ART. XLVI.—*A description of the "Bernardston Series" of Metamorphic Upper Devonian Rocks*; by BEN K. EMERSON.

[Continued from p. 275.]

The position and extension of the basal quartzite was the first clue to the complex stratigraphical arrangement of the series in its eastward continuation. Beginning at the point already described, east of the road to East Mountain (back of "Mrs. Haley's" on the map), with a strike due east, it has bent round to N. 65° E. before it goes under the massive drumlin which lies east of the river, and on its emergence, it is abundantly exposed, with the same strike, along the southern of the two northwest roads mentioned above, especially south of A. G. Chapin's house. Taking the direction of this road across the valley of Dry brook, it can be followed readily, with the same strike and low S.E. dip and physically unchanged, through the chestnut woods N.W. of the end of Purple's blind road, crossing the first north and south road in Northfield, where a loop of the brook crosses the road; and gradually bearing round to the north, it crosses the State line with a strike N. 10° W.

(b) *The quartzite conglomerate.*—Back of Mrs. Haley's, on the Fall River road, and just east of the Williams farm, across the valley, ledges of the rock appear, and it outcrops abundantly along the second road running east from the Fall River road (A. G. Chapin's) to its end. Where the road begins it is an obscurely bedded conglomerate of quartz pebbles, in a dark paste containing much slaty material. The conglomerate here toward its base is exactly like the same rock west of the lime-

stone on the Williams farm, and I have no doubt that they were formerly connected across the valley. Higher up, the rock is a pudding stone with rounded quartz pebbles up to 100^{mm} in length, but mostly 20–30^{mm} long; the abundant quartz sand paste, which wraps round them, cleaves into thick layers coated with muscovite scales and iron rust, so exactly like the upper quartzite of the Williams farm, especially the conglomerate layer, that it is difficult to avoid the conclusion that they are also parts of a single stratum. Calculated upon its average dip of 20° the thickness of the bed is 123 meters, which is only a rough approximation.

In the field south of A. G. Chapin's house is an interesting outcrop. The rock is here jointed with almost mathematical accuracy, into acute rhombs, the joint-planes passing through the quartz pebbles; and the latter are finely compressed, and indented one by another. The rock here carries garnets 5^{mm} across. The rock is unchanged across Dry Brook for a long distance to the northeast, when it crosses the last road; but once over the range (J. M. Pickett) at a point where the brook makes a loop across the road, the pebbles are flattened out into thin disks, resembling the small lenses of quartz common in crystalline rocks, making it almost doubtful if they may not be of secondary origin—a doubt which does not extend to the range described above. In the woods, southwest of this point, the rock in some beds is in appearance a fine-grained biotite-gneiss, with large garnets surrounded by a broad annular colorless space, in which the biotite is wanting; and in following the band farther north, the pebbles grow smaller, and where it crosses the State line it is below a thin-bedded biotitic quartzite, above a muscovitic quartzite; and in some layers the muscovite becomes abundant and wraps around pencils of quartz, so that the rock obtains a rude columnar or ligniform structure. It has here an apparent thickness of 107 meters.

At the point already mentioned on the grist mill road (J. M. Pickett) where the brook makes a short loop across the road, at the south bridge is a fine section in a high bluff, west from the bridge. The conglomerate strikes N. 45° E. and graduates downward through fifty feet of quartzite into fine micaceous quartzite and this into flat argillite with minute transverse biotites. The whole is well exposed and plainly conformable. Its dip increases from 22° at the south end to 45° at the north end, where the upper portion of the bed has this high dip, while the lower portion runs up on the argillite with the low dip of 20°. It thus folds around and dips away from a great promontory of the argillite; and it is blackened in many places by a remnant of the argillitic material.

Just after crossing the State line into South Vernon it bends sharply to the southwest, recrosses the Stateline and, at the point where the grist-mill road (J. M. Pickett) crosses the town-line, bends again northwest and swings in a great curve north across Vernon. All this is well exposed just north of the last house before crossing the line (M. Merrills), and the argillite where it is nipped by the sharply bending quartzite is greatly crushed and filled with quartz combs. This boundary crosses the next road north—the old Bernardston-Vernon road—at a small abandoned house (two houses below the school house) where the brook comes nearest the road. Just behind this house in the side of the brook is exposed a most interesting junction of the conglomerate upon the argillite. Commencing at a ruined dam perhaps 15 rods from the house we find typical argillite which changes through a few feet of spangled schist into thin fissile black muscovitic quartzite with some thicker highly crystalline layers, and this graduates into a highly muscovitic very vitreous quartzite, which is at one place a conglomerate of rounded quartz pebbles 2 to 4 in. long. This is where the water falls over a reef 3 to 4 feet high; it is 2 rods below a wooden bridge. Immediately below is a bed of heavy hornblende rock, massive, in places showing a reticulated structure: masses of this rock built into the piers of a wrecked bridge just behind the house show pebbles, and contain also much green mica, often quite coarse and resembling the more gneissoid rock found out over the South Vernon plain to the river and classed by Professor Hitchcock as Bethlehem gneiss. The series strikes N. 55° W. and dips 45° E. The outcrop is continuous and shows a gradual passage through a spangled argillite and fine-grained quartzite into conglomerate, often coarsely garnetiferous, the change being effected within 50 feet and showing no trace of unconformity. Many masses of a thin fissile pyritous magnetite occur here, but the bed could not be found in place.

East of the boundary line just described, across Vernon to the river, the whole area is underlaid by the basal quartzite except where the West Northfield schist series extends across the State line, west of the village of South Vernon; and across the brook it rises in the hill back of S. Titus's, where the road to the lily pond branches from the Brattleboro road. It dips for the most part to the east except east of the lily pond, where a minor fold of considerable size occurs, caused by the sharp bend of the quartzite on the State line, and here the beds dip south. Followed eastward it becomes more and more feldspathic and the muscovite is largely replaced by biotite, forming a completely gneissoid rock. It is here not distinguish-

able from the feldspathic quartzite occurring east of the West Northfield series and described below.

The Vernon limestone.—On the Lily Pond road above mentioned and just east of E. G. Scott's house occurs a band of limestone. It is a coarse granular limestone, highly crystalline, of light color, containing some garnet, hornblende and green mica. It contains what seem to be distinct traces of corals and crinoids and in everyway closely resembles the Bernardston bed with which I identify it without hesitation. Especially do the weathered surfaces show a peculiar conglomerate-like structure common at Bernardston. Large rounded fragments of a fine grained white limestone are cemented by a coarser and more highly crystalline limestone, the latter in large amount, as if the rock had been brecciated by pressure and then the fragments rounded by percolating waters and re-cemented. This bed is exposed about 30 rods and may have a thickness of as many feet, but its boundaries are not well exposed. Toward the west it graduates on the strike into a calcareous hornblende schist, and above that, to the south, through an actinolitic quartzite into a quartzite abounding in large garnets and blotches of a greenish mica, while below it is succeeded by very coarse hornblende schist in large force. The whole series is enclosed in the gneissoid quartzite.

Description of the range from Bernardston to South Vernon.—Directly opposite the Williams farm and 200 rods distant, on the east side of Fall River, begins a range of low hills, which runs northeast between the two towns named above. This range of hills is backed on the northwest by a much higher range of argillite hills—Bald Mountain, Pond Mountain—and bounded on the southeast by the high terrace sands through which one large area and many smaller islands, of the rocks of the Bernardston series, emerge. I have called this the West Northfield range, from the town in which it for the most part lies. The road running along the east side of Fall River skirts the range at its western end, and the main road from Bernardston to South Vernon borders it on the south and east, while the roads which branch from the latter and cross the range are named from some resident upon each, as given in Beers' atlas, and as marked on the map on page 264.

The mapping of this area was difficult both because the rocks are thrown into great confusion, many beds being in places echeloned, so that the local strike regularly disagreed with the general run of the bands, and because of the presence of several large drumlins which effectually conceal the underlying rock. The intervening areas are, however, so entirely free from drift, up to the very foot of these hills, that, were it not heavily wooded, the region would furnish abundant outcrops, and, as

it is, the fragments on the surface can be safely used to determine the rock below. The series wraps round the argillite, and uniformly dips away from it, generally at low angles, at first south, and then for a long distance southeast; then it swings sharply round, crossing the State line with dips a little north of east, making thus a great bend to the westward as it crosses the town of Vernon. I have not been able to prove the existence of folds or overturns, and the present position of the beds seems to be best explained as the result of very extensive faulting.

(a.) *The Argillite*.—I have assigned to the argillite the broad area marked "Coos" upon Professor Hitchcock's map, to which he also assigns the slates of the Bernardston series, because I have found that the boundary between it and the argillite to the west, as given upon that map, has no justification in any physical change in the character of the rock where it is drawn, and the argillite can be traced unchanged up to and dipping beneath the quartzite next described. It is true that minute scattered garnets and very small staurolites are found sparingly in the rock in some places in this area, and these seem to have been relied upon by Professor Hitchcock in making the assignment of the rocks to the Coos; but the same garnets can be found at times in the undoubted argillite in West Mountain, and these, and the same minute staurolites, occur in the center of the Whately argillite, and both the minerals are very different from their representatives in the Coos group. Both in macroscopical and microscopical structure, the rock remains quite constant up to the quartzite, and in its finer grain, its darker color, its excessive contortions, and its abundant and large quartz veins, it is well distinguished from the slates of the higher series.

(c.) *The mica schist and hornblende beds*.—Resting on the basal quartzite, and dipping from it with low angle to the south, southeast and east successively, as it folds around conformably with it, is a broad area of mica schist, with several bands—probably five—of hornblende rock, and a central band of gneissoid quartzite. From the unequal rigidity of these rocks, they are thrown into great confusion, and from the similarity of the rock in the separate bands, the tracing of them is very difficult, and as they are placed upon the map, a greater regularity appears than exists in the field, many bands being made up of the slightly shifted portions of what was originally one, and many minor faults being of necessity neglected.

In general the schist is, below, finer grained, more slaty, with small development of the transverse mica, without staurolite.

lite, and with quite small garnets, becoming, above, coarser, of rougher surface, and knotted with large staurolites.

At the south end, nearest the Williams farm, the basal quartzite dips beneath a very fine-grained flat fissile mica slate, which dips 20° in the direction S. 10° E., its surface sparsely pimpled with small garnets, and without other accessories and closely like the underlying schist of the Williams farm section.

The lowest bed of hornblende rock, here thin and poorly exposed, is followed by a second band of mica slate exactly like the first, which passes with the same dip and strike beneath a massive, dark gray to greenish-black hornblende rock, greatly jointed, and this is exposed in a broad area nearly down to the main road running east from Bernardston, and extending east to the house of S. J. Green, 100 rods west of the locality mentioned by Professor Dana.* It contains a central band of dark limestone at times 30^{cm} thick. The hornblende rock is capped by a thin layer, never more than a meter thick, of a shining, white arenaceous mica schist, with scattered scales of biotite, and a similar layer was found to cap a similar hornblende rock, in so great a number of instances between this point and South Vernon that it attracted particular attention. It was found to pass in every case up into the common dark gray mica schist, and to differ from it only in the entire absence of coaly matter and magnetite; and it seems possible that the former may have been discharged by the ferruginous matter of the hornblende band adjacent. It is, however, wanting below the hornblende bands which rest directly on the dark gray and finer mica schist. This makes it probable that none of the hornblende bands are overturned.

The schists of the area just described are cut off, going eastward, by a great drumlin, though the quartzite can be followed by the north end of it; beyond one finds sections which expose the whole thickness of the schists and hornblende bands.

They are best studied in the area east of the Purple blind road—see map—where, commencing in the chestnut woods northeast of the end of the road, at the basal conglomerate, we pass south over a broad area of the lowest mica schist, broad because of the low dip, and come upon the lowest hornblende rock, a band—about four meters thick—here, as always quite ferruginous and pyritous. Fifteen meters beyond there is a second bed of hornblende rock like the first, and both are capped by the white mica schist layer described above. Going on twenty meters to the top of the ridge, at a large chestnut tree conspicuous in the open field, there is a third rudely laminated layer of hornblende rock, thicker than the others and distinctly laminated. This is capped by a bed one meter

* This Journal, III, vi. 342, 1873.

thick, of a very rusty limestone, carrying abundantly light colored garnet, in large shapeless masses, and light green pyroxene. A long slope follows with scanty outcrops of mica schist, still fine-grained and without staurolite, but with no trace of hornblende; and, at its foot, succeeds a heavy bed of hornblendic rock about twenty meters thick, which by the quite abundant development of feldspar is in large part a complete *quartz-diorite*. Except for the appearance of feldspar, in small irregular white spots, it does not deviate from the usual type of the hornblendic rock of the area. It is followed almost immediately, though the exact contact could not be found, by a bed about fifteen meters thick, of a fine-grained granitoid quartzite, which is indeed, in its whole extent, a *complete granitoid gneiss*, never fissile, and faintly laminated only by the parallel arrangement of the biotite, or wholly lacking this even, and becoming a fine-grained tough *granite*, *largely feldspathic*, and with many streaked cleavage surfaces, and light gray from the small amount of the biotite. It can be followed here for a long distance, breaking off against a fault in the northeast direction, and going southwest, across Dry brook. Its place between the two heavy hornblende bands seems to be taken by a very fine-grained massive quartz rock, with abundant fine scales of muscovite, and with large round plates of biotite set at every angle. It appears again farther northeast at the last road across the range, and can be followed thence continuously, over the high hill west of South Vernon station and across the plain in Vernon, trending here directly toward the point where the road to Vernon goes beneath the railroad. It is unlike the quartz-conglomerate on the west, and feldspathic quartzite to be described on the east; and conforming in dip and strike with the mica schist, and making all the curves with it, it must be looked upon as a separate band in the mica schist, and cannot well be derived by folding or faulting from the other quartzite.

On the section line it is separated by a small thickness of mica schist from another heavy hornblendic bed, which latter is itself parted by a thin layer of schist, and separated by a heavy bed (30 meters) of a dark gray mica schist, much coarser than the beds below, and carrying abundantly transversely placed biotite, small garnets, and large staurolite crystals, the latter in single crystals, and in twins according to both the common laws. This greater coarseness of the texture, and the great abundance of staurolite in the upper beds of the mica schist, are the rule through the whole length of the range, and militates against any attempt to make out repetitions in the series now gone over. This band is capped by another heavy bed of hornblende rock 20-25 meters thick, which rises in a

prominent ridge overlooking an isolated house (W. Soudin's), and is followed by one more repetition of mica schist, before coming to a fault, upon a broad area of feldspathic quartzite—to be described later—which continues to the railroad at the northwest corner of Gill; and if the section is continued across Grass Hill to the Connecticut river, it cuts first a broad continuation of this upper quartzite, followed by a complete repetition of the mica-schist series, with five hornblende bands, one feldspathic, and the eastern sloping down the hillside from the Moody school buildings to the river, and thus covering a large area.

Sections carried across the area anywhere from the quartzite base southeastward, give substantially the same succession as that detailed above, only for a distance east of the line there chosen, there is a fault and a repetition of the beds; so that starting from the same point as the one chosen for the beginning of that line, and going directly east, to the saw-mill, on the South Vernon road, nine distinct hornblende bands are passed, and in almost every case each band is found capped by the whitish schist described above. Also along the State line, and for a distance north and south; either by the thinning of the beds of mica schist or by the slipping of the hornblende bands over them, the latter are unusually approximated, the three bands below the middle quartzite coming into close proximity to each other, and with the basal quartzite; it is separated by a broad mica-schist valley from a prominent hornblende-rock ridge, just in the east edge of the woods looking down on South Vernon, which is subdivided by only very thin layers of schist. Still farther east, in the large pasture above the South Vernon Hotel, the beds are greatly faulted as indicated upon the map. It illustrates the abundant faulting of the region that at the two short railroad cuts in these beds there are in each case two marked faults, bringing quite distant beds into contact.

Just south of the South Vernon station nearly horizontal mica schist is faulted, on the north, against a dike like mass of hornblende rock, about 10 meters wide; and on the south, an equally distinct east-west fault-line separates the latter rock from the feldspathic quartzite, also nearly horizontal.

At the next cutting, three miles farther north, near where the road crosses the railroad, one band of the hornblende rock is pushed over another and the quartzite over both, so that they have a common dip of 25° S. 65° E.; but the fault planes are distinctly visible, and both the hornblende rock bands are capped by the whitish schist layer which marks their transition into the common mica schist.

The type of the hornblende rock, as seen in the area described above, and in many bands stretching across the country to South Vernon, a type from which there is little variation, is a dark gray to black, fine grained, wholly massive rock, *resembling* so exactly, especially in its jointing, *an intrusive diorite*, that it was connected with the Mesozoic diabase in the first work of President Hitchcock, and the occurrence of it faulted between mica schist and quartzite at the South Vernon station, was called trap, by so experienced an observer as Professor C. H. Hitchcock in his latest work on the area.* The hornblende is generally arranged in fibrous radiated tufts, just visible with the lens, which aids in giving the rock its great toughness. It is not prone to weathering, and stands up generally in long ridges, the schists having been considerably lowered on either side of it, but at the railroad cutting in South Vernon, its fissures were coated with an abundant deposit of calcite and pyrite.

Because of its position in the hollows between the hornblende ridges, the mica-schist, which really occupies much more of the surface than the former, seems, on casual inspection, to be of subordinate extent and importance.

The thickness of the beds, calculated on the average dip of 22° is, quartzite 107 meters, mica schist 113 meters, hornblende rock 158 meters; which is certainly far too large judging from the long line of outcrops farther northeast, and it is probable that each is partially repeated several times by cross faults.

I have elsewhere suggested that hornblende bands of this type are generally derived from limestone beds, and in fact the hornblende bands are still locally quite rich in carbonates, as at the locality first described above just east of Fall River, the broad hornblende band contains layers of limestone 20–30^{mm} thick; and farther northeast, at a large chestnut tree east of the end of the Purple blind road, there occurs in the same association a bed nearly a meter thick of impure limestone carrying garnet and pyroxene.

The development of hornblende at the upper surface of the crinoidal bed has been detailed above, and the large development of hornblende in the quartzite in South Vernon points in the same direction. The hornblende derived from calcite has always a very low absorption.

The feldspathic Quartzite.—Reserving the question of the identity of this rock with the basal conglomerate, I may first call attention to its curious distribution on the map. It occupies a broad area along the eastern border of the schist series, dips everywhere away from it to the eastward with apparent

* Geol. N. H., ii, 438.

conformity, makes the same folds with it all the way from the State-line, south to the point where the main South Vernon-Bernardston road crosses the railroad, even swinging round to a N.-S. strike where the schists do. Beyond this point it occupies a broad area stretching from the railroad across to the Purple blind road, and is plainly separated from the schists on the north by a curvilinear fault. Thence it continues in a broad band southeastwardly, a long distance, and can be followed in scattered outcrops across the sand plains into the town of Gill. Beyond Dry Brook it seems to regain its conformity with the schists. Across the narrow neck by which the West Northfield sands join those of Bernardston, the same quartzite reappears in the northwest shoulder of Grass Hill, and is apparently continuous under the sands with the larger area west of the railroad. It dips under the hornblende rock to the east.

It is everywhere a fine grained light gray fissile quartzite, with small fresh feldspar crystals porphyritically disseminated in it, often quite abundantly. These reach 1-2^{mm} in cross-section, are often but not always striated. They are much larger than the quartz grains and have often sharp crystalline outlines.

In the area south of the great fault at the Purple blind road, and far west from here, it is marked by the abundance of the grains of lavender quartz included in it, which appear to have come from the Archæan gneiss of the Green Mountains. Muscovite, so abundant in the lower quartzite, is wholly wanting; rarely a small amount of biotite in fine scales, or, at one outcrop, of hornblende in scattered needles appear.

The dips of the rocks and of the slates below are so low, and, with the strike, vary so rapidly and irregularly within narrow limits, that I am left in slight doubt as to the exact conformity of the two for any long distance. Going north or south from the northern road over the range, along the line of junction for two miles, no contact of the two could be found, but in the whole distance they seem exactly conformable, and to have shared all minor disturbances together; for instance, although the rocks are tilted so that they strike N. 65° E. and dip 40° S.E., they have also been subjected to an E.-W. thrust, as is seen on a large scale farther south, so that small portions placed irregularly among the rest have a N.-S. strike, which is shared by both the schists and the quartzite.

The basal conglomerate often blackened by argillitic material is a rock of very different habit from this fine grained biotitic feldspathic quartzite; but the description above given of the passage of the beds across Vernon indicates that the former passes into the other going eastward beneath the schists

and is then brought up by a fault along the eastern base of the schist series, and in places thrust over the latter in apparent conformity. The fault line must be an exceedingly tortuous one, and on the east the Grass Hill series must be a repetition of the West Northfield series.

The Bernardston Series east of the Connecticut.—The adjoining area east of the river in Northfield, is unfortunately so covered by the terrace sands, that only few outcrops appear. I think that the rocks of the Bernardston series find their eastern limit through the whole length of Northfield, Ewing and Montague, at the foot of the high ground which bounds the Connecticut Valley on the east; that it ends without any marked shore deposit; but with great crushing of the fine quartzite, probably on a fault of great magnitude and extent, and finally that the quartzite schists and amphibolite, which succeed to the east in the Northfield Hills, though presenting some points of similarity with the Bernardston rocks, are to be associated rather with the series which lies west of the argillite and which are presumably older.

The Quartzite in Northfield.—North of this village, a porphyritic quartzite identical with the eastern band in the West Northfield range, crops out along the eastern edge of the high terrace, but is immediately followed on the east by an older series mentioned above. It is much brecciated and abundantly cemented by hematite. It appears also in the brook bottoms; and just over the line in Winchester, a shaft has been sunk a hundred feet in it for lead, which appears very sparingly in narrow interrupted fissures of a few millimeters width, associated with barite and fluorite in equally small quantities, and at the bottom with beautiful druses of pale yellow, saddle-shaped, dolomite crystals. Below the surface the quartzite is snow-white, but otherwise unchanged. The rock is a hard white saccharoidal sandstone, regularly porphyritic with small clear feldspars in stout rectangular cross sections for the most part striated, and plainly of secondary growth since they enclose sand grains. It is here everywhere massive. Outcrops are seen in all brook beds in the north part of the town, and it approaches nearest to the older series, in a lane running east from the Moody homestead and along the Winchester road. It is here greatly brecciated and full of quartz and hematite veins. On the east of the boundary line several bands of the older series abut obliquely against this line, so that the quartzite on the west rests in manifest discordance, either due to unconformability or faulting against the older series.

The Mica Schist east of the Connecticut River in Northfield.—East of the river only a single limited outcrop of mica schist occurs, a half mile below the village, just opposite Grass

Hill, and 200 rods from the nearest outcrop of hornblende rock, on the west side of the river. It agrees in texture with the lowest beds of schist on the west of the Connecticut, is fine grained, and carries few accessions. It abounds in flattened cavities, which seem to be the obscure traces of fossil shells, but they are wholly indeterminable, if indeed they be of organic origin at all. Upon the joint faces are abundant weathered crystals of a flesh colored zeolite, apparently chabazite. The exact locality is by the brook crossing, at a mill pond near A. Billings'.

Conclusion.

The section below seems to me to represent the succession of the beds represented, the newest above.

1. Mica schist,	9. Hornblende schist and
2. Hornblende schist,	Magnetite,
3. Mica schist,	10. Limestone.
4. Hornblende schist,	11. Hornblende schist,
5. Mica schist,	12. Quartzite conglomerate,
6. Hornblende schist,	13. Argillite,
7. Mica schist,	14. Calciferous mica schist.
8. Quartzite,	

Originally heavy beds of shale (*a*) graduated upward into a great series of feldspathic sandstones (*b*) and conglomerates, which contained a band of crinoidal limestone with a local development of iron ore near its surface. Above this was an extensive series of shales (*c*) with several intercalated beds of impure limestone. The first series has changed into a crumpled and cleaved phyllite to which the name argillite has been for a long time appropriated. The second series has passed through all the changes to a gneiss so complete that Professor Hitchcock insists on associating it with the Bethlehem gneiss—quartzite with flattened pebbles, muscovite quartzite, biotite quartzite, feldspathic quartzite often porphyritic, and complete biotite gneiss often becoming chloritic from superficial change.

The limestone has become most coarsely crystalline and the lime and iron have been carried far out into the quartzites above and below to form hornblende schists and complex hornblende-chlorite pyrite rocks.

The iron ore forms a bed of magnetite or a magnetite rock.

The upper series is changed to complete mica-schists span-gled with transverse biotite crystals, often loaded with garnets and staurolites; while the limestone beds are changed from the surface toward the center into hornblende schist beds abstracting the iron from an adjacent band of the shales.

The dips are all to the east and the beds are several times repeated by monoclinical faulting and with each reappearance of the quartzite it is finer grained and more feldspathic.

The whole series has a slight pitch to the south, so that in Vernon the whole upper series tapers northward and disappears; and then in going eastward from the argillite we pass from the more quartzose conglomerates through muscovite and biotite quartzites to complete gneisses, as in the successive reappearances farther south.

The most abundant and characteristic fossils are Chemung with several Hamilton forms, so that the limestone, magnetite, and the base of the quartzite above the limestone may be placed with certainty near the base of the Chemung. That the whole series must go together is, I think, clear from the map and the preceding discussion. The suggestion of Professor Hitchcock, that the limestone was bounded on both sides by faults* prove true for the west side, but is not true for the east side, and the important deduction made by him that the limestone was greatly newer than all the surrounding rocks is also disproved.

The argillite, though the oldest rock, is least decomposed, crumpled and cleaved with dull surfaces and full of coal grains and kaolin, in its most eastern exposures showing minute pustules on its slaty surfaces, and at last developing garnet and biotite in some abundance. In the western exposures of the mica-schist series, kaolin could scarcely be detected, and biotite, garnet and staurolite were quite abundant, but almost microscopic, while farther east the surfaces show clearly the muscovite sheen, and the above accessions are abundant and large. In the calciferous mica schist which lies below the argillite the separate muscovite scales are clearly visible to the eye, and the same accessories occur still larger and with a very different and much more complex structure.†

* 15, p. 315.

† The note in the former part of this paper at the foot of page 264 should be transferred to page 266. It applies to figure 2.