ART. XLVI.—*On the Hudson River Age of the Taconic Schists, and on the Dependent Relations of the Dutchess County and Western Connecticut Limestone belts*; by JAMES D. DANA.

THE paper by the writer on the Relations of the Geology of Vermont to that of Berkshire, in volume xiv of this Journal (1877), closed (on p. 264) with the following paragraph:

"The magnitude of the results are strong evidence that the so-called limestone-area is really but a small part of a larger region of cotemporaneous disturbance and uplift. The true breadth of the area, as well as length—whether it reached to the Connecticut Valley on the east and to the Hudson River Valley on the west, and so had the breadth of the Appalachian disturbance of a later epoch, or whether it had narrower limits—may be ascertained by studying the stratification. Some of the results of such a study as regards Connecticut and a portion of New York I propose to give in another paper."

Since the above was written I have spent much time in endeavoring to complete my observations in Connecticut and the neighboring counties of New York. I have sought to determine the strike and dip and stratigraphical relations of the rocks of Western Connecticut—points on which Percival's Report contains little, since he aimed chiefly to describe the *kinds of rocks and their geographical distribution*, and did not note where, in any case, lines of stratification and of lithological distribution were, as is often true, not coördinated.* I have

* Dr. Percival was a very exact man in all his work. He made great numbers of observations on the dip of the crystalline schists of the State, but, unfortunately, did not publish them. They had a secondary importance with him because he believed that the different kinds of crystalline rocks were formed from an original crystallizing magma by successive segregations, and did not credit the ordinary views as to stratification and metamorphism. Lines of bedding very often strike across the boundaries of his lithological areas, showing that the latter as laid down on his map, while of interest, are no guide to the stratification, except in the case of the limestone areas and those of a few other formations of persistent lithological characters. It is due to Percival to say that his theory did not lead him to the slightest perversion of the stratigraphic or other facts before him, but only to a misappreciation of some of their bearings; and had the State of Connecticut been more generous to him in its allowance of time for the completion of the survey, and of money for the publication of his notes, there would have been little left for later geologists to do.

made observations toward the same end, and also widely, over Dutchess and Westchester Counties, New York. The work is still far from finished. But the discoveries by Mr. Dale at Poughkeepsie throw so much light on the general question at issue—the age of the Taconic schists, when they are connected with the facts already learned, that I here anticipate my fuller memoir by a brief statement of the facts and their bearing.

1. ON THE HUDSON RIVER AGE OF THE TACONIC SCHISTS.

(1.) The discovery, by Mr. A. WING, of Trenton fossils, *Trinucleus concentricus* and other species, in beds of the crystalline limestone formation of Vermont that directly adjoin and underlie conformably the slates of the north-and-south Taconic belt, has established the fact that these Vermont slates are of the age of the Upper Trenton or the Hudson River group; and the fact that this Taconic belt continues southward, in an uninterrupted line, into and through Western Massachusetts, constituting the Taconic Mountains (lying on the boundary between that State and New York), and the additional fact that the same great limestone formation follows the belt through its course and underlies, in a synclinal, its slates or schists—as the writer has shown, the limestone of the east side dipping under the mountains and becoming the limestone of Copake and Hillsdale on the west—affords scarcely less positive proof that these Berkshire Taconic slates also, the original typical Taconic slates of Emmons long supposed to be Cambrian or pre-Silurian, are of Hudson River age.

This conclusion loses nothing of its certainty in consequence of the fact of a change in the schists of the belt from argillaceous schists at the north (one source of the roofing-slate industry of Vermont), to hydromica, chloritic and garnetiferous mica schists, and staurolitic schists, toward the south extremity of the mountains; for the introduction of hydromica schists (formerly called *magnesian* and *talcose schists*) takes place in Vermont not far from the localities that afforded the fossils; and these hydromica schists continue the whole length of the belt, though more chloritic, more coarsely micaceous, and often garnetiferous, to the south. As to the synclinal of the Mt. Washington portion of the Taconic range in southwestern Massachusetts, Professor W. W. Mather, in a section on Plate 16 of his New York Geological Report (1843), across the mountains fifteen miles farther south, represents the limestone of Salisbury as dipping *westward* beneath the slates while those of the west dip eastward, as they do elsewhere on that side of the mountains. Further; my own recent observations in Northern Salisbury, within three miles of the Massachusetts line, confirm those which I made just north in Western Sheffield;

that the limestone along the eastern foot of the mountains (near or west of the nearest road to them) dips *westward*—the dip being found to be 45° to 60° to the west, with the strike between $N. 3^{\circ} E.$ and $N. 3^{\circ} W.$ (true).

(2.) The recent discovery, by T. Nelson Dale, Jr., of fossils of the Hudson River group in the slates or argillaceous schists of Poughkeepsie, on the Hudson River, (sustaining the early views of the New York geologists, Professor W. W. Mather and Professor James Hall,) affords another line of approach to the Taconic Mountains of Massachusetts, and presents further evidence of their Hudson River age. In the first place, the limestone belt which lies, as above remarked, at the western foot of these mountains along through Hillsdale and Copake, and which is the western side of the mountain synclinal, branches off from Copake south-southwest through middle and western Ancram, and extends along the whole course of the valley of Wappinger Creek to the Hudson River, which it reaches only four miles below Poughkeepsie, with a single interruption of less than three miles; and it is everywhere conformable to the argillaceous schists which border it on the east, including those of Poughkeepsie; and also with those on the west, except along a region of faulting near Bangall and Stissing Mountain (a range bordering the limestone area on the west between Stissingville and Pine Plains.) This continuation of the slates and limestone northeastward, from the Poughkeepsie region to the Copake, renders it highly probable that the same limestone formation which adjoins, and is conformable to, the Hudson River slates or schists of Poughkeepsie, adjoins, is conformable to, and underlies the schists of the Taconic Mountains.

The limestone of Wappinger Valley is the Barnegat limestone of Mather—so named from a locality on the Hudson, south of Poughkeepsie, where it is burnt for lime; and this geologist gives it the course here described, mentioning that it outcrops on the Hudson at the mouth of Wappinger Creek between Barnegat and New Hamburg, and follows the river northeastward to Copake (not noting the break in it);* and he also states that it appears on the *west* side of the Hudson and stretches on to the south-southwest, passing within one mile of Newburgh, into the town of New Windsor, in which it ends, not far from the Archæan of the New Jersey Highlands, in a small body of water called Little Pond. The writer has examined the limestone at various points along the valley; and he has found the conformability to the slates, stated by Mather, to be very generally true. The limestone area is

* Geol. Rep. 4to, 1843, pages 413 and 437. In the paragraph on p. 437 here referred to, there is some confusion as to the courses of the other Dutchess County limestone areas.

similar to the limestone region east of the Taconic Mountains in having large limonite beds, not only in Copake and farther north, but also in Central Ancram and beyond to the south; among them the Reynold's ore-pit, three to four miles southwest of the Weed ore-pit of Southern Copake, and the Morgan, a mile and a half farther south. Thus the observations accord well with the view that the limestone belt which borders conformably the Hudson River argillaceous schist of Poughkeepsie is the same that borders the Taconic schists in Copake and Hillsdale. If so, since the Copake and Hillsdale, or Western, belt of limestone dips under the Taconic Mountains and comes up, on the east, as the "Great Central belt" of the Green Mountain region, the Barnegat or Wappinger Valley limestone is only a southwestern extension of the great limestone formation that outcrops around Dorset, Rutland and Middlebury, Vermont. The occurrence of limonite beds along the junction between the schists and limestone, as a result of their alteration, in both the eastern and western belts, is an additional mark of general identity.

[On the accompanying map, representing a portion of Eastern New York, with also part of Western Connecticut and the southwest corner of Massachusetts, the general position of two Dutchess County limestone belts is shown, from their outcrops along the Hudson River to their junction with one another in the Copake limestone belt, west of the area of the Taconic Mountains. The map also gives the position of the southern part of the "Great Central" limestone belt of the Green Mountain region, as laid down by Percival on his geological map of Connecticut, from Sheffield in Massachusetts, and Canaan in Connecticut (where it has the width which characterizes it farther north in Berkshire and Vermont), through Salisbury and Sharon, and thence through Eastern New York, here gradually narrowing, to its end among contorted beds of micaceous gneiss eight miles south of Pawling, and just east and north of the Archæan Highlands. These areas, where broadest, include some intercalated beds of schist and isolated schist ridges. The map also gives the position of two eastern limestone belts in Connecticut, that of Kent and Cornwall, and that of Brookfield and New Milford. The T-like symbols over the map, indicate the strike and dip from my observations.]

(3.) Besides this stratigraphical evidence we now have *more positive evidence from the occurrence of Trenton fossils in the limestone of some parts of Wappinger Valley.*

Professor Mather makes the statement in his quarto New York Report (repeating it from his Annual Report of 1838), that in a bed of slaty limestone existing in the slates one-and-a-fourth to one-and-a-half miles north of Barnegat, "a few fossils were

Map of Dutchess and the adjoining Counties of Eastern New York, with a portion of Western Connecticut and Southwestern Massachusetts.

Dutchess County is included between the boundary lines AB B.C. on the north, and CD on the south. On the north is Columbia County, and on the south, Putnam. The Archæan Highlands of Putnam County are a continuation of those of Orange County, New York, and Sussex County, New Jersey. The light areas represent areas or belts of limestone. The notched line just west of the Connecticut boundary is the course of the Harlem Railroad. B. C., Boston Corners; Cwl. Br., Cornwall Bridge; Mbb., Mabbittsville; P. Valley, Pleasant Valley; Sh., Shekomoko Station, on the Dutchess and Connecticut railroad—the two streams in the adjoining limestone area being tributaries to Shekomoko Brook.

Scale, 1-10th of an inch to a mile.

found that have been recognized as belonging to the Trenton limestone."* The names of the species are not given. The Barnegat limestone is not far distant to the south and is the next adjoining stratum. The Poughkeepsie slates dip *beneath* the limestone, the dip being southeastward. But if the rocks are in folds and the limestone makes an *anticlinal*, it is an inferior bed notwithstanding the position.† In the Barnegat or Wappinger Valley limestone, which is a dark gray, semi-crystalline rock, Professor Mather found no distinct fossils. He states that his assistant, Professor C. Briggs, "in making his section from Poughkeepsie to Canaan in Connecticut, discovered faint traces of shells at a quarry a little south of Pleasant Valley on the bank of Wappinger's Creek; but they were too imperfect for determination. They were situated between the slaty layers, which have a dip to the south-southeast of 35° to 40°." Mather quotes also Professor Briggs as reporting that Mr. William Thorn of this place (Pleasant Valley) had informed him that "he had often seen shells in the lime rock, although they are rare."‡

Had Professor Mather himself visited that quarry half a mile southwest of Pleasant Valley (about seven miles northeast of Poughkeepsie), he would not have left the fossiliferous character of the limestone in doubt, and inserted discrediting remarks in his Report. Besides, Logan's unfortunate idea of the Quebec group extending over the region, and some other wrong geological inferences, would never have had birth. At a visit to the locality this spring, in order to ascertain the facts in the case (in which I was accompanied by Professor Wm. B. Dwight of Vassar College, Poughkeepsie) I found fossils abundant and distinct. Among them we observed at the time of our visit, remains of two or three species of *Crinoids*, *Cyathophylloid corals*, *Leptaena sericea*, *Orthis tricenaria*, *O. testudinaria*, *Orthoceras junceum*, § forms suggesting *Strophomena alternata* and fragments of *Trilobites*. What appeared to be the rounded pebbles of a conglomerate layer, proved to be worn specimens of a *Chaetetes* —? with columns not over 1-250th of an inch in diameter. The snow was deep over the country (so deep that our geological excursion was made "on runners," since either "on foot" or "on wheels" would have been attended with some difficulty), and hence a full examination of the locality could not then be made. It cannot be, for the

* Page 401.

† Professor Mather calls the Barnegat limestone *Calcliferous*, apparently because he had proved a limestone bed above it—that above referred to—to contain Trenton fossils; he could have had no other reason for it, for he says that he had no fossils from it.

‡ Page 410.

§ The form, size, and distance between the septa, are the same as in this species.

same reason, at the present time (March 21), and I have left the region to be reported on further by Professor Dwight.

Another locality of fossils in the Wappinger Valley limestone at Rochdale, four miles east of Poughkeepsie, had been visited by Professor Dwight the week before—he having been informed with regard to fossils there the day after he received my invitation to join me in the excursion—and it is not less prolific. Great surfaces are covered with the Crinoidal remains, and all the species observed at Pleasant Valley are found there; and, besides, a portion of an *Endoceras*, ten inches long and two inches wide at its larger end, and remains of large specimens of *Receptaculites*. I refer to the article following this for Professor Dwight's preliminary account of the fossils.

Previously, early in December (the day before the first snow-storm of the late snowy winter), I made a search for fossils at the northern end of the Wappinger Valley limestone, in eastern Ancram, just west of the extremity of Winchell's Mountain and not three miles distant from the Taconic Mountains, and found what I then and now believe to be the common Trenton species, *Orthis occidentalis*,* and with it there is another kind, of uncertain character, which may possibly be the Trenton *Strophomena alternata*. The specimen of the *Orthis* presents to view a section of the shell, having the size, form and thickness indicated in the accompanying figure. The thin shell is converted into white calcite (through the metamorphism) excepting in some parts an extremely thin exterior layer; and over a portion of the exterior (at *c*) there are sections of a few of the costæ. The hinge side of the shell is wanting in the specimen. A horizontal section made through the more convex (or ventral) valve was found to have the form which it should have if of the species here supposed; and so for the other valve. The evidence is therefore quite strong in favor of its being this common Trenton Brachiopod.

The forms referred doubtfully to *Strophomena alternata* have the arcuated outline, shape and thickness, that would belong to sections of this arcuate shell. They are of white calcite and correspond to individuals one to two inches broad and diminishing mostly from a fourth to a sixteenth of an inch in thickness. Besides the sections, there are also broad concave surfaces like the inner surface of valves. No appearance of striation can be detected in connection with any of the forms.

* The specimens were from a large freshly broken mass of limestone by the road side that was evidently derived from an outcrop near by.

I have been again over the Ancram region, but without finding other specimens—the limestone being much more crystalline than it is toward Poughkeepsie.

The fossils of Pleasant Valley and Rochdale, prove that the limestone of Wappinger Creek Valley contains a stratum of the age of the Trenton; and that of Ancram has the same bearing. The width of the part of the belt at the two former places is two-thirds to three-fourths of a mile; and since the bed containing the fossils is, at each of these localities, within 200 to 230 yards of the *eastern margin* of the limestone belt, it is probably one and the same bed. The lithological character of the rock sustains this. The *western margin* lies conformably against the Poughkeepsie "Hudson River" slate; and hence the

western portion also must be Trenton.

It follows then: *first*, that the belt is an anticlinal of limestone (as represented in the figure, *f*, toward the east side, being the observed fossiliferous bed); and, *secondly*, that the slate on the *east* of it is of Hudson River age, as well as that *west*. Further: these facts, and the concurring evidence from Ancram, where the limestone is essentially the Copake limestone,

leave little doubt that Trenton beds continue northward to the very foot of the Taconic Mountains; and that the schists of the Taconic Mountains, like those of either side of the Wappinger Valley, including Winchell's Mountain, are *Hudson River in age*.

The Wappinger Valley belt may have at centre a Chazy or other subjacent limestone stratum; and if so, the fact would only make more complete the identity of the Poughkeepsie and Vermont formations.

In the vicinity of Stissing Mountain there are quartzite outcrops; and, if the rock is of the age of the Potsdam sandstone, the portion of the limestone next adjoining may be Calciferos. The mountain consists of fine-grained, gray gneiss, along with slate on the west, and at the southern end the gneiss contains minute zircons; I reserve the discussion of the age of the gneiss for another paper—the first draught of which was made nearly eight years since.

(4.) But this Wappinger Valley limestone is not the only southward extension of the Copake limestone. Another (see Map) extends from it southward by the western foot of the Taconic Mountains through Boston Corners and Millerton; and in the vicinity of the latter place it has its limonite beds. Thence it takes a south-by-west course through Western Amenia, and

Eastern Washington. It stops in the latter town just east of Mabbitsville. But six miles south, in the next town, Unionvale, it appears again in the valley of the Clove, and follows Fishkill Creek to its junction with the Hudson. At Poughquag, it has the extraordinary breadth of three miles, and it continues to have great width past the village of Old Fishkill; but it then narrows, becomes confined to the south side of the Fishkill Creek in Glenham, and is very narrow toward the mouth of the creek.* It evidently loses in breadth in this part because of its nearing the Archæan region of the Highlands, which is not half a mile distant; and its more western course from Poughquag to the Hudson has the same origin. The Hudson River slates border it conformably on the north. Limonite beds occur along this belt in Unionvale, where is the Clove ore bed, two on Sylvan Lake, and one in East Fishkill.

Through this Millerton-and-Fishkill belt of limestone there is hence a second connection between the Hudson River slates of the borders of the Hudson River region and the schists of the Taconic Mountains.

The limestone is throughout as decidedly crystalline as in the northern half of the Wappinger Valley belt (though never coarsely so); and hence fossils would be uncommon if occurring in it at all. In many places forms suggesting a fossil origin are to be met with.

Wherever the limestone contains seams of quartz such indications rarely occur, the most suggestive appearances being small and thin isolated bits of quartz, arcuate in section. Since the silicification, or the making of the siliceous seams, was carried forward by *hot* siliceous waters (not *cold*, as in the case of silicified shells in an unaltered limestone) during a time of metamorphism in which the limestone was crystallized and quartz veins were made in the slates or schists, fossils, if any were present, would naturally have been dissolved away. Almost the only chance for recognizable forms is in places where the limestone is without quartz, and the seams and spots it contains are of white calcite. One of this kind, which I observed in the limestone seven miles north of Millerton, near the base of the Taconic Mountains, seemed to be part of a valve of a ribbed Brachiopod, and others of like suggestiveness were met with in some of the limestone cuts between Hopewell and Fishkill. Such appearances favor the expectation that distinct fossils may yet be found in this belt. Three

* I found the limestone outcropping at the village of Lithgow, and east of Mabbitsville (*Mbb.* on map), as stated by Mather. South of this, the country is high, the elevated region to the eastward (called farther south Chestnut Ridge) spreading over it, and having its rocks small in dip, with undulations, and with the limestone evidently concealed beneath. The limestone reappears where the valley opens again, along Clove Brook, and is thence continuous to the Hudson.

miles west of Hopewell I obtained specimens looking closely like the Wappinger Valley *Chætetes*, but with its structure lost.

Between the Wappinger-Valley and Fishkill-and-Millerton belts, there are other outcrops of limestone.

One area, nearly six miles long, lies between the northern ends of these belts, in the Shekomeko Valley. (See the map.) Winchell's Mountain bounds it on the east, and Husted station is toward its northern extremity. The limestone is similar to that of the Fishkill-and-Millerton belt, but has in many parts

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a delicate bedding that shows the action of slowly moving water during its accumulation. The accompanying figure (from a photograph) represents, natural size, figures on a specimen of blue limestone, from a ledge near Shekomeko Station (*Sh.*), which are of white calcite and similar to those alluded to above as suggestive of Brachiopods.

Another specimen contains a group of *black* curving surfaces, which are unquestionably of organic origin, and look like impressions of a few successive broken segments of a *Trilobite* $1\frac{1}{4}$ in. broad.

Another area exists just below the Verbank railroad station, where two small hills of a badly rifted, quartz-seamed, gnarled limestone occur, which is various in strike, but mostly nearly north and south, and is without continuation at surface either north or south. A third occurs at Arthursburg, hardly eight miles south of Verbank. I learn from Professor Dwight, that a ledge, 1,800 feet wide occurs two miles southeast of Pleasant Valley. Mather mentions one between Redhook and Milan.

Over the country between the two Dutchess County limestone belts, the dip, excluding some local exceptions, is eastward (mostly between east-by-south and east-southeast) and the beds, as has been stated, are all conformable. It is true that the *cleavage* of slates is not always conformable to the stratification; but since over this region the lamination in them corresponds in all cases with the bedding of the many intervening limestone strata, the uncertainties which are thus introduced do not affect the above general statement as to conformability and eastward dip. In a supplement to this paper, the actual dips and courses observed, will be given.

Rocks.—The schists and limestone east of the Taconic Mountains are more crystalline than those *west*, and the crystalline

character diminishes from these mountains *westward* toward the Hudson, just as it diminishes along their line northward toward Central Vermont. The rocks are mica schist and hydromica schist, and to the south micaceous gneiss, over the eastern part of Dutchess County; but, approaching Poughkeepsie, the schist in part fails even of the glossy luster, and becomes dull argillaceous and partly carbonaceous schist. North of Dutchess County, in Columbia County, argillaceous schist is the prevailing rock, and it is often carbonaceous in Ancram and part of Copake. The micaceous gneiss of the Taconic schist belt is well seen two miles west of Pawling; and here, against its eastern side, between it and the limestone, there lies a large limonite ore-bed. And this gneiss-like character continues to its extremity, south of Towner's, where, in a dry portion of a large marsh, north of Croton Lake, the limestone is exposed to view, alternating with coarse gneiss. In the slate ridge next west, the northern extremity of which is called Winchell's Mountain (west of Boston Corners and Millerton), the rock is argillite, and hydromica schist, partly chloritic; but to the south, it becomes gradually coarser, being a mica schist on its eastern or more crystalline side, at Wassaic; and ten miles farther south, a decided mica schist on its western side, and still coarser on the east; and even gneissoid south of this.* Mather recognized the same changes, in this range of slate, stating it thus (Rep. N. Y. Geol., p. 433): "in its northern part, of slate and talcose and chloritic slates; the middle part, of mica slate; and the southern portion, of gneiss." The extremity of the "Great Central" limestone belt is in the area of Croton lake.†

The facts in Dutchess County thus show that argillaceous schist, hydromica schist, mica schist of garnetiferous, chloritic, staurolitic and other varieties, and micaceous gneiss, which are the occurring rocks of the so-called "Taconic system" or "Taconian," are here of one and the same age, and they leave little reason to doubt that they are, together, *of the age of the Hudson River Group*.

Quartzite occurs adjoining the Archæan, southwest of Matteawan, three miles from the Hudson River—a locality pointed out to me by Mr. Charles M. Wolcott of Fishkill. The quartzite

* According to a section by Prof. N. H. Winchell (received by the author from him in 1872) from the top of Winchell's Mountain eastward to Lakeville, seven miles, along a line $\frac{1}{2}$ m. north of Millerton, the rock of Winchell's Mountain west of the summit is argillite, and east of it mica schist; next east is the Millerton limestone nearly two miles wide; next, mica schist, of the same width, having, on the west a thin stratum of "compact, fibrous hornblende schist, somewhat micaceous" (as seen in a section on the Connecticut Western R. R.); and then, the limestone of Lakeville. The dip is stated to be north of east, except at Lakeville where there is a low anticlinal.

† It is rather probable that an outcrop exists two miles farther south, in the site of another pond south of Dykeman's, though none is in view. There is here a final termination of the valley by high Archæan hills.

was jointed and obscure in its bedding; but since a limonite deposit (usually situated in these regions, between conformable strata of schist or quartzite and limestone) adjoins it, and the proprietor, Mr. Wolcott, found this one resting on beds approaching the quartzite in character, it is very probable that the stratum is conformable with the limestone, whose outcrops are not far distant, and that it is of the age of the Potsdam sandstone. The adjoining portion of the limestone may hence prove to be Calcareous or Chazy. Quartzite rests on the Archæan also at Poughquag, but in nearly horizontal beds (see this Journal, III, iii, 250, 1872) indicating a fault between it and the adjoining limestone. Mather mentions its occurrence also at Shenandoah.

At Glenham near Fishkill, a flesh-red, coarse granite-like stratum (or "bastard granite," as it has been called) lies between the limestone and the slate, conformable to both; and it is evidently one of the stratified deposits, as is shown by its conformable position, and its taking the color of the slate near the junction. The adjacent Archæan Highlands were the source of the coarse granitic sand of which it was made.

2. DEPENDENT RELATIONS OF THE TWO DUTCHESS COUNTY LIMESTONE BELTS AND TWO EASTERN BELTS IN CONNECTICUT.

The preceding map also represents, from Percival, two eastern belts of limestone in Connecticut, the *Kent* belt and the *New Milford* belt; and I may add that I have been over these regions pretty thoroughly, and can attest to Percival's correctness.

Viewing these belts and the three to the west together, and remembering that the Great Central belt is identified with the Green Mountains through Massachusetts and far into Vermont, it seems to be a safe conclusion that all are parts of one system; and that they owe their existence to a series of extensive cotemporaneously-made folds of the wide-spread Lower Silurian formation of the region. The New Milford and Kent belts are the *opposite sides of a synclinal*; for the schistose rocks between have, as I have found, a westward dip along the eastern portion, and an eastward dip along the western portion, as indicated by the symbols for the dip and strike on the map. The Great Central belt and the Kent belt *pass one into the other* in the vicinity of South Dover (see map), and also to the north in the eastern part of Canaan, and thus they are one.

Over the large gneiss area next west of Kent, the schistose rocks are, for the most part, conformable to the adjoining limestone belts—the strike about N. 20° E. along the southern half and on the eastern side of the northern half, and with N. 50° E. as the average near the Housatonic River, as if from a

wrench in the mass. On the southern portion of the *east* side both north and south of Kent, and also along a large part of the *west* side, the rock adjoining the limestone is *quartzyte*; and next follows gneiss; *the quartzite in several places is gneissoid, and graduates into the hard gneiss*. South of Sharon, the rock next to the quartzite is *granulyte*, and there is a partial transition from one to the other. The quartzite of the two sides of the area is, with little doubt, the same stratum, and probably the Potsdam sandstone; and in that case the conformable gneiss will correspond to inferior beds of the Primordial, and the adjoining portion of the limestone belts may be Calcareous; further, the strata make an anticlinal over the intervening area of gneiss. This area includes some unconformable ledges, both in the northern and southern half, in which occur chondroitic limestone, syenite, beds of titaniferous magnetite, and hard gneisses, which may be Archæan; and if so, they are outliers of the large Archæan area of the Highlands which exists to the southwest.

3. INFLUENCE OF THE LIMESTONE BELTS ON THE FEATURES OF THE SURFACE.

Limestone being a brittle rock, the region of flexures, whatever the thickness of the overlying mass, would have been profoundly fractured, especially in anticlinals; and being also a soft rock, it would have been easily carried away by denuding agencies. The limestone belts are the chief courses, as Percival pointed out, of all the greater valleys and streams of the limestone region; and in these valleys, as I have found, the underdipping side of the limestone is generally the bold, precipitous side, owing to the undermining which it has occasioned. This is so generally true that vertical fronts in these metamorphic regions (and I may add in Westchester County as well as farther north and northeast) are pretty sure evidence of outcropping limestone below.

4. CONCLUSIONS.

1. The Taconic schists are, according to the evidence, of the age of the Hudson River group.

2. The conformability in the rocks between the eastern of the Connecticut belts and the Hudson, being established by observation, the five limestone belts are plainly, as above suggested, but five outcropping bands of the Lower Silurian limestone formations, brought to the surface by a series of flexures.

3. The disturbance which upturned and crystallized the limestones and other conformable formations in the Green Mountain area, through Vermont and Massachusetts, extended south over

certainly a large part of Western Connecticut, and over Eastern New York at least to the Hudson.

That hard gneisses and mica schists are among the included formations does not, in any way, affect the evidence or the conclusions here deduced.

These conclusions coincide partly with those reached by Professor Mather, as stated on pages 438, 464, and 628 of his Report, namely: (1) That the limestone of Eastern New York and the Green Mountain region, including that of Westchester County down to New York Island, is of the Trenton or Calcareous (Canadian) periods; (2) that the slates, gneiss, mica schist and other rocks, directly associated with the limestone in Massachusetts and elsewhere, are of the Hudson River age; (3) that the quartzite is of the age of the Potsdam; (4) that the making of the Green Mountains and the metamorphism of Western New England, took place at the close of the Lower Silurian. Proposition (1) appears to me to be established, if we admit, in addition, that the limestone may in some places be in part Primordial, and leave out of consideration, for the present, that of Westchester County. Proposition (2) is pretty well demonstrated as far as the slates or schists of the Taconic Range are concerned; but,—as I present in the second of my articles on Berkshire geology—we cannot say now of the gneiss and mica schist ridges to the east of the Taconic range more than this, that they are Lower Silurian; and among the gneisses are those also of local Archæan areas. Proposition (3) is almost certainly true for part of the quartzite, but it is not yet safe to say this of all. Proposition (4) has strong support in all the observations which I have made in the Green Mountain region.

Professor Mather has a separate chapter on "Primary rocks" under which head he includes the rocks of the Highlands, and, with these, the gneisses and mica schists of Westchester County and New York Island. The distribution of the limestone areas of Westchester County with reference to one another and those of Connecticut, and their stratigraphical relations to the gneisses and mica schists associated with them, are a basis of evidence on this question of age, and the facts I have observed and mapped I shall present in a following number of this Journal.

The nature and stratification of the schistose rocks intervening between the Connecticut limestone belts I have studied with some detail, and I propose, after further investigations, and the removal of some doubts as to the limits of the included Archæan, to make these also the subject of another paper.