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TALC INVESTIGATIONS IN VERMONT
PRELIMINARY REPORT

By

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ABSTRACT

Commercial talc deposits in Vermont are derived from ultramafic igneous rocks confined chiefly to a narrow belt that extends northward through the central part of the state from Massachusetts to Canada. This belt forms part of a more extensive belt that may be traced from Alabama to Newfoundland.

Bodies of ultramafic rock occur in phyllites, schists, gneisses, greenstones and amphibolites. Most of the ultramafic rocks are emplaced in or near greenstones or amphibolites. Knowledge of the regional structural and stratigraphic relations of the belt is incomplete, but in general the country rock forms a homoclinal sequence and exhibits little repetition of formations by folding.

The ultramafic bodies range in width from a few feet to about a mile, and in length from less than 100 feet to at least 3½ miles. They are of two types. Most of them, referred to here as the verde antique type, are completely serpentinized and more or less extensively steatitized. The second type, with which no commercial talc deposits are known to be associated, consists of partly serpentinized dunite or peridotite and minor pyroxenite, and commonly contains more or less chrysotile asbestos; this type occurs in one or two localities in southern Vermont and in several localities in northern Vermont. The mineral assemblage associated with the verde antique type of body reflects the effects of regional metamorphism alone, whereas the country rock bordering some bodies containing peridotite and dunite also reflects contact metamorphic effects attributable to the ultramafic intrusive.

The typical ultramafic body of the verde antique type contains steatite and grit, (a mixture of talc and carbonate at the margins), and a core of serpentinite. The steatite zone, at the outer border of the body, commonly ranges from a few inches to a few feet in thickness. The grit zone, between the steatite and serpentinite zones, is commonly several feet to a few tens of feet thick. There are, however, all gradations from ultramafic bodies formed almost entirely of serpentinite to bodies made up exclusively of grit and steatite. Inclusions, septa, and tongue-like projections of wall rock, which range widely in size, are common in the talc deposits; they are called "cinders" by the miners.

The structural features of the ultramafic rocks contrast rather markedly with those of the country rock. Serpentinite and grit show local schistosity that varies from poor to good, and steatite commonly exhibits a good schistosity. Some ultramafic masses appear to be folded. A layering or banding of undetermined origin is conspicuous at a few localities. Most serpentinite bodies are made up of rather distinct blocks of massive serpentinite as much as several feet across, termed shear polyhedrons, surrounded by thin, irregular layers of slickensided serpentintite. This feature contrasts markedly with the structural features of the country rock; it may be interpreted in several ways, but suggests that the serpentinite was intruded in solid state. Minor faults are found in a few ultramafic bodies. Current general conceptions of the intrusion, serpentinization, and steatitization of the ultramafic bodies are stated briefly; a definitive statement of the genesis of the ultramafic rocks is not attempted.

It is inferred from the wide distribution of localities in which ultramafic rocks are known and the general prevalence of steatitization at those localities, that the talc reserves in Vermont are large. The geographic positions of 145 localities are indicated. Suggestions for exploration and further geologic study are made.

INTRODUCTION

Commercial talc deposits, with a few exceptions, 1/ fall into two classes: those derived from or very closely associated with ultramafic igneous rocks and those formed from carbonate rocks of sedimentary origin. In commercial usage of the term pyrophyllite, whose properties are similar to those of talc, is commonly included with talc. Nearly all of the talc deposits in Vermont, and all of those of economic value in the state are of ultramafic origin.

Talc deposits related to ultramafic bodies were formed by the metamorphism and alteration of the ultramafic rocks, accompanied by minor steatitization of the country rock. Although such talc deposits are commonly in or closely associated with highly serpentinized ultramafic bodies, it is generally recognized that the processes of serpentinization and steatitization are unrelated and that serpentinization is an earlier process. Talc deposits derived from carbonate rocks are generally considered to have been produced by contact metamorphism of the carbonates where intruded by granitic rocks.

Talc derived from carbonate rocks is generally superior in "color" (whiteness) to talc associated with ultramafic rocks. But, many carbonate-derived deposits contain a large amount of tremolite which is undesirable in some talc products. Talc associated with ultramafic rocks commonly contains a relatively large amount of carbonate, and minor amounts of chlorite and serpentine, to which the generally inferior color of this type of talc is attributed.

Uses of Talc

Massive talc, called soapstone or steatite, 2/ has peculiar properties, particularly softness,

[1] A. E. J. Engel (written communication, March 29, 1950) states: "In California, for example, several economic talc deposits of appreciable size, purity, and value are formed as replacements of granitic and intermediate types of igneous rock. At Natural Bridge, N.Y., also, commercial 'talc' (actually talc and serpentine) has formed as a replacement of granite, syenite, and migmatite."

[2] For a definition of these terms, as used in this paper, see p. 3.

denseness, impermeability, and high heat-resistivity, which have made it useful to man from very early times for making pipes, ornaments, and cooking utensils. Talc has a wide variety of uses in modern industry. 3/ Soapstone is sawed into crayons and pencils which are used in foundries to mark white-hot steel and in the garment industry to mark fabrics. Because of its resistance to acids, soapstone is used extensively for laboratory tables and sinks. Its refractory properties make it suitable for molds for such materials as iron and glass. Its dielectric properties make it suitable for insulators and base plates for switchboards. The pure, dense, cryptocrystalline variety of steatite known as "lava grade" is valuable because it can be machined into intricate forms and then heat-treated to great hardness with negligible shrinkage. 4/

The soft varieties of talc which are not suitable for sawing or machining are ground to various degrees of fineness for a great variety of industrial uses. Some of the products in which ground talc is used are: paper, toilet and pharmaceutical preparations, pottery and porcelain, rope and twine, wall plaster, paints, electrical insulation, textiles, linoleum and oil cloths, soaps, roofing papers, rubber, lubricants, foundry facings, glass, agricultural insecticides, pipe-coverings, leather, cement, asbestos shingles, candy, shoe polish, and crayons. Ground talc is used also to polish some articles of food, such as coffee and rice.

The talc deposits of Vermont furnish varieties suitable chiefly for grinding, but small quantities of material suitable for pencils to mark structural steel are produced as a by-product. The largest producer of talc in Vermont reports the following consumption data, in terms of percentages of total sales, for 1949. 5/

	Percent
Paper	30
Rubber	18
Textiles	2
Roofing	5
Paint	5
Ceramics	1
Cosmetics	0.5
Insecticides	23
Asphalt filler	13
Miscellaneous	2.5
Total	100.0

Preliminary maps available

As a result of the studies made by the U. S. Geological Survey in the period August 1944-November 1945, the following maps have been prepared and placed in open file:

The Johnson talc mine:
- Geologic surface map, scale: 1 inch to 30 feet.
- Geologic map of the 200-foot level, scale: 1 inch to 30 feet.
- Structure sections, scale: 1 inch to 30 feet.

The Waterbury talc mine, preliminary maps 3-225:
- Geologic surface map, scale: 1 inch to 80 feet.
- Underground maps, including geologic maps and outline map of the underground workings, scale: 1 inch to 80 feet.
- Structure sections, scale: 1 inch to 80 feet. (3 sheets).

The Barnes Hill talc prospect, preliminary map 3-221.
- Geologic surface map, scale: 1 inch to 50 feet.

The Vermont Talc Co. quarry, Windham, preliminary map 3-221:
- Geologic surface map and structure sections, scale: 1 inch to 30 feet.

The Hammondsville talc quarry, preliminary map 3-221:
- Geologic surface map and structure sections, scale: 1 inch to 30 feet.

The Rousseau talc prospect, preliminary map 3-227:
- Geologic surface map and structure sections, scale: 1 inch to 50 feet; geologic map of the underground workings, scale: 1 inch to 20 feet.

The Mad River talc mine, preliminary map 3-227:
- Geologic surface map, scale: 1 inch to 50 feet; geologic map of the underground workings and structure sections, scale: 1 inch to 20 feet.

The Carleton talc quarry, preliminary map 3-227:
- Geologic surface map and structure sections, scale: 1 inch to 20 feet.

Copies of these maps, released as Strategic Minerals Investigations, Preliminary Maps, may be obtained by persons directly interested in the talc deposits upon application to the U. S. Geological Survey, Washington 25, D. C.

Scope of the report

The primary purpose of the report is to make available to interested persons the results of field work to date. The report is based almost exclusively on field studies and is chiefly a description of the structural relationships of the talc deposits. Interpretations based on laboratory data are not included, as laboratory work is still in progress.

Acknowledgments

The authors appreciate the courtesy and cooperation of the officials of the following companies for their assistance in this investigation: Eastern Magnesia Talc Co., Burlington, Vt., Vermont Talc Co., Chester Vt.; Vermont Mineral Products Co., Chester, Vt.; Mad River Talc Corp., New York, N. Y.; and Vermont Marble Co., Rutland, Vt.

The Geological Survey is also indebted to a number of individual geologists, including P. H. Chang, P. H. Osberg, J. L. Rosenfeld, James Skehan, and J. B. Thompson, for their contributions to various aspects of the investigations. The authors are grateful to these persons for unpublished information concerning the regional geology, and for invitations to join in several interesting and informative field excursions.

[3] For a more complete discussion of the uses of talc see Engel (1949, pp. 1035-1038) or Gillson (1937, pp. 882-888).

[4] For further discussion of the properties and uses of "lava grade" steatite see Engel (1949, pp. 1036-1037; also references cited in his bibliography, pp. 1039-1041).

[5] Quoted with permission of Eastern Magnesia Talc Co., Burlington, Vt.

The authors benefitted from several days spent in the field with R. H. Jahns and T. P. Thayer of the Geological Survey. Jahns furnished unpublished information on the regional geology. M. R. Klepper and A. E. J. Engel of the Geological Survey read the manuscript critically and suggested numerous improvements.

Definitions of technical terms

The following technical terms have been variously used in the past by different geologists, and many are in common use among talc miners. Because some of the miners' terms are apparently peculiar to the Vermont talc industry and may not be known in other areas, the terms in this report are defined.

Ultramafic. -- The term is used throughout the report in a broad sense with reference to the igneous rocks peridotite, dunite, and pyroxenite and their derivities. Thus the term ultramafic body refers to the unaltered igneous rock, the serpentinite, the grit, and that part of the steatite which is an alteration of the original igneous body.

Serpentinite. -- The term is applied to rocks composed essentially of serpentine, after the usage of Lodochnikov (1933, p. 145), Phillips and Hess (1936, p. 333), and Selfridge (1936, p. 501). However, no genetic significance is attached to the term, as is apparently done by Phillips and Hess. The term serpentine is used here only in the mineral sense; it is used by miners in the sense of serpentinite as defined above. Verde antique is a trade term for serpentinite intricately veined with carbonate, and capable of taking a high polish so that it is suitable for use as an ornamental stone. Ultramafic bodies composed entirely of serpentinite, grit, and steatite are referred to as the verde antique type, and the serpentinite of such bodies is similarly distinguished. 6/

Serpentinization is the process by which ultramafic igneous rocks were partly or completely altered to serpentinite. The term has no genetic significance as used here. The serpentinite zone includes the part of the ultramafic body that consists principally of serpentinite; it commonly forms the core of the verde antique type of ultramafic body.

Talc. -- The word talc is used here only in the mineral sense. Grit is a miners' term for a rock composed essentially of talc and carbonate. The grit zone is that portion of an ultramafic body composed almost entirely of grit; it lies between the serpentinite zone and the steatite zone. The term steatite is used in a broad sense to designate a rock that consists almost entirely of talc. The important distinction is that there is practically no carbonate; chlorite may be more or less abundant. 7/

The steatite zone is the portion of the ultramafic body and immediately adjacent altered country rock between the grit zone and the blackwall zone (see next paragraph) at the outermost edge of the ultramafic body. The term soapstone is restricted to steatite that is suitable for making sawn and shaped slabs. Pencil stock is a variety of soapstone with physical properties that make it suitable for "pencils" used in marking structural steel. Steatitization is the term applied to the process by which an ultramafic rock is partly or completely altered to talc or talc and carbonate. No genetic significance is attached to the term.

Blackwall. -- The altered country rock at the outer border of the steatite zone is called blackwall by the miners. In the majority of deposits the blackwall is chlorite schist, but in a few it is biotite schist. The blackwall zone is the altered part of the country rock between the steatite zone and the unaltered country rock; it lies outside of the ultramafic body.

Cinder. -- The term "cinder" is applied by miners to masses of schist within a steatite-grit body. Cinders may range in size from small fragments less than an inch across to very large tabular masses. In practice, any body of schist which is not demonstrably a part of the accepted hanging wall or footwall of a deposit is referred to as cinder.

Geographic distribution of the talc deposits

The talc deposits of Vermont are associated with ultramafic rocks that form part of a belt more than 2000 miles long, which extends from Alabama to Newfoundland. The belt lies in the terrane of crystalline rocks of the Appalachian Mountains.

In Vermont the ultramafic rocks are nearly all confined to a rather narrow belt that trends northward through the central part of the state from Massachusetts to Canada. The belt is almost 25 miles wide at its northern end, but it narrows rather markedly southward so that south of the Winooski River it is not more than 5 miles wide except at the latitude of Plymouth, where it broadens to a maximum width of 10 miles. Plate 1 shows the location of all known ultramafic bodies in Vermont; their distribution indicates the pattern of the ultramafic belt.

6 This application of the term *verde antique type of serpentinite* is somewhat more restricted than that of Bain (1936, pp. 1967-1974) who distinguishes two principal types of serpentinite: the "verde antique (white weathering) type" and the "red-weathering type." The verde antique type of serpentinite as defined by Bain on the basis of weathering characteristics is found to some extent in ultramafic bodies that contain relatively large masses of unserpentinized dunite and peridotite, but is found principally in bodies that contain only serpentinite of the verde antique type. The commercial verde antique occurs only in the latter, and the term verde antique may be logically restricted to such intrusives for the purpose of designating a type of ultramafic body. We believe that this usage does not violate that of Bain in any essential way, inasmuch as the verde antique type of serpentinite as defined by Bain is overwhelmingly more abundant in the verde antique type of ultramafic body as defined herein. We believe that the classification of the ultramafic bodies on the basis proposed (see pp. 4-5) has greater genetic and practical merit.

7 Various meanings have been attached to the word "steatite" in geologic literature. Priority and general geologic usage favor the definition given here, but in some geologic literature and especially in writings on high-quality ceramic talcs a different usage has evolved. The term "steatite" is used in the ceramic industry to denote a massive, compact, and comparatively pure variety of talc which must meet certain chemical and physical requirements for the manufacture of ceramics. The U. S. Bureau of Mines, from study of commercial shipments, fixes specifications at not more than 1.5 percent CaO, 1.5 percent Fe_2O_3, 4 percent Al_2O_3, and 5 to 10 percent non-talc minerals. Individual manufacturers' standards vary considerably, and some will accept as much as 6.5 percent CaO for certain uses (see Engel, 1949, p. 1037). In our opinion, it is best to define "steatite" in a broad sense, and to apply such terms as "ceramic-grade steatite" or "electrical-grade steatite" when it is desired to indicate a specific grade or type of steatite.

GEOLOGY

Most of the ultramafic rocks of Vermont occur in schists, phyllites, and greenstones on the east flank of the Green Mountain anticlinorium; but in the northern part of the state, north of the approximate latitude of the village of Johnson, several occurrences are known in similar formations west of the anticlinorial axis; for example, in Cambridge, Waterville, and Berkshire townships. C. H. Hitchcock and A. D. Hager (Hitchcock et al., 1861, pp. 539, 543, 788-789) report occurrences of both serpentinite and steatite in schists and gneisses in extreme eastern Vermont; these are apparently separated from those in the central part of the state by a broad synclinal belt of interbedded crystalline limestone and slate. Scattered occurrences of serpentinite, steatite, and grit are found in comparable rocks throughout both New Hampshire and Maine (Hitchcock, C. H., 1878; Smith, Bastin, and Brown, 1907, pp. 8-9). Further knowledge of the regional relationships of the ultramafic rocks must await completion of areal mapping now in progress.

The country rock

Rock types

The country rocks of the ultramafic belt include phyllites, schists, and gneisses, with intercalated schistose greenstones and amphibolites that represent altered volcanic rocks, both tuffs and flows, and intrusive rocks, chiefly sill-like dikes. Most of the ultramafic bodies are emplaced in greenstone or amphibolite or in schist and phyllite in the immediate vicinity of greenstones or amphibolites. Mafic dikes formed after regional folding and metamorphism intrude the ultramafic rock and country rock at several localities. There are no known granitic intrusive rocks, other than small felsic dikes at a few localities, associated with the ultramafic bodies.

The ages of the various formation into which the ultramafic rocks are intruded are uncertain, but it is probable that they range from Cambrian to Lower or Middle Ordovician.

Structure

Knowledge of the structural relations in the ultramafic belt is yet far from complete. Throughout most of the belt the rocks are vertical or dip steeply east or west on the east limb of the Green Mountain anticlinorium. The strike ranges from slightly west of north to northeast and averages about north. Schistosity and bedding are nearly parallel or parallel in most places where bedding is recognizable. There is remarkably little repetition of beds in folds, but very small folds with amplitudes of a few inches are present almost everywhere throughout the belt. At some localities there are folds with amplitudes of tens or hundreds of feet, and in a few areas, as much as a mile. These reflect the regional structural pattern, particularly that of the Green Mountain anticlinorium. However, such large folds appear to be the exception rather than the rule.

This rather simple homoclinal structure passes in the vicinity of Chester township into broad anticlinal arches and large overturned and recumbent folds. 8/ These structural features are responsible for the relatively greater width of the ultramafic belt in the latitude of Chester.

The ultramafic rocks

Composition and alteration

The original minerals of the ultramafic rocks have been nearly or completely altered at most localities, and only rare relics and ghosts of olivine and pyroxene remain. It is difficult or impossible to determine accurately the composition of the rocks when first emplaced. At several places in northern Vermont, however, and in at least one place in southern Vermont, the ultramafic rocks are, at least in part, remarkably unaltered (Bain, 1936, pp. 1968-1971). They apparently range from dunite, composed almost entirely of the mineral olivine, to pyroxenic peridotite in which the mineral pyroxene as well as olivine is abundant. Most of the ultramafic rocks were probably of peridotitic composition originally.

The ultramafic bodies may be divided into two types on the basis of absence or presence within each body of unserpentinized peridotite or dunite. Those that do not contain peridotite or dunite are called the verde antique type (see footnote on p. 3 for a fuller discussion). Those that contain unaltered peridotite and dunite correspond in a broad way to the red-weathering type described by Bain (1936, pp. 1973-1974).

All the commercial talc deposits in Vermont are associated with the verde antique type of ultramafic body, whereas none is known to occur in ultramafic bodies that are only partly serpentinized. On the other hand, cross-fiber asbestos appears to occur in appreciable quantities only in ultramafic bodies that contain unaltered dunite or peridotite, and is extremely rare or absent in the verde antique type. Small amounts of slip-fiber asbestos, commonly brittle and altered, have been found in association with a few talc deposits, and so have a few examples of what appear to be talc pseudomorphs after cross-fiber asbestos.

Several investigations of ultramafic rocks (Selfridge, 1936, pp. 497-498; T. P. Thayer, oral communication, August 1949) from widely separated regions, supplemented by incomplete petrographic studies made in connection with the current investigation in Vermont, indicate that the serpentine mineral in the verde antique type of ultramafic body is antigorite, whereas the serpentine mineral in serpentinite associated with unaltered dunite and peridotite is a non-asbestiform variety of chrysotile. 9/

[8] Thompson, J. B., Oral communication, September 1948.

[9] G. C. Selfridge (1936, pp. 468-469) defines the serpentine group of minerals as consisting of two mineral species, serpentine and antigorite. He considers chrysotile to be an asbestiform variety of the species serpentine.

Bain's conclusion that the "white-weathering" and "red-weathering" serpentinite are two genetic types (1936, pp. 1978-1979) may be interpreted to support the foregoing definition. He identifies the serpentine mineral in both types as antigorite, but presents no supporting data. It is commonly difficult to distinguish the serpentine minerals by optical characteristics (see Selfridge, 1936, pp. 484-496), and in thin-section serpentine may easily be mistaken for antigorite.

The weathering characteristics of the two types of ultramafic rocks generally serve to distinguish them quickly and easily. The verde antique type of serpentinite weathers to a characteristic pale greenish-white or light buff color. Dunite and peridotite, and commonly the associated serpentinite, weather to a red-brown color referred to as "buckskin." The buckskin color may not be an inherent character of the mineral serpentine but the effect of the presence of abundant small relics of olivine, whose weathering gives the entire rock a red-brown color.

The verde antique type of serpentinite shows various degrees of alteration to grit and steatite. The wide range in degree of steatitization is striking. Many of the serpentinite bodies, such as those at the Mad River and Waterbury mine localities (localities 46 and 41) 10/, show only relatively thin zones of grit and steatite at the margins. At the other extreme are the talc deposits at the Johnson mine, the Rousseau prospect, and Sterling Pond (localities 28, 23, and 25), which are, throughout much of their extent, entirely altered to grit and steatite; only small residual cores of serpentinite occur at the Johnson mine and the Sterling Pond localities, and no serpentinite is known at the Rousseau prospect.

In addition to the changes within the ultramafic body proper, associated changes in the country rock at the contact with the ultramafic body are evident. The latter changes include the alteration of the country rock to chlorite or biotite schist referred to as the blackwall. The serpentinites and country rocks that border them exhibit a rather well-defined zonal arrangement as an effect of these changes. An ideal sequence from the center of such an ultramafic body outward (to be described in more detail later) is serpentinite, grit, steatite (or talc-actinolite rock), and blackwall, each of which occupies a more or less definite zone. The blackwall grades into unaltered country rock.

The mineral assemblages in the different zones differ considerably among the ultramafic bodies of the verde antique type. At one extreme is an assemblage considered to be characteristic of low temperatures of formation; at the other extreme an assemblage characteristic of higher temperatures.

In the low temperature assemblage the blackwall zone is composed almost entirely of chlorite, the steatite zone is almost entirely talc, and the grit zone is talc and carbonate. In the higher temperature assemblages the blackwall zone is chiefly biotite, part or all of the steatite zone is composed of actinolite with minor talc, and the grit zone is composed of flaky talc, carbonate, and radiating acicular talc probably pseudomorphic after enstatite or anthophyllite (Phillips and Hess, 1936, pp. 344-347; see also Bain, 1934, pp. 398-399). The mineral assemblage of the serpentinite zone consists of serpentine and carbonate, with minor magnetite, and shows little or no variation within the range of temperature effects encountered in the belt of ultramafic rocks.

The metamorphic grade of the ultramafic bodies of the verde antique type appears to vary sympathetically with that of the country rock. Moreover, the metamorphic grade of the country rock is fairly uniform over moderately large areas, remote from and also close to these ultramafic bodies. In other words, it is regional in scope and apparently not produced by a contact metamorphic action of the ultramafic body; but contact metamorphic zones a few feet in width were observed in the country rock adjacent to some of the ultramafic bodies that contain dunite and peridotite.

Size and shape

The ultramafic bodies range in width from a few feet to about 1 mile, and in length from less than 100 feet to at least $3\frac{1}{2}$ miles. They vary widely in shape. Most of them are lenticular or pod-shaped, and pinch and swell markedly in both plan and section; some are more or less tabular bodies that have been folded; and a few very irregular ones are branched, folded, and faulted.

Many ultramafic bodies of the verde antique type exhibit minor protuberances, or small tongues of steatite, which branch out for short distances from the main body. In most deposits these irregularities are minor, and the tongues are commonly only a few inches thick and several feet long. However, in a few deposits and notably at the Johnson mine, these irregularities are prominent features, which make extensive drilling and exploration necessary in order to keep the workings in the main ore bodies.

In many places it is difficult to determine the exact nature of these features, but it is believed that at least three different modes of origin are involved: Some probably are completely altered tongues of serptntinite; others reflect alteration of schist in zones especially susceptible because of composition or accessibility to solutions; and a few apparently reflect post-mineral movement of the soft steatite into fractured zones and in fault slivers. Probably most of the smaller tongues are of replacement origin.

The ultramafic bodies in Vermont are comparatively free of folds, although most of them exhibit small folds a few inches in amplitude. A few talc deposits, however, are clearly associated with larger folds with amplitudes of tens or hundreds of feet. This is especially true at the Johnson mine, the Rousseau prospect, Sterling Pond, the Waterbury mine, and the Hammondsville quarry (localities 29, 23, 25, 41, and 117). The structural features at these localities range from simple, broad, anticlinal arches as at Hammondsville, to very irregular, tight folds as at Johnson.

Distribution of steatite and grit

Relatively thin zones of steatite and grit occur at the margins of a central, pod-like mass of serpentinite in the simple, or idealized, verde antique type of ultramafic body. The grit zone is commonly not more than a few feet thick, and the steatite zone a few inches to a few feet. Grit and steatite are commonly thickest along the "keels" of the serpentinite pods at "rolls" and folds in the contact, and at narrow strictures in the ultramafic bodies (see Phillips and Hess, 1936, pp. 338-339). The serpentinite core of the simple as well as of the strucurally

10 Locality numbers refer to pl. 1.

more complex types of deposit is irregularly embayed by more or less completely steatitized zones. In some deposits, notably at Barnes Hill (locality 40), the grit is very irregularly distributed in large interconnected masses throughout the zone normally occupied by the serpentinite core, as well as in its usual position at the margins of the deposit. At a few localities, for example, at the Johnson mine, the Rousseau prospect, and Sterling Pond (localities 28, 23, and 25) the ultramafic bodies are almost entirely altered to steatite and grit. In such deposits the grit zone is as much as 100 feet wide.

The position of the boundary of an ultramafic body before steatitization is difficult to determine. All of the grit and most of the steatite probably were derived from serpentinite, and it is believed that the original contact between ultramafic rock and country rock lay near the outer border of the steatite zone. At most places, probably not more than a few inches of the outer part of the steatite zone is derived from country rock, but locally, especially in very irregular deposits, the steatite zone appears to extend as much as 10 feet outward into the country rock beyond the original border of the ultramafic mass. Long, narrow tongues of steatite commonly extend for a considerable distance along the strike at the ends of a lenticular ultramafic body. They may swell locally into small, lenticular steatite masses nearly isolated from, but not unrelated to the original ultramafic body. Undoubtedly, a large part of each of these tongue-like extensions is steatized country rock.

Inclusions and nearly isolated septa and tongue-like projections of more or less completely chloritized country rock are common and locally abundant in the grit and steatite. These are referred to by the miners as "cinders." Some of the cinders are small, irregular fragments less than an inch through and occur in clusters. More commonly, the cinders form rather widely separated masses, the smaller of which are spheroidal and as little as 6 inches in diameter. The larger cinders form tabular masses as much as 20 feet thick; their greatest observed dimension is 400 feet. Most of the cinders are probably inclusions or tabular projections from the walls formed during emplacement of the ultramafic body, but some appear to form tongues and slivers faulted from the wall rock after formation of the grit and steatite.

Figure 1 shows the distribution of steatite, grit, and serpentinite in a typical ultramafic body and a small, nearly isolated lens.

Structural details

The structural deatils of the ultramafic rocks are varied in contrast with the rather uniform schistosity of the enclosing country rock formations. The sequence of development of some features of ultramafic rocks cannot be determined until critical petrographic studies and a geologic map of the ultramafic belt are completed. The more common isolated structural features are banding, schistosity, and shear polyhedrons.

Banding.-- A few serpentinite bodies, notably at the Barnes Hill and Belvidere Mountain localities

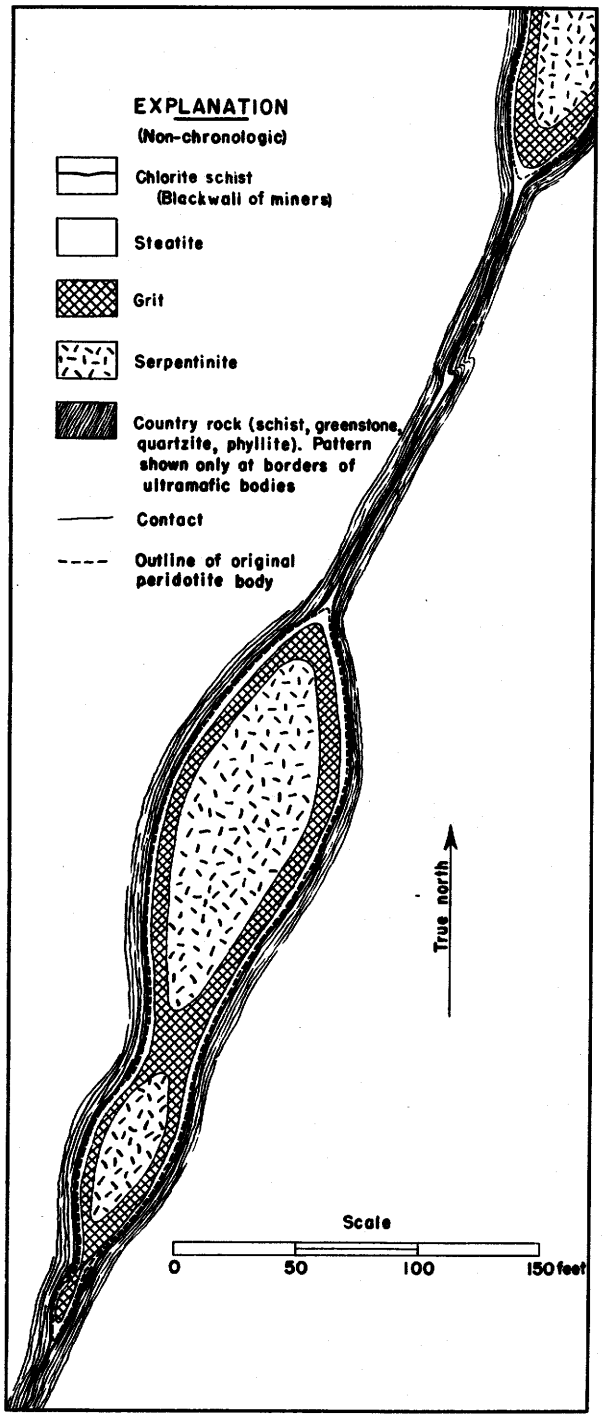

Figure 1.--Idealized sketch map of a typical steatite-grit-serpentinite body showing the distribution of rock types, and illustrating small, nearly isolated lenses of steatite in the country rock. The width of the steatite zone outside the borders of the original ultramafic body is slightly exaggerated.

(40, 9), exhibit a conspicuous banding. The banding is produced by alternating light- and dark-colored layers which range in thickness at Barnes Hill from one-sixteenth to one-fourth of an inch, and at Belvidere Mountain from one-fourth of an inch to at least 1 inch. It is best preserved in the serpentinite, but can be distinguished in many outcrops of grit at Barnes Hill where it shows up especially well on weathered surfaces. The bands may be primary (original layers) or they may be a later shear feature. Possibly both types exist.

Schistosity. The ultramafic bodies are all partly schistose, and orogenic movement since their emplacement is indicated. Serpentinite, grit, and steatite are all affected, although not to the same degree; furthermore, the range in degree of schistosity is rather wide. In most of the deposits the steatite exhibits good schistosity; the grit is commonly non-schistose, but locally shows poor-to-good schistosity; and the serpentinite is normally non-schistose, although in some places it shows rude-to-excellent schistotosy at the borders of and locally within the serpentinite mass. Their schistosity commonly is parallel to the general trend of the schistosity of the country rock, but is locally more variable. At some localities, for example, at the Johnson mine (locality 28) and at the Carleton quarry (locality 124), the steatite shows a local cleavage that roughly parallels the axial planes of folds as much as 30 feet in amplitude.

Shear polyhedrons. Almost all of the suitably exposed serpentinite bodies of the verde antique type that were examined exhibit a striking feature. Close-packed units of massive, essentially unsheared serpentinite, irregularly polyhedral in shape, ranging in size from a mean diameter of a few inches up to a limit unknown but certainly as great as several feet, lie within thin zones of highly sheared serpentinite. The sheared zones are irregular in shape and attitude and do not conform to any apparent system. The massive, unsheared units are termed shear polyhedrons.

This feature contrasts markedly with the well-defined bedding schistosity of the country rock. Its significance is not clear because several interpretations are possible and none is adequately supported by data now at hand. (See pp. 38a-38c for further discussion.)

Faults

Minor faults are found in many of the ultramafic bodies. They are commonly difficult to recognize because they are small and poorly exposed, and the rocks affected lack distinguishable markers with which to gage displacement. Extensive minor faults are favorably exposed, however, in the Johnson, Waterbury, and Mad River talc mines (localities 28, 41, and 46). These faults strike slightly east of north, roughly parallel to the strike of the ultramafic bodies. The faults are nearly vertical at the Waterbury and Mad River mines; at the Johnson mine they dip from 30 degrees eastward to 30 degrees westward, most of them at low angles. Zones of gouge and fault breccia as much as 4 feet thick are formed along some of the fault planes. Slickensides, deep grooves, and gouges indicate that they are chiefly diagonal-slip faults. The total displacement is commonly indeterminate, owing to the lack of markers. Relative movement of the foot-wall and the hanging-wall rarely can be demonstrated. At the Waterbury mine, however, where a mafic dike serves as an excellent marker, and probably at the Mad River mine, the east side moved northward and downward; the strike slip of the fault at the Waterbury mine is about 135 feet.

Minor faults are much more prevalent in and near the ultramafic rocks than in the country rock. These faults probably reflect a tendency of the steatitized ultramafic bodies, in contrast with the country rock, to yield by slip rather than by flexure.

Origin

There is considerable disagreement among geologists concerning the origin of ultramafic rocks and their derivatives. Some believe that the rocks were intruded as magmas. Others, who believe that magmas of ultramafic composition do not exist, postulate that the rocks were formed by crystal accumulation and were intruded in the solid or partly solid state. Serpentinization is generally considered to be a hydrothermal or a deuteric process accomplished relatively soon after intrusion. In contrast, some exponents of solid intrusion believe that serpentinization is independent of deuteric or hydrothermal action and is an integral part of the mechanism of intrusion.

Shear polyhedrons (see p. 36), which are particularly well formed in serpentinite bodies of the verde antique type, may be interpreted to support the conception of intrusion in the solid state, but the evidence is not conclusive. Several interpretations are more or less interrelated.

One is that regional stresses, which originated entirely outside of the serpentinite bodies, were responsible for the formation of the shear polyhedrons, and that the contrast between the structural features of the ultramafic bodies and of the country rock is due solely to the differences in physical characteristics of the two rock types. Another interpretation is that the shear polyhedrons are the result of expansion within the ultramafic body during serpentinization, most of the adjustment that accompanied expansion having taken place along the shear zones, formed concurrently with serpentinization, which bound the polyhedrons. In both these interpretations, the polyhedrons are considered to have formed without appreciable movement of the ultramafic body as a whole. A third interpretation, which combines some features of the other two, explains the shear polyhedrons more satisfactorily: Regional compression, perhaps aided by expansion during serpentinization, resulted in extensive transport of the ultramafic rocks, particularly in directions parallel to the bedding, to form thin tabular and podlike intrusive bodies. The smallest structural unit believed to have been involved in such transport and emplacement is the shear polyhedron, whose sheared and finely brecciated borders reflect the conditions of movement. Such extensive movement of the serpentinite, with consequent rotation and jostling of the unsheared units as they moved past one another, may explain the diverse orientations of the shear zones and the approach to equidimensional form of the shear polyhedrons. Serpentinization, facilitated by stress and

and by the shear zones which furnished access to water supplied from the surrounding country rock, is conceived to have taken place contemporaneously with transport and emplacement, essentially in the manner suggested by Sosman (1938, p. 359) and by Bowen (1947, pp. 269-271; 1949, pp. 454-457). Under such conditions of genesis, ultramafic bodies intermediate between the verde antique type and the partly serpentinized dunite or peridotite type may have been formed, although none has yet been recognized in the current studies.

The lack of contact metamorphic effects in the country rock that borders the verde antique type of ultramafic body may be cited as further evidence favoring an origin by intrusion in the solid state. On the other hand, the contact metamorphic zones observed adjacent to some of the ultramafic bodies that contain dunite or peridotite (see p. 5) suggest that the latter type of body was derived more directly from a magma, the heat of which accounted for the contact metamorphic effects. Possibly the ultramafic bodies that contain dunite or peridotite represent the parent type from which the verde antique type of ultramafic body was derived.

Steatitization is generally recognized as a later process, independent of serpentinization, and is commonly attributed to the effects of hydrothermal solutions from underlying magmas. It is possible, however, that steatitization is an expression of regional metamorphism.

TALC RESERVES

Indicated and inferred reserves of talc are apparently large, as is shown by the widespread occurrence and the general prevalence of steatitization of ultramafic bodies in Vermont. They are probably adequate to meet normal as well as emergency demands for many years to come. A discussion of proven talc reserves is not practicable because the mining companies do not attempt to block out ore reserves several years in advance. One of the purposes of the investigations now in progress is to derive a detailed estimate of the indicated and inferred talc reserves and of proven reserves when data may become available.

TALC DEPOSITS

Geographic location of known deposits

To the best of our knowledge, the following localities comprise all of the known ultramafic bodies in Vermont. Nearly all of them probably have talc associated and many are potentially talc producers. Four are now being mined for talc, and many have been intermittently prospected or mined in the past. Several ultramafic bodies, especially in northern Vermont, are known to contain asbestos, and one is an active producer.

We have examined about 45 of the localities. Descriptions of the rest have been taken from the literature or have been furnished by members of the Geological Survey and others recently or now engaged in mapping several quadrangles in the belt of ultramafic rocks. The localities are numbered to conform with the key to their general location on Plate 1.

Deposits examined in the course of this investigation are marked with an asterisk(*). Thirty-three of the talc deposits examined to date and indicated by a double asterisk (**) are described in the section "Description of deposits." These and deposits located by geologists now mapping in the area are accurately located by reference to some feature on the Geological Survey topographic maps, scaled about 1 inch to the mile. Other deposits described in the literature of the region may not be exactly placed, although descriptions and map points have been translated as nearly accurately as possible to topographic maps. Descriptions of locations are quoted if they are adequate, but many are vague. Inaccuracies in early topographic maps and the small-scale of many locality maps have contributed further to the difficulties of making accurate locations.

Quadrangle maps may be obtained from the U. S. Geological Survey, Washington 25, D. C. at a price of 20 cents each.

Enosburg Falls quadrangle

1. C. H. Hitchcock (in Hitchcock, Edward, Hitchcock, Edward, Jr., Hager, A. D., and Hitchcock, C. H., 1861. p. 542) reports a "bed of steatite... in Berkshire [township]*** near the west line in the south part of town." Hitchcock shows this locality to be approximately $2\frac{1}{4}$ miles N. 20° W. of Enosburg Falls on the Geological Map of Vermont.

Jay Peak quadrangle

2. Hitchcock (1861, p. 542) reports a "bed of steatite" in Berkshire township "rather east of the middle of the town." He locates this area about $2\frac{1}{2}$ miles due east of Berkshire village on the Geological Map of Vermont.

3. Hitchcock (1861, p. 542) reports "a bed of steatite, serpentine, and actinolite at Wright's Mill in Richford [township]." This locality is shown to be approximately in the village of South Richford in Hitchcock's geologic atlas of New Hampshire (1878). It is probably about half a mile due north of elevation 852 on the quadrangle map.

4. Hitchcock (1861, p. 541) reports "a bed of steatite in the east part of Enosburg [township]." He places this locality about $2\frac{1}{2}$ miles S. 70 ° E of the village of East Enosburg on the Geological Map of Vermone, but the locality is shown only $1\frac{1}{2}$ miles S. 65° E. of East Enosburg in his geologic atlas of New Hampshire (1878). The latter is published on a larger scale and is presumably more nearly accurate, although the planimetric detail of both maps is poor in this area.

5. ** A talc deposit, known locally as the Montgomery Center talc prospect, is exposed in west-central Montgomery township 1.45 miles S. 62° W. of the junction, in Montgomery Center, of state routes 118 and 58.

6. Hitchcock (1878) shows a body of "serpentine and

steatite" in the southwestern part of Montgomery township, about 1 mile northeast of the southwestern corner of the township.

7. Hitchcock (1861, p. 541) reports "a bed of steatite in Belvidere [township], 3 miles northeast of the meeting house. The bed is about six rods wide where it has been quarried. The central part of the bed is rather a coarse serpentine." He shows presumably the same body on the border between Averys Gore and Belvidere township in his geologic atlas of New Hampshire (1878). Comparison with the quadrangle map indicates that the planimetry of the atlas is probably incorrect here.

8. Hitchcock (1861, pp. 543-544) states that he was informed of, but did not visit, "an immense mass of serpentine at Hazens Notch."

9. ** The Belvidere Mountain asbestos quarry is in a large ultramafic body lying on the boundary between Eden and Lowell townships, on the southeast flank of Belvidere Mountain. The present quarry is located 0.6 mile N. 10° W. of Corez Pond.

Irasburg quadrangle

10. Bain (1936, fig. 1) shows an ultramafic body in the northwestern part of Troy township, about 0.75 mile N. 25° W. of the road triangle in North Troy. According to C. H. Hitchcock (1861, p. 542) "a bed of steatite, from one to eight feet wide" is associated with this body.

11. An ultramafic body, apparently at least a mile long and several hundred feet wide, is reported (Bain, 1936, fig. 1) in northeastern Troy township, about 2 to 2½ miles east of the road triangle in North Troy.

12. A small ultramafic body is located in northern Troy township 2¼ miles S. 30° E. of the road triangle in the village of North Troy (Bain, 1936, fig. 1).

13. Bain (1936, fig. 1) shows an ultramafic body about 2 miles long from north to south on the boundary between Jay and Troy townships; the center of the body is half a mile west of the West Road School, 2½ miles south of North Troy. This is apparently the serpentinite mass that Hitchcock (1861, p. 542) says contains "steatite beds" on the west side, and also veins of "chromic iron ore" up to 2 feet wide.

14. A narrow ultramafic body about 2 miles long terminates at the north about midway between River Road School and East Hill School in Troy township (Bain, 1936, fig. 1).

15. * A small ultramafic body lies 0.3 mile due east of the road triangle in Troy village.

16. ** An ultramafic body crops out in west-central Troy township, 0.8 mile S. 65° E. of the road triangle in Troy village.

17. ** Another ultramafic body crops out in west-central Troy township, 1.1 miles N. 70° E. of the road triangle in Troy village.

18. Bain (1936, fig. 1) shows a nearly continuous belt of ultramafic rocks that extends from about 2 miles northeast of Troy village to a mile east of Lowell village. Hitchcock (1861, p. 542) reports "a bed of steatite" about a mile east of Lowell village, which is probably associated with this belt of ultramafic rocks.

19. * Serpentinite crops out in central Lowell township at an old dam site on the East Branch of the Missisquoi River 0.5 mile northwest of the road triangle in Lowell village.

20. * The eastern edge of a large ultramafic body crops out on the Hazens Notch Road 1 mile northwest of the road triangle in Lowell village. The deposit, as shown by Bain (1936, fig. 3), is at least one-fourth mile wide and extends both north and south of the Hazens Notch Road for at least 1½ miles. Hitchcock (1861, p. 542) states that there is talc associated with the "west range of serpentine" at Lowell; he apparently refers to this locality.

21. Hitchcock (1861, p. 542) reports that "half a mile west of the Troy [township] line, and two and a half miles north of the south line of Westfield [township], there is a bed of steatite." He shows the locality as 1.4 miles S. 21° E. of Westfield village on the Geological Map of Vermont.

Mount Mansfield quadrangle

22. ** A talc deposit, on which the abandoned Waterville talc quarry is located lies in northern Waterville township 3.45 miles N. 12° E. of the center of Waterville village. This is probably the locality stated by C. H. Hitchcock (1861, p. 541) to contain "stone of most excellent quality," and of which he further says, "We have considered it the finest in the State."

23. ** The Rousseau talc prospect is in Cambridge township, 2.1 miles N. 59°E. of Cambridge Junction.

24. C. H. Hitchcock (1861, p. 541) reports that "in Cambridge on Sterling Mountain, near its top upon the east side, there is a bed of steatite." He states further that "much steatite of excellent quality occurs near the center of the old town of Sterling."

25. ** Several large bodies of grit, steatite, and some serpentinite crop out near Sterling Pond, in the northwest part of Stowe township, about 1.2 miles due east of Smugglers Notch.

Hyde Park quadrangle

26. C. H. Hitchcock (1861, p. 541) reports that "there is a bed of excellent steatite in Eden [township]. It is on Mr. Phillip's land, one mile west of the church. It is 15 feet wide and runs N. 16° E. "Hitchcock (1878 shows this deposit 0.7 mile west of the center of the village of Eden Mills in his geologic atlas of New Hampshire.

27. * A small outcrop of talc is exposed 2.4 miles N. 28°E. of the center of the village of Johnson about 0.3 mile N. 5° W. of Christy School in Johnson township. It is less than 10 feet wide and between 15 and 20 feet long.

28. ** The Johnson talc mine, largest in Vermont,

lies in the northeast part of Johnson township, 2.58 miles N. 39° E. of the center of Johnson village.

29. A talc deposit is reported (oral communication from Mr. Heming Franz, Johnson, V., 1945) about a mile west of the Johnson mine.

30. **A small talc deposit is exposed about 500 feet south of the mill of the Eastern Magnesia Talc Co., in Johnson village; the locality is 0.75 mile S. 60° W. of the center of the village.

Hardwick quadrangle

31. C. H. Hitchcock (1861, p. 541) reports a "bed of steatite on Lowell Mountain" in Eden. The location is uncertain, but possibly the reference is to the Lowell Mountains in northeastern Eden township.

Camels Hump quadrangle

32. Hitchcock (1861, p. 541) reports talc on top of Woodward Mountain on the boundary between Waterbury and Bolton townships. The probable location is 6.2 miles N. 37° W. of the junction in Waterbury village of State Route 100 and U. S. Route 2.

33. * A body of serpentinite crops out in the southeastern part of Duxbury township, 0.5 mile N. 30° W. of the church in the village of South Duxbury.

34. Hitchcock (p. 541) reports that "near Waterbury Street," now known as Waterbury village, "there is [a bed of steatite] twelve feet wide belonging to H. H. Pinneo."

35. Hitchcock (p. 541) reports that "there is another bed [of steatite] two miles north of Pinneo's, upon the same stream, belonging to W. Eddy."

Montpelier quadrangle

36. * A small body of grit is exposed about 0.2 mile southwest of the village of Colbyville in Waterbury township.

37. Hitchcock (p. 541) reports a "bed of steatite... three-fourths of a mile south of the village of Stowe."

38. It is reported locally that talc was found in a well on the farm of Craig Burt, about 2 miles northeast of Stowe village.

39. Hitchcock (p. 541) reports a "bed [of steatite] from ten to fifteen feet wide... at Barret and Gilman's ledge north of Waterbury Center."

40. ** A large body of talc and serpentinite is exposed on Barnes Hill in northeastern Waterbury township. The deposit is 2.2 miles N. 35° E. of the road triangle at Waterbury Center. Two occurrences reported by C. H. Hitchcock (1861, p. 541), "a bed of steatite in Stowe [township] near [the] Waterbury [township] line", and a "bed of steatite in the north part of [Waterbury] town[ship], upon D. Gray's land", probably may be identified with the Barnes Hill deposit.

41. ** The Waterbury talc mine is in northwestern Moretown township on the south bank of the Winooski River, 2.0 miles S. 45° E. of the junction in Waterbury village of State Route 100 and U. S. Route 2.

42. * A small outcrop of grit lies approximately half a mile west of the ultramafic body at the Waterbury mine. The locality is 0.8 mile S. 45° W. of the Rock Hill School in the northwest part of Moretown township.

43. Local reports place a small talc prospect about half a mile south of the highway intersection in Middlesex village.

44. C. H. Hitchcock (1861, p. 543) states that the Rev. S. R. Hall showed, on a manuscript map, a "bed of serpentine" in the east part of Middlesex township. Hitchcock shows this locality about 6 miles due north of the city of Montpelier, and about three-fourths mile east of the village of Shady Rill on the Geological Map of Vermont.

45. * A small body of grit and steatite is exposed 1 mile due east of the summit of Mt. Hunger in Worcester township.

Lincoln Mountain quadrangle

46. ** The Mad River talc mine is in northeastern Fayston township, 2.0 miles S. 63° W. of the center of the village of Moretown.

47. * A small grit and steatite outcrop lies 2150 feet S. 10° W. of the Mad River mine, on the right (east) bank of Shepard Brook and about 50 feet south of a road bridge over the brook. This outcrop is possibly on the same talc deposit as the Mad River mine.

48. Bain (1936, fig. 1) shows an ultramafic body about 1 mile south of the Mad River mine, probably between a quarter and half a mile due west of North School in northwestern Waitsfield township. A resident of Warren village informed us that talc occurs at this locality.

49. C. H. Hitchcock (1861, p. 541; see also Hager, A. D., p. 789) reports "a bed of steatite... upon Mrs. Jocelyn's land... one mile southeast of the village of Waitsfield." He gives the length and width of the body as 90 by 8 feet.

50. ** An ultramafic body crops out 0.25 mile due east of the church in Warren village. This is probably the locality to which C. H. Hitchcock (1861, p. 541) refers in reporting the occurrence of "a bed of steatite *** four feet wide near the River village in the south part of town."

51. ** A small serpentinite body is exposed 0.75 mile N. 24° E. of the four corners at East Warren. The outcrop is approximately 100 feet west of B. M. 1371.

52. E. C. Jacobs (1916, p. 240) reports the occurrence of steatite "on Mr. Edgar Towne's farm" in eastern Warren township. This locality is 0.4 mile southwest of South Hill School.

53. Edward Wigglesworth (1916, p. 285) reports a

serpentinite body on the east slope of Scrag Mountain, "5½ miles north of the Roxbury quarries and near the western border of Northfield [township]."

54. ** A small abandoned talc quarry is located in southern Roxbury township, 40 feet west of State Route 12 A and 330 feet north of the boundary between Addison and Washington Counties.

Barre quadrangle

55. * A small body of grit and serpentinite crops out in Roxbury township 0.88 mile S. 66° W. of the four corners in Roxbury village.

56. * A small ultramafic body is exposed 1.2 miles N. 42° W. of the four corners in Roxbury village.

57-65. Bain (1936, fig. 1) shows ultramafic bodies approximately as follows with respect to the four corners in Roxbury village:

57. 0.85 mile N. 75° W.
58. 1.45 miles N. 9° W.
59. 0.9 mile N. 21° W.
60. 0.7 mile N. 25° W.
61. 0.75 mile N. 35° W.
62. 0.45 mile N. 44° W.
63. 0.35 mile S. 50° W.
64. 0.6 mile S. 28° W.
65. 0.7 mile S. 28° W.

66. ** An ultramafic body is exposed 1.1 miles S. 28° W. of the four corners in Roxbury village.

67. ** An ultramafic body crops out 1.1 miles S. 25° W. of the four corners in Roxbury village.

68-71. Bain (1936, fig. 1) shows ultramafic bodies southwest of the four corners in Roxbury village approximately as follows:

68. 1.00 mile S. 31° W.
69. 0.95 mile S. 28° W.
70. 0.85 mile S. 30° W.
71. 0.45 mile S. 35° W.

72. ** The East Granville talc deposit lies about 4½ miles south of the Roxbury area, immediately west of the east border of Granville township and about 1 mile from the junction of the east border of Granville township and the south border of Roxbury township. An abandoned mine in the deposit is 0.3 mile due east of the center of the village of East Granville.

Rochester quadrangle

73. ** The Rochester verde antique quarry is in northern Rochester township, 2.95 miles due north of the square in the center of Rochester village.

74. ** The Williams talc mine, now abandoned, lies in the eastern part of Rochester township, 2.65 miles S. 70° E. of the square in the center of Rochester village.

75. ** A large serpentinite and talc body is exposed half a mile N. 30° W. of the Williams mine at Cushman Hill.

76-78. Jacobs (1914, p. 409) shows, on a crude sketch map, several other small talc deposits in the vicinity of the Williams mine. They are:

76. The Hubbard prospect, about 0.4 mile north of Cushman Hill.
77. A small prospect about 0.5 mile south of the Williams mine.
78. The McPherson mine, about 1 mile S. 15° W. of the Williams mine.

79-82. P. H. Osberg (oral communication, February 1949) reports ultramafic bodies northeast of Hancock village as follows:

79. 2.6 miles N. 80° E.
80. 3.15 miles N. 82° E.
81. 3.05 miles N. 83° E.
82. 2.45 miles N. 84° E. An ultramafic body that contains considerable talc is exposed at this locality, which is known locally as "Talc Ledge."

83-88. Bain (1936, fig. 1) shows ultramafic bodies east and southeast of Hancock village approximately as follows:

83. 3.2 miles due east
84. 3.3 miles due east
85. 3.35 miles S. 87° E.
86. 3.3 miles S. 84° E.
87. 3.5 miles S. 82° E.
88. 3.55 miles S. 78° E.

89. Osberg (oral communication, February 1949) reports an ultramafic body 2.95 miles S. 77° E. of Hancock village.

90. Bain (1936, fig. 1) shows an ultramafic body 3.55 miles S. 76° E. of Hancock village.

91-93. Osberg reports (oral communication, February 1949) ultramafic bodies southeast of Hancock village as follows:

91. 3.6 miles S. 74° E.
92. 3.7 miles S. 69° E.
93. 3.9 miles S. 55° E.

94. The Greeley talc mine, now abandoned, lies in western Stockbridge township about 1.1 miles N. 46° W. of the center of the village of Stockbridge. Bain (1936, fig. 1) shows a large body of serpentinite and two smaller masses a few hundred feet to the south of the large body. The north end of the large body lies at an elevation of about 800 feet above sea level and is immediately west of the grade of the abandoned White River Railway.

Randolph quadrangle

95. C. H. Hitchcock (1861, p. 539) reports that "there...is one [bed of steatite] in the village [of Bethel], upon the east side of White River.... Its length is twenty four rods."

96. Hitchcock (p. 540) reports that "In the westerly part of the town[ship (Bethel)] there is another bed of steatite."

97. Hitchcock (p. 540) reports that "In the north part of Bethel there is a bed of laminated talc." He shows this locality as 6 miles N. 48° W. of Bethel village on the Geological Map of Vermont.

Mt. Cube quadrangle

The deposits in this quadrangle lie about 20 miles to the east of the main belt of ultramafic rocks, from which they are separated by a barren strip.

98. C. H. Hitchcock (1861, p. 539) reports an occurrence in Thetford township, that "near the middle of the east side of this town... is an irregular bed of soapstone, about eight feet thick."

99. Hitchcock (p. 539) reports that "fifty rods west [of locality 98] is another mass of impure steatite."

100. Hitchcock (p. 543) reports a large mass of serpentinite in the northern part of Norwich and the southern part of Thetford townships. "It is about half a mile wide where it crosses the town line. Its eastern limit is just one mile from the Connecticut River. It is probably of great length."

Woodstock quadrangle

101. C. H. Hitchcock (1861, p. 539) reports "a bed of steatite" in Bridgewater township, "one mile north of the center of the town... on the west bank of the North Branch of the Ottauquechee River." The location has been confirmed by P. H. Chang (oral communication, February 1949) as 1 mile N. 5° W. of the bridge across the North Branch at Bridgewater Center.

102. Hitchcock (p. 539) reports another "bed of steatite" in Bridgewater township, 2 miles south of locality 101 and on the west bank of North Branch. He states that it is of little consequence.

103. Hitchcock (p. 539) reports a large serpentinite body in eastern Plymouth township. This deposit, with which there are associated several "steatite beds," is said by Hitchcock to extend southward for nearly 3 miles, into the Ludlow quadrangle. It is shown by E. L. Perry (1929, fig. 2, p. 40) at the village of Five Corners and south of there.

104. Hitchcock (1878) shows an ultramafic deposit on the west slope of Southgate Mountain near the summit, about 1 mile N. 25° E. of Bridgewater Corners.

105. Hitchcock (1878) shows an ultramafic body on the east slope of Cobb Hill near the summit, about 1 mile N. 40° E. of Bridgewater Center.

106. E. L. Perry (1929, fig. 3, p. 9) shows a body of "steatite" in western Bridgewater township 1.65 miles N. 63° E. of West Bridgewater village and "about one hundred yards north of the McElroy farmhouse."

107. Perry (1929, fig. 3, p. 9) shows another body of "steatite" in western Bridgewater township 1.65 miles N. 83° E. West Bridgewater village and "about a thousand yards south" of locality 106.

Hanover quadrangle

The ultramafic rocks in the Hanover quadrangle, like those in the adjoining Mt. Cube quadrangle, lie outside of the ultramafic belt proper.

108. C. H. Hitchcock (1861, p. 543) reports a "very compact serpentine rock, half a mile north of the Norwich depot on the railroad."

Ludlow quadrangle

109. Hitchcock (1861, p. 539; see also Hager, A. D., 1861, p. 787) reports steatite "in the southeast part of [Plymouth township] half a mile west of the meeting house [in Plymouth Kingdom?]." An attempt to find the deposit was unsuccessful, but an approximate location was obtained from a local resident, the door-sill and foundation of whose house contain blocks of grit of excellent quality, said to have been obtained from a quarry on this deposit more than 100 years ago.

110** A small body of talc is exposed in the northeastern part of Ludlow township, 0.8 mile S. 22° E. of North Hill School.

111. J. B. Thompson (oral communication, September 1948) reports a small body of talc in northeastern Ludlow township, 0.5 mile N. 50° E. of the road bridge over the Black River in Ludlow village.

112. ** A small body of talc, in which is an abandoned talc mine known as Valentine No. 2, is exposed in northeastern Ludlow township. 0.85 mile N. 70°E. of the road bridge over the Black River in Ludlow village.

113. ** Another small body of talc, in which is an abandoned talc mine known as Valentine No. 1, is exposed in northeastern Ludlow township, 0.9 mile N. 85° E. of the road bridge over the Black River in Ludlow village.

114. ** A talc deposit lies in eastern Ludlow township, 1.0 mile S. 57° E. of the road bridge over the Black River in Ludlow village.

115. * One of the larger ultramafic bodies in Vermont lies in southeastern Ludlow and southwestern Cavendish townships. The deposit is 3.5 miles long and as much as a mile wide. It is exposed along State Route 103, which bisects the body, in several road cuts between points half a mile and 1½ miles west of the village of Proctorsville.

116. J. B. Thompson (oral communication, September 1948) reports a small ultramafic body 2 miles S. 45° E. of the road bridge over the Black River in Ludlow village.

117. ** The Hammondsville talc quarry is located in eastern Reading township, 0.2 mile northeast of B. M. 969 in the village of Hammondsville.

118. J. B. Thompson (oral communication, September 1948) reports that a small talc deposit lies about half a mile west of the Hammondsville quarry.

119-123. Several other talc deposits were noted by J. B. Thompson (oral communication, September 1948) as follows:

119. Southwestern Weathersfield township at Quarry Pond, 0.9 mile due west of the village of Perkinsville.
120. Western Chester township, about 0.1 mile east of the junction of the townships of Ludlow, Andover, and Chester; a small deposit.
121. Eastern Andover township, about 0.1 mile west of the boundary between Andover and Chester townships and 2 miles south of the junction of Ludlow, Andover, and Chester townships; a small deposit, possibly a continuation of that at locality 120.
122. Eastern Andover township, 0.8 mile N. 45° E. of the village of Simonsville; a small body.
123. Eastern Andover township, 1.1 miles N. 40° E. of the village of Simonsville; a small body.

124. ** The Carleton talc quarry, now abandoned, is in Chester township, 2.2 miles N. 85° W. of Chester Depot.

Saxtons River quadrangle

125. J. L. Rosenfeld (oral communication, October 1948) reports a small body of serpentinite in northern Windham township, 1.6 miles N. 80° E. of the junction in the village of North Windham of State Routes 11 and 121.

126. ** The Vermont Talc Co. quarry is in a large ultramafic body in northern Windham township, 1.2 miles S. 60° E. of the junction in North Windham village of State Routes 11 and 121.

127. ** A large ultramafic body crops out in northern Windham township, 1.8 miles S. 55° E. of the road junction in North Windham village.

128. ** A talc deposit is exposed in northern Windham township 1.8 miles S. 65° E. of the road junction in North Windham village.

129. ** The Barton talc quarry, now abandoned, is in southwestern Chester township, 3.7 miles S. 48° W. of Chester Depot.

130. ** The Davis or Holden quarry, now abandoned, lies in southern Chester township, 2.1 miles S. 5° E. of Chester Depot.

131. C. H. Hitchcock (1861, pp. 542-543) reports a large serpentinite body "east of the village of Windham." He shows the locality as half a mile northeast of Windham Center on the Geological Map of Vermont.

132. Hitchcock (p. 542) reports a body of serpentinite in southeastern Windham township "northwest of [locality 133] about a mile and a half." This locality is probably about half a mile northeast of Burbee Pond.

133. J. L. Rosenfeld (oral communication, October 1948) reports serpentinite and grit 1.3 miles N. 45° E. of the village of South Windham.

134. Rosenfeld (oral communication, October 1948) reports outcrops of serpentinite in the trail 1.8 miles N. 85° E. of Burbee Pond, in southeastern Windham township.

135. Hitchcock (1861, p. 538) reports "One of the largest [steatite bodies] is in ... the southeast corner of [Windham township] upon the farm of Simeon Pierce... half a mile south of Pierce's house... . The bed is fifteen rods long and four rods wide... . It occupies the crest of the hill." Rosenfeld (oral communication, October 1948) locates the old Pierce house 1.75 miles N. 53° E. of South Windham village.

136. ** Several quarries, now abandoned, are opened on a presumably single deposit of steatite in southern Grafton township, 2.1 miles S. 15° E. of the center of Grafton village.

137. Hitchcock (1861, p. 536) reports "a tubercular mass of steatite of small size, in the east part of Townshend [township], upon the land of David Beamis... . The widest part of the bed is 30 feet." This location is confirmed by Rosenfeld (oral communication, October 1948) as 0.67 mile N. 80° E. of the pond at the village of Simpsonville.

138. Rosenfeld (oral communication, October 1948) reports a small steatite body 0.7 mile N. 83° E. of Lily Pond in southern Athens township.

Wilmington quadrangle

139. James Skehan (written communication, October 1949) reports a steatite body 0.95 mile S. 77° E. of the four corners in West Marlboro village.

140. Hitchcock (1861, p. 535) reports steatite "on the top of a hill in the west part of [Marlboro township], north of the Methodist church, [on] the property of Hosea Ballou." A small quarry was opened in the southern end, where "the bed is 50 feet wide... The total length of the bed was estimated at 25 rods." Probably the locality is about 0.2 mile N. 30° E. of the four corners in West Marlboro village.

141. Skehan (written communication, October 1949) reports a steatite body 0.6 mile N. 10° W. of the four corners in West Marlboro village. This is probably a locality referred to by Hitchcock (1861, p. 535): "Half a mile north [of locality 140] on the land of Ward Belus... in the bed of a brook there are two small beds of steatite... each fifteen feet wide."

142. Skehan (written communication, October 1949) reports a steatite body 1.3 miles N. 18° E. of the four corners in West Marlboro village.

143. Skehan (written communication, October 1949) reports a steatite body 0.6 mile due south of the junction of the townships of Dover, Newfane, and Marlboro. This is the locality reported by Hitchcock (1861, p. 535) "in Marlboro [township] in the northern part of town... upon the land of Clark Worden." Hitchcock (p. 535) states that this body is 20 rods long and 4 rods wide.

144. Hitchcock (1861, p. 542) reports a large body of serpentinite in eastern Dover and western Newfane townships that extends from near the junction of Dover, Newfane, and Marlboro townships "for a distance of 3 miles along the line of Dover and Newfane [townships]. Where Rock River cuts through the serpentine in Dover and Newfane, the serpentine is nearly a mile wide."

Brattleboro quadrangle

145. Hitchcock (1861, pp. 535-536) reports steatite in Newfane, which he considers as possibly a continuation of the ultramafic body at locality 144. The deposit is described as situated on a hill in the northwest part of Newfane at an altitude of about 1620 feet, and as at least half a mile long and not less than 12 rods wide at the north end. The locality is probably about 5 miles N. 40° W. of the junction of Marlboro Branch and Baker Brook at Williamsville.

Descriptions of deposits

Most of the deposits that the authors have examined are described briefly in the following section. The descriptions include directions for access, a statement of the size and shape of the body, if known, and a general description of the character of the ultramafic rocks. Several of the deposits have been mapped in considerable detail and are more completely described.

The locality numbers correspond with those in the foregoing section.

Montgomery Center talc prospect Locality 5

The Montgomery Center talc prospect lies in west-central Montgomery township, 1.45 miles S. 62° W. of the junction in Montgomery Center of State Routes 118 and 58. The deposit is in a small saddle at an altitude of 1170 feet. Total relief in the general area is about 1200 feet; in the immediate vicinity of the deposit, it is low to moderate.

To reach the locality from the village of Montgomery, drive westward on State Route 118 for 0.5 mile from the center of the village and turn left (south) a little east of the bridge over West Hill Brook. Continue southward about $2\frac{1}{2}$ miles to an old lane on the left (east) side of the road. The talc prospect is at the east end of this lane, about 0.6 mile from the road. The lane is impassable by auto.

The nearest railroad is the Central Vermont at East Berkshire village, 6 miles to the northwest.

The prospect.-- Grit crops out about 150 feet north of the lane which provides access to the prospect, along the base of a small ledge that faces southward. Near the west edge of the ledge is a shaft, inclined about 60° to the north; its depth is unknown because it is now filled with water. Three small pits have been opened at the foot of the ledge to the east of the shaft; grit and steatite are exposed in two of these. Although the extent of the underground workings is unknown, the small size of the dump indicates that mining operations were probably not extensive.

Geology.-- Outcrops are insufficient to determine the size and shape of the deposit. Grit is exposed in the shaft, in two of the pits on the north side of the lane, and in two small [outcrops] about 20 feet south of the lane. Although these exposures seem to indicate a maximum width of about 180 feet, the grit outcrops north and south of the lane are probably on two separate deposits whose aggregate thickness is much less than the 180-foot maximum, the length is indeterminate. Possibly the two series of outcrops represent a single, tabular body that is folded.

Serpentinite is nowhere exposed in the deposit, and insofar as can be determined from the limited exposures and from an examination of material on the dump, it has been altered entirely to grit and steatite. The talc is of good quality although the surficial material examined was stained deeply brown from weathering of iron-bearing carbonate.

The country rock in the immediate vicinity of the prospect consists of quartz-mica schist and dark, blue-green, vitreous quartzite. The bedding and schistosity are nearly or quite parallel. They vary widely in attitude. The strikes range from north to west, the dips from vertical to nearly horizontal. Probably the predominant attitude is strike northwest, dip steep to the northeast.

The structural relationships of the ultramafic rocks to the country rock are obscure. That the country rock is folded is shown by small folds visible in individual outcrops and by the wide range in attitude exhibited by both bedding and foliation on a larger scale throughout the area. Foliation in the steatite indicates that the ultramafic rock has been subjected to stress. It is not possible to say at present, whether the deposit is a tabular mass that has been folded or whether it is an irregular tabular body or lens (or two separate lenses) injected into previously folded rocks and affected by only the late stages of movement.

Reserves.-- It is impossible to arrive at a quantitative estimate of reserves because the size and shape of the deposit cannot be predicted except within very wide limits on the basis of work to date. If the deposit is a single, large lenticular body, reserves are probably several hundred thousand tons. If, on the other hand, the deposit is a folded tabular body, reserves are possibly only a few thousand tons.

Belvidere Mountain asbestos quarry, Locality 9

The Belvidere Mountain asbestos locality is on the southeast flank of Belvidere Mountain in northern Eden and southwestern Lowell townships. The operating quarry is in Lowell township, 0.6 miles N. 10° W. of Corez Pond. The old quarry is about 1 mile S. 75° E. of the present quarry. The altitude of the operating quarry is about 1300 feet; the old quarry, about 2150 feet. Total relief within a radius of 1 mile of the old quarry is about 2100 feet.

To reach the operating quarry from the village of Hyde Park, drive north on State Route 100 for 11.1 miles from the junction with State Route 15 to the center of Eden Mills. Turn half left off Route 100, continue northeastward 0.15 mile, and turn half left

again. Drive 3.5 miles north to the entrance to the quarry. Turn left and continue on to the mill and quarry offices.

The nearest railroad is the St. Johnsbury and Lamoille County at Hyde Park village, about 15 miles southwestward by road.

The geology of the locality has been described by Marsters (1905, pp. 419-446).

We have made two short trips to the locality. The ultramafic body appears to be at least a mile long and several hundred or perhaps a few thousand feet wide. The trend of the long axis of the body is about east or east-northeast. Both serpentinite and dunite occur. Details of occurrence of asbestos have not been investigated. Talc is reported to occur at the locality, but we saw none. Within the ultramafic body in tabular or lenticular masses, and at least locally along the contacts there is a lime-silicate rock, composed principally of garnet, diopside, and vesuvianite.

Reserves. Total reserves of asbestos and talc are not known, but the asbestos reserves are likely sufficient for more than 10 years, at the present rate of production of about 30,000 tons annually 11/.

Locality 16

An ultramafic body of unknown, but probably large size is exposed in west-central Troy township, 0.8 mile S. 65° E. of the road triangle in Troy village. The talc deposit lies at an altitude of about 960 feet, a little below the brow of a hill on the east slope of the Missisquoi valley. Relief in the immediate area is moderately low and totals less than 200 feet in a radius of half a mile.

To reach the locality from the village of Troy, drive eastward on State Route 100 for 0.5 mile from the road triangle at the center of the village and turn right (south) immediately after crossing the Missisquoi River. Continue southward for about 0.4 mile. The talc crops out about 1000 feet east of this point, a little below the brow of the hill.

The nearest railroad is the Canadian Pacific at Newport Center, about 5 miles to the northeast.

Geology.-- Only a few minutes were spent at this locality. The size and shape of the deposit are not known, but grit crops out for a distance of at least 200 feet in a north-south direction, and for at least 70 feet east-west. Serpentinite crops out a short distance southeast of the grit outcrops.

The talc is of good quality but locally the grit contains abundant specular hematite. This would undoubtedly destroy the value of the talc unless beneficiation should be practicable.

The country rock in the immediate vicinity of the grit outcrops is not exposed, but a short distance to the west light-colored volcanic rocks are well-exposed.

Reserves. -- The possibilities are good that a large deposit of talc exists at this locality, although an accurate estimate of reserves is not possible. The commercial value depends largely upon the extent of hematite throughout the deposit, and whether beneficiation is practicable.

Locality 17

A large ultramafic body crops out on the land of Arnold Peters, 1.1 miles N. 70° E. of the road triangle in Troy village. Relief in the immediate vicinity of the deposit is about 400 feet.

The locality is only a few minutes drive from Troy village. Drive eastward on State Route 100 a distance of 1.1 miles from the road triangle in the center of the village. The Peters' farm is on the left-hand (north) side of the road. The talc deposit crops out about 600 feet north of the house; the outcrops extend from the bed of a westward-flowing creek to at least midway up the southwestern slope of the hill on the right bank of the creek.

The nearest railroad is the Canadian Pacific at Newport Center, about 5 miles to the northeast.

Geology. -- The exact size and shape of the ultramafic body are not known, but it is almost certainly large, because the grit outcrop in the stream valley is at least 200 feet wide, and serpentinite and grit crop out about 1000 feet to the north. The grit examined was of good quality. It is believed that the ultramafic body is extensively steatitized.

No exposures of country rock were noted near the ultramafic rocks.

Reserves. -- A quantitative estimate of reserves is not attempted, but it is believed that the deposit is large. Moreover, it is possible that the steatite, grit, and serpentinite at this locality and at locality 16 are part of one large deposit. Should this prove to be true, the total reserves of talc and grit probably are great.

Waterville talc quarry, Locality 22

An abandoned talc and soapstone quarry in northern Waterville township lies 3.45 miles N. 12° E. of the center of Waterville village. The quarry is at an altitude of about 1000 feet above sea level on the eastern slope of Bears Den Hill. Relief in the immediate vicinity of the quarry is moderate; total relief within a radius of a mile is about 1100 feet.

The locality can be reached from the village of Waterville by driving northeastward from the road junction near elevation 493 (as shown on the topographic map) in the center of the village for a distance of 3.1 miles on the road to Belvidere Junction. Turn left (west) on the side road opposite elevation 699 (Hyde Park quadrangle) and continue westward for 0.2 mile; turn right (north) and drive 0.55 mile to the most northerly of two houses several hundred feet apart. The old quarry is approximately 1900 feet N. 50° W. of this house.

11 Quoted by permission of the Vermont Asbestos Mines, written communication, May 19, 1950.

The nearest railroad is at Cambridge Junction, about 7 miles to the southwest, where the Central Vermont and the St. Johnsbury and Lamoille County railroads join.

The quarry.-- The quarry workings are now slumped, overgrown with brush, and filled with water, so that it is difficult to assess the former operations. It is apparent, however, that operations were on a small scale. Some of the quarry walls reveal that part of the product was extracted as sawn blocks for soapstone, but the ruins of an old mill in which there were several millstones indicate that part of the product was marketed as ground talc.

Near the eastern contact of the deposit are two small quarries. The southernmost is the larger, being about 60 feet long by 40 feet wide and of unknown depth. The smaller quarry measures about 20 by 30 feet and lies 15 feet to the north of the larger one. It is evident that most of the soapstone came from these two quarries.

Approximately 80 feet to the northwest, along the western contact, is an irregular pit about 40 feet in diameter. This pit was probably the source of steatite and grit used for a ground talc product.

Geology.-- The deposit has about 130 feet maximum width, but it is pinched down to less than 40 feet at the southern end of the exposure. The exposed length of the body is at least 160 feet. The deposit, insofar as could be seen, consists of grit and steatite, with considerable actinolite along the eastern contact. No serpentinite is exposed. The country rock is quartz-mica schist.

The eastern contact of the deposit, exposed for a distance of about 60 feet, is fairly regular in attitude, striking N. 30° to 35° E. and dipping 70° to 75° westward. The western contact, exposed intermittently over a distance of about 160 feet, is variable in attitude: the strike at the northern end ranges from N. 10° E. to N. 55° E., the dip from 40° westward to 70° northwestward; at the center of the exposure the strike of the contact is N. 25° W., the dip 60° southwestward; at the southern end of the exposure the strike of the contact is N. 20° E., the dip 40° northwestward.

The schistosity of the country rock is apparently everywhere conformable with the contact of the ultramafic body. A well-developed schistosity is found locally in the steatite and grit. The strike of this schistosity is almost parallel to the general strike of the country rock (about N. 20° to 30° E.), but the dip is vertical or steep to the east, in contrast to the schist which dips moderately to steeply westward.

Reserves.-- On the basis of brief examination, the deposit does not appear to contain a significant reserve. However, the grit is of good quality, and detailed study might disclose additional reserves.

Rousseau talc prospect, Locality 23

The Rousseau talc prospect is in northern Cambridge township, 2.1 miles N. 59° E. of Cambridge Junction. The deposit is on the south side of the Lamoille River near the base of the northernmost mountain of the Sterling Range. An old prospect adit lies at an altitude of about 530 feet above sea level and 70 feet above the flood plain of the Lamoille. Maximum relief within a radius of a mile is about 800 feet.

For access to the prospect from Johnson village, drive westward on State Route 15 for 5.9 miles from the center of the village. The dump of the talc prospect is plainly visible about 200 feet south of the highway.

The St. Hohnsbury and Lamoille County Railroad passes within a few hundred feet of the prospect.

The prospect.-- A prospect adit has been driven southward in the grit-steatite body along the eastern contact with the schist for a distance of 125 feet. Twenty-five feet south of the adit entrance, a 20-foot cross-cut extends to the western contact, and an 80-foot drift continues southward along that contact, making a total of a little more than 200 feet of workings. Six diamond drill holes that total almost 1100 feet have been drilled at the prospect.

Geology.-- Surface exposures, underground workings, and diamond drill cores show the talc body to be wedge-shaped. The deposit is 100 to 125 feet wide at a depth of 180 feet below the adit, measured along the dip. It narrows upward at a fairly constant rate to a thickness approximately 40 feet at the altitude of the adit. At a point 100 feet southeast of the adit, the talc body is not more than 5 feet thick. Within a few hundred feet farther to the southeast, it is believed to pinch out entirely or to become very thin, at least at the surface. The known length of the deposit is 350 feet.

The entire ultramafic body, as nearly as can be determined, is altered to grit and steatite. The material is of excellent quality, although much of that near to the surface is stained brown from weathering of iron-bearing carbonate.

The country rock consists of quartz-mica schists and greenstones. Locally, the schist contains garnet, biotite, and albite.

Diamond drill cores indicate that the attitudes of both the foot- and hanging-walls of the deposits are fairly constant below the level of the adit. The strike of both varies generally from about north to N. 5° W. The dip of the hanging-wall is approximately 25° westward; the dip of the footwall varies from 45° to 60° westward.

Above the level of the adit, at an altitude of about 570 feet, the hanging-wall is involved in several folds with amplitudes of 10 to 20 feet and widths from crest to crest as much as 40 feet. It is not known whether the foot-wall is folded sympathetically.

The talc deposit lies on the western limb of the Green Mountain anticlinorium. The contact of the ultramafic body is conformable with the foliation and bedding wherever exposed. The general strike of bedding and foliation is slightly west of north; the dip is, in general, 20° to 40° to the west. Small scale

drag folds, including those in the hanging wall of the ultramafic body, show a rather consistent gentle plunge to the south, comparable with the plunge of the Green Mountain anticlinorial axis in this latitude. The plan of the fold pattern of both the small drags and of the larger folds is dominantly such as to indicate that they are on the western limb of a southward-plunging anticline, which would seem to indicate that the minor folds are genetically related to the formation of the Green Mountain anticlinorium.

Reserves. -- The Rousseau prospect is one of the more promising talc deposits of Vermont. Indicated reserves are conservatively estimated at 500,000 tons on the basis of underground prospecting and diamond drilling. Inferred reserves are at least that large and may well total several million tons.

Sterling Pond talc deposits, Locality 25

Several large talc deposits are exposed near Sterling Pond, in the northwestern part of Stowe township, about 1.2 miles due east of Smugglers Notch. The deposits are at altitudes of 3000 to almost 3600 feet above sea level. Relief within a radius of a mile of Sterling Pond is about 1700 feet, and topography is rather rugged.

Because of the altitude, snowfall is heavy and snow accumulates to great depths. Winters are long and cold. On the average, the area is snow-free for only about 4 or 5 months each year.

Access to Sterling Pond is by foot trail. From Stowe village, drive northwestward on State Route 108 for approximately 10 miles to the height of land at Smugglers Notch. About 600 feet north of the height of land, and directly opposite the site of a souvenir stand, a well-marked (white-painted blazes) trail leads from the road eastward to Sterling Pond, which is $1\frac{1}{4}$ to $1\frac{1}{2}$ miles away by trail. The ascent is about 1000 feet.

One of the greatest drawbacks to development of the deposits is the relative remoteness of the area from shipping facilities. The nearest road, through Smugglers Notch, is more than a mile distant across rugged terrain, and the nearest railway shipping point is at Cambridge Junction, about 7 miles to the north.

Geology. -- The country rock is predominantly quartz-mica schist in which small albite porphyroblasts are common and locally abundant. Garnet also is abundant locally, and some biotite was noted. The strata everywhere exhibit folds which range from a fraction of an inch to several hundred feet across. The bedding and schistosity dip gently to moderately east or west in folds which plunge about 15° southward. The locality is about a mile east of the axis of the Green Mountain anticlinorium.

Grit is exposed in at least seven localities within a mile of Sterling Pond. Grit of excellent quality crops out about 500 feet west of the pond for a distance of 200 feet along the trail between Smugglers Notch and Sterling Pond. The eastern contact with the schist was not found, but the western contact strikes about west-northwest and dips at a moderate angle northeastward.

Grit crops out at a point 300 feet southwest of the outlet of the pond, in the trail (marked by blue-painted blazes) leading southward from Sterling Pond over Spruce Mountain. The schistosity in the grit strikes about northeast and dips 45° to 50° to the southeast. Southeastward from the outcrop in the trail (and about normal to the strike of the schistosity), grit crops out intermittently over a distance of at least 80 feet. A serpentinite outcrop of 20 or 30 feet wide is exposed about 100 feet southeast of the grit outcrop in the trail. Southeastward beyond the serpentinite, or about 150 feet southeast of the outcrop of grit in the trail, is another outcrop of grit. Schist is exposed 10 feet or so to the southeast of this last grit outcrop. The wallrock schistosity, and therefore probably the margins of the ultramafic body, strike northeast and dip 30° - 40° to the southeast.

Grit crops out almost continuously along the entire southeast shore of Sterling Pond, and some grit occurs on the peninsula that juts out from the western side of the pond. The outcrop width of the grit along the southeast shore, measured normal to the strike of the body, is 200 feet. The general attitude of the body is: strike east-northeast, dip 15° to 20° southward.

Grit crops out about 500 feet east of the pond for about 20 feet along the trail between Sterling Pond and Madonna Peak.

A talc body at least 200 feet wide and more than 750 feet long is exposed about 1500 feet east of the pond, on the trail to Madonna Peak and at the divide between a north- and a south-trending intermittent stream. The eastern contact of the ultramafic body strikes north and dips 45° eastward.

Two other outcrops of grit and steatite occur between the saddle and Madonna Peak; one about 200 feet east of the saddle, and another at an altitude of 3580 feet about 500 feet south of the summit of Madonna Peak.

Probably the first three occurrences described represent one tabular body, involved in folds several hundred feet across. The other outcrops are probably on separate masses, although it is possible that they all represent one sheet-like body repeated in folds.

The grit in this locality is of very good quality. The high outcrop ratio of grit and steatite to serpentinite indicates that the ultramafic rocks have been extensively steatitized.

Reserves. -- All indications are that reserves at this locality are very large, at least several million tons. The greatest drawback to their development is the relative inaccessibility of the area.

Johnson talc mine, Locality 28

The Johnson talc mine, the largest in Vermont, is in northeastern Johnson township, 2.85 miles N. 39° E. of the center of Johnson village. The altitude at the southern end of the deposit is about 950 feet; at the northern end, about 1300 feet; the altitude of the collar of the shaft is approximately 1050 feet. Relief in the immediate vicinity of the mine is rather low, and of the general area, moderate; total relief within a radius of a mile is about 1000 feet.

To reach the mine from Johnson village, drive northeastward on State Route 100 C from its junction with State Route 15 for a distance of 2.8 miles, to the four corners. Turn left (west) at the schoolhouse and continue westward for 0.8 mile, to a fork in the road; take the right-hand fork and continue about 0.6 mile to the mine.

The nearest railway is the St. Johnsbury and Lamoille County at the village of Johnson, about 4½ miles to the southwest by road.

The mine. -- Before the beginning of modern operations by the present owners (Eastern Magnesia Talc Co.), the deposit was worked intermittently and on a rather small scale by several operators. These operations date probably to the early 1900's, possibly earlier. Most of the old workings are now inaccessible, being caved or flooded. The various groups of workings are now designated Mine No. 1, Mine No. 2, Mine No. 3, and Mine No. 4.

Mine No. 1 includes the 1st, 2d, 3d, 4th, 5th, and 6th levels. Levels 1 to 4 were worked from an old shaft, long since caved, located 120 feet east of the so-called Mine No. 1 shaft, now also caved and inaccessible. Levels 1, 2, 3, and 4 were mined entirely by hand methods, and the workings were not extensive. The levels were spaced probably not more than 40 feet apart vertically.

The 5th and 6th levels were mined from Mine No. 1 shaft, near the south end of the ultramafic body. The shaft was inclined about 46° southward. The altitude of the 5th level is 876 feet 12/ at the shaft. The workings consist of a system of rooms and pillars over an area 650 feet long north-south and 200 feet wide. These openings are now caved and inaccessible.

The 6th level is at an altitude of 796 feet (mine datum) at the shaft. Workings total about 8000 feet, but only 3500 feet of these at the northern end of the level are now accessible, the southern part of the level being caved and flooded.

Mines No. 2 and 3 were worked by small, vertical shafts not more than 50 feet deep. Both were mined by hand methods, and the workings associated with each were not more than 200 feet in extent. At present, Mine No. 2 is flooded; Mine No. 3 has been broken into by stoping operations from the 200-foot level below.

Mine No. 4 includes the 200-foot level and the 170-foot level the latter a small drift no longer being mined. The 200-foot level is mined from the Mine No. 4 shaft, inclined 45° southward. The designation "200-foot level" refers to the distance in feet below the collar of the shaft, measured along the incline. The altitude of the 200-foot level is 940 feet at the shaft. The workings total more than 7500 feet. The Mine No. 4 shaft recently has been extended downward to the old 6th level so that mining operations may be resumed on that level.

Mining operations at the Johnson mine are on a moderate scale (about 50,000 tons annually) but are efficient and chiefly mechanized. The drifts are driven almost entirely in grit, which is massive and holds up well with little or no timbering. Pneumatic drilling equipment is used throughout the mine. Broken rock at the working face is loaded with pneumatic mucker.

The stoping method is a flexible system of overhand benching, readily modified to suit the size and shape of the talc body being mined. In general, a steeply inclined raise is driven from the side of a drift near the roof. The raise is continued into the grit body for as far as is practicable, and near to the hanging wall of the talc deposit. A chute is installed at the bottom of the raise about 5 feet above track level, and a grizzly installed in the raise about 25 feet above the track. Thereafter, the grit and steatite are mined back from the raise in a series of benches so that it runs to the grizzly and chute by force of gravity. Near the end of mining operations in a given stope, especially if the body is fairly flat-lying at that location, it is sometimes necessary to use an electrically powered scraper to get the rock to the grizzly.

At the chutes, the broken rock is loaded into 1-ton cars and hauled by battery-driven locomotives to the foot of the shaft, where the cars are emptied into a 1-ton skip. The skip is hoisted to the surface by an electrically-powered winch, and dumped into a sorting device which separates the material into coarse, medium, and fine. From the bins the ore is dumped into trucks and hauled to the mill at Johnson village, about 4½ miles distant by road.

Geology. -- The talc deposit has a known length underground of 3500 feet, and extends northward beyond the known extent for an unknown distance under a cover of glacial drift. The southern limit of the deposit is definitely established.

At the southern end, the deposit is a single, simple, lenticular mass about 180 feet thick, that strikes N. 20° E. and dips 75° to the east. Northward, however, the deposit becomes more complex. A septum of schist appears on the 5th and 6th levels about 300 feet north of the southern end of the deposit, and divides it into an eastern and a western body. Farther north the relations become more and more complex, so that the cross-cut at the foot of the shaft on the 200-foot level discloses five talc bodies. Probably all are separate masses; that is, they are not a single tabular body repeated by folding. It is possible, however, that they branch from a single body and that they join downward. Elsewhere, folds further complicate the form of the deposit; and irregular septa (called "cinders" by the miners) that range widely in size are distributed sporadically throughout the talc bodies. The general picture, then in the northern end of the mine, is of a series of pinching and swelling, irregular tabular bodies which strike a little east of north and dip steeply

[12] All elevations are relative to mine datum; to correct approximately to sea level datum, subtract 35 feet from the altitude given.

to moderately eastward, and which are locally complicated by the existence of folds and by numerous included septa of schist.

The ultramafic mass has been very largely altered to grit and steatite, with a few relatively small remnants of serpentinite. There is an elliptical, pipelike remnant of serpentinite at the south end of the body, about 250 feet long and 75 feet wide, which plunges to the north at 45° to 50°. The size and shape of this serpentinite mass is inferred from limited surface exposures and from mining company maps of the 5th and 6th levels which are inaccessible in the vicinity of the serpentinite. Serpentinite has been encountered at three or four places in the northern end of the mine in relatively small- to moderate-sized masses, more or less altered locally to grit. Elsewhere, the ultramafic body has been entirely altered to steatite and grit.

The country rock consists of quartz-mica schist and micaceous quartzite; the schist is locally graphitic. At the contact with the ultramafic body the country rock is altered to chlorite schist, the blackwall, for a distance of 0.5 to 2 feet outward from the contact. The contact of the blackwall with the steatite is abrupt, but locally gradational over a distance of a fraction of an inch or a few inches. The blackwall grades into the unaltered schist, commonly over a distance of a few inches, but locally over a distance of a foot or more.

The sequence outward from any of the masses of serpentinite, except where subsequent faulting has disturbed the original relationship, is the normal one: serpentinite, grit, steatite, blackwall (chlorite schist), and unaltered schist. Locally, however, post-steatite faulting has cut out one or more of the zones so that serpentinite may be in contact with blackwall, or steatite with unaltered schist, etc.

The serpentinite is fine-grained, dark green and, at least where exposed, nonschistose. Where favorably exposed, the serpentinite exhibits shear polyhedrons which have been more or less completely obliterated by the alteration to talc and carbonate. Serpentinite grades into grit, in most places rather abruptly, but also commonly through distances of a foot or more.

The grit, which is medium to light gray in color, is an aggregate of talc and carbonate. The carbonate, which forms 30 to 50 percent of the rock, is scattered rather uniformly in grains one-eighth to three-fourths of an inch in diameter throughout a fine groundmass of talc. Commonly the carbonate is anhedral, but locally a rather large percentage of grains have subrhombic outlines. The grit is commonly nonschistose.

The steatite is dark gray to light gray-buff in color and is composed almost entirely of fine-grained talc. It generally shows a poor to good schistosity nearly or quite parallel to the contact with the blackwall, and to the schistosity of the country rock. In some places the schistosity of the steatite departs by a few degrees from that of the country rock which is almost always, except at fault contacts, parallel to the contact. At a few places where the steatite is involved in folds a few feet or tens of feet in amplitude, a schistosity roughly parallel to the axial plane of the fold is present in the steatite.

On the average, the schists strike about N. 20° E. and dip steeply to the east or are vertical in surface exposures. Underground, the dips are in general somewhat less steep. This apparent difference in dip is possibly a reflection of resistance to weathering and erosion, which has favored the preservation of outcrops of areas with steep schistosity.

Throughout most of the underground workings the schist represents a homoclinal sequence with tops of beds to the east. Bedding and schistosity everywhere appear to be essentially parallel, and dip an average of about 60° to the east, with only minor folds represented by flattening of the dips to horizontality or slightly to the west. Such folds are commonly not over a few feet from crest to crest. In some places, however, there is evidence of rather tight folds. In other places, such as in the rolls common in the hanging wall of the talc deposit, where chloritization has completely destroyed the original structures of the schist, it is difficult to demonstrate that the feature is a fold and not an intrusive phenomenon. But in the northern end of the workings, several synclinal "rolls," clearly of fold origin, include both the talc rock and the schist.

Faults formed after steatitization are rather prominent in the Johnson talc body. The faults, in general, strike about north-northeast and dip predominantly 30° to 60° eastward; a few faults strike northwest and dip westward at moderate angles. There is no reliable evidence as to the direction and amount of movement along the faults, although strias and gouges generally indicate diagonal slip. Breccia zones up to 4 feet thick are developed along several of the faults. It is probable that the net slip of the faults is several tens to a few hundred feet. It has certainly been enough to complicate noticeably the structure of the deposit.

The serpentinite and grit are probably entirely of ultramafic origin. The steatite is believed to be derived dominantly from the ultramafic rock, but a small amount of the steatite, chiefly a thin layer next to the blackwall, has been formed by alteration of the blackwall. Locally, this alteration of blackwall to talc has been proportionately greater, so that steatite derived from blackwall makes up the greater part of the steatite zone. It should be emphasized, however, that this is a local feature and that, for the deposit as a whole, the larger part of the steatite zone is derived from the serpentinite.

The complexity of the Johnson deposit is due to a combination of several factors, the relative importance of which varies from place to place. These factors are: the complex and irregular shape of the original intrusive body, irregular steatitization of the schist, and folding, and faulting. It has not yet been demonstrated whether the folds involving the ultramafic body are forms impressed upon the intrusive body by previously folded rocks or whether at least part of the folding is post-intrusive.

Reserves.-- The operators make no attempt to evaluate reserves on the basis of "measured,"

"indicated," and "inferred" ore, chiefly because the character of the deposit and the methods of mining do not make such a practice economically feasible. Underground diamond drilling is practiced extensively at the Johnson mine, but has proved rather disappointing as a means of measuring reserves. The extreme irregularity of the deposit makes it impossible to form a quantitatively reliable estimate of reserves on the basis of diamond drilling alone.

The aim of the operators is at all times to have a 6 months reserve of ore in sight (about 20,000 to 25,000 tons). This amount constitutes the only "measured" reserve, but the geologic evidence suggests considerable "inferred" reserves of ore. It is probably a safe prediction that at least one or two years' supply of ore is left on the 200-foot level, and an unknown but considerable reserve on the 6th level, down to which the Mine No. 4 shaft has now been extended. A conservative conclusion is that there are probably sufficient reserves for at least 3 to 5 years more of operation at the present rate of production, or from 150,000 to 250,000 tons of ore. Further exploration may disclose much larger reserves. 13/

Locality 30

There is a small, abandoned talc mine near the southwest corner of the village limits of Johnson; the location is 0.75 mile S. 60° W. of the center of the village. The deposit is at an altitude about 640 feet above sea level and about 140 feet above the Lamoille River. Relief in the area is moderate, the maximum within a mile being about 800 feet.

To reach the locality from Johnson village, turn southwest off State Route 15 at the dummy policeman in the center of the village and drive for 0.5 mile to a fork in the road just beyond the railroad tracks. Take the right-hand fork and continue for about one-fourth of a mile to the mill of Eastern Magnesia Talc Co. The dump and a grove of small trees around the cave-in and open pit of the old workings are plainly visible in the open pasture about 500 feet south of the mill.

A railway shipping point on the St. Johnsbury and Lamoille County Railroad is only a quarter of a mile northeast of the locality.

The mine.-- The deposit was first mined in 1904, and small-scale operations were carried on more or less continuously until shortly after World War. 1. There are no accurate reports on the total extent of the workings but, judged by the durations of operations, the workings are probably rather extensive.

Geology.-- The country rock in the vicinity of the deposit consists of quartz-mica schist and blue-green, vitreous quartzite. Geological relations of the ultramafic body are poorly exposed in the badly slumped and caved open pit. The deposit appears to be similar to the Johnson mine deposit, being nearly or completely altered to grit and steatite. The grit exposed in the west wall of the cave-in is of good quality and superior color.

[13]Quoted with permission of Eastern Magnesia Talc Co., Burlington, Vt. Since the above was written, exploration and development about 150 feet below the 6th level have exposed large additional reserves of excellent talc.

The country rock strikes about N. 20° E. and dips steeply to the east. The steatite has a very well developed schistosity which is about parallel to that of the country rock. At the northeastern corner of the cave-in, the blackwall zone is discordant with the schistosity; presumably, this means that the ultramafic contact was also discordant at this point, although it was probably only a local feature.

The schists and quartzites show rather widespread folding on a small scale. In the schists, the folds are tight and have amplitudes measured in inches or one or two feet; in the quartzite beds, folds up to 10 feet in amplitude were observed.

Reserves.-- Knowledge of the size and nature of the deposit and of the extent to which it was worked in the past is meager. Consequently, it is difficult to arrive at any valid estimate of reserves. It is probable, however, that reserves of recoverable material are small.

Barnes Hill talc prospect, Locality 40

The Barnes Hill talc prospect is in the northeastern part of Waterbury township, about 2.2 miles N. 35° E. of the road triangle at Waterbury Center. The deposit lies at an altitude of about 1180 feet on a gently rolling upland of low relief.

To get to the prospect from Waterbury village, take State Route 100 northeastward from Waterbury for a distance of 3.5 miles from the junction with U. S. Route 2. Turn right (east) off Route 100 and continue east for 0.35 miles to the eastern corner of the road triangle, a few hundred feet beyond the traffic light. Turn left (northward) and continue northeastward along the main graveled road for 2 miles. The talc deposit lies about 1000 feet east of the road at this point on the crest of a low ridge.

The deposit is in open country and is of easy access. The nearest railroad is at Waterbury village, about 6 miles to the southwest.

Wigglesworth (1916, pp. 284-286) has studied and described briefly the locality.

The prospect.-- Limited prospecting has been carried out at the Barnes Hill locality at several times in the past. A small prospect shaft, reportedly about 15 feet deep, was sunk near the center of the east side of the deposit, and a number of small pits and trenches were opened. In 1947 the Eastern Magnesia Talc Co. drilled six diamond-drill holes, which total about 1300 feet in length, along the east side of the deposit.

Geology.-- The ultramafic body is crudely elliptical in plan and has a known length of about 1400 feet and a maximum width of 375 feet. The trend of the long axis is about N. 20° E. At the northern end the western contact strikes somewhat east of north and dips steeply to moderately eastward; at the southern end the western contact strikes northwest to west-northwest and dips moderately northward. The attitude of the eastern contact is not known, but judging from the schistosity of several outcrops of schist to the east of the ultramafic body, probably it also dips steeply eastward.

The deposit consists almost entirely of grit and serpentinite, but locally within the ultramafic body there are thin tabular masses of carbonate rock. Possibly these are septa or inclusions of sedimentary carbonate, or they may be segregations formed during the steatitization process. The greatest concen- northern end of the deposit. However, the spatial relation between the serpentinite and grit is not as simple as that found in most lenticular deposits, for grit occurs sporadically in the serpentinite throughout the width of the deposit. Apparently, the transition from grit to serpentinite is nearly always very abrupt, taking place in a fraction of an inch. However, petrographic study may disclose that the transition is not so abrupt as the megascopic appearance seems to indicate.

A fine banding is readily distinguishable in the majority of serpentinite outcrops and more faintly preserved in many of the grit outcrops. The banding is emphasized on weathered surfaces. Megascopically, the banding appears to consist of alternating dark and light layers one-sixteenth to one-fourth of an inch thick. Microscopically, banding in the two sections examined consists of alternating layers of serpentine and carbonate. The banding commonly has a fairly uniform attitude within the limits of a small outcrop, but from outcrop to outcrop the attitude is variable, ranging from strike north to east, dip moderate to steep either side of vertical. The average strike of the banding at the north end of the body is about north to northwest, the average dip probably steep to the east; at the south end the average strike is more nearly east, the dip moderately to steep northward. Thus, in a general way, the average attitude of the banding appears to reflect the attitude of the nearby contact between ultramafic rock and country rock. The origin of the banding is, as yet not established. It is possibly primary, possibly a later shear feature.

The country rock is quartz-mica schist, graphitic phyllite, and fine-grained chlorite amphibolite; the schist and phyllite contain garnet and biotite. The blackwall is nowhere well exposed; so, its mineralogy is not known.

The average strike of the schist is about N. 20° E. and the general dip is steep to the east. Around the margins of the ultramafic body the strike and dip of the country rock range sympathetically with that of the contact; thus, at the southwestern end of the body the amphibolite strikes far into the northwest and dips moderately to the northeast in conformity with the contact of the ultramafic body with the amphibolite. Small folds in the amphibolite plunge 25° to 50° northward.

Reserves.-- Reserves are almost certainly large. It is possible, however, that the irregular alteration of the serpentinite to grit, resulting in numerous inclusions of serpentinite within the grit bodies, will cause difficulties in mining that will seriously reduce the tonnage of recoverable material. This factor cannot be evaluated nor a quantitative estimate of reserves be made until contemplated further diamond drilling operations are carried out.

Waterbury talc mine, Locality 41

The Waterbury talc mine, the second largest in Vermont, is in northwestern Moretown township on the south bank of the Winooski River, 2 miles S. 45° E. of the junction in Waterbury village of State Route 100 and U. S. Route 2. The area is one of moderately high relief, the maximum within a mile of the mine being more than 1200 feet. The altitude of the millsite at the north end of the ultramafic body is about 470 feet; the southern end of the body attains an altitude of at least 1300 feet.

The mine can be reached from Waterbury village by driving southeastward from the junction of State Route 100 and U. S. Route 2 for 2 miles on U. S. Route 2, turn right (south) into the driveway of Eastern Magnesia Talc Co. Mill No. 2. The mine entrance is at the south end of the mill.

The central Vermont Railroad at Waterbury village, about 2 miles northwest, is the nearest railway shipping point.

Gillson (1927, pp. 271-274) discusses the petrology and origin of the Waterbury deposit.

The mine. -- There are three levels in the Waterbury mine-- the Tramway level, the 1st (or Adit) level, and the 2d level. The Tramway level, which has been abandoned for many years, has an adit entrance at an altitude of 680 feet above sea level. The level is about 700 feet in total length, but only the first 100 feet are accessible. The 2d level, which is reached by a raise from the 1st level, is at an altitude of 712 feet. The workings total about 900 feet, but only 250 feet are accessible. The 1st level, the only one now being mined, is at an altitude of 520 feet at the adit entrance and contains about 5000 feet of workings. The combined workings of all the levels total approximately 6500 feet.

Mining operations are on a small scale, and mining methods are simple but efficient. In general, drifts are driven in steatite or grit, and heavy timbering is necessary throughout almost the entire length of the mine. The broken rock at the working face is loaded into 1-ton mine cars by pneumatic mucker. A self-caving method of stoping is employed where possible; where self-caving methods are not feasible, inclines are driven in the steatite and grit along the hanging-wall and the talc is mined by benching. The ore is trammed by battery locomotive to the mill where it is sorted and dumped into several bins according to grade. Pencil stock is sorted by hand.

Geology. -- The main ultramafic body has a minimum length of 4500 feet and a maximum width of 550 feet. The general strike of the deposit is N. 10° to 15° E. Along the strike, both on the surface and in the underground workings, the body pinches and swells from a minimum thickness of 1 foot underground and 30 to 40 feet at the surface to a maximum of 150 feet underground and 550 feet at the surface. In cross-section, the body at its simplest is crudely

V-shaped or Y-shaped. The southern half of the deposit has, however, been complicated by folding of the eastern contact, which shows up in the 2d level as a fold over 80 feet across, and on the surface as a fold probably several hundred feet across. It is this feature which is responsible for the great width of the serpentinite body at the surface as contrasted with its underground at the south end of the deposit. The average attitude of the deposit is vertical or steep to the east. Both walls, on the average, dip steeply inward, although there are numerous local reversals of this attitude.

About 500 feet east of the main ultramafic body is a narrow body of steatite, grit, and serpentinite. The maximum width of the deposit at the surface is 80 feet, the average width probably under 10 feet. The probable length is at least 4000 feet. The attitude of the deposit is about the same as that of the main body. This deposit is not developed to any extent and its relations to the wall rock and to the main ultramafic body are not well known.

The country rock in the immediate vicinity of the ultramafic bodies consists entirely of quartz-mica schist and albite-quartz-mica schist. A thousand feet or so to the west, however, greenstones are numerous.

The general relations within the ultramafic body, which hold everywhere except in the narrow places in the body where the serpentinite core is absent or where late faulting has disturbed the normal relationship, are as follows: The center of the ultramafic body is serpentinite varying from less than a foot to more than 500 feet thick. A zone of grit from less than 1 foot to 20 feet thick borders the serpentinite core. Outside the grit zone is a zone of steatite reaching a maximum thickness of 6 feet and generally less than 1 foot. The average width of the combined talc and grit zones is between 5 and 10 feet. The blackwall zone, on the average, is between half a foot and 1 foot thick.

The ultramafic bodies are in most places concordant with the enclosing schists, which strike on the average about N. 10° to 15° E. and are vertical or dip steeply east or west. Locally, however, the ultramafic bodies are cross-cutting. This cross-cutting relationship is best exposed in the underground workings, where detailed mapping shows that (tracing the deposit southward) the concordant relationship holds for distances of several hundred feet, whereupon the ultramafic body becomes cross-cutting slightly for a short distance so that it is offset to the west a few inches or a few feet. In one or two places the offsetting is apparently due to minor folds rather than to discordance. Practically all of these locations are marked by long, thin septa of schist projecting into the talc body; they were apparently peeled off the schist wall during the late-stage faulting, tongues of talc being forced into the resulting spaces between the septa and the main schist body.

Near the southern end of the underground workings, the ultramafic body is cut by a mafic dike which appears to have been intruded after steatitization. A fault about parallel to the western contact of the ultramafic body cuts the mafic dike which is nearly vertical, and offsets it about 135 feet horizontally, the east side having moved north. Slickensides and deep grooves on the fault surface plunge 30° to 40° to the northeast; so the net slip on the fault has probably been of the order of 175 feet.

The eastern body probably is entirely separate from the main body. Possibly, however, both deposits are part of a tightly folded, originally sheetlike mass, with the main body on the western limb and the eastern body on the eastern limb of an anticline plunging to the north, the nose of the anticline plunging beneath the schists somewhere between the mill and the Winooski River.

Reserves. -- The practice of evaluating reserves at the Waterbury mine is the same as at the Johnson mine. "Measured" ore totals about 10,000 to 20,000 tons, or 6 months supply. "Indicated" and "inferred" ore, on the basis of geologic evidence and past mining experience, is believed to be adequate for at least 5 years, or at least 150,000 to 200,000 tons.

Mad River talc mine, Locality 46

A large ultramafic body is exposed in the southeastern part of Duxbury and the northeastern part of Fayston townships. The Mad River talc mine is in the southern end of the body, and there are two abandoned verde antique quarries at the northern end. Possibly localities 33 and 47 are continuations of this body.

The Mad River mine at the southern end of the deposit, is 2 miles S. 63° W. of the center of the village of Moretown. The mine lies at an altitude of about 950 feet. Relief in the immediate area is moderate; the maximum within a mile of the mine is about 1300 feet.

To reach the mine from Moretown, drive south on State Route 100 for a distance of 0.45 mile beyond the junction with Route 100 B, which is about a mile south of the village. Turn right (west) on a dirt road at this point and continue westward for about 1.1 miles to the mine.

The nearest railway shipping point is at Middlesex village on the Central Vermont Railroad, about 7 miles to the northeast.

Bain (1936, pp. 1971-1972; fig. 4) gives a brief general discussion of the Mad River ultramafic body; Gillson (1927, pp. 268-271) discusses the petrology and origin.

The mine. -- The Mad River deposit has been mined at several times over a period of many years. The operations have been carried out by different companies and the mine known by several names. The last organization to engage in mining operations was the Mad River Talc Corp., under whose management the mine was known as the Mad River talc mine. The mine has been idle since 1946.

There are five so-called levels or groups of workings in the mine. For convenience these have been designated as the 890-, 900-, 907-, 930-, and 968-foot levels; the numbers refer to the altitudes of

the floors of the levels above sea level. The total length of the underground workings, is about 1000 feet. Of this total, the southern 160 feet of the 907-foot level was flooded and inaccessible in 1945 at the time of mapping.

The 890- and 900-foot levels were worked by a shaft inclined an average of 46° to the north and approximately 115 feet deep, measured along the incline. The 907-foot level is accessible through a small opening from the west side of the inclined shaft, but mining operations on that level appear to have been carried out from a short vertical shaft known as "Skunk Shaft." located 110 feet S. 20° W. of the collar of the incline. The 968-foot level has an adit entrance in the northeastern corner of the open pit. The 930-foot level is now accessible only through a winze located about the middle of the east side of the 968-foot level. It is probable, however, that a raise from the 890-foot level once connected it and the 930-foot level, and that the ore was carried out through the 890-foot level; if so, this raise is now inaccessible because of caving.

Mining operations were carried out, apparently, by drifting and caving, and were entirely by hand. The material was moved probably by wheel barrow to the foot of the incline where it was dumped into a skip and hoisted to the surface. There the ore was dumped into small cars and hand trammed to the mill.

Geology. -- The ultramafic body has a known length of about 4500 feet and a maximum width of 800 feet at the north end, narrowing down to less than 50 feet at the south end. If the serpentinite and grit at localities 33 and 47 are part of this same body, the total length of the deposit is more than 10,000 feet. The general trend of the body is about N. 25° E. The contacts dip steeply either side of vertical; in the open-cut and cave-in at the talc mine, the contacts dip steeply inward.

Considered as a whole, the ultramafic body is composed almost entirely of serpentinite; the only known talc is at the north and the south ends of the deposit. It is probable, however, that a thin zone of steatite and grit exist along the contacts throughout the length of the body. No unaltered peridotite masses have been found, but detailed petrographic studies have not yet been made. Bain (1936, pp. 1971-1972) describes relics and ghosts of olivine and pyroxene from this locality.

The steatite and grit zones as exposed in the underground workings of the mine vary in total width from 2 to 10 feet, the steatite zone occupying 0.5 to 3 feet of the total. Steatite and grit occupy the entire width of the deposit in the open pit immediately north of the mill, where the body narrows down to less than 25 feet wide. Tremolite is abundant locally, especially along the eastern contact in the outer part of the steatite zone, and occurs sporadically throughout the zone. In a few places, tremolite is so abundant that the rock is essentially a tremolite rock with minor talc and /or carbonate.

Several eastward-trending, nearly vertical mafic dikes cut the ultramafic body and the country rock. The dikes probably are later than the steatization. Small faults or shear zones are prominent along both edges of the body, and to a lesser extent, within the serpentinite core. The offset along these shears has displaced the mafic dikes considerably, but it cannot be accurately determined.

The country rock is phyllite, quartz-mica schist, and greenstone. All of these are altered to chlorite at the contact with the steatite. In general the ultramafic body is concordant with the schistosity and bedding of the schists, although the relations locally are cross-cutting.

A number of small outcrops of serpentinite, grit, and steatite are exposed between 200 and 350 feet east of the eastern contact of the main ultramafic body, and within or at the western border of a greenstone bed about 80 feet thick. Probably these outcrops are on a series of discontinuous, lenticular bodies rather than on a single, long, narrow body. The grit and steatite are generally rather dark and impure. Most of the outcrops have been prospected for talc by trenching, probably many years ago.

Reserves. -- Reserves are probably small, the greater part of the easily accessible talc having been mined out. The best chance for locating sizable reserves lies in exploration at greater depths and in explorations southward from the old workings and at the north end of the body. Such exploration would have to be by diamond drilling, supplemented in a few favorable places by trenching, or by geophysical methods, or both, for outcrops are almost entirely absent in the critical areas.

Locality 50

There is an ultramafic body in central Warren township on the farm of L. W. Freeman, 0.25 mile due east of the church in Warren village. The deposit lies at an altitude of about 960 feet at the foot of the south-western slope of Warren Pinnacle, a 1700-foot hill north-east of Warren village.

To get to the locality from Warren village, drive northeast from the church on the road along the left (south) bank of Freeman Brook for 0.1 mile and turn right. Continue southeast for 0.2 mile to a fork in the road and take the left-hand fork. The farm house on the land where the deposit is located is about 100 feet beyond the fork, on the left (north) side of the road. The southern end of the outcrop of serpentinite is 200 feet due south of the house.

The nearest railroad is the Central Vermont at Roxbury village, about 7 miles eastward over Roxbury Gap, which is at an altitude of 2416 feet.

Geology. -- The size and shape of the body are indeterminate, because the country rock is exposed only at the southeastern edge of the outcrop area. The serpentinite forms essentially one large, continuous outcrop nearly 500 feet long and more than 200 feet wide, and is roughly elliptical. The long axis of the outcrop, which is probably parallel to the long axis of the deposit, trends about N. 15° E., or about parallel to the strike of the schistosity in the region.

The country rock schist is exposed in only two small outcrops near the ultramafic body. The schist strikes N. 15° E. and dips 60° to 70° eastward.

The deposit is chiefly serpentinite. Locally, especially on the southern nose of the outcrop, relatively large patches of rock are somewhat talcose. The contacts with the schist are nowhere exposed, nor are there any exposures of steatite or grit to indicate the probable location of the contacts. Although this lack of exposures of steatite and grit may be taken as an indication that talc is not extensively present here, a Mr. Freeman of Warren (oral communication, September 1948) stated that soapstone reportedly was sawed at this locality for freestones approximately 100 years ago.

Reserves. -- Although the evidence is inconclusive, there are no positive indications that steatite and grit are extensive at this locality.

Locality 51

A small ultramafic body is exposed 0.75 mile N. 24° E. of the four corners in East Warren village. The outcrop is approximately 100 feet west of U. S. Geological Survey bench mark 1371. The deposit lies at an altitude of 1380 feet near the crest of a low hill on a gently rolling upland surface with a relief of little more than 100 feet.

To reach the locality from Warren village, drive northeast from the church on the road along the left (south) bank of Freeman Brook for 0.1 mile and turn right. Continue southeast for 0.2 mile to a fork in the road and take the right-hand fork. One and one-half miles beyond the fork, turn left (north) and continue northward 0.75 mile beyond the four corners at East Warren, to a point opposite B. M. 1371. The ultramafic body is situated about 200 feet west of the road near a line fence.

The nearest railroad is the Central Vermont at Roxbury village 5 miles to the east and across the Northfield Mountains by way of Roxbury Gap (altitude 2416 feet); or at Middlesex, about 15 miles to the northeast down the valley of the Mad River.

Geology.-- The outcrop area of the deposit is less than 100 feet long (north-south) and 50 feet wide. The deposit may extend under cover for a considerable distance to the north and to the south.

The serpentinite is dark green, fine-grained, and rather highly fractured. The country rock nearby is a peculiar whitish-green rock, apparently a highly altered greenstone. More or less "normal" greenstone occurs locally within the whitish-green rock. Quartz-mica schist, somewhat graphitic, crops out 500 feet northwest of the serpentinite. The schist strikes about N. 15° to 20° E. and dips 70° to the east.

The relationship of the tremolite-chlorite rock to the serpentinite suggests that the greenstone formed the roof of an ultramafic body only a small part of which has been exposed by erosion, and that the alteration of the greenstone is related to steatitization, although evidence of extensive steatitization is lacking.

Reserves.-- No outcrops of steatite or grit were found. Consequently, it is considered probable that the serpentinite has not been extensively steatitized, and that the potentialities of the deposit as a talc producer are small.

Locality 54

There is a small abandoned talc quarry in southern Roxbury township, 1.35 miles N. 2° W. of the railroad bridge at East Granville over the Third Branch of the White River. The deposit is located 40 feet west of State Route 12 A and 330 feet north of the boundary between Addison and Washington Counties. Its altitude is 900 feet and it is about 40 feet above the river. Relief in the area is moderately high.

To reach it from East Granville, drive northward on State Route 12 A about 1¼ miles from the center of the village to the sign marking the boundary between Addison County and Washington County. Continue northward 330 feet beyond the sign. The old quarry, completely invisible from the road because of heavy underbrush, is 40 feet west of this point.

The Central Vermont Railroad is a few hundred feet east of the quarry.

Geology. -- The deposit has been completely mined out to a depth of at least 30 feet, and the quarry is now partly filled with water. There are no exposures except in the quarry walls, which are so difficult of access that a close examination could not be made.

The quarry is oval in plan, with a maximum length of 200 feet and a maximum width of 75 feet. The full width of the body has been quarried, and no serpentinite was found on the dump; presumably the entire deposit was composed of grit and steatite. Material collected from the dump indicates that at least some of the talc was of fairly good quality.

The contacts dip inward about 75 degrees on both sides of the quarry. The country rock exposed in the walls is chlorite-quartz-sericite schist, altered to chlorite (the blackwall) for a width of 0.5 to 1 foot at the contact with the ultramafic rock.

Reserves. -- It appears that all of the easily accessible ore has been mined. Probably only a small reserve is left below the quarry floor, unless the inward dip of the walls reverses at moderate depth.

Roxbury verde antique quarries, Localities 66 and 67

Half a mile or so west of Roxbury village is the center of a north-trending belt of numerous ultramafic deposits (localities 55-71), several of which have been quarried for verde antique. Two of the bodies have been examined briefly.

Locality 67, which is now being quarried for verde antique by the Vermont Marble Co., is 1.1 miles S. 25° W. of the four-corners in Roxbury village. Locality 66, an abandoned verde antique quarry, is about 200 feet northwest of locality 67. Both deposits lie at an elevation of about 1150 feet, on the crest of an oval-shaped hill some 150 feet high.

The Central Vermont Railroad runs along the base of the precipitous southeastern face of the hill.

Access from Roxbury village is as follows: Drive south on State Route 12 A a distance of 0.7 mile from the four corners. (Note: the right of way of Route 12 A has been changed since the Barre quadrangle map was issued, and the road is on the east side of the railroad for the entire distance between Roxbury village and Roxbury Flat, rather than as shown on the topographic map.) Turn right across the railroad and drive west for 0.2 mile; turn left and continue for about 0.3 mile to the end of the road. The quarry at locality 67 is immediately to the left.

Phillips and Hess (1936, pp. 349-351; fig. 8) describe and figure the ultramafic body at locality 66.

Geology. -- Both ultramafic bodies are lenticular or pod-like, elongate a little east of north, and are about vertical. Both have a central core of serpentinite surrounded by a thin shell of steatite. Locally, the serpentinite core is irregularly altered to highly serpentinous grit.

The country rock is greenstone and quartz-chlorite-sericite schist. At the contact with the ultramafic rock the country rock is altered to chlorite. At these two localities only the greenstone has been observed in contact with the ultramafic rock.

The ultramafic body at locality 66 is about 200 feet long by 75 feet wide, and has reportedly been mined to a depth of more than 150 feet, where the serpentinite core bottomed in grit. The quarry is now filled with water.

The ultramafic body at locality 67 is possibly continuous with an outcrop of grit in the railroad cut and with one in the road cut on Route 12 A due south of the quarry. The deposit, then, is perhaps nearly half a mile long and more than 100 feet wide. It has been mined to a depth of more than 200 feet, and the quarry floor is still in verde antique of good quality.

Reserves. -- Having made only a cursory examination of a small part of the area, we have little basis for evaluating the potentialities of the deposits as talc producers. We believe, however, in the possibility of fairly large reserves of good quality talc, particularly in the southern extension of locality 67.

East Granville talc mine, Locality 72

The East Granville mine, reportedly the largest mine in the state during its period of operation, but long since abandoned, was operated for several years on a talc deposit in northeastern Granville township. The mine site is 0.3 mile due east of the center of the village of East Granville, and just a few hundred feet west of the eastern border of Granville township. The deposit is at an altitude of 1150 feet on the steep western slope of a north trending ridge and on the east side of Third Branch of the White River.

To reach the locality from the center of East Granville, drive southward on State Route 12 A for 1.3 miles. (Note: the right of way of 12 A has been changed since publication of the Lincoln Mountain, Randolph, and Barre quadrangles; the road is now on the west side of the Central Vermont Railroad for the entire distance between East Granville and Braintree.) Turn left 150 degrees onto the old right of way of Route 12 A, cross the railroad tracks, and continue northward for about 0.3 mile; turn right over the bridge across Third Branch of the White River. Continue northward for about half a mile; then, immediately after crossing a small creek, turn left on an old wood road into a small pasture. Park here and continue northward on foot along the wood road. A few hundred feet from the small pasture, near the top of the first steep pitch in the trail, take the left-hand fork and continue about half a mile to the mine.

The Central Vermont Railroad at the village of East Granville is only 0.3 mile west of the mine.

Geology. -- In the few hours spent at this locality, we examined only two of several cave-ins. So we know little of the size and shape of the deposit. The location of the old underground workings is marked by a series of half a dozen or more cave-ins. The individual cave-ins are nearly or quite concordant with the schistosity of the country rock, but as a group they are in echelon.

About 300 feet northeast of the old waste dump is a cave-in about 100 by 50 feet in plan. Highly schistose grit, steatite, blackwall, and chlorite-quartz-sericite schist are exposed in the north wall. The relations, however, are different from those encountered in most of the other deposits examined. The grit is coarsely flaky with a strong but wavy schistosity, buff-colored, and contains scattered knots, streaks, and folia of chlorite and irregular nodules of carbonate. The steatite is rather high in chlorite which is somewhat patchily distributed and has good schistosity.

Some of the grit grades directly into blackwall and has obsiously been derived from it, and it is possible to trace relic bedding and schistosity from the schist through the blackwall into the grit. Elsewhere, grit grades into steatite in the usual manner. All of the grit is identical in appearance. Because some has obviously been formed by alteration of the country rock, and because that which is definitely of such origin appears no different from the rest, there is no compelling evidence that any of the talc rock exposed is of ultramafic origin. The exposures of this cave-in may not, however, be typical of the deposit as a whole. Probably they represent a striking but local alteration of the country rock to talc, whereas the deposit as a whole is of ultramafic origin. Detailed study of the area and examination of material on the dump for evidence of what was encountered in the mine should provide an answer.

The country rock is quartz-chlorite-sericite schist. The schistosity and bedding are parallel, strike slightly west of north, and dip steeply east or vertical.

Reserves.-- Probably most of the accessible talc has been mined.

Rochester verde antique quarry, Locality 73

There is a large abandoned verde antique quarry

in northern Rochester township, 2.95 miles due north of the square in the village of Rochester. The deposit lies about 1480 feet above sea level and near the southwestern edge of a small upland flat between the Braintree Mountains and a range of high hills along the east bank of the White River.

To reach the locality from Rochester village, drive north from the square in the center of the village for about 2 miles on State Route 100. Turn right on the North Hollow road and drive 0.55 mile to a fork in the road. Take the left-hand fork and continue 1 mile to the quarry, which is on the left (northwest) side of the road. Large grout piles on either side of the road mark the location.

The nearest railway is the Central Vermont at Randolph village, about 15 miles eastward by road across Rochester Gap, which is at an altitude of 2100 feet. There is also a railway at Bethel, 20 miles southeastward by road along the valley of the White River.

Gillson (1927, pp. 266-268) discusses the petrology and origin of the Rochester quarry under the title of "The Verde Antique Quarry at North Hollow."

Geology.-- The only exposures noted are those due to quarrying operations which are confined almost entirely to the ultramafic body. So, the size and shape of the ultramafic body are not known. The quarry, however, is about 300 feet long and 150 to 200 feet wide; its depth is not known because the quarry is now filled with water. Most of the rock exposed in the quarry walls is serpentinite. In the northeastern corner of the quarry, a concordant contact between the ultramafic body and schist is exposed for a distance of 10 to 15 feet. The contact strikes east and dips 85° to the south, whereas the regional trend of the schistosity in the area is about N. 10° W., dip steep to the east. The schist exposed at the contact, then, has a strongly abnormal attitude. It may be only a septum within the ultramafic body and not the true wall.

Grit and steatite for a width of 3 or 4 feet are exposed next to the contact. The grit-serpentinite boundary is irregular and gradational over a width of several inches. The schist has been altered to chlorite (blackwall) at the contact with the steatite for a width of approximately 1 foot. The blackwall is gradational into unaltered schist over a width of 1 or 2 inches. Between the blackwall and the steatite is a 3 to 5 inch zone composed almost entirely of actinolite in rosettes from 1 to 3 inches across.

A few hundred feet south of the quarry and on the opposite side of the road, bulldozing operations performed in the spring of 1948 exposed a narrow southern continuation of the ultramafic body. The exposure is about 20 feet wide and 120 feet long. The maximum width of grit exposed is about 15 feet. Bordering the grit, which is rather impure and contains rather abundant serpentine, is a thin zone of steatite, which is bordered in turn by a foot of actinolite. That, in turn, is bordered by 1 foot of blackwall chlorite which grades into unaltered greenstone. The schistosity of the greenstone in the southern and central part of the exposure is N. 30° E., dip 60° eastward; at the northern end of the exposure the schistosity strikes northwest and dips 50° to 70° northeast. A well developed schistosity in the grit and steatite has a uniform attitude of strike north, dip about 35° to the east.

Reserves.-- It does not appear, on the basis of a brief examination of the locality, that the ultramafic body is extensively steatized.

Localities 74 and 75

Several ultramafic bodies are reported in southeastern Rochester township. Two of these, the old Williams mine deposit and the Cushman Hill deposit, were examined and will be described briefly below.

The Williams mine, at locality 74, is 2.65 miles S. 70° E. of the square in the center of Rochester village. The mine was one of the larger in Vermont prior to 1927, when it was abandoned because of a destructive flood that washed out part of the White River Railroad tracks. The deposit is located on the west flank of the Braintree Mountains at an altitude of 2040 feet.

The Cushman Hill deposit, locality 75, lies half a mile N. 30° W. of the Williams mine and crops out over the entire hill above the altitude of approximately 1940 feet.

Relief in the immediate vicinity of the deposits is low; within a radius of a mile of the mine, total relief is about 1600 feet.

The locality is most readily accessible from Rochester village. Drive eastward along the north side of the village square to a fork in the road 0.1 mile beyond the square. Take the right-hand fork and continue eastward for about 1.2 miles to the four corners. Turn right (south) and continue southwestward for 1.3 miles to the South Hollow School. At the school house take the left fork and drive southeastward for 0.3 mile. Cushman Hill lies about a quarter of a mile due north of this point. About 900 feet N. 45° E. of this point on the road is an old talc prospect, marked by a small dump and the foundation of an old building.

To reach the Williams mine, follow the same route from Rochester village but continue on to a point 0.6 mile beyond the South Hollow School. The site of the old mine is 600 feet to the east.

The nearest railway shipping point is at Bethel on the Central Vermont Railroad, about 20 miles southeastward by road down the valley of the White River.

These localities have been described briefly by Jacobs (1914, pp. 410-412), and Gillson (1927, pp. 262-266).

Geology. -- In the vicinity of the Williams mine serpentinite, grit, and steatite crop out intermittently in a narrow, north-trending belt more than 1000 feet long.

The size and shape of the deposit is not known. All the outcrops may be of a single body, or they may represent exposures of several separate lenses.

Several of the steatite outcrops exhibit a good schistosity having the same general attitude as that of the schists. The country rock is quartz-mica schist, greenstone, and amphibolite. The schistosity strikes N. 20° to 50° E. and dips 45° to 85° to the northwest. Abrupt changes in the attitude of the schistosity and bedding (which are locally divergent in attitude) and numerous minor folds observed in outcrop suggest that folding may be of considerable importance in determining the form and distribution of talc at this locality

Cushman Hill, half a mile northwestward from the Williams mine, is upheld by a large serpentinite mass, which is well exposed on the upper slopes and the crest of the hill. Grit crops out in the shallow saddle about 260 feet east of the eastern limit of serpentinite outcrop, or about 450 feet N. 18° W., of the waste dump. An old shaft, a small dump, and several caved areas indicate that talc has been mined in the past on a small scale, but give no conclusive evidence on the extent of the talc deposit. The grit exposed in outcrop and that upon which the mining was done are possibly marginal to the serpentinite exposed on Cushman Hill. If so, the grit-steatite zone may be as much as 260 feet wide.

The contact of the ultramafic body was not observed, but quartz-mica schist is extensively exposed on the southern slope of Cushman Hill near its base. The strike of the schist averages about N. 60° W., ranging between N. 5° E. and N. 75° W.; the dip is gentle to moderate to the northwest. Numerous folds as much as 10 feet in amplitude and 20 to 30 feet across are exposed in outcrop. The folds plunge 20° to 40° to the north and northwest.

Reserves. -- Reportedly the Williams mine was abandoned because a flood destroyed the railroad to Rochester, rather than because the supply of talc was exhausted. The old workings, now caved and in disrepair, probably would constitute a serious obstacle to reopening the deposit.

Although exposures at Cushman Hill are lacking in critical areas, the relations noted in the reconnaissance of the area suggest the possibility that large reserves of talc exist on the eastern edge of the large serpentinite body.

Locality 110

A small ultramafic body crops out in northeastern Ludlow township, 0.8 mile S. 22° E. of the North Hill School, and 3 miles N. 25° E. of the Road bridge over the Black River in Ludlow village. The deposit lies at an altitude of 1500 feet in an area of low relief.

To reach the locality from Proctorsville, drive northward on the graveled road at the east edge of the village for 3 miles after leaving State Route 131. Take the left fork at this point and continue 0.5 mile to another fork in the road. Take the right fork and drive northwest for 0.75 mile. The ultramafic body is about 400 feet west of this point, in a small open wood.

The nearest railway is the Rutland, about 3 miles southeastward at Ludlow village.

Geology. -- The deposit is exposed for about 100 feet along the strike. At the southern end of the exposure, the width of the ultramafic body is 5 to 10 feet; at the northern end, the deposit widens to 30 or 40 feet. The deposit strikes about N. 15° E. and appears to be essentially vertical.

Structurally below (west of) the ultramafic body, the country rock is dark green amphibolite, which grades upward into ankeritic amphibolite. This, in turn, grades into a chlorite-carbonate greenstone, which grades through a chlorite-talc rock into a poor grade of grit, low in carbonate but dark in color, apparently owing to the presence of abundant chlorite. Above the grit lies quartz-sericite-chlorite schist; the transition between the grit and the overlying schist is sharp.

Reserves. -- On the basis of a perfunctory examination, this deposit does not appear to be of mineable quality or size.

Localities 112 and 113

Two small talc and grit bodies, both of which were mined on a small scale many years ago and which were known as the Valentine Mines No. 1 and No. 2, are located in east-central Ludlow township. Valentine No. 1 is 0.9 mile N. 85° E. of the road bridge over the Black River in Ludlow village. Valentine No. 2 is 0.85 mile N. 70° E. of the road bridge. Mine No. 1 lies at an altitude of 1140 feet above sea level; No. 2 at an altitude of about 1260 feet. Total relief within a mile of the mines is about 500 feet.

From Proctorsville, drive westward on State Route 103 for 2.5 miles from the junction of State Routes 103 and 131. Turn right on the dirt road and continue north for 0.3 mile. The water-filled shaft of old Mine No. 1 is about 50 feet east of the road at this point. To reach the Valentine No. 2, drive 0.1 mile north beyond the location of Mine No. 1 and walk westward along the power line for a distance of about 500 feet from the road. The open cut of the old mine is about 100 feet north of the power line at this point, on the east side of a small south-trending ridge.

The Rutland Railroad is only about a mile westward, at Ludlow village.

Geology. -- Both deposits are narrow, tabular or lenticular bodies between 10 and 20 feet wide; they strike nearly north and dip steeply east. The relations at Mine No. 1 are obscured by slumping. The central part of the Mine No. 2 deposit is grit, with a narrow steatite border. The country rock of both deposits is quartz-sericite-chlorite schist, altered to chlorite at the contact with the steatite.

Reserves. -- Both deposits appear to be very small and to be more or less completely mined out.

Locality 114

In east-central Ludlow township, 1 mile S. 57° E. of the road bridge over the Black River in Ludlow village is an old abandoned talc quarry. The deposit lies at an elevation of 1000 feet, about 200 feet south of the Rutland Railroad and at the foot of the north slope of a steep hill. Total relief within a mile is about 500 feet.

The locality is easily accessible. From Proctorsville, drive westward on State Route 103 for 2.4 miles from the junction of State Routes 103 and 131. Turn left across the Black River for about 0.3 mile to a point just south of the railway and take the left-hand fork. A hundred feet or so beyond the fork, turn left onto a wagon road through a small meadow. The old quarry is at the north edge of the meadow.

Geology. -- The quarry is about 125 feet long north-south and 75 feet wide. The quarry is filled with water; so, the depth is unknown. Only grit of excellent quality is exposed. The country rock which is exposed 100 feet east of the quarry in a small gully is quartz-chlorite-sericite schist.

Reserves. -- A thick cover of glacial drift blankets the deposit, but the fact that the entire quarry is in grit of good quality indicates the possibility that the deposit is large.

Hammondsville talc quarry, Locality 117

The Hammondsville talc quarry is located in eastern Reading, 0.2 mile northeast of U. S. Geological Survey B. M. 969 in the village of Hammondsville. The deposit lies at an altitude of 1000 feet above sea level at the foot of the west slope of Wardner Hill. Relief in the immediate area is moderate; total relief within a mile of the quarry is about 1000 feet.

The deposit is readily accessible by auto. From Proctorsville, drive eastward on State Route 131 about 7.8 miles to the junction with State Route 106; turn left (north) on 106 and continue about 7¼ miles to a point 0.15 miles beyond Hammondsville. The talc quarry is 200 feet east of this point on the road.

The nearest railway is the Rutland at Proctorsville, about 14 miles by road to the southwest.

The quarry.-- The quarry, in 1945, was 200 feet long and 125 feet wide; the greatest depth, which was at the southern end, was 45 feet. Operations are entirely mechanized; overburden is removed by bulldozer, the rock is broken by pneumatic drilling and by blasting, and the ore loaded by gasoline shovel into trucks. The ore is hauled by truck to the mill at Chester, about 15 miles to the south. Only the coarse rock is saved, the "wet fines being discarded because the mill is not equipped to dry the material before grinding."

Geology. -- The full extent of the deposit is not known. As exposed in the vicinity of the quarry, the deposit is at least 450 feet long, 150 feet in outcrop width, and 90 to 100 feet thick.

The contact between the steatite and schist is concordant with the foliation and bedding of the schist and varies from strike north, dip 40° to 50° east at the southeastern end of the quarry to strike northwest, dip 25° to 30° northeast at the northwestern end of the quarry. Thus the talc deposit and the country rock are involved in a broad anticlinal arch. Minor folds plunge 15° to 30° to the north or slightly east of north.

The deposit consists entirely of coarse, flaky grit and of steatite; no serpentinite has been found. In the southwestern face of the quarry there is a large mass of actinolite rock. Near the top of the southeastern quarry face there are several thin but extensive septa of schist which are largely altered to coarse biotite and chlorite.

The country rock is quartz-mica schist. Next to the talc body the schist is altered to blackwall, which is coarse biotite for about the first half a foot and grades abruptly into chlorite for about an equal thickness. The blackwall grades over a short distance into unaltered schist.

Both the steatite and grit have a very good schistosity, parallel to that of the country rock and to the contact with the country rock. The schistosity of the talc body is involved in small tight folds and broad rolls in precisely the same manner as that of the country rock. This may be explained either as a relic structure preserved in steatite and grit which was formed by the alteration of schist, or as a structure formed in the talc by folding later than the steatitization.

It is possible that much, perhaps even most, of the talc-rock exposed is not of ultramafic origin, but was formed by alteration of the schist. Nevertheless, the deposit is believed to be related to an ultramafic body.

Reserves. -- Reserves are certainly adequate for several probably for many, years at the present rate of production.

Locality 124

The Carleton talc quarry is located in west-central Chester township, 2.2 miles N. 85° W. of Chester Depot. The deposit lies at an altitude of 880 feet, about midway up the eastern slope of a steep hill. Total relief within a mile of the quarry is about 600 feet. The locality is well-known among mineral collectors for the variety of minerals that occur there. The quarry was operated for many years prior to 1943, when a serious cave-in cause the management to abondon it.

To reach the locality from Chester, drive westward on State Route 11 for 2.2 miles from the road bridge over the Middle Branch of the Williams River at the junction of State Routes 11 and 103; turn right on a dirt road and drive northwestward for 0.25 miles; turn left through a gate onto the quarry road and continue 0.1 mile to the quarry.

The nearest railroad is the Rutland, at Chester Depot, about 2.5 miles to the east.

Phillips and Hess (1936, pp. 343-345) describe the Carleton quarry (Vermont Mineral Products quarry) as an example of the higher temperature type of metamorphic differentiation at the borders of an ultramafic body. Gillson (1927, pp. 254-258) discusses the petrology and origin of the deposit.

Geology.-- The size and shape of the deposit are not known, but it is at least 300 feet long and 160 feet wide. The quarry is now filled with water and its depth is not accurately known, but it is probably at least 75 feet.

Serpentinite, grit, and steatite occur in the deposit. The steatite is at the margins of the body, next to the contact with the blackwall. Grit and serpentinite are somewhat irregularly distributed, but in general serpentinite forms the core of the body, with grit developed between the serpentinite core and the steatite, and also irregularly invading the serpentinite core.

The country rock is a feldspathic-quartz-muscovite-chlorite gneiss or schist, with locally abundant tourmaline, garnet, biotite, amphibolite, and pyrite. At the contact with the steatite, the country rock is altered to biotite and chlorite schist, the blackwall.

The schistosity in the country rock strikes about N. 10° W. and dips 55° to 75° west. At the south end of the quarry the country rock and steatite are involved in several folds with amplitudes as much as 10 or 15 feet and widths from crest to crest as much as 30 feet. This folding affects both bedding and schistosity of the country rock, which are here parallel. The axial planes of the folds strike to N. 15° W. and dip 85° east to vertical; the axes of the folds plunge 30° to 60° to the north or northeast. Thus the axial planes of the folds strike nearly parallel to the regional schistosity but are appreciably steeper. In one of the synclinal folds some steatite with well-developed axial-plane schistosity is left. The underlying schist shows only a bedding plane schistosity. Here the schistosity of the talc is not an inherited feature retained in the alteration of the schist to steatite, and therefore the folding is probably later than the steatitization.

Reserves.-- The quarry was abandoned because of a serious cave-in which made continued operations impractical. Nearly all accessible grit and steatite have been exhausted.

Vermont Talc Co. quarry, Locality 126

The Vermont Talc Co. quarry is in northern Windham, 1.2 miles S. 60° E. of the junction of State Routes 11 and 121 in north Windham village. The deposit is exposed at an altitude of 1900 feet near the top of a broad hill. Total relief within a mile of the quarry is about 500 feet.

The quarry may be reached as follows: From Chester village, drive westward on State Route 11 for 10.5 miles from the road bridge over the Middle Branch of the Williams River at the junction of State Routes 11 and 103 to a point ¼ mile northeast of the junction of State Routes 11 and 121; turn left (east) on a dirt road and continue for 0.9 mile. Turn right and drive 0.3 mile to a fork in the road; take the right-hand fork and continue 0.2 mile; turn left onto the quarry road and continue about 0.1 mile to the quarry.

The Rutland Railroad at Chester is about 12 miles distant by road.

The quarry.-- Both underground mining and open-pit quarrying have been carried on at this locality.

At present only quarrying is practiced. The rock is broken by pneumatic drilling and by blasting, hand loaded into 1-ton railway cars, which are hand trammed to the foot of an inclined railway, and dumped into an electric-powered skip which hoists the ore to the loading bins. From the bins, the talc-rock is loaded into trucks and transported to the mill at Chester.

Geology.-- The ultramafic body is at least 700 feet long and is more than 300 feet and possibly more than 500 feet, wide. Grit and steatite are extensively exposed along the eastern part of the body. In the western wall of the quarry, and west of the quarry for a distance of 150 feet, a large mass of serpentinite is exposed. Though the western margin of the ultramafic body is not exposed, it is probable that the serpentinite mass represents the core of the deposit, and that grit and steatite exist to the west of the serpentinite mass.

Locally within the deposit, the grit contains so much carbonate that it is essentially a carbonate rock with a small amount of talc. A zone of steatite in the eastern wall of the quarry contains many small, irregular veins of chlorite a fraction of an inch to an inch or so wide. At the southern end of the lowest bench (altitude 1862 feet) several peculiar and interesting veins cut the grit. Seemingly these veins formed along joint surfaces because they are regular in attitude over areas of many square feet. The central part of each vein is white, flaky talc. Bordering the talc is coarsely crystalline, bright-green chlorite, grading into fine-grained, dull-green chlorite. Small (half an inch) rosettes of white, fine-grained talc are present in the fine-grained chlorite, which grades over a distance of about an inch into grit.

A schistosity almost parallel to that of the country rock is developed locally within the grit, and almost everywhere in the steatite. A number of shear zones or small faults cut the grit and steatite; how far they extend into the schist is not known. The faults vary considerably in attitude, but may be divided into four groups upon the basis of their attitudes: Those that (1) strike about N. 30° W. and dip steeply west or vertical; (2) strike N. 15° W. and dip 40° to 50° west; (3) strike N. 15° E. and dip steeply west; and (4) strike east and dip 65° to 75° south. Slickensides, which plunge moderately (2° to 50°, averaging about 25°) southward, are conspicuous on the first and second group.

The country rock is quartz-sericite gneiss and greenstone; the schistosity strikes N. 20° to 25° E. and dips steeply east or vertical. At the contact with the steatite the country rock is altered to coarse

biotite and chlorite schist; biotite occurs next to the contact for a width of about 6 inches, and chlorite outside the biotite zone for a width of 6 to 12 inches.

Reserves.-- Reserves are probably adequate for several years at the present rate of mining, but none is actually blocked out. If the postulated grit-steatite zone on the west margin of the deposit is present, the reserves may be large.

Localities 127 and 128

A large body of serpentinite and grit crops out in northern Windham township, 1.8 miles S. 55° E. of the junction in North Windham village of State Routes 11 and 121. Seven or eight hundred feet north-northeast of this locality is a small outcrop of grit. Likely the two localities are part of one body; so, the two will be described together. The large serpentinite-grit mass of Locality 127 forms a prominent rounded hill about 100 feet high, the top of which has an altitude of 2000 feet. The grit of Locality 128 crops out on the southwest side of the road at an altitude of 1930 feet. Total relief within a radius of a mile is about 400 feet.

To reach these localities from Chester, drive westward on State Route 11 for 10.5 miles from the road bridge over Middle Branch of the Williams River at the junction of State Routes 11 and 103 to a point ¼ mile northeast of the junction of State Routes 11 and 121; turn left (east) on a dirt road and continue for 0.9 mile. Turn right and drive 0.3 mile to a fork in the road; take the left fork and continue 0.9 mile to the second house on the right side of the road. The grit body of Locality 128 crops out on the southwest side of the road 100 feet southeast of the house. Locality 127 is 700 to 800 feet to the south-southwest.

The Rutland Railroad at Chester is about 13 miles distant by road.

Geology. -- The entire exposure at locality 128 is fine grained grit with abundant carbonate. A faint schistosity which strikes N. 60° E. and dips 70° SE is present locally in the grit. The only country rock exposed is greenstone, at least 40 feet thick, about 50 feet west of the grit outcrop. The foliation in the greenstone strikes N. 27° E. and dips 70° east.

The size and shape of the serpentinite-grit body at locality 127 has not been determined, but the deposit is at least 1000 feet long and 500 feet wide. Along the western side of the outcrop area a zone of grit and steatite at least 100 feet wide is exposed. The grit is of good quality. The remainder of the exposed area is entirely serpentinite. Much of the serpentinite is non-schistose, but a number of schistose zones were noted within the body. Locally within these zones the schistosity is folded in small, tight folds. Near the east-central margin of the exposure the schistosity in the serpentinite has a strike of N. 30° E. and a dip of 75° to the east. A small fold nearby has an attitude as follows: strike of axial plane N. 27° E., dip 80° eastward; plunge of fold axis 47° to the northeastward. Thus the axial plane of the fold is sub-parallel to the schistosity of the greenstones a few hundred feet distant, but is somewhat steeper. Whether this is a general relationship is not known.

Several hundred feet west of the grit at the western edge of the ultramafic body are several exposures of greenstone.

Reserves.-- Reserves at this locality are believed to be large and of good quality.

Barton talc quarry, Locality 129

The Barton quarry is an abandoned talc quarry in southwestern Chester township, 3.7 miles S. 48° W. of Chester Depot. The quarry is at an altitude of 1620 feet on the steep northeastern slope of a hill, whose summit is 2000 feet above sea level. Total relief within a mile is about 1100 feet.

To reach the quarry from the village of Chester, drive southward on the road to Grafton from its junction with State Route 11 for 1.7 miles; take the right fork and continue 1 mile to another fork in the road; take the left fork and drive 0.7 mile to where an old road branches off to the right (west). The quarry is at the end of this road, about half a mile distant.

The Rutland Railroad at Chester Depot is about 4 miles distant by road.

Geology. -- The quarry is about 150 feet long and 50 feet wide, and is elongate north-south. The deposit appears to consist entirely of grit and steatite; no residual serpentinite was noted. Actinolite is abundant at the outer part of the steatite zone. The country rock schist has been altered to chlorite for a width of 0.5 to 1 foot from the contact. The schistosity of both the steatite and the schists strike N. 15° E. and dips 55° to 70° westward. Minor folds of the schistosity in the steatite have axial planes that strike N. 30° E. and are vertical or dip steeply eastward, with axes that plunge gently to moderately south or southwest. A small cross-cutting granitic dike one foot thick is exposed in the west wall of the quarry.

Reserves.-- Reserves are probably small.

Davis (or Holden) talc quarry, Locality 130

The Davis (or Holden) talc quarry lies 2.1 miles S. 5° E. of Chester Depot in southern Chester township. The deposit is at an altitude of 1000 feet and is at the foot of the steep eastern slope of a hill whose altitude is 1200 feet. Total relief within a mile is about 800 feet.

To reach the locality from Chester, drive southward on the road to Grafton from its junction with State Route 11 for 0.65 mile. At this point, which is 0.15 miles beyond the first bridge over South Branch of Williams River and a few hundred feet before the second bridge, turn left and continue 1.5 miles. The quarry, whose location is marked by several buildings, is 100 feet or so west of this point.

The Rutland Railroad at Chester is about 3 miles distant by road.

The locality is described by Phillips and Hess (1936, pp. 345-348) as an example of the higher temperature type of metamorphic differentiation at the borders of an ultramafic body.

Geology. -- The ultramafic body is exposed intermittently along the western wall of the old quarry for a distance of more than 400 feet. The deposit consists of a series of lenses, each composed of a central core of flaky talc—acicular talc pseudomorphic after enstatite, according to Phillips and Hess (1936, p. 347)—and carbonate, with a little biotite near the margin of the core. Surrounding the central core is a thin shell of radiating actinolite, which is bordered by a shell of biotite.

The country rock consists of a feldspar-quartz-biotite gneiss, cut by pegmatite stringers and by at least one mafic dike. The schistosity of the gneiss strikes N. 5° to 15° E. and dips 30° to 40° west. The structure is complicated, however, by at least one very tight, rather large recumbent fold with an amplitude of at least several tens of feet, whose axial plane is about parallel to the general schistosity.

Reserves. -- The mineable material at this locality appears to be exhausted.

Locality 136

Several abandoned quarries are in what appears to be a single steatite deposit in southeastern Grafton, 2.1 miles S. 15° E. of the center of Grafton village. The deposit crops out at several places between the altitudes of 1500 and 1550 feet in a broad saddle. Total relief within a radius of a mile is about 600 feet.

To get to the locality from Grafton, turn south off State Route 121 immediately west of Saxtons River and drive southward for 2.3 miles on a dirt road. Park here and continue on foot along the left fork of the road for 1000 feet. At this point, opposite an old shack, a road branches off to the right (southwest). Between 1000 and 1200 feet along this road are several abandoned quarries on either side.

The Rutland Railroad at Chester Depot is about 9 miles away by road.

Geology. -- This locality was examined very briefly. The talc body, insofar as was seen, consists entirely of steatite and is tabular in form. The steatite consists of flaky talc, acicular talc probably pseudomorphus after enstatite or anthophyllite, and a small amount of carbonate. Only the upper contact is exposed at the places examined. The blackwall zone at this contact consists of coarse biotite and chlorite, which grades outward into pure chlorite. The country rock is gneiss, which strikes east of north and dips moderately to the northwest.

Reserves. -- The size and probable extent of the deposit are not known.

Suggestions for exploration and further geologic study

Geologic relationships are useful guides to exploration and evaluation of the potentialities of a talc deposit. It has been observed in Vermont that commercial talc deposits are associated with the verde antique type of ultramafic body, whereas none is known in partly serpentinized peridotite and dunite. This association may serve to predict whether an ultramafic body contains commercial talc. Criteria for distinguishing the two types of ultramafic bodies, discussed more fully on pages 7 and 8, may be tabulated as follows:

Type of ultramafic rock 1/ / Criteria	Verde antique type	Partly serpentinized dunite and peridotite
Weathering characteristics	Pale greenish-white to light buff on weathered surface.	Reddish brown on weathered surface; commonly referred to as "buckskin."
Rock types	Serpentinite, grit, steatite.	Large volumes of dunite and peridotite, minor or moderate quantities of serpentinite.
Species of serpentine mineral 2/	Antigorite.	Serpentine (plus chrysotile).
Abestos	Cross-fiber rare or absent; slip-fiber present at some localities in small quantities.	Both cross-fiber and slip-fiber common, possibly in commercial quantities.
Remarks	Considerable amounts of talc always associated; may or may not be in commercial quantity.	Commercial amounts of talc are not known to be associated.

[1]Ultramafic bodies intermediate between the verde antique type and the partly serpentinized dunite or peridotite type may be expected under conditions of genesis suggested on pages 7 and 8, although none has yet been recognized in the current studies.

[2]The nomenclature is that of Selfridge (1936, pp. 468-469).

Structural controls appear to be important factors in localization of talc within the verde antique type of serpentinite body. Steatitization commonly is greater at irregularities along the contact of the ultramafic body; rolls, folds, and "keels" are favorable locations for large grit-steatite deposits. Therefore, before exploration and development of a deposit are undertaken, an attempt should be made to locate such structural features. This is best accomplished by detailed geologic mapping on a large scale. Exploratory drilling, trenching, and mining may then be carried out more intelligently.

Faults locally cut the talc deposits and the country rock. Most of the faults are of small displacement and do not so seriously complicate the form of a deposit that a talc body is completely offset and its continuity lost. However, in areas that contain numerous faults, drifting and stoping operations may be seriously handicapped through weakening of the walls of mine openings and through contamination of the grit and steatite with gouge and breccia fragments of wall rock. Some of the barren "cinders" are of fault origin. Thus faults constitute more of an engineering than a geologic problem.

Geologic study of talc deposits may not yield uniformly satisfactory results. In the first place, many ultramafic bodies are extensively covered with surficial deposits that prevent direct observation. The structural features of some are complex and irregular and the different features, particularly folds, intrusive contacts, and faults, are so intricately related that it is difficult or impossible to evaluate them properly at the present time. The grit and steatite zones are relatively easy to delimit in the simpler deposits. Detailed geologic study, supplemented perhaps by exploratory diamond drilling and trenching, should, under favorable conditions, enable a geologist to infer the approximate form and dimensions of a deposit and arrive at the order of magnitude of the reserves. They should enable the mining engineer to determine the best plan for development and exploitation. Under only moderately favorable conditions, geologic study will enable the geologist and engineer to classify a deposit as favorable or unfavorable for development.

Many years ago, when practically all of the talc mines now operating were opened, labor was readily available, operations were on a comparatively small scale, and only a relatively small outlay of capital was necessary to begin mining operations. Consequently, it was possible to open a mine without risking a large sum of money. Under those conditions, geologic studies of deposits about to be exploited were considered unnecessary. At present, however, with the large initial outlays of capital required to begin mining operations, a deposit should be exploited only after thorough geologic study.

The study of the regional geology of the belt of ultramafic rocks in Vermont is incomplete, and it is not yet possible to explain the great range in degree of steatitization of ultramafic bodies. It is hoped that some explanation will soon be forthcoming to aid in predicting the economic value of talc deposits and to facilitate their exploration. One critical problem to be solved in this connection is that of the source of the solutions responsible for steatitization. It has been pointed out in earlier discussion (pp. 1 and 8) that the solutions are probably derived from outside the ultramafic body. The solutions may have originated in the adjacent wall rock formations under conditions of regional metamorphism, or they may have come from greater depth as emanations from igneous bodies not exposed. Should the adjacent regionally metamorphosed country rock be the source, mapping of the regional stratigraphic and metamorphic patterns may be expected to furnish supporting evidence and to furnish information useful in exploration. If igneous rocks at depth constitute the source of solutions, regional mapping may reveal the presence of such rocks and of structural features through which the solutions gained access to the ultramafic bodies. With these data available, differences in the talc content in ultramafic bodies may be explained and the areas most favorable for exploration delimited.

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