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TALC RESOURCES OF THE CONTERMINOUS UNITED STATES

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Abstract

Talc has been extracted from deposits in the United States for more than two centuries, some for dimension stone but most for ground talc products. This report is designed to summarize the current knowledge of the talc deposits and includes locations and descriptions of occurrences in 27 states, with emphasis on important producing districts. Permissive areas for additional deposits are shown and suggestions for exploration are given.

Talc is a hydrous magnesium silicate, with the ideal formula $Mg_3Si_4O_{10}(OH)_2$. Fe substitution for Mg is much less than in most ferromagnesian minerals, but may be as much as 3% in talc derived from ultramafic rocks. Talc is very soft and is a standard in the Mohs scale, with a hardness of 1.

Ground talc is a commercial product which commonly contains impurities of other minerals, including amphiboles, micas, serpentine, and carbonates. Soapstone and steatite are other common names for talc-bearing rocks.

Many of the most productive deposits of talc are formed by the metasomatic introduction of silica into carbonate rocks. Silica is mostly derived from adjacent siliceous sedimentary rocks. Important gangue minerals formed during metasomatism include chlorite, Fe oxides, tremolite, serpentine, diopside, and forsterite. Intrusive magmas locally appear to be heat and solution sources; elsewhere, evidence for their presence is lacking.

Other deposits are derived from ultramafic rocks. These rocks are commonly, at least in part, converted to serpentinite during their emplacement as ophiolite fragments or during cooling as intrusive rocks. Later, low-temperature hydrothermal solutions have steatized part or all of the serpentinite bodies, producing either a body having zones of talc-carbonate, pure talc, and chlorite blackwall or a soapstone containing talc, chlorite, actinolite, serpentine, carbonate, and Fe-oxide minerals.

Ground talc is widely used in ceramics, paint, paper, plastics, and roofing. Other uses include textiles, rubber, lubricants, and cosmetics. Dimension-stone talc is used for building stone, stoves, carvings, and other products.

Talc is extracted from both open-pit and underground mines. Some is dry-ground, other material undergoes complex beneficiation to produce a pure finely-ground product. There are few environmental problems of a chemical nature associated with talc mining, but dust mitigation is a necessity.

Important talc mining districts, including both recent producers and historically important ones, are located in California, Nevada, Washington, Montana, Texas, Arkansas, Alabama, Georgia, North Carolina, Virginia, Maryland, Pennsylvania, Massachusetts, Vermont, and New York.

Districts in California include two important producers, the Inyo-Panamint and the Southern Death Valley-Kingston Range. In the former district, hydrothermal replacement of Ordovician and Silurian carbonate rocks and quartzite has produced deposits of exceptionally pure talc. In the latter district, Proterozoic carbonate rocks have been replaced by talc and tremolite with the aid of solutions formed by connate water heated by adjacent diabase sills.

The Palmetto and Sylvania districts in westernmost Nevada have produced talc from carbonate and clastic rocks of Late Proterozoic and Early Cambrian age. Low-temperature hydrothermal solutions possibly derived from Jurassic plutonic rocks have formed talc and chlorite.

Districts in Washington near Mount Vernon and Marblemont, as well as an area west of Waterville, have all produced talc. Deposits are in blocks of serpentinized ultramafic rocks, metamorphosed at various times in the Mesozoic and Tertiary.

The Dillon-Ennis district in Montana features talc deposits in Archean marbles interlayered with gneiss, quartzite, and other metamorphic rocks. Granulite facies metamorphism was followed by retrograding and replacement of dolomite and silicate minerals by talc.

The Allamoore district in western Texas has talc deposits in phyllite, cherty limestone, and dolomite of Precambrian age. Hydrothermal alteration of these rocks has produced a dark talc very low in Fe.

A talc district west of Little Rock, Arkansas is in Ordovician rocks of the Ouachita fold and thrust belt. Talc deposits are in zoned lenticular serpentinite bodies.

Talc deposits in the Winterboro district, Alabama are in the Shady Dolomite of Cambrian age. Hydrothermal solutions of unknown origin have replaced dolomite with talc and minor chlorite.

The Chattsworth district in northernmost Georgia has produced talc from a number of ultramafic pods enclosed in Proterozoic gneiss. Hydrothermal alteration has formed serpentinite and rocks composed of pure talc or talc accompanied by chlorite and tremolite.

Talc in the Murphy belt, North Carolina and Georgia, is found in the Cambrian Murphy Marble. Hydrothermal solutions of unknown origin have replaced dolomitic marble with talc and tremolite.

Talc deposits in Virginia are all derived from ultramafic rocks and are abundant. The principal producing district is at Schuyler, where soapstone in a Late Proterozoic mélange unit has been quarried principally for dimension stone uses.

Talc production in Maryland has been from various serpentinite bodies present in the eastern part of the Piedmont belt. These are Late Proterozoic and Cambrian mélange blocks or slabs of serpentinized ophiolite, locally altered to talc-chlorite schist.

Most of the talc deposits in Pennsylvania are in altered serpentinite and are similar to those in Maryland. Deposits in Middle Proterozoic dolomitic marble containing much serpentine and phlogopite but little talc are located near the east border of the state at Easton and are responsible for most of the recorded production.

Talc deposits in Massachusetts are mostly located in a north-trending belt of Cambrian and Ordovician metasedimentary rocks which traverses the state. Blocks of serpentinized rocks are probably ophiolite fragments. Local steatization has resulted in the formation of soapstone, much of which has been quarried for dimension stone.

Talc deposits in Vermont are mostly located in a north-trending belt of Cambrian and Ordovician metasedimentary rocks continuous with that in Massachusetts; some are in Middle Proterozoic gneiss. They are in blocks of serpentinized ultramafic rocks, probably ophiolite fragments. Many bodies have zones of talc-carbonate and especially valuable steatite; others are soapstone.

The Balmat-Edwards district in the Adirondacks of New York state features talc deposits formed in metasomaticaly altered dolomitic marble and quartzite. These rocks and the enclosing migmatitic gneisses are of Middle Proterozoic age. Abundant early-formed tremolite has been partially replaced by anthophyllite, serpentine, and talc.

Introduction

The United States is rich in resources of talc. Native Americans used talcose rocks for carved dishes, tools and ceremonial objects long before the coming of European settlers. Talc has been produced in the form of dimension soapstone since the late 1700's and as a ground product since the late 1800's. Production and use rose rapidly between 1930 and 1970, and have since amounted to 1.0 to 1.2 million tons per year (Brown, 1973, Virta, U.S. Bureau of Mines, 1990, R.L. Virta, oral communication, 1994). Small amounts are imported, and larger amounts are exported.

This report summarizes the geology of these talc deposits and their distribution in the conterminous United States. It is designed to assist in the search for additional deposits in order to supply domestic and export needs and to maintain the position of importance of the United States in the production of talc.

Locations of most of the known talc occurrences, prospects, and mines are shown on the accompanying Talc map of the United States (pl. 1). Occurrences are assigned numbers keyed to a description in the text and to table 1. The treatment is arranged by states; deposits in California are discussed first, followed by a general movement eastward. The deposits in the Appalachians are treated from southwest to northeast, and those in New York and Wisconsin, last.

The description of each occurrence includes the type of deposit; mineralogy of core, talc-bearing, and wall rocks; suggested origin; and the formation name, lithology, structure, and age of the country rocks, where known. Important districts are treated in general discussions.

Larger scale maps (figs. 2-15) showing simplified geology are included for a number of areas in California and Oregon, and for important producing districts in Montana, Texas, Georgia, North Carolina, Vermont, and New York. Localities for which production is reported are indicated by mine symbols on these figures, however, the quantity of material that must have been removed to constitute a mine is an indefinite one.

Areas that are permissive for additional talc deposits are also shown on plate 1, in so far as the scale permits. Criteria for their selection vary from place to place, but permissive areas generally include stratigraphic units, mélange belts, fault zones, and scattered blocks of ultramafic rocks that are on strike with known deposits. Additional comment on permissive areas is included in the state and district discussions. Locally, the permissive areas may include serpentinite or metamorphic rocks that are distant from talc occurrences but lithologically similar to talc bearing units. For carbonate-derived deposits, permissive areas include the outcrop extent of the host rocks of known deposits and of lithologically similar units.

This report is an expansion and modernization of "Talc and Soapstone in the United States" (Chidester and Worthington, 1962), and "Talc resources of the United States" (Chidester and others, 1964), which were indispensable aids to the writer. Subsequent publications, particularly state geologic maps and geologic quadrangle maps, provide a modern framework for the stratigraphy, structure, and age of the rocks enclosing the talc deposits. Plate-tectonic setting is provided by various broad-ranging articles and maps, particularly those by Houston and others (1993), Reed (1993), Rankin (1993), and Rankin and others (1993a and 1993b) in the Geological Society of America's Decade of North American Geology volumes. Economic geology reports by the U.S. Geological Survey and state geological surveys also have supplied updated information, as has the USGS-MRDS data file. However, in many cases, the only information on the talc deposits themselves remains the publications cited by Chidester and Worthington (1962), some of them very old, for example, Pratt and Lewis (1905). Deposits cited only once in an old publication and not confirmed by modern geologic mapping showing an appropriate host rock are generally noted as "unconfirmed".

Talc and talc-bearing rocks

Talc is a distinct mineral species, and the principal one extracted from these deposits. Commercial talc is a mined and processed product which may be 100 percent talc, but which commonly contains other minerals such as amphiboles, micas, serpentine, or carbonate minerals. The types and amounts of mineral impurities allowable in a product depends on its end uses. Rarely, a different mineral, usually chlorite, has been mined and sold as talc. Soapstone is a term widely applied to rocks containing talc and other minerals, the proportions varying widely. Soapstone is more commonly massive rather than schistose. Thus, it is suitable for dimension stone applications, as well as a source for ground talc products. Steatite may be something similar to soapstone, or it may refer to deposits containing exceptionally impurity-free talc. No distinction is made in this report between talc, soapstone, and steatite, because the usage of these terms is fraught with inconsistencies and changes through time. I have generally used the terminology of the authors cited, but some terms have been changed to conform with recent usage. Also, I have translated unusual mineral names into more generic ones.

Physical, chemical, and optical properties of talc

Talc is a hydrous magnesium silicate, which may be colorless, white, pale to dark green, or brown. Talc is monoclinic and has a layered atomic structure similar to that of the micas; a sheet of octahedrally coordinated Mg ions is sandwiched between two sheets of linked SiO_4 tetrahedra. As there are 3 Mg-centered octahedra for every 4 Si-centered tetrahedra, talc has tri-octahedral structure, analogous to biotite. These composite sheets are linked only by van der Waals bonds; the large interlayer cations present in the micas are lacking. Further details on the structure of talc and its Al analogue, pyrophyllite, with diagrams, are provided in Deer and others (1962, p. 115-116 and 121-124) and in Evans and Guggenheim (1988, p. 229-242).

The presence of van der Waals bonds may account for the extreme softness of the mineral, which has been made a standard in the Mohs hardness scale with a hardness of 1 (Evans and Guggenheim, 1988, p. 225). Talc has perfect {001} cleavage forming flexible, inelastic plates. It is commonly found in massive to foliated or fibrous aggregates or in globular-radiating form, rarely as single crystals. It is commonly described as having a greasy feel and pearly luster (Deer and others, 1962, p. 126).

The chemical formula for talc is $Mg_3 Si_4O_{10}(OH)_2$, giving an ideal composition of SiO_2 63.36 percent, MgO 31.89 percent, and H_2O 4.75 percent. There is little variation in composition; small amounts of Al or Ti may substitute for Si; and Fe, Mn, or Al for Mg. Very small amounts of Ca or alkalis may substitute for Mg, but, if shown to be present in chemical analyses, are more likely to be interlayer ions or impurities (Deer and others, 1962, p. 124). Talc generally has a higher Mg/Fe ratio than any other ferromagnesian mineral with which it is found. Talc derived from dolomite commonly contains <1 percent FeO, while that derived from ultramafic rocks may contain 1-3 percent FeO. Uncommon hydrothermal, high-pressure, or metasedimentary talcs may contain more iron. Minnesotaite, found in iron formation in Minnesota, but rare elsewhere, is a talc with nearly complete substitution of FeO for MgO. Pyrophyllite is the Al analogue of talc, having the formula $Al_2Si_4O_{10}(OH)_2$ and a similar atomic structure, but with octahedrally co-ordinated Al ions instead of Mg in the central layer (Deer and others, 1962, Evans and Guggenheim, 1988). Thus, it has dioctahedral structure analogous to muscovite. Pyrophyllite and talc have many similar properties, and the former is locally mined as a substitute for talc. Pyrophyllite is not further considered in this report.

The refractive indices of talc are as follows: α=1.539-1.550, β= 1.589-1.594, γ=1.589-1.600 (Deer and others, 1962, p. 121, 126). These indices are surprisingly varied for a mineral with such a narrow composition range; apparently small amounts of substituted ions, such as Ti, Mn, or Fe, have large effects. Adsorbed water may also have an important effect. Talc is commonly uniaxial (-), owing to the small difference between the β and γ refractive indices. The high birefringence produces third-order interference colors with crossed polarizers.

Geology and Genesis of Talc Deposits

Most talc originates in one of two different ways: (1) metasomatic replacement of dolomite or, less commonly, other sedimentary rocks, by talc, and (2) alteration of ultramafic rocks, generally first to serpentinite and later to talc. Deposits of each type are found in both the eastern and western United States. General discussions of the chemistry of talc formation are provided by Deer and others (1962, p. 126-129) and Evans and Guggenheim (1988, p. 257-280).

Deposits in sedimentary rocks

Formation of talc from carbonate and other sedimentary rocks results from interaction with hydrothermal solutions. The silica required to convert carbonate rocks to talc is most likely derived from adjacent siliceous rocks, though some may originate from an intrusive magma. In exchange, carbonate rocks may supply magnesium to convert siliceous rocks. Plutonic rocks which may have served as sources for heat or hydrothermal solutions are present near some deposits, but absent near others. This type of deposit is found in a very wide range of geologic environments. Some are found in terranes of high-grade gneisses and schists, such as the Dillon district (37) in Montana, the Silver Lake district (14) in California, and the Balmat-Edwards district (180-183) in New York. Others are in unmetamorphosed to low-grade sedimentary rocks, such as the Inyo-Panamint (10-11) and Death Valley-Kingston Range (13) districts in California, the Allamoore district (49) in Texas, the Winterboro district (52) in Alabama, and the Murphy belt (61, 83) in Georgia and North Carolina. Even those in low-grade rocks are in orogenic belts, such as the Basin and Range in the west and the Appalachians in the east. As with other hydrothermal mineral deposits, fault, shear zone, or bedding control of solution movement is an important factor in localizing deposits.

Metasomatic replacement of carbonate rocks generates a variety of calc-silicate and ferromagnesian minerals. In what appear to be the lowest temperature deposits, such as Palmetto and Sylvania, Nevada (19, 20), and Winterboro, Alabama (52), chlorite is the principal metasomatic mineral accompanying talc, along with clay minerals, calcite, and quartz. Higher temperature deposits, such as those in the Death Valley-Kingston Range, California (13), Allamoore, Texas (49), and Murphy belt, Georgia and North Carolina (61, 83), contain tremolite as the principal secondary gangue mineral, along with chlorite and iron oxides. Deposits in the highest grade rocks, such as Dillon, Montana (37), and Balmat-Edwards, New York (180-183), contain local forsterite and diopside, along with serpentine, chlorite, tremolite, and talc formed as retrograde products. Phlogopite (Dillon, Montana (37) and Francestown, New Hampshire (175)) is less common, as is anthophyllite (Balmat, New York (180-183), and Dalton, Massachusetts (147)). Talc locally replaces tremolite-actinolite or other ferromagnesian minerals.

Further discussions of the origin of talc in sedimentary rocks are provided by Blount and Vassiliou (1980, Alabama), Anderson and others, (1990, Montana), Wright (1968, California) and Engel (1962, New York).

Deposits in ultramafic rocks

The formation of talc by the alteration of ultramafic rocks is generally preceded by the conversion of the original rocks to serpentinite. Because forsterite has a higher Mg/Si ratio than serpentine and ortho- and clino-pyroxenes have a lower ratio, serpentinization can be accomplished by the addition of water without addition or subtraction of either SiO_2 or MgO. Fe in the original olivine and pyroxene goes into Fe oxides, most commonly magnetite. Serpentinization may take place at various stages during the history of an ultramafic body. In general, small- to medium-sized bodies such as those in fault or mélange zones have been completely converted to serpentinite, whereas peridotite or dunite cores remain in larger bodies. Very large, sheet-like bodies, such as the Trinity and Josephine ophiolites in the Klamath Mountains, commonly are serpentinized only near their margins.

Steatization, or formation of talc and associated minerals from serpentinite, is generally believed to be accomplished by hydrothermal solutions related to plutonic activity, or, more commonly, to regional metamorphism. Carbon dioxide may have been an important component in these solutions. Steatization generally appears to be a separate, later, event unrelated to serpentinization (Chidester, 1962, Sanford, 1982, and Cocker, 1991). However, Heitanen (1981) believes that serpentinization and steatization were simultaneous in the northern Sierra Nevada foothills belt of California.

Chidester (1962) investigated talc-bearing ultramafic rocks at three mines in Vermont (locality 168 of this report), establishing the classic zonation (fig.1). Several series of samples extending from ultramafic rocks into the country rocks were studied. The ultramafic bodies are enclosed in quartz-chlorite-sericite schists, with or without albite and (or) biotite. These bodies contain 1) a serpentinite core followed outward by 2) talc-carbonate, 3) steatite, and 4) blackwall zones (fig. 1). The talc-carbonate zone contains ferroan magnesite and talc; the steatite zone is essentially pure talc. The blackwall is a narrow zone of altered country rock consisting mostly of chlorite. Locally, the country rock is a carbonate and a tremolite zone is formed instead of blackwall. At the localities studied by Chidester (1962), replacement textures suggest that the steatite zone has locally moved beyond the original margin of the ultramafic body, replacing the country rock.

Sanford (1982) studied three zoned ultramafic bodies in Vermont (localities 158, 159, and 166 of this report) and one in Massachusetts (locality 150). These bodies intrude both mafic and felsic country rocks at metamorphic grades ranging from greenschist to amphibolite. Samples from traverses extending from ultramafic rocks into the country rocks were studied, but results were more varied and complex than those for the mines investigated by Chidester (1962). The general zonation found by Sanford (1982) was as follows: 1) ultramafic assemblage, 2) talc-carbonate, 3) talc, 4) calcic amphibole+chlorite, 5) chlorite, 6) transitional country rock, and 7) country rock. This may be recognized as similar to the zonation of Chidester (1962), but with the addition of the Ca amphibole+chlorite zone. Moreover, the differing country rocks and metamorphic grades in the areas studied resulted in considerable variation in the content of each zone, for instance, at Rochester (locality 166) the talc-carbonate zone consists of talc and dolomite with about one-third serpentinite; magnesite appears only near the inner edge of the zone. The Ca amphibole+chlorite zones contain chlorite and talc with actinolite,

Figure 1. Sketch cross-sections of typical "Vermont-type" talc deposits, based on Waterbury and Barnes Hill localities (Chidester, 1962). Scale approximately 1"=200'. Dunite or peridotite cores to serpentinite bodies are absent here, but present elsewhere. Serpentinite bodies are typically 100-500' wide, locally wider. Talc-carbonate zones are typically 5-10' wide, may be 10-100' wide at fold axes, stretched or separated pods of serpentinite. Steatite envelope around talc-carbonate is a few inches to a few feet thick. Blackwall of chlorite rock is a few inches to approximately 1' thick. Where country rock is carbonate, blackwall is absent and a few inches of tremolite rock are present.

EXPLANATION

Serpentinite

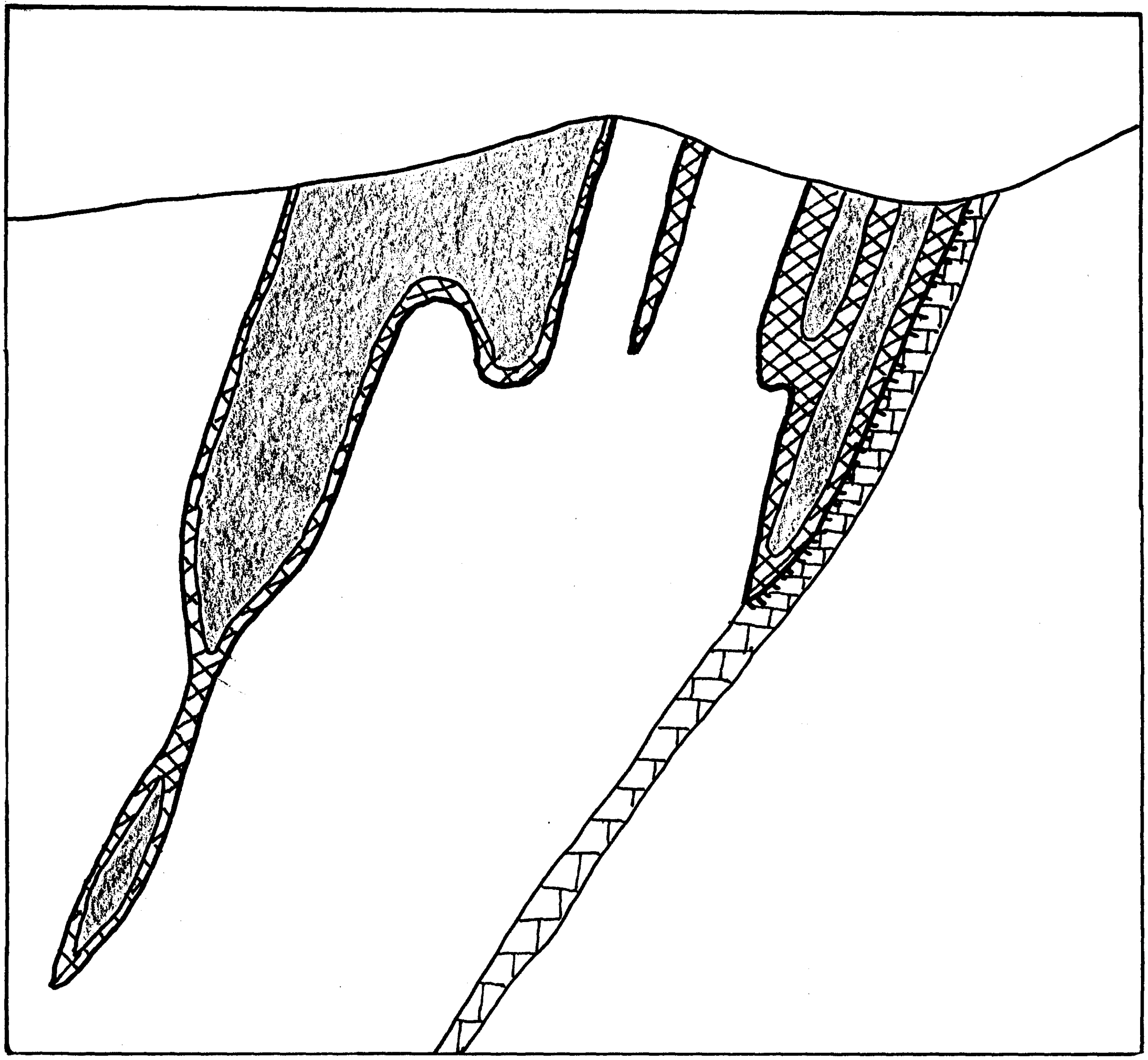
Talc-carbonate and steatite

Metavolcanic or metasedimentary rocks

Carbonate rocks

Blackwall -- chlorite rock

Tremolite rock



anthophyllite, or hornblende. Finally, the outer edge of the ultramafic body appears to be fixed at the outer edge of the Ca amphibole +chlorite zone, as shown by the presence of chromian magnetite from the center of the ultramafic body to that surface and the presence of Ti minerals beyond.

Talc deposits in ultramafic rocks elsewhere may generally be compared with these zoned Vermont occurrences. Many contain similar features, but lack a complete sequence. Limited zonation is found in some occurrences in the Sierra Nevada foothills, Arkansas, the Virginia Piedmont, and elsewhere, as described in this report.

Other minerals are locally important components in zoned and unzoned talc-bearing serpentinites, particularly tremolite-actinolite, anthophyllite, phlogopite, chromian magnetite, and hematite. Uncommon minerals reported include corundum, tourmaline, chromite, and pyrite. Fe-Ti oxides, though generally confined to the country rocks, are locally present in ultramafic rocks. Talc deposits which are not zoned are mostly of the soapstone type, composed of a mixture of minerals commonly including talc, serpentine, chlorite, actinolite, carbonate minerals, and Fe oxide minerals.

The ultramafic rocks containing talc deposits are generally found in orogenic belts, and many are near major faults which are now interpreted as sutures joining exotic terranes to each other and to the North American protocontinent. Thus, it appears likely that they are fragments of oceanic crust, or ophiolite, caught up between converging plates. Geologic maps of areas such as the Sierra Nevada foothills belt, (6-9, see text for references), north-central Washington (27-30), and the Blue Ridge and western Piedmont of Virginia (96-113) all show a pattern of clusters of blocks of ultramafic rocks, commonly near faults. Mélanges containing fragments of ultramafic rocks also occur in these areas. Areas such as the Klamath Mountains, California and Oregon, (1-5, 22-24) contain large ultramafic sheets, now believed to be ophiolite of island arc affinity (Quick, 1981a, b; Saleeby, 1990). The origin of ultramafic bodies enclosed in Archean to Middle Proterozoic metamorphic rocks, such as those in Wyoming (38-47) and the Llano uplift of Texas (50), is obscure, nevertheless, plate tectonic scenarios involving accretion of ophiolite fragments have been proposed for them (Houston and others, 1993; Garrison, 1981; Rankin and others, 1993b).

The chemistry of the steatization process is discussed in further detail by Chidester (1962) and Sanford (1982) for examples in Vermont and by Heitanen (1981, California) , and Cocker (1991, Georgia).

Uses for Talc

Talc is a versatile and useful mineral. Industries using major quantities for their products include ceramics, paint, paper, plastics, and roofing. Smaller quantities go into textiles, rubber, lubricants, cosmetics, and other uses.

In ceramics, talc imparts low, uniform, shrinkage upon firing and high strength to the product, especially valuable for bathroom fixtures, wall and floor tile, pottery, and dinnerware. Mixtures for these purposes may contain 40-70% talc, the remainder being mostly clay. Other, more specialized, ceramic uses include electrical insulators, commonly containing 85% talc (Piniazkiewicz and others, 1994).

Talc is used as an extender and filler in paint, providing whiteness, oil absorption, chemical inertness and viscosity. Talc reinforces paint films, prevents sagging, and improves suspension in the can, dispersing readily in both aqueous and solvent-based paints. Because of the softness of the mineral, abrasion of application equipment is minimal (Piniazkiewicz and others, 1994).

As a filler in paper, talc has minimal negative effect on strength but improves ink receptivity. It enhances opacity, whiteness, and brightness, providing these properties with lower density, and lower cost, than TiO_2. Another important function of talc in paper is the absorption of pitch originating in the pulp, which would otherwise tend to deposit at various places in the paper-making machinery. Ultra-fine talc is also used as a pigment for color-coating high-quality paper (Piniazkiewicz and others, 1994).

Talc is a useful filler in plastics. It is used mostly in polypropylene, but also in vinyl, polyethylene, nylon and polyester. Because of its platy particle shape, talc increases the stiffness of polypropylene; it also increases the heat resistance and reduces shrinkage. Talc is less abrasive than competing fillers (Piniazkiewicz and others, 1994).

In roofing materials, talc is used as a filler to help stabilize the melted asphaltic components. It increases the weather resistance of the finished product. When sprinkled on the surface, it prevents sticking in either shingles or roll roofing (Piniazkiewicz and others, 1994).

Talc is also used as a sizing in textiles, and in foam-rubber backing for carpets. It is an additive in lubricants needed to operate under extreme temperature ranges. It is used as an anti-stick dusting compound for rubber goods, and as an insecticide carrier.

Cosmetic and pharmaceutical uses consume small quantities of the highest purity talc. It is used in face and body powders, antiperspirants,and lotions. It is also an inert carrier in medicine tablets. Still other uses are discussed by Piniazkiewicz and others (1994).

Talc, commonly in impure soapstone form, has been a useful dimension stone from the earliest stages of the industry. Products include hearthstones, furnace linings, wood stoves, sinks, washboards, and carved figurines and statuary.

Mining and Processing

Most talc is extracted from open-pit mines. The size of these operations varies from small pits run by two or three men to large quarries such as those in the Dillon, Montana district. Mining in the Inyo-Panamint and Death Valley-Kingston Range districts in California was by both open pit and underground methods. Large underground mines, now closed, are located at Johnson and Windham, Vermont (Roe, 1975), whereas other operations in Vermont are from open pits. Underground mining has been important in the Gouverneur district, New York, and one mine remains open (Piniazkiewicz and others, 1994). Mining methods are generally standard, but some advantage can be taken of the softness of the mineral, which drills and breaks easily. An unusual aspect of talc mining is the necessity to keep the material free from contamination, as whiteness and absence of abrasive materials are important attributes of the product.

Talc milling has traditionally been a dry process, involving production of an impure product by grinding without further beneficiation, which is suitable for many ceramic uses (Roe, 1975). However, hand and mechanical sorting have more recently become necessary to produce a purer product. Froth flotation is an effective process for the removal of most mineral impurities (Piniazkiewicz and others, 1994). Further grinding is by roller mill where preservation of the platy nature of the particles is desired, as for plastics and roofing materials. The finest, micronized, grades of talc for paint and cosmetic uses are produced in hammer mills, fluid energy mills or jet mills (Piniazkiewicz and others, 1994).

Environmental Considerations

Talc mining is a generally clean operation involving very little environmental damage. Unlike the mining of sulfide ores, it produces no acid mine drainage and very little other contamination of a chemical nature. No smelter fumes are produced, nor are cyanide or other reagents leaked into the ground.

The principal environmental problem with talc production is dust generation. This is a benign problem if the material being mined is free of tremolite, however, it is more serious if tremolite is present, because this mineral has been identified as carcenogenic. Thus, considerable effort at dust mitigation is necessary where tremolitic talc is being mined. However, the Environmental Protection Agency has taken a hand in the matter and required warning labeling for talc products containing tremolite; thus, the mining of tremolitic talc has been substantially curtailed.

Acknowledgments

The sections of this report on Virginia, District of Columbia, Maryland, and Pennsylvania contain much input supplied by Avery A. Drake, Jr., which is gratefully acknowledged. Several state geological surveys, including Washington, Oregon, Texas, New Mexico, Arkansas, Alabama, Georgia, and North and South Carolina answered inquiries and supplied copies of published and unpublished information. Helpful reviews of the sections covering California, Washington, Montana, Wyoming, Texas, Arkansas, Alabama, Georgia, North Carolina, Virginia, Maryland, Pennsylvania, and Vermont were received from geologists in the respective state geological surveys. Also much appreciated are recent state geologic maps of Washington (part), Alabama, North Carolina, Virginia, Connecticut, Massachusetts, and Maine.

California

California contains a number of talc districts including both 1) deposits formed by the alteration of serpentinite or other ultramafic rocks and 2) deposits formed by the replacement of carbonate rocks. Serpentinite-derived deposits are located in the Klamath Mountains, Coast Ranges and Santa Catalina Island, Transverse Ranges, and the Sierra Nevada foothills. Carbonate-derived deposits lie east of the Sierra Nevada in the Basin and Range province.

Klamath Mountains and Northern Coast Ranges, Del Norte, Siskiyou, Humboldt, and Trinity Counties

The Klamath Mountains is a complex geological province located in northwestern California and adjacent Oregon. In California, it is commonly divided into four belts or provinces according to the predominant ages of the metasedimentary and metavolcanic rocks present there (fig. 2). These belts are 1) the eastern Paleozoic belt, an early Paleozoic to Middle Jurassic arc complex, 2) the central metamorphic belt, oceanic crust and overlying sedimentary rocks metamorphosed during the Devonian, 3) the western Paleozoic and Triassic belt, oceanic volcanic and sedimentary rocks and ophiolitic basement, and 4) the western Jurassic belt, volcanic and sedimentary rocks mostly of Jurassic age with extensive ultramafic sheets (Ando and others, 1983; Wagner and Saucedo, 1987) Each belt is a complexly folded and faulted layered sequence, and the contained ultramafic masses are believed to be parts of ophiolites, which have been locally serpentinized (Ando and others, 1983; Wagner and Saucedo, 1987; Strand, 1962). The belts represent at least four different ages of oceanic crust, which have undergone complex histories of ocean-floor genesis, subduction, and arc magmatism, and have been accreted onto the proto-North American continent (Ando and others, 1983; Saleeby, 1990). The larger ultramafic masses are commonly found adjacent to strike-slip or thrust faults, some of which may be sutures, or the actual boundaries joining accreted terranes with each other and continents. Large to small bodies of Jurassic and Cretaceous plutonic rocks intrude the layered sequence. They range in composition from granite to diorite; lithologically similar bodies in adjacent Oregon are believed to be the source of hydrothermal solutions involved in the formation of talc (Ferns and Ramp, 1988).

Talc occurrences generally are complete hydrothermal replacements of small serpentinite bodies and replacements of the margins of large ones,

Figure 2. Geologic sketch map of the Klamath Mountains and northernmost Coast Ranges in California, showing the locations of talc occurrences. Geology adapted from maps of Wagner and Saucedo (1987) and Strand (1962).

EXPLANATION

Sedimentary and volcanic rocks (Quaternary, Tertiary, and Mesozoic)

Metasedimentary and metavolcanic rocks (Mesozoic and Paleozoic)

Area underlain in part or in whole by ultramafic rocks, mostly serpentinite in smaller bodies, peridotite and other ultramafic rocks in larger bodies

Plutonic rocks (Cretaceous and Jurassic) -- Only larger bodies shown

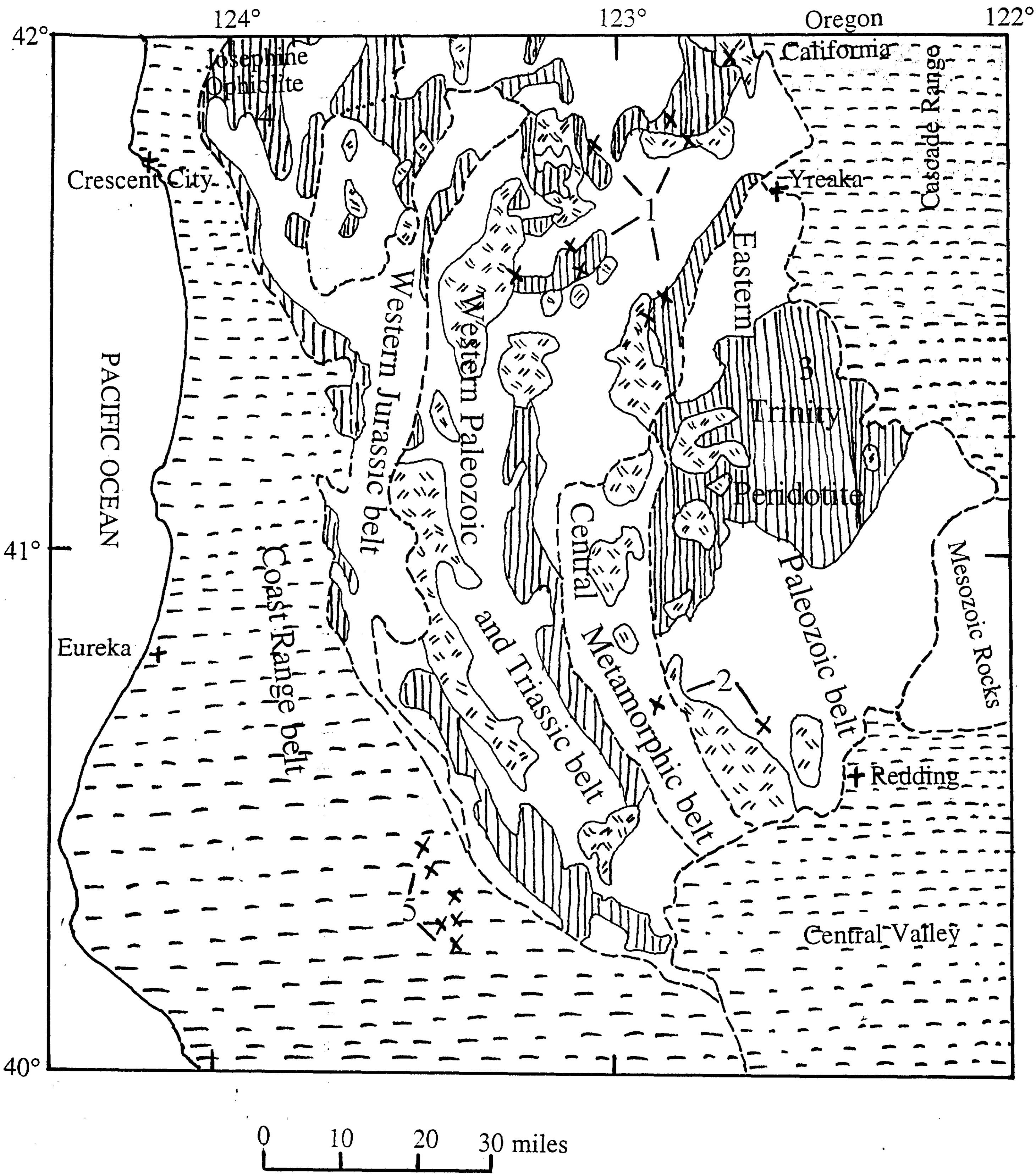
Boundary of geologic province

Talc occurrence

Locality referred to in text

1 Marble Mountains and other occurrences in western Paleozoic and Triassic belt
2 Ganim Mine and Browns Mountain soapstone
3 Trinity peridotite
4 Josephine ophiolite
5 Pickett Peak quadrangle

City or town



124°
123°
Oregon
California
122°
42°
41°
40°
Josephine Ophiolite
4
Crescent City
Yreka
Cascade Range
1
Western Jurassic belt
Western Paleozoic and Triassic belt
Eastern Paleozoic belt
3
Trinity Peridotite
PACIFIC OCEAN
Central Metamorphic belt
Coast Range belt
Mesozoic Rocks
Eureka
2
Redding
5
Central Valley
0 10 20 30 miles

Central and Northern Sierra Nevada Foothills Metamorphic Belt Plumas, Sierra, Nevada, Placer, Eldorado, Amador, and Calaveras Counties

The Sierra Nevada foothills metamorphic belt consists, like the Klamath Mountains, of several belts of metasedimentary and metavolcanic rocks having complex structure but more or less distinct ages. The Paleozoic belt (easternmost) consists of metasedimentary and metavolcanic rocks of the Calaveras Complex of Schweickert and others (1984), Shoo Fly Complex, and other units (Saucedo and Wagner, 1992). The dominant rock types are chert, argillite, sandstone, metabasalt, and mélanges of these rocks. The Triassic and Jurassic belt includes the (informal) Smartville complex of Watkins and others (1987), Mariposa and Logtown Ridge Formations, and other units of metasedimentary and metavolcanic rocks, probably including some rocks of Paleozoic age. Layered rocks in this belt include pyroclastic and volcaniclastic rocks, pillow lavas and breccias, slate, sandstone, and conglomerate (Saucedo and Wagner, 1992). The Jurassic belt (easternmost) includes the Copper Hill and Gopher Ridge Volcanics and other units. It consists dominantly of mafic and felsic metavolcanic rocks, but also includes slate and schist (Wagner and others, 1981).

Each belt contains serpentinite and other ultramafic rocks and was intruded by Mesozoic granitic to dioritic plutonic rocks (fig. 3; Wagner and others, 1981; Saucedo and Wagner, 1992). Also analogous to the Klamaths, these belts have been interpreted as terranes accreted to the North American continent, and the ultramafic rocks as fragments of ophiolite (Saleeby, 1990, 1992).

6. Northernmost foothills belt -- Talc is abundant in association with ultramafic rocks in this area, north of latitude 39°30' N., (Hietanen, 1973, 1981). Larger ultramafic bodies are bordered by serpentinite, followed outward by antigorite-talc-carbonate rock, talc-carbonate rock, and talc schist; small bodies may be entirely talc schist. This is a variation of the typical Vermont sequence (fig. 1). Specific localities shown are near Bucks Lake and Downeville (fig. 3). A mine with small production is located in the canyon of the North Fork Feather River southeast of Paradise (fig. 3; O'Brien, 1949).

7. Central foothills belt -- Numerous talc occurrences, prospects, and mines are present between Angels Camp and Placerville (fig. 3;

Carlson and Clark, 1954; Clark and Carlow, 1956; Clark and Lydon, 1962; Clark, 1970). They consist mostly of talc schist; some are pure talc, whereas others contain tremolite, chlorite, carbonate, and iron oxide minerals (R.C. Greene, unpub. data). The occurrences in the Triassic and Jurassic belt are adjacent to serpentinites, but at those in the Paleozoic belt, talc schist is the only ultramafic rock present. Whether hydrothermal solutions derived from the Mesozoic plutonic rocks are a factor in talc formation remains uncertain.

Saleeby (1990) interprets the principal belts of ultramafic rocks in the central and northern Sierra Nevada as partially serpentinized dunite-harzburgite tectonite slabs with bounding zones of serpentinite melange. These originated as ophiolites formed both in sea-floor spreading and transform environments, and are of both Paleozoic and Mesozoic age. The talc-schist occurrences in the Paleozoic belt are in the Calaveras Complex, a chaotic unit of mostly argillaceous and cherty strata but containing lenses of mafic and ultramafic rocks suggesting a disrupted ophiolite basement (Saleeby, 1992).

Production: Production for the entire Sierra Nevada foothills belt is about 90,000 tons through 1955 (Wright, 1957). Mining has been revived sporadically since. A surface mine of substantial size near Angels Camp was operating in 1994.

Exploration: Talc occurrences in the north part of this area are concentrated close to the large serpentinite bodies; in the south part, they are close to serpentinites in the Triassic and Jurassic belt and occur as small pods in the Paleozoic belt. Both the north part and the Paleozoic belt in the south part of the area appear to be good exploration bets, and perhaps the central part has just suffered from a lack of attention. For guides, the smaller scale maps of Saucedo and Wagner (1992) for the north part and of Wagner and others (1981) for the south part of the area provide a start. Larger scale maps are provided by Heitannen (1973, 1981) for the north part and by Clark and others (1963) and Clark (1970) for the San Andreas quadrangle in the south part. Additional, unpublished mapping may be available from the California Division of Mines and Geology.

Figure 3. Geologic sketch map of the northern and central Sierra Nevada foothills metamorphic belt, California, showing the locations of talc occurrences. Geology adapted from maps of Wagner and others (1981) and Saucedo and Wagner (1992).

EXPLANATION

Sedimentary rocks (Quaternary and Tertiary)

Metasedimentary and metavolcanic rocks (Mesozoic and Paleozoic)

Area underlain in part or in whole by ultramafic rocks, mostly serpentinite in smaller bodies, peridotite and other ultramafic rocks in larger bodies

Plutonic rocks (Mesozoic) -- Only larger bodies shown

Boundary of geologic province

Talc prospect or occurrence

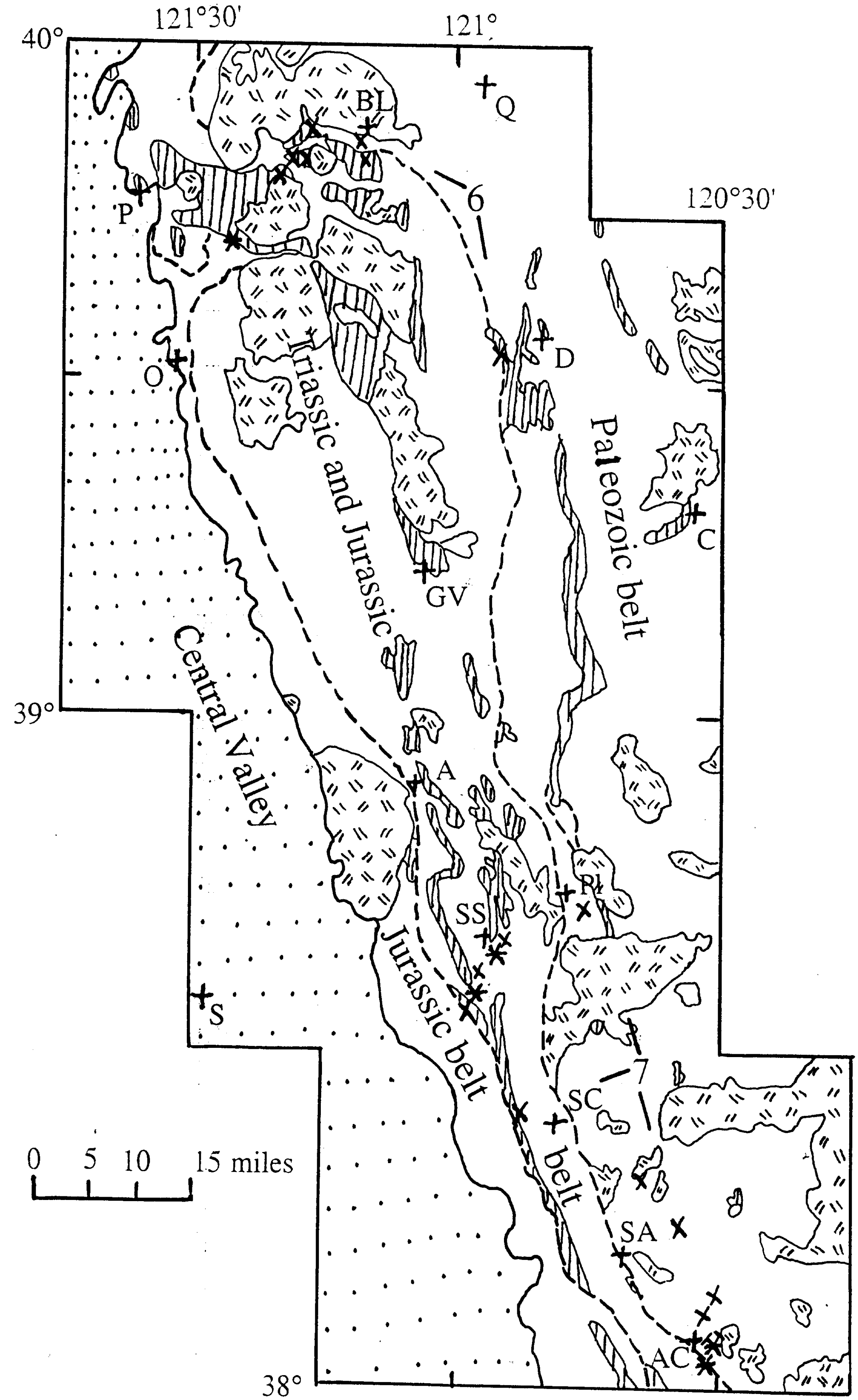
Talc mine, recorded production — Active 1992

Areas referred to in text

- 6 Northernmost foothills belt
- 7 Central foothills belt

City or town

- A Auburn
- AC Angels Camp
- BL Bucks Lake
- C Cisco
- D Downieville
- GV Grass Valley
- O Oroville
- P Paradise
- Pl Placerville
- Q Quincy
- S Sacramento
- SA San Andreas
- SC Sutter Creek
- SS Shingle Springs



40°
121°30'
121°
120°30'
39°
38°
BL
Q
P
6
O
D
C
GV
Triassic and Jurassic
Paleozoic belt
Central Valley
A
Pl
SS
S
Jurassic belt
7
SC
belt
SA
AC
0 5 10 15 miles

4. Geologic sketch map of the southern part of the Sierra Nevada foothills metamorphic belt and plutonic belt, California, showing the locations of talc occurrences. Geology adapted from maps of Wagner and others (1989), Bateman (1992), and Mathews and Burnett (1965).

EXPLANATION

Sedimentary rocks (Quaternary and Tertiary)

Metasedimentary and metavolcanic rocks (Mesozoic and Paleozoic) -- South of Mariposa, ages of pendants of layered rocks poorly known

Area underlain in part or entirely by ultramafic rocks, mostly serpentinite in smaller bodies, peridotite and other ultramafic rocks in larger bodies

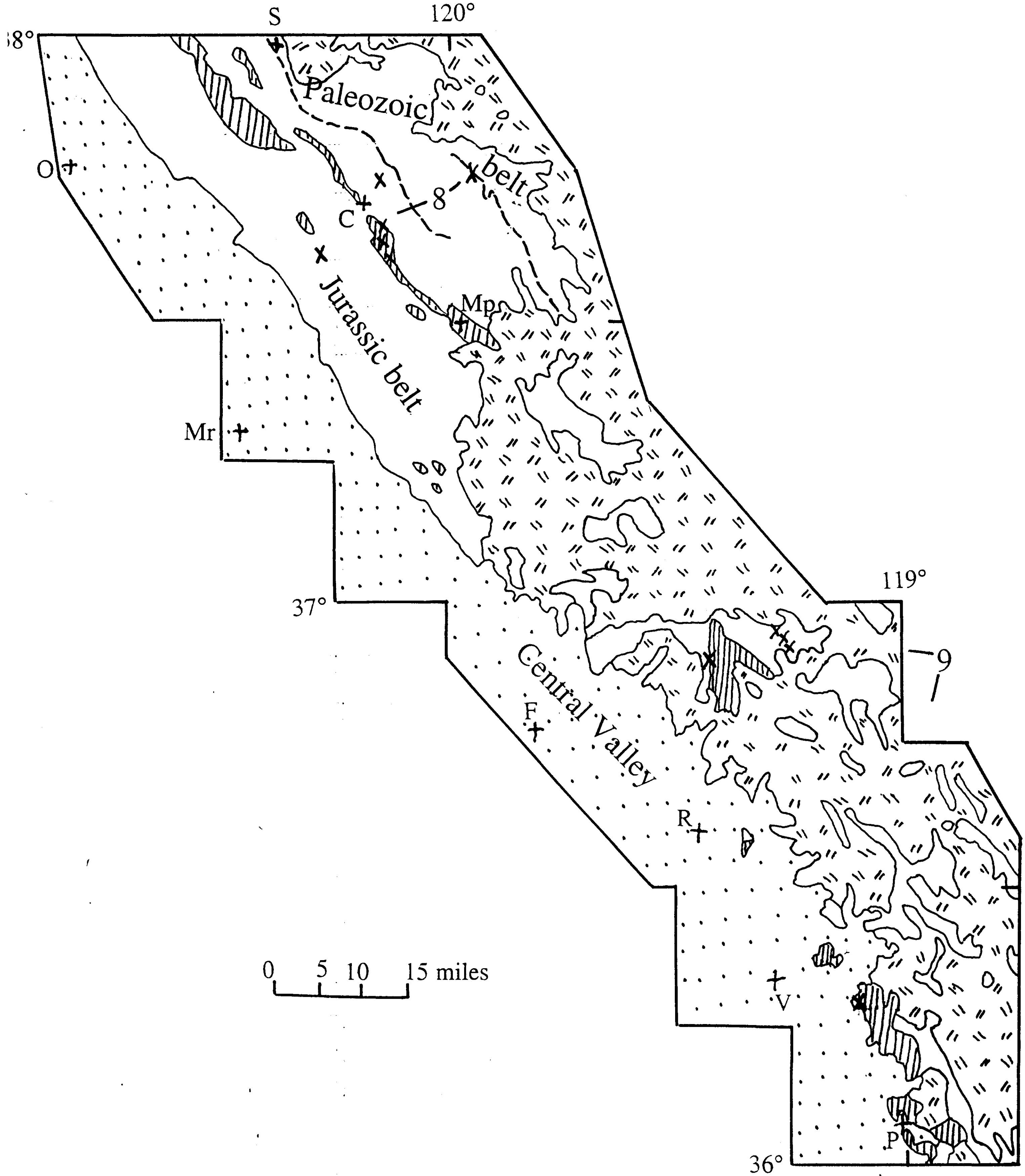
Plutonic rocks (Mesozoic) -- Only larger bodies shown

Boundary of geologic province -- Discontinuous at longitude 120° because of difference in interpretation.

X Talc prospect or occurrence

Area referred to in text
- 8 Coulterville area
- 9 Kings-Kaweah belt

\+ City or town
- C Coulterville
- F Fresno
- Mp Mariposa
- Mr Merced
- O Oakdale
- P Porterville
- R Reedley
- S Sonora
- V Visalia


S
120°
38°
Paleozoic
belt
O
8
C
Jurassic belt
Mp
Mr
119°
37°
9
Central Valley
F
R
0 5 10 15 miles
V
P
36°

Southern Sierra Nevada Foothills Metamorphic Belt and Southern Plutonic Belt
Tuolumne, Mariposa, Madera, Fresno, and Tulare Counties

8. Coulterville area -- Occurrences of talc schist in this vicinity, both at the margins of large serpenitinite bodies and in isolated blocks, are similar to those described above (fig. 4; Bowen and Gray, 1957; Taliaferro and Solari, 1948; Dodge and Calk, 1987; R.C. Greene, unpub. data). No large Mesozoic plutons are present nearby.

9. Kings-Kaweah belt -- Talc occurrences in the plutonic belt south of Mariposa are, in part, in and near the Kings River ophiolite (fig. 4, east of Fresno) and in part in the Kaweah serpentinite mélange (fig. 4, east of Visalia to Porterville; MacDonald, 1941; Putnam and Alfors, 1965; Saleeby, 1978a, 1978b, 1990, 1992). Saleeby believes that a ductile shear zone connects the Kaweah and Kings River occurrences and is part of a major oceanic transform fracture zone. The abundant Mesozoic plutonic rocks are possible sources of hydrothermal solutions.

Production: A small contribution to the production for the foothills belt reported above came from the south part of the belt.

Exploration: Both the area near Coulterville and the Kings River-Kaweah belt appear to be good possibilities. The Coulterville area is shown on the maps of Wagner and others (1989) and Dodge and Calk (1987) and the Kings River-Kaweah belt by MacDonald (1941), Matthews and Burnett (1965), and Saleeby (1978a, b).

Inyo Mountains-Northern Panamint Range District
Inyo County

The Inyo Mountains and Panamint Range in the Basin and Range province directly east of the Sierra Nevada are underlain principally by Proterozoic and Paleozoic sedimentary rocks that have been intruded by Jurassic and Cretaceous granitic rocks, and locally overlain by Tertiary volcanic rocks (fig. 5; Ross, 1967; Streitz and Stinson, 1974). Talc deposits are hydrothermal replacements of dolomite and locally of limestone, quartzite, or plutonic rocks (Page, 1951, Gay and Wright, 1954, Wright, 1957). Although Mesozoic granitic rocks are abundant in the area, no relationship between them and hydrothermal solutions involved in talc formation has been established. Many of the talc deposits are of "steatite grade," consisting of white talc uncontaminated by other minerals.

10 Central part -- Deposits located south of latitude 37° N. (fig. 5) are in the Pogonip Group and Eureka Quartzite of Ordovician age and in the Ely Springs Dolomite of Ordovician and Silurian age. Page (1951) reports on several deposits on the west edge of Saline Valley (fig. 6), several high in the Inyo Mountains, and several on the edge of Owens Valley. I have located and examined most of these; however, I was unable to find the Blue Stone Mine (about 10 mi northeast of Independence, Page, 1951, fig.3 #1) despite considerable effort. Further details on these deposits are in Close (1985). The White Eagle mine, northernmost of those adjacent Saline Valley (fig.5) is currently in operation (David Beeby, written comm., 1995)

11. Talc City -- Deposits are in the same units as the central part, Talc City is the earliest and the leading producer. Nine mines and prospects are described by Page (1951) and further details are given by Gay and Wright (1954). I have examined several mines in this area.

12. Big Pine and Eureka Valley -- A deposit lies in an enclave of marble, believed to be Cambrian in age, enclosed in plutonic rocks in the Sierra Nevada west of Big Pine (fig. 5; Wright, 1957; Bateman, 1992; Ross, 1967, R.C. Greene, unpub. data). Several mines are shown by Wright (1957) and by McHugh and others (1984) in Cambrian rocks at the edge of Eureka Valley. The material which had been removed at the mine which I examined was magnesian chlorite, however McHugh and others (1984) state that high-grade steatite talc is also present.

Production for Inyo Mountains-Northern Panimint Range district: About 340,000 tons through 1955 (Chidester and others, 1964).

Exploration: As fig. 5 shows, the Ordovician and Silurian rocks in the Inyo Mountains part of this district have been thoroughly prospected, perhaps less so in the belt east of Independence, shown on the maps of Ross (1965, 1967). Extensive exposure of these units in the Panamint Range are largely in Death Valley National Park, and are now closed to mineral exploration.

Figure 5. Geologic sketch map of the Inyo-Pananint talc district, California. Geology adapted from maps of Ross (1967), Streitz and Stinson (1974), and Bateman (1992).

EXPLANATION

Alluvium

Intrusive rocks (Mesozoic) -- Granite to diorite. As mapped, consists mostly of Jurassic and Cretaceous rocks; in Sierra Nevada also includes Triassic rocks

Sedimentary and metamorphic rocks (Silurian and Ordovician) -- Includes Pogonip Group, Eureka Quartzite, and Ely Springs Dolomite

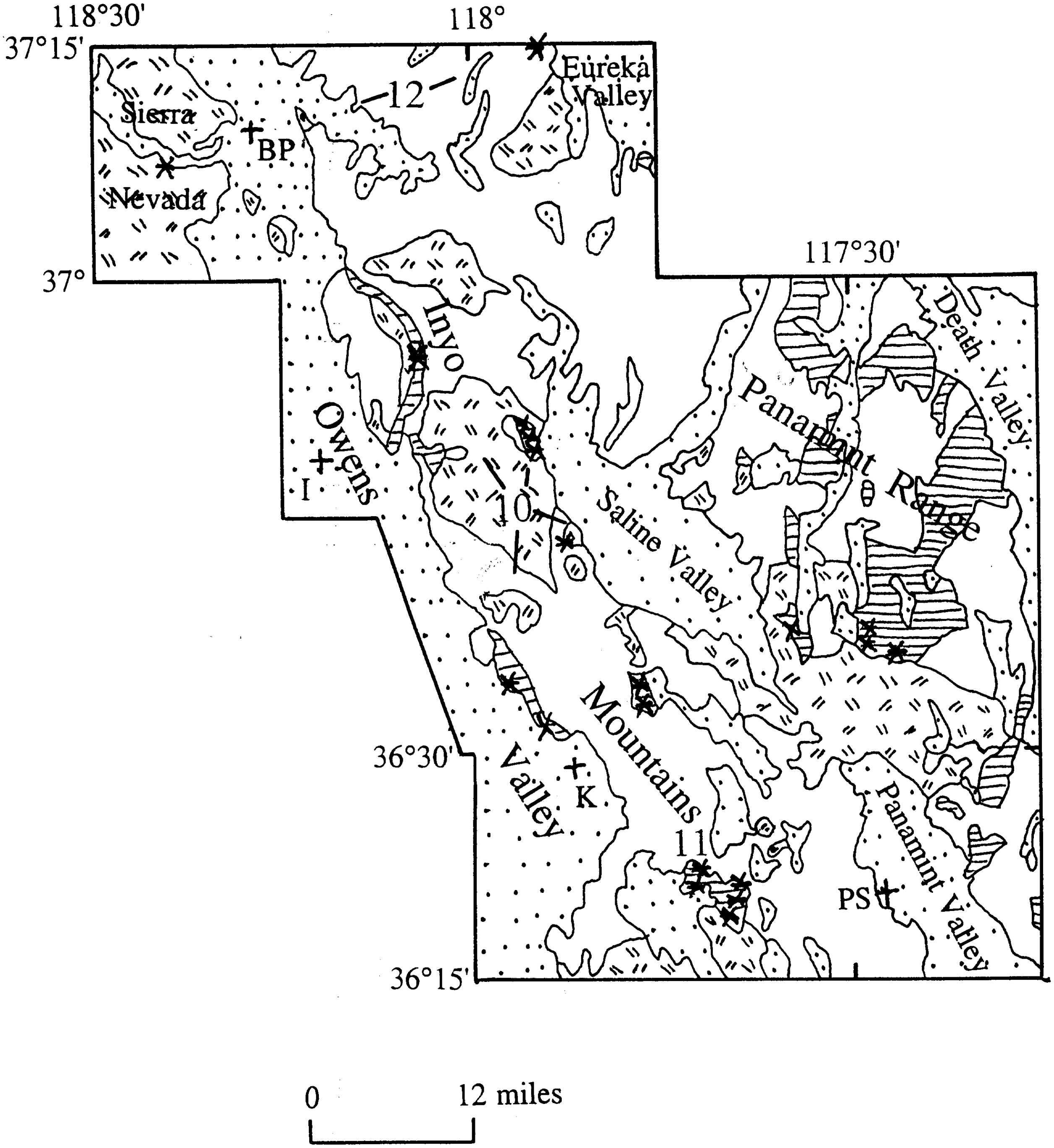
Other sedimentary and volcanic rocks (Mesozoic to Proterozoic)

Talc occurrence or prospect

Talc mine, record of production

Areas referred to in text
- 10 Central part
- 11 Talc City
- 12 Big Pine and Eureka Valley

Town
- BP Big Pine
- I Independence
- K Keeler
- PS Panamint Springs



118°30'
118°
37°15'
Eureka Valley
12
Sierra
BP
Nevada
37°
117°30'
Inyo
Death Valley
Panamint Range
Owens
I
10
Saline Valley
Mountains
36°30'
Valley
K
11
Panamint Valley
PS
36°15'
0
12 miles

Southern Death Valley-Kingston Range District, including Silver Lake to Yucca Grove
Inyo and San Bernardino Counties

This part of the Basin and Range province is underlain principally by Proterozoic and early Paleozoic sedimentary rocks and Cretaceous and Tertiary granitic rocks, with local Tertiary volcanic cover (Jennings and others, 1962).

13. Panamint Range to Silurian Hills -- A large number of talc deposits are found in this area, which includes parts of the Panimint Range, Owlshead Mountains, Black Mountains, Ibex Hills, Avawatz Mountains, Nopah Range, Kingston Range, and Silurian Hills (fig. 6). Deposits are in the carbonate member of the Crystal Spring Formation, part of the Middle and Late Proterozoic Pahrump Group (Wright, 1952, 1957, 1968; Evans, Taylor, and Rapp, 1976). Most of the deposits are in metasomaticly replaced zones in dolomite near the base of the carbonate member, above the contact with a regionally prominent diabase sill. Other deposits are at other horizons in the carbonate member, near other diabase sills. Talc is accompanied by tremolite, chlorite, minor iron oxides, and residual carbonate minerals. Hydrothermal waters effecting the formation of talc are believed to be connate; the diabase supplied heat (Wright, 1952, 1957, 1968). Additional outcrops of the Crystal Spring Formation, with associated diabase, have been mapped on the west flank of the Panimint Range, just to the west of the area of fig. 6 (Albee and others, 1981, and Miller, 1985), however, no talc has been reported.

14. Silver Lake-Yucca Grove -- This belt lies south and southeast of the Silurian Hills (fig. 6). The talc deposits are found in enclaves of high-grade metamorphic rocks, in part carbonate rocks, enclosed by granite and formerly believed to be early Precambrian in age (Wright, 1954,1957; Jennings, 1961; Jennings and others, 1962). Wright (1954) described a productive area near Silver Lake. In a recent reinterpretation, the talc-bearing strata have been referred to the Crystal Spring Formation (L.A. Wright, oral commun., 1994).

Production: About 340,000 tons from the Silver Lake-Yucca Grove area and 820,000 tons from the rest of the district, through 1955 (Chidester and others, 1964). A mine in the Kingston Range was operating in 1992.

Exploration: Much talc remains in the ground in this district, adjacent to mined areas, prospected, or as yet undiscovered. However, all deposits west of the Ibex Hills and some within that range are in Death Valley National Park, and are now closed to exploration. The reports with maps of Wright (1952, 1954 and 1968) provide an excellent guide, and Wagner and Hsu (1987) provide additional mapping in the southern Panamint Range. Regional coverage is provided by the maps of Jennings (1961, Kingman sheet, east of long. 116°W.) and Jennings and others (1962, Trona sheet, west of long. 116°W). A new Trona sheet is in preparation by the California Division of Mines and Geology.

Other areas

Central and Southern Coast Ranges

Much of the central and southern Coast Ranges is underlain by rocks of the Jurassic and Cretaceous part of the Franciscan Complex (pl. 1; Bailey and others, 1964; Blake, 1984; Jennings and Strand, 1960; Wagner and Bortugno, 1982)). The Franciscan consists of graywacke sandstone, siltstone, shale, chert, minor carbonate rocks, and pillow basalt, partly in coherent strata and partly in mélange. It also contains bodies of serpentinite and other ultramafic rocks. Talc occurrences are rare, however, apparently owing to the lack of any externally caused metamorphism or hydrothermal alteration (M.C. Blake, Jr., oral commun., 1991).

15. Mount Hamilton, Santa Clara County -- Unconfirmed occurrence reported by Crittenden (1951).

16. Santa Catalina Island, Los Angeles County -- This island is underlain, in part by the Franciscan Complex (including serpentinite) and, in part, by Tertiary volcanic and intrusive rocks (Jennings, 1962). A soapstone deposit, apparently formed by alteration of serpentinite, produced small quantities during the 1890's. (Gay and Hoffman, 1954; Wright, 1957).

Transverse Ranges

17. Boquet-Hauser Canyons, Los Angeles County -- This area lies west of Palmdale 3 to 5 miles south of the San Andreas Fault. It is underlain by the Paleocene and (or) older Pelona Schist and Mesozoic granitic rocks (Jennings and Strand, 1969; Bortugno and Spittler, 1986).

Figure 6. Geologic sketch map of the southern Death Valley-Kingston Range talc district, California. Geology adapted from maps of Jennings and others (1962), Jennings (1961), and Wright (1968).

EXPLANATION

Alluvium

Intrusive rocks (Mesozoic) -- Granite to diorite

Pahrump Group and diabase (Late and Middle Proterozoic)

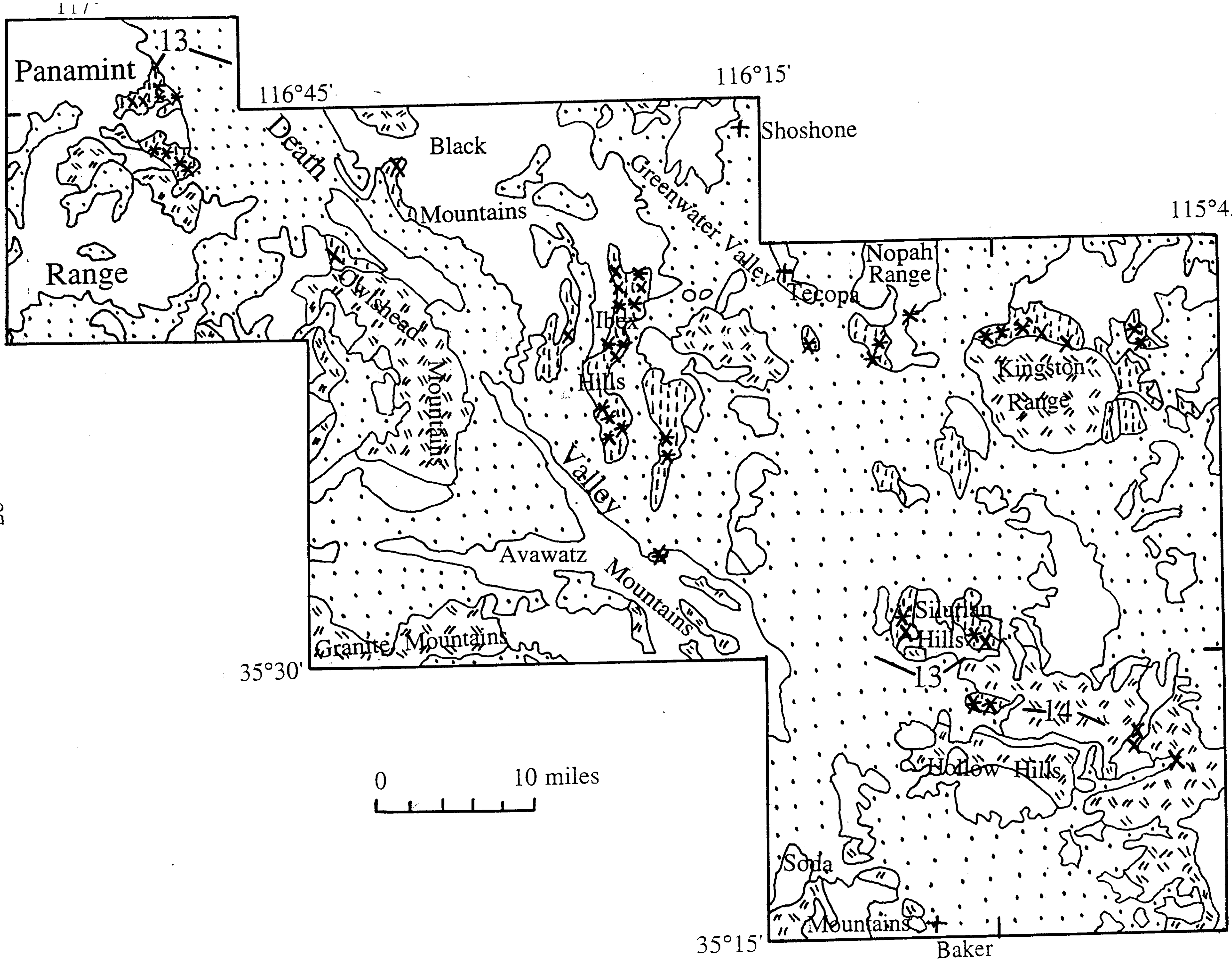
Sedimentary and volcanic rocks, undivided (Tertiary to Proterozoic)

Talc occurrence or prospect

Talc mine, record of production   Active 1992

Area referred to in text
13 Panamint Range to Silurian Hills
14 Silver Lake-Yucca Grove

Town



13
Panamint
Range
36°
116°45'
Death
Valley
Black
Mountains
116°15'
Shoshone
Greenwater Valley
115°45'
Nopah
Range
Tecopa
Owlshead
Mountains
Ibex
Hills
Kingston
Range
Avawatz
Mountains
Silurian
Hills
13
14
Hollow Hills
Granite Mountains
35°30'
0
10 miles
Soda
Mountains
Baker
35°15'

The Pelona Schist in this area contains serpentinite masses and pillowed greenschist (Ehlig, 1981). Ehlig states that the protolith of the Pelona Schist was probably deposited on oceanic crust, but does not identify the mafic-ultramafic masses as ophiolite, believing instead that the serpentinite was emplaced diapirically and some distributed by sedimentary processes. Talc deposits consist of talc-actinolite and talc-carbonate rocks and are found at sheared contacts between serpentinite and metasedimentary schist.

Production: The Katz Mine has produced altered material consisting of serpentine, chlorite, and talc, as much as 6,000 tons yearly from 1935 to at least 1954 (Gay and Hoffman, 1954); thus, total production may be as much as 100,000 tons.

Exploration: Three other prospects in this area have been explored by open cuts or adits, and additional discoveries appear to be possible.

Western Mojave Desert

18. Rand Mountains, Kern County -- This area lies directly southwest of the Randsburg mining district and is underlain by schist of Mesozoic age, probably the equivalent of the late Mesozoic Orocopia Schist (R.M. Tosdal, oral commun., 1994). Talc layers in the schist are of obscure origin. Four prospects are reported by Troxel and Morton (1962).

Production total for California: Production figures for California are given in the U.S. Geological Survey's Mineral Resources of the United States series from 1920 to 1923, the U. S. Bureau of Mines Mineral Resources of the United States from 1924 to 1931, and in the U.S. Bureau of Mines Minerals Yearbook series from 1932 to 1986. Adding the production figures for 1920 to 1955 to estimates for earlier years gives about 1.9 million tons total production to 1955, a figure of the same magnitude as the 1.7 million tons obtained by adding the district totals cited above. The total for 1956 to 1986 plus estimates to 1994 gives 4.2 million tons, thus the total for the state may be as much as 6.1 million tons.

Nevada

Two adjacent districts, Palmetto and Sylvania, in westernmost Nevada have had substantial production of talc and chlorite, and one minor occurrence also contains talc (Papke, 1975). The Palmetto and Sylvania districts are two northwest-trending belts (19 and 20, below) only a few miles apart, and are located in the Palmetto Mountains and neaby areas. Deposits are derived from the hydrothermal alteration of carbonate and other sedimentary rocks.

19. Palmetto district, Esmeralda County -- Talc deposits in this district are in limestone, siltstone, and sandstone of the Early Cambrian Harkless and Poleta Formations (Papke, 1975; McKee, 1985; McKee and Nelson, 1967; USGS-MRDS data file). They contain talc with abundant chlorite, montmorillonite, calcite, and quartz. The sedimentary rocks are intruded by Jurassic plutonic rocks, which may have supplied the hydrothermal solutions that altered carbonate and siliceous rocks to talc. Detailled descriptions of the mines and prospects are provided by Papke (1975).

20. Sylvania district, Esmeralda County -- Talc deposits in this belt are in the Late Proterozoic and Early Cambrian Reed Dolomite and in sandstone, shale, and dolomite of the Late Proterozoic Wyman Formation (Papke, 1975; McKee, 1985; McKee and Nelson, 1967; R. C. Greene, unpub. data). They consist of talc and chlorite, commonly found at fault contacts with intrusive rocks that may be related to talc formation. Tungsten skarn deposits nearby appear to be unrelated (USGS-MRDS data file). Detailled descriptions of the mines and prospects are provided by Papke (1975).

Exploration: Although thoroughly prospected, this district might respond to additional exploration effort. The maps of McKee and Nelson (1967) and McKee (1985) provide a geologic guide, and the USGS-MRDS data file along with the report of Papke (1975) provide locations to distinguish the talc mines and prospects from those for base metals.

21. Lodi Hills, north of Gabbs, Nye County -- Talc and magnesian chlorite formed by hydrothermal alteration of the margin of Tertiary porphyritic granitic rocks (Papke, 1975; Kleinhampl and Ziony, 1984, 1985). Several tons of material are reported to have been shipped. Papke reports four other occurrences of talcose minerels in Nevada, none of which contain talc.

Production for Nevada: Papke (1975) quotes U.S. Bureau of Mines figures indicating 217,000 tons produced from 1941 to 1970. He estimates that earlier production coupled with unreported production brings the total to 300,000 tons. Of this amount, approximately half is talc and the other half is chlorite or various mixtures including talc, chlorite, serecite and pyrophyllite. The U.S. Bureau of Mines reports small additional production to 1980.

Oregon

All talc deposits in Oregon are derived from ultramafic rocks. They are located in two provinces, the Klamath Mountains and Coast Ranges in southwestern Oregon and the Aldrich and Blue Mountains in northeastern Oregon.

Southwestern Oregon
Coos, Douglas, Curry, Josephine, and Jackson Counties

The Klamath Mountains and Coast Ranges in southwest Oregon are continuous with the same provinces in adjacent California, and two of the Klamath belts, the western Jurassic and the western Paleozoic and Triassic belts, are also continuous. Like their counterparts in California, each of the Klamath belts is a complexly folded and faulted layered sequence which contains large and small masses of ultramafic rocks believed to be ophiolites, in part serpentinized. They are terranes of oceanic crust, sutured onto the proto-North American continent (Irwin, 1977; Saleeby, 1990). The Coast Range belt is also comprised of metavolcanic and metasedimentary rocks with local ultramafic bodies and is continuous with the California Coast Ranges.

Talc occurrences in southwestern Oregon are partly in hydrothermally altered serpentinites along fault zones and partly in regionally metamorphosed ultramafic rocks (Ferns and Ramp, 1988). All are relatively near Jurassic or Cretaceous granitic plutons. Hydrothermal solutions derived from them may be responsible for talc formation, as well as for gold mineralization since placer gold districts are common downstream from the talc occurrences (Ferns and Ramp, 1988).

Much of the talc in this area is in soapstone which consists of varied amounts of talc, carbonate minerals, tremolite, anthophyllite, and chlorite. Other occurrences contain talc schist, talc-carbonate rock, talc-chlorite schist, and talc-bearing serpentinite.

22. Western Paleozoic and Triassic belt -- This belt contains the Applegate Group, Condrey Mountain Schist, May Creek Schist, and related units. The rocks are principally basalt, andesite and dacite flows, tuffs, and breccias; mélange, schist, quartzite, and amphibolite (Smith and others, 1982). Scattered to continuous bodies of serpentinite are also present, and much unaltered peridotite in the southernmost part of

Figure 7. Geologic sketch map of the Klamath Mountains and south part of the Coast Ranges in Oregon, showing the locations of talc occurrences. Geology adapted from maps of Smith and others (1982), Ferns and Ramp (1988), and Walker and MacLeod (1991).

EXPLANATION

Sedimentary and volcanic rocks (Quaternary to Mesozoic)

Metasedimentary and metavolcanic rocks (Mesozoic and Paleozoic)

Area underlain in part or in whole by ultramafic rocks, mostly serpentinized. Includes mostly Jurassic rocks, but some may be Paleozoic or Triassic in age

Plutonic rocks (Cretaceous and Jurassic) -- Selected bodies

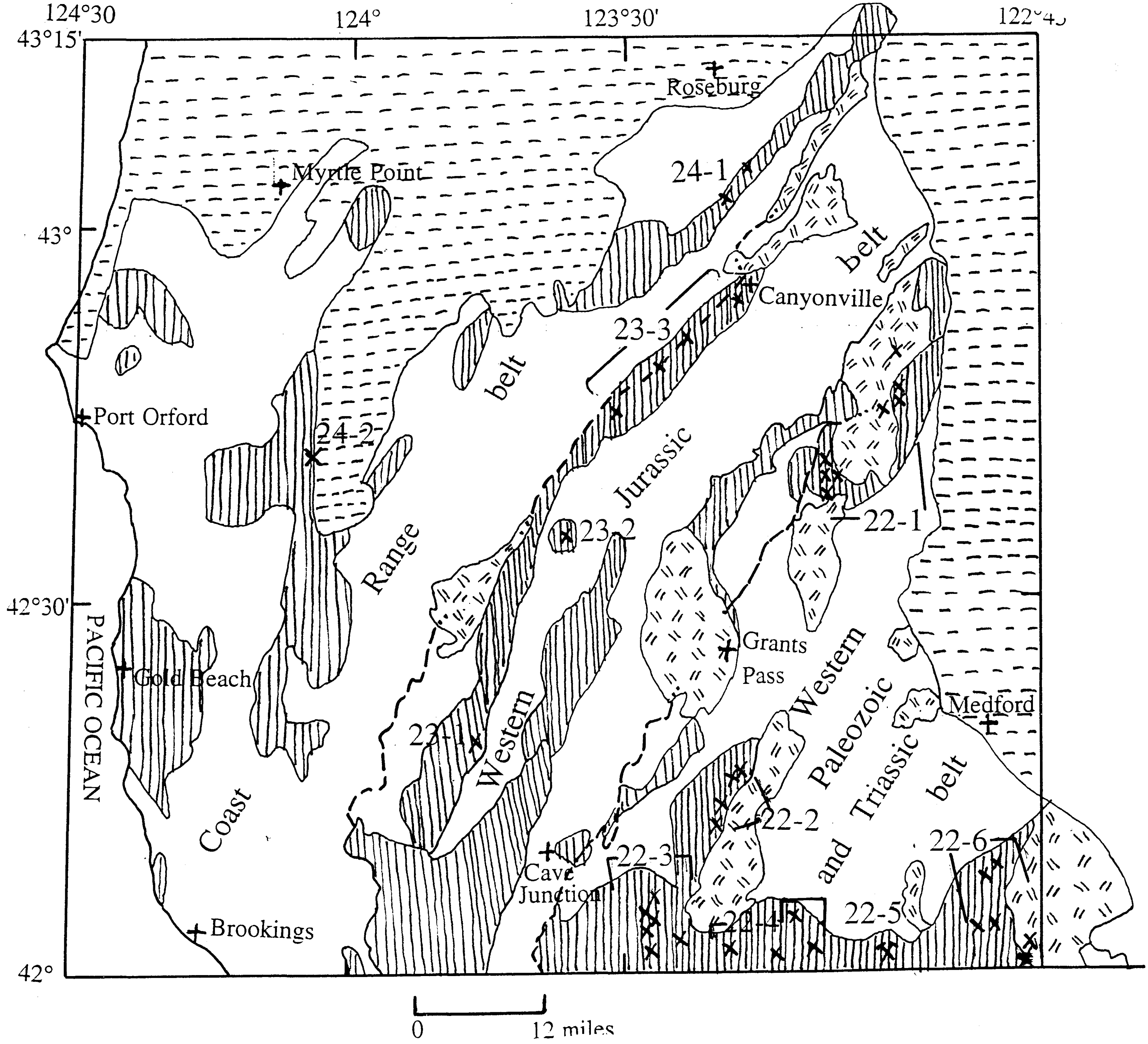
Boundary of geologic province

X Talc occurrence or group of occurrences

- 22 Western Paleozoic and Triassic belt
  - 22-1 Red Mountain-Tiller
  - 22-2 Williams
  - 22-3 Sucker Creek
  - 22-4 Cranberry Creek
  - 22-5 Elliot Creek Ridge
  - 22-6 Siskiyou Peak
- 23 Western Jurassic belt
  - 23-1 Pearsoll Peak
  - 23-2 Galice
  - 23-3 Coast Range Thrust
- 24 Coast Ranges
  - 24-1 Myrtle Creek
  - 24-2 Powers fault zone

Talc mine, active 1992

City or town


124°30
124°
123°30'
122°45
43°15'
43°
42°30'
42°
Roseburg
Myrtle Point
Port Orford
Gold Beach
Brookings
Canyonville
Grants Pass
Medford
Cave Junction
PACIFIC OCEAN
Coast Range belt
Western Jurassic belt
Western Paleozoic and Triassic belt
24-1
24-2
23-1
23-2
23-3
22-1
22-2
22-3
22-4
22-5
22-6
0
12 miles

the belt. There are several large bodies of Jurassic or Cretaceous granitic rocks, and many talc occurrences in altered serpentinite (fig. 7, loc. 22-1 to 22-6).

Production: A mine currently (1992) producing soapstone used in carvings is located in the Elliott Creek Ridge area (loc. 22-5). Descriptions of this and other occurrences are provided by Ferns and Ramp (1988).

23. Western Jurassic belt -- This belt contains the Galice Formation and other units and consists principally of shale, siltstone, and mudstone with subordinate andesitic tuff, agglomerate, and flows (Smith and others, 1982). It also contains scattered to continuous bodies of serpentinite and unaltered peridotite. Large plutons of Jurassic or Cretaceous granitic rocks lie partly or wholly in the belt. There are several talc occurrences, mostly in fault or shear zones adjacent to serpentinite (fig. 7, loc. 23-1 to 23-3).

24. Coast Range belt -- The Coast Range belt is underlain by the Dothan Formation and related rocks of Jurassic and Cretaceous age. Layered rocks are both metavolcanic and metasedimentary, with local ultramafic bodies, also believed to be ophiolite fragments. These rocks are continuous with the Franciscan complex in California (Smith and others, 1982; Ferns and Ramp, 1988). This belt contains sparse occurrences of talc, chlorite, and related minerals (fig. 7, loc. 24-1, 24-2; Ferns and Ramp, 1988). The adjacent Josephine ophiolite consists of peridotite, cumulate ultramafic rocks, gabbro, pillow basalt, and dike complexes (Smith and others, 1982), but no talc is reported from it (fig. 7).

Exploration: There appears to be much talc in the Oregon Klamaths, but little utilization of the deposits. The maps of Smith and others (1982) and Ferns and Ramp (1988) provide considerable detail on the locations of ultramafic bodies and talc occurrences. As in adjacent California, small ultramafic pods and the margins of larger serpentinite bodies may provide the best exploration targets.

Northeast Oregon
Grant, Baker, and Malheur Counties

25 Aldrich and Blue Mountains region -- In this area, Paleozoic, Triassic, and Jurassic volcanic and metasedimentary rocks, locally

enclosing ultramafic rocks, are exposed in large and small windows in the cover of Tertiary volcanic rocks . Jurassic or Cretaceous plutonic rocks intrude the layered sequence. Ultramafic rocks, plutonic rocks, and the Dooley Mountain Rhyolite of Ferns and Ramp (1988) are shown in fig. 8. Talc is found in slab and block melange zones with serpentinite matrix or along thrust and high-angle fault zones cutting serpentinite or other ultramafic rocks (Ferns and Ramp, 1988). Most of the occurrences are in small, disrupted ultramafic masses rather than in the larger ultramafic sheets, such as the Canyon Mountain Complex (Aldrich Mountains). The ultramafic rocks are Paleozoic and Triassic in age, according to Walker and MacLeod (1991). They have been described as disrupted oceanic crust and island-arc fragments forming a belt (Baker terrane) lying between two relatively coherent island-arc fragments (Brooks and Vallier, 1978, and Silberling and Jones, 1984). Most talc deposits are relatively near large Jurassic or Cretaceous granitic plutons, suggesting that hydrothermal solutions associated with these intrusions were responsible for the formation of talc. Others are near the Dooley Mountain Rhyolite, also believed to be a source of solutions. As in southwestern Oregon, placer gold deposits are commonly present downstream from the talc occurrences, further suggesting a relation between these solutions and gold mineralization (Ferns and Ramp, 1988).

Detailed descriptions of talc occurrences, many of which are well exposed along U.S. Forest Service roads, are given by Ferns and Ramp (1988). The occurrences are characterized by outcrops containing complex sequences of any of the following: chlorite schist, talc schist, talc with tremolite, chlorite, or carbonate minerals, limonitic talc, serpentinite, argillite, greenstone, diorite or gabbro. Also present are mélanges containing any of these rocks (fig. 8, loc. 25-1 to 25-6).

Production: None recorded.

Exploration: Talc occurrences, although abundant in this area, are apparently too small and too mixed with other rocks to have, heretofore, been considered commercially viable. Search might be directed towards ultramafic pods away from mélange or imbricately faulted zones, using the maps of Ferns and Ramp (1988), Brown and Thayer (1966), and Brooks and others (1976) as guides.

Figure 8. Geologic sketch map of parts of the Aldrich and Blue Mountains in Oregon, showing the locations of talc occurrences. Geology adapted from maps of Brown and Thayer (1966), Ferns and Ramp (1988), and Walker and MacLeod (1991)

EXPLANATION

Dooley Volcanics (Miocene)

Volcanic and sedimentary rocks (Tertiary and Mesozoic) -- Mainly Tertiary volcanic rocks

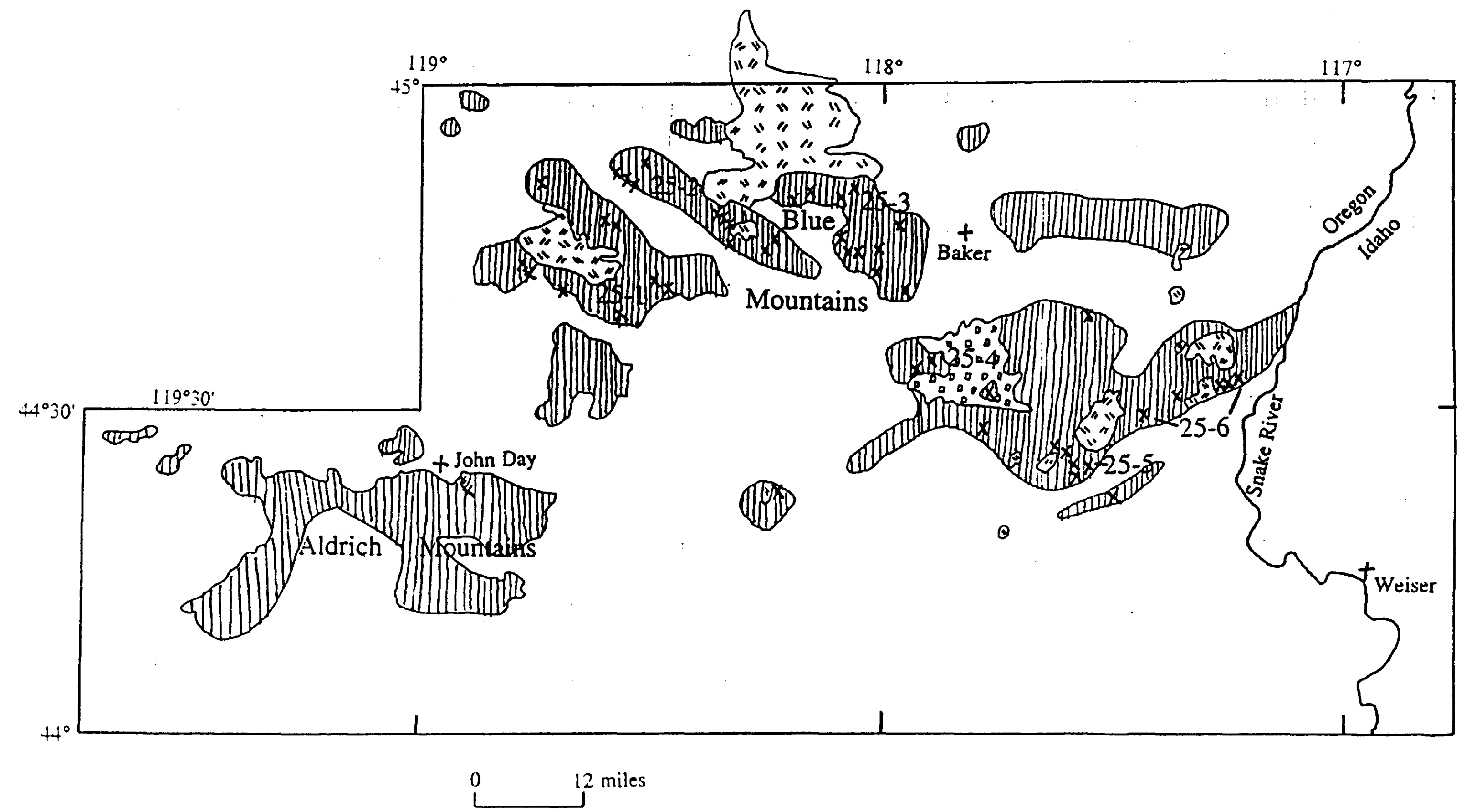
Plutonic rocks (Cretaceous and Jurassic) -- Selected bodies only

Mafic to ultramafic rocks (Triassic or Paleozoic) -- Locally serpentinized

+ City or town

× Talc occurrence or group of occurrences

25-1 Greenhorn
25-2 Sumpter
25-3 Elkhorn
25-4 Dooley Mountain
25-5 Basin Creek
25-6 Conner Creek



119°
118°
117°
45°
44°30'
119°30'
44°
25-1
25-2
25-3
Blue
Mountains
Baker
25-4
25-5
25-6
Oregon
Idaho
Snake River
Weiser
John Day
Aldrich Mountains
0
12 miles

Washington

Much of northern Washington is underlain by north- to northwest-trending terranes comprised of Proterozoic, Paleozoic, and Mesozoic metasedimentary and metavolcanic rocks that are intruded by Mesozoic and Tertiary plutonic rocks and which contain small bodies of ultramafic rocks of unknown age (Huntting and others, 1961). Most of the blocks of ultramafic rocks are adjacent to faults, and most may be ophiolite fragments. Talc deposits in most of northern Washington are derived from ultramafic rocks, but those in the easternmost belt are derived from carbonate rocks. There are three principal districts and a number of scattered occurrences.

Principal Districts

26. District east and north of Mount Vernon, Whatcom County -- Valentine (1960) reports a talc mine 6 mi. due east of Mount Vernon, in a serpentinite block containing lenses of talc. The mine is on or near the Table Mountain fault, separating the Early Cretaceous Shuksan Metamorphic Suite of Misch (1966), (Darrington Phyllite of Misch, 1966) from the Late Cretaceous (?) Haystack terrane of Whetten and others, (1979), (Whetten and others, 1980, 1988). The Darrington Phyllite is a graphitic and micaceous metasandstone, while the Haystack unit contains greenstone, metasedimentary rocks, and metaplutonic rocks including serpentinite and silica-carbonate rock. It is, in part, melange with serpentinite matrix (Whetten and others, 1988). Whetten and others' (1980) detailed map shows lenses of serpentinite, greenstone, and silica carbonate on both sides of the Table Mountain fault, lending support to the concept of either a wide fault zone with many exotic blocks or a sedimentary mélange in this area (R.W. Tabor, oral communication, 1995). The talc was apparently formed by hydrothermal alteration, but no younger intrusive rocks have been mapped nearby.

Additional talc localities (Valentine, 1960), all derived from serpentinite, include two occurrences lying directly south of the Sagit River enclosed in surficial deposits as mapped (Whetten and others, 1988). These may be glacial erratics or local bedrock highs. Another reported locality is about 6 mi. to the north in an area also underlain by the Darrington Phyllite and Haystack terrane, other small occurrences are present in this area as well (R.W. Tabor, oral comm., 1995).

Tabor and others (1989) place the rocks of the Mount Vernon area, in part, in the Helena-Haystack and, in part, in the Easton tectonostratigraphic terranes of the north Cascades Range, which they believe were accreted to the North American continent in Late Cretaceous to Eocene time.

Exploration: A permissive area for additional talc deposits (pl. 1) extends southeast from this district. It includes those parts of the Darrington-Devils Mountain fault zone and the western and eastern Late Cretaceous to middle Eocene mélange belts which contain blocks of ultramafic rocks. Geologic maps of the Port Townsend (Whetten and others, 1988), Sauk River (Tabor and others, in press), and Skykomish River (Tabor and others, 1982b) 30-x60-minute quadrangles will serve as guides.

Another permissive area (pl. 1) is present on Fidalgo Island and smaller adjacent islands northwest of Mount Vernon, where serpentinite occurs.

27. Marblemont district, Sagit County -- Talc mines and prospects are in bands of talc-, talc-magnesite- and talc-tremolite schists enclosed in hornblende-mica schist and mica-quartz schist of the Late Cretaceous and Tertiary Napeequa unit (Misch, 1979; Tabor and others, 1994). Tabor and others (1989) believe that the Napeequa unit represents oceanic crust. Some of the talcose material is soapstone, and some is high-grade talc (Valentine, 1960; Vhay, 1966). Small bodies of serpentinite and peridotite are present near the talc bands (Misch, 1979). Plutonic rocks of the Marblemount Meta Quartz Diorite of Misch (1966) are present nearby and may have supplied hydrothermal solutions.

These localities are east of the Straight Creek fault and some are near the Entiat fault; all are in the Chelan Mountains tectonostratigraphic terrane (Tabor and others, 1989)

Exploration: The Napeequa unit and associated ultramafic rocks form a permissive area (pl.1) extending this district to the south (Mt. Baker, Tabor and others, 1994; and Sauk River, Tabor and others, in press, 30-x60-minute quadrangles).

28, 29, and 30. West of Waterville, Chelan County -- This area contains parts of several fault-bounded tectonostratigraphic terranes, as shown on the Chelan quadrangle (Tabor and others, 1987). The rocks in each of these terranes are identified with their metamorphic ages; the protoliths are necessarily older. The terranes are believed to have been accreted to North America during pre-Late Cretaceous time.

28. West of Entait -- Three talc occurrences are reported (Valentine, 1960) in a belt of Late Cretaceous heterogeneous schist and gneiss of the Mad River terrane (Tabor and others, 1987) which extends west-northwest from the Columbia River near Entait. Reported occurrences appear to be in lenses of serpentinized ultramafic rocks and are within 8 mi. of Entait; however, mapped occurrences of ultramafic rocks also occur in this belt south of Sugarloaf Peak, and are abundant in a subsidiary belt of the heterogeneous schist and gneiss unit lying adjacent to the Entiat fault and extending 8 mi. to the southeast. Talc occurrences in this belt are likely. This area lies at the west margin of the map area of Stoffel and others (1991).

Exploration: Additional blocks of ultramafic rocks occur along the Entiat fault, which is shown as permissive for talc deposits (pl.1).

29. West of Leavenworth -- A talc occurrence is reported (Valentine, 1960) in a serpentinite body 5 mi. north-northwest of Leavenworth. It is near the Leavenworth fault and is part of the Late Jurassic or Early Cretaceous Ingalls Tectonic Complex, which locally appears between plutonic rocks of the Late Cretaceous Mount Staurt batholith and Late Cretaceous gneiss of the Nason terrane (Tabor and others, 1987; Miller, 1980). The Ingalls tectonic complex contains abundant serpentinite and continues for about 20 mi. to the west and 20 mi. to the south (Tabor and others, 1982a, 1982b). The serpentinite near the Mount Staurt batholith is largely metamorphosed to talc-tremolite and anthophyllite rocks containing metamorphic forsterite.

30 West of Wenatchee Lake -- A talc deposit is located near the Wenatchee River 6 mi. west of the head of Wenatchee Lake. The talc here is apparently formed by hydrothermal alteration of a serpentinite lens enclosed within Late Cretaceous light-colored gneiss of the Nason terrane (Tabor and others, 1987, 1989). Talc is currently (1995) being removed from loose surface blocks for use by local carvers (Raymond Lasmanis, written comm., 1992, 1995). Another occurrence reported by Valentine (1960) is located on Nason Creek 5 mi. to the south, and is apparently also in serpentinite enclosed within Late Cretaceous biotite schist and amphibolite. Two additional poorly located occurrences are present in the area 5-10 mi. northwest of the head of Wenatchee Lake.

Exploration: A permissive area (pl.1) encompases localities 29 and 30 and a large part of the terrane between the Straight Creek and Leavenworth faults which contains ultramafic rocks. The Skykomish River (Tabor and others, 1982b), Chelan (Tabor and others, 1987), and Wenatchee (Tabor and others, 1982a) 30-x60-minute quadrangles will serve as guides.

Other occurrences

31. North of Omak -- Mafic intrusive rocks are altered to serpentinite and some talc in this area; Cretaceous granitic rocks are present nearby (Valentine, 1960; Stoffel and others, 1991)

32. East of Republic -- Serpentinite and some talc are present along the Sherman fault, a structure bounding the Republic graben. Permian greenstone, gabbro, and diorite are present west of the fault, and Eocene quartz monzonite lies to the east. Serpentinite is believed by Meussig (1967) to have been emplaced tectonically along the fault (Stoffel and others, 1991).

Exploration: Five additional areas containing scattered occurrences of ultramafic rocks (pl.1) are permissive for talc deposits. They are located: 1) west of Palmer Lake, 2) south of Danville, 3) east of Lauier, 4) north of Nespalem, and 5) east of Nespalem and are shown on the state geologic map (Stoffel and others, 1991) and larger-scale maps credited therein.

33. Huckleberry Mountain, northwest of Spokanne -- Meta-argillite, quartzite, and dolomite of the Proterozoic Deer Trail Group are cut by greenstone dikes; dolomite is locally altered to talc (Valentine, 1960; Stoffel and others, 1991; Campbell and Raup, 1964).

34. Spokane River, west of Spokane -- Low-grade metasedimentary rocks of Proterozoic to Ordovician age (Stoffel and others, 1991) have interlayered talc; Cretaceous granodiorite and Tertiary intrusive rhyodacite(?) are present nearby (Becraft and Weis, 1963); talc may have formed by hydrothermal alteration of carbonate rocks.

35. East of Davenport -- Proterozoic metasedimentary rocks at this locality are, in part, calcareous; Cretaceous or Tertiary granitic rocks are

found nearby (Stoffel and others, 1991); talc schist layers may have formed by hydrothermal alteration.

Exploration: An area surrounding localities 33-35 (pl. 1) underlain, in part, by Proterozoic metasedimentary rocks is permissive for additional carbonate-derived talc deposits.

Production in Washington: Talc production ranging from 2,400 to 5,400 tons/yr is reported for some years between 1940 and 1967, and similar amounts were probably produced in unreported years. Most of this probably came from the Marblemont district. Small, but indeterminate, amounts are reported to 1986 (U.S Bureau of Mines Minerals Yearbook series). On the basis of these figures, I estimate total production for the state at 150,000 tons.

Idaho

36 Salmon River, Idaho County -- Lenticular bodies of ultramafic rock are present in the Paleozoic or Mesozoic Riggins Group, a sequence of metavolcanic and metasedimentary rocks exposed along the Salmon River in westernmost Idaho (Hamilton, 1963). Ultramafic rocks consist dominantly of serpentinite containing magnesite and talc and minor amounts of actinolite, tremolite, chlorite, magnetite, and phlogopite. Schists consisting almost entirely of talc were seen at two localities (Hamilton, 1963), and serpentine, tremolite-actinolite, chlorite, and phlogopite also locally form monomineralic rocks. Chidester and Worthington (1962) noted a talc prospect in this area.

Poole and others (1992) place a hypothetical fault representing the extension of both the Sonoma and Antler orogenic belts in apparent coincidence with the Rapid River thrust as mapped by Hamilton (1963). This thrust is a major structural feature which lies 2-3 mi. from the ultramafic bodies. Hamilton believed that the ultramafic rocks are intrusive alpine-type peridotites, but an interpretation consistent with plate-tectonic theory would identify them as ophiolite fragments.

Production: None recorded.

Exploration: The best possibilities for talc deposits are in the rocks of the Riggins Group, north of, south of, and between the known ultramafic bodies, close to the Rapid River thrust. The two maps in

Hamilton (1963) are a guide. Possibly similar terranes in central Idaho in the Antler orogenic belt indicated on the map of Poole and others (1992) may also be considered.

Montana

37. Dillon-Ennis district, Madison and Beaverhead Counties -- Talc prospects and mines in Montana are mostly confined to the Ruby Range and parts of the Greenhorn and Gravelly Ranges to the east (fig. 9; Anderson and others; 1990, Olson, 1976; Heinrich and Rabbitt, 1960; Heinrich, 1960; Klepper, 1950; Ruppel and others, 1993). There are also a few occurrences in the adjacent Tobacco Root Mountains to the north (Olson, 1976).

The host rocks for the talc occurrences in the Ruby and Gravelly Ranges are marbles interlayered with other metasedimentary rocks and with granitic gneiss. These rocks were formerely placed in two large units, the Cherry Creek Group and the Dillon Granite Gneiss (Heinrich, 1960; Heinrich and Rabbitt, 1960; Olson, 1976). These rocks are Archean in age and were metamorphosed at about 2.75 Ga (James and Hedge, 1980). Marble bearing metasedimentary rocks in the Greenhorn Range and Tobacco Root Mountains have also been placed in the Cherry Creek Group by several writers quoted by Olson (1976), but Olson cautions that not all may correlate with rocks of the type locality in the Gravelly Range.

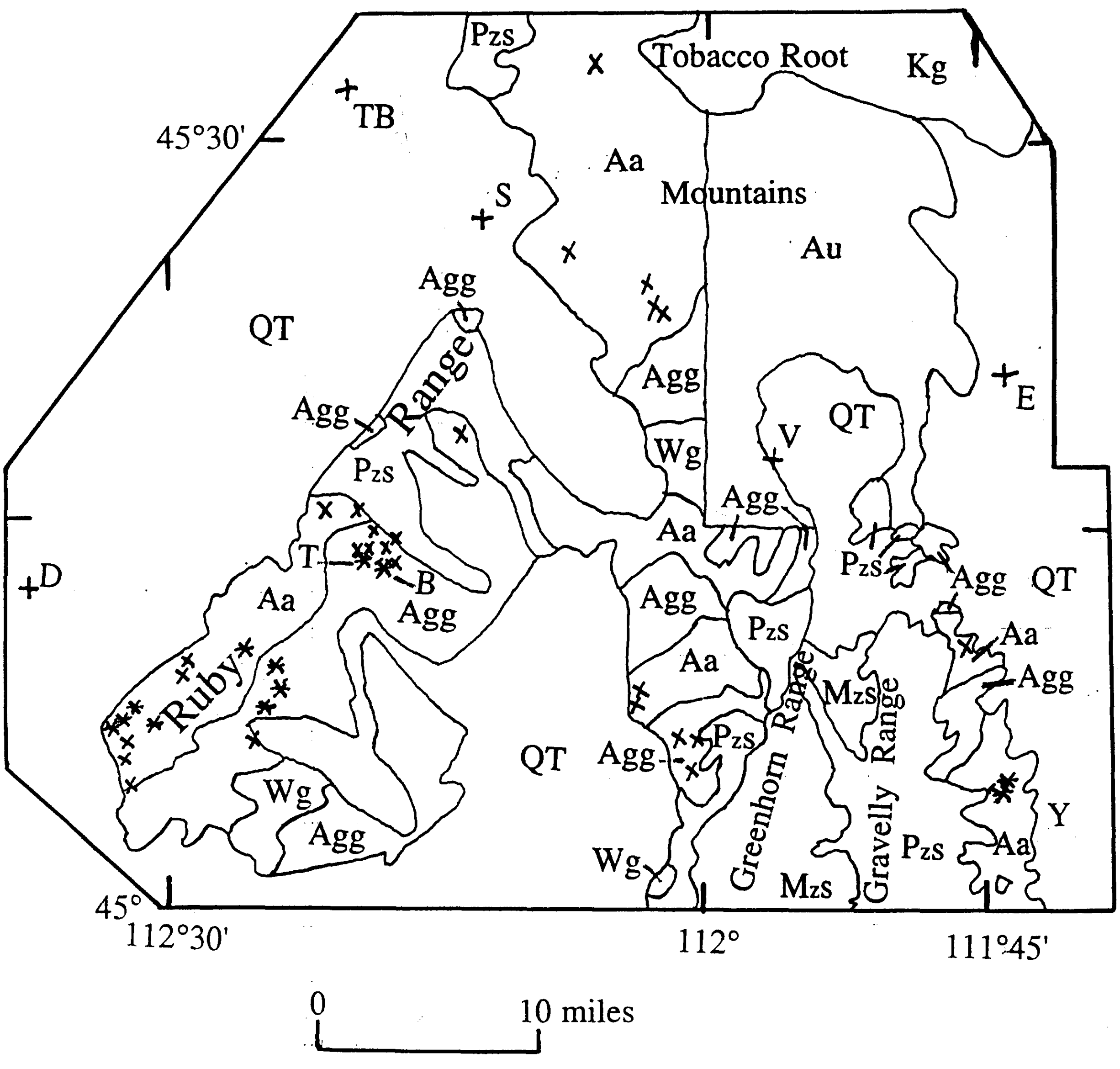
A recent map (Ruppel and others, 1993) which includes part of this area (fig. 9, west of long. 112°) provides considerable additional detail in the Ruby Range, as well as revisions to the sequence. The names "Dillon Granite Gneiss" and "Cherry Creek Group" are not used; instead a thick unit termed Middle(?) to Late(?) Archean quartzofeldspathic gneiss is used insted of the Dillon. The gneiss contains lenticular interlayered units of amphibolite, schist, marble, mixed schist and gneiss, and quartzite, lithologies previously assigned to the Cherry Creek; these rock types are mapped seperately and are predominant near the top of the sequence. An older gneiss is shown at the base, in agreement with previous mapping (Heinrich and Rabbitt, 1960; Heinrich, 1960; Klepper, 1950). Local pods of ultramafic rocks, some containing talc, are also shown; they are enclosed within the quartzofeldspathic gneiss and in the older gneiss.

Figure 9. Simplified geologic map of the Dillon-Ennis talc district, Montana. Geology from Ruppel and others (1993) west of longitude 112°, from Hadley (1969a, b) east of longitude 112° and south of lattitude 45°15', remainder from King and Beikman (1974). Talc occurrence and mine locations from Heinrich and Rabbit (1960), Heinrich (1960), and Olson (1976).

EXPLANATION

QT	Sedimentary and volcanic rocks (Tertiary and Quaternary)
Kg	Granite (Cretaceous)
Mzs	Sedimentary rocks (Mesozoic)
Pzs	Sedimentary rocks (Paleozoic)
Au	Gneiss and metamorphic rocks, undivided (Archean)
Agg	Granite gneiss with minor interlayered amphibolite, schist, marble, and quartzite (Archean) -- Essentially equivalent to Dillon Granite Gneiss of Heinrich (1960)
Aa	Amphibolite, schist, marble and quartzite, with interlayered granite gneiss (Archean) -- Essentially equivalent to Cherry Creek Group of Heinrich (1960)
Wg	Gneiss, migmatite, and schist (Late Archean)
——	Contact, some may be faults
X	Talc occurrence; Talc mine, having recorded production
	Talc mine, active 1995
+	Town

B Beaverhead
T Treasure
Y Yellowstone
D Dillon
E Ennis
S Sheriden
TB Twin Bridges
V Virginia City


Pzs
Tobacco Root
Kg
TB
45°30'
Aa
Mountains
S
Au
Agg
QT
Range
Agg
V
E
Pzs
Wg
45°15'
Agg
Aa
D
T
B
Pzs
Agg
QT
Aa
Agg
Agg
Pzs
Aa
Aa
Agg
Ruby
Mzs
Range
Greenhorn Range
Pzs
QT
Agg
Wg
Gravelly
Y
Agg
Pzs
Aa
Wg
Mzs
45°
112°30'
112°
111°45'
0
10 miles

Units shown on fig. 9 are based on the mapping of Ruppel and others (1993) and on the two quadrangle maps by Hadley (1969a, b). Units that are dominatly metasedimentary rocks ("Cherry Creek" equivalent) and gneiss ("Dillon" equivalent), respectively, are shown. Both contain interlayered marble and talc deposits.

The Ruby, Greenhorn, Gravelly, and Tobacco Root Ranges lie near the west margin of the Wyoming province, a part of the North American craton underlain by Archean basement (Houston and others, 1993). Houston and others also provide a summary of the sequence in the Ruby and nearby Ranges. Similar and possibly correlative sequences of gneiss and metasedimentary rocks occur in the southern Madison Range and near Hegben Lake, east of the Gravelly Range. They include dolomitic marble and, locally, ultramafic rocks (Houston and others, 1993, map, p. 124; Erslev, 1983).

A Proterozoic retrograde event at about 1.6 Ga may have involved fluid movement along major faults and resulted in hydrothermal alteration of marble to talc (Giletti, 1966; Berg, 1979). Anderson and others (1990) proposed the following sequence of events leading to the formation of talc: (1) granulite-facies metamorphism producing marbles with the mineral assemblage calcite-olivine-phlogopite±tremolite, (2) retrograde metamorphism to greenschist facies producing serpentine, chlorite, and dolomite, and (3) replacement of dolomite and silicate minerals by talc. Structural control is provided by faults and by layer-parallel fractures.

Talc mines, prospects, and occurrences reported by Heinrich and Rabbitt (1960), Heinrich (1960), and Olson (1976) are shown on fig. 9, as are additions from the USGS-MRDS data file. Because this talc is free of tremolite, it has a competitive edge in the current market.

Production: As indicated on fig. 9, there are three mines currently operating in the Dillon-Ennis district (1995), the Beaverhead, Treasure, and Yellowstone.

Chidester and others (1964) estimate production at about 200,000 tons through 1948. Based on combined figures in the U.S. Bureau of Mines Minerals Yearbook series, I estimate 2.0 million tons for 1949 to 1975. For 1976-1994, Minerals Yearbook supplies figures totalling 6.5 million tons, giving a total estimated production of 8.7 million tons through 1994.

Exploration: While the marble occurrences in the Ruby Range and adjacent ranges appear to have been thoroughly prospected, permissive areas (pl. 1) in the southern Madison Range provide possibilities, as much dolomitic marble and some ultramafic rocks occur there. This range is well covered by geologic maps at a scale of 1:62,500 or greater (Sonderegger and others, 1982; Erslev, 1983; Witkind, 1969, 1972, 1976; Witkind and Prostka, 1980).

Wyoming

Most of the talc occurrences in Wyoming are derived from serpentinite enclosed in Archean rocks. They are found in the Teton Range, Wind River Range, and Bighorn Range in the Central Rocky Mountains province and the Laramie Mountains in the Southern Rocky Mountains province. An unusual authigenic occurrence is in Eocene sedimentary rocks in the Wyoming Basin. Placement of the rock units in subdivisions of the Archean Era follows the usage of Love and Christiansen (1985). Bounding ages of these subdivisions are Late Archean, ranging from 2,500 to 3,000 Ma, Middle Archean, ranging from 3,000 to 3,400 Ma, and Early Archean >3,400 Ma, according to the Geological Society of America (1983).

Wyoming is almost entirely in the Wyoming province, a part of the North American craton underlain by basement composed of Archean rocks (Houston and others, 1993). Tectono-stratigraphic evidence for the history of the province is fragmentary, but suggests a mobilistic history similar to Phanerozoic plate tectonics. The Wyoming province is believed to have been welded to the Superior Province during the Late Archean, then separated by Early Proterozoic rifting.

38. Teton Range, Teton County -- The several reported talc occurrences lie in the 2,500-Ma Mount Owen Quartz Monzonite as mapped but they are actually in discontinuous masses of serpentinite enclosed in the pluton (Geological Survey of Wyoming, 1970; Harris and others, 1985; Love and Christiansen, 1985, Harris 1995, #14). The northern occurrence consists of massive soapstone and fibrous talc in olivine diabase cut by granite (Beckwith, 1939, Harris, 1995, #13). Harris (1995, #15) also reports that soapstone used by native Americans occurs in the Gros Ventre Range southeast of the south end of the Teton Range; however specific localities are unknown.

38A. Southwest of Green River, Sweetwater County -- Harris (1995, #12) reports talc in a core hole in the Eocene Green River Formation. Talc, chlorite, lazurite, and sapionite(?) occur as authigenic minerals in a salt bed. This talc probably has no commercial potential but is of mineralogic interest (Bradley, 1964).

39. Northern Wind River Range, Fremont and Sublette Counties -- Talc in the northern Wind River Range is present in Early Archean gneiss typically of tonalitic composition but ranging to granite (Granger and others, 1971; Harris and others, 1985; Love and Christiansen, 1985; Love and others, 1978a, 1979b). The gneiss encloses discordant bodies of amphibolite, biotite schist, and, locally, ultramafic rocks. The ultramafic rocks are typically composed of primary tremolite, olivine and enstatite, with alteration minerals talc, serpentine, and chlorite. Migmatites and intrusive granite are common in this area. Talc occurrences are mostly soapstone and are commonly found as blocky float in areas of felsenmeer. Two localities are reported by Harris (1995, #8 and #11). The latter, Pipestone Lake, contains substantial quantities of good quality steatite but is in the remote Bridger Wilderness area and is a Native American quarry site.

40. South Pass, Wind River Range, Fremont County -- Massive to schistose serpentinite, commonly containing abundant magnetite, and locally containing chrysotile asbestos is present adjacent to schist and iron formation of the Late Archean Goldman Meadows Formation in an imbricately faulted area (Bayley and others, 1973; Love and others, 1978b). Talc schist is present along the southeast margin of the body, as well as locally throughout it. A large iron mine is present nearby. Additional serpentinite is shown, apparently in error, 12 miles south-southwest near the Sweetwater River (Bayley and others, 1973, p. 5). The error is repeated in Houston and others (1993, p. 139).

40A. West of South Pass, Fremont County -- Large boulders and possible outcrops of steatite, chloritic talc and serpentinite are found in association with amphibolite and granite country rocks (Harris, 1995, #7). Some material has been quarried for sculptors.

41. Southeast of Lander, Fremont Coounty -- Asbestos and vermiculite are reported to be present in a serpentine lens forming a roof pendant in Late Archean (Love and Christiansen, 1985) granitic gneiss (Beckwith, 1939; Love and others, 1978b). Talc is reported as present by Harris and others (1985).

42. South end of Bighorn Range, Natrona County --Talc lenses and pods occur in Early Archean quartzofeldspathic gneiss, quartzite and amphibolite (Harris and others, 1985; Love and Christiansen, 1985; Love and others, 1978c). Harris (1995, #9) reports that a number of prospect pits and worked pieces of steatite are present, suggesting that this was a major steatite source for Native Americans.

43. Margin of Bighorn Range, south of Sheridan, Sheridan County -- An occurrence of talcose rock, locally known as sheridanite, is in Middle and Late Archean granitic gneiss at the contact with probable mafic to ultramafic enclaves (Harris and others, 1985; Love and Christiansen, 1985; Love and others, 1978a).

44. Bighorn Range, West of Hazelton Peak, Washakie County -- An occurrence of talc is enclosed in Early Archean granitic gneiss containing abundant biotite- and hornblende-rich layers, coarse pegmatitic layers, and, less common schist. Masses of chlorite-talc-actinolite schist are enclosed in amphibolite that formed along shear zones (Harris and others, 1985; Love and Christiansen, 1985; Osterwald, 1959; Love and others, 1978a). Talc and amphibole asbestos are also found in folded hornblende schist and olivine metadiabase (Osterwald and others, 1959; Beckwith, 1939, Harris, 1995, #16).

45. Casper Mountain (northernmost Laramie Mountains), south of Casper, Natrona County -- Serpentinite containing asbestos and chromite is enclosed in granitic gneiss; hornblende schist, chlorite schist, and quartzite are also present (Beckwith, 1939), as is talc (Harris and others, 1985; Love and others, 1979a). The rocks are Late Archean in age (Love and Christiansen, 1985).

46. Laramie Mountains, north part, Converse and Natrona Counties -- Talc and serpentinite are enclosed in Late Archean granitic gneiss (Harris and others, 1985; Love and Christiansen, 1985; Love and others, 1979a, 1980, Harris, 1995, #6); formed by retrograde metamorphism of mafic and ultramafic enclaves. Beckwith (1939) describes a serpentinite body containing asbestos at one locality.

47. Laramie Mountains, central part, Albany and Platte Counties -- Talc occurrences are in Middle and Late Archean granitic gneiss, metasedimentary and metavolcanic rocks (Harris and others, 1985; Love and Christiansen, 1985; Love and others, 1980, Harris, 1995, #s 1-5 and 10). Graff and others (1982) separate gneissic rocks (consisting of quartz-

plagioclase-biotite gneiss, migmatite, and equigranular and porphyritic granites) from greenstone belts (consisting mostly of amphibolite and local ultramafic rocks). Talc and asbestos are believed to be derived by the alteration of ultramafic rocks containing chromite. Osterwald and others (1959) described talc, actinolite, and anthophyllite schists derived from hornblende schist. The maps of Snyder (1984) show additional detail in the area of the southernmost occurrences. Harris (1995) describes talc in veins and stringers up to 5 ft wide in granite, schist and vein quartz at his locality #10. Harris believes that talc at his locality #1 is formed by alteration of metadolomite.

Production: None recorded.

Exploration: Permissive areas are indicated (pl. 1) for parts of the exposure of Archean rocks in Wyoming. However, most of the talc occurrences are small and some are far from roadheads. Harris (1995) believes further investigation is warranted in the central Laramie Mountains (#47) and the northern Wind River Range (#39).

New Mexico

48. San Andres Mountains, Sierra and Donna Ana Counties

The only talc district in New Mexico is in Hembrillo Canyon in the San Andres Mountains, a part of the Mexican Highland section of the Basin and Range province. The San Andres Mountains are a north-trending fault block with a west-dipping section of Paleozoic sedimentary rocks forming the crest and west slopes and with Proterozoic rocks exposed on the east slope (Kottlowski and others,1956; Seager and others, 1987; Fitzsimmons and Kelley, 1980). The Proterozoic section contains schist, phyllite, quartzite, and amphibolite intruded by minor diabase dikes and sills and by large amounts of pink, gray, and reddish-brown granite. In the southernmost part of the range, granite is the predominant rock-type, but north of San Andres Peak, the layered rocks enter the section and are the predominant lithologies at Hembrillo Canyon (Seger and others, 1987). The metamorphic age of the layered rocks is 1650-1700 Ma. This area is near the southwestern limit of the Transcontinental Proterozoic provinces (Reed, 1993).

The talc is in lenticular bodies and much of it is of pure "steatite grade," but carbonate minerals and chlorite appear in the outer few feet of each body. Contacts with the enclosing quartz-chlorite phyllite or, locally, with masses of carbonate or silica-carbonate rocks are sharp (Fitzsimmons and Kelley, 1980; Chidester and others, 1964; Page, 1942). The talc appears to have been formed by the hydrothermal replacement of carbonate rocks and phyllite, but the source of the solutions is unknown.

Production: Two mines, the Hembrillo and Red Rock mines, have operated in the district. The Hembrillo is reported to have produced <10,000 tons in the late 1920's or early 1930's (Chidester and others, 1964), and the Red Rock 2,602 tons in 1942-45.

Exploration: Hembrillo Canyon is now in the White Sands Missile Range and access to it is restricted. If permission to explore is obtainable in the future, more talc would likely be found in the Proterozoic layered rocks, which extend for about 10 miles both to the north and to the south of the canyon.

Texas

The main talc occurrences in Texas are in the Allamoore district, near Van Horn in the western Texas panhandle (fig. 10). A secondary area containing talc is located in the Llano uplift in central Texas.

49. Allamoore district, Hudspeth and Culbertson Counties

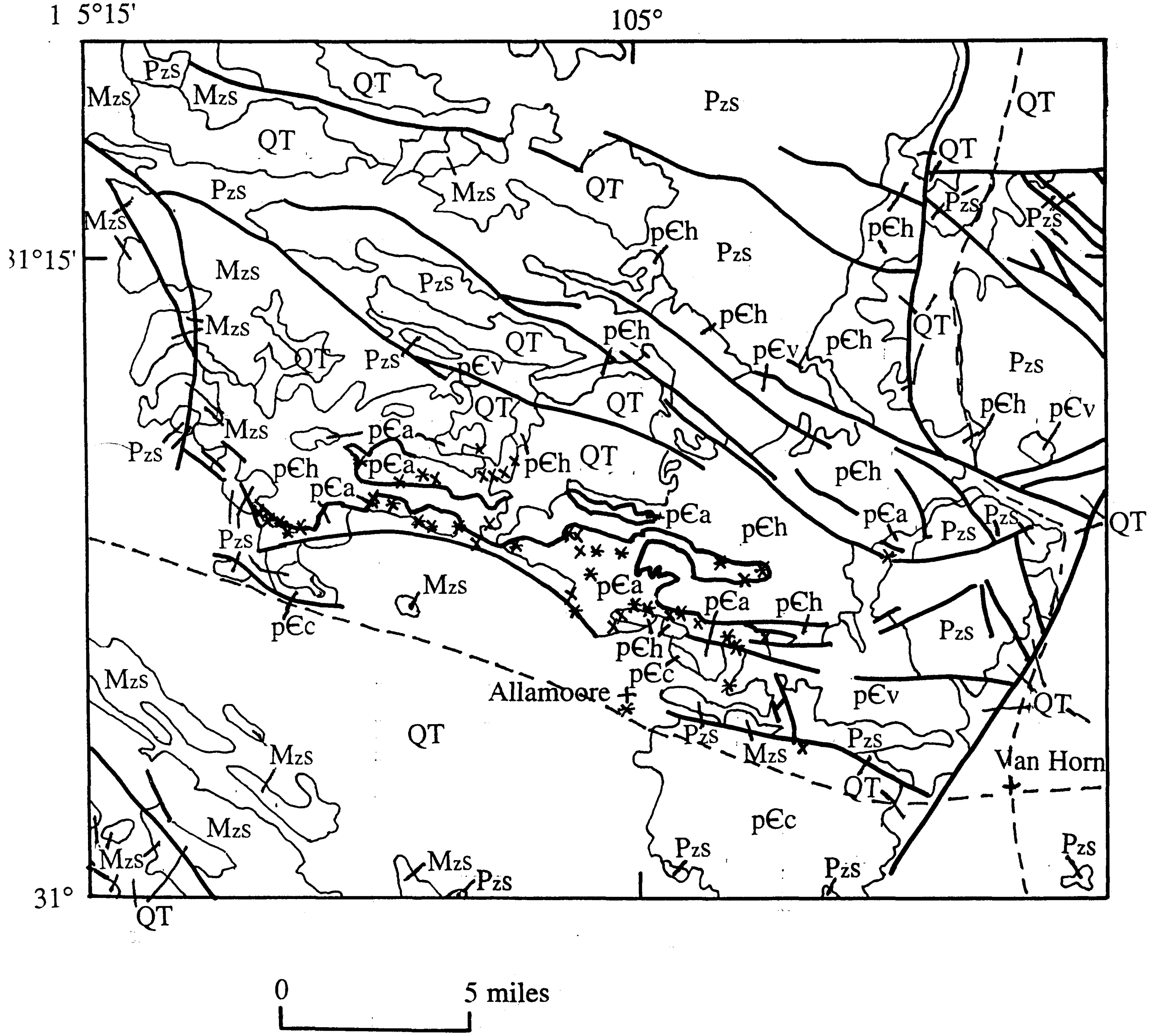
This district is in the Mexican Highland section of the Basin and Range physiographic province and within the Trans-Pecos geologic province, an area notably rich in deposits of mercury, silver, lead, zinc, flurospar, sulfur, barite, and other commodities (Price and others, 1983).

The Allamoore district lies in the foothills south of the Sierra Diablo Mountains and is underlain by Precambrian, Paleozoic, and Mesozoic rocks. The Precambrian rocks are both sedimentary and volcanic and have a complex east-trending folded and faulted structure (fig. 10, King and Flawn, 1953; King, 1965, 1980; Barnes, 1968). The Carrizo Mountain Formation is the lowest unit in the section and consists of metaquartzite, schist, and phyllite intruded by rhyolite and greenstone. The Allamoore

Figure 10. Simplified geologic map of the Allamoore talc district, Texas. Geology after Barnes (1968).

EXPLANATION

QT	Sedimentary and volcanic rocks (Quaternary and Tertiary)
Mzs	Sedimentary rocks (Mesozoic)
Pzs	Sedimentary rocks (Paleozoic)
p€v	Van Horn Sandstone (Precambrian)
p€h	Hazel Formation (Precambrian)
p€a	Allamore Formation (Precambrian)
p€c	Carrizo Mountain Formation (Precambrian)
	Contact
	Fault
	Highway
	Talc mine
	Talc prospect or occurence
	Town


1 5°15'
105°
31°15'
31°
QT
Pzs
Mzs
pЄh
pЄv
pЄa
pЄc
Allamoore
Van Horn
0
5 miles

Formation consists principally of cherty limestone and dolomite, subaqueous or subaerial amygdaloidal basalt, mafic pyroclastic rocks, and phyllite (King, 1965; Bourbon, 1981, 1982; Denison, 1980). The Hazel Formation and Van Horn Sandstone each consist principally of sandstone and conglomerate. The Precambrian rocks are overlain by flat-lying sedimentary rocks, including a thin Ordovician through Pennsylvanian section and thick Permian and Cretaceous sections.

The Allamoore Formation and overlying Precambrian rocks are part of the Debacca terrane of the Transcontinental Proterozoic provinces (Reed, 1993). The older Carrizo Mountain Formation is separated from the other units by the Streeruwitz fault and is a part of the Llano terrane.

Most of the talc deposits are in the Allamoore Formation. Tabular bodies of talc are present in the parts consisting principally of phyllite. Quartzite and dolomite are interbedded with the phyllite; magnesite and tremolite, some of the latter asbestiform, are also locally present, but calcite is absent. Most of the talc is black or dark gray owing to included carbonaceous material (Berg, 1995). Lighter-colored "pink and white foliated" talc is commonly found adjacent to diabase sills, but the diabase is not, however, considered to be a major factor in talc formation. Locally, light-colored talc beds are found interlayered with dark talc, suggesting that color variations may be owing to the amount of carbonaceous material originally present in the replaced beds (R.B. Berg, written communication, 1995). Some of the talc has fine laminae, dessication cracks, and quartz casts after halite(?) crystals (Bourbon, 1981, 1982). Bourbon believes that the talc formed by hydrothermal alteration of magnesite precipitated in saline lakes adjacent to the sea. Nyberg and Schopf (1981) report on microfossils including cyanobacteria and eukaryotes in chert of the Allamoore Formation, also indicating shallow-water, occasionally subaerial, conditions of deposition. The talc deposits are of excellent quality; most of the dark talc contains <15% impurities, mostly dolomite and quartz. Lack of Fe makes this talc an excellent raw material for white ceramic products. The light talc generally has <5% impurities and is suitable for use in paint.

One deposit (southernmost on fig.10) is in a sliver of Allamoore(?) Formation which is enclosed within rhyolite of the Carrizo Mountain Formation. The deposit is talc-tremolite-calcite rock with asbestiform actinolite (USGS-MRDS data file).

Production: Large-scale production of talc began in the Allamoore district in 1952 and exceeded 200,000 tons/yr. by 1972. Total production for the district through 1994 is about 8,880,000 tons (U.S. Bureau of Mines Minerals Yearbook series).

Exploration: The Allamoore Formation is unique among west Texas rock units, is found only in the Sierra Diablo foothills, and has been rather thoroughly explored. However, reserves undoubtedly remain in the ground. A search for similar deposits would have to concentrate on finding windows of, or shallow alluvium over, other Proterozoic rocks in the Debacca terrane, as shown on the map of Reed (1993).

50. Llano uplift, Llano, Gillespie, and Blanco Counties -- This area in central Texas is underlain mostly by Middle Proterozoic gneiss, schist, and granite (Barnes, 1981). It is part of the Llano terrane, bounded by the Llano front to the northwest and the Ouachita front to the southeast, according to the map of Reed (1993).

The Packsaddle Schist, an important unit in the south part of the area, contains the informally named Coal Creek serpentinite of Garrison (1981), which consists of several large and many small serpentinite bodies (Barnes and others, 1950; Garrison, 1981). Garrison (1981) believes that the Coal Creek serpentinite is an ophiolite fragment involved in continent-island arc interactions in the Greenville belt. The serpentinite and adjacent rocks underwent a complex history of deformation, metamorphism, and basalt dike intrusion culminating at about 1.2 Ga. Some of the serpentinites have occurrences of talc or soapstone at their margins, and many small lenses of soapstone are enclosed in the country rock schists nearby (Barnes and others, 1950; Dietrich and Lonsdale, 1958). Dietrich and Lonsdale tabulate 17 soapstone occurrences and show many more on a series of area maps. These are combined into four symbols on plate 1.

Production: Small, mostly from the area near the Llano-Gillespie County line (pl. 1, westernmost symbol), both of dimension stone and ground soapstone.

Exploration: A permissive area is shown (pl.1) for the entire Proterozoic exposure area in the Llano uplift; however, the best possibilities are in the south part. Any of the abundant small bodies of serpentinite enclosed within the Packsaddle Schist and shown on the maps of Barnes and others (1950) or Dietrich and Lonsdale (1958) may prove to contain substantial quantities of talc.

Arkansas

51. Little Rock west, Saline County -- Talc deposits are present in a 2.5-mile long east-trending belt located 15 mi. west of Little Rock. This area is part of the east-west-striking Ouachita belt of tightly folded and thrust-faulted sedimentary rocks of Late Cambrian through Pennsylvanian age (Haley, and others, revised, 1993; Hart and others, 1986). Elongate talc bodies within hydrothermally altered serpentinite are found as unattached masses near the contact between the Middle Ordovician Womble Shale and the Middle and Upper Ordovician Bigfork Chert (Stone and McFarland, 1981). The core of these bodies is soapstone consisting of talc, carbonate minerals, and serpentine; outer zones are nearly pure talc with a narrow blackwall zone consisting mostly of chlorite in the surrounding country rock. The soapstone locally contains nickel-bearing sulfide layers (Sterling and Stone, 1961). Stone and McFarland (1981) believe that the serpentinites are middle Paleozoic intrusions, hydrothermally altered in later Paleozoic time by solutions related to those which created the abundant quartz veins throughout the Ouachita region. However, later work by Morris and Stone (1986) and Cox (1988) suggests that the serpentinites are likely middle Proterozoic melange blocks or diapiric serpentinized slabs of ophiolite.

Recent interpreters of the Ouachita orogenic belt (Viele, 1989, Arbenz, 1989 and Nielson and others, 1989) have divided it into several tectonic provinces, including the Benton uplift, an anticlinorium made up of a series of stacked fold and thrust nappes. The Paron nappe is part of the Benton uplift and is bounded on the south by the Paron thrust, whose position is placed at the talc-bearing serpentinite masses, directly below the Bigfork Chert. There are outcrops of alkalic metagabbro 6 mi. to the southeast (Morris and Stone, 1986). The association of serpentinite, gabbro, and thin-bedded chert is suggestive of an ophiolite fragment.

Production: This district has had recorded production from 1953 to 1993, the total produced is about 120,000 tons.

Exploration: The serpentinite masses in the 2.5 mile-long belt described above have apparently been thoroughly explored, but it is possible that there is undiscovered serpentinite with talc elsewhere along the Paron thrust fault, or along other faults adjacent to the Bigfork Chert. For guides, interpretive maps in Nielson and others (1989) must be combined with larger scale maps, such as that of Viele (1979). C.G. Stone (written comm., 1995) reports that fieldwork for a geologic quadrangle mapping program in co-operation with the U.S. Geological Survey has recently been completed for the entire Ouchita Mountains and Arkoma Basin in Arkansas. Publication of most of these maps at 1:100,000 and a few at 1:50,000 scale is anticipated.

Southern and central Appalachian Mountains, Introduction

This section of the Appalachian Mountains extends for 950 miles from the coastal plain overlap in northern Alabama to the Hudson River north of New York City. It has been conventionally divided into four parallel belts, each substantially different from the other in rocks, structure, and physiography. These are, from southeast to northwest, the Piedmont, Blue Ridge, Valley and Ridge, and Allegheny-Cumberland Plateaus. The Plateau and Valley and Ridge sections are underlain mostly by fossiliferous sedimentary rocks of Cambrian through Permian age which are either flat-lying or deformed into open folds accompanied by relatively simple thrust and normal faults, hence they have been well understood for some time. In contrast, the Piedmont and Blue Ridge are underlain mostly by unfossiliferous metasedimentary, metavolcanic, and plutonic rocks and are of extremely complex structure. Multiple episodes of metamorphism have rendered reliable radiometric ages of protoliths difficult to obtain.

Recently, plate-tectonic theory coupled with improved methods of radiometric dating have focused renewed interest on the Piedmont and Blue Ridge. Many large units have been established as Middle and Late Proterozoic to Cambrian in age (North Carolina Geological Survey, 1985; Virginia Division of Mineral Resources, 1993), and plate-tectonics has provided a scenario for the development of the Appalachians involving a proto-North American continent (Laurentia) and an array of accreted terranes (Rankin, 1993; Rankin and others, 1993a, b). The accreted terranes are in part stacked up and thrust northwestward over the proto-continent. Of fundamental importance is the Iapetus suture, the northwestern limit of possible to probable accreted terranes. Its position is largely within the Blue Ridge province, or at the boundary between Blue Ridge and Piedmont.

Talc deposits in the southern and central Appalachians are mostly in ultramafic rocks, and nearly all of these are in the accreted, or exotic, terranes. Many of the ultramafic bodies have been interpreted as ophiolites, or fragments of oceanic crust. This interpretation is based in part on geochemistry, but more convincingly on structural position, i.e., if a body is at a suture between terranes, in a mélange in an exotic terrane, or at a fault which divides such a terrane, it may be reasonably be called an ophiolite fragment. In the descriptions which follow, it will be apparent that most of the ultramafic bodies that have been interpreted recently are believed to be ophiolite fragments. Some, however, are of uncertain, perhaps continental, origin.

Maps by Rankin (1993), Rankin and others (1993a), and Rankin, Drake, and Ratcliffe (1990) show the positions of accreted terranes and provide them with names. The Valley and Ridge and Blue Ridge provinces northwest of the Iapetus suture belong to the Laurentian Appalachians section of the proto-North American continent. Southeast (outboard) of the Iapetus suture lie the probable accreted terranes; those referred to in this section include the Jefferson, Inner Piedmont composite, Juliette, Smith River, Milton, and Potomac composite terranes. Terranes farther southeast that are clearly exotic to Laurentia include the Carolina composite, Savannah River, Falls Lake, and Goochland terranes.

Alabama

Talc deposits in Alabama are found both in carbonate and ultramafic rocks. They are in the Valley and Ridge and Piedmont provinces near the southwestern terminus of the Appalachian Mountains.

52 Winterboro District, Talladega County -- Talc deposits near Winterboro are in the Early and Middle Cambrian Shady Dolomite (Blount and Helbig, 1987). The Shady Dolomite is near the base of the sequence of Paleozoic sedimentary rocks that characterizes the Valley and Ridge province in the southern Appalachians. Underlying the Shady Dolomite are clastic sedimentary rocks of the Weisner and Wilson Ridge Formations of the Chilhowee Group that form the base of the Cambrian section. The Shady Dolomite is overlain in turn by rocks of the Rome Formation and, above it, the Conasauga Group (Osborne and others, 1988; Rheams, 1992).

The talc forms massive, nonfoliated lenticular bodies in dolomite (Rheams, 1990, 1992). The deposits are 95-99% talc; impurities are mostly chlorite with minor pyrite, calcite, kaolinite, and quartz. The adjacent dolomite contains traces of chlorite, talc, and quartz but no illite, a common mineral elsewhere in the dolomite. Talc is believed to have been formed by hydrothermal solutions that replaced dolomite with talc and illite with chlorite (Blount and Vassiliou, 1980). Because there are no intrusive rocks in the Winterboro area (Osborne and others, 1988), the source of the hydrothermal solutions is unknown. This high-purity talc, suitable for cosmetic and pharmaceutical uses, was most recently mined from 1988 to 1992 (Dean, 1994).

A short distance northeast of Winterboro there are several prospects in chlorite rock associated with metasandstone (Blount and Hebig, 1987). Clastic sedimentary rocks lie above the chlorite rock in the prospects, and the chlorite is believed to have formed by metasomatic alteration of slate or phyllite. Hydrothermal solutions of similar origin to those which formed talc may be responsible for the formation of chlorite.

Production: Prospecting for talc in this area began as early as 1917, mining began in 1953 and lasted to 1976. Mining was resumed from 1988 to 1992 (Dean, 1994). From 1955 to1976, approximately 130,000 tons of talc was produced. The later period of production resulted in small additional amounts.

Exploration: High-purity talc such as that at Winterboro forms an attractive exploration target (Rheams, 1990). Additional deposits may possibly be found by following the outcrop of the Shady Dolomite and applying geochemical methods to locate areas of alteration similar to that at the talc deposits. Further work is needed on the detailed structure and possible sources of the hydrothermal solutions.

53 Dadeville District, Chambers and Tallapoosa Counties -- Talc in this area of the Piedmont near the Brevard fault zone is present in altered and weathered sill-like parts of mafic-ultramafic complexes in the early Paleozoic Dadeville Complex (Steltenpohl and others, 1990; Osborne and others, 1988). The talc is intimately mixed with anthophyllite and appears to have replaced it, creating a soapstone composed of anthophyllite, talc, chlorite, and chromite. Altered pyroxenite and serpentinite are associated rocks. The area is part of the Inner Piedmont composite terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

The area has been much prospected but no production is reported.

54 Prospect near Delta, Clay County -- The USGS-MRDS data file reports a talc prospect in an ultramafic pod in the Precambrian to Paleozoic Ashland Supergroup (Mies and Dean, 1994). The area is part of the Jefferson terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

Georgia

The principal talc deposits in Georgia are in the Chatsworth district (#60), in the Appalachian Blue Ridge province in the northernmost part of the state. There are other smaller districts, as well as individual mines, prospects and occurrences at scattered localities in the Blue Ridge and Piedmont provinces. Occurrences of ultramafic rocks in the Blue Ridge and Piedmont of Georgia, as well as in North Carolina and Virginia, are reviewed by Misra and Keller (1978). Both provinces are underlain principally by northeast-trending metasedimentary and metaigneous rocks and local unmetamorphosed plutonic rocks. While the state geologic map does not give the ages of these rocks, extension of units from adjacent Alabama and North Carolina plus limited dating within the state suggests that their ages are mostly Middle and Late Proterozoic and Cambrian. The rocks of the Ocoee Supergroup of the Blue Ridge are almost certainly Late Proterozoic in age. Country-rock lithologies identified below come mostly from the geologic map of Georgia (Georgia Geological Survey, 1976).

Exploration: The several belts of ultramafic rocks in Georgia offer attractive exploration targets (pl. 1). The geologic map of Georgia (Georgia Geological Survey, 1976) serves as a general guide and the report of Vincent and others (1990) shows details on many of the ultramafic bodies. The most promising belts are shown as permissive for additional deposits on plate 1. Search for additional talc-bearing bodies may be concentrated in these belts and extensions thereof, especially those near major faults interpreted as terrane boundaries (Rankin, 1993). The Murphy belt also offers possibilities.

55. La Grange area, Troup, Harris, and Meriwether Counties -- Pods of partly to wholly steatized serpentinite are enclosed in sericite schist, gneiss, and amphibolite (Hopkins, 1914, pg. 289-292). The southernmost two occurrences are near the Towaliga fault, an important, throughgoing structure having either strike-slip or dip-slip movement.

Localities 55, 56, and 57 are all part of the Inner Piedmont composite terrane, as interpreted by Rankin (1993) and Rankin and others (1993a). An alternative interpretation is presented by Higgins and others (1992).

56. Centralhatchee, Heard County -- Several small soapstone bodies, one containing tourmaline and corundum, were apparently formed by alteration of small peridotite bodies (Hopkins, 1914, p. 289). The ultramafic rocks are enclosed in mica schist, quartzite, gneiss, and amphibolite in the Brevard fault zone, an important belt of cataclasis and either strike-slip or dip-slip movement.

57. Soapstone Ridge, DeKalb, Fulton, and Clayton Counties -- Soapstone Ridge, which lies directly southeast of Atlanta is underlain by mafic and ultramafic rocks interspersed with country rocks consisting of schist, gneiss, and amphibolite (Vincent and others, 1990, pg. 22). Formerly assigned to the Soapstone Ridge Complex (Vincent and others, 1990), these rocks are now assigned to the Late Proterozoic(?) to Middle Ordovician(?) Paulding Volcanic-Plutonic Complex (Higgins and others, 1992). Hopkins (1914, p. 280) described the ultramafic rocks as altered pyroxenite(?) consisting of chlorite, talc, amphibole, and magnetite.

58. Carrollton, Carroll County -- Five small ultramafic lenses directly east of Carrollton that consist of talcose serpentinite and chlorite schist have been prospected for talc (Vincent and others, 1990, pg. 22). Country rocks are hornblende gneiss, amphibolite, and mica schist. An apparently similar occurrence lies 12 mi to the northeast near Villa Rica.

Localities 58, 59, and 62 are part of the Jefferson terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

59. Holly Springs, Cherokee County -- A lens of ultramafic(?) rocks is enclosed in garnet-mica schist, quartz-biotite schist, and amphibolite of the Late Proterozoic and (or) early Paleozoic Univeter Formation of McConnell and Abrams (1984). Two building-stone quarries expose massive carbonate-chlorite-talc rock and talc-chlorite schist with veins of dolomite, chlorite, magnesite, and local gem quality apatite (Vincent and others, 1990, p. 20; B.J. O'Conner, written comm., 1995). The locality is near the Chattahoochee thrust fault. A somewhat similar occurrence, but one containing anthophyllite, is located about 25 mi southwest along strike near Dallas, Paulding County (Hopkins, 1914, p. 281) .

60. Chatsworth district, Murray County -- Substantial tonnages of talc have been produced from a number of deposits in this district, located in the Blue Ridge province in the north-central part of the state (fig. 11; Georgia Department of Mines, Mining, and Geology, 1969)). Most deposits are in the Proterozoic "Fort Mountain Gneiss", a metamorphosed granitic rock unit that lies beneath Late Proterozoic clastic rocks (Furcron

and others, 1947; Vincent and others, 1990, p. 5). The Great Smoky (Cartersville) thrust fault and a subsidiary thrust place these Proterozoic rocks over the sedimentary rocks of the Middle and Late Cambrian Conasauga Group (fig. 11). The talc deposits are in the "Cohutta Schist", a unit consisting of ultramafic pods within the "Fort Mountain Gneiss". Controversy about the origin of the "Cohutta Schist" has been settled by Needham (1972), who found chromite and relict olivine grains and elevated concentrations of cobalt and nickel, which all suggest an igneous origin. The ultramafic rocks are locally altered to massive serpentinite, massive talc, or to rocks also containing chlorite and tremolite.

Localities 60 and 61 are in the Blue Ridge belt of the Laurentian Appalachians, as interpreted by Rankin (1993) and Rankin and others (1993a).

Production: Recorded production of talc in the Chattsworth district began in 1898 and totaled about 340,000 tons by 1945 (Furcron and others, 1947). Production was remarkably steady at 40 to 60,000 tons /yr for most years from 1946 to 1972, declining thereafter (U.S. Bureau of Mines, Minerals Yearbook series). The total production for 1945 to 1990 is 1,735,000 tons, giving a total for the district of over 2 million tons.

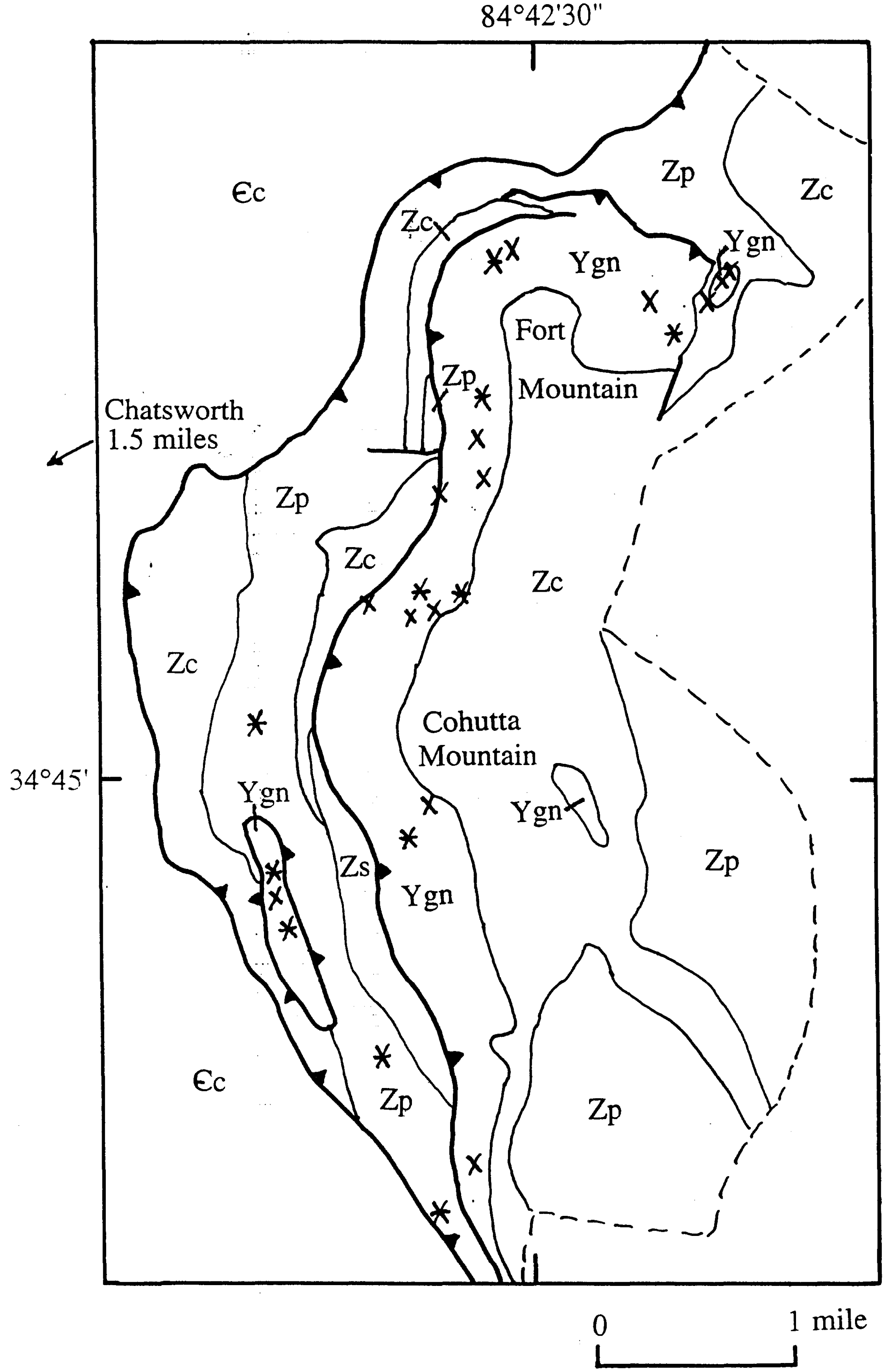
61. Murphy belt, Fannin and Gilmer Counties -- This belt was an important talc producer in adjacent North Carolina and additional deposits are located in the part lying in Georgia (Georgia Department of Mines, Mining, and Geology, 1969). The northeast-trending belt consists of rather thin, continuous, metasedimentary units. In Georgia, the rocks are mica schist and graphitic phyllite, with lenticular bodies of marble containing interbedded quartzite. There is also massive marble which has been produced fro dimension stone. Talc and associated tremolite were formed by alteration, presumably hydrothermal, of marble and quartzite, according to Hopkins (1914, p. 199, 235). However, B.J. O'Conner (written comm., 1995) believes deposits were formed by regional metamorphism of sandy dolomite. Deposits in the Mineral Bluff quadrangle are discussed by Hurst (1959). The main part of the belt ends near the town of Blue Ridge, but there is another talc occurrence near Ballground, 35 miles to the south.

62. Laurel Creek and Beavert Mountain, Rabun County -- This area is in the Blue Ridge province near the northeast corner of the state. At Laurel Creek, pods of mafic and ultramafic rocks are enclosed in metagraywacke and amphibolite of the Late Proterozoic and (or) early Paleozoic Tallulah Falls Formation (Vincent and others, 1990, pg. 15;

Figure 11. Geologic map of the Chatsworth talc district, Georgia. Geology after Vincent and others (1990).

EXPLANATION

€c	Conasauga Group (Late and Middle Cambrian)
Zs	Schist (Late Proterozoic)
Zp	Phyllite (Late Proterozoic)
Zc	Coarse clastic rocks (Late Proterozoic)
Ygn	Gneiss (Middle Proterozoic) -- "Fort Mountain Gneiss", includes pods of "Cohutta Schist"; see Furcron and others (1947)
	Contact
	Fault
	Thrust fault, sawteeth on upper plate
	Talc prospect
	Talc mine



84°42'30"
Єc
Zp
Zc
Zc
Ygn
Ygn
Fort
Mountain
Zp
Chatsworth
1.5 miles
Zp
Zc
Zc
Zc
Cohutta
Mountain
34°45'
Ygn
Ygn
Zs
Ygn
Zp
Єc
Zp
Zp
0
1 mile

Petty, 1982). The largest body has a dunite core surrounded by serpentine, talc schist, soapstone, and chlorite schist. Smaller bodies consist entirely of soapstone and serpentinite. At Beavert Mountain about 18 miles to the west, three small serpentinized dunite bodies in the same formation contain disseminated talc and some talc schist (Vincent and others, 1990, pg. 13). Small occurrences of ultramafic rocks extend for 50 mi southwest to Dahlonega (Georgia Geological Survey, 1976). Chidester and Worthington (1962) reported additional soapstone deposits in this belt; however, Hopkins (1914, pg. 271-274) stated that these are chlorite with little or no talc. Deposits in this belt are also shown on the Georgia mineral resource map (Georgia Department of Mines, Mining, and Geology, 1969). Chidester and Worthington (1962) also reported an occurrence near Center, Jackson County, 50 mi southeast of Dahlonega, but it has not been confirmed.

On the basis of structural and geochemical studies, Hatcher and others (1984) believe that the Laurel Creek ultramafic rocks are ophiolite fragments.

63. Cody Creek, Elbert and Wilkes Counties -- In this part of the Piedmont province, adjacent the Savannah River, schist, gneiss, and metavolcanic rocks were intruded by gabbro and small ultramafic masses, now metamorphosed (Vincent and others, 1990, p. 32). The ultramafic rocks are schistose, homogeneous masses of chlorite and talc containing remnants of pyroxene. A belt of small masses of ultramafic rocks, some probably talc-bearing, continues southwest for nearly 100 miles to the informally named Gladesville complex of Hatcher and others, 1984, near Forsyth.

64. Gladesville complex of Hatcher and others, 1984, Forsyth, Monroe, Jones, and Jasper Counties -- Several gabbro bodies and a linear mass of soapstone, believed to be parts of a mafic arc complex (Hatcher and others, 1984). Higgins and others (1992) interpret the Gladesville as a mélange complex . According to the maps of Rankin (1993) and Rankin and others (1993a), the ultramafic bodies between Cody Creek and Forsyth lie in either of two parts of the Juliette terrane, a probably exotic terrane lying outboard of the Inner Piedmont but inboard of the Carolina terrane. Rankin (1993) identifies the Juliette terrane as a mélange complex with mafic and ultramafic blocks, perhaps an accretionary wedge.

65. Burks Mountain, Columbia County -- This area is also in the Piedmont near the Savannah River, 40 mi southeast of Cody Creek. Country rocks are migmatitic gneisses, amphibolites, and granites of the

informally named Burks Mountain complex of Sacks and others (1989), and lying in the Kiokee belt (Cocker, 1991, Vincent and others, 1990, pg. 30). Cocker (1991) believed that the ultramafic rocks were originally harzburgite and were highly metamorphosed, then serpentinized, steatized, and silicified. Ultramafic rocks present consist of serpentinite, talc-anthophyllite (asbestos) rock, and talc-chlorite schist, the last lithology locally silicified (Vincent and others, 1990; Hopkins, 1914, p. 298). Additional discussion of the serpentinites of the Burks Mountain complex appears in Cocker (1992a, b).

This area is in the Savannah River terrane of Rankin (1993) and the Kioke belt of Butler (1989). A belt of ultramafic pods is continuous to locality 82 across the Savannah River in South Carolina; the pods appear to consist mostly of talc schist and soapstone. They may be parts of an ophiolitic mélange unit (Butler, 1989).

Other occurrences of ultramafic rocks in Georgia: The map of Larrabee (1966) shows 1) dunite bodies in a belt from Chatuge Lake to Young Harris and Brasstown Bald, Towns County, and 2) ultramafic bodies including soapstone in a belt from Stratham to Nicolson, Barrow and Jackson Counties. A petrographic and structural study of some ultramafic bodies in the Georgia Piedmont is provided by Prowell (1972).

South Carolina

Talc occurrences in South Carolina are all derived from ultramafic rocks, and are found in several of the major belts constituting the Piedmont province. Localities 66 to 75 are in the inner Piedmont composite terrane, 76 to 81 in the Carolina terrane, and 82 in the Savannah River terrane, as interpreted by Rankin (1993) and Rankin and others (1993a). None of these deposits have been important producers. Most of these localities were reported by Sloan (1908), but some are unconfirmed because of the lack of published geologic mapping indicating occurrences of ultramafic rocks.

Additional occurrences of ultramafic rocks containing little to no talc are reported by Butler (1989). Yet other occurrences, possibly talc-bearing, are shown on the map compiled by King (1955).

Exploration: Exploration for talc in South Carolina might start with a search for some of the unconfirmed deposits listed below. Other ultramafic bodies can be located using the report of Butler (1989) or the map of King (1955). Alined ultramafic bodies, especially near a fault, are the best possibilities.

66. Long Creek, Oconee County -- The Long Creek soapstone lens is about 1,000 ft long and consists of slightly greater than 50% talc, along with chlorite, anthophyllite, tremolite, and an opaque mineral (Hatcher, 1970, Cazeau, 1967). Surrounding country rocks are Late(?) Proterozoic micaceous schists and gneisses, in part assigned to the Whetstone Group of Hatcher (1969). This locality lies about 1 mi west of the Brevard fault zone, and is near the Laurel Creek area in Georgia (locality 62).

67. Soapstone Hill, Oconee County -- Talc schist consisting of talc, muscovite, tremolite, and corrundum is present enclosed in quartz-mica schists in the Brevard fault zone (Sloan, 1908, p. 118). This and the following four occurrences are in gneisses and schists of Proterozoic to early Paleozoic age, according to King and Beikman (1974).

68. Fairview Church, Oconee County -- "Soapstone" reported by Sloan (1908, p. 118) consists of chlorite schist. The country rock is hornblende gneiss (Cazeau, 1967). Material has been quarried for local dimension stone use.

69. Central, Pickens County -- Unconfirmed soapstone occurrence (Sloan, 1908, p.119)

70. Norris Station, Pickens County -- Unconfirmed soapstone occurrence (Sloan, 1908, p. 119).

71. Cedar Springs, Spartanburg County -- Unconfirmed occurrence of greenish-gray steatite (Sloan, 1908, p. 120).

72. Pacolet Mills, Spartanburg County -- Soapstone consisting of 50 to 80% talc, 5 to 15% each actinolite and chlorite, and minor opaque minerals, calcite, antigorite, and anthophyllite is present in the middle Paleozoic Hammett Grove Meta-Igneous Suite of Mittwede (1990). This unit consists of metamorphosed mafic and ultramafic rocks, and lies near the contact between rocks of the Proterozoic to early Paleozoic Inner Piedmont gneiss terrane and Devonian granite and granodiorite (Mittwede, 1990). Deposits, not yet developed in 1990, probably formed by prograde, followed by retrograde, metamorphism of harzburgite and lherzolite.

Mittwede (1989) concludes that the Hammett Grove Meta-Igneous Suite is a thrust slice of ophiolite and that its presence implies that the nearby Kings Mountain shear zone which forms the Inner Piedmont-Kings Mountain belt boundary marks an accretionary suture. Mittwede (1989) provides additional structural detail and chemical analyses.

73. North of Laurens, Laurens County -- Unconfirmed occurrence of steatite in metamorphosed dike (Sloan, 1908, p. 120). This appears to be in Cambrian metasedimentary rocks (King and Beikman, 1974).

74. Tylersville, Spartanburg and Laurens Counties -- This part of the Inner Piedmont is underlain by a complex of orthogneiss and paragneiss with a locally overlying allochthon of mafic and ultramafic rocks, gneiss, and mélange (Niewendorp, 1992). All these rocks are Proterozoic to early Paleozoic in age (King and Beikman, 1974). Talc-tremolite schist is found in both the mélange and the mafic complex and has been locally prospected for talc.

75. Southwest of Gaffney, Cherokee County -- Unconfirmed occurrence of amphibolite, in part metamorphosed to steatite. The country rock is quartz-mica slate (Sloan, 1908, p. 120). Material has been quarried for local use.

76. Northwest of Lockhart, Union County -- Unconfirmed occurrence of steatite in metamorphosed dike (Sloan, 1908, p. 120).

77. Halselville, Chester County -- Unconfirmed steatite occurrence (Sloan, 1908, p.121). This and the next locality are in Cambrian metasedimentary rocks or middle Paleozoic granitic rocks (King and Beikman, 1974).

78. Southeast of Chester, Chester County -- Unconfirmed steatite occurrence (Sloan, 1908, p. 121).

79. Nation Ford, York County -- "Steatite" occurrence reported by Sloan (1908, p. 121) is actually a metagabbro. Material has been quarried for local use. This and the next two localities are in Cambrian metasedimentary or volcanic rocks (King and Beikman, 1974).

80. West of Catawba Junction, York County -- Unconfirmed steatite occurrence (Sloan, 1908, p. 122).

81. Edgemoor, Chester County -- Unconfirmed steatite occurrence (Sloan, 1908, p. 121).

82. South of Edgefield, Edgefield County (Burks Mountain belt)-- Soapstone occurrence reported by (Sloan, 1908, p. 119). In Precambrian(?) and early Paleozoic gneiss, schist, and phyllite (Sacks and others, 1989). In the Savannah River terrane of Rankin (1993) and the Kioke belt of Butler (1989). A belt of ultramafic pods are continuous from Burks Mountain across the Savannah River in Georgia, and appear to consist mostly of talc schist and soapstone. They may be parts of an ophiolitic mélange unit (Butler, 1989).

North Carolina

The Blue Ridge and Piedmont provinces of the Appalachian Mountains both host talc deposits in North Carolina . Major past production occurred in the Murphy belt of the Blue Ridge in the extreme southwestern part of the state. There the talc formed by hydrothermal replacement of dolomite. Talc occurrences elsewhere in the state all formed by replacement of ultramafic rocks and include a second important district in the Blue Ridge in Madison County. Deposits in the Blue Ridge are either in the Laurentian Appalachians (83, 88) or in the Jefferson terrane (84-87, 89-91), as interpreted by Rankin (1993) and Rankin and others (1993a).

83 Murphy belt, Cherokee, Macon, and Swain Counties

The Murphy belt in North Carolina extends for about 35 mi from the Georgia state line to Wesser (fig. 12). A distinctive section of schist, quartzite, phyllite, slate, and marble forms a syncline broken by a thrust sheet and complicated by additional folding on the southeast limb (fig.12; North Carolina Geological Survey, 1985). These rocks include the Cambrian Murphy Marble, a unit generally 200-350 ft thick, consisting mostly of sandy, argillaceous, and other impure marbles, but generally having about 50 ft of pure, white dolomitic marble in a central zone (Van Horn, 1948). On the state geologic map (North Carolina Geological Survey, 1985), the Murphy belt section is shown as being of Late Proterozoic age, and in a position overlying rocks of the Great Smoky Group (Ocoee Supergroup); however, these age assignments have been recently called into question, and the Murphy Marble is here shown as Cambrian in age (E.D. Koozmin, written comm., 1994).

The talc replaced the central dolomitic zone of the Murphy Marble. Although tremolite is abundant throughout the marble, it appears to be mostly replaced by talc in talc-rich zones. Other impurities include calcite, pyrite and tourmaline; silica rock is locally abundant. Van Horn (1948) believes the deposits were formed by hydrothermal solutions, possibly related to a diorite sill or to granitic rocks. However, Blount and Helbig (1987) assert that the diorite was misidentified and granitic rocks are absent, so that the source of solutions remains problematic.

Production: Commercial talc mining began in the Murphy belt in 1859, material being shipped by horse and wagon (Van Horn, 1948). The arrival of a railroad in the late 1880's brought about expansion of the industry. It was, however, mostly shut down by 1948, production during this period having been somewhat more than 100,000 tons (Chidester and others, 1964). Mining was resumed during the 1960's and lasted until the early 1990's. Production during this period is roughly estimated at 200,000 tons in total (L.S. Wiener, written comm., 1995), bringing the district total to 300,000 tons.

Exploration: The Murphy belt has evidently been thoroughly explored by surface prospecting. There is surely more talc present, but it would have to be found by drilling downdip from prospects or other favorable looking outcrops, or along strike where the favorable beds are covered with surficial deposits. The southeastern belt of the Murphy Marble, passing near Brasstown (fig. 12), appears to be little explored and an attractive target.

Blue Ridge province, Other Districts

Talc deposits elsewhere in the Blue Ridge province are associated with small to medium-sized ultramafic bodies of Late Proterozoic or Paleozoic age (North Carolina Geological Survey, 1985; Pratt and Lewis, 1904; Hunter, 1941). More than 250 ultramafic bodies are known (Stuckey and Conrad, 1958; Hunter, 1941; Larrabee, 1971). These rocks are harzburgite, dunite, and other types of peridotite, commonly, in part, altered to serpentinite and talc-rich rocks. Many of these bodies have a dunite core, an intermediate variably serpentinized zone, and an outer zone of talc-rich rocks (Hunter, 1941). Small bodies may be wholly serpentinite or talc schist, many such occurrences are reported by Pratt and Lewis (1905). Chromite, averaging as much as 1%, is an important accessory,

Figure 12. Geologic map of the Murphy Marble Belt, North Carolina, showing talc mines and prospects. Locations from Van Horn (1948). Geology modified from North Carolina Geological Survey (1985).

EXPLANATION

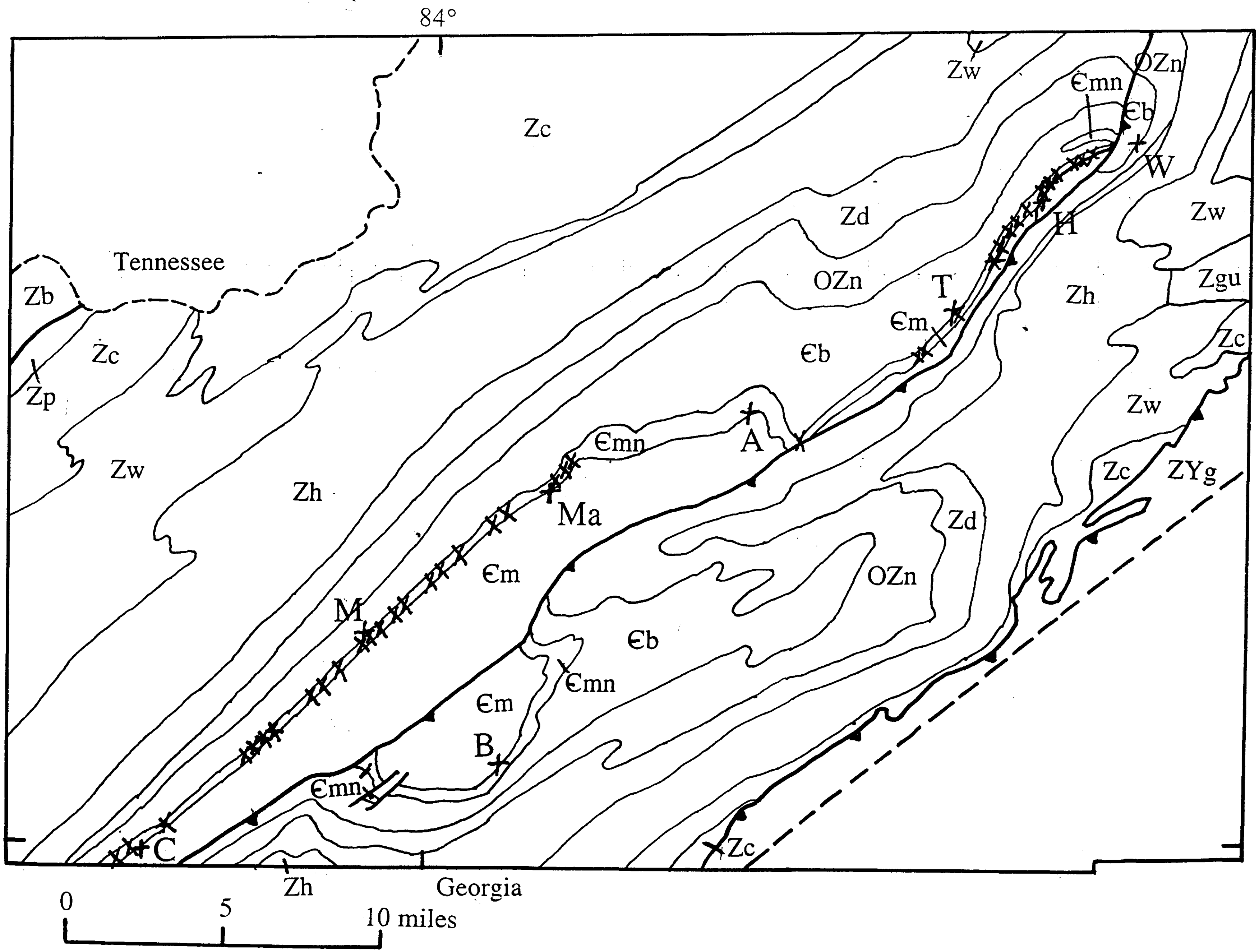
Єm	Mineral Bluff Formation of Hurst (1955) (Cambrian?)
Єmn	Nottely Quartzite, Andrews Formation, and Murphy Marble, undivided (Cambrian)
Єb	Brasstown Formation (Early Cambrian)
OZn	Nantahala Formation (Middle Ordovician to Late Proterozoic)
Zgu	Great Smoky Group, undivided
Zd	Dean Formation (Late Proterozoic)
Zh	Hothouse and Hughes Gap Formations, undivided (Late Proterozoic)
Zw	Wehutty Formation (Late Proterozoic)
Zc	Copperhill Formation (Late Proterozoic)
Zp	Phyllite (Late Proterozoic)
Zb	Boyd Gap Formation (Late Proterozoic)
ZYg	Biotite gneiss (Late and Middle Proterozoic)

Contact
Fault
Thrust fault, sawteeth on upper plate

X Talc prospect   ✳ Talc mine

+ Town

A Andrews	Ma Maltby	W Wesser
C Culbertson	M Murphy	B Brasstown
H Hewitt	T Topton	


84°
Tennessee
Zc
Zw
OZn
Єmn
Єb
W
Zd
H
Zb
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Zp
OZn
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Zd
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OZn
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Єb
Єmn
Єm
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35°
C
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Georgia
0
5
10 miles

and corrundum is locally present, particularly in larger bodies containing unaltered peridotite (Pratt and Lewis, 1905; Hunter, 1941). Many of these bodies have been prospected for olivine, anthophyllite, chromite, vermiculite, corundum, and talc, and some production of each commodity has resulted. A few ultramafic bodies give rise to nickel-rich laterite (Worthington, 1964).

Reported occurrences of talc or soapstone are listed below by districts, along with the country rocks shown on the geologic map of North Carolina (North Carolina Geological Survey, 1985). Beneficiation studies on samples from 57 deposits, mostly from the Blue Ridge, provide useful information for evaluating the quality of the contained talc for industrial purposes (Bentzen, 1975).

Exploration: It is very likely that there are many more talc occurrences, both within and between the districts discussed below. The geologic map of North Carolina (North Carolina Geological Survey, 1985), along with the discussions below, helps identify the promising belts. Most attractive are those near terrane-bounding faults, as shown by Rankin (1993). Some promising areas are shown as permissive for additional deposits on plate 1.

84. Elf, Clay County -- Dunite body with serpentinite and talc zones (Hunter, 1941, p. 108; Pratt and Lewis, 1905, p. 36), in biotite gneiss and amphibolite of Middle and Late Proterozoic age. This deposit is now largely covered by Lake Chatuge.

85. Norton to Franklin and Ellijay, Macon County -- At Ellijay and Corundum Hill are dunite bodies with outer zones of talc (Hunter, 1941, p. 100, 104); near Norton and Otto are small talc schist bodies (Pratt and Lewis, 1905, p. 38-40). The Carroll Knob complex (Hatcher and others, 1984) includes small bodies of talc-chlorite schist enclosed in a large body of amphibolite and metagabbro. Country rocks are gneisses and amphibolite of the Late Proterozoic and early Paleozoic Tallulah Falls Formation, the Cambrian and Early Ordovician Ashe Formation, and Middle and Late Proterozoic biotite gneiss (North Carolina Geological Survey, 1985).

86. Sapphire to Glenville and Black Mountain; Jackson and Transylvania Counties -- Many ultramafic bodies occur here associated with biotite gneiss, two-mica gneiss, and amphibolite of the Late Proterozoic and early Paleozoic Tallulah Falls Formation and the Cambrian and Early Ordovician Ashe Formation (Pratt and Lewis, 1905,

p. 46). Bodies of Devonian granitoid rocks have intruded the gneiss and amphibolite. Some of the ultramafic bodies have yielded anthophyllite or corundum and many contain substantial quantities of talc (Conrad and others, 1963)

87. Webster, Sylva, and Balsam, Jackson County -- These deposits are in the Webster-Addie dunite body and in nearby smaller ultramafic bodies. The Webster body, an oval ring structure, is 6 mi in maximum diameter by 3 mi. in minimum diameter. Width of the outcrop is mostly less than 1,000 feet. The dunite contains serpentinite and talc zones (Hunter, 1941, p. 67-97; Pratt and Lewis, 1905, p. 44). The body's outcrop pattern is now thought to be the result of doming and subsequent erosion of an ultramafic sheet (L.S. Wiener, written comm. 1995). Surrounding country rock is Middle and Late Proterozoic biotite gneiss (North Carolina Geological Survey, 1985). Rankin (1993) shows a window of Laurentian province rocks in the center of the ring.

Lippin (1984) discusses the occurrence and chemistry of chromite from metamorphosed dunite bodies in a belt extending from Webster to Frank, and including talc occurrences 87, 88, and 89 of this report. Principally on the basis of trace-element geochemistry, Lippin (1984) concludes that the dunites are tectonicly emplaced ophiolite fragments.

88. Canton to Leicester, Democrat, Burnsville, and Daybook, Haywood, Buncombe, Madison, and Yancy Counties -- This district contains several zoned bodies of dunite and serpentinite; discontinuous talc-rich zones are commonly present around the larger bodies (Hunter, 1941, p. 48-52, 58-67). Small occurrences of talc schist are also present (Pratt and Lewis, 1905, p. 48-56). Country rocks are Middle Proterozoic migmatitic biotite-hornblende gneisses with abundant amphibolite.

88A Sandymush to Marshall, Big Laurel, Faust, and Ramseytown; Buncombe, Madison, and Yancey Counties -- Several tens of ultramafic bodies consisting of talc schist or soapstone are located in this belt (L.S. Wiener, written comm., 1995). The rocks consist of talc, chlorite, ferroan magnesite, and chromian magnetite. They form podiform bodies a few feet to 100 feet across (Merschat and Wiener, 1988). Scheelite is locally found in mafic, ultramafic, and calc-silicate rocks in this area (Wiener and Bentzen, 1973).

Production -- Records are scanty and production figures non-existant, however this district produced at least a few thousand tons during the early 1900's and during and after World War II. Production was for both pencil and ground talc; most came from central Madison County northeast of Marshall (L.S. Wiener, written comm. 1995).

89. South Toe River to Frank and Spruce Pine, Yancey and Mitchel Counties -- Small occurrences of talc schist (Pratt and Lewis, 1905, p. 56; Conley, 1958, p. 58) and several zoned dunite bodies with talc border zones are present in this area (Hunter, 1941, p. 46-47, 53-57). Some of the ultramafic bodies have been exploited for anthophyllite (Conrad and others, 1963) and others for olivine. Some contain scheelite and pyrite. They are in part in gneiss, schist, and amphibolite of the Late Proterozoic and early Paleozoic Tallulah Falls Formation and the Cambrian and Early Ordovician Ashe Formation and in part in metasedimentary gneiss of the Late Proterozoic and (or) early Paleozoic Alligator Back Formation.

90. Boone to Sparta, Watauga, Ashe, and Alleghany Counties -- This belt contains small occurrences of harzburgite and other peridotites with associated talc and smaller bodies of talc schist (Pratt and Lewis, 1905, p. 57-60). Country rocks are gneiss, schist, and amphibolite of the Late Proterozoic and early Paleozoic Tallulah Falls Formation and the Cambrian and Early Ordovician Ashe Formation.

91. Ferguson to Millers Creek, Wilkes County -- Several occurrences of soapstone occur in a linear belt near the boundary between the gneiss unit and the mica schist and phyllite unit of the Late Proterozoic and (or) early Paleozoic Alligator Back Formation (L.S. Wiener, written comm. 1995, Bentzen, 1975, p. 76-78). The occurrence at Oak Grove Church, near Reddies River, cited by Chidester and Worthington (1962, #9), is apparently part of this belt.

Piedmont Province

92. Newton, Catawba County -- Several occurrences of soapstone of unknown composition (Conley, 1958, p. 19) are probably associated with ultramafic bodies mapped in this area. Country rocks are Late Proterozoic to Cambrian biotite gneiss, schist, and amphibolite.

93. Turnersburg, Iredell County -- Butler (1989) reports that there are numerous small bodies of ultramafic rocks enclosed in mica schist and gneiss in this area. Talc schist composes the smaller bodies and the edges of larger ones. The bodies are believed to be disrupted fragments of intrusions of dunite, orthopyroxenite, or peridotite.

94. Calahaln, Davie County -- A dike of pyroxenite as much as 650 ft wide and a swarm of dunite dikes have all been altered to talcose rocks and serpentinite (Butler, 1989).

95. Bayleaf, east of Durham; Wake and Franklin Counties -- Ultramafic bodies in this area are partly soapstone containing talc and actinolite (Conley, 1958, p. 71). Butler (1989) reports that the country rocks are the informally named Falls Lake mélange of Horton and others (1986), now metamorphosed to schist. There are hundreds of separate bodies of ultramafic rocks, including serpentinite, chlorite-actinolite schist, and talc schist or soapstone; relict olivine or chromite are present in some. They are believed to be fragments of a dismembered ophiolite.

Talc occurrences at localities 92, 93, and 94 are in the Inner Piedmont composite terrane, and those at locality 95 are in the Falls Lake terrane (outboard of the Carolina terrane), as interpreted by Rankin (1993) and Rankin and others (1993a).

Additional occurrences of ultramafic rocks, shown on the map of Larrabee (1966): 1) a belt of dunnite and other ultramafic rocks extending from Fairview to Asheville and the Great Craggy Mountains, Buncombe County 2) ultramafic rocks near Shelby, Cleveland County, and 3) near Bryson City, Swain County.

Exploration: Localities 92-94 are all near the Kings Mountain shear zone, a suture between the Inner Piedmont and Carolina terranes, according to Rankin (1993a). The likelihood of additional talc-bearing ultramafic bodies in this belt is quite high. Locality 95, also near a suture, is an equally good bet.

Virginia

Most of the many talc deposits in Virginia are in the eastern part of the Blue Ridge and the adjacent Western Piedmont (province names after the geologic map of Virginia, 1993). Other deposits are at scattered localities in provinces constituting other parts of the Piedmont. All are derived from ultramafic rocks. The principal productive belt extends from Lynchburg to Charlottesville, where production of both soapstone blocks and ground talc centered around Schuyler.

small production of block soapstone from 1912 to 1917. A similar soapstone occurrence lies 12 mi to the southwest.

100. Northeast of Axton, Pittsylvania County -- Talc-tremolite schist containing chlorite, accessory magnetite, and relict pyroxene probably represents a mélange block in quartz-muscovite-chlorite schist of the Late Proterozoic and Cambrian Fork Mountain Formation of Conley and Henika (1973) (Price and others, 1980a; Virginia Division of Mineral Resources, 1993; A.A. Drake, written commun., 1994).

Localities 100-104 are in the Smith River terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

101. West of Swansonville, Pittsylvania County -- Talc schist similar to above; probably a melange block in biotite gneiss the of Late Proterozoic and Cambrian Bassett Formation of Conley and Henika (1973) (Price and others, 1980b; Virginia Division of Mineral Resources, 1993; A.A. Drake, written commun., 1994).

102. Fork Mountain and Snow Creek to Ajax, Franklin and Pittsylvania Counties -- Numerous pods and stringers of ultramafic rocks contain talc, tremolite, chlorite, serpentine, anthophyllite, vermiculite, and opaque minerals with relict olivine and pyroxene; metagabbro is associated. Probably constitutes melange blocks enclosed in biotite gneiss of the Late Proterozoic and Cambrian Bassett Formation of Conley and Henika (1973) (Conley, 1985; Virginia Division of Mineral Resources, 1993; A.A. Drake, written commun., 1994).

103. Worlds to Redeye, Pittsylvania County -- Pods and stringers of ultramafic rocks in the Late Proterozoic and Cambrian Bassett Formation of Conley and Henika (1973), similar to above (Conley, 1985).

104. Otter River, Campbell County -- A talc quarry on the bank of the Otter River is reported by Schrader and others (1916), Dietrich (1953), and Smith (1961). Smith (1961) reports small production during the earliest 1900's. Other localities in Campbell County, both east and west of Rustburg, are shown on the map of Smith (1961, p. 2). These occurrences may be in either the Late Proterozoic and Cambrian Fork Mountain and Bassett Formations of Conley and Henika (1973), or the Late Proterozoic and (or) early Paleozoic Alligator Back Formation.

105. Grassy Hill, Franklin County -- An oval ultramafic body 4.5 mi long consists of serpentine, chlorite, talc, and tremolite with relict

olivine and pyroxene; marginal chlorite zone is locally altered to vermiculite. Metapyroxenite dikes and anthophyllite veins are also present. The ultramafic body is associated with metasedimentary and metavolcanic rocks of the Late Proterozoic and (or) early Paleozoic Alligator Back Formation (Conley, 1978, 1985, 1987).

Localities 105, 106, and 107 are in the Jefferson terrane near the Bowens Creek fault, as interpreted by Rankin (1993) and Rankin and others (1993a).

106. Jacks Mountain, Franklin County -- An oval ultramafic body 3 mi long and similar to the one described above, also associated with the Late Proterozoic and (or) early Paleozoic Alligator Back Formation (Conley, 1978, 1985, 1987).

107. Brier Mountain, Franklin County -- Metagabbro and ultramafic rocks similar to the above; a probable infolded part of the Late Proterozoic and (or) early Paleozoic Alligator Back Formation enclosed in the Cambrian and Early Ordovician Ashe Formation (Conley, 1985).

108. Bedford County, south part-- Several unconfirmed talc localities in the southern part of Bedford County are shown in Smith (1961, p. 2) and Gooch and Pfarr (1959). They are in rocks of the Late Proterozoic Charlottesville Formation, Late Proterozoic and (or) early Paleozoic Alligator Back Formation, and the Cambrian and Early Ordovician Ashe Formation (Virginia Division of Mineral Resources, 1993).

Localities 108-113 are in the Jefferson terrane, near the Iapetus suture, as interpreted by Rankin (1993) and Rankin and others (1993a).

109. Lynchburg, Bedford County -- Alternating belts of gneisses and schists of the Late Proterozoic and (or) early Paleozoic Alligator Back Formation and the Cambrian and Early Ordovician Ashe Formation cross the Lynchburg quadrangle from southwest to northeast. Several long bands of ultramafic rocks enclosed within and parallel to the strike of the country rocks are also present (Brown, 1958). He reported that most of the ultramafics rock consist of actinolite-chlorite schist but some northeast of Lynchburg and extending northeastward are soapstone consisting of talc, serpentine, chlorite, carbonate minerals, and accessory opaque minerals. The Virginia geologic map (Virginia Division of Mineral Resources, 1993) shows fewer ultramafic rocks in this area, assigning some bands to mafic

intrusions, logically sills as they are elongate and conformable. Furthermore, A.A. Drake (written comm., 1994) expressed doubt that these units are as continuous as shown, and believes that the soapstone may be in melange blocks. This interpretation applies also to localities 110 and 111 below.

110. Nelson-Amherst, Nelson and Amherst Counties -- One or more metapyroxenite sills are nearly continuous from the boundary of the Lynchburg quadrangle to Schuyler (Hopkins, 1957). This rock unit is probably mostly chlorite-actinolite schist. Parts of it, however, are composed of commercial quality soapstone, and nine groups of quarries are located in those areas.. A nearly continuous soapstone belt from south of Lynchburg to south of Charlottesville is shown by Sweet (1983).

111. Schuyler to Charlottesville, Nelson and Albemarle Counties -- The belt of metapyroxenite sills continues from Schuyler to Charlottesville (Fairley and Prostka, 1958; Nelson, 1962), and some of the contained soapstone is of commercial quality. The principal soapstone quarries are at Schuyler; and at Alberene, 3 mi northeast of Schuyler, a hard soapstone is quarried. The soapstone in this belt is enclosed in the Late Proterozoic Charlottesville Formation of the Lynchburg Group (Nelson, 1962; Virginia Division of Mineral Resources, 1993).

Production: Soapstone was discovered in the Schuyler district in the early 1880's and was produced continuously from about 1900 at least into the 1960's (Smith, 1961). Intermitent production continued until 1995 (M.L. Upchurch, written comm. 1995). Total production is estimated at 2,000,000 tons; more than 80% of this was sawn slabs (Chidester and others, 1964).

112. Western Orange County -- Two unconfirmed occurrences shown by Burfoot (1930), and Smith (1961), possibly also in the Late Proterozoic Charlottesville Formation of the Lynchburg Group, represent a continuation of the Schuyler-Charlottesville belt (localities 109, 110, 111).

113. Uno to Fordsville, Madison County -- A belt of ultramafic bodies, one as much as 4 mi long, is enclosed in metasedimentary rocks of the Late Proterozoic Charlottesville Formation and other units in the Lynchburg Group (Allen, 1963, p. 36; Virginia Division of Mineral Resources, 1993). These rocks are, in part, soapstone and represent a probable continuation of the Schuyler-Charlottesville belt.

Exploration: Ultramafic bodies are very numerous in the Jefferson and Smith River terranes in southwest Virginia (localities 97 to 113). As elsewhere, belts adjacent to terrane-bounding sutures are likely to contain the most ultramafic bodies, and the search mostly involves finding the ones that are most steatized. The geologic map of Virginia (Virginia Division of Mineral Resources, 1993), along with the more detailed maps cited above, will serve as guides. Promising areas are indicated as permissive for additional deposits on plate 1.

Central Virginia volcanic-plutonic belt

114. Cullen, Charlotte County -- Unconfirmed talc occurrence reported by Schrader and others (1916), Dietrich (1953), and Smith (1961). Apparently in Cambrian gneiss and amphibolite (Virginia Division of Mineral Resources, 1993).

Localities 114 and 115 are in the Milton terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

115. Tabscott, Goochland County, and south side James River, Cumberland County-- A soapstone prospect of unknown mineralogy is reported in a pod of pyroxenite located near Tabscott by Brown (1937). The ultramafic body is enclosed in gneiss of the Cambrian Ta River Metamorphic Suite (Virginia Division of Mineral Resources, 1993). An unconfirmed talc occurrence is reported (Smith, 1961) in Cumberland County about 15 mi on strike to the southeast; however, the Virginia geologic map shows Cambrian gneiss and Ordovician granite near there.

Exploration: These less-than-mappable size ultramafic pods in the central Virginia belt do not offer attractive exploration targets. However, guides for mineral collecting are provided in Dietrich (1959, 1960, 1963).

Carolina slate belt, Central and Eastern Piedmont

116. Lunenburg, Lunenburg County -- Unconfirmed talc occurrence south of Lunenburg (Smith, 1961, p. 2). Apparently in plutonic rocks of unknown age which intrude Late Proterozoic volcanic rocks (Virginia Division of Mineral Resources, 1993). This locality is in the Carolina terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

117. Walnut Creek, Amelia County -- Talc occurrence reported by Schrader and others (1916), Dietrich (1953), and Smith (1961). Two pods

of ultramafic rocks are shown on the Virginia geologic map, one in migmatitic paragneiss of unknown age, the other in Late Proterozoic biotite gneiss (Virginia Division of Mineral Resources, 1993).

Localities 117 and 118 are in the Goochland terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

118. Jetersville and Winterham, Amelia County -- Two additional talc localities in Amelia County are shown by Burfoot (1930, p. 806) and by Smith (1961, p. 2). An ultramafic body is shown in this area on the Virginia geologic map, enclosed in Middle Proterozoic biotite-garnet gneiss (Virginia Division of Mineral Resources, 1993). Smith (1961) reports small production from quarries at each locality during the period 1900-1907.

Exploration: The Goochland terrane in Amelia County near the suture(?) with the Carolina terrane probably contains additional ultramafic bodies, some of which may be talc-bearing.

Western Piedmont, Central and Northern Parts

119. Buckingham County -- Three unconfirmed talc localities in Buckingham County are shown by Burfoot (1930) and Smith (1961). They are probably blocks in a Late Proterozoic and Cambrian graywacke, schist, and mélange unit (Virginia Division of Mineral Resources, 1993).

Localities 119 to 127 are all in the Potomac composite terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

120. Solitude Plantation, Fluvanna County -- Soapstone containing 85% talc and 15% chlorite is in a pod of altered ultramafic rocks within the Early Cambrian Evington Group (Smith and others, 1964; Smith, 1961). The material was quarried about 1900 and utilized for crayons (Smith, 1961). Three other talc localities are present in the area. The quarry is in mélange of the Cambrian and (or) Ordovician Mine Run Complex, and the other localities are in the same unit as the Buckingham county localities described above (Virginia Division of Mineral Resources, 1993)

121. Mineral, Louisa County -- Unconfirmed talc occurrence reported by Burfoot (1930), Smith (1961), and Dietrich (1963). Burfoot (1930) and Smith (1961) showed several additional talc occurrences in Louisa County, more or less on strike with this one. All appear to be

blocks in melange units of the Cambrian and (or) Ordovician Mine Run Complex (Virginia Division of Mineral Resources, 1993; Pavlides, 1989).

122. Rhoadesville, Orange County -- Talc occurrence reported by Schrader and others (1916), Dietrich (1963), and Smith (1961). Material was quarried from about 1905 to 1918 and utilized for various dimension-stone purposes (Smith, 1961). Additional locations in eastern Orange County, more or less on strike with this one, are shown by Burfoot (1930), and Smith (1961). All appear to be blocks in mélange unit III of the Cambrian and (or) Ordovician Mine Run Complex (Virginia Division of Mineral Resources, 1993; Pavlides, 1989).

123. North of Stafford, Stafford County -- Unconfirmed talc occurrence (Smith, 1961), appears to be a mélange block in the Cambrian and (or) Ordovician Lunga Reservoir Formation (Virginia Division of Mineral Resources, 1993; Pavlides, 1989).

124. Fairfax, Fairfax County -- The Late Proterozoic and (or) Cambrian Piney Branch Complex extends 10 miles to the southwest from Fairfax. It is an allochthonous mélange of altered peridotite, pyroxenite, gabbro, and local soapstone and is part of the central Appalachian ophiolite (Drake and Morgan, 1981; Drake, 1986; Drake and Lee, 1989). Johnston (1962, p. L-17, pl. 1) mapped several small bodies of talc schist and talc-chlorite schist in the part of the complex extending 4 mi from Fairfax to the southwest. Another body reported by Dietrich (1953) lies about 2 mi farther west. Drake reported (written communication, 1994) that steatization is exceptionally irregular in the Piney Branch Complex.

125. North of Burke, Fairfax County -- A lenticular body of soapstone is shown here by Gooch and Pfarr (1959). Drake (1986) mapped this area as sedimentary mélange of the Late Proterozoic and (or) Early Cambrian Indian Run Formation; the soapstone occurrence is a melange block (Drake, 1985a, b).

126. North of Fairfax, Fairfax County --Much of this area is underlain by the Late Proterozoic and (or) Early Cambrian Mather Gorge Formation, which consists of quartz-rich schist and metagraywacke and locally interlayered well-bedded schist or micaceous gneiss (Drake and Lee, 1989; Drake, 1986, Drake and Froelich, 1986, Virginia Division of Mineral Resources, 1993). These rocks were initially mapped as Peters Creek Schist on the Vienna and adjacent quadrangles (Drake and Lee, 1989; Drake, 1986), but were later found to be miscorrelated (A.A. Drake, written comm., 1994). The Mather Gorge Formation also contains blocks

of serpentinite with associated talc, chlorite, and actinolite-rich schists. Several talc occurrences in this area, including two quarries with records of production (Burfoot, 1930, Dietrich, 1953, Smith, 1961) appear to be in these blocks.

127. Falls Church and Annandale, Fairfax County -- Talc occurrences in these two cities are reported by Chidester and Worthington (1962). The Annandale occurrence is apparently in a melange block in the Indian Run Formation, and the Falls Church occurrence is probably in an inclusion in tonalite of the Falls Church Intrusive Suite. The Falls Church Intrusive Suite and associated ultramafic inclusions, probably many containing talc, continue north for 5.5 mi to the Potomac River (Drake and Froelich, 1986, 1995; Drake and others, 1979). Other talc occurrences in the Falls Church and Annandale areas are noted by Bernstein (1980, p. 110), including one on Fourmile Run in Arlington (p. 103).

Production, Fairfax County: Smith (1961) reports production of ground talc from a number of localities in Fairfax County during the period 1905 to 1942.

Production, Virginia: As noted above, talc and soapstone production began before 1900 in Virginia. The U.S. Geological Survey's Mineral Resources of the U.S. series reports production of nearly 22,000 tons for 1920, but following this year, figures are withheld or combined with those for Maryland for many years. For most years from 1946 to 1961 production was 30 to 45,000 tons/yr for the two states combined (U.S. Bureau of Mines, Minerals Yearbook series). Virginia production reported separately was 3,500 to 4,600 tons/yr for most years from 1962 to 1973, apparently declining to smaller amounts in the years following. The estimate of 2,000,000 tons from the Schuyler district accounts for most of Virginia's total production.

Exploration: The talc occurrences in the central and northern parts of the Western Piedmont (Potomac terrane) are mostly in mélange blocks, thus their distribution is irregular and their size limited. However, there are probably many more, as yet undiscovered, blocks containing ultramafic rocks, some of which may be talc-bearing. The northern part of this area is indicated as permissive for additional deposits on plate 1.

District of Columbia

128. Fort Baylor Park and other localities, Washington, D.C. -- An occurrence of foliated steatite containing talc, chlorite, and limonite (after pyrite) can be seen in a roadcut along 46th Street between Fessenden and Garrison Streets (Bernstein, 1980, p. 22). It is a Late Proterozoic or Early Cambrian olistolith in the Early Cambrian Sykesville Formation. Other small olistoliths of talc-bearing rocks are present in the Sykesville Formation in the western part of the District of Columbia. Steatized pyroxenite of the Early Ordovician Georgetown Intrusive Suite crops out east and west of Connecticut Avenue between Cleveland Park and Military Road (Fleming and others, in press). These localities are in the Potomac composite terrane, as interpreted by Rankin (1993) and Rankin and others (1993).

Maryland

Talc deposits in Maryland are all in the Piedmont province. They occupy a northeasterly trending belt of serpentinite bodies extending from the Potomac River to beyond the Pennsylvania state line. The southernmost bodies are large olistoliths in quartzose schist and metagraywacke of the Late Proterozoic and (or) Early Cambrian Mather Gorge Formation (Drake, 1994). A tadpole-shaped body of serpentinite, the Late Proterozoic and (or) Early Cambrian Soldiers Delight Ultramafite, forms a large horse between rocks of the Early Cambrian Sykesville Formation and those of the Late Proterozoic and (or) Early Cambrian Loch Raven Schist and other units in the Loch Raven thrust sheet between Triadelphia Reservoir on the Patuxent River and Delight, Maryland (Drake, 1994). Blocks of serpentinite are fairly abundant in rocks of the Loch Raven thrust sheet between Rocky Gorge Reservoir on the Patuxent River and the Pennsylvania state line. Serpentinite is a minor constituent of the early Paleozoic Hollofield Layered Ultramafite of Crowley (1976) of the Baltimore Complex, which forms a major thrust sheet in the Baltimore area . Scattered layers of serpentinized and steatized pyroxenite also are present within the early Paleozoic Mount Washington Amphibolite of Crowley (1976) of the Baltimore Complex . The talcose rocks formed by hydrothermal alteration of serpentinite, along contacts and in shear zones in the large bodies, and commonly throughout small bodies.

Morgan (1977) interprets gabbro and ultramafic rocks in the entire belt from northernmost Virginia to the Maryland-Pennsylvania state line as a dismembered ophiolite and includes them in the Baltimore Complex. The ultramafic rocks contain the talc deposits described below. Others, such as Drake (1994), agree that these rocks are ophiolite fragments, but some are now assigned to other units. Hanan and Sinha (1989), however, believe that they formed in either a marginal basin inland from a continental margin volcanic arc or as a sub-arc plutonic complex. Earlier interpretations of the stratigraphy and structure of the Maryland Piedmont are found in Peare and Heyl (1960) and Higgins (1972).

129. Muddy Branch, Montgomery County -- Talc prospect at margin of a 1-mile-long serpentinite body (Froelich, 1975). The soapstone may contain talc, chlorite, tremolite, carbonate minerals, and (or) magnetite. Quartzose schist and metagraywacke of the Late Proterozoic and (or) Early Cambrian Mather Gorge Formation, a unit which is continuous from Fairfax, Virginia (locality 108) encloses this serpentinite. Other serpentinite blocks, parts of which are steatized, extend for about 10 miles to the northeast (Hopson, 1964; Drake, 1994). Chemical analyses suggest that most of the blocks were harzburgite (Drake, 1994).

Localities 129-137 are all in the Potomac composite terrane, as interpreted by Rankin (1993) and Rankin and others (1993a).

130. Ednor, Montgomery County -- Lenticular body of steatite enclosed in quartz-mica schist of the Late Proterozoic and (or) Early Cambrian Loch Raven Schist in the Loch Raven thrust sheet (Bernstein, 1980; Crowley and Reinhardt, 1979). The steatite consists mostly of talc, chlorite, and minor magnetite and limonite pseudomorphs of pyrite. Iron- and magnesium-rich carbonate rocks are also present.

131. West of Baltimore, Baltimore County -- Several serpentinite bodies within the early Paleozoic Mount Washington Amphibolite and the Hollofield Layered Ultramafite of Crowley (1976) of the Baltimore Complex are shown by Crowley and Reinhardt (1979, 1980). Each body consists, in part, of talc-chlorite schist, probably mainly on the margins.

132. Marriottsville and Henryton, Carroll County -- Considerable production of both block soapstone and ground talc has come from three groups of quarries in this area (Pearre and Heyl, 1960, p. 796; Bernstein, 1980, p. 61). Talc schist is bordered by chlorite schist and both have been mined. The quarries are in altered pyroxenite in the "tadpole tail" of the Late Proterozoic and (or) Early Cambrian Soldiers Delight Ultramafite, a large horse between the Early Cambrian Sykesville Formation and the Late

Proterozoic and (or) Early Cambrian Oella Formation in the Loch Raven thrust sheet (Drake, 1994).

133. Soldiers Delight, Baltimore County -- This area lies between Holbrook and Delight and is the "tadpole head" of the Late Proterozoic and (or) Early Cambrian Soldiers Delight Ultramafite (Drake, 1994). The margins of the serpentinite body and rock in shear zones within the body have been altered to talc schist (Bernstein, 1980, p. 28; Pearre and Heyl, 1960; Drake, 1994). Petrography and chemistry suggest that this serpentinite was originally dunite, a conclusion supported by the presence of podiform chromite deposits (Drake, 1994).

134. Rocks-Chrome Hill, Harford County -- A talc quarry having small production lies 1 mi south of Rocks (Pearre and Heyl, 1960, p. 797). The parent serpentinite body is within the Late Proterozoic and (or) Early Cambrian Loch Raven Schist (Moller, 1979).

135. Scarboro-Dublin, Harford County -- A group of quarries in a 2.5-mi long stretch of a serpentinite body which extends from here across the Susquehanna River and into Pennsylvania has had substantial production, of both block soapstone and ground talc (Pearre and Heyl, 1960, p. 797; Cleaves and others, 1968). Brooks (1985) reported a quarry in operation in 1983, but it is now shut down (E.T. Cleaves, written comm. 1995). Hydrothermal solutions related to a nearby pegmatite may have been responsible for talc formation here (Pearre and Heyl, 1960). The rock sampled contained 85% talc, 15% chlorite, and minor magnesite. The body is within the informally named Cambrian Broad Creek mélange of Howard (1994) or the informally named Cambrian Mill Green mélange of Drake (1985a) (A.A. Drake, written comm., 1994, oral comm., 1995).

136. Bald Friar and Schofield quarries, Rock Springs, Cecil County -- Small production of both talc and feldspar has come from each of these quarries, which are in altered zones in the same serpentinite body referred to above (locality 116) (Pearre and Heyl, 1960, p. 799).

137. Octoraro and Pilot Station, Cecil County -- Two lenticular bodies of talc schist in mafic plutonic rocks of the early Paleozoic Baltimore Complex are shown by Higgins and Conant (1986). Hanan and Sinha (1989) reported that the mafic rocks are cut by a plagiogranite dated at 520 Ma (Late Cambrian); however, supporting data are unpublished.

Production: Production of soapstone slabs began in Maryland in the 1850's and of ground talc in the 1890's. There has been recorded production every year from 1906 to 1954, during which time 17 quarries contributed to a total estimated at 320,000 tons (Pearre and Heyl, 1960, p. 795). Figures in the U.S. Bureau of Mines, Minerals Yearbook series are not given separately for Maryland, but suggest additional production of about 440,000 tons to 1974 for a total of 760,000 tons for the state.

Exploration: Both the Soldiers Delight Ultramafite and the ultramafic band extending from Chrome Hill to Pilot Station and on into Pennsylvania are of substantial size but thoroughly explored for talc, chromite, and other commodities. Indications of down-dip extensions from known deposits must be sought after. A belt of narrower ultramafic bodies lies a short distance northwest, closely following the position of the Huntingdon Valley-Pleasant Grove fault, as shown by Rankin (1993). It is less well known and offers possibilities. The maps of Pearre and Heyl (1960, pls. 40, 41), Moller (1979), Higgins and Conant (1986), Drake (in press, d), Muller (1985, 1991), and Southwick and Owens (1969) will serve as guides. Owing to the abundance of ultramafic rocks therein, a wide belt in the Maryland and Pennsylvania Piedmont is indicated as permissive for additional talc deposits.

Pennsylvania

Talc deposits derived both from ultramafic and carbonate rocks are found in southeastern Pennsylvania. Ultramafic-derived deposits are in the Piedmont province in the serpentinite bodies which form discontinuous extensions of the several belts in Maryland. Pearre and Heyl (1960) report on three localities including the important Philadelphia district. B.C. Smith II (written comm., 1995) reports that an additional locality (#137A, below) has commercial possibilities. Locally abundant talc float indicates that other serpentinite bodies are also talc-bearing (Blount and Spohn, 1982). Carbonate-derived deposits are found in the Valley and Ridge province at Easton.

137A. Rock Springs Church, Fulton Township, Lancaster County -- The Ben Brookmyer deposit at this locality has been been explored by drilling and a reserve of 1.1 million tons established. There has been no production as yet (B.C. Smith, written comm., 1995). This deposit is apparantly in serpentinite of the early Paleozoic Baltimore complex.

138. Embreeville, Chester County -- A soapstone quarry believed to have been worked by Indians is in small serpentinite body in the Late Proterozoic and (or) Early Cambrian Peters Creek Schist (Pearre and Heyl, 1960, p. 801; A.A. Drake, written commun., 1994).

Localities 138-140 are all in the Potomac composite terrane near the Pleasant Grove-Huntingdon Valley fault, as interpreted by Rankin (1993) and Rankin and others (1993a).

139. West Chester (West Goshen), Chester County -- Talc is associated with a small body of serpentinite near contact between the Late Proterozoic and (or) Early Cambrian Peters Creek Schist and Middle Proterozoic rocks of the Avondale massif (Pearre and Heyl, 1960, p. 801, A.A. Drake, written commun., 1994).

Additional occurrences of serpentinite in Chester and Lancaster Counties are shown on the map of Larrabee (1966). They occur in a broad belt from Phoenixville and Elverson through Coatsville and Mount Airy to New Providence.

140. Philadelphia district, Montgomery and Philadelphia Counties -- Quarries on both sides of the Schuylkill River directly northeast of Gladwyn produced large amounts of dimension soapstone and small amounts of ground talc. The deposits are derived from a lens of serpentinite enclosed in schist of the Late Proterozoic to early Paleozoic Wissahickon Formation (Pearre and Heyl, 1960, p. 799).

Production: Quarries in this district operated during the late 1700's and early 1800's, but the amount produced is unknown (Pearre and Heyl, 1960, p. 794).

Exploration: The ultramafic bodies shown on the map of Pearre and Heyl (1960, pls. 41, 42) appear to have been well explored for talc and other commodities. However, B.C. Smith (written comm., 1995) states that there are numerous undocumented occurrences of talc in the south part of this area. The ultramafics in a belt extending southwest from the Philadelphia district to Mount Alverno, and possibly beyond into northernmost Delaware, may also offer possibilities. Maps by Bascom and Stose (1932), Bascom and others (1909), and Knopf and Jonas (1929) will serve as guides.

141. Easton, Northampton County -- Dolomitic marble (Drake, 1967a) on the lower slopes of Chestnut Hill and vicinity has been

hydrothermally altered to rock containing diopside, serpentine, tremolite, phlogopite, talc and less common sulfides, oxides, and uranium minerals (Peck, 1911; Miller, 1939; Montgomery, 1957). Maps by Peck (1911) and Drake (1967a) each show a number of quarries, several of which are described by Peck (1911) and by Miller (1939). Most of the rock quarried was serpentinized marble, locally called verdolite, which was sold as dimension stone. Also quarried was softer rock consisting mostly of serpentine and phlogopite with local talc; this was ground and sold as filler for paint and paper. Talc also appears in shear zones and minor pockets; some was quarried by hand and ground for talcum powder.

The dolomitic marble is part of a sequence of Middle Proterozoic metasedimentary, metavolcanic, granitic, and gneissic rocks in a thrust sheet rooted in the Reading Prong and superposed on Cambrian and Ordovician sedimentary rocks of the Valley and Ridge province (Drake, 1967a; King and Beikman, 1974).

Production: Talc production for all of Pennsylvania is estimated at 250,000 tons for 1906 to 1954. Most of this came from the Easton district, according to Pearre and Heyl (1960, p. 795). This production mostly consisted of dimension stone and ground product neither of which contained much talc, as described above. According to the U.S. Bureau of Mines Minerals Yearbook series, production continued to 1970, but quantities are not reported.

Exploration: The fault slice of Proterozoic rocks forming Chestnut Hill ends near the west edge of the Easton quadrangle (Drake, 1967a), however other fault slices, possibly containing talc-bearing marble, continue southwest through Allentown to Reading. The following quadrangle maps will serve as guides: Nazareth (Aaron, 1975), Allentown West (Drake, 1993), Allentown East (Drake, in press, a), Hellerton, (Drake, in press,b), Catasauqua (Drake, in press, c), Temple and Fleetwood (MacLachlan, 1979), Reading and Birdsboro (MacLachlan, 1983), Sinking Spring (MacLachlan and others, 1975).

New Jersey

142. North of Phillipsburg, Warren County -- A number of quarries located on the western end of Marble Mountain overlook the Delaware River, and yet another one is located near Lower Harmony, 3 mi

to the northeast (Peck, 1911; Drake, 1967a) The rocks are the same as those at Easton, locality 141.

Production: Production has not been reported separately for New Jersey's share of this district.

Exploration: The fault slice composed of Proterozoic rocks on Marble Mountain continues to the northeast from Lower Harmony, and additional talc-bearing marble may possibly be found in it or elsewhere in the Reading Prong in northern New Jersey or adjacent New York state. The geologic map of New Jersey (Drake and others, 1994) and the following quadrangle maps will serve as guides: Bloomsbury (Drake, 1967b), Portland and Belvedere (Drake and others, 1969, 1985), Blairstown (Drake and Lytle, 1985), Frenchtown (Drake and others, 1961), Riegelsville (Drake and others, 1967), Unionville (Drake and Monteverde, 1992), Newton East (Drake and Volkert, 1993), Tranquility (Drake and others, 1993), Washington (Drake and others, 1994), Chester (Volkert and others, 1990), Stanhope (Volkert and others, 1989), and Hackettstown (Volkert, in press).

Appalachian Mountains in New England, Introduction

The northern section of the Appalachian Mountains is, in part, continuous with the southern and central sections and extends from the Hudson River for 1150 miles to the eastern coast of Newfoundland Island. Only that part in the New England states is considered in this report.

The Valley and Ridge Province crosses the Hudson River and is continuous with the Taconic Klippe in western Vermont and eastern New York state. The Reading Prong, which is the equivalent of the Blue Ridge province, also crosses the Hudson River and continues northward as the Berkshire Highlands in Massachusetts and the Green Mountains in Vermont. The Mantattan Prong, a more southerly branch of the Berkshire Highlands, ends at New York City. Serpentinite localities in the Manhattan Prong, both on Manhattan Island and on Staten Island, are shown on the maps of Larrabee (1966, 1971). The rest of New England is equivalent to the Piedmont province.

Structurally, New England is divided into a series of complex anticlinoria and synclinoria. The most important of these include, from west to east and southeast: the Green Mountain anticlinorium, the Connecticut Valley-Gaspe synclinorium, the Bronson Hill anticlinorium and continuous structures in Maine, the Merrimac synclinorium and the Kearsarge-central Maine synclinorium. Other complex terranes lie to the south and east of these in eastern Connecticut, Rhode Island, eastern Massachusetts, and coastal Maine.

With the exception of the Connecticut Valley lowland, the New England rocks are largely metasedimentary, metavolcanic, and plutonic, and are commonly complexly folded. (Rodgers, 1985; Zen, 1983). Ages have been known for some time to be Proterozoic through Devonian, with a few younger ages possible (Billings, 1955; Doll and others, 1961).

As in the southern and central Appalachians, recent developments in plate-tectonic theory and improved methods of radiometric dating have contributed to a much clearer picture of the geology. Ages of layered rocks are known in more detail and are confirmed to be Middle Proterozoic through Devonian, and locally as young as Pennsylvanian. The age range of the plutonic rocks has been considerably extended; many have been shown to be of various late Paleozoic and Mesozoic ages (Rodgers, 1985; Zen, 1983; Osberg and others, 1985).

The plate-tectonic approach provides further continuity between the central and the northern Appalachians. Both sections developed from a proto-North American continent (Laurentia) and an array of accreted terranes (Rankin, 1993; Rankin and others, 1993a, b), the accreted terranes being stacked up and thrust northwestward over the proto-continent. As shown on the maps of Rankin (1993), Rankin and others (1993a), and Rankin, Drake, and Ratcliffe (1990), the Iapetus suture forms the northwestern limit of possible to probable accreted terranes. Its position lies on the east flank of the Green Mountain anticlinorium in Vermont and Massachusetts. The suture continues across western Connecticut, crossing the Hudson River at New York City.

Talc deposits in New England are nearly all in ultramafic rocks, and nearly all of these are in the accreted, or exotic, terranes. Those deposits in the principal belt which extends from western Connecticut through western Massachusetts and Vermont and into Quebec are all within a few miles of major fault zones interpreted as the Iapetus suture (Rankin 1993; Rankin and others, 1993a). Stanley and others (1984) believe that metasedimentary and ultramafic rocks are highly faulted to form a tectonic stratigraphy in which serpentinite and talc-carbonate rocks appear as slivers along faults separating contrasting lithologies. They further believe that sedimentary rocks in this belt were imbricated with oceanic crust to hydrothermally altered to rock containing diopside, serpentine, tremolite, phlogopite, talc and less common sulfides, oxides, and uranium minerals (Peck, 1911; Miller, 1939; Montgomery, 1957). Maps by Peck (1911) and Drake (1967a) each show a number of quarries, several of which are described by Peck (1911) and by Miller (1939). Most of the rock quarried was serpentinized marble, locally called verdolite, which was sold as dimension stone. Also quarried was softer rock consisting mostly of serpentine and phlogopite with local talc; this was ground and sold as filler for paint and paper. Talc also appears in shear zones and minor pockets; some was quarried by hand and ground for talcum powder.

The dolomitic marble is part of a sequence of Middle Proterozoic metasedimentary, metavolcanic, granitic, and gneissic rocks in a thrust sheet rooted in the Reading Prong and superposed on Cambrian and Ordovician sedimentary rocks of the Valley and Ridge province (Drake, 1967a; King and Beikman, 1974).

Production: Talc production for all of Pennsylvania is estimated at 250,000 tons for 1906 to 1954. Most of this came from the Easton district, according to Pearre and Heyl (1960, p. 795). This production mostly consisted of dimension stone and ground product neither of which contained much talc, as described above. According to the U.S. Bureau of Mines Minerals Yearbook series, production continued to 1970, but quantities are not reported.

Exploration: The fault slice of Proterozoic rocks forming Chestnut Hill ends near the west edge of the Easton quadrangle (Drake, 1967a), however other fault slices, possibly containing talc-bearing marble, continue southwest through Allentown to Reading. The following quadrangle maps will serve as guides: Nazareth (Aaron, 1975), Allentown West (Drake, 1993), Allentown East (Drake, in press, a), Hellerton, (Drake, in press,b), Catasauqua (Drake, in press, c), Temple and Fleetwood (MacLachlan, 1979), Reading and Birdsboro (MacLachlan, 1983), Sinking Spring (MacLachlan and others, 1975).

New Jersey

142. North of Phillipsburg, Warren County -- A number of quarries located on the western end of Marble Mountain overlook the Delaware River, and yet another one is located near Lower Harmony, 3 mi

Paleozoic sequence that forms the western part of the Connecticut Valley synclinorium (Rodgers, 1985). The age of the serpentinite is Ordovician or older (Rodgers, 1985). The ultramafic rocks range from steatite to serpentinite to amphibolite (Stanley, 1964, p. 41). Martin (1970, p. 44) reported that the talc-bearing rocks contain also serpentine, tremolite, and accessory magnetite and pyrite.

145. Maltby Lakes, New Haven County -- Unconfirmed soapstone occurrence reported by Chidester and Worthington (1962). Apparently in metavolcanic rocks of the Middle(?) Ordovician Maltby Lakes Metavolcanics (Burger, 1967; Rodgers, 1985), which are part of the Orange-Milford belt of the Connecticut Valley synclinorium (Rodgers, 1985).

Additional occurrences of ultramafic rocks shown on the map of Larrabee (1971) include: 1) Milford, New Haven County, on strike with locality 145, above, 2) South Britain, New Haven County, and 3), a belt from Ivoryton to north of Chester, Middlesex County.

Production: There is no reported production from talc occurrences in Connecticuit; however, Stanley (1964) reports that most of the nine talc occurrences which he found in the Collinsville quadrangle (locality 144, above) were marked by old mines. These probably date from the middle 1800's or earlier.

Exploration: The belt of serpentinite occurrences extending from East Litchfield to New Hartford is a possible locus for further search for talc deposits and is indicated as permissive on plate 1. Extensions of the belt composed of the Rowe Schist both to the north and south could also be investigated. The geologic map of Connecticut (Rodgers, 1985) will serve as a guide.

Rhode Island

146. Limerock, northwest of Pawtucket, Providence County -- Metavolcanic rocks of the Precambrian Hunting Hill Greenstone of the Blackstone Group (Quinn and others, 1949; Quinn, 1963) contain two small lenses of talc schist and two lenses of serpentinite. This unit is continuous with Late Proterozoic rocks in the Milford-Dedham zone in Massachusetts (Zen and others, 1983).

This locality is in the Esmond-Dedham terrane, a part of the New England Avalonian terranes, according to the maps of Rankin (1993) and Rankin and others (1993a). Several faults in this area include the Fundy fault and may be sutures; therefore, the ultramafic rocks are possibly ophiolite fragments.

Production: Small production for Rhode Island, presumably from the above-described locality, was reported for 1910 (U.S. Geological Survey, Mineral Resources of the U.S., 1910).

Massachusetts

Talc deposits in Massachusetts are chiefly in the belt composed of the Cambrian and (or) Early Ordovician Rowe Schist or in the adjacent Ordovician Moretown or Cobble Mountain Formations. These units strike mainly north and extend in an unbroken belt across the western part of the state. They are part of the Rowe-Hawley zone (Zen and others, 1983) and flank the Green Mountain anticlinorium to the west and the Connecticut Valley synclinorium to the east. The deposits are in altered ultramafic rocks and are similar to those in Connecticut and to many in the Appalachian Blue Ridge and Piedmont. There is one deposit, possibly formed in limestone, in Proterozoic rocks of the Berkshire massif in the Green Mountain anticlinorium, and two occurrences in ultramafic pods in the Late Proterozoic, Cambrian, or Ordovician Monson Gneiss. Domes composed of the Monson and other gneisses characterize the Bronson Hill anticlinorium, which lies east of the Connecticut Valley synclinorium.

147. Dalton (Hinsdale), Berkshire County -- A talc deposit was reported (Chute, 1969, p. 32-36; Pearre, 1956) 4 mi east of Dalton (9 mi east of Pittsfield). It is enclosed in Middle Proterozoic biotite gneiss within the Berkshire massif (Zen and others, 1983; Hinsdale Biotite Gneiss and Becket Granite Gneiss of Chute, 1969). The deposit consists of talc schist that contains 10-20% carbonate minerals and local cross-fiber anthophyllite. A chlorite border zone is locally exposed but no serpentinite is present. The deposit may have formed by alteration of limestone, although none is visible (Chute, 1969, p. 33). However, Chute (1969, p. 36) reported outcrops of talcose limestone 5-6 mi south of the Dalton quarry.

These localities are part of the Laurentian Appalachians, according to the maps of Rankin (1993) and Rankin and others (1993a).

Production: Intermittent production of both ground talc and dimension stone occurred at the Dalton quarry from 1894 to 1906.

148. Granville, Hampden County -- A soapstone quarry lies 5 mi southwest of Granville (Emerson, 1898; Pearre, 1956). It is apparently in ultramafic rocks in a narrow belt composed of the Cambrian and (or) Early Ordovician Rowe Schist (Knapp, 1978). This belt ends against a thrust fault near the Connecticut state line 2.5 mi to the south.

Localities 148 to 155 are all in the Brompton-Cameron terrane, according to the maps of Rankin (1993) and Rankin and others (1993a). They are mostly within 2 mi of the Whitcomb Summit thrust (Zen and others, 1983) which is identical to the Iapetus suture. Therefore, as suggested by Stanley and others (1984), the ultramafic bodies are probably ophiolite fragments.

149. Granville Center to Little River, Hampden County -- Three small lenses of ultramafic rocks are present in mica schist of the Middle Ordovician Cobble Mountain Formation (Knapp, 1978), adjacent to the Granville dome (Zen and others, 1983). The ultramafic rocks are composed of serpentine, talc, calcite, and magnetite (Knapp, 1978).

150. Blandford area, Hampden County -- Eleven small lenticular bodies of ultramafic rocks enclosed within the Cambrian and (or) Early Ordovician Rowe Schist in the Blandford quadrangle (Hatch and Stanley, 1976) are mostly serpentinite containing little talc; however, the Osborne quarry, 1 mi south of Blandford, exposes soapstone consisting of talc, anthophyllite, actinolite, and opaque minerals but little carbonate, at the contact between schist and amphibolite (Chute, 1969). A reported soapstone quarry near Blair Pond, 2 mi west of Blandford, (Emerson, 1898), and one near the present route of the Massachusetts Turnpike, 4 mi northwest of Blandford (Emerson, 1898; Chute, 1969, p. 25), were not found by Hatch and Stanley (1976).

Production: The Osborne quarry was worked intermittently from about 1833 to 1918, producing an unknown quantity of slabs of talc for building purposes.

151. Middlefield, Hampshire County -- There is a group of quarries and prospects 2 miles northeast of Middlefield (Chute, 1969, p. 21; Pearre, 1956; Hatch and others, 1970). The deposits are in two small altered serpentinite bodies in the Cambrian and (or) Early Ordovician

Rowe Schist, at and near the contact between mica schist and amphibolite (Chute, 1969, p. 21-25; Hatch and others, 1970). Although there are eight ultramafic bodies in the belt composed of the Rowe Schist in this area, including one about 2 mi long, none of the others contain significant talc (Hatch and others, 1970). A minor occurrence of talc-bearing ultramafic rocks is located 1 mi north of the Middlefield quarries (Hatch, 1969), at the contact between the Rowe Schist and the Ordovician Moretown Formation.

Production: Quarrying of talc began in Middlefield about 1800 and continued to about 1815. Operations were resumed in 1853 and continued to about 1860; about 1,000 tons/yr were produced during this period. All the material was used for dimension stone purposes.

152 . East Windsor and West Cunningham, Berkshire County -- A small ultramafic lens containing talc-carbonate rock, steatite, and serpentinite at a bend in Westfield River 1 mi north of East Windsor (Hatch, 1969) is enclosed in schist, granulite, and greenstone of the Ordovician Moretown Formation, 0.5 mi. from its contact with the Cambrian and (or) Early Ordovician Rowe Schist. A similar occurrence (West Cunningham) is located 1.3 mi to the north (Osberg and others, 1971; Chute, 1969, p. 20-21).

Production: The West Cunningham (Northampton Talc Co.) mine operated from 1905-1908; the quantity produced is unknown.

153. Savoy, Berkshire County -- The Ley talc mine is located 2.5 mi southeast of Savoy (Chute, 1969, p. 18-20) It appears to be in the Cambrian and (or) Early Ordovician Rowe Schist (Zen and others, 1983) and is similar to others in this belt.

Production: The Ley mine operated from 1909 to 1912, producing an unknown quantity of ground talc.

154. Drury and Hoosac Tunnel, Franklin and Berkshire Counties -- This area contains a soapstone quarry and a group of prospects (Chute, 1969, p. 14-18; Chidester and others, 1967). The latter authors showed 13 talc-bearing serpentinite occurrences in the Rowe quadrangle. The talcose rocks generally form rims on large serpentinite bodies and may form the entirety of small masses. The rocks contain, in addition to talc, as much as 50% magnesite and other carbonate minerals and lesser amounts of tremolite, chlorite, serpentine, and opaque minerals. These ultramafic rocks are all enclosed in the Cambrian and (or) Early Ordovician Rowe Schist.

Production: The Hoosac Tunnel soapstone quarry had small production of soapstone blocks in about 1890, and of ground talc in 1909 (Chute, 1969). The nearby Florida prospect had small production about 1900.

155. Rowe, Franklin County -- Two talc mines and one prospect directly north and east of Rowe reported by Chute (1969, p. 8-13; see also Pearre, 1956) and additional quarries (Chidester and others, 1967) are in the Cambrian and (or) Early Ordovician Rowe Schist. An amphibolite unit becomes the dominant member of the Rowe Schist here, and continues north into Vermont (Hatch and Hartshorn, 1968).

Production: The Foliated Talc Co. Mine operated from 1905 to 1922 and the Massachusetts Talc Co. Mine from 1901 to 1912. Each produced substantial, but unknown, amounts of ground talc (Chute, 1969).

Exploration: Additional talc in ultramafic bodies, both mapped and unmapped, must surely be present in the belt of Rowe schist and Moretown Formation (localities 148-155). This belt is indicated as permissive on plate 1. The excellent series of detailed quadrangle maps covering this belt (Hatch, 1969; Hatch and Hartshorn, 1968, Hatch and others, 1970; Hatch and Stanley, 1976; Osberg and others, 1971; Knapp, 1978) will serve as a guide for further search.

156. Soapstone Hill, Petersham, Worcester County -- Two soapstone quarries located on the east side of Quabbin Reservoir 4 miles west of Petersham (Chute 1969, p. 37-38; Pearre, 1956) are in a small lens of ultramafic rocks enclosed within the Late Proterozoic, Cambrian, or Ordovician Monson Gneiss (Zen and others, 1983). This area is part of the Bronson Hill anticlinorium, featuring elongate north-striking domes composed of the Monson Gneiss and other gneisses and overlying Ordovician, Silurian, and Devonian metasedimentary rocks (Robinson, 1977; Zen and others, 1983). The soapstone apparently consists mostly of talc and chlorite. Tracy and others (1984) discuss the mineralogy of other small ultramafic bodies in this area.

Localities 156 and 157 are in the central Maine terrane, according to the maps of Rankin (1993) and Rankin and others (1993a).

Production: Two quarries operated on this deposit from 1878 to 1882, producing first dimension soapstone and later ground talc. Quantities are unknown.

157. Tully Mountain, Franklin County -- A soapstone deposit is present in a lens of amphibolite enclosed in the Tully dome composed of the Late Proterozoic, Cambrian, or Ordovician Monson Gneiss on the west side of Tully Mountain (Hadley, 1949; Pearre, 1956; Robinson, 1977). The soapstone consists of talc, chlorite, and carbonate minerals and is surrounded by a narrow zone of chlorite-actinolite schist (Hadley, 1949). Structure and age of the rocks are as described above (locality 156).

Exploration: Additional soapstone finds seem unlikely in the area of localities 156 and 157, except immediately adjacent to or downdip of the mined bodies, as ultramafic rocks are rare, and sutures are absent, in central Massachusetts.

Additional occurrences of ultramafic rocks shown on the map of Larrabee (1971) include: 1) northeast and southeast of Amherst, Hampshire and Franklin Counties, and 2) New Braintree, Worcester County.

Production for Massachusetts: Consistent with the periods of operation noted above, the U.S. Geological Survey's Mineral Resources of the U.S. series volumes report small production for Massachusetts for most years from about 1900 to 1920, including 7,800 tons for 1910. I estimate total production for the state at 100,000 tons.

Vermont

Vermont is rich in talc deposits and many have had substantial production. All are derived from ultramafic rocks and most are in a north-trending belt along the strike of Cambrian and Ordovician metasedimentary and metavolcanic rocks on the east flank of the Green Mountain anticlinorium (west flank of the Connecticut Valley-Gaspe synclinorium). This belt is continuous with the one in Massachusetts, localities 148-155. It also continues northward from the international boundary into Quebec. A few deposits are in Middle Proterozoic gneiss of the Chester and Albany domes and are closely related to the main belt.

Many small ultramafic bodies in this belt appear on the state geologic map (Doll and others, 1961). Additional bodies are mentioned by Chidester and others (1951), who obtained locations from co-workers and the reports of Hitchcock and others (1861) and Bain (1936). Deposits are also shown on the map of Pearre and Calkins (1957b). Others certainly remain to be discovered. As elsewhere in the Appalachians, most of these bodies are serpentinite and most contain some talc; the largest bodies have peridotite cores and the small ones are mostly talc. A typical ultramafic pod is mostly serpentinite, has marginal zones of talc-carbonate rocks followed by steatite and finally by chlorite blackwall at the contact with country rock (fig.1, Chidester, 1962; Sanford, 1982; this report, Introduction). Steatization is generally believed to be a late hydrothermal event (Chidester, 1962, p. 91, and elsewhere).

Stanley and others (1984) suggest that all of these ultramafic bodies may be slivers of oceanic crust adjacent to faults and, hence, are ophiolite fragments. Rankin (1993) and Rankin and others (1993a) place the Iapetus suture (Hazens Notch thrust) at the contact between the Hazens Notch and Underhill Formations in the north part of Vermont and at the contact of the Ottauquechee and Pinney Hollow Formations (Whitcomb Summit thrust) in the south part (figs. 13, 14). Laurentian North America west of the Iapetus suture contains few ultramafic rocks. The Hazens Notch slice, lying between the Hazens Notch thrust and the Belvidere Mountain thrust to the east, contains abundant ultramafic rocks and talc deposits, as do the formations in the Brompton-Cameron terrane immediately to the east of the Belvidere Mountain and Whitcomb Summit thrusts (figs. 13, 14; Rankin (1993) and Rankin and others (1993a))

A minor belt of talc occurrences, partly in Vermont and partly in New Hampshire, is in metavolcanic rocks of the Ordovician Orfordville Formation as shown by Doll and others (1961) and Billings (1955).

Production: Talc producers in Vermont have been reluctant to release production data, thus production for the state is known for certain years but must be estimated for others. Figures in the USGS and USBM Minerals Yearbook series combined with estimates give a total talc production of 10,800,000 tons through 1994 for Vermont.

158. East Dover and Newfane to West Marlboro, Windham County -- A 3-mi-long body of serpentinite and peridotite near East Dover (fig. 13) contains only minor talc (Chidester and others 1951, p. 14; Doll and others, 1961). Several steatite occurrences in small ultramafic bodies are also present. All are in the Early Ordovician Stowe Formation or the Ordovician Moretown Member of the Missisquoi Formation.

Figure 13. Simplified geologic map of the southern part of the principal ultramafic belt in Vermont, showing talc mines and prospects. Locations mostly from Chidester and others (1951). Geology adapted from Doll and others (1961) with modifications from Rankin (1993).

EXPLANATION

DSu Northfield, Waits River, and Gile Mountain Formations, undivided (Devonian and Silurian) -- Slate, phyllite, limestone, schist, and quartzite

Om Missisquoi Formation (Ordovician) -- Slate, phyllite, schist, gneiss, and amphibolite; also includes Moretown Member: quartzite and granulite

Os Stowe Formation (Early Ordovician) -- Phyllite, schist, and greenstone. Shown by line where too thin to show pattern

Єo Ottauquechee Formation (Late and Middle Cambrian)-- Phyllite, quartzite, schist, and amphibolite. Shown by line where too thin to show pattern

ЄZp Pinney Hollow Formation (Early Cambrian and Late Proterozoic) -- Phyllite, schist, and quartzite. Shown by line where too thin to show pattern

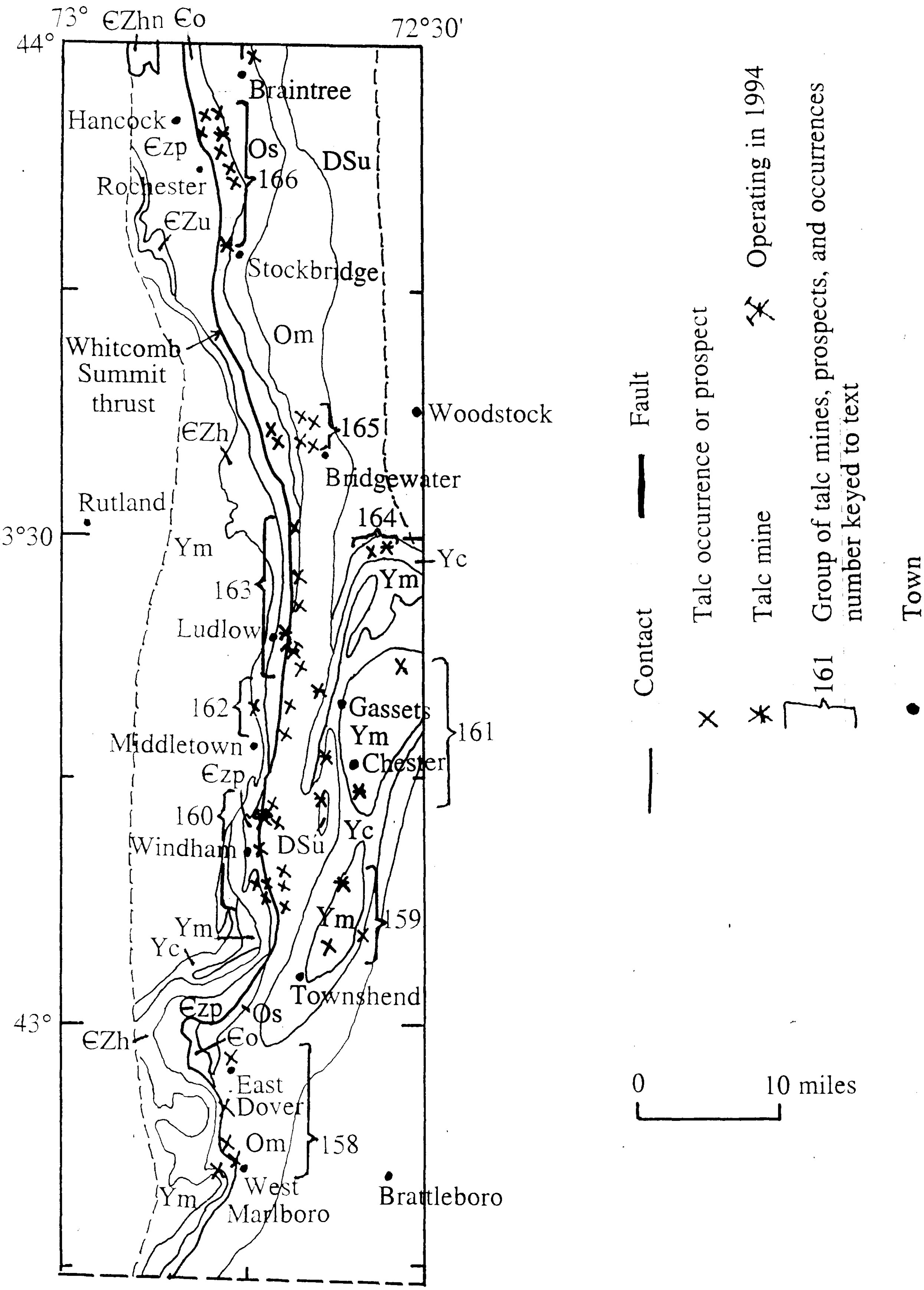
ЄZhn Hazens Notch Formation (Early Cambrian and (or) Late Proterozoic) -- Schist and quartzite

ЄZh Hoosac Formation (Early Cambrian and Late Proterozoic)-- Schist, quartzite, and amphibolite

ЄZu Underhill Formation (Early Cambrian and (or) Late Proterozoic -- Schist, quartzite, and phyllite

Yc Cavendish Formation (Middle Proterozoic) -- Schist. As mapped, includes Hoosac, Underhill, Pinney Hollow, Ottauquechee, Stowe, and Missisquoi Formations where too thin to show pattern.

Ym Mount Holly Complex (Middle Proterozoic) --Gneiss, quartzite, marble, and calc-silicate rocks


73°
ЄZhn
Єo
72°30'
44°
Braintree
Hancock
Єzp
Os
DSu
166
Rochester
ЄZu
Stockbridge
Om
Whitcomb Summit thrust
Woodstock
ЄZh
165
Bridgewater
Rutland
164
43°30
Yc
Ym
163
Ludlow
162
Gassets
Ym
161
Middletown
Chester
Єzp
160
Windham
DSu
Yc
Ym
159
Yc
Townshend
43°
Єzp
Os
ЄZh
Єo
East Dover
Om
158
West Marlboro
Brattleboro
Contact
Fault
Talc occurrence or prospect
Talc mine
Operating in 1994
161
Group of talc mines, prospects, and occurrences number keyed to text
Town
0
10 miles

Localities 158, 160, 162, 163, and 165-168 are in the Brompton-Cameron terrane, according to the maps of Rankin (1993) and Rankin and others (1993a). The ultramafic bodies nearly all lie less than two miles east of the Whitcomb Summit thrust, which is interpreted as the Iapetus suture.

159. Townshend to Athens and Grafton, Windham County -- Several small quarries located between Athens and Grafton (fig.13) reveal a body of steatite with minor carbonate minerals and blackwall of chlorite and biotite enclosed in Middle Proterozoic gneiss of the Athens dome (Chidester and others 1951, p. 13, 31; Doll and others, 1961). Another steatite body is also present in Proterozoic gneiss and a third is on the east flank of the dome at the contact between the Ordovician Moretown Member of the Missisquoi Formation and the Early Ordovician Stowe Formation.

Localities 159, 161, and 164 are in or on the flanks of the Chester-Athens domes, an outlier of the Greenville province (Laurentia), according to the maps of Rankin (1993) and Rankin and others (1993a). A thrust fault separates granite and gneiss in the central parts of the domes from surrounding layered rocks of the Brompton-Cameron terrane.

160. Windham, Windham County -- The Vermont Talc Co. quarry located north of Windham (fig. 13) exposes part of a large serpentinite body with a talc-poor carbonate zone followed by a steatite zone having talc-chlorite veins at its margin (Chidester and others 1951, p. 13, 29-31; Doll and others, 1961). Another quarry located nearby exposes only talc-carbonate rock adjacent to a hill of serpentinite. Several other bodies of serpentinite are present. All deposits in this area are in the Early Ordovician Stowe Formation or the Ordovician Moretown Member of the Missisquoi Formation.

Production: The Vermont Talc Co. quarry was in production from the early 1900's to about 1930, and again in the early 1990's. The Hamm mine, also producing in the early 1990's, is scheduled for closure in late 1995.

161. Chester-Gassetts, Windsor County -- The Davis or Holden quarry located south of Chester (fig.13) exposes several lenses of talc, some of it exhibiting pseudomorphs of enstatite. Carbonate minerals surround the talc, and are in turn surrounded by radiating actinolite and biotite. The country rock is Middle Proterozoic gneiss of the Chester dome (Chidester and others, 1951, p. 13, 30-31; Doll and others, 1961). Another

occurrence in gneiss lies near the north end of the dome. The Carleton quarry exposes serpentinite containing irregular zones of talc-carbonate and steatite and a chlorite-biotite blackwall, while the Barton quarry shows similar zonation except for actinolite being prominent in the outer part of the steatite zone. These localities are in Ordovician Moretown Member of the Missisquoi Formation in a tight syncline west of the Chester Dome.

162. Middletown, Windsor County -- Several small bodies of talc and serpentinite north and south of Middletown (fig.13) are in the Ordovician Moretown Member of the Missisquoi Formation or the Early Ordovician Stowe Formation, and another is in the Late Proterozoic and Early Cambrian Hoosac Formation (Chidester and others 195l, p. 13, Doll and others, 1961)

163. Ludlow, Windsor County -- Several quarries near Ludlow (fig.13) expose small lenticular bodies of steatite and talc-carbonate rock, mostly at the contact between the Ordovician Moretown Member of the Missisquoi Formation and Early Ordovician Stowe Formation, but some in Cambrian rocks lower in the section (Chidester and others, 195l, p. 12, 27-28; Doll and others, 1961). The Vermont Geological Survey (written commun., 1995) reports that one mine near Ludlow is currently operating. A 3-mi-long ultramafic body containing only minor talc lies directly east of Ludlow and is enclosed in schist and quartzite of the upper part of the Missisquoi Formation. Several other minor occurrences are in Cambrian rocks near Plymouth.

164. Hammondsville, Windsor County -- The Hammondsville quarry (fig.13) exposes coarse talc-carbonate rock and steatite within a blackwall of biotite followed by chlorite; no serpentinite is exposed. The country rock is quartz-mica schist in the upper part of the Missisquoi Formation at the north end of the Chester dome (Chidester and others, 195l, p. 12, 28; Doll and others, 1961).

165. Bridgewater, Windsor County -- A group of serpentinite and steatite occurrences, mostly unconfirmed, located near Bridgewater (fig.13, Chidester and others, 195l, p. 12) are apparently in Cambrian and Ordovician rocks.

166. Rochester area, Windsor and Orange Counties -- The Williams Mine and Cushman Hill deposits near Rochester (fig. 13) are part of a north-trending belt exposing serpentinite, talc-carbonate, and steatite. Many ultramafic bodies, some containing talc prospects, are found north of Rochester (Chidester and others, 195l, p. 11, 25-27). A quarry operated

for verde antique (decorative stone of serpentine with carbonate veins) also exposes talcose rocks. All deposits are in schist of the Middle and Late Cambrian Ottauquechee Formation (Doll and others, 1961).

Production: The Williams mine was productive from the early 1900's to 1927.

167. Granville, Roxbury, and Warren, Orange, Addison, and Washington Counties -- Two quarries near Roxbury (fig. 14) have been operated for verde antique and are located in small vertical serpentinite pods with centers that are altered to serpentine-carbonate rock and outer zones of steatite (Chidester and others, 1951, p. 10-11, 24-25). A large talc mine lies 1.5 mi southeast of East Granville. There, no serpentinite is exposed; instead, talc-carbonate rock forms the exposed core, locally impinging on blackwall and locally surrounded by steatite. Talc-carbonate and steatite both contain streaks and knots of chlorite and textures suggest that talcose rocks and blackwall have replaced much of the schist country rock. Additional serpentinite bodies, some containing talc, are exposed near Warren and Roxbury. The former are in the Middle and Late Cambrian Ottauquechee Formation and the latter in the Early Ordovician Stowe Formation and Ordovician Moretown Member of the Missisquoi Formation (Doll and others, 1961; Cady and others, 1962).

168. Mad River, Waterbury, Barnes Hill and vicinity, Washington County -- Deposits at three large mine areas both north and south of Waterbury (fig. 14) are described by Chidester (1962) in a classic work on talc. Deposits in the Mad River area consist of steatite and talc-carbonate rock, locally containing tremolite, exposed at the north and south "tail ends" of an elongate serpentinite body. Additional talcose rocks are present in a band of chloritic greenstone lying a short distance to the east. At the Waterbury mine area, a serpentinite body more than 4,500 ft long but mostly less than 300 ft wide has a continuous rim of talc-carbonate rock and steatite. Where the serpentinite narrows at depth or on strike, talc-carbonate rock is thickest. At the Barnes Hill locality, a serpentinite body about 1,500 ft long is replaced, possibly for more than half its volume, by talc-carbonate rock and steatite (Chidester and others, 1952a). The Mad River deposits are in the Middle and Late Cambrian Ottauquechee Formation and the Waterbury and Barnes Hill deposits are in the Early Ordovician Stowe Formation (Doll and others, 1961; Cady, 1956). Additional talc-bearing serpentinite bodies in the Ottauquechee Formation extend this belt south to Waitsfield (Chidester and others, 1951, p. 10, 23; Doll and others, 1961; Cady and others, 1962). There are additional,

mostly unconfirmed, localities near Waterbury (Hitchcock and others, 1861).

Production: The Mad River mine was producing from 1905 to 1946. Total production was about 60,000 tons. The Waterbury mine produced sawn slabs during the mid-1800's and ground talc from 1913 to about 1950.

169. Sterling Pond and Waterville, Lamoille County -- Talc deposits at Sterling Pond near Smugglers Notch at the crest of the Green Mountains (fig. 14) consist of irregular lenticular bodies of talc-carbonate rock, steatite, and minor serpentinite, apparently the remnants of a thoroughly steatized and dismembered serpentinite body (Chidester and others, 1951, p. 9, 17; Chidester, 1953). The Rousseau talc prospect, on the south side of the Lamoille River 1.5 mi south of Waterville, consists of a poorly exposed west-dipping pod of talc-carbonate rock and steatite, representing complete steatization of a small serpentinite body (Chidester and others, 1951, p. 9, 16; 1952b). The Waterville talc quarry ,3.5 mi. north of Waterville, exposes talc-carbonate, steatite, and abundant actinolite at the outer contact; no serpentinite is exposed. These and other ultramafic bodies nearby are all in schist of the Late Proterozoic and (or) Early Cambrian Hazens Notch Formation or Late Proterozoic and (or) Early Cambrian Underhill Formation (Doll and others, 1961; Albee, 1957).

Localities 169, 170, and 171, except for the Enosburg Falls occurrence, are all in the Hazens Notch slice, according to the maps of Rankin (1993) and Rankin and others (1993a). This slice lies between the Hazens Notch thrust (Iapetus suture) to the west and the Belvidere Mountain thrust to the east.

170. Johnson, Lamoille County -- The Johnson talc mine, 2.9 mi northeast of Johnson (fig. 14), was, in 1951, the largest in Vermont. It is in a serpentinite body longer than 3,500 ft which has been almost completely steatized. This body divides upward into several septa which are altered to innermost talc-carbonate rock, then steatite, and chlorite blackwall zones (Chidester and others, 1951, p. 9-10, 17-20; Albee, 1957). A small talc mine, 0.8 mi southwest of Johnson, also is in a completely steatized ultramafic body (Chidester and others, 1951, p. 20; Albee, 1957) These and other ultramafic bodies nearby are enclosed in schist of the Late Proterozoic and (or) Early Cambrian Hazens Notch Formation.

Om Missisquoi Formation (Ordovician) -- Slate, phyllite, schist, gneiss, and amphibolite; also includes Moretown Member: quartzite and granulite

Os Stowe Formation (Early Ordovician) -- Phyllite, schist, and greenstone

Єo Ottauquechee Formation (Late and Middle Cambrian)-- Phyllite, quartzite, schist, and amphibolite. Shown by line where too thin to show pattern

ЄZp Pinney Hollow Formation (Early Cambrian and Late Proterozoic) -- Phyllite, schist, and quartzite. Shown by line where too thin to show pattern

ЄZhn Hazens Notch Formation (Early Cambrian and (or) Late Proterozoic) -- Schist and quartzite

ЄZu Underhill Formation (Early Cambrian and (or) Late Proterozoic)-- Schist, quartzite, and phyllite

ЄZpc Pinnacle Formation (Early Cambrian and Late Proterozoic) -- Graywacke and greenstone

Contact

Fault

× Talc occurrence or prospect

Talc mine

}168 Group of talc mines, prospects, and occurrences number keyed to text

● Town

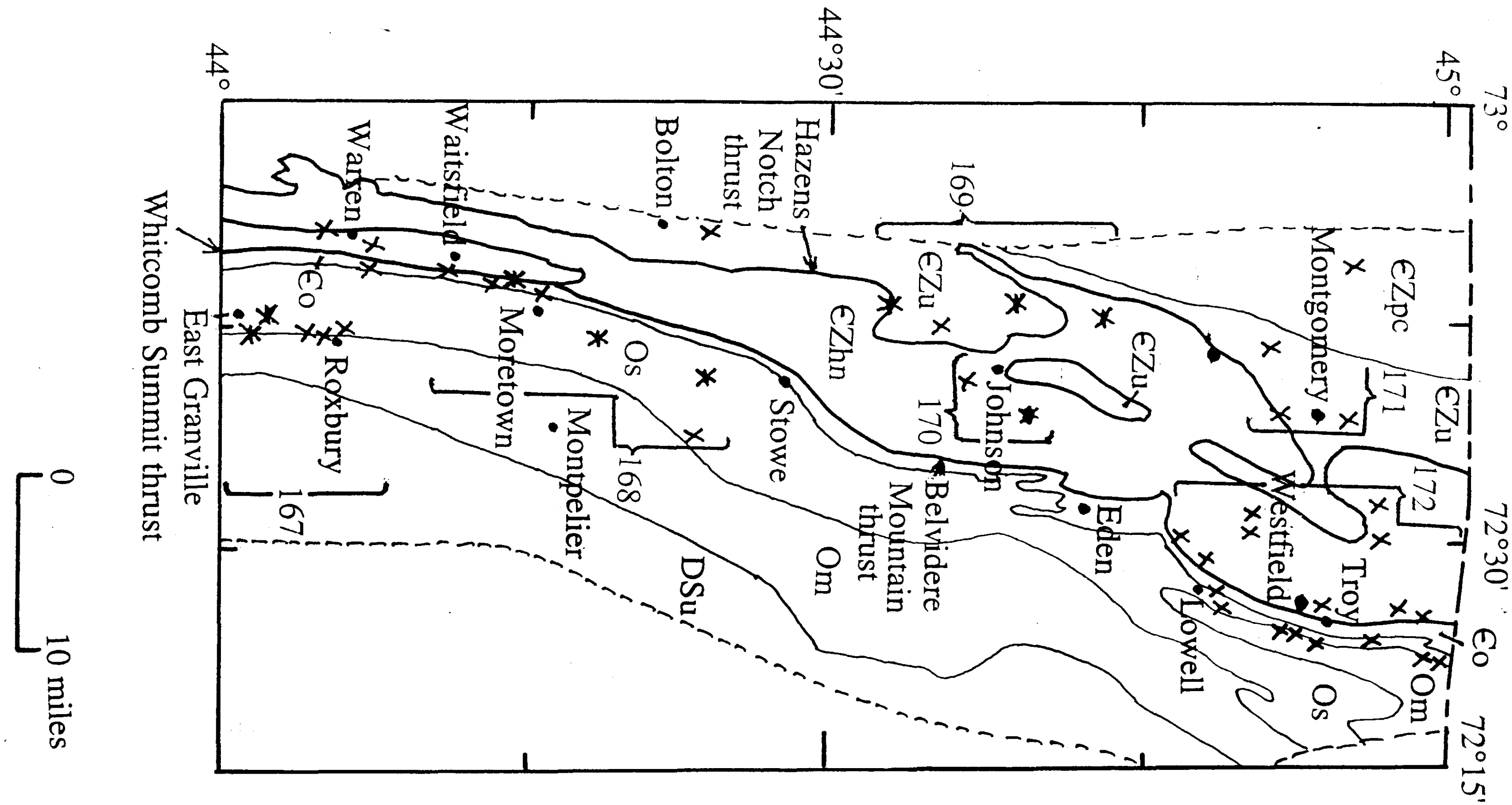


Figure 14 Simplified geologic map of the north part of the principal ultramafic belt in Vermont, showing talc mines and prospects. Locations mostly from Chidester and others (1951). Geology adapted from Doll and others (1961) with modifications from Rankin (1993).

EXPLANATION

DSu Northfield, Waits River, and Gile Mountain Formations, undivided (Devonian and Silurian) -- Slate, phyllite, limestone, schist, and quartzite

Production: The Johnson Mine operated from the early 1900's to 1970. In 1951, production was estimated at 50,000 tons/yr, declining to 22,000 tons in 1954.

171. Montgomery and vicinity, Franklin and Orleans Counties -- A prospect near Montgomery Center (fig. 14) exposes only small amounts of talc-carbonate rock. It and several nearby occurrences are enclosed in schist of the Late Proterozoic and (or) Early Cambrian Hazens Notch Formation (Chidester and others, 195l, p. 8, 14; Doll and others, 1961). Numerous additional occurrences of ultramafic rocks, some bearing talc, are reported to be in this area (Hitchcock and others, 1861; Bain, 1936; Cady and others, 1963). The USGS Mineral Resources Data System computer file confirms two of Hitchcock and others' localities, one in the Hazens Notch Formation southwest of Montgomery and another lying considerably farther west in the Late Proterozoic and Early Cambrian Pinnacle Formation north of Enosberg Falls. The latter is in the Laurentian Appalachian province, according to the maps of Rankin (1993) and Rankin and others (1993a).

172. Belvidere Mountain to North Troy, Lamoille and Orleans Counties -- At Belvidere Mountain (fig. 14), a body of partially serpentinized dunite 2.5 mi long has been quarried for asbestos. A thorough study by Chidester and others (1978) revealed talc-carbonate rock and steatite masses in several parts of this body, but a general lack of talcose marginal zones except in small lenses outside the main body. There was apparently no talc production (Chidester and others, 195l, p. 8, 14-15). A belt of peridotite bodies, some of substantial size and some little affected by serpentinization, extends from Belvidere Mountain to North Troy and across the Canadian border (Doll and others, 1961; Cady and others, 1963). Talc is not generally abundant in these bodies. However, one body ,nearly 4 mi long lying east of Troy and Westfield and parts of another elongate body have been extensively steatized. A talc mine directly east of Troy was opened on this body in 1987 (Meade, 1993), but is no longer operating in 1995. Talc-carbonate rock at a locality 0.8 mi southeast of Troy contains abundant specular hematite (Chidester and others, 195l, p. 9, 15). This belt of peridotite bodies is enclosed in the Late Proterozoic and (or) Early Cambrian Hazens Notch Formation, Middle and Late Cambrian Ottauquechee Formation, and Early Ordovician Stowe Formation. The USGS-MRDS data file shows talc occurrences on Jay and North Jay Peaks northwest of Troy. Some serpentine bodies have been mapped in the Late Proterozoic and (or) Early Cambrian Hazens Notch Formation at these localities and nearby (Doll and others, 1961).

The principal belt of peridotite bodies follows the Belvidere Mountain thrust, which forms the boundary between the Hazens Notch slice and the Brompton-Cameron terrane, according to the maps of Rankin (1993) and Rankin and others (1993a). The Jay Peaks localities are within the Hazens Notch slice.

173. Thetford-Norwich, Orange and Windsor Counties -- Several unconfirmed occurrences of serpentinite and steatite are reported by Hitchcock and others (1861) to lie between Thetford and Norwich, near the Connecticut River, east of the main ultramafic belt. They lie within metavolcanic rocks of the Ordovician Orfordville Formation (Doll and others, 1961). There are several unconfirmed occurrences in a similar setting in adjacent New Hampshire (locality 177).

These occurrences lie at or near the Monroe fault; this fault forms the boundary between the Brompton-Cameron and Central Maine terranes, according to the maps of Rankin (1993) and Rankin and others (1993a).

Exploration: Talc-bearing ultramafic rocks are so abundant in Vermont that no preliminary exploration is necessary and matters of grade, quantity, accessibility, and ease of mining become paramount. Large reserves at several mines were noted by Chidester and others (1951). These include the Vermont and nearby quarries near Chester (locality 160), Hammondsville (164), Williams and Cushman Hill (166), Roxbury (167), Waterbury and Mad River (168), Sterling Pond and Rousseau (169), and Johnson (170). Some of these reserves will have been exhausted since, but undoubtedly much remains.

Eight soapstone quarries and two prospects are indicated on the New Hampshire mines and prospects map (Meyers and Stewart, 1955), and all but one are also shown by Pearre and Calkins (1957) and Chidester and Worthington (1962). However, none of these occurrences are shown on the appropriate geologic quadrangle maps except for the one near Francestown (Greene, 1970).

174. Richmond, Cheshire County -- This occurrence is either in the Ordovician Ammonoosuc Volcanics or the adjacent Late Proterozoic, Cambrian, or Ordovician Monson Gneiss (Moore, 1949; Zen and others, 1983). It is probably similar to the two occurrences located a short distance to the south in Massachusetts (localities 156 and 157).

Localities 174-176 are in the Central Maine terrane, far from any proposed suture, according to the maps of Rankin (1993) and Rankin and others (1993a).

175 . Francestown and Ferrin Pond, Hillsborough County -- I examined the Francestown soapstone quarry while mapping in the Peterborough quadrangle (Greene, 1970). The remaining soapstone is a talc-chlorite-phlogopite-actinolite schist; rosettes of talc as reported by Hitchcock (1878) were not found. Country rocks are mica schist and biotite granulite, mapped as the Peterborough Member of the Early Devonian Littleton Formation. However, more recent mapping, particularly that in the Hillsboro quadrangle which is adjacent to the north (Nielson, 1981), and in Massachusetts to the south (Zen and others, 1983), has cast doubt on the age and correlation of these rocks, which may actually be Ordovician or Silurian. There is no serpentinite present, and the presence of phlogopite, indicating substantial potassium content, is unusual. The deposit may have formed by the hydrothermal alteration of Mg-rich metasedimentary rocks, at lower temperatures during retrograde metamorphism.

Production: The U.S. Geological Survey's Mineral Resources of the U.S. series of volumes reports small production for New Hampshire from at least 1890-1900, probably from this locality.

Meyers and Stewart (1955) indicated a deposit near Ferrin Pond on the Hillsboro quadrangle, 3.5 mi north of the Francestown occurrence, in either the Crotched Mountain or Francestown Formations (Ordovician or

Silurian), as mapped by Nielson (1981). Deposits at localities 175 and 176 are in the Merrimack synclinorium (Billings, 1955).

176. Contoocook and Penacook, Merrimack County -- Meyers and Stewart (1955) indicate deposits near these towns, in schist of what was believed to be the Early Devonian Littleton Formation (Vernon, 1971; Honkala, 1960, unpub. mapping) but what may actually be Ordovician or Silurian rocks if the units mapped by Nielson (1981) were extended to the northeast.

177. Orfordville to Woodsville, Grafton County -- Meyers and Stewart (1955) indicated the presence of four deposits near Orfordville and one near Woodsville. The deposits are in or adjacent to a belt of Ordovician rocks which includes the Orfordville and Albee Formations as mapped by Hadley (1942) and Billings (1937) and the Ammonoosuc Volcanics. Their tectonic setting is similar to nearby deposits in Vermont (locality 173), and they may be of similar origin.

Exploration: New Hampshire does not appear to be a good bet for finding further talc deposits, owing to the lack of either ultramafic rocks or a favorable tectonic setting.

Maine

Talc deposits in Maine are confined to a small area in the west-central part of the state. All are on the north limb of the Lobster Mountain anticlinorium, a structure lying directly south of the Moose River synclinorium and the Chain Lakes massif (Osberg and others, 1985).

178. White Cap Mountain, Franklin and Oxford Counties -- Serpentinite, containing residuals of pyroxenite and peridotite, and metadiorite are present in a body 4 mi long whose western end underlies White Cap Mountain (Harwood, 1973). Layers of talc-carbonate rock are present, but not zoned relative to the margins of the body. Similar occurrences of mafic and ultramafic rocks extend 15 mi eastward from White Cap Mountain (Osberg and others, 1985). They are in either fault or intrusive contact with Cambrian metasedimentary and metavolcanic rocks on the south side and in fault contact with Precambrian gneiss of the Chain Lakes massif on the north side. Another serpentinite occurrence containing some talc-carbonate rock is located near Moosehorn, 11 mi north of White Cap Mountain.

This belt is at or near a fault separating the Chain Lakes block from the Central Maine terrane, according to the maps of Rankin (1993) and Rankin and others (1993a). The ultramafic rocks are likely to be ophiolite fragments.

179. Spencer Lake area, Somerset County -- Three lenticular serpentinite bodies, the largest 1.8 mi long, were mapped by Wing (1951) between Spencer Lake and Dead River. Talc-carbonate rock was seen in one of these and in other isolated outcrops. Boucot's (1969) map and report on the adjacent bedrock units ends at these ultramafic rocks and makes no mention of them. Osberg and others (1985) showed the serpentinites at or near a fault contact between Silurian and Devonian rocks to the north and Cambrian metasedimentary, metavolcanic, and diorite intrusive rocks to the south in the Lobster Mountain anticlinorium.

This locality is at or near a fault separating the Brompton-Cameron terrane from the Central Maine terrane, according to the maps of Rankin (1993) and Rankin and others (1993a).

The map of Larrabee (1971) shows additional serpentinite occurrences which extend the belt containing localities 178 and 179 both westerly to just beyond the New Hampshire line (shown on Billings, 1955) and easterly to West Forks, a total distance of 55 mi. Other ultramafic rocks shown by Larrabee (1971) include 1) a belt extending from near West Warren to Hope, Knox County, and 2) Deer Isle and Little Deer Isle, Hancock County.

Production: No production is reported for talc deposits in Maine.

Exploration: Further search for steatized parts of the belt of ultramafic bodies including White Cap Mountain may prove to be rewarding.

Figure 15. Geologic map of a part of the northwest Adirondack lowland showing the Balmat-Edwards and Natural Bridge talc districts. Geology after Fisher and others (1971); mine locations from USGS-MRDS data file.

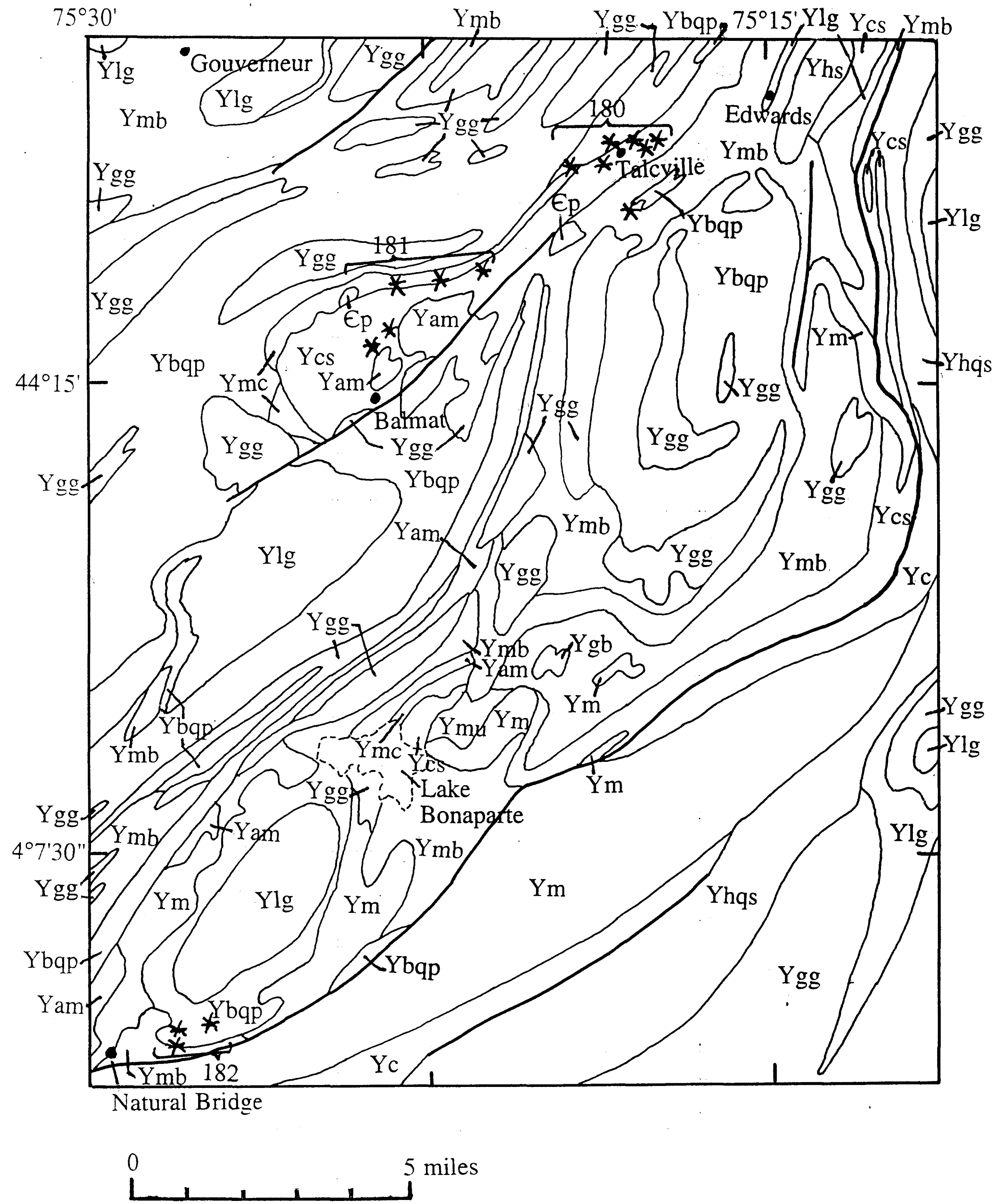
EXPLANATION

Cp	Potsdam Sandstone (Late Cambrian)
Ygb	Metagabbro (Middle Proterozoic)
Ybqp	Biotite-quartz-plagioclase gneiss (Middle Proterozoic)
Ycs	Marble and calc-silicate rock (Middle Proterozoic)
Ymb	Marble (Middle Proterozoic)
Ymu	Metasedimentary rocks, undivided (Middle Proterozoic)
Yhqs	Hornblende-quartz-syenite gneiss (Middle Proterozoic)
Yhs	Hornblende syenite gneiss (Middle Proterozoic)
Yc	Charnockite and related gneisses (Middle Proterozoic)
Ym	Mangerite and related gneisses (Middle Proterozoic)
Yam	Amphibolite (Middle Proterozoic)
Ygg	Granitic gneiss (Middle Proterozoic)
Ylg	Leucogranitic gneiss (Middle Proterozoic)
Ymc	Mangeritic to charnockitic gneiss (Middle Proterozoic)

contact fault talc mine

town

180 locality number keyed to text


75°30'
75°15'
44°15'
4°7'30"
Gouverneur
Edwards
Talcville
Balmat
Lake
Bonaparte
Natural Bridge
180
181
182
Ymb
Ygg
Ybqp
Ylg
Ycs
Yhs
Ym
Yhqs
Yam
Ymc
Ygb
Ymu
Yc
Єp
0
5 miles

at 7,150,000 tons through 1961 and 6,150,000 more to 1992 for a total of over 13.3 million tons.

180. Talcville area, St. Lawrence County -- Talc mines in eastern part of the Sylvia Lake-Cedar Lake marble belt.

181. Area north of Balmat, St. Lawrence County -- Talc mines in western part of the Sylvia Lake-Cedar Lake marble belt.

182. Natural Bridge district, Lewis County -- Talc mines in a similar marble belt.

183. Richville, St. Lawrence County -- An occurrence of talc-tremolite-anthophyllite schist overlying dolomitic marble is similar to that in the Balmat-Edwards district and is believed to have economic potential (Brown, 1969).

Exploration: While the main part of the district has probably been thoroughly explored, the entire Adirondack lowland from Potsdam to Carthage and west to the Thousand Islands appears to be a good bet for talc and other mineral deposits, and is shown as permissive on plate 1. See the Adirondack sheet of the Geologic map of New York (Fisher and others, 1971). Bands of marble and calc-silicate rocks occur throughout this area, and the occurrence near Richville shows that talc has been formed in at least one place which is distant from Gouverneur.

Wisconsin

184 Milladore, Wood County -- Soapstone deposit derived from ultramafic(?) rocks enclosed in Early Proterozoic metavolcanic rocks near the contact with Middle Proterozoic granitic rocks (King and Beikman, 1974). The locations of the pits are shown on pl. 1 in the report of Clayton (1991).

Production: At least two quarries operated here during the period 1929-1931. Total recorded production is 4,700 tons (U.S. Bureau of Mines Mineral Resources of the U.S. series)

Table 1. Summary of Deposit Locations and Characteristics

Number	Locality or Area	State	Geographic/Geologic Province
1	Western Paleozoic & Triassic	California	Klamath Mountains
2	Central metamorphic	California	Klamath Mountains
3	Trinity peridotite	California	Klamath Mountains
4	Josephine ophiolite	California	Klamath Mountains
5	Pickett Peak quadrangle	California	North Coast Ranges
6	Northernmost part	California	Sierra Nevada foothill belt
7	Central part	California	Sierra Nevada foothill belt
8	Coulterville area	California	Sierra Nevada foothill belt
9	Kings-Kaweah	California	Sierra Nevada foothill belt
10	Central part	California	Inyo Mtns-Panimint Range
11	Talc City	California	Inyo Mtns-Panimint Range
12	Big Pine and Eureka Valley	California	Inyo Mtns-Panimint Range
13	Panimint Rng to Silurian Hls	California	So. Death Valley-Kingston Rng
14	Silver Lake-Yucca Grove	California	So. Death Valley-Kingston Rng
15	Mt. Hamilton	California	Central-south Coast Ranges
16	Santa Catalina Island	California	Offshore islands
17	Boquet-Hauser Canyons	California	Transverse Ranges
18	Rand Mountains	California	Mojave Desert
19	Palmetto	Nevada	Great Basin
20	Sylvania	Nevada	Great Basin
21	Lodi Hills	Nevada	Great Basin
22	Western Paleozoic & Triassic	Oregon	Klamath Mountains
23	Western Jurassic belt	Oregon	Klamath Mountains
24	Roseburg to Brookings	Oregon	Coast Ranges
25	John Day to Snake River	Oregon	Aldrich and Blue Mountains
26	Mount Vernon	Washington	North Cascades
27	Marblemont	Washington	North Cascades
28	West of Entait	Washington	North Cascades
29	West of Leavenworth	Washington	North Cascades
30	West of Wenatchee Lake	Washington	North Cascades
31	North of Omak	Washington	North-central
32	East of Republic	Washington	North-central
33	Huckleberry Mountain	Washington	Northern Rocky Mountains
34	Spokane River	Washington	Columbia Basin
35	East of Davenport	Washington	Columbia Basin
36	Salmon River	Idaho	Northern Rocky Mountains
37	Dillon district	Montana	Northern Rocky Mountains
38	Teton Range	Wyoming	Central Rocky Mountains
38A	Southwest of Green River	Wyoming	Wyoming Basin
39	Northern Wind River Range	Wyoming	Central Rocky Mountains
40	South Pass, Wind River Range	Wyoming	Central Rocky Mountains
40A	West of South Pass	Wyoming	Central Rocky Mountains
41	Southeast of Lander	Wyoming	Central Rocky Mountains
42	South end of Bighorn Range	Wyoming	Central Rocky Mountains

Latitude, N	Longitude, E	Type	Development
41°25' to 42°00'	123°17' to 122°40'	ultramafic	occcurrences
40°35' to 40°42'	122°35' to 122°55'	ultramafic	occurrences, 1 mine
41°00' to 41°30'	123°00' to 122°15'	ultramafic	occcurrences
41°40' to 42°00'	124°05' to 123°45'	ultramafic	occcurrences
40°15' to 40°22'	122°23' to 122°29'	ultramafic	occcurrences
39°30' to 39°55'	121°30' to 120°55'	ultramafic	occurrences, 1 mine
38°00' to 38°45'	121°00' to 120°30'	ultramafic	prospects and mines
37°35' to 37°50'	120°20' to 119°55'	ultramafic	occcurrences
36°15' to 37°00'	119°30' to 119°05'	ultramafic	occcurrences
36°30' to 36°50'	118°07' to 117°25'	carbonate	occcurrences
36°20' to 36°22'	117°45' to 117°39	carbonate	prospects and mines
37°07'; 37°15'	118°24'; 117°55'	carbonate	prospects and mines
35°30' to 36°02'	116°57' to 115°49'	carbonate	prospects and mines
35°23' to 35°28'	116°03' to 115°46'	carbonate	prospects and mines
37°29'35"	121°49'20"	ultramafic	occurrence
33°28'	118°33'	ultramafic	mine
34°32' to 34°37'	118°24' to 118°15'	ultramafic	prospects and mines
35°18' to 35°23'	117°39' to 117°45'	unknown	prospects
37°26' to 37°30'	117°46' to 117°42'	carbonate	prospects and mines
37°24' to 37°28'	117°47' to 117°41'	carbonate	prospects and mines
39°00'	117°53'	unknown	prospect
42°00' to 42°50'	123°30' to 122°45'	ultramafic	occurrences, 1 mine
42°15' to 42°55'	123°48' to 123°15'	ultramafic	occcurrences
42°40' to 43°05'	124°05' to 123°15'	ultramafic	occcurrences
44°20' to 44°55'	118°55' to 117°10'	ultramafic	occcurrences
48°18' to 48°45'	122°23' to 121°40'	ultramafic	occurrences, 1 mine
48°27' to 48°40'	121°30' to 121°15'	ultramafic	prospects and mines
47°37' to 47°47	120°32' to 120°20'	ultramafic	occcurrences
47°35' to 47°40'	120°40' to 120°50'	ultramafic	occcurrences
47°45' to 48°05'	120°47' to 120°05'	ultramafic	occurrences, 1 mine
48°29'	119°36'	ultramafic	occurrence
48°36'45"	118°34'30"	ultramafic	occurrence
48°04'	118°00'	carbonate	prospect
47°54'	118°00'	carbonate	occurrence
47°20'	117°53'	carbonate	occurrence
45°20' to 45°27'	116°21' to 116°19'	ultramafic	occcurrences
45°03' to 45°33'	112°35' to 111°43'	carbonate	prospects and mines
43°32' to 43°55'	110°40' to 110°52'	ultramafic	mine, prospects
41°17'	109°58'	authigenic	occurrence
43°09' to 43°34'	109°48 to109°30'	ultramafic	occcurrences
42°33'	108°48'	ultramafic	occcurrences
42°33'	109°12'	ultramafic	prospect
42°32'	108°21'	ultramafic	occurrence
43°27'	107°28'	ultramafic	occurrence

43	South of Sheridan	Wyoming	Central Rocky Mountains
44	West of Hazelton Peak	Wyoming	Central Rocky Mountains
45	Casper Mountain	Wyoming	Southern Rocky Mountains
46	Laramie Mountains, north part	Wyoming	Southern Rocky Mountains
47	Laramie Mountains, central part	Wyoming	Southern Rocky Mountains
48	San Andres Mountains	New Mexico	Trans Pecos, Basin & Range
49	Allamore district	Texas	Trans Pecos, Basin & Range
50	Llano uplift	Texas	Central
51	Little Rock west	Arkansas	Ouachita Mountains

44°34'	106°58'	ultramafic	occurrence
44°06'	107°08'	ultramafic	occurrence
42°44'	106°20'	ultramafic	occurrence
42°37' to 42°45'	106°15' to 105°50'	ultramafic	occcurrences
41°52' to 42°04'	105°25' to 105°11'	ultramafic	occcurrences
32°56' to 32°57'	106°35'	carbonate	2 mines
31°03' to 31°11'	105°11' to 104°55'	carbonate	prospects and mines
30°25' to 30°39'	98°48' to 98°33'	ultramafic	prospects and mines
34°44'	98°36' to 98°33'	ultramafic	prospects and mines

Table 1, continued

Number	Locality or Area	State	Geographic/Geologic Province
52	Winterboro district	Alabama	Valley and Ridge
53	Dadeville district	Alabama	Piedmont
54	Delta	Alabama	Piedmont
55	La Grange	Georgia	Piedmont
56	Centralhatchee	Georgia	Piedmont
57	Soapstone Ridge	Georgia	Piedmont
58	Carrollton	Georgia	Blue Ridge
59	Holly Springs	Georgia	Blue Ridge
60	Chatsworth	Georgia	Blue Ridge
61	Murphy belt	Georgia	Blue Ridge
62	Laurel Creek-Beavert Mtn.	Georgia	Blue Ridge
63	Cody Creek	Georgia	Piedmont
64	Gladesville	Georgia	Piedmont
65	Burks Mountain	Georgia	Piedmont
66	Long Creek	South Carolina	Piedmont
67	Soapstone Hill	South Carolina	Piedmont
68	Fairview Church	South Carolina	Piedmont
69	Central	South Carolina	Piedmont
70	Norris Station	South Carolina	Piedmont
71	Cedar Springs	South Carolina	Piedmont
72	Pacolet Mills	South Carolina	Piedmont
73	North of Laurens	South Carolina	Piedmont
74	Tylersville	South Carolina	Piedmont
75	Southwest of Gaffney	South Carolina	Piedmont
76	Northwest of Lockhart	South Carolina	Piedmont
77	Halseville	South Carolina	Piedmont
78	Southeast of Chester	South Carolina	Piedmont
79	Nation Ford	South Carolina	Piedmont
80	West of Catawba Junction	South Carolina	Piedmont
81	Edgemoor	South Carolina	Piedmont
82	South of Edgefield	South Carolina	Piedmont
83	Murphy belt	North Carolina	Blue Ridge
84	Elf	North Carolina	Blue Ridge
85	Norton-Elijay	North Carolina	Blue Ridge
86	Saphire-Black Mountain	North Carolina	Blue Ridge
87	Webster-Balsam	North Carolina	Blue Ridge
88	Canton-Day Brook	North Carolina	Blue Ridge
88A	Sandymush-Ramseytown	North Carolina	Blue Ridge
89	South Toe River-Spruce Pine	North Carolina	Blue Ridge
90	Boone-Sparta	North Carolina	Blue Ridge
91	Ferguson to Millers Creek	North Carolina	Blue Ridge
92	Newton	North Carolina	Piedmont
93	Turnersburg	North Carolina	Piedmont
94	Callahan	North Carolina	Piedmont

New York

The Balmat-Edwards, or Gouverneur, district in northern New York has been one of the leading talc producers in the United States. It is located in a lowland between the northwest flank of the Adirondack highlands and the St. Lawrence River, which is part of the Frontenac axis joining the Precambrian rocks of the Adirondack Mountains to those of the Canadian shield. The lowland is underlain by a complexly folded sequence of Middle Proterozoic metamorphic rocks, mostly gneiss, amphibolite, marble, and calc-silicate rocks of amphibolite to granulite metamorphic grade, that have been intruded by rocks that are now granitic and charnockitic gneisses (Fisher and others, 1971). The predominant strike of fold axes is northeast.

The talc deposits are mostly in the Sylvia Lake-Cedar Lake marble belt, which consists of a sequence of dolomitic marble (most of which is partly converted to silicate minerals), actinolite schist; and rusty, pyritic, and quartzitic marbles (Engel, 1962). Metamorphic minerals in the marble include forsterite (rare), diopside, tremolite, anthophyllite, serpentine, and talc. Migmatitic gneisses both overlie and underlie the marble belt. Talc is believed to have been formed by hydrothermal metasomatism of dolomitic marble and quartzitic interbeds. In the talc-bearing zones, abundant tremolite was formed early; decreasing temperatures resulted in the formation of anthophyllite, serpentine, and talc, generally in that order, and deposition of quartz and calcite. Serpentine and talc concentrated in zones of shearing and were subject to later brittle deformation.

The product produced from this district is a talc-tremolite mixture, which runs from 25% to 75% talc. The area is also an important zinc mining district, with byproduct lead. At several localities, talc and zinc deposits are adjacent, and the age of hydrothermal sulfide mineralization is the same as that which resulted in in talc formation (Engel, 1962, p. 325). Pyrite and pyrrhotite were produced from the district early in this century.

The general distribution of rock types and the location of talc mines for localities 180-182 are shown in figure 15 (Fisher and others, 1971; Engel, 1962; Gilluly, 1945).

Production: Chidester and others (1964) estimated production from this district at 6,500,000 tons through 1961. Production figures are not available after 1954; however, based on production for earlier years and mixed totals in the USBM Minerals Yearbook series, I estimate production

95	Bayleaf	North Carolina	Piedmont
96	Troutdale	Virginia	Blue Ridge-Western Piedmont
97	South of Galax	Virginia	Blue Ridge-Western Piedmont
98	Henry	Virginia	Blue Ridge-Western Piedmont
99	Floyd	Virginia	Blue Ridge-Western Piedmont
100	Northeast of Axton	Virginia	Blue Ridge-Western Piedmont
101	West of Swansonville	Virginia	Blue Ridge-Western Piedmont
102	Fork Mountain-Ajax	Virginia	Blue Ridge-Western Piedmont
103	Worlds-Redeye	Virginia	Blue Ridge-Western Piedmont
104	Otter River	Virginia	Blue Ridge-Western Piedmont
105	Grassy Hill	Virginia	Blue Ridge-Western Piedmont
106	Jacks Mountain	Virginia	Blue Ridge-Western Piedmont
107	Brier Mountain	Virginia	Blue Ridge-Western Piedmont
108	Bedford County south	Virginia	Blue Ridge-Western Piedmont
109	Lynchburg	Virginia	Blue Ridge-Western Piedmont
110	Nelson-Amherst	Virginia	Blue Ridge-Western Piedmont
111	Schuyler-Charlottesville	Virginia	Blue Ridge-Western Piedmont
112	Western Orange County	Virginia	Blue Ridge-Western Piedmont
113	Uno-Fordsville	Virginia	Blue Ridge-Western Piedmont
114	Cullen	Virginia	Central volcanic-plutonic
115	Tabscott	Virginia	Central volcanic-plutonic
116	Lunenburg	Virginia	Carolina slate belt
117	Walnut Creek	Virginia	Carolina slate belt
118	Jetersville-Winterham	Virginia	Carolina slate belt
119	Buckingham county	Virginia	Western Piedmont
120	Solitude Plantation	Virginia	Western Piedmont
121	Mineral	Virginia	Western Piedmont
122	Rhoadesville	Virginia	Western Piedmont
123	North of Stafford	Virginia	Western Piedmont
124	Fairfax	Virginia	Western Piedmont
125	North of Burke	Virginia	Western Piedmont
126	North of Fairfax	Virginia	Western Piedmont
127	Falls Church-Annandale	Virginia	Western Piedmont
128	Fort Baylor Park	Dist Columbia	Piedmont
129	Muddy Branch	Maryland	Piedmont
130	Ednor	Maryland	Piedmont
131	West of Baltimore	Maryland	Piedmont
132	Marriottsville-Henryton	Maryland	Piedmont
133	Soldiers Delight	Maryland	Piedmont
134	Rocks-Chrome Hill	Maryland	Piedmont
135	Scarboro-Dublin	Maryland	Piedmont
136	Bald Friar-Schofield	Maryland	Piedmont
137	Octoraro-Pilot Station	Maryland	Piedmont
137A	Rocks Church	Pennsylvania	Piedmont
138	Embreeville	Pennsylvania	Piedmont
139	West Chester	Pennsylvania	Piedmont
140	Philadelphia	Pennsylvania	Piedmont

35°54' to 36°05'	78°42' to 78°35' *	ultramafic	occurrences
36°42'	81°25'	ultramafic	occurrence
36°33' to 36°40'	80°58' to 80°50' *	ultramafic	occurrences
36°49'45"	79°59'30"	ultramafic	mine
36°52' to 36°55'	80°20' to 80°10'	ultramafic	prospects and mines
36°41'00"	79°40'20"	ultramafic	occurrence
36°44'25"	79°36'55"	ultramafic	occurrence
36°50' to 36°57'	79°54' to 79°35' *	ultramafic	occurrences
36°50' to 36°55'	79°35' to 79°29' *	ultramafic	occurrences
37°10' to 37°18'	79°20' to 79°00' *	ultramafic	occurrences and mine
37°00'	79°55'	ultramafic	occurrences
36°57'	79°43'	ultramafic	occurrences
36°54'	79°54'	ultramafic	occurrences
37°05' to 37°15'	79°40' to 79°20' *	ultramafic	occurrences
37°18' to 37°30'	79°17' to 79°03' *	ultramafic	occurrences
37°30' to 37°46'	79°03' to 78°43' *	ultramafic	prospects and mines
37°46' to 38°03'	78°43' to 78°30' *	ultramafic	prospects and mines
38°10' to 38°15'	78°20' to 78°10' *	ultramafic	occurrences
38°15' to 38°25'	78°16' to 78°05' *	ultramafic	occurrences
37°07'	78°38'	ultramafic	occurrence
37°51'	78°05'	ultramafic	occurrences and prospect
36°52'	78°24'	ultramafic	occurrence
37°18'	78°12'	ultramafic	occurrences
37°23'	78°02'	ultramafic	prospects and mines
37°28' to 37°43'	78°42' to 78°28' *	ultramafic	occurrences
37°51'12"	78°16'48"	ultramafic	occurrences and mine
37°57' to 38°07'	78°12' to 78°05' *	ultramafic	occurrences
38°08 to 38°22'	78°02' to 77°47' *	ultramafic	occurrences
38°32'	77°28'	ultramafic	occurrence
38°48' to 38°50'	77°25' to 77°21'	ultramafic	occurrences and prospects
38°48'30"	77°14'25"	ultramafic	occurrence
38°53' to 39°03'	77°20' to 77°16'	ultramafic	occurrences and mines
38°48' to 38°58'	77°09' to 79°13'	ultramafic	occurrences
38°57'	77°06'	ultramafic	occurrence
39°04' to 39°08'	77°18' to 77°14' *	ultramafic	occurrences and prospect
39°08'	76°58'	ultramafic	occurrence
39°16' to 39°22'	76°53' to 76°44' *	ultramafic	occurrences
39°21' to 39°22'	77°01' to 76°54' *	ultramafic	occurrences and mines
39°23' to 39°27'	77°52' to 77°49'	ultramafic	occurrences
39°37'30"	77°24'40"	ultramafic	mine
33°38.5' to 38°39.7'	77°18.7' to 77°15.8'	ultramafic	occurrences and mines
38°42' to 38°43'	77°12' to 77°10'	ultramafic	mines
39°41'20"	76°12'00"	ultramafic	occurrences
39°42'30"	76°07'00"	ultramafic	
39°42'53"	76°09'44"	ultramafic	prospect
39°56'20"	75°42'30"	ultramafic	prospect
39°56'50"	75°36'20"	ultramafic	occurrence
40°03.0' to 40°03.3'	75°16.2' to 75°15.5'*	ultramafic	prospects and mines

141	Easton	Pennsylvania	Valley and Ridge
142	North of Phillipsburg	New Jersey	Valley and Ridge
143	Wilton	Connecticut	Conn Valley Synclinorium
144	East Litchfield-New Hartford	Connecticut	Conn Valley Synclinorium
145	Maltby Lakes	Connecticut	Conn Valley Synclinorium
146	Limerock	Rhode Island	Milford-Dedham Zone
147	Dalton	Massachusetts	Green Mountain Anticlinorium
148	Granville	Massachusetts	Green Mountain Anticlinorium
149	Granville Cntr-Little River	Massachusetts	Green Mountain Anticlinorium
150	Blandford	Massachusetts	Green Mountain Anticlinorium
151	Middlefield	Massachusetts	Green Mountain Anticlinorium
152	E Windsor -W Cunningham	Massachusetts	Green Mountain Anticlinorium
153	Savoy	Massachusetts	Green Mountain Anticlinorium
154	Drury-Hoosac tunnel	Massachusetts	Green Mountain Anticlinorium
155	Rowe	Massachusetts	Green Mountain Anticlinorium
156	Soapstone Hill	Massachusetts	Bronson Hill Anticlinorium
157	Tully Mountain	Massachusetts	Bronson Hill Anticlinorium
158	E Dover-W Marlborough	Vermont	Townshend-Brnington Syncline
159	Townshend-Athens	Vermont	Chester-Athens Domes
160	Windham	Vermont	Townshend-Brnington Syncline
161	Chester-Gassetts	Vermont	Chester-Athens Domes
162	Middletown	Vermont	Townshend-Brnington Syncline
163	Ludlow	Vermont	Green Mountain Anticlinorium
164	Hammondsville	Vermont	Green Mountain Anticlinorium
165	Bridgewater	Vermont	Green Mountain Anticlinorium
166	Rochester	Vermont	Green Mountain Anticlinorium
167	Granville-Warren	Vermont	Green Mountain Anticlinorium
168	Mad River	Vermont	Green Mountain Anticlinorium
169	Sterling Pond-Waterville	Vermont	Green Mountain Anticlinorium
170	Johnson	Vermont	Green Mountain Anticlinorium
171	Montgomery	Vermont	Green Mountain Anticlinorium
172	Belvidere Mountain	Vermont	Green Mountain Anticlinorium
173	Thetford-Norwich	Vermont	Bronson Hill Anticlinorium
174	Richmond	New Hampshire	Bronson Hill Anticlinorium
175	Francestown-Ferrin Pond	New Hampshire	Merrimack Synclinorium
176	Contoocook-Penacook	New Hampshire	Merrimack Synclinorium
177	Orfordville-Woodsville	New Hampshire	Bronson Hill Anticlinorium
178	White Cap Mountain	Maine	Moose River Synclinorium
179	Spencer Lake	Maine	Moose River Synclinorium
180	Talcville	New York	NW Adirondack lowland
181	Balmat	New York	NW Adirondack lowland
182	Natural Bridge	New York	NW Adirondack lowland
183	Richville	New York	NW Adirondack lowland
184	Miladore	Wisconsin	Superior province

*Localities are in strike belt
First lat and long = SW end
Second lat and long = NE end

	Table 2	Talc Production by States	thousands of short tons
State	Year, first production(1)	Year, last production(2)	Total reported production(3)
California	1855	1994	6,033
Nevada	1930	1980	300
Washington	1940	1986	150
Montana	1946	1994	8,700
New Mexico	1926	1945	10
Texas	1946	1994	8,880
Arkansas	1953	1993	120
Alabama	1917	1991	130
Georgia	1883	1990	2,000
North Carolina	1859	1991	300
Virginia	1900	1994	2,000
Maryland	1852	1985	760
Pennsylvania	1780	1970	250
Rhode Island		1910	small
Massachusetts	1800	1922	100
Vermont	1905	1994	10,800
New Hampshire	1890	1900	small
New York	1878	1994	13,300
Wisconsin	1929	1931	5

(1) Some of these figures are approximate
(2) 1994 is last year for which data are included. Some of these figures are approximate
(3) These figures are in part reported amounts and in part estimates.

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