ART. XXXVII.—*On Rocks of the Helderberg era, in the valley of the Connecticut—the kinds including Staurolitic slate, Hornblendic rocks, Gneiss, Mica schist, etc., besides Fossiliferous Limestone;* by JAMES D. DANA.

IN my memoir on the rocks of Berkshire, I have shown, on stratigraphical grounds, that the metamorphic rocks, gneiss, mica schist, mica slate, chloritic mica slate, chlorite slate and others occur, underlying and overlying quartzite, in *one of the later Lower Silurian formations*; and also that staurolite crystals abound in a mica schist of the same age.

In the following pages, it is further demonstrated that not only the same kinds of metamorphic rocks, but even hornblende rock and schist and syenitic gneiss are extensively developed in *a formation of Helderberg age*, and probably the Upper Helderberg or Lower Devonian. Moreover, crystals of staurolite are here also abundant; so that this mineral species, which some American geologists have thought as good as a fossil for distinguishing pre-Silurian rocks of a specific age, has the chronometric virtues only of a species of immensely wide range.

That I may not be supposed to misrepresent the views of "some American geologists," I here cite a paragraph from the observations of Professor James Hall on metamorphic rocks, to be found in the third volume of his N. Y. Paleontology (1859), p. 93.

"The imperfect study of these metamorphic rocks which I was able to make, while engaged in other duties, during the years 1843, 1844 and 1845, enabled me to recognize among these deposits a certain order which appeared to me to be marked by the presence of characteristic minerals which had been segregated from the surrounding mass. These observations, combined with subsequent considerations of the subject, convinced me that much might be done in the recognition of metamorphic masses by the contained minerals; and that a proper study of these would reveal some means of identification of beds at distant points, analogous to the mode of distinguishing successive formations by their contained fossils. I have subsequently, on many occasions, advocated this view, in discussion before the American Association for the Advancement of Science, and I am convinced that something of this kind will yet grow out of the farther investigation of the metamorphic rocks and their contained minerals."

To which is added in a note—

"Every observing student of one or two years' experience in the collection of minerals in the New England States, well knows that he may trace a mica schist of peculiar but varying character from Connecticut through Central Massachusetts, and thence into Vermont and New Hampshire, by the presence of staurotide and some other associated minerals, which mark with the same unerring certainty the geological relations of this rock, as the presence of *Pentamerus oblongus*, *P. galeatus*, *Spirifer Niagarensis* or *S. macropleura*, and their respectively associated fossils, do the relations of the several rocks in which they occur."

If Professor Hall intended, in the last paragraph, to imply only that the staurolite crystals afford aid in tracing a given continuous formation over Central New England from south to north, he is right. But the paragraph from the text shows that he means more,—that he holds that this mineral may be used for the "identification of beds at distant points, analogous to the mode of distinguishing successive formations by their contained fossils;" and this general principle has been since applied by more than one investigator of crystalline rocks.

It has, further, been put forth, by a geologist who agrees in the above with Professor Hall, that "the old idea of the conversion of great masses of Paleozoic, Mesozoic and Cenozoic rocks into series of crystalline schists, which so long found favor in Europe and in America, is now proved to be an hypothesis based on very slender grounds."

From the time these ideas were first published, I have had a strong desire to learn whether facts sustained them. My stratigraphical observations over Western New England, in which the Taconic rocks were also studied, were begun some years since with special reference to the discovery of the truth on this subject; and through the whole this object was prominent. The examination of the Bernardston region, the results of which are here given, was undertaken partly for the same purpose. Both have led to the conclusion that—

Lithological evidence of geological age among metamorphic rocks *of distant regions* is in general* worse than worthless. It is easy to use, and presses itself on the mind most insinuatingly when a conclusion is eagerly wanted; and on this account it should be treated with extreme distrust. I have further found that—

The Earth did not finish up its metamorphic work in pre-Silurian time, or even by the epoch closing the Primordial, as it did not its mountain-making. And this should be so, if, as Mallet has demonstrated, the motion attending the uplifting and folding of rocks, or mountain-making, is, like other motion, transformable into heat.

It is now twenty-two years since the first announcement, by Professor Edward Hitchcock, of the unexpected discovery of a bed of limestone containing well preserved stems of Crinoids in the very center of New England,† and twelve years since the detailed report on the locality by C. H. Hitchcock, in the Geological Report of Vermont.‡ Mr. Hitchcock observes that Professor Hall had examined the Crinoidal remains (some of the stems of which are three-fourths of an inch to an inch in diameter) and had inferred from them that the beds were probably of *Upper Helderberg* age. The conclusion, as stated by Prof. E. Hitchcock, locates a Devonian sea in central Massachusetts; and the distribution of the underlying roofing slate was regarded by him as indicating the extension of this sea northward over Eastern Vermont.

The locality of Crinoidal limestone is about three-fourths of a mile north of the "New England House" in Bernardston—a village a few miles west of the Connecticut River in Northern Massachusetts. On the accompanying map of part of the town of Bernardston § the position is marked by the letter *l*.

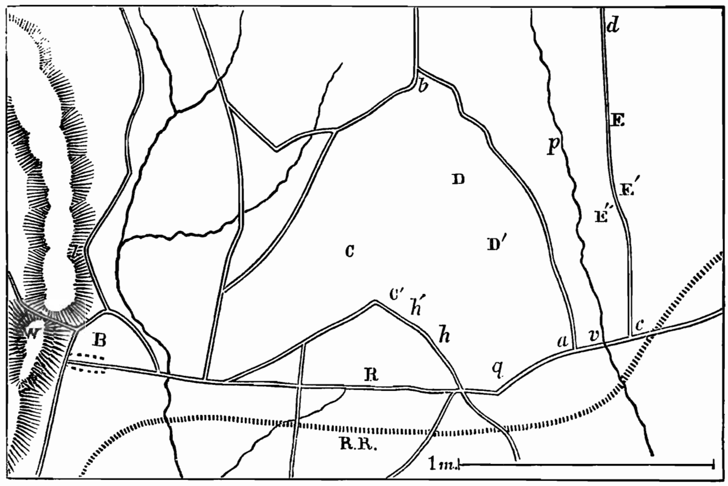
* The exceptions here in view are certain of the earlier Archæan (Azoic) rocks, as hypersthenite and other coarsely crystallized labradorite rocks, the very coarse reddish and dark gray syenites, zircon-syenite, and chrysolitic rocks. At the same time, it is far from certain that these rocks are exclusively Archæan.

† Report Amer. Assoc. for the year 1851, p. 299.

‡ Rep. Geol. Vermont, 2 vols. 4to., 1861, p. 447.

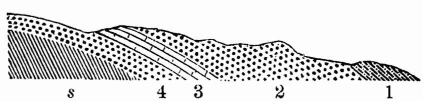
§ This map is here inserted that geologists may have no difficulty in finding the places referred to, and so verifying the facts. Bernardston is on the Connecticut River railroad; and its depot is the last stopping place for trains going north, before entering Vermont. South Vernon is about seven miles by road northeast of the village of Bernardston, but hardly six in a direct line.

Directly west of the village (B) rises the ridge called West Mountain (W); the locality is on the eastern slope of a low part of this ridge, north of the higher portion.*



The rock of West Mountain and of its continuation to the north is clay-slate, it being part of the great slate formation of Eastern Vermont, quarried in several places for roofing slate. The Helderberg beds overlie the slate.

Hitchcock's section in the Vermont Report gives the order of succession. Another is here annexed. There is, first, as



the upper member (though near the foot of the slope), a grayish-black mica slate (1); below this (higher up the slope), a thick bed of quartzite (2); next, the Crinoidal limestone (3), the bed at least 30 feet thick; and, finally, underlying this (though at a still higher elevation), another stratum of quartzite (4), which, in some places, passes locally into a black siliceous slate. The strike of the beds, along a line from the foot of the slope up to the limestone, is about N. 45°–50° E.,† with the dip 30° to 35°; the dip of the limestone at the quarry is 25° to 30°; and, higher on the hill, that of the lower quartzite is 10° to 15°,

* The locality is on the land of Mr. Williams. After passing his house (white), take the path leading up the hill back of the northern end of the barn. The first rock encountered is the slate of the Helderberg series; then quartzite; finally, after ascending about 150 feet, the limestone. The Crinoidal remains are found on the weathered surfaces of blocks quarried out from the more western openings.

† Compass course, as elsewhere. The variation of the compass is 10° to the westward.

but generally not distinct. Following the outcrops of the upper stratum of quartzite (No. 2) to the southward, the strike changes to N. 65°–70° E., making the dip S. 20°–25° E. in direction, with the amount unchanged.

The clay-slate of West Mountain (or that of western Vermont), is made in the section (at *s*) an earlier *unconformable* formation.* At the nearest outcrop of this slate to the Helderberg beds—about 300 yards distant—the strike of the slate is N. 14° E., and the dip 60° to the eastward (that is, S. 76° E.). A few rods south, the same slate has the strike N. 20°–30° E., and dip 55° to the eastward; and higher up West Mountain, half a mile to the south, the strike is N. 50° E., and dip 80° to the eastward; the slate varying much in strike. Thus, while the Helderberg beds have a small dip everywhere, and the smallest as they approach the clay-slate toward the top of the ridge, the slate is very high in dip. Moreover, this difference characterizes the formations in other parts of the town of Bernardston; and hence, although no section of the two together was found exhibiting to the eye their relative position, the facts left little doubt of their unconformability.

Again, the Helderberg slate is a widely different rock from the older clay-slate, it being strictly a *mica slate.* Under a lens, the scaly glistening texture is apparent; moreover, there are distributed through all of it numerous small prisms of brown mica, usually lying on their sides or oblique to the plane of bedding, which show their foliation and luster on a cross fracture of the slate, or by an oblique view of the surface of a slab. These prisms are from a line to half a line in breadth and length. The prismatic edges are rounded, so that the prisms have really a narrow elliptical base. They have the aspect of phyllite (chloritoid) in some clay slates; but the folia are easily separable and flexible. There are also minute red dodecahedral garnets in the slate. On account of the mica crystals and garnets, the slabs freshly broken out are covered with small pimples and pits.† The clay-slate, on the contrary, is without the prisms of mica, and is far finer in texture; what unevennesses it has are not due either to mica or garnets. The Helderberg slate carries this feature through the region, and far beyond it; and the clay-slate is as persistent in its different characteristics.

The Helderberg garnetiferous mica slate is in all cases lami-

* Hitchcock, in the Report of the American Association, makes both slates alike in character and conformable. In the Vermont Report, the section represents the lower slate as conformable, but the text leaves it in doubt.

† An examination of the slate for water has been made by Mr. George W. Hawes, assistant in the Sheffield Scientific School; and in it he obtained 2·41 to 2·94 per cent. In a blowpipe trial of one of the little prisms of mica, only traces of water were found. The amount of water seems hardly sufficient to warrant calling the slate a hydromica slate: and, moreover, it does not feel at all greasy.

nated parallel with the bedding. Whether this is so or not with the roofing slate of the region is not positively known; the probability is against it.

The limestone is crystalline, some of it coarsely so, and much of it impure. It contains in places disseminated pyrites, and large portions have consequently rotted away, and left beds of limonite. The purer kinds, on the surface of fresh fractures, are generally coarsely crystalline, and have nothing clearly indicating the presence of fossils; while a weathered surface of the same block may be covered with prominent crinoidal stems.

The sight of a locality of Crinoids in the heart of metamorphic New England is calculated to impress the mind strongly with the belief that it is a key that will open the mysteries of New England geology. The Geological Report of Vermont states that a quartzite formation occurs in the next town to the north, Vernon, the southeast town of Vermont, and the Massachusetts Report, that it is also largely developed just across the Connecticut River, in the town of Northfield; and this suggested the true way of bringing the key into use.

After a first visit to the village of South Vernon—six miles northeast of Bernardston—with this object in view, I visited the region again in 1871, by appointment with Prof. C. H. Hitchcock, then, as now, State geologist of New Hampshire. The quartzite of South Vernon was found to be overlaid by an extensive hornblendic formation; mostly a coarse or fine grayish-green hornblende rock, or rather, in view of its color, actinolite rock, but part grayish-black Some beds are speckled with feldspar, and others are a handsome syenitic gneiss. The quartzite and the other rocks have an eastward dip of 30° to 35°, and the strike is N. 15° E. to N. 40° E.; but much of the hornblende rock is massive and jointed, and obscure in its bedding.

Besides these rocks, there is, at a cut on the railroad, a few rods south of the depot, quartzite associated with a mica schist varying from fine to very coarse scaly in its different beds, and part of it gneissoid. Again, along a north and south road a mile west of South Vernon, a slate rock was found, part of which contained crystals of staurolite; and near it there was an outcrop of quartzite giving positive evidence of the conformability of the two. The strike of the beds at this place is N. 35°–40° E., and the dip 40° to the eastward.

We thus passed over a considerable variety of rocks conformable to the quartzite—namely, coarse and fine mica schist, gray hornblende rock, both a pure and a feldspathic kind, syenitic gneiss containing the hornblende partly in oblong pointed crystals, and staurolitic slate; but we failed to find any limestone, and did not obtain good evidence that the quartzite was the same in age with the Bernardston quartzite. Prof. Hitchcock observed that the staurolitic slate, quartzite and hornblende rocks were just those of his Coös group in New Hampshire, a formation that covers a narrow band east of the Connecticut River from Massachusetts to Northern New Hampshire We crossed the river together, and saw these rocks in Northfield, Mass., and Hinsdale, New Hampshire. It was evident that the South Vernon rocks were Coös, whether the Bernardston were so or not.

The characteristics of the Coös group, as given in Prof. Hitchcock's Annual Report for 1869, are, "the presence of quartzite, staurolitic rocks, mica schists, hornblende schists, perhaps gneiss, protogine and other rocks, lying west of the White Mountain series and east of the Connecticut River, along the whole of western New Hampshire," besides argillaceous slates, whetstone, mica schists, grits, etc., of Coös Co., etc. The occurrence of beds of limestone at intervals is mentioned in the Report of 1870.*

The facts observed in the region at that visit made it evident that the relation as to age of the Bernardston and South Vernon quartzites was a subject of great interest, especially in connection with New Hampshire geology. Prof. Hitchcock appreciated it, and expressed his intention of soon having the South Vernon region—for the investigation of which he had a kind of prior right—carefully studied.

The year 1872 passed without anything being accomplished, owing, as he informed me, to the demands on his time made by portions of the New Hampshire Geological Survey. A day's excursion was planned in the course of the summer; and, finding that he could not join me, I took a rapid turn over the country alone, in order to gratify a reasonable curiosity. Crossing from South Vernon westward, to the road next west, nearly a mile, the hornblende rock of the first ridge was left for a whitish or grayish gneiss, which, while mostly poor in its bedding, showed in some places the strike N. 15° E. and a dip of 30° to 55°, not essentially different from the same in the overlying hornblende rock. The gneiss became to the westward hornblendic in many of its layers, and also graduated into hornblende schist and hornblende rock; next beyond, appeared the staurolitic clay slate, with the same eastward dip. The hornblende rock stratum and that of gneiss were each several hundred feet in thickness.

* In Prof. Hitchcock's Report for 1870, four sections across the Coös group are given. In the description of that through Lyme there is the entry 2200 feet of quartzite and limestone; that through Orford, 100 feet of limestone; that through Lisbon, 50 to 100 feet of limestone. It is stated that "mineralogically the schists of the Coös group are distinguished by the presence of cyanite, andalusite or staurolite," which are "silicates of alumina without alkalies." "Garnetiferous clay slates" are mentioned as 4,500 feet thick in one section and 3,078 in another, evidently the same rock essentially that occurs at Bernardston and in Vernon.

The quartzite, which overlies the hornblende rock, constitutes a ridge just west of the road to Bernardston, commencing a short distance south of the village of South Vernon; one outcrop of it and of the conformable underlying hornblende rock was met with two and a half miles east of Bernardston, between the two railroad crossings. About two miles east of Bernardston, I took a road leading northward to "Purple's slate quarry" (*p*, on the map), and found the slate identical in every respect with that of the Bernardston Crinoid locality—the same in texture and in its imbedded crystals of mica and garnets. Its strike was northeast, and the dip 20° to the southeast. Thus a mica slate identical with that of Bernardston, and the hornblende rock and quartzite characteristic of South Vernon, were found within two and a half miles of the old Bernardston locality, and all had approximately the same dip. The probability of an identity of age was strong; but still doubt remained.

Another year having passed, and the important question still remaining unsettled,—as shown by Prof. Hitchcock's geological report issued in July last, apparently preliminary to his final report—I thought myself released from further obligation to leave the field alone, and in August went to Bernardston for a final settlement of the question; and in an hour's excursion it was done. In September, I was over the ground again to point out the decisive localities to Prof. Hitchcock.*

The facts are simply these:—

The Bernardston Helderberg locality (*l* on the map) is situated, it will be remembered, on the *western* sloping border of the plain on which the village stands. On the ridge forming the opposite or *eastern* border, just north of the road to South Vernon (R), and only 1¾ miles from the Crinoid locality (1½ miles from the village), there is visible from the road a hill with a quartzite summit (*q*). The beds dip 15° to 25° to the southward and southeastward. In the fields to the northwest, still nearer Bernardston, just east of a road but little traveled (at *h*, *h'*), there are ledges of *hornblende rock* precisely similar to that of South Vernon, a gray compact jointed rock, generally obscure in bedding, in some beds speckled with feldspar, and thence graduating into a syenitic gneiss. The dip of the rock was 15° in the direction S. 30° E. Between an upper and a lower stratum of the hornblende rock, constituting ledges a short distance apart, there was an outcrop of mica slate, identical in all respects with that of the Bernardston Crinoid locality, the small imbedded prisms of mica and dodecahedrous of red garnet making it easily recognized; and it dipped with the hornblende rock. Moreover, the lower stratum of hornblende rock

* Between these two visits, I learned that Prof. Hitchcock had contemplated examining the region this autumn.

contained intercalated portions of the same slate; further, the proportion of slate in this ledge increased much to the eastward. Part of it contained the mica crystals very thickly disseminated so as to crowdedly spangle the surface of a cross-fracture—a variety closely like part of the rock at the railroad cut just south of the South Vernon depot. Thus the fact that the Bernardston garnetiferous mica slate and the South Vernon hornblende rock were of one and the same formation was made certain, for here, besides occurring in alternating beds, they graduate into one another. The position and dip of these ledges indicated that they were all inferior in stratigraphical position to the quartzite of the hill above mentioned.

Decending the quartzite hill on the north side and continuing in that direction, the rock changed first to the same mica slate, the slate outcropping at one place from beneath the quartzite. The prisms of mica in some of the slate were an eighth of an inch in breadth and length; and, on a worn surface of it, they appeared as dull black, squarish spots. The garnets in all cases were minute and not very numerous.

Such facts, observed right on the eastern border of the Bernardston plain, establish the identity of the western and eastern groups of rocks, although limestone was not found in the latter. They prove that *hornblende rock*, *syenitic gneiss* and hornblende schist are rocks of the Helderberg series, as much as the Bernardston garnetiferous mica slate. The surface between these eastern and western outcrops is covered partly by the Triassico-Jurassic red sandstone formation, and for the rest of the way by alluvium and stratified drift.

East of this region (marked CC′ on the map) there are two ridges (D D′ and E E′), one to two hundred feet high, separated by a valley (*v p*), and in this valley lies the road (*a b*), and also, adjoining the brook, Purple's slate quarry (*p*), mentioned on the preceding page. The road *c d* is on the ridge E E′.

West of the ridge D D′ and of the valley there bounding it, there is an outcrop of the mica slate with the mica crystals an eighth of an inch across. On the east side of this valley, and at the west foot of D D′, stands in the field a small ledge of grayish white *gneiss*. Part of it seemed to be in place, and had a small southward dip; yet it is not too large a mass to be a transported boulder. Rounded masses of the same gneiss were found scattered over the slopes and summit of ridge D D′, but no other outcrop was met with.

In the meadow at the eastern foot of ridge D D′, lies the slate of Purple's quarry, having the dip and strike already stated; and it is beyond question the Bernardston slate, whatever be true of the gneiss of ridge D D′.

In the top of the ridge (E E′), bounding this valley on the east, near E′ and E″, there is true quartzite, having a dip of 20°

to 28°, with the strike S. 20°–30° E. But, at both E′ and E″, the *quartzite directly overlies and graduates into gneiss.* It is itself in places micaceous, and then becomes true gneiss. A little north of E″, the gneiss is well-characterized; and it is an old-looking kind, that might be thought pre-Silurian by a believer in the lithological test. The outcrops on the ridge were numerous, and the intimate connection of the unlike rocks too plain for the strongest doubter to question it.

This adds to the *Helderberg* series, gneiss in extensive strata, another of the rocks observed at South Vernon. From the relative position of the quartzite and underlying gneiss in the ridge E E′, and the slate in the valley over a hundred feet below, the mica slate must be an inferior bed in the series, unless there is a fault.

While at Purple's quarry, Prof. Hitchcock remarked to me that the slate was precisely the rock that in the Coös group contains staurolites; and a moment afterward I found in some slabs of it a few cross-crystals of the mineral, representing among them both of the known kinds of twins.

This adds *staurolitic slate* to the *Helderberg* series of Central New England.

We are now prepared for our conclusions.

1. This Helderberg series in Central New England comprises a large part of the common kinds of metamorphic rocks, gneiss of several varieties, undistinguishable lithologically from the oldest; hornblende rock and schist; syenitic gneiss; coarse mica schist and mica slate; staurolitic slate.

2. A large part of the rocks that have been distinguished as of the "Montalban" or "White Mountain series" in New Hampshire, and regarded of pre-Silurian age, are here included, and are hence nothing but altered Helderberg sediments. It is hence far from true that "the crystalline rocks of the Green Mountain and White Mountain series" and "the whole of our crystalline schists of Eastern North America are not only pre-Silurian, but pre-Cambrian in age."*

3. The passage of quartzite into gneiss is exhibited in different ways. The presence of mica in the quartzite is one of the steps But, at the locality marked *q* on the map, part of the quartzite is very finely banded with white and gray, and the

* Hunt's Address before the American Association in 1871, pp. 8, 36. The rocks referred to the "White Mountain series" are stated, in the Address, to include "well defined mica schists interstratified with micaceous gneisses" and every variety "down to a fine-grained schist which passes into argillite;" "beds of micaceous quartzite," "dark-colored gneisses and schists, in which hornblende takes the place of mica," which "pass occasionally into beds of dark hornblende rock, sometimes holding garnets;" "beds of crystalline limestone in the schists," which are intimately associated with the highly micaceous schists containing staurolite, andalusite, cyanite and garnet."

white portions are feldspathic, as is proved by their fusibility before the blowpipe, while the light gray are quartz, and some short darker lines are micaceous. Thus this region, like that of Berkshire, demonstrates that gneiss and quartzite are rocks of the most intimate relations, as intimate as mud and sand along seashore flats. Part of the feldspathic layers widen at intervals into forms an inch or more thick at the middle; but they are generally nearly even.

4. Hornblende rocks of the purest kind, and of great extent, are here so intercalated with quartzite and mica slate, and so often graduate into one or the other, that all must have been alike a result of the metamorphism of sedimentary beds. It is not possible that these hornblende rocks, constituting part of a Devonian or Upper Silurian formation, should have come from the metamorphism of beds of a pre-Silurian, chemically-deposited, meerschaum-like hydrous silicate.*

5. The Bernardston, South Vernon and Northfield beds being of Helderberg age, the Coös group, which is but the northern continuation of the same series, is, if correctly traced out, also Helderberg. Hence, in the era of the Lower Devonian, the Connecticut Valley, from the latitude of Bernardston northward, was an arm of the sea, extending down from the great Devonian Gulf of St. Lawrence. Crinoids require the best of ocean water, and thus they had it in central New England.

6. The Bernardston beds have been supposed to be Lower Devonian or Upper Helderberg on the ground of Hall's opinion, and also on that of Billings's, recently obtained. But both of these paleontologists speak of it only as the most probable conclusion from the fossils thus far found: they may belong to the Lower Helderberg or later part of the Upper Silurian. According to Prof. Hitchcock, a slate containing imbedded crystals of mica, just like that of Bernardston, occurs near Lake Memphremagog, where there are fossil corals of unquestionable Lower Devonian types;. and, as the same slate follows the Coös series through to that region, the lithological resemblance suggests identity of age, though not proving it without a further stratigraphical study of the region between.

7. At Littleton, also, fifty miles south-southeast of Lake Memphremagog (S. 24° E.), there is a limestone, half metamorphosed, containing Helderberg corals—one of the important discoveries of Prof. Hitchcock, to whom I am indebted for guidance over the region. The limestone is associated with quartzite and clay slate, and also with a series of chloritic rocks partly feldspathic, including chlorite slate and a kind of protogine in which a pseudophite-like mineral is disseminated in small grains; and it appeared to me that all were conformable.

* Hunt's Address, page 12.

If this conformability is sustained by further observations, we shall have here the additional lithological fact that—

Chlorite rocks, including protogine, may constitute metamorphic beds of Helderberg age.

8. The facts which have been presented sustain the statement, made on an early page of this article, that lithological evidence of geological age is to be distrusted. If, when used by one who has made it a special study, it leads to the conclusion that true *Helderberg* rocks in the White Mountain series are of Cambrian or earlier age, it is surely a bad reliance. If it also makes out that Green Mountain rocks are of Huronian age, or of some other pre-Silurian period, when in reality belonging to the later part of the *Lower Silurian*, geologists may well be afraid even of its suggestions, unless it have sure stratigraphical support. "Huronian" areas have been defined in various parts of the country and the world, on the basis of this evidence alone; and in such cases who knows any thing whatever with regard to the real age of their rocks? It is probable that the rocks considered characteristic of the Huronian occur also among true Laurentian terranes; it is certain that they do in formations later than the Lower Silurian.

Finally, what reason is there in chemistry or geology why crystals of andalusite and staurolite should have been made only in pre-Silurian time? Andalusite consists simply of silica and alumina, and staurolite of the same, along with iron. These three ingredients are now and ever have been the most abundant of all the mineral constituents of the globe. With or without the iron, they are the materials of all clay deposits; and clay deposits from the decomposition of granite, gneiss and related rocks have been forming over the globe, and increasing in amount, ever since these rocks began their existence.

They are therefore the very last minerals that should be thought of as pre-Silurian "fossils." Were zirconium or any other of the rare metals a constituent in the species, there would be some reason for suspecting their restriction to the more ancient formations; since later sediments would contain only traces of them. But silica, alumina and iron belong to all time. These remarks apply equally to chlorite, in which these three ingredients occur, with only a little magnesia beside, and water.

9. The epoch of disturbance, in which these Helderberg rocks of the Connecticut Valley were upturned and crystallized, was probably that closing the Devonian, when, as Dawson and others have shown, extensive upturning, plication and crystallization of Devonian and older rocks took place over New Brunswick and Nova Scotia. It was the most prominent epoch of mountain-making on this eastern border of the continent,

after the Lower Silurian. Facts are against any earlier epoch; and the only other probable suggestion is that the time was after the Carboniferous age, when the Alleghanies were made. Hence, the various Helderberg rocks of the Connecticut Valley have their actual date as crystalline or metamorphic rocks either from the close of the Devonian, or that of the Carboniferous era.

The conclusions which have been presented are based on a foundation of facts—certainly as far as the region of Bernardston, Vernon, Northfield and Hinsdale is concerned, where my own observations were made; and, judging from the descriptions of Prof. Hitchcock, they appear to be sustained as regards the Coös range to the north.

I now pass to what is at present hypothetical, since I can appeal only to the observations of others, and they are not sufficient in detail for positive conclusions. I propose to examine the region personally, another season.

2. *The Connecticut Valley in Massachusetts.*

The region of the Connecticut Valley, south of Vermont and New Hampshire, commencing in the northern towns of Bernardston and Northfield, is covered to a breadth of ten to twenty miles with the Triassico-Jurassic Red Sandstone formation; so that the opportunities for observing the continuation of the more northern formations southward are thus much restricted. Still there are pertinent facts on record.

In the geological map of Massachusetts connected with Hitchcock's Report, the hornblendic rocks of South Vernon and Northfield are made to extend southward in two lines, one south of South Vernon, passing by Leverett, Amherst and Granby, the other south of Northfield, through Shutesbury, Belchertown, Palmer, Monson and Wilbraham, each line quite crossing the State to Connecticut. Gneiss, mica schist and clay slate occur with the hornblendic rocks, as at the north. Quartzite is spoken of as occurring with the hornblendic rock of Northfield, Palmer, Monson and Granby.

The varieties of rocks described by Hitchcock are similar to those of the Vernon and Northfield region, excepting that no staurolitic slate is mentioned.

There is hence a probability, that these lines of hornblendic rocks are but a continuation southward of the Coös formation: and, if either is so, then the wide Helderberg sea of the Connecticut Valley extended southward across the State of Massachusetts.

3. *The Connecticut Valley in Connecticut.*

In Connecticut the Connecticut Valley terminates at New Haven Bay—not at Saybrook. The river leaves the great central valley of New England at Middletown, it there passing out of the area of the Triassico-Jurassic Red Sandstone (which continues through to New Haven) by cutting through the metamorphic rocks of Eastern Connecticut.

Percival, in his Report on the Geology of Connecticut, states that, adjoining the Red Sandstone region on the east, there extends, southward from Massachusetts, a range of hornblendic and chloritic rocks associated with gneiss, and in some places with imperfect quartzite. He remarks that he has traced this chloritic and hornblendic range into Massachusetts as far as Wilbraham, one of the localities of hornblendic rock mentioned by Hitchcock, showing that it is identical with the eastern of the ranges in Massachusetts. He followed it in Connecticut through Somers, Ellington and Glastonbury to North Chatham, in the latitude of Middletown, where it disappears beneath the Red Sandstone formation.

The chloritic rocks include a chloritic gneiss, related to protogine, and also a compact rock which he says resembles greenstone. Percival suggests that this chlorite formation is continued on the west of the Red Sandstone formation abreast of New Haven, stating that part of the eastern chloritic rocks are more like those near New Haven (in the towns of Orange and Woodbridge) than any others in the State. In fact, part of the rock of the latter region much resembles greenstone or diorite, and was called "primitive greenstone" in the first published account of New Haven geology, by Prof. Silliman, in 1811.*

If Percival is right in his suggestion, then all these Connecticut chloritic rocks adjoining the Connecticut Valley are as much Helderberg rocks as the hornblendic and associated rocks of Massachusetts from Monson to Northfield, or those of the Coös group of New Hampshire. Even diabase, a labradorite rock which, under the name of diorite often given it, is of intensely Huronian look to the Huronian-seeker, is one of the New Haven Helderberg rocks like the rest. Much limestone occurs in the formation west of New Haven.

Thus the observations of Hitchcock and Percival, in connection with those made farther north, lead toward the view that in the Helderberg era the Connecticut Valley, through its whole length from north to south, was a wide crinoidal and coral-growing sea separating eastern from western New England. These are suggestions—but suggestions with probability enough in their favor to give profound interest to further investigations throughout the valley.

* Bruce's Mineralogical Journal, vol. i, p. 145.