idea that the two are of the same age—both of the Cincinnati or Hudson River group if one is.

These remarks make apparent the difficulties and doubts surrounding the question as to the age of the quartzite, doubts which only new discoveries of fossils can wholly set aside.

The collections of Yale College contain specimens of the "Modiolopsis" and "Orthoceras" reported by the Vermont Report as occurring in the Quartzite, which were received by me from the late Professor Adams, many years since, when he had charge of the earlier uncompleted survey of that State. There is but one specimen of each—not enough for a decided opinion about them. Quite recently I have seen other specimens in the Amherst College Museum. One is a piece of quartzite with many casts of one valve of the so-called "Modiolopsis;" and another contains several of the "Orthoceras;" and I have found that both are unquestionable fossils. The former is the shell of a small lamellibranch about six and a half lines long and five broad. The so-called *Orthoceras* is a slender conical tube filled with quartzite; and it was apparently without septa—no remains of them being present within; the specimen in the Yale collections has a length of 0.6 in.: a diameter, at the larger (broken) end, of 0.24 in., and, within a twentieth of an inch of the smaller rounded end, of just half this. It appears to be a *Theca*-like species. The lamellibranch seems to indicate, as Professor James Hall concluded, that the quartzite is not Primordial, and that it must be later in age.

The facts that have been reviewed have established: (1) The Lower Silurian age of the limestone series as a whole; (2) the unity of position, and of epoch of uplift, of the series; (3) the very probable Trenton and Chazy age of the limestone adjoining the whole of the Taconic slate-belt or range; (4) the equally probable Upper Trenton or Cincinnati age of the Taconic rocks. But the age of the more eastern portion of the limestone and of the quartzite and schists remains undetermined. My opinion is that the quartzite will be found to be newer than the Red Sandrock, and of the same age essentially as the Taconic slates.

[To be continued.]