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W. E. Wrather, Director

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CONTENTS

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

		Page
(A)	Tungsten investigations in the Republic of Argentina, 1942–43, by Ward C. Smith and E. M. Gonzalez	1
(B)	Geology and chromite deposits of the Camagüey district, Camagüey Province, Cuba, by Delos E. Flint, Jesus Francisco de Albear, and Philip W. Guild	39
(C)	Aluminous lateritic soil of the Republic of Haiti, by Samuel S. Goldich and Harlan R. Bergquist	63
(D)	Optical calcite deposits of the Republic of Mexico, by Carl Fries, Jr	113
(E)	Manganese deposits of the Talamantes district near Parral, Chihuahua, Mexico, by I. F. Wilson and V. S. Rocha	181
(F)	Manganese deposits of Mexico, by Parker D. Trask and José Rodríguez Cabo, Jr	209

ILLUSTRATIONS

		Page
Plate 1.	Index map showing location of the tungsten deposits of the Argentine Republic	In pocket
2.	Map showing claims on the Cerro Morro tungsten property	In pocket
3.	Geologic and topographic map of a part of the Cerro Morro tungsten property	In pocket
4.	Geologic structure sections, Cerro Morro tungsten property	In pocket
5.	Geologic and topographic map of the Josefina tungsten mine	In pocket
6.	Plan and projection of main adits and partly completed main tunnel, Josefina mine	In pocket
7.	Josefina vein, Josefina mine, plan and projections of No. 1 adit and lower drift	In pocket
8.	Josefina vein, Josefina mine, plan and projections of adits 2, 3, 4, and 5	In pocket
9.	Primera vein, Josefina mine, plan and projections	In pocket
10.	Rica vein, Josefina mine, plan and projections of workings	In pocket
11.	Blanca vein, Josefina mine, plan and projections of workings	In pocket
12.	Sur vein main adits, Josefina mine, plan and projections	In pocket
13.	Sur vein upper workings, Josefina mine, plan and projections	In pocket
14.	Marchant vein, Josefina mine, plan and projection	In pocket
15.	Sketch map of San Antonio tungsten mine	In pocket
16.	Plan and sections of part of the Toro workings, San Antonio tungsten mine	In pocket
17.	Sketch map, Santo Domingo mine	In pocket
18.	Geologic map of the Camagüey chromite district, Camagüey Province, Cuba	In pocket

Page
PLATE 19. Geologic map and sections of the Victoria mine, Camagüey district, Cuba ... In pocket
20. Rochelois Plateau ... 72
21. Index map of the Republic of Haiti ... In pocket
22. Isopach map of aluminous lateritic soil deposits ... In pocket
23. Index map of Mexico showing location of optical calcite districts examined and relative importance of productive districts ... In pocket
24. Various vein structures in which commercial calcite occurs ... In pocket
25. Map and sections of the El Porvenir and El Caimán calcite deposits ... In pocket
26. Map and sections of the La Aurora calcite deposit ... In pocket
27. Sketch showing location of calcite veins mined near Areponápuchic, Chihuahua ... In pocket
28. Sketch map and section of the El Murciélago calcite district, southeast of Manuel Benavides, Chihuahua ... In pocket
29. Map and section of the La Esmeralda calcite deposit, near Guagüeybo, Chihuahua ... In pocket
30. Geologic map and section of the La Fe calcite deposit, near Rodeo, Durango ... In pocket
31. Map and sections of the La Flor de Esperanza calcite deposit ... In pocket
32. Map and section of the La Perla calcite deposit ... In pocket
33. Cliffs of rhyolite ... 184
34. Geologic map and structure section of the Talamantes manganese district, State of Chihuahua, Mexico ... In pocket
35. *A*, Hill east of the Mesa de Talamantes; *B*, East side of the Mesa de Talamantes, showing fault-line scarp formed by La Concepción fault ... 192
36. *A*, Specimen of typical ore from San Antonio mine; *B*, Specimen of ore from San Antonio mine ... 200
37. *A*, Specimen of psilomelane from San Antonio mine; *B*, Hand jigs used to concentrate manganese ore at the San Antonio mine ... 201
38. Map and longitudinal sections of the San Antonio manganese mine ... In pocket
39. Index map of Mexico, showing distribution of manganese deposits ... 214
FIGURE 1. Index map of Cuba showing location of the Camagüey chromite district ... 40
2. Sketch of face at Lolita mine, Camagüey Province ... 54
3. Schematic section showing inferred origin of the Camagüey ultramafic complex ... 59
4. Variations of the principal chemical constituents, Ste.-Croix deposit ... 80
5. Sketch map of trenches, Lachicotte Valley, Beaumont, Haiti ... 88
6. Belt of low-silica aluminous lateritic soil deposits in the West Indies ... 103
7. Proportions of Al_2O_3:Fe_2O_3:TiO_2 in lateritic soils and in igneous rock families ... 105
8. Drawings of calcite crystal forms: rhombohedrons ... 121
9. Drawings of calcite crystal forms: scalenohedrons and base ... 122

Page

FIGURE 10. Drawings of calcite crystal forms: first- and second-order prisms and second-order pyramid 124
11. Drawings of the four types of calcite twin crystals 125
12. Drawings of a twin crystal typical of those found near Areponápuchic, Chihuahua 126
13. Drawings of cleavage rhombohedrons showing positions of twinning planes and some defects in optical calcite 127
14. Drawings of cuts made from smallest cleavage rhomobohedron accepted for suboptical use, and of a common crystal habit in southwestern Chihuahua 133
15. Drawings of a plate of calcite typical of those in the La Fe deposit near Rodeo, Durango 134
16. Index map of Mexico showing location of the Talamantes manganese district 182

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Bulletin 954-A

TUNGSTEN INVESTIGATIONS IN THE REPUBLIC OF ARGENTINA, 1942-43

BY

WARD C. SMITH AND
E. M. GONZÁLEZ

Prepared in cooperation with the

DIRECCIÓN GENERAL DE MINAS Y GEOLOGÍA, REPUBLICA ARGENTINA
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CONTENTS

	Page
Foreword	1
Acknowledgments	2
Cerro Morro tungsten mine, Province of San Luis	2
Summary statement	2
Introduction	3
General geology	5
Ore deposits	8
Mineralogy	8
Origin	9
Grade and size of the ore bodies	9
Recommendations for increasing production	10
Mine workings	10
Josefina tungsten mine, Province of Mendoza	12
Summary statement	12
Introduction	13
Production	15
Geology	15
Schist and gneiss	15
Intrusive rocks	16
Structure and its relation to the veins	17
Alterations of the schist and gneiss	19
Ore deposits	20
Mineralogy	20
Origin	21
Grade of the ore bodies	21
Reserves	22
Description of the veins	23
Josefina vein	23
Primera vein	23
Rica vein	24
Blanca and Sur veins	24
Marchant vein	26
San Antonio tungsten mine, Province of Catamarca	26
Summary statement	26
Introduction	26
Location and transportation	27
Climate, vegetation, and water supply	28
History and production	28
Acknowledgments	29
Geology	29
Schist contact	30
Ore deposits	31
Mineralogy	31
Grade of the ore	32
Size of the ore bodies	32
Future production and reserves	34

	Page
Santo Domingo tungsten mine, Province of San Luis	34
Introduction	34
Geology	35
Occurrence of scheelite	35
Grade of the ore	36
Index	37

ILLUSTRATIONS

PLATE 1.	Index map showing location of the tungsten deposits of the Argentine Republic	In pocket
2.	Map showing claims on the Cerro Morro tungsten property	In pocket
3.	Geologic and topographic map of a part of the Cerro Morro tungsten property	In pocket
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9.	Primera vein, Josefina mine, plan and projections	In pocket
10.	Rica vein, Josefina mine, plan and projections of workings	In pocket
11.	Blanca vein, Josefina mine, plan and projections of workings	In pocket
12.	Sur vein main adits, Josefina mine, plan and projections	In pocket
13.	Sur vein upper workings, Josefina mine, plan and projections	In pocket
14.	Marchant vein, Josefina mine, plan and projection	In pocket
15.	Sketch map of San Antonio tungsten mine	In pocket
16.	Plan and sections of part of the Toro workings, San Antonio tungsten mine	In pocket
17.	Sketch map, Santo Domingo mine	In pocket

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TUNGSTEN INVESTIGATIONS IN THE REPUBLIC OF ARGENTINA, 1942–43

By Ward C. Smith and E. M. González

FOREWORD

This is a progress report describing four tungsten mines in the Republic of Argentina that were examined between October 1942 and May 1943. The work leading to this report was carried on by the Geological Survey, United States Department of the Interior, and Dirección de Minas y Geología, Ministerio de Agricultura de la República Argentina. This work was part of a larger cooperative program sponsored by the Interdepartmental Committee on Scientific and Cultural Cooperation and was carried on under the auspices of the United States Department of State. It is hoped that this cooperative work will be continued, for it is not only of direct practical use to miners but of high scientific interest.

It was the special and varied scientific interest attached to these particular mines that chiefly determined their being selected for study. They provide examples of mineralization by the two tungsten ore minerals important in Argentina, wolframite and scheelite; they exemplify ore bodies of different types; and they are widely separated geographically. Equally important was their economic interest; these mines contribute substantially to Argentina's tungsten production. Of the 1,923 tons of concentrates produced in 1942 by the 50 or 60 active tungsten mines in Argentina, the first three mines described in this report produced about 125 tons, and they may be capable of producing 200 or 300 tons per year. A hope of helping to bring about an increase in the production of the three mines made them well worth examining. The fourth property investigated was only a prospect, and although it was reported to have promise of becoming a large producer the examination seemed to show that it has little value.

As this is a progress report, the material in it is presented as separate descriptions of four mines, without any attempt at making the generalizations that might result from a comprehensive study. Each of the mines illustrates, in a different and interesting fashion, control of ore deposition by the structure or composition of the country rock. An understanding of such control helps one to judge the probable extent of an ore deposit and consequently to predict its future productivity, and it is therefore especially valuable in the development of mines that, like many in Argentina, have not been systematically explored and sampled.

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CERRO MORRO TUNGSTEN MINE, PROVINCE OF SAN LUIS

SUMMARY STATEMENT

Operations were begun in 1937 at the Cerro Morro mine. The mine produced in each of the years 1941 and 1942 about 25 metric tons of scheelite concentrates, with an average WO_3 content of about 65 percent. The production during the years 1937–40 is unknown but was probably smaller than that for 1941–42. An ore supply adequate for continuing production for at least 2 more years at the 1942 rate seemed assured. This is inferred from the geologic character of the ore deposit and from its extent; ore is exposed at many headings in small workings scattered through a belt 3 kilometers long. The reserves cannot be classed as measured, however, for no bodies of ore are blocked out.

The ore bodies are in metamorphosed parts of limestone beds. The ore consists of disseminated scheelite in a gangue of epidote, actinolite, and chlorite, and is thus mineralogically similar to some contact-metamorphic tungsten ores, although no igneous contact is exposed near the deposits. Individual ore bodies are lenticular and commonly less than 30 meters long. As the limestones dip steeply and have extensive outcrops, it seems probable that they continue to considerable depth and that they contain concealed ore bodies that are much the same in size and grade as those at the surface. Before exploration at depth is undertaken, however, the value of the partly exposed bodies of disseminated ore should be determined by stripping and systematic sampling. The most promising place for deeper exploration is in the southern part of the property, near the group of wolframite-quartz veins once mined at the adjoining Loma Blanca mine. It is there that the largest bodies of disseminated ore occur, and some of these ore bodies are cut and locally enriched by crosscutting pegmatitic veinlets that contain scheelite.

The mine production might well be doubled by the installation of a small quantity of mine and mill machinery and by improved technical direction of mining and milling. As deeper workings are developed, the present simple hand methods of mining probably must give way to methods involving the systematic use of machinery. Any large increase in production would involve installing machinery for a larger mill and the opening up of more centralized, deeper workings.

INTRODUCTION

The Cerro Morro tungsten property (also known as Cerro Morro No. 1 and El Morro No. 1) is in the Province of San Luis, about 23 kilometers east of La Toma, a small town on the Villa Dolores branch of the Buenos Aires and Pacific Railroad (pl. 1). There is a truck road from La Toma to the mine, and all parts of the property are easily accessible. The Cerro Morro mine is the leading producer of a group that lies on the western piedmont of the isolated mountain known as Cerro del Morro.

The property, which consists of 19 claims, is owned and operated by Horacio Pérez Mendoza. The claims begin at the Arroyo del Dique and extend southward some 3,000 meters, covering a mineralized belt 200 to 300 meters wide (pl. 2). The belt continues both to the north and to the south, but the writers mapped only about 1 kilometer of its length, covering the southern third of the Pérez Mendoza property.

The field examination was made in the period February 4 to March 7, 1943, and its chief products were a geologic and topographic map (pl. 3) of areas surveyed by plane-table methods, and sketch maps of the underground workings surveyed by compass-and-tape methods. The party is indebted to Sr. Pérez Mendoza for a courteous reception at the property and to the mine officials, Sr. A. Perelli and Sr. C. A. Wareing, for suggestions during the field work.

Before the writers' visit, the tungsten deposits of the Cerro Morro mine had been studied less than those of the older Loma Blanca mine, which adjoins the Cerro Morro on the south. Long descriptions of the Loma Blanca were published by Beder[1] in 1913 and by Kittl[2] in 1930. The wolframite in the quartz veins of the Loma Blanca was discovered shortly before Beder's examination in 1913, and the veins were mined during the years 1914–18 and 1921–23. An attempt to revive the mine in 1929 resulted in legal controversy, and since then it has remained idle.

The ore bodies of the Cerro Morro were known in 1918, but, being relatively inconspicuous, they were considered unimportant. Little or no ore was mined until 1937, when contractors began working on a small scale. In 1938 an attempt to develop a large centralized mining operation was made by the American Mining Co., which held an option on the property for 11 months. The company sank a well-timbered two-compartment shaft, 80 meters deep, at a point 200 meters north of the boundary of the area shown on the geologic map that accompanies this report. Although crosscuts are said to have shown that the ore continued to the depth of the shaft, the company relinquished its option, and the shaft was later abandoned when contractors wrecked the timbers in taking ore from a 12-meter level.

At present, small-scale contract mining at scattered workings sustains a mill located on Arroyo del Dique. The mill has a capacity of 1¼ tons per hour and is said to mill 500 tons a month, with two shifts a day working. The ore goes through a 14- by 8-inch jaw crusher and a ball mill that is in closed circuit with a trommel having a 1-millimeter screen and then passes onto three concentrating tables. The fine grinding in the ball mill probably results in considerable loss of scheelite in the fines; also, the practice of tabling without proper classification gives an imperfect separation, so that making a clean concentrate probably involves a substantial loss of scheelite in tailings.

Water for the mill is taken from Arroyo del Dique. The supply has been adequate in every year but one, in which the mill was shut down for 2 months of the dry season. In normal years the water supply would suffice for three shifts in the present mill or a slightly larger one, but construction of a much larger mill would create a water problem.

All drilling is done by hand except at headings mined "on company account," for which there is a single jackhammer with a small compressor. The ore is hoisted by a hand windlass or by a horse hitched to a simple tripod-and-pulley arrangement. The miners who work for wages are paid about 4 pesos a day, but most of the mining is done by contractors, who are paid 80 centavos per kilogram (about 10 cents a pound) for the scheelite concentrate milled from their ore. The

[1] Beder, R., Las vetas con magnetita (martita) y las de wolframita de la pendiente occidental del Cerro Morro, Provincia de San Luis: Argentina, Direc. Minas, Geol. e Hidrol., Bull. 3, ser. B, pp. 1–15, 1913.

[2] Kittl, E., El yacimiento de wolfram de la mina "Loma Blanca," Provincia de San Luis: Rev. Minera, vol. 2, pp. 17–30, 33–55, 1930.

mine owner supplies drill steel and tools and trucks the ore to the mill. A scarcity of skilled miners, together with a lack of equipment, has restricted mining to shallow depths. Deep mining is avoided as much as possible, because at depths of 10 or 12 meters the rocks become somewhat harder, hoisting by hand takes much more time, and unsystematic mining makes the ground dangerous. Moreover, the ore bodies are lenticular, and when the ore thins out work stops, for a contractor cannot afford to do much dead work in searching underground for another lens. Each ore body is followed as far as the individual contractor thinks it is profitable, which generally is farther horizontally than downward. The old workings thus represent approximately the extent of the ore that was minable by the contractor's standard, but not, of course, that of the scheelite-bearing rock that was considered marginal or submarginal.

Samples are rarely taken in mining, and not often in milling. Some of the ore is inspected under ultraviolet light, but this great aid to scheelite mining and milling is not used as regularly as it might be. For the most part, both in mining and ore sorting, reliance is placed, a little precariously, on the miners' skill at seeing the scheelite.

GENERAL GEOLOGY

The mountain called Cerro del Morro consists mostly of schist and gneiss, and its topographic form is the joint result of erosion and faulting.[3] Broad gentle lower slopes surround its central mass, which has steep sides culminating in a dissected, rugged rim that encircles a central basin, so that the Cerro on the whole has a deceptive resemblance to a symmetrical volcano. Advanced erosion in the semiarid climate of the region produced the broad pediment encircling the steep-sided residual "cone," and graben faulting produced the central "crater." Several small hillocks of volcanic rocks are scattered along the main fault lines bounding the central basin, and remnants of surficial tuff deposits cover much of the pediment, but these are relatively small elements in the topography. The western pediment of Cerro del Morro slopes gradually downward, to end in an eroded strip of sharply dissected ground that extends along the upthrown (eastern) side of a northward-trending fault. West of the eroded strip the bedrock is covered by the recent alluvial fan deposits of the basin that contains the town of La Toma. It is within the eroded strip, where the bedrock is especially well exposed, that the tungsten deposits described in this report are found.

The bedrock in the tungsten belt is mostly schist and gneiss—a quartzose biotite-oligoclase variety common throughout Cerro del

[3] Pastore, Franco, Estudio geológico y petrográfico de la Sierra del Morro: Argentina, Min. Agric., Sec. Geol. Minas. y Miner., An. Vol. II, no. 2, 1915.

Morro[4]—in which are intercalated layers of limestone that is partly altered to epidote-actinolite rock. The altered masses contain scheelite, the calcium tungstate mineral. Irregular bodies of barren pegmatite have been intruded into the metamorphic rocks, and younger quartz veins and micaceous veinlets containing scheelite cut both the pegmatite and the metamorphic rocks.

Structurally the metamorphic rocks conform with the regional trend. Their strike is north to northeast, and their prevailing dip is eastward at steep angles. Their foliation is parallel to the original bedding. Locally the metamorphic rocks are contorted by small folds and broken by faults, as is illustrated by the geologic map and sections (pl. 4).

The attitude of the micaceous veinlets and quartz veins in the area mapped is rather uniform; they strike east and dip north at various angles. The present workings cut some of the veins, and they will encounter others at greater depths if the veins extend downward with the dips they have where exposed. Farther south, at Loma Blanca, the veins have some diversity of attitude, but most of them dip northward like those on the Cerro Morro property.

Although most of the schist is of the biotite-oligoclase variety, some of it contains much epidote and amphibole, and the rocks characterized by these minerals have a distinctive green color and a less marked schistosity than the micaceous rocks. In places the epidotic and micaceous rocks grade into each other, but generally they are separated by well-defined boundaries and may be traced as layers that parallel those of limestone. It is evident that these rocks were derived from sediments, including limestone, limy shale, and silty shale, and that their present character was chiefly determined by their original composition. Some of their differences, however, are due to differences in degree of metamorphism.

Of particular interest, because they contain the scheelite ores, are the rocks derived from limestone. The limestone layers are lenticular, and they change in thickness as well as in number within short distances along the strike. At the south end of the area, for example on the ridge adjacent to shaft 5, there are six limestones, half a meter to 2 meters thick. Although on the next ridge top, 100 meters to the north, one bed (that mined in shaft 5) shows little change, two others west of it seem to be represented by a single, thicker bed. On the western part of the next ridge, 200 meters farther north, there are three layers of limestone, averaging about 5 meters in thickness, but still farther north these combine into a single layer at least 25 meters thick. At the northern end of the area, rows of prospect pits trace out two main limestones, but other smaller ones are present. At the mine it is common to speak of an "eastern vein" and a "western vein,"

[4] Pastore, Franco, op. cit., pp. 12–16.

but these merely designate two rows of workings that are more or less grouped in two lines but that actually do not follow two continuous beds.

The intensity of mineralization and alteration is uneven along each lens of limestone, and no sizable bed is made up of either continuous ore or continuous silicate rock. In greater part the limestone is composed of gray or white crystalline calcite, containing only scattered grains or thin layers of the silicate minerals. Where alteration is greater, the crystalline limestone grades, rather abruptly as a rule, into a green rock, made up of the silicate minerals epidote, actinolite, and chlorite. Calcite, quartz, and pyrite are minor constituents. In some of the gradational zones calcite and silicate layers are interfingered, in others the alteration cuts sharply across the beds. Masses of silicate rock that contain enough scheelite to average more than half a percent of WO_3 are minable as tungsten ore. Unfortunately, by no means all of the green silicate rock is ore; some of the masses that are most thoroughly altered contain practically no scheelite.

Mineralogically the silicate rocks are similar to epidote-rich varieties of the well-known scheelite ores found in contact-metamorphic deposits, although at the Cerro Morro property no related igneous contacts are exposed. As no large intrusive body is exposed near the Cerro Morro tungsten deposits, the mineral composition of the silicate rocks raises the question whether or not a major intrusive body lies below the deposits at shallow depths. But this mineral composition might have developed at a great distance from a contact as well as close to one, and there is little reason to expect that granite will be found at depths likely to be reached in mining. The nearest granite outcrop is 6 kilometers to the south, at Pueblo del Morro, and the nearest place where granite seems likely to lie hidden below schist at a shallow depth is 5 kilometers northeast, at Cerro de Guanacopampa, where exposures of sillimanite-garnet gneiss mark especially intense metamorphism, of the kind expectable near a contact.[5]

Small bodies of barren pegmatite are exposed in the area mapped, but these apparently have no relation to the tungsten ore bodies. Neither the limestone nor the schist adjacent to these pegmatite bodies is unusually mineralized or altered. The pegmatite forms thin sills, crosscutting dikes, and irregular bodies. It consists mainly of pink orthoclase, quartz, and muscovite, but some of it contains a little white plagioclase and black tourmaline. Tourmaline is also found in thin veinlets and irregular lenses of quartzs, which may be related to the barren pegmatite. These barren bodies of pegmatite are not to be confused with those younger veinlets of micaceous material which contain scheelite and are associated with quartz veins.

[5] Pastore, Franco, op. cit., p. 15.

The quartz veins exposed in the extreme southern end of the area cut the barren pegmatite bodies and are therefore younger. Practically every quartz vein has a thin selvage of scheelite-bearing micaceous material, and identical material is also found in thin veinlets that have no central rib of quartz. The micaceous material apparently formed in a set of northward-dipping fractures, some of them on the walls of quartz veins, others in the country rock nearby. The veins probably are outlying members of the group mined at Loma Blanca, although they lack the abundant wolframite that characterized the Loma Blanca veins.

ORE DEPOSITS

MINERALOGY

The scheelite at the Cerro Morro property is either disseminated in the masses of metamorphosed limestone that have been described above, or it occurs in micaceous veins. Only the disseminated ore has been found in bodies large enough to be minable. The micaceous veins are too thin to be mined separately, although where they cut through disseminated ore the scheelite they contain is a valuable addition to the ore.

In the disseminated ore the diameter of the scheelite grains is generally less than 3 millimeters and rarely more than 5 millimeters. The green silicates of the gangue are equally fine-grained, so that the ore is generally hard to drill or crush. In spite of the small size of the scheelite grains and their quartzlike appearance, the miners are skillful at following the richer layers and sorting the ore.

Mineralogically, the material in the micaceous veinlets has little similarity to the disseminated ore except that both contain scheelite. The thin veinlets are made up chiefly of muscovite and quartz, but small masses of fluorite are rather common, and crystals of beryl and grains of pyrite are found in a few places. Kittl [6] also found crystals of epidote in the veinlets. Micaceous scheelite-bearing material forms very continuous selvages along veins of barren milky quartz. Although these quartz veins are as much as 40 centimeters thick, the thickest selvage seen was about 1 centimeter thick. The veins have been prospected by shallow pits at several places, but none have been mined on the Cerro Morro property.

Although the thickest vein seen underground measured only 6 centimeters, it contained several "eyes" of scheelite 2 to 3 centimeters in diameter. The scheelite in veinlets adds to the value of the disseminated ores. There seems, also, to be slightly more scheelite in the disseminated ore near the crosscutting micaceous veinlets than elsewhere, although inspection under the ultraviolet lamp indicates that

[6] Kittl, E., op. cit., figs. 3, 4.

the increase is small at best. Assay data showing the true distribution of the tungsten would be valuable.

ORIGIN

The metamorphism that formed the epidote-rich rocks was probably a metasomatic process, effected by solutions that also introduced the disseminated scheelite early and the vein scheelite and wolframite later. It is evident that the scheelite in veinlets was introduced late, but it does not follow that all the scheelite in the disseminated ore is likewise of late, postmetamorphic introduction. Probably the small enrichment near the veinlets may be taken as a measure of the relative proportion of late scheelite, most of the disseminated scheelite having been formed earlier. This was the conclusion of Kittl, who, in addition, listed the wolframite-quartz veins of Loma Blanca as the final product of the tungsten mineralization.[7]

GRADE AND SIZE OF THE ORE BODIES

The grade of the ore can only be estimated, for no assay data are available. For approximate data on milling, one may calculate that the ore milled contained on the average about 0.8 percent of WO_3. As there is considerable selection or sorting during the hand mining, most of the ore in place and of minable widths probably averages no more than 0.5 percent. Inspection under the ultraviolet light shows that ore richer than this is generally less than half a meter thick and that the thickness changes within short distances.

The size and distribution of the lenticular ore bodies may be judged from the extent of the workings shown on the map and projections. In the southern part of the property individual bodies were mined for as much as 30 meters along the strike and 20 meters down the dip. In the northern part, the 10 largest pits average less than 15 meters in length and 6 meters in depth. The thickness of the ore in these northern workings probably averaged about half a meter.

A generalized but fairly truthful picture of how the ore changes in value along the strike of the limestones is given by the longitudinal projections. The length and depth of each working shows the extent of an ore lens as the miners found it workable, considering size and grade as well as their mining methods. The spacing of lenses is likewise represented.

The moderate size and grade of the exposed ore bodies make it uncertain whether or not the property could support a large centralized mining operation, even if the ore-bearing limestones extend to considerable depth. It is fair to assume that the outcrops adequately represent the grade of the ore bodies within the beds, and systematic sampling of the surface exposures would indicate what to expect with

[7] Kittl, E., op. cit., p. 35.

deeper mining. There is no apparent geologic reason why the ore-bearing limestones should not continue downward, with the same character they display at the surface, to depths of at least several hundred meters, as their outcrop length exceeds 3,000 meters.

RECOMMENDATIONS FOR INCREASING PRODUCTION

The steep dip of the ore bodies has handicapped the miners, who have been able to work only with vertical shafts and short adits adapted to their hand methods and scant equipment. There is a real need for an experienced engineer to direct efficient, safe methods of working by inclined shafts and stopes and of handling and hoisting ore. On the present operating scale one engineer could not only direct mining but improve the milling practice, but to that end some new milling machinery, especially a classifier and a table, would be needed. By working more faces and by running the mill 24 hours a day the property might produce about 50 tons of concentrates annually, or twice as much as in 1942.

There is some hope of finding larger and richer ore bodies at depth in the southern part of the property. The ore bodies there have been a little better than average, and their proximity to the Loma Blanca mineralization is encouraging. The micaceous veinlets provide additional evidence that mineralization has been stronger in that area, and if at depth they increase in number and size they might add much to the value of the disseminated ore bodies, even though not minable themselves. As many veinlets dip northward under the ground already explored in shaft 5, deepening of the workings there would test the most favorable ground. Also promising is the deeper ground between shafts 1 and 2. At both places inclined shafts following the ore would be better than the present vertical ones.

Although exploration at depth is recommended for testing the ground where scheelite-bearing veinlets and disseminated ore bodies may combine to make richer ore, a thorough test of the surface exposures is recommended as the first step toward possible expansion of mining the disseminated ore bodies alone. Stripping and sampling of the partly exposed lenses of disseminated ore would show their value at the surface, and this would indicate what can be expected at depth. If systematic sampling at the surface is encouraging, exploration at depth could be undertaken with considerable confidence that it would lead to larger-scale mining and milling operations.

MINE WORKINGS

All but one of the mine openings in which work was being done at the time of the writers' examination are included in the area shown on the geologic map. All have certain features in common. They are short because the ore is lenticular, and they are shallow because mining is done by hand methods. The shafts are vertical, and the length of the crosscuts reaching from them to the inclined ore bodies increases with depth. Much of the ore has been extracted from closely spaced levels instead of from stopes.

Shafts 1, 2, and 3, near the south end of the area, are connected with the most extensive workings on the property. These shafts are 17, 8, and 12 meters deep, respectively, and the levels extending from them have a total length of 300 meters. The ore bodies, which are notably long for this property, follow curving beds of limestone that dip 45°–55° E. It seems unlikely that the folds served to localize exceptionally rich ore, for equally folded beds elsewhere are not especially mineralized. Ore that was being mined from the 1,045-meter level of shaft 2 at the time of the writers' examination appeared to contain about 1 percent of WO_3 through an average thickness of 40 centimeters. The south end of this level lacked about 2 meters of connecting with the 1,043-meter level that leads to shaft 3.

For deeper prospecting, the ore between shafts 1 and 2 seems attractive. In planning to prospect this ore, it is more important to consider the prevailing eastward dip than the curves of the beds, and a shaft inclined eastward at 45° would probably follow the ore with a minimum of dead work.

Shaft No. 5 also is attractive for deeper prospecting. The workings are 20 meters deep, with 4 levels having a total length of 80 meters. The disseminated scheelite ore ranges from 20 to 60 centimeters in thickness and averages about 0.75 percent of WO_3. The ore body dips 55° E. and is cut by a micaceous veinlet 3 to 6 centimeters thick that dips 25° N. The veinlet is unusually rich, containing much granular scheelite mixed with muscovite, as well as several "eyes" that attain a diameter of 3 centimeters. As several other outcropping quartz veins and micaceous veinlets dip northward into the ground that lies below this shaft, deeper prospecting seems worth while. Very poor outcrops indicate that this limestone layer continues northward to shaft 4, where ore was mined on three levels, the deepest at 12 meters.

In the Quebrada de los Burros, a layer of good ore, only 35 centimeters thick but containing more than 1 percent of WO_3, was seen in the adit at an altitude of 1,029 meters, marked "A" on plate 3. Such ore could be worked profitably, and it is all the more worth following in that workings on it might reach other ore bodies in the same limestone layer, under shaft 2, 75 meters south and 30 meters higher.

Two openings in Quebrada del Tala are interesting. One of them, the so-called Pozo del Agua, an open pit in the creek bottom, was filled with water. The ore is said to have been unusually rich, and the ore body seems to have been at least 40 meters long and a meter thick. The southward continuation of the ore body is being mined from a 12-meter shaft 30 meters south, but it could be mined more economically through an adit from the creek bottom or, for greater depths, through an inclined shaft out of the creek bottom only far enough to be beyond reach of storm water. The limestone also continues northward, where it is exposed in a series of pits, the two largest of which are workings more than 30 meters long; these are spaced more than a hundred meters apart.

The so-called Túnel Viejo, also in Quebrada del Tala, was driven northeastward 50 meters, beginning at the side of the creek at an altitude of 1,016 meters. To penetrate below the pits that expose ore on the hilltop to the north (at an altitude of 1,062 meters) would require drifting 80 meters farther in a direction N. 20° E., but this work is not advisable unless very good ore is developed on the hilltop.

On the broad hilltop north of Quebrada del Tala, a row of pits exposes one of the most continuous limestone layers. This layer extends 250 meters within the mapped area and continues northward an equal distance, reaching past the 80-meter test shaft of 1938 to an old 10-meter shaft at which work was resumed in March 1943. Apparently this layer was selected for the deep test in 1938 because it is so continuous and contains so many lenses of ore. The structure of the bed seems simple, for all of the bed dips 78°–80° E. Its relation to the next limestone to the east is unknown, however, and there may be unrecognized folds or faults between the two beds.

JOSEFINA TUNGSTEN MINE, PROVINCE OF MENDOZA

SUMMARY STATEMENT

The Josefina tungsten mine, in the Province of Mendoza, produced 132 tons of wolframite concentrates averaging more than 65 percent of WO_3 in the years 1938–42, and it might produce 100 to 120 tons per year. The mine reserves were sufficient for at least 2 years' operation at the rate of 50 tons of ore a day. The ore bodies, which are somewhat pockety, average between 0.5 and 1 percent of WO_3. They consist of wolframite-bearing quartz veins in which there are minor quantities of sulfide minerals. Scheelite occurs in the veins but only in insignificant quantities. Ore has been mined from six veins. The largest of these is 40 to 70 centimeters thick and has been explored for a length of 200 meters and a depth of 75 meters.

Geologically the veins are of interest as an example of structural control, for their size depends on the structure of the enclosing rocks. The principal veins are all in a block of schist and gneiss of simple structure that lies east of a premineral fault, whereas in the deformed schist west of the fault there are only small, short veins. In general, the veins that crosscut the schist at a large angle to the schistosity and linear structure are larger than those that cut across at a smaller angle. A postmineral major fault lies west of the premineral fault and parallel to it; no veins have been found west of this fault.

Of direct economic interest are minor faults that displace the veins as much as 50 meters. These faults trend northward, and on all of them the eastern block of ground moved northward.

INTRODUCTION

The Josefina mine, which is also known as the San Pablo mine, is in the Province of Mendoza (pl. 1), at latitude 33°29′ S., longitude 69°29′ W. It is about 100 kilometers south of the city of Mendoza and may be reached from there by automobile by way of either Tunuyan or Tupungato and Los Arboles. It is at an altitude of 2,000 to 2,300 meters, on the eastern slope of the rugged Cordón de Portillo, a minor range of the eastern foothills of the Andes. About 25 kilometers northwest of the mine, on the Argentine-Chilean border, is the famous peak of Tupungato (altitude 6,550 meters).

The Josefina property is owned and operated by the Compañía Minera de San Pablo, in which there are two partners, Roger M. Faraut and Aurelio Mosso. Sr. Faraut, who was at the mine during the examination on which this report is based, extended many courtesies for which the writers are grateful. Sr. C. J. Artero, engineer in charge of operations, was also helpful in many ways, notably in providing the maps of the main mine levels, which were used as a base for geologic mapping underground. During the period of field work, from October 20 to December 20, 1942, a geologic and topographic map of the surface was also prepared.

The history of the Josefina mine is very short. The first discovery of a wolframite-quartz vein was made by Sr. Faraut in September 1937. Other richer veins were uncovered nearby, and contractors began work at once. At first all work was done by hand, but in 1938 a compressor and drills were brought to the mine, then other pieces of equipment were accumulated, and by 1941 a small mill was working on ores mined partly by hand and partly by power equipment. In 1942 a new development program was under way, involving the construction of a new mill having a capacity of 50 to 75 tons a day and new camp buildings, the installation of additional mine machinery, and the completion of a haulage tunnel that had been started in 1941.

The main features of this program were determined by the mine's topographic setting, which is shown on the accompanying topographic map (pl. 5) and plan of workings (pl. 6). As the mine is in the midst of steep hills, all early mining was by adits. The principal adits are on the east side of a northward-trending valley that will be referred to here as Quebrada del Norte. The original camp and the first mill were constructed in this valley, but the available water supply in the small drainage basin was found to be inadequate. The new mill and the proposed main camp site are at a fork in the deeper and larger valley just to the south, 500 to 700 meters from the old camp, where a stream flows all the year round. The large valley that comes to this fork from the south and thence extends eastward will be called, for convenience, Quebrada del Agua, and the branch that drains from the west will be called Quebrada de la Planta.

The truck road between the old camp and the new mill crosses the intervening ridge through a saddle, which was assumed, in preparing the topographic map of the mine area, to have an altitude of 2,200 meters. The altitude of the old camp is 2,150 meters and that of the new mill is 2,073 meters. There would be obvious advantages in having the mine workings connected with the mill by a tunnel. Such a tunnel would reduce the cost of moving ore from the mine to the mill and would avoid interruption of hauling by winter snows. It would also develop ore by crosscutting the veins at depths as great as 80 meters below the adit workings. Unfortunately, difficulties have arisen as a result of starting the tunnel from two portals that are not at appropriate levels, because of errors in surveying. From the portal near the mill, an adit has been driven northward at an altitude of 2,069.9 meters, whereas from Quebrada del Norte an adit has been driven southward at an altitude of 2,060. 9 meters.[8] In an attempt to bring the two sections to a common level, a new level was adopted for the north adit as soon as the first vein was reached, but through another incorrect survey the new level was established at an altitude of 2,066 meters, midway between that of the two portals. As the tunnel is thus on three levels, with the section at the discharge end the highest, it is hardly well adapted for haulage. Pending an engineering solution of the problem, work on the haulage tunnel was stopped late in 1942.

However, the apparent reserves of the mine were greatly increased, as expected, by the tunnel's crosscutting the main veins at depth. The ore blocked out by the older adits was approaching depletion, and the principal reserves now lie between them and the tunnel. These reserves, which are discussed in some detail in a later section, are now sufficient to sustain a larger production than has been attained in previous years.

[8] These altitudes were determined by plane-table methods and may be in error as much as 0.2 meter; horizontal distances may be in error as much as a meter.

PRODUCTION

The recorded production of wolframite concentrates from the Province of Mendoza, all of which came from the Josefina mine, is as follows:[9]

	Metric tons
1938	15
1939	12
1940	52
1941	36
1942	17
Total	132

All the concentrates, both those produced by hand in the early years and the recent mill product, are of high grade, averaging more than 65 percent of WO_3.

GEOLOGY

The country rocks that enclose the wolframite-quartz veins of the Josefina mine are mica schist and gneiss.[10] Minor intrusives near the mine include biotite granite, quartz porphyry, andesite, and basalt (?), but none of these seem to be directly related to the ore deposits. The size and distribution of the veins are mainly controlled by two major faults, one premineral and the other postmineral, and to a lesser extent by the fabric of the metamorphic rocks. Several minor faults have displaced the veins as much as 50 meters. Faults have also localized rock alteration; there is an early quartz-chlorite-sulfide alteration along the premineral fault and a later chloritization along the postmineral faults.

SCHIST AND GNEISS

The schists and gneisses are light-gray or dark-gray rocks, their color depending upon the relative proportions of biotite, muscovite, quartz, and feldspar. Mineralogically, their most interesting feature is a profusion of clusters of very small biotite flakes, which obviously have replaced crystals of some other mineral. Most of the clusters appear to have replaced garnet, for they are equidimensional, and some of them enclose remnants of garnet. Other clusters that have long shapes must have replaced an unidentified prismatic mineral, of which no remnants were found. Both a schistosity and an older linear structure are well-defined. The schistosity is imparted by a plane-parallel arrangement of the micaceous minerals. The linear structure is represented most clearly by elongate masses of quartzose material, apparently derived from strongly sheared layers or veinlets.

[9] According to Estadistica Minera de la Nación, published annually by Argentina Min. Agric., Dir. de Geol. y Min.

[10] Description of the rocks is based on inspection in the field; there has been no opportunity to study the rocks microscopically.

Small pitching folds or crenulations in the gneissic rocks and lines of biotite flakes on the cleavage planes of the more schistose ones are conformable to the linear structure. The fabric of the schist is of economic interest, for it partly controlled the size and location of the tungsten veins.

Both the fabric and the mineralogy show that the schist and gneiss have been metamorphosed at least twice. At one time they were contorted rocks that had a linear structure, upon which a schistosity was superposed, and they once contained garnet and an unknown prismatic mineral, which have been replaced by biotite. The schistosity is probably of regional extent, but the biotitization may have been local and related to the intrusive biotite granite stock exposed east of the mine. The granite cuts across the schistosity, but its biotitic composition suggests a kinship with the biotite alteration in the schists, which may thus represent the latest stage of the metamorphism. At the granite contact the schists contain, through a thickness as great as 50 meters, an unusually large proportion of feldspar, in layers and "eyes." Otherwise they do not differ from the schists near the Josefina veins, a kilometer west.

INTRUSIVE ROCKS

The outcrop of the biotite granite begins a kilometer east of the Josefina mine and extends eastward about 5 kilometers to the foot of the mountain range. The contact of the stock, where examined in Quebrada del Agua, dips 60° W., crossing the foliation of schists that dip 65° E. Most of the granite is even-grained, though parts of it are porphyritic. It is light-colored, being composed mostly of plagioclase, orthoclase, and quartz. Biotite makes up less than 5 percent of the rock. Sphene and epidote appear in some specimens. There are some small dikes of granite in the schist near the main intrusive body. These seem to be offshoots of the stock.

Quite distinct lithologically from the granite are a series of thin, lenticular masses of quartz porphyry, a few of which are faulted but all of which are so closely alined that it is convenient to call them one dike. The position of the quartz porphyry dike is marked by large prominent outcrops of jointed buff rock. Typical outcrops lie 500 meters east of the Josefina workings, and from there they extend both north and south for several kilometers. The dike is generally parallel to the schists in strike but dips more steeply. Freshly broken specimens of the quartz porphyry are gray, and texturally they range from a very fine-grained rock containing sparse phenocrysts of quartz to a holocrystalline rock with more numerous phenocrysts of quartz and of orthoclase. Some of the finer-grained rock has a layered or fluidal structure.

The wolframite veins strike toward the quartz porphyry dike, and according to Sr. Faraut some wolframite was found in small quartz veinlets in the schist east of the dike. But as none of the exposed veins can be traced to the dike, and as workings on the main veins must be extended 300 meters before they could reach the dike, the relation of the dike to the veins presents no immediate mining problem. No evidence has been found as to the relative age of the quartz prophyry and the wolframite veins.

Several short, thin dikes of andesite, which cut the quartz porphyry, are exposed in the southern part of the area. Most of these dikes consist of a dark-gray rock containing phenocrysts of plagioclase in a fine-grained groundmass of plagioclase and hornblende, but some of them consist of altered green andesite that contains much chlorite.

Two dikes that may be either andesite or basalt were seen in the mine workings, one in La Rica adit No. 1 and one in an open cut on the ridge crest east of the La Rica workings. These dikes are black and so fine-grained that the minerals in them could not be identified with a hand lens.

STRUCTURE AND ITS RELATION TO THE VEINS

Two major faults that strike north and dip 45° W. extend through the mine area—a western fault, which is younger than the veins, and an eastern one, which is older. Despite their difference in age, they are approximately parallel to each other. The two faults divide the schist and gneiss into three blocks in which the structure and rock alteration differ, and it is in the east block, where the structure of the schist is most simple and uniform, that the principal veins are found.

In the east block, the schist and gneiss strike N. 20° E. to N. 20° W. and dip 30°–60° E. The linear structures pitch northeastward, that is, they strike about N. 30° E. and they lie in the foliation of the schist. In the middle block, between the two faults, the schist is much more complexly deformed than the schist in the east block. It generally strikes north and dips west, but much of it is so crushed and sheared that the attitudes of the foliation and the linear structure cannot be determined by inspection in the field. In the block west of the postmineral fault the schist strikes N. 40°–50° E. and dips 20°–60 NW., except in the zone close to the postmineral fault, where it is intensely mashed and contorted. In this western block the linear structures, which are best exposed on the ridge west of the road saddle, pitch northwest, and this fact suggests that these schists may be overturned relative to those in the east block.

The distribution and size of the wolframite veins seems to be directly related to the schist structure. All the longer and thicker veins are in the east block, presumably because its relatively uniform schistosity and linear structure favored the development of those clean-cut and continuous fractures in which the veins were formed. In contrast, the middle block contains only a few veins, none very long, probably because its structure was so disrupted by premineral deformation that extensive fractures did not develop. There are no veins in the west block, which seems to have been brought some unknown distance to its present position near the center of the Josefina mineralized area.

The best ore-bearing ground thus lies east of the premineral fault. Though wolframite-bearing veins appear at the surface in the middle structural block, they are small, so that a search for western extensions of the main veins in that block is not likely to be as profitable as prospecting for eastern extensions in the eastern block.

The veins that cut the linear structure of the schist at a wide angle are generally longer than those that cut it at a small angle. The biggest vein, the Josefina, strikes east and dips 70° S., cutting the linear structure of the enclosing schist at an angle near 60°. The Primera and Rica veins cut it at about the same angle and likewise dip southward at steep angles. The smaller veins in the Blanca and the Sur workings, on the other hand, strike N. 60° W. and dip 40°–50° N., nearly parallel to the northeastward-pitching linear structures.

The length and thickness of a vein are not dependent solely on its attitude in relation to the schist structure, for in the Josefina workings a single thick vein (double in one short section) in the lowest adit divides upward without change of attitudes into a group of thinner veins, exposed on the hilltop above. But as these ramified upper veins do lead down to stronger veins they tend to show that the fissures crossing the grain of the schist at a large angle are the longer and the more favorably situated for the development of the larger veins. On the other hand, one feels little confidence that the thin veins on the hilltop east of the Sur workings will continue downward to any considerable depth, because they cut the foliation at a small angle.

Most of the minor faults that cut the wolframite-quartz veins are in two sets; one set, includng the two faults of greatest displacement, strikes about N. 25° W., and the other strikes about N. 10° E. The dips of the faults range from vertical to 45° east or west. On all the known faults the eastern block is displaced northward; in driving adits eastward along the veins, therefore, offset parts were always found by crosscutting to the north. Striations and flutings on the fault surfaces are commonly inclined 15° to 25° to the north or south.

One of the faults trending N. 25° W. cuts the Josefina vein at the face of the lowest adit (No. 1). The fault is represented by a shear zone a meter thick containing vertical fissures that strike N. 25° W. What seems to be the same fault displaces the small veins on the hilltop above the face of the adit. The horizontal displacement could not be determined conclusively but appeared to be 40 or 50 meters.

The second noteworthy fault trending N. 25° W. displaces the Primera vein about 25 meters. On the surface the trace of the fault could not be identified except by its offsetting of the vein, but in the haulage tunnel it is exposed as a vertical shear zone. Only the eastern part of the vein has been found underground, but the western part should be within easy reach, no more than 3 or 4 meters from the middle exploratory headings (see pl. 9). Projection of this fault southward indicates that it is the same as that which cuts the Rica vein in the lowest adit, and if that is true the eastern continuation of the Rica vein lies about 10 meters north of the face.

ALTERATIONS OF THE SCHIST AND GNEISS

Two kinds of alteration in the schist and gneiss are localized along the faults and, to a much smaller extent, along fractures. A quartz-chlorite-sulfide alteration affected the rocks along the premineral fault, and later the rocks along the postmineral faults were chloritized. The rocks affected by the first alteration are exceptionally resistant to erosion, whereas those affected by the second are comparatively nonresistant.

The older alteration affected the schist and gneiss in the middle structural block. These are the dark rocks, conspicuously stained with iron oxides, that form the ridge west of Quebrada del Norte, and also minor topographic crests farther south, on the sides of Quebrada de la Planta. The rocks owe their resistance to an unusually large proportion of quartz; they also contain much chlorite, and the presence of iron sulfides is inferred from the iron stain. These secondary minerals were formed mainly in the hanging wall of the premineral fault, although they also permeate the footwall, in places to a distance of as much as 5 meters. The general location of the premineral fault is indicated by the zone of resistant rocks, but the alteration obscures the reversal of dip in the foliation that marks the exact position of the fault. Similar iron-stained resistant rocks are exposed in a small area along the hilltop east of the Josefina vein; they may represent alteration adjacent to another old fault not otherwise identified.

The rocks affected by the younger, chloritic alteration disintegrate readily on exposure to the weather and consequently make few natural outcrops; they generally are in topographic depressions. They are best exposed in the new cuts along the road to Tupungato, which extends northward from the camp; there they appear as soft light-green rocks. These chlorite-rich rocks lie west of the iron-stained rocks of the middle structural block and form a zone in the hanging wall of the postmineral fault. The zone ranges from 5 to 50 meters in width of outcrop, and the rocks in it grade westward, with decreasing proportions of chlorite, into biotite-muscovite schist and gneiss. The rocks nearest the fault, which contain the most chlorite, are so smashed and sheared that solid pieces as much as 10 centimeters long are common. The thoroughly smashed condition of the rocks along the hanging wall of the postmineral fault suggests that there may have been recurrent movements, including earlier ones that opened the fault zone to the passage of chloritizing solutions and later ones that crushed the rocks. The chloritized rocks, being structurally weaker than the unaltered schist and gneiss on either side, would be especially vulnerable to crushing by late movements.

Chloritized schist and gneiss are also found along the minor faults that cut the veins. Particularly good examples of this alteration appear in the Primera workings west of the haulage tunnel. Smaller quantities of chlorite can be seen in the schists in scattered places, where the alteration is related to fractures rather than to recognizable faults. At several places along the truck road, for example, the schist is cut by veinlets of quartz that average a millimeter in thickness, and by joints, each of which is bordered by a thin zone of resistant quartz-chlorite rock.

ORE DEPOSITS

In the Josefina mine there are six eastward-trending wolframite-quartz veins, known as the Primera, Rica, Josefina, Blanca, Sur, and Marchant veins (see pl. 3). All of these lie in an area less than 500 meters square. The largest and richest vein is the southward-dipping Josefina, which actually comprises a main vein at least 200 meters long and a group of much smaller subparallel veins, which are exposed on the surface higher and farther east. North of the Josefina lie the Primera and Rica veins, which dip south, and south of it lie the Blanca and Sur veins, which dip north. The Marchant is a minor vein that lies northeast of the Josefina; its outcrop probably marks the eastern limit of strong tungsten mineralization.

MINERALOGY

Almost all the tungsten at the Josefina mine is contained in wolframite, the tungstate of iron and manganese, and the principal gangue mineral is quartz. Scheelite, the tungstate of calcium, is found, but only rarely; Angelelli reported its occurrence in the Blanca vein,[11] the mine engineer, C. J. Artero, found it in the Josefina vein, and the writers saw it at one place in the Rica workings. In the richest ore the wolframite is in clusters of radiating tabular crystals that attain

[11] Angelelli, Victorio, Los yacimentos de minerales y rocas de aplicación de la República Argentina: Argentina, Direc. Minas y Geol., Bull. 50, p. 76, 1941.

lengths of 5 centimeters. These clusters commonly occur along the walls and project into the vein quartz; no wolframite was seen in the wall rock. Lenses or pockets in which these clusters are abundant constitute typical ore, but some blocks or ore consist of small wolframite crystals a centimeter or less in diameter scattered rather evenly through the quartz gangue. Muscovite and fluorite are widely distributed in the veins, though always in minor quantities. Other minor constituents include marcasite, sphalerite, molybdenite, and bismuth minerals. Grains of bismuth oxides were seen in concentrates, but none were found in place.

As the tungsten veins consist mainly of wolframite and quartz with only a very small quantity of sulfide minerals, it is possible to make high-grade concentrates by gravity separation combined with a short roasting that reduces the sulfur content. Sr. Faraut provided the following partial analysis (by Hickethier and Bachman of Buenos Aires) of the concentrates in a recent shipment:

	Percent
WO_3	68.46
Silica and insolubles	5.55
Tin	.07
Copper	.02
Arsenic	Trace
Sulfur	1.56
Phosphorus	Trace
Molybdenum	None
Lead	None

ORIGIN

The veins ar fissure fillings deposited by solutions. The presence of muscovite and fluorite suggested to Kittl [12] that the veins were pegmatitic in character, and he thought it probable that they were genetically related to the nearby intrusive granite. The writers, in their brief study, were unable to prove that this is true, for they obtained no evidence as to the relative age of the veins and the granite.

GRADE OF THE ORE BODIES

As the mine operators have never made a practice of taking systematic samples or keeping mill records, the grade of the ore can only be estimated by inspection. Such estimates indicate that the average WO_3 content of ore in blocks long enough to be stoped (5 meters or more in length) is not less than 0.5 percent and probably not more than 1 percent. Pockets containing 10 percent of wolframite or even more are found, but most of these are less than 5 meters long. No rule governing the distribution of the richer shoots or of stretches of barren

[12] Kittl, Erwin, Sobre has relaciones entre rocas igneas y yacimientos metaliferos en Mendoza: Rev. Minera, Buenos Aires, vol. 10, no. 1, pp. 3–22, 1939.

quartz has yet been recognized. Although the grade of the ore undoubtedly has a wide range, the larger veins are sufficiently uniform to be mined by stoping and milled as mine run. Large pieces of the schist wall rock generally break cleanly away from the quartz and are thrown aside. Some of the ore is hand-sorted, wolframite being picked from the richest ore and barren lumps of quartz discarded, but it is said that there is less hand sorting now than when most of the mining was done by hand. Sorting tends to keep the grade of the ore sent to the mill more uniform than mine run, but it involves some loss of the wolframite hidden within apparently barren lumps of quartz that are discarded.

RESERVES

The reserves in the three largest veins amount to more than 25,000 tons, of which the Josefina contains more than 20,000 tons. This may be regarded as a conservative figure, accurate within about 10 percent for the blocks listed below. The amount of reserves might be reduced to allow for ore that is unminable because it is faulted or barren, but this allowance would be more than offset by including contributions from the three minor veins not credited with reserves—the Blanca, Sur, and Marchant.

The ore classed as "indicated" includes blocks exposed on three sides; such ore would be classifiable as "measured" if its grade were known. The ore classed as "inferred" includes blocks exposed only on one side, the other dimensions being estimated by projecting the veins 10 meters below the workings and, for the Josefina, down to the projected position of the lower drift.

Estimated reserves of the Josefina mine

	Average thickness of vein (centimeters)	Reserves (metric tons)	
		Indicated	Inferred
Josefina vein, between adits 1 and 2	40	2, 400	----------
Josefina vein, between adit 1 and drift	50	7, 970	----------
Josefina vein, 10 meters below A drift	50	----------	1, 060
Josefina vein, below adit 1 and down to projected drift	50	----------	10, 300
Primera vein, east of fault	15	350	----------
Primera vein, west of fault	15	----------	750
Rica vein, between adit and lower drift	30	2, 800	----------
Rica vein, 10 meters below drift	30	----------	550
Blance vein, between adit and lower tunnel	20	----------	----------
Sur vein, below lowest adit	15	----------	----------
Marchant vein, below and west of workings	10	----------	----------
Total	----------	13, 520	12, 660

DESCRIPTION OF THE VEINS [13]

JOSEFINA VEIN

The main vein of the Josefina workings has been mined through adits on 10 levels, only 5 of which were examined and appear on the mine maps and projections (pls. 7, 8). The intermediate levels were omitted because the adits are so closely spaced within a vertical distance of only 57 meters, the altitude of the lowest (No. 1) being 2,128 meters and that of the highest (No. 5) 2,185 meters. Above the adits on the main vein there are about 15 shorter adits and several open cuts on a group of 8 thin veins that lie subparallel to the main vein. These upper veins could not be continuously traced and exactly correlated, and they may be duplicated to some extent by faulting that was not recognized. Farther to the northeast other thin veins are exposed, but, although there is no doubt that they are the Josefina veins offset by a fault that strikes N. 25° W., their displacement can only be estimated. The horizontal displacement seems to be between 40 and 50 meters.

The main vein, which is followed by the lowest (No. 1) adit for 200 meters, strikes N. 80°–85° W. and dips 50°–70° S. Its thickness ranges from 20 to 70 centimeters and averages nearly 50 centimeters. The vein is divided by cross faults into segments 5 to 30 meters long, which are invariably so displaced that the eastern part has moved northward. The position and inclination of these segments ought to be considered in planning the location of stopes.

The vertical fault zone that cuts off the vein near the end of the No. 1 adit is almost certainly the same as the fault that offsets the thin veins 40 or 50 meters on the surface above. It was recommended to the mine operators that the offset part be sought by crosscutting northward from the last curve in the adit.

PRIMERA VEIN

The Primera vein is exposed in Quebrada del Norte, 180 meters north [14] of the Josefina vein (pl. 9). On the surface the vein is in two segments, for it is cut by an unexposed fault, on which the horizontal displacement was nearly 25 meters. The western segment has been mined out to the level of the valley bottom, and the eastern segment, in which almost no wolframite was uncovered, has been explored by

[13] For convenient reference, the plans of the mine workings show coordinate lines equivalent to those that appear on the geologic and topographic sheet. The mining company uses a different set of coordinates, which were not used for this report because the locations according to the company coordinates could not be reconciled with locations determined by the plane-table survey. The most notable difference was in the distance between the north and south portals of the incomplete haulage tunnel, in which there was a difference of 10 meters. Locations by plane table are not likely to be in error more than a meter horizontally and 0.2 meter vertically.

[14] This and subsequent distances from the Josefina vein are measured from the portal of the lowest Josefina adit, known at the mine as the No. 1 tunnel.

a 20-meter adit. The eastern segment of the vein was also encountered in the haulage tunnel and explored by a 20-meter drift, from which a few tons of ore have been taken. The western segment had not been found there, though exploratory drifts and crosscuts totaling 70 meters in length had been driven in search of it. At the surface, both segments strike N. 70° W. and dip 60°–65° S., and projection of the western segment to the tunnel level indicates that it should lie 3 or 4 meters south of the nearest exploratory heading. As the western segment was of higher grade than the eastern at the surface, it was recommended that the workings be extended to the projected position of the missing segment.

RICA VEIN

On the Rica vein, 90 meters north of the Josefina, the two lowest adits were driven eastward and westward from the bottom of Quebrada del Norte (pl. 10). The west adit, at an altitude of 2,108 meters, follows the vein to its termination in the premineral fault zone. Two crosscuts with a total length of 25 meters have been driven in search of the vein, but further work in this unfavorable ground does not seem advisable. The east adit, at an altitude of 2,111 meters, follows the zigzag course of the vein for 50 meters to a fault that strikes N. 25° W. and dips 80° W. Its location and strike indicate that the fault is the same one that displaced the Primera vein 25 meters. If so, the missing part of the vein could be reached by extending the adit about 10 meters on its present northeast course. This exploration was recommended to the mine operators.

An air shaft follows the vein up to the surface from the point where it is crossed by the haulage tunnel. At the foot of the shaft, on the tunnel level, there is a 50-meter drift on the vein, mainly west of the tunnel. The vein is faulted into segments 10 meters in average length. The average thickness is 30 centimeters, and the average WO_3 content appears to be less than 0.5 percent.

BLANCA AND SUR VEINS

The accessible workings on the Blanca vein (pl. 11) comprise four open cuts with a total length of 65 meters and 2 adits about 30 and 50 meters long, respectively. A third adit, 130 meters south of the Josefina and at an altitude of 2,156 meters, is the lowest on the vein, but it was not examined because it was blocked with camp refuse.

The Blanca vein strikes in general about N. 60° W., but its course is marked by small, sharp curves; it dips about 50° NE. In the two upper adits the vein is offset a few centimeters by steep faults at intervals of 10 to 25 meters, and in the last 10 meters of the middle adit a group of closely spaced faults cuts the vein into pieces too small to be minable. Beyond this group of faults the vein has not been prospected, apparently because the segments exposed contain a little wolframite. The only part of the vein that appeared rich was a section 3 meters long in the middle adit, at its junction with the first crosscut. The absence of stopes on this easily accessible vein further indicates that it was not thought to be worth mining. Because of its apparently low grade, the Blanca vein is not included in the tabulation of reserves.

The Sur vein has been mined on five levels, of which the lowest, at an altitude of 2,215 meters, lies 230 meters S. 28° E. of the Josefina (pl. 12). The workings may be taken as typical of those produced by hand mining (see map and sections), for the vertical distance between adits averages only 5 meters. The total length of the adits is 400 meters, not including a 30-meter crosscut on the lowest level. The main vein strikes N. 65° W. and dips 60° NE. Most of it is no more than 20 centimeters thick, and it tends to pinch and to split. Parallel veins are exposed both on the hill surface above the workings (pl. 13) and on the lowest level, but they have yielded only pockets of wolframite, and their average thickness is less than 10 centimeters.

Neither the Blanca nor the Sur vein has been positively identified in the haulage tunnel, although their projected positions have been reached. Two quartz veins are exposed in the tunnel, however, near the projected position of the Blanca vein. The more northerly one dips 60° S., opposite to the dip of the Blanca; it has been explored for 12 meters and is barren. The other, though also barren and shattered, seems to dip north and is at least 30 centimeters thick, and it would seem to be worth prospecting for at least 10 meters.

It is possible that the Blanca and Sur are parts of one faulted vein, for they are close together and dip nearly alike. No fault could be recognized, however, in the 50-meter gap between the highest open cut on the Blanca (at an altitude 2,198 meters) and the lowest adit on the Sur (altitude 2,215 meters). Prospect pits in the intervening area expose only two thin, barren quartz veins, neither of which is convincingly like the Blanca or Sur, but if the lower one represents the northwestward continuation of the Sur, it overlaps the Blanca and lies 25 to 30 meters northeast of it. The best method of prospecting the Sur vein downward would be by sinking on it from the lowest adit level.

As the tunnel lies 90 meters below the lowest outcrop of the Blanca and 150 meters below the lowest adit of the Sur, there is a large block of potentially ore-bearing ground between it and the surface. The size of this block justifies rather thorough prospecting of any quartz vein encountered on the tunnel level, especially eastward from the tunnel, even though the veins on the surface are thinner and less rich than the northward-dipping Primera, Rica, and Josefina.

MARCHANT VEIN

The Marchant vein is 350 meters N. 55° E. of the Josefina, in a gully that lies between Quebrada del Norte and a steep hill underlain by resistant quartz porphyry (see pl. 14). The vein strikes N. 70° W. and dips 45°–50° S. The main adit extends westward for about 60 meters. At its portal there is a zone 2 meters thick in which there are three minor veins, each less than 5 centimeters thick, parallel to the main vein, which is only 10 centimeters thick. Faults that strike northwest divide the main vein into several segments, and two of these have been mined through the adit. A third segment of the vein is exposed in a 10-meter adit, from which the vein may be projected to a position 20 or 25 meters S. 40° W. of the last curve in the main workings. Though the Marchant vein is thin it is said to have been rich, and it probably would be profitable to crosscut to the third segment. The Marchant vein may be the eastern extension of the ramified veins of the Josefina, offset by unrecognized faults, but no veins could be traced through the intervening ground.

SAN ANTONIO TUNGSTEN MINE, PROVINCE OF CATAMARCA

SUMMARY STATEMENT

The San Antonio mine is in the northwestern part of the Province of Catamarca. Although its ore bodies were discovered in 1918, the mine did not enter its main productive period until 1936, when it came into the possession of the Vélez brothers of Belén. The early production is not recorded, but since 1936 the mine has produced between 400 and 450 tons of wolframite concentrates.

The ore bodies are wolframite-bearing quartz veins, of which more than 50 have been discovered in an area 500 meters square. All the veins lie in a body of granite, and only the parts of the veins closest to the schists into which the granite is intrusive seem to be rich in wolframite. Further work is needed to determine the position of the slate contacts that limit the extent of the ore bodies, and meanwhile it is unsafe to make long-range predictions as to the future of the mine. There seems to be no question, however, that reserves were ample to permit the increase in production planned for 1943 and 1944. By more efficient mining and milling and use of additional equipment, the operators hoped to increase the annual production to 170 tons of concentrates per year, double the average rate of 1940–42.

INTRODUCTION

The San Antonio mine, in the Province of Catamarca, was brought to the senior author's attention in late May 1943, when a change in mining methods was being planned. It seemed that a geologic examination might be of value to the mine operators and also of interest to Government agencies concerned with tungsten production, even though there was time for only a hasty visit. Four days were spent at the mine, almost all of them devoted to mapping the newest part of the underground workings. Although this was obviously the most useful thing to do, the underground work did not provide a well-rounded picture of the ore deposits; consequently the following report includes both descriptions of observed features and questions, unanswered but apparently significant, about the major problem of the extent of the ore. Most of these questions might soon be answered by exploration and by a comprehensive engineering and geologic survey of the property, which it is hoped will be made. In the meantime, the known features of the ore deposits are sufficiently interesting and well established to make this incomplete description seem worth including in a progress report.

LOCATION AND TRANSPORTATION

The San Antonio mine is in the northwestern part of the Province of Catamarca, at longitude 67°02′ W., latitude 27°38′ S. (see pl. 1). It is 30 kilometers south of Belén, where the owners live and have their warehouse. The two nearest railroad stations, both on the North Central Argentina Railroad, are at Tinogasta, about 100 kilometers southwest, and at Andagala, about 80 kilometers east. Train service is intermittent, and it is often more practical to go to Belén by automobile from the city of Catamarca, 300 kilometers to the east, or from Tucuman (where the Panagra planes stop), 350 kilometers to the northeast.

A description of the road to the mine will show the difficulty of bringing supplies to the property and carrying ore from it. To reach the mine from Belén, one travels southward on the road toward Cerro Negro for 15 kilometers beyond the town of Londres, then westward 10 kilometers on a truck road to its junction with a mule trail that leads to the mine. The end of the truck road is less than 2 kilometers from the mine but about 525 meters below it. A half hour's mule ride takes one from the end of the truck road, at an altitude of about 1,225 meters, up to the main or administration camp (altitude 1,550 meters). From this camp to the principal mine workings (altitude 1,750 meters) there is a second length of truck road about 3 kilometers long. The truck used on this upper portion of the road was brought up piecemeal by men and mules. The ruggedness of the surrounding country is further shown by the contours sketched on the map.

CLIMATE, VEGETATION, AND WATER SUPPLY

The climate of the region is semiarid, the annual rainfall averaging about 200 millimeters.[15] The sparse vegetation provides fuel and thatch for the miners' houses but no timber for the mine. The nearby springs supply scarcely enough water for domestic use and for hand-washing the richest part of the ore, and hence ores that are to be milled are taken by burro and truck a distance of 27 kilometers to a concentrating plant near Londres.

HISTORY AND PRODUCTION

The San Antonio mine was discovered in June 1918, but after being worked about 2 years it was left idle until 1936, when it was reopened by the present owners, Segundo and Manuel Vélez of Belén. The concentrating plant at Londres was built early in 1942.

The mining has been done in open cuts and through adits driven into the steep valley walls of Quebrada Agua de las Mulas, upstream from the administration camp. The workings on the principal cluster of veins (see pl. 15) include an older group of between 20 and 30 adits in the so-called Rincón section on the northwest, and a group of drifts, reached through the Toro crosscut, on the southeast. One adit in the Rincón section, about 40 meters below the Toro crosscut, was being driven southward on what is believed to be the Manuel vein, in the expectation that it will become a main working level in the future. Except for the work in this adit, mining activity at the time of the examination centered in the Toro workings. No work was being done on the outlying veins.

The wolframite concentrates produced by this mine are not listed separately in the statistical reports of Argentina. Wolframite concentrates produced in the Province of Catamarca in recent years are listed below.[16]

	Metric tons		*Metric tons*
1936	3	1940	106
1937	36	1941	102
1938	117	1942	115
1939	91		
			570

Of this total, probably 70 to 80 percent, or about 400 to 450 metric tons, was produced by the San Antonio mine. The quantity of concentrates produced in 1918–19 is not recorded. The concentrates average more than 65 percent of WO_3 and contain no objectionable impurities.

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[15] Beder, R. Informe sobre estudios geológico-económicos en la Provincia de Catamarca; Argentina, Direc. Minas, Geol. e Hidrol., Bull. 31, ser. B, p. 15, 1922.

[16] Estadística Minera de la República, published annually by Argentina Min. Agric., Dir. Min. y Geol.

Production was expected to increase in 1943 and 1944. In April 1943 the South American Mining Co. contracted to manage the mine and mill, and the company hoped to double the production by adding mine machinery and improving mining methods, by installing a cableway with which to move milling ore down from the mine, and by improving both the capacity and the efficiency of the mill. If the increased production was achieved by July, the mine may have produced about 125 tons of concentrates in 1943 and 170 tons in 1944.

Although the reserves that would be needed for the higher rate of production were not blocked out, because the mine practice was to extract ore as fast as it was developed, it seemed safe to say that there was sufficient ore for operations through 1944. There are many wolframite-quartz veins on the property, and the headings in more than a dozen of them displayed promising ore. In addition there was much wolframite that might be recovered from the dumps. There was some uncertainty about the reserves required for a longer period, because certain critical features of the geology were unknown.

ACKNOWLEDGMENTS

In the geologic description that follows the writer has drawn freely from an excellent description of the ore deposits published by Beder after an examination that he made in 1918, shortly after the deposits were discovered.[17] A geologic map from Beder's report is also used, with slight modifications (pl. 15); it shows clearly the significant larger geologic features of the mining area. In the present report the chief addition to Beder's data is a detailed map, made with tape and compass, of the geology in a part of the Toro workings (pl. 16).

The field work was greatly facilitated by the mine owners, Segundo and Manuel Vélez, by their engineer, E. Stroman, and by engineers Fritz Mella and F. C. McNutt, of the South American Mining Co. To all these the writer is grateful for many courtesies, including transportation from Belén to the mine, and for helpful discussion of the ore deposits.

GEOLOGY

The ore bodies at the San Antonio mine are quartz veins that contain rich pockets of wolframite, the iron-manganese tungstate. More than 50 veins have been found in an area about 500 meters square. All are in a body of granite, and almost all are near the contact of the granite with the schist into which it was intruded. The full extent of the ore bodies is not yet known, for the positions of the granite-schist contacts, which appear to limit the veins upward and laterally, are unknown, and it is also uncertain how far down into the granite the veins will be rich in wolframite.

[17] Beder, E., op. cit.

The abundance of veins in the granite and their absence in the schist may be accounted for on the hypothesis that in the massive granite there was developed an extensive system of fissures that were well-defined and wide enough to contain fair-sized veins, whereas in the adjoining schist the accompanying displacements were dispersed among countless fractures, each very small. The contrasting result in granite and schist is clearly exposed in the low adit on the Manuel vein, where the principal vein is 15 centimeters thick through the granite and ends abruptly at the schist contact. Only a closed joint marks the line of the vein in the schist. The writer heard of no exceptions to the rule that the veins end at the schist contacts.

SCHIST CONTACT

The metamorphic rocks of the mining area are called schist in this report for the sake of brevity, though actually they consist of mica schist, phyllite, and lenticular layers of quartzite. They are regionally metamorphosed sediments. Their strike ranges from N. 45° E. to N. 30° W., and their prevailing dip is steeply westward.

The granite is a muscovite-bearing variety, containing orthoclase, quartz, and albite as its major constituents. Most of the rock is of uniform medium-grained texture, though Beder described marginal parts that are porphyritic and also apophyses that are aplitic.[18] Alongside the veins the granite is altered to the muscovite-quartz rock commonly called greisen. The greisen is further mentioned in the section of this report that deals with the mineralogy of the veins.

Exposures of schist surround those of granite. In general the schist forms the ridge tops and the granite the lower slopes. Granite forms most of the steeply sloping bottom of the valley known as Quebrada Agua de las Mulas, but east of the granite body the valley is entirely in schist. No veins have been found along this eastern contact, which is nearly vertical. The schist on the south, west, and north lies, in general, above the granite. The bottom of the schist dips, on the average, about 15° N. but locally is very irregular, as is well shown east and southeast of the Toro crosscut (see pl. 15). From this vicinity the contact extends northeastward down the steep hillside, passing close to the crosscut 27 meters below the Toro; it also extends southwestward, and the veins in the Toro workings end against it on the south. Where exposed underground, this part of the contact dips 30° SE., but it is said [19] to be vertical in a part of the workings now backfilled, as it appears, from the course of its outcrop, to be on the surface.

Both the overlying position of the schist and the local irregularity of its contact with the granite are shown on the south side of Que-

[18] Beder, E., op. cit., pp. 16–18.

[19] Stroman, E., personal communication.

brada Aqua de las Mulas, in the Rincón section. West of the adit that is there being driven on the Manuel vein, the trace of the contact has a Z-shaped pattern on the hillside. The veins are in the granite, most of them under the flat parts of the contact that form the top and bottom of the "Z."

A schist-granite contact that seems to be more regular in attitude lies above the Manuel adit. From there the contact rises southward at an inclination of about 25°, and it apparently continues southward and upward into the Toro workings and there caps the granite and its enclosed veins. This cannot be asserted with confidence, however, in the absence of an adequate survey of the mine workings and of the geology both on the surface and underground.

ORE DEPOSITS

MINERALOGY

Practically the only minerals in the tungsten veins are wolframite and quartz. The presence of sparse grains of sulfides is suggested by spots of secondary copper and arsenic (?) minerals, but no sulfides were seen. A few crystals of beryl were found in one vein. Most of the wolframite is in masses of coarse crystals but some is in small scattered grains. Because the mineralogy is simple and the ore pockety the first stage in concentration is generally hand-cobbing. Clean concentrates are easily produced both by hand-washing at the mine and by gravity milling at Londres.

The following analyses of crystals from the San Antonio mine show that they are true wolframite.

Analyses of crystals from San Antonio mine

	A [1]	B [2]
WO_3	75. 76	74. 24
MnO	12. 09	10. 50
FeO	11. 31	13. 85
Insoluble residue	--------	. 30
Ta_2O_5	0	. 24
Cb_2O_5	0	. 80
CaO	0	--------
MgO	0	--------
	99. 16	99. 93

[1] Beder, R., Informe sobre estúdios geológico-económicos en la Provincia de Catamarca: Argentina, Direc. Minas, Geol. e Hidrol., Bull. 31, ser. B, p. 35, 1922.
[2] Angelelli, Victorio, Los yacimientos de minerales y rocas de aplicación de la República Argentian: Argentina, Direc. Minas y Geol., Bull. 50, p. 58, 1941.

The greisen formed by alteration of the granite along the walls of the veins is commonly only a centimeter or two thick, although a few masses are as much as a meter thick. As the quartz veins break cleanly away from the greisen, this alteration facilitates stoping and sorting of the vein material. Some wolframite may be disseminated in the greisen, for an assay showed that there was considerable tungsten in one body of greisen sampled by Mella.[20] One mass of greisen seen by the writer contained stringers of pure wolframite, but these plainly were at the tip of a quartz vein and not to be classed as disseminated wolframite.

GRADE OF THE ORE

The average tenor of the ore from the San Antonio mine is unknown, but it is probably high, for 17 kilograms of wolframite per ton was said to be recovered from the ore being milled at the time of the examination. This was ore from which both barren quartz and coarse wolframite had already been removed by hand-sorting; it consisted of fines from old dumps and rejects from ore recently sorted and handwashed at the mine. The mine engineer, Stroman,[21] claimed that the ore mined from pockets averaged 8 percent of wolframite and that fines from the dumps milled in August 1942 averaged 3.2 percent of wolframite, according to his vanning tests. In the veins that were seen, the rich parts contain as much as 20 percent of wolframite along stretches of 5 meters or more, but other parts are practically barren, and an average could not be determined without making elaborate tests.

Although the ore bodies are "pockety" and individual pockets are not very large, the practice of always working on many veins at the same time results in always having some faces in good ore, and a fairly steady production is thus maintained. Extraction of ore would undoubtedly be more complete and would include lower-grade ores if all mining were done "on company account" instead of by contract. The contractors, being paid on the basis of wolframite recovered, at the rate of 1.80 pesos a kilogram, press the work in rich parts of the veins and neglect parts that, though lower in grade, could be taken out profitably.

SIZE OF THE ORE BODIES

A striking feature of the San Antonio tungsten mine is the great number and close spacing of the veins, well shown on the map of a part of the Toro workings (pl. 16). The newer drifts and stopes opened through the Toro crosscut, which were the only ones mapped by the writer, include six on steep veins that strike northwestward, two on steep veins that strike nearly northward, and two on flat-lying veins that strike northward and northeastward.

The thickness of the principal veins and the extent to which they have been developed are given in the following table. The positions and attitudes of the veins are shown on the map.

[20] Mella, Fritz, personal communication.
[21] Stroman, E., personal communication.

Dimensions of the principal veins in the San Antonio mine

	Length in drift (meters)	Thickness (centimeters)
Steep veins striking northwestward:		
Trece	55	15–20
Segundo	50	5–15
Victoria	40	5–20
Manuel	70	20–35
Cuto	45	10–40
Nueva	0	20
Steep veins striking northward:		
First	35	30
Second	15	30
Flat-lying veins striking northward and northeastward:		
First	40	10–20
Second	35	10–25

These veins, as well as several smaller ones not stoped, were all cut by the Toro crosscut in a distance of 60 meters. Because the veins are so closely spaced, in some places two or even three are mined in one stope; this partly offsets the disadvantages of the veins being thin and uneven. Some stopes shift from one vein to another as they progress. Where the veins are most closely spaced, it would seem worthwhile for the mine operators to plan their extraction carefully, in order to get out the most ore with the least danger from caving.

The vertical extent of the ore bodies is not known. Above the Toro crosscut the upward limit seems to be the schist contact, which is exposed in the north end of both the Cuto and Manuel drifts. What is thought to be the same contact appears in the highest part of the first inclined workings and also just above the mouth of the adit on the Manuel vein in the Rincón section, 38 meters below and 120 to 140 meters north of the Toro crosscut. If this schist contact actually limits the potentially ore-bearing ground above the Toro crosscut, the maximum possible height of stopes above the Toro level for the veins already developed would be about 35 meters on the south and would decrease to a minimum northward. If, on the other hand, the ore is not limited or only partly limited by this contact, stopes might extend to the surface, which is 80 meters and more above the crosscut level. Some preliminary exploration should be of value, though possibly the schist contact is so irregular that no reasonable amount of test work will help in predicting its position.

The downward extent of the rich ore is a matter of speculation. In general, the appearance of the workings in the Rincón section indicates that most, though not all, of the old adits were driven in wolframite-bearing quartz just below bodies of schist and that ore was not found much below the contact, even though the veins continue downward in the granite. Conspicuously large quartz veins are exposed in granite in the quabrada bottom a hundred meters below the contact, and doubtless there are many small ones, but there are no workings on any of them. This suggests that the rich ore has been found only close to the contact, probably not more than 25 meters below it. To know whether or not any rich wolframite shoots extend farther downward would, of course, be highly desirable when plans are made to develop a second working level from the low adit on the Manuel vein, or levels still lower.

A very promising feature of the mine is the appearance of new veins in the latest extensions of the Toro crosscut. The questions previously raised as to the major outlines of the ore-bearing ground above, below, north, and south of the crosscut, do not necessarily apply to the new ground straight ahead on the new line of the crosscut level. Actually, the present appearance of the overlying schist contact indicates that the crosscut is heading toward ground where the schist cap is higher. These views regarding the limits of ore-bearing ground may need to be revised greatly when the workings are extended or when a comprehensive geologic examination is made.

FUTURE PRODUCTION AND RESERVES

The engineers of the South American Mining Co. hope that by revising the mine operations they will be able to double monthly production. Considering the low efficiency of the present mining, transportation, and milling methods, this hope seems reasonable. Assuming that production doubled after June, the mine produced about 125 tons in 1943 and about 170 tons in 1944.

The reserves can be estimated only in a general way, for neither the veins nor the dumps have been measured or adequately sampled. From the number of veins and their obvious richness, it seemed certain that the mine contained enough ore for a year, and it probably contained enough for 2 years, even with the rate of production doubled. This general estimate was based on a rough comparison of the ground already mined with that which remained to be explored, the dumps being regarded as an added reserve.

SANTO DOMINGO TUNGSTEN MINE, PROVINCE OF SAN LUIS

INTRODUCTION

The Santo Domingo tungsten property is in the Province of San Luis, near longitude 65°55′ E. and latitude 33°02′ W. (see pl. 1). The senior writer examined the property early in October 1942, at the beginning of a sampling test by the South American Mining Co., which held an option on the property. Mr. F. C. McNutt, engineer of the company, and Mr. B. R. Bates, an engineer of the Board of

Economic Warfare of the United States, helped prepare the sketch map (pl. 17) showing part of the deposits. The company's exploration was abandoned after about 2 months' work, and there was no opportunity to revisit the property to inspect the final results of the test work.

The examination was restricted entirely to the three claims that cover the so-called No. 1 vein (the ore bodies are mineralized dikes), because the engineers at the property agreed that other "veins" in the group, all of which they had seen under ultraviolet light, were much less promising. The workings on the No. 1 vein include an adit and a row of prospect pits extending about 700 meters N. 45° E. through the El Bolchito, San José, and La Delicia claims. The sketch map (pl. 17) shows the workings and the outline of the so-called veins in this one zone.

The production from the property is not recorded, but it probably has never exceeded a few kilograms of scheelite concentrates per month. Even though not minable on a large scale, the deposits are interesting because of the type of ore control that localized the scheelite mineralization.

GEOLOGY

The tungsten deposits are situated in an area underlain mainly by schists, which evidently are metamorphosed sediments. Chlorite-muscovite schists, some of them highly chloritic, predominate, and there are some thin layers of quartzite. Other layers are of uncertain origin, being made up of granular crystalline material that might originally have been either sedimentary or igneous.

The bodies of rock that contain the scheelite are almost undoubtedly dikes. Most of them are parallel to the foliation of the enclosing schist, but some of them cut across it. In these intrusive bodies, quartz and feldspar grains, together with an abundance of white mica flakes, all less than 2 millimeters in diameter, make up an evenly granular unfoliated cream-colored rock, which seems to be an altered aplite. The rock is much jointed, and the joint surfaces are more or less heavily stained with brown and red iron oxides.

OCCURRENCE OF SCHEELITE

The scheelite is in thin veinlets in the aplitic dikes; it is accompanied by quartz, and many veinlets consist wholly of quartz. Most of the veinlets are so thin that they may be described as seams that fill joints. As the rock breaks most easily along the veinlets, joint blocks faced with parts of split veinlets are typical features of the outcrops and waste dumps. Some veinlets contain alternate quartz and scheelite, and when split they show a patchy distribution of the minerals. In some however, the scheelite is continuous for lengths of more than a meter and when they are split open display a flat surface evenly coated with scheelite. Blocks thus coated, when seen under ultraviolet light, may appear strikingly rich, although they may be merely veneered with scheelite and otherwise barren.

The scheelite and the accompanying quartz apparently were deposited in joints or fractures in the aplitic dikes, which, being relatively brittle, fractured more readily than the enclosing micaceous schists. The fractured parts of the dikes occur at irregular intervals; no uniformity in their position was noted, nor is the attitude of the scheelite-bearing joints everywhere the same. Consequently, in appraising the extent of the ore, one must consider not only that the dikes are lenticular but also that the mineralization is secondary and irregular. Unless some regularity of occurrence is discovered on further exploration, the location of the parts of the dikes that can be considered potential ore is unpredictable.

GRADE OF THE ORE

In the open cuts examined the veinlets did not seem remarkable for abundance and richness. The richest ore was seen near the south end of the pit called the Pozo Grande, where there are several veinlets, none more than 2 millimeters thick, spaced 10 millimeters or more apart. Such ore might contain more than 1 percent of WO_3. It was said [22] that a random sample from the dump of this pit contained 0.66 percent of WO_3. As the best ore extends less than 2 meters along a wall that is exposed for a length of 12 meters but shows little scheelite elsewhere, the average grade of the ore now exposed in the pit does not seem as high as the dump sample indicated. In other workings, also, barren rock predominates over that containing scheelite veinlets. A hasty inspection between the workings showed nothing of promise among the natural exposures.

It is probable that the average WO_3 content of systematic samples taken from blocks of ore minable on a large scale would not be as high as the 0.4 percent regarded as a minimum for milling ore and would more likely be less than 0.2 percent. Being of such low grade, even the richest parts cannot be classed as ore, and there seems to be little likelihood of the property producing a significant quantity of tungsten.

[22] McNutt, F. C., personal communication.

INDEX

Page

Acknowledgments for aid 1, 2, 3, 13, 29
American Mining Co., operations by 4

Blanca vein, description of 24–25, pl. 11

Catamarca Province, tungsten mine in 26–34
Cerro del Morro, description of 5
Cerro Morro mine, geology of 5–8, pls. 3, 4
  location and extent of 3, pl. 1
  maps and sections of pls. 2–4
  operations at 2–5
  ore deposits of 8–12
    grade and size of 9–10
    mineralogy of 8–9
    origin of 9
  production from 2
    methods for increasing 3, 10
  workings in 10–12
Compañía Minera de San Pablo, operations by 13

El Morro No. 1 mine. *See* Cerro Morro mine.

Faults, description of 17–19

Gneiss, alteration of 19–20
  character of 5, 6, 15–16
Granite, alteration of 31
  occurrence and character of 16, 30–31

Josefina mine, geology of 15–20
  intrusive rocks of 16–17
  location of 13, pl. 1
  maps and plans of pls. 5–14
  operations at 13–15
  ore deposits of 20–26
    grade of 21–22
    mineralogy of 20–21
    origin of 21
  production from 15
  reserves of 22
  structure in 17–19
  veins, description of 23–26
Josefina vein, description of 23, pls. 7–8

Limestone, character of 6–7
Loma Blanca mine, tungsten deposits of 3–4

Marchant vein, description of 26, pl. 14
Mendoza Province, tungsten mine in 12–26

Page

Metamorphic rocks, character of 6, 30–31

Ore deposits, analyses of 21, 31
  See also names of mines.

Pérez Mendoza, Horacio, operations by 3
Primera vein, description of 23–24, pl. 9

Quartz porphyry, occurrence and character of 16

Rica vein, description of 24, pl. 10

San Antonio mine, climate, vegetation, and water supply in the area of 28
  geology of 29–30
  location of 27, pl. 1
  operations at 28–29
  ore deposits of 31–34
    grade of 32
    mineralogy of 31–32
    size of 32
  production from 26, 28–29, 34
  reserves of 29, 34
  sketch map of pl. 15
  Toro workings in 28, 30, 32, pl. 16
San Luis Province, tungsten mines in 2–12, 34–36
San Pablo mine. *See* Josefina mine.
Santo Domingo mine, geology of 35
  location of 34, pl. 1
  ore of, grade of 36
  sketch map of pl. 17
Scheelite, occurrence and character of 8–9, 35–36
Schist, alteration of 19–20
  occurrence and character of 6, 15–16, 30–31
South American Mining Co., operations by 29, 34
Sur vein, description of 25, pls. 12–13

Toro workings, features of 28, 30, 32, pl.16

Veins, character of 6, 8, 17–19, 32–34, 35–36
Vélez, Segundo and Manuel, operations by 28

Wolframite, occurrence of 12, 17, 26
  production of 26, 28