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METALLIC MINERAL DEPOSITS OF THE TUSAS MOUNTAINS

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INTRODUCTION

This paper describes deposits of gold, silver, copper, lead, zinc and iron in the Tusas Mountains of northern New Mexico. Most deposits lie within the Hopewell and Bromide mining districts. The Hopewell district includes complex epithermal gold-silver-copper-lead-zinc lodes, metamorphic iron deposits, and placer gold deposits. The Bromide district includes epithermal deposits of gold-silver-copper-molybdenum.

This text is a condensed version of district descriptions presented in detail in New Mexico Bureau of Mines and Mineral Resources Bulletin 91, Geology and Mineral Deposits of Rio Arriba County, New Mexico. Mine, claim, and geologic maps of the Hopewell and Bromide districts are included in the county report, but along with details of the geology, are omitted here.

HOPEWELL DISTRICT

The Hopewell mining district is in the central part of the Tusas Mountains, sixteen air miles west of Tres Piedras and eighteen air miles east of Tierra Amarilla. The district is bounded on the west by the Rio Vallecitos, on the north by Jawbone Mountain, on the east by the Rio Tusas, and on the south by Burned Mountain, an area of about twenty-five square miles; most of the mines and prospects occupy less than one square mile along Placer Creek southwest of Hopewell Lake. The central part of the district is drained by Placer Creek, which flows southwestward, and the Rio Vallecitos, which flows southeastward. Both are perennial streams with a moderate flow, except when charged with runoff from melting snowpack in the spring. Hopewell Lake is a man-made body of water formed by construction of an earth dam on Placer Creek.

The Hopewell district is accessible from Tres Piedras to the east and Vallecitos to the south via State Highway 111 and U.S. Highway 64. Precarious jeep roads extend from Hopewell Lake southwest via Placer Creek gorge to the lower flat placer area (private) and from Hopewell Lake south-southwest across the densely wooded northern slopes of Burned Mountain (public) to the lower flat placer area.

Mining Activity

The location and operation of the Fairview gold placer on Placer Creek in the late 1870's represents the earliest mining activity in the Hopewell district (Lindgren, Graton, and Gordon, 1910, p. 130). The claim was located in the valley of Placer Creek just west of the present site of Hopewell Lake. The richest gravel was found where the valley narrowed immediately above the gorge. The Fairview placer is reported to have produced $175,000 over a three-year period.

The discovery of alluvial gold prompted a search for lode deposits, culminating about 1881 with the location of the Croesus, Clara D., Mary E. Steele, Grand Mogul, and Little Casino claims on replacement veins and quartz veins in Precambrian schist. The upper, thoroughly oxidized, parts of these veins produced several thousand dollars in gold, silver, copper, and lead, but the rapid depletion of oxidized ore combined with narrow ore shoots and low values in the sulfide mineral suite resulted in diminished activity by 1890. Small-scale placer operations on local pockets of alluvial gold in Placer Creek gorge continued during the period of active lode mining.

In 1903, an extensive hydraulicking operation was set up in the lower flat area southwest of Placer Creek gorge. A natural lake, formed by talus and other debris that choked the narrow gorge at the southern end of the flat, was drained. Placer Creek was dammed near the Fairview placer claim and overflow was routed to the lower flat through a system of ditches and pipe. Within a year, the operation proved unsuccessful, however, because of the failure of dams on Placer Creek, heavy runoff, and disappointingly low gold values in the gravel. Only the upper 15 to 20 feet of gravel in a narrow strip along the axis of the meadow was washed.

Intermittent, largely one-man operations on lode and placer claims continued until 1935, when the Amarillo Gold Company acquired the Mineral Point claim. The company constructed a 30-ton mill and processed about 3500 tons of ore from the claim. At first, ore was brought by wagon to the mill site on the south side of Placer Creek; later, a trestle was constructed across the creek to connect the mill with the lower levels of the Mineral Point mine. The operation was unprofitable and closed in 1937. About this time, Rufus Little of Tesuque acquired most of the patented claims in the vicinity of the gorge. Little has conducted the only lode mining activity in the district since the late 1930's, principally minor exploration and development work.

Early in 1964, the Amistad Mining Company located four placer claims in the lower flat area and assembled a dry-land dredge on the site. A small amount of gravel was washed, probably less than 10,000 cubic yards, during the summer months before the project was abandoned. Very low gold values and illness of the principal investor are cited for the project's failure.

Geology

The oldest rocks in the Hopewell district are quartzite, schist, leptite, and quartz diorite gneiss of Precambrian age. In the western half of the district, quartzite, schist, and gneiss form a northwest-trending layered sequence. In the eastern part of the district, pink and gray, prominently foliated quartz diorite gneisses intimately intermingle. These ancient crystalline rocks are the host for all the replacement vein deposits in the district.

Younger conglomerate, part or all of which is of Tertiary age, obscures much of the Precambrian terrane. The lower part of the conglomerate sequence is locally derived and includes colluvial, talus, mudflow, and related deposits. Fluviatile volcaniclastic rocks derived from intrusive and extrusive volcanic rocks to the east overlie and grade into the locally derived conglomerates. Northwest-trending normal faults predate glacial deposits. Down-to-the-west separation on several of these faults is probably related to, if not responsible for, the gentle eastward tilt of the Precambrian-Tertiary unconformity and bedding in the volcanic-clastic rocks. Quaternary deposits of glacial and alluvial origin now occupy many of the present stream courses and local depressions.

Mineral Deposits

Mineral deposits of the Hopewell district include hydrothermal sulfide replacement veins, gold-bearing quartz veins, metamorphic segregations of iron minerals, and placer deposits of alluvial gold. The principal products of mining in the district have been free gold and silver plus small amounts of copper, lead, and zinc. Alluvial gold was recovered from placers along Placer Creek, and lode gold and sulfide minerals from very narrow stopes in mines clustered around the northern end of Placer Creek gorge. All mines in the district are caved and inaccessible.

Primary Deposits

Primary hydrothermal sulfide replacement and quartz fissure veins in phyllitic schist and quartz diorite gneiss are the most extensively mined lode deposits in the district.

The replacement veins consist of tabular zones or veinlike masses of sericitic, sheared schist and gneiss impregnated with varying amounts of pyrite, auriferous pyrite, chalcopyrite, galena, sphalerite, and fluorite. These veins range in thickness from a few inches up to a maximum of about 2 feet. In many of the veins, disseminated sulfide minerals impregnate sheared, altered, and limonite-stained schist; some of the host rock is compact, tough, and only weakly fissile schist or gneiss. The alteration observed in some veins largely results from the alteration of plagioclase feldspar in the metamorphic host rock. The boundaries of many of the veins are indistinct, for they consist of the gradual decrease in concentration of scattered pyrite or pyrite that is partly to completely altered to limonite. Many of the replacement veins represent thin zones of concentrated sulfides within a sheath of pyritized wall rock not necessarily symmetrically disposed with respect to the vein it encloses.

Hydrothermal quartz veins occur both intimately associated with the replacement veins and as distinct tabular masses enclosed by fresh, unaltered schist or gneiss. These quartz veins range in thickness from less than 1 inch up to about 3 feet and occur both concordant and discordant to the layering or cleavage in the host rock or replacement vein. Some veins are made up of lenticular masses that pinch and swell and are discontinuous along the strike; others are uniform in thickness and continuous within the limits of most exposures of bedrock. The quartz veins consist of quartz, massive aggregates and rhomboid crystals of brown siderite, sheaves of chlorite, limonite pseudomorphs after cubes of pyrite, sometimes fringed with irregular specks of native gold, and clusters of black tourmaline. Although some areas of schist contain much disseminated and altered siderite, no genetic relationship between sideritic quartz veins and siderite-rich host rock was found.

There appears to be a minor variation in the distribution of some ore minerals in the district. Native gold occurs in most, if not all, of the mines in and around Placer Creek gorge. However, Lindgren, Graton, and Gordon (1910, p. 129) reported the most productive gold mine in the district as the Croesus mine, located near the upper end of the gorge. Sphalerite and galena have been found on the dumps and are also reported from the Mineral Point and Hoover claims at opposite ends of the gorge. Finely divided disseminated crystals of fluorite were found on the dump of a northeast-trending adit driven near the Bear Creek fault.

Structural control of the replacement and quartz veins is obvious and well displayed along the steep walls of Placer Creek gorge. Here, disseminated sulfides impregnate layers parallel to compositional layering and a northwest-trending, steeply east-dipping phyllitic cleavage (Si). Some quartz veins parallel this plane of weakness and some parallel other cleavage directions (S2,S3). All the replacement veins parallel the northwest-trending S1. The host rock in some of the replacement veins is considerably brecciated in addition to being schistose. A sample taken from one vein on the Hoover group of claims consisted of a breccia of phyllitic schist fragments cemented by yellowish-brown limonite. This brecciation is restricted to zones parallel to the principal cleavage and replacement veins and appears to represent minor movement after mineralization.

Disseminated grains of siderite appear to represent some part of the ore-forming process rather than a primary phase produced as part of the regional metamorphism. Unlike dolomite, which is present as augen and scattered porphyroblasts in the greenschists, siderite is present in all types of phyllitic schist and quartz diorite gneiss. Most of this siderite is now altered to yellowish-brown limonite that either fills or lines cavities that once contained the siderite. Some parts of the phyllitic schist in the gorge are now composed largely of these vugs where alteration, through introduction of siderite, was intense.

An extensive oxidation mantle exists below the Tertiary-Precambrian unconformity in the gorge. This zone of oxidation is marked by the alteration of pyrite, dolomite, siderite, and chlorite, both in unmineralized schist and in replacement and quartz veins. This alteration by weathering takes the form of replacements of these minerals by earthy, yellow to reddish-brown limonite. Nearly all the limonite is indigenous. Only in rare brecciated veins does limonite form a cementing agent, providing evidence of local transport of iron. The lower surface of the oxidation zone is very irregular and extends downward in spike- or sheetlike projections parallel to shear zones and cleavage in the schist and gneiss wall rock. The presence of both weathered and unweathered rock in Placer Creek gorge suggests that the lower boundary of oxidation has been exposed by erosion that cut the gorge and that the period of oxidation is related to exposure of Precambrian rocks prior to deposition of the Tertiary gravels. Thus, it is expected that the form of the oxidized surface will closely reflect the configuration of the buried Precambrian surface rather than any present surface of erosion or groundwater level.

The age of the hydrothermal mineralization in the Hopewell district has not been determined because of the lack of direct evidence. There is, however, some evidence that brackets a range of geologic time during which vein emplacement probably occurred. The presence of clasts of abraded, subrounded schist containing disseminated pyrite limonite pseudomorphs after pyrite, and siderite in Ritito Conglomerate indicates that mineralized Precambrian rock was exposed to subaerial processes and eroded during early Tertiary time. Indicators of a maximum age, though, are more ambiguous. The presence of replacement veins parallel to S1 cleavage in phyllitic schist and quartz diorite gneiss suggests that the transfer of material and the movement of mineralizing fluids was controlled by this structural feature and thus post-dates it. The gold-pyrite-siderite quartz veins in the district are both conformable and discordant to S1 and in addition appear to have been emplaced along cleavages (S2, S3) younger than S1. This configuration indicates that the formation of the quartz veins may have been either a late feature of the replacement vein formation or a separate, younger event.

Secondary Deposits

Sedimentary deposits of free gold are located along and in Placer Creek west of Hopewell Lake. The largest deposit, the Fairview placer, was located at the head of Placer Creek gorge. Other small pockets of placer material were located in Placer Creek along the length of the gorge. The lower flat area southwest of the gorge, and once the site of a lake, was worked for placer gold on at least two occasions, but no gold production was recorded.

The free gold recovered from the gravels of Placer Creek is of recent alluvial origin, no older than Placer Creek itself, which is a young, superposed stream that has pirated several subsidiary consequent streams in the area. Most of this alluvial gold has probably been washed into Placer Creek from colluvial debris along the mineralized bedrock flanks of Placer Creek gorge. Some of the gold may also be reworked from the site of the Fairview placer. In any event, these young deposits of alluvial gold are small and low in gold values compared to the Fairview.

The origin of the rich Fairview placer is obscure, largely because of the complex, post-Precambrian geologic history of the district and the location of the placer where it could have been produced by several geologic processes. Briefly, three hypotheses are: 1) gold was derived from bedrock north of the placer site, carried south by Placer Creek or its tributaries, and deposited along with alluvial sand and gravel in the bed of Placer Creek; 2) gold of colluvial origin, occurring as an erosional and weathering residue along the Precambrian-Tertiary unconformity, was exposed at the Fairview site by the downcutting of Placer Creek; 3) gold of early Tertiary age formed in part of a drainage network made up of east-flowing streams that were eroding bedrock and depositing, in part, the clastic debris now represented by the Ritito Conglomerate.

The first hypothesis linking the placer gold with deposition from Placer Creek is the weakest of the three hypotheses of origin for the following reasons. First, Placer Creek north of the Fairview placer site drains a relatively small area south of Jawbone Mountain. This drainage area is underlain largely by Tertiary clastic rocks not known to be gold-bearing. Also, exposed Precambrian rocks within the drainage area contain little mineralization and no productive gold mines. Second, the site of the placer at the head of Placer Creek gorge is very unusual if the gold-bearing gravel were transported and deposited by Placer Creek. Alluvial gold placers commonly form where the gradient of a stream suddenly decreases, only rarely, if ever, where the stream gradient *increases.* Third, the angularity of the gold (914 fine) panned from the placer, together with the numerous grain imprints and adhering quartz grains, suggests only a short distance of transport for the gold particles.

The colluvial origin of the placer gold is supported by the texturally immature form of the gold fragments, the presence of high gold values at the bedrock surface (Little, personal commun.), and the tendency of the gold fragments to occur deep within cracks, joints, and cleavage planes in the bedrock surface. The latter two facts of the gold occurrence are equally likely if the gold is of alluvial origin because of the well-known riffle effect produced by prominently layered schist with an uneven upper surface.

I favor the third hypothesis for the origin of the Fairview placer and believe that it best fits the known facts. The placer deposit is envisioned as the result of fluviatile transport of sediment eastward and northeastward across the auriferous replacement veins and gold-bearing quartz dikes near the head of Placer Creek gorge. These streams washed debris from the deeply weathered and mineralized Precambrian rocks, and native gold, freed from disintegrated schist and oxidized pyrite, was concentrated by natural stream action. Thus, the Fairview placer is viewed as an exhumed early Tertiary deposit, laid bare by the erosive action of Placer Creek which cut down to the base of the Tertiary conglomerate. This would explain the textural immaturity of the gold fragments as a natural consequence of limited transport of only a few hundred feet. Further, it would explain the meager placer gold occurrences elsewhere along Placer Creek.

BROMIDE MINING DISTRICT

The Bromide mining district is centered around Tusas Peak at the southern end of Burned Mountain. It takes its name from the Bromide mine and is generally regarded as a southern extension of the Hopewell district. The center of the Bromide district lies ten airline miles due west of Tres Piedras, and is accessible from Hopewell Lake and State Highway 111 via the Burned Mountain road. Heavy summer rains may render this route temporarily impassable, effectively isolating the district. All land is within the Carson National Forest, except for patented mining claims.

The earliest record of mining activity in the Bromide district is marked by the location of the Bromide mine May 31, 1884. During the next 20 years, 35 lode claims were located and eventually patented. The peak of mining activity was reached about 1890. Patented claims in the district form four clusters: at the head of Rock Creek, at Cunningham Gulch, at Cleaveland Gulch, and along the lower reaches of Cow Creek. All these properties are located on sulfide replacement veins and quartz veins. Initial values were high enough in oxidized ore to support mining, hut lower grade sulfides encountered at shallow depth gradually forced the abandonment of many properties. By 1910, mining activity had ceased.

In 1956, Charles Besre, J. N. Eddy, and Sterling Lord reopened the Bromide mine. The old drift was opened and retimbered, and a shallow shaft and short crosscut were driven to intersect the vein. A 2-ton mine run of sulfide ore was shipped to the American Smelting and Refining Company in El Paso late in 1957. The pilot sample returned $34.67, mostly in silver. The Bromide mine has not been operated since 1957; John Eddy of Santa Fe now owns it.

The bedrock geology of the Bromide district closely resembles that of the Hopewell district. Rock types include greenschist, quartz diorite gneiss (both with and without biotite), and granitic gneiss. Schistosity and fracture cleavage in greenschist and quartz diorite gneiss trend from N. 30° W. to N. 60° W.; contacts between these units nearly parallel schistosity. Granitic gneiss has a nearly circular outcrop pattern within the area around Tusas Peak. Cleavage within granitic gneiss trends N. 45° W., N. 30° E., and east-west. Mineral deposits include sulfide replacement veins and quartz veins, as in the Hopewell district. Ore minerals include gold, chalcopyrite, argentiferous tetrahedrite, native copper, copper carbonates, and molybdenite. Traces of fluorite, galena, and cuprite also are reported (Lindgren, Graton, and Gordon, 1910). Mineral deposits of the Bromide district differ from those of the Hopewell in having higher silver and copper and lower gold content. Molybdenite occurs only in the Bromide district at the Tampa mine.

Mineral Deposits

Mineral deposits of the Bromide district include sulfide replacement veins in Precambrian schist and gneiss and thin pyritiferous quartz veins. These deposits are similar to those in the Hopewell district. Mineralogy of the veins in both districts is the same except for the occurrence of molybdenite at the Tampa mine. Lindgren, Graton, and Gordon (1910, p. 130) reported that chalcopyrite is more abundant and pyrite less abundant than in the Hopewell district; gold values are lower, and silver values are higher. Also, tetrahedrite, a major constituent of the ore suite in the Bromide mines, is found in only trace amounts in the Hopewell district.

No placer deposits were located in the Bromide district.

Mines and Prospects

There is no mining activity at the present time in the Bromide district. All workings visited by the writer in 1966 were caved and inaccessible. Descriptions of individual mines and properties are taken largely from Graton (Lindgren, Graton, and Gordon, 1910) and examination of samples taken from mine dumps. J. N. Eddy supplied much unpublished data regarding the redevelopment of the Bromide mine during the 1950's.

Bromide Mine

The Bromide is the oldest mine in the district, having been located May 31, 1884, by the Bromide Mining Company. According to Graton (Lindgren, Graton, and Gordon, 1910, p. 132), initial high production values were obtained from a carload of oxidized silver ore believed to be silver bromide. A shaft was sunk to a depth of 140 feet, encountering sulfides at 50 to 60 feet. Low values and flooding closed the mine prior to 1929.

The mine was reopened between 1955 and 1958 by J. N. Eddy, Sterling Lord, and Charles Besre of Santa Fe. The main haulageway and a short winze were opened and retimbered and a 38-foot shaft sunk. In all, 30 tons of ore were mined. In the fall of 1957, a 2-ton shipment of mine-run ore was sent to the American Smelting and Refining Company smelter at El Paso, which reported 25.9 ounces per ton of silver and 2.05 percent copper. There has been no further activity at the mine.

Graton (Lindgren, Graton, and Gordon, 1910) gave the following description of the geology and mineralization in the workings:

> "A quartz vein containing siderite and chalcopyrite is said to strike about N. 70° W., with almost vertical dip. Parallel to and near it the schist is impregnated with stringers and lenses of tetrahedrite, associated with calcite. This copper-antimony sulphide is in some places intergrown with chalcopyrite and associated with quartz, and it seems probable that it is a primary mineral. This mineral is probably the one which carries the silver. The ore is said to have followed a shoot in the vein. In the bottom of the shaft, at a depth of 140 feet, a 22-inch streak, running well in copper and silver, was left when work was stopped. It is stated that the gold values are low, ranging from $1 to $4 a ton.
>
> A parallel vein about 20 feet north of the Bromide vein furnished some good copper ore to lessees when water interfered with working on the main vein. The production of this mine is reported at $27,000."

Tampa Mine

The Tampa mine lies in the south-central part of sec. 13, T. 28 N., R. 7 E. about one fourth of a mile north of Tusas Peak. Access to the mine is by primitive road connecting with the Burned Mountain road.

During the period of active mining in the Bromide district, the Tampa was the largest mine in the district in amount of workings. A 400-foot shaft served 800 to 1000 feet of drifting in five levels. Water problems were encountered below the 300-foot level. Samples taken from the dump indicate that bedrock in the mine is biotite and chlorite-rich quartz diorite gneiss and granite gneiss. Disseminated chalcopyrite, molybdenite, and cubes of pyrite occur in the dump material. The stringers and blebs of sulfide minerals commonly occur within or are intimately associated with segregations of chlorite and biotite.

Lindgren, Graton, and Gordon (1910) give the following detailed description of the mining geology:

> "The vein strikes about N. 30° W. and dips steeply to the northeast. On the 45-foot level good ore was reached just north of the shaft. It consisted mainly of malachite, copper glance, and a little chalcopyrite. In a few places azurite, cuprite, and a little native copper were found. Some free gold was present in hematite, which probably resulted from pyrite. Little scales of molybdenite were occasionally found. On the 100-foot level a strong body of partly oxidized ore was reached, but the grade was lower than that of the ore above. The best ore is said to have been found on the 200-foot level. A crosscut extending 25 feet northward from the shaft reached the ore body, which was 14 feet wide. Specimens from this level show several narrow and coarsely spaced quartz veinlets, carrying along their borders a mixture of chlorite and chalcopyrite, and in some places considerable molybdenite. Two carloads shipped from this mine are said to have averaged about $15 a ton—one-eighth ounce of gold, 6 ounces of silver, and the rest copper. On the 300-foot level the vein cut on the levels above has not been sought, but a 300-foot crosscut has been run a little north of east to reach an ore body which is known on the surface. In this crosscut the country rock is granite with a few streaks of schist. Chalcopyrite and malachite are enountered in small bunches here and there, but no ore body has yet been reached. A vein holding low-grade ore is said to have been cut on the 400-foot level, but whether it is the same as the one known on the 200-foot level is not certain."

Rock Creek Group

This group of claims located midway between Burned Mountain and Tusas Peak includes the Payroll, Whale, Whale No. 1, Denver, Lucky Bay, Ora, Philadelphia, and Chicago claims. The Payroll claim appears representative of the group and is described below.

The Payroll mine is now marked at the surface only by a large dump and a caved shaft. Graton's (Lindgren, Graton, and Gordon, 1910) description of the Payrol mine follows:

"The country rock is a sericite-chlorite schist, with foliation striking northwestward and dipping very steeply to the northeast. Along a zone of some width the rock is impregnated with chalcopyrite in stringers parallel to the foliation of the schist. Little lenses of calcite occur here and there along with the sulphide. A shaft 250 feet deep is sunk in the hanging wall of this sulphide zone or fahlband, and crosscuts are driven to it. The upper portion of the ore body is oxidized and consists of hematite and limonite streaks stained with copper, in the schist. At a depth of about 60 feet flakes of native copper are found, and below this depth sulphides appear. Chalcopyrite is the principal sulphide, pyrite being only sparingly present. A 50-foot crosscut to the south at the 150-foot level shows some ore in certain streaks. At the 250-foot level a crosscut to the south, after passing through a kaolin seam 4 feet from the shaft, reaches soft schist with stringers of chalcopyrite, said to average 4 percent of copper and $6 to the ton in gold. It is said to be 20 feet wide, and the last 4 feet of the ore is harder, carrying 9 percent copper and $30 a ton in gold. Beyond this is a kaolin streak, then a width of 70 feet of 2 to 3 percent copper ore, gradually decreasing in value beyond a point 90 feet south of the shaft. Some of the chalcopyrite along fractures appears to be secondary."

IRON DEPOSITS

Iron-rich zones in Precambrian metamorphic rocks of the Tusas Mountains have been intermittently prospected in the past. Graton (Lindgren, Graton, and Gordon, 1910, p. 128)' briefly described iron-rich greenschist underlying Iron Mountain in the northern part of the Hopewell district. Bertholf (1960), Harrer and Kelly (1963), and Harrer (1965) noted the presence of similar schist at Cleveland Gulch and reported the results of assays and metallurgical work done on several grab samples taken from prospect sites. McLeroy (1970) described the banded iron deposits of the northern Tusas Mountains and advocated a hydrothermal replacement origin. Barker (1958) described the Moppin metavolcanic unit, which is the host rock for most of the iron occurrences, and Bingler (1965) described an occurrence of iron-rich quartzite at La Madera Mountain. There is no record of production from any of the localities described.

Iron Mountain Area

Iron-rich phyllitic schist crops out in several small workings on Iron Mountain in the northern part of the Hopewell mining district. Iron Mountain is formed on grayish-green phyllitic schist composed of quartz, chlorite, muscovite, albite, and magnetite. Compositional layering is marked by alternating layers of fine-grained, quartz-rich and mica-rich schist. Several layers of porphyroblastic schist were noted on the south flank of the hill, and one zone of magnetite-rich schist 12 to 14 feet wide was mapped near the crest of the ridge.

Several samples of iron-rich schist were taken from the layer that crops out near the west end of the ridge and from the portal of an inclined shaft on the south flank of the ridge. The shaft was sunk on a 2-foot-wide zone of reddish-brown to black iron-rich schist interlayered with greenish-brown quartzose schist and highly sheared greenschist. Within the iron-rich schist, 2- to 3-inch layers of pale green quartzite alternate with 1/4-inch seams of magnetite and hematite. Under the microscope, the iron-rich schist is a very fine-grained (average grain size, about 50 microns) magnetite-quartz-chlorite phyllitic schist with a crystalloblastic and lepidoblastic fabric. Xenomorphic quartz and magnetite make up the bulk of the rock with interstitial, aligned flakes of chlorite defining the schistosity . Scattered porphyroblasts of muscovite up to 4 mm in diameter poikiloblasticly include quartz and magnetite. The grain size of magnetite averages 0.05 mm and ranges from 0.20 mm to a fine dust. Quartz and chlorite range from about 0.05 to 0.01 mm, with most grains near the average diameter of 0.03 mm. Nearly all quartz grains below 0.03 mm include smaller grains of magnetite. The modal composition of this rock based on a point count of 700 grains is magnetite, 59 percent; quartz, 19 percent; chlorite, 22 percent.

A characteristic sample from this locality collected by the U.S. Bureau of Mines contained 40.1 percent iron, 0.26 percent phosphorus, 0.12 percent sulfur, 0.1 percent titania, less than 0.1 percent manganese, and 38.4 percent silica (Harrer and Kelly, 1963, p. 60).

A reliable estimate of reserves in the Iron Mountain area is difficult to obtain. Harrer and Kelly report tracing the Iron Mountain deposit for more than half a mile in a 100-foot-wide zone by dip-needle survey. However, the magnetite content of the greenschist unit is uniformly high, and this factor should be carefully considered in the evaluation of a dip-needle survey. A conservative estimate of the amount of iron-rich schist present would include at least two layers or zones of magnetite-rich greenschist, ranging in thickness from 10 to 20 feet with a strike length of at least several hundred feet.

Cleveland Gulch Area

Several prospect pits have revealed the presence of iron-rich schist in the Cleveland Gulch area. Bertholf constructed a magnetic profile across the strike of layered Moppin metavolcanic rocks, based on dip-needle measurements at 59 stations arranged in northeast-trending traverses along an east-west base line. Anomalies of several thousand gammas were recorded. Iron content of a composite channel sample collected at the highest anomaly was 35.6 percent.

Harrer and Kelly (1963, p. 62) traced iron-rich schist 3000 feet along an east-west outcrop belt; analyses of two iron-rich schist samples are shown below:

CHEMICAL ANALYSES (percent)

Fe	*P*	*S*	*TiO_2*	*Mn*	*SiO_2*
29.7	0.15	0.12	0.1	0.2	53.2
37.7	0.10	0.04	0.16	0.2	44.4

La Madera Mountain

Bingler (1965) described a small lens of quartz-specularite-kyanite schist occurring in the quartzite that underlies La Madera Mountain:

"A lens of specularite-quartz schist with an exposed thickness of from three to four feet and a length of about forty feet crops out on the northwest flank of the western spur of La Madera Mountain. In outcrop, it is grayish green to black, compact, and coarsely crystalline. The essential constituents are kyanite, 36 percent; specularite, 35 percent; and quartz, 21 percent. It contains accessory amounts of rutile, muscovite, and sillimanite. In thin section, xenomorphic quartz with sharp extinction includes porphyroblastic kyanite idiomorphs and faint planar segregations of hematite. Most hematite occurs as large irregular patches of subhedral to anhedral gains. Numerous small orange anhedra of rutile are associated with the larger masses of hematite. Individual hematite grains range in size from submicroscopic to 0.7 mm, kyanite has an average prism cross-section diameter of 0.8 mm, and matrix quartz averages 0.35 mm in diameter."

Potential Reserves

Several writers have classified the Precambrian iron-rich greenschist in the Tusas Mountains as taconite—that is, the typical ferruginous chert of the Lake Superior iron districts (Bertholf 1960; Harrer and Kelly 1963; Harrer 1965)—and have indicated potential reserves in excess of 100,000,000 tons. It is probable that such an estimate is grossly exaggerated, for at least two reasons. First, iron-rich schist is invariably interlayered with common greenschist as thin and discontinuous laminae. Second, the greenschist of the Moppin metavolcanic unit has a uniformly high iron-oxide content; for example, Barker (1958) reported analyses of greenschist in which the combined iron-oxide content ($FeO + Fe_2O_3$) ranged from 10 to 14 percent. Any redistribution of this iron content during metamorphism, or its appearance as magnetite instead of in the minerals chlorite or hornblende, could result in locally developed layers of unusually high iron content. Such layers scattered over a large area of poorly exposed greenschist might register as a large body of iron ore in a magnetic survey. At the very least, considerable caution should be observed when estimating iron reserves in the matamorphic terrain of the Tusas Mountains.

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