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PRELIMINARY REPORT
ON THE
CHROMITE OCCURRENCE
AT
THE WOOD MINE,
PENNSYLVANIA

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FOREWORD

Chromite occurrences in Pennsylvania have been and are currently of interest to many people. The Bureau of Topographic and Geologic Survey has recognized this interest and is concerned with the chromite ore potentialities of Pennsylvania. The genetic relationships between the chromite and the rocks in which they occur must be studied before an accurate estimate of these potentialities can be made. It is the purpose of Progress Report 153 to discuss the initial progress made in studying the origin of chromite at the Wood Mine, Lancaster County, Pennsylvania.

As its title indicates, however, this booklet is a "preliminary report" only. This report is part of a project started under Professor Paul F. Kerr of Columbia University while the author was studying at that institution. Dr. Lapham is continuing this project and expects to publish a more comprehensive study of this work in the future.

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INTRODUCTION

Chromite has long been classed as a strategic mineral both because of its importance as a steel alloy and because of its scarcity in the United States. The only noteworthy occurrences of chromite in this country are in North Carolina, Pennsylvania, Wyoming, Montana, Washington, Oregon and California. None of these are significant producers. Since chromite ore has to be imported, however, the exploration for new occurrences and the review of old localities is of extreme importance to our economy.

This report presents an examination of the geologic environment of the chromite at the Wood mine, Lancaster County, Pennsylvania in the hope that additional information may lead to the discovery of new economic chromite deposits in this region.

LOCATION OF THE WOOD MINE

The old mine shaft and dumps are three miles southeast of Wingsdale on the road to Lee's Bridge, about nine miles southwest of Oxford, Pennsylvania, and half a mile west of the Wood home along a bend of Octararo Creek.

The Wood mine has been inoperative for over seventy years, but was once the major domestic source of chromite. Several other similar occurrences were sporadically mined, both in Pennsylvania and Maryland, along a northerly striking group of chromiferous ultrabasics (Knopf, 1921).
GEOLOGIC SETTING OF CHROMITE DEPOSITS

Chromite, FeCr$_2$O$_4$, is a potential ore mineral with a distinctive geologic environment which greatly facilitates the exploration for and development of new occurrences. It is found within ultrabasic intrusives which are of two types: (1) layered sills or plutons exemplified by the Bushveld complex of South Africa, and (2) pod or lens shaped intrusives, generally referred to as the Alpine type because of their widespread occurrence in deformed tectonic belts.

The ultrabasics of the Alpine type, which includes the Wood mine, are either partially or completely serpentinitized. Since serpentinization represents a water-rich phase of alteration after the crystallization of olivine and/or enstatite (the main mineral components of an ultrabasic), it may also affect early formed chromite through processes of re concentration and the addition of iron and chromium. Thus serpentinization is able to control the composition of chromite through variation in the iron to chromium ratio, and through the substitution of aluminum for chromium. It also affects chromite textures with respect to the enclosing rocks.

Generally, as serpentinization proceeds, chromite tends to become richer in ferric iron and aluminum, decreasing in chromium content. Textures tend to change from disseminated grains and layered bands to veinlets, lenses, chimneys, and stringers, often exhibiting cross-cutting relations with earlier banded textures. The recognition of such textures is an important factor in the economic exploitation of all chromite deposits.

As a result of serpentinization three types of chromite may crystallize. The first belongs to the magmatic stage and is nearly contemporaneous with the formation of olivine and enstatite. Secondly, new chromite forms euhedral crystals, often around remnant cores of the early chromite, as altering solutions attack the early magmatic minerals. This process liberates aluminum, magnesium, and iron, and probably adds these constituents during the early hydrothermal stages. The last chromite to crystallize is seen as small veinlets transecting both previous types.

DESCRIPTION AND PETROGRAPHY OF THE COUNTRY ROCK

The altered ultrabasic at the Wood mine intruded regional schists and gneisses. The igneous intrusives in this area are in the following sequence from north to south and earliest to latest (Gordon, 1921): metapyroxenite
(serpentine, etc.) and metaperidotite, norite, gabbro, and granodiorite. Country rock is best observed in a road cut at Sleepy Hollow, half a mile to the north. It is both gneissic and schistose. The gneiss contains some biotite, while the schist is largely chloritic with 2M detrital muscovite. Between the gneiss and schist are parallel lenses of quartz up to a foot or more in diameter. Gordon (1921) states that the schist has been intruded by "a fine grained gray granitic gneiss and pegmatite", although there seems to be no evidence of intrusion at Sleepy Hollow. No country rock outcrops are visible at the mine. However, both chlorite-mica schists and quartz are commonly found on slopes surrounding the altered ultrabasic and are similar to the Sleepy Hollow meta-sediments, containing quartz, muscovite, chlorite, magnetite and minor accessory minerals.

The chlorite in this schist is significantly different from both the green and violet chlorites associated with the ultrabasic. It has a low c₀ (basal) spacing of 14.07A., characteristic of chlorite structures for metamorphosed sedimentary chlorite. In addition, both the high indices of refraction and low (001) intensity indicate a total iron content of more than 20 per cent. The c₀ spacing and the position of the (003) reflection indicate approximately two tetrahedral aluminum ions per 14A. unit cell, considerably more than is found in chlorites associated with ultrabasics, and suggest that it is the orthochlorite Fe-corundophilite (pseudothuringite of Hey, 1954).

In addition to the above mentioned chlorite and muscovite, thin sections of the schist reveal magnetite, quartz, and pyrite in order of decreasing abundance. These minerals form two distinct assemblages, a quartz-muscovite and a muscovite-magnetite-chlorite association. Magnetite is almost entirely within or along the borders of chlorite grains. A large number of magnetite grains are euhedral, indicating either addition of iron or remobilization of iron after sediment deposition. It seems probable that metamorphism of a high iron sedimentary chlorite produced a more ordered structure, exsolving iron in the process, and resulted in additional magnetite. Muscovite and chlorite are closely interleaved, as is common in low grade pelitic mica schists (Williams, Turner, and Gilbert, 1955).

The country rock at Sleepy Hollow strikes northeast-southwest and dips southeast. According to Knopf (1921), the "contact between the serpentine and the crystalline schists on the northwest border of the intrusion also dips southeast". Thus it seems that the intrusive entered along planes of schistosity. A north-south strike within the ultrabasic was observed on the lower levels, although an east-west strike was often observed on the surface (Gordon, 1921). These relations are no longer visible, both because of the dense soil cover and because the shaft is now completely filled with water.
THE ULTRABASIC

The only well exposed outcrop of the intrusive is at a large quarry face north of the pit and dumps. No unserpentinized ultrabasic is visible. There are several joint sets and fractures along which minor movement has taken place after serpentinization. These are generally unmineralized. Folding and fracture zones strike north-south, corresponding to east-west compression later than the intrusion of the ultrabasic. Five notable horizontal white bands largely composed of magnesite and chrysotile occur near the center of the quarry face. Contacts of the bands with serpentine above and below are sharp. They are from 3 inches to 1 foot thick, folded, and are themselves composed of finer horizontal bands largely orthochrysotile, but also containing some clinochrysotile (Whittaker and Zussman, 1956). The magnesite is cut by vertical fracture fillings of dolomite. (Identification of magnesite and dolomite was by optical and X-ray methods.)

Several interesting features are revealed in a series of thin sections from highly altered to relatively unaltered ultrabasic. Least altered portions contain about 20 per cent relict olivine and 20 per cent relict enstatite. However, the more highly altered specimens show a preponderance of enstatite over olivine, due to the greater resistance of enstatite to serpentinization. Thus, the original ultrabasic composition of this intrusive corresponds to that of a harzburgite (saxonite).

Textures are typically cellular (Plate I-A), composed of networks of chrysotile fibers with either incompletely altered olivine or limonite-chrysotile centers. In the latter case, the difference is heightened by the color contrast between iron oxide stained centers and the surrounding yellowish to clear chrysotile.

THE CHROMITE AND ASSOCIATED MINERALS

The chrome ore body was described as being 300 feet long by 10 feet to 35 feet wide and dipping 40° to 60° to the southeast. Mining was carried on to a depth of 720 feet (Gordon, 1921). The shape of the body has been variously described as a "vein with distinct footwall and hanging wall" (Knopf, 1921), as a "pipe-like" deposit (Fisher, 1929), and as an "ore shoot (a vein)" of chromite (Glenn, 1895). In addition, small veinlets and trails extend into the walls (Gordon, 1921). The chromite present in the one visible quarry face is of three types: (1) disseminated chromite scattered throughout the ultrabasic in both serpentine and magnesite zones; (2) nearly vertical trails of ellipsoidal grains transecting serpentinization banding and offset by minor
fault displacements, and (3) narrow veins probably equivalent to the veinlets mentioned by Gordon. Chromite veinlet displacements are filled by contemporaneous or later serpentine.

The relations between chromite, chromium chlorite, and chrysotile furnish information concerning chromite genesis and serpentinization. Chromite, whether euhedral or anhedral, is often surrounded by short, colorless fibers of chromium chlorite, perpendicular to the outer edge or face of the chromite (Plate I-B). Often there are long cracks partially or completely within the chromite containing chromium chlorite and chrysotile (Plate I-B). The chromium chlorite has a low birefringence (.005), anomalous blue interference colors indicating more than 2 per cent. Cr₂O₃, and octahedrally substituted chromium, designating the variety kammererite. It forms disoriented aggregate fibers, colorless in plane polarized light. Occasionally, chrysotile is found between chromite and kammererite, indicating that serpentinization began earlier than the formation of chromium chlorite. Chrysotile occurs as long fibers within chromite cores (Plate I-B, D), closely surrounding later chromite (Plate I-A, D) and around relict grains of olivine and enstatite (Plate II-A). It has a birefringence of .007 to .009 and usually a yellowish color in plane polarized light. In some instances, chrysotile is completely enclosed within chromite (Plate I-B, D). The interpretation placed upon the chlorite-chrysotile relationship is that chrysotile represents the first alteration of olivine during serpentinization. Original chromite grains were also altered (Plate II-B). As chromium and probably iron were introduced, a second chromite replaced the early formed chrysotile and chromite, leaving small chrysotile inclusions in chromite and producing zoned chromite crystals (Plates I-A, II-C). Continued serpentinization resulted in the further alteration of olivine, chromite, and the early chrysotile to form kammererite and cross-cutting veinlets of black opaque chromite (Plates I-C, II-C). Oriented short fibers of chromium chlorite formed perpendicular to crystal faces of secondary chromite (Plates I-A, B; II-D).

Since the later chromite is closely associated with serpentinization (Plate II-A), it may be concluded that it formed during post-magmatic (hydrothermal) processes. Iron and chromium must have originated at depth below the visible portions of the altered harzburgite, and it seems probable that this was also the source of the harzburgite. In this case, the harzburgite does not represent an original magma composition, but is itself a differentiation product.

PARAGENESIS

The paragenesis during the magmatic stage would be as follows:
PHOTOMICROGRAPHS OF THIN SECTIONS FROM
THE WOOD MINE, PENNSYLVANIA

Plate 1

A. X 150. Polarized light with crossed nicols. Black chromite surrounded
by light serpentine (chrysotile) and gray kammererite in serpentinized
harzburgite.

B. X 150. Plane polarized light. Euhedral opaque black chromite with
inclusions of chrysotile (light) and chlorite (gray) surrounded by oriented
laths of kammererite. Euhedral chromite indicates little alteration, and
hence acted as a nucleus for chlorite growth, not as a source of chromium.

C. X 150. Reflected light, illustrating zoned chromite with inner core (dark
and more translucent in transmitted light), outer opaque zone, and tran-
secting black veinlets later than both previous chromites.

D. As in C., but in polarized light with crossed nicols, showing chrysotile
fibers between core chromite and later outer chromite in serpentinized
harzburgite matrix.
PHOTOMICROGRAPHS OF THIN SECTIONS FROM THE WOOD MINE, PENNSYLVANIA

Plate II

A. X 150. Polarized light with crossed nicols. Black opaque chromite parallel to serpentinization bands (not shown), cutting a long enstatite lath (white) and replacing it along cleavage planes.

B. X 150. Polarized light with crossed nicols. Black translucent early primary chromite corroded by later alteration. Typical of early chromite where secondary chromite has not formed zonal structure.

C. X 150. Reflected light showing early altered core of translucent chromite surrounded by black opaque chromite veinlets. No kammererite developed with the secondary chromite here.

D. X 150. Polarized light with crossed nichols. Black euohedral opaque secondary chromite surrounded by kammererite laths (light gray) and chrysotile aggregates (light) with inclusions of chrysotile.
brown translucent chromite -- now highly altered (Plate II-B); olivine, and enstatite. The magmatic stage was followed by hydrothermal solutions causing serpentinization, resulting in chrysotile and chromite rims around early chromite (yielding zoned chromite crystals) and finally, in late chromite veinlets (Plates I-C; II-D) often replacing enstatite (Plate II-A). This later chromite is probably richer in Fe$^{3+}$ and aluminum than earlier crystals, since these relations are similar to those described by Miller (1953) for the Webster-Addie, North Carolina deposit. In part, the later chromites may represent alteration of early chromite, with contemporaneous development of kammererite, as Miller suggests. However, not all chromium-rich chlorite is associated with zoned or altered chromite. In addition, late black chromite cuts across all other minerals indicating continued introduction of chromium (Plate II-A). Chromium-deficient green chlorite (Cr-clinochlore), and minor chalcopryite appear to have been the last minerals to crystallize.

The following is a proposed sequence of events:

1. Regional metamorphism of sediments resulting in chloritemic schist and biotite gneiss. This may have occurred later or been intensified during compression (Step 6.).

2. Intrusion of harzburgite along planes of schistosity; early chromite.

3. Beginning of a continuous process of serpentinization, both preceding and extending beyond chromite crystallization.

4. Alteration of olivine and enstatite to chrysotile, and of some early chromite to more aluminum-rich chromite, with introduction of chromium and/or remobilization of iron yielding zoned chromite and kammererite during later stages of serpentinization.

5. Crystallization of green Cr-clinochlore and minor chalcopryite; as serpentinization ends, magnesite and dolomite may have formed.

6. Compression with folding, fracturing, and minor faulting.

7. Weathering with formation of limonite and possibly magnesite and dolomite.
CONCLUSIONS

The Wood mine contains early, middle, and late chromite with a probable decrease in total chromium content from early to late. An abundance of the late chromite (containing less chromium in the chromite) produces a deposit with less total extractable chromium compared to deposits of early chromite.

Certain chromite textures (i.e. veinlets and stringers) present at the Wood mine are associated with late chromite.

These conclusions suggest that the deposit is not of economic merit. Further study is necessary, however, to arrive at a definite conclusion, especially as concerns the possible occurrence of associated ore lenses in the vicinity.

REFERENCES CITED


Glenn, W m., 1895, Chrome in the southern Appalachian region, AIME Trans. vol. 25, pp. 481-499.

Gordon, Samuel G., 1921, Texas, Lancaster County, Pa., Am. Min. vol. 6, pp. 113-117.


