GEOLOGY AND ORE DEPOSITS OF LAS GUIJAS TUNGSTEN DISTRICT,
PIMA COUNTY, ARIZONA

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. Spencer R. Titley, director of thesis, whose able guidance on this problem has been most helpful.

The author is also indebted to Dr. Willard D. Pye and Dr. William C. Peters for their valuable criticisms and suggestions during the preparation of this manuscript. The author is especially thankful to Dr. John W. Harshbarger and the other faculty members for providing the author insight, information, advice, and aid.

The United States Geological Survey, Ground Water Branch, Tucson, assisted by lending the author aerial photographs. Robert T. O'Haire, U. S. Bureau of Mines, provided the facilities for spectrographic analysis.

Messrs. James Stewart, Ralph Erickson, Marvin Deem, Mitchel, and Lester G. Fernstrom, who kindly allowed the author to use their facilities, deserve special mention.

The author would also like to thank the Dawood Foundation of Pakistan, who provided the interest free loan travel grant, and his father, Mr. Abdul Rahman Sheikh, and other family members who have been a source of constant inspiration from a distance of more than 13,000 miles during the author's long stay in the United States.

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ABSTRACT

Las Guijas tungsten district is located 58 miles southwest of Tucson, Arizona and is accessible by road. The geology of the Las Guijas Mountains is complex. The area studied has six pre-Quaternary mappable rock units, namely, granite, granite dikes, volcanic breccia, andesite and rhyolite dikes, black biotite minette, and sediments of Cretaceous age. The granite and volcanic breccia occupy most of the area and host the ore deposits.

The ore controls of these deposits were studied in detail. Regional and local controls are conspicuous and affinity of vein materials to host rock exists.

The sequence of geological events in the area is: (1) the deposition of volcanic breccia, (2) deposition of sediments of Cretaceous age, (3) intrusion of the Las Guijas granite stock during the Laramide orogeny accompanied by the fracturing and deposition of mineralized quartz veins, and (4) erosion and deposition of Tertiary and Quaternary alluvium.

Field observations of mines, shafts, and adits have been described with their brief history. These deposits are mined by underground methods, and there is no active mining at the present time.

The mineralogy is simple. Wolframite, huebnerite, and scheelite are the principal ore minerals. Sulphides such as chalcopyrite, pyrite, galena, sphalerite, and chalcocite are also present. Oxide minerals in this district include magnetite, hematite, limonite, psilomelane and other iron and manganese oxides. Quartz is the most prevalent gangue.

Spectrographic analyses were made in order to ascertain the elements present in the ore minerals. Oxidation is present but has no economic significance. The only hydrothermal alteration found is sericitization.

On the basis of field observations and in the light of the recent experimental studies, the Las Guijas tungsten deposits have been classified as epigenetic epithermal deposits.

INTRODUCTION

Location and Accessibility

The Las Guijas tungsten mining district is located in southeastern Pima County, Arizona, about 58 miles south-southwest of Tucson (Fig. 1). The district lies within T. 20. S. and R. 9. E. and is found on the Arivaca Quadrangle of the U. S. Geological Survey.

The area is accessible by automobile, preferably four-wheel drive, and is reached by driving seven miles, off the road, from the Cerro Colorado Mine, 14 miles west of Arivaca Junction (Lakewood Estate, formerly Kinsley Ranch), a picnic place on U. S. Highway 89 between Tucson and Nogales, Arizona. There is an alternate route which, though not used, is on the northwestern side of the district connecting Altar Valley and State Highway 286. All roads are motorable except during periods of heavy rains and storms.

Amado is the nearest railroad point which has a siding of the Southern Pacific Railroad on Nogales branch. It is located about two miles southeast of Arivaca Junction. Ore concentrates from the mills in the Las Guijas Mountains have been trucked to Amado for shipment.

FIG.1 . Index map showing location of THESIS AREA.

Topography, Drainage, Climate, and Vegetation

The Las Guijas tungsten district lies in the Basin and Range province. The area lies in the Las Guijas Mountains which are a moderately dissected range eight miles long and four miles wide and 3,500 to 4,664 feet in altitude. These mountains lie between the Cerro Colorado Mountains to the east and San Luis Mountains to the southwest.

Drainage is largely controlled by the underlying rock and structure and consists of intermittent and ephemeral streams flowing northeastward and southwestward to join the large washes in the Altar Valley.

The typical arid climate is similar to that found in Southern Arizona. Precipitation has two distinct seasons, intermittent winter rains and summer storms. The area experiences temperature variations between 20°F and 120°F.

The area has sparse vegetation.

Purpose of Study and Method of Treatment

The tungsten ore deposits in the Las Guijas Mountains (also referred to as the Arivaca Tungsten District) have been known since early 1900 and worked intermittently until 1957 by underground methods. No known comprehensive geological investigations have been undertaken prior to this study. The purpose of the study was to carry out a detailed investigation of the ore controls and the origin of the mineral deposits.

The area studied is on the northern flank of Las Guijas Mountain and covers sections 25, 26, 35, and 36, T.20.S., R.9.E. in Arivaca Quadrangle. The geology of the area was mapped on aerial photographs provided by the U. S. Geological Survey and taken on February 27, 1936. These were enlarged to a scale of approximately one inch to 500 feet.

The field work was accomplished during the summer and fall of 1965. The mapping was done by the isolation of outcrops method (McKinstry, 1948, pp. 9-10).

Samples from the seven mines located in the district were collected for megascopic studies in the field and laboratory. Polished sections were prepared in the laboratory for identification of minerals by optical methods and by microchemical tests as described by Short (1940). Petrographic work consisting of the examination of 36 thin sections was done to determine rock units.

No supplies or accommodations are available at Las Guijas, an old settlement, but water may be obtained at various nearby wells and ranches (Fig. 3).

Previous Work

Wilson (1941) described these deposits along with the tungsten deposits of Arizona; Dale et al. (1961) and Kerr (1946) mentioned these deposits in two publications on tungsten deposits. Li (1947) also mentioned these deposits in his comprehensive book.

Figure 3. Las Guijas Mountains (photograph taken standing north, looking south).

History and Production¹

In the late nineteenth century, part of this area was located for silver and copper by C. Bent. During the World War I, H. Whitcomb and associates purchased 16 of the claims and worked the deposits extensively.

The acquisition of the principal claims in 1930 by Tungsten Alloys Corporation led to the construction of a gravity mill of 30 tons per day capacity. Mill heads during the first part of 1931 Wilson (1941) averages 1.5 to 2.0 percent, and the tailings little over 0.2 percent WO_3 . These concentrates carried pyrite, chalcopyrite and about 40 percent WO_3 . The magnetic separation of these concentrates was done by E. C. O'Brien and Company, Globe, Arizona. Tungsten Alloy Corporation continued to operate until 1933 when they sold their holdings.

In 1934 the district again became active when the Ore Metal and Engineering Corporation and the Southwestern Ore Corporation worked the deposits and produced about 1,000 units until 1936. In 1936 they ceased operation.

In 1936 the General Electric Company acquired the Whitcomb Group and several other claims in the district. The production until 1941 is reported to have been 1,200 units, largely by lessee operations.

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1. The main source of the following account is Wilson (1941), but additional and vital information is supplemented by the writer.

During this time a gravity mill was built by Fernstrom and Company which continued operating until 1956. Also, Zappia built their own mill on their property in 1954. This company Zappia operated between 1952 and 1954.

During the period 1950-52, Pacific Drilling Company, Long Beach, California, operated several mines in the district and drilled several holes to promote the mining.

Fernstrom and Company, a lessee of General Electric Mines and also owner of Soto claims has remained in business since 1936.

At present, the General Electric claims are held by Tungsten Mining Corporation, New York, a subsidiary of General Electric Company. In 1965 the only active operation in the district is Fernstrom.

DESCRIPTION OF ROCK UNITS

The geology of the Las Guijas tungsten district is complex. Wilson (1941) reports that the host rock of the tungsten mineral deposits is medium-grained granite. Also present are andesite volcanics, dikes of granite porphyry, aplite, and black biotite minette. Kerr (1946) comments on the granite and states that in the field it exhibits an unusual trachytic texture.

Wilson, Moore, and O'Haire (1960) group the rocks of the area into two units. Their map shows Laramide granite intruding locally metamorphosed sediments of Cretaceous age.

In the area examined, six pre-Quaternary units are present. Large Quaternary alluvial deposits composed of unsorted, locally derived material are also present in the northeastern and southwestern corners of the area mapped. The thickness of alluvial cover in the northeastern part of the area is estimated at approximately 30 feet. The thickness of the alluvial cover to the southwest could not be definitely measured as the material is part of the filling of the Altar Valley.

Of the six units studied, one is sedimentary and five are igneous. Among the igneous rocks two are extrusive and cover most of the area mapped (see Fig. 2). The classification of rock units

adopted here is the one recommended by Travis (1955). The units mapped need further detailed discussion and are described below under the titles Intrusive Rocks, Extrusive Rocks, and Sedimentary Rocks.

Intrusive Rocks

Medium-Grained Granite

The medium-grained granite is the most conspicuous and recognizable rock unit in the mapped area. It covers almost the entire northwest quarter of the map and extends further north. The total area underlain by medium-grained granite is approximately 1.5 square miles. The granite has light gray to dark reddish gray color and has been fractured particularly in its westerly and southwesterly portions. These portions are also extensively altered. Surface alteration due to weathering is conspicuous. This body is considered a stock.

Megascopic examination reveals a holocrystalline texture. Quartz makes up about 40 percent and the feldspar about 60 percent. The remaining minerals are altered and could not be recognized in the field (Fig. 4).

Several large and small dikes pass through the granite. They are mostly composed of lamprophyre rock. Mineralized quartz veins pass through or radiate from the granite.

Thin section study of the granite indicates it to be composed of about 30 percent quartz and about 70 percent feldspar. The feldspar

Figure 4. Fractured medium-grained granite and intruded quartz veinlets.

is composed of about two-thirds potassium feldspar and one-third plagioclase. The rock type, therefore, lies between a granite and a quartz monzonite. In this report, it will be called a granite. The only accessory minerals are a few grains of magnetite contained within the quartz and feldspar. Kerr (1946) gives a chemical and mineral analysis of a sample from this intrusive granite (Table 1). Variations in mineralogy are to be expected since in the field the intrusive rock shows internal variations.

The characteristic weathering of granite in arid climate is conspicuous as described by Pearl (1963).

Granite Dikes

Granite dikes are exposed in the center of the mapped area and also on the southern border. The exposures of these dikes in the volcanic breccia are conspicuous owing to their greater resistance to weathering. These dikes have no sign of tungsten mineralization of any kind.

Under the microscope, two thin sections of the granite dikes were examined. They show microcline and quartz phenocrysts set in a fine groundmass composed of quartz, potash feldspar, and plagioclase. Small amounts of altered biotite and magnetite are present. Veinlets in the granite contain sericite and pistacite epidote.

Table 1. Analysis of medium-grained granite.

SiO ₂	75.18	Albite	34.58
TiO ₂	0.21	Anorthite	0.56
Al ₂ O ₃	13.48	Quartz	31.26
Fe ₂ O ₃	0.87	Orthoclase	30.58
FeO	0.21	Hypersthene	0.20
MuO	none	Magnetite	--
MgO	0.06	Ilmenite	0.46
CaO	0.08	Pyrite	--
BaO	none	Calcite	--
SrO	none	Corundum	0.92
Na ₂ O	4.08	Aplite	--
K ₂ O	5.21	Diapside	--
H ₂ O-	0.03	Hematite	0.96
H ₂ O+	0.32	Gypsum	--
CO ₂	--	Titanite	--
P ₂ O ₅	0.02		
SO ₃	<u>0.06</u>		
Total	99.81		

Analyses by F. A. Gonyer.

Extrusive Rocks

Volcanic Breccia

The volcanic breccia is the predominant volcanic rock in the mapped area and serves as host rock for the andesite porphyry, porphyritic granite, rhyolite porphyry dikes, and several mineralized veins. The color is gray, but is darker at several places owing to weathering of its surface. Evidence of stratification is extremely rare.

It is difficult to tell whether the rock is igneous or sedimentary. It is a porphyritic rock having about 50 percent phenocrysts and 50 percent groundmass. The phenocrysts consist of about 40 percent quartz, 40 percent microcline or other potash feldspar, and 20 percent plagioclase. The groundmass is a fine-grained assemblage of quartz and feldspar in roughly equal proportions, containing small groups of biotite crystals and local radiating clusters of tourmaline as well as euhedral zircon and magnetite.

The quartz phenocrysts are commonly embayed, but some show moderately good euhedral outlines. Some appear rounded, while others appear to be fragments of larger crystals. The feldspar fragments do not conform in shape to those one would expect to be produced by fracture of pre-existing crystals along cleavage planes. Most are microcline, but some show no trace of the characteristic twinning. A few of the crystal fragments have plagioclase inclusions, and a few appear to contain embayed openings. The average size of the large

crystals of quartz and feldspar is about two to three millimeters. The phenocrysts commonly show frilly margins growing into the groundmass a few hundredths of a millimeter.

The groundmass is rather uniformly crystalline, and is made up of small quartz and feldspar crystals a few hundredths of a millimeter across. A few epidote crystals are present in plagioclase, and a few small euhedral zircons are present in the biotite clusters. Magnetite crystals are sparsely present in the groundmass, and local clusters are present in the biotite clusters.

In hand specimen the character of the rock is difficult to determine. In the field, the rock unit shows no layering or foliation of any kind; it covers quite an extensive area. It shows no discernible definitely igneous or sedimentary features.

The presence of embayed, euhedral doubly terminated quartz crystals and the presence of biotite and radiant tourmaline in a groundmass of quite uniform crystal size indicates that the rock is of igneous origin.

It is possible that the rock is an arkosic shale which has been strongly thermally metamorphosed, but there is no evidence of any nearby intrusive anywhere in the area from which the specimens were taken. The rock is almost certainly igneous; it is probably some type of volcanic breccia, though whether flow or intrusive cannot be told at present.

Rhyolite Porphyry

Dikes are very common in the whole mapped area. In the southeastern corner of the mapped area Rhyolite porphyry dikes are observed which are wider than most of the other dikes.

The weathering is more or less the same type as in the other volcanic rocks. Gray is the prevalent color. Dikes stand out in the field due to their greater resistance to weathering.

Thin sections of the rocks show that the texture is porphyritic consisting of 50 percent phenocrysts and 50 percent groundmass. The phenocrysts are equal amounts of quartz and microcline. The quartz crystals are occasionally euhedral, but more often show resorption outlines of anhedral shapes. The microcline crystals usually show anhedral outlines; some Carlsbad twins are common.

The groundmass is made up of crystals of quartz, feldspar, and small masses of sericite, which in some cases appears to have replaced feldspar crystals. A few opaque grains which are probably magnetite are present.

Andesite Porphyry Dike

The exposure from which the sample studied was collected is in the southern portion of the mapped area (Fig. 2). A large area around the andesite porphyry dike is covered by dump material from quarrying operations.

The rock consists of feldspar phenocrysts in a quartz-feldspar biotite groundmass. The feldspar crystals are euhedral; all but one observed are plagioclase; the one exception was microcline. Phenocrysts average about 5 mm. but some may be as long as 15 mm.

The groundmass is about 50 percent quartz; the remainder is about 45 percent feldspar, with the balance composed of biotite and magnetite. It is difficult to tell what proportion of the groundmass feldspar is plagioclase, but vague albite twining is present in many of the grains. Biotite occurs as single crystals and clusters of small crystals, associated with magnetite, epidote, chlorite, and zircon which are frequently in both clusters and crystals.

The rock is termed an andesite porphyry although the phenocrysts are slightly more than half of the rock.

Black Biotite Minette

The black biotite minette dikes are observed in the field along the Fernstrom and General Electric Mine II (Immense Lode). Their general trend is east-west and they dip roughly vertically. They are intermittently covered by overburden and are baked near the veins. This rock is dark brown color and has been weathered on the surface very extensively. The width of the dikes is variable and ranges from 6 inches to 3 feet.

Identification of minerals with the naked eye or with hand lens is not possible and they are classified in the field as Lamprophyres. The rock is very fine grained and has a fine holocrystalline texture.

Sedimentary Rocks

Sandstone, Shale, Limestone, and Conglomerates

Sandstone, shale, limestone, and conglomerates underlie the northeastern corner of the map area adjacent to the medium-grained granite stock. These rocks are of sedimentary origin and are earlier than the intrusive rocks. Wilson et al. (1960) have assigned them a Cretaceous age.

These rocks have been metamorphosed locally by the stock (Fig. 5). On the scale of the mapping, it is not possible to map these rocks separately owing to local facies change. Therefore they have been mapped as a single unit. Shale interfingered with sandstone, and sandstone with conglomerate is common. The conglomerate is composed of angular or weakly rounded volcanic rock fragments. Some granitic rock fragments are present in the conglomerate; these originally may have been derived from some basement granitic rock.

The well-defined bedding and fracturing in these clastic rocks are common but there are no signs of lineation and cleavage which are characteristic of metamorphic rocks. Therefore, in this report they are referred to as sedimentary rocks of a Cretaceous age.

Figure 5. Metamorphosed shale exposed in wash; ocatillo and love grass is in the vegetation.

Agglomerate Breccia

In hand specimen the color is dark gray and consists of numerous pebbly fragments in a medium- to fine-grained groundmass. The matrix is very fine-grained and contains calcite, chlorite, and some other minerals in very minor quantities. The rock is a conglomerate, or a coarse greywacke. The rounded nature of some of the larger fragments indicates a period of stream transport for at least some of the material.

Medium-Grained Greywacke

Two shale specimens were studied under the microscope. The rock consists of approximately 50 to 60 percent fragments of up to 4 to 5 mm. in size in a very fine-grained matrix. The fragments in the rock are angular and consist predominantly of volcanic rock detritus of many kinds together with individual grains of quartz, plagioclase, and potash feldspar. Minor patches of chlorite and magnetite may have been altered from biotite.

The fragments lie in a very fine-grained matrix whose composition cannot be wholly determined but which consists in parts of sericite, chlorite, red iron oxides and carbonates. Other specimens of the same rock reveal the same mineral constituents but are finer grained. This rock is classified as a medium-grained greywacke.

ORE CONTROLS

Several kinds of ore controls have been recognized in the precious and rare metal deposits. The ore controls in the Las Guijas tungsten deposits are mainly structural. Other controls, including host rock affinity, exist and will be discussed in the course of this report.

Structural Controls

The Las Guijas tungsten deposits have structural controls which are both conspicuous and intricate. These controls can best be described as regional and local.

Regional Controls

The Las Guijas tungsten deposits are located in the Western Cordillera. Kerr (1946) made the first comprehensive, authoritative regional study of these deposits. He divides the Western Cordilleran tungsten deposits into three belts, which he calls arcs. They are (1) Eastern, (2) Central, and (3) Western. The Las Guijas deposits lie in the Central Arc (Fig. 6).

The deposits of the central arc are associated with intrusive bodies which encircle the Colorado Plateau and whose age has been found by Damon and Mauger (1965) to be Laramide. The genetic and

FIG. 6. Tungsten-bearing zones in the western States. More productive regions are hatched both directions. Important districts are shown by name. (After Kerr)

temporal significance of these regional relationships is poorly understood and still offers many challenging problems.

Local Controls

Unlike most surrounding areas, the Las Guijas Mountains provide better opportunities for studying the structural features owing to the fact that mining operations remained active until recently.

The entire area of tungsten mineralization is contacted by the Las Guijas stock. The most important expression of this is a well defined fissure zone which can be observed in the field as either quartz veins or as dikes of lamprophyre and felsite types of rocks (Fig. 2).

Some of the local structural controls of the deposits apparently follow in Arizona the general regional trends of faulting as established by Wilson (1962) and Schmitt (1933). They generalize that all the major structures are roughly north-south and east-west and are related to Laramide revolution.

Faults

The area under study is traversed by a series of complex vertical faults which can be subdivided into a north-south system and an east-west system. The east-west faults generally seem to be pre-mineralization in age and have greater extent. The faults having a north-south trend are post-mineralization in age. The assignment of relative ages is supported by the displacement of mineralized veins,

especially the General Electric Mine II. Several mines like Fernstrom, Immense Lode I, and Immense Lode II have no corresponding veins on the opposite side of the fault which leads to the inference that this contact fault is pre-mineralization.

Dikes

At several places, such as the Immense Lodes, biotite-minette dikes occur independently along the veins and sometimes forming a control of deposition. Also the General Electric Mine II (Immense Lode I) and the Fernstrom Mine are at some places controlled by dike material which is considered black biotite minette by Wilson (1941).

Relationship with Intrusive and Extrusive Rocks

The Las Guijas deposits are associated structurally and genetically with the Las Guijas granite stock. All the veins encircle the stock indicating that the vein fluids are related to the granite intrusion.

In the past, the exploration and developmental work has been confined to the granite and its periphery. Wilson (1941) described the veins as forming a peripheral pattern to the medium-grained granite stock.

The Zappia mines deposits discovered in 1952 have provided new incentive for exploration in the Las Guijas tungsten district. The host rock in these deposits is not granite but volcanic breccia.

AGE RELATIONSHIPS

The Basin and Range province presents a unique geological problem regarding the determination of ages of different rocks and their correlation. This is a challenging task, owing to the fact that the province contains isolated blocks of exposed rocks (ranges) surrounded by valley fill (basins).

The earlier dating and correlation studies were based mostly on the field relationships, fossil content of sedimentary rocks, and mineralogic similarities and associations in the volcanic rocks.

Titley (1959) presented a summary and correlation chart of the igneous in Arizona, and stated that the correlation of the volcanic rocks in the Basin and Range province is possible and being undertaken.

Owing to the lack of dated rock units adjacent to the igneous rocks mapped throughout the Las Guijas Tungsten district, the assignment of definite ages is not possible. Rocks having similar lithology and field relationships in other areas have been designated as Tertiary age.

The work of Schmitt (1933) still stands uncontested. He has related the important ore deposits of Arizona to four periods of orogeny, namely, Precambrian, Nevadian, Laramide, and late Tertiary. According to Schmitt all the southern Arizona ore deposits and igneous intrusions

belong to Laramide--late Cretaceous and the early Tertiary. Damon and Mauger (1965) have used radioactive dating methods to establish an age for the southern Arizona Laramide igneous rocks ranging from 40 million years to 100 million years.

From the above discussion and further by the nature of the deposits studied together with the Cretaceous host rock, it is suggested that Las Guijas mineralization occurred during the Laramide revolution.

Sequence of Events

The geological events which were discussed in the preceding pages have occurred in the Las Guijas Mountains area in the following chronological order:

1. The deposition of volcanic rocks and volcanic breccia, which are the oldest rocks, is followed by fracturing and formation of dikes of andesite porphyry and rhyolite porphyry.
2. Post-volcanic deposition of fine-grained shale, sandstone, and limestone over the entire area.
3. Deposition of fragments derived from the earlier volcanic rocks as a conglomerate.
4. Laramide orogeny and intrusion of the granitic stock and associated granite dikes.
5. Mineralization in at least three stages.
6. Development of Quaternary alluvium and placer deposits.

SUMMARY OF ECONOMIC GEOLOGY

A number of quartz veins crop out throughout the area investigated. Some of them are barren and some mineralized. All veins are associated with the dominant directions of structural weakness. The workings, both deep vein mining as well as shallow pits, have been mined in the past for the tungsten minerals; however, no mining is being done in the investigated area at this time.

Ore textures and mineral assemblages indicate that mineralization probably occurred in a moderate to low temperature near-surface environment.

Description of Deposits

Wilson (1941) described some of these deposits and mine developmental workings of Las Guijas Tungsten district of Arizona. The present study included all the old workings and current developments as well.

Tungsten Mining Corporation Group

Tungsten Mining Corporation, New York, holds all the 36 patented claims of General Electric Company which include four major mines and some short adits (Fig. 2). These mines are locally known as General Electric Mines I, II, III, and IV.

Kerr (1946) has described General Electric Mines I and II as the Grand and Immense Lodes respectively.

General Electric Mine I (Grand Lode)

This mine is located in the heart of the granite stock and follows a vein bearing N 65°W and dipping 78°N along the general zone of fracturing. The mineralogy is complex but consists mostly of hypogene minerals. The quartz vein is about 800 feet long and has been mined at three levels. The uppermost level does not show anything other than the oxide zone. All the other levels have mineralized quartz which is pinkish in color and hosts chiefly wolframite, pyrite, chalcopyrite, galena, and bornite. Oxidized minerals include azurite, limonite, psilomelane, and other iron and manganese oxides. Oxidation extends to only a depth of 10 to 20 feet.

The present condition of the mine is not good. Thus, a thorough investigation could not be made. The samples were collected from the three mine dumps present at the mine shafts and were supplemented by material from the mine walls (see Fig. 7).

Mineralization occupies the N 65°W fault zone which ends abruptly on the northwest at the intrusive contact and on the southeast where it is cut off by a northeast-southwest trending fault.

The production data for this mine could not be obtained from a reliable source.

Figure 7. General Electric Mine I (Grand Lode) upper level, caving in the old workings and limonitic stains in the quartz.

General Electric Mine II
(Immense Lode I)

This is the second largest mine in the district and produced until 1952. It was first operated by Whitcomb and General Electric Company and later by Fernstrom and Company. It is located in an extensively fractured area of medium-grained granite.

The mining has been limited to two levels; one is an adit level and the second is an upper level having a shaft. Both levels are connected by a jeep road. This is the deepest mine in the district but the exact depth could not be measured owing to flooding. (In 1941 it was reported as being 150 feet deep.)

The mineralogy is not the same type as that found at the Grand Lode. Wolframite and huebnerite are the principal tungsten minerals at this mine along with the sulphides in the deeper levels and oxides at the upper levels. The following minerals were identified: wolframite, huebnerite, pyrite, chalcopyrite, bornite, galena, magnetite (?), sphalerite (?), chalcocite (?), azurite, limonite, psilomelane, and sericite.

There are several characteristic features of this and the Immense Lode II that are observable at this mine. The most important are:

1. The vein was displaced by a post-mineralization fault which is running almost perpendicular to the vein and displaces it about 50 feet to the north.

2. Sericitization is very conspicuous but occurs about 10 feet away from the vein-wall rock contact. A lamprophyre dike passes parallel to the vein and has been extensively weathered at the surface. (This dike is referred to by Wilson, 1941, and Kerr, 1946, as a black minette dike.)

3. Another characteristic feature noted is that disseminated pyrite in the host rock of the vein is common.

General Electric Mine III

This mine is comparatively small in size. There are two levels in the mine which are partially caved; consequently no attempt was made to examine the underground workings. Two small shafts sink from the upper level which is connected by a jeep road to the old Fernstrom Mill.

Oxidation at this mine is very extensive; a commonly occurring black botryoidal mineral in this zone is considered to be a manganese oxide. Field studies support the idea that mineralization developed at the contact of medium-grained granite stock with volcanic breccia.

The mineralization is limited to wolframite which was enclosed in a quartz vein. Sulphides are generally absent in this mine. Pyrite was the only sulphide observed and is found on the waste dumps.

Several prospect pits are found around this mine and some of them show a little tungsten mineralization but the openings are not deep.

General Electric IV

This General Electric Mine also is located on the contact of the medium-grained granite stock with volcanic breccia; the contact has a strike of N 40°W and dips 73°NE. The old workings are limited to the hanging wall of the contact and are completely caved. A prominent quartz vein forms a ridge that follows the contact; it eventually joins the General Electric Mine III quartz vein.

The mineralization includes wolframite, pyrite, azurite, and manganese oxide minerals.

Immense Lode II

The Immense Lode II formed parallel to the Immense Lode I and the Fernstrom Mine. This vein also was displaced by the same fault which displaces the Immense Lode I. The Immense Lode II has all the characteristic features which are observable at the General Electric II, i. e., offset of the vein, sericitization and association with a black biotite minette dike. The Immense Lode II has the same mineralogy as Immense Lode I.

Fernstrom Mine Area

The Fernstrom mine area includes the former Stewart Claims and Placer Claims. Fernstrom and Company were very active with mining operations during World War II and Korean War boom years.

The Fernstrom mine is located south of the Immense Lodes. The strike of the vein at the Fernstrom mine is parallel to the Immense Lodes. The vein could be followed along the contact of the medium-grained granite and volcanic breccia. The vein ranges from thin stringers to about 18 inches in width and carries mostly wolframite and scheelite.

The concentration of minerals is limited to rich pockets which are 50 to 60 percent wolframite ore in bright pink quartz. Other minerals identified at this mine are scheelite, pyrite, chalcopyrite, and galena. The sulphides occur, as in other veins, in non-commercial amounts.

A large number of shafts, inclines, adits, and prospect pits are present in the vicinity of the Fernstrom mine. Here most of the deep workings are accessible and were investigated. The main adit is approximately 1,500 feet long and terminates on contact with black biotite minette. The total ore recovered from this mine is reported at 125,000 tons of varying grade.

Zappia Claims Area

The area covered by the Zappia mining claims includes two major mines called numbers 9 and 10 by the local miners; it also includes several prospect pits, tunnels, adits, and waste dumps (Fig. 2).

The most characteristic and notable feature is that all these veins have country rock of volcanic origin. The deposits are not formed within the stock or along the contact of the stock with its country rock. The wallrock alteration is limited to iron oxide stains extending laterally several feet.

The mineralogy of these claims is different than that found at the other mines because the minerals, such as scheelite, huebnerite, bornite, chalcocite, azurite, limonite, are absent.

These mines have the same structural trends and alignments as the preceding mines. The number 9 is located on the contact of the andesite porphyry and volcanic breccia. The vein has a strike N 60°W and dips 50°NE.

The number 10 mine was more extensively worked during World War II and the Korean War when the price of tungsten was high and stable enough to support the small-scale mining.

Buster Lode

The Buster Lode consists of three quartz plugs located along the contact of the medium-grained granite and shale, sandstone, limestone and/or agglomerate. The sedimentary rocks are covered by the colluvium deposits of granite detritus.

Kerr (1946) described the Buster Lode as a barren quartz vein. A number of shallow and deep workings were examined. They are on

the hanging wall and show no conspicuous tungsten mineralization. Sparse crystals of wolframite and dark stains of oxidation minerals are common. The field examination leads to the conclusion that although several attempts have been made to discover tungsten, little has been found. There is no clear reason to believe that these plugs are heavily mineralized but extensive work might lead to the discovery of rich tungsten deposits at depth as is found at the Fernstrom mine.

Methods of Mining

All the preceding mines were worked by underground methods. Adits, inclines, shafts, raises, and stopes are present.

Beside the underground mining in the quartz filled veins, placer mining was undertaken in the past, especially during World War II. Placer mining remains limited to the northeastern slopes of the Las Guijas Mountains. These operations were active year round but heavy rains supported the placer deposits.

Ore Reserves

No accurate production data for these mines are available. As stated by Wilson (1941) and in reports of the U. S. Bureau of Mines, a considerable amount of tungsten was obtained from the Grand and Immense Lodes. The Zappia mines and Fernstrom mine supplemented this production.

Figure 8. Buster Lode which is considered to be a barren quartz dike; Baboquivari Mountains and peak are in the background.

At present there are no known proven or probable ore reserves in this district, but it is possible that ore might be found. Prospective mines for further development are the Fernstrom Mine, General Electric Mines III and IV, and Zappia 9 and 10. The extension of General Electric Mine I also is possible.

MINERALOGY

The mineralogy of this tungsten district is simple. During the field study the nature of mineralization which was both primary and secondary was noted. The results of field study were supplemented by the polished section studies.

The primary ore minerals present are wolframite, huebnerite, and scheelite. The associated sulphide minerals include pyrite, chalcopyrite, bornite, galena, sphalerite (?), chalcocite (?), magnetite, hematite(?), and oxide minerals.

Secondary minerals include azurite, limonite, psilomelane, and iron and manganese oxides.

The prevalent gangue is vuggy quartz having conspicuous iron stains. Generally the quartz is milky; however, locally grey and even clear crystals may be encountered.

In veins, as reported by the old miners, all tungsten is irregularly distributed; even the rich pockets contain considerable areas of solid quartz devoid of mineralization.

Small quantities of scheelite have been mined in the Fernstrom Mine. This mineral is not unusual in the quartz-filled fissure deposits of Central Arc.

The primary minerals are found in deeper workings, or, on dumps associated with workings 5 to 15 feet in depth. This depth apparently represents the extent of oxidation in this region.

Spectrographic Analyses

Qualitative spectrographic analyses of ore samples were conducted in order to ascertain the elements present. The major element was tungsten and intermediate elements were iron, manganese, and silicon; aluminum, calcium, copper, lead, and phosphorus occur in minor quantities.

Magnesium, mercury, molybdenum, potassium, silver, strontium and zinc were detected as trace elements. A number of elements such as antimony, arsenic, barium, bismuth, cadmium, cerium, cobalt, columbium, gallium, germanium, lanthanum, nickel, samarium, scandium, tin, vanadium, and yttrium were found in slight traces.¹

The generally recognized association of tin and molybdenum minerals with tungsten minerals found in most of the world deposits, such as the Malaysian, Burmese, and Australian, does not occur in Las Guijas tungsten district.

The presence of Scandium and Yttrium in the Las Guijas deposits supports the work of Ganeev and Sechina (1960) who proved

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1. These elements are reported in alphabetical order without any quantitative implication.

their possible entrance in the wolframite lattice by a scheme:

Leutween (1952) finds that the ferberite-huebnerite series is not a series of continuous substitution. He also considers huebnerite as a secondary alteration product and sometimes pseudomorphic after scheelite.

Supergene Enrichment

The phenomenon of supergene enrichment is common in tungsten deposits. In outcrops, the tungsten minerals are weathered and may alter to tungstite, ferritungstite, cuprotungstite, and iron oxides. Jones (1918) described the secondary enrichment in the Burmese tungsten deposits. Las Guijas tungsten deposits show evidence of small-scale secondary enrichment which has taken place in an arid climate. The enriched zones do not persist to any great depth, usually 10 to 15 feet. Azurite, limonite, and iron and manganese oxide stain on the quartz veins are commonly observed in the field which clearly indicates that the processes of oxidation took place.

The writer did not study this enrichment in this district owing to its small past economic significance. So far there has been no report of a commercial supergene or secondary enriched tungsten deposit in any of the tungsten provinces of the world.

TYPES OF DEPOSITS

Las Guijas tungsten deposits have well defined fissure-veins ranging from a few inches to six feet in width, striking northwest-southeast and dipping at very steep angles. These have been categorized as the quartz-filled tungsten vein deposits by Kerr (1946). Wilson (1941) generalized that most of the tungsten production in Arizona came from lode type of deposits. This type of deposit is frequently found in the western United States. The classical localities are Germania, Washington; Alma Mine, Idaho; the Hub Mines, eastern Nevada; and Boulder, Colorado (Fig. 6). Lindgren (1907) and Lovering (1941) have done extensive work on the Boulder, Colorado deposits which has been the largest tungsten producing district in the world and has been the leading producing area in the United States for several decades.

The tungsten vein deposits of the western United States are simple quartz-filled fissures in which ferberite, wolframite, and huebnerite are the chief tungsten minerals. Small amounts of scheelite are commonly associated in each case. The quartz veins are considered of hypogene origin and genetically connected with upper and outer portions of granitoid stocks.

Lingren (1933) regarded wolframite as a high temperature mineral. Later temperature and pressure studies on the

ferberite-huebnerite series indicate that this series is not a continuous substitution series and considerable amounts of niobium and tantalum are contained as replacements of iron and manganese. Experimental studies on the synthesis of wolframite led Leutween (1952) to state that wolframite is formed not only under magmatic conditions but also frequently under deuteric, meso- and possibly also epithermal conditions. Lovering (1941) assigned epithermal conditions of depositions for the Boulder tungsten district.

The characteristic features of the Las Guijas tungsten deposits are: (1) the vuggy and drusy ore textures with sharp wall rock boundaries, (2) very conspicuous sericitization, and (3) simple mineralogy with tungstates followed by the basic sulphides and oxides. Quartz is the most prevalent gangue mineral. The relation of ore deposits to the intrusive and extrusive rocks are structural and genetic as has been described previously. These field observations are frequently characteristic features of epithermal types of deposits.

Based on the above discussion and field observations, the Las Guijas tungsten deposits are here classified as of epigenetic, epithermal type of deposit.

RECOMMENDATIONS FOR FUTURE STUDY

There are several unsolved problems in connection with the geology of the Las Guijas tungsten district. The three most important are:

1. Dating of the volcanic units and their correlation with other rock units of the same type in Arizona should be undertaken in order to determine their relative ages and origin. Courtright (1958) has discussed the correlation problem of the widely accepted "Cretaceous volcanics" of southern Arizona and presented a correlation chart of several studied areas which might be helpful for future study of this area.

2. Leutween (1952) in Germany and recently Ganeev and Sechina (1960) at Kara-Oba, Russia studied the geochemical peculiarities of tungsten deposits and found a change in the ratio of the FeO/MnO in wolframite with decreasing temperature. This is helpful in determining their origin and the relative ages of different vein deposition.

3. The relationships of the tungsten arcs to regional tectonics both as to genesis and to time and space.

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Fig. 2a

FIG.2a

GEOLOGIC CROSS SECTION OF LAS GUIJAS TUNGSTEN DISTRICT
PIMA COUNTY, ARIZONA

See Explanations on Fig. 2.

GEOLOGIC MAP OF LAS GUIJAS TUNGSTEN DISTRICT PIMA COUNTY, ARIZONA

FIGURE 2.