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THE CALCITE MARBLE AND DOLOMITE OF EASTERN VERMONT

BY

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The reports of the United States Geological Survey that relate in particular to the mineral resources of the country are of two kinds—annual reports containing statistics of production and discussing the general conditions of the mineral industries of the country and reports describing the mineral resources in the ground. The former comprise a valuable summary record of the mineral development in the United States; the latter constitute fragments of an incomplete survey of the mineral wealth of the country.

Most of the reports describing the unexploited mineral resources are devoted each to the consideration of some particular resource, such as coal, iron, oil, or copper, in a given area, but others treat of all the economically important minerals of the particular regions they cover. By far the greater number of these reports are by-products embracing the more succinct economic results derived from general geologic studies or detailed areal examinations. On the searching thoroughness of scope and the precision of the scientific studies and examinations depend, other things being equal, the completeness, accuracy, and value of the qualitative and quantitative results. It should be added that, after all, the vastly greater part of the information regarding the mineral resources of the country that has been brought to light by the Geological Survey has not been segregated and published apart from the folios, monographs, professional papers, and bulletins describing and mapping the geology of the areas with whose stratigraphy, structure, and geologic history the economically useful minerals are inseparably connected.

Occasionally, however, the Survey makes special reconnaissance examinations of the mineral prospects and localities in certain districts in order to compile the readily available information and to place it in the hands of the public for immediate use. A report of this kind may concern but a single mineral resource, in which case it constitutes a census of that mineral material as then recognized in the district. Such reports are those by Mr. Dale on the chief commercial granites of Massachusetts, New Hampshire, and Rhode Island (Bulletin 354), published in 1908; on the granites of Vermont (Bulletin 404), published in 1909; and on the commercial marbles of western Vermont (Bulletin 521), published in 1912.

In Bulletin 521 Mr. Dale described the known marbles in western Vermont—their mode of occurrence, extent, characters, availability, exploitation, and uses. The region covered includes the most extensive marble industry in the United States. The present report on the marbles of eastern Vermont is a companion to that bulletin. In this region, which lies east of the Green Mountain axis, there is practically no marble industry. The report relates to a virgin field where, in the lack of a general study of the stratigraphy, the structure, the paleontology, and the areal geology, it is at present not only impossible to determine the area and general attitude of many of the beds but also even the thickness of some of the marble formations which are but partly exposed.

The eastern area appears to be one of greater metamorphism than the western, and the deposits are more interesting in their conditions of occurrence and their associated minerals. Although it is likely that a detailed areal survey of the region will show that some of the deposits are of considerable extent, many of the exposed marbles are believed by Mr. Dale to be probably lenticular.

In the descriptive review of the known marble outcrops of the region, most of which Mr. Dale has personally examined, the marbles are discussed as to texture, color, composition, adaptabilities, etc., in accordance with the methods followed in Bulletin 521.

It will be noted that these marbles of eastern Vermont, many of which are dolomitic, vary widely in kind and character and that the outcrops, though few in number, are scattered from the Massachusetts line to the Canadian boundary. Many of the marbles are suited only for indoor ornamental use. About a dozen outcrops occurring in as many areas are regarded by Mr. Dale as more important than the others, but the greater part of the ledges are to be counted in the mineral reserves of the New England States.

THE CALCITE MARBLE AND DOLOMITE OF EASTERN VERMONT.

By T. Nelson Dale.

INTRODUCTION.

The object of this bulletin is twofold—to locate definitely and to describe accurately the marbles and dolomites of eastern Vermont, with a view to setting forth their possible economic uses and to discuss whatever features of scientific interest they may present.

The calcite marbles and dolomites of eastern Vermont generally differ from those of the western part of the State not only by their inconsiderable thickness but by their sporadic distribution. Instead of marble or dolomite belts that can be followed for many miles, such as occur in the Vermont Valley, there are roughly aligned series of lenses and outcrops of uncertain continuity, but the quartzose marble of Orange County constitutes a formation which continues into the adjoining counties on the north and south.

This bulletin is based on a reconnaissance of the deposits of dolomite and marble in Windham and Windsor counties, made by the writer in the execution of a plan to determine the relations of the calcareous beds east of the Green Mountain axis to those west of it, from July 12 to August 23, 1888; on a second visit to them and those of Orange County, from July 10 to September 1, 1911; and on a visit to the deposits in Franklin, Lamoille, Washington, and Addison counties, the eastern part of Rutland County, and the western part of Windsor County in September and October, 1912. Many abandoned prospects or small openings adjacent to the remains of old limekilns had to be rediscovered from clues obtained from old inhabitants. When the entire State is geologically mapped other similar outcrops will undoubtedly be found.

As only a part of the region has been topographically mapped and as none of it has been geologically mapped on an adequate topographic base map, much of the geology is yet to be unraveled. Although the structural observations recorded in this bulletin are likely to be of service when the final geologic mapping is done, they are insufficient by themselves to determine the exact place in the geologic column to which many of the marble and dolomite beds

should be assigned. Such indications of their age as the data afford will, however, be found in the section on geologic age.

Many of these calcite and dolomite deposits have been exploited for the manufacture of lime. Some of them were used for this purpose between 50 and 75 years ago, and a few are still being so used. Those in Orange County and one in Washington County have been prospected as marble. The calcite at Richford, in Franklin County, was used for lime and was also prospected for its content of copper ore. The possibility of utilizing the rock in all these deposits for construction or decoration is discussed in the closing section of this bulletin.

For a general discussion of the origin, composition, physical qualities, and texture of calcite and dolomite marble the reader is referred to Survey Bulletin 521, The commercial marbles of western Vermont, pages 11–36. The following table, taken from that bulletin, is repeated here in order to make the numerical designations of marble texture used in this bulletin intelligible:

Grades of marble texture.

Grade.	Grain diameter.		General average.	
	Maximum (millimeters).	Average (millimeters).	Millimeter.	Inch.
1. Extra fine	0.2	0.05–0.1	0.06	0.0023
2. Very fine	.5	.07– .16	.10	.0039
3. Fine	.75	.10– .25	.12	.0047
4. Medium	1.0	.12– .31	.15	.0059
5. Coarse	1.5	.20– .60	.24	.0094
6. Extra coarse	2.54	.30–1.35	.50	.0196

The numbers given in connection with some of the specimens mentioned are the numbers borne by them in the collection at the United States National Museum.

BIBLIOGRAPHY.

The literature on the eastern Vermont marbles consists of brief papers by C. H. Hitchcock, A. D. Hager, and C. H. Richardson, the titles of which follow:

HAGER, A. D., Brief report on the geology of Plymouth: Report on the geology of Vermont, vol. 2, pp. 691, 731, 732, 775, 776, Pl. XVIII, 1861.

HITCHCOCK, C. H., Saccharoid Azoic limestone: Idem, vol. 1, pp. 555–558; vol. 2, Pl. I. See also Limestone, vol. 2, pp. 748, 749.

RICHARDSON, C. H., The terranes of Orange County, Vt.: State Geologist Vermont Rept., vol. 3, pp. 61–101, 1902.

RICHARDSON, C. H., "Washington limestone," The areal and economic geology of northeastern Vermont: Idem, vol. 5, pp. 86–90, 1906.

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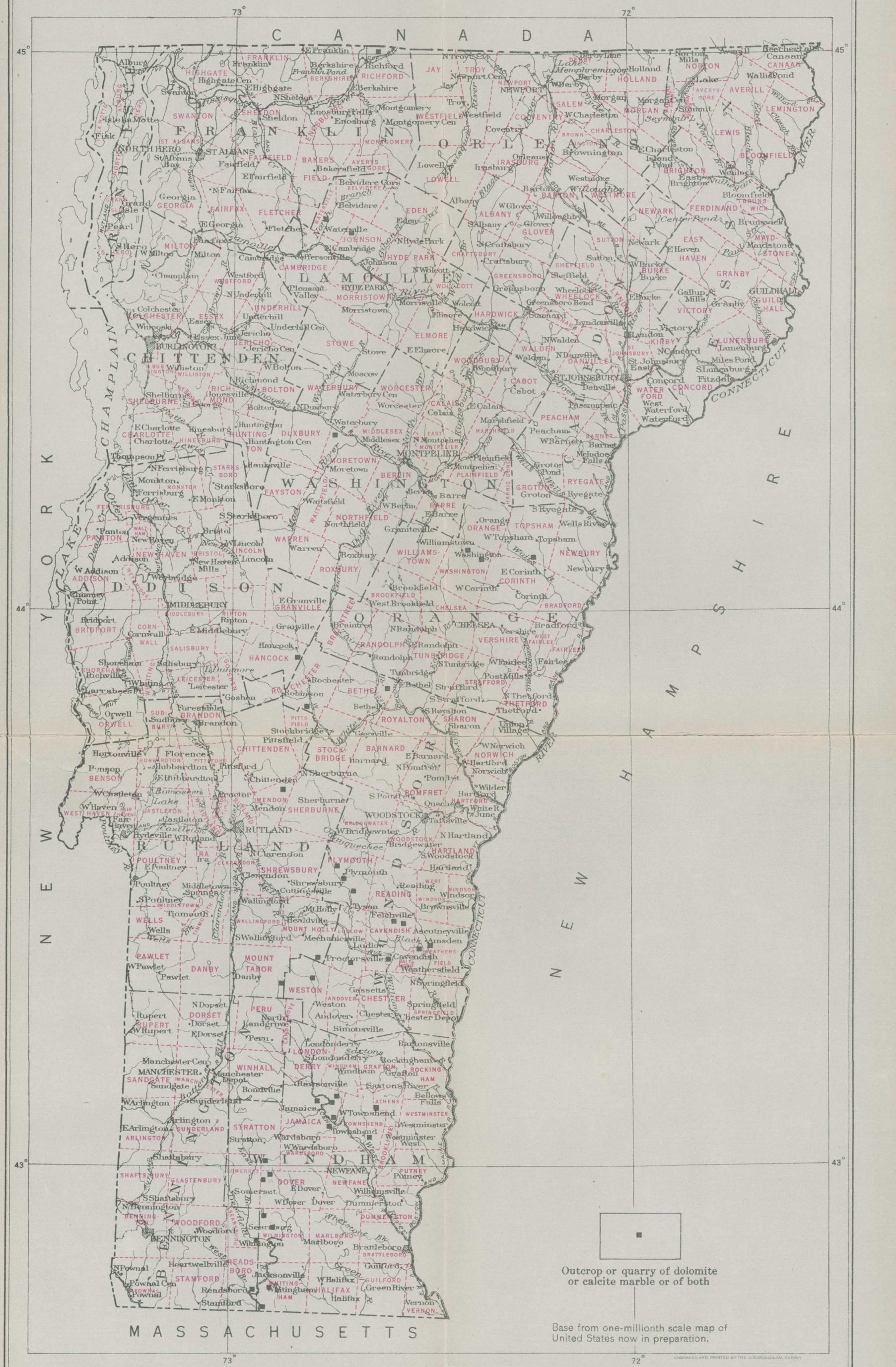


MAP OF VERMONT SHOWING OUTCROPS AND QUARRIES OF CALCITE MARBLE AND DOLOMITE IN THE EASTERN PART OF THE STATE.

By T. Nelson Dale.

1914

Scale $\frac{1}{750,000}$

10 0 10 20 30 Miles

10 0 10 20 30 40 Kilometers

GEOGRAPHIC DISTRIBUTION.

Aside from the four localities in Windsor and Orange counties (in Bethel, Washington, and Topsham), which presumably belong to continuous belts of quartzose marble and which are also reported to extend northward into Caledonia County,[1] 35 localities of calcite marble and dolomite are shown on the map (Pl. I), 30 of which lie east of the axis of the Green Mountain Range. The others in Richford (Franklin County), in Mount Tabor, and Mendon (Rutland County), and in Waterville and Johnson (Lamoille County), lie either on or west of that axis.

The northernmost outcrop is within half a mile of the Canadian boundary in Richford, Franklin County. The marble of Lamoille County lies along two belts, a western belt in Waterville and another a few miles farther east, in Johnson.

In Washington County but one outcrop was found, a little south of Waterbury, in Moretown.

The outcrops in Hancock, in the southeast corner of Addison County, and in Rochester, in the northwest corner of Windsor County, belong to one belt, which may continue northward into Granville Township, where Hitchcock observed it.

The dolomites of Mount Tabor and of Mendon, in the eastern part of Rutland County, probably belong to a single belt.

The calcite marbles and dolomites of the southern half of Windsor County occur in three belts—a western belt in the townships of Plymouth and Ludlow; an eastern belt 5 miles west of Connecticut River, in the township of Weathersfield; and a central belt in Cavendish. The outcrop in Weston, in the southwestern part of Windsor County, probably belongs to the same belt as that in Mount Holly Township, Rutland County.

The marbles of Windham County also lie in three belts—an eastern belt about 8 miles west of Connecticut River, in the townships of Athens and Townshend; a central belt in the township of Jamaica; and a western belt on the ridges drained by the main branches of Deerfield River in Stratton, Dover, Somerset, Wilmington, and Whitingham.

The marbles of the eastern extension of Bennington County occur on Deerfield River in Searsburg and Readsboro and belong to the western belt of Windham County, close by.

The writer failed to find the marble mentioned by Hitchcock as occurring at Andover, in Windsor County, and inquiries at Marlborough, in Windham County, as to the marble reported in that township were also fruitless. Limestone was reported by C. T. Jackson and

[1] See Richardson, C. H., The terranes of Orange County: State Geologist Vermont Rept., vol. 3, pp. 61–101, 1902; and "Washington limestone," The areal and economic geology of northeastern Vermont: Idem, vol. 5, pp. 86–90, 1906.

also by H. A. Cutting to occur in Essex County, but the writer's visit to the localities in Lunenburg and Concord cited by Cutting showed something very different, as explained on page 53.

DEPOSITS BY COUNTIES AND TOWNS.

FRANKLIN COUNTY.

RICHFORD.

Marble was quarried and burned for lime before 1861 at a point about 2 miles N. 60° E. from the village of Richford, on what was formerly the Frederick White farm, now the O. W. Corliss farm, on the road to Glen Sutton, in Canada, about half a mile south of the international boundary. The marble continues northward into the adjacent L. H. Smith farm. A tunnel was also begun near the quarry before 1861, with a view of mining the copper ore with which the marble is in places impregnated.

Here beds of calcite marble from 86 to 107 feet thick strike about N. 15° E. and dip from 60° N. 70° W. to 90°. Sericite schist, more or less graphitic, lies east and west of them and has like strike and dip but is crossed by slip cleavage. Between the marble and the sericite schist on the west side is several feet of dark-green chlorite-quartz-muscovite schist abounding in minute lenses of sideritic dolomite that weathers into limonite at the surface. A few feet of this rock occurs also interfolded or interbedded with the marble. The outcrops of marble on both farms indicate a total length of about 1,000 feet for the deposit but do not afford conclusive evidence as to whether the marble lies in an anticline, a syncline, or a monocline. As the chalcopyrite must be assumed to have been brought up by ascending solutions, however, it may be more probable that the ore was concentrated in an anticline below the originally overlying schist. This is a slight indication only.[1] The amount of marble below the surface of this locality depends, of course, on the answer to the question whether the schist of both sides dips under the marble or formed an anticline over it. In the latter case the deposit might be much thicker than in the former.

The marble (specimens D, XXXIV, 86, g, h, i) varies from a white to a faintly pinkish or faintly greenish calcite marble, with some local dolomitic phases and also dark bluish-green streaks. Its texture belongs to grade 4, medium, the grain diameter ranging from 0.12 to 1, mostly 0.25 to 0.6 millimeter. The colors are likely to be in bands (beds). The pinkish tint is due presumably to a small percentage of an oxide of manganese and iron (see p. 39), the light green evidently to minute grains of epidote, and the dark green to chlorite and probably actinolite. The rock contains grains of quartz, some

[1] See Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 1211–1217, 1904.

muscovite, and in places small veins of smoky quartz. One minute bed carries magnetite and chlorite.

The copper ore (chalcopyrite, $CuFeS_2$), a sulphide of copper and iron containing about 34 per cent of copper, occurs in small particles, in joint and bedding planes, and in some joints crystallized with quartz (specimen D, XXXIV, 86, f). In some beds it is altered to malachite, coloring the marble bright green in narrow streaks (specimens 86, j, l).

The geologic processes which have taken place at this locality thus appear to include the deposition of marine clayey sediment, either before or after the organic deposition of calcium carbonate. This was followed by the metamorphism of both deposits, the clayey sediments into mica (sericite) schist and the lime into calcite marble, and by the folding of both series of beds. Then joints were produced by various strains, and at some later time occurred the impregnation of both joint and bedding planes by ascending siliceous solutions carrying also $CuFeS_2$. Lastly came the erosion of the rock surface, truncating the tops of the folds.

The economic value of this marble is very uncertain. If the deposit is deep enough to furnish a considerable supply of large and sound blocks of white marble banded with pink and green, such blocks might be used for interior decoration.

BAKERSFIELD.

Marble or dolomite is reported as occurring on the Converse farm, in Bakersfield Township.

LAMOILLE COUNTY.

WATERVILLE.

The Tillotson prospect is about 2 miles north of Waterville village and about 500 feet east of the road to Belvidere, on a brook flowing southward in a hollow separated from the road by a small schist ridge. A conspicuous ridge with a northerly trend lies west of the road.

The marble, which was burned for lime here 50 years ago, is 60 to 65 feet thick, strikes N. 17° E., and dips 45°–50° N. 73° W. Muscovite (sericite) schist lies east and west of it in like attitude. The schist 140 feet west of the marble is an intensely plicated graphitic, slightly pyritiferous sericite schist with slip cleavage. It contains quartz lenses and secondary feldspars (probably albite) inclosing black particles that form lines of rock bedding and show enlargement beyond those lines. (See p. 64.) An 18 by 5 foot schist mass within or east of the marble is a highly calcareous chlorite-quartz-muscovite schist with feldspars (albite), magnetite, and epidote. The schist near the marble on both sides is a plicated, more or less graphitic schist. On the west side marble and schist are somewhat interbedded.

The marble (specimen D, XXXIV, 80, c) is a calcite marble of irregular coarse texture, of grade 5, with grain diameter 0.07–1.37, mostly 0.25–0.75 millimeter, containing a few roundish quartz grains, a little pyrite, and rarely muscovite.

There are no outcrops to show the extent of the marble along the strike nor anything at the locality to indicate whether the structure is that of an overturned syncline or an anticline and thus to show the probable depth of the marble.

On the H. M. Start farm, about three-fourths of a mile south of the Tillotson prospect, along the strike, close to and east of the road from Waterville, is a mass of white marble 8 feet long and 4 feet thick, which strikes N. 25° E. and dips 20° S. 65° E. This may be an outcrop. About 250 feet east of it is a ridge of schist striking N. 7° E. and dipping 62° W. The marble (specimen D, XXXIV, 81, a) is a faintly cream-colored calcite marble with some fine-grained dolomite beds up to a quarter of an inch thick or muscovitic streaks half an inch to 1 inch apart. The calcitic part is of grade 5 (coarse) with grain diameter 0.07–1.25, mostly 0.25–0.75 millimeter, and contains minute quartz grains.

Marble is also reported as occurring about 4,000 feet west of the Waterville-Belvidere road, on the second farm south of Westcott's. This would be in the direction of the strike of the Tillotson prospect beds.

JOHNSON.

Marble was quarried and burned for lime many years ago at a point about 4 miles N. 10° W. of the village of Johnson, on the south side of a low schist ridge with an easterly trend. The outcrop is about a quarter of a mile N. 60° E. of the Bradford house and 140 feet above it. The marble is about 11 feet thick, strikes N. 27° E., and dips 50° S. 33° E. Sericite-quartz-chlorite schist occurs on both sides of it—that is, both above and below it. The slip cleavage of the schist dips 70° E. or S. 33° E. The schist is very rusty from oxidation, probably of pyrite. The marble, which is much plicated and contains minor beds of cream-colored granular dolomite with sparse albite feldspars, is banded with graphite and has suffered some brecciation. At the south end the marble incloses a lens of very feldspathic schist, 3 to 5 feet thick and about 10 feet long, to which the marble is closely welded and with which it is slightly interbedded (specimen D, XXXIV, 83, c). This schist consists largely of secondary albite feldspars, 0.1–0.2 inch across, many of them simple twins, in a cement of chlorite, muscovite, quartz, carbonate, magnetite, and pyrite, these minerals being named in descending order of abundance. These feldspars, like those in the marble at Waterville (p. 11), contain stratified particles and show secondary enlargement. (See p. 64.)

The marble also contains a few brownish to black lenses, half an inch to 3 inches in diameter, projecting on weathered surfaces. A

laboratory test shows them to be rich in manganese, and a thin section shows that the manganese contains a little quartz and carbonate.

The marble (specimen D, XXXIV, 83, a) is a whitish calcite marble with chloritic streaks and has a fine to medium texture (grades 3 and 4), with grain diameter 0.05–0.62, mostly 0.2–0.37 millimeter.

The outcrop at the south and lower end, near the old kiln, looks as if the schist from either side might unite a few feet below to form a syncline. In that case, as the outcrop is only 50 to 70 feet long, the quantity of marble left would be very small.

In passing from the Bradford locality along the strike north-northeastward onto the ridge small masses of marble are found in

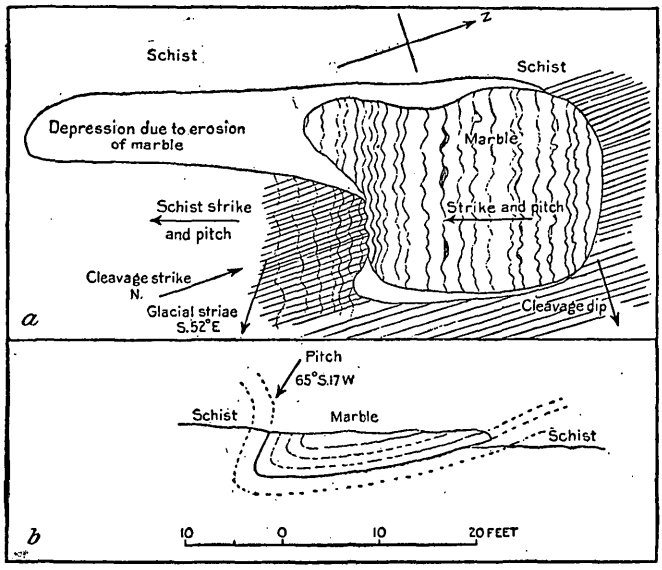


FIGURE 1.—Marble outlier on George Butler farm, in Johnson, Lamoille County, Vt.

the schist, and just over the crest on the adjoining George Butler farm is a larger outcrop of marble, also formerly quarried, and the remains of a kiln lower down, near a brook flowing south-southeastward. The marble is 70 feet thick but not much over 100 feet in length, and is bordered by plicated sericite schist on both sides, all striking about N. 27° E. and dipping 50° S. 33° E., like the beds on the other side of the ridge. The marble (specimen D, XXXIV, 82, b) is a whitish calcite marble with fine black (graphitic) bands. Its texture is fine to medium (grades 3 and 4), with grain diameter 0.07–0.62, mostly 0.2–0.5 millimeter, and it contains some quartz grains and graphite.

About 15 feet west of this marble mass and separated from it by schist is a small marble outlier about 10 feet wide and 15 feet long, surrounded and underlain by schist and containing some lenses of schist and of dolomite. Its relations and structure are shown in figure 1.

The marble contains some schist and dolomite lenses. It is strongly plicated, the axes of the folds having the strike of the ridge but pitching 65° S. The schist in contact with it has similar plications but a slip cleavage striking about north and dipping steeply east. At the S. 17° W. end the marble plications pitch southward under the schist, but at the N. 17° E. end the schist underlies the marble, which is only 18 to 24 inches thick. The surface form shows that the outlier was originally over 30 feet long and about 12 feet wide, though tapering to half that width at the south, but has been dissolved away. The schist has deep glacial striæ trending S. 50°–55° E. The course of the plications on the marble surface, meandering from east to west, is the result of a transverse compression that gave the normally plicated beds a steep southerly pitch (65°) and produced a system of small transverse folds along the strike (see fig. 1), in the synclinal part of one of which the little outlier has been preserved from further erosion.

The economic bearing of the outlier on the larger marble outcrops is important, for it shows that these folds are not anticlines projecting through the schist but synclines underlain by schist and therefore contain but a very small amount of marble.

WASHINGTON COUNTY

MORETOWN.

The north end of Moretown Township is just south of the town of Waterbury. Winooski River bounds the township on the northeast, and Duxbury Brook, for a mile or so from its junction with the Winooski, bounds the township on the northwest. Marble was prospected in 1863–1873 at a point about 1½ miles south of Waterbury, on the west side of Moretown Hill, between the road to Moretown Center and Duxbury Brook, 200 feet above the brook and about half a mile from its mouth. The land, originally settled by Jesse Arms, is now owned by Henry Carpenter, of Waterbury. The opening is about 35 feet square and more than 25 feet deep.

The marble strikes N. 23° E., dips 75° S. 67° E., is 10 feet thick, and is bordered on both sides by schist. On the east side there is a transition from marble to schist, the marble containing schistose phases. The exposure is limited to the excavation. The schist (specimens D, XXXIV, 75, d, e) is a dark-grayish, slightly greenish sericite-chlorite-quartz schist, with a little biotite alternating with light quartzose beds up to 3 millimeters thick, both finely plicated. The little quartzose beds contain some calcite, rare grains of feldspar, and a black nonmagnetic mineral.

The marble (specimens D, XXXIV, 75, a, b, c) is a handsome white to cream-colored calcite marble, in places mottled with light bluish gray, of somewhat irregular texture—that is, with portions of different

texture. The coarser parts have a grain diameter of 0.05–0.42, mostly 0.125–0.25, averaging about 0.18 millimeter—about grade 4 (medium). The finer and greater part has a grain diameter of 0.02–0.2, mostly 0.07–0.12, averaging about 0.1 millimeter—about grade 2 (very fine). The marble has a few quartz grains.

Farther down Duxbury Brook there are large outcrops of schist similar to that in contact with the marble. This schist strikes N. 25° E. and has a steep eastward-dipping cleavage and a plicated bedding foliation of uncertain dip. A thin section from one of these outcrops consists of alternating little beds of chlorite and biotite containing some pyrite, rarely epidote, and minute nodules of uncertain character, with beds of quartz and calcite not over a millimeter thick containing some grains of feldspar.

ORANGE COUNTY.

TOPSHAM.

One of the principal openings (locality 1, fig. 2) in Topsham is a trifle over a mile about east of the Waits River village church and 250 feet above it, in a small brook on the east side of a road which runs northeast from the main road from Bradford, about 1,600 feet southwest of the J. Felch farmhouse. Here a finely banded and acutely plicated marble strikes about N. 15° W. The plications in places are extremely elongate, measuring up to 3 feet in length. Lenses of quartz are abundant through a bed several feet thick containing muscovite and pyrite. The beds are not sufficiently exposed for measurement, but over 10 feet of marble is in sight. The opening is small and is abandoned.

The marble (specimens D, XXXIII, 1, a, c–e) is of a general medium-gray shade. It consists of plicated alternating bands, from 0.02 to 0.5 inch thick, of very light bluish-gray and of dark bluish-gray color. In weathering the stone becomes dark brownish gray and finally, as the calcite is dissolved, becomes coated with a residual brownish network of quartz grains with some scales of muscovite. In the little cemetery about 600 feet N. 25° W. of the J. Felch house are two polished stones of this marble dated 1897, but said to have been erected in 1899, that have lost their bluish tint and become light brown, particularly on the west side. Some more quartzose bands project slightly on their upper surfaces.

In thin section this marble is seen to consist of calcite grains with diameters of 0.02–0.75, mostly 0.12–0.37 millimeter; roundish and angular quartz grains, 0.05–0.5, mostly 0.07–0.25 millimeter, forming possibly 25 per cent of the rock; very much less muscovite, still less pyrite; and some very fine powdery opaque matter, probably graphite. C. H. Richardson [1] gives the insoluble residue in the marble of this or

[1] State Geologist Vermont Rept., vol. 3, p. 70, 1902.

a near-by opening as 41.75 per cent. It is a very quartzose and muscovitic pyritiferous graphitic calcite marble. Some of the quartz grains cohere, as in a quartzite. The grain diameter of the calcite places the marble about in grade 3 (fine).

It takes a fair polish and the finely plicated banding of light and dark gray renders it attractive, but its considerable content of pyrite and possibly also of iron carbonate is bound on oxidation by exposure

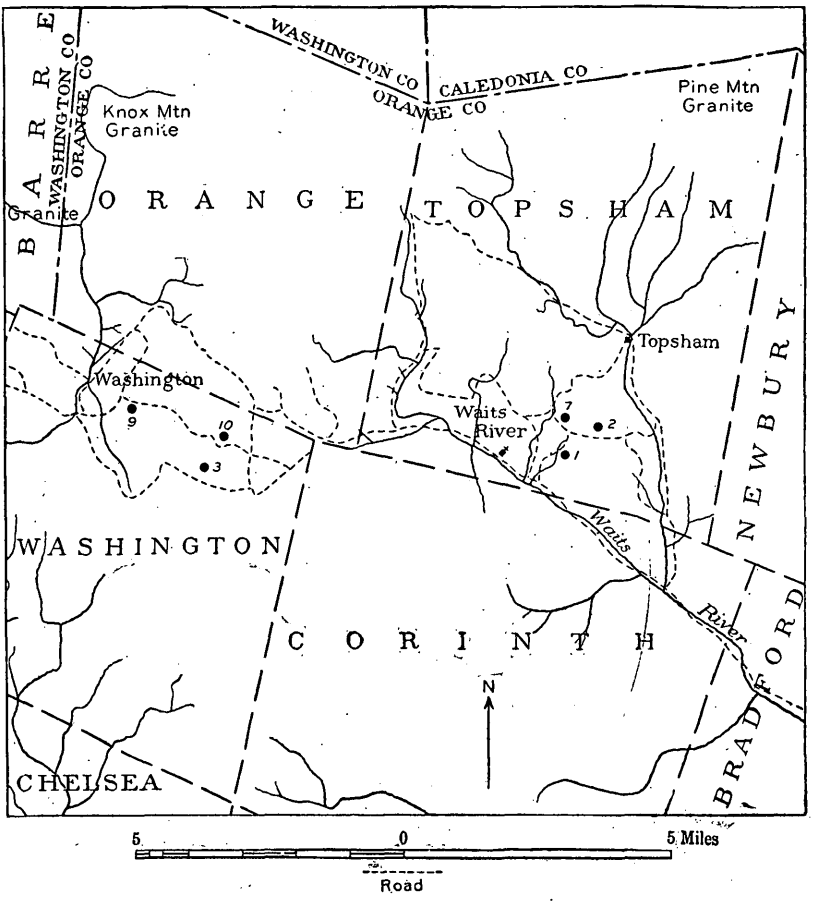


FIGURE 2.—Map of Topsham and Washington townships, Orange County, Vt., showing marble prospects (•) in limestone to which the Vermont State Survey has given the name Waits River limestone. From Beers's Atlas. The southern part of the area shown on this map is in the northern part of the Strafford quadrangle, mapped by the United States Geological Survey.

to rain to give it a brownish color, and the polished surface soon will become rough owing to the large content of quartz, which also will make the cost of polishing high. It appears, therefore, to be suitable only for indoor use. Several large blocks of the marble can be seen back of the present Waits River post office, near the sawmill where the marble from the Henry C. Richardson openings was sawn.

This quartzose banded marble belongs in the formation described by C. H. Richardson[1] as the Waits River limestone. It is the calcareous member of the calciferous mica schist of the Vermont Geological Survey report of 1861. Its age is regarded as Ordovician.

At a small prospect about 2,350 feet east of the J. Felch house (locality 2, fig. 2), and about 3,150 feet east-northeast of locality 1, a calcareous schist, striking N. 10° W. and dipping 50° E., is cut by a granitic dike, 12 feet 6 inches wide, with a northerly course. The banded marble crops out about 2,500 feet N. 45° W. of the dike, where it strikes about north, dips 45° W., and pitches 30° N., and outcrops of it continue toward the dike, but the relations to the schist are not well defined. It is assumed, however, that the schist and marble belong approximately to one period and that the dike is later than both. The dike rock is a dark-gray porphyritic biotite granite, in which the matrix consists of quartz, microcline, and biotite (particles under 0.5 millimeter), with accessory pyrite, apatite, titanite, and secondary carbonate. The porphyritic feldspars are oligoclase under 0.2 inch, intergrown with microcline and quartz and with inclusions of biotite and carbonate. The nearest granite masses include that about Pine Mountain, in the northeast corner of the township, about 5½ miles N. 12° E., that about Knox Mountain, in Orange Township, about the same distance N. 45° W., and the Barre mass, about 10 miles N. 68° W. This dike is very probably of about the same age as these granites.

WASHINGTON.

At a disused quarry (locality 9, fig. 2), 3,780 feet east-southeast of the Washington village church, there is a marble much like that of Topsham but with little or no banding and of darker shade. The opening is 75 by 50 feet and about 5 feet deep. The beds strike N. 15°–20° W. They are cut by quartz veins up to an inch thick with N. 80° W. course, faulted every 3 to 6 inches, also by a pegmatite dike up to 6 inches thick, consisting of smoky quartz, oligoclase-andesine much intergrown with quartz, orthoclase (probably), and pyrite.

The marble (specimen D, XXXIII, 9, d) is of dark bluish-gray color. It weathers dark brownish (specimens 9, b, c), and the surface finally becomes a very dark brownish gray, consisting of a network of quartz grains (diameter up to 0.2 inch) with some mica. Owing to the variation in the amount of quartz it projects in ridges on the weathered surface. In thin section this marble is seen to consist, in descending order of abundance, of calcite with grain diameter of 0.07–0.87, mostly 0.25–0.5 millimeter, quartz in more or less roundish grains with a diameter of 0.05–0.5, mostly 0.12–0.25

[1] State Geologist Vermont Rept., vol. 3, pp. 84-90, 94-98, 1902; vol. 5, pp. 86-90, 112-114, 1906.

millimeter, making up about 25 per cent of the rock; sparse muscovite and biotite up to 0.62 millimeter; pyrite in irregular particles; and a mineral that is probably graphite, though not determinable. It is a very quartzose and pyritiferous graphitic calcite marble with some muscovite and biotite. The grain diameter of the calcite places the texture in grade 3 (fine).

Several gravestones of this marble in the Washington village cemetery, bearing date of 1895, have suffered more or less rusty discoloration, probably owing to the oxidation of the pyrite. Richardson [1] states that the cut surface of the fresh stone is much lighter than the polished surface, affording a more marked contrast than in other marbles. He also gives its compressive strength as 15,675 pounds. This marble is evidently as unsuited for external use as that of Topsham. It would probably do better for inscribed tablets and other polished indoor ornamentation.

The following analysis, made by C. H. Richardson [2] from a piece of a drill core, obtained 35 feet below the rock surface at a quarry near Washington village, shows a high percentage of quartz but no sulphur, whereas pyrite, which would yield sulphur, is conspicuous in the writer's thin sections and is probably one of the causes of the limonitic discoloration. If the marble analyzed became discolored like that of the monuments in the village cemetery, then its discoloration would have to be attributed to the oxidation of iron carbonate.

Analysis of quartzose calcite marble from quarry near Washington village, Orange County, Vt.

Silica (SiO_2)	35.748
Titanium dioxide (TiO_2)	.190
Carbon dioxide (CO_2)	22.860
Iron sesquioxide (Fe_2O_3)	.010
Alumina (Al_2O_3)	6.113
Iron oxide (FeO)	.940
Glucinum oxide (GlO)	.313
Manganous oxide (MnO)	.076
Barium oxide (BaO)	.210
Lime (CaO)	27.305
Magnesia (MgO)	3.248
Soda (Na_2O)	.186
Potash (K_2O)	.063
Lithia (Li_2O)	.823
Water (H_2O)	.108
Phosphorus pentoxide (P_2O_5)	1.359
Chlorine (Cl)	.307
Fluorine (F)	.026
Carbon (C)	Microscopic trace.
	99.885
Less oxygen=F and Cl	.079
	99.806

[1] State Geologist Vermont Rept., vol. 3, p. 88, 1902. [2] Idem, p. 68.

A similar marble (specimen D, XXXIII, 3, a) was prospected in 1894 on the R. F. Richardson farm, about 2½ miles S. 50° E. from Washington village church (locality 3, fig. 2). The openings lie along a small brook that flows south, toward the house, which is on a road running about three-fifths of a mile south of the old stage road.

The beds strike N. 20°–30° E., are plicated, and are cut by pegmatite dikes as much as 2 feet thick with a N. 20° E. course. The pegmatite consists of orthoclase, smoky quartz, oligoclase-albite, and muscovite, with garnet, pyrite, and magnetite. One of the dikes is itself crossed by a quartz veinlet.[1]

On the old stage road 2⅔ miles east-southeast of the Washington village church, about 900 feet above it, and about northeast of the Richardson locality there is a small cliff of similar quartzose marble which strikes about N. 40° E. and is cut by a 2-inch granite dike with N. 20° E. course (locality 10, fig. 2). A specimen (D, XXXIII, 10, a) from a small opening at the foot of the cliff, is a very dark, slightly bluish gray quartzose and micaceous calcite marble weathering dark brown. In thin section this marble is seen to consist, in descending order of abundance, of calcite with grain diameter 0.11–0.62, mostly 0.18–0.37 millimeter; roundish to angular quartz grains, 0.03–0.44, mostly 0.11–0.37 millimeter in diameter, forming about 25 per cent of the rock; muscovite, biotite, pyrite, and probably a little graphite. Some of the calcite shows a brownish discoloration, the source of which is not apparent. This marble also belongs as to texture in grade 3 (fine).

The only difference between the marbles of Topsham and Washington is that the former are lighter in shade, finely banded, and do not contain biotite.

Richardson[2] tested the solubility of marbles from 10 localities in Orange County and found that it varied from 52.90 to 60.15 per cent.

The marbles of Washington evidently belong to the same formation as those of Topsham. Those of Washington are only 2 to 3½ miles from the granite mass of Barre and 3 to 3½ miles from that of Knox Mountain. The pegmatites described differ from those observed in some of the Barre quarries. The faulting and veining of the dikes shows that the region suffered a crustal movement after the disturbance associated with the granitic intrusions.

ADDISON COUNTY.

HANCOCK.

In Hancock, the southeastern township of Addison County, dolomite has been burned for lime on the west side of the White River valley near the Rochester town line, which is also that of Windsor

[1] These outcrops are described by Richardson, op. cit., vol. 3, p. 87, 1902. [2] Idem, pp. 69, 70.

County. The locality is about 750 feet above the river, nearly due west of a bridge over it, on the D. G. Marsh farm.

The dolomite is 25 feet thick, strikes N. 67° E., dips 80° S. 23° E., and is overlain, on the south, by a fine-grained banded muscovite granite gneiss (specimens D, XXXIV, 70, c, d). Underlying the dolomite on the north is a rock of sedimentary origin (specimen D, XXXIV, 70, e), a finely plicated chlorite-muscovite-quartz schist made up of beds of chlorite and muscovite 0.1 inch or less thick, alternating with similar beds of quartz and sideritic dolomite.

The dolomite itself (specimens D, XXXIV, 70, a, b) is a buff-colored, rusty-weathering dolomite with films of sericite and white calcitic streaks. It is both granular and twinned with grain diameter of 0.009–0.56 millimeter, but mostly granular and under 0.09 millimeter, of about grade 2 (very fine). It has some quartz grains, rare prisms of zircon, and limonite stains from siderite combined with the dolomite.

From the fragments between this ledge and the road there must be large outcrops of muscovite-chlorite schist near by. (See further under Rochester, p. 23.)

The limestone referred to by Hitchcock as occurring in Middle Granville, of this county, may be a continuation of the Hancock bed.[1]

RUTLAND COUNTY (EASTERN PART).

MENDON.

Dolomite was quarried in 1900 in Mendon Township at a point 7¼ miles northeast of Rutland, between the northern continuation of the central mass of the Green Mountain Range (Shrewsbury Peak, Killington, and Pico) and the masses which form its western flank (Bald and East mountains and Blue Ridge). On account of its magnesia the rock was shipped to a paper mill at Bellows Falls. The quarries are about 500 feet east of the road from Mendon to North Sherburne, on the 1,900-foot level and thus about 1,300 feet above Rutland.

The dolomite is not less than 50 feet thick, strikes N. 30° E., dips 35° S. 60° E., and has vertical close joints striking N. 40° E.

The dolomite (specimen D, XXXIV, 46, a) is milk-white to very faintly rose-colored and consists of irregular but not interlocking grains, very few of which are twinned, having a diameter of 0.02–0.14, averaging about 0.03–0.06 millimeter, and is thus of grade 1 (extra fine). It contains rare grains of quartz, a few scales of a pale-brown mica (phlogopite?), and minute black specks.

MOUNT TABOR.

A trifle over 5¼ miles due east of Danby Station on the Rutland Railroad and 1,540 feet above it, on the Green Mountain Range, at

[1] Hitchcock, C. H., and Hager, A. D., Geology of Vermont, vol. 1, p. 557, 1861.

the 2,200-foot level (see Wallingford topographic sheet, United States Geological Survey), at the divide which separates the drainage basin of the Connecticut from that of Lake Champlain, a little below the road from Danby to Weston, is an eastward-facing overhanging cliff known as the Devils Den. It is 50 to 75 feet high, and at its base lies a talus of large blocks which have fallen from the upper part by the opening of north-south joints and fractures and the undermining of the lower part. At the foot of this talus begins a brook which finally empties into West River 9 miles to the southeast, near Londonderry. The cliff consists of a banded garnetiferous biotite-muscovite granite gneiss with a little chlorite (specimen D, XXXIV, 66, a). Its foliation strikes N. 5°–10° W. and dips at a very low angle to the west.

A few hundred feet east of this locality, on the northeast side of the road, is a cliff 40 feet high exposing the following series, beginning at the top: Muscovitic quartzite with magnetite (specimen 65, a), 20 feet; slightly muscovitic quartzite with a few rounded grains of zircon (specimen 65, b), 10 feet; dolomite, 20 feet—all striking N. 5°–10° W., dipping 25°–30° E., and having minor plications that indicate a pitch of 10° N.

The dolomite (specimen D, XXXIV, 65, c, d) is cream-colored and veined with quartz, consists of irregular grains, some of them twinned, and contains a few quartz grains, muscovite scales, rarely a grain of zircon, and minute black dots.

About 350 feet farther east there is an outcrop of similar dolomite (specimen 65, e) that strikes N. 20° E. and dips up to 30° S. 70° E. In grain diameter these dolomites range from 0.02 to 1.12, mostly 0.07–0.5 millimeter, and are thus of grades 2 to 4 (very fine to medium).

A little east of the outcrop last mentioned are the remains of a kiln where dolomite from these localities was burned many years ago.

The gneiss of the Devils Den is of pre-Cambrian age, and the dolomite and quartzite are presumably of Cambrian age, as are also the large outcrops of quartzite cut by Big Branch in the lower part of its course, within 1½ miles of the village of Mount Tabor, in the west flank of the range, on the road to the Devils Den.

MOUNT HOLLY.

In the southeastern part of Mount Holly Township, 3¾ miles southeast of Mechanicsville, on the road to Weston, marble has been burned for lime at intervals for over 50 years. The locality is on the old Fuller farm, now the C. D. Edgerton farm, and was noted by C. L. Whittle in his United States Geological Survey explorations of 1891 and has been referred to by him in two papers.[1] It is on the

[1] Whittle, C. L., The occurrence of Algonkian rocks in Vermont and the evidence for their subdivision: Jour. Geology, vol. 2, pp. 396–429, 1894. The general structure of the main axis of the Green Mountains: Am. Jour. Sci., 3d ser., vol. 47, pp. 347–355, 1894.

incised plateau which lies between the western (Mount Tabor) and eastern (Terrible and Ludlow Mountains) crests of the Green Mountain Range (see Wallingford topographic sheet), at the 2,140-foot level. The marble crops out on both sides of the road northwest, southeast, and southwest of the house.

At the opening northwest of the house (Whittle's localities 1046, 1048) marble 24 feet thick is both underlain and overlain by garnetiferous sericite-biotite-quartz schist, with epidote and magnetite, the garnets partly chloritized. The marble strikes N. 20° E. and dips 35°–40) S. 70° E. Between the marble and the underlying schist is 5 feet of actinolite schist with epidote and biotite (specimen D, XXXIV, 51, c). The marble is cut by diagonal and transverse joints, the latter filled with fibrous actinolite (specimen 51, e). The marble from this point (specimen 51, a) is whitish, consists of twinned dolomite grains with diameter 0.07–2.2, mostly 0.5–1.4 millimeters, and is thus of grade 5 (coarse) but has some particles of 0.2 inch, and contains a little actinolite.

At the opening about 600 feet southeast of the house, on the southwest side of the road, marble 15 to 20 feet thick strikes N. 25° W. and dips steeply east. The rock in contact on the east and south (specimen 52, b) appears to be a fine-grained hornblende granite gneiss. The marble here (specimen 52, a) is a cream-colored coarse-textured calcite marble.

The marble from the locality southwest of the house, which was not visited (specimen 53, a), is faintly rose-colored to cream-colored. It is a calcite marble of irregular texture with grain diameter of 0.1–2.5, exceptionally 4 but mostly 0.4–1.68 millimeters, and thus of grade 6 (extra coarse). It contains minute black particles and larger ones of magnetite (?).

WINDSOR COUNTY.

BETHEL.

The area mapped by C. H. Richardson[1] as Waits River limestone (Ordovician), which includes the quartzose marble of Topsham and Washington, described on page 15, extends southward into Windsor County and crops out along a small brook tributary to White River, 2 miles northeast of Bethel, half a mile west of East Bethel, near a crossroads and the Quarry School. The locality is about a mile east of the granite area of Christian Hill.[2]

The marble occurs in beds 1 to 5 feet thick in graphitic sericite schist, striking north, N. 5°–15° W., and N. 30° W., and dipping 80° W., 90°, and 60° E., being evidently in minor pitching folds. It was at one time burned for lime.

[1] The terranes of Orange County, Vt.: State Geologist Vermont Rept., vol. 3, Pls. IX and IX, A, 1902.
[2] See Dale, T. N., The granites of Vermont: U. S. Geol. Survey Bull. 404, pp. 109, 110, fig. 24, 1909.

A specimen (D, XXXIV, 71, b) from a ledge about 1,000 feet S. 10° W. of the crossroads is a dark bluish-black (weathering brownish) quartzose, muscovitic, and graphitic calcite marble. The calcite, much of which is twinned, greatly exceeds the quartz, which in turn is more plentiful than muscovite. The calcite has grain diameters of 0.05–0.25, mostly 0.07–0.2 millimeter, and is of grade 2 (very fine); the quartz has like extremes but is mostly of 0.05–0.12 millimeter, or a little finer than the calcite. The color of the weathered stone indicates that the calcite must contain some siderite.

The interbedded sericite schist is very quartzose, graphitic, garnetiferous, and magnetitic and contains isolated plates of biotite. It is much plicated and crossed by slip cleavage at an angle of 27° to the dip of the bed.

The highly metamorphic character of this marble is shown by the thin sections of both marble and schist. Owing to the thinness of its beds, its large content of quartz, and the rustiness of its weathered surface it is difficult, notwithstanding the fineness of its texture, to see any economic possibilities in this marble at this locality.

ROCHESTER.

In the southern part of Rochester Township, 3 miles south of Rochester Center, on the west side of the White River valley, marble was formerly quarried and burned for lime on the F. F. Kezer farm, northwest of the house. The base of the ridge consists of an eastward-dipping schist. About 200 feet above the valley, dipping under this schist and west of it, is a thin-bedded marble with streaks of bluish to greenish muscovite schist, striking N. 20° W. and dipping about 35° S. 70° E. This strike, which corresponds to the course of the valley, brings this locality in line with the dolomite of Hancock, described on page 20, and the schist of the base of the ridge here resembles the fragments so abundant below the dolomite at that place. About 70 feet higher on the ridge the marble is coarser grained but still has schistose streaks. A little higher is an outcrop of epidote schist with quartz, carbonate, and magnetite. Both of these outcrops strike and dip like the one first mentioned.

The thin-bedded rock of the lowest outcrop (specimen D, XXXIV, 68, a–c) consists of streaks of whitish calcite marble (grain diameter 0.06–0.5 millimeter; grade 2, very fine) merging into or alternating with dolomite without twinning (grain diameter 0.009–0.047 millimeter; grade 1, extra fine), both containing some muscovite, quartz, plagioclase, epidote, and magnetite, and alternating with laminæ of closely plicated bluish or greenish-gray sericite schist with minute yellowish-green prisms of epidote lying transverse to the strike of the plications. The rock also contains a greenish biotite. In specimen 68, d, the little calcitic beds, the thickest 0.3 inch thick, alternate with greenish-gray dolomitic beds containing much epidote and a little muscovite.

The coarser rock higher on the ridge (specimen 69, c) is a mixture of medium-grained cream-colored calcite marble (grain diameter 0.04–1.3 millimeters; some grains with curved twinning planes) and clouded cream-colored dolomite (grain diameter 0.009–0.09 millimeter, grade 1, extra fine), mostly granular but in part twinned, containing quartz, muscovite, greenish biotite, epidote, apatite, and magnetite. The rock is veined with smoky quartz and at intervals has micaceous streaks.

There is a bare possibility that these marbles, owing to their variety of color and design, resulting from their being interbedded with plicated schist, may, if obtainable in large and sound blocks, have some economic value for ornamental work.

WESTON.

It is reliably reported that dolomite or marble was at one time burned in a very small way for lime on the Shattuck farm, in Weston Township, about 2¾ miles S. 13° W. from the Edgerton (Fuller) farm, in Mount Holly Township (p. 21).

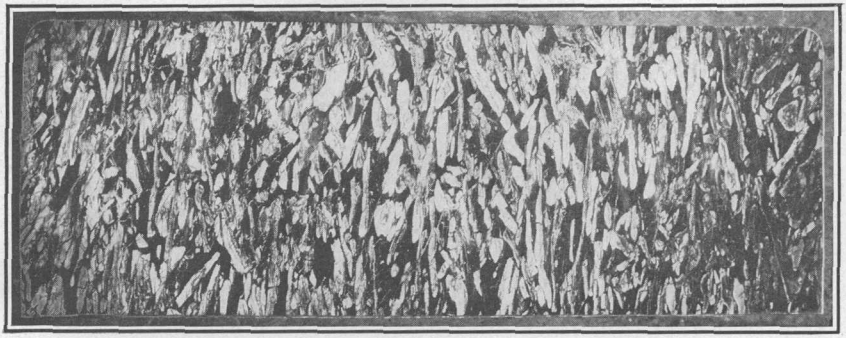
PLYMOUTH.

The marbles of Plymouth are dolomite and dolomite breccia, occurring either as lenses in a very quartzose mica schist formation or associated with and gradually passing into an underlying quartzite. On the west side of Lake Amherst, a little west of the dolomite, are conspicuous ledges of quartzite or conglomerate with small elongated quartz pebbles. The strike of these ledges is north and the dip east. The principal outcrops of the dolomite are shown on the map, figure 3.

The Scott quarry is on the east side of the north end of Lake Amherst and 120 feet above the lake. It has a working face on the north measuring 50 feet east to west and 35 feet high. It has been idle for many years. The owner is C. H. Scott, Tyson, Vt.

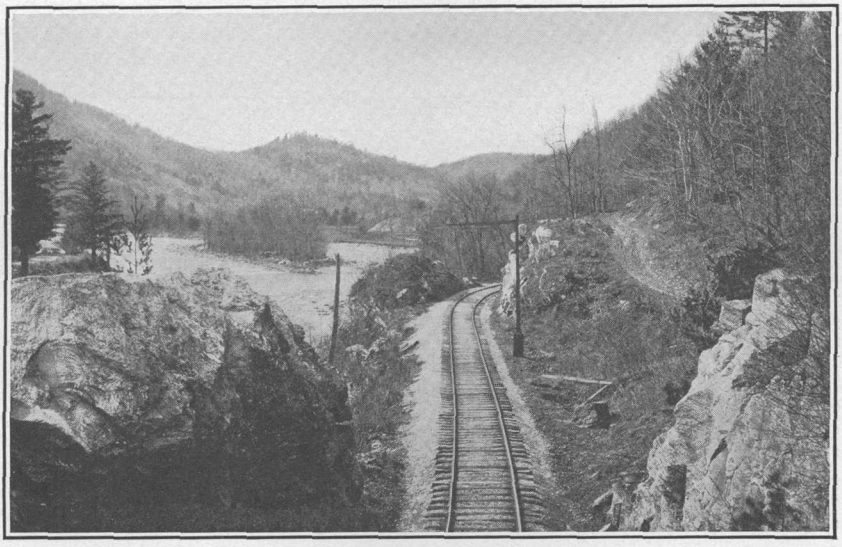
The dolomite strikes N. 15°–25° W. and dips 45°–55° E. The beds are crossed at intervals for a thickness of 2 to 4 feet by steep close joints striking N. 45°–60° E. The entire thickness of the dolomite is not far from 75 feet.

The marble (specimen D, XXXIII, 11, a, b) is a dolomite breccia with very dark bluish-gray ground and very light gray brecciated beds, the fragments of which are mostly under 4 and not over 6 inches in length, nor over 0.5 inch thick. (See Pl. II, *A*.) The ground is of granular or untwinned dolomite, having grain diameter of 0.009–0.094, mostly 0.03–0.076 millimeter, and thus of grade 1 (extra fine), with interstitial graphite and rare muscovite. The whitish fragments are also of granular dolomite, having grain diameters of 0.009–0.141, mostly 0.02–0.09 millimeter, of grade 1, with some coarser portions consisting of twinned dolomite plates as much



A. POLISHED SLAB OF GRANULAR DOLOMITE BRECCIA FROM PLYMOUTH, VT.

Size 26½ by 9½ inches. The ground is very dark bluish gray, almost black when polished, and the fragments of small beds are light gray, almost white. Photograph by W. B. Claflin, Tyson, Vt.



B. RAILROAD CUT 1¾ MILES SOUTHEAST OF JAMAICA, VT., LOOKING UP WEST RIVER.

Rose-colored calcite and white dolomite marble exposed behind the guard pole on the right, the beds dipping into the hill. The rock masses in the foreground are feldspathic mica schist overlying marble series.

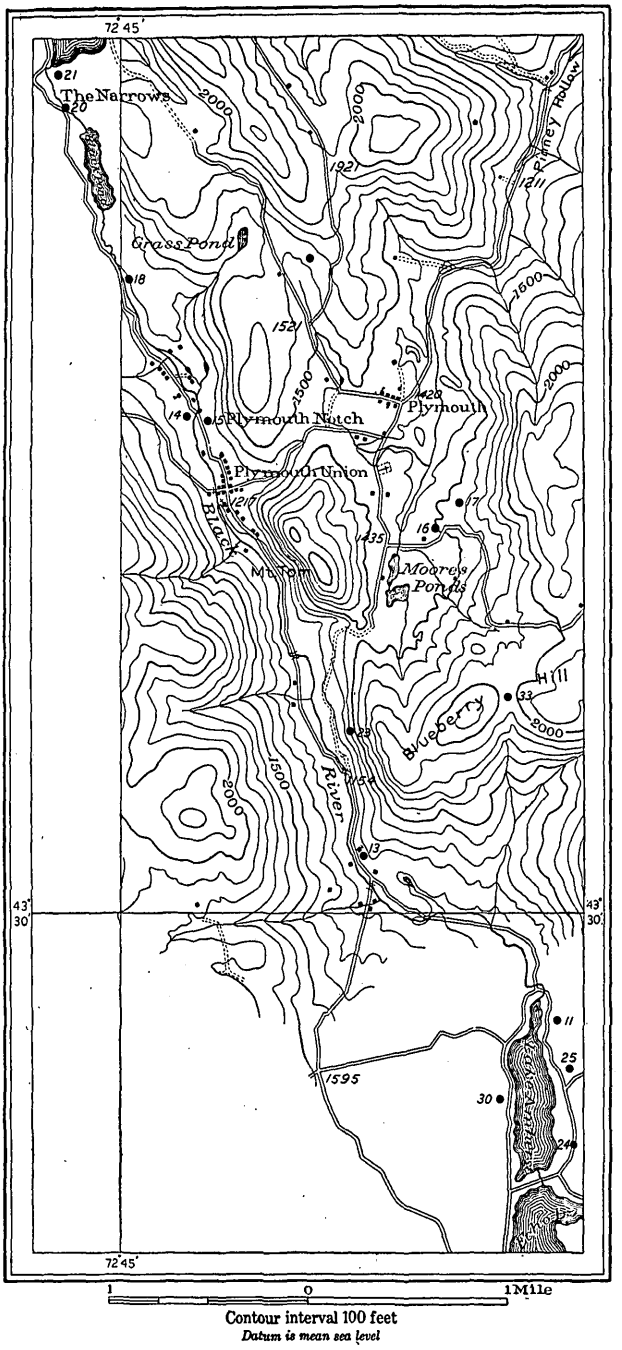


FIGURE 3.—Map of part of Plymouth Township, Windsor County, Vt., showing marble and dolomite prospects (•). Schist occurs at localities 13, 17, and 33.

as 0.47 millimeter across, large quartz grains, and rare black particles of uncertain nature.

The following analysis of a mixture of the dark and light parts was made by T. S. Hunt in 1847:

Analysis of dolomite breccia from Plymouth, Vt.[1]

Calcium carbonate ($CaCO_3$)	53.9
Magnesium carbonate ($MgCO_3$)	44.7
Iron oxide and alumina (FeO, Al_2O_3)	1.3
	99.9

The stone takes a fair polish and is very suitable for interior decoration. It has a general resemblance to some of the dolomite from Swanton, but the ground is graphitic instead of hematitic and no corals are apparent. The value of the deposit depends on the number and size of the blocks that can be obtained free from joints.

The dolomite is both underlain and overlain by very quartzose mica schist, and at a distance of a few hundred feet along the strike to the north these upper and lower schist masses unite, cutting off the dolomite. Its continuation to the south is also improbable unless it be under the lake. How far the dolomite beds extend eastward along the dip under the schist ridge can be determined only by drilling.

A dolomite breccia like that of the Scott quarry is reported on the Orich Ward farm, about a quarter of a mile east of Grass Pond and three-fourths mile N. 22° W. of Plymouth Church. The location on the map (fig. 3) is only approximate.

About half a mile south of Plymouth Church, on the north side of the road to Five Corners, are the remains of a limekiln and a small dolomite opening in which some of the weathered beds show brecciation. A bluish, slightly muscovitic and quartzose dolomite, in the road near by, strikes N. 50° W. and dips 32° S. 50° E. About a quarter of a mile N. 22° E. of the opening and 240 feet above it is a conspicuous ledge of quartzite and interbedded biotite schist striking north and dipping 50° E. The dolomite opening is locality 16 in figure 3.

A little east of Lake Amherst, 1⅓ miles N. 15° E. of Tyson, near a road fork (locality 25, fig. 3), the following section is exposed, beginning at the top:

Section east of Lake Amherst.

	Ft.	in.
Muscovite (sericite) schist	20+	
Dolomite, quartzose, cream-colored	2–3	
Quartzite	4	0
Dolomite, quartzose, with some rose and smoke colored calcite marble	5	6
Quartzite	2	6
Dolomite		6
Quartzite	5	0

[1] Hitchcock, C. H., and Hager, A. D., Geology of Vermont, vol. 2, p. 691, 1861.

The strike of these beds is N. 25° W. and the dip N. 65° E. The calcite marble (specimens D, XXXIII, 25, a, b) has a grain diameter of 0.14–2.03, mostly 0.37–0.93 millimeters, and belongs in grade 5 (coarse). The rose and smoke colored (biotitic) bands are an inch thick. The rose color, as is shown on page 39, is due to a very small percentage of manganese oxide.

On the west side of Mount Soltudus there is a bench about 80 feet above the nearest bridge. Here (locality 23, fig. 3) 10 to 20 feet of cream-colored dolomite is overlain by a muscovite schist containing large disseminated feldspars (probably albite), all striking N. 10° W. and dipping 45° E.

About half a mile north of Plymouth Union and about 600 feet north of a schoolhouse is Hall's limekiln, some 850 feet west of which are several small openings (locality 14, fig. 3). The stone (specimen D, XXXIII, 14, a) is a very light rose-colored dolomite with films of muscovite and quartz. In thin section it shows a ground of dolomite grains, many of them twinned, with diameters of 0.02–0.4, mostly 0.04–0.09 millimeters, and is thus of about grade 2 (very fine). At irregular intervals are groups of twinned dolomite plates or single ones up to 0.75 millimeter across. There are also very minute, very dark, faintly reddish specks, shown by a test by W. T. Schaller, of the United States Geological Survey, to contain both iron and manganese, which as oxides and carbonate account for the rose color. The beds strike N. 30° E. and dip 30°–50° S. 60° E.

A little over a mile north of Plymouth Union (locality 18, fig. 3) are the remains of a limekiln and, on the east side of a brook, large outcrops of dolomite in thick and thin undulating beds. In the brook is a sericitic, chloritic quartzite in vertical beds striking east. The dolomite (specimen D, XXXIII, 18, b) is milk white with delicate purplish spots. The color was found by W. T. Schaller to be also probably due to oxides of iron and manganese. The dolomite grains, some of which are twinned, have diameters of 0.02–0.16, mostly 0.37–0.094 millimeter, and a few plates reach 0.14 millimeter. The stone thus belongs about in grade 2 (very fine). This seems to be the most promising marble of Plymouth, but the thickness of the beds and their freedom from joints require careful testing.

At The Narrows, on the 1,358-foot level about midway between Black Pond and Woodward's reservoir (locality 20, fig. 3), is a dolomite mass 30 feet high that was formerly quarried on the east side of the road. It strikes N. 10° W. and dips 35° E. The rock is much jointed in two directions and thus unfit for "marble." It is a slightly pinkish fine-grained dolomite resembling that of locality 14, described above. A little north of the quarry the road cuts a series of beds of quartzite and dolomitic quartzite which dip under the dolomite and show a gradual transition across the beds from a pure

quartzite to the overlying dolomite. At the south end of Woodward's reservoir (locality 21, fig. 3) 20–30 feet of dolomite strike N. 10° W. and dip 30° E. possibly underlying the quartzite of The Narrows.

LUDLOW.

About 2 miles south of Ludlow, on the east side of the road to Andover, a little south of a road leading to Weston and about 3 feet north of a brook crossing, are an old dolomite opening and the remains of a kiln. The rock, which is much jointed and veined with quartz, is not over 15 feet thick, tapering out about 100 feet to the north, and dips east under a mass of finely banded muscovitic, feldspathic quartzite which is deeply cut farther east by a northward-flowing brook. Some of the minute bands in this rock are mostly quartz; others are micaceous, with plagioclase and microcline. A less micaceous quartzite overlies this rock, and west of the strike of the dolomite other schistose rocks underlie it. The dolomite may be simply a lens in these mechanical sediments. From the location and strike it is evidently more or less synchronous with the beds of the Plymouth belt.

The dolomite (specimen D, V, 108, a) is of slightly bluish-gray tint with fine yellowish calcitic streaks. It consists of untwinned dolomite grains with diameter 0.02–0.05 millimeter and is thus of grade 1 (extra fine), but it contains sparse groups or single plates of twinned dolomite, mostly 0.25–0.75 millimeter in diameter or of grade 3 (fine), with a little muscovite and iron carbonate going into limonite.

CAVENDISH.

The marbles of Cavendish Township occur in three belts—a western belt, about 4½ miles east of the Plymouth-Ludlow belt and cropping out in the northern part of the township; a central belt in Cavendish Gorge, recurring south of it in the railroad cut, and again 3 miles N. 25° E. of the north end of the gorge; and an eastern belt in the northeastern part of the township near the Weathersfield line.

WESTERN BELT.

About 3 miles N. 13° E. of Cavendish village, south of a road fork, a few hundred feet northwest of the old Stearns farmhouse and west of the road (locality 140, fig. 4), white calcite marble was formerly quarried and burned. On its west side is a granite gneiss with a foliation striking N. 25° E. and dipping 42° N. 65° W. and thus apparently overlying the marble. About 100 feet north of the road fork on the eastern road the marble is in contact with an overlying granite gneiss that has a foliation striking N. 25° E. and dipping 35° N. 65° W. At the road fork is a garnetiferous schist with like strike and dip, apparently underlying the marble, which probably does not exceed 20 feet in thickness.

CENTRAL BELT.

About half a mile southeast of Cavendish station, just south of the sharp railroad curve and a little east of the track (locality 38, fig. 4), are a disused limekiln and a quarry. Here white dolomite, 10 to 15 feet thick, exposed for about 200 feet along the strike, dips 5°–10° W. in contact with and under a considerable thickness of evenly foliated granite gneiss. The gneiss consists, in descending order of abundance, of quartz, plagioclase (probably oligoclase), microcline, muscovite, and biotite. A few rods to the east, near the kiln, is an evenly foliated, more biotitic gneiss, consisting, in like order, of quartz,

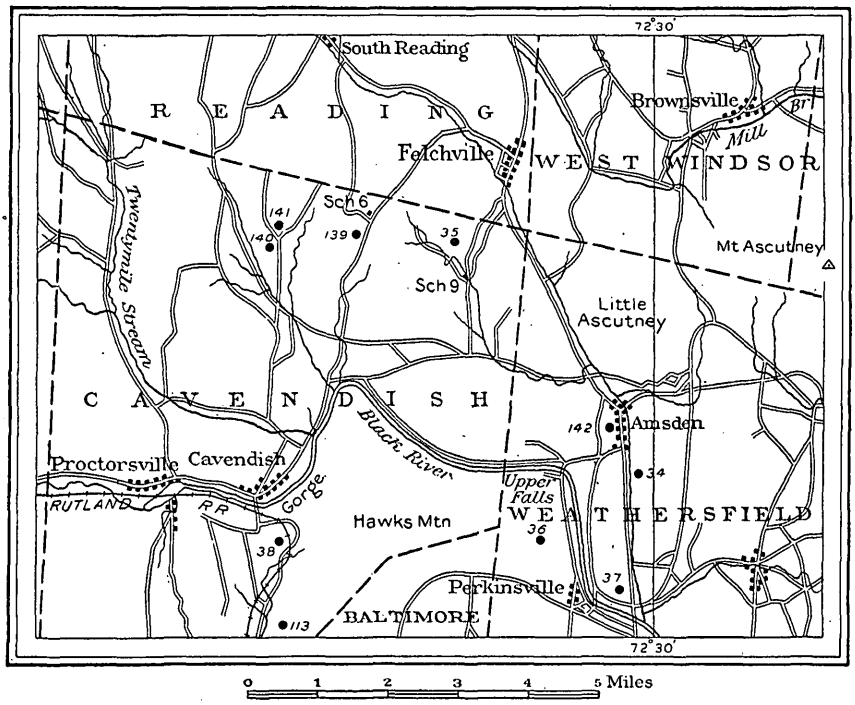


FIGURE 4.—Map of parts of Cavendish and Weathersfield townships, Windsor County, Vt., showing marble outcrops (•). From Hitchcock, C. H., Geology of New Hampshire, atlas, and Beers, F. W., Atlas of Windsor County, Vt.

biotite, microcline, plagioclase, and muscovite. This rock also dips east at a low angle toward and under the dolomite, but the lower contact is not exposed. The difference in the two gneisses is only what would be expected in any large body of gneiss. The same white dolomite reappears along the strike at the south end of the railroad cut, where it is also overlain by a granite gneiss that curves upward in such a way as to suggest the beginning of an anticline, in which case the dolomite would lie in a syncline of gneiss. The gneiss has evidently been greatly disturbed here, for east of the strike of the dolomite on both sides of the cut thick pegmatite dikes cross the steep foliation of the gneiss almost horizontally.

The dolomite (specimen D, XXXIII, 38, a) is milk-white and contains some lenses of pink calcite about 1 by 0.2 inch, also veinlets of light smoky quartz 0.01–0.2 inch thick, films of muscovite, and scales of brownish mica. The calcite veins and quartz lenses are more abundant near the gneiss contact. The dolomite grains are clear and twinned, 0.05–0.062 and even 1.12 millimeters in diameter, but mostly 0.15–0.5 millimeter, and the rock is thus of grade 2 (very fine). The calcite grains are large and are much clouded from manganese oxide. Although the twinning of the dolomite makes it susceptible of high polish, the quartz veins would be troublesome and a somewhat close jointing would prevent the quarrying of large blocks.

About three-quarters of a mile south of the railroad curve (locality 113, fig. 4) the dolomite recurs. Here it is over 30 feet thick, strikes north, and dips 30° W., and the gneiss is in contact with and above it.

A preliminary exploration of the complex geology of the little canyon of Black River, called Cavendish Gorge, shows that dolomite marble about 75 feet thick, resembling that near the railroad cut but including some beds of actinolitic calcite marble and mica schist, is both underlain and overlain by a feldspathic schist or granite gneiss, which on the west side of the gorge dips west but at one point on the east side dips east. As the gorge meanders in the direction of the strike, which ranges from N. 35° E. to N. 15° W., and as the gorge is also crossed by a diabase dike and a fault, the distinction between its metamorphic igneous and metamorphic sedimentary rocks is not clear; the locality requires much further study.[1]

About 3 miles north of the north end of Cavendish Gorge and a quarter of a mile south of the road fork at school No. 6, west of the road (locality 139, fig. 4), the following section was observed, in natural order:

Section near school No. 6.

	Feet.
Garnetiferous mica schist	15
Granite gneiss	15
White and pink dolomite	15
Granite gneiss	5
Covered space.	
Garnetiferous mica schist on both sides of road and forming the east side of a north-south ravine	40

The whole series strikes N. 10° E. and dips 20° W.

EASTERN BELT.

The eastern belt (locality 35, fig. 4) is south of Felchville, a village of the next township on the north. It includes a long, roughly north-south ridge of granite gneiss possibly 200 feet high, with a conspicu-

[1] Hitchcock and Hager (Geology of Vermont, vol. 2, p. 931, 1861) state that the dolomite of the gorge is underlain by gneiss and overlain by schist.

ous saddle. The highest point of the ridge is S. 70° W. from Mount Ascutney. It is separated from Little Ascutney by the wide north-northwesterly valley through which flows Felchville Brook, a tributary of Black River. The gneiss of this ridge appears to be continuous with the "Gneissic series" mapped by Daly[1] in his study of Ascutney Mountain. The principal marble outcrops occur over an area extending 600 feet across the ridge and 700 feet on it. They have been quarried on its west side, where stand the remains of a kiln. The total thickness of the marble could not be determined. The structural relations are complex, but the general strike of the gneiss is N. 25° E. Both rocks are probably interfolded and the marble may not be in continuous beds. The strike of the marble ranges from N. 25° W. to N. 10° E. On the west side of the southern knoll the dip is vertical, but farther up it is at a low angle to the west, pointing to a possible anticlinal structure for the ridge, and the pitch seems to be north. Some of the marble beds are crossed by small fault planes filled with secondary calcite. A small basaltic dike cuts the marble in the northern part of the west side of the ridge. Along the west foot is a considerable mass of schist made up of epidote, hornblende, and calcite, possibly of sedimentary origin, and associated with the marble.

Some of the marble (specimens D, XXXIII, 35, a, b) is a bluish or whitish-gray calcite marble, rose-colored in spots and streaks, with grain diameters up to 2.96 and 3.33 millimeters (in hand specimens even 0.25 inch), and thus of grade 6 (extra coarse), but it contains finer streaks of twinned dolomite marble with grain diameters of 0.11–1.1, mostly 0.18–0.55, millimeters, and therefore of grade 4 (medium). Muscovite and biotite occur in streaks and here and there is a little actinolite. There are also generally disseminated grains of quartz, apatite, and pyrite, rarely epidote.

Another variety of the marble (specimen D, XXXIII, 35, c) is finer grained, intricately plicated, and more micaceous and contains beds 0.2 inch thick of bright-green actinolite, and this mineral has also developed secondarily along the planes of slip cleavage. If large solid blocks of this variety could be obtained it would be valuable as a decorative marble, but the outcrops are too small to indicate either the quantity or the quality of the deposit.

WEATHERSFIELD.

The marbles of Weathersfield Township occur in three parallel belts of outcrops—a western belt on the ridge which lies west of the north-south part of Black River and is cut by it at Upper Falls (fig. 4); an eastern belt on the east side of the north-south ridge east of the tribu-

[1] Daly, R. A., Geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, Pl. VII, pp. 17, 18, 1903.

tary of Black River upon which Felchville and Amsden are situated, and a central belt on Pine Hill, the north-south ridge between Black River and its tributary.

WESTERN BELT.

About midway between Perkinsville and Upper Falls, on the Hawks Mountain ridge, in a small east-west ravine N. 70° W. of the Foster house, about 1,400 feet west of Black River and 150 feet above it, are some outcrops of marble which continue at intervals for 50 feet higher. The inclosing rock is a coarse muscovite-biotite schist containing large crystals and lenses of feldspar (presumably albite) and beds of quartzite. A few hundred feet south the schist is intruded by a mass about 300 feet square of coarse pegmatite containing feldspars up to 6 inches across. Pegmatite dikes as much as 3 feet thick run parallel to the foliation of the schist.

The marble (specimens D, XXXIII, 36, a, b) consists of alternating plicated beds, 1 or 2 inches thick, of rose-colored and light-greenish actinolitic calcite marble of grade 6 (extra coarse), with grains up to 3.33 millimeters in diameter in thin section and some attaining 0.2 inch in the hand specimen. The bunches of actinolite prisms are as much as 0.5 inch long. The rose color, as elsewhere (p. 39), is to be attributed to a small percentage of manganese oxide, and the green to actinolite. Biotite, quartz, a little plagioclase and apatite, and rarely zircon are present.

This is a very attractive stone in both longitudinal and transverse fracture. Only a few feet of marble is exposed at any point. Whether it could be obtained in large and sound blocks would have to be determined.

EASTERN BELT.

The Amsden quarries are east of the stream which joins Black River three-quarters of a mile east of Perkinsville. At the largest one, about half a mile south of the Amsden store (locality 34, fig. 4), the marble exposed is about 45 feet thick, strikes N. 30° W., and has an undulating dip, in places with minor plications that have a northerly pitch. It is cut by two trap dikes, amygdaloidal in places, 4 to 5 feet thick, and about 125 feet apart. The northern dike has a N. 50° E. course and dips 65° N. 40° W.; the other has a N. 75° E. course and a vertical dip. The marble for 25 feet on the north side of the northern dike is close jointed. One of the dikes sends off small branches into the marble (specimen D, V, 146, b, c). The marble has north-south joint faces on which, owing to solution by underground water, the more quartzose and micaceous bands project above the more purely calcareous bands.

The marble (specimens D, XXXIII, 34, a–e) consists of bands of milk-white, light to medium or dark bluish or slightly greenish gray or light-buff color in irregular alternations, from 0.1 inch to over 1

inch in width. The texture varies from fine to very coarse. The fine bands consist mostly of twinned dolomite with grain diameters of 0.07–0.87, mostly 0.25–0.5 millimeter, and are thus of about grade 3 (fine). The coarse bands are of calcite with grain diameters of 0.1–2.43 millimeters, in some specimens even 0.2 inch but mostly 0.25–1.68 millimeters, and are thus of grade 6 (extra coarse). The two minerals are not confined to separate beds, there being generally a slight mixture, particularly in the dolomite beds. The colors and shades of these little beds are due to muscovite, biotite, hematite, and limonite from pyrite. The bluish tint is due to finely disseminated specular iron (metallic hematite). In places there are little beds of this iron alone (specimens D, XXXIII, f, g), and there are also lenses of it a few inches thick (specimen h). The marble also contains streaks largely of biotite, and, as shown by the weathering, quartz is somewhat plentiful. This marble is properly a calcite and twinned dolomite marble, in which the two minerals occur mostly in small irregular alternating beds and which also contains quartz, hematite, biotite, and muscovite, named in descending order of abundance. At some of the now disused openings the marble contains actinolite (specimens D, V, 144, a, 145, a). Here and there the marble is rose-colored, presumably from manganese oxide.

The quarries have long been worked for the manufacture of lime, and are now operated by the Amsden Lime Co., of Amsden, Vt. The lime owes its peculiar properties to the combination of the two carbonates and its cement color probably to the presence of the hematite.

The following analyses made for the company by W. U. Buch, of Palmerton, Pa., have been furnished by the manager, Mr. L. C. White, jr. They complement the microscopic results given above.

Analyses of calcite and dolomite marbles from Amsden, in Weathersfield, Vt.

	Gray.	Pink.	Pink-red.
Water (H_2O)	0.04	0.085	1.0
Iron sesquioxide (Fe_2O_3)	1.43	.83	.77
Manganese oxide (MnO)	.6	.84	.61
Alumina (Al_2O_3)	1.35	.42	.37
Lime (CaO)	38.94	52.78	50.00
Magnesia (MgO)	11.32	1.60	1.66
Silica (SiO_2)	3.33	.49	5.98
Carbon dioxide (CO_2)	42.74	42.74	40.09
Phosphorus (P)	.087	.013	.065
	99.837	99.798	100.545

It should be stated that in selecting the stone for lime burning the more micaceous and quartzose pieces are thrown out and that the analyses were made on the selected material.

At the most northern of the Amsden quarries, east of the brook and store, the beds strike N. 30°–50° E. and dip 50°–70° NW. under several feet of feldspathic mica schist. The marble is much jointed. Its exposed thickness is about 40 feet.

The possibility of using some of the banded marbles of Amsden for decorative work can not be determined from present exposures. Any prospecting for solid beds should be made away from the dikes, where close jointing is likely to occur.

CENTRAL BELT.

The central belt is on Pine Hill, the ridge between the Black River and its tributary. About half a mile east of Perkinsville, at the south end of Pine Hill, about 100 feet above the east-west road, is a small opening (locality 37, fig. 4) in dolomite over 30 feet thick, which strikes N. 17° W. and dips 45° E. under more than 20 feet of muscovite-biotite schist with large disseminated crystalloids of plagioclase (probably albite). The dolomite along the contact, 60 feet north of the opening, incloses fragments of the schist as much as 14 inches in length, possibly as the result of brecciation. At the west foot of the ridge 400 feet west of the opening is another ledge of schist with a foliation dipping eastward toward and apparently under the dolomite. The schist resembles the other, but has fewer feldspars.

The dolomite (specimen D, XXXIII, 37, a) is slightly cream-colored at the surface. It is twinned, with grain diameters of 0.05–0.75, mostly 0.17–0.5 millimeter, and is thus of about grade 3 (fine). It contains a little tremolite here and there.

Two miles farther north, in the hollow back of the Amsden School, west of the brook (locality 142, fig. 4), is another disused quarry, where 10 feet of dolomite, with room for at least 30 feet more, strikes N. 35° E. and dips about 40° W. The dolomite underlies more than 50 feet of feldspathic muscovite schist and overlies similar garnetiferous, chloritic biotite schist, all dipping alike.

As outcrops 37 and 142 dip toward each other the structure of Pine Hill appears to be synclinal.

WINDHAM COUNTY.

ATHENS.

Marble occurs in the western part of Athens Township, just north of the west-northwesterly part of the Townshend line, on the east side of the road from Townshend to Athens, on what was formerly the Bemis farm but is now the Guilds farm (locality 42, fig. 5). Here are several old openings and the remains of a kiln.[1]

[1] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556; vol. 2, p. 618.

The marble outcrops cover a width of about 200 feet and are bordered on both sides by biotite granite gneiss striking N. 55°–70° E. and dipping 45° NW. Some of the gneiss of the east side is very finely banded; some of that on the west is less finely banded and contains plagioclase as the chief feldspar and garnets and hornblende as accessory minerals. At none of the openings is the marble over 10 feet thick. The width of 200 feet probably includes some minor folds and repetitions of the same beds. At one opening the marble is interfolded with a few feet of dark yellowish-green schist (specimens D, XXXIII, 42, d, h), which consists of a ground of diopside

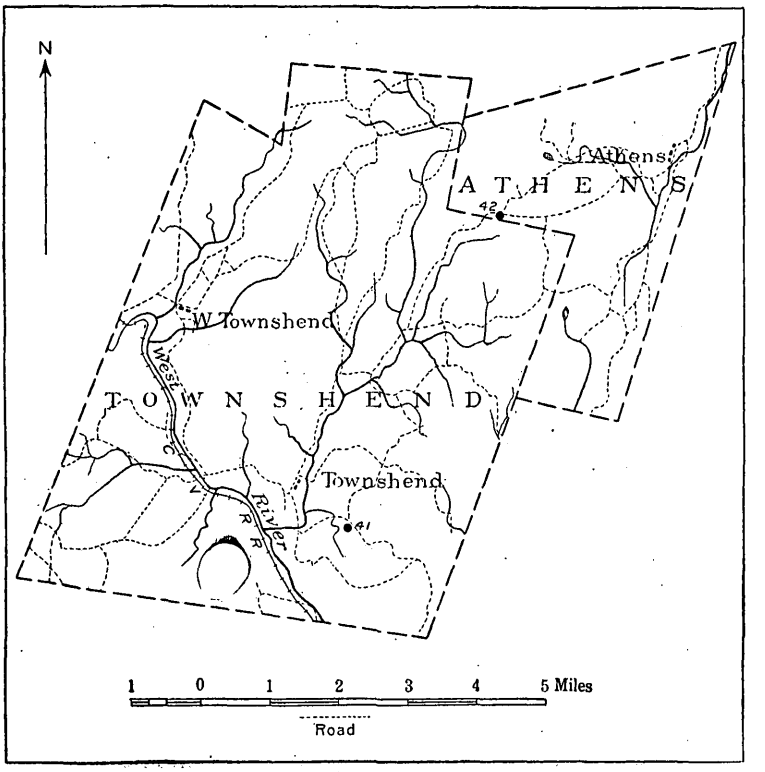


FIGURE 5.—Map of Athens and Townshend townships, Windham County, Vt., showing marble outcrops (•).

containing disseminated crystals of hornblende up to 0.5 inch across and which is in contact with an epidotic calcitic biotite gneiss. This schist contains a little calcite, rare grains of zircon, and a mineral regarded by Mr. Larsen as possibly belonging to the humite group.

The marble varies considerably. Some of it (specimen D, XXXIII, 42, f) is a very light pinkish and light-greenish calcite marble in alternating bands from 0.2 to 0.5 inch wide. Its grain diameters are 0.18–1.8, mostly 0.37–1.1 millimeters, and it is thus of about grade 5 (coarse). The pinkish tint is probably due to manganese oxide and the green to actinolite. Some of the bands contain a brownish

mica, phlogopite. Some of the marble (specimens D, XXXIII, 42, c, e, g, j) contains more actinolite and more manganese oxide, and consequently shows a deepening of the colors. It also has black streaks of biotite. Parts of this marble (specimen k) are of grade 6 (extra coarse) with grain diameters up to 0.2 or even 0.3 inch.

The colors of these marbles are very attractive, but the exposures are insufficient for determining either the quantity of the stone or the solidity and thickness of its beds.

TOWNSHEND.

Marble occurs at a road corner about a mile east-southeast of Townshend village and about 500 feet above it, on the Horace Gale (formerly Sharon Gray) farm. Here are the remains of a kiln used about 50 years ago.[1] There are outcrops and small openings on both sides of the east-west road and about south of the house (locality 41, fig. 5). The outcrops indicate a width of about 85 feet of marble, with finely foliated biotite gneiss on both sides striking N. 25° E. and dipping more or less steeply.

Some of the marble (specimens D, XXXIII, 41, a, b) is in alternating white or faintly rose-tinted and light-greenish beds a few inches thick. This is a calcite marble, the rose color, as in other localities, being probably due to manganese oxide and the green to actinolite. The calcite grains (in one section much twinned and slightly flexed) have diameters of 0.11–1.48 and even 2.38 millimeters, but mostly 0.37–1.48 millimeters (in a hand specimen up to 0.2 inch), and the marble is thus of grades 5 to 6 (coarse to extra coarse). It contains rare grains of twinned dolomite and of quartz. Another specimen (41, c), of grade 6, is of deep pink and cream color and contains biotite and epidote.

Another variety (specimens D, XXXIII, 41, f–h) is a greenish-gray, slightly foliaceous calcite marble with grain diameters of 0.37–2.59, mostly 0.74–1.85 millimeters, and is thus of grade 6 (extra coarse). It contains two chlorites, epidote, pyrite, and an orange-colored mineral which Mr. Larsen regards as probably belonging to the humite group.

The exposures are inadequate for determining the value of the deposit as marble.

JAMAICA.

The marble beds of Jamaica are in the eastern half of the township, within a radius of 2.7 miles of the village of Jamaica and N. 25° E., N. 45° E., S. 45° E., and S. 25° E. of it.[2] (See map, fig. 6.) The deposits of Turkey Mountain and Peirce farm are just east of the eastern edge of the area mapped.

[1] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556; vol. 2, p. 618.
[2] Idem, vol. 1, p. 556.

The marbles consist of rose-colored calcite alternating with white twinned dolomite, or else of the latter alone, both associated with schist of sedimentary origin and with gneissoid quartzite.

Whetstone Brook enters West River about 3 miles southeast of Jamaica village. At a bend in the brook, on its north bank, about 2.6 miles S. 25° E. of the village (locality 73, fig. 6), on the Prouty farm (formerly the Muzzy farm), 10 to 20 feet and possibly more of marble strikes N. 60° E. and dips 40° S. 30° E., lying conformably under about 100 feet of muscovite-biotite schist containing porphyritic plagioclase (probably albite), garnets, chlorite, and pyrite. The feldspars are crossed by plicated bedding streaks of pyrite, mica, etc.[1] The marble beds are faulted at intervals in a N. 10° E. direction, with displacement of 1 to 6 inches, and the fault planes are filled with quartz.

The marble (specimens D, XXXIII, 73, a, b) consists of beds of rose-colored calcite marble an inch or so in thickness alternating with beds of white twinned dolomite from 0.3 to 1 inch thick. The calcite

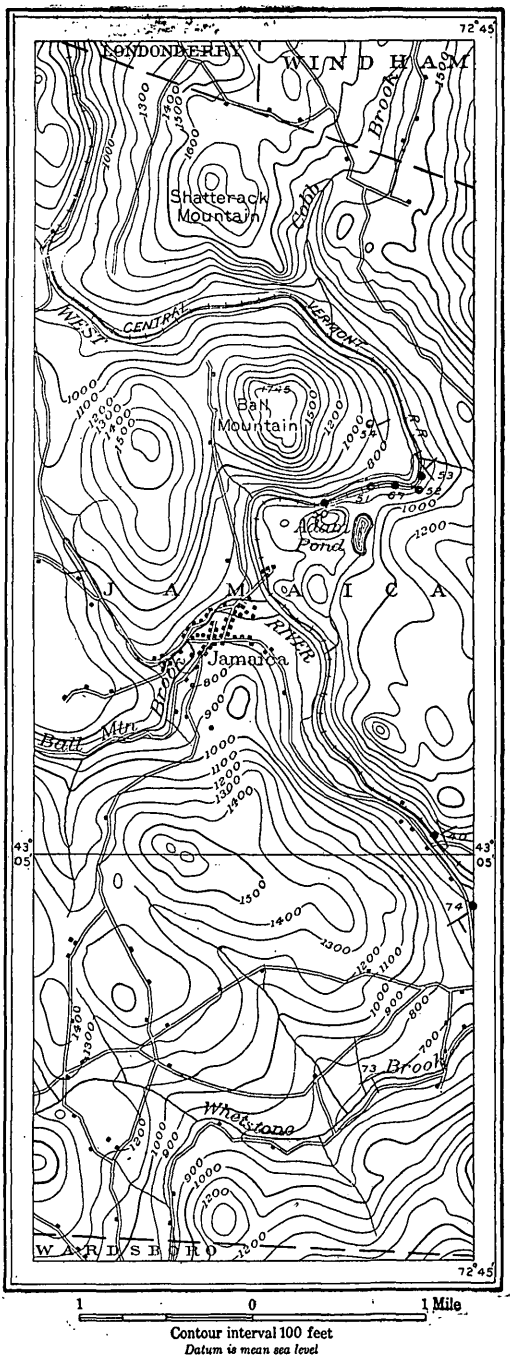


FIGURE 6.—Map of part of Jamaica Township, Windham County, Vt., showing marble outcrops (•). From Londonderry topographic sheet, United States Geological Survey.

[1] See U. S. Geol. Survey Bull. 195, pp. 16–18, 1902.

has grain diameters of 0.5 to 2.2, mostly 0.74 to 1.48 millimeters, and is thus of about grade 5 (coarse). The dolomite has grain diameters of 0.04 to 0.56, mostly 0.14 to 0.3 millimeters, and is thus of grade 2 (very fine). Both marbles contain grains of quartz and microcline and a little muscovite.

About 40 feet vertically above the marble the overlying schist contains two beds of dolomite 1 and 2 feet thick, separated by a little schist, showing that dolomitic and argillaceous sedimentation were intimately connected.

Two miles southeast of Jamaica village and probably less than 500 feet southeast of the road corner close to the edge of the area mapped (locality 74, fig. 6), on the N. F. Peirce farm, a white dolomite marble crops out here and there over a width of 125 feet. It strikes N. 60° E. and dips S. 30° E., corresponding in structure to the marble near Whetstone Brook, 1.2 miles to the southwest, and is associated with albitic mica schist. This dolomite (specimen D, XXXIII, 74, a) consists of twinned grains with diameters of 0.05 to 0.5, mostly 0.12 to 0.25 millimeter, and is thus of grade 2 (very fine).

At the west bank of West River, along the strike, this dolomite crops out again for a length of 60 feet with uncertain structure and in contact on the west with a mass of contorted gneiss. The dolomite here contains a few beds up to 1½ inches thick of pink calcite marble.

The Brattleboro and Whitehall branch of the Central Vermont Railway, at a point 1¾ miles southeast of Jamaica, on the north side of a road crossing and north of the "covered bridge" over West River, cuts a series of beds of schist, micaceous quartzite, and marble that strike N. 25° E. to N. 20°–25° W. and dip 25°–30° S. 65° E. to S. 65° W. (See locality 40, fig. 6, and Pl. II, *B*.) The beds occur in the following natural order.

Section in railway cut southeast of Jamaica, Vt.

	Feet.
Muscovite-quartz-biotite schist with plagioclase crystalloids (albite) exposed above the cut, also under the road crossing	20+
Muscovitic quartzite with some thinly foliated parts containing no mica. The foliation much plicated, transversely to adjacent beds[1]	18
Calcite and dolomite marble, thinly interbedded	2–5
Muscovite-quartz-biotite schist, like upper bed	5
Calcite and dolomite marble, thinly interbedded	70

About 450 feet east of the carriage bridge over the river, on the north side of the east-west road, the schist that overlies the highest member of the above section is finely exposed by recent blasting. It is a garnetiferous muscovite-quartz-hornblende-chlorite schist containing a little black tourmaline, graphite, and pyrite (specimens D, XXXIII, 47, a, c). Its thickness is probably considerable; the strike is N. 25° W. and the dip 20° N. 65° E.

[1] A sketch of these transverse plications will be found in U. S. Geol. Survey Sixteenth Ann. Rept., pt. 1, fig. 83, 1896. The rock might easily be mistaken for a granite gneiss.

About 600 feet north of the road crossing and 150 feet west of the track, opposite the north end of the marble cut, is a ledge of contorted banded muscovite gneiss or micaceous and feldspathic quartzite (specimen D, XXXIII, 48, a) with a foliation that strikes about like the marble but has a steep west dip. From its situation this rock appears to underlie the marble, although there is a short covered space between them. The marble beds crop out also at the river west of the track, near the south end of the cut.

The marble (specimens D, XXXIII, 40, a–e) consists of beds of more or less intensely rose-colored calcite marble from 0.5 to 1.5 inches thick and possibly thicker, alternating with beds of like thickness of white twinned dolomite marble. Streaks of mica occur at the junctions of many of the beds or form with quartz little darker beds here and there. George Steiger, of the United States Geological Survey, found that a specimen of this rose-colored calcite marble contains 0.23 per cent of manganese oxide, to which it evidently owes its color.

The calcite, with minute specks presumably of the manganese, has grain diameters of 0.18 to 2.2, mostly 0.74 to 1.48 millimeters, and thus belongs to grade 5 (coarse). The dolomite has grains, also twinned, measuring 0.07 to 0.37, mostly 0.11 to 0.26 millimeters, and is of grade 2 (very fine). These marbles contain some grains of quartz, microcline, scales of phlogopite, and a little pyrite.

Both the calcitic and the dolomitic bands take a high polish. This marble if obtainable in large and sound blocks would be well adapted for internal decoration on account of the pleasing contrast between the rose-colored and milk-white bands, but the rose color would not be durable under outdoor exposure.

Between locality 40 (fig. 6) and the next bridge north over West River, which is near Jamaica station, some of the same beds are finely exposed by the railroad cuts. At the foot of the knoll shown next to the letter A on the map, transversely plicated quartzite about 30 feet thick, banded with biotite, dips eastward under a thick mass of albitic biotite schist; and 200 feet to the south the quartzite is slightly calcareous and the schistose portions albitic. At a point about 550 feet south of the outlet of Adam Pond is transversely folded, more or less micaceous quartzite, 35 feet thick, containing slightly calcareous pinkish streaks. This mass appears to occur within the albitic schist. About a quarter of a mile farther south biotite-muscovite-albite schist with abundant quartz lenses containing rusty-weathering calcareous beds and lenses as much as 2 inches thick. At a point about two-fifths of a mile south of the outlet of Adam Pond the same schist contains small calcareous beds and a bed of bluish-gray dolomite up to 2 feet thick. All these occurrences indicate the association of dolomite and calcite marble with a gneissoid quartzite (with biotite, muscovite, and probably albite) and both belonging

within a great mass of albitic muscovite-biotite schist typical of the Hoosac schist. Before any quarrying operations are undertaken near locality 40 it will be necessary to determine how far the marble extends under the schist hill east of it.

Ball and Shatterack mountains originally formed a continuous schist mass but have been cut down 1,000 feet across the strike by West River in its meandering course. (See map, fig. 6.) East of Ball Mountain the river follows the strike and separates that mass from that of Turkey Mountain. Marble crops out in this vicinity at three points—along the east foot of Ball Mountain, in "Wheeler's pasture" (locality 54); recurring along the strike on the south bank of the river at locality 67; and about 1,000 feet east of the first locality, at the foot of Turkey Mountain, along the railway.

The "Wheeler's pasture" locality (54) is above a terrace, 120 feet above the river and about 1,000 feet west of it. Here dolomite strikes N. 25° W., dips 40° N. 65° E., and measures about 160 feet in width, which, if there is no duplication by folding, would make it 100 feet thick; but this includes two or three small quartzite beds. A bed of quartzite also underlies the dolomite on the west. A hundred feet higher, at the foot of the steep east slope of Ball Mountain, muscovite-biotite schist containing feldspars and garnets strikes N. 25° W. and dips 30° N. 65° E., apparently under the quartzite and dolomite. East of the dolomite, at the west side of the terrace, similar schist dips east, apparently overlying the dolomite.

The dolomite (specimen D, XXXIII, 54, b) is a glistening white to faintly cream-colored marble of twinned grains with diameters of 0.05–0.5 (one 0.87), mostly 0.125–0.25 millimeters, and is thus of grade 3 (fine). It contains a few grains of quartz and microcline and scales of muscovite. It weathers brownish, probably owing to a small content of iron carbonate. At one outcrop the dolomite includes small bodies of coarse calcite.

In following the strike of the dolomite north-northwestward to the river the dolomite is found to be cut off by large outcrops of mica schist that strike N. 25°–30° W. and dip 45° N. 65° E., and these continue 500 feet downstream, becoming more garnetiferous; but in following the strike south-southeastward marble is found on the south bank of the river at locality 67. The marble here strikes N. 25° W., dips 40° N. 65° E., and is exposed for a width of about 100 feet, which gives it a thickness of 65 feet. Apparently overlying it on the east is a fine-grained epidotic muscovite-biotite gneiss whose foliation strikes N. 10° E. and dips 45° E. Apparently underlying the marble on the west is a micaceous quartzite or gneiss striking N. 25° E. and dipping 35° S. 65° E. This is exposed for a width of 70 feet. A little farther west (locality 50) are large outcrops of feldspathic

muscovite-biotite schist like that at the east foot of Ball Mountain, striking N. 25° W. and dipping 45° N. 65° E.

This marble is in places a rather coarse rose-colored calcite (specimen D, XXXIII, 67, a), interbedded with a fine-grained white twinned dolomite, but some of the dolomite has bands and mottling of light bluish gray (specimen 67, b). In thin section the marble consists of mixed calcite and twinned dolomite in alternating minute beds and lenses. The calcite has grain diameters of 0.25–1, mostly 0.37–0.75 millimeter, and thus belongs between grades 3 (fine) and 4 (medium), and the dolomite has grains measuring 0.03–0.3, mostly 0.04–0.14 millimeter, and thus belongs in grade 2 (very fine). The bluish-gray tint of some of the bands and lenses is due to very minute nodules of magnetite, as shown by their high magnetism. Quartz and muscovite occur sparsely.

An unsuccessful effort was made to trace this marble belt farther south-southeast.

At the west foot of Turkey Mountain, just above the point where West River turns from a due south to a due west course, at the extreme eastern part of the curve known as the oxbow, there is another marble outcrop (locality 53, fig. 6). It extends 300 feet along the railway. As its strike of N. 40° W. makes a very acute angle with the track and the dip is east in plications, but these are crossed by joints spaced 4 to 12 inches apart striking N. 20° E. and dipping 15° W., the outcrop is misleading as to thickness, which probably does not exceed 30 feet.

The marble is a fine-grained white twinned dolomite with some small beds of rose-colored calcite. Specimen D, XXXIII, 53, a, from the river edge, shows the calcitic parts and contains some mica.

The dolomite at the north end is overlain by 10 feet of quartzite and that in turn by schist. In the river are large outcrops of muscovitic quartzite (specimen D, XXXIII, 53, b) containing small dolomitic beds up to 3 feet thick, both much plicated along the strike in folds whose axes pitch 35° E. These beds all underlie the marble.

Turkey Mountain is the long, little-incised ridge east of Ball and Shatterack mountains. Only the western base of it is shown on figure 6. On the west side of this ridge, about 550 feet above the river (a little east of the area mapped), is a longitudinal bench or hollow, about 600 feet wide from east to west, caused by the partial erosion of beds of dolomite between harder rocks above and below. At a point about 1¼ miles south of the Windham Township line this dolomite was burned for lime, as shown by the remains of a kiln and small quarries. The dolomite strikes N. 25°–30° W. and dips 45° N. 65° E. and forms a low ridge on the bench. Its thickness is at least 125 feet and possibly greater.

The dolomite of the southern opening (specimen D, XXXIII, 58, a) is of light cream-color with grayish streaks. It consists of twinned grains with diameters of 0.05–0.25, mostly 0.1–0.2 millimeter, and is thus of grade 1 (extra fine). It contains some quartz and muscovite. The dolomite from the northern opening (specimen 61, b) is of light bluish-gray tint, in places whitish, with light to very dark purplish plicated streaks, also with some faintly pinkish calcite lenses and a little muscovite here and there. The grains are twinned and measure 0.025–0.37, mostly 0.075–0.125 millimeter, and the stone is thus of grade 2 (very fine). The bluish-purplish streaks, as at locality 67, are due to minute bluish particles of magnetite.

The possibility of using these Turkey Mountain twinned dolomites as marbles is diminished by the presence in the northern opening of joints, which strike N. 35° E., dip 50° S. 55° E., and are spaced 2 to 12 inches apart.

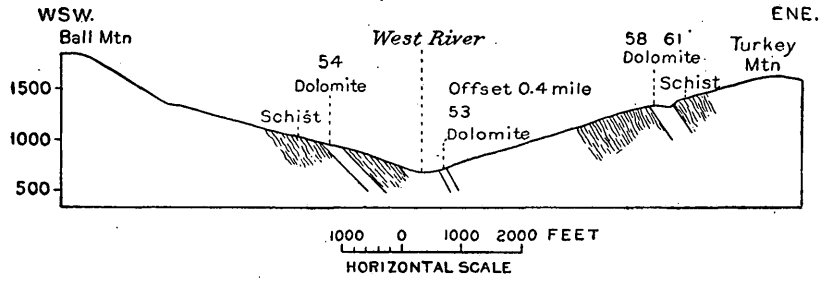


FIGURE 7.—Section between Ball and Turkey mountains, Jamaica, Vt.

At the east side of the bench is a cliff and talus of muscovite-chlorite schist, abounding in garnets and tourmaline, striking N. 25° W. and dipping 40° N. 65° E. On the west side of the bench are gneissoid rocks, apparently dipping under the dolomite at about 40°.

In ascending the Turkey Mountain ridge from locality 53 (see fig. 6) at the river to the bench the first satisfactory outcrops are found at 180 feet above the track. Here is a feldspathic biotite schist or gneiss with a foliation striking N. 10° E. and dipping 45° E. This becomes finer grained 200 feet higher and recurs 50 feet higher still, continuing thence to the bench, where it resembles a granite gneiss. All the observations between Ball and Turkey mountains have been brought together in a provisional section (fig. 7).

The lowest rock in the West River cut is probably the granite gneiss of locality 52 (fig. 6). Overlying that is probably the micaceous quartzite in the river at locality 53, followed by the dolomite, and this by the garnetiferous or feldspathic biotite-muscovite schists which form the east side of Ball Mountain, crop out near locality 54, and are cut by the railway at localities 50 and 51.

As schist occurs west of the dolomite at the foot of Ball Mountain and similar schist occurs east of that on the Turkey Mountain bench,

and as the dolomite and schist at both places dip eastward, these dolomite outcrops may belong to the opposite limbs of one or two westward-overturned anticlines. The limestone mentioned by Hitchcock [1] as occurring in South Windham may be a continuation of that on Turkey Mountain in Jamaica.

STRATTON.

Stratton Mountain and Haystack Mountain, south of it, are about 8 miles west of the strike of the marbles of Jamaica, along the axis of the Green Mountain Range. The marble in Stratton lies about 1½ miles east of the line connecting these summits, opposite a point about midway between them. It is 2½ miles southeast of the now deserted village of Stratton and about a mile west of the Wardsboro Township line (see fig. 8, locality 43), near a tributary of Whetstone Brook. The locality is shown approximately on Hitchcock and Hager's map of 1861.[2]

Lime was extensively manufactured a few years ago at a kiln one-fifth of a mile S. 45° W. of A. J. Pike's house. The quarry lies between the forks of a small brook, about a quarter of a mile S. 45° W. of the kiln and 100 feet above it.

Here about 60 feet of marble striking N. 55° E. and dipping 50° S. 35° E. is in contact both above and below with mica schist and has been quarried along the strike. The overlying schist (specimen D, XXXIII, 43, d) is a graphitic sericite-quartz-chlorite schist with garnets, black tourmaline, magnetite, and much limonite stain. The underlying schist (specimen 43, e) resembles the other but contains apatite and no graphite or tourmaline; in places it contains a feldspar.

The marble (specimens D, XXXIII, 43, a, b) consists of slightly bluish-white calcite marble, most of it alternating with beds 1 to 3 inches thick of fine-grained milk-white or pale-bluish dolomite. The calcitic part has grain diameters of 0.148–1.48, mostly 0.37–0.92 millimeters, and thus belongs to grade 5 (coarse). The dolomite consists of twinned grains with diameters of 0.05–0.25, mostly 0.07–0.175 millimeter, and is thus of grade 1 (extra fine). It is spangled with minute flakes of muscovite. The marbles contain a little quartz, rarely feldspar, and biotite. In thin section the demarkation between the calcite and dolomite beds is abrupt.

On the northwest side of the quarry the lower 5 feet of the marble is banded with rose-colored calcite marble (specimen 43, c) consisting of grains 0.18–1.85, mostly 0.37–1.1 millimeters, in diameter and thus of grade 5 (coarse). It has streaks of quartz, muscovite, and biotite. In the lower part of the marble there are also schistose portions (specimen 43, f) consisting of quartz, muscovite, biotite, chlorite,

[1] See Hitchcock, C. H., and Hager, A. D., op. cit., vol. 1, p. 556.
[2] See also their report, vol. 1, p. 555; vol. 2, pp. 613, 748.

carbonate, large porphyritic (plagioclase) feldspars, also apatite, epidote, pyrite, zircon, and black tourmaline, and inclusions of apatite, two micas, and quartz in the feldspars.

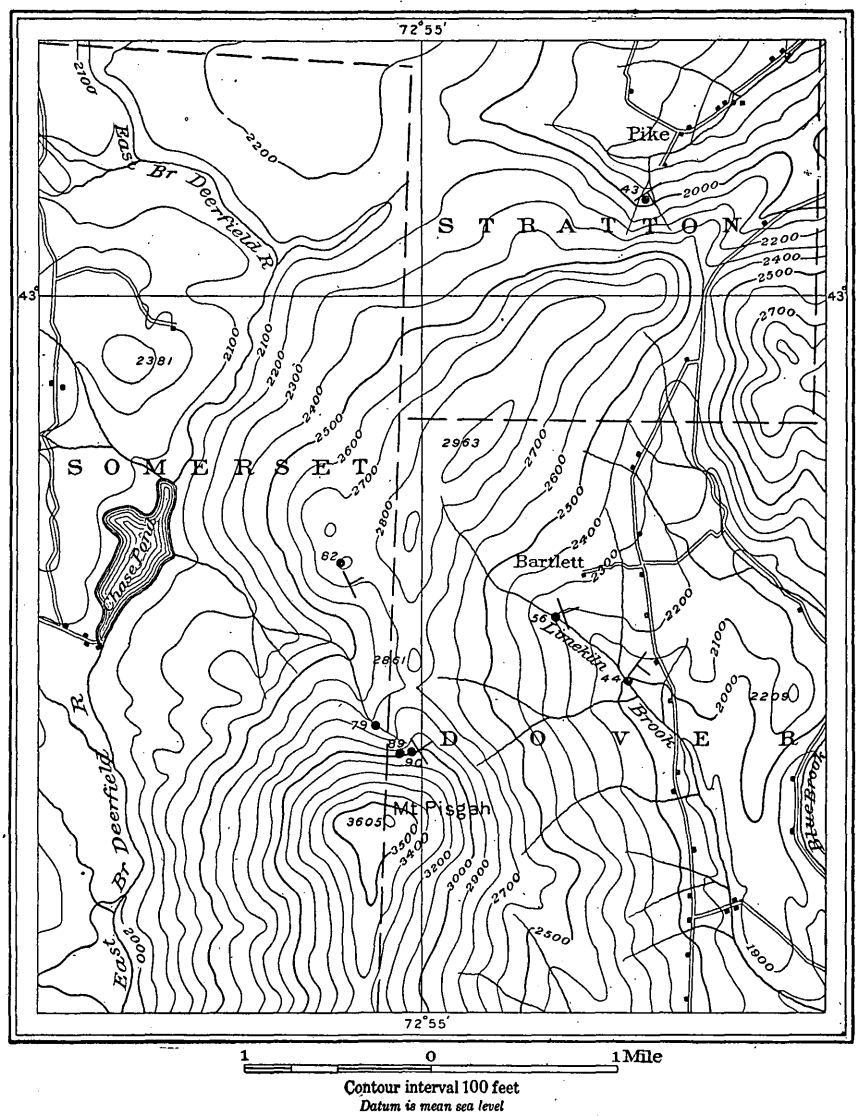


FIGURE 8.—Map of parts of Stratton, Dover, and Somerset townships, Windham County, Vt., showing marble deposits (•). From Londonderry and Wilmington topographic sheets, United States Geological Survey.

But for the slight differences between the schist on the east and west sides and between the upper and lower beds of the marble the structure here might be taken for an eroded compressed fold with inclined parallel sides.

As the dolomite here is twinned it is susceptible of high polish. The marble has been so shattered by the use of explosives that it is

impossible to tell whether the beds are sound enough to furnish solid blocks for decorative purposes.

In connection with the search for marble in Stratton, Kidder Brook, which rises on the east side of Stratton Mountain and flows into the North Branch of Ball Mountain Brook 2 miles west of Jamaica village, was explored in 1888 to a point 2 miles west of the Stratton-Jamaica line, but nothing except sericite schist was found.

DOVER.

Hitchcock and Hager's map shows two marble deposits in an area which was the extreme northern part of Wilmington but which, owing to changes in township lines, is now in the northwestern part of Dover.

One of these deposits is in the northern continuation of the Haystack Mountain mass on its east side on Limekiln Brook (locality 56, fig. 8), where lime was made many years ago. Although this outcrop is only 2¾ miles southeast of that in Stratton, there is a difference of 65°–95° in the strike of the two.

The marble, exposed for a width of about 47 feet, strikes N. 10°–40° W., dips 25° N. 67° E., and is at least 19 feet thick. It crops out on the east bank of the brook about a quarter of a mile S. 45° W. of the E. J. Bartlett farmhouse, 140 feet below it, and about 400 feet upstream from the kiln location. Another outcrop is reported on the west bank of the brook, which would make the thickness much greater. About 50 feet vertically above the marble and a few hundred feet up the brook are feldspathic mica schists that strike N. 10°–15° W. and dip 65° E., thus apparently underlying the marble. Graphitic muscovite schist like that in contact with the marble at locality 43, in Stratton, crops out about 1,200 feet west of the Bartlett house (locality 57), where it has a N. 33° W. strike and an undulating dip. This schist probably overlies the marble. Between the Bartlett sugar house and the brook, possibly 1,000 feet south of the house, is an amphibolite dike. Finally, in descending the brook half a mile from the marble, at locality 44, is a muscovite-biotite granite gneiss striking N. 35° E. and dipping 15° E., discordantly to the marble and its associated schist.

The marble (specimen D, XXXIII, 56, a, c) is coarse (grade 5) and rose-colored but contains some pale-greenish bands whose color is of uncertain origin and some whitish dolomitic bands and fine streaks of pyrite. It was not practicable to obtain perfectly fresh specimens. Considerable work would be necessary to obtain a complete exposure of the marble at this locality.

The other marble locality in Dover is close to the Somerset line on Mount Pisgah, the northern summit of the Haystack Mountain mass, 143 feet higher than Haystack itself. North of Mount Pisgah

there is a saddle at the 2,700-foot level, which was formerly utilized by a road that ran from Dover to the sawmills in Somerset. On the south side of this saddle, 450 to 500 feet below the summit, at about 3,605 feet, rises a brook that flows N. 25° W. into Chase Pond, in Somerset, which in 1914 was absorbed by the Somerset reservoir. On the 3,000-foot level and about 500 feet east of the Somerset line (locality 90, fig. 8) this brook crosses beds of white dolomite, about 50 feet thick, striking N. 25°–40° W. and dipping about 30° N. 58° E. A little farther west and 20 feet lower (locality 89) 10 to 15 feet of rose-colored calcite marble crops out in the woods. About 75 feet west of it are garnetiferous muscovite-graphite schists like those associated with the marble in Stratton and at Bartlett's. These schists form the steep mountain side west of the brook. They strike N. 25°–30° W. and dip 45° N. 63° E. and thus appear to underlie both calcite marble and dolomite.

The dolomite (specimens D, XXXIII, 90, a, b) is milk-white with grayish specks 0.1 inch across and 0.3–1 inch or more apart. The dolomite grains, rarely twinned, measure 0.037–0.296, mostly 0.074–0.185 millimeter, and the rock is thus of about grade 2 (very fine). The grayish specks consist of large dolomite grains (as much as 0.55 millimeter) crowded with very minute black particles, and of one or two quartz grains attaining 0.85 millimeter. The rock also contains sparse minute muscovite and minute black specks (pyrite?) that give rise to limonite stain.

The rose-colored calcite marble (specimens 89, a, b) has grain diameters of 0.18–1.66, mostly 0.37–1.1 millimeters, and is thus of grade 5 (coarse). It contains some small roundish quartz grains. The calcite is speckled, presumably with manganese oxide. The total thickness of this marble could not be determined.

The granular texture of most of the dolomite, probably preventing a high polish, the uncertainty as to the amount of the calcite marble, and the rather inaccessible location render this deposit of very doubtful economic value.

SOMERSET.

In descending the brook from locality 90 (fig. 8), on Mount Pisgah in Dover, to the 2,715-foot level in Somerset, a fork is seen to enter the brook from the west. At this point there is a ledge of weathered cream-colored calcite marble of texture grade 5 (coarse), striking N. 25° W. and dipping 50° N. 65° E. and having an exposed thickness of at least 10 feet. This is in the line of the strike of the rose-colored marble at locality 89, in Dover. Farther down the brook, near the road crossing (locality 80), schists like those west of the marble at locality 89 strike N. 25° W. and dip 50° N. 65° E.

A conspicuous low bluff between the 2,700-foot and 2,800-foot levels a mile northeast of Chase Pond is divided by a slight depression.

Two experienced local surveyors and woodsmen report "limerock" as cropping out between these two parts of the bluff. The schist of the southern outcrop (locality 82) has the same strike as that west of the marble on Mount Pisgah and dips 55° N. 65° E. Owing to the difficulty of orienting oneself in a cut forest on a mountain side where the topography is not bold, the writer failed in a day's excursion to find this "limerock," but he is not disposed to question its existence, as it would be in the line of the strike of the marble on Mount Pisgah.

Marble is also reported as having been found by a trapper in Somerset on one of the two masses between the East and West branches of Deerfield River, south of the road from Somerset to Dover.

WILMINGTON.

Hitchcock and Hager's map shows marble in the northwest corner of Wilmington Township near Haystack Pond. This was found by the writer. There is another outcrop of marble 1¾ miles west-northwest of Wilmington village, where lime was burned many years ago.

About 350 feet southeast of the south end of Mud Pond, the small pond south of Haystack Pond, on the 2,760-foot level, a gully, which evidently at times is one of the outlets of Mud Pond (locality 85, fig. 9), cuts beds of marble at least 100 feet thick, striking N. 25° W. and dipping N. 65° E. The south end of the low ridge east of Haystack Pond (locality 84) consists of biotite schist with albite feldspars and quartz lenses, having a N. 10° E. strike and a westward dip. As the schist of the summit presumably dips east under the marble, the latter may lie in the trough of a fold. It would not be surprising if the hollow that holds Haystack Pond were a syncline from which the marble had been largely eroded.

The marble (specimens D, XXXIII, 85, a–c) ranges from a cream-colored to a rose-colored calcite marble that has grain diameters of 0.11–1.48, mostly 0.26–0.74 millimeters, and is thus of grade 5 (coarse). It contains some quartz, biotite, zircon, magnetite (?), and small lenses of dolomite. While the quality of this marble adapts it to decorative uses and its thickness is adequate, the extent of the beds along the strike and their soundness require careful investigation.

As the strike corresponds with that of locality 85, 2 miles S. 25° E., this marble may crop out between the two places.

Marble occurs about 700 feet west of the W. S. Grimes farmhouse, on the 1,800-foot level, 1¾ miles N. 60° W. of Wilmington village (locality 83, fig. 9). Here dolomite and calcite marble with a N. 10°–35° W. strike and easterly dip crop out over a width of at least 120 feet and are succeeded on the east by a grass-covered area twice that width. A kiln, a little north of the outcrop, is reported as not having been used for 65 years. West of the marble is a garnetiferous

muscovite-quartz-chlorite schist (specimen D, XXXIII, 83, e) containing a little feldspar, tourmaline, and biotite, striking N. 35° W. in minor folds, and inclosing synclinal remnants of marble up to 16 inches thick with a southerly pitch. The schist thus clearly underlies the marble and may possibly inclose it.

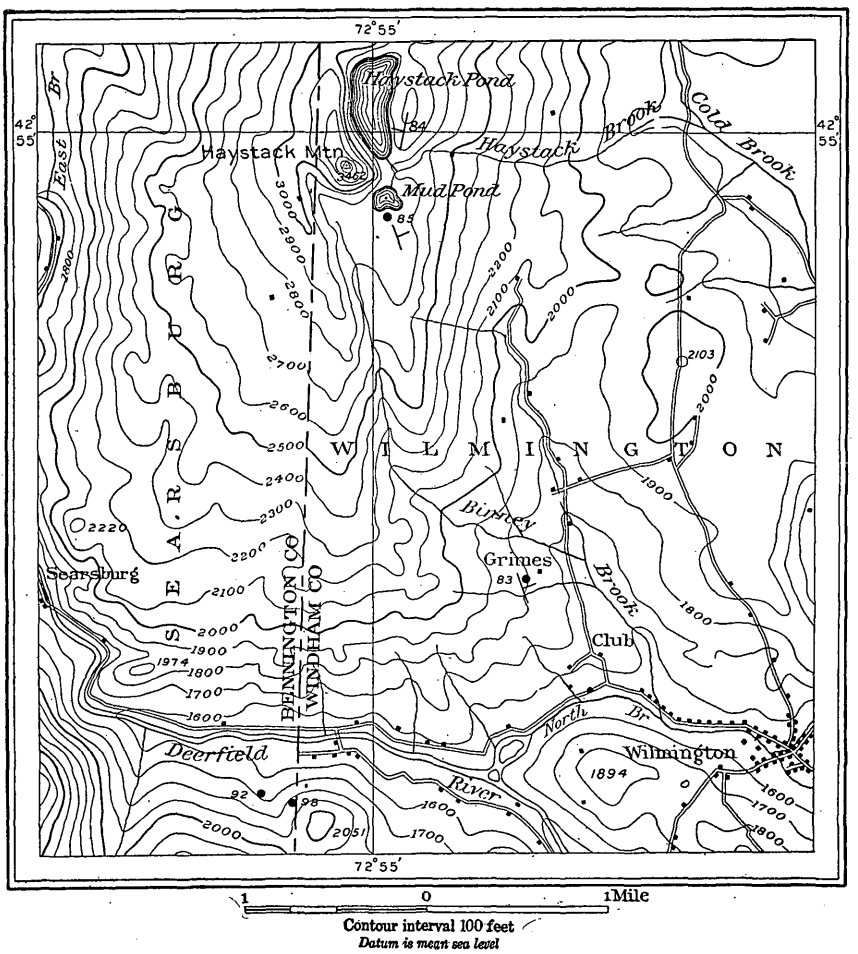


FIGURE 9.—Map of parts of Wilmington and Searsburg townships, in Windham and Bennington counties, Vt., showing marble outcrops (•). From Wilmington topographic sheet, United States Geological Survey.

The marble (specimens D, XXXIII, 83, b-d) consists of alternating little beds of fine-grained twinned milk-white dolomite marble and of coarse rose-colored calcite marble. The width of the beds varies from 1 to 1.5 inches. One specimen shows this series:

	Inch.
Calcite	0.6
Dolomite	1.0
Calcite	.1
Dolomite	0.1–.2
Calcite	.6

The calcite has grain diameters of 0.29–1.48, mostly 0.55–0.74 millimeter, and is thus of grade 5 (coarse). The dolomite has grain diameters of 0.05–0.35, mostly 0.12–0.2 millimeter, and is thus between grades 1 (extra fine), and 2 (very fine). Both marbles contain some quartz, and the dolomite contains some muscovite.

As the dolomite is twinned it takes a good polish, as does also the calcite. Pieces exposed about the opening for many years show a loss of color in the calcite bands. The exposures afford no clue as to the thickness of the deposit or the soundness of the beds. The fresh marble when polished must be very attractive.

WHITINGHAM.

Several deposits of graphitic and micaceous marble in Whitingham Township, shown on Hitchcock and Hager's map as "Azoic saccharoid limestone," were cursorily examined by the writer in 1888. Most of them have been utilized for lime. (See map, fig. 10.)

One of these deposits (locality 38, fig. 10) is three-fourths of a mile S. 25° W. of Whitingham village. The kiln is west of the brook, but the outcrop is east of it. The marble (specimen D, V, 38, a) is a calcite marble of grain diameters 0.18–2.2, mostly 0.74–1.48 millimeters, and thus of grade 5 (coarse). It abounds in scales of phlogopite, from 0.1 to 0.6 inch across, and contains some graphite, quartz grains, and rarely actinolite. Another specimen (D, V, 38, b), equally coarse, is free from mica and graphite but carries numerous minute prisms of actinolite.

At a point 2 miles S. 25° W. of Whitingham village (locality 40), about 1,000 feet south of the east-west road, are some old quarries which supplied Kenfield's limekiln, near the road. Some of the rock is a white calcite marble with twinned grains 0.25–1.25, mostly 0.37–1 millimeter in diameter and is thus of grade 4 (medium).

Marble recurs about a quarter of a mile S. 25° W. (locality 54), on both sides of the southeasterly road, where it was also burned.

In the railroad cut south of Lime Hollow, opposite the point where a carriage bridge crossed Deerfield River in 1888 (locality 41, fig. 10), marble is exposed on the east side of the track for over 100 feet, the beds striking N. 10°–22° W. and dipping on the average 45° N. 75° E. Parallel to the bedding at irregular intervals are five schistose beds, 1 foot, 1 foot 6 inches, 2 feet, 2 feet 6 inches, and 3 feet thick, respectively. The widest space of clear marble between them is 88 feet, amounting to 62 feet measured vertically to the dip. The schistose beds are made up of a bronze-colored micaceous plicated amphibolite, consisting of hornblende, biotite, chlorite, muscovite, plagioclase, magnetite or ilmenite, pyrite, apatite, zircon, and carbonate (specimens D, V, 41, c–e), and are evidently metamorphosed basic dikes.

The marble (specimen D, V, 41, a) is a whitish calcite marble with grayish streaks abounding in graphite scales up to 0.2 inch across, lying parallel to the bedding. The calcite has grain diameters of 0.18–1.66, mostly 0.37–1.1 millimeters, and is thus of grade 5 (coarse). Some of the twinning planes are flexed. A little quartz, pyrite, and actinolite are present.

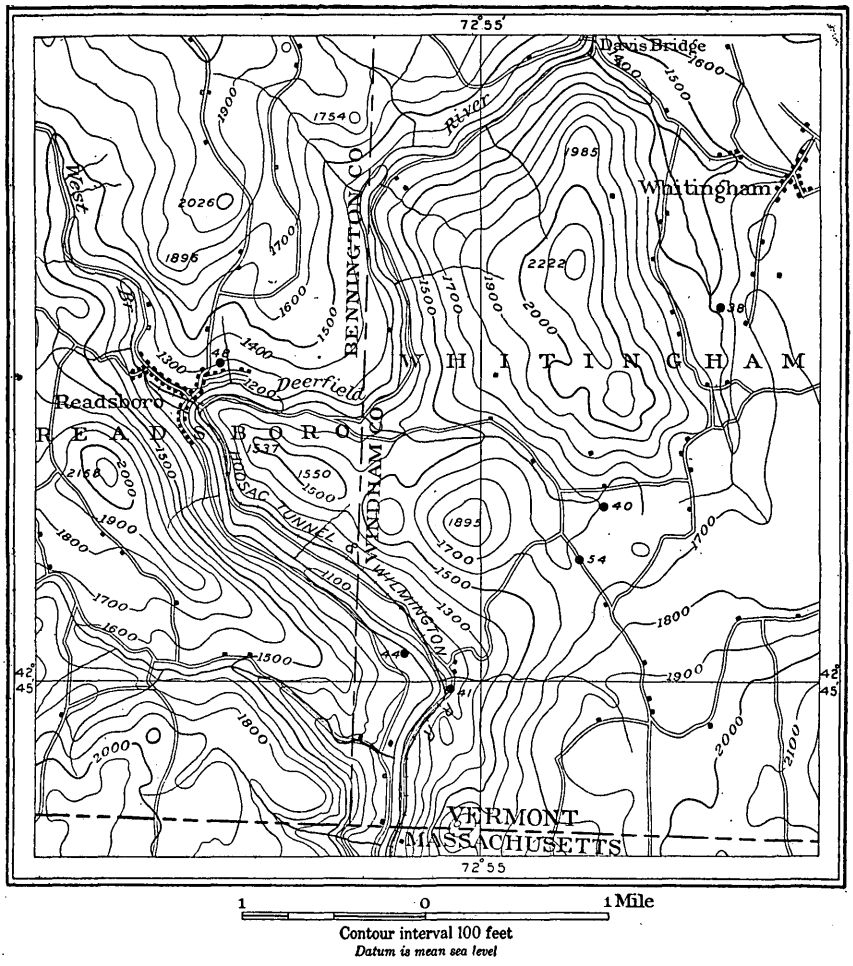


FIGURE 10.—Map of parts of Whitingham and Readsboro townships, in Windham and Bennington counties, Vt., showing marble outcrops (•). From Wilmington topographic sheet, United States Geological Survey.

In ascending from the railroad eastward the marble is traced up a small knoll and the west side of a ravine east of it. On the steep slope east of the ravine schist or gneiss, with an eastward-dipping foliation, crops out at a point 350 feet above the railroad and again higher up.

On the west bank of Deerfield River, about 1,000 feet north of the bridge abutment above the second river terrace (locality 44),

graphitic marble crops out, and about 500 feet west of the river and a little west of the marble albitic schist strikes N. 20° E. in minor folds. The relation of the schist to the marble is not clear.

BENNINGTON COUNTY.

SEARSBURG.

The marbles of Wilmington recur in the adjoining township of Searsburg, in Bennington County (localities 92, 98, fig. 9), less than 2 miles east of their strike. The localities are on both sides of a small north-south hollow through which a brook flows northward into Deerfield River, about a quarter of a mile west of the Searsburg-Wilmington line and a third of a mile south of the river, in the pasture of the W. C. Wheeler farm. West of the brook the outcrops indicate a width of 280 feet and a possible maximum thickness of 200 feet of dolomite and calcite marble. In contact with them on the west is an albite diorite schist (specimen D, XXXIII, 93, a) consisting of biotite, albite (full of inclusions of quartz and biotite), quartz, carbonate, pyrite, and zircon. Its foliation strikes N. 5° E. and dips 60° E.

A bowlder of this albite diorite schist occurs in Wilmington about a quarter of a mile N. 55° E. of the W. S. Grimes house (locality 83, fig. 9) on the east bank of a brook west of the road and about 100 feet above the village, showing that the rock probably crops out on the Haystack Mountain mass, which lies in the course of the ice motion.

A space of about 225 feet east of the brook seems to be occupied by various schists more or less albitic; then follows 20 feet of dolomite striking N. 25°–35° W. and dipping 45°–60° N. 60° E., and in contact with it, about 245 feet east of the brook, is a garnetiferous muscovite schist containing chlorite, two or three feldspars, tourmaline, and magnetite. This schist forms a 40-foot cliff and in places gives way to a fine-grained biotite-muscovite gneiss. This little cliff forms the west side of a bench which is 200 feet wide. Here dolomite and calcite marble again appear in a belt about 50 feet wide, with schist east and west of it. The schist on the east contains feldspar crystalloids. It strikes N. 30°–35° W. and dips N. 60° E. at a low angle, apparently overlying the marble. The schist on the west is like that at the north end and west foot of the cliff and seems to underlie the marble on its west side. On the north this bench passes into a gully, and the marble is bordered on both sides by feldspathic schist. The schist on the west side strikes N. 25°–30° W. and has plications 8 to 10 inches wide with a general vertical dip, containing remnants of dolomite folds. The garnetiferous schist crops out within a few feet of the feldspathic schist on the west, and both prob-

ably merge a little farther north. These stratigraphic data are combined in a tentative section, shown in figure 11.

The marble of the bench (specimens D, XXXIII, 98, a, b) consists of cream-colored dolomite with small beds of rose-colored calcite marble, but some of the calcitic beds are slightly dolomitic. The rock contains some little biotitic beds. The calcite has grain diameters of 0.18–1.48, mostly 0.55–1.1 millimeters, and is thus of grade 5 (coarse), and the dolomite plates, mostly twinned, measure 0.07–0.25 and even 2.59 millimeters, or from very fine to extra coarse. The accessory minerals are quartz, plagioclase, microcline, muscovite, biotite, and magnetite.

The thickness and extent of this deposit and the character of the beds would have to be determined to obtain a basis for economic forecasts.

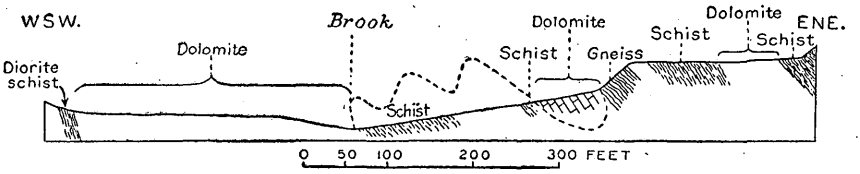


FIGURE 11.—Tentative section across marble and schist in W. C. Wheeler pasture, Searsburg Township, Bennington County, Vt.

READSBORO.

About a quarter of a mile north of the Readsboro dam, on the north side of Deerfield River (locality 48, fig. 10), a graphitic, micaceous calcite marble like that of Whitingham (localities 38, 41, p. 49) was formerly quarried and burned for lime. It strikes N. 25° E. and dips west in minor folds. About 45 feet north of the marble is a high ledge of plicated schist having the same strike but an easterly dip. This ledge at the base is biotitic with large disseminated feldspars, presumably albite. Higher up it is muscovitic and in the center it incloses a small marble bed, the schist being thus clearly a metamorphic sedimentary rock. These schists continue up the hill eastward to a level 250 feet above the marble quarry.

ESSEX COUNTY.

Jackson[1] and Cutting[2] reported the occurrence of dolomite in Essex County. Jackson says:

> In Lunenburg, Vt., I visited a tract of land belonging to Col. White, where a blue and gray limestone is found in abundance, but is not sufficiently rich to make good lime, although it may serve a useful purpose in agriculture. It contains nearly 50 per cent of carbonate of lime but is liable to melt into slag in burning, on account of

[1] Jackson, C. T., Final report on the geology and mineralogy of the State of New Hampshire, Concord, N. H., pp. 147, 160, 177, 1844.

[2] Cutting, H. A., Natural history of Essex County: Gazetteer of Vermont, edited by Abby Maria Hemenway, volume for Essex County, pp. 1051, 1052, Burlington, 1867.

the formation of fusible silicates of lime, alumina, and oxide of iron. By careful burning it will make a tolerably good hydraulic lime. This limestone occurs on the east side of the hill, near a pond, is stratified, and runs N. 30° E., S. 30° W., and dips northwest. It is N. 30° W. from Lunenburg meetinghouse, and on the west side of the pond. The top of the hill is composed of a greenish clay slate of the Cambrian system and dips 50° NW. * * *

Crossing the Connecticut River at Lancaster, we came to Lunenburg, Vt., where a bed of limestone was formerly examined. The principal rocks in this town are mica slate, the strata of which dip very boldly to the northwest, and a greenish Cambrian clay slate, with a less steep inclination to the northwest, and occupying the summit and side of a steep hill, where a bed of blue limestone occurs embedded in the slate. * * *

Limestone from Col. White's quarry, Lunenburg, Vt., second bed, grayish blue, 100 grains yielded:

Siliceous matter	40.6
Carbonate lime and magnesia	47.6
Peroxide iron and alumina	11.0
	99.2
Loss	.8
	100

Cutting describes the dolomite as follows:

In the southern portion of Concord there is a dike of magnesian limestone that is traceable in a straight line nearly 3 miles, varying from 2 to 6 feet wide. * * *

In the northern part of the town there are considerable deposits of limestone, yet not sufficiently pure for the manufacture of lime and probably belonging to this same talcose formation. On Miles Mountain are several caves in this rock, some of them quite small and some possessing considerable size. * * *

[In one of these caves visited by him] there were small stalactites hanging from the rock overhead—some of the longest about 3 inches. * * * There is also in the northern part of Lunenburg a cave in the same formation, nearly like the one I have described, only perhaps not so large, and one much larger than either in Maidstone. The limestone in this section has been analyzed: Silica 40.5; carbonate of lime and magnesia 51.3; oxide of iron and loss 8.

The writer endeavored to find the Lunenburg and Concord localities with these results: About 3 miles N. 15° W. from Lunenburg village and 400 feet above it, on Pond Hill, N. 65° E. from Mount Tug and N. 5° W. from Baldwin Hill, on the Elijah Blood farm (formerly Woods farm) is a large outcrop of fine-grained quartzite (specimen D, XXXIV, 87, a) that contains microscopic sericitic beds with biotite and chlorite, also similar beds an inch or so thick of very quartzose, finely plicated chloritic sericite schist containing biotite and magnetite, striking N. 60° E. About half a mile north of this ledge is a ridge of very quartzose, chloritic, pyritiferous sericite schist (specimen 87½, a), striking north and dipping 45° W., on the east side of which is a shallow hollow and talus and one or two small openings in the ledge but no indications whatever of any calcareous rock.

In Concord about half a mile west of a conspicuous saddle in the crest of Miles Mountain, on a shoulder of the mountain, 700 feet above

and roughly 1¼ miles N. 23° W. of Miles Pond station, is a well-known cave about 25 by 5 to 10 feet and 4 feet in height. The roof, which strikes N. 45° E. and dips 35° N. 45° W., has in places a whitish incrustation and stalactites half an inch or less in length. Some of this material effervesces with dilute hydrochloric acid and some does not. The rock of the cave (specimen D, XXXIV, 88, f) is a brecciated biotite granite gneiss with a sericitic cement winding in and out between the feldspar and quartz fragments, and without carbonate. It strikes N. 45° W. and dips 65° N. 45° E. Another part of the same ledge (specimen 88, d) is a fine-grained biotite quartz schist, with muscovite plates inclosing quartz and biotite particles. This schist is cut by little dikes about an inch thick of biotite granite containing much plagioclase. The rock near the mouth of the cave is cut by other little dikes(?) altered to exceedingly fine-grained feldspathic biotite schist in which garnets have formed about the other minerals.

Other ledges in the vicinity consist of an exceedingly tough, finely foliated, in places garnetiferous biotite gneiss striking N. 25° W., dipping 52° S. 65° W., and cut by little dikes of granite (specimen 88, e). Many of the glacial bowlders south of the cave are granite containing basic segregations and also inclusions of a dark schist with foliation and bedding planes. The surface in the vicinity of the cave is pitted from the falling in of small caves, the cause of which is problematic. No trace of dolomite was found, and even the thin sections fail to show carbonate. The calcareous parts of the incrustations may have come from the carbonate arising from the alteration of plagioclase in the granite dikes or from a very minute amount of carbonate in parts of the schist.

Further explorations may result in the rediscovery of the locality described by Jackson.

GENERAL PETROGRAPHIC CHARACTER OF THE MARBLES AND DOLOMITES.

The calcite marbles of eastern Vermont are generally of medium, coarse, or very coarse texture. Some carry scales of graphite and mica or of specular hematite. Several are rose-colored from a very small content of manganese oxide. Some are greenish from actinolite or epidote. Most of the rose-colored marbles are interbedded with white dolomite, usually twinned. The gray calcite marbles of Orange County and the blue-black of Bethel, in Windsor County, are distinguished from the others by their large percentage of quartz. Some of the dolomites, especially those of Plymouth, are pinkish from hematite or manganese oxide or grayish from graphite and are brecciated. The dolomite of Mendon is pure white; that of Hancock and of Mount Tabor is cream-colored to buff from siderite.

The presence of iron sulphide, or of iron carbonate also, in the quartzose marbles producing a rusty discoloration; the excessive jointing in others (Mendon); the presence of manganese oxide in others, producing a rose tint that is liable to fade on outdoor exposure; and the inconsiderable quantity of still others (Moretown and Waterville) will prevent nearly all these marbles from being used for external construction or decoration. Their economic adaptations are given on page 65.

CLASSIFICATION.

In the following table all the marbles and dolomites described in the foregoing pages are grouped by their chief characteristics, with page references to the descriptions. They fall into 20 varieties of marble based on differences of color or combinations of colors, on differences of texture, or on the minerals they contain. These minerals include a red manganese oxide, red hematite, metallic hematite, magnetite, pyrite, chalcopyrite, malachite, siderite, limonite, graphite, quartz, several feldspars, muscovite, biotite, phlogopite, chlorite, epidote, actinolite, apatite, zircon, and a mineral of the humite group. The variation in texture is extreme, ranging from grade 1 (extra fine), with an average grain diameter of 0.06 millimeter, to grade 6 (extra coarse), with an average diameter of 0.5 millimeter, or from a minimum of 0.02 millimeter to a maximum of 2.5 millimeters. Some of the dolomite is granular and some of it is twinned.

Classification of the calcite marbles and dolomites of eastern Vermont.

	Locality.	Township.	County.	Texture, grade.	Described on page—
Calcite, cream-white, mottled with gray.	75	Moretown	Washington.	4,2	14
Calcite, white	80	Waterville	Lamoille	5	12
Calcite, white to pink with light and dark-green bands.	86	Richford	Franklin	4	10
Calcite and granular dolomite with interbedded sericite schist.	68	Rochester	Windsor	2,1	23
Calcite, rose-colored, interbedded with white twinned dolomite.	73,40,53	Jamaica	Windham	a5	37,39,41
	83	Wilmington	do	b2	48
Calcite, rose-colored, with greenish actinolite bands.	42	Athens	Windsor	5–6	35
	41	Townshend	do	5–6	36
	36	Weathersfield	do	6	32
Calcite, grayish (metallic Fe_2O_3), interbedded with white twinned dolomite.	34	do	do	a6 b3	32
Calcite, rose to cream colored, with but little interbedded dolomite.	89,56	Dover	Windham	5	45
	85	Wilmington	do	5	47
	53	Mount Holly	Rutland	6	22
Calcite, white, interbedded with white twinned dolomite.	43	Stratton	Windham	a5–6	43
	35	Cavendish	Windsor	b1, 2, or 4	31
Calcite, whitish, with large scales of graphite and mica.	38,41 (of 1888), 48(of 1888)c	Whitingham Readsboro	Windham Bennington.	5 5	49,50 52
Calcite, grayish, with fine graphite, muscovite, pyrite, much quartz.	3, 9, 10	Washington	Orange	3	17,19
Calcite, like above, but with fine light and dark gray plicated beds.	1	Topsham	do	3	15

a Calcite.
b Dolomite.
c As some of the explorations were made in 1888, others in 1911 and 1912, there was a duplication of locality numbers.

Classification of the calcite marbles and dolomites of eastern Vermont—Continued.

	Locality.	Township.	County.	Texture, grade.	Described on page—
Calcite, bluish black, containing graphite, muscovite, and much quartz. Probably sideritic.	71	Bethel	Windsor	2	23
Dolomite, white or whitish, granular or with very few twinned grains.	108	Ludlow	do	1	28
	90	Dover	Windham	2	46
	58	Jamaica	do	1	42
	46	Mendon	Rutland	1	20
Dolomite, white, twinned	38	Cavendish	Windsor	2	30
	54, 74	Jamaica	Windham	2–3	38, 40
	37	Weathersfield	Windsor	3	34
	51	Mount Holly	Rutland	6	22
Dolomite, white, twinned, with faint purplish spots (MnO, Fe_2O_3).	18	Plymouth	Windsor	2	27
Dolomite, white, twinned, with fine purplish lenses and streaks (Fe_3O_4).	61, 67	Jamaica	Windham	2	41, 42
Dolomite, pinkish, twinned (Fe_2O_3 or MnO).	14, 20	Plymouth	Windsor	2	27
Dolomite, gray, graphitic, with small brecciated white dolomite beds, both granular.	11	do	do	1	24
Dolomite, cream-colored, granular, some twinned grains.	65	Mount Tabor	Rutland	2–4	21
	70	Hancock	Addison	2	20

STRATIGRAPHIC RELATIONS.

The relations of these various marble beds are evidently complex and some are very different from others. Their geologic positions can not be satisfactorily determined without extensive areal geologic work. All that can be done here is to bring together the more important stratigraphic data, draw such inductions as they justify, and show the relation of these results to what is established in Vermont geology. Each belt or group of localities will be taken up separately.

In Richford (p. 10) about 100 feet of white calcite marble with pinkish and greenish portions lies between parallel, steeply inclined beds of more or less graphitic sericite schist. The impregnation of the marble along joint and bedding planes with chalcopyrite may possibly indicate its having been overlain by the impervious schist and thus its anticlinal structure.

In Waterville (p. 11) coarse white calcite marble, about 62 feet thick, dips somewhat steeply between parallel beds of more or less graphitic sericite schist, some of it albitic.

In Johnson (p. 12) 11 to 70 feet of fine to medium whitish calcite marble is underlain by sericite schist and contains a large lens consisting mainly of secondary albite.

In Moretown (p. 14) medium-grained white to cream-colored calcite marble, 10 feet thick, with grayish clouds, dips steeply between parallel beds of sericite-chlorite schist with minute quartzose beds.

All these marbles are intimately associated with sericite schist, in Johnson the schist clearly underlying the marble and in Richford possibly overlying it.

In Hancock (p. 20) cream-colored sideritic granular dolomite, 25 feet thick, underlies (presumably by overturn) a fine banded musco-

vite granite gneiss and overlies (also by overturn) a slightly dolomitic chlorite-muscovite-quartz schist.

In Rochester (p. 23) a few feet of calcite marble mixed with dolomite and containing epidote is finely interbedded with sericite schist. The schist overlying this marble on the east resembles that along the base of the hill below the dolomite in Hancock. This marble is also associated with and probably underlain by several feet of epidote schist.

In Mendon (p. 20) 50 feet or more of white granular dolomite occurs in undetermined relations.

In Mount Tabor (p. 21) cream-colored granular dolomite, 20 feet thick, underlies 30 feet of more or less muscovitic quartzite, and both occur but a few hundred feet away from and a little above a considerable thickness of pre-Cambrian banded biotite-muscovite granite gneiss (Devils Den). Both series have the same strike but dip in opposite directions and are probably unconformable.

In Mount Holly (p. 22) white coarse twinned dolomite, 24 feet thick, dips at a medium angle, and sericite-biotite schist occurs above and below it. A few hundred feet south coarse cream-colored calcite marble, about 18 feet thick, is in contact on one side with and possibly underlain by what appears to be a fine-grained hornblende granite gneiss.

In Plymouth and Ludlow (pp. 24, 28) fine-grained twinned white or pinkish or granular gray dolomite, from 50 to 75 feet thick, lies within a mass of more or less quartzose and feldspathic mica schist and appears to be in disconnected lenticular masses. At one point (locality 25, p. 26) interbedded dolomite, rose-colored and smoke-colored calcite marble, and quartzite, in all about 20 feet thick, underlie a considerable thickness of sericite schist and overlie a like thickness of quartzitic biotite-muscovite schist. The dolomite beds are intimately associated with a schist formation.

In Stratton (p. 43), nearly 8 miles S. 60° W. of the Jamaica locality 73, coarse white calcite and fine dolomite marble, both twinned, about 60 feet thick, including a few feet of rose-colored calcite marble, are both overlain and underlain by muscovite schist having a dip of 50°, in monoclinal, synclinal, or anticlinal attitude.

In Dover (p. 45), at Bartlett's, rose-colored calcite marble, over 19 feet thick, appears to be both underlain and overlain by muscovite schist, striking N. 10°–40° W. Half a mile southeast of the marble and about 200 feet below it is muscovite-biotite granite gneiss with a foliation striking N. 35° E., unconformably to the marble. On Mount Pisgah about 50 feet of white granular dolomite and at least 10 to 15 feet of rose-colored calcite marble appear to be underlain by muscovite schist (p. 46).

On Haystack Mountain, in Wilmington (p. 47), cream-colored to rose-colored calcite marble, at least 100 feet thick, is probably underlain by biotite schist containing porphyritic feldspars. Near the village, along the strike (p. 47), interbedded rose-colored calcite and white dolomite marble of undetermined thickness are underlain by muscovite schist.

In Readsboro (p. 52), about 8 miles S. 23° W. of the locality last mentioned, is a coarse calcite marble, containing large scales of graphite and mica, associated with a biotite-muscovite schist that contains porphyritic (albite) feldspars. The strike points toward the marble of Wilmington (N. 25° E.), although that has a strike of N. 10°–35° W. Southeast of Readsboro, $1\frac{3}{4}$ miles down Deerfield River (localities 44, 52, p. 50), graphitic calcite marble again appears, associated with feldspathic schist striking N. 20° E. At locality 41 in this township the calcite marble contains five small basic dikes, altered to micaceous amphibolite and about parallel to the bedding of the marble.

The outcrops in Searsburg (p. 51) belong to a belt a little west of the Wilmington belt. Calcite and dolomite marbles, 50 feet or more in thickness, are both underlain and overlain by mica schist, as shown in the section (fig. 11), but at one point these marbles are underlain by a mass, probably a dike, of mica diorite schist, and at another they are in contact with a biotite-muscovite granite gneiss.

The induction from all these observations is that at the north, on the west side of the Green Mountain axis (Richford, Waterville), and also 26 miles south of Waterville (Moretown), on the east side, calcite marbles occur associated with a schist formation. In Hancock granular dolomite overlies a granite geiss and underlies a schist. In Mount Tabor, on the Green Mountain Range, such a dolomite, associated with quartzite, overlies a granite gneiss, and in Mount Holly a calcite marble overlies a granite gneiss, and a dolomite marble near by is associated with a schist. East of the axis, in Plymouth and Ludlow, 25 to 100 feet of dolomite or of calcite marble or of both interbedded lies within a muscovite or biotite schist formation of considerable thickness, which in places is quartzitic. These calcareous deposits seem to occur as lenses at irregular intervals within the schist. Finally, at the south, east of the axis (Stratton, Dover, Wilmington, Readsboro, Whitingham), rose-colored or white calcite marbles interbedded with dolomite are intimately associated with schist of sedimentary origin, and in Searsburg these rocks are in contact with granite gneiss and in Dover are not far from the gneiss and have a different strike.

The Jamaica localities show 70 to 125 feet of dolomite and calcite marble, in some places with some interbedded quartzite, in others

with a few feet of quartzite at both the top and the bottom, the whole both underlain and overlain by muscovite-biotite schist of sedimentary origin. In some localities, however, the marble is in contact with a transversely folded micaceous quartzite, either underlying it or, probably by an overturned fold, also overlying it. The marble apparently occurs in lenses, the schist from either side joining to cut it off.

In the belts east of the Jamaica belt the marble is intimately related to gneiss, possibly of granitic origin, although schist of sedimentary origin is generally also present in the more northern localities.

In Townshend (p. 36) there may be 50 feet of coarse calcite marble, in places actinolitic, in others chloritic, with biotite granite gneiss on both sides.

In Athens (p. 35) there may be 50 feet or more of coarse calcite marble, in places actinolitic or biotitic, with biotite granite gneiss on both sides of it.

In Cavendish (locality 140, p. 28) the marble underlies, probably through overturn, and thus really overlies a granite gneiss, and is also overlain by a mica schist. At locality 38 (p. 29) 10 to 15 feet of white dolomite is both underlain and overlain by granite gneiss. In the gorge (p. 30) dolomite and calcite marble, about 75 feet thick, are in similar relations to granite gneiss. At locality 139 (p. 30) about 15 feet of dolomite is in like relations. At locality 35 (p. 31) the calcite marbles appear also to occur within granite gneiss.

In Weathersfield (locality 36, p. 32) coarse rose-colored and actinolitic calcite marble appears to be inclosed in coarse muscovite-biotite schist containing porphyritic feldspars and beds of quartzite(?). Pegmatite dikes lie in the foliation, and a large intrusive mass of very coarse pegmatite is near by. At Amsden (locality 34, p. 32) coarse calcite marble not less than 45 feet thick, with finely interbedded dolomite and containing some specular iron ($Fe_2 O_3$), in places also actinolite, appears to be overlain by feldspathic mica schist. At locality 37 (p. 34) dolomite over 30 feet thick is in contact with overlying feldspathic muscovite-biotite schist and appears to be also underlain by similar schist. At locality 142 (p. 34) 10 to 40 feet of dolomite is both underlain and overlain by such schist.

In the Orange County belt of marble the quartzose calcite marbles of Washington and Topsham (pp. 15, 17), of uncertain thickness, but certainly 20 and 35 feet thick, are associated with more or less calcareous mica schist and are cut by dikes of pegmatite and biotite granite. This belt continues into Bethel Township, in Windsor County, where the marble is more graphitic and occurs in beds 2 to 5 feet thick in a graphitic sericite schist.

GEOLOGIC AGE.

All but one of these deposits are unfossiliferous and the smallness and discontinuity of the areas examined prevent their definite assignment to geologic periods, yet whatever indications as to age they do afford are here given.

The granite gneisses upon which some of the marbles seem to have been deposited and with which they are interfolded are presumably of pre-Cambrian age. The presence of a mineral that is probably of the humite group in the marble of Townshend (p. 36) and in the diopside schist that is interfolded with the marble of Athens also points to the great age of the marble of those places. The relation of the gneiss associated with the marble in the northern part of Cavendish has been shown by Daly.[1] If the interfolding took place prior to the deposition of the Cambrian beds the interfolded marbles are also of pre-Cambrian age, but if the interfolding was due to a crustal movement that occurred at the close of Ordovician time then the marbles belong to the earliest Cambrian sediments. That calcareous sedimentation took place in pre-Cambrian time within the area of the Green Mountain Range has been shown by the occurrence of an inclusion of marble with a reaction rim in the pre-Cambrian gneiss east of Mount Moosalamoo, in the town of Ripton. This determination was made by Arthur Keith in 1908. It seems probable that the marbles of Athens and Townshend, at least, possibly some of those of Cavendish and Weathersfield, and that of Mount Holly are pre-Cambrian.

The granular dolomite of Mount Tabor associated with quartzite and at a higher level than the neighboring pre-Cambrian gneiss of the Devils Den may easily be of Lower Cambrian age, as is the quartzite along the west foot of the range cut by Big Branch. The dolomites of Plymouth occur in a schist mass that is in close proximity to a quartzite and quartz conglomerate.

During a reconnaissance made in 1888 the writer observed on the west side of the Green Mountain axis, in the township of Shrewsbury, the Lower Cambrian conglomerate in contact with a large mass of muscovite (sericite) schist containing some calcareous streaks. In 1899, while exploring Downer Glen, on the west side of the Green Mountain Range in Manchester, the writer found schist up to 75 feet thick, some of it biotitic, associated with the Lower Cambrian quartzite. This schist occurs also at several other points on that side of the range, as well as on the intermediate ridge west of the Vermont Valley. The schists of Plymouth may therefore be of Lower Cambrian age.

The marbles that at various points (Dover, Searsburg) lie upon granite gneiss and are conformably overlain by schist of sedimentary origin may for the same reason also belong to the Lower Cambrian.

[1] Daly, R. A., The geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, Pl. VII, p. 17, 1903.

The Berkshire schist (Ordovician), which overlies the marbles of the Vermont Valley, includes here and there in Vermont and Massachusetts small areas of marble and in Vermont some thick beds of quartzite. On Mount Greylock, in Massachusetts, this formation includes an area several miles in length and width of dolomite and quartzite of variable thickness (25 to several hundred feet) and also of irregular continuity, schist taking the place of both rocks at intervals. From the foregoing facts and the occurrence of Cambrian schists west of the Green Mountain axis it follows that the schist that overlies, underlies, or incloses calcite and dolomite marbles in Richford, Waterville, Johnson, Stratton, Dover, Wilmington, Whitingham, and Readsboro may belong either to the Lower Cambrian or to the Berkshire schist (Ordovician) and probably is the Hoosac schist of Survey Monograph XXIII. The age of these last-named marble deposits will probably not be fully determined until the reason for the absence of the Ordovician marble of the Vermont Valley east of the axis of the Green Mountain Range has been ascertained by further geologic mapping.

The quartzose calcite marbles of Topsham and Washington belong to the formation described by C. H. Richardson as the Waits River limestone, which is regarded by him on paleontologic evidence as of Ordovician age.[1]

The dikes associated with the marbles described in this bulletin differ greatly in age. The diabase dike in Cavendish may be of Triassic age. The pegmatite and biotite granite dikes of Washington and Topsham probably belong at the close of Carboniferous or in Devonian time. The metamorphism of the amphibolite dikes in Whitingham and Dover probably took place at the close of Ordovician time, but the age of the dikes themselves would in any case be later than Lower Cambrian. J. E. Wolff[2] described an amphibolite dike near Mount Holly, southeast of Rutland, which is in quartzite.

GENERAL SCIENTIFIC SIGNIFICANCE OF THE DATA.

Perhaps the most important scientific feature of these deposits is the prevalence of a coarse-textured manganese-bearing rose-colored calcite marble, alternating in very small beds with equally small beds of fine-textured white dolomite. In thin sections the demarkation between the calcite and dolomite is usually sharp. The small percentage (0.23–0.49) of manganese oxide in one and its absence in the other set of beds point to different kinds of sediment rather than to an

[1] Richardson, C. H., The terranes of Orange County, Vt.: State Geologist Vermont Rept., vol. 3, p. 94, 1902.

[2] U. S. Geol. Survey Mon. 23, pp. 65–69, fig. 25, 1894.

intermittent process of dolomization affecting only the beds without the manganese. The interval of time represented by each little bed must have been relatively short.

Some very recent chemical investigations by Bertrand and Medigreceanu [1] show that both the calcareous and soft parts of marine mollusks (Ostrea, Pecten, and Mytilus) contain manganese in percentages ranging from 0.15 to 1.91 (or in one extreme case, 3.66) and averaging about 0.5. May not the manganese to which the rose color of these calcite marbles is largely due have been extracted from sea water by the organisms whose remains produced the calcitic sediments? Does not also the absence of the manganese coloration from the intervening dolomite beds point to the possible inorganic deposition of dolomitic sediments under conditions not yet perfectly understood.[2]

As the thickness of the dolomite and calcite beds together can hardly exceed 150 feet at any of the localities visited, whereas these beds in the western part of the State measure several hundred feet each, it is evident that conditions favorable to calcareous sedimentation were of much shorter duration in the eastern part than in the western part.

Another interesting feature is that the dolomites here described are nearly all twinned, whereas those in western Vermont are generally granular. Whether this difference is due to the pressure on the dolomite having been more intense east of the Green Mountain axis or to some more obscure cause is uncertain.

Some of the rose-colored marbles are finely interbedded with greenish actinolitic marbles. As actinolite is a silicate of magnesia, iron, and lime there must have been at some time such a change in the sediments as to have supplied manganese in a form that combined with carbonic acid to produce a carbonate and at another time a change that brought in silica, magnesia, and iron oxide, which under metamorphism combined with lime as actinolite.

The brecciated dolomite of Plymouth (Pl. II, *A*, p. 24) resembles the brecciated dolomite of Swanton, except that the ground in the former is graphitic but in the latter hematitic and that the breccia of Plymouth, so far as explored, is without corals.[3] The brecciation of the little nongraphitic beds must be attributed to their having been of rigidity greater than that of the intervening graphitic parts. In thin section the only other perceptible difference between them is that the white beds contain a few quartz grains.

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[1] Bertrand, Gabriel, and Medigreceanu, F., The presence of manganese in animals: Am. Jour. Sci., 4th ser., vol. 35, p. 321, 1913, Abstract of article in Soc. chim. France Bull., 4th ser., vols. 13–14, pp. 18–24, Jan. 5, 1913.

[2] See, for discussion of origin of dolomite, Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, pp. 33–36, 1912.

[3] Idem, Pls. V, *B*, and VIII, *A* (*c*).

The quartzose graphitic calcite marble of Orange County owes its peculiarity to contemporaneous calcareous and mechanical quartzose sedimentation, so that over 25 per cent of the rock is quartz. The graphite is of organic origin. This is really a quartzite (quartz sandstone) and a calcite marble combined. The banding is due to variation in the amount of quartz and graphite at intervals and to a repetition of such variation.

The history of those marble beds which are interfolded with pre-Cambrian granite gneiss involves either the deposition of calcareous sediments upon a denuded intrusive granite and the alteration of these rocks by subsequent metamorphism respectively into marble and gneiss, followed by interfolding, or else the metamorphism in pre-Cambrian time of a granite intrusive into gneiss, the deposition thereon in Cambrian time of calcareous sediments, followed by their metamorphism into marble and the interfolding of both marble and gneiss in late Cambrian or late Ordovician time.

The history of the marbles inclosed in schist begins with a period of clayey and sandy sedimentation from the erosion of granitic rocks on the neighboring land masses, followed by a period of clear water and organic sedimentation, possibly accompanied by or alternating with some chemical dolomitic precipitation and followed by another period of mechanical sedimentation like the first. During the post-Ordovician crustal movement the clays and sands went into feldspathic and garnetiferous mica schist and the calcareous sediments into calcite and dolomite marble. At this time also the beds were folded into close overturned synclines and anticlines. Later movements elevated and modified them. Erosion during the long period since the close of Ordovician time has produced the present surface features and exposed the edges of the marble beds.

At several points along the contact of marble or dolomite and granite gneiss chemical reactions between silicates and carbonates have taken place under regional metamorphism, resulting in the formation of a few inches or feet of actinolite or diopside schist or in the growth of crystals of actinolite or tremolite within the calcareous beds. The most interesting example of this is in Athens (p. 35), where the calcite marble is sharply interfolded with biotite gneiss, and between them is a few feet of diopside schist containing large disseminated hornblende crystals half an inch in diameter. In Cavendish (locality 35, p. 31, fig. 4) the marble is associated on one side with a mass of calcareous epidote-hornblende schist. In Mount Holly (locality 51, p. 22) the dolomite marble and garnetiferous sericite-biotite schist are separated by 5 feet of actinolite schist with a little epidote and biotite, and the dip joints in the marble are filled with fibrous actinolite. In Weathersfield, on Pine Hill, half a mile

east of Perkinsville (locality 37, p. 34, fig. 4), the dolomite at its contact with muscovite-biotite schist contains a little tremolite.

To similar reactions should be attributed the presence of "mountain leather," or felty asbestos, in bedding and joints of the dolomite and marble of Swanton and Ira;[1] also the rim of scapolite and garnet surrounding a large oval autoclastic block of hornblende granite gneiss within the pre-Cambrian calcite marble of Flat Rock, near Fort Ann, in Washington County, N. Y., visited by the writer with James F. Kemp, in 1899.[2]

Of scientific interest is the occurrence of a 10-foot lens, mostly of secondary albite, in the marble of Johnson, described on page 12. Albite feldspars occur throughout the schist of the Taconic Range, though in varying amount, and were also found in the schists associated with the marbles and dolomites at Waterville, Plymouth, Weathersfield, Jamaica, Stratton, Dover, Wilmington, Whitingham, Searsburg, and Readsboro.[3] In thin section the albites of this lens, many of them simple twins, measure up to 0.2 inch in diameter and contain minute objects in stratiform arrangement, and as the feldspar extends beyond the ends of the little beds it seems to have had two periods of growth. Many of the minute particles are tourmaline prisms; some are exceedingly minute and opaque (graphite?). Rutile needles are present. There are also roundish to oval particles of uncertain nature. In one of the feldspars the little bed of inclusions is sharply plicated, and slip cleavage is about to arise. There can hardly be a question as to these feldspars being entirely secondary and not altered pebbles of another feldspar.

This lens of albite-chlorite-muscovite-quartz schist contains a half-inch bed of marble plicated with it. The general inference from the facts here is that the mechanical argillaceous sediment under metamorphism passed into a very albitic schist just as the organic calcareous sediment passed into marble.

The impregnation of the marble of Richford (p. 10) with chalcopyrite is, so far as known, unique in the white marbles of the State. As the ore occurs in some of the dip joints the impregnation may not have occurred until long after the first metamorphism of the region.

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[1] See Dale., T. N., U. S. Geol. Survey Bull. 521, pp. 44, 147, 1912.

[2] See Kemp, J. F., Crystalline limestone, ophicalcite, and associated schists of the eastern Adirondacks: Geol. Soc. America Bull., vol. 6, pp. 252, 253, 1895.

[3] See the literature of this subject:

Emmons, Ebenezer, Geology of the second district of New York State, p. 158, 1842.

Wolff, J. E., Metamorphism of clastic feldspar in conglomerate schist: Harvard Coll. Mus. Comp. Zool. Bull., vol. 16, No. 10, p. 183, 1891.

Whittle, C. L., Some dynamic and metasomatic phenomena in a metamorphic conglomerate in the Green Mountains: Geol. Soc. America Bull., vol. 4, pp. 164, 165, 1893.

Pumpelly, Raphael, Wolff, J. E., and Dale, T. N., Geology of the Green Mountains in Massachusetts: U. S. Geol. Survey Mon. 23, pp. 52, 60–62, 183, 186–188, fig. 73, Pls. VII, *A*, and VIII, 1894.

Dale, T. N., Structural details in the Green Mountain region and in eastern New York (second paper) U. S. Geol. Survey Bull. 195, pp. 16–18, figs, 5, 6, 1902.

The occurrence of a mineral of the humite group in the marble of Athens and Townshend should be mentioned here. Inasmuch as the humite minerals are usually found in rocks of pre-Cambrian age this occurrence affords an indication of the age of the marble, and this indication is corroborated by the presence of the granite gneiss and the unusual reaction zone of diopside schist.

The detrital zircons in the marble of Haystack Mountain, in Wilmington, are presumably derived from the pre-Cambrian gneiss of the land mass of Cambrian and Ordovician time.

Of special structural interest is the marble outlier at Johnson, described on page 13 and shown in figure 1. Here are illustrated in miniature principles governing the structure of large mountain masses in a region of folding. An intensely folded marble synclinorium, as it were, having a pitching axis, has been folded transversely and in the direction of the pitch, while the surrounding and underlying schist mass has acquired slip cleavage with a strike parallel to the pitch of the folds and a steep eastward dip. Finally marble and schist have suffered glacial striation in a diagonal direction. The little outlier thus combines several of the typical structural features of the Green Mountain region.

One general characteristic of all the marble and dolomite localities is the truncation of the folds, which makes it impossible to determine whether the beds are synclines or anticlines; and in view of the number and duration of the geologic periods that have passed since the schist of the Ordovician became exposed to erosion and of the vast amount of erosion the region has consequently suffered this minor effect of it is not surprising.

ECONOMIC POSSIBILITIES.

The possibilities here set forth for the economic use of the eastern Vermont marbles are exclusively those of architectural decoration.

The quartzose marbles of Orange County, owing to their content of pyrite or of iron carbonate or of both, are quite unsuitable for monumental work, but the banded variety described on page 15 might be used for internal decoration wherever the demand is sufficient to offset the extra cost of polishing due to its large content of quartz.

The rose-colored coarse-grained calcite marble, finely interbedded with fine-grained white dolomite, which is also twinned and therefore polishable, is a very attractive stone well suited for internal decoration, but owing to the nondurability of its color it is unsuitable for outdoor exposure.

As stated in the descriptions some of the marble and particularly the dolomite is so cut up by close joints as to preclude a supply of large blocks suitable for sawing and polishing.

At most of the localities the exposures are insufficient to show either the entire thickness of the marble or the soundness of its beds. At Waterville and Moretown the white calcite marble, although of superior quality, occurs in so small a quantity and is so remote from railroad facilities as to have no commercial architectural value.

The following list includes those localities where the colors and quality of the stone and its possible thickness warrant prospecting by trenching and core drilling, but it is to be distinctly understood that this prospecting should be done only on such a financial basis as would stand purely negative results.

Athens (locality 42, p. 34, fig. 5): Coarse light pinkish and greenish calcite marble.

Cavendish (locality 35, p. 30, fig. 4): Coarse white and rose-colored calcite marble with some actinolitic beds.

Jamaica (locality 40, p. 38, fig. 6): Interbedded rose-colored calcite and white twinned dolomite.

Plymouth (locality 18, p. 27, fig. 3): White twinned dolomite with some purplish spots; (locality 11, p. 24, fig. 3; also Orich Ward prospect, p. 26): Brecciated gray and white granular dolomite.

Richford (p. 10): White calcite marble with pinkish and light-greenish bands and dark-greenish streaks, and local phases of malachite-green.

Rochester (p. 23): Whitish calcite marble and dolomite, thinly interbedded with sericite schist.

Townshend (locality 41, p. 36, fig. 5): Coarse light pinkish and greenish calcite marble.

Weathersfield (locality 36, p. 32, fig. 4): Coarse rose-colored calcite and green actinolitic marble.

Wilmington (locality 83, p. 47, fig. 9): Interbedded rose-colored calcite and white twinned dolomite marble; (locality 85, p. 47, fig. 9): Cream to rose-colored coarse calcite marble.

In connection with the economic side of the subject attention should be called to the fact that wherever a bed of marble is both overlain and underlain by granite gneiss the marble must be doubled upon itself and its real thickness can be only one-half of its apparent thickness, and that in such places the extent of the doubled bed along the dip should be determined, as it may be very slight.

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