UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY
W. E. Wrather, *Director*

Bulletin 948

STRATEGIC MINERALS INVESTIGATIONS
1945

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1949

CONTENTS

[The letters in parentheses preceding the titles are those used to designate the papers for separate publication]

ILLUSTRATIONS

TABLES

INDEX

INDEX

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

Bulletin 948-A

TUNGSTEN DEPOSITS OF VANCE COUNTY NORTH CAROLINA, AND MECKLENBURG COUNTY, VIRGINIA

By
G. H. ESPENSHADE

Strategic Minerals Investigations, 1945
(Pages 1-17)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1947

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 50 cents

CONTENTS

ILLUSTRATIONS

TUNGSTEN DEPOSITS OF VANCE COUNTY, NORTH CAROLINA AND MECKLENBURG COUNTY, VIRGINIA

By G. H. Espenshade

ABSTRACT

Economically important deposits of tungsten minerals were found in Vance County, N. C., in 1942 by Mr. Joseph Hamme of Oxford, N. C., and Mr. Richard H. Hamme of Virgilina, Va. The Hamme brothers mined the deposits on a small scale until August 1943, when their properties were acquired by Haile Mines, Inc. These operations were taken over in June 1945 by the Tungsten Mining Corp., a new company formed by Haile Mines, Inc., and the General Electric Co. The combined production of the Hamme brothers, Haile Mines, Inc., and the Tungsten Mining Corp., from about May 1, 1943, to March 1, 1946, was 23,652 units of WO_3. The Southern Aggregates Corp., the other organization interested in tungsten mining in the region, did some mining in the fall of 1943, but has since been inactive except for several drilling programs. Topographic and geologic maps of the region were prepared by the Geological Survey during the period from July to December 1943, in conjunction with an exploration program of the Bureau of Mines.

The tungsten minerals, huebnerite with small amounts of scheelite, occur in quartz veins which cut granite and schist. Fluorite, rhodochrosite, pyrite, galena, sphalerite, chalcopyrite, and tetrahedrite accompany huebnerite and scheelite. Numerous barren quartz veins are also found in the district. The tungsten veins lie in a northeast-trending belt about 8 miles long and a mile wide. Most of the veins are in granite within 1,500 feet of the contact between the granite and schist to the west; a few of the veins lie in schist. The richer veins, carrying as much as 1.0 percent WO_3 in minable bodies are localized in the central part of the district in a zone about 2 miles long and 1,500 feet wide. Drilling and mining operations on several veins have shown that the veins are lenticular in shape and that they appear to pitch gently west or southwest.

Ore reserves in the central part of the district to a depth of 50 to 360 feet beneath the surface were estimated by the Geological Survey in early 1944 to be 130,000 tons of indicated ore and 155,000 tons of inferred ore averaging about 0.9 percent of WO_3. It is probable that mining and exploratory work at greater depths will increase these reserves. An additional 25,000 tons of ore carrying about 0.5 percent of WO_3 is inferred to a depth of 100 feet for a group of leaner veins, some of which are outside the central part of the district.

INTRODUCTION

The tungsten deposits of Vance County, N. C., and Mecklenburg County, Va., lie in a northeast-trending belt about 8 miles long and a mile wide (fig. 1 and pl. 1). All the veins described in this report are located south of the Roanoke River, and the majority of them are in the northwest corner of Vance County. A few veins have been reported from north of the river. Townsville, the nearest village, is on North Carolina Highway No. 39, 3½ miles southeast of the center of the tungsten district.

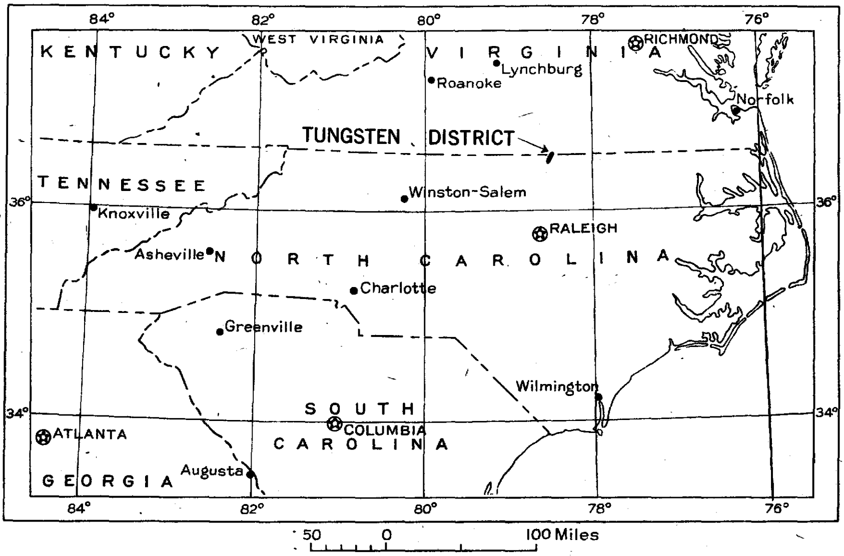


Figure 1. Index map of the southeastern states showing location of the tungsten deposits of Vance County, North Carolina, and Mecklenburg County, Virginia.

Tungsten minerals were found in this region by Mr. Joseph Hamme of Oxford, N. C., and Mr. Richard Hamme of Virgilina, Va., late in 1942.1/ The region has since become popularly known as the Hamme tungsten district. The Hamme brothers prospected the area considerably and mined several of the veins by shallow shafts and pits. Haile Mines, Inc., acquired the Hamme properties in August 1943, and has since been mining on a larger scale by surface and underground methods. A new company, the Tungsten Mining Corp., was formed in June 1945 by Haile Mines, Inc., and the General Electric Co. The combined production of these operations from about May 1, 1943, to March 1, 1946, was 23,652 units of WO_3.

1/ The presence of tungsten minerals in the area was reported as early as 1901. J. H. Pratt, in North Carolina Geological Survey Economic Paper 4, 1901, p. 32, states, "wolframite has been reported as occurring in some quantity on the Cheek farm, near Henderson, Vance County." Evidently the potential importance of the deposits was not recognized, for the occurrence was forgotten and no prospecting for tungsten done until the "rediscovery" of the deposits by the Hamme brothers.

The Southern Aggregates Corp. also began mining in August 1943, and was very active during the fall of that year. About 8 veins were opened by surface pits using small power shovels, and the ore was trucked over 20 miles to a gravity concentrating plant at Greystone, N. C. Little or no mining has been done since late 1943, although some diamond drilling was in progress in October 1944, and July 1945. Production data of the Southern Aggregates Corp. are not available.

During the second half of 1943, the Bureau of Mines carried out an exploration project in the tungsten district. The better veins were traced and sampled by numerous trenches and bulldozer cuts, and 41 diamond-drill holes, totaling 7,000 feet, were put down.

The first detailed geological work in the tungsten district was done by W. A. White, Assistant State Geologist of North Carolina, in February and March 1943. He mapped on aerial photographs the geology of the part of the district then known.2/ In March 1943, A. H. Koschmann and R. J. Wright of the Geological Survey, U. S. Department of the Interior, examined the deposits briefly. From July to December 1943, a Geological Survey party composed of G. H. Espenshade, R. J. Wright, M. H. Staatz, T. W. Amsden, E. A. Brown, and N. D. Raman prepared topographic and geologic maps of the region and cooperated with the exploration project of the Bureau of Mines. The central part of the district was mapped by plane-table methods on a scale of 100 feet to 1 inch, and the rest of the district was mapped on aerial photographs. C. J. Cohen, geological engineer of the Bureau of Mines, also participated in some of the mapping. Underground workings at the Haile mine were mapped in April 1944, by C. F. Park, Jr., and the writer, and again in October 1944, and July 1945, by the writer. A short preliminary report on the district, "Tungsten deposits of Vance County, N. C., and Mecklenburg County, Va.," by G. H. Espenshade, accompanied by large-scale topographic and geologic maps, and smaller-scale regional maps, was released by the Geological Survey in December 1943. The present report discusses the district in more detail.

Thanks are due the mine operators of the district for their aid and courtesies extended during the investigation. The Hamme brothers, James I. Moore, Jr., Daniel Gregg, and Howard Cunningham of Haile Mines, Inc., and Charles T. Cate of the Southern Aggregates Corp. were particularly helpful. T. B. Nolan, C. S. Ross, C. F. Park, Jr., D. F. Hewett, and others of the Geological Survey visited the party in the field, and have contributed valuable aid and advice then and since. The study of the ore minerals, particularly of the supergene minerals, has been greatly aided by the investigations of J. J. Glass, C. S. Ross, Charles Milton, and others of the Geological Survey. The contributions made by the writer's coworkers in the field studies are sincerely appreciated.

GEOLOGY

The tungsten district lies in the Piedmont province, about 50 miles west of the Coastal Plain. The relief of the region is

---

2/ White, W. A., Tungsten deposit near Townsville, N. C.: North Carolina Dept. Cons. and Devel., Div. Min. Resources, Mineral Investigation, August 1943; Tungsten deposit near Townsville, N. C.: Am. Mineralogist, vol. 30, pp. 97-110, 1945.

gentle, the surface ranging in elevation from about 250 feet to a little over 400 feet above sea level. Outcrops are few, because of the thorough weathering which the region has undergone, and float rock and character of the soil must be utilized in mapping the geology. Granite and schist are the principal rock types of the district, the eastern half of the mapped area being underlain by granite and the western half by schist (pl. 1). Some dikes of diorite, aplite, and diabase are also present. Tungsten-bearing quartz veins cut granite and schist near the contact between the two rocks; most of the veins lie in granite.

Metamorphic rocks

The schists comprise a variety of rocks, but because of the few scattered outcrops, it is not possible to trace the contacts between the different kinds. The most widespread variety is chlorite-epidote schist, similar in appearance to some of the "greenstone" of the Virgilina copper district about 20 miles to the west. Sericitic schist with many small martite grains is common in the central part of the region. Large platy crystals of chloritoid occur in chlorite-epidote schist in the southwestern part of the area; coarse-grained hornblende gneiss is associated with this chloritoid schist. At Morrow Chapel (pl. 1) several pieces of float of unsheared amygdular basalt or andesite were found. This amygdular rock is definitely of volcanic origin, and it is very likely that the widespread chlorite-epidote schist is of similar nature. The sericitic schist may originally have been shale or acidic tuff. Some of the schist is evidently volcanic in origin, and may possibly be correlated with the volcanic rocks of the nearby Virgilina region, which were thought by Laney 3/ to be of lower Paleozoic age. White 4/ has questioned the volcanic nature of the schists in the tungsten district and refers them to the Wissahickon schists.

Igneous rocks

Granite is the predominant igneous rock of the region and is the host rock for most of the tungsten veins. Outcrops are scarce, but the granite areas are characterized by rather sandy soil containing grains of opalescent quartz. The granite is typically coarse-grained and is composed of large albite crystals (making up 50 percent or more of the rock), blue quartz with wavy extinction, perthite and microcline, and aggregates of tiny green biotite flakes. The albite crystals carry an abundance of epidote and sericite in their interiors, but the potash feldspars are little altered. Common accessory minerals are magnetite, pyrite, sphene, apatite, and zircon. The rock is perhaps best classed as an albite granite, although it may originally have been a granodiorite whose calcic plagioclase has been transformed to albite and epidote.

There is no direct evidence to indicate the geologic age of the albite granite, but as it is apparently intrusive into rocks which are possibly lower Paleozoic, the granite may be upper Paleozoic in age as suggested by White.5/

3/ Laney, F. B., The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geol. Survey Bull. 14, p. 56, 1917.

4/ White, W. A., op. cit. (1943), p. 2; (1945), p. 98.

5/ White, W. A., op. cit. (1943), p. 5; (1945), pp. 101-102.

Much of the ground in the central part of the district (pl. 2) is covered with float of a reddish, iron-stained schistose rock, which in hand specimen appears to be composed mostly of sericite and lenticles of blue quartz. This rock was considered by White 6/ to be a phase of the schist which had been silicified by solutions from the granite. However diamond drilling and underground development have shown that the underlying rock in this area is granite which has been sheared, in places extremely so, and altered by the formation of considerable sericite, calcite, and pyrite.

Near the southern end of the district, white granite, composed chiefly of white feldspar and colorless quartz, is more abundant than the granite with blue quartz and biotite. Exposures are insufficient to permit showing the two varieties separately on the geologic map. Fine- to medium-grained biotite granite gneiss is rather common to the east and southeast of the district.

Several types of dike rocks occur in the region. A dike of aplitic granite and aplite cuts granite in the central part of the district (pl. 2). The aplite has the appearance of a sugary quartzite and is composed principally of nearly equal amounts of fine-grained quartz and albite, with some sericite and a little biotite. Fine-grained, white aplite, composed mostly of quartz and albite with some sericite, also accompanies many of the veins. Pegmatite seems to be very sparsely developed in the region. A very small amount of quartz-feldspar pegmatite was found in drill holes on the Morton 1 and Walker 3 veins. At several places (east of the Haile mill and north of the Burwell veins, but not shown on the geologic maps) the granite is intruded by a medium-grained hornblende-feldspar rock resembling diorite. The aplite and diorite dikes are probably pre-Triassic in age, and may be upper Paleozoic. The granite, the schist, and the tungsten veins are cut by diabase dikes, which trend in a northerly direction and are as much as several hundred feet wide (pls. 1 and 2). The diabase is coarse-grained and massive, and was emplaced after the cessation of deformation in the region. The dikes are similar to diabase dikes elsewhere in the Piedmont which are Triassic in age.

Structure

Granite underlies the eastern part of the district and schist the western part (pl. 1); both rocks extend beyond the limits of the mapped area. The contact between the two rocks has a general trend of about N. 10° E., but in the central portion of the district the contact curves convexly westward for a distance of about 2½ miles. The contact is best exposed in two small tributaries of Little Island Creek, about half a mile southeast of Morrow Chapel. Seams of schist a few feet thick occur here in granite in a zone several hundred feet wide just east of the contact. The granite mass appears to have intruded the schist and to have included thin layers of schist near its borders. The schist seams dip steeply, about conformable to the local dip of the foliation. This relation and the fairly uniform trend of the contact in the district suggest that the contact also dips steeply, possibly toward the west. The granite is rather gneissic near the contact, but becomes more massive farther east. Throughout the region the foliation of the schist

6/ White, W. A., op. cit. (1943), pp. 5-6; (1945), pp. 98-99.

and granite strikes between due north and N. 20° E., and dips to the east or west at angles of 70° or more. Linear structures, in the form of tiny crinkles in the foliation of the sheared granite, are present near many of the veins. Many of these linear structures pitch to the north at angles of 30° or less, although some pitch gently south.

In the central part of the district, a zone of shearing appears to extend into the granite mass for more than 2 miles in a N. 35° E. direction from the center of the westerly curve in the contact. The existence of such a zone is strongly suggested by the alinement of veins northeast from Sneed 2 vein as far as Walker 12 vein (pls. 1 and 2). The granite is considerably sheared across a width of 50 to 100 feet wherever it is exposed along this zone. All gradations of deformation are present, from moderately sheared granite to strongly sericitized, schistose granite with relict blue quartz grains, to sericitic schist in which no quartz is visible to the naked eye. Crinkled quartz lenses and small drag folds in the schistosity have been observed at about a dozen places along the zone, and the uniform character of their drag shows that the block east of the shear has moved southwest relative to the western block. This shear zone seems to have been one of the dominant features in the localization of the tungsten veins. Most of the richer veins lie either along the zone or in granite to the west.

Joints striking N. 60°-70° W., and dipping steeply south have been observed in the granite at several places. From the drainage pattern of the district, White 7/ has deduced the presence of a series of cross faults striking about N. 70° W. Although there does appear to be a system of joints having this trend and the development of the drainage pattern may have been influenced by the joints, there seems to be no evidence that significant movement has taken place along these structures.

ORE DEPOSITS

The tungsten deposits are huebnerite-quartz veins, most of which occur in granite within half a mile of the granite-schist contact. The veins lie in a belt about 8 miles long, which trends northeast nearly parallel to the contact. Most of the veins are in a small area 2 miles long in the central part of the district, in or near the zone of sheared granite, or near the contact between granite and schist. These veins are more strongly mineralized than the veins in the outlying parts of the district. Minable bodies of some of the central veins average from 0.5 to 1.0 percent WO_3, although several percent WO_3 may be present locally in the richest parts of certain veins. Few of the outlying veins carry as much as 0.5 percent WO_3, and many of them contain less than 0.1 percent WO_3.

Mineralogy.—The principal metallic minerals in the veins are huebnerite, pyrite, galena, tetrahedrite, sphalerite, chalcopyrite, and scheelite. Quartz is the dominant gangue mineral and is accompanied by fluorite, sericite, and rhodochrosite. Huebnerite is the chief tungsten mineral. It is reddish brown, has a tan streak, and occurs as elongate, platy crystals as much as 6 inches long. Scheelite is much less abundant and rarely occurs unassociated with huebnerite; scheelite has been found in excess

7/ White, W. A., op. cit. (1943), pp. 4-5; (1945), pp. 100-101.

of huebnerite in only a few places. The scheelite is usually white to tan in color, although some is light green. Small amounts of molybdenum, 0.04 to 0.14 percent, were determined to be present in the scheelite by K. J. Murata of the Geological Survey.

The huebnerite and scheelite typically occur in quartz veins as irregular masses, or in thin seams or zones parallel to the sheeting of the veins. Insignificant quantities of the tungsten minerals have been found in pegmatite stringers and in the country rock near the veins, but such occurrences are rare. Much of the vein quartz, especially in the central part of the district, is strongly crushed. The huebnerite crystals are also commonly broken, the fragments separated slightly, and the interstices filled with quartz. The many irregular surfaces in the huebnerite and quartz along which movement took place are coated with a film of small sericite flakes. In veins characterized by granulated quartz, veins and stringers of glassy quartz of later generation are common. Crushed quartz and broken huebnerite crystals are less abundant away from the center of the district.

Next to quartz, fluorite is the most widespread and abundant mineral associated with the tungsten minerals; it is found in nearly every tungsten-bearing quartz vein. The fluorite is very pale green, blue, or purple where fresh, but loses its color upon weathering. About 4 percent of fluorite was found in the mill tailings by C. S. Ross of the Geological Survey, giving an indication of the relative abundance of fluorite. Considerable rhodochrosite is present in Walker 2 vein (pl. 3), but seems to be scarce or absent in other veins. A few crystals of apatite, which fluoresce an orange yellow, have been found with the rhodochrosite. Small amounts of calcite were noted in drill cores. Some golden-brown garnet occurs, and is probably spessartite, according to C. S. Ross. About 0.1 percent garnet was found in the tailings by E. S. Larsen.

Several percent of sulfide minerals also accompany the tungsten minerals. Pyrite is the most abundant sulfide; galena, tetrahedrite, sphalerite, and chalcopyrite are also present. Thin films of what appears to be molybdenite have been seen at a few places, and a few specks of bornite were found in one specimen from the Morgan 1 vein (pl. 1). The content of sulfide minerals in some of the veins is about equal to that of tungsten minerals present. The average analysis of some table concentrates produced at the Haile mill, chiefly from unweathered ore carrying fresh sulfide minerals, is given below:

Average partial analysis of several lots of table concentrates shipped by Haile Mines, Inc., to the National Reconditioning Co.

	Percent	Ounces per ton
WO_3	36.58	
Pb	4.92	
Zn	1.72	
Cu	1.20	
S	15.45	
Au	...	0.02
Ag	...	18.34
SiO_2	7.08	

Some galena from the main Burwell vein has octahedral parting and carries small amounts of bismuth, tellurium, and silver, according to spectrographic and microscopic studies made by K. J. Murata and Charles Milton of the Geological Survey.

Numerous barren quartz veins occur throughout the district, and are distinguished from the tungsten veins on the geologic maps (pls. 1 and 2). The quartz in some of them is more glassy than the quartz of the tungsten veins. Pyrite is common in some of the veins, and many of the veins near the Morton Estate group carry large clusters of light-green mica. Tourmaline was noted in a vein south of Morrow Chapel (pl. 1), and tourmaline and specularite were seen in quartz veins several miles southwest of the mapped area.

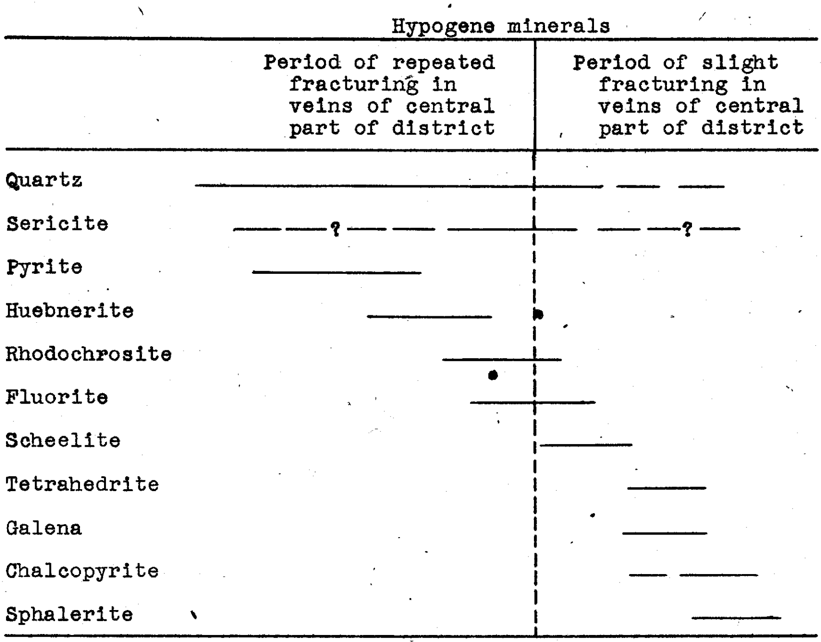
Oxidation and leaching of huebnerite have taken place only to a minor extent, for float of unleached huebnerite ore littered the ground surface near veins in the central part of the district before the deposits were explored. Although some tungsten has been dissolved at the surface and transported to depth, the process appears to have been quantitatively small and of little importance. The sulfides near the surface, however, have been largely removed by ground water, and the former presence of pyrite or chalcopyrite is usually shown by limonite-stained cavities. There is a suggestion (from comparison of the surface and underground exposures of Walker 2 and 3 veins) that huebnerite is leached to a greater extent in the vein (Walker 2) having a relatively high sulfide content; considerably more rhodochrosite is also present in Walker 2 vein than in Walker 3 vein. The leached portions of many of the veins are stained by manganese oxides, which were evidently derived from the weathering of huebnerite and rhodochrosite. Some huebnerite crystals are partly leached from their matrix. The huebnerite is commonly coated along its cleavage and parting by a powdery white film which fluoresces bluish white like scheelite. This white powder appears to be supergene scheelite, but does not represent enrichment, for the scheelite is derived from the huebnerite crystal itself. This variety of powdery scheelite is uncommon at depth and seems to be most abundant in the huebnerite ores occurring near the surface. Other powdery substances, yellow to green in color, are also rather common in the upper parts of the veins. Most material of this type has been identified by J. J. Glass and others of the Geological Survey as bindheimite, a hydrous lead antimonate. In several specimens the powdery substance was found to be tungstite.

A nonfluorescent green mineral, occurring in small quantities in some veins near the ground surface, contains tungsten and copper and is cuprotungstite, according to C. S. Ross and W. T. Schaller. The cuprotungstite is possibly of supergene origin. Small grains of pyromorphite, fluorescing with a reddish-orange color, were identified by J. J. Glass in specimens taken from the surface of the Taylor vein. The pyromorphite may also be supergene in origin. A few grains of covellite and chalcocite were found by Charles Milton in a specimen from the Walker 2 vein.

The various minerals identified in the tungsten deposits and their apparent sequence of formation are listed on page 9.

Wall-rock alteration.—Along the walls of the veins the granite is sheared and altered over widths of several feet, usually to light-green sericitic schist, but in some places to chloritic schist. In this altered rock which envelops the vein, quartz and feldspar crystals are crushed, and an abundance of sericite, calcite, chlorite, and pyrite are formed. Some biotite and traces of fluorite and garnet are also present; epidote is very scarce, in contrast to its prominence in the less altered granite. Half a dozen thin sections of altered wall rock were examined for clay minerals by C. S. Ross, but none were found.

Sequence of formation of minerals in the tungsten deposits



The relative ages of the following hypogene minerals have not been determined: spessartite, apatite, calcite, molybdenite, and bornite.

Supergene minerals

Manganese oxides
Limonite
Covellite
Chalcocite
Pyromorphite

Bindheimite
Scheelite—powdery form
Cuprotungstite
Tungstite

Veins.—The tungsten-bearing quartz veins lie in a narrow northeast-trending belt about parallel to the contact between granite and schist. Most of the veins are in granite, within half a mile of the contact. The majority of the veins occur in a small area about 2 miles long and 1,500 feet wide in the central part of the district. Nearly all the veins of this group lie either along the zone of sheared granite, or in granite or schist to the west of the shear zone. As a rule the veins in granite are stronger and better mineralized than those in schist.

The trend of a vein generally follows one of three directions: northeast, nearly east, or northwest. Most of the veins in the central and southern parts of the district strike to the northeast (pls. 1 and 2). Those veins lying along the shear zone (including the important Walker 2 and Sneed 1 and 2 veins) strike N. 30°-35° E., parallel to the direction of the shear zone. Some of the veins outside of the shear zone also strike in about the same direction (as Walker 9, Morton Estate 1, and Morgan 2), but others trend from north to N. 20° E. (the Edwards, some of the Scott group, Morgan 1, and others south of the center of the area), nearly parallel to the foliation of the granite or the schist. Veins trending east or nearly east are few, but include two of the principal veins, Walker 3 and Morton 1 (pl. 2). Most of the northwest-striking veins are in the northern part of the district, and are represented by Jamieson 2 and 3, the main Burwell, Kimball, and Taylor veins, as well as a few minor veins in the center of the district (Walker 3A and 4).

Practically all the veins dip eastward at angles of 70° or more, but several, such as the Morgan 1, Kimball, and Taylor veins, dip more gently toward the east at 40° to 50°. The few veins dipping to the north or northwest include the Walker 7 and Morton 1 veins, which dip at angles of 50° to 65°.

Some of the veins appear to be lenticular and to pitch to the southwest or west at an angle of 30° or more.8/ Diamond drilling has indicated such a pitching structure of the Sneed 1 and 2, Morton 1, and Walker 2 veins, and possibly the Walker 3 vein. Underground development on the Walker 2 vein has given additional evidence that the vein pitches southwest (pl. 4). The Walker 3 vein is made up of individual lenses which seem to pitch about vertically, but its structure is not altogether clear (see pl. 5, and discussion under "Description of properties"). Drilling on other veins in the district has not been extensive enough to show whether a southwest pitch might be typical of many of the veins, but the possibility should be kept in mind in guiding development of the veins.

In other districts the pitch of ore bodies or ore shoots in foliated rocks is commonly about parallel with linear structures in the country rock—such as folds in the foliation, the intersection of two foliation planes, or the direction of mineral alinement. In the Hamme district, however, this relation does not appear to exist, because the linear structures (crinkles in the foliation of the wall rock, mineral alinement in the vein, etc.) usually pitch gently to the northeast (pls. 2, 3, 4, and 5). Further study and future development of the veins may shed light on this apparent anomaly.

The length of the veins ranges from a few feet to a thousand feet or more; many veins are several hundred feet in length. The Kimball vein is one of the most persistent in the region, being over 1,700 feet long. Some of the veins in the central part of the district, such as the Walker 4, 8, and 9 veins, are short lenses, 50 feet or less in length. The more important veins have an average width of 5 to 10 feet, but are 25 to 30 feet wide in places (Walker 2 and 3, and Sneed 1 veins).

Some of the veins are simple lenses (such as Walker 2, Morton 1, Sneed 1 and 2, and others), but many veins are made up of a series of lenses, which may be arranged en echelon. This echelon arrangement of lenses is well developed in the Walker 3 vein (pls. 3 and 5). It is composed of lenses 130 to 200 feet in length, which are successively offset a few feet to the right,

---

8/ This discussion of pitch refers to the vein as a whole, and not to ore shoots within the vein. The ore shoots of some veins are about coextensive with the vein limits, but in other veins information of the habits of the ore shoots is lacking.

as the observer looks along the strike. The veins commonly pinch and swell, and stringers may extend into the wall rock (pls. 3 and 5). These offshoots usually strike more nearly north than does the trend of the vein; that is, as the observer looks along the strike, an offshoot of the vein extends into the left wall, or comes into the vein from the right wall. Sheeted zones and inclusions of schistose granite with a similar northerly trend are common, and suggest that the veins have formed, at least in part, by replacement of the schistose country rock.

Repeated movement occurred along the veins during the formation of some of them, for the quartz is commonly granulated and veined by stringers of glassy quartz, huebnerite crystals are broken, and slickensides are present on the walls and partings of the veins. These characteristics are developed most strongly in the veins of the central part of the area; outlying veins, such as the Morgan veins and the Taylor vein, show few signs of movement. In the veins along the shear zone, drag folds show that the eastern wall of the veins has moved southwest relative to the western wall.

Origin.—The tungsten veins have been deposited by solutions from depth along fissures in granite and schist. Inclusions of schistose granite in the vein commonly pass into thin micaceous partings parallel to the local foliation and suggest that some replacement of the schistose rock by the vein minerals has taken place. Intermittent movement occurred along some of the veins during their formation. The walls of many veins have been strongly altered to pyrite-bearing sericitic schist over widths of several feet. The source of the mineralizing solutions is not known, but they may have risen into schist and solidified granite from deep-lying portions of the same magma mass which formed the granite.

Localization of the veins.—Practically all the tungsten veins except the Kimball vein lie within half a mile of the granite-schist contact. The majority of the veins occur in granite, and are stronger and better mineralized than the veins in schist. The massive character of the granite seems to have favored development of more numerous and more persistent fissures in granite than were formed in schist. The localization of the better veins in the central part of the district appears to be related in some way to the zone of strongly sheared granite, along which some of the veins lie. Nearly all the other veins in this central area lie west of the shear zone, and probably occupy fissures which are subsidiary to the shear. In this group the east-trending veins, Walker 3 and Morton 1, are stronger than the veins striking northeast parallel to the local foliation, or to the northwest. The development of stronger fissuring in the central part of the area may be related to the westerly curve of the granite-schist contact. Outside the central part of the district, proximity to the schist contact is the one obvious feature which has determined the localization of veins. The Kimball and Taylor veins may lie along a shear trending northwest from the main shear zone.

DESCRIPTION OF PROPERTIES

Tungsten Mining Corporation

Most of the veins controlled by the Tungsten Mining Corp. are in the central part of the district and include the various Walker veins, Morton 1 vein, and the Scott group of veins. In early 1943 the Hamme brothers, discoverers of the tungsten deposits, mined some ore from shallow shafts and pits on the Walker 1, 2, and 3 veins. Haile Mines, Inc., acquired the Hamme properties in August 1943, and since then has directed its efforts mainly toward the development of the Walker 2 and 3 veins. In June 1945, the Tungsten Mining Corp. was formed by Haile Mines, Inc., and the General Electric Co. to operate the Haile properties. Nearly all the veins were trenched and sampled, and the better veins drilled, by the Bureau of Mines during the second half of 1943.

The ore milled by the Hamme brothers and Haile Mines, Inc., from about May 1, 1943, to December 15, 1944, the majority of which came from the Walker 2 and 3 veins, amounted to 22,283 tons and yielded 13,025 units of WO_3. Concentrates produced from December 16, 1944, to March 1, 1946, contained 10,627 units of WO_3. Emphasis was placed on underground development, rather than stoping, during this latter period. The ore treated from October 16 to December 16, 1944, averaged 1.18 percent of WO_3, and yielded 2,598 units of WO_3 from 2,657 tons of ore. About 75 percent of the ore treated during this 2-month period came from stopes on the Walker 2 and 3 veins.

Until early 1946 the ore was concentrated in a small gravity mill equipped with jaw crusher, stamps, hydraulic classifier, and Wilfley tables. Capacity of the mill was about 50 tons of mill feed daily. A new 200-ton gravity mill, located just west of Walker 3 vein, was placed in operation in March 1946.

Walker 2 vein.—On the Walker 2 vein the vertical shaft (No. 2 shaft) started by the Hamme brothers was extended to a depth of 100 feet, and 425 feet of drifting was done at this level (pls. 3 and 4). About 200 feet southwest of the shaft an inclined winze has been sunk along the footwall of the vein to a depth of about 200 feet below the level. A new level has been established at a depth of 100 feet below the 100-foot level. Ore was being mined in the spring of 1945 from two stopes above the 100-foot level, northeast and southwest of the winze.

The Walker 2 vein strikes about N. 35° E., and dips 80° E. The 100-foot level has shown the vein to be 13 to 22 feet wide over a distance of 250 feet southwest of the shaft, although outcrops of the vein were less than 10 feet wide. The vein is continuous for the full length of the drift, but carries partings of schist in both ends and is only 2 to 3 feet wide at the northeast end. Probably the lateral limits of the vein have nearly been reached in the drift, for the vein was traced on the surface for only about 350 feet. Apparently the vein pitches southwest at angles of 30° to 40° (pl. 4); in the southwest stope the vein was found to grade upward into sheared granite with small quartz lenses and no vein was found in the trenches above.

Crinkles and larger drag folds in the foliation and linear orientation of sericite and fluorite along partings in the vein pitch to the northeast at about 20°, except for a southwest-pitching drag fold noted at the southwest end of the drift. Several thin fluorite seams exposed in the backs of the drift and stopes are crinkled, suggesting that the fluorite has replaced drag folds in foliation at these places. Broad swells are present on the walls of the vein and trend about vertically down the dip. Nearly horizontal joints, spaced about 5 feet apart, are common in the vein. For a considerable distance along the vein, the hanging wall is overlain by several feet of broken quartz and sericitic gouge.

Huebnerite is most abundant in the thicker part of the vein extending about 250 feet southwest of the shaft. It usually occurs as crystals up to several inches in size along seams parallel to the sheeting of the vein. Numerous seams of purple fluorite and sulfides—pyrite, galena, sphalerite, and tetrahedrite—also follow the sheeting. Considerable rhodochrosite occurs as local masses in the thickest part of the vein; scheelite is rather scarce. Along the walls of the vein the granite is altered to pyritic sericite schist over widths of several feet. Small quantities of fluorescent apatite are associated with the rhodochrosite.

Walker 3 vein.—Near the southwest end of the Walker 3 vein a vertical shaft (No. 3 shaft) has been sunk to a depth of 80 feet and a drift run northeast on the vein (pls. 3 and 5). Seven hundred twenty feet of drifting had been done by July 1945, an inclined shaft had been driven near the center of the vein, and a stope started near the No. 3 shaft. The inclined shaft is to be deepened and another level established 100 feet below the 80-foot level. Considerable ore has been mined from the large open cut and other pits on the surface, and the vein has been stripped over much of its length.

The Walker 3 vein curves in strike from N. 50° E. at its southwest end to N. 75° E. at its northeast end; it dips 70° to 80° SE. This vein is about 900 feet long and is made up of lenses en echelon which are offset a few feet to the right, as the observer looks along the strike. Individual lenses are 130 to 200 feet long and range in width from a few feet to as much as 30 feet in the large open cut. The average width of the vein is about 7 feet. Stringers and offshoots of the vein extend into its walls in directions more northerly than the trend of the vein, and partings in the vein have trends similar to the offshoots. Sericitic or chloritic shear zones several feet wide lie along the walls of the vein in places, and extend beyond the ends of individual lenses. Crinkles in the foliation pitch 20° to 40° NE. in the southwestern part of the vein, and are horizontal or pitch gently to the southwest near the northeastern end. Several thin diabase dikes cut the vein near its northeast end; they are probably offshoots of the wide dike lying about 100 feet northeast of the vein (pl. 2).

The thick lens in which the inclined shaft lies on the 80-foot level appears to be the same lens as the one at the collar of the shaft on the surface, suggesting that individual lenses pitch steeply. However, the wide lens exposed in the large surface pit seems to die out in depth, for the vein is split into several segments on the 80-foot level; and at 10 to 30 feet below the level, sericite and chlorite schist and aplite, rather than vein, were cut in drill hole 2. The pinching out of this lens might be due to one of two possible structural conditions: (1) the steeply pitching individual lenses may be arranged in a zone which pitches more gently to the southwest (as other veins seem to do), or possibly to the northeast, and the barren stretch in the drift and drill hole 2 may lie beneath this vein zone. In this event, hidden lenses would probably not exist beneath the drill-hole 2 intersection. (2) The barren drill hole may simply have cut the vein zone at a place where the vein was absent, and a lens might exist vertically below the intersection of drill hole 2.

Huebnerite is more abundant in the thicker parts of the lenses than in the thinner parts. The best ore occurs in the lens mined from the large open cut and in the lens opened by the inclined shaft. Some stretches of the vein are rather lean. Bluish fluorite is abundant, but sulfides are not so plentiful as in the Walker 2 vein, and rhodochrosite is rare. Some coarsely crystalline scheelite was found in the large surface pit, and is more common here than elsewhere along the vein.

Morton 1 vein.—The Morton 1 vein, lying about 800 feet north of the Walker 3 vein, strikes nearly due east for 700 feet and dips about 65° N. Its width ranges from 3 to 15 feet and averages about 5 feet. The vein appears to be a single lens and to have few inclusions of wall rock. Two shallow drill holes (1 and 4, pl. 2) near the east end of the vein did not cut any vein, whereas deeper holes (3, 6, and 7) to the west intersected vein, suggesting that the Morton 1 vein pitches to the west. Pronounced grooves in the walls of the vein pitch gently to the west or east. A diabase dike about 100 feet wide cuts across the Morton 1 vein west of its center. In the spring of 1945, open-pit mining was started at the west end of the Morton 1 vein and a short adit was driven on the vein east to the diabase dike.

Other veins.—The Walker 1 and Walker 8 veins, 1,300 and 600 feet respectively southwest of the Walker 2 vein, have been prospected by shallow pits, but no drifting has been done. The Walker 1 vein lies in the shear zone and is exposed for a length of about 100 feet on the surface. Drill hole 21 found 3½ feet of fair ore at a depth of 100 feet below the surface. The Walker 8 vein is a small lens with no determined trend, although sheeting in the vein strikes northeast. Good ore was found in the vein over an area about 15 feet square, but trenching failed to reveal its extension in any direction. Other small veins in the shear zone or west of the shear have been trenched and sampled, but not explored by drilling. Few of these veins are more than 100 feet long, and they are commonly several feet thick and carry moderate amounts of huebnerite. The Sneed veins, which are also in the shear zone, are described below.

A group of veins—Walker 3A, 7, and 6—lying southwest of the Walker 3 vein, may represent extensions of the Walker 3 vein zone, although the Walker 7 vein dips north. The Walker 3A and 7 veins lie in granite and carry fair ore, whereas the Walker 6, which is in schist, is very irregular and not so well mineralized. The Scott group of veins are thought to represent a similar case of the fraying out of a vein or shear zone in passing from granite to schist. They lie in schist along the extension of the shear zone, and are irregular in their trends and distribution of huebnerite.

Southern Aggregates Corporation

Surface mining using bulldozers and small power shovels was started by the Southern Aggregates Corp. and subsidiaries on a number of veins late in August 1943, and continued until about the end of the year. A considerable tonnage of low-grade ore was shipped by truck to a gravity mill erected at the Greystone quarry of the Raleigh Granite Co., about 20 miles away. Data on the amount of concentrate produced are not available. The veins worked by open cuts are from south to north as follows: Tippett, Crowder, Edwards, Jamieson 1, 2, and 3, Burwell, and Kimball (Edwards veins on pl. 2, the rest on pl. 1). Little or no mining was done in 1944, but some shallow diamond drilling was done in the fall of that year on the Burwell and Kimball veins, and in July 1945 on the Jamieson veins. Previously the Tippett, Jamieson 1 and 2, and Burwell veins had been drilled by the Bureau of Mines. Most of these veins are very leanly mineralized, although sporadic pockets of fair ore occur in the Jamieson and Kimball veins. Good tungsten values were found in the drill-hole intersection of the Jamieson 2 vein and a shaft was started to explore this place, but it is believed that the vein was not reached.

Other prospects

Other veins in the district that were explored by trenching or drilling during the Bureau of Mines program are the Morgan, Morton Estate, Taylor, and Sneed veins. The two Sneed veins seem to be the best of this group, but mining rights to the Sneed property are under dispute between the Tungsten Mining Corp. and the Southern Aggregates Corp., and no mining has yet been done. Both these veins lie in the zone of sheared granite southwest of the Walker 1 vein (pl. 2). The Sneed 1 vein is about 400 feet long, and ranges from 2 feet to 23 feet wide at the surface. The vein splits into several parts in places and contains lenses of sheared granite, resembling the structure at the southwest end of the Walker 2 vein on the 100-foot level (pl. 3). An abundance of good huebnerite ore originally mantled the surface around the vein. Drill hole 27 intersected about 11 feet of vein carrying 2.33 percent WO_3 at a depth of 100 feet, but the drill holes to the northeast cut a lean vein, suggesting a southwest pitch to the vein. The Sneed 2 vein is 300 feet long and has an average width of $5\frac{1}{2}$ feet. The northeastern drill hole (33) found lean values at a depth of 100 feet, which suggested that the Sneed 2 vein also pitches southwest.

The Morton Estate property was at one time optioned to Haile Mines, Inc., who trenched several of the veins. These veins are in schist and, except for the Morton Estate 1 vein (not to be confused with the Morton 1 vein), are short and very poorly mineralized.

The Morgan 1 and 2 veins are the principal veins on the Thomas A. Morgan property (pl. 1). Each is made up of a number of lenses several hundred feet long which form a zone 1,000 feet or more in length. The lenses average 2 to 3 feet in width and reach a maximum width of 6 feet. Fair to good ore occurs in a few pockets, but the distribution of huebnerite is rather erratic and the average grade of the ore is under 0.5 percent WO_3. Tungsten float was found just east of Little Island Creek near the Haile mill (Morgan 3 vein, pl. 1), but trenching and drilling found only short disconnected lenses which carried very little tungsten.

The Taylor vein, lying half a mile northwest of the Kimball vein, carries fair ore along its length of about 350 feet, but the vein has an average width of $1\frac{1}{2}$ feet or less. The vein has a somewhat irregular northwest strike, and at the surface dips eastward at angles of 40° to 60°. Considerable float ore was scattered over the surface near the vein. The Bureau of Mines explored the Taylor vein in early 1945 by stripping and putting down a number of drill holes. The Taylor vein is the northernmost vein known in the area shown in plate 1. Other veins are reported to exist north of the Roanoke River, but their characteristics are unknown to the writer. None of them has been developed commercially.

FUTURE OF THE DISTRICT

Ore reserves.—Estimation of ore reserves in the district is based upon the results of the drilling and trenching program of the Bureau of Mines, supplemented by the results of recent work by Haile Mines, Inc. The general practice followed in estimating the reserves has been to classify the block of ore outlined by drill-hole intersections as indicated ore, and ore outside this block to a depth below the surface of about twice the depth of the deepest drill-hole penetration as inferred ore. Ore has also been inferred on a few undrilled veins. No blocks of ore have been considered as measured, although some of the indicated ore in the Walker 2 and 3 veins may now be regarded as measured ore because of recent development on these veins. The better veins in the central part of the district (11 in number, comprising most of those shown on plate 1 as being moderately to strongly mineralized) were estimated in early 1944 to have 130,000 tons of indicated ore to a depth of about 100 feet (to a depth of 190 feet below the surface for Walker 3 vein), and 155,000 tons of inferred ore to depths of 100 to 200 feet (360 feet for Walker 3 vein). The grade of indicated and inferred ore averages 0.9 percent WO_3. More than 95 percent of the indicated reserves and about 80 percent of the inferred reserves are contained in the following five veins: Walker 2 and 3, Morton 1, and Sneed 1 and 2.

In addition to the above reserves estimated for the better veins, about half a dozen other veins in the central part of the district and five veins outside the central area contain some ore which may be minable. The estimation of reserves in these veins is somewhat difficult because of the irregular distribution of tungsten minerals in many of them, but probably 25,000 tons of ore carrying 0.5 percent WO_3 can be inferred conservatively to a depth of 100 feet for this group. Because of the pockety nature of some of these veins and the small size of several of them, it is expected that mining costs for these veins would be considerably higher than for the better veins.

Outlook.—Since the huebnerite-quartz veins are very resistant to weathering, and either are exposed at the surface or are marked by trains of float, there is little doubt that practically all the veins in the district which reach the surface have been discovered. Some tungsten veins have been reported to exist in Virginia north of the Roanoke River, but their characteristics are not known to the writer. Most of the known reserves are contained in a few veins in the center of the district, and it can be expected that these central veins will be the principal producers for some time to come. Life of the district will probably depend on the downward continuation of this group of veins. The greatest depths below the surface at which vein has been cut are 190 feet in the Walker 3 vein (drill hole 23, pl. 5), and 230 feet in the winze on Walker 2 vein. At these places the veins are wide and as rich as at many places above, and no change in the mineralogy is apparent. It seems reasonable to infer that the veins continue to at least an equal depth below these points.

Most of the known veins lie near the contact between granite and schist, and it is possible that their continuation to greater depth is rather closely dependent upon the attitude of that contact. If the contact dips steeply, structural conditions would appear to favor continuity in depth for individual veins. On the other hand, if the contact dips at low or moderate angles to the east or west, it is possible that individual veins might have a shallower vertical extent, but other veins which do not reach the present ground surface might lie near the contact in depth.

Although no prediction of the ultimate depth extension of the veins or series of veins is possible, it is not improbable that they extend below the depths to which ore has been inferred. Whether or not tungsten minerals will be found throughout the vertical extent of the veins cannot be predicted. Quartz veins elsewhere in the Piedmont province have been mined to depths of 300 feet or more. The Vaucluse gold deposit in Orange County, Va., was mined to a depth of about 300 feet 9/ and the chalcocite-bornite-quartz vein of the Durgy mine in the Virgilina copper district was opened to a depth of 515 feet.10/ In the Gold Hill district of Rowan and Cabarrus Counties, N. C., the quartz veins of the Gold Hill mine were worked to depths of more than 800 feet.11/

Suggestions for exploration.—A few general recommendations for exploration in the central part of the district seem to be justified. The shear zone and vicinity should be explored in depth between the Walker 2 and Sneed 2 veins, in order to investigate the outcropping veins and to search for possible hidden veins which do not reach the surface. Some good float was found on the surface near the shear zone between Walker 1 and 2 veins, but trenching did not reveal any strong veins here. Possibly this float is residual from lenticular veins which have been completely eroded away. If so, buried veins may exist in depth along the shear zone. Another area deserving exploration in depth is the extension of Walker 3 vein toward Walker 3A, 7, and 6 veins; all these veins may be part of the same structure.

9/ Bass, C. E., The Vaucluse gold mine, Orange County, Va.: Econ. Geology, vol. 35, no. 1, pp. 79-91, 1940.

10/ Laney, F. B., op. cit., pp. 130-139.

11/ Laney, F. B., The Gold Hill mining district of North Carolina: North Carolina Geol. and Econ. Survey Bull. 21, pp. 98-103, 1910.

U. S. GOVERNMENT PRINTING OFFICE: 1946 O—723838