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GEOLOGY OF TUNGSTEN DEPOSITS IN NORTH-CENTRAL CHILE

BY
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ABSTRACT

The tungsten deposits described herein are in north-central Chile, near Salamanca in the Province of Coquimbo, and around Vallenar in the Province of Atacama. The deposits occur as moderately high temperature replacements in several of the more silicic facies of the Andean diorite complex, within a few kilometers of its intrusive contact with the Porfiritica formation of Mesozoic andesitic rocks. Dikes of aplite and of lamprophyre are common. Scheelite, in places stained with cuprotungstite, is the only tungsten ore mineral of the deposits, with the exception of some wolframite at Salamanca. Several of the deposits have been worked for gold or copper. The vein minerals associated with much of the ore are black tourmaline, quartz, sericite or white mica, pyrite, chalcopyrite, and supergene copper or iron minerals; and more rarely, amphibole, magnetite, orthoclase, calcite, arsenopyrite, molybdenite, and galena. The mineral assemblage favors an origin from magmatic solutions at moderately high temperatures. Deposition of the minerals was controlled by minor structures, such as joints and discontinuous faults. Most of the ore shoots mined have been small, podlike, and high grade. They are at unpredictable places within the mineralized zones. No ore reserves could be inferred. Descriptions of mining properties in the Salamanca, Domeyko, and Vallenar regions are given.

INTRODUCTION

The tungsten deposits described in this report are in the northern part of central Chile, in the region from Salamanca, east of Illapel in the Province of Coquimbo, to northeast of Vallenar in the Province of Atacama, a strip 350 kilometers long. (See fig. 8.) The Lipangui tungsten-molybdenum deposit near Santiago is the only well-known tungsten deposit not visited. All except the Llamuco deposit near Salamanca are around Vallenar and within 70 kilometers of one another. The deposits, except the small one of Minillas, are in the foothills of the Andes, at altitudes between 1,200 and 2,200 meters, in areas of moderate relief. They are within 50 kilometers both of the stations on the longitudinal railroad and of the central highway, which in this part of Chile follows the longitudinal railroad rather closely. Some of the side roads, which are rough and impassable at time, end 3 to 5 kilometers short of the mines.

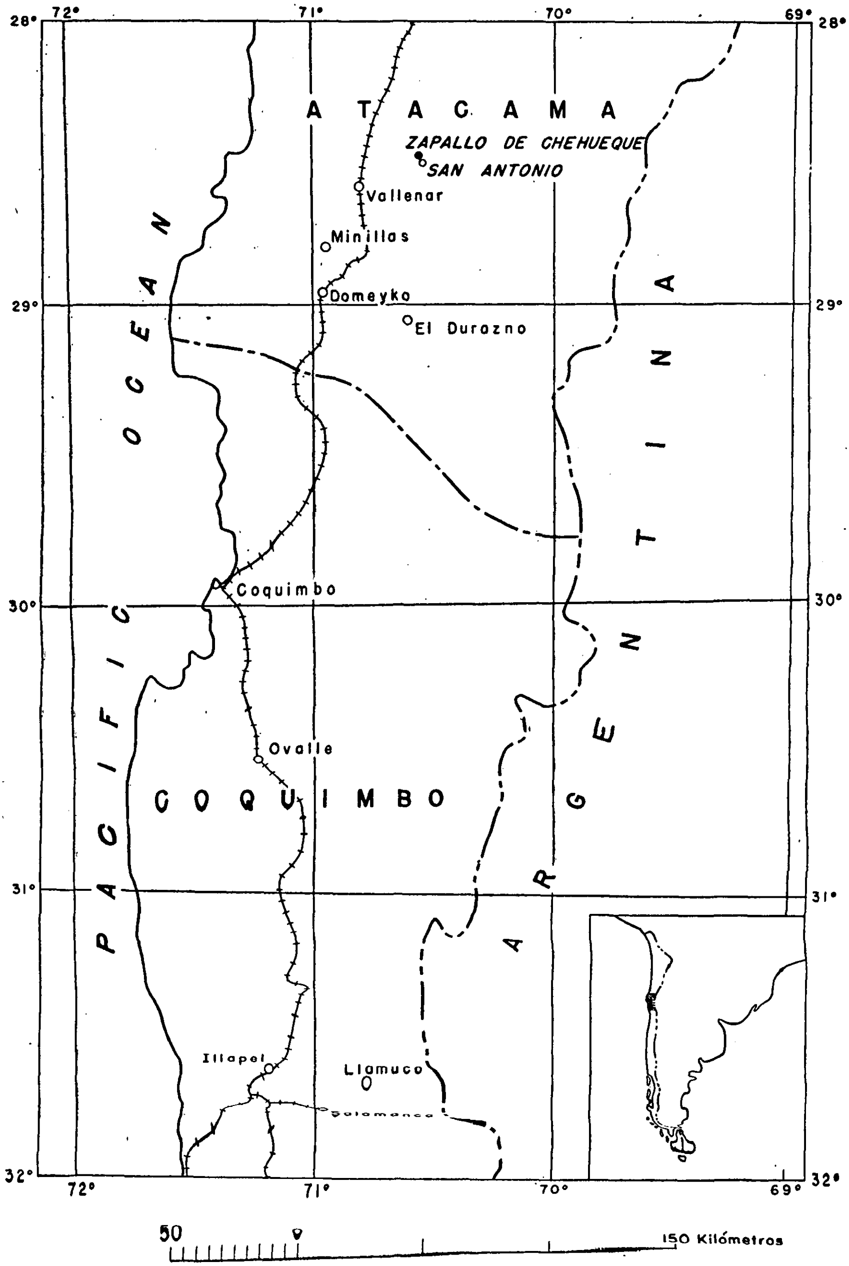

FIGURE 8.—Index map showing location of tungsten deposits in north-central Chile.

Production of tungsten in Chile from 1935 to 1938, as published by Minería e Industria, of the Chilean Dirección General de Estadísticas, is shown in the following table.

Year	Concentrate (kilograms)	WO_3	
		Percent	Kilograms
1935	5, 701	70. 06	3, 994
1936	3, 655	70. 36	2, 572
1937	1, 517	75. 08	1, 139
1938	3, 848	73. 48	2, 826

Complete later figures were not available, and little information concerning earlier production was found, although it is known that some of the deposits were worked during World War I. No tungsten was being mined during the summer of 1944. The only production was a trickle from hand-sorting of dumps at the Castañeda de Llamuco mine.

The work leading to this report was carried on by the United States Geological Survey, in cooperation with the Chilean Departmento de Minas y Petróleo, as part of a larger cooperative program sponsored by the Interdepartmental Committee on Scientific and Cultural Cooperation under the auspices of the United States Department of State.

The purpose of the work was to investigate the geology of the tungsten deposits of Chile and to obtain some idea of the importance of this resource in Chile. All deposits that had produced tungsten, except Lipangui near Santiago, were examined during July 1944. Geologic and topographic maps were made, based on surveys by alidade and plane table, using an aneroid barometer to determine the altitudes of reference. All bearings are from magnetic north. The mine-map bases were submitted by others, but all geologic notations are the work of the writers.

The writers are specially indebted to officials of the Compañía Minera Castañeda de Llamuco for the mine maps by Walter Biese, for transportation between Salamanca and Llamuco, and for hospitality at the mine; to Sr. Raúl Fergie for facilities in examining some of the deposits in the Vallenar region; to Sr. Alfredo Cood of Copiapó and Sr. Tomás Giove of Vallenar for their cooperation in the examination of the El Durazno deposits; and to numerous others who aided in planning and arranging for the field program.

M. E. Lemon, J. V. N. Dorr, Jr., and C. F. Park, Jr., of the United States, Geological Survey, made valuable suggestions in the preparation of the manuscript.

GEOLOGY

ROCKS

The tungsten deposits are in granite, granodiorite, and quartz monzonite, which are facies of an instrusive complex known in Chilean literature as the Andean diorite,[1] and considered to be of Cretaceous age. The rocks at the deposits vary in their component proportions of orthoclase, plagioclase, quartz, biotite, hornblende, and accessory apatite, magnetite, and sphene; the proportions that make up granodiorite predominate. Aplite, which occurs in large masses as well as thin dikes, grades in texture from aplitic, through somewhat porphyritic, to pegmatitic. The aplite is closely associated with the granitic rocks. Other dikes are composed of lamprophyre, consisting of andesine laths and hornblende in a felty mass. The tungsten deposits are within several kilometers of the contact between the intrusive rocks and the thick group of volcanic andesitic rocks known as the Porfiritica formation, of earlier Mesozoic age.[2]

STRUCTURE

No major structures are associated with the tungsten deposits. The mineralization was controlled by joints in rather obscure systems and by short faults, rarely traceable for more than a few meters. The discontinuity of the faults suggests that the displacements along them are small; there are no markers in the granitic country rock, however, to show the amounts of displacement. Some of the minor mineralized fractures make up moderately long mineralized zones, as at San Antonio, where a zone was mapped for 1,200 meters. (See p. 103.) Lamprophyre dikes here, unlike many of those at gold and copper mines in north-central Chile, had no bearing on the mineralization.

MINERALS

Tungsten ore usually occurs as scheelite ($CaWO_4$) in the Chilean deposits, commonly in medium to coarse grains with a strong tendency to form crystal faces. Under ultraviolet light it fluoresces bluish white to light yellow, showing the presence of molybdenum in the yellow parts. Under ordinary light some of it is bright green, and although this type has been called cuprosheelite, it probably is what

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[1] Ruiz, Carlos, Estudio geológico de la región Ojancos-Punta del Cobre; Anales del Primer Congreso Panamericano de Ingeniería de Minas Y Geología, Santiago de Chile, vol. 3, pp. 1199–1205, 1942.

[2] Muñoz Cristi, Jorge, Geología de la región de Longotoma y Guaquen en la Provincia de Aconcagua, con la carta geológica provisoria: Bol. de Minas y Petróleo, vol. 8, pp. 272–281, 1938.

F. L. Hess[3] considered a mixture of scheelite and cuprotungstite ($CuWO_4.2H_2O$)—or, according to Schaller,[4] $WO_3.2CuO.H_2O$—which results from reaction with copper minerals that are in the process of being oxidized.

Wolframite ($(Fe, Mn)WO_4$) is said to have been an important ore mineral at one deposit, the Castañeda de Llamuco, where a little was seen in the dumps in 1944. At that time scheelite was much more abundant there than wolframite.

Vein minerals associated with the scheelite and wolframite are quartz, black tourmaline, sericite and coarser white mica, amphibole, magnetite, coarse pink orthoclase, calcite, barite, pyrite (some of it bearing gold), chalcopyrite, bornite, molybdenite, arsenopyrite, and galena; also minerals resulting from oxidation, such as azurite, malachite, and abundant limonite. No one deposit contains all these minerals; the assemblages and proportions vary somewhat within any one district and even more so from one district to another. The more abundant and widespread minerals are quartz, tourmaline, pyrite, chalcopyrite, and the products of weathering. Only one deposit, Minillas, lacked abundant tourmaline.

The time sequence for the entire series of minerals is difficult to determine, partly because it is far from complete at any one place and partly because of the great capacity of some of the minerals, notably tourmaline and pyrite, to form euhedral crystals when replacing other minerals. In general, the orthoclase, tourmaline, and quartz were early, tourmaline being earlier than quartz at El Durazno, and at least some quartz being earlier than tourmaline at San Antonio; calcite and sulfides were later.

TYPE, SIZE, AND GRADE OF ORE DEPOSITS

Fitting the Chilean tungsten deposits into a simple classification of ore deposits is difficult. The best generalization that can be made is that the deposits are replacements of granitic rock. At least the earliest part of the mineralization—that responsible for orthoclase, amphibole, magnetite, white mica, coarse tourmaline, and probably scheelite—occurred at moderately high temperature, and was according to some classifiers, pneumatolytic. The coarse texture and the presence of some of the minerals associated with the scheelite led some investigators to call the deposits pegmatites.

Too little of the tungsten ore was in sight at the time of the examinations to permit direct observation of the form of the deposits. The

[3] Hess, F. L., Tungsten minerals and deposits: U. S. Geol. Survey Bull. 652, p. 32, 1917.

[4] Schaller, W. T., Chemical composition of cuprotungstite: Am. Mineralogist, vol. 17, pp. 234–237, 1932.

stopes and remnants of ore, however, suggest that the ore shoots were pod-shaped, and in some places sufficiently tabular to be called short veins.

All mined ore bodies were small except at the Castañeda de Llamuco mine. Here, in 1944, an open stope from which tungsten ore had been mined was about 20 meters long, 10 meters wide, and about 20 meters high. Above the stope, an open-cut averaging 20 meters in diameter and between 20 and 30 meters deep was said to have yielded tungsten ore. These workings, however, show the order of magnitude of combined copper and tungsten ore bodies and not solely that of the tungsten ore shoots. Workings at the San Antonio group of mines were mostly inaccessible, but the small size of dumps probably indicates that the workings were short. The largest ore bodies at other properties were about 15 to 20 meters long, 1 or 2 meters wide, and a few meters in known depth.

The ore shoots may have been rather high grade, as the coarse-grained scheelite was almost entirely sorted by hand. The grade of most of the ore mined could not be determined with certainty, but a stock pile at the El Durazno concentration plant was said [5] to contain between 1.2 and 2 percent WO_3.

All the deposits were so poorly exposed or thoroughly mined out that it was impossible to infer reserves of ore.

DESCRIPTIONS OF MINING PROPERTIES

The tungsten deposits are grouped for convenience into regions referred to the nearest well-known town on the railroad.

SALAMANCA REGION

CASTAÑEDA DE LLAMUCO MINE

The Castañeda de Llamuco deposit is 20 kilometers in a direct line northeast of Salamanca in the Province of Coquimbo; it is somewhat farther by the mountain road up the Chalinga Valley. Salamanca is at the end of a railroad branch, between 20 and 25 kilometers from the trunk line at Choapa, which is south of Illapel.

At Castañeda de Llamuco, tungsten was recovered from what was primarily a copper mine dating from the ninteenth century. A small quantity of tungsten was produced during World War I, and a little more has been recovered from the dumps since that time. No mining was going on in 1944, but most of the workings were accessible.

A small concentration plant used in 1944 for treating tungsten ore from the dumps consisted of a jaw crusher, jigs, simple grinders, and two tables. The capacity was said to be 60 tons of ore daily. A seri-

[5] Tomás Glove, personal communication, 1944.

ous difficulty was the separation of scheelite from arsenopyrite, which has about the same specific gravity and which was highly undesirable in the concentrates. The plant was not operating in July 1944, and the few tons of concentrates produced from the dumps were sorted by hand.

Copper was recovered from the mine by turning water into the upper workings; the water soaked through the mine and ran out the lowest adit, where the copper was precipitated on scrap iron.

The mineral deposits (pl. 21) are in relatively coarse-grained granite composed of predominant orthoclase, which is incipiently microperthitic, and moderately plentiful plagioclase, and quartz, biotite, hornblende, and accessory apatite and magnetite. A large mass of aplitic rock containing, nevertheless, scattered conspicuous phenocrysts, crops out 200 meters north of the deposit. The major part of this rock consists of micrograndular orthoclase and quartz, of aplitic nature; phenocrysts, as much as 3 millimeters long are largely andesine; a few smaller phenocrysts, rarely 1 millimeter in diameter, are microperthite in clusters, with quartz, and rarely biotite.

Altered lamprophyre dikes about 5 meters thick intruded the granite and porphyritic aplite. The original rock probably was similar to the dark-colored dikes that are common in Chilean mineralized zones and which have been grouped as lamprophyre. The rock is now composed of a felty mass of albite laths, interstitial chlorite, and a conspicuous quantity of magnetite.

No obvious major structures controlled the mineralization. Joints determined the position of some minor veins and the details of dissemination. Some faults and premineral breccia were seen in underground workings, but they seem to be local. Most of the veins strike between north and northeast; however, a rough alinement of the mineralized areas trends westward and is emphasized by being in line with a wide zone of tourmalinized breccia on the west, which itself is elongate westward. (See pl. 21.)

The conspicuous tourmalinized breccia of granite crops out on the ridge above and west of the mine, in an area about 300 meters long and 160 meters wide, narrowing toward the west. Some large blocks that have rolled down the steep hillside as far as the road are in some places sufficently well buried to resemble outcrops. The breccia consists of angular blocks, 10 to 25 centimeters in diameter, and interstices filled with black tourmaline. Some of the larger angular interstices are filled with concentric zones of coarse black tourmaline, coarse subhedral quartz, and in the central part large grains of anhedral calcite containing a few clusters of barite.

The origin of the breccia is obscure. No faults could be discovered extending from the zone of breccia, therefore the pluglike mass cannot be called a pocket of breccia along a major fault zone or at the intersection of several faults.

Neither tungsten nor copper minerals were seen in the breccia. Bright stains from oxidation of copper minerals are lacking, in strong contrast to weathered outcrops of the nearby ore-bearing deposits. An ultra-violet lamp revealed no scheelite.

The ore shoots are east of the breccia. Two steeply plunging ore zones about 50 meters apart are exposed in pits that are 20 to 35 meters in diameter and at least 25 meters deep (pl. 21), and a third steeply plunging zone was exposed only in underground workings about 100 meters east-southeast of the eastern pit. Tungsten, according to the operators, was mined from only one of the ore zones—the one exposed in the eastern pit, whereas copper was mined from all the zones. Mine workings as represented on the composite map (pl. 22) locate the three zones, and the geologic maps of the three main levels (pl. 3) show some of their details. Inspection of the mine maps brings out the facts that the northwestern mineralized mass plunges about 75° SW. between the surface and the Planes level; that the northeastern mass plunges about 85° NW. down to the Norte level and has not been intersected by the other levels; and that the southern zone, although poorly defined at the surface, plunges roughly 75° SW. to the Casa level and was not intersected by the underlying Planes level.

The mineralization produced black tourmaline, quartz, sericite, and pyrite as replacements of the granite, in some places as veins; and quartz, scheelite, arsenopyrite, white mica, some chalcopyrite, coarse galena, pyrite, calcite, and a little wolframite in veins. Some of the chalcopyrite was replaced by chalcocite and some was oxidized to azurite, malachite, and limonite. Part of the scheelite is bright green and probably contains cuprotungstite.

The one tungsten ore shoot seems to have been at the northeast pit and the underlying workings. The large dump east of the pit (see pl. 21) contained, in 1944, considerable coarse scheelite and was considered by the operators as the chief reserve of measurable ore. In the stope on the Norte level, 70 meters below the surface, under the east pit, massive quartz on the eastern and southern walls contained coarse scheelite, commonly 1 centimeter in diameter. It was mostly associated with pockets of fine-grained white mica and some arsenopyrite and chalcopyrite, but not with tourmaline, which was abundant in the surrounding rock. No wolframite was seen in place. The grade of ore was said to have been 7 percent WO_3.

Isolated occurrences of a few grains of scheelite that were detected with an ultraviolet lamp are shown on the geologic maps of the Planes and Casa levels (see pl. 23A, C). The three levels were examined carefully with the ultraviolet lamp without finding more scheelite. The few occurrences were generally in quartz-sericite stringers, within tourmalinized zones; some were merely a few grains scattered through the replaced granite.

The only recommendation offered for future exploration for tungsten ore is to sink at the northwest side of the stope on the Norte level, or attempt to intersect the same ore body by driving a crosscut for at least 75 meters normal to the adit on the Planes level on the north side at 95 meters from the portal.

PICHE PROSPECT

Because the Piche prospect, the property of the Compañía Minera Llamuco, has been called Llamuco, it is included here primarily to differentiate it clearly from the Castañeda de Llamuco property described above, which also has been referred to as Llamuco. The Piche 1 to 8 claims are across the El Tome Valley, east of the well-known Castañeda de Llamuco mine.

The one small working, which consists of an inclined shaft about 10 meters down to a drift 7 meters long, is in granitic rock and follows a minor fault that controlled some rock alteration. Limonite and a little copper staining were about the only signs of ore mineralization; an ultraviolet lamp showed no trace of scheelite. On the dump, however, the lamp disclosed a little scheelite in a mineral assemblage that is unlike any seen in the working but that is typical of the Castañeda de Llamuco mine.

DOMEYKO REGION

EL DURAZNO DISTRICT

The tungsten deposits in the El Durazno district, Province of Atacama, are 36 kilometers by unimproved road east of Cachiyuyo, which is a station on the railroad and which is on the longitudinal highway (fig. 8). Cachiyuyo is 11 kilometers by highway south of Domeyko, and 67 kilometers south of Vallenar, the principal city in this part of Atacama.

The deposits are almost entirely in granodiorite, and to a minor extent in aplite, of the Andean diorite complex. The contact between the granodiorite and aplite is not well exposed on the gentle slopes of the area, and on the map it is drawn very approximately. (See pl. 24.) Mesozoic andesite and volcanic breccia are exposed within a few kilometers west of the road to Cachiyuyo. The granodiorite about 500 meters southeast of the Boliviana mine (see pl. 24) contains 50 percent or more of inclusions of a dark porphyritic rock that appears similar to that in zones near the contact with Mesozoic volcanic rocks. It is possible, therefore, that the roof of the intrusive rock in the

Boliviana area was stripped by erosion a short distance above the present surface.

Alternation of the granodiorite and aplite, principally to sericite and some quartz and to pockets of black tourmaline, is conspicuous at the tungsten deposits and also at nearby localities where tungsten is lacking.

No major structures are exposed. Joints and minor discontinuous faults somewhat erratically localized the mineralization. Joints in the area around the Boliviana mine perhaps form an obscure system composed of essentially vertical joints striking N. 10° to 15° W., and of other joints striking N. 20° to 40° E., dipping steeply east. Minor vertical joints strike east. Mineralization in a general way, although not necessarily in detail, favored the northeast fractures.

Minerals of the deposits, roughly in chronological order, are: coarse amphibole with closely associated magnetite, coarse-grained pink orthoclase, coarse-grained black tourmaline, massive white quartz, calcite and scheelite, pyrite, chalcopyrite, and supergene copper and iron minerals. The coarse-grained amphibole and magnetite were seen in prospect pits several hundred meters from the tungsten deposits. Black tourmaline is the most conspicuous and most widely distributed mineral of the assemblage. Much of it is in large euhedral or subhedral crystals in clusters that tend to extend radially from points or planes. The tourmaline appears to have replaced altered granodiorite rather than to have lined open vugs and fissures. A very little of the tourmaline is nearly colorless. Massive quartz later replaced the rock that remained in some of the clusters, thus misleadingly seeming to fill open spaces between the tourmaline crystals. Moderately coarse grains of scheelite formed around some of the tourmaline crystals in quartz, but more scheelite occurs with quartz in sericitized granodiorite. Calcite, in some places darkly stained with manganese, is in grains that range in size up to 30 centimeters. Chalcopyrite was seen in some of the calcite, and was the source of copper stains in weathered outcrops. Scheelite is the only tungsten ore mineral.

An ultraviolet lamp was used to examine the workings on the Boliviana property and others within a kilometer to the south and southwest. The surface of the mapped area (pl. 24) also was examined with the lamp, and scheelite float marked on the map. Scheelite was seen in place at the Boliviana mine and in a pit on the ridge 240 meters east of the mine, and traces in a granite outcrop 115 meters south of the pit. Scheelite float containing considerable quartz and tourmaline was seen within a few hundred meters of the northeast edge of the mapped area. Other belts of tourmaline flat, such as the north-trending one about 200 meters northwest of the Boliviana mine, and the tourmaline outcrop at the road about 50 meters northeast of the mine, showed no scheelite under the lamp.

A thousand meters or so south of the Boliviana property, an inclined working about 25 meters long showed scheelite with tourmaline and quartz for 20 or 30 centimeters at the lower end. Several grains of scheelite were seeen in a 15-meter adit about 500 meters southeast of the Boliviana. Otherwise no scheelite was seen in any of the small workings and prospect pits. Little scheelite remained in the walls of even the Boliviana mine. The high-grade, coarse-grained scheelite specimens from the mine, and the ore stock-piled at the concentration plant must have been in pockets that were mined completely.

The scheelite remaining in place and in the float was too sparse and spotty in occurrence to permit valid sampling.

BOLIVIANA MINE

The principal workings of the district are in the Boliviana mine, which was mapped by Herbert Hornköhl for the Caja de Crédito Minero. His map is reproduced in figure 9 to show the small extent of mining. The deepest part in 1944 was about 20 meters below the surface, and the greatest length was 50 meters at about 10 meters below the surface. This was the principal exploration working, and it extended southwest into fresh granodiorite. The accessible entrance in 1944 was the steeply inclined irregular working in the southern part of the mine; a vertical shaft connected to levels in the northern part. The minor workings north of the shaft were inaccessible at that time.

The mine followed an essentially vertical, poorly defined zone of fractures, consisting mostly of joints but also of some rather short faults, probably of minor displacements. The fractures were channels for hydrothermal solutions that sericitized and spottily silicified the granodiorite.

Large lenses and other more irregular masses of coarse black tourmaline, some nearly horizontal and others practically vertical, are distributed unsystematically through the zone. Some of the mineral pockets are made up of a concentric shell of pink orthoclase around a center of quartz, or of tourmaline around quartz. The shape of the irregular workings suggests that two overlapping ore shoots 15 to 20 meters long plunged 40° S. Almost no scheelite remained in the walls.

No reserve of ore could be inferred.

MINILLAS PROPERTY

The Minillas gold-tungsten property is about 14 kilometers in a straight line due north of Domeyko, a station on the main railroad and about 53 kilometers south of Vallenar by the longitudinal highway. An automobile can be driven to within a few kilometers of the property.

The Minillas deposits are entirely in granodiorite, several hundred meters from its intrusive contact with Mesozoic volcanic rocks of the

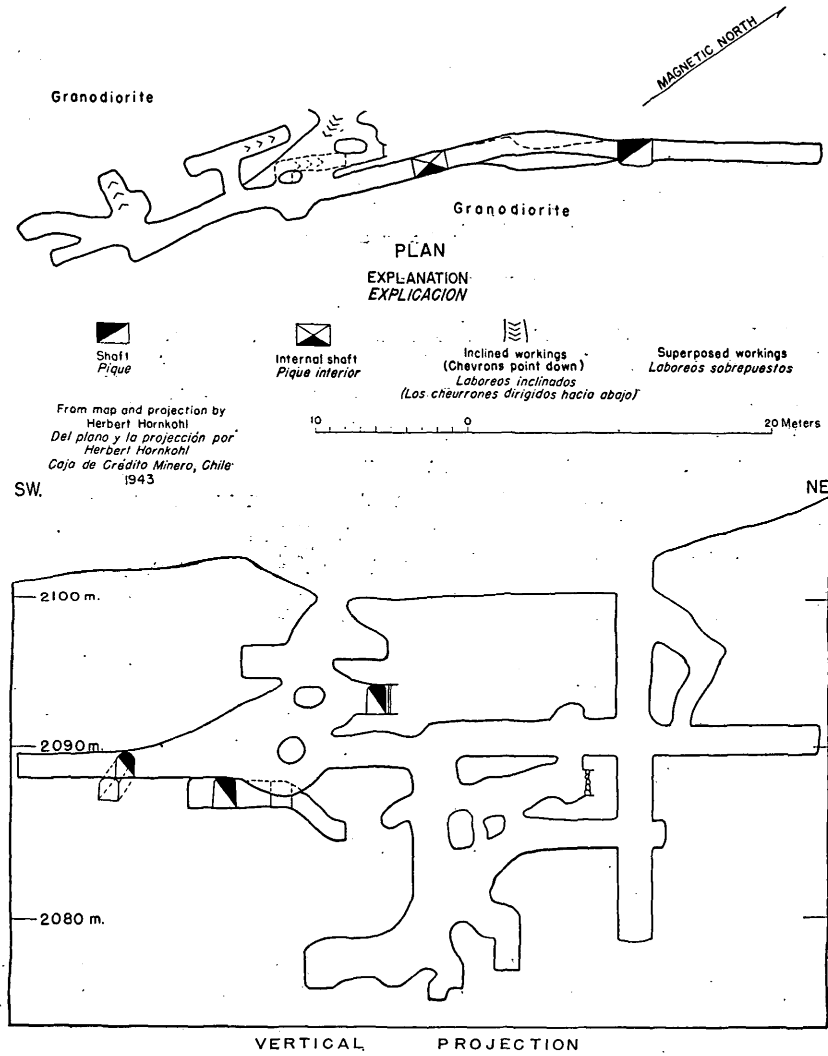


FIGURE 9.—Plan and vertical projection of the Boliviana tungsten mine, El Durazno district, Domeyko, Chile.

Porfiritica formation. The map of the Minillas area (pl. 25) is too small to show these volcanic rocks. The granodiorite is medium-grained, and consists of predominant plagioclase, abundant orthoclase and quartz, a moderate quantity of bioite, some hornblende, and accessory magnetite and apatite. It is altered in places along vein zones to rock of fine-grained white mica and quartz, and at others is merely kaolinized and stained with limonite.

The only other rock in the area mapped is a fine-grained, greenish-gray, altered dike rock tentatively called lamprophyre. It is composed of a felty mass of andesine laths (about Ab_{64}) commonly 0.5 millimeter long and a tenth as wide, and interstitial chlorite, calcite and abundant magnetite.

No conspicuous structure was found in the area. Mineralization followed three zones of minor fractures, which strike N. 70° E. and dip steeply north or south. Joints are not obviously systematic, although there is a tendency for them to strike northwest rather than parallel to the veins, and to dip northeast or vertically. The lamprophyre dike also trends northwest, and near the curve in outcrop dips 70° NE. (See pl. 25.)

The tungsten ore mineral at Minillas is scheelite; some of the scheelite, which is green, may be mixed with cuprotungstite. The scheelite is in large grains, commonly 3 centimeters across. Associated with it are a little quartz, remnants of unoxidized pyrite, and considerable limonite from oxidized pyrite. Some cooper carbonate strains indicate that probably chalcopyrite was part of the original mineral assemblage.

The workings as well as the surface of the mapped area were examined with an ultraviolt lamp. Scheeelite was seen in the vertical pit marked A on plate 25; a little of it in workings B, and some in the dump of a pit 50 meters southwest of A, along the same vein. No scheelite was seen in the short adit at C, or in the more extensive workings along the southeasternmost of the three veins, which was worked solely for gold.

The principal tungsten ore shoot was mined at workings A, a vertical projection of which is shown in figure 10. Sheelite remaining in the walls, as shown in the figure, indicates that pockets of ore occurred over a vertical distance of 15 meters, and over a total horizontal distance of about 7 meters. The average stope length, however, was about 3 meters and the usual width between 1 and 2 meters. In the floor, a well-defined vein of quartz with limonite after pyrite contained scheelite over a length of 50 centimeters but the vein did not reach the roof 2 or 3 meters above the floor.

Other small pockets of tungsten ore may exist at depth, but there was no basis for estimating inferred reserves of ore.

VALLENAR REGION

In this group of the Vallenar region are considered the San Antonio deposit and the Zapallo de Chehueque deposit, which are about 27 kilometers in a straight line northeast of Vallenar. These deposits, which are southeast of Cerro Chehueque and west of Cerro Grandon, are reached by a mountain road passable in automobile up the Quebrada del Jilguero for 30 kilometers, and by horse or foot the remaining 5 kilometers.

SAN ANTONIO MINING PROPERTY

The San Antonio mining property belonged in 1944 to the Compañía Minera San Antonio. The surface workings, showing the trend of

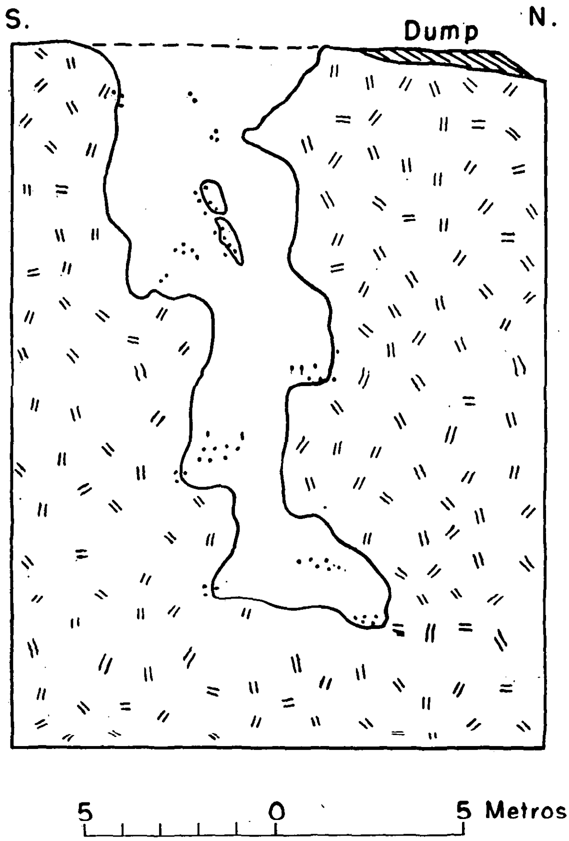


FIGURE 10.—Vertical projection of workings A, Minillas tungsten property, Domeyko, Chile.

the deposit, are represented on the geologic and topographic map of a part of the property (pl. 26). The country rock is hornblende-biotite granodiorite, cut by narrow dikes of aplite and lamprophyre. The granodiorite is moderately coarse textured, a common size of the grains being 2.5 millimeters. It consists in decreasing order of abundance of dominant plagioclase, orthoclase and quartz in about equal quantities, biotite, hornblende, and accessory magnetite and apatite. Some of the hornblende and biotite are deuteric alterations of pyroxene, of which remnants are distinguishable. The aplite is typical, but some of it contains pegmatite cores. The dark gray, fine-grained lamprophyre is composed of hornblende and plagioclase. In some places it contains conspicuous radial clusters of black tourmaline, 5 centimeters in diameter. The contact of the dike with granodiorite is sharp and chilled.

Individual structures that controlled mineralization—such as joints and shears—are local and discontinuous. They tend, however, to comprise long zones of mineralized local structures. Segments of the zones are somewhat en echelon, particularly at the eastern end. (See pl. 26.) No well-defined system of joints was observed. The strikes of both types of dikes may change so that the traces of the dikes on the surface do not necessarily express the attitudes at depth. For instance, the lamprophyre dike clearly dips 45° N. in a pit, yet the trace to the west continues straight, as if the dip were vertical. Similarly, the north aplite dike dips 60° S. in a pit, yet the trace continues straight over the hill.

The tungsten ore mineral, seen in dumps but rarely in place, is relatively coarse-grained scheelite. It is associated with black tourmaline, quartz, actinolite, chalcopyrite, molybdenite, bornite, copper minerals of oxidation, and limonite. The scheelite is light buff rather than white and usually occurs in euhedral or subhedral crystals 1 to 2 centimeters long. Some scheelite set in massive fine-grained tourmaline is cut by stringers of tourmaline; one euhedral grain showed tourmaline along two minute shears that displaced the middle segment. Another euhedral grain of scheelite showed small inclusions of tourmaline that formed narrow bands parallel to two of the faces, suggesting that some of the two minerals crystallized simultaneously. In the same grain, however, tourmaline lined a small vug in the center of the scheelite. The tourmaline was later than at least some of the quartz, because the quartz had brecciated and filled interstitially with fine-grained tourmaline. The quartz is also cut by fine-grained stringers of tourmaline. Molybdenite was seen in flakes as much as 1 centimeter in diameter in stringers of tourmaline, quartz, and chalcopyrite. One occurrence of scheelite was noticed in the lamprophyre dike, where scheelite containing a few needles of tourmaline formed a small elongate eye with indistinct boundaries. A little chalcopyrite and bornite were associated with the scheelite in the lamprophyre.

The veins contain also some gold and silver, shown in an assay reported to Ing. Jorge Hevia.[6] The assay showed: copper, 7.75 percent; gold, 1.0 grams per ton; and silver, 20.0 grams per ton.

[6] Hevia, Jorge, Manuscript report in files of the Caja de Crédito Minero, Santiago, Chile.

As the principal workings at San Antonio in 1944 were caved or had slumped full of waste, and as dump material covered much of the intervening parts, there were almost no good exposures of the veins. The veins observed ranged from single stringers to zones of veins, or lodes, 50 centimeters thick. A common thickness was about 20 centimeters. Even the best veins, from San Antonio adit eastward, seemed to have been mineralized erratically, and contained only local pockets. The dips in the main western part of the area are moderate, between 45° and 55°, steepening to 75° in the eastern part.

The main zone of veins extends eastward from the caved Adelaida shaft, down the hill to the Changallo inclined shaft, over to the San Antonio adit, and up to the top of the ridge. The zone still farther east, as indicated by the series of prospect pits (pl. 26), is discontinuous, and the segments are somewhat en echelon. A branch trends at an acute angle toward the north. Another small-angled branch toward the north starts about 75 meters east of the Adelaida shaft and is insignificant 150 meters beyond. Up to where the zone branches good showings of scheelite were scattered along the dumps, although no scheelite was seen in place. Some of the dumps 70 to 90 meters below on the hillside also contained scheelite, but the pits had slumped, covering possible outcrops. Diggings along another minor vein about 140 meters south of the Changallo shaft had scheelite in one of the dumps. Coarse and abundant scheelite, perhaps as much as 2 percent, was seen in the Adelaida dump, in the dumps at Changallo and San Antonio, and on the top of the ridge. In San Antonio adit, which is about 52 meters long, very little scheelite remained. An inclined winze near the face was flooded. The accessible part of the working showed only a little vein material, erratic in size and shape, which was chiefly tourmaline.

Insufficient scheelite was seen in place to permit an inference as to reserves of ore. The abundance of coarse scheelite in some of the dumps favors the idea of further exploration should it become economically feasible.

ZAPALLO DE CHEHUEQUE MINING PROPERTY

The tungsten deposit on the Zapallo de Chehueque property is about 4 or 5 kilometers by trail northwest of the San Antonio property. It can be reached either by going up the Quebrada San Antonio tributary of the Jilguero and then westward along the ridge, or by going up the first parallel tributary west of San Antonio to several hundred meters north of the divide. The peak shown on the map of the deposit (pl. 27) is at the head of the tributary.

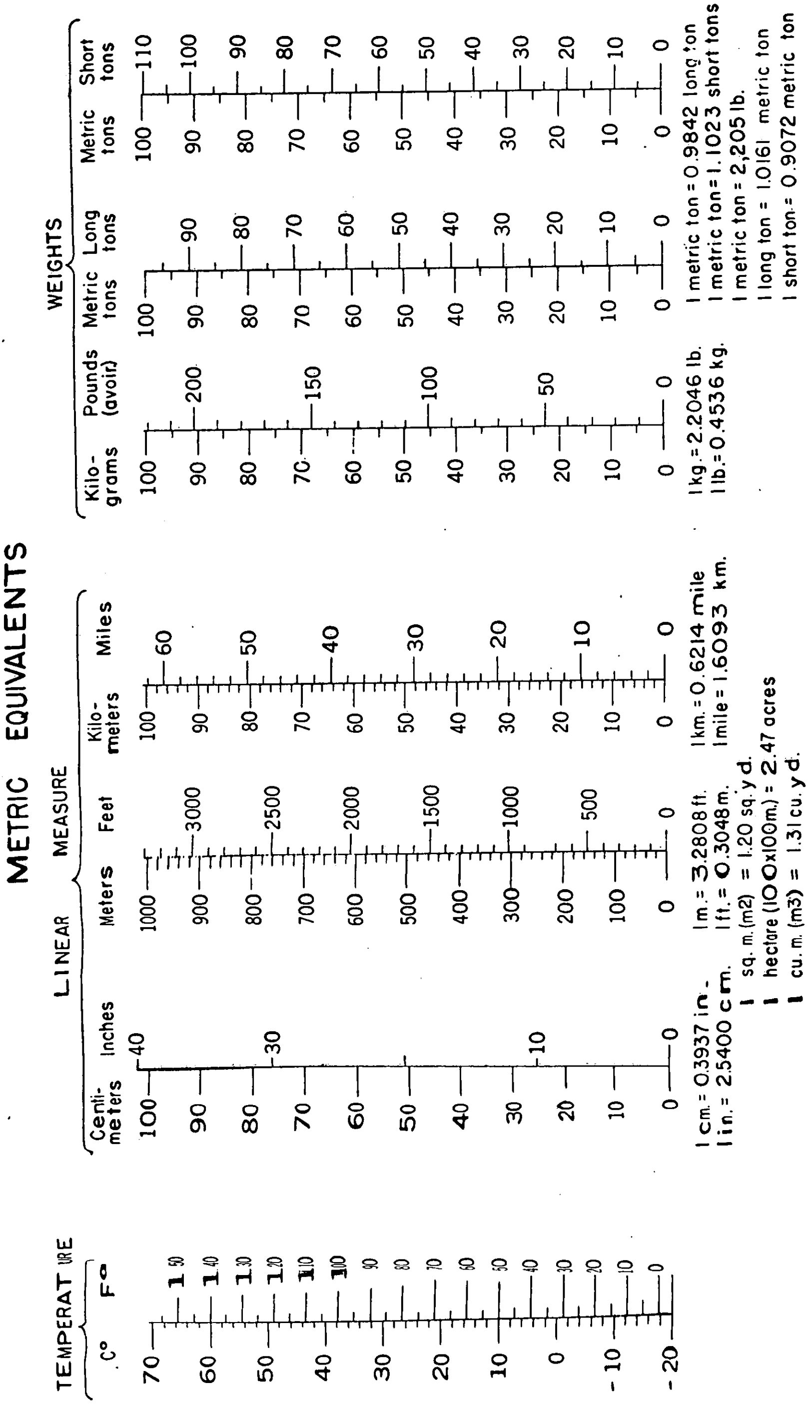
The predominant rock of the area is rather fine grained, hornblende-biotite-quartz monzonite, a facies of the Andean diorite complex, and contains as much or slightly more orthoclase than plagioclase and rather abundant quartz. There is somewhat less hornblende than biotite. Other facies contain some coarser-grained biotie than poikilitically encloses the other minerals. There is some aplite but no lamprophyre.

The main structure is a fault that strikes about N. 80° E. and dips between 55° and 65° N., but seems to die out shortly on both sides of the principal working. The chief scheelite vein follows the fault. Joints and minor shears strike consistently northeast and dip either vertically, or between 45° and 65° N. The aplite strikes N. 55° E., which suggests that the joints may have formed early.

The ore mineral is scheelite. It tends to be light buff in color, and most of it is associated more or less closely with black tourmaline and coarse gray quartz. Other associated minerals are needles of relatively fine-grained actinolite, chalcopyrite, pyrite, and supergene copper and iron minerals. There is some orthoclase, which may have been part of the rock that was mineralized.

The best scheelite was seen in the south walls of the long trenches that extend eastward, where it occurs sporadically over a total distance of 80 meters. (See pl. 27.) A little was seen in the next dump to the east, but none in the tourmaline-quartz vein that was exposed 20 meters farther east. No outcrops of the vein were found beyond the mapped area. Pits 60 meters west of the western end of the trenches contained scheelite. Scheelite may occur at the fork of a northwestern branch vein along which scheelite float was seen. The shallow pits were nearly filled with slumped material. Southeast of the long trenches traces of scheelite in outcrops of the granitic rock, either in stringers of tourmaline, or alone, fluoresced. Float of coarse tourmaline and quartz, containing some scheelite, was found as much as 130 meters southeast of the eastern end of the trenches toward the peak, but the source was not discovered.

An inclined adit, heading eastward along the vein from the western end of the trenches, had slumped and was accessible for only 15 meters. It exposed a vein, 12 to 15 centimeters thick, of tourmaline, some scheelite, pyrite oxidized to limonite, and other minerals resulting from weathering. A wider zone contains parallel stringers, some of which appear aplitic and contain scheelite, in rock little altered except by weathering.


METRIC EQUIVALENTS
LINEAR MEASURE
Centi-meters
Inches
Meters
Feet
Kilo-meters
Miles
1 cm.= 0.3937 in.
1 in.= 2.5400 cm.
1 m.= 3.2808 ft.
1 ft.= 0.3048 m.
1 km.= 0.6214 mile
1 mile = 1.6093 km.
1 sq. m. (m2) = 1.20 sq. yd.
1 hectare (100x100m.) = 2.47 acres
1 cu. m. (m3) = 1.31 cu. yd.
WEIGHTS
Kilo-grams
Pounds (avoir.)
Metric tons
Long tons
Metric tons
Short tons
1 kg.= 2.2046 lb.
1 lb.= 0.4536 kg.
1 metric ton = 0.9842 long ton
1 metric ton = 1.1023 short tons
1 metric ton = 2,205 lb.
1 long ton = 1.0161 metric ton
1 short ton = 0.9072 metric ton
TEMPERATURE
C°
F°

INDEX