

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XIII.—*The Geology of the North End of the Taconic Range*; by T. NELSON DALE.* (With Plate XI.)

THE Taconic range lies west of the Green Mountain range, and extends from near Fishkill on the Hudson, N.N.E., to a point two miles south of Brandon in Rutland County, Vt., where, geologically speaking, it ends. It consists mainly of schists of Ordovician (Hudson) age, but as its northern part is more or less merged in a hilly belt of Cambrian slate and quartzite, flanking it on the west and extending four miles beyond it, the range may be said, physiographically at least, to extend almost to the Addison-Rutland County line and thus to have a total length of 200 miles.

In the published geological maps the north end of this range has been variously represented: (1) As consisting of a narrow tongue of Cambrian slate extending as far north as Cornwall, bordered on both sides by the schist of the Taconic range, which extends only to Sudbury village on the west and to a point S.W. of Brandon village on the east.†

(2) Of similar constitution but cut off between Whiting and Sudbury by a narrow strip of limestone connecting the limestone of the Vermont Valley with that of Orwell.‡

(3) Of a simple belt of Cambrian shale, etc., extending as far north as Weybridge.§

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† Hitchcock and Hager: Report of the Geology of Vermont, vol. ii, pl. i, 1861.

‡ Dana (James D.): An account of the discoveries in Vermont Geology of the Rev. Augustus Wing, this Journal, vol. xiii, 1877. Map opposite p. 334 but modified by explanations on pp. 336, 339, and embodied in another map in vol. xiv, p. 36, in paper by same author entitled: Supplement to the account of the discoveries in Vermont Geology of the Rev. Augustus Wing.

A copy of Mr. Wing's original MSS, kindly loaned to the author of the present paper by Prof. H. M. Seely of Middlebury, contains a sketch map showing the topographic details of this E.-W. strip of limestone.

§ Walcott (Charles D.): The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature; this Journal, vol. xxxv, pl. iii, 1888.

The north end of the Taconic range is an important locality, for the principal formations of the Taconic region, the Cambrian slate etc., the Stockbridge Limestone of the valleys, and the Ordovician schists of the Taconic range, all meet there within an area of a few square miles. The topographic map of the Brandon quadrangle, recently finished by the U. S. Geological Survey, has at last made careful exploration of this key locality possible; and the results amply justify the opinion that careful geological mapping with a reliable topographic base is the only method of settling intricate geological problems, and that this mapping should cover large areas, not only to prevent the overlooking of such crucial localities but also to show the wideness of their significance.

The writer and his assistants, Messrs. Louis M. Prindle and Fred H. Moffit, were engaged from 1894 to 1896 in going over and extending Mr. Charles D. Walcott's reconnaissance work in the Slate belt of Washington County, N. Y., and Rutland County, Vt. The results were published in 1899 accompanied by a geological map extending from lat. 43° to $43^{\circ} 45'$, and covering a strip from 10 to 12 miles wide along the west side of the Taconic range, covering in all about 720 square miles.* The fact was there brought out by Mr. Walcott's paleontological data and corroborated by our stratigraphical observations,† that in that region along many miles of intricate geological boundaries, where faulting is out of the question, the Lower Cambrian slates, with their *Olenellus* fauna, occur in apparently conformable contact with the Ordovician slates, shales, etc., containing Hudson Graptolites. Similarly, the Ordovician schists of the Taconic range were found to be in contact on the west with Lower Cambrian slates along a stretch of 50 miles south of the township of Sudbury, and at only two points (Hubbardton) was there any marked divergence in the strike of the two formations. This involved the anomalous absence of the Stockbridge Limestone along the west foot of that range, whereas on the east side of it the upper part of this formation (of Chazy and Trenton age) dips everywhere conformably under the overlying schists of the Hudson.

During the summer of 1903, the north end of the Taconic range and the adjacent country were somewhat carefully, although not exhaustively, explored by the writer assisted by his son. The exposures were found to be sufficiently numerous to show the mutual relations of the several formations, and the results

* The Slate belt of Eastern New York and Western Vermont, by T. Nelson Dale, 19th Ann. Rept. U. S. Geol. Survey, 1889, Part III, pp. 153-307. Map, pl. xiii. Reviewed in this Journal, vol. clix, p. 382.

† See *ibid.*, pl. xiii and pp. 290-295, on the relation of Cambrian and Ordovician.

are shown in the accompanying map and section, Plate XI.* The map shows a central tongue of Cambrian slate, quartzite, etc., bordered both on the east and west by narrow strips of Ordovician schist or slate, and, in its southern and eastern side, adjacent to a larger mass of Ordovician schist, two miles wide, which constitutes the north end of the Taconic range proper. This tongue of Cambrian is bordered on the north and at several points on the sides by the Stockbridge Limestone. The mass of Ordovician schists, shown at the upper edge of the map, which continues, with a possible interruption east of West Cornwall, 12 miles north to Middlebury and even beyond, is cut off, as was first shown by Wing, from the slate and schist on the south by the Stockbridge Limestone, and is not even indirectly connected, as one of his maps showed, with the Ordovician schists of the Taconic range. The Ordovician part of the Stockbridge Limestone, as shown by fossil localities, touches the Cambrian slates on three sides. The Cambrian part† of that formation, not indicated on the map, crops out near Brandon village, and extends north and east of it, forming a longitudinal belt between the Lower Cambrian quartzite (Vermont Formation) of the Green Mountain range on the east, and the Ordovician part of the Stockbridge Limestone on the west.

The determination of the age of the slates and schists of the north end of the Taconic range is based upon the following evidence: The Lower Cambrian age of the central slate mass in Sudbury is shown by the occurrence at intervals, as far north as the northern slope of Government Hill, a mile east of Sudbury Church, of a slightly ferruginous, calcareous, quartz sandstone, typical of that formation in Washington County, N. Y.;‡ by the fact that typical Lower Cambrian roofing slates are being quarried a half mile north of Stiles Mountain in Sudbury;§ by the presence of six localities of Lower Cambrian fossils in the same belt within two and one-half miles south of the southern edge of the area shown on the map; by the general petrographic character (massive quartzite, quartzose slates, greenish and purplish roofing slates, calcareous sandstone) of a large part of the area designated as Cambrian. In places, however, petrographic distinctions fail, as the slates become schistose and resemble the Ordovician schist. The Ordovician age of the schist and slate masses bordering the Cambrian (Sh on map) is shown by the presence of red roofing slates, typical of the Hudson,|| a mile S.S.E. of Hyde

* As to this map: those parts of the geological boundaries which are more or less uncertain are shown in dotted lines to distinguish them from those which are well established and indicated in full lines. The round black dot a half mile E.S.E. of Hyde Manor represents what seems to be an outlier of Ordovician limestone, about 70 x 40 ft. across, resting upon the Cambrian slates.

† Whether this Cambrian includes some Beekmantown is not yet determined.

‡ Horizon E of the slate belt. Op. cit. table facing p. 178.

§ Locality shown on map by crossed hammers.

|| Horizon Irs of Slate belt. Op. cit. table facing p. 178.

Manor, and three-fifths of a mile E.S.E. of Sudbury Church, and again, apparently, in a badly weathered condition, one and one-fourth mile E.N.E. of Huff pond on the east side of the Cambrian belt; by the presence of typical schists of the Taconic range at the most northern summit of that range, three miles S.S.W. of Brandon village (elevation 1295 ft.); by indications of Ordovician fossils (Crinoid stems, etc.) in a small mass of included limestone, a mile N.N.W. of that hill;* and by the presence of graphitic sericite schist, so common at the base of that schist formation in Vermont and Massachusetts, in the small strip N.E. of Hincum pond. These age determinations are furthermore corroborated by a dominant, though not universal, N.E. strike in the Cambrian slates, and an almost equally prevalent N. or N.15W. or N.N.W. strike in the Ordovician schists and in the underlying limestone.

The structural relations of the formations are shown by symbols on the map and by the section above it, Plate XI. It will be noticed that the parallelism between the strike of the Cambrian and Ordovician, already referred to as characteristic of the slate belt to the south, still persists on the west side of the Cambrian slates near Horton and Burr ponds; but within a mile of Hyde Manor a marked divergence begins to appear, the Cambrian striking more or less N.E., the Ordovician N.15–25W.;† and this continues to the extreme N. end of the mass. The prevalent strike of all the rest of the Cambrian area is about N.E.; exceptionally, however, as east of Huff pond, possibly owing to a minor pitching fold or a small fault, a few N.W. strikes appear, and there may be others. The Ordovician schists of the east side of the Cambrian tongue are likewise marked by a N.15–25W. strike. This, indeed, is the trend and strike of the Taconic range as far south as West Rutland, eleven miles from the south edge of the map. A similar strike also appears in the limestone of the valley towards Brandon. But to this N.N.W. strike of the Ordovician there is also an exception, for the schists of the west side of the schist mass E. and N.E. of Stiles Mountain strike N.E. and a similar strike appears at several points in the limestone embayment east of the Cambrian. The cause of these N.E. strikes in the Ordovician is not apparent, unless it be a system of transverse folds like that occurring on the north end of Mount Anthony in Bennington. A mile N.E. of the Cambrian point the limestone resumes the normal strike of the Green Mountain region, and this recurs again at Leicester Junction, two miles north of the map. To all this should be added that the Cambrian slates have here and there a secondary cleavage foliation, striking N.15W., i. e. parallel to the strike of the bedding of the Ordovician schist.

* Locality marked F on map.

† Exceptionally also N.—N.15E.

The section is drawn so as to cross contacts where the unconformity is manifest but owing to insufficiency of data, the folds represented in the Cambrian portion away from the contacts are largely hypothetical. The straightness of the Cambro-Ordovician boundary on the west side may be the result of faulting; but as the unconformity is quite as great at several points on the east side, where faulting is improbable, and as N.E. strikes are quite as characteristic of the center as of the sides of the Cambrian tongue, it is evident that faulting is not the cause of the unconformity. If it exists, it is between rocks which were already unconformable. Such a fault would have to be a reversed one and would hade to the east, bringing the Cambrian beds to overlie the Ordovician ones. The section has been constructed to show the relations without the faulting, although such faulting is regarded as quite possible. That the limestone once covered at least the western border of the Cambrian, is probable from the presence of the small outlier in the Hyde Manor Golf grounds, already referred to and shown in the section. This limestone strikes N.10E., as does also the nearest Ordovician limestone east of it, but the Cambrian slate about it strikes N.40E.

The interpretation of the facts set forth in the map and section is this: The Lower Cambrian slate formation, which is now regarded as the off-shore equivalent of the quartzite of the Green Mountain range (Vermont Formation of U. S. G. S. Monograph XXIII), was folded at the close of Lower Cambrian time and in places, raised above sea level, forming one or more islands in the Champlain oceanic arm. The direction of this Cambrian folding was generally the same as that of Ordovician time, known as the Green Mountain movement, but at this point the axes of these Cambrian folds, for some reason, had a more easterly course, resulting in N.E. strikes. A very gradual depression, beginning during the latter part of Stockbridge Limestone time and continuing into Hudson time, caused the deposition of some of the limestone and of all the schist upon these former islands of Lower Cambrian rocks. This, as suggested to the writer by Professor C. R. Van Hise, resulted in some places in an overlapping of the limestone by the Hudson schist and slate, and in others, in the deposition of the schist and slate immediately upon the Cambrian slates. This overlap, in particular, accounts for the absence of the Stockbridge Limestone for 50 miles along the west side of the Taconic range. In 1898* the writer sought to explain this by a local change from calcareous to argillaceous sedimentation during Stockbridge Limestone time, as had been proven by Pumpelly and

* *Op. cit.* Slate belt, etc., p. 295, last paragraph, to p. 297.

Wolff to have occurred on Hoosac Mountain.* That explanation of the relations about the Taconic range is now shown to be erroneous.

Then came the Ordovician folding which, here and as far south as West Rutland, produced N.15–25 W. strikes, principally, and which may have produced the N.15 W. secondary cleavage in the Cambrian slates, and must also have otherwise more or less modified the Cambrian structure as well as the Cambrian surface. The central part of the section shows the Cambrian folding, and the ends of it the overlapping and the Ordovician folding. Denudation through long geological periods must account for the presence of only shred-like remnants of the great mass of Ordovician argillaceous sediments and for the severance of the northern extension of the schist from the Taconic range, and, generally, for the exposure of the Stockbridge Limestone. The salient fact is the unconformity between the Lower Cambrian and the Ordovician, which is masked in the slate region of Washington Co., either by the parallelism in the strike of the two foldings or by the effect of the later one upon the earlier, but which was accentuated at the north end of the Taconic range by the original divergence in the strike of the two periods and is still shown in the dips. This unconformity thus fully corroborates, stratigraphically, the time break shown, paleontologically, by Mr. Walcott's fossil localities.†

Although the Taconic controversy was settled long ago, and has ceased to be of other than historical interest, as it was shown by Dana, Walcott and the authors of Monograph XXIII, that Ordovician rocks had been included by Ebenezer Emmons in his Taconic System owing to the overlooking of faults, the mistaking of cleavage for bedding and insufficient exploration of the areal relations, yet it is remarkable that at this late day it should appear that his contention that there was an extensive formation, marked by a peculiar fauna, now known as Lower Cambrian, unconformably related both to the underlying gneisses (pre-Cambrian) and to the overlying Lower Silurian rocks (Hudson, etc.), should be confirmed, at least for a part of the Taconic region, for no trace of the unconformity shown by this paper has yet been found along the Green Mountain border. During the Taconic controversy, however, conformable succession of the Cambrian and Ordovician beds was supposed by the opponents of Emmons to hold for the entire region.‡

* *Geology of the Green Mountains in Massachusetts*, by Raphael Pumpelly, J. E. Wolff, and T. Nelson Dale. Monograph, U. S. Geological Survey, XXIII, 1894, pp. 14–18, 104.

† *Op. cit.* Slate belt, pp. 163, 166.

‡ Rogers (Henry D.), *this Journal* (1), vol. xlvii, D., p. 152, 1844; Walcott (Charles D.), *op. cit.* *this Journal*, vol. xxxv, 1888, p. 320.