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STRUCTURAL DETAILS

IN THE

GREEN MOUNTAIN REGION

AND IN

EASTERN NEW YORK

(SECOND PAPER)

BY

T. NELSON DALE

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By T. NELSON DALE.

INTRODUCTION.

Since the publication of the first paper with the above title, in 1896,[a] a few other details have been collected in the course of further explorations, and these are here presented with the same intent and in a similar manner.[b]

HORIZONTAL ISOCLINES.

The southern part of the Dorset Mountain mass in Dorset, Vt., called Mount Eolus by President Hitchcock, but known locally as Green Peak, is a mass of marble and calcareous rocks in almost horizontal position, capped by schists, and it probably forms the center of a very open syncline. Scarcely half a mile west of the schist cap the

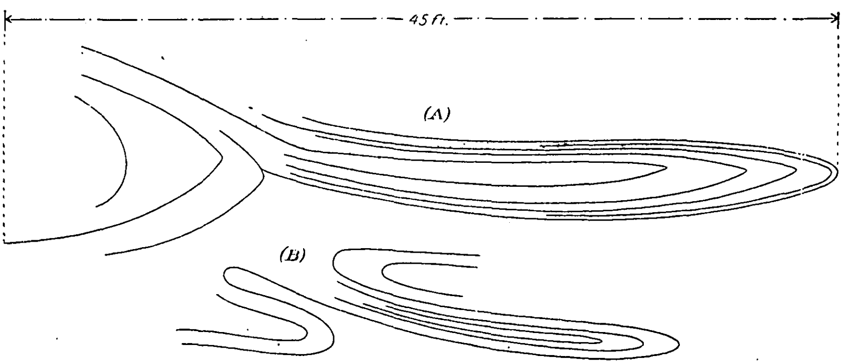

FIG. 1.—(*A*) Diagram sketch of horizontal isoclinal fold in white marble; old quarry seven-eighths mile west of the Owl's Head, Dorset, Vt. (*B*) diagram showing the probable general structure of (*A*)

strike suddenly changes from N. or N. 15° E. to N. 50° E., and a similar strike recurs in the marble across the valley, a mile and a half to the southwest. The folds at the former place are most intricate, and include a horizontal isocline 45 feet long, as shown in fig. 1.[c]

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[a] Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, pp. 549-570.

[b] This paper, however, does not include the structural details of the New York and Vermont slate belt, which will be found on pp. 199-217 of the Nineteenth Ann. Rept., Pt. III, 1899.

[c] A rough diagram of this appears in Hitchcock and Hager's Geological Report of Vermont, 1861.

Such completely recumbent isoclines are exceptional in this region, and their presence at this locality in the midst of a gently undulating structure is yet to be accounted for.[a]

PINCHED FOLDS.

Readers of the great masterpieces of Swiss geologists are familiar with those effects of extreme compression shown in the pinching of folds and in the tearing off of their cores or apices and their envelopment by the adjacent rock mass. Some of the earlier stages in this process are seen on a small scale at the locality in Dorset, Vt., just referred to. In Pl. I, *B*, the pinching off of the apex of the fold has just begun.

Sometimes this constriction occurs lower down on the limbs of the fold and results in the formation of more or less complete circles when the beds are seen in vertical cross section. Such a complete circle, a few inches in diameter, was observed by Mr. C. W. Hayes and the writer at a new quarry in banded marble opened in Pittsford, Vt., in 1901.

FAULTING IN A ZONE OF INTENSE FOLDING.

Tangential compression, after having partly expended itself in intense folding, may then result in faulting. The overthrust which begins in the town of Pittsford, Vt., and extends more than 10 miles

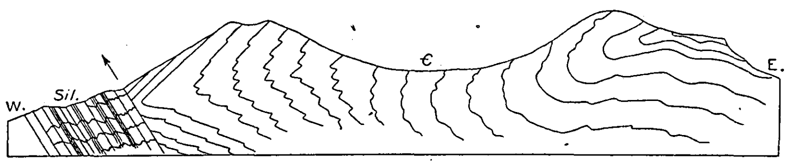


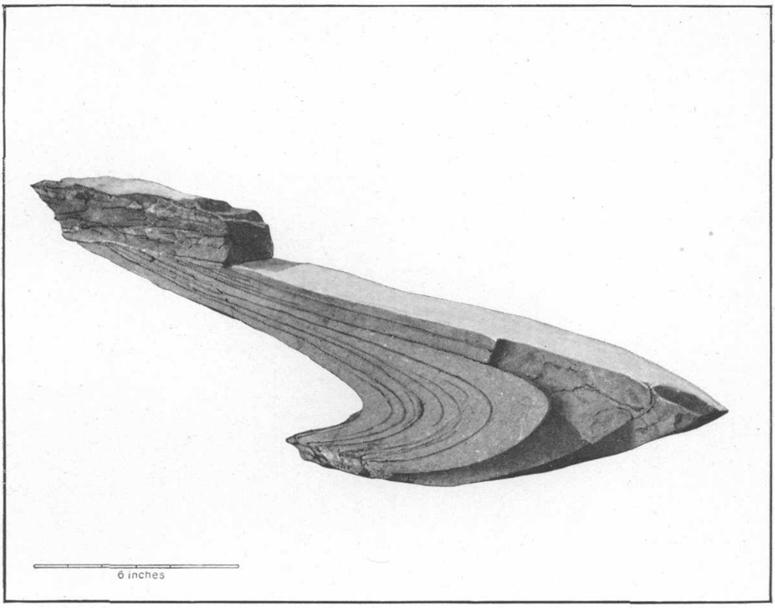
FIG. 2.—Diagram showing the probable general relations of the ledges (Pls. II and III) to the overthrust at the top of Boardman Hill, Clarendon, Vt.

into the town of Clarendon, and which nas brought the Lower Cambrian of the eastern part of a ridge onto the Upper Ordovician of its western side, passes through Pine Hill in Proctor and Boardman Hill in Clarendon. Some of the characteristics of this fault have been published.[b]

At the top of Boardman Hill the Cambrian quartzite and schist come within a few inches of the Upper Ordovician schist. The former are intensely folded, as shown in Pls. II and III, and similar folding marks a large area east of the fault. In Pl. II is shown an overturned syncline of quartzite, the axial plane of which passed through the now dislocated piece at the left. In the inner part of the fold the pressure

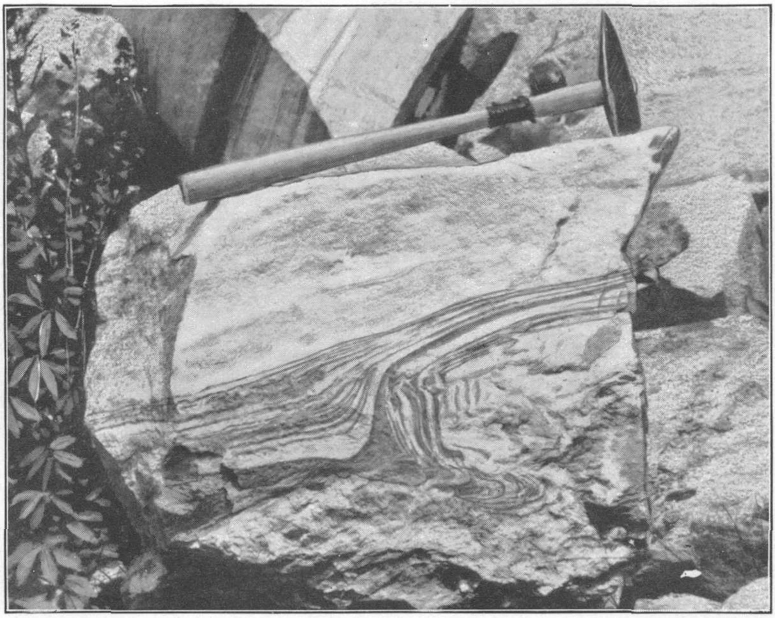
[a] For similar folds see Dr. Wolff's section of Hoosac Mountain in Mon. U. S. Geol. Survey Vol. XXIII, Pl. VI, and the writer's section on Lake Bomoseen in Nineteenth Ann. Rept., Pt. III, Pls. XVIII and XXXIV, *N*.

[b] On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont, by T. Nelson Dale: Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1895, pp. 525–549.



A. ELONGATED QUARTZITE FOLD FROM HILLOCK AT WEST END OF MAIN STREET, WILLIAMSTOWN, MASS.

In the lower part of specimen a quartz vein traverses the fold. The upper part shows the beginning of another fold.



B. PINCHED FOLD IN WHITE MARBLE.

Hammer, 21 inches long. The lower part of the block consists of impure dolomite. Quarry dumps seven-eighths of a mile west of the Owl's Head, Dorset, Vt.

has found relief in the formation of secondary folds zigzagging vertically across the major fold and giving little idea at that point of the general character of the fold. The axes of the major and minor folds must originally have lain at a considerable angle to the direction of compression, and the overturn was an after effect. The more plastic Ordovician graphitic schists on the under side of the thrust are marked by the usual cleavage, which, judging from other localities, is probably approximately parallel to the fault plane.[a] In fig. 2 the probable relations of the ledges in Pls. II and III to one another and to the fault are shown.

ELONGATION IN FOLDING.

Some of the more minute evidences of elongation were referred to in the first paper, but folding frequently involves more or less elongation. Where the folding is intense the elongation may become apparent. There is thinning of the beds along the limbs of the folds and thickening of them at their apices. Many cross sections of plicated rock, whether in a cliff or a microscopic section, illustrate this familiar geological principle.

Pl. I, *A*, represents a specimen of vitreous quartzite taken from a locality of intense and transverse folding,[b] being one of a descending series of overturned folds along the limb of a major anticline exposed in cross section on a vertical joint plane. While the limb of the fold at its narrowest place measures 1½ inches, its apex measures 11½ inches. If the bed be assumed to have measured 6½ inches prior to the folding—i. e., the average of the thinnest and thickest parts—there will have been a transfer of 77 per cent of material from the limb to the apex.

As the microscopic structure of the rocks of the vicinity indicates that metamorphism preceded as well as followed the folding, it may be assumed that this bed was quartzite prior to the folding. There is good evidence that the folding took place under a full half mile of other sediments.

The proportions of the specimen will be found repeated on a gigantic scale in many an Alpine section, but these proportions will, of course, vary with the intensity of the folding, and the limbs of the softer members of a fold may be so attenuated as to disappear altogether.

CAVES FORMED BY TENSION AND RUPTURE.

About a half mile northeast of the extreme southwest corner of the State of Vermont and of the town of Pownal, on the eastern side of the Taconic Range, the Ordovician schists are fissured in a direction

[a] See Fourteenth Ann. Rept., U. S. Geol. Survey, Pt. II, p. 537, fig. 56, and Sixteenth Ann. Rept., U. S. Geol. Survey, Pt. I, p. 565, fig. 95.

[b] Sixteenth Ann. Rept., U. S. Geol. Survey, Pt. I, pp. 553, 554, figs. 77, 78.

parallel to the prevalent transverse jointing of the region. These fissures and joints strike N. 75°–80° E. and dip 90°. Between two of these a mass of rock 10 feet wide has been faulted down. In another the schists, which are noncalcareous and veined with quartz, have a cleavage striking N. 12° E. and dipping 45°–50° E. across a bedding dipping east at a much lower angle. These foliations have been parted in a N. 75° E. direction, leaving an irregular fissure from 1 to 5 feet wide and more than 130 feet deep across the schistosity and the veins which lie in it.

Such a cave is evidently formed by tension of the schist mass in the direction of the strike, and is the result of some later movement than that which produced the synclinoria and anticlinoria of the region.

SHEAR INDICATED BY ANNELID BORINGS.

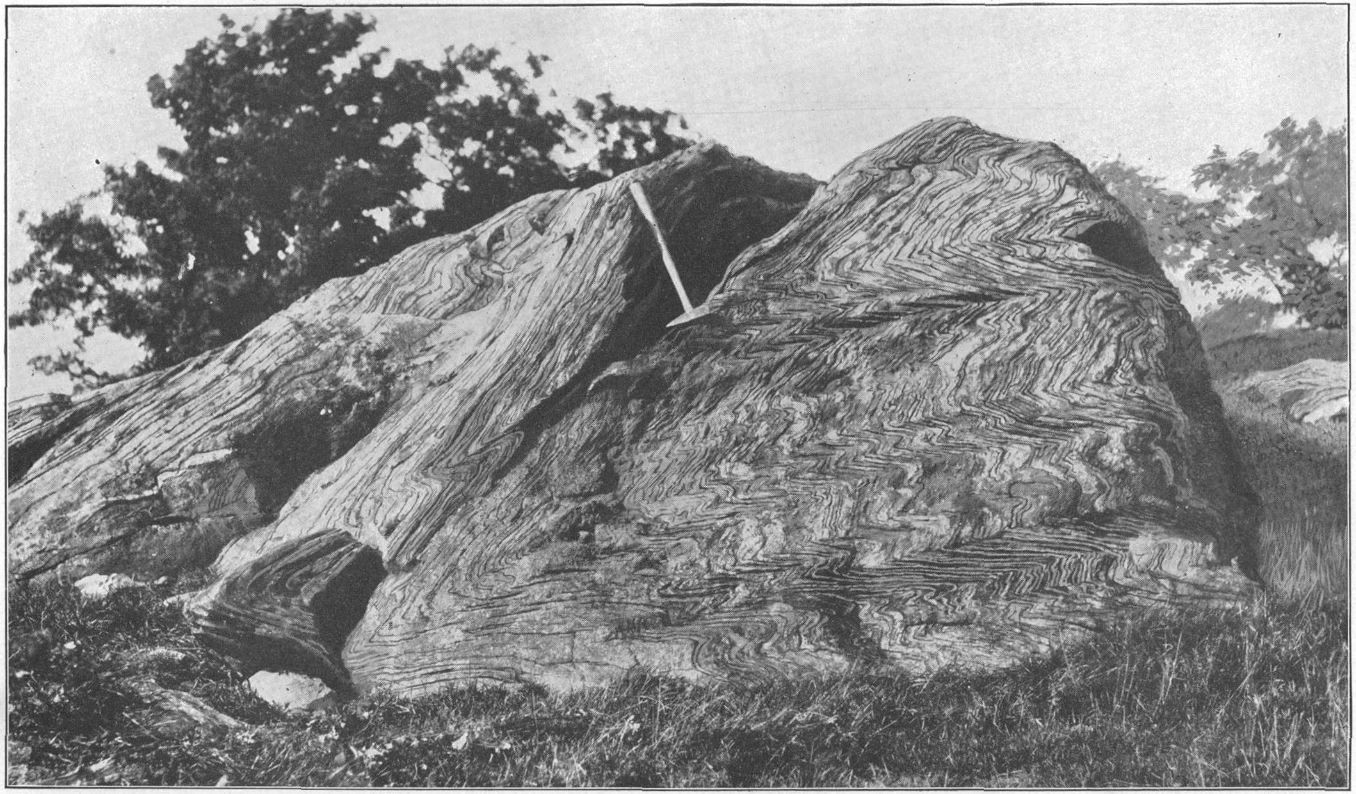
While Cambrian quartzite bowlders with annelid borings (*Scolithus*) are not infrequent in western Massachusetts and Vermont, the places where the borings may be studied in situ are few. One of these is in Arlington, Vt., on Roaring Brook, which has cut a ravine a thousand feet deep in the quartzite of the western flank of the Green Mountain range, and then, entering the Vermont Valley, flows into the Batten Kill.

At a point a half mile southeast of East Arlington, on the eastern side of the brook and road, the quartzite crops out, filled with annelid borings and dipping about N. 20° W. at an angle of 10°, the direction of the dip being probably due to the northerly pitch of a fold with a N.-S. axis. As borings made by annelids in sand are vertical, they should remain vertical to the bedding, which here dips 10°. This would give the borings an inclination of 10° from the vertical, or 80° from the horizontal in the opposite direction, which is S. 20° E., but they actually dip at an angle of 45° about S. 65° E. The amount of shear has thus deflected them 35°, and the direction of the shear has also deflected them 45° farther eastward.

The relation of deflected annelid borings to shear is akin to that of distorted fossil shells, trilobites, etc.

PLANO-CONVEX LIMESTONE CONCRETIONS.

In the belt of little or no metamorphism which borders the Hudson River in Rensselaer County, N. Y., there are large areas of Cambrian shales containing here and there beds of limestone. In the town of Nassau, about 2 miles southeast of the village of that name, these shales contain plano-convex disks of limestone which afford no evidence of organic structure and also differ in form from ordinary concretions and septaria. Fig. 3 shows one in cross section. They measure from



OVERTURNED SYNCLINE OF CAMBRIAN QUARTZITE ADJACENT TO AN OVERTHRUST; TOP OF BOARDMAN HILL, CLARENDON, VT.

Looking N. 35° E. Hammer, 21 inches long.

19 to 52 inches in diameter and about 5 inches in thickness and have a slight depression on the under side. They occur in a bed of shale about 6 inches thick traversed by joints filled with calcite, and are separated from the overlying bed of limestone by a thin film of shale. As the beds dip at an angle of 50°, unless they have been overturned

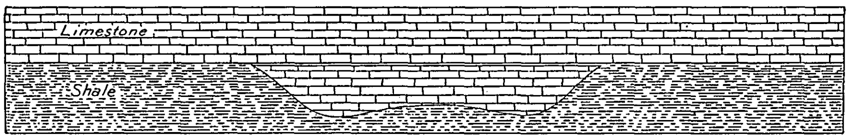


FIG. 3.—Diagram cross section of a plano-convex limestone concretion; Nassau, Rensselaer County, N. Y.; size of concretion, 42 by 5 inches.

they represent one side of a syncline, and the convex side of the disks would thus be the under side.

It is suggested that they may have been formed by limestone sedimentation on an uneven clayey sea floor and have received their circular form from concretionary action.

INTERBEDDED CRYSTALLINE CALCITE AND DOLOMITE.

Vogt, in his exhaustive work on the marbles of Norway,[a] gives a section of interbedded and slightly plicated calcite and dolomite marble, and describes them as occurring usually in such association in that region. Although he does not undertake to account for their origin, he thinks that the dolomite is plainly not due to metasomatic processes.

In the Vermont marble belt there is an extensive deposit of more or less microcrystalline yellowish dolomite, which the painstaking local geologist Wing regarded as lying between the Cambrian quartzite and the Lower Ordovician calcite marble. There are, however, other minor beds of dolomite among the Ordovician marbles.

At the Green Peak quarries, already referred to,[b] there is an interbedding of the two rocks, like that described by Vogt in Norway, and they are also capped by schist. The dolomite, however, is quartzose and so very fine grained as to be properly termed microcrystalline, while the calcite marble is much coarser grained (see fig. 4). That this was calcite marble was determined by its strong effervescence under dilute hydrochloric acid. Mr. E. T. Allen, chemist of the Survey, reports it as "effervescing strongly in the cold and containing only a very little magnesium. Not a dolomite." A chemical analysis

[a] Norsk marmor, by J. H. L. Vogt: Norges Geologiske Undersögelse, No. 22, Kristiania, 1897, p. 219, fig. 42. This work contains, on pp. 334-364, a résumé in German. See also an abstract of it with several illustrations in Zeitschr. für prak. Geol., Jan., 1898, p. 9, and fig. 5.

[b] P. 9.

of the dolomite made by Mr. George Steiger in the laboratory of the United States Geological Survey yielded these results:

Chemical analysis of dolomite from Green Peak quarries, in Dorset, Vt.

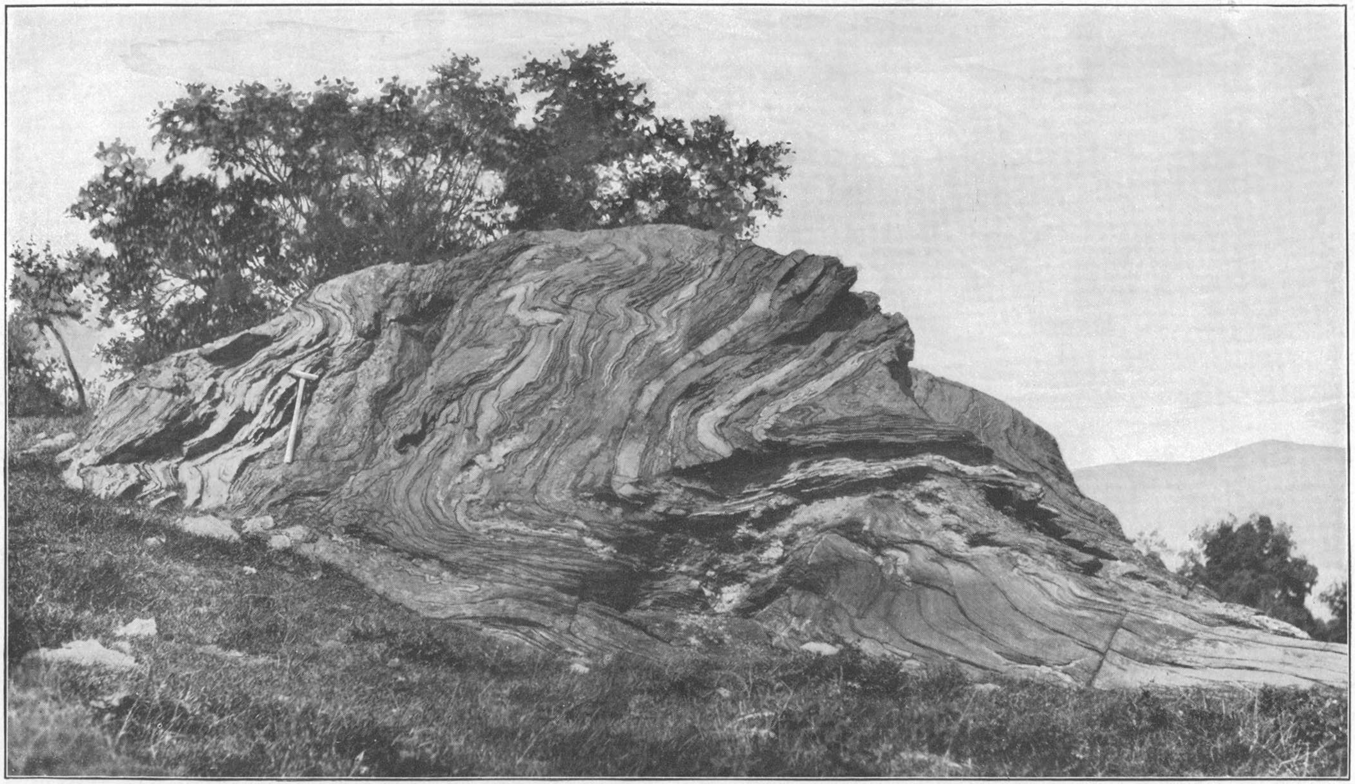
Constituent.	Molecular weight.	Soluble in boiling HCl.	Insoluble in boiling HCl.
		Per cent.	*Per cent.*
SiO_2	60.4		8.36
Al_2O_3	102		1.77
Fe_2O_3	160		.22
FeO	72	1.08	
MgO	40.3	16.44	.24
CaO	56	29.03	
Na_2O	62		.06
K_2O	94		1.08
H_2O-	18	.03	
H_2O+			.42
CO_2	44	41.66	
SO_3	80	None.	
Total		88.24	12.15
Soluble		88.24	
Insoluble		12.15	
Total		100.39	

A microscopic section of the same rock shows a granular mass of more or less angular but not interlocking transparent grains ranging from 0.025 to 0.07 mm. in diameter, without twinning and rarely with cleavage. The fineness of this grain appears by comparison: The West Rutland Statuary ranges from 0.07 to 0.3 mm., averaging about 0.15 mm., while the finest European marbles, as given by Vogt, range from 0.02 to 0.03 mm.

This mass contains sparsely disseminated grains of quartz, and rarely a grain of microcline or plagioclase or a flake of muscovite.

The quartz, feldspar, and muscovite account for the SiO_2, Al_2O_3 FeO, Na_2O, K_2O, and H_2O of the analysis. About 90 per cent of the rock is thus a dolomite in an extremely fine-grained crystalline condition. A piece of it was polished at the Survey laboratory.

The difference in the size of the grain of the two rocks is greater than at the Norwegian quarries. As both beds, calcite and dolomite, must have been subjected to an almost identical amount of pressure, this difference in grain must be due either to a difference in the condition of the original sediments, which must account for similar differ-



OVERTURNED SYNCLINE OF CAMBRIAN SCHIST, 50 FEET EAST OF OVERTHRUST; TOP OF BOARDMAN HILL, CLARENDON, VT.

Looking N. 35° E. Hammer, 21 inches long.

ences of grain in a continuous series of calcite marble beds, or to the different behavior of dolomite and calcite under equal pressure. Vogt points out that the greater tendency of bedded dolomite to complete its individual crystals than bedded calcite when subjected to the same regional metamorphism indicates that it possesses greater power of resistance to the effects of pressure. It is also harder than calcite.

In the section represented in fig. 4 there is a small quartzose bed between the dolomite and the calcite. This proves to be mainly fine-grained dolomite, but with more quartz grains and muscovite flakes and the same feldspars. It has also stringers of muscovite and lenses of coarsely crystalline calcite and quartz. This little bed probably represents a brief period of mingled argillaceous and calcareous sedimentation. As shown in the figure, there is also a lens of dolomite in one of the beds of calcite.

On the eastern side of Otter Creek Valley, 1½ miles SSE. of Proctor

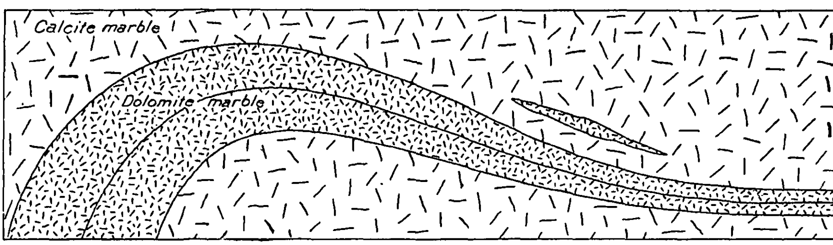


FIG. 4.—Diagram sketch of interbedded crystalline calcite and dolomite. Length, 40 feet. The dolomite is veined with quartz. Old quarry three-fifths mile west of the Owls Head, Dorset, Vt.

and near the Pine Hill overthrust, the calcite marble contains angular fragments of dolomite. In weathering, the dolomite, being less soluble by CO_2, stands out from the calcite as would hard pebbles in a conglomerate with a soluble cement. Thin sections of this rock show the same differences between the matrix and the fragments that were described as existing between the interbedded dolomite and calcite. This is probably a breccia formed from alternating beds of dolomite and calcite, the calcite having become coarsely crystalline and the dolomite microcrystalline in the process.

Do these alternations of dolomite and calcite correspond to alternations of chemical and organic sedimentation or to a difference in the calcium compounds extracted from the sea by different classes of organisms?[a]

[a] Professor Van Hise, notwithstanding Vogt's opinion, regards it possible that the alternations are due to the dolomitization of some beds and not of others.

Thin sections of plicated interbedded dolomite and phyllite, in which the beds of each rock measure about a millimeter in thickness, have been recently described from the Alps. See G. Allenspach, Dünnschliffe von gefälteltem Röthidolomit-Quartenschiefer am Piz Urlaun: Vierteljahrs. Naturforsch. Gesells. Zürick, 45. Jahrgang (1900), pp. 227-237. There can be little question as to the mechanical sedimentary origin of the phyllite beds.

LINES OF ROCK BEDDING CROSSING FELDSPAR CRYSTALS.

The frequent occurrence of albite feldspar in the rocks of the Green Mountain and Taconic ranges has been several times referred to in geological papers.[a]

In 1897 Mr. L. M. Prindle, then the writer's assistant, while working on Mount Anthony, in Bennington, came across a "prospect," about half a mile west of the top and 650 feet below it, known locally as Tibbetts mine. Here the Ordovician schists contain a vein, a few inches thick, of crystallized albite associated with quartz, chlorite, and pyrite.

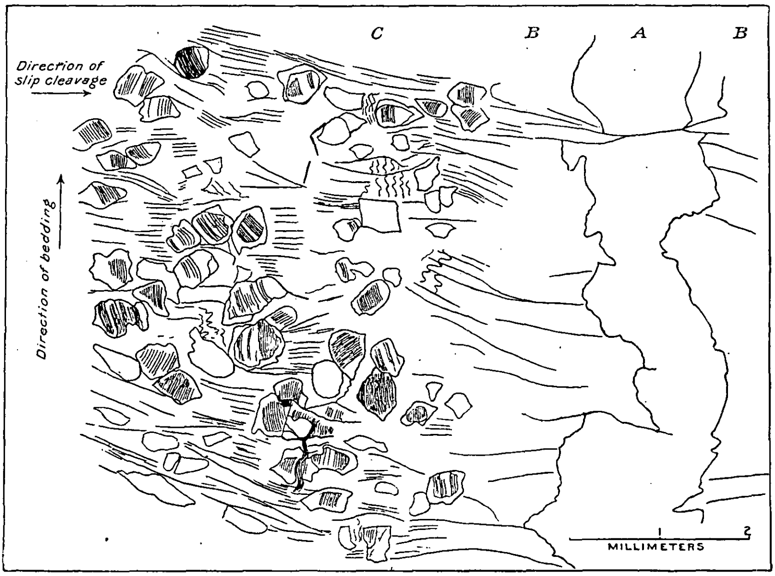


FIG. 5.—Diagram sketch of thin section of muscovite, chlorite, quartz, and albite schist from ledge three-fourths mile north of Green Peak, Dorset, Vt. *A*=quartz in bedding. *B*=Muscovite beds. *C*=Feldspar zone. Ordinary light.

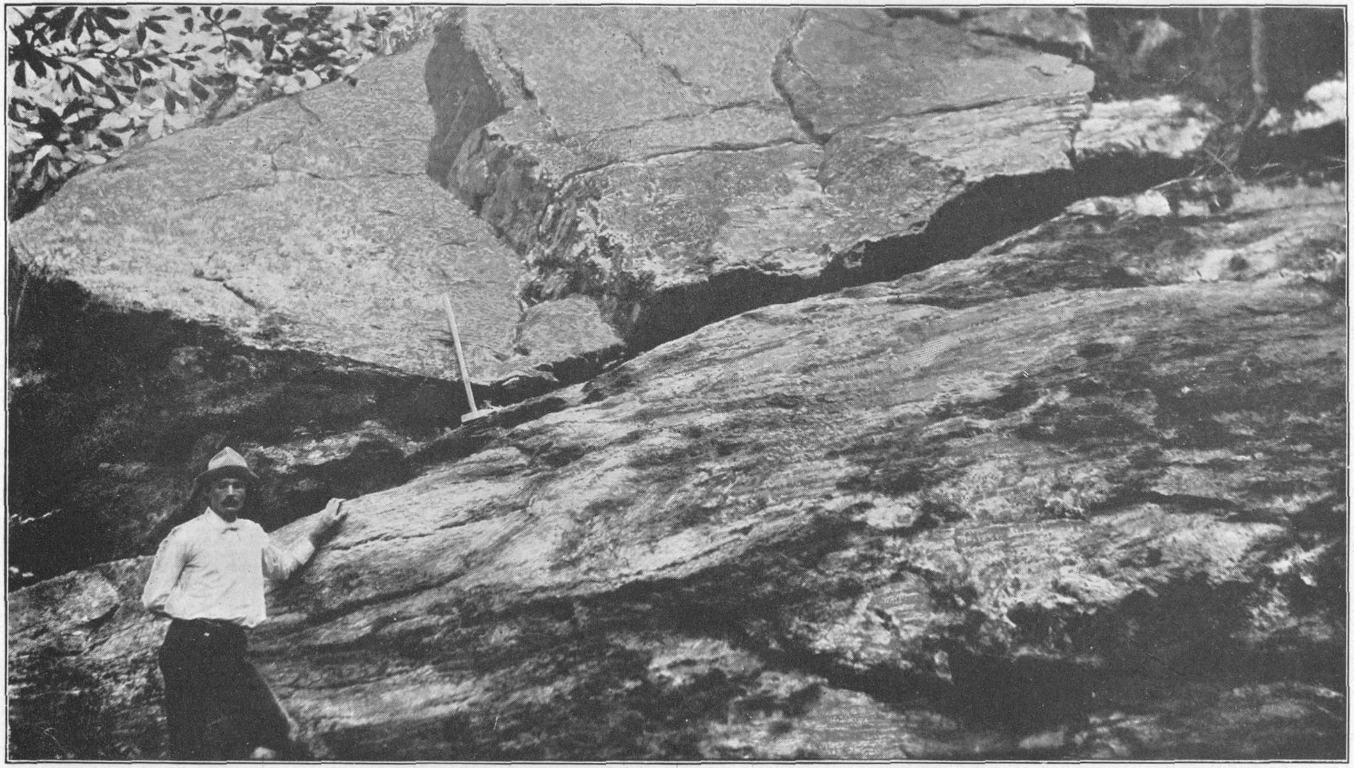
"The feldspar is also irregularly mixed with the schist over a width of 2 feet or more."

A specimen of schist of the same age which caps the marble at Green Peak, in Dorset, Vt., collected by the writer's assistant, Mr. Fred H. Moffit, in 1899, shows the usual speckling with albite. The cleavage foliation at the ledge is horizontal, and a quartz vein, 6 inches thick, lies in it. Thin sections made anywhere across the cleavage show some very exceptional features. The rock consists mainly of muscovite and quartz, with a little chlorite, a few tabular octahedra of magnetite, black streaks and dots, possibly graphitic (although the

[a] Geology, Second District of New York State, 1842, by Ebenezer Emmons, p. 158. The specimen there referred to is probably the one still preserved in the Williams College collection.

Metamorphism of clastic feldspar in conglomerate schist, by J. E. Wolff: Bull. Mus. Comp. Zool., Cambridge, Mass., Vol. XVI, No. 10, 1891.

Geology of the Green Mountains in Massachusetts, by Pumpelly, Wolff, and Dale: Mon. U. S. Geol. Survey Vol. XXIII, 1894, pp. 52, 60–62, 183, 186–188, fig. 73, Pls. VII, *A*; VIII.



CONTACT OF PRE-CAMBRIAN GNEISS AND CAMBRIAN QUARTZITE, SOUTHWEST SIDE OF THE DOME, 2,200-FOOT CONTOUR, GREEN MOUNTAIN RANGE, POWNAL, VT.

Looking N. 70° E. Sledge handle, 30 inches long. The head of the sledge rests on gneiss; its handle on quartzite. Between these is a partially eroded be.. of muscovite-schist. A secondary foliation in the gneiss is parallel to the bedding of the quartzite.

rock itself makes no black marks), limonite stain from the oxidation of the magnetite, and many albite feldspars. The bedding is extremely plicated and about at right angles to the slip cleavage. Some beds are more micaceous, others more quartzose (see fig. 5). Parallel to the course of the bedding are irregular zones of albite grains without crystal boundaries traversed by undulating graphitic (?) streaks, and sometimes inclosing a magnetite crystal. Where the grains are massed the black streaks of the different grains are parallel to one another, and in some places to the black streaks in the micaceous matrix, and also to the plications in the muscovite folia. The black streaks are apparently, therefore, stratified material. Usually, however, these feldspar

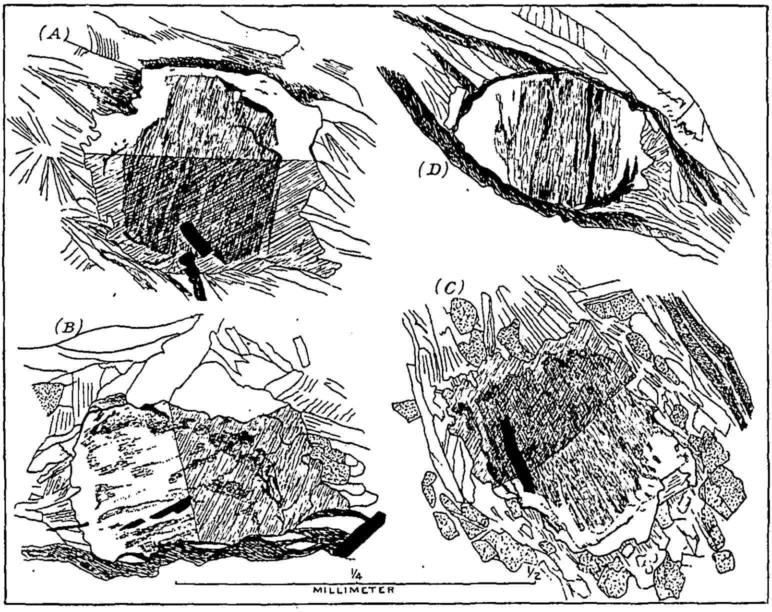


FIG. 6.—Sketches of albite feldspars from thin sections of muscovite-schist from ledge three-fourths mile north of Green Peak, Dorset, Vt. Polarized light. In *A*, *B*, *C*, *D*, inclusions of stratified material. In *A*, *B*, *C*, secondary enlargement beyond the ends of the bedding lines, also twinning across those lines, and inclusions of magnetite. The dark bands in the matrix are planes of slippage between fibers of muscovite discolored by limonite. Dotted grains are quartz; the rest is muscovite.

grains have been so displaced by the shearing which produced the slip cleavage that the inclosed bedding lines have lost their proper orientation and point in any direction, appearing then like scattered pebbles from an older stratified rock.

In most of these feldspars there has evidently been a secondary mineral growth, as a rim of clear feldspar extends beyond the termination of the bedding streaks, but the rim extinguishes with the core. Some of the albites are simple twins, the twinning plane being usually at right angles or diagonal to the included bedding lines (see fig. 6). Some of the feldspars are also irregularly disseminated in the cleavage foliation outside of the feldspathic zones.

This occurrence is a more complex phase of that described by Professor Wolff in the "White gneiss" of Hoosac Mountain,[a] in which feldspars are filled with inclusions of epidote, biotite, muscovite, etc., lying in "planes parallel to the arrangement of the minerals outside the feldspar, and entirely independent of the crystallographic directions in the feldspar." Such feldspars are necessarily secondary.

The history of the Green Peak schist appears to be this: Argillaceous and carbonaceous (?) sediment metamorphosed into muscovite, quartz, chlorite, magnetite, graphite (?), and feldspar schist; continued pressure produced plications; slip cleavage ensued, and displacement of feldspars, followed by their secondary growth. Whether the albite has replaced some other feldspar is uncertain.

DIVERGENT STRIKES IN UNCONFORMABLE DEPOSITS.

In a drift-bestrewn and forested region satisfactory contacts between distinct geological formations must needs be few. In the many miles of boundary between the pre-Cambrian gneisses and the Cambrian quartzites and schists and conglomerates of northwestern Massachusetts and western Vermont there are but few such points, and at these both formations are in apparent conformity.

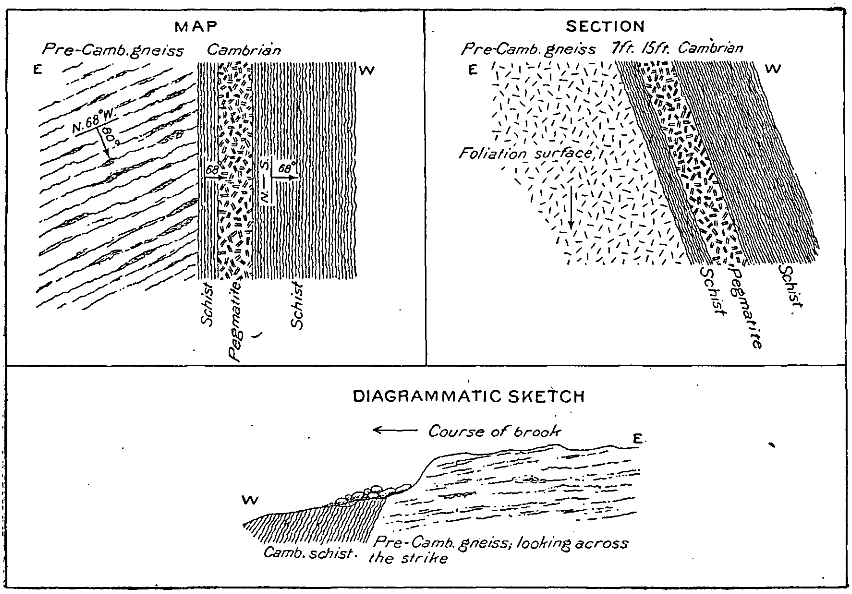


FIG. 7.—Diagrams illustrating the contact between pre-Cambrian gneiss and Cambrian schist in Downer Glen, Manchester, Vt.

There are some localities, however, where these formations are clearly unconformable. One of these is in a deep transverse incision in the western flank of the Green Mountain range, 3½ miles ESE. of

[a] Mon. U. S. Geol. Survey Vol. XXIII, 1894, p. 52, Pl. VII, *A*.

Manchester village, known as Downer Glen. The pre-Cambrian gneisses form the bed of Bourn Brook, striking almost with its course. In looking up the stream the parallelism between the foliation lines of the gneiss, the course of the stream, and the sides of the ravine is apparent, but in looking downstream the micaceous quartzites of the Cambrian are seen striking at right angles to the bed of the brook and parallel to the trend of the range. The two formations approach within 50 feet of each other, the interval in the brook bed being covered with gravel and bowlders, but on the southern side of the ravine the actual contact can be observed, and a hand specimen, partly Cambrian, partly pre-Cambrian, could be secured. The relations are shown in fig. 7.

Another locality of like purport occurs about 26 miles SSW., on the southwestern side of The Dome, in Pownal, 2,200 feet above sea level

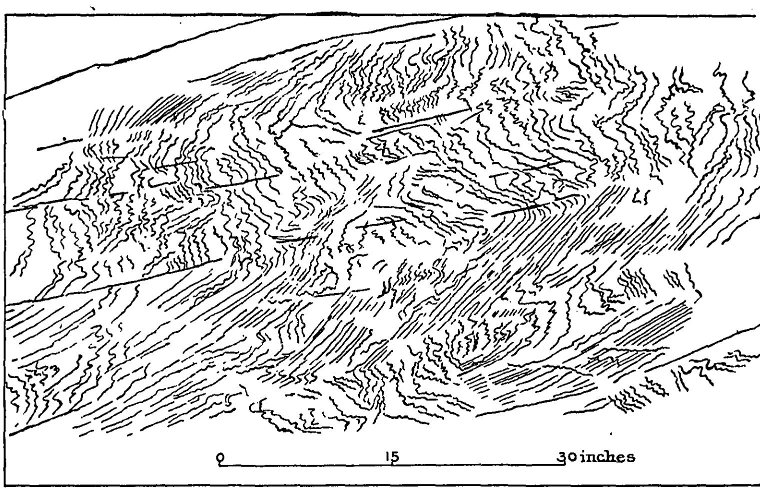


FIG. 8.—Structure in pre-Cambrian gneiss at its contact with Cambrian quartzite on The Dome in Pownal, Vt., as shown in Pl. IV. The axes of the plications strike about E.-W. and dip across the cleavage foliation; they are also unconformable to the bedding of the overlying quartzite. From a photograph.

(see Pl. IV). Here a mass of gneiss with a plicated foliation striking about E.-W. (N. 70° E. to N. 80° W.), underlies a bed of quartzite striking N. 45° W. and dipping 40° NE. This NE. dip is probably due to the local pitch of a fold striking NNE., as a half mile south the same rock dips gently SW. and the prevalent strike of the quartzite a little east of these localities is NNE. Between the gneiss and the quartzite is a bed, 1 foot thick, of muscovite-schist with some microcline. It appears to belong to the Cambrian, although it may belong to the gneiss, its original foliation having been obliterated in the shearing. The details of the gneiss are shown in fig 8.

On the western slope of Harmon Hill, in Woodford, Vt., about 19 miles SSW. of the first locality and 7 miles NNE. of The Dome, the pre-Cambrian and the Cambrian come very near together, although not in actual visible contact. The gneisses strike generally diagonally to the Green Mountain axis, while the Cambrian quartzite and schist strike a little west of north.

The questions that such localities awaken when compared with the conformable contacts which Professor Wolff describes on Hoosac Mountain[a] are these: Which of these relations is the normal one? Do the strikes of the gneiss which are at right angles to the Green Mountain range represent the result of the Algonkian orogenic movement unaffected by the Ordovician one? In that case the conformable strikes would be due to the powerful Ordovician movement having affected both Algonkian and Ordovician masses, turning the Algonkian axes about into conformity to the Ordovician axes. Or are these pre-Cambrian strikes transverse to the Green Mountain range purely local and exceptional? These few localities may be insufficient to decide so important a matter. Further investigations in Vermont and Canada ought to throw light upon it. The question whether we have here indications of the probable course of the first hills and valleys of Algonkian time is an interesting one.[b]

Michel Lévy, in a sketch map of central France collated mostly from official maps of the French geological survey,[c] gives in different colors the directions of two superposed orographic systems, one dating to Carboniferous time and meandering from east to west, the other to Tertiary time with axes nearly north and south. Could such a map be constructed for any considerable area in North America showing the difference between the directions of compression in Algonkian and Ordovician time?

CONCLUSIONS.

Notwithstanding the somewhat heterogeneous character of these local geological details, they all point to the complex interaction of mechanical stratigraphical processes with more obscure chemical molecular processes, and in one case at least with biological processes; and they also indicate what far-reaching inductions may be drawn or questions awakened by the study of phenomena occupying but an insignificant amount of space.

[a] Mon. U. S. Geol. Survey, Vol. XXIII, 1894, fig. 27, p. 73.

[b] See, on the effect of a secondary horizontal movement on beds previously folded, Die Dislocationen der Erdrinde, by Emm. de Margerie and Albert Heim, Zürich, 1888, p. 87, and references on p. 118.

[c] Bull. Soc. géol. France, ser. 3, Vol. XVIII, 1889-90, Situation stratigraphique des régions volcaniques de l'Auvergne, pp. 692-693, Pl. XXII, fig. 1.

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