Chromite and Other Mineral Deposits in Serpentine Rocks Of the Piedmont Upland Maryland, Pennsylvania And Delaware

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The geology, distribution, production, and mining development of deposits of chromite, titaniferous iron ore, rutile, talc, asbestos, magnesite, sodium-rich feldspar, corundum, and serpentine

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CHROMITE AND OTHER MINERAL DEPOSITS IN SERPENTINE ROCKS OF THE PIEDMONT UPLAND, MARYLAND, PENNSYLVANIA, AND DELAWARE

By Nancy C. Pearre and Allen V. Heyl, Jr.

ABSTRACT

The Piedmont Upland in Maryland, Pennsylvania, and Delaware is about 160 miles long and at the most 50 miles wide. Rocks that underlie the province are the Baltimore gneiss of Precambrian age and quartzite, gneiss, schist, marble, phyllite, and greenstone, which make up the Glenarm series of early Paleozoic (?) age. These are intruded by granitic, gabbroic, and ultramafic igneous rocks. Most of the ultramafic rocks, originally peridotite, pyroxenite, and dunite, have been partly or completely altered to serpentine and talc; they are all designated by the general term serpentine. The bodies of serpentine are commonly elongate and conformable with the enclosing rocks. Many have been extensively quarried for building, decorative, and crushed stone. In addition, chromite, titaniferous magnetite, rutile, talc and soapstone, amphibole asbestos, magnesite, sodium-rich feldspar (commercially known as soda spar), and corundum have been mined or prospected for in the serpentine.

Both high-grade massive chromite and lower grade disseminated chromite occur in very irregular and unpredictable form in the serpentine, and placer deposits of chromite are in and near streams that drain areas underlain by serpentine. A group of unusual minerals, among them kämmererite, are typical associates of high-grade massive chromite but are rare in lower grade deposits.

Chromite was first discovered in the United States at Bare Hills, Md., around 1810. Between 1820 and 1850, additional deposits were discovered and mined in Maryland and Pennsylvania, including the largest deposit of massive chromite ever found in the United States—the Wood deposit, in the State Line district. A second period of extensive chromite mining came during the late 1860's and early 1870's.

Production figures are incomplete and conflicting. Estimates from the available data indicate that the aggregate production from 27 of 40 known mines before 1900 totaled between 250,000 and 280,000 tons of lode-chromite ore; information is lacking for the other 13. Placer deposits produced considerably more than 15,000 tons of chromite concentrates. Exploratory work in several of the mines and placer deposits during World War I produced about 1,500 long tons of chromite ore, 920 tons of which was sold.

Most of the chromite from Maryland and Pennsylvania was used to manufacture chemical compounds, pigments, and dyes before metallurgical and refractory uses for chromite were developed. Available analyses of the ores indicate that

they would satisfy modern requirements for chemical-grade chromite. With the exception of such deposits as the Line Pit and Red Pit mines, the chromite contains too much iron for the best metallurgical grade, but many would be satisfactory low-grade metallurgical chromite. Perhaps 30,000 to 50,000 tons of chromite concentrates that would range from 30 to 54 percent Cr_2O_3 could be obtained from placer deposits in the State Line and Soldiers Delight districts. A small tonnage of chromite remains in dumps at six of the old mines. Lode and placer deposits in the Philadelphia district, placers in Montgomery County, Md., and possible downward extensions of known ore bodies below the floors of high-grade mines now flooded have not been completely explored. Although other chromite deposits probably lie concealed at relatively shallow depths, no practical method of finding them has been developed.

Small deposits of titaniferous iron ore in serpentine were mined for iron before 1900, but the titanium content troubled furnace operators. Ore bodies are similar in occurrence to chromite deposits; they are massive or disseminated and are found near the edges of serpentine intrusive rocks. The small size of the deposits and comparatively low titanium content limit their importance as a potential source of titanium.

A single rutile deposit in Harford County, Md., has been prospected but not mined. Pockets in schistose chlorite rock, probably altered from pyroxenite, contain as much as 16 percent rutile and average 8 percent. Rutile-bearing rock has been proved to a depth of about 58 feet.

Talc and soapstone deposits that have been worked in the State Line and Jarrettsville-Dublin districts are the result of steatitization of serpentine at its contact with intrusive sodium-rich pegmatites. Deposits in the Marriottsville and Philadelphia districts seem to be related to shear or crush zones in the serpentine, which served as channelways for steatitizing solutions. Massive soapstone was extensively used in the 19th century for furnace, fireplace, and stove linings and for washtubs and bathtubs. Every year from 1906 until 1960 talc and soapstone have been produced from one or more of the deposits in Maryland and Pennsylvania. Deposits near Dublin and Marriottsville, Md., have produced steadily for years and production continues. Lava-grade steatite from Dublin, Md., is manufactured into ceramic products for electrical and refractory purposes.

Slip-fiber amphibole asbestos deposits were known in the area as early as 1837, but early production was limited. The product was used mostly for linings of safes, boiler covers, and paints. During World War I the demand for domestic asbestos for chemical filters led to further development of deposits in Maryland. Between 1916 and 1940 many small veins of good-quality tremolite and anthophyllite were mined, and the fiber was prepared for market at Woodlawn, Md. Only the upper parts of veins, softened by weathering, were usable. Because prospecting was reportedly fairly thorough and known deposits are said to be mined out, and because demand for amphibole asbestos is limited, the possibility of future asbestos production from the area seems small, except as a byproduct of talc quarrying.

Magnesite from several mines in Pennsylvania and Maryland was much in demand between 1828 and 1871 for the manufacture of epsom salt. Exploratory work at the old Goat Hill mines in 1921 indicated that the product could not be profitably prepared for market at that time. Although reportedly high grade, the magnesite veins are thin and small in comparison with other domestic deposits.

Sodium-rich feldspar and corundum deposits occur in pegmatites that are unusual because they characteristically contain little or no quartz and mica and because, insofar as known, they are confined to serpentine rocks. Many of the known deposits of sodium-rich feldspar—commercial soda-spar—are reportedly mined out. It is possible, however, that other commercial deposits will be found in the area.

At various times from 1825 until about 1892 in Pennsylvania, corundum mined or found at the surface was used to meet a demand of the abrasives industry. The increased use of artificial abrasives has diminished the demand for natural corundum, and interest in the small, irregular Pennsylvania deposits is at present largely historical or mineralogical.

INTRODUCTION

The geologic province known as the Piedmont Upland is a northeast-trending belt of ancient metamorphosed rocks that persists from Alabama to Trenton, N.J. In Maryland, Pennsylvania, and Delaware the province is about 160 miles long and at the most 50 miles wide, extending northeastward from the Potomac River through Philadelphia, Pa., to a point across the Delaware River from Trenton, N.J. (fig. 65). The Fall Line marks its southeastern boundary,

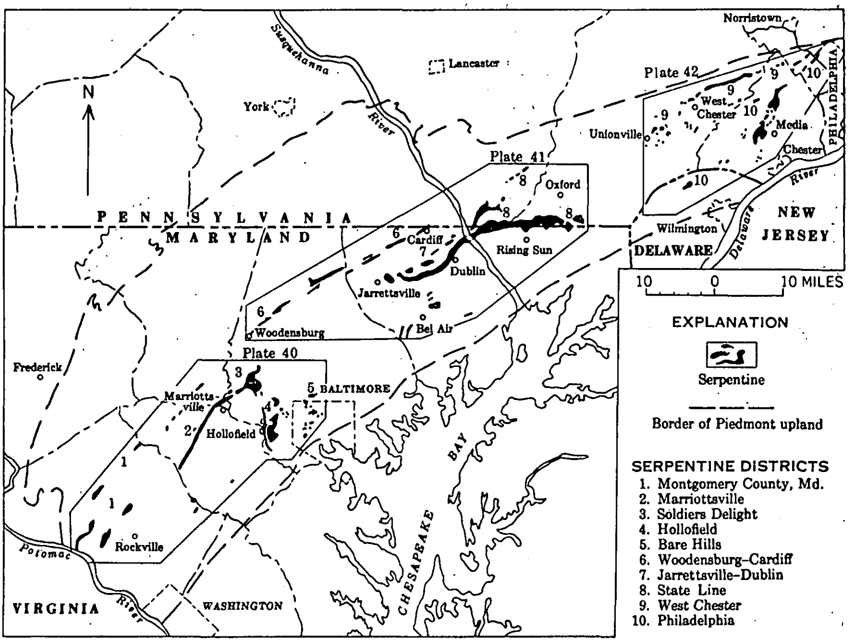

FIGURE 65.—Index map of the Piedmont Upland in Maryland, Pennsylvania, and Delaware, showing serpentine districts.

where Tertiary sediments of the Coastal Plain overlie the older metamorphosed rocks of which the province is composed. Along this boundary are situated the seaboard cities of Washington, Baltimore, Wilmington, Chester, and Philadelphia. On the northwest the Piedmont Upland is bordered by relatively lower land underlain by marble of early Paleozoic age and crystalline limestone of the Frederick, Lancaster, and Chester Valleys and by conglomerate, sandstone, and shale of Triassic age.

The Piedmont Upland is underlain by the crystalline Baltimore gneiss of Precambrian age and by quartzite, schist, gneiss, marble, phyllite, and greenstone constituting the various formations in the Glenarm series of early Paleozoic(?) age. Intrusive into these is a group of igneous rocks including granite, quartz monzonite, quartz diorite, gabbro, and norite, as well as the ultramafic rocks peridotite and pyroxenite, which have been more or less altered to serpentine or talc and are grouped in this report under the general name "serpentine." Pegmatites and dikes of Triassic diabase cut the rocks of both groups.

Topographically, the Piedmont Upland in Maryland, Pennsylvania, and Delaware is characterized by rolling hills with gentle slopes, except along the major streams, where rejuvenation has produced comparatively steep-walled valleys that cut across the trend of the underlying rocks. Maximum relief in parts of the upland where serpentine rocks occur is about 300 feet, and the maximum altitude is about 700 feet above sea level.

Areas underlain by serpentine have a physical appearance that contrasts markedly with the fertile farmland prevalent in other parts of the Piedmont Upland. Such areas, locally termed the "serpentine barrens," are wild, desolate, and uncultivated. Soils formed from the decomposition of serpentine are rich in magnesia and correspondingly poor in lime and potash; they are typically thin and therefore unable to retain moisture. In places such soils support practically no vegetation except grasses and are truly barren; elsewhere, scrub pines and cedars thrive, and greenbrier grows in profusion, making penetration extremely difficult.

SCOPE OF REPORT

The serpentine areas in the Piedmont Upland are now generally considered unimportant for mineral deposits, but this has not always been true. Numerous successful mining and quarrying operations have flourished within their boundaries at various times in the past; some have stood the test of time and continue as steady producers today.

In this report attention is focused on the mineral deposits that occur in these serpentine areas, including chromite, titaniferous magnetite, rutile, talc and soapstone, amphibole asbestos, magnesite, sodium-rich feldspar, and corundum. The serpentine rocks themselves have been of considerable commercial value for building, decorative, and crushed stone. Their economic geology, therefore, also comes within the scope of this work. The report is based mostly on extensive library and office research carried on intermittently during the years 1953 to 1956. Compilation was supported where possible by field examination of localities and by some mine and reconnaissance mapping.

The work was undertaken for a two-fold purpose. First, no reasonably accurate picture of the former worth of the mineral deposits found in the area is readily available, as the data are scattered through many published and unpublished references, some of them obscure. Further, a reasonably complete account of past operations and present indications will be necessary for intelligent planning of future work involving the deposits.

The report includes a general discussion of the occurrence of serpentine rocks in the area insofar as studied to date and a résumé of the various mineral deposits associated with them, followed by a more detailed economic account of each commodity and descriptions of each producing locality, arranged in geographic order from southwest to northeast. Chromite has been stressed over the other mineral deposits because it is a strategic mineral of growing importance and dwindling supply, our domestic reserves of which are far from adequate for our needs, and because the deposits in Maryland and Pennsylvania were at one time extremely important and have since been the object of repeated interest. Details of the eventful history of chromite mining in the area are recounted in another report by the writers (Pearre and Heyl, 1959) and a more detailed account of corundum mining in Pennsylvania has been published separately (Pearre, 1958).

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COMPOSITION AND DISTRIBUTION OF SERPENTINE

Ultramafic rocks are igneous rocks composed principally of one or more of the common magnesium-iron silicate minerals olivine, pyroxene, and, less commonly, amphibole. Feldspar, if present at all, is a very minor component. A rock consisting essentially of olivine is called a dunite; of pyroxene, a pyroxenite. The name "peridotite" is applied to rocks that contain both olivine and pyroxenite; several varieties of peridotite are recognized, depending on mineral composition.

The dunite, peridotite, and pyroxenite that occur in the Maryland-Pennsylvania-Delaware Piedmont have, for the most part, been subjected to the complex process of serpentinization and are therefore partly or completely altered from their original composition. Locally the rocks have been further changed, or steatitized, to form deposits of soapstone and relatively pure talc. Geologists who have mapped in the area have tended not to differentiate the rock types, but to group partly altered dunite, peridotite, and pyroxenite together with their serpentinized and steatitized equivalents under the general name "serpentine." This usage has been followed by the writers.

Bodies of serpentine are numerous throughout the length of the Piedmont Upland. To facilitate discussion of the mineral deposits, the serpentine bodies in Maryland, Pennsylvania, and Delaware have been arbitrarily grouped into 10 districts (fig. 65), which correspond generally to local concentrations of mines and quarries. Most of the serpentine bodies are fairly small. In general, they are elongate parallel to the regional northeasterly trend and are conformable with the enclosing rocks. Such ultramafic intrusive rocks are a recognized association of fold mountains such as the

Appalachians. Originating deep in the earth's crust, they were injected and squeezed upward into the central axial zone of the folded belt, probably during the first great deformation (Hess, 1948, p. 432), and were subsequently deformed along with their enclosing rocks.

ASSOCIATION OF SERPENTINE WITH OTHER IGNEOUS ROCKS

Most of the larger serpentine bodies throughout the Piedmont Upland in Maryland, Pennsylvania, and Delaware seem to be part of a group of plutonic igneous rocks that intrude mica schists and Precambrian gneisses in the eastern and southeastern sections of the province (pls. 40–42). The Hollofield and Bare Hills serpentine districts in Maryland (pl. 40) and the serpentines of the Philadelphia and West Chester districts in Pennsylvania (pl. 42) are closely associated with large masses of gabbro and occur along the periphery of the gabbro. The single body of serpentine in Delaware (pl. 42) is likewise very near a large mass of gabbro.

The State Line and Jarrettsville-Dublin districts (pl. 41) are the northwesternmost part of an extensive sequence of intrusive rocks, which Florence Bascom (1902, p. 110–113) describes from southeast to northwest as follows: Biotite-quartz monzonite, containing dikes of metarhyolite; hornblende-quartz monzonite; quartz-biotite-hornblende gabbro; quartz-hornblende gabbro; hornblende norite and quartz norite; norite and hypersthene gabbro; pyroxenite and peridotite. Bascom interprets these as the differentiation products of a single magma. H. H. Hess (*in* Sampson, 1942, p. 124) considers the ultramafic belt to be a line of separate intrusions not directly related to the gabbroic rocks, because it diverges from them in the southwestern part of the belt (pl. 41) and because of a notable lack of banded structural features in the ultramafic rocks. This igneous sequence southeast of the State Line district and its Harford County extension is not duplicated elsewhere in Maryland and Pennsylvania, and the other serpentine bodies are less extensive, discrete intrusions.

As mapped, the serpentine bodies in Montgomery County, Md. (pl. 40) and the Woodensburg-Cardiff district (pl. 41) have no surface contact with other igneous rocks. The same is true of the Soldiers Delight and Marriottsville serpentines (pl. 41), except that a very small area of gabbroic rocks separates the two districts. However, the serpentines of Soldiers Delight and Marriottsville are near, and the serpentines of Montgomery County are somewhat near, to an extensive belt of granitic rocks; and the Montgomery County serpentines crop out near a group of small bodies mapped as "undifferentiated basic rocks" (Cloos and Cooke, 1953).

GENERAL GEOLOGY OF THE SERPENTINE DISTRICTS

MONTGOMERY COUNTY, MD.

The serpentine bodies in Montgomery County, Md. (fig. 65), are not at all well known, and published geologic maps disagree considerably as to the extent and even the existence of some. Plate 40 shows the serpentine as mapped by Ernst Cloos (Cloos and Cooke, 1953), along with the unmapped Etchison serpentine body, in which chromite deposits are known to occur. All intrude schist of the Wissahickon formation.

The serpentine has not been described in detail. Where quarried west of Rockville (loc. 1, pl. 40) it is described as serpentinized gabbro, and the distribution of numerous small bodies of gabbroic rocks in the area between Gaithersburg and Etchison suggests that some of the serpentine nearby may likewise be derived from gabbro.

SOLDIERS DELIGHT AND MARRIOTTSVILLE DISTRICTS

In western Baltimore County, Md., between Owings Mills and the North Branch of the Patapsco River, is the Soldiers Delight serpentine district (pl. 40). A long, narrow belt of serpentine separated from the Soldiers Delight district by a small area of gabbroic rocks continues southwestward as the Marriottsville district, crossing the southeast corner of Carroll County and the entire width of Howard County (fig. 65 and pl. 40). The surrounding rocks are quartzite and schist of the Wissahickon and Peters Creek formations. Most of the serpentine in the Soldiers Delight district is altered peridotite. According to Knopf and Jonas (1929a, p. 116, 122), the original rock type was lherzolite, which consists of olivine, orthorhombic pyroxene, and monoclinic pyroxene; however, the original constituents are no longer easily recognizable. The serpentine is typically bluish black and massive. Jointing is well developed. Near Holbrook in the southwest corner of the district, the rock is apparently altered pyroxenite; it grades southwestward into metagabbro and then back into serpentinized pyroxenite.

Serpentine in the Marriottsville district is reported to be almost completely altered pyroxenite (Stose and Stose, 1946, p. 90). Its borders are soapstone or talc schist and chlorite schist. It trends about N. 40° E., forming a characteristic ridge thinly covered with soil and strewn with serpentine boulders. On the southeast side the serpentine dips 30° to 35° NW., and on the northwest side the dip is steeper, in the same direction.

HOLLOFIELD DISTRICT

The Hollofield serpentine district is southeast of the Soldiers Delight district in Baltimore County, Md., along the east and northeast sides of the Patapsco River west of Baltimore city (fig. 65 and pl. 40). The area, underlain by several discontinuous serpentine bodies surrounded by gabbro, is about 6 miles long and 3½ miles wide. It is in the western part of a large gabbroic intrusion bordered on the north and west by paraschist. The ultramafic rocks, only partly serpentinized, are both pyroxenite and peridotite, pyroxenite predominating (Jonas and others, 1925). They are described by Williams (1886, p. 50–59; 1890) and Knopf and Jonas (1929a, p. 116, 119–121), from whose work the following information is abstracted.

The typical pyroxenite is medium- to coarse-grained grayish-green websterite, with a silky luster. It is composed of orthorhombic pyroxene (hypersthene or bronzite) and monoclinic pyroxene (diallage or other varieties of diopside). The peridotite is typically dense fibrous greenish-black lherzolite, made up of bronzite, diallage, and olivine. Locally a few small white crystals of plagioclase feldspar (bytownite) are reported, nowhere constituting more than 5 percent of the rock. A pseudoporphyritic texture in the peridotite consists of crystals of pyroxene in a dense groundmass of serpentinized olivine.

BARE HILLS DISTRICT

The Bare Hills serpentine district is a small oval area about 3 miles north of the Baltimore city line (pl. 40). It it at the northeastern edge of the same large gabbroic mass in which lie the Hollofield serpentines, but it is not completely enclosed by the gabbro; on two sides it is in contact with mica schist. The serpentine mass is about a mile and a quarter long and a half a mile wide.

The serpentine at Bare Hills is described by Knopf and Jonas (1929a, p. 116, 122) as originally peridotite of the type lherzolite. According to them, it has been almost completely serpentinized and is now typically a bluish-black massive rock containing original olivine and bronzite in a matrix of blue-green serpentine. Williams (1886, p. 57), however, describes thin sections of serpentine from Bare Hills, in some of which he found traces of diallage (a monoclinic pyroxene) but in most of which the pyroxenes were completely altered to amphibole in a serpentine matrix.

The serpentine at Bare Hills is well jointed, and the joints show slickensides, commonly with coatings of bright-green williamsite (a variety of serpentine) or seams of white magnesite a quarter of an inch to half an inch thick. Near the center of the serpentine mass, east of Falls Road, the rock has been further altered to ferruginous white soapstone.

WOODENSBURG-CARDIFF DISTRICT

The several long, narrow serpentine bodies that are included in the Woodensburg-Cardiff district (fig. 65) trend about N. 65° E. in a discontinuous line for a distance of 30 miles, crossing Baltimore and Harford Counties, Md., and ending just north of the State Line at Delta, York County, Pa. (pl. 41). The Baltimore County part of the district has been described by Knopf and Jonas (1929a, p. 116–117, 122–123) and the Harford County part by Johannsen (1928, p. 276–280, 284–285).

The rocks, which intrude mica schist, vary from massive bluish-black serpentine, through typical dark- and light-green serpentine containing some magnetite, to green chlorite schist and white talc schist. Soapstone and talc are abundant and are generally iron stained. At Cardiff the rock is verde antique, a dark-green massive serpentine veined with white carbonate minerals. From Woodensburg to Yeoho, although mapped as serpentine, it is described by Knopf and Jonas as hornblende gneiss, and Johannsen found some similar hornblende rock in the serpentine area north of Federal Hill.

The little evidence available suggests different original rock types for the individual masses, most of which have been completely altered to serpentine or soapstone. Johannsen found indications that the massive serpentine body at Cardiff may have been dunite originally. He interprets the two bodies north of Federal Hill as the alteration products of either pyroxenite or pyroxene-rich gabbro, and similarly, Knopf and Jonas consider the serpentine southwest of Yeoho to be derived from a quartz gabbro. Tomlinson (1946, p. 322–325) found what he considered strong evidence that the rock in the vicinity of the Dinning rutile prospect, about a mile and a half north of Clermont Mills, was originally a pyroxenite rich in ilmenite and apatite, altered first to an amphibolite and later to a chlorite rock containing rutile and apatite. Amphibole asbestos deposits, which seem to be found in pyroxenitic rather than peridotitic rocks, occur in the eastern part of the same serpentine body.

JARRETTSVILLE-DUBLIN DISTRICT

The Jarrettsville-Dublin serpentine district is in Harford County, Md.; it begins 1 mile northeast of Jarrettsville and extends northeastward to the Susquehanna River (fig. 65 and pl. 41). Numerous ultramafic bodies, ranging in length from about 500 feet to 13 miles, are in the district. They have been described by Johannsen (1928), and most of the following information is from his report.

In general, the district consists of a row of isolated serpentine lenses that are derived from olivine-bearing rocks and south of these (fig. 65 and pl. 40), a continuous belt and several small lenses interpreted by Johannsen as serpentinized pyroxenite or pyroxene-rich gabbro. The enclosing rocks are mostly mica schist. The southern boundary of the altered pyroxenite is contiguous with gabbro in its eastern part, and for about a mile and a half southeast of Scarboro, with granitic rocks.

The areas of altered peridotite are: (a) northeast of Jarrettsville, (b) at Chrome, (c) at Cherry Hill, and (d) farther northeastward, along Broad Creek. At (a), (b), and (c) the serpentine is predominantly light-green, massive, and compact. Some is schistose, and in the Jarrettsville area some is fibrous. Pyroxene (bronzite) in the original peridotite has been partly or completely altered to amphibole (hornblende) and then incompletely serpentinized. Johannsen also found a little serpentinized pyroxenite in the Jarrettsville area.

The serpentine along Broad Creek is massive and compact and ranges from pale green mottled with black, through medium green, to nearly black. In places it is veined with carbonates (verde antique). The lens is bordered on all sides by white to light-green talcose rocks containing some magnetite, which are in turn bordered by a zone of dark-green chloritic schist. The rocks are thoroughly serpentinized, but Johannsen (1928, p. 285) suggests that originally they may have been dunitic in composition.

A long continuous belt of serpentine begins a mile west of Chrome and extends eastward and northeastward for a distance of about 13 miles to the Susquehanna River, averaging about 1 mile in width. Beyond the river, it continues as the main body of the State Line district. Johannsen interprets this belt in Harford County as altered pyroxenite or pyroxene-rich gabbro; he describes two distinctly different types of serpentine from it. The rock in the eastern part is mostly light to dark green and compact; cracks in it are commonly filled with fibrous serpentine. A narrow band of similar rock extends westward along the northern boundary of the serpentine mass almost to Deer Creek. Some pure compact serpentine, containing much magnetite, also occurs in the extreme western end of the belt between Jarrettsville and Chrome but may not be continuous with the main belt. The rest of the rock in the western half is predominantly chloritic or hornblendic serpentine, locally altered to talc or soapstone.

The reported existence of numerous prospect pits for magnetite and perhaps also for chromite along the northern boundary of this belt suggests that the narrow strip of massive, compact serpentine as well as the rocks in the eastern part of the belt may be derived from peridotite rather than pyroxenite. Johannsen himself recognizes the possibility that the tongue of serpentine mapped as the extreme western end of this belt, between two peridotitic serpentine masses, may be isolated from the main pyroxenitic belt and may be of peridotitic origin (Johannsen, 1928, p. 265).

The serpentine bodies at Macton, east of Macton, northeast of Ady, and near Bel Air are interpreted by Johannsen as derived from pyroxenite or pyroxene-rich gabbro. Much of the serpentine is chloritic. At Macton, soapstone is abundant. The serpentine at Mill Green is a compact green rock, in part soapstone and in part chlorite, of undetermined origin. Between Macton and Mill Green is Soapstone Knoll, a small body of somewhat iron-stained silvery-white soapstone.

Reported occurrences outside of the serpentine areas of mineral deposits that would be expected to occur in serpentine (notably magnesite and soapstone) strongly suggest that the boundaries as mapped may be inaccurate or that other unmapped serpentine bodies exist in the district.

STATE LINE DISTRICT

Northeast of the Jarrettsville-Dublin district and partly continuous with it is the State Line district, which extends from the Susquehanna River across northern Cecil County, Md., and southern Lancaster and Chester Counties, Pa., to Little Elk Creek—a total distance of about 16 miles (fig. 65 and pl. 41). Most of the district is a single belt of serpentine about 13 miles long ½ to 1½ miles wide. Several small isolated patches of serpentine are south of the main belt, and several somewhat larger bodies are east of it. The Lyles serpentine is an irregular intrusion about 5 miles long in the western part of the district north of the main belt. Farther north, near White Rock, are three small, narrow serpentine lenses in schist.

To the south the serpentine is bordered by norite and gabbro. The wallrock on the north is schist, except in the western part of the district, where the geologic map of Pennsylvania (Pennsylvania Topographic and Geologic Survey, 1931) shows granodiorite between the main State Line belt and the Lyles serpentine mass. In the vicinity of Octoraro Creek, drilling (McIntosh and Mosier, 1948) has shown that the northern contact between serpentine and schist dips deeply southward.

The serpentine rocks in the district range from light buff or light yellowish green to deep emerald green, dark blue-green, or almost black. In texture they are massive, fibrous, or schistose. Gordon (1922a, p. 451–453) studied the serpentine near the chromite deposits in the northern half of the belt and concluded that:

The parent rocks were largely peridotites of the type saxonite, composed of olivine and enstatite. A pseudoporphyritic type is found consisting of a light grayish-green serpentine, with small patches rich in magnetite, the particles of which are arranged in definite patterns, indicating a possible derivation from a ferriferous pyroxene, probably hypersthene.

Fisher (1929, p. 701) noted several varieties of serpentine among the chromiferous rocks of the belt, which he interpreted as derived from saxonite and wehrlite (peridotites), dunite, and websterite (a pyroxenite). Bascom (1902, p. 94, 132–135) points out that both pyroxenite and peridotite also occur along the southern border of the belt, in places where the rocks are only partly altered to serpentine. Fibrous varieties of serpentine in Cecil County contain remnants of tremolite or other fibrous amphiboles which Bascom interprets as indicating derivation from pyroxenite, whereas massive varieties show remnants of original olivine.

The rocks in the vicinity of the Wood chromite mine (loc. 57, pl. 41) are believed to have been essentially dunite. Partly serpentinized dunite only was found in drill cores examined by the U.S. Geological Survey in 1941, and the exposures mapped during exploration for chromite by the Bureau of Mines and Geological Survey were dunite (T. P. Thayer, written communication). The least altered facies is a dark-gray to light-green massive rock in which fresh olivine is abundant locally. The principal minerals are platy serpentine and olivine, and accessory minerals are chromite and secondary magnetite. The color varies with the amount of magnetite. Magnesite is associated with the serpentine in drill cores, and in places it almost completely replaces the other minerals. Talc and vermiculite schists have been formed at the contact with country-rock schist. Much of the platy serpentine is oriented, and near the Rock Springs mines (locs. 39, 40, pl. 41) the rock is highly schistose. Some of the serpentine near the Rock Springs mines has been altered to a jasperlike rock.

It seems that, in general, in both the State Line and the Jarrettsville-Dublin districts, peridotite lies to the north and pyroxenite to the south. The association of chromite with the olivine-rich rocks to the north is characteristic (Thayer, 1956, p. 38).

WEST CHESTER DISTRICT

The West Chester district (fig. 65) includes numerous small, roughly oval or elongate serpentine bodies and a long, narrow body in Chester County, as well as a few small bodies in Delaware County, Pa. (pl. 42). They are scattered along the northern and western borders of an extensive mass of gabbro and Baltimore gneiss injected with gabbro. Bascom, who has described the serpentines (Bascom and Stose, 1932; Bascom and others, 1909), interprets associated outcrops as disconnected exposures of a single large mass.

The serpentine is typically a massive dark or light-green granular rock. In places fibrous serpentine is associated with it, and also varying quantities of talc, quartz, magnetite, and limonite. The serpentine at Brinton's stone quarries (loc. 13, pl. 42) is pale, faintly mottled green, and unusually uniform, showing traces of enstatite and of accessory talc and calcite. Some of the smaller lenses of serpentine in the district are thoroughly steatitized; for example, the one on the Newlin-West Bradford Township line. On the basis of microscopic texture, Bascom classifies most of the serpentine in the district as altered peridotite.

PHILADELPHIA DISTRICT

The serpentines of the Philadelphia district (fig. 65 and pl. 42) are along the southeast margin of the same gabbro-gneiss area that is bordered on the northwest by the West Chester serpentines. Numerous elongate bodies extend from Mount Cuba, Del., northeastward across Delaware and Montgomery Counties, Pa., into Philadelphia County. Bascom (Bascom and others, 1909; Bascom and Stose, 1932) groups most of the serpentines into two belts, a southeastern one extending from Chestnut Hill southwestward through Gladwyne and a northwestern one extending southwestward from the Schuylkill River almost to Chelsea and including two fairly large intrusive bodies east of Newtown Square and near Blackhorse (pl. 42).

Bascom interprets the southeastern belt as altered peridotite. She describes the rocks as typically either massive blue-green or dark-green serpentine with remnant olivine crystals, or fairly pure light-gray to gray-green soapstone. Locally, reddish-yellow siliceous rocks occur, and calcite, quartz, and iron oxides are formed in varying amounts.

Serpentine in the northwestern belt is interpreted as derived from pyroxenite in which enstatite was the dominant pyroxene (Bascom and others, 1909, p. 6). The amphibole minerals tremolite and anthophyllite are abundant. The occurrence of chromite in the two large intrusions near Newtown Square and Blackhorse suggests that some of the serpentine was originally peridotite rather than pyroxenite. More in keeping with a pyroxenitic origin are amphibole asbestos deposits in several of the smaller serpentine bodies between and south of the serpentines near Newtown Square and Blackhorse.

The only serpentine body mapped in the State of Delaware extends 1½ miles northeastward from Mount Cuba and is ⅓ to ¾ of a mile wide (pl. 42). The surrounding rock is the Wissahickon formation. Bascom (*in* Bascom and Stose, 1932, p. 9) describes four major rock types within the body mapped as serpentine: (a) pale-green pure serpentine, containing crystals of magnetite and lustrous scales of talc; texture smooth; (b) dark-green massive peridotite (wehrlite), composed of augite and serpentinized olivine; (c) medium-green peridotite, composed of tremolite, augite, and serpentinized olivine; texture fibrous; weathers rusty yellow; (d) massive green gabbro, composed of hypersthene, hornblende, and labradorite.

Veins of magnesite and asbestos are common in the serpentine near Mount Cuba, but no commercial production of either mineral has been reported. The only mineral deposit known to have been exploited at Mount Cuba is soda spar from pegmatites intruding the serpentine.

Two small outlying bodies of serpentine, of no known commercial value, lie east of the Philadelphia district (and east of the area covered by fig. 65) in southeastern Bucks County (Willard and others, 1950).

MINERAL DEPOSITS

GEOLOGIC OCCURRENCE

The mineral deposits found in serpentine rocks of the Maryland-Pennsylvania-Delaware Piedmont are chromite, titaniferous magnetite, rutile, talc and soapstone, amphibole asbestos, magnesite, sodium-rich feldspar, and corundum. They occur in various ways:

1. As massive and disseminated ore bodies that are concentrations or segregations of metallic oxides in serpentine (chromite and titaniferous magnetite).
2. As placer deposits in streambeds (chromite).
3. As products of metamorphic alteration of the entire serpentine rock or of one or more of its constituent minerals (talc and soapstone, possibly rutile).
4. As veins in serpentine, mostly small, commonly occupying faults or shear zones (amphibole asbestos, magnesite, and possibly some chromite).
5. In or directly associated with pegmatites intruded into serpentine (sodium-rich feldspar, corundum, and talc).

Concentrations of chromite into ore bodies (group 1) are generally attributed to differentiation from an original magma. Some writers believe that chromite deposits were differentiated early in the cooling period of the magma (Thayer, 1956, p. 37–44; Rynearson and Wells, 1944, p. 10–12); others believe that some deposits were differentiated early and some late (Fisher, 1929; Sampson, 1929; Bateman, 1951, p. 71, 82–83). In addition, Ross (1929), Sampson (1931), and others have suggested that some chromite may have been deposited in veins by hydrothermal solutions (group 4) rather than as magmatic segregations. Placer chromite deposits (group 2) are formed when weathering processes attack serpentine containing disseminated chromite. The heavy resistant grains of chromite are gradually concentrated in stream sands, in places forming deposits of commercial size and grade.

The massive and disseminated bodies of titaniferous magnetite were probably deposited by differentiation from the original magma, possibly during the later stages of magmatic differentiation (Bateman, 1951, p. 72–83).

The process by which talc and soapstone are formed is called steatitization (Hess, 1933, p. 636–647). It is a later stage of metamorphism than serpentinization and involves alteration of the rock-forming magnesian minerals (pyroxene, amphiboles, olivine, and serpentine). In places the rock mass is almost completely altered to a soapstone. Most of the talc that has been quarried in the Piedmont upland of Maryland and Pennsylvania is the result of steatitization by pegmatites intruded into serpentine (group 5).

Tomlinson (1946, p. 325) interprets the rutile deposit in Harford County, Md. (pl. 41), as a result of alteration, during regional metamorphism, of ilmenite-rich pockets in an original pyroxenite group 3).

Amphibole asbestos and magnesite occur in veins or networks of veins cutting serpentine (group 4). In Maryland and Pennsylvania the asbestos deposits are commonly along faults or shear zones; they are small, the fibers are parallel to the vein walls (slip fiber), and the depth to which they can be worked seems to depend on the depth to which weathering has sufficiently softened the fiber. The magnesite veins are attributed to the reaction with serpentine of hot aqueous solutions containing carbonic acid (Bain, 1924, p. 417–419) or of meteoric waters containing carbon dioxide (Sagui, 1929, p. 654–657). The veins commonly form intersecting networks, and individual veins are small. Many follow fractures in the serpentine.

Sodium-rich feldspar and corundum deposits occur in pegmatites (group 5) that are unusual because they characteristically contain little or no quartz and mica and because, insofar as known, they seem to be confined to serpentine rocks.

PRESENT STATUS AND FUTURE OUTLOOK

Of these mineral deposits, only talc and serpentine continue to be produced in the area, along with a very small quantity of byproduct amphibole asbestos from the talc quarries. Production is expected to continue in the near future. Most of the talc is ground for industrial use; however, part of the product from quarries at Dublin, Md., is lava grade and is manufactured into ceramic products for electrical and refractory purposes. Serpentine is quarried in quantity and will continue to be available for such uses as road metal, roofing granules, and terrazzo flooring, and verde antique for decoration continues to be produced at Cardiff, Md. As building stone, serpentine is less practical than many other rock types; and although used as such in the past, it probably has little or no future in this field. The small amount of amphibole asbestos currently produced as a byproduct commands good prices, but uses are so limited that the possibility of any expanded future production in Maryland or Pennsylvania seems small.

Large-scale mining of chromite in the area ceased before 1880, and even small-scale, intermittent production ended in 1928. Some placer and disseminated chromite reserves are known, but their recovery would require low-cost handling of large quantities of rock and sand. Other undiscovered deposits probably exist in the area, particularly in the Soldiers Delight district, but prospecting techniques that were used between 1928 and 1943 were unsuccessful in locating any.

Known deposits of soda-spar are mostly mined out; others could probably be found in the area, but there is little to guide the prospector in searching for them. Soda-spar would continue to find a ready market if deposits large enough to work were found.

The single rutile deposit in Harford County, Md., is a very small potential titanium reserve. Titaniferous magnetite, magnesite, and corundum deposits in Maryland, Pennsylvania, and Delaware are so small and irregular that they are not expected to be of economic significance in the foreseeable future, under anticipated conditions of supply and demand.

SERPENTINE FOR DECORATIVE, BUILDING, AND CRUSHED STONE

Rock serpentine has been quarried at numerous localities in Maryland and Pennsylvania during the last 2 centuries, its relative softness, ease of quarrying and dressing, and attractive green color making it popular for various uses. During the 1870's and 1880's, when it was particularly fashionable as a building stone, numerous small quarries were able to flourish as well as the larger, more famous ones. Of particular note during this era were the Broad Creek quarries in Harford County, Md., and Brinton's quarries in Chester County, Pa. Decorative stone was an equally popular and more suitable use for the serpentine, particularly the verde-antique variety, a mottled, green massive rock containing some magnesium and calcium carbonates, usually as crisscrossing white or pale-green veinlets. Cardiff "green marble" for decorative purposes continues to be produced today (1956) from a deep quarry in northern Harford County, Md. Crushed, the serpentine has been used in bituminous and concrete roads and as railroad ballast; the outstanding producers of crushed serpentine in the area have been the Blue Mount "trap" quarries and the Soldiers Delight quarry, both in Baltimore County, Md., the Rockville quarry, Montgomery County, Md., and the Cedar Hill serpentine quarries in Lancaster County, Pa.; all were active in 1956. Crushed serpentine for granules in terrazzo flooring was produced at Cedar Hill in the 1930's and during the 1950's was the principal product of the quarry at Cardiff, Md.

Serpentine has certain limitations for most uses. It is by nature more or less extensively jointed and seamed, so that quarrying it in blocks for decorative or dressed building stone is generally difficult and entails much waste. It is susceptible to pressure and atmospheric weathering and thus tends to break or spall. It also weathers to a dark gray or olive green and soon loses its pleasing hue when used as rubble or dressed building stone, although some of it has exhibited remarkable color durability. As a road material, it has good cementing properties, is very tough, and is easily worked, but some of it lacks the wearing qualities of harder rock such as gabbro.

QUARRY DESCRIPTIONS

Most of the major serpentine quarries that have been worked in the Maryland-Pennsylvania Piedmont are described in the following pages, and others are listed in table 1. No attempt has been made to locate all the small-scale workings or quarries for very local use, but those noted in the course of field investigations are included.

TABLE 1.—*Other road-metal and small building-stone quarries in serpentine, Maryland and Pennsylvania*

Quarry	District	Map location	When active	Remarks	References
Maryland					
Rockville	Montgomery County.	Loc. 1, pl. 40.	1950's	Large; in serpentinized gabbro. Road metal.	
Cambria (Whiteford).	Woodensburg-Cardiff.	Loc. 7, pl. 41.	1890's	Decorative stone, light-green, mottled, somewhat schistose; slabs 8 ft by 4 ft by 2 in obtainable.	Mathews, 1898, p. 196.
Reed mine	Jarrettsville-Dublin.	Loc. 9, pl. 41.	Before 1928	Road metal. Quarry at the chromite mine, about 180 ft long, 15 ft high. Smaller one 0.3 mile southeast of it.	
Weiant	State Line	Loc. 30, pl. 41.	1930's	Verde antique, previously a feldspar quarry. (See p. 813.)	Ostrander and Price, 1940, p. 59.
Conowingo Marble and Mineral Co.	do	Loc. 32, pl. 41.	1920's	Use of stone not known. Feldspar also shipped.	Singewald, 1928, p. 108.

TABLE 1.—*Other road-metal and small building-stone quarries in serpentine, Maryland and Pennsylvania*—Continued

Quarry	District	Map location	When active	Remarks	References
Pennsylvania					
Wood mine	State Line	Loc. 57, pl. 41.	1930's	Road metal. Material from the large chromite-mine dump also used.	
Dunlap (Dunlap and Martin, Rhodewalt).	do	Loc. 76, pl. 41.	1870's and 1920's.	Building stone, closely and irregularly jointed. About 20 ft high, 60 ft into hillside.	Stone, 1932, p. 186.
White Barrens	do	Loc. 92, pl. 41.	Not known.	Road metal, light-green to brown serpentine with abundant magnesite veinlets; some accessory chromite.	
White Rock	do	Loc. 96, pl. 41.	1930's	Road metal, at site of old asbestos prospect.	Stone, 1939, p. 4.
Burkholder (Stillwell's).	do	Loc. 97, pl. 41.	Early 20th century.	Quarry 150 ft long, walls 10-30 ft high in 1932. Dark- to light-green massive serpentine and soft shaly serpentine. Pronounced jointing.	Stone, 1932, p. 186; Beck, 1952, p. 11, 12.
Taylor's	West Chester	Loc. 10, pl. 42.	1820's to 1850's.	Building stone, used mainly in West Chester. Dulled and faded by exposure to atmosphere.	Lesley and others, 1883, p. 88; Gordon, 1922b, p. 180.
Marshall's and McCall's.	do	Loc. 12, pl. 42.	19th century.	Building stone, used mainly in West Chester. McCall is a few hundred yards east of Marshall.	Rand and others, 1892, p. 187; Gordon, 1922b, p. 180.
Devon	do	Loc. 16, pl. 42.	19th century.	Building stone, particularly for the Devon Inn.	Rand, 1887, p. 1614-1615.
Stacker	do	Loc. 17, pl. 42.	19th century.	Very dark compact serpentine.	Rand, 1887, p. 1613-1614.
Lenni (Sellers')	Philadelphia	Loc. 21, pl. 42.	1880's	Building stone	Hall, 1885, p. 63, 70.
Martin & Co.'s	do	Loc. 24, pl. 42.	Latter 19th century.	Building stone	Hall, 1885, p. 62, 64.
Mineral Hill (Crump's).	do	Loc. 29, pl. 42.	Early 1870's.	Small quarry. Building stone used at University of Pennsylvania. Dark green, massive, broken by numerous joints.	Hall, 1885, p. 62, 70; Lesley and others, 1883, p. 65; Rand and others, 1892, p. 200.
Rose's	do	Loc. 34, pl. 42.	19th century.	Hard, very dark green building stone. Pyroxenite and serpentinized peridotite. Probably obliterated.	Rand, 1887, p. 1608; Gordon, 1922b, p. 213.

SOLDIERS DELIGHT DISTRICT

The Dyer or Soldiers Delight quarry in the northern part of the Soldiers Delight district (loc. 11, pl. 40) produces crushed stone for road material. It is reportedly on the site of a shaft of the Calhoun chromite mine. The quarry has been worked intermittently since sometime before 1928 (Singewald, 1928, p. 189; Mathews and Watson, 1929, p. 254; Ostrander and Price, 1940, p. 26). Veins of deweylite and chalcedony are common in the serpentine, and in places large rhombs of calcite bounded by picrolite have been found. In some parts of the quarry, grains and bands of chromite are disseminated in the serpentine.

BARE HILLS DISTRICT

Two quarries in the Bare Hills district at the junction of Pimlico and Falls Roads (loc. 18, pl. 40) have produced block serpentine for building and decorative stone, including some verde antique, and crushed serpentine for roads and concrete. Three other small stone quarries in the district are shown on plate 40.

Stone was quarried at Bare Hills in the 1890's by the Lake Chrome and Mineral Co. and in the 1920's by Lewis O. Stern. Several small houses and a church in the vicinity were constructed from the serpentine during the 1920's, when production was about 5,000 tons of rock a year. The quarries were probably operated until sometime after 1940; they were idle in the 1950's.

Serpentine at the Bare Hills quarries ranges from light-straw-yellow to dark-purplish-green and is extensively veined by thin stringers of white magnesite, chalcedony, calcite, deweylite, chrysotile, and common opal. It is intricately and irregularly fractured, so that blocks produced from it are uneven and hackly.

WOODENSBURG-CARDIFF DISTRICT

Blue Mount quarries

The large Blue Mount crushed stone quarries and plant, operated by the J. E. Baker Co., of York, Pa., are 1 mile southwest of Whitehall, Baltimore County, Md., along Gunpowder Falls (loc. 1, pl. 41). A railroad spur connects the plant with the Pennsylvania Railroad. L. J. Duersmith, head of the Department of Geology and Resources Development of the J. E. Baker Co., has furnished the following information about the quarries (written communication, 1957).

The No. 1 Blue Mount quarry, east of the stream, was opened in 1910. In January 1957 it was 1,080 feet long, 600 feet wide, 257 feet deep on the north side, and 112 feet deep on the west; the No. 2 quarry, a more recent opening west of Gunpowder Falls, was 60 feet deep, about 600 feet long, and 150 feet wide. Overburden averages 3 feet and is machine stripped. The small amount of water entering the quarry is pumped from a sump to Gunpowder Falls.

The rock quarried is typically a purplish-black serpentine. It has a hackly fracture. The main jointing strikes N. 75° W. and dips 75° N. A few veins and irregular masses of green serpentine occur in the rock, and some of the fracture surfaces are covered by thin films of aragonite, deweylite, and brucite. The contact between the serpentine and the Wissahickon formation is exposed in the No. 1 quarry on the east and north and in the No. 2 quarry on the north.

The plant produces railroad ballast, crusher-run, and all sizes of road metal for macadam and concrete. The stone, which is used in Maryland, Pennsylvania, and Virginia, meets the physical requirements for "Type A" highway specifications.

Cardiff "green marble" quarry

Near the Maryland-Pennsylvania line a quarry (loc. 8, pl. 41) was opened before 1900 to produce verde-antique ornamental stone. It has been maintained continuously since then, by various operators. Since the 1940's the operator has been the Maryland Green Marble Co., Inc., and the principal product has been "Cardiff green granito," or serpentine granules for use in terrazzo flooring. Currently (1956), about 90 percent of the total production is terrazzo aggregate; the other 10 percent is verde-antique ornamental stone for table and counter tops, fireplace facings, and other decorations. Serpentine from Cardiff is marketed throughout the United States and is exported. The company also sells irregular slabs for flagstone.

The verde antique is quarried from a channeled opening 247 feet deep, the present floor of which is 120 feet long and 60 feet wide. At a depth of 197 feet a platform leads from the quarry into extensive room-and-pillar workings, where the terrazzo stone is mined. The tunnels underground are about 35 feet wide and 40 feet high; roughly 40 percent of the total volume of rock is left as pillars. Two sets of joints in the serpentine—one dipping about 45° and the other dipping 10° to 15°—cause little trouble in mining or quarrying operations. Water accumulates slowly and is not a problem.

The verde antique is removed from the quarry in 14-ton blocks, which are then sawed to various thicknesses, sized, and polished. Serpentine for terrazzo aggregate is blasted out underground and then taken to the mill to be crushed and sized. The rock is not excessively hard, and therefore it crushes easily; capacity of the crusher is 120 tons per 8-hour day. Waste from the mill is 22 to 27 percent of the mill feed. The product is sized to ¼ inch, ⅝ inch, and ¾ inch; a combination or Venetian size is also produced. The granules sell for as much as $27 a ton and are used in floors, with cement and water as a binder. The fines, from 3/32-inch to dust in size, are not currently used.

The serpentine at Cardiff is a streaked and mottled rock that ranges from light green, through emerald green to very dark gray-green, cut by numerous veinlets of white carbonate. Pyrite is fairly common. The pale-green variety, sold under the name of "Cardiff green," was once a popular decorative stone but is no longer quarried.

JARRETTSVILLE-DUBLIN DISTRICT

Broad Creek quarries

Despite its relative inaccessibility, the serpentine body along Broad Creek a mile and a half southwest of its mouth (loc. 23, pl. 41) was among the most extensively exploited of the massive serpentines in Maryland. During the early 1870's and again in the 1880's the Broad Creek quarries produced a large quantity of stone for building and decoration (Mathews, 1898, p. 193-195). The principal market was New York. The Protestant Episcopal Church in Darlington, Md., is the largest building constructed of serpentine from the Broad Creek quarries.

The stone is described as a massive, somewhat slaty, translucent to semitransparent serpentine with a uniform texture; it ranges from pale green to dark blackish green and contains magnetite and, less commonly, thin seams of dolomite (Mathews, 1898, p. 195). It takes a polish well. Quarrying operations, although above water level, were unusually expensive, partly because of the hardness of the rock, and partly because abundant seaming and faulting caused considerable waste.

STATE LINE DISTRICT

Cedar Hill (Geiger) quarries

Several openings for serpentine have been made on the west bank of Octoraro Creek in Lancaster County, about 0.4 of a mile north of the Pennsylvania-Maryland line (loc. 50, pl. 41). One of the quarries was probably originally worked for building stone before 1900. Quarrying began again in 1924, for road material. In the 1930's Walter Geiger crushed the serpentine to produce dark- and light-green granules for terrazzo flooring (Stone, 1932, p. 186). The locality was popular among mineral collectors, particularly for its fine specimens of gem serpentine (williamsite), foliated talc, and brucite.

In 1953 or 1954 the Geiger quarries were reopened as the Cedar Hill crushed stone quarries by D. M. Stoltzfus and Son, Inc., of Talmage, Pa. When visited by the writers in 1956, the active quarry was about 300 feet long and 180 feet deep. Serpentine exposed in the quarry ranges from fine to coarse grained and from pale yellow-green through bright green to dark gray or black. About 20 different sizes of stone, all for road material, are produced with crushing and screening equipment on the premises. Crushed stone from the Cedar Hill quarry is used in Pennsylvania, Delaware, Maryland, and, to a lesser extent, Virginia.

WEST CHESTER DISTRICT

Brinton's quarries

Perhaps the most famous serpentine quarries in Pennsylvania were Brinton's quarries on Radley Run, in the southwestern part of

Westtown Township, Chester County (loc. 13, pl. 42). Other names by which the three quarries have been known are the West Chester, Westtown, Birmingham, and Ingam's quarry. Brinton's quarries furnished a total of about 500,000 cubic yards of stone before 1883, as estimated by the Census Bureau (Lesley and others, 1883, p. 63).

Quarrying began in 1730. About 1862 Joseph H. Brinton began working the quarries in partnership with J. W. Sabery, and they produced as much as $30,000 worth of building stone in prosperous years. Faced with a scarcity of stone cutters, Brinton helped to perfect a saw for dressing the serpentine (James, 1943, p. 191). From 1870 until 1888 Brinton's serpentine was widely used for building purposes, and to a lesser extent for ornamental stone. Many churches and homes were constructed of it, and it was popular for building facings and bridge construction. Its principal markets were in Philadelphia, New York, Washington, D.C., Baltimore, and Chicago.

In 1888 a fire destroyed the pumps and most of the plant, and the main quarry was consequently flooded below a depth of 60 feet. Subsequent intermittent operations were confined to the side walls above the water line (James, 1943, p. 191).

The serpentine at Brinton's quarries is a massive, even-grained rock of uniform color. It is relatively free from the typical serpentine jointing and could therefore be sawed into cubical blocks. The largest block ever taken out was 16 feet long and 3 feet square in section (Lesley and others, 1883, p. 63). Irregular pegmatites that cut the serpentine at places in the quarries are described by McKinstry (1916, p. 58).

Brinton's quarries have been famous as a mineral collecting locality, particularly for crystals of clinochlore (a variety of chlorite) and jefferisite (a variety of vermiculite). The jefferisite occurred in sufficient quantities to become a commercial byproduct of serpentine quarrying in the 1930's, when there was a considerable demand for the bright-gold paint produced by calcining it (Bascom and Stose, 1932, p. 13; Stone, 1939, p. 45). Several shipments were made.

CHROMITE

Chromite, the only ore of chromium, has been mined in almost all the serpentine districts of the Maryland-Pennsylvania Piedmont. Major mines were in the State Line district and the western part of the Jarrettsville-Dublin district. Soldiers Delight produced a substantial quantity of ore, and Bare Hills, although not among the large producers, was the first chromite-producing district in the United States and one of the first in the world. Minor production has been reported from mines in the Philadelphia and West Chester districts of Pennsylvania and the Montgomery County district of Maryland.

These mines provided all the chromite produced in this country before about 1865 and a substantial part of it until about 1880. They not only satisfied the limited domestic demand of the 19th century, but ore was also exported to Europe in large quantities. Most of the ore was used to manufacture chemical compounds, pigments, and dyes, before metallurgical and refractory uses for chromite were developed. The area produced rock or lode chromite, including high-grade massive ore and lower grade disseminated ore, and placer chromite. More than 40 lode-chromite mines and prospects are known, and most of the streams that drain the chromite-bearing serpentine districts are known to have been sites of placer operations.

Chromite is a black to brownish-black mineral belonging to the spinel group. It has a brown streak and submetallic to metallic luster. It crystallizes in the isometric system, in octahedral form, but it is more commonly massive or fine granular to compact. The fracture is uneven; hardness, about 5.5 on the Mohs scale. Specific gravity ranges from about 4.1 to 4.9. Most chromites are nonmagnetic or very feebly magnetic, but some are moderately to strongly magnetic.

The chemical composition of chromite is indicated by the general formula $(Mg,Fe^{+2})(Cr,Al,Fe^{+3})_2O_4$. The range in composition is wide; in fact, the Cr_2O_3 content of chromites usable as chrome ore ranges from less than 30 percent to more than 60 percent. The suitability of an ore for one or another of three major uses—metallurgical, refractory, or chemical—depends in general on its chemical composition. The most desirable chromite ores for metallurgical uses have high chromic oxide content (42 to 54 percent) and low iron and silica content. Refractory ores may be relatively low in chromic oxide (31 to 33 percent is preferred) but must have relatively high alumina content; silica and iron must be low. Chemical-grade ores must be low in alumina and silica but are not particularly affected by high iron content, as long as chromic oxide is fairly high (43 to 45 percent).

In general, the Maryland and Pennsylvania ores are excellent chemical grade, and it was as chemical ore that they were most extensively used. Iron content is high, but because chromium content is also high some of the ores qualify fairly well as metallurgical-grade chromite, and material from several of the mines was successfully used by steel companies during World War I. Two or three of the deposits are excellent metallurgical chromite, according to available analyses. No refractory chromite is known in the area, although some of the placer chromite from Solders Delight was at one time considered particularly suited for setting colors on porcelain ware and therefore brought high prices in European markets.

MINING AND EXPLORATION

Chromite was first discovered in the United States at the Bare Hills, Baltimore County, Md., between 1808 and 1810; it was mined there as early as 1811 to supply a Philadelphia paint manufactory (Pearre and Heyl, 1959). During the next few years two small deposits near Philadelphia were also mined. In 1819 about 3,000 pounds of chromate of lead, or "chromic yellow" paint, was manufactured from these ores (Cleaveland, 1822, p. 624). During this period the chromite deposits came to the attention of Isaac Tyson, Jr., of Baltimore, who recognized their potential worth and was responsible for mining them at least as early as 1817.

By 1822 loose boulders of massive chromite had been found in Harford County, Md., and chromite was also known to occur as lode and placer deposits at Soldiers Delight, Baltimore County, Md. First production from the Soldiers Delight district appears to have been placer chromite, obtained by washing the stream sands several times in a troughlike concentrator known as a buddle.

In 1827 the fortuitous discovery of loose boulders of chromite on the Reed farm in Harford County, Md., led to the first large-scale mining of high-grade ore and a rapid expansion of Isaac Tyson's chromite interests. A shaft sunk in an area covered by nearly 30 tons of boulders revealed rich ore in place at a depth of 8 feet. The Reed mine (loc. 9, pl. 41) was so profitable that other operations were temporarily suspended, and it ultimately proved to be the second most productive chromite mine in the United States.

Tyson subsequently located other serpentine areas in Maryland and Pennsylvania and purchased or leased property wherever indications were favorable for chromite; he also searched carefully but unsuccessfully for chromite in Delaware (Booth, 1841, p. 35). Not long after the Reed discovery, the Wood mine (loc. 57, pl. 41), in the State Line district, was opened, and it proved to be the most productive chromite mine in the United States. For some years thereafter other deposits were developed rapidly under the stimulus of a high market price, and between 1828 and 1850 the world's supply of chromium came almost entirely from Isaac Tyson's mines. About 1845, in anticipation of further discoveries that might flood the foreign market with chromite, Tyson and his son Jesse established a factory in Baltimore for the large-scale treatment of chromite ores, and until about 1880 their firm virtually monopolized the manufacture of chromium compounds in the United States.

In spite of this home market, however, the discovery of large chromite deposits in Turkish Asia Minor in 1848 marked the beginning of a decline in chromite mining in Maryland and Pennsylvania. By 1860 exports from this country had practically ceased, for want of a European market. The death of Isaac Tyson in 1861, the Civil War, and probably also the exhaustion of near-surface ores, combined to halt operations at a number of mines. The Wood mine at least remained a steady producer, but its output was reduced considerably.

In 1867 the Tyson Mining Co. was incorporated to carry on Isaac Tyson's mining business. The following year, however, the company lost its two most important sources of chromite when the Wood mine became flooded because pumping facilities were inadequate and the Red Pit mine (loc. 37, pl. 41) was permanently closed by an explosion and cave-in. During the late 1860's and early 1870's the company therefore renewed operations at most of its Maryland deposits, particularly the Soldiers Delight mines and the Reed mine. For a few years several independent operators were also able to mine chromite profitably; the Ayres and Wilkins mines (locs. 12, 13, pl. 41), Moro Phillips' and Stence mines (locs. 83, 84), and Hilaman's mine (loc. 86) were worked at this time. In 1873 the Tyson Mining Co., Inc., unwatered the Wood mine to a depth of 200 feet, sealed off the lower levels, and began to mine ore left in the walls of the upper workings.

Chromite was discovered in California in the early 1860's by a representative of the Tyson interests. After 1874, as the Tyson Mining Co. opened more mines in the West, the eastern mines were gradually closed, but reports disagree as to why. Exhaustion of ore, depth of mining, inadequate pumping facilities, decline in price, in some places litigation over mining rights, have been cited; all these, reportedly combined with mismanagement of Tyson's businesses by his heirs, were probably contributing factors. The eastern mines were not long able to compete with the new, near-surface California deposits, in spite of the long shipment involved from the West; however, several of the mines continued to produce some ore as late as 1880, notably the Wood, Reed, Choate, Calhoun, and Bare Hills mines. Only placer chromite was produced in the east for many years thereafter. From 1880 to 1882 the Wood mine was held open as a reserve against possible failure of shipments from California, but after 1882 it, too, was closed.

Intermittent production of placer chromite continued in the Soldiers Delight district until about 1920, mostly on a small scale, and production was resumed in 1881 in the White Barrens, Chester County, Pa., where it continued sporadically, probably almost until 1900. Elsewhere in the State Line district, placers were worked between 1897 and the early 1900's. Much of the production was never recorded. The Soldiers Delight ore met a small annual demand in Europe, where it was found to be particularly suited for use in setting colors on porcelain ware (Singewald, 1928, p. 175).

Sporadic interest in the lode chromite mines has been repeatedly shown since 1900, particularly during World War I. Around 1915 about 40 tons of ore was produced at the old Carter mine (loc. 58, pl. 41), probably by reworking the dump, but the low price of ore and scarcity of labor prevented further work. In 1917 the Choate mine (loc. 15, pl. 40) was cleaned out by the Maryland Chrome Corp., and a little high-grade ore was shipped, but plans to mill the lean ore were dropped when the war ended in 1918. In the State Line district (pl. 41) the Chrome Mining Co., headed by F. L. Garrison, of Philadelphia, unwatered the Line Pit mine (loc. 35), extended it, mined a lens of massive ore, and planned to mill disseminated ore from the other mines. Garrison is reported to have had adequate backing and a sound basis for the work he did, but even his company could not long survive the sudden loss of market that the armistice brought. About 100 tons of high-grade metallurgical chromite was mined but still on hand in November 1918, and only a part of it could subsequently be sold. His plan to mill disseminated ore left on dumps at the North Rock Springs mine (loc. 40), the Wet pit (loc. 39), and the Tyson Reynolds mine (loc. 49) was never put into effect.

Farther east in the State Line district the National Minerals Co., operated by H. S. Pyle and Craig Adair, of Wilmington, Del., prospected and developed 6 localities to some extent, from 3 or 4 of which a little ore was shipped. Included in the investigation were the Scott, Kirk, Hillside, and Wood mines, and the Reisler placer (locs. 80, 69, 56, 57, 90, pl. 41). Old dumps were reworked, shafts were cleaned and reopened, several new shafts were sunk, and numerous placer deposits were investigated. It was reported that no lode-chromite ore of commercial quality was in sight in any of the shafts when work stopped after the armistice. Also during the war the Electro-Metallurgical Co. leased mining rights on Hilaman's mine (locs. 85, 86, pl. 41) with concentration rights on Northeast Creek but produced no ore (Knopf, 1922, p. 95). Another company built a mill on Black Run (near loc. 71, pl. 41) to process placer deposits, but work was still in the experimental stage when the war ended (Ashley and others, 1944, p. 143).

The Reed mine was unwatered and partly cleaned out in 1922 by the Maryland Chromite Co. Nine pockets of ore were located by diamond drilling in the vicinity, and the company reported a small production for several years until 1928.

In 1937 the American Chrome Corp. of W. F. Gorrecht unwatered the Wood mine but did not produce any ore. It is not certain that the mine was actually cleaned to its full depth of 720 feet. In 1941 the old Kirk mine near Nottingham, Pa., was unwatered, and some low-grade ore was mined or sorted from the dumps but apparently not sold. In 1944 and 1945 the vicinity of the Kirk and Scott mines was again investigated. Bulldozing at the old Scott mine indicates that some exploratory work was done at this time, but no ore was produced.

Several attempts have been made to locate chromite deposits in the vicinity of the old mines by using geophysical prospecting techniques. Between 1932 and 1937 F. W. Lee and J. H. Swartz, U.S. Bureau of Mines geophysicists, cooperated with the Bethlehem Steel Co. in a geophysical prospecting program. A Hotchkiss superdip magnetic survey was made first of most of the State Line district, followed by electrical-resistivity surveys near the Wood mine and the Chester County Moro Phillips' mine. Anomalies at Moro Phillips' mine were drilled without finding ore. During the same period Bethlehem Steel geologists also did some magnetic work in the Soldiers Delight and Jarrettsville districts. In 1935 another mining company is reported to have conducted a geophysical survey at Soldiers Delight and to have diamond drilled at anomalies near the Harris and Weir mines without finding ore.

In 1941 the U.S. Geological Survey, in cooperation with the U.S. Bureau of Mines and Hans Lundberg, Ltd., conducted an experimental magnetometer and gravimeter survey in the vicinity of the Wood mine. The magnetic work was done by F. W. Lee and J. L. Swartz;[1] the gravitational survey and some electrical-resistivity work were conducted by M. C. Malamphy, of the Geological Survey. High gravity anomalies east of the mine that coincided with magnetic conditions favorable for chromite were drilled, and considerable trenching was done by the Bureau of Mines (McIntosh and Mosier, 1948). Results were negative (Hawkes, 1951, p. 16); however, the only conclusion that could be drawn was that geophysical methods to date were inadequate for finding chromite in the area, because of many complicating factors involved. Chromite in the vicinity of the Wood mine is weakly or not at all magnetic. Concentrations of titaniferous magnetite are common in the area, and the serpentine contains magnetite in extremely variable amounts; thus any magnetic indications of chromite would be indirect and inconclusive at best. Such factors as extreme variations in specific gravity of the serpentine and a southward dip of the serpentine-schist contact complicated the gravity results, and the instrument

[1] Lee and Swartz were then with the U.S. Geological Survey; formerly they were with the U.S. Bureau of Mines.

used (a "Boliden" gravimeter) was subject to considerable drift and was unsatisfactory in its application to a problem requiring a high degree of accuracy.

PRODUCTION

No accurate record of production data has survived from the years when the eastern chromite mines were most productive. Figures that were published before 1900 for the better known localities disagree and are at best only rough estimates, although most were supplied by men who had been connected with mining operations in the area. The available information has been pieced together and tabulated for this report (tables 2, 3, 4) to give a frame of reference, rough though it is, for evaluation of the district's productiveness. Much of the information requires some qualification or discussion.

TABLE 2.—*Production of chromite ore and concentrates from lode mines and placer deposits in Pennsylvania and Maryland before 1900*

[See notes following table for explanation and discussion]

Mine	District and map location	Type of ore	Reported grade crude ore (percent Cr_2O_3)	Reported production (tons [1])	Production estimated by writers on basis of dumps, visible workings, and descriptions (tons)
Lode chromite mines					
Wood mine	State Line, Pa. (loc. 57, pl. 41).	Mostly massive; only about 5 percent required concentration.	48-63	96,000-200,000	>96,000.
Red Pit mine	State Line, Pa. (loc. 37, pl. 41).	Massive, disseminated.	>50	20,000-150,000	>25,000.
Reed mine	Jarrettsville-Dublin, Md. (loc. 9, pl. 41).	do	45-47	>100,000	<100,000.
Hillside mine	State Line, Pa. (loc. 56, pl. 41).	Disseminated, some massive.	42		4,000-5,000.
Scott mine	State Line, Pa. (loc. 80, pl. 41).	Massive, disseminated.	48	3,000- 6,000	Report apparently correct.
Line Pit mine	State Line, Pa. (loc. 35, pl. 41).	Mostly massive, some disseminated.	50 30	700- 4,000	5,000-10,000.
Choate mine	Soldiers Delight, Md. (loc. 15, pl. 40).	Disseminated, some massive.	30 41-55	>1,600	>3,000.
Weir mine	Soldiers Delight, Md. (loc. 8, pl. 40).	Mostly disseminated, some massive.		Larger than Choate.	>3,500.
Tyson Reynolds mine.	State Line, Pa. (loc. 49, pl. 41).	Disseminated, reported low in iron.		3,000	
North Rock Springs (Jenkins) mine.	State Line, Pa. (loc. 40, pl. 41).	Mostly disseminated, some massive.		1,000- 3,000	Report apparently correct.
Bare Hills mines	Bare Hills, Md. (locs. 19, 20, pl. 40).	do	39-48	>100	300-1,000.
Carter (Texas) mine.	State Line, Pa. (loc. 58, pl. 41).	Mostly massive, some disseminated.		400- 600	Considerably larger than reported.
Unnamed mine	Soldiers Delight, Md. (loc. 13, pl. 40).	Disseminated			100-500.
"Newbold" mine	State Line, Pa. (loc. 53, pl. 41).	do			500-900.
Ayres mine	Jarrettsville-Dublin, Md. (loc. 13, pl. 41).	Massive and disseminated.			500.

See footnote at end of table.

TABLE 2.—*Production of chromite ore and concentrates from lode mines and placer deposits in Pennsylvania and Maryland before 1900*—Continued

Mine	District and map location	Type of ore	Reported grade crude ore (percent Cr_2O_3)	Reported production (tons [1])	Production estimated by writers on basis of dumps, visible workings, and descriptions (tons)
Lode chromite mines—Continued					
Moro Phillips' mine (Chester County).	State Line, Pa. (loc. 83, pl. 41).	Massive and disseminated.	----------	250	Report apparently correct.
Kirk mine--------	State Line, Pa. (loc. 69, pl. 41).	Disseminated, massive.	----------	>240	Considerably smaller than reported.
White Barrens, 3 pits.	State Line, Pa. (pl. 41).	------------------	----------	150	
Hilaman's mine---	State Line, Pa. (loc. 85, pl. 41).	Disseminated-----	----------	50	
L. Melrath's pits--	State Line, Pa----	------------------	----------	50	
Black Horse mine-	Philadelphia, Pa--	------------------	----------	50	
Walter Green's mine.	-----do------------	Massive----------	26.7	50	
Little Horse Shoe mine.	State Line, Pa----	------------------	----------	30	
Moro Phillips' mine (Delaware County).	Philadelphia, Pa. (loc. 32 or 33, pl. 42).	Massive----------	51.56	25	
Amos Pugh's mine.	State Line, Pa. (loc. 89, pl. 41).	------------------	----------	20	
Lode and placer chromite					
Preston farm (Swaggart Run).	State Line, Md. (locs. 33, 34, pl. 41).	Probably mostly placer, but not specified.	----------	<100	
Bailey's mine------	West Chester, Pa-	------------------	----------	30–50	
Placer chromite deposits					
Soldiers Delight and Bare Hills placers.	Soldiers Delight and Bare Hills, Md. (pl. 40).	Concentrates------	28–43	[2] >5,200	
White Barrens----	State Line, Pa. (pl. 41).	Probably concentrates.	----------	>3,000	
Pine Run---------	State Line, Pa. (loc. 60?, pl. 41).	-----do------------	----------	1,500	
Rock Springs Run (Peoples tract).	State Line, Pa. (loc. 42, pl. 41).	-----do------------	----------	1,000	
Fairlamb's farm---	Philadelphia, Pa. (loc. 27, pl. 42).	-----do------------	----------	200	
Tweed mine-------	State Line, Md.-Pa. (loc. 66, pl. 41).	Concentrates------	----------	>100	Considerably larger than reported.
Hibbard's farm----	Philadelphia, Pa. (loc. 22, pl. 42).	-----do------------	[3] 53	75	

[1] Long or short tons not specified; probably long tons.
[2] Both districts to 1884, more than 5,000 tons. Production of 100 tons in 1885 reportedly from Soldiers Delight (U.S. Geol. Survey, 1885, p. 358), may have included some from Bye's placers in West Nottingham Tp., Chester County, Pa. Another 100 tons reported in 1886 (Glenn, 1893, p. 122) probably also included both sources.
[3] Pure chromite crystals; not shipped ore.

Most of the production figures in table 2 for mines in Pennsylvania are attributed to E. Mortimer Bye, at one time a partner of Isaac Tyson. Many are published by Genth (1875, p. 41–42); others, by Eyerman (1889, p. 9–10). The few available figures for mines in Maryland are from Day (1885, p. 568) unless otherwise specified below. The writers have estimated production from a number of mines on the basis of size and shape of visible workings, reported underground workings, size and content of old dumps, and existing mine descriptions.

Wood mine (table 2).—The range of reported production is wide. In 1878 William Glenn, the mine superintendent, gave the total as about 95,000 tons and annual production continuing at about 500 to 600 tons a year (Frazer, 1880, p. 192). The mine remained productive until 1880, in which year it produced 300 tons (Pumpelly, 1886, p. 839, 983). Thus, a total figure of about 96,000 tons seems to be the most reliable. Rough estimates made by the writers agree with this figure. Genth (1875, p. 41), however, quotes 120,000 tons as the production to 1875, and Eyerman (1889, p. 9), a total production of 200,000 tons. These discrepancies may be partly explicable. Production from several smaller openings near the main Wood mine shaft may be included in one figure but not in others. The Carter mine is on the Wood property; ore from it seems to have been similar to the Wood ore; and the production of 400 to 600 tons reported from it seems much too small, judging from the size of visible workings and dumps. The two may have been mined as one operation by Tyson, and 120,000 tons may include production from both mines; the 400 to 600 tons may belong to a period when the Carter mine was worked by operators other than the Tysons. Another source of confusion may have been the general usage of the locality name "Texas, Pa.," at one time to include the Wood and Line Pit mines, and probably the Red Pit and other mines near Rock Springs as well.

Red Pit mine (table 2).—The reported 150,000 tons is probably too much. The sudden closing of the mine by an explosion seems to have created a great deal of confusion about its former productivity, and the only definite information is that it was large, unusually deep, and second only to the Wood mine, at least in Pennsylvania. Eyerman (1889, p. 9) gives combined production from the Line Pit and Jenkins mines as 25,000 tons, and it is possible that "Jenkins mine" here refers to the Red Pit mine; first, because the Line and Red Pits are on the same property, and secondly, because the "Jenkins mine" elsewhere refers either to the North Rock Springs mine, the relatively small production for which is given separately, or to a locality near Rock Springs Church that was little more than a prospect pit. If it is the Red Pit, about 20,000 of the 25,000 tons could be assumed as its production. The mine workings are all caved, and no descriptions of them exist; so the writers' estimate of 25,000 tons minimum is based only on number of surface workings and former size of the dump, particularly in comparison to the former size of the Wood mine dump, assuming the ratio of waste to ore at the two mines to have been roughly comparable.

Reed mine (table 2).—All accounts agree that the Reed mine was one of Tyson's largest producers, and most agree that it was second only to the Wood mine. A remote possibility exists that it was confused with the Red Pit mine, also reported second only to the Wood mine. The few available descriptions of the underground workings are so old or incomplete that no estimates of the production can be made from them. The grade is the grade of ore shipped in the 1920's from the Reed mine vicinity (table 4) and may or may not be representative of the mine itself.

Hillside mine (table 2).—Unpublished sources estimate production as large as 15,000 tons, but this figure would necessitate very much more extensive underground mining than one may assume with any assurance from the accessible workings and relatively small dumps (1956).

Line Pit mine (table 2).—Genth's figure (700 tons) is definitely too low and may only represent production from the small part of the mine in Pennsylvania, or "Lowe's mine." As early as 1854, Rogers (Lesley and others, 1883, p. 93) noted that the mine had yielded several thousand tons. The depth was later extended about 90 feet, and the production increased. Eyerman (1889, p. 9) quotes a figure of 25,000 tons for the Line Pit and Jenkins mines together, at least 4,000 or 5,000 tons of which almost certainly have come from the Line Pit. Size of the stoped areas suggests a total production between 5,000 and 10,000 tons of mostly massive ore.

Choate mine (table 2).—Lode chromite production up to 1839 from the Solders Delight district is reported as 1,600 tons; mine or mines not specified (Ducatel, 1840, p. 40). The Choate mine is known to have been worked prior to that, but the others probably were too, and this incomplete figure could refer to the Weir, Harris, or Calhoun mine just as well. The writers' estimate is based on accessible workings and description of the rest and assumes an average thickness of 2 feet for the ore body.

Bare Hills mines (table 2).—The reported production figure represents 1 year's production in the later period only (census year 1880) and does not include the early, more important years, before 1825. All reports indicate that the early production was comparatively small.

Moro Phillips' mine, Delaware County (table 2).—Two Moro Phillips mines probably existed in Delaware County (see p. 789), one in Radnor and the other in Marple Township. Genth cites the Marple Township mine as the source of high-grade chromite; however, the chromic oxide content (51.56 percent) reported by Genth is exactly equal to that in an analysis of ore from "Chester County," adding some doubt to the accuracy of this grade figure. The production figure probably does not include ore mined before 1820.

Placer chromite (table 2).—Eyerman (1889, p. 10) attributes to the State Line district a production of 10,000 tons of sand chromite (probably concentrates). This figure would include the Peoples tract, Pine Run, and the White Barrens as well as Black Run and others that are not reported separately. At least 100 tons more was produced in the district at a later date (Tweed mine, 1897). The placers at Bare Hills and Soldiers Delight alone produced more than 5,200 tons (Day, 1885, p. 568). An additional 500 tons of concentrates are reported to have been produced in the Philadelphia district (Eyerman, 1889, p. 10). Thus 15,800 tons of concentrates is a reasonable and probably reliable minimum placer chromite production figure for the whole area before 1900, but no grade figures can be given.

Table 3.—Most of these mines apparently were small. Some were probably little more than prospects; however, the Harris, Calhoun, Wilkins, Stence, Brown's mine, Wet pit, and Engine pits are known to have produced marketable ore. According to the available descriptions, the Harris mine may have produced about 500 tons of ore and the Calhoun mine, the visible workings of which are much larger, may have produced about 1,000 to 3,000 tons of ore. The rest were probably all very small, so that the total production from all seven was probably no more than a few thousand tons of ore, mostly disseminated, that had to be sorted or milled and yielded a small tonnage of commercial-grade concentrates.

TABLE 3.—*Lode chromite mines in Pennsylvania and Maryland for which no production figures are available*

Mine or property and location	District and State	Type and grade of ore
Etchison mine (loc. 2, pl. 40)	Montgomery County, Md.	Massive, low-grade ferroan magnesiochromite; 20–35 percent Cr_2O_3.
Griffith property (loc. 3, pl. 40)	do	Massive, high-iron content, 35–40 percent Cr_2O_3.
Harris mine (loc. 9, pl. 40)	Soldiers Delight, Md.	Mostly disseminated, some massive.
Calhoun mine (loc. 12, pl. 40)	do	Disseminated, massive.
Wilkins mine (loc. 12, pl. 41)	Jarrettsville-Dublin, Md.	Massive, disseminated.
Cherry Hill mine (loc. 17, pl. 41)	do	Do.
Brown's mine (loc. 95, pl. 41)	State Line, Pa.	Disseminated.
Wet pit (loc. 39, pl. 41)	do	Do.
"Damp" pits (loc. 38, pl. 41)	do	Do.
"Jenkins" mine (loc. 41, pl. 41)	do	
Geiger pits (loc. 51, pl. 41)	do	
Engine pits (loc. 81, pl. 41)	do	Disseminated.
Stence mine [1] (loc. 84, pl. 41)	do	Do.

[1] May be included in production reported from Moro Phillips' mine (Chester County, Pa.).

Table 4.—There is every indication that between 1900 and 1917 more placer chromite was produced than was reported. During World War I the Line Pit and Choate mines were the most significant producers of lode chromite, but ore was reported to be on

hand at both mines in the spring of 1919, when the market for domestic ore had failed completely. The U.S. Bureau of Mines (1925, p. 133) quotes a figure of 431 long tons as the 1918 production from these two mines, which is not included in table 4 because it cannot be reconciled with detailed data on file at the U.S. National Archives, prepared in 1919.

TABLE 4.—*Production of chromite ore and concentrates in Maryland and Pennsylvania since 1900*

Year	State and mine, property, or district	Production (long tons)		Type	Percent Cr_2O_3	Reference
		Shipped	Mined and on hand			
1900–1913	[1]					
1908(?)	Maryland, Stevenson farm.	[2] 37		Concentrates (placer).	low	Singewald, 1928, p. 180.
1914	Maryland, Soldiers Delight.	85		Placer		Singewald, 1928, p. 160.
1915	[1]					Do.
1916	Maryland, Soldiers Delight.	89		Placer		Do.
1917(?)	Pennsylvania, Texas (Carter) mine.	[2] 40		Rock		Knopf, 1922, p. 97.
1917	Maryland, Soldiers Delight.	100		Placer		Singewald, 1928, p. 160.
1917	Maryland, Choate mine.	50		Lode		Do.
1918	Maryland, Line Pit mine.	55		Disseminated	30	U.S. Natl. Archives.[3]
1918	do	7	[2] 100	Massive	50–52	Do.
1918	Maryland, Choate mine.	50	10	Massive	40–41	Do.
1918	do	5	5	Concentrates (placer).	36	Do.
1918	do		15	Disseminated(?)	20	Do.
1918	do		[4] >500	Low-grade disseminated.	11–35	Do.
1918	Pennsylvania, Scott mine.	[2] 30		Disseminated	36	Do.
1918	Pennsylvania, Reisler farm.	[2] 15		Concentrates (placer).	54	Do.
1918	Pennsylvania, Hillside mine.	[2] 12		Massive	36–47	Do.
1919	Maryland, Line Pit and Choate.[5]	54			>45	U.S. Geol. Survey, 1919.
1919	do.[6]	4			35–45	Do.
1919	do.[5]	11			<35	Do.
1920	Maryland, Line Pit mine.		4	Lode	>45	U.S. Geol. Survey, 1920.
1920	do		5	Lode	35–45	Do.
1921						
1922	Maryland, Reed mine vicinity.	113		Massive	47	U.S. Geol. Survey, 1922.
1923	do	80	10	Massive	>45	U.S. Geol. Survey, 1923.
1924						
1925	Maryland, Reed mine vicinity.	25		Massive	>45	U.S. Bur. Mines, 1925.
1926	do	50	17	Massive	>45	U.S. Bur. Mines, 1926.
1927						
1928	Maryland, Reed mine vicinity.	8	4	Massive	>45	U.S. Bur. Mines, 1928.
Total		920	[7] >670			

[1] No production reported; however, the placers at Soldiers Delight, Md., were intermittently active 1900–1917 and produced up to 100 tons of ceramic-grade chromite annually. Concentrates were shipped to Europe.
[2] Long or short tons not specified.
[3] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.
[4] 500 or more tons of lean disseminated ore sorted out by Maryland Chrome Corp. from back-filled waste and dump material. Plans to concentrate it never materialized. Probably was later used as road material.
[5] Production history strongly suggests this was all from the Line Pit mine.
[6] Production history strongly suggests this was all from the Choate mine.
[7] 69 tons shipped in 1919 from stock on hand in 1918.

Total production.—The reported production figures in table 2 are not totaled because of the wide ranges given. They can be added up to a minimum of about 235,000 tons or a maximum of about 500,000 tons of lode chromite ore produced from 27 mines before 1900. The most careful conservative estimate from the data given in table 2 and from all the other available data about each mine is that these 27 mines produced between 250,000 and about 280,000 tons of ore. Table 3 gives 13 additional mines, some apparently fair sized, for which no figures are available. Three of the 40 known mines are unrecorded in the literature. Other mines may exist in the area, and some were probably filled in when operations ceased. Thus, the production picture is far from complete.

The minimum placer-chromite production figure for the whole area before 1900 is 15,800 tons of concentrates, grade unknown. Notable exclusions from table 2 are (a) Jarrettsville-Dublin district, where a number of deposits were worked and one produced considerable sand chromite, and (b) the placers in Cecil County, Md., and most of those in the Elk Township part of the White Barrens, Pa., which are probably not included in Eyerman's figure of 10,000 tons for the State Line district. Therefore, the total production of placer chromite before 1900 was probably nearer to 20,000 tons of concentrates.

Production since 1900 is much more accurately known but is only a small fragment of the total production from the area. Table 4 gives the available figures for the years 1908–28. The amount of chromite ore and concentrates shipped during these years was at least 920 long tons, a large part of which was used by steel manufacturers. Total ore mined during the period was about 1,500 long tons, of all grades. Much of this represents small-scale, individual efforts under wartime stimulation, abruptly halted by the 1918 armistice. The most interesting aspect of table 4 is geographic: activity was concentrated on the big mines in Maryland, although in the 19th century many more mines, better quality ore, and larger producers existed in Pennsylvania. Wartime efforts to reactivate the Pennsylvania mines were small and so late that they had not made enough headway to prove or disprove their value when the chromite market was suddenly lost. It is impossible not to wonder what more work in the State Line district might have produced.

Prices.—An incomplete record of prices paid for Maryland-Pennsylvania chromite from 1822 to 1928 is given in table 5. Most of these prices represent value of the chromite ore in domestic markets. In 1833 the value of pigments and dyes manufactured in the United States from eastern chromite ores was $56,000, of which $45,000 represents products that were exported (Ducatel and Alexander, 1834).

Until about 1845 much of the ore was not used domestically but was exported to meet foreign demands. Between 1845 and 1861 these demands decreased and domestic demands expanded; the prices during this period are to a large extent those set by Isaac Tyson, as half partner in the Baltimore Chrome Works, for ore bought from his own mining company. Chromite ore continued to be exported at intervals after 1861. Day (1885, p. 572) reports the total value but not the tonnage or price per ton of ore exported during four fiscal years, ending June 30:

Fiscal year	*Value*
1864	$39,585
1865	19,078
1873	2,080
1874	4,288

The ore exported in 1864 and 1865 was probably from mines in the East; the ore exported in 1873 and 1874 may have been from California.

TABLE 5.—*Maryland-Pennsylvania chromite prices*

Year	Type of ore	Approximate price per ton	Remarks	Reference
1822	General price range for ores.	$40–60	"In market"—probably domestic markets in Philadelphia and Baltimore.	Cleaveland, 1822, p. 624.
Early 1800's	Placer	45		Lesley and others, 1883, p. 92.
1837	Cecil County, Md., ore.	20–25		Ducatel, 1838, p. 16.
1837	Chester County, Pa., massive ore.	40	In Baltimore	Ducatel, 1838, p. 34.
1838	Chester County ore	16		Rogers, 1840, p. 22.
1839	Placer ore, Soldiers Delight.	18	In Baltimore	Ducatel, 1840, p. 40.
1839	Choate mine, rock ore and cleaned concentrates.	25	Isaac Tyson agreed to buy ore from Herod Choate for this price.	Isaac Tyson record book, Maryland Historical Society.
1840	Philadelphia ore	[2] 55–60	Contract made by Isaac Tyson.	Do.
1844	Line Pit ore	[2] 23.50	Price paid by Tyson to Gibson & Co.	Do.
1844–45	Preston placer concentrates.	[2] 22	Price paid by Tyson to Joseph Preston.	Do.
1854	Wood mine ore	25		Lesley and others, 1883, p. 93.
1879–80	Wood, Reed, and Bare Hills ore.	30	Tenth Census report	Pumpelly, 1886, p. 839.
1882–84	California ores [1]	[2] 18–20	In San Francisco	U.S. Geol. Survey, 1883–84, p. 572.
1882–84	do	[2] 35–40	Delivered in Baltimore	Do.
1885	do	[2] 26	Delivered in Baltimore or Philadelphia.	U.S. Geol. Survey, 1885, p. 358.
1908		[2] 10–20		U.S. Geol. Survey, 1908, p. 760.
1914	Soldiers Delight placer	15	Average price	Diller, 1920, p. 147.
Before World War I.	Soldiers Delight placer	30–35	Cost of production about $22. Price paid for ore was about twice the price at which chrome ores sold during this period.	Singewald, 1928, p. 176.
Early 1916	do	44		Do.

See footnotes at end of table.

TABLE 5.—*Maryland-Pennsylvania chromite prices*—Continued

Year	Type of ore	Approximate price per ton	Remarks	Reference
1917	Soldiers Delight, either placer or Choate mine ore.	$24		U.S. Geol. Survey, 1917, p. 38.
1918	Line Pit and Choate mine ore.	48	Average wartime price	U.S. Geol. Survey, 1918, p. 674.
1918	Line Pit, massive, 50 percent Cr_2O_3.	[3] 56	Wartime price	U.S. Natl. Archives.
1918	Choate mine, massive, 40–48 percent Cr_2O_3.	50	Sold to steel company	Do.
1918	Choate mine, placer conc., 36 percent Cr_2O_3.	39	Experimental, cost $35 per ton to produce. Sold to steel company.	Do.
1918	Line Pit, disseminated, 30 percent Cr_2O_3.	[3] 29	Sold to steel company	Do.
1918–19	Scott mine, massive, 35–40 percent Cr_2O_3.	42	Wartime price	Do.
1919	Maryland mines, massive, >35 percent Cr_2O_3.	[2] 55–56	High wartime price prevailed during early part of the year only; during the latter part, the ore could not be sold.	U.S. Geol. Survey, 1919, p. 87–89.
1919	Maryland ore, dissem. (?), <35 percent Cr_2O_3.	[2] 23		Do.
1922	Reed mine vicinity, massive, 47 percent Cr_2O_3.	[2] 29	Average value	U.S. Geol. Survey, 1922, p. 107.
1923	Reed mine vicinity, massive, >45 percent Cr_2O_3.	[2] 23	do	U.S. Geol. Survey, 1923, p. 114.
1925	do	[2] 18	do	U.S. Bur. Mines, 1925, p. 132.
1926	do	[2] 22	do	U.S. Bur. Mines, 1926, p. 2.
1928	do	[2] 20	do	U.S. Bur. Mines, 1928, p. 71.

[1] Cited for comparison.
[2] Long ton specified.
[3] Short ton specified.

GEOLOGIC OCCURRENCE

Three types of chromite deposits in Pennsylvania and Maryland —massive, disseminated, and placer—have been productive in the past. The massive ore is a dense aggregate of pure or almost pure chromite, ranging from 48 to 63 percent chromic oxide. Characteristically, it is highly fractured, and the fractures are filled with serpentine, kämmererite, magnesite, or related minerals, but dumps at the Wood and Carter (Texas) mines contain ample evidence that some of the massive ore, at least at these two localities, is very pure and compact.

The disseminated or "birdseye" ore contains euhedral to rounded grains of chromite embedded in serpentine in all degrees of concentration. In some occurrences the grains are distributed more or less evenly throughout the rock or form gradational boundaries between massive chromite bodies and the country rock; more frequently, they are concentrated to form separate, extremely irregular lenses, layers, or bunches in relatively barren serpentine. Disseminated deposits that were mined in the past are reported to have averaged about 35 percent chromite and required grinding and gravity concentration, whereas massive ore was hand sorted and shipped as mined.

Known massive and disseminated deposits in Maryland and Pennsylvania are in forms so irregular and unpredictable that they defy general description. Some, such as the Harris and Weir ore bodies, are reported to be bands of small irregular lenses; others, such as the Choate deposit, are tabular and more like thin wide pinching and swelling blankets. Still others, such as the Line Pit deposit, are roughly pipelike or resemble strings of sausage in overall form, with short stringers and veinlike projections of ore extending into the surrounding rock; and some are in irregular masses with rounded edges, such as the Wood mine ore body. "Podlike" and "sackform" are among the general terms that have been used by writers to describe similar ore bodies. Sampson's description of sackform bodies (1942, p. 111) applies very well to the major chromite deposits in Maryland and Pennsylvania, especially the deposit at the Wood mine, insofar as information is available about them:

> The masses are of irregular though rounded shape of great variety of form. Protuberances are for the most part rounded, though reentrants may be deep and narrow. Converging reentrants may split the lode into several portions. Some have transitional boundaries with enclosing rocks, but many are sharply defined * * *. These sackform bodies may be irregularly distributed or their distribution may be along planes. In some instances there is distinct linear control, commonly with steep dips, to form chimneylike lodes * * *. In a few instances distinct veinlike protuberances are known.

The alinement of ore bodies in the direction of plunge was noted early in the history of chromite mining in Maryland and Pennsylvania (Ducatel, 1838, p. 32). Glenn (1896, p. 499) speaks of massive ore deposits like those at the Wood, Reed, and Line Pit mines as having well-defined footwalls and persisting in depth. When pockets or sacks of high-grade ore pinched out, miners commonly followed narrow stringers or seams that were likely to open out into other mineable ore bodies at no great depth below. Twentieth-century operations at the Line Pit mine reemphasized this persistent alinement by revealing a body of massive chromite well down the plunge from the original ore body, which had pinched considerably at the bottom of the older workings. Visible workings of several of the mines mapped by the writers strongly indicate that alinement of ore bodies at some localities in the area is along zones of shearing in the serpentine. (See figs. 66, 67; pls. 44, 47). The ore bodies of the Line Pit (pl. 45) and Wood mines (pl. 47) resemble boudins—tabular, lenticular or pencillike bodies with their long axes, or plunges, alined parallel to the steeply southward plunging lineation of the serpentine and their intermediate axes parallel to the eastward-striking foliation of the rocks. Downward, both ore bodies tended to curve and rotate counterclockwise.

The known lode-chromite deposits—both massive and disseminated—in Maryland and Pennsylvania are mostly near the outer edges of serpentine masses; in the State Line district they are along or near the northwest border of a long body of serpentine that strikes northeastward and eastward and dips steeply southeastward and southward. Plunge of the Wood mine ore body, about which the most information is available, is roughly parallel to the dip of the northern contact between serpentine and country rock. At the outcrop the body is also elongated parallel to the eastward contact of the serpentine, but at depth it is reported to be elongated northward at right angles to this contact (Glenn, 1896, p. 499).

At the borders of many of the ore bodies the serpentine has been altered. Gordon (1922a, p. 450) describes in detail a sheathing of translucent bright-green serpentine (williamsite) encasing the massive chromite body at the Line Pit. Evidence of similar alterations on a small scale can be found in hand specimens on dumps of the Hillside, Bare Hills, and Cherry Hill mines and the "Road" pit. Individual grains of chromite in disseminated ore from Bare Hills are surrounded by williamsite in a matrix of ordinary serpentine. Other hand specimens from the Wood mine and elsewhere show veinlike bands or irregular concentrations of chromite with borders of serpentine considerably lighter in color than the country rock.

Several rather unusual minerals are associated with the massive deposits but are rare in the disseminated deposits. Most typical is pink or purple kämmererite, a chromian chlorite, which is uncommon with disseminated chromite except at the Bare Hills, where it encases chromite grains or replaces the walls of small joints or fractures that crosscut the deposits. Many thin fissure veins of magnesite, and, less commonly, veinlets or acicular crystal crusts of hydromagnesite, cut massive ore in several deposits, including the Line Pit, Wood, and Hillside mines. Deweylite, a colloidal hydrous magnesian silicate, and apple-green genthite, similar to deweylite in composition but with nickel replacing some of the magnesium, are found as incrustations on massive chromite. Zaratite, a secondary nickel carbonate, forms emerald-green coatings on or fills thin fractures in massive chromite at the Wood and Red Pit mines. The magnesium hydroxide brucite, a product of the decomposition of magnesium silicates, is also somewhat typical, particularly at the Wood mine, where it occurs in pearly white masses and crystals.

Other minerals that are associated with the lode chromite deposits, massive or disseminated, in Maryland and Pennsylvania are the serpentine minerals antigorite and chrysotile (including such varieties as chromian antigorite,[2] bastite, picrolite, williamsite, and marmolite), white and green talc, varieties of chlorite (bright-green penninite, bluish-green clinochlore, and ripidolite), brown vermiculite, olivine, enstatite, halloysite, uvarovite(?), green chrome muscovite (fuchsite) and tourmaline, vesuvianite, titaniferous magnetite, quartz (drusy, ferruginous, and jasper), calcite, and dolomite. Most of these minerals are present at the Wood mine and the Line Pit mine. Gill (1889) noted that fuchsite and chrome tourmaline, which occur at the low-grade Etchison mine in Montgomery County, Md., are not reported from any of the higher grade chromite mines farther north.

Placer deposits of chromite-bearing sand and gravel occur in the beds of streams that drain serpentine areas or in flats alongside the streams, thinning toward the hills. They are generally overlain by a few inches to several feet of alluvium. Workable deposits vary considerably in thickness, ranging from a few inches to 4 or 5 feet; many are self-renewing as erosion of a chromiferous area continues. Natural concentrations run as high as 40 percent chromic oxide, but they are commonly much lower grade. Concentrates that generally run 40 to 50 percent chromic oxide, and in places more, can be produced from some sands that average as little as 2 percent chromic oxide. Under favorable market conditions such concentrates can be produced profitably. Other sands cannot be concentrated profitably because the composition of the pure chromite grains is below commercial grade.

CHEMICAL COMPOSITION

The chemical composition of chromite is best expressed by the general formula $(Mg,Fe^{+2})(Cr,Al,Fe^{+3})_2O_4$. One of the spinel group of minerals, chromite is not a simple mineral but a complex, isomorphous mixture of several end members, so that its range in composition is very wide. The complex mineralogy and composition of chromite are discussed in detail by Thayer (1956) and Stevens (1944).

Because the range in composition of chromite is so wide, commercial ores may contain anywhere from about 30 percent to 65

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[2] The chromian antigorite is a fibrous purple serpentine mineral having macroscopic physical properties similar to the variety of serpentine called picrolite but optical and other properties identical with antigorite (Glass and others, 1959).

percent[3] or more Cr_2O_3. Knowledge of the chemical composition of an ore is necessary to determine the kind of use for which it is suited, and each of the three industries utilizing chromite ores—metallurgical, refractory, and chemical—has its own specifications based on composition (U.S. Bur. Mines, 1953, v. 1, p. 318–319). Alumina content of nearly all chromite ores from Maryland and Pennsylvania is much too low for refractory grade.

The most desirable metallurgical-grade chromite contains at least 48 percent chromic oxide (Cr_2O_3) and has a chromium to iron ratio of 3:1. Silica (SiO_2) content is less than 5 percent, and magnesia (MgO) and alumina (Al_2O_3) together are not more than about 25 percent. These specifications are more or less traditional, and in practice all types of chromite are blended and used. National Stockpile specifications in 1953 included minimum Cr:Fe ratios of 2.7:1 for high-grade and 1.5:1 for low-grade metallurgical chromite. Hard lump ore is preferred for metallurgical use, but fines and concentrates are also used.

For chemical chromite the most important specification is low (less than 5 percent) silica content. High iron content is not detrimental, and the demands of the chemical industry are so much more limited than those of metallurgy that current specifications for chemical-grade chromite are based on available ore too rich in iron to be used for metallurgical purposes. All this chromite is currently obtained from the Transvaal in South Africa because it is cheap and reserves of relatively uniform ore are large. Specifications include 2.5 to 3.5 percent silica, 43 to 45 percent chromic oxide, and a chromium to iron ratio of about 1.6:1.

Available chemical analyses of chromite ore and of cleaned chromite concentrates from Maryland and Pennsylvania, reported in weight percentages, are given in table 6. Weight percentages of chromium and iron are calculated from chromic oxide and iron oxide content, and the ratio of chromium to iron by weight (Cr:Fe) is given. Many of the analyses included, notably those in which the silica is high, show composition of the ore as mined rather than of the pure chromite; the state of the sample must be taken into consideration in evaluating the tabulated data.

[3] The percentages and ratios used in this section are expressed in terms of weight.

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TABLE 6.—*Complete and partial chemical analyses of chromites from Maryland and Pennsylvania*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cr_2O_3	20.56	45.5	41.56	43.23	43.59	34.1	41.5	[2] 55.5	28.10	36.12	43.23.	42.09	48.5	39.0	30.0	46.1	58.0	57.57
Al_2O_3	17.88	7.5				8.3	7.7		13.43	15.82	17.98		6.19	12.9	9.8	8.6	9.1	
Fe_2O_3*		45.0																
FeO*	17.62		[1] 24.96	[1] 20.49	[1] 12.99	14.4	17.6	24.6	47.52	32.54	27.07	[1] 28.66		22.5	23.3	17.3	23.4	
MgO	20.98	.0				19.6	17.9		3.22	3.05	3.65		5.03	14.4	17.5	15.9	8.6	
CaO	1.08					.0	.6		.26	.10	.45			.0	.0	.0		
TiO_2						.07	.09		.40	.80	.48			.38	.35	.13	.08	
SiO_2	16.42	2.5	6.82	4.44	4.16	16.9	8.8		3.67	9.82	6.28	3.30		7.5	12.5	8.1	.70	
H_2O	6.64					6.3	3.7							3.0	5.2	2.2	.17	
CO_2						.0	1.4							.0	.1	.0		
Other																	(3)	
Total	101.18	100.5				99.67	99.29		96.60	98.25	99.14			99.68	98.75	98.33	100.05	
Cr	14.07	31.1	28.44	29.58	29.83	23.3	28.4	38.0	19.23	24.72	29.58	28.80		26.7	20.5	31.5	39.7	39.39
Fe	13.70	31.5	[1] 19.40	[1] 15.93	[1] 10.10	11.2	13.7	19.1	36.94	25.29	21.04	[1] 22.28		17.5	18.1	13.5	18.2	15.90
Cr:Fe	1.0	1.0	1.5	1.9	2.9	2.1	2.1	2.0	.5	1.0	1.4	1.3		1.5	1.1	2.3	2.2	2.5
Sp gr								4.63									4.63	

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Cr_2O_3	51.3	59.2	51.6	59.5	31.6	30.6	[4] 56.2	32.7	[5] 50.7	61.13	[7] 52.2	52.64	24.26	51.21	36.44	[10] 33.68	60.836	53.36
Al_2O_3	11.0	10.2	11.0	9.7	7.0	9.5		5.0		10.54	7.0	10.00	4.40		13.28		.928	5.98
Fe_2O_3*														48.79			38.952	7.41
FeO*	15.4	14.7	18.1	17.2	18.1	12.1	22.1	12.1	18.1		27.6	16.00	14.54		33.12			26.64
MgO	15.4	14.7	14.1	12.8	21.1	24.3		28.0		7.85	9.9	13.22	26.07		3.64			6.53
CaO	.0		.0		.0	.0		.2				.36	.45		.23			
TiO_2	.04	.11	.10	.11	.09	.08		.08			.35				.96			
SiO_2	4.4	.58	3.5	.30	14.5	14.8		11.9			.64	5.60	24.20		9.66	21.44	.619	
H_2O	1.8	.21	1.5	.10	5.4	5.4		4.1			.25	[8] 1.90	[8] 7.44					
CO_2	.6		.2		.2	2.0		5.9										
Other		(3)		(3)							(3)						[11] .100	[12] .53
Total	99.94	99.70	100.10	99.71	97.99	98.78		99.98			97.94	99.72	101.36	100.00	97.33		101.435	100.45
Cr	35.1	40.5	35.3	40.7	21.6	20.9	38.5	22.4	34.7	41.83	35.72	36.02	16.60	35.04	24.93	23.05	41.63	36.51
Fe	12.0	11.4	14.1	13.4	14.1	9.4	17.2	9.4	14.1		21.45	12.44	11.30		25.74	13.02	27.24	25.89
Cr: Fe	2.9	3.5	2.5	3.0	1.5	2.2	2.2	2.4	2.5	(6)	1.7	2.9	1.5		1.0	1.8	1.5	1.4
Sp gr		4.50		4.53			4.58		4.51		4.61							4.780

*Total iron is reported in older analyses as Fe_2O_3 and in more recent analyses as FeO. Only 1 analysis is available with ferric and ferrous iron reported separately.

[1] Reported as iron oxide; ferrous or ferric not specified. Fe is calculated assuming ferrous iron.
[2] Cr_2O_3 in bulk sample 35.4 percent.
[3] For quantitative spectrographic analysis for minor elements see table 7.
[4] Cr_2O_3 in bulk sample 32.9 percent.
[5] Cr_2O_3 in bulk sample 45.0 percent.
[6] The minimum ratio possible for this sample is about 2.6, assuming the unreported residue is all FeO.
[7] Cr_2O_3 in bulk sample 46.2 percent.
[8] Loss on ignition.
[9] Reported as alumina and iron oxide.
[10] 49.2 percent Cr_2O_3 after cleaning.
[11] Ni.
[12] 0.39 percent MnO, 0.14 percent NiO.

Montgomery County, Md.:
1. Etchison mine (loc. 2, pl. 40). Grab sample from dump. Analyst, E. V. Shannon (1926).
2. Griffith mine (loc. 3, pl. 40). Ducatel (1838, p. 34). Analyst, David Stewart.

Soldiers Delight district:
3-5. Choate mine (loc. 15, pl. 40). Rock ore shipped by Dolfield. Singewald (1928, p. 187). Analyst, Penniman and Browne.
6. Choate mine (loc. 15, pl. 40). 18-in. vertical channel sample from ore pillar. U.S. Geol. Survey, 1956, Lab. No. 142645, Field No. P-1. Analyst, J. I. Dinnin.
7. Unnamed mine (loc. 13, pl. 40). Grab sample from dump. U.S. Geol. Survey, 1956, Lab. No. 142646, Field No. P-2. Analyst, J. I. Dinnin.
8. Unnamed mine (loc. 13, pl. 40). Cleaned concentrate of grab sample from dump. U.S. Geol. Survey, 1957, Lab. No. 147999, Field No. 5NCP-2. Analyst, J. I. Dinnin.
9. Triplett placer (loc. 7, pl. 40). Buddle concentrate. Singewald (1928, p. 168). Analyst, Penniman and Browne.
10. Gore placer (loc. 14, pl. 40). Same as 9.
11. Dolfield placer (loc. 16, pl. 40). Same as 9.
12. Demmitt's meadow. Test concentrate from placer. Singewald (1928, p. 189). Analyst unknown.

Bare Hills district:
13. Bare Hills mines. Massive chromite. Analyst, O. Dieffenbach (1855, p. 534).
14. Main workings (loc. 19, pl. 40). Massive, from dump. U.S. Geol. Survey, 1956, Lab. No. 142648, Field No. P-5. Analyst, J. I. Dinnin.
15. Main workings (loc. 19, pl. 40). Grab sample from dump. U.S. Geol. Survey, 1956, Lab. No. 142647, Field No. P-4. Analyst, J. I. Dinnin.

Jarrettsville-Dublin district:
16. Reed mine (loc. 9, pl. 41). Massive sample from dump. U.S. Geol. Survey, 1956, Lab. No. 142649, Field No. P-8. Analyst, J. I. Dinnin.
17. Reed mine (loc. 9, pl. 41). Cleaned concentrate of massive ore from dump. U.S. Geol. Survey, 1957, Lab. No. 148002, Field No. 4NCP-8a. Analyst, J. I. Dinnin.

State Line district:
18. Line Pit mine (loc. 35, pl. 41). Concentrate of mixed ore from dump. U.S. Geol. Survey, 1943, Sample No. PM-25. Analyst, M. K. Carron.
19. Line Pit mine (loc. 35, pl. 41). Massive sample from old ore pile. U.S. Geol. Survey, 1956, Lab. No. 142650, Field No. P-9. Analyst, J. I. Dinnin.
20. Line Pit mine (loc. 35, pl. 41). Cleaned concentrate of massive ore. U.S. Geol. Survey, 1957, Lab. No. 148003, Field No. 3NCP-9a. Analyst, J. I. Dinnin.
21. Red Pit mine (loc. 37, pl. 41). Massive chromite from main dump. U.S. Geol. Survey, 1956, Lab. No. 142651, Field No. P-11. Analyst, J. I. Dinnin.

State Line district—Continued
22. Red Pit mine (loc. 37, pl. 41). Cleaned concentrate of massive chromite. U.S. Geol. Survey, 1957, Lab. No. 148004, Field No. 5NCP-11a. Analyst, J. I. Dinnin.
23. Red Pit mine (loc. 37, pl. 41). Disseminated chromite, grab sample from main dump. U.S. Geol. Survey, 1956, Lab. No. 142652, Field No. P-12. Analyst, J. I. Dinnin.
24. North Rock Springs mine (loc. 40, pl. 41). Disseminated chromite, grab sample from dump. U.S. Geol. Survey, 1956, Lab. No. 142653, Field No. P-15. Analyst, J. I. Dinnin.
25. North Rock Springs mine (loc. 40, pl. 41). Concentrate of disseminated chromite from dump. U.S. Geol. Survey, 1957, Lab. No. 148000, Field No. 5NCP-15. Analyst, J. I. Dinnin.
26. Tyson Reynolds mine (loc. 49, pl. 41). Disseminated chromite from gulley near old mine location. U.S. Geol. Survey, 1956, Lab. No. 142654, Field No. P-16. Analyst, J. I. Dinnin.
27. Tyson Reynolds mine (loc. 49, pl. 41). Concentrate of disseminated chromite from gulley. U.S. Geol. Survey, 1957, Lab. No. 148001, Field No. 5NCP-16. Analyst, J. I. Dinnin.
28. Wood mine (loc. 57, pl. 41). Massive chromite. Analyst, O. Dieffenbach (1855, p. 534).
29. Wood mine (loc. 57, pl. 41). Cleaned concentrate of massive chromite from dump. U.S. Geol. Survey, 1957, Lab. No. 148005, Field No. 3NCP-17a. Analyst, J. I. Dinnin.
30. Wood mine (loc. 57, pl. 41). Massive chromite from dump. Corbin (1923, p. 6). Analyst unknown.
31. Wood mine (loc. 57, pl. 41). Disseminated chromite rock from dump. Corbin (1923, p. 6). Analyst unknown.
32. Scott mine (loc. 80, pl. 41). Concentrate from average disseminated chromite on dump. Knopf (1922, p. 91). Analyst unknown.
33. Swaggart Run placer (loc. 34, pl. 41). Natural concentrate. Singewald (1928, p. 168). Analyst, Penniman and Browne.
34. Swaggart Run placer (loc. 34, pl. 41). Test concentrate before cleaning. U.S. National Archives, 1918. Analyst unknown.

Philadelphia district:
35. Placer 6 miles west of Chester. Pure chromite crystals. Garrett (1852, p. 47). Analyst, Isaac Starr.
36. Hibbard's placer (loc. 22, pl. 42). Pure chromite crystals. Genth (1875, p. 43). Analyst, F. A. Genth.

Except for the low chromic oxide concentrate from Triplett placer (analysis 9, table 6), the samples analyzed without appreciable admixed rock (those in which the silica content is very low) are excellent chemical-grade chromite; most of the rest, if concentrated, would probably also be chemical grade. In general the iron content is high or fairly high; however, two purified samples of massive ore, from the Line Pit and Red Pit mines, are ideal metallurgical chromite, having a Cr:Fe ratio of at least 3:1. Three additional samples, from the Choate, Line Pit, and Wood mines, have a ratio greater than 2.7:1.

There is a general improvement in grade of the massive chromite from Montgomery County, Md., northeastward to the State Line district; however, four analyses of ore from the Wood mine indicate that grade of the chromite in a single deposit may be variable. Chromite in the disseminated deposits seems to be somewhat lower in chromium and somewhat richer in iron than the massive chromite, and placer chromite seems to be considerably richer in iron than either massive or disseminated chromite. Average[4] Cr:Fe ratio in 10 samples of massive chromite from the Soldiers Delight, Jarrettsville-Dublin, and State Line districts is 2.6:1; in 9 samples of disseminated chromite, 2.0:1; and in 7 samples of placer chromite, 1.3:1.

Samples of massive chromite from the Wilkins and Ayres mines (Jarrettsville-Dublin district) reportedly contained 46 to 49 percent Cr_2O_3 with Cr:Fe about 2.2:1. In the State Line district, concentrates of disseminated chromite from the Geiger mines reportedly contained 48 to 51 percent Cr_2O_3 with Cr:Fe between 2:1 and 2.2:1, and samples of massive chromite from the Kirk mine, 36 to 40 percent Cr_2O_3 with Cr:Fe about 1.7:1.

Table 7 gives quantitative spectrographic analyses for minor elements in cleaned chromite from samples of massive ore collected at the four largest mines in Maryland and Pennsylvania. The zinc content (0.5 percent) and the nickel content (0.3 percent) of iron-rich chromite from the Wood mine are particularly notable. Garrett (1852, p. 45) reported that the nickel content of a sample of Wood mine ore from which he had carefully removed all traces of the green secondary nickel minerals was as high as 2.28 percent NiO (about 1.8 percent nickel). The nickel content of most commercial chrome ores is between 0.1 and 0.25 percent NiO (Thayer, 1956, p. 25).

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[4] The three shipments of rock ore from the Choate mine (analyses 3-5, table 6) are not included because massive or disseminated chromite is not specified. Also excluded is the low-chromium sample from the Triplett placer (analysis 9, table 6).

TABLE 7.—*Quantitative spectrographic analyses, in percent, for minor elements* [1] *in cleaned chromite samples, Maryland and Pennsylvania*

[Analyst, Harry Bastron, U.S. Geol. Survey]

	Mine, Lab. No., Field No.			
	Reed 148002 4NCP-8a	Line Pit 148003 3NCP-9a	Red Pit 148004 5NCP-11a	Wood 148005 3NCP-17a
Mn	0.6	0.1	0.1	0.3
Ni	.02	.1	.04	.3
Zn	.05	(2)	.05	.5
Ti	.06	.08	.06	.2
Co	.02	.01	.02	.05
V	.04	.02	.05	.04
Ca	(2)	.001	.001	.003
Cu	.008	.002	.003	.002
Zr	(2)	.007	.004	(2)
Ga	(2)	.001	.001	.003
Sc	.0002	.0004	.0005	.0004

[1] Looked for but not found: Ag, Au, Hg, Ru, Rh, Pd, Ir, Pt, Mo, W, Re, Ge, Sn, Pb, As, Sb, Bi, Te, Cd, Tl, In, Y, Yb, La, Hf, Th, Nb, Ta, Be, Sr, Ba, P, B.
[2] Not detected.

CONCLUSIONS AND FUTURE OUTLOOK

Investigations have disclosed that Maryland and Pennsylvania contain more old chromite mines and produced more chromite ore than is anywhere recorded; collectively they have accounted for 20 to 25 percent (and possibly as much as 40 percent) of the total chromite produced in the United States to date. The ores were for the most part good chemical grade and were produced at a time when the uses for which they were best suited were almost the only uses for chrome ores, before chromite became necessary for metallurgical purposes and before iron content became an important factor in determining the value of a deposit. In 1955 chemical-grade ore made up 10 percent of the total chromite consumed in the U.S.

These old mining districts are ideally situated with regard to today's consumers, the bulk of chromite consumption being in Maryland, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. Insofar as can be judged from the remaining dump material and old ore piles, much of the chromite in Maryland and Pennsylvania, although too rich in iron to meet present-day nonpenalty specifications, was nevertheless comparable in quality to, and some of it considerably better than, lower grades of chromite that are being used more and more by the metallurgical industry. At least two of the deposits, the Line Pit and Red Pit, contained some good metallurgical-grade chromite (analyses 20, 22, table 6).

Although massive chromite is comparatively rare, it was abundant enough and a few ore bodies were extensive enough to satisfy a large part of the limited demand for chromite during the 19th century. Isaac Tyson consequently did not fully develop all his other holdings, especially those properties where milling of disseminated ore was necessary, but kept them mainly as a safeguard against competition. Some of these were later worked, and some rich disseminated ore was milled and shipped, but much more disseminated ore was apparently mined in the hope that it would grade into massive ore at depth and was discarded. Concentrating experiments on some of this dump material during World War I were short lived, and the only use yet made of it has been locally for road material.

The remnants of these dumps contain the only visible reserves of rock chromite in the area. The writers estimate that at least 4,000 tons of rock that may be 10 to 30 percent chromite are available on 6 mine dumps, or about 400 to 1,200 tons of chromite that probably contains between 48 and 56 percent Cr_2O_3. These are the North Rock Springs, Scott, Engine, "Birdseye," and "Newbold" mines, and the unnamed mine at Soldiers Delight. A small amount of sparsely disseminated material remains at the Wet pit and the pits south of it. In addition, small quantities of massive chromite that could be concentrated remain in parts of the Red Pit mine dump and in what is left of the once-extensive dumps of the Reed and Wood mines, and a little massive ore is available in the Carter mine dump.

Not long after the mines in Maryland and Pennsylvania were closed, Day (1885, p. 570–571) wrote: "The mines in the eastern States are by no means exhausted; the reason why the California ores have been substituted is because they are nearer the surface and therefore richer."

Most other reports agree that these mines were not all worked out during the 19th century and that some contain unmined reserves (Genth, 1875, p. 42; Glenn, 1893, p. 121; Knopf, 1922, p. 87–88). Moreover, ore was found in 4 of the 5 mines that have been completely reopened and examined since 1900. At the Hillside mine it amounted to only about 12 tons and was mined out. At the Choate mine several hundred tons was mined that required milling, which was never attempted, and records suggest that at least 15 tons was visible in the face at the bottom when the mine was closed again. A small chemical-grade ore body reportedly found in the Kirk mine was considered too low grade to justify mining at the time. The Line Pit mine, one of the few which was specifically reported to be mined out in 1874, contained more than 100 tons of high-grade ore in a lens below the depth where mining had previously stopped; most but reportedly not all of this was mined during World War I. No ore was found in the Wood mine, which is said to have been unwatered to its full depth of 720 feet; however, the possibility of a massive ore lens existing farther down the plunge of the mined-out ore body, as at the Line Pit mine, was apparently not investigated, and there is some question as to whether the bottom of the mine workings was actually reached when the mine was pumped out.

Some unmined reserves of disseminated chromite may remain in the area. In 1923 nine pockets of ore were found in the vicinity of the Reed mine. Some of these were probably not exploited, and some of the other deposits which contained only disseminated chromite may not have been mined out before a continued search for massive ore at depth became impractical. The State Line district appears to be the most favorable for such deposits because, insofar as known, milling of disseminated ores was never attempted there and interest in mining them was never strong, whereas disseminated ores were milled to some extent in the Soldiers Delight and Jarrettsville-Dublin districts.

Reserves of placer chromite are considerably more certain because of investigations and experiments made during both world wars; however, little information is available about iron content. Placer reserves in the State Line district are estimated as 25,000 to 45,000 tons of concentrates that would range in grade from 32 to 54 percent Cr_2O_3; in the Soldiers Delight district, about 5,000 tons of concentrates that would run 30 to 40 percent Cr_2O_3. Placer chromite at Soldiers Delight, although it once met a special demand of the ceramic industry, seems to be rich in iron, to contain considerable aluminum, and to be comparatively low in chromium (Singewald, 1928, p. 168); however, some of the State Line placer chromite has proved considerably richer in chromium, particularly on the Reisler property (loc. 90, pl. 41). The extent to which the poorer concentrates could be upgraded with modern concentrating methods has not been explored for many of the known deposits. In the long interval since mining ceased, some of the worked-out placers have probably been renewed by new accumulations of chromite-bearing sand.

Placers in the Philadelphia district do not seem to have been recently investigated, although those formerly worked were comparatively rich in Cr_2O_3. Some of the known deposits were valueless because of admixed garnet (Genth, 1875, p. 40), which was hard to remove from the concentrates using a primitive buddle but would not be a problem with modern concentrating methods, should the need be sufficient. The lack of known placer workings near the Reed mine, where drainage conditions appear to be favorable for the accumulation of placer chromite, suggests that further search there might be rewarding. No placer deposits are known in Montgomery County, Md., but no records have been found suggesting that anyone ever searched for them.

Efforts to revive chromite mining have been largely concerned with the ore bodies already known and worked, but the serpentine districts in Maryland and Pennsylvania may conceal other, undiscovered deposits. Not only is prospecting for chromite extremely uncertain because ore bodies occur so irregularly and unpredictably, but prospecting in the so-called serpentine barrens presents many additional difficulties. The poor, serpentine soil supports a tangled growth of greenbrier and scrub pine that in some places is virtually impenetrable. Tyson was an extremely capable man and is said to have combed the area thoroughly, but it seems probable that he missed some deposits and that he never found it necessary to develop others. The nine pockets of ore found near the Reed mine in 1923, for example, were in a former Tyson mining district that is dotted with shallow prospect pits and trenches dating back to his time. Parts of the area have been prospected since by others, but no thorough, exhaustive search other than Tyson's seems to have been made.

Geophysical surveys were at one time considered the answer to prospecting for chromite in the area. Several have since been tried, with negative results, but they proved only that methods used were not applicable to the problem at hand. Recent geophysical prospecting for chromite in Cuba with more sensitive gravity equipment has met with notable success, and new techniques may likewise prove useful in the Maryland and Pennsylvania districts.

Geochemical prospecting for chromium or for trace elements that occur in chromite is another technique that may some day prove valuable in the overgrown eastern serpentine districts. The U.S. Geological Survey is currently working on a rapid and sensitive method for the determination of chromium in soils.

A relation that may prove useful to the prospector is the typical close association of unusual minerals such as kämmererite, williamsite, magnesite, deweylite, brucite, zaratite, and genthite with the massive chromite deposits in the district.

MINE DESCRIPTIONS

Information about the chromite mines in Maryland and Pennsylvania is scattered in the literature, incomplete and in some places contradictory. Known mines and placer deposits are described in the following pages; others, long forgotten, may exist in the area, and many small openings that produced less than 25 tons of ore are excluded.

MONTGOMERY COUNTY, MD.

Little prospecting for chromite has been done in the Montgomery County district since Isaac Tyson's time, and it is the most incompletely known of all the serpentine districts. Only one of several mines reported in the district has been exactly located, the Etchison mine, and recently published maps do not even show serpentine in its vicinity.

Etchison mine

The Etchison mine, three-fourths of a mile west-northwest of the present town of Etchison (loc. 2, pl. 40), was worked intermittently before the Civil War, and the ore was hauled to Woodbine for shipment (Singewald, 1928, p. 191). The southwesternmost, and in 1928 the only accessible one, of 3 pits was 30 feet in diameter and 15 feet deep; from it a steeply inclined working shaft extended 50 feet N. 20° W. and entered a water filled stope that extended N. 70° E. for a distance of 30 feet. The stope is reportedly under the house west of a private road. About 1950 the workings were bulldozed over.

The serpentine is talcose schist. Shannon (1926, p. 16) described and analyzed a grab sample from what he interpreted as an old chromite ore pile. It was a brownish-black ferroan magnesiochromite with comparatively low specific gravity. Highly fractured and intimately mixed with margarite and serpentine, it assayed only 20.56 percent Cr_2O_3 (table 6, analysis 1), and Shannon's calculations indicate that in its purest form it would contain less than 35 percent Cr_2O_3 and about 30 percent FeO. In 1951, however, Heyl collected some dark-gray-blue massive ore from the Etchison mine dump that was probably better grade than Shannon's specimen. Other minerals reported from the mine are chrome tourmaline, fuchsite, rutile, and magnesite.

Lyde Griffith property

Ducatel (1838, p. 33–34) describes ore from a mine on the estate of Col. Lyde Griffith near the old town of Etchison (half a mile north of the present town) and locates the mine on his map some distance from the other Etchison mine (loc. 3, pl. 40). The ore assayed 35 to 45 percent Cr_2O_3 but was very rich in iron (analysis 2, table 6). Several tons of chromite were mined prior to 1838.

SOLDIERS DELIGHT DISTRICT

LODE CHROMITE

The Soldiers Delight district is about 15 miles northwest of Baltimore city, in Baltimore County, Md. (pl. 40). Four lode chromite mines are recorded in the literature—the Choate, Weir, Harris, and Calhoun mines. A fifth old mine was found by the writers in 1955 and accessible parts of it were mapped. Estimates of total production from the district vary widely. Between 6,000 and 10,000 tons would be a reasonable minimum estimate for the 5 mines based on history, dump size, and reported workings. Massive and disseminated chromite from the district assayed 30 to 50 percent Cr_2O_3 (Knopf, 1922, p. 91).

Weir and Harris mines

The Weir and Harris mines are in the western part of the district, on the same property but on opposite sides of a small run 0.3 mile apart (locs. 8, 9, pl. 40). Both were worked before 1880, and the property was included in a geophysical and diamond-drilling program in the 1930's. The southwestern group of workings, the Weir mine, is reported to have been the largest mine at Soldiers Delight. Singewald (1928, p. 187–188) describes four old shafts and several surface cuts that were parts of the Weir mine. Reportedly 200 or 250 feet deep, the shafts are now caved and partly water-filled; the dumps are removed.

In 1928 the Harris mine (loc. 9, pl. 40) consisted of 4 caved and water-filled shafts, 1 of which was enlarged at its mouth to 25 by 8 feet (Singewald, 1928, p. 188). The northernmost shaft was reportedly the deepest, probably extending downward 80 or 85 feet. The mine was obliterated before 1955.

The Weir and Harris ore bodies appear to have been a series of northeast-trending isolated masses of chromite 2 to 4 feet wide, surrounded by much disseminated ore. Disseminated chromite was visible in the walls of the Harris shafts before they were filled, and specimens of richer ore were on the dump (Singewald, 1928, p. 188). Probably a large percentage of the ore from both mines was disseminated, inasmuch as a concentrating mill was built on the north bank of the stream between the two. Both are reportedly mined out; although the Harris mine may not have been completely cleaned of disseminated chromite, it is now completely inaccessible. Exploratory drilling in the 1930's southeast of the mines is reported to have revealed magnetite downdip from the ore bodies but no chromite.

Choate mine

About a mile southeast of the Harris mine and 3 miles west-southwest of Owings Mills is the Choate (Shote) mine (loc. 15, pl. 40). Because the Choate mine was cleaned and retimbered under the stimulus of World War I, more information is available about it than about most of the other Tyson mines. Accessible parts of the mine were mapped by pace, tape, and compass methods in 1954 and 1955 (pl. 43).

The Choate mine was opened during the early period of chromite mining, sometime before 1839, and was worked intermittently until 1877 or 1880. Its two main periods of activity were during the decade before 1840 and the decade after 1865. In 1917 J. H. Buxton, Jr., unwatered, cleared, and retimbered it to the bottom and sorted out some shipping ore in the process. During the summer of 1918, after 500 to 800 tons of lean ore had been sorted out to be milled, mining was stopped. Plans to mill the ore were halted by the armistice. In the late 1920's an attempt was reportedly made to pump out the mine with gasoline-powered pumps, but pumping was stopped when several men were asphyxiated (E. L. Dinning, Jr., 1956, oral communication). An unsuccessful geophysical survey of the mine area was reported in 1928.

The Choate mine consists of an inclined shaft that slopes 20° WSW., opening at a depth of about 50 feet into a gently west-dipping stope (pl. 43). The stoped area is reported to widen continually downward and to end with a mine face 160 feet long. The total depth down the incline is between 165 and 200 feet. Knopf (1922, p. 96) speaks of a drift 160 feet long at the bottom of the shaft, but the Tyson Mining Co. had backfilled the mine with waste rock, so that the bottom of a wide stope may have appeared to be a drift before it was completely cleaned out. A vertical shaft northwest of the incline leads into a smaller stope and is connected with the main stoped area by a tunnel.

The ore body at the Choate mine appears to have been mostly disseminated chromite concentrated in either a series of closely spaced lenses or an irregular, pinching and swelling blanket that plunged about 20° W. Former miners reported ore lenses not more than 4 or 5 feet thick that pinched out completely in places (Singewald, 1928, p. 187). The upper parts of the mine that were accessible in 1954–55 are thoroughly mined out; chromite exposed in one ore pillar is 18 inches thick, and edges of the ore body still visible in the walls are less than 1 foot thick. The ore body seems to have widened considerably with depth. At the bottom an ore lens was reported to extend the entire width of the 160-foot face and to be from several inches to 4½ feet thick, dipping westward. Other reports, however, suggest that the Maryland Chrome Corp. turned its attention to problems of concentration because the ore in sight in the bottom of the mine was the pinching edge of a lens only about 8 to 18 inches thick and therefore unprofitable to mine.

The ore is mostly granular disseminated chromite in green serpentine. Some massive ore was found on the dump, but none was seen in place; according to one report, the Tysons produced massive ore from the Choate mine that was as high as 55 percent Cr_2O_3. The grade of ore shipped in 1918–19 is shown in table 6 (analyses 3–6).

Minerals reported from the Choate mine in addition to chromite include the serpentine varieties williamsite and picrolite, kämmererite, talc, magnesite, brucite, deweylite, aragonite, chalcedony, and jasper.

Unnamed mine

The unnamed mine found by the writers at Soldiers Delight is about 0.4 mile north-northeast of the Choate mine (loc. 13, pl. 40; fig. 66). The mine consists of 2 shafts, 1 of which is caved, a shallow

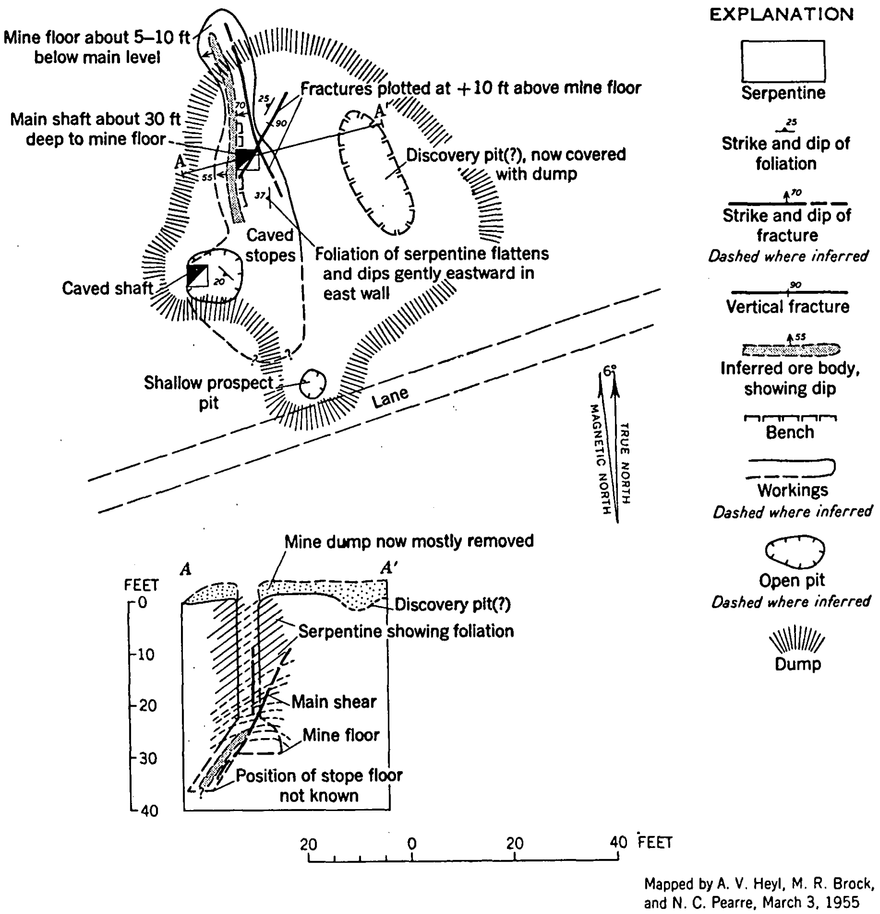

FIGURE 66.—Geologic map and section of unnamed chromite mine in Soldiers Delight district (loc. 13, fig. 40), Baltimore County, Md.

prospect pit, and the remains of a fair-sized dump on which chromite is abundant (fig. 66). The main shaft is accessible to a depth of about 25 feet; and from the floor timbered stopes, now mostly caved, slope down in all directions. The stoped area is visible to the north for a distance of about 30 feet and also apparently continues downdip to the west.

The ore body seems to be a thin veinlike lens, massive in the center and disseminated near the margins, that strikes generally about N. 10° W. and dips about 55° W. Where mined, the lens was probably between 1 and 2 feet wide and at least 40 feet long; its extension downdip is unknown.

The chromite remaining on the dumps is mostly high-grade disseminated ore, but some is massive; it occurs in yellowish- to bluish-green serpentine. A grab sample of typical ore from the dump yielded 41.5 percent Cr_2O_3, and a concentrate from similar ore assayed 55.5 percent Cr_2O_3 (analyses 7, 8, table 6).

Calhoun mine

The Calhoun mine is a mile and a quarter west-southwest of Delight in the northern part of the Soldiers Delight district (loc. 12, pl. 40). Two shafts about 1,000 feet apart were worked before 1880. The more westerly one has since been completely removed in a large serpentine quarry (loc. 11, pl. 40). The eastern or main shaft was reported 100 feet deep. Northeast of it is an opencut over 100 yards long and at least 25 feet deep that trends N. 20° W. Both disseminated and massive ore are reported.

PLACER CHROMITE

Placer deposits in the beds of small streams throughout the district were extensively worked and by 1839 had produced 1,000 tons of chromite concentrates (Ducatel, 1840, p. 40). By 1884 concentrates from this district and the Bare Hills district together totaled 5,000 long tons. Small-scale production of concentrates by farmers in the district continued intermittently until about 1920.

The four major localities at Soldiers Delight in later years were the Triplett, Old Triplett, Gore, and Dolfield placers. The locations of known buddles where sands from the deposits were concentrated are shown on plate 40 (locs. 7, 10, 14, 16), but very little is known of the location of buddles worked during the early, more productive years beginning sometime between 1810 and 1820. According to Knopf (1922, p. 91), chrome sand concentrates from the district assayed 28 to 43 percent Cr_2O_3; analyses are given in table 6 of several samples (analyses 9–12).

Triplett and Old Triplett placers

A. R. Triplett, the largest and most regular producer of concentrates in the district, first operated the Old Triplett buddle (loc. 10, pl. 40), on the stream between the Harris and Weir mines. His more productive locality was 0.4 mile south of the Weir mine on Chimney Branch (loc. 7, pl. 40), where conditions are very favorable for chrome washing, the streambed being broad yet the grade sufficient to permit concentration of chromite in irregularities and depressions without much accumulation of detrital material (Singewald, 1928, p. 190). Triplett sold his ore first to the Baltimore Chrome Works and later to W. C. Lowndes in Baltimore. At intervals from 1880 to 1917 he produced as much as 40 to 50 tons monthly of concentrates running about 38 percent Cr_2O_3, for which he received $28 to $30 a ton—only $5 more than the cost of production. Singewald (1928, p. 168, 170) reported that a sample of concentrate collected from Triplett's buddle was notably coarse and was high in iron (47.52 percent FeO) and low in chromium (28.10 percent Cr_2O_3); also that serpentine nearby contained small pockets of magnetite. The complete analysis is given in table 6 (analysis 9).

Gore placer

Jay Gore's buddle, half a mile northeast of the Choate mine on a branch of Red Run (loc. 14, pl. 40), was operated intermittently for a number of years until 1915 (Singewald, 1928, p. 189) and produced 5 to 6 tons of concentrates each year. The product was sold to Pusey Bye, of Philadelphia; in 1914 it brought $44 a ton. The ratio of concentration of the sand after screening was 8 : 1. (See analysis 10, table 6.)

Dolfield placer

The area southeast of the Choate mine was a good source of sand chrome for many years. About 1856 the property owner shipped 80 tons of concentrates. From 1880 until about 1920 local farmers together produced perhaps 25 to 50 tons of concentrates a year.

The Dolfield buddle on a branch of Red Run (loc. 16, pl. 40) was built in 1914 and was operated until 1916 by William Rose. The product was sold to W. C. Lowndes, of Baltimore. Concentrates from the buddle were, for the district, comparatively rich in Cr_2O_3 (analysis 11, table 5). Preliminary tests in 1917 with a hand magnet indicated that the nonmagnetic part, 68 percent of one sample, was unusually rich in iron and the magnetic part was unusually rich in Cr_2O_3.[5]

In 1917 the property was examined for sand chrome reserves. Deposits were considered generally too small and too variable in grade to justify a plant for processing them, except in Demmitts meadow, where development work indicated an average of 6 inches of sand that was 20 percent chromite over an area of 200,000 square feet along a stream. On the basis of very limited concentrating experiments, Demmitts meadow was estimated to be capable of yielding about 2,000 tons of concentrates that would contain about 42 percent Cr_2O_3 (Singewald, 1928, p. 189).

BARE HILLS DISTRICT

Numerous prospect pits and trenches were dug in the quest for chromite in the Bare Hills district, north of Baltimore, Md., where chromite was first discovered in the United States (Hayden, 1833; Singewald, 1928, p. 184). Most of these openings are shown on plate 40. Placer deposits of chromite were also worked in the stream valleys at Bare Hills, particularly in the ravines on the eastern slopes east of the State highway; but little is known about them, except that they produced at intervals over many years.

The Discovery workings (loc. 20, pl. 40) and the Main workings (loc. 19, pl. 40) were mapped with tape and compass in March 1955,

[5] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

when an unusually low water table permitted access to the uncaved parts that were underground (pl. 44). The Discovery workings consist of several shallow open pits and trenches west of a small creek branch. The dumps contain much disseminated chromite. A caved adit that extends westward under them is reported to be 80 feet long and in barren serpentine (Singewald, 1928, p. 185); a few small pieces of ore, however, were found by the writers on the adit dump. The Main workings, which are east of the stream, consist of an inclined shaft, a drainage adit 180 feet long and an area at least 200 feet long of old stopes that are now mostly caved. The shaft is inclined 60° S. 70° E. and is reported to be 80 feet deep. The stoped area extends southwestward from the shaft, toward the Discovery workings, and comes to the surface in a small ravine; its extension northeastward is not known. Loose fragments of chromite coated with kämmererite were found on the dumps and in the accessible workings.

Several hundred feet west of the Discovery workings, a trench about 50 feet long is incised into the western slope of the same hill. Chunks of orange-yellow serpentine from the trench are encased in bluish-green fibrous serpentine and lavender kämmererite as thick as half an inch. Grains of chromite are fairly evenly disseminated through both varieties of serpentine and through the kämmererite. The fibrous serpentine and kämmererite appear to have replaced the walls of fractures in chromite-bearing yellow serpentine. The dump from a small, shallow prospect pit between the Discovery workings and the trench is barren of chromite.

The Bare Hills ore seems to have occurred in several pipelike bodies or elongate lenses that plunged gently eastward. The size of the workings indicates that the pipes or lenses were small in cross section, and the quality of ore left on the dumps indicates that the ore consisted mostly of sheared disseminated chromite mixed with purple kämmererite. Crushed and sheared massive chromite intimately mixed with kämmererite was found in the Main workings and on the Main dumps. Some of the chromite is nodular. The inclined shaft and stopes of the Main workings apparently follow a major shear zone 7 to 8 feet wide that strikes northeastward, dips 60° southeastward, and is filled with chlorite and actinolite. The hanging wall is massive serpentine; the footwall, brecciated serpentine. Indications are that the chromite ore body was along the hanging wall. At the Discovery workings the eastward-plunging pipes or lenses of chromite were approximately concordant with the slope of the hill and about 10 feet below the surface (Hayden, 1833, p. 356).

Available analyses indicate that the chromite at Bare Hills is comparatively rich in iron (analyses 14, 15, table 6). Some high-grade ore was reportedly mined at Bare Hills, assaying as high as 60 percent Cr_2O_3 (Anonymous, 1880, p. 48).

Minerals and textural varieties of serpentine characteristic of the Bare Hills mines, in addition to chromite and kämmererite, are: the serpentine varieties picrolite, baltimorite, williamsite, and marmolite; talc, deweylite(?) (some of which is illite by X-ray determination), hydromagnesite, magnesite, and amphibole asbestos.

Operations were confined to an early period when little was known about chromite and were discontinued because, although it was widespread, most of the ore was too low grade to justify the difficulties of mining it (Ducatel, 1840, p. 40). Later, when the excitement of high-grade discoveries died down and efforts were made to concentrate and ship leaner ore, the Bare Hills deposits remained forgotten. The district is now in the suburbs of an expanding city, and it seems unlikely that it will ever produce chromite again, even should the disseminated ore prove sufficiently abundant and amenable to concentration.

WOODENSBURG-CARDIFF DISTRICT

Most of the serpentine in the Woodensburg-Cardiff district is derived from pyroxenite or gabbro and is markedly lacking in chromite. Philip Tyson (1862, p. 66) noted that some chromite intimately mixed with magnetite occurs in the serpentine on either side of Gunpowder Falls, near the junction of its north and west branches south of Whitehall, Baltimore County (pl. 41), but that it is of little or no commercial value. Two deposits of titaniferous magnetite nearby produced iron before 1900. (See p. 791–792.)

JARRETSVILLE-DUBLIN DISTRICT

LODE CHROMITE

Of the five lode chromite mines known in the district, only one—the Reed mine—seems to have been important. It was worked intermittently over a span of about 50 years by the Tyson Mining Co. The Cherry Hill, Wilkins, and Ayres mines were worked briefly before 1900, and the "Birdseye" mine was worked during the 1920's.

Disseminated ore from the Wilkins and Reed mines, and possibly from the Ayres mine as well, was concentrated during the 1870's in the Wetherill mill, 0.3 mile southeast of the Wilkins mine on State Route 23. The old building was still standing in 1956.

In 1922 the Maryland Chromite Co. reported that by diamond drilling they had located nine ore pockets in the vicinity of Jarrettsville (U.S. Geol. Survey, 1922, pt. 1, p. 107). Between 1922 and 1928 they mined 307 long tons of chromite with a Cr_2O_3 content greater than 45 percent; of this chromite, 276 tons was shipped. Some of the ore came from the "Birdseye" mine, and some may also have been mined from an ore-bearing drift reported at the 40-foot level of the Reed mine, although local residents do not recall that there was any production from the mine when the upper workings were unwatered.

Reed mine

The Reed mine, 1.4 miles northeast of Jarrettsville, Harford County, Md. (loc. 9, pl. 41), was one of the world's first chromite mines as well as one of the largest chromite producers in the United States. It was most active during the 1870's (Singewald, 1928, p. 181–182). The Reed mine seems to have escaped attention during World War I, but in 1922 it was reopened by the Maryland Chromite Co., and the old shaft was unwatered to the 40-foot level.

The surface workings consist of a shaft and several series of opencuts, prospect pits, and trenches spread over an extensive area; some are described and sketched by Singewald (1928, p. 181–182). The main shaft is a timbered opening 8 by 10 feet, now filled with water. The groups of opencuts and pits are northwest and southeast of the shaft in a zone several hundred feet wide; they trend N. 75° E. and S. 60° E. Immediately southeast of these openings is a serpentine quarry. The wooded area around the Reed mine, particularly east and southeast of the mine workings as far as the "Birdseye" mine, is dotted with numerous old prospect pits and shallow, brush-covered trenches.

Although the underground workings must be extensive, no map or written description of them is known. Singewald quotes the mill-owner as saying that the openings were all less than 100 feet deep; however, about 1929 the Reed brothers, who were employed at the mine in the 1920's, said that the main shaft is 160 feet deep, a platform at the 40-foot level shuts off the lower parts of the mine, and a drift at the 40-foot level is 100 feet long and ore-bearing (E. L. Dinning, Jr., 1956, oral communication). Mr. Martin Kurtz, of Jarrettsville, told the writers in 1956 that he also had seen the platform when the upper part of the mine was unwatered and that the water level in the connected opencuts southeast of the shaft was lowered considerably at that time, revealing a large inclined stope extending northward or northeastward from the largest cut east of the shaft for a considerable distance. Extensive underground stopes are required to account for the total reported production.

The ore bodies at the Reed mine consisted of several lenses or sack-form bodies of chromite that appear to have been echeloned northwest. The discovery shaft, sunk at a spot where nearly 30 tons of chromite boulders lay on the surface, reached an ore lens at a depth of 8 feet that dipped 75° W. and was 80 feet long, 25 feet wide, and 4 to 8 feet thick (Glenn, 1896, p. 488); two smaller pockets were found nearby. These ore bodies were probably massive chromite in the center, grading into disseminated ore near the edges. The Reed brothers seemed to recall a band of chromite in the bottom of the 100-foot drift on the 40-foot level that was about 3 feet wide and in places widened to 16 feet (E. L. Dinning, Jr., 1956, oral communication).

The dumps are extensive although a large part has been removed for road material. They contain disseminated and some massive chromite. A grab sample of the massive ore analyzed 46 percent Cr_2O_3 and a cleaned concentrate analyzed 58 percent Cr_2O_3 (analyses 16, 17, table 6). Results of a quantitative spectrographic analysis for minor elements are given in table 7. Talc, kämmererite, chromian antigorite, and bright-green serpentine are associated with the ore; magnesite and brucite are also reported.

"Birdseye" mine

About 0.2 mile east of the Reed mine workings is another small mine, locally called the Birdseye pit because its dumps contain much disseminated chromite (loc. 10, pl. 41). The mine was worked in the 1920's and undoubtedly contributed some of the production reported from the Jarrettsville vicinity at that time. It is in an area of numerous old prospect pits.

The mine is an inclined shaft that trends N. 65° W., and the shaft opening is about 20 feet long at the surface. It was filled with water in 1956; its depth is not known. Northwest of it are two smaller, shallow pits. At the western end of the main opening is a shear zone that strikes S. 80° W., dips 75° S., and contains a vein of amphibole asbestos about an inch thick. This appears to be part of a wider shear zone along which the chromite may have occurred. Schistosity of the country rock at the western edge of the pit strikes approximately parallel to the shear zone and dips 45° S. E. L. Dinning (oral communication, 1956) reports that there was ore in the mine when he pumped it out some years ago.

The dumps of the "Birdseye" mine are unusually rich in disseminated chromite and also contain considerable massive chromite. No attempt seems to have been made to mill the ore. The main dump is about 20 by 20 feet and averages about 2 feet in thickness; it is estimated roughly to contain about 30 to 40 percent chromite.

Wilkins (Wilkens) mine

The Wilkins mine is 0.4 mile southeast of the Reed mine on the north side of State Route 23 (loc. 12, pl. 41). It was worked for about 2 years about 1870 by Wilkins and Streett but was closed when the showing of ore became unfavorable (Singewald, 1928,

p. 182). When Singewald visited the mine it consisted of six small pits alined about N. 55° W.; these were later mostly filled in and the dumps used for road material; one pit and a small dump were still evident in 1956.

Nothing is known of the size and shape of the ore bodies except that they were undoubtedly small. Both massive and disseminated chromite were collected by the writers from the extant dump. The proportion of disseminated ore was probably large, inasmuch as a concentrating mill was used. The ore is said to have been easily concentrated and possibly to have a high ratio of chromium to iron. A dump sample, presumably of massive ore, reportedly assayed 47 percent Cr_2O_3 and 19 percent FeO, making the Cr:Fe ratio about 2.2:1.

Minerals associated with chromite at the Wilkins mine include kämmererite and the serpentine textural varieties williamsite and picrolite.

Ayres mine

About 0.3 mile east of the village of Chrome, north of Chrome Hill Road, is the old Ayres mine (loc. 13, pl. 41). A water-filled opening about 50 feet long and 8 to 12 feet wide trends N. 45° E. and is surrounded by dump material; nearby are several small prospect pits. The mine, worked about 1870, is reported to be 75 feet deep (Singewald, 1928, p. 183).

Small pieces of massive and disseminated chromite with thin fractures filled by kämmererite can readily be found on the dump. A dump sample of massive ore is reported to have assayed 49 percent Cr_2O_3 and 19 percent FeO, making the Cr:Fe ratio about 2.3:1.

Cherry Hill mine

Figure 67 is a sketch map of the Cherry Hill mine (loc. 17, fig. 41). The dump within the L of the pit contains considerable massive and disseminated chromite, but the larger dumps south and west of the pit are relatively barren of ore. Green williamsite is conspicuous on the dumps and in veins along fractures in the walls of the pit.

The eastern limb of the pit follows a conspicuous shear zone that strikes N. 75° E. and dips 88° SE.; the hanging wall of the shear zone forms the southeastern wall of the pit. A shear zone in the opposite wall also strikes N. 75° E. but dips 50° northwestward.

In the south wall of the pit are two thin, nearly flat seams of chromite in place. They are 6 inches apart, strike about N. 75° E., and dip about 15° to 20° SE. The upper seam thickens eastward from 1 inch to 3 inches; the bottom one is about 1 inch thick and is mostly disseminated chromite.

The production is not known but must have been small.

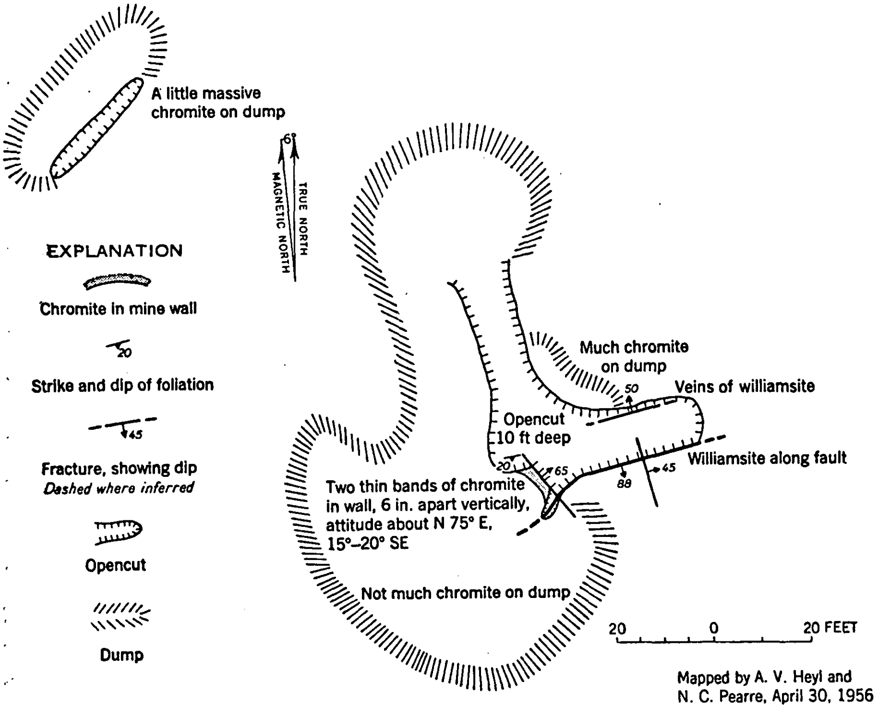

FIGURE 67.—Sketch map of the Cherry Hill chromite mine, Jarrettsville-Dublin district, Harford County, Md.

PLACER CHROMITE

Chrome-bearing sands were reportedly washed at a number of localities in the Jarrettsville-Dublin district (Singewald, 1928, p. 180), but detailed information is available for only one, a small tributary of Deer Creek about a mile southeast of the village of Cherry Hill (loc. 16, pl. 41), a short distance west of and down slope from the Cherry Hill rock chromite mine. Favorable localities were the numerous small flats where branches joined the main stream. The operations yielded considerable sand chromite before 1900 (Singewald, 1928, p. 183). A buddle was also built, and some sand chrome mined in the vicinity of Chrome, near the Ayres mine.

STATE LINE DISTRICT

LODE CHROMITE

The State Line serpentine district (pl. 41) was the major chromite-mining district in the Piedmont of Maryland and Pennsylvania. Twenty-four lode-chromite mines are known to have been worked in the district, among them the Wood mine and the Line Pit mine. Others almost certainly were operated. Most of the mining was done before 1900, but several of the mines were reopened during

World War I and a few produced some ore. The western part of the district between Conowingo Creek and Octoraro Creek, in Fulton and Little Britain Townships, Pa., is called Texas in the older literature, and the name is used with considerable confusion by older writers.

Production of lode chromite from the district was large; how large is not known. It is safe to say that production was considerably greater than 150,000 tons, much of it high-grade ore.

Line Pit (Lowe's) mine

The Line Pit mine (loc. 35, pl. 41) is three-quarters of a mile northwest of Rock Springs, Md., and is crossed by the Mason and Dixon Line. Straddling the State Line as it does, the locality produced much confusion in the literature. The initial discovery of chromite was made north of the Line, in Lancaster County, Pa., on the property of Andrew Lowe. The deposit was mined for a while before 1838 by William Scott and Joshua Lowe, and afterward by Isaac Tyson. Operations continued intermittently until 1874, when a local paper[6] reported that the ore was no longer being obtained in paying quantity.

In 1917 the Chrome Mining Co. worked over the dump, unwatered the mine, sank 20 feet below the old level, and located a new ore body, part of which they mined. Loss of a chromite market following the armistice forced the mine to close in February 1919. About 1937 the Line Pit mine was leased by the American Chrome Corp. but was apparently not operated.

The Line Pit workings (pl. 45) consist of 2 shafts about 60 feet apart, the northwesterly one of which—probably Lowe's mine—begins as an enlarged pit and is connected with the other, the Line shaft, at a depth of 92 feet by a gently sloping drift or stope 75 feet long. The Line shaft is vertical to this depth (92 ft.); below it, a steep incline continues southeastward for an additional 107 feet, at the end of which another gently sloping drift or stope followed ore for about 40 feet. A lower incline continues downward an additional 60 feet at an angle of 60°.

The ore body at the Line Pit mine has been described by Gordon (1922a, p. 450). It is an irregular, pinching and swelling pipelike mass of coarse massive chromite, with short stringers of chromite extending from it into the surrounding serpentine. At the surface workings the central mass was dumbbell shaped in cross section and plunged vertically or nearly so (pl. 45), whereas near the bottom of the mine it was elliptical in cross section and plunged eastward. Average diameters of the ore body in the lower parts of the mine were 5 feet and 8 feet. A sketch made by F. L.

[6] Daily Local News of West Chester, Nov. 18, 1874.

Garrison in 1918 when the mine was unwatered (see pl. 45) indicates that the ore body plunges in a steplike pattern, with marked local changes in plunge from nearly vertical to nearly horizontal. Glenn (1896, p. 490) describes a northward plunge, which may have existed locally in the nearly vertical near-surface discovery workings.

The Line Pit deposit is unusual in that the chromite body is surrounded by translucent emerald-green serpentine, or williamsite, in what Gordon describes as a sheathing averaging about a foot in thickness (pl. 45, section). Surrounding this are ordinary types of serpentine. At the surface, much of the ore body with its williamsite sheathing is separated from the ordinary serpentine wallrock by curved smooth-walled shear zones. Gordon describes veins of williamsite that extend into the ordinary serpentine in other parts of the mine, and tabular masses of it that form partings in the central chromite body; he considers the williamsite to be a result of hydrothermal metamorphism of enstatite. The emerald-green williamsite is highly prized as a semiprecious stone.

Clinochlore, kämmererite, and chromian antigorite fill fractures in the chromite. At depth, numerous veins of magnesite containing residual green serpentine cut both chromite and serpentine.

According to F. L. Garrison (*in* Singewald, 1928, p. 178), the ore body had pinched to 2 or 3 feet at the bottom of the 19th-century workings. When Garrison extended the shaft downward he found a high-grade elliptical body of massive chromite about 11 feet long and 4 feet wide. He mined several feet wider to include small stringers from the main body and leaner, disseminated ore from the side walls. According to Singewald (1928, p. 178), the ore body pinched again at the end of Garrison's extension, and there was a heavy inflow of water. Available data[7] indicate, however, that the ore body was not mined out when the mine closed.

The ore was mostly massive and averaged 50 percent Cr_2O_3, and there was some disseminated ore that averaged about 30 percent. The concentrate from a sample of massive ore assayed 59.2 percent Cr_2O_3, with Cr: Fe ratio 3.5:1 (analysis 20, table 6; see also analyses 18, 19).

Peoples tract

The Peoples tract is an area southwest of Rock Springs Church in Fulton Township, Lancaster County, Pa.; it embraces Lowe's mine and the Red Pit, Wet, North Rock Springs, and "Jenkins" mines (locs. 35, 37, 39, 40, 41, pl. 41). Lowe's mine has been discussed as a part of the Line Pit mine. The other four were field checked and the surface workings mapped in 1955. Some trenches are evident in the area between the Red Pit and North Rock

[7] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

Springs mines (locs. 37, 40, pl. 41), dating back either to the time the mines were active or to a period of exploration about 1919. Two shallow shafts or prospect pits, the "Damp" pits, are in a swamp 0.2 mile east of the Red Pit mine, on the northeast side of the road and alined parallel to it (loc. 38, pl. 41). The dump of the eastern one contains much disseminated chromite. At least 1 and probably 2 or more additional mines have been reported nearby in the densely wooded parts of the Peoples tract. The mine names that survived have been thoroughly confused in the literature.

Red Pit mine.—The mine is along a dirt road 0.15 mile north of the Pennsylvania-Maryland line in Fulton Township (loc. 37, pl. 41). One of the largest of Tyson's mines, it was reportedly closed in 1868 by an explosion on the 400-foot level, and no dependable records are available. The mine is reported to have been at least 500 feet deep and to have produced many thousand tons of ore that ran better than 50 percent Cr_2O_3. It is said to have been almost as large a producer as the Wood mine, but no efforts to reopen it after the explosion are recorded, and knowledge of it was virtually lost.

In 1955 the Red Pit mine showed abundant evidence of former activity (fig. 68). A caved shaft and part of a large dump remain, just south of the road. An extensive area of shallow pits and prospects east of the shaft extends about 340 feet along the road and 220 feet south of it. Some of the larger pits probably produced ore at one time. Sixty feet northwest of the main shaft and north of the road is another old shaft with a small overgrown dump. This is called the Wet pit in some reports; however, it is more probably a part of the Red Pit operations. An area of shallow prospect pits extends about 100 feet east of the northern shaft.

Both massive and rich disseminated chromite remain on the main dump; disseminated is more abundant than massive. Some loose pieces of disseminated ore in lenses and veinlets were collected in the walls of the main shaft and in the shallow pits to the east. Cleaned concentrate of a sample of massive ore contained 59.5 percent Cr_2O_3, and the Cr:Fe ratio was 3:1 (analysis 22, table 6). Complete analyses are given in table 6.

Associated with the chromite at the Red Pit mine are abundant chalcedony stained green with genthite, amphibole asbestos veinlets, and some bright green williamsite. Red siliceous float containing an unusual type of lustrous magnetite is abundant in the prospected area east of the main shaft and seems to be the characteristic feature that gave the Red Pit mine its name. Some pieces of granitic rock were found on the older, overgrown part of the dump, although the mine is almost half a mile south of the serpentine-granodiorite contact as mapped (pl. 41).

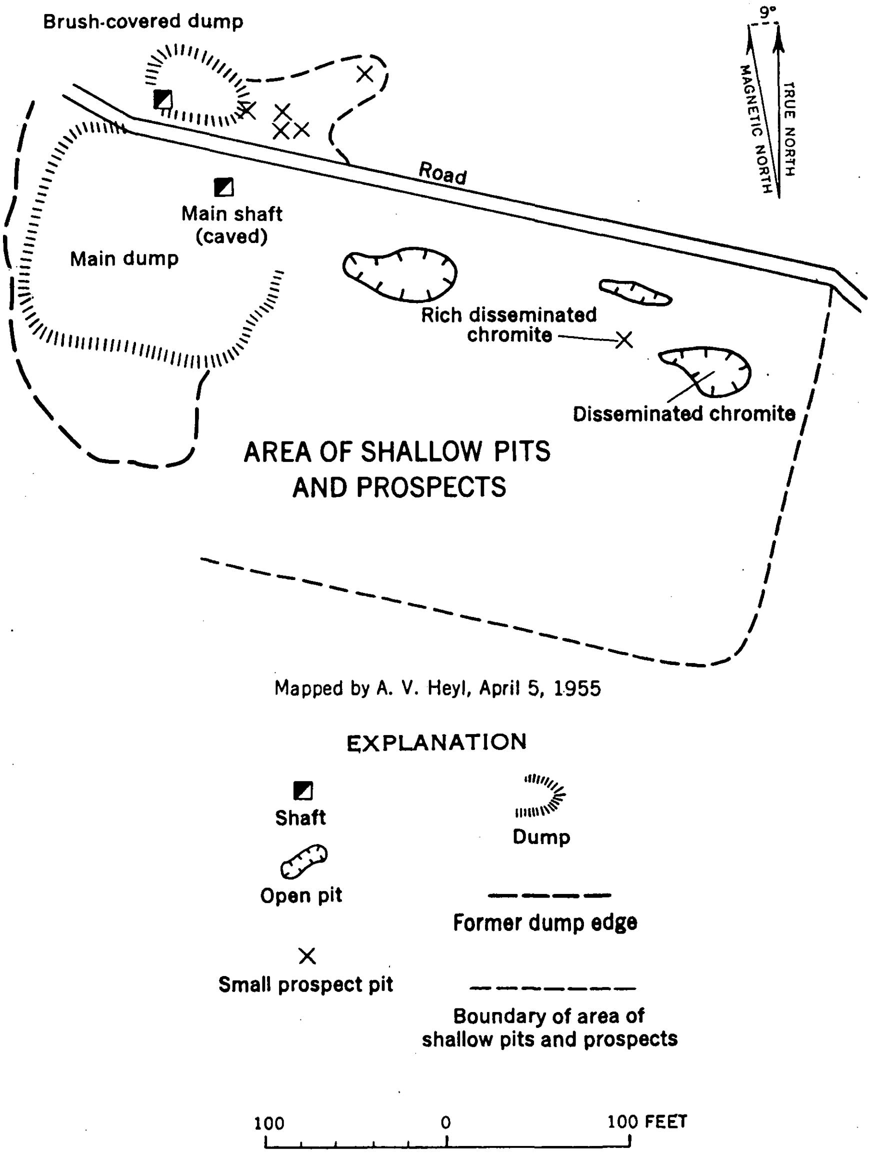

FIGURE 68.—Sketch map of surface workings of Red Pit chromite mine, State Line district, Lancaster County, Pa.

North Rock Springs (Jenkins) mine.—About 220 yards S. 55° W. of Rock Springs church on the west bank of a small stream (loc. 40, pl. 41) is an old mine that consists of three water-filled shafts with large coalescing dumps, a smaller caved shaft or prospect with a small dump, and several prospect pits (fig. 69). The mine is reported to be 240 feet deep. The three main shafts are still open, and the northern one appears to have been recribbed, probably dur-

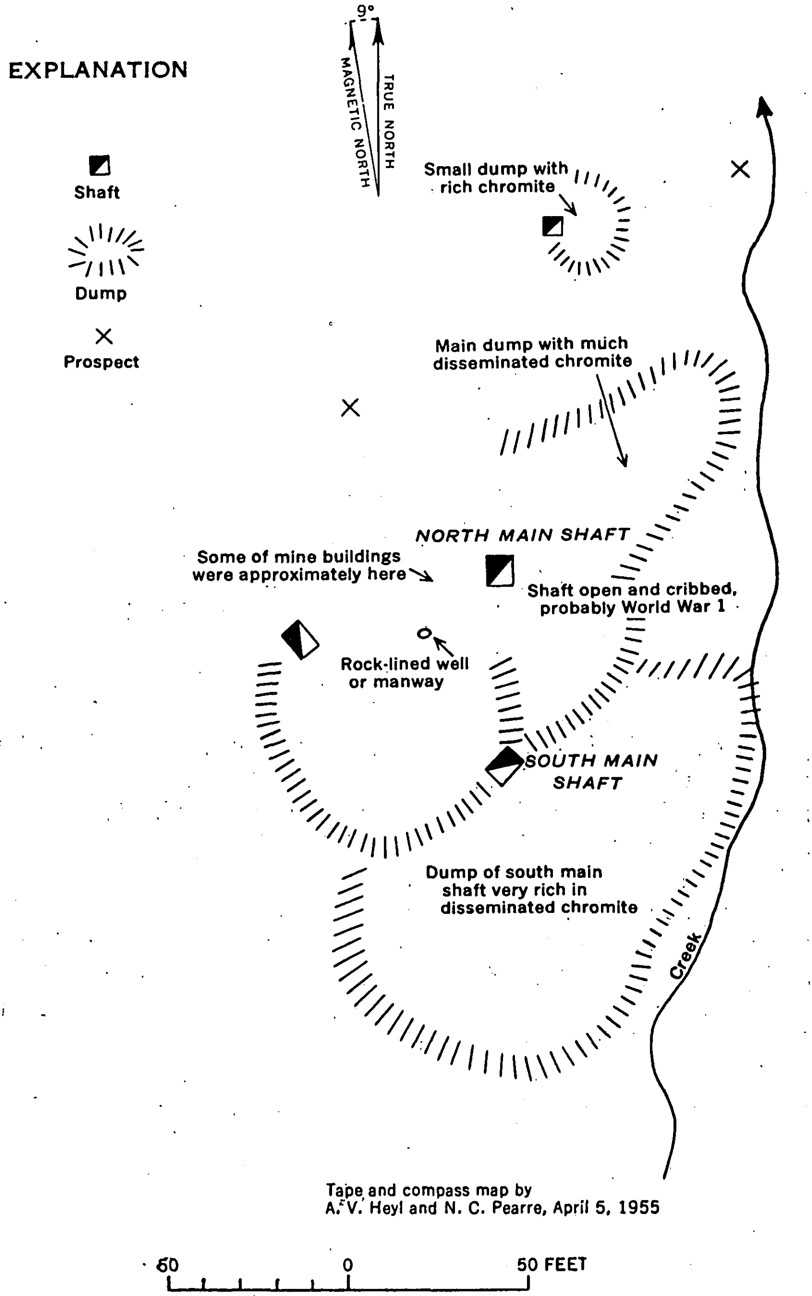

FIGURE 69.—Surface workings of the North Rock Springs (Jenkins) chromite mine, State Line district, Lancaster County, Pa.

ing World War I by the Chrome Mining Co. This group of workings is probably the fairly productive mine called Jenkins mine or the Rock Springs pits in most of the literature. The mine was worked by the Tyson Mining Co. during the company's early period of activity and was reopened for a short time between 1865 and 1870. Disseminated chromite, concentrated in broad veinlets as much as 6 inches wide, is abundant on the dumps from all three shafts. (See analyses 24 and 25, table 6.) A little massive chromite was also found on the dumps.

The size of the North Rock Springs dumps and the quantity of fairly good disseminated ore left on them give credence to the report that the mine was never very successful although a great deal of work and money went into it. No milling of the ore was ever attempted, and, as mined, much of it must have been too low in grade to be marketable.

Minerals associated with chromite on the dump include much fibrous serpentine, hydromagnesite, and some green williamsite. In addition, Gordon (1922a, p. 451) reports clinochlore, kämmererite, genthite, and zaratite from the "Jenkin's pit." Some schist was found on the dumps, indicating that the ore body lies close to the northern boundary of the serpentine body.

Wet (South Rock Springs) pit.—The name "Wet pit" is applied to various locations on the Peoples tract and has been taken by some writers to be synonymous with part or all of the Red Pit mine, although the two were more probably separate operations. The group of shafts here called the Wet pit is most deserving of the name by virtue of its location just northeast of a swamp, near the head of a shallow north-trending valley (loc. 39, pl. 41). It seems most probable that this was the original Wet pit.

The mine consists of three small water-filled shafts in a line trending N. 23° W. The northernmost shaft appears to have been the main one. In 1955 it was open and timbers were visible for a depth of at least 20 feet. Two small piles of low-grade disseminated ore remain northeast and southeast of this shaft. The large dump from the three shafts contains much sparsely disseminated chromite in schlieren bands and irregular lenses in serpentine and probably represents most of what was mined in a prospecting venture that failed, partly because of lack of milling facilities. The Wet pit seems to have been included in the World War I plans of F. L. Garrison, who hoped to concentrate and sell the lean ore discarded in earlier days.

Minerals associated with chromite at the Wet pit include a little magnesite, brucite(?), and radiating quartz pseudomorphous after zeolites or hydromagnesite. Aside from a little williamsite, none of the more unusual serpentine minerals occur.

"Jenkins" mine.—Another small mine on the Peoples tract is about 200 yards S. 80° W. of Rock Springs church, near the north

crest of a hill west of Rock Springs creek (loc. 41, pl. 41). This mine consists of two main shafts, enlarged at the mouth and now filled with water, and several old shallow prospect pits, all alined N. 30° E. The highly sheared, platy, bleached condition of the serpentine in the dump material suggests that the contact between serpentine and schist is probably nearby. The dumps are small and very nearly barren, but a little disseminated chromite and some fine-grained gray magnetite were found.

Tyson Reynolds mine and Geiger pits

The old Reynolds property is about a mile south of Wrightsdale in Lancaster County, Pa. At least two of Tyson's mines were on this property. The Tyson Reynolds mine, in the northern part (loc. 49, pl. 41), is reportedly 200 feet deep. Traces of the old mine still remained in 1955; field evidence, however, gives no indication of the former extent of operations. It is impossible to tell where the old shaft was, but what remains of the old dump is still visible on a hillside, near the ruins of a brick house.

The dump spills over into a forked gulley, in both branches of which disseminated chromite is abundant, fairly well concentrated along broad layers in pale-green serpentine. The chromite is dark bluish gray and is associated with white foliated talc and magnesite. The Tyson Reynolds mine alone among the State Line workings is said to have produced ore known as blue chrome, unusually low in iron. A cleaned concentrate of the disseminated chromite yielded 50.7 percent Cr_2O_3, and the Cr:Fe ratio was about 2.5:1 (analysis 27, table 6; also analysis 26).

A second group of workings, here called the Geiger pits, is on the Geiger farm in the southern part of the old Reynolds property (loc. 51, pl. 41). The Geiger pits are reported to have been operated first in 1844 and to consist of one small pit, one shallow shaft, and a tunnel in the hillside along Octoraro Creek. The tunnel, about 250 feet south of the Cedar Hill stone quarry, is an inclined shaft 15 feet long that slopes westward at an angle of 35°. In place at the tunnel's mouth are several narrow layers of disseminated chromite in a zone about 16 inches thick. The layers strike S. 82° W. and dip 78° NW. Disseminated chromite is abundant on the dump from the incline, and nearby some disseminated chromite appears to be in place in the access road that extends along Octoraro Creek to the quarry. Some of the Geiger workings for chromite that have been completely obliterated are reportedly beneath the stone piles east of the active quarry near the office. The locality was known to mineral collectors as a source of gem williamsite.

A specimen of crude ore from the Geiger farm is reported to have contained 22 percent Cr_2O_3 and about 22 percent silica. Tests made from time to time on samples of the disseminated ore reportedly produced concentrates of good quality, containing 48 to 51 percent Cr_2O_3 and 20 to 21 percent FeO, with silica below 4 percent. This would make the Cr:Fe ratio greater than 2:1.

"Newbold" mine and prospect pits

The "Newbold" mine and prospect pits are 1 mile east of the Geiger pits, within a bend of Octoraro Creek in Lancaster County, Pa. (locs. 53, 54, pl. 41). No record of these workings, published or unpublished, has been found, and the name under which the mine was operated is not known.

The largest opening (loc. 53) is in the woods on a hillside, at the northeast edge of an open field. It is a partly caved egg-shaped pit 42 feet long and about 25 feet wide. Its depth in 1956 was about 15 feet; however, it appears to have been deeper. It is elongate N. 15° W. A large dump covers the hillside east of the mine, and several small piles of disseminated ore remain southwest of the pit. Twenty-three feet N. 75° W. of this opening is a group of four shallow pits alined N. 80° W. A deep-green translucent tremolite is associated with the chromite.

About 500 feet south and southeast of the "Newbold" mine are 3 other prospect pits in an eastward-trending line, 2 of which are fairly large and have disseminated chromite along with some kämmererite and williamsite on their dumps. The third pit is a small opening east of these, in dense brush on the edge of the hill, the dumps of which contain a little disseminated chromite.

Hillside mine

The Hillside mine is a quarter of a mile west of the Wood mine and on the west side of Octoraro Creek in Chester County, Pa. (loc. 56, pl. 41). Reports indicate that a large deposit of chromite was mined out before 1900, by surface workings only, and some reports suggest that the mine produced an estimated 15,000 tons of chromite under Tyson ownership.

During World War I the National Minerals Co. found on the Hillside property a deposit 8 to 10 feet long and 12 to 18 inches wide of chromite that analyzed 42 percent Cr_2O_3.[8] The company developed the property with an adit about 30 feet long into the hillside and a "winze" (shaft) about 30 feet deep, and shipped 12 tons of ore.

In 1956 the old Hillside mine (pl. 46) consisted of a deep cut into the side of a hill, a caved timbered shaft, partly caved stopes, and a large dump. The shaft, at the eastern end of the opencut, formerly led into a stope beneath the floor of the opencut. By

[8] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

means of a cave-in at the north edge of the opencut, the stope is accessible for a length of 25 feet. It is about 5½ feet high. A little rich disseminated chromite in small lenses and schlieren bands remains in place in the roof and walls of accessible parts of the stope (pl. 46). A tunnel, now caved, probably extended northwestward from the northwest end of the opencut.

Both massive and disseminated chromite are fairly abundant in the dump, particularly in the lower, older parts. Some magnetite was also found. Williamsite, picrolite, amphibole asbestos, magnesite, and kämmererite are characteristically associated with chromite in the dump and workings.

Wood mine

The largest and most famous of the chromite mines in Pennsylvania and Maryland is the Wood mine in Little Britain Township, Lancaster County, Pa. (loc. 57, pl. 41). From 1828 until 1880 it produced steadily except for the period from 1868 to 1873, when it was flooded, apparently because pumping facilities were inadequate. After the Civil War the Wood mine is reported to have reduced its output from 400–500 tons a month to 500–600 tons a year. In 1867 Rand (1867, p. 406) reported the status of the Wood mine as follows:

> It is 700 feet in depth, and has yielded an immense amount of chromic iron. The vein was very irregular—at one place 20 feet in width—then running into mere strings and again widening out. Excavation downward has ceased, it being believed that the ore is practically exhausted. Much ore is still being extracted from ramifications of the principal vein.

Later work involved only the upper part of the mine; water was pumped out to the 200-foot level, a wooden platform built, and ore mined that had been left in the walls when the richer parts of the ore body were worked. From about 1880 until 1882 the Tyson Mining Co. kept the Wood mine open as a reserve against difficulties attendant upon the long shipments of chromite from their mines in the west.

Some work was done in the Wood mine and adjoining shafts during World War I by the National Minerals Co., of Wilmington, Del. The company opened an old shaft, locally known as the Dog Pit and said to be on an offshoot from the main ore body of the Wood mine, unwatered it, and retimbered it to the bottom, a depth of 125 feet. Although they are said to have found numerous stringers of ore in the shaft, appearances were not favorable and work was stopped. Other work done by the company included unwatering the Wood mine itself to a depth of about 50 feet and producing a small quantity of ore. They prospected north of the Wood mine and reportedly sank a shaft in that area.

In 1937 the Wood mine was unwatered by the American Chrome Corp. and examined by W. D. Johnston, Jr., of the U.S. Geological Survey, and Edward Sampson, of Princeton University. According to Mrs. J. F. Garvey (1956, oral communication), whose husband was secretary of the corporation, some chromite was found in the mine, but in a part where the workings were caving and timbers were rotten. This part was probably in one of the old stopes closed by bulkheads; the major part of the mine was reportedly in good condition and not caved. The showing did not justify the expense of retimbering, and in March 1938 the pumps were removed.

In the 1930's a geophysical prospecting program was carried out near the Wood mine by the U.S. Bureau of Mines and Bethlehem Steel Co., and in 1941 more geophysical work was done by the U.S. Geological Survey, U.S. Bureau of Mines, and Hans Lundberg, Ltd. Anomalies found by magnetometer and gravimeter surveys of an area 6,000 feet by 2,000 feet to the east of the mine were diamond drilled in 1941 with unfavorable results. Ten holes were put down, totaling 2,272 feet (McIntosh and Mosier, 1948, p. 4).

The Wood mine (pl. 47) is the largest and deepest of all the eastern chromite mines. The main inclined shaft, enlarged at its mouth during the later period of mining to a glory hole about 60 feet wide and 90 feet long, dips southward and is reported to be 720 feet deep. A vertical shaft south of its connects with the main shaft through a drift. In 1878 the mine superintendent reported that the rate of accumulation of water in the mine was 60 to 110 gallons per minute (Frazer, 1880, p. 193).

The underground workings shown in plate 47 were surveyed in 1938; no information is available below the 400-foot level. Numerous drifts that followed offshoots and branches from the main ore body for tens of feet into the wallrock totaled about 1,000 feet in length in 1875 (Genth, 1875, p. 41). Sampson (1942, p. 124–125) reports that the most extensive workings cover a horizontal distance of about 800 feet and are roughly parallel to and only about 100 feet from the northern boundary of the serpentine. The serpentine wallrock is so massive that for the most part timbering was scarcely necessary even in large openings. Mining operations thoroughly cleaned the mine of ore, so that almost no chromite is visible in the walls except in one large pillar at the bottom of the vertical shaft, 185 feet below the surface (Sampson, 1942, p. 124). However, the last mine superintendent, William Glenn (1893, p. 121), reported that the mine was not exhausted. The bottom was filled with mud and water in 1938 and apparently was not examined; moreover, indications are that it may not have been the real bottom of the old mine, so that a possible downward extension of the ore body has not been satisfactorily investigated.

Many smaller shafts, pits, and prospect trenches lie in the dense brush northeast and east of the main Wood mine, extending nearly continuously to the Carter mine, about a quarter of a mile away. Very old, small prospects for chromite are in the forests about 1,000 feet north and 400 feet south of the mine, and a shallow shaft penetrating disseminated chromite ore is reported in the meadow on the east bank of the Octoraro, about a quarter of a mile west of the main mine.

Several descriptions of the Wood mine were written by William Glenn during the waning years of its importance. According to these accounts, the outcrop of massive chromite was 30 feet long and 6 feet wide, striking approximately east. At a depth of 20 feet the ore body narrowed, but it broadened again to 120 feet long and from 10 to 35 feet wide. The ore zone plunged 60° to 40° to the south and varied considerably in length and width; the greatest length was 300 feet. Mining reached a depth of 720 feet on the plunge. Glenn speaks of a well-defined footwall, the lower 400 feet of which is "a warped surface, which bends, through a quadrant, to the left, as one looks down the incline * * *" (Glenn, 1896, p. 499). In the lowest levels the strike of the ore body is north. According to W. F. Gorrecht, of the American Chrome Corp., the ore body was much larger below the 400-foot level, in places reaching a thickness of 70 feet (Ostrander and others, 1946, p. 17).

Further information about the mode of occurrence of the Wood ore body is sparse. Sampson (1942, p. 125) has drawn the following conclusions from the shape of the workings and from what little ore was left in place when he saw the mine in 1938:

> The ore occurred in sack form with definite linear alignment down the dip of about 45° * * *. The horizontal sections of sacks seem to have been more or less equidimensional rather than linear. The degree of connection between sacks of ore is uncertain, but strong pinches between major ore bodies must have existed if they were not actually discontinuous. * * * The ore is commonly, if not universally, essentially free from intergrown silicates, and the chromite grains interlock."

He goes on to say that where the boundaries of the ore bodies can be seen there is no disseminated ore, and the contact between chromite and serpentine is sharply defined. The serpentine is intruded into schists; the footwall contact dips steeply southward as shown by drilling at the farmhouse to the east near the Carter mine. The serpentine at the deposit was originally a dunite (Thayer, 1941, written communication) as no traces of pyroxene were noted by Thayer in exposures of fresh rock. The least altered facies is a dark-gray to light-green massive rock in which fresh olivine is locally abundant and associated with antigorite, accessory chromite, and secondary magnetite. The massive chromite, however, is commonly sheathed by a light-yellowish-green serpentine (Pearre and Heyl, 1959, fig. 2), in some places associated with coarsely crystalline magnesite, which J. F. Garvey considered a definite guide to ore. Gordon (1922a, p. 450) describes a prismatic structure in the serpentine at the contact, with deweylite- and magnesite-filled cracks normal to the chromite.

All but about 5 percent of the ore from the Wood mine was pure enough to be shipped without crushing and washing. The chromite averaged about 48 percent Cr_2O_3, but the grade varied notably (analyses 28–31, table 6). A cleaned concentrate of massive chromite from the dump assayed 52.2 percent Cr_2O_3 and the Cr:Fe ratio was 1.7:1 (analysis 29, table 6); the chromite contained minor but unusual amounts of zinc and nickel (table 7). Most of the chromite on the dump is nonmagnetic; however, one specimen of magnetic chromite, bordered by williamsite, was collected.

The Wood wine has been famous as a mineral-collecting locality. Brucite, deweylite, magnesite in sparry masses resembling dolomite, hydromagnesite, zaratite, and genthite were abundant, and other characteristic minerals reported in the deposit and wallrock include olivine, uvarovite(?), clinochlore, antigorite, lavender fibrous chromian antigorite, deep-green serpentine, penninite, kämmererite, calcite, dolomite, and magnetite. Most of these can still be found on the dump.

Carter (Texas) mine

The Carter, or Texas, mine is about a quarter of a mile northeast of the Wood mine in Little Britain Township, Lancaster County, Pa. (loc. 58, pl. 41). It was probably opened and operated by Isaac Tyson, Jr., about 1830. In 1867 it was 120 feet deep and "yielding a large quantity of chromic iron of good quality * * *" (Rand, 1867, p. 406). The mine was closed before 1875 because the operators were unable to cope with water in the shafts.[9]

Field evidence at this locality corroborates Rand's estimate of the mine quoted above but conflicts so markedly with most published information about it that another, much smaller Carter mine may exist elsewhere in the district. Although reportedly small and not worth much, the Carter mine consists of three caved shafts, supposedly 200 feet deep, and remnants of large and extensive dumps. The ore is reported to be low grade and mostly disseminated but the writers found a great deal of massive chromite on the dumps similar to the high-grade ore from the Wood mine, as well as some disseminated chromite. One specimen of massive chromite from the dump is magnetic. No analyses are available.

9 The Daily Local News of West Chester, Feb. 21, 1885.

The Carter mine was briefly active about 1915, when the Texas Mining and Manufacturing Co., of New York, tried to reopen it, but the low price of ore and scarcity of labor forced them to close after producing about 40 tons (Knopf, 1922, p. 97). This ore was probably from reworking the dumps; all three shafts are caved and show no signs of having been open at any time during the 20th century.

Most of the unusual minerals associated with chromite at the Wood mine are reported here—zaratite is more abundant on the dumps now than others of these minerals.

Scott and Engine mines

One of the more important mines of the Tyson Mining Co. was the Scott mine, 1½ miles southwest of Nottingham, Chester County, Pa. (loc. 80, pl. 41). Several chromite mines were worked in the vicinity, and reports differ somewhat as to which group of openings is the old Scott mine. The one so called on plate 41 is considerably larger than the others. It consists of an incline or trench that slopes N. 30° E. to a large partly filled shaft; a group of pits southwest of it, roughly alined in the same direction; two old shafts northwest of it; a fairly large area of dumps; and remnants of former dumps that have been removed. About 500 feet east of this mine are three old shafts with fairly large brush-covered dumps called the Engine mine (loc. 81, pl. 41). The dump of a prospect pit southeast of the Engine (loc. 82, pl. 41) is reported to contain relatively rich chromite. Farther southward, along the south side of Black Run and mostly southeast of the Scott and Engine mines, is an area of numerous shallow prospect pits that are reported to show lean chromite.

The Scott mine is considered one of Tyson's secondary "best" mines, although indications are that he did not work it very long because of legal difficulties. Even so, the mine is reported to have produced about 3,000 tons (some sources say 6,000) of ore and to have reached a depth of 200 to 250 feet (some sources say 400 feet). Most of the ore produced by Tyson was probably massive chromite.

During World War I the National Minerals Co. sorted and shipped almost 30 tons of ore that ran 36 percent Cr_2O_3 from several thousand tons of rock on the old Scott dumps. Knopf (1922, p. 91) reports that average samples of disseminated ore from the dumps showed 33 to 34 percent by weight of chromite in the ore and that the dumps contained about 2,000 tons of this disseminated ore (analysis 32, table 6); however, much of this dump has since been removed for road material. If any attempt was made by the company to reopen the mine, it was brief and soon abandoned because of caving. Some bulldozing has been done at the mine, dating in large part at least from a later period of interest about 1945.

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Not many associated minerals were noted here except kämmererite and magnesite. Two schlieren bands of disseminated chromite were exposed in the shaft in 1956.

Kirk mine

The Kirk mine is about a mile southwest of the Scott mine and 2½ miles east of Octoraro Creek, in Chester County, Pa. (loc. 69, pl. 41). An old shaft 65 or 75 feet deep, probably inclined southward, was cleaned and retimbered by the National Minerals Co. in 1918, and again in 1941 by J. A. Wilson, who removed about 300 tons of waste from it. Another shaft is about 20 feet southwest of the first one, and a drift is reported to extend southeasterly from this shaft. Some ore—no more than a few tens of tons—may have been mined in 1918 and sold along with ore from the Scott mine dumps in a shipment that averaged 36 percent Cr_2O_3. In 1941 some ore was mined or sorted from the dump, but the grade was too low to warrant continued work.

The Kirk ore body was reportedly a small lens of chromite, some massive but mostly disseminated. Lean schlieren bands of disseminated chromite were seen by the writers at the Kirk locality. The ore was mined by underhand stoping. Available information suggests that only one of several old stopes was cleared during the two wartime operations and that caving ground and old back-filled waste caused difficulties. Reports of the National Minerals Co.[10] are conflicting but generally suggest that chromite was in sight in the mine when it was closed by them; the finding of a small lens of low-grade ore in 1942 confirms this suggestion, but the lens is not of commercial quality except possibly as a low-chromium chemical ore. Unusual associated minerals are notably absent.

Pine Grove mines

About three-quarters of a mile south of Nottingham, West Nottingham Township, Pa., are the Pine Grove mines (pl. 41), now known as Moro Phillips' mine (loc. 83, in the woods west of a north-trending road) and the Stence mine (loc. 84, east of the road and out of the woods). Both were formerly operated by Moro Phillips, of Philadelphia, probably in the late 1860's and early 1870's. In 1937 Bethlehem Steel Co. drilled geophysical anomalies on the Moro Phillips property in search of a commercial deposit of chromite. Results were negative.

Ore from the Pine Grove mines is reported to be black massive chromite and disseminated chromite similar to that at the Scott mine (Gordon, 1922b, p. 181; Knopf, 1922, p. 97–98). Such ore was found on the dump west of the road. Reported minerals include a

[10] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

good quality of amphibole asbestos, talc, and the nickel mineral zaratite.

Moro Phillips' mine.—Published references to "Moro Phillips' mine" are apparently to the larger of the two Pine Grove mines (loc. 83, pl. 41). The workings visible today consist of a main shaft, a fairly large dump, and many small prospect pits in the vicinity. The main dump is lean in chromite. A 10-inch pipe and pump rods remain in the old shaft, and a steam-pump foundation remains beside it. Water was constantly a major problem in Moro Phillips' mine, and pumping costs were high.

The total depth of the mine is conflictingly reported as 110 feet and 300 feet. A contemporary account records that operations had reached 100 feet in 1872 and ore was visible in the bottom of the mine. Work continued, probably for about a year thereafter. Drifts or stopes totaled about 80 feet in length (Genth, 1875, p. 41).

A small quantity of massive and disseminated fine-grained chromite was gleaned from the dump, part of which has been removed. Other minerals noted were green fibrous serpentine, white crystallized talc in breccia, and kämmererite.

Stence mine.—The Stence mine (loc. 84, pl. 41) consists of two caved shafts or pits now filled with debris, small waste dumps, and the remains of an old ore pile. Black massive chromite collected from the ore pile has a high luster, is not magnetic, and consists of masses of large discrete grains separated by septa of kämmererite. One specimen shows octahedral crystals of magnetite along and near fractures in the chromite, and grains of lustrous chromite in the specimen are rimmed with magnetite. Fragments of amphibole asbestos were found on the dump. During World War I some chromite was sorted from the dump.

Smith Hilaman's mine

Smith Hilaman's mine about a mile southeast of Nottingham, Chester County, Pa., is approximately located on plate 41 (locs. 85, 86). The older pit (loc. 85), west of the road, was reportedly worked during the early period of chromite mining, probably by Isaac Tyson. The pit east of the road (loc. 86) was worked by Hilaman in 1873–74. The Electro-Metallurgical Co. acquired mining rights on the property during World War I, worked one pit briefly, but apparently did not produce any ore. Disseminated chromite at Hilaman's mine is fair to good grade (Knopf, 1922, p. 98).

Mines in the White Barrens

The easternmost and least known part of the State Line district east of the village of Chrome, Pa., contains an area of serpentine called the White Barrens, drained by the western branches of Little

Elk Creek. This area is mostly in Elk Township, Pa., but also includes a part of East Nottingham Township, Pa. (pl. 41).

Knowledge of the chromite localities is sparse. Isaac Tyson, Jr., leased a large number of properties in the area between 1835 and 1838, many of which were undoubtedly of interest for placer chromite. When Tyson sketched the area he wrote across the William Collom property (loc 88, pl. 41) that there was "plenty of chrome about the diggings."[11] These diggings could have been for placer chromite or for lode ore. Approximate locations of two other "diggings" are shown on plate 41. These are Amos Pugh's mine and the Sidwell mine (locs. 89, 91); they are located from Tyson's sketch map and may not be accurate. Plate 41 also outlines the approximate area considered favorable for chromite by Tyson and included in his estate at the time of his death.

Although most of the chromite produced from the White Barrens was placer ore, a small quantity of lode chromite is known to have been mined also. Genth (1875, p. 41–42) reports that Amos Pugh's mine produced about 20 tons and that three old pits in the White Barrens together accounted for 150 tons of ore.

Preston farm

Location: Cecil County, Md.; about 1½ miles northwest of Rock Springs, on both sides of Conowingo Creek (approximately at loc. 33, pl. 41).

Workings and occurrence: About 15 shallow pits 3½ to 23 feet deep; one 20 feet deep with a body of massive foliated chromite reportedly 3 inches wide in the upper 12 feet, widening to 4 feet at the bottom. Other seams or pockets of chromite reported from 1 inch to 2 feet in width.

History: Worked before 1864 by Joseph Preston and prospected in 1864 by American Chrome Co., of New York.

Ore: Massive and disseminated.

Minerals: Magnesite, feldspar also mined on the property.

Production: About 100 tons before 1864, most of which was probably sand chromite (see p. 784).

Reference: Roberts and Dickison, 1864.

Pits southwest of Rock Springs, Md.

Location: Half a mile southwest of Rock Springs, Cecil Co., Md., northwest side of route 222 (loc. 44, pl. 41).

Workings: 7 prospect pits. The largest is crescent shaped, 20 feet long, 6 feet deep; 4 smaller pits alined N. 25° W. of it; 2 small pits east of them. Brush-covered dumps.

Ore: Disseminated chromite on dump.

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[11] Isaac Tyson's record book, manuscript in Maryland Historical Society library, Baltimore, Md.

John R. Harris property

Location: Cecil County, Md., about 1 mile north of Rising Sun. Exact location indefinite.

Workings: Shaft about 60 feet deep sunk by Adair and Pyle in 1918, following a "vein" of chrome ore.

Production: None reported.

Reference: U.S. National Archives.

Brown's mine

Location: Lancaster County, Pa., Fulton Township; 1¼ mi. northeast of Lyles on Soapstone Hill (loc. 95, pl. 41).

History: Long abandoned and filled up.

Ore: Reported to be disseminated chromite.

References: Frazer, 1880, p. 177–178; Knopf and Jonas, 1929b, p. 151; Gordon, 1922b, p. 204.

Little Horse Shoe mine

Location: Lancaster County, Pa. Exact location is not known. The southwesternmost loop of Octoraro Creek in Pennsylvania is known as the "Horse Shoe"; so the mine may be the Geiger pits (loc. 51, pl. 41).

Production: About 30 tons.

Reference: Genth, 1875, p. 41.

"Road" pit

Location: Chester County, Pa., West Nottingham Township (loc. 55, pl. 41), about a quarter of a mile west of the Wood mine and less than 200 feet southeast of a sharp turn in an unmaintained township road.

Workings: A small water-filled pit and dump; probably little more than a prospect. Area trenched by the U.S. Bureau of Mines in 1941; trenches trend N. 70° E. and total 1,465 feet in length.

Ore: A lens of disseminated chromite that strikes generally westward; in serpentine with considerable quantities of bright-green williamsite. The lens, or a similar one, is poorly exposed and marked by float in the old road 50 feet to the west.

Reference: McIntosh and Mosier, 1948, fig. 2 and p. 5.

L. Melrath's pits

Location: Chester County, Pa., West Nottingham Township. Exact location not known.

Workings: 3 pits.

History: Worked about 1845.

Production: About 50 tons.

Reference: Genth, 1875, p. 41.

PLACER CHROMITE

Tributaries of all the major streams in the State Line district have produced sand chromite from time to time, and many old placer workings remain along the banks as evidence of past activity. Sand washing in the district began in the early 1830's, and probably was very active until 1860. Most of the work seems to have been done by local people, some of whom sold their ore to Isaac Tyson. After Tyson's death other operators continued to produce concentrates from chrome-bearing sands in the district. Among these were E. Mortimer Bye (1870's to 1890's), Mansell Tweed (1897 to 1899), Howard Brown (about 1898), Joseph P. Cain (1890's and early 1900's), and Craig Adair and Henry S. Pyle of Wilmington (about 1916).

Before 1900 the State Line district produced over 10,000 tons of chrome sand, probably concentrates (Eyerman, 1889, p. 10). In 1874 Genth (1875, p. 40) estimated that 25,000 additional tons could be recovered from the Pennsylvania part of the State Line and Philadelphia districts together. Prospecting work during World War I indicated that this figure may be as high as 45,000 tons of concentrates for the State Line district, the grades of which would range from 32 to 54 percent Cr_2O_3. No information is available about the iron content. Two careful concentrating experiments carried out in 1918 produced high-grade concentrates containing 49 and 54 percent Cr_2O_3; these figures indicate a considerably higher grade than is generally imputed to placer chromite in the district.

Conowingo Creek and tributaries

Chrome sands have been washed along Conowingo Creek and its tributaries between Lyles, Pa., and Oakwood, Md., at various times in the past. Total production is not known but is more than 1,100 tons of concentrates. The largest producing area of which records exist is the Peoples tract in Lancaster County, where placer deposits along Rock Springs Run and its branches (loc. 42, pl. 41) were thoroughly exploited before 1875. Reserves on the West property along Swaggart (Sweigart's) Run in Cecil County, Md. (loc. 34, pl. 41), were estimated during World War I.

Weiant property.—A deposit of chrome-bearing sand is reported on the Weiant property about 1 mile northwest of Oakwood, Cecil County, Md. (loc. 31, pl. 41). It is in the bed of Conowingo Creek and is covered by about 5 feet of overburden. The chromite content is said to be low and Cr:Fe ratio fair; no systematic sampling or investigation of the deposit seems to have been done.

Swaggart (Sweigart's) Run.—Chrome sands were washed along the course of a stream about half a mile southwest of the Line Pit mine in Cecil County, Md. (loc. 34, pl. 41), at least as early as 1844 by Joseph Preston. In 1864 the Preston farm was advertised as containing about 35 acres of bottom ground along Conowingo Creek and its tributaries that averaged 4 feet of chromite-bearing gravel

(Roberts and Dickison, 1864). This included the lower reaches of Swaggart Run. During World War I, the stream was again investigated for sand chrome reserves by F. L. Garrison and W. T. West. A layer of chrome sand runing about 1.5 to 2 percent Cr_2O_3 was carefully prospected with 83 test pits to bedrock, and experiments were made by the Massachusetts Institute of Technology to determine how the sands could best be concentrated.[12] With a Hindred settling classifier and Wilfley table, a concentrate was obtained containing 33.68 percent Cr_2O_3 (analysis 34, table 6); the concentrate was cleaned to a product that was 49.2 percent Cr_2O_3. Results indicated that under favorable market conditions several thousand tons of concentrates could be obtained from the property at a profit. The war ended before further work was done.

Singewald (1928, p. 178) describes Swaggart Run as cutting through detrital material on a broad, flat valley floor for most of its course. He noted many small accumulations of black sand in riffles; a sample of one such natural concentration in the lower course of the stream (analysis 33, table 6) was considerably lower grade than the sands sampled by Massachusetts Institute of Technology in 1918.

Two samples from Thornbottom Run (apparently synonymous with Swaggart Run) were treated by heavy-liquid separations and sieve analyses in 1943 by R. W. Lemke, of the U.S. Geological Survey. The resulting concentrates contained only 39.5 and 39.6 percent chromite, indicating that additional techniques are required to produce commercial concentrations from some of these sands. Further tests on the samples by Mr. Lemke indicated that, although the chromite appears highly magnetic, this apparent magnetism is due to the mixture of magnetite and chromite in single crystals and is dispelled when the magnetite is dissolved from the grains in steaming hydrofluoric acid.

Rock Springs Run.—The sands of Rock Springs Run and its branches were extensively explored for placer deposits before 1875 and concentrates were produced from them (table 2). These streams drain the Peoples tract southwest of Rock Springs church, Lancaster County, Pa. (loc. 42, pl. 41), an area known to contain disseminated chromite deposits.

North Run.—North Run, a tributary to Conowingo Creek east of Pleasant Grove in Lancaster County, Pa., is said to have produced placer chromite. The sands reportedly average more than 1 percent Cr_2O_3. The area was examined by the Foote Chemical Co. in 1922.

Octoraro Creek and tributaries

Chrome sands have been washed at various places along Octoraro Creek and its tributaries in Cecil County, Md., and in West Notting-

[12] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

ham Township, Chester County, Pa. More than 1,600 tons of concentrates was produced from placers along two streams before 1900, and two other streams are known to have produced extensively. More than 10,000 tons of concentrates that would contain over 40 percent Cr_2O_3 are estimated to be available in the drainage area. Iron content of the concentrates is not known.

Cedar Run.—A small stream that flows northeastward into Octoraro Creek east of Rock Springs, Cecil County, Md. (loc. 48, pl. 41), is reported to have been worked and prospected at various times before 1898 and at various places along its course. The valley is narrow and steep walled, and the stream is swift for most of its course, so that the accumulation of fine sand is not favored. Known deposits are reportedly shallow, and the grade is variable. A narrow flat more than 100 yards long near the middle course of the stream has been thoroughly worked over and shows traces of an old buddle location (Singewald, 1928, p. 179). The chrome-bearing sands are said to average about 1 percent Cr_2O_3 and to be considerably more concentrated in places. Evidence of prospecting nearby for lode chromite also is reported.

Black Branch Run.—Considerable quantities of stream chrome were washed in Black Branch Run 1 mile southeast of the Wood mine (Frazer, 1880, p. 195). This run is probably the small stream that flows down the northwest slope of Goat Hill into the Octoraro; a possible location of the placer is shown on plate 41 (loc. 59). The concentrates contained 38 percent Cr_2O_3.

Pine Run.—A small stream north of Goat Hill in Chester County, Pa., flows northwestward through a narrow valley into Octoraro Creek (pl. 41). This stream, Pine Run, is said to have produced at least 1,500 tons of sand chrome concentrates before 1874 (Genth, 1875, p. 42). Where the sands were washed is not definitely known; however, an old atlas (Bridgens and others, 1873) gives the location of a "chrome mine" on Pine Run (loc. 60, pl. 41), and it seems likely that this was a placer rather than a lode chromite mine.

Stone Run.—Detrital material covering numerous broad flats along the upper part of Stone Run in Cecil County, Md., north of Rising Sun (pl. 41), has been worked intermittently over the years and may have produced considerable quantities of placer chromite. The four localities shown on plate 41 (locs. 63 to 66) are the sites of most recent work. Three localities (the Reynolds, Lincoln, and Stevenson farms) are located and described by Singewald (1928, p. 179–180), and the fourth (the Tweed mine) is recorded in the Engineering and Mining Journal (Anonymous, 1899).

The Stephen J. Reynolds farm, three-quarters of a mile northwest of Rising Sun (loc. 63, pl. 41), was prospected by Craig Adair and

Henry Pyle in 1916, but Singewald (1928, p. 179) quotes Mr. Pyle: "We could not find any deposit of workable size that gave over 8 or 9 percent chromic oxide in the concentrate." On the Lincoln farm (loc. 64, pl. 41), about half a mile northeast of the Reynolds placer, an area about 150 feet in diameter appears to have been worked for sand chrome. Singewald reports that it was last worked by Joseph Cain about 1908. At the same time, Cain shipped 37 tons of concentrates from the John Stevenson farm, about three-quarters of a mile farther upstream (loc. 65, pl. 41), but the chromic-oxide content was too low to justify further work. Prospecting by Adair and Pyle in 1916 likewise failed to find a deposit of commercial value on the Stevenson farm.

Unlike the low-grade Reynolds, Lincoln, and Stevenson placers, the Mansell Tweed property (loc. 66, pl. 41) is within the boundaries of serpentine outcrop and thus appears to be more favorable for the accumulation of chrome-bearing sands. An extensive area on both sides of the Mason and Dixon line, in Cecil County, Md., and Chester County, Pa., shows evidence of work. In 1897 about 100 tons of concentrates was shipped, and work continued through 1899.

Black Run.—Black Run flows northwestward through Chester County, Pa., into Octoraro Creek from the Scott-Engine-Kirk mines area, where disseminated chromite is abundant in the serpentine to feed placer deposits along the stream's course. The valley is broad and flat and favors the accumulation of chrome-bearing sands. One placer is located on plate 41 (loc. 71).

In 1874 E. M. Bye was washing sands along the stream course (Genth, 1875, p. 40), but there is no record of how much he produced. Genth mentions that one of the few areas of sand-chrome reserves remaining in 1874 was about 20 acres near Octoraro Creek in West Nottingham Township, which he estimated to contain 10,000 tons of concentrates that would run 40 to 45 percent Cr_2O_3. This area is most probably on Black Run. His reserve figures should still be valid, as subsequent production by Bye was comparatively small, and no work has been done since, other than minor prospecting under the duress of two world wars. One property on Black Run, known as the Barren Farm property, was found in 1918 to contain an area of 100,000 to 400,000 square feet averaging 6 feet of sand that ran about 1.49 percent Cr_2O_3 and could be concentrated to 40 percent Cr_2O_3.[13]

Northeast and Little Northeast Creeks

The only placer deposit known along Northeast Creek is on the Frank A. Brown farm a mile and a quarter northeast of Calvert, in

[13] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

Cecil County (loc. 87, pl. 41), in broad, flat meadows at a fork in a small tributary of the creek. Singewald (1928, p. 180) quotes a worker as saying that the sand was dug over an area of about 3 acres from numerous pits 15 feet long, 10 feet wide, and 6 to 7 feet deep. The chrome sands and gravels were 18 inches to 3 feet thick. The ratio of concentration after screening was 10 to 1.

An area along Northeast or Little Northeast Creek was prospected for sand chromite reserves in 1918 by F. L. Garrison, whose work suggested the possibility that 20,000 to 25,000 tons of concentrates that would run about 32 percent Cr_2O_3 are available. No extensive concentrating tests were made to explore the possibility of upgrading the concentrates, and it is not known how completely the 32-percent material was cleaned.

Little Elk Creek and tributaries

The area known as the White Barrens, drained by Little Elk Creek and its tributaries (pl. 41), has provided a large quantity of the sand chrome production from the State Line district. At least three properties were investigated for sand chrome during World War I: the Reisler, Collom, and Grier farms. An area of 20 acres of meadow adjoining the Oxford road on the west branch of Little Elk Creek, owned by James Reisler and leased to the National Minerals Co., was developed with 16 test pits to bedrock, each 10 feet square, and 2 large open cuts. The chromite-bearing gravel was found to be 2 to 4 feet thick, covered by 3 to 5 feet of overburden. The company produced 15 tons of concentrates, assaying 53.9 percent Cr_2O_3, which they sold as a sample for $101 a ton. Preparations for larger scale production were underway when the armistice was declared.[14] This placer chromite has the highest chomic oxide content reported in the district.

The Collom tract is said to have been worked by E. M. Bye, and Stanley Grier's farm, adjoining it on the west, by the Tyson Mining Co. The two were prospected in 1918 by F. L. Garrison, whose work indicated the possible existence of several thousand tons of concentrates containing over 40 percent Cr_2O_3.

WEST CHESTER DISTRICT

Both lode and placer chromite are reported to have been produced from the West Chester district in Chester County, Pa., at Bailey's mine, which was probably on Corundum Hill, 1½ to 2 miles northeast of Unionville (pl. 42). Several tons of chromite was also produced from a small ore body on the Thomas Webb farm (loc. 1, pl. 42) before 1840 (Rogers, 1840, p. 18–19).

[14] Data from records of War Minerals Relief Comm., U.S. Natl. Archives.

PHILADELPHIA DISTRICT

Chromite production from the Philadelphia district was comparatively small. Three mines and two placers, all in Delaware County, are reported to have produced more than 600 tons of lode chromite and chromite concentrates before 1900. Lode chromite is reported to be abundant on the farm of Lewis Moore at Mineral Hill, near Crump's serpentine quarry (loc. 29, pl. 42), but no production is reported (Rand and others, 1892, p. 200).

LODE CHROMITE

Moro Phillips' mines

The name "Moro Phillips' mine" is applied to two different localities in Delaware County, about 2 miles apart. Chromite was mined from one and possibly both localities as early as 1818, but the information available about Moro Phillips' mine cannot be definitely tied to one site or the other.

Rand (1887, p. 1606, 1610) locates Moro Phillips' property southwest of Darby Creek in the southernmost corner of Radnor Township (loc. 33, pl. 42) and states that chromite was mined there, probably unprofitably. Three shallow brier-covered pits and dumps remain at this locality in a small clearing southeast of the railroad tracks. A few small pieces of serpentine containing irregular blebs of lustrous black fairly coarse massive chromite were found on the dumps.

The second locality is in Marple Township, about 2 miles southwest of the first (loc. 32, pl. 42). Gordon (1922b, p. 189) identifies this as Moro Phillips' mine on H. H. Battle's farm; an old mine in serpentine remains at this locality, but no chromite was found on the dump.

Black Horse mine

Location: Delaware County, Pa. Black Horse is about 2 miles west of Media. Locality may be at Mineral Hill or on Schertz' farm, west of locality 28, plate 42.

Depth: 75 feet.

Production: About 50 tons.

References: Genth, 1875, p. 41; Gordon, 1922b, p. 192.

Walter Green's mine

Location: Delaware County, Pa., near Media. Specific location of mine is not known, but it may be south of the Marple Township Moro Phillips' mine.

Ore: Lustrous hard massive "ore," assayed only 26.7 percent Cr_2O_3.

Production: About 50 tons.

Reference: Genth, 1875, p. 41, 42–43.

PLACER CHROMITE

A few small placers in Delaware County produced about 500 tons of sand chrome before 1900 (Eyerman, 1889, p. 10). Other known placer deposits contained too much garnet to be profitably worked with the crude concentrating methods then used. Concentrates that could be produced were high grade (Genth, 1875, p. 40), but by 1867 the deposits were considered totally depleted (Rand, 1867, p. 274).

Production came from Middletown Township, in the center of which Chrome Run flows southward into Chester Creek, draining the southern part of the Blackhorse serpentine body. Hibbard's placer, on a small tributary of Chrome Run (loc. 22, pl. 42), was small and soon exhausted. More productive was Fairlamb's placer, a quarter of a mile west of Elwyn, which is approximately located on plate 42 (loc. 27). Hibbard's and Fairlamb's placers were both noted for their large octahedral crystals of chromite. Placer chromite is also present as octahedral crystals in the small streams that drain Mineral Hill near Crump's serpentine quarry (loc. 29, pl. 42), but no record of production has been found.

TITANIFEROUS IRON ORE

Numerous deposits of titaniferous iron ore have been reported in the serpentine rocks of the Piedmont Upland. At least five were mined for iron during the 19th century: two deposits near Deer Creek, Harford County, Md.; the Norris and McComas ore banks, both in Baltimore County, Md.; and a mine near Rock Springs, Lancaster County, Pa. They were never of great importance as iron deposits; all were small, and the titanium content apparently caused some furnace operators trouble. An old magnetite mine is reported in the Broad Creek serpentine, Harford County, Md., but no information is available as to whether or not the ore is titaniferous. Other reported occurrences of titaniferous magnetite in serpentine are near Moro Phillips' chromite mine, Delaware County, Pa., and near Pleasant Grove and Soapstone Hill, both in Lancaster County, Pa. (Genth, 1875, p. 39).

In the Piedmont of Maryland and Pennsylvania, titaniferous magnetite is concentrated near the edges of serpentine masses in disseminated and massive form. The known deposits are probably small. Tyson (1862, p. 56) reports that ore from the Deer Creek mine contained 18 percent TiO_2. Two other recorded analyses are given in the following table. The Harford County ore is from one of the mines near Deer Creek, probably the Cherry Hill mine.

	Norris ore banks, Baltimore County, Md. (Singewald, 1911, p. 319)	Harford County, Md. (Genth, 1875, p. 39)
SiO_2	20. 96	2. 60
TiO_2	Small amount	6. 60
Al_2O_3	12. 54	11. 96
Cr_2O_3	----------	2. 41
Fe	30. 36	----------
Fe_2O_3	----------	51. 98
FeO	----------	18. 65
MnO	Little	[1]. 22
MgO	----------	3. 80
P	0. 06	----------
S	. 16	----------
Ignition loss	5. 54	1. 78
Total	[69. 62]	100. 00

[1] Includes NiO, CoO.

The titaniferous magnetite deposits are in a geologic environment similar to that of the chromite deposits; that is, in peridotitic rather than pyroxenitic serpentines, commonly near the borders of serpentine masses. The minerals are both members of the spinel group, and both occur in massive as well as disseminated form. The Rock Springs and Cherry Hill magnetite deposits are very near to known chromite deposits, and the small serpentine body in which the Norris and McComas deposits were mined is reported to contain some iron-rich chromite. (See p. 762.) The Harford County magnetite contains a little chromium. Titaniferous magnetite is commonly disseminated in the peridotite near Woods chrome mine and the Weir and Harris mines at Soldiers Delight.

WOODENSBURG-CARDIFF DISTRICT

McComas mine

The ore banks of the McComas mine were worked during the 1840's on the north bank of a small stream one mile southeast of Whitehall (loc. 2, pl. 41). About 1860 the locality was prospected again with no success. The workings consist of an opening about 200 feet long and 20 feet wide in the side of a hill and several small pits (Singewald, 1911, p. 321). The ore occurs in soapstone and garnetiferous chlorite schist. An average sample of ore contained 28.7 percent total iron (Jackson, 1857, p. 245).

Norris mine

The Norris mine, about 2¾ miles northeast of Whitehall on First Mine branch (loc. 3, pl. 41), was worked for several years in the 1860's by the Ashland Iron Co. (Singewald, 1911, p. 320–321). The workings include an opencut 200 feet long, a shaft 75 feet deep, and a tunnel 100 feet long and 8 feet high. The ore body is about 12 feet wide and consists of fine-grained magnetite disseminated through serpentine.

JARRETTSVILLE-DUBLIN DISTRICT

Deer Creek and Cherry Hill mines

Ducatel (1839, p. 5) reports that there were at least two operations in titaniferous iron ore near Deer Creek, Harford County, Md. One deposit, the exact location of which is not known, was reportedly mined out before 1860 (Tyson, 1862, p. 56). The magnetite contained 18 percent TiO_2.

The Cherry Hill iron mine (loc. 15, pl. 41), half a mile east of Cherry Hill on a tract of land called The Mine Old Fields, is described by Singewald (1911, p. 320). Ore was removed from three pits about 30 feet long, 15 feet wide, and 10 feet deep; several smaller pits are nearby. The iron was found unsatisfactory at the LaGrange furnace near Rocks. Later it was reportedly shipped to Havre de Grace.

Broad Creek mine

A deposit of magnetite (loc. 22, pl. 41) is reported to have been worked on Broad Creek, Harford County, Md., north of the Broad Creek serpentine quarries. The shaft reached a depth of about 90 feet (E. L. Dinning, Jr., 1956, oral communication).

STATE LINE DISTRICT

The only titaniferous magnetite mine known to have been worked in the State Line serpentine district is the Rock Springs iron mine in Lancaster County, Pa. (loc. 36, pl. 41), It is very close to a group of chromite mines and is near the border of the serpentine mass.

WEST CHESTER DISTRICT

A body of magnetite in Willistown Township, Chester County, Pa. (approximately at loc. 15, pl. 42), was mined from serpentine on a very small scale about 1822; the miners were apparently under the impression that it was chromite (Rand and others, 1892, p. 187). Only about 500 pounds of ore was removed. No indication is given as to whether the magnetite is titaniferous.

RUTILE

Rutile (TiO_2), an ore of titanium, occurs in red or reddish brown to black prismatic crystals, commonly twinned. Its luster is adamantine to submetallic. Its hardness is 6 to 6.5, its specific gravity 4.18 to 4.25. Rutile is a common accessory mineral in rocks, and concentrations of rutile into actual or potential ore deposits are not uncommon. Such concentrations are, however, unusual in ultramafic rocks.

There is one noteworthy deposit of rutile in the Piedmont Upland—the Dinning deposit, a mile and a half north-northeast of Clermont Mills, Harford County, Md. (loc. 4, pl. 41). The property is owned by Ernest L. Dinning, Jr., president of the Harford Talc & Quartz Co., Dublin, Md., and was prospected by E. L. Dinning, Sr., sometime in the 1930's. A shaft about 20 feet wide was sunk, and several trenches 2 to 3 feet deep were cut along a hillside. The longest trench is about 120 feet. Depth of the shaft is not known. Test drilling proved rutile-bearing rock to a depth of about 58 feet (Ostrander, 1942, p. 73). No rutile has been produced commercially.

The rutile occurs in pockets along the north side of a narrow, northeast-trending belt of serpentine. Although it is north of the mapped serpentine boundary (pl. 41), the deposit is in a schistose chlorite rock that Tomlinson (1946) considers to be altered from pyroxenite and therefore a part of the ultramafic body. Accessory minerals are, in order of abundance, magnetite, rutile, apatite, ilmenite, talc, biotite, pyrite, and zircon. Tomlinson reports that ilmenite in samples collected north and east of the prospect pits shows various stages of alteration to rutile, and he suggests that the rutile-bearing pockets are the product of alteration of ilmenite in the original pyroxenite.

The rutile occurs as dark red crystals in sagenitic groups. According to Tomlinson, pockets contain as much as 16 percent rutile and average 8 percent. Ostrander (1942, p. 73) reports the following results of an analysis of ore concentrates:

	Percent
Titanium oxide	91.20
Iron oxide	4.28
Silica	2.35

With better facilities the ore was considered capable of yielding 6 percent or more of concentrates that would be 93 to 96 percent TiO_2.

TALC AND SOAPSTONE

Almost all commercial talc and soapstone deposits are found in one of two general metamorphic environments: altered ultramafic igneous rocks or metamorphosed carbonate rocks of sedimentary origin. Only the first group is within the scope of this report. The nomenclature of talc and soapstone deposits is confusing in that the same few terms have been used in different ways by different writers, without definition in the older literature, and it is difficult to know precisely what sort of material is under discussion.

The mineral talc is a white to greenish-white hydrous magnesium silicate with a specific gravity of about 2.75, a hardness of 1 to 1.5 in the Mohs scale, and a greasy feel. The mineral talc is one important constituent of industrial talcs, but commonly not the only one, Massive talc has properties that make it particularly useful, including softness, denseness, impermeability, low electrical and thermal conductivity, chemical inertness, and low shrinkage on firing. When relatively pure and compact, massive talc is commonly called steatite, block talc, or "lava" talc. Such talcs are manufactured into ceramic products for various specialized uses, particularly in the electrical industry (Eagle, 1947). The term "lava," originally a trade name, is generally used for material suitable for making fired block talc products. In industrial usage, steatite has come to denote a special grade of talc rock that meets rigorous requirements for the manufacture of electronic insulators (Irving, 1956, p. 854, 859–860), but in geologic literature it is generally used for any rock composed essentially of talc.

Less pure varieties of massive talc and mixtures of magnesian silicates are referred to as soapstone or are simply designated talc. Soapstone, like lava-grade talc, is generally quarried in blocks or slabs, but much soapstone not suitable for sawing is used for ground talc.

Talcs that are ground for industrial use vary considerably in chemical composition, form, and occurrence. Grain size of usable material ranges from coarse to cryptocrystalline, and rocks ground include talc schist as well as soapstone.

The process whereby ultramafic igneous rocks and the bordering country rocks are altered to talc and genetically related minerals is called steatitization.

PRODUCTION HISTORY

Talc deposits that are associated with serpentines in the Piedmont of Maryland and Pennsylvania were used by the Indians and have been exploited by almost every generation since. A small soapstone body a mile and a half northeast of Embreeville, Pa. (loc. 9, pl. 42), and the Dublin talc deposits in Harford County, Md. (loc. 20, pl. 41), are among the localities that furnished the Indians with easily carved massive soapstone, and pieces of soapstone utensils are still occasionally found near ancient Indian diggings.

Deposits along the Schuylkill River in the Philadelphia district, Pa. (locs. 35, 36, pl. 42), were worked before 1800 and on into the 19th century, when massive soapstone was considerably in demand for furnace, fireplace, and stove linings, and also to some extent for doorsills. The quarries were famous in their day, but the product was not of a particularly good quality. During the 1830's deposits in the vicinity of Jarrettsville, Cherry Hill, and Rockville, Md., were worked for massive soapstone, and some of the product was also ground for a newly discovered use in making paints. Washtubs and bathtubs were manufactured from soapstone slabs quarried near

Marriottsville, Md., in the 1850's, and ground talc for paint was produced from the same locality in the 1880's and 1890's. From 1906 until the present (1957) there has been production yearly from one or more of the talc and soapstone deposits in the area, most of which has been ground. Seventeen operators in Maryland and one in Pennsylvania are known to have quarried talc during the 20th century, most of them for short periods of time. Two in Maryland—the Harford Talc & Quartz Co. with quarries near Dublin, and the Clinchfield Sand & Feldspar Co. with quarries near Marriottsville—have been steady producers for many years and are active today (1957).

Complete statistics on the production of talc and soapstone in Maryland and Pennsylvania are not available. The U.S. Bureau of Mines (D. R. Irving, 1955, written communication) estimates production from 1906 through 1954 at about 320,000 short tons in Maryland and 250,000 short tons in Pennsylvania. Most of the Pennsylvania production so reported has been from talc deposits near Easton, Northampton County, which are associated with serpentine derived from limestone rather than from ultramafic rocks and therefore are not described in this report.

GEOLOGIC OCCURRENCE

The talc deposits of the Maryland and Pennsylvania Piedmont are the result of alteration, under metamorphic conditions, of the magnesian minerals that form the ultramafic rocks (pyroxene, amphiboles, olivine, and serpentine) by enrichment in silica and commonly also addition of water and carbon dioxide. The resulting talc is massive, foliated, flaky, or granular. It is white to greenish blue and commonly iron stained. Some soapstones in the area contain nodules of unaltered serpentine or concretions of carbonate minerals. In places, minute crystals of magnetite are disseminated through the talc or soapstone.

Talc deposits in the State Line district and at Dublin are at the borders of sodium-rich pegmatites that intrude the serpentine. A vermiculite zone is commonly developed adjacent to the pegmatite. In the Cecil County deposits a zone of actinolite with more or less talc is next outward from the vermiculite. The talc zone, adjacent to the serpentine, is very irregular in width, ranging from 6 inches to many feet.

Talc deposits in the Philadelphia and Marriottsville districts are not associated with pegmatitic intrusions; instead, they seem to be related to shear or crushed zones in the serpentine, which probably served as channel ways for steatitizing solutions. These deposits of talc or zones of talc schist are commonly bordered by chlorite schist.

QUARRY DESCRIPTIONS

MARRIOTTSVILLE DISTRICT

Marriottsville quarries

About a mile northwest of Marriottsville are two groups of talc quarries within a span of about a quarter of a mile where Piney Run crosses a long, narrow ultramafic body (locs. 5, 6, pl. 40). Soapstone slabs for washtubs and bathtubs were produced from several of these quarries during the 1850's. In the 1880's the product was ground talc for use in fireproof and acidproof paints, and minor amounts of sawed slabs for firebrick and hearthstones. Production in 1892 amounted to 372 short tons, valued at $1,860 (Williams, 1893, p. 142). Between 1912 and 1915 most of the product was sold rough as quarried, but some was sawed and some ground. In 1937 the Clinchfield Sand and Feldspar Co. began production of ground talc and massive soapstone from the deposits; they have continued production to date (1957).

The older quarries (loc. 5) are in a zone about 600 feet wide of dense, massive soapstone. The largest one, a channeled opening 200 feet long parallel to the road and about 50 feet wide, is filled with water but is reportedly 80 feet deep (Singewald, 1946, p. 147). About 100 feet northwest of it is a small channeled opening, and farther northwestward, inside a sharp bend in the road, is a large quarry in a zone of schistose talc. Material from this quarry was being crushed in the nearby Clinchfield mill in 1956. Another small quarry about 50 feet square southeast of the large channeled opening was operated by the Clinchfield Co. for massive soapstone.

About 250 yards southeast of the southeasternmost of these quarries, in a crushed zone about 35 feet wide where the serpentine has been altered to soft, flaky talc, are two more quarries on opposite sides of the stream (loc. 6). Much of the chlorite schist that borders the talc can be quarried and ground with it, so that the rock is usable for a width of about 75 feet (Singewald, 1946, p. 146). The larger quarry and the Clinchfield Company's mill are on the northeastern bank of the stream. Most of the ground talc is used as a filler; a specially sized product is used as a carrier for DDT insecticide, and the harder stone for roofing granules.

Oursler quarries

About half a mile northwest of Henryton, Carroll County, Md., a number of small openings have been made along the northwest side of a ravine in narrow layers of talc schist (loc. 4, pl. 40). The layers are a few feet thick and are separated by greater thicknesses of chloritic schist. Between 1920 and 1935 the Ourslers produced crude talc, principally for foundry facings. From 1939 to 1948 they shipped crude and ground talc (Singewald, 1946, p. 147). The quarries were worked by others on a small scale for several years after 1948.

JARRETTSVILLE-DUBLIN DISTRICT

Rocks (Air's) quarry

A talc deposit was once worked about 1 mile from Rocks station and half a mile from the Maryland and Pennsylvania Railroad tracks in Harford County, Md. (approximately at loc. 14, pl. 41). The Harford Talc & Quartz Co. began quarrying the deposit in 1921 (U.S. Geol. Survey, 1921, pt. 2, p. 99).

Dublin quarries

In the vicinity of Dublin, Harford County, Md. (locs. 19–21, pl. 41), the Harford Talc & Quartz Co., Inc., produces blocks, blanks, and powdered or ground talc, and its associate, the Maryland Ceramics & Steatite Co., Inc., manufactures lava ceramics from local and imported talc. The main quarries were opened in 1916 and have been in continuous production since then except for about 3 months each winter. Previously, in the 1850's and 1860's, the deposit produced slabs of soapstone for a variety of uses. The company uncovered Indian workings under 8 feet of soil and, rarely, pieces of soapstone utensils are found.

The two main quarries, 1 mile west of Dublin and north of Route 440 (loc. 20, pl. 41), are worked alternately. The largest one is about 75 feet deep, and operations are continuing downward. Quarrying is selective, following irregular masses and seams of talc, so that the outlines of the quarries are very irregular and the quantity of waste is large. A smaller quarry west of these two (loc. 19) produces talc that is ground for use as filler in graphite, and a small quarry 0.8 mile north of Dublin (loc. 21) is worked intermittently for special-grade talc. A fifth quarry half a mile west-southwest of Scarboro (loc. 18) was worked until the early 1940's.

The main talc deposit is extremely irregular in width. It occurs along the borders of yellowish-brown thoroughly decomposed pegmatitic material, which is the company's major guide to prospecting. Between the pegmatite and the talc is a narrow zone containing small flakes of vermiculite. The vermiculite also penetrates the talc in places, rendering it useless for lava manufacture. Some amphibole asbestos is associated with the talc along shears and fault zones.

The deposit differs from other talc and soapstone deposits in the area in its usability for lava products. Block talc so used must be soft, compact, fine grained, and of uniform composition and texture. From the Dublin quarries they have been able to obtain flawless cubes of talc as large as 12 inches on a side (Gillson, 1937, p. 884). During the first World War when better quality block talc could not be imported, Harford County was the chief source of talc for making gas burner tips (Diller and others, 1920, p. 668). More recently Dublin talc has been successfully used for many electrical and refractory purposes where exceptional electrical properties are not required (Eagle, 1947, p. 273).

A sample of Dublin block talc was analyzed in 1920 as follows (Diller and others, 1920, p. 671):

	Percent		*Percent*
SiO_2	58.68	CaO	None
Al_2O_3	3.75	H_2O-, H_2O+	5.33
Fe_2O_3	Indeterminate		
FeO	5.52	Total	100.08
MgO	26.80		

In addition to the mineral talc, the sample contained about 15 percent chlorite and a very little magnesite. Talc for lava manufacture is more carefully selected today than it was in 1920, and chlorite and sand are as nearly as possible eliminated. FeO content ranges from 4.2 to 5.60 percent (E. L. Dinning, Jr., 1958, written communication).

For comparison, specifications for electronic-grade steatite, set up by the U.S. Bureau of Mines using California steatite as a standard (Irving, 1956, p. 860), include the following maximum limits: 1.5 percent CaO; 1.5 percent iron oxides; 4.0 percent Al_2O_3; and less than 5–10 percent nontalc minerals.

Blocks of talc quarried at Dublin for lava products were calcined elsewhere until 1932, when the Maryland Lava Co. was formed to manufacture lava products on the premises. The quarried talc is first sawed into blocks; the refuse from sawing operations is ground for use in such products as paints and insecticides. The blocks are then cut into blanks of various shapes and sizes, from which intricately tooled articles are shaped. These are slowly heated in kilns to 1,900°F and then slowly cooled. The product is harder than steel and shrinkage is so slight and uniform that threads and other dimensions are accurate to 0.008 inch.

The high iron content of Dublin talc causes it to fire a medium brown; Mr. Dinning, however, has recently patented a process whereby the color is bleached considerably. The finished product is entirely free of cracks, although loss from breakage during the firing process, caused by seams or flaws in the raw material, is somewhat greater for the Dublin talc than for the highest grades of block talc.

Production of talc from the Dublin quarries prior to 1942 was reportedly about 5,000 tons. Annual output in the early 1940's averaged about 800 tons and in the 1950's, about 1,200 tons. Increased shipments of crushed talc for refractories added about 150 tons to this total in 1957 (E. L. Dinning, Jr., 1958, written communication).

STATE LINE DISTRICT

Bald Friar quarries

The Bald Friar quarries are a number of small openings along the cliffs that border the Susquehanna River in Cecil County, Md., 1½ miles south of the Pennsylvania line (loc. 25, pl. 41). At Bald Friar the ultramafic country rocks are intruded by albitite dikes and are altered locally to talc schist. The albitite commonly has a border 6 to 12 inches wide of white to greenish-blue talc. Originally worked for feldspar, the quarries were reopened for talc and byproduct feldspar in 1906 by the Deland Mining and Milling Co. of Havre de Grace. The talc was ground at a mill on the property. In 1907 production was 15 to 18 tons a day of ground talc that sold for $6 to $12 a ton and was used in acidproof and fireproof paints (U.S. Geol. Survey, 1908, pt. 2, p. 878). According to Singewald (1928, p. 106), the deposits at Bald Friar were nearly exhausted by 1928 (see also p. 812, this report).

Rock Springs quarries

The Schofield quarry, about half a mile west of Rock Springs, Md. (loc. 43, pl. 41), was worked about 1913 by Thomas Weaver, producing small quantities of both feldspar and talc. The pit is 30 feet in diameter and 8 feet deep (Singewald, 1928, p. 108).

A feldspar quarry southeast of Rock Springs, Md. (loc. 47, pl. 41), was worked before 1899, and about 1913 or 1914 it supplied small quantities of talc for the mill at Bald Friar. According to Singewald (1928, p. 109), the opening, known as the Riley quarry, is 150 feet by 30 feet and filled with water.

PHILADELPHIA DISTRICT

A belt of steatitized ultramafic rocks in Montgomery and Philadelphia Counties, Pa., has long been known for its soapstone deposits, which were quarried on a notable scale for more than a century on both sides of the Schuylkill River southeast of old Lafayette station (locs. 35, 36, pl. 42). The steatitized rocks are about 200 feet wide; they strike N. 40° to 60° E. and dip 45° to 60° SE. They are more talcose near the center of the belt, where shearing is more pronounced.

At least three quarries were once active in the belt: Prince's quarry, on the northeast bank of the river (loc. 36, pl. 42), was the largest; southwest of the river were the two Gladwyne quarries (loc. 35, pl. 42). The soapstone was used for stove, furnace, and fireplace linings, as a filler in paint and paper manufacture, and as a lubricant. At one time it was much in demand for doorsills, although hard nodules of serpentine scattered through the soapstone give it a knotty appearance, emphasized by weathering.

Prince's quarry

Prince's quarry, in Philadelphia County (loc. 36, pl. 42), was opened before 1800 to furnish soapstone doorsills for the old State House. It was a steady producer for about a century but by 1908 was closed and partly buried by a landslide. A small attempt to work it was made several years thereafter, but little was accomplished. During the 19th century Prince's quarry was a famous mineral-collecting locality.

Gladwyne quarries

The Gladwyne soapstone quarries (loc. 35, pl. 42), about three-quarters of a mile northwest of Rose Glen (Gladwyne Station) in Montgomery County, were active at about the same time as Prince's quarry. One of them was reopened briefly between 1906 and 1911 by the Atlas Mineral and Machine Co. In 1911 this company sold almost 1,400 tons of soapstone as quarried at $2 a ton and about 1,100 tons of ground soapstone at $5 a ton. Little of the Gladwyne soapstone was free from iron staining, and concretions of dolomite and other carbonates lessened the value of the stone, even though it was less jointed and could be obtained in larger blocks than the soapstone at Prince's quarry (Rogers, 1840, p. 15).

One of the Gladwyne quarries is sometimes referred to as Rose's quarry, but that name is more familiarly attached to an old serpentine quarry about three-quarters of a mile to the north. Construction of the Schuylkill Expressway about 1951 obliterated one and probably both of the old Gladwyne quarries.

OTHER LOCALITIES

Other small quarries and numerous occurrences of soapstone have been reported in Maryland and Pennsylvania. Table 8 gives those that are associated with ultramafic rocks. Where possible, the areas have been indicated on the maps (pls. 40–42). Occurrences known to be of mineralogical interest only or associated with altered carbonate rocks instead of ultramafic rocks have been excluded.

TABLE 8.—*Reported minor occurrences of soapstone and talc in Maryland and Pennsylvania*

District	Locality	Remarks	Reference
Montgomery County, Md. (pl. 40).	Near Andrew Clopper's Mill on Seneca Creek (Clopper is 3 miles west of Gaithersburg).	Soapstone quarried	Ducatel, 1838, p. 35.
Do	Robert Y. Brent quarry, 7 miles from Georgetown on the road to Rockville.	Soapstone quarry about to be opened and arrangements being made for cutting and trimming.	Do.
Do	Joseph Bond quarry, near Snell's Bridge.	do	Do.
Do	6 miles west of Rockville on Rockville-Darnestown road.	Talc suitable for use in paints.	Do.
Jarrettsville-Dublin, Md. (pl. 41).	Near head of Winter's Run.	Iron-free soapstone for furnaces, fireplaces, stoves.	Ducatel, 1839, p. 6.
Do	"Mine Old Fields" (Cherry Hill).	do	Do.
Do	Macton	Abundant soapstone	Johannsen, 1928, p. 267.
Do	Soapstone Knoll, 1 mile southwest of Macton, south of road.	Abundant soft soapstone, silvery white; iron-oxide staining.	Johannsen, 1928, p. 268.
Do	Chrome Hill	Soapstone, iron staining	Johannsen, 1928, p. 272-3.
State Line, probably Md. side (pl. 41).	West property, near Line Pit chromite mine.	Talc in great abundance, commonly containing disseminated chromite. Mr. West was working a deposit of talc in 1918.	Rogers, 1840, p. 22; U.S. National Archives.
State Line, Pa. (pl. 41).	White Rock, Lancaster County.	Slightly discolored talc quarried for a short period, crushed, ground, and bolted.	Beck, 1952, p. 12.
West Chester, Pa. (pl. 42).	1½ miles northeast of Embreeville (on map, loc. 9).	Soapstone deposit said to have been worked by the Indians.	Bascom and Stose, 1932, p. 9.
Do	West Goshen Tp. (on map, loc. 11).	Compact talc worked by mineralogist in 1834 to make pencils and supply lyceums with specimens.	Rand and others, 1892, p. 187.

AMPHIBOLE ASBESTOS

PRODUCTION HISTORY

Deposits of amphibole asbestos in serpentine have been mined in both Maryland and Pennsylvania. Little is known about the Pennsylvania deposits except that they were worked mostly before 1900 and production was small. As early as 1837 asbestos was known to occur in Baltimore and Cecil Counties, Md., and was mined in Harford County at the head of Broad Creek, particularly on "Mrs. Brown's farm" (Ducatel, 1839, p. 5). It sold for $10 a ton and was used for lining the external casings of iron safes. The deposit at "Mrs. Brown's farm" may well have been what was later worked as the Jenkins mine (loc. 6, pl. 41), and most of the other areas that were productive in the 20th century seem to have been exploited to some extent, or at least recognized, before 1900. In 1880 1 mine in Harford County and 3 in Baltimore County together produced 40 tons of "inferior" fiber valued at $1,000 (Williams, 1893, p. 147).

Prior to 1916 the United States obtained its supply of chemical filter-fiber asbestos from Italy, but in that year the war created a need for a domestic source. From tremolite occurring near his home, Fred A. Mett, of Powhatan, near Baltimore, aided by the U.S. Geological Survey and the National Bureau of Standards, succeeded in developing a filter fiber that was superior to the Italian fiber. His Powhatan Mining Co. (later Corporation) worked the deposit for a year, then opened the Jenkins mine in a better quality deposit near Pylesville. By extensively prospecting in Harford, Baltimore and Howard Counties, Mett found a number of other small deposits, which collectively yielded a large tonnage of good-quality fiber.

Because of its toughness, chemical stability, and resistance to acids, the Maryland asbestos was particularly well suited for making filter mats, and in 1920 it was the only domestic asbestos known that was suitable for this purpose (U.S. Geol. Survey, 1920, p. 318). Of the States reporting asbestos production in 1920, Maryland was fifth and last in order of quantity but second in order of value; the following year 3 short tons of Maryland asbestos was valued as high as $12,000.

The Powhatan Mining Corp. prepared its fiber for market in a plant at Woodlawn, near Baltimore, and sold it under the trade name "Powminco." In 1923 two types of fiber were marketed. "Technical" asbestos was a long, carefully prepared fiber that sold for about $1.20 per pound and was used in chemical laboratories. "Commercial" asbestos, used by chemical industry, was a shorter fiber worth about $120 per ton (U.S. Geol. Survey, 1923, p. 343).

As the Maryland deposits were exhausted the Powhatan Mining Corp. carried its operations outside the State, and after the Jenkins mine was closed in 1940 the company obtained all its raw material elsewhere.

GEOLOGIC OCCURRENCE

The asbestos deposits in Maryland and Pennsylvania are slip-fiber amphibole that occurs in small veins associated with ultramafic igneous rocks. Deposits of both anthophyllite, $(Mg,Fe)_7Si_8O_{22}(OH)_2$, and tremolite, $Ca_2Mg_5Si_8O_{22}(OH)_2$, have been exploited. Only the upper part of a deposit, softened by weathering, has been used. Good fiber occurs along shear zones, where movement and pressure have been greatest and weathering is deepest. The parts of the Maryland deposits used averaged about 25 feet in depth, although usable fiber at the Jenkins mine extended to depths of from 50 to 75 feet.

Merrill (1896, p. 288) describes in detail a deposit of asbestos in Howard County, near Alberton. There, fibrous bundles of anthophyllite 12 to 18 inches long occur in a fault zone between schistose actinolite rock on the north and dark impure serpentine on the south. Nearby, a pure, white finely fibrous anthophyllite coats the walls of joint planes, not in serpentine, but in magnesian limestone.

The amphibole deposits are almost all closely associated with talc, and at least two talc quarries, at Dublin, Md. (loc. 20, pl. 41), and Gladwyne, Pa. (loc. 35, pl. 42), produced some asbestos as a byproduct.

Chrysotile asbestos is reported to occur in Lancaster County, Pa., at the Burkholder and White Rock serpentine quarries (locs. 97, 96, pl. 41); and in Delaware County, Pa., at Mineral Hill, Blue Hill, Castle Rock, Elwyn, Moro Phillips' chromite mine, and Radnor (Gordon, 1922b, p. 123).

FUTURE OUTLOOK

Although amphibole asbestos is suitable for limited uses only, it is a commercial byproduct of talc quarrying in Maryland, and good filter fiber commands high prices. The possibility that other asbestos deposits of economic value similar to the Jenkins and Neikirk deposits will be found in Maryland seems small. F. A. Mett appears to have prospected favorable parts of the State thoroughly, except possibly in Montgomery County, and to have mined out whatever usable, weathered fiber he found. He may have carried his prospecting across the State line into Pennsylvania where the geologic environment is the same, although there is no record that he did. The Foote Mineral Co. obtained a little amphibole asbestos in Chester County, Pa., in 1940 and must have prospected some in the area. It is possible that these two companies did not thoroughly explore the possibilities of filter-fiber amphibole in the serpentine areas in Pennsylvania and that small deposits of economic value may exist. Occurrences of amphibole asbestos that apparently have not been prospected but probably are not economic are known in the State (Gordon, 1922b).

Bowles (1937, p. 11) suggests the possibility that the tougher, more brittle, unweathered amphibole in deposits such as those in the Maryland-Pennsylvania Piedmont can be fiberized and made marketable. If this is feasible, unweathered material remaining in some of the Maryland deposits might someday be usable.

MINE DESCRIPTIONS

Except for the Jenkins and Alberton mines, few of the asbestos deposits have been described; many cannot even be accurately located on the maps.

HOLLOFIELD DISTRICT

Alberton deposit

A low-grade deposit of amphibole asbestos in Howard County, Md., near Alberton on the Patapsco River (pl. 40, exact location unknown), was mined to some extent before 1895. Merrill (1896, p.

288–291) describes two distinct varieties of fibrous anthophyllite at Alberton. One is white and silky. The other is dull yellowish brown, translucent, and compact, with sharp cross fractures; "by beating, it is readily reduced to a fibrous condition, though the fibers are brittle" (Merrill, 1896, p. 288).

Bok mine

Sometime after 1917 a small mine on the property of Frederick Bok 0.6 mile northeast of Hollofield Station, Baltimore County (loc. 17, pl. 40), produced slip-fiber anthophyllite for making asbestos shingles (Bangs, 1946, p. 70–71). It operated for only a short time. Talc and chlorite were associated with the anthophyllite.

WOODENSBURG-CARDIFF DISTRICT

Jenkins (Todd) mine

The largest and most important of the asbestos deposits in Maryland and Pennsylvania was the Jenkins mine, about three-fourths of a mile north of Pylesville, Harford County, Md. (loc. 6, pl. 41). Mining began in 1917 and continued until 1941, when the weathered part of the deposit was mined out. The deposit, consisting of slip-fiber tremolite and possibly a little anthophyllite, was worked by narrow opencuts to depths of 50 to 75 feet. At first the overburden was removed with pick and shovel after the zones of asbestos had been located, and the long fibers were then removed by hand. In 1926, to reach greater depths, a derrick and bucket arrangement was used, and from 1928 until 1941 a power shovel was required (Bangs, 1946, p. 71). The mine was reportedly bulldozed over in the 1950's.

Neikirk mine

Another deposit of high-grade fiber similar to the Jenkins deposit but smaller was located on the adjoining property west of the Jenkins mine (loc. 5, pl. 41) and was worked for a short while about 1917 by Mr. Mett. The Neikirk mine was repoened briefly in 1923.

Other localities

Small tonnages of filter fiber were mined by the Powhatan Co. from the Slade farm in northern Harford County and from the Durham farm in western Harford County (Bangs, 1946, p. 70, 72). At Parkton in Baltimore County, north of the Woodensburg-Cardiff serpentine bodies, amphibole asbestos was mined sometime before 1900 (Bangs, 1946, p. 71).

JARRETTSVILLE-DUBLIN DISTRICT

Several small asbestos deposits in this district have been worked. Exact locations are not known except for the Dublin talc quarries of the Harford Talc & Quartz Co. (loc. 20, pl. 41), where a little long-fiber anthophyllite—no more than 1 ton per year—continues to be collected and sold as a minor byproduct of operations for talc.

Other deposits include one at Rocks and one near Coopstown, both in Harford County (pl. 41), worked by the Powhatan Mining Co. (Bangs, 1946, p. 70, 72).

STATE LINE DISTRICT

White asbestos associated with talc is reported by Ducatel (1838, p. 15–16) in Cecil County, Md., between Octoraro and Conowingo Creeks and father eastward (pl. 41). It was used in the 1830's as a substitute for metallic pigments in "stone paints."

The White Rock prospect, on the West Branch of Octoraro Creek in Colerain Township, was a small source of amphibole asbestos (Stone, 1939, p. 4). It was under development in 1895 (Anonymous, 1895, p. 523); the serpentine was later quarried for road material (loc. 96, pl. 41).

In Chester County, Pa., East and West Nottingham Townships likewise produced asbestos before 1900 (Smock and others, 1883, p. 721). Asbestos of "very excellent quality" (Genth, 1875, p. 68) was reported to occur near Moro Phillips' chromite mine in West Nottingham Township (loc. 83, pl. 41). More recently, the Foote Mineral Co. obtained amphibole asbestos from Chester County (U.S. Bur. Mines, 1940, p. 1325), either in the State Line district or the West Chester district.

PHILADELPHIA DISTRICT

Village Green pits

The Village Green pits, on the William Hannum farm half a mile southwest of Village Green, Aston Township (loc. 18, pl. 42), worked an asbestos deposit reported to be large and of good quality (Rand and others, 1892, p. 198).

Rockdale pits

The Rockdale pits on Jacob H. Side's farm, a quarter of a mile west of Mount Alverno Station, also in Aston Township (loc. 20, pl. 42), were mined to some extent before 1900 for two varieties of yellowish-white asbestos: a hard variety with a silky luster, the fibers of which were broken across in places by seams of quartz; and a soft, pliable fibrous variety (Genth, 1875, p. 68). Similar material was found on the farm to the north. Both deposits were associated with talc. The asbestos was manufactured into pulp and felt, for such uses as boiler covers. The old pits were filled in sometime before 1921 (Gordon, 1922b, p. 185).

Smedley's mine

Smedley's asbestos mine is located by Gordon (1922b, p. 200) in Upper Providence Township, half a mile west of Rose Tree, north of the road to Sycamore Mills (loc. 31, pl. 42). The asbestos occurred as white fibrous masses in pyroxenitic serpentine, associated with enstatite and chlorite.

MAGNESITE

For more than 40 years during the earlier part of the 19th century, magnesite ($MgCO_3$) mined in Pennsylvania and Maryland was much in demand for the manufacture of epsom salt. It was our principal national source of magnesia from 1818 to 1860 and much was exported. The industry was started in this area long before the German deposits were important and before the California deposits, which are commonly considered the first ones developed in this country, were found.

Most important were the mines near the State line east of Goat Hill or Mount Ararat in West Nottingham Township, Chester County, Pa. (locs. 61, 62, pl. 41), and those of McKim, Sims and Co. in Fulton Township, Lancaster County, Pa. (probably loc. 93, pl. 41). In Maryland, magnesite production was reported from the Bare Hills and Soldiers Delight districts, Baltimore County (pl. 40), and from "Mrs. West's farm" near Coopstown, Harford County (pl. 41). An occurrence remarkable for its purity was noted by Gill (1889, p. 102) about 4 miles north of Gaithersburg, Montgomery County, Md. (pl. 40, exact location not known), but was apparently never of commercial interest.

The earliest production was apparently from the Bare Hills, where mining was "extensive" sometimes after 1814 and before 1828. Isaac Tyson, Jr., of Baltimore was a prominent producer and probably also a processor of magnesite in the area. By 1828 the principal manufacturer of epsom salt in this country, McKim, Sims and Co., in Baltimore, was producing epsom salt at the rate of 1.5 million pounds, or 750 short tons a year (Carpenter, 1828, p. 10). In 1833 the production was 1.1 million pounds (550 short tons) valued at $45,000, of which $40,000 worth was exported (Ducatel and Alexander, 1834, p. 18–19, map). Most of their raw material came from mines in Pennsylvania and Maryland.

The Goat Hill mines were opened in 1835; they were operated almost continuously until 1871, when competition of kieserite imported from Stassfurt, Germany, forced them to close permanently. Between 1854 and 1871 the operator was Powers and Weightman, of Philadelphia.

BARE HILLS AND SOLDIERS DELIGHT DISTRICTS

The "magnesites" mined at Bare Hills and Soldiers Delight in Baltimore County, Md. (pl. 40), were reported to be "silicates and hydrates of magnesia," but apparently were true magnesite. Exact locations of the mines in these districts are not known. The deposits were comparatively small and veins were thin. By 1839 Soldiers Delight had produced about 400 tons of magnesite that sold for $7.50 a ton (Ducatel, 1840, p. 40).

JARRETTSVILLE-DUBLIN DISTRICT

Ducatel (1839, p. 5) reports that veins of "silicates of magnesia" were being mined in 1838 on the farm of Mrs. West, near Coopstown, Harford County, Md. (pl. 41, location unknown), and were ground on the property.

STATE LINE DISTRICT

Goat Hill

The mines east of Goat Hill in Chester County, Pa. (locs. 61, 62, pl. 41), were opened in 1835 and worked until 1850, probably by Isaac Tyson, Jr., and the product was sent to Baltimore and Philadelphia. From 1854 to 1871 they were worked on a larger scale by Powers and Weightman, of Philadelphia. These old openings may have extended southward into Cecil County, Md. (Rand, 1867, p. 406). Deweylite and meerschaum were reportedly mined with the magnesite for manufacturing epsom salt (Rand, 1867, p. 406).

According to one of the old miners, the Goat Hill mines produced about 150 tons per year during the earlier period of operation, or 2,250 tons in 15 years, and 500 tons a year during the later period, or 8,500 tons in 17 years (Genth, 1875, p. 158–159). Total production from Goat Hill was thus well over 10,000 tons in 32 years. In 1838, production was as great as 800 tons at $4 per ton (Rogers, 1840, p. 22), and in 1867 it was estimated as 900 tons (Rand, 1867, p. 406).

Genth (1875, p. 158) reports an analysis of Pennsylvania magnesite, probably from the Goat Hill locality, made by J. H. Campbell in the laboratory of the University of Pennsylvania:

	Percent		*Percent*
Silicic acid	3.50	Magnesia	45.96
Carbonic acid	47.97	Lime	.40
Alumina	.45	Water	2.46
Ferrous oxide	Trace		

During the summer of 1921 some development work was done at the old Goat Hill pits (Stone, 1939, p. 23–24). A shaft with underground drifts was reopened and drained and a few tons of ore mined, but results were not satisfactory.

In 1955 the two main pits were found on the east side of a small valley, one of them directly under a powerline (loc. 61, pl. 41). In the southeast part of the northeastern pit is a caved shaft, and partly caved drifts and stopes extend eastward and southward from both pits, indicating fairly extensive underground workings, now mostly inaccessible (fig. 70). Many small open pits, trenches, and prospects extend about 100 yards east and northeast of the large pits. Other magnesite and possibly albitite prospects are widely spaced for a mile northeastward (loc. 62, pl. 41).

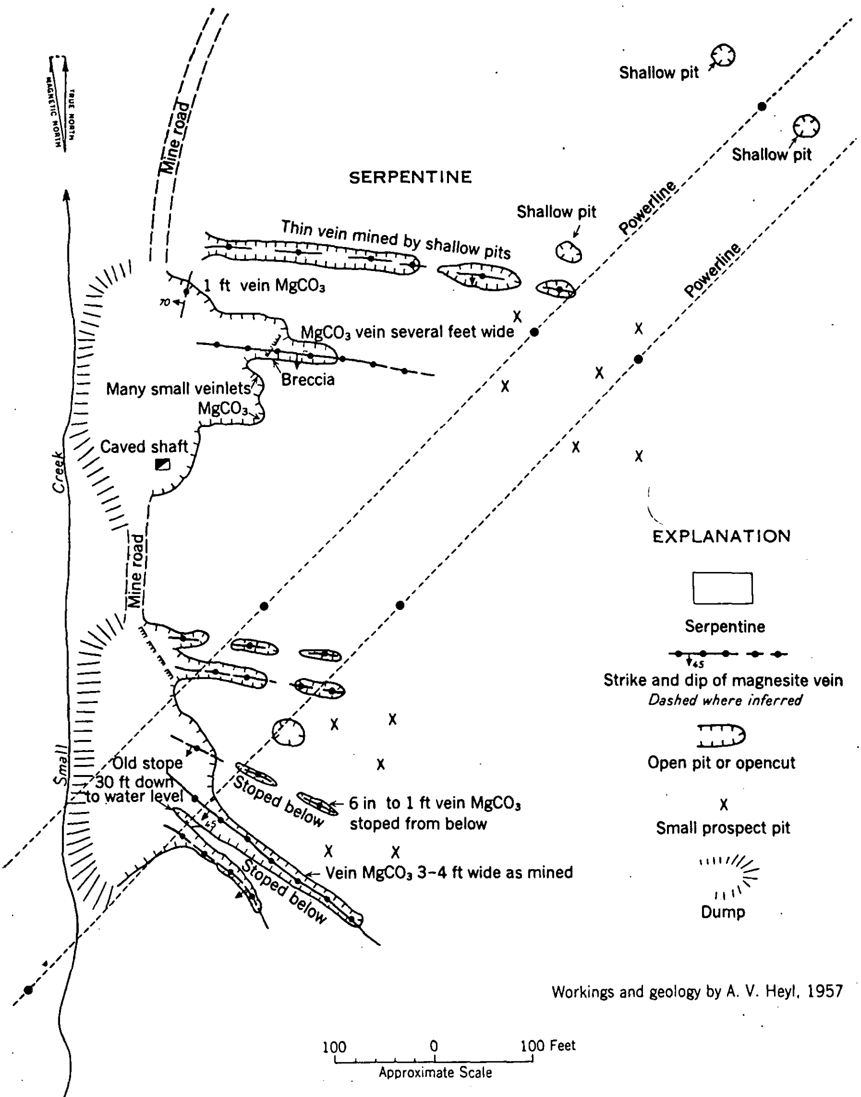

FIGURE 70.—Sketch map of Goat Hill magnesite mines, West Nottingham Township, Chester County, Pa.

The magnesite at Goat Hill occurs as a network of veins and veinlets in brecciated serpentine. Two main sets of veins occur in the area: one set is in fractures that strike eastward and southeastward and dip steeply southward; veins in the second set strike northward and dip steeply westward. The magnesite veins are mostly less than 1 inch wide, but several as wide as 14 inches have been reported, and some of those mined were probably 3 or 4 feet wide, judging from the size of accessible stopes. Exploratory work in 1921 in the shaft revealed a body of magnesite about 30 inches wide where two major veins crossed. The magnesite is white, unbanded, and very fine grained. Locally it is associated with much white foliated talc and albite.

Other mines

Although much less information is available concerning the magnesite workings in Lancaster County, Pa., they appear to have been of considerable size, at least during the late 1820's and the 1830's and probably longer. The most productive locality, operated by McKim, Sims and Co., of Baltimore, had produced 400 or 500 tons of magnesite by 1828 (Carpenter, 1828, p. 10). This locality is probably the Boyce (Spence) farm, in Fulton Township, Lancaster County, Pa. (loc. 93, pl. 41), reported by Frazer (1880, p. 179) to have produced considerable quantities of magnesite. Magnesite was also reported (Frazer, 1880, p. 97) to be abundant at a large quarry on Uriah Gray's farm, south of Spence's farm (loc. 94, pl. 41).

SODIUM-RICH FELDSPAR

Feldspar is a basic raw material in the manufacture of glass, burned clay products, and enamel; it is used in soaps, scouring powders, dental porcelain, abrasives, roofing granules, and poultry grit, and as a binder in abrasive wheels. Sodium-rich varieties of feldspar, known commercially as soda spar, are used chiefly for glazing purposes.

Most of the feldspar quarried in the Piedmont upland is potassium feldspar from granitic pegmatites, which are out of the scope of this report. Intrusive into the serpentine rocks of the Jarrettsville-Dublin, State Line, West Chester, and Philadelphia districts, however, are some unusual sodic pegmatites, consisting mainly of the sodium-rich plagioclases albite and oligoclase, with little or none of the quartz, mica, and tourmaline that are common constituents of most pegmatites. Sodium feldspar produced at one time in the State Line district commanded a better price than potassium feldspar.

GEOLOGIC OCCURRENCE

The sodium feldspar of Maryland, Pennsylvania, and Delaware ranges in composition from albite to oligoclase but is mostly albite. It is granular white, yellowish, or bluish gray, and translucent, and most of it is untwinned. The sodium-feldspar pegmatites, or albitite dikes, range in width from a few inches to more than 100 feet and are as much as 400 or 500 feet long. They are irregular in shape, pinching and swelling and bifurcating in many places. Those that have been described in the State Line district commonly form strings of podlike lenses or lentils, probably along fractures or shear zones. The general strike of individual pegmatites ranges widely; recorded strikes in the State Line district range from N. 15° W. to N. 75° W. and from N. 30° E. to N. 55° E. Dikes that have been mapped at Mount Cuba, Del., and many of those in the West Chester district (pl. 42) strike northeastward, parallel to the general regional trend; two of the Unionville pegmatites in the West Chester district trend northward (pl. 42).

Gordon (1921a, p. 177–179) describes the State Line district albitite dikes and zoning in the rocks adjacent to them. Of the accessory minerals, hornblende is most abundant, in minute radiating groups. Tiny crystals of biotite are scattered through the albite in local concentrations. A small albitite dike in one of Brinton's serpentine quarries, Chester County, Pa. (loc. 13, pl. 42), contained abundant tourmaline; a single feldspar quarry 1½ miles northwest of Sylmar, also in Chester County, contained quartz, muscovite, and anorthoclase; and some of the pegmatite at Mount Cuba appears to have contained some potassium feldspar, tourmaline, mica, and in places abundant quartz; but these are exceptions rather than the rule.

Some of the rare accessory minerals are molybdenite, found in the Nottingham quarries northwest of Sylmar, sodic amphibole, and actinolite, in green radiating clusters through the albite, particularly near the margins. Also occasionally found near the edges of the dikes is a green and white porphyritic rock, which Gordon describes as consisting in thin section of aggregates of zoisite in a groundmass of serpentine, with actinolite needles dispersed throughout. Bastin (1910, p. 76) reports in some places an abundance of pyrite and narrow zones of fibrous serpentine near the pegmatites.

FUTURE OUTLOOK

The feldspar industry has developed specifications in accordance with the most abundant material available, and is therefore geared to the use of potassium-rich rather than sodium-rich feldspar. Nevertheless, sodium feldspar is usable and seems to be preferable for a special use in glazing. Few areas are known where sodium-rich feldspar occurs so nearly free from quartz as it is in the Maryland, Pennsylvania, and Delaware dikes. Although many of the largest and most easily found of these dikes have been worked out or nearly so, at least one of the Nottingham quarries reportedly has reserves. The supply of sodium-rich feldspar in the area is probably not exhausted, should the demand be sufficient to warrant extensive exploration for similar undeveloped lenses. Numerous undeveloped dikes are reported in the area between Pilot, Md., and the Susquehanna River (pl. 41), for example.

Several factors should be considered in exploration of this sort. Because most known albitite dikes are confined to serpentine and related rocks, prospecting should begin in areas underlain by serpentine, and particularly in the State Line district, where most of the known dikes occur. Prospecting there is not easy because of the dense brush; hence, possibly not all the lenses of albitite have been found. Known lenses may be parts of strings or lines of lenses that could be found by following known trends, and some small dikes that are not commercial as they crop out may expand to larger dimensions with depth. Pegmatite lenses tend to pinch and swell with greater depth, but they also tend to occur as echeloned groups in vertical section, so that other lenses may exist near the lower or footwalls of those that are considered to be worked out, as, for example, the lens found by drilling at the Conowingo Marble and Mineral Co. quarry. (See p. 814.)

Although small albitite dikes may not be economically mined for feldspar alone, the quarrying of some might be worthwhile if talc, vermiculite, and amphibole asbestos zones are sufficiently developed between feldspar and serpentine to contribute usable byproducts.

QUARRY DESCRIPTIONS

Albitite dikes that have been most extensively quarried are in the State Line district. A single quarry just southwest of the Susquehanna River is in the Jarrettsville-Dublin district, and smaller quarries are in the West Chester and Philadelphia districts.

The following information describing individual quarries is principally taken from three references. Bastin (1910) describes the most important quarries in the two States at a time when they were in operation. Singewald (1928) locates and describes the quarries in Maryland. Stone and Hughes (1931) draw much of their information on quarries in Pennsylvania from older literature, but some additional information is based on Stone's visit to the localities and petrographic work on material he collected.

JARRETTSVILLE-DUBLIN DISTRICT

H. Clay Whiteford and Co. quarry

The small quarry of H. Clay Whiteford and Company (loc. 24, pl. 41) is the only albitite quarry known in Harford County. About 1909 it produced a few carloads of soda spar; later, in 1917, several more carloads were shipped to Golding Sons Co., which operated mills at Trenton, N.J. The quarry is elongate N. 75° W., and is about 50 feet by 20 feet and 20 feet deep. No quartz and practically no mica are associated with the albite.

STATE LINE DISTRICT

Bald Friar quarries

In Cecil County, Md., along the cliffs that border the Susquehanna River on the east (loc. 25, pl. 41), openings were made for soda spar, probably about 1900. White albite quarried at Bald Friar was shipped to Worth Brothers, at Brandywine Summit, Pa., for milling. Irregular, pinching and swelling veins of albitite as wide as 15 feet intrude serpentine, which is locally altered to talc schist. The talc zone is commonly 6 to 12 inches wide, and locally pyrite and narrow zones of asbestos are abundant near the pegmatite. The Bald Friar dikes are reported to be free of quartz. Other undesirable minerals, including mica, are rare or completely absent.

In the years subsequent to 1906 the Bald Friar quarries were reopened principally for talc, with secondary production of feldspar from stringers and branches of the main dikes. Bastin (1910, p. 76) reported that "the quantity of material is probably not sufficient to warrant mining for feldspar alone, but the feldspar forms an important adjunct in the quarrying of talc."

In 1928 the largest opening at Bald Friar was elongate N. 40° W. for 200 feet; it was 120 feet wide and about 40 feet deep. A second quarry southeast of it was more than 100 feet long, 50 feet wide, and 30 feet high at its upper face. The deposits were nearly exhausted (Singewald, 1928, p. 106).

Weiant workings

Farther south on the same hill slope (loc. 26, pl. 41), F. S. Weiant's Maryland Mineral Co. produced about 7,000 tons of feldspar from other pegmatites from 1922 to 1928 (Singewald, 1928, p. 107). The largest quarry followed for 100 feet a dike up to 20 feet wide that strikes N. 50° W. and dips 50° S. In 1928, pegmatite was still exposed at the southeast end of the quarry. The feldspar dike, in talc schist, contained some black tourmaline and more abundant black mica.

Caldwell quarries

About two-thirds of a mile southeast of Pilot, Cecil County, Md. (pl. 41), three albitite quarries were worked early in the 20th century. At least two of them were worked out before 1928. West of Conowingo Creek (loc. 28, pl. 41), a narrow albitite dike trending N. 25° W. for about 80 feet was worked out by Thomas Weaver. The two small quarries east of the creek (loc. 29, pl. 41) were also worked by Weaver, although originally opened for Worth Brothers. One produced 150 tons of feldspar from a dike 40 feet long, 4 feet wide, and 6 feet deep that trends N. 55° E. The second, 50 feet southeast of it, was worked out (Singewald, 1928, p. 107–108).

Weiant (Wiant) quarry

About 1918 F. S. Weiant opened a feldspar quarry northeast of Pilot, Cecil County, Md., on the west bank of Conowingo Creek (loc. 30, pl. 41) and worked it for several years. The albitite dike is about 18 feet wide and has a horse of serpentine in the middle. Contact zones of brown vermiculite, green actinolite, and talc are developed along the margins of the pegmatite. At the north end of the quarry the two branches of pegmatite are separated by about 12 feet of serpentine; the west branch is 15 feet wide and the east branch, 25 feet. The quarry, which trends N. 15° W., is about 75 feet long and about 50 feet wide. Albite quarried by Weiant was free of quartz and practically free of mica but locally contained radiating tufts of actinolite. Production was about 3,500 tons of feldspar (Singewald, 1928, p. 108). The quarry was later worked for serpentine.

Riley quarry

The Riley quarry, 0.4 mile southeast of Rock Springs in Cecil County, Md. (loc. 47, pl. 41), was worked until about 1899 and again about 1913, when a little talc was also produced. The "Rock Springs quarry" described by Bastin (1910, p. 76–77) was opened in 1907 by the Verona Mining Co., of Trenton, N.J., is probably either the Riley quarry or the smaller Schofield quarry west of Rock Springs.

Singewald (1928, p. 109) gives the dimensions of the Riley quarry as 150 feet by 30 feet; depth unknown. Considerable orthoclase feldspar was reported on the dump—unusual for the albitite pegmatites in the district.

Taylor quarry

The Taylor feldspar quarry, worked not long before 1902, is 1.7 miles east of Rock Springs in Cecil County, Md. (loc. 52, pl. 41). It is reported to be 150 feet long, 30 feet wide, and 25 feet deep. The pegmatite lies between serpentine and gabbroic gneiss that strikes N. 40° E. Feldspar quarried on the Taylor property was shipped to pottery works in Trenton, N.J., and Liverpool, Ohio, and is said to have totaled about 10,000 tons (Mathews, 1902, p. 218).

Worth Bros. quarry

Location: Cecil County, Md., 0.4 mile east of Pilot (loc. 27, pl. 41).

History: Worked before 1913.

Size: 100 feet long by 20 feet; elongate N. 70° W.; large waste dumps.

Occurrence: Not a typical albitite dike; feldspar contains some quartz in fine graphic intergrowths, small flakes of mica, and a little tourmaline. Some coarse striated feldspar and large blades of mica. Wallrock is serpentine.

Reference: Singewald, 1928, p. 107.

Conowingo Marble and Mineral Co. quarry

Location: Cecil County, Md., three-fourths of a mile northeast of Pilot, east side of Conowingo Creek (loc. 32, pl. 41).
History: A serpentine quarry; two carloads of feldspar shipped in the 1920's. Drill core reported to have contained 20 feet of feldspar at depth.
Reference: Singewald, 1928, p. 108.

Schofield quarry

Location: Cecil County, Md., 0.4 mile west of Rock Springs (loc. 43, pl. 41).
History: Worked by Thomas Weaver about 1913.
Size: Quarry 30 feet in diameter, 8 feet deep.
Production: Feldspar and talc, amount small.
Reference: Singewald, 1928, p. 108.

Dawson and McVey quarries

Location: Cecil County, Md., 0.3 mile southeast of Rock Springs (locs. 45, 46, pl. 41). Dawson is south of road; McVey, north.
History: One was worked before 1899 as the Tweed mine. The other was opened in 1901; feldspar was hauled to Conowingo for shipment. Active for only a few years.
Size: Dawson quarry, 30 feet in diameter; McVey quarry, 50 feet by 30 feet.
Occurrence: Small pegmatite, strike N. 30° E. Talc zone.
References: Bascom, 1902, p. 97; Mathews, 1902, p. 218; Singewald, 1928, p. 109.

Nottingham quarries

The largest of the State Line albitite quarries are in West Nottingham Township, Chester County, Pa., 2 to 3 miles southwest of Nottingham. Numerous openings have been made for feldspar in this area, most important of which are the Sparvetta, Keystone, and Brandywine quarries (locs. 67, 68, 72, pl. 41). At all three the sodium feldspar is "generally in crystals that are from 1 inch to 2 inches across, though some are as much as a foot across. The crude feldspar varies from white through cream to gray; the ground product is pure white" (Bastin, 1910, p. 69). Aggregates of dark-green to black crystals of sodic amphibole commonly fill spaces between the feldspar grains. Locally, small garnets occur, and intergrowths of muscovite and feldspar form more or less rounded aggregates. Talc, vermiculite, and fibrous serpentine contact zones are characteristic but not notably large.

Many smaller pits in the area southwest of Nottingham are conspicuous on aerial photographs but are not shown on plate 41. Most are probably albitite pits; a few could be chromite prospects. The writers have not checked them in the field. Others, known to be feldspar pits and briefly described by Stone and Hughes (1931, p. 21, 28–31), are located on plate 41 (locs. 70, 73–75, 77–79).

Sparvetta (Tweed) quarry.—A quarter of a mile north of the State Line near the head of a branch of Stone Run (loc. 67, pl. 41) is the quarry of the Sparvetta Mining Co., which was closed sometime between 1907 and 1916, possibly in 1911. When Bastin (1910, p. 68) visited the quarry in 1907, it was active, and he described it as an open pit alined N. 55° W., following the general trend of the pegmatite, 400 or 500 feet long, 50 to 150 feet wide, and 80 feet in maximum depth. In 1956 the writers found the Sparvetta quarry to be more nearly as Stone describes it (Stone and Hughes, 1931, p. 22)—an old water-filled pit about 310 feet long and 150 feet wide. A smaller pit 50 feet long and 10 feet wide is 150 feet southeast of it, and Stone suggests that the two may have been continuous at the time of Bastin's visit, to account for the reported length. A large waste dump 20 to 30 feet high is on the southwest side of the larger pit. The feldspar was milled on the property.

Bastin (1910, p. 68) gives the following description:

> The working taps two feldspar masses of nearly parallel trend, but of different dip, the dip of one being approximately vertical, while that of the other is so inclined that it joins the first near the bottom of the quarry to form a single vein. The southwestern of these two feldspar masses is only 5 to 10 feet wide near the surface, but broadens downward. There is no evidence that the pegmatite dies out for some little distance in either direction along its trend, and presumably it also continues downward to a considerable depth.

Between the feldspar and dark-green serpentine is a contact zone about 1 foot wide of talc with some fibrous serpentine, the fibers of which are 1 to 1½ inches long and perpendicular to the contact.

Stone and Hughes (1931, p. 24–26) describe a thin section of material collected at the Sparvetta quarry, which they consider typical of the product. It is "a microperthitic intergrowth of oligoclase with a little orthoclase, in which is contained a minimum of quartz and other minerals whose presence is detrimental."

The Sparvetta quarry appears to be the same as the Mansell Tweed quarry described by Hopkins (1899).

Keystone quarry.—About 1,000 feet southeast of the Sparvetta quarry and probably on a continuation of the same pegmatite a second large quarry was worked by the Keystone Feldspar Co., of Philadelphia (loc. 68, pl. 41). Operations were suspended in 1908, and the feldspar was reportedly exhausted (Watts, 1916, p. 158). Bastin, however, who visited the quarry only about a year before it closed, wrote (1910, p. 69): "The amount of material here seems to be large, and there is no indication of its dying out for some distance downward or along its trend." The Keystone pit is 350 feet long, 150 feet wide, and 80 feet in maximum depth. Long waste dumps south of the quarry resemble those at the Sparvetta quarry except that they contain more muscovite and amphibole. The quantity of feldspar that is valueless because of impurities is large. Usable spar was not milled on the property but was sold in the crude state.

A smaller pit lies about 400 feet northwest of the large Keystone quarry, between it and the two Sparvetta openings. It is about 75 feet long and 50 feet wide, and is filled with water. Either this pit or the main opening is probably the Monahan quarry of Hopkins (1899, p. 17) and the Walker quarry of Bascom (1902, p. 97).

Brandywine (Old Brandywine) quarry.—The Brandywine Summit Kaolin and Feldspar Co. produced sodium feldspar in the early 1900's from a large quarry 2 miles southwest of Nottingham near the south bank of Black Run (loc. 72, pl. 41). Part of their product was ground by the Sparvetta Co. and the rest in the Brandywine Summit Co's. mill near Brandywine Summit, Pa. Operations had ceased before 1916. Although Watts (1916, p. 158) reports that the deposit was considered exhausted, not long before the quarry closed Bastin (1910, p. 69) reported that the vein probably extended beyond both quarry ends at that time, and possibly also to greater depths. Smaller pegmatites continued to be worked in the area east of the Old Brandywine quarry after 1916.

The large Brandywine, or Old Brandywine quarry, is 200 feet long, 70 to 80 feet wide, 90 to 100 or more feet deep, and elongate N. 10° W. It is filled with water. According to Bastin (1910, p. 69) the pegmatite was about 12 feet wide at the south end of the quarry and broadened northward. A contact zone of blue-green talc, largely decomposed, lies between feldspar and serpentine.

Extensive dumps on the north side of the quarry were worked over after the quarry closed. A considerable quantity of second-grade feldspar was shipped to grinding mills, and some of the dump material was later used for surfacing private roads.

Stone and Hughes (1931, p. 27–28) describe a thin section of feldspar from the Old Brandywine quarry. It is a mixture of the sodium plagioclases albite and oligoclase with orthoclase. The grains overlap and are irregularly intergrown, giving a mottled appearance. Alteration to sericite and kaolin is pronounced. The relation of the specimen examined to the rest of the dike is not known, so that this is not necessarily typical of the product.

Other quarries.—For about a mile east of the Brandywine quarry (pl. 41), the area is dotted with quarries and pits of various sizes and shapes, most of which were small feldspar producers or prospect pits for feldspar. Those known to have been opened for feldspar are:

1. A small quarry about 500 feet southwest of the large Brandywine quarry, northwest of the road (loc. 70, pl. 41).
2. A trench south of quarry 1, across the road from it. The trench trends N. 30° E. for about 150 feet and is 12 feet wide and narrows at its southern end. It is about 20 feet deep and partly flooded (Stone and Hughes, 1931, p. 28–29).
3. Another small quarry about 100 yards southeast of the large Brandywine quarry (loc. 73, pl. 41). It is an irregular opening 60 feet long in a pegmatite that strikes N. 40° W. The quarry is a maximum of 25 feet in width and tapers at both ends; a narrow opening about 2 feet wide parallels it a few feet away (Stone and Hughes, 1931, p. 29, fig. 3b).
4. Rhodewalt's Cooper-place quarry, about a third of a mile south of the Brandywine quarry (loc. 74, pl. 41). It is a long (225 feet), narrow (2 to 12 feet) water-filled opening that strikes N. 70° W. in its southern half but bends sharply to N. 20° W. in the northern half, and the dike appears to dip northeastward (Stone and Hughes, 1931, p. 29, fig. 3a). In 1927 the large dumps were being removed for road material.
5. Rhodewalt's Cooper-place pit, 300 yards N. 60° E. of the quarry (loc. 75, pl. 41). It is a curving pit about 75 feet long; it is 10 feet wide near the center and pinches at both ends (Stone and Hughes, 1931, p. 29–30). Stone found some clean feldspar on the dump, but also a considerable quantity of muscovite and biotite. Between numbers 4 and 5 are several small pits and trenches, as well as a great deal of iron gossan and a deposit of sugary quartz used for building sand.
6. Rhodewalt's Jones quarry, originally opened by the Brandywine Summit Feldspar Co., about half a mile east of the Cooper-place quarry (loc. 77, pl. 41). The Jones quarry is at least 20 feet deep in a pegmatite that strikes N. 30° W. and is about 15 feet wide near the center. In 1927 Stone found albite exposed at both ends of the quarry, for a width of about 5 feet at the southeast end and 8 feet at the northwest end. During the 1920's Harry Rhodewalt screened out some feldspar from an opening 5 feet deep at the north end of the quarry, and also shipped quite a few tons of No. 2 spar from the old dump for use in linoleum manufacturing. Muscovite, biotite, and a little tourmaline are associated with the feldspar.
7. Pits and trenches 1,000 feet northwest of the Jones quarry, along strike (Stone and Hughes, 1931, p. 31) (loc. 78, pl. 41).
8. Numerous small pits (loc. 79, pl. 41), possibly the same locality that Watts (1916, p. 156–158) refers to as the "Brandywine quarry." Operations were in progress in 1916, and the irreg-

ular, lenticular pegmatite dike was opened in several places over a distance of about 100 feet to depths of 60 to 80 feet. The dike is about 20 feet wide and is mostly coarsely crystalline albite with a few isolated crystals of muscovite and hornblende but no quartz. Watts (1916, p. 157) describes the albite and gives an analysis, its properties in standard porcelain mixture, its deformation range, and its temperature of fusion.

WEST CHESTER DISTRICT

Unionville quarries

Several small feldspar quarries were operated before 1900 northeast of Unionville, Chester County, Pa. (loc. 8, pl. 42), in the area known as Corundum Hill. As early as 1853, according to the notes of H. D. Rogers (Lesley and others, 1883, p. 91), feldspar from the vicinity was in demand for use in dentistry, and a successful quarry was in operation. The product, however, was reported as orthoclase feldspar, "entirely free from extraneous associations," locally associated with much oligoclase; and the notes do not make it clear whether the dike was actually in serpentine. The only available description of the Unionville feldspar quarries, by Hopkins (1899, p. 14–15), indicates that the corundum-free pegmatites in serpentine at Unionville do not differ greatly from those in the schist nearby:

> Feldspar was quarried from four openings during the present season and there are not less than half a dozen other openings from which spar has been removed within the last few years. The quarries are comparatively shallow * * *. The spar lies in the loose disintegrated [country rock] * * * and the vein walls are not clearly defined. The rock is a mica schist bordering on serpentine, and some of the quarries are apparently within the serpentine area. Muscovite and biotite are quite abundant in places, and there is considerable diffused quartz but no large masses were observed. * * * Tourmaline crystals are reported.

Detailed studies of the feldspar-producing pegmatites in this serpentine area, in comparison with those in the State Line district and in contrast with those that are not intruded into serpentine, would probably be of considerable scientific interest to petrologists concerned with problems of pegmatite origin.

PHILADELPHIA DISTRICT

Although sodium-rich pegmatites are known to occur in the serpentine bodies of the Philadelphia district (Gordon, 1922b, p. 184–200), little quarrying has been done except at Mineral Hill, Pa., and Mount Cuba, Del. (pl. 42).

Some of the albite and oligoclase in the Philadelphia district occur as the gem varieties moonstone and sunstone. Moonstone is an opalescent feldspar; sunstone is feldspar with small inclusions that cause a metallic orange play of colors. During the 1880's small nodular lumps of moonstone and sunstone scattered through the soil were collected at various localities near Media and sold for use as semiprecious stones. Kunz (1883, p. 495–496) reported that the combined annual sales of each type from Media and a locality in Virginia amounted to about $250.

Among the places near Media where moonstone and sunstone were obtained were John Scofield's farm (south of loc. 25, pl. 42), production from which was about a ton (Kunz, 1885, p. 771); John Hibbard's farm (loc. 22, pl. 42); and Mineral Hill (loc. 30, pl. 42, and ravine south of loc. 29, pl. 42). Specimens of opalescent albite from Mineral Hill were particularly noteworthy.

Mineral Hill quarry

A very small feldspar quarry (loc. 30, pl. 42) was worked at Mineral Hill, one-eighth of a mile north of Crump's serpentine quarry. The quarry may have been worked, at least partly, for semiprecious stones. Gordon (1922b, p. 191) lists minerals occurring there; feldspars include aventurine orthoclase and microcline (amazonstone) as well as the sodium-rich plagioclase albite (moonstone) and oligoclase (sunstone). Neither quartz nor muscovite is listed. Almandite, vermiculite, microlite, bluish-green beryl, and crystals of columbite are reported.

Mount Cuba quarries

A pegmatite dike in the serpentine of Mount Cuba, Del. (pl. 42), was exploited for feldspar between 1828 and about 1840. The product was used by William E. Tucker in Philadelphia for making a fine porcelain ware (Carpenter, 1828, p. 11). A "Tucker's quarry" (probably the same) was producing an exceptionally pure variety of feldspar in 1883 and 1884 (U.S. Geol. Survey, 1883–84, p. 933). The exact location is not known.

The feldspar at Tucker's quarry is mostly albite (Booth, 1841, p. 34–36). Two types of serpentine were exposed in the quarry: a soft light-green variety containing fibrous and foliated talc and a tougher, more massive, dark-green variety. Asbestos and talc were common. Talc was particularly abundant in another quarry a few yards west of Tucker's.

The serpentine at Dixon's quarries, on a farm adjoining Tucker's, was veined with magnesite and asbestos, and beryl, apatite, black tourmaline, and cyanite are reported from the pegmatite. Both Dixon's quarries and Way's quarries, about 2 miles south of Centreville (loc. 37, pl. 42), contained granular quartz—abundant enough to be used in the poreclain industry. Apatite, mica, and deweylite are reported as accessory minerals.

CORUNDUM

Corundum, a naturally occurring aluminum oxide (Al_2O_3), is one of the hardest of minerals. It was widely used as a polishing and abrasive material before the development of artificial abrasives and continues to be used for special kinds of grinding, particularly by the optical industry. Corundum occurs in both crystalline and massive form, has an uneven to conchoidal fracture and a notable rhombohedral parting that makes sharp fragments when the corundum is ground. It is brittle, but is very tough when compact. Sapphire and ruby are rare gem varieties of corundum.

At various times from 1825 until about 1892 corundum was found in plowing, well-digging, and small-scale mining ventures in Chester County, Pa., and to a lesser extent in Delaware County (Pearre, 1958). Most important were the Corundum Hill mines in Newlin Township, Chester County, 1 to 2 miles northeast of Unionville (locs. 2–5, 7, pl. 42), the largest of which was reportedly 160 feet deep. Other pits and small mines were in Delaware County (pl. 42), south and east of the Black Horse Hotel, Middletown Township (locs. 23, 25, 26, 28), and near Village Green, Aston Township (loc. 19). Production from these localities was at first shipped to England and later ground at a local mill for use in the abrasives industry. In 1882 a large part of the domestic corundum production came from Pennsylvania (U.S. Geol. Survey, 1882, p. 477).

PRODUCTION AND VALUE

Production of corundum in Pennsylvania was small, although apparently larger than records indicate. Fragmentary records place the minimum production from both Chester and Delaware Counties at 650 to 750 tons of high-grade corundum ore and concentrates.

In 1866 corundum from Unionville sold for $60 a ton. Willcox (1883, p. 349) reports that shortly afterwards the demand became so great that the price was as high as 50 cents a pound ($1,000 a ton). In 1873 the price was between $200 and $500 a ton. In 1882 crude rock brought only $10 to $15 a ton, whereas ground corundum brought $240 to $300 a ton (U.S. Geol. Survey, 1882, p. 477).

GEOLOGIC OCCURRENCE

Corundum occurs in diverse environments but is commonly associated with silica-deficient rocks—in Pennsylvania, sodium-rich pegmatites that are intrusive either into serpentine bodies or at the contact between serpentine and schist. These pegmatites are similar to the albitites from which feldspar was produced except for the corundum that they contain, very irregularly distributed in granular masses and euhedral crystals. They are decomposed near the surface, and residual boulders and crystals of corundum are found in the soil. Between pegmatite and serpentine a zone is commonly developed containing white foliated talc, green actinolite, much dark-green chlorite, and in places large yellowish-green plates of jefferisite.

Under metamorphic conditions corundum alters readily to other aluminous minerals, particularly margarite and damourite, zoisite, sillimanite, and cyanite; less commonly diaspore, gibbsite, andalu site, spinel, and tourmaline. All these minerals except andalusite have been reported with the corundum deposits in Pennsylvania.

At the Unionville mines (Gordon, 1921a, p. 183) white, brownish-white, or gray crystals and blue-black masses of corundum were found in rock consisting of sodium-rich feldspar, black or bluish- to brownish-green tourmaline, margarite, and euphyllite (a basic sodium and potassium mica for which Unionville is the type locality). The feldspar ranges from granular white albite to pale-yellow oligoclase.

The Chandler-Ball mine (loc. 4, pl. 42) reportedly worked a solid mass of corundum and margarite that was 14 feet long, 7 feet wide, and 54 feet deep (Jefferis, *in* Rand and others, 1892, p. 188; Gordon, 1921a, p. 183). A zone of foliated talc separated it from the serpentine. On one side of the corundum mass was a 2-inch coating of fawn-colored diaspore 3 feet long, 2 feet wide, and well crystallized on the surface. Crystals of corundum were sheathed by margarite or damourite, and margarite formed yellow or pink foliated masses and secondary scaly aggregates around cores of corundum. Laminated masses and clear crystals of diaspore were associated with the margarite and were penetrated by translucent prismatic crystals of tourmaline in shades of blue or green. Kunz (1885, p. 738) suggested that the Unionville diaspore crystals were potential gems, closely resembling topaz in appearance. He also mentions that some of the corundum is of near-gem quality.

The corundum deposits in Delaware County were largely white to brown or gray crystals averaging about 6 cm in length, found loose in the soil or in road gutters. As the Black Horse pits (loc. 23, pl. 42) white to brown slender bipyramidal crystals of corundum occurred in granular white albite-oligoclase rock. Masses of corundum-bearing rock were irregular, less than 5 feet in diameter, and pinched out at depths of about 30 to 60 feet.

FUTURE OUTLOOK

Increased use of artificial abrasives since the 1890's has diminished the demand for natural corundum, but corundum wheels continue to be preferred for grinding certain types of castings, and corundum is still considered essential to the optical industry for lens grinding (Chandler, 1956). The deposits in Pennsylvania, however, are very irregular and concentrations are small, so that no production of corundum is anticipated from them in the foreseeable future.

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