UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
GEOLOGICAL SURVEY
W. E. Wrather, Director

Bulletin 946–C

SCHEELITE DEPOSITS IN THE NORTHERN PART OF THE SIERRA DE JUAREZ NORTHERN TERRITORY LOWER CALIFORNIA, MEXICO

By
CARL FRIES, Jr., and EDUARDO SCHMITTER

Prepared in cooperation with the
UNIVERSIDAD NACIONAL DE MEXICO, INSTITUTO DE GEOLOGIA
under the auspices of the
INTERDEPARTMENTAL COMMITTEE ON CULTURAL AND
SCIENTIFIC COOPERATION, DEPARTMENT OF STATE

Geologic investigations in the American Republics, 1944
(Pages 73–101)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1945

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

CONTENTS

ILLUSTRATIONS

SCHEELITE DEPOSITS IN THE NORTHERN PART OF THE SIERRA DE JUAREZ, NORTHERN TERRITORY, LOWER CALIFORNIA, MEXICO

By Carl Fries, Jr., and Eduardo Schmitter

ABSTRACT

Scheelite deposits occur at many places in the northern part of the Sierra de Juárez, in the northern part of Lower California. The Sierra de Juárez forms the east side of the southern extension of the Peninsular Ranges of southwestern California, where tungsten deposits also occur and have been mined. The region examined, which covers nearly 600 square kilometers, is 65 kilometers by road northeast of Ensenada, a port on the west coast, and 88 kilometers by road southeast of Tecate, a town on the railroad at the international boundary.

The rocks in the region consist of strongly folded, metamorphosed, late Paleozoic sediments intruded by early Mesozoic biotite, hornblende, and quartz diorite and by pegmatite dikes. The metamorphic rocks consist mainly of schist but include thin beds of hornfels, marble, and a little impure quartzite, and the most abundant igneous rock is quartz diorite. The metamorphic rocks occur in northwest-trending belts and less regular groups as roof pendants in the quartz diorite batholith. Individual pendants range in length from a few meters to several kilometers.

Tactite, composed principally of garnet and pyroxene, has wholly or partly replaced calcareous beds in the pendants along or near contacts with the quartz diorite. Scheelite, the only commercial tungsten-bearing mineral in the region, occurs mainly in the tactite, particularly along the under sides of steeply dipping beds of marble, and its gangue therefore consists mainly of garnet and pyroxene. A little scheelite is locally disseminated in all the other rocks. It is believed that the tactite was formed in part if not wholly after the pegmatite dikes were emplaced, and that the scheelite was deposited at essentially the same time, for tactite minerals and scheelite weakly replace the borders of some of the pegmatite dikes that cut through the tungsten ore bodies.

Tungsten was first found in the region during World War I, when the El Fenómeno deposit was discovered and mined. About 4,000 units of WO_3 was then produced, but at the end of the war, when the price of tungsten dropped, mining was discontinued. It was resumed, however, in 1937, and production from then until December 1943, when mining was again discontinued for lack of

ore, amounted to about 60,000 units of WO_3, in concentrates averaging about 65 percent WO_3. Only the El Fenomeno mine has made any commercial production.

It is estimated that only 600 or 700 tons of ore containing 0.4 or 0.5 percent WO_3 remains in the El Fenómeno deposit, and 150 or 200 tons of ore containing about 1.3 percent WO_3 in the La Raza deposit. In the other deposits that have been prospected, there may be 26,000 tons of scheelite-bearing rock containing 0.25 or 0.3 percent WO_3, but as such rock is too lean to be mined commercially at the current price of tungsten, and as none of these deposits appears to contain more than 6,000 tons of this low-grade material, none of them appears to be worth developing.

There is some hope, however, of finding ore bodies larger than those already known. As the scheelite is in tactite associated with marble, new ore bodies are most likely to be discovered by looking first for large bodies of marble in and around the larger bodies of metamorphic rock, and then prospecting any tactite associated with them for scheelite. No pendant that does not contain marble is likely to yield any significant quantity of ore.

INTRODUCTION

Location

Tungsten deposits are scattered through the northern part of the broad Sierra de Juárez, in the north-central part of Lower California. Those found hitherto lie within a belt 20 kilometers wide that extends southeastward for 40 kilometers from a point about 25 kilometers south of Jacumba, Calif., which is on the international boundary. The Sierra de Juárez is the southeastward extension of the Peninsular Ranges of southwestern California, along the east side of which tungsten deposits have been mined in several places, and the tungsten deposits in the Sierra de Juárez form an extension of this southern California tungsten belt.

The deposits examined lie between latitudes 32°03' and 32°17' N. and longitudes 115°53' and 116°08' W. (see fig. 14). The Sierra de Juárez is there a rather gently rolling upland having an altitude of about 1,500 meters, above which isolated hills rise 100 to 200 meters higher, and in which valleys are incised to a maximum depth of about 200 meters. The region is reached from Ensenada, on the west coast, or from Tecate or Mexicali, on the international boundary, by dirt roads passable for most of the year. The west side of the area is 65 kilometers by road northeast of Ensenada, and the north end is 88 kilometers by road southeast of Tecate, the nearest point on a railroad. Most of the deposits examined can be reached by automobile, but some lie 1 to 3 kilometers from the nearest road.

The higher parts of the region are covered by a thin stand of pine, but elsewhere trees are few and there is a fairly heavy growth of underbrush, mainly chamiza colorada and manzanita. Only one arroyo in the area carries a perennial flow of water, but in most of the large arroyos moderate quantities of water can be obtained from shallow wells. The one perennial stream has supplied sufficient water to operate a 200-ton mill and to supply the domestic needs of a village, near the El Fenómeno mine, with over 200 inhabitants. At Los Gavilanes, the only other mining settlement in the area, sufficient water for more than 150 people

has been obtained from wells in the nearby arroyo, and these wells were believed capable of yielding enough in addition to run a 50-ton mill.

History

Tungsten ore was first discovered in the region during World War I, when the El Fenómeno deposit, which earlier had been explored for copper and gold, was mined for its tungsten. When the price of tungsten dropped at the end of the war the mine was closed, and it was not reopened until 1937, when the Cía. Minera El Fenómeno again began to mine tungsten. Under the stimulus of this mining operation the surrounding country was explored for other deposits, but with little success. During 1941 and early 1942 the capacity of the El Fenómeno mill was increased to 200 tons, and in 1942 the Cía. Minera del Gran Oeste acquired some properties near Cerro El Topo and began construction of a small mill at a place that is now known as Los Gavilanes (see pl. 25).

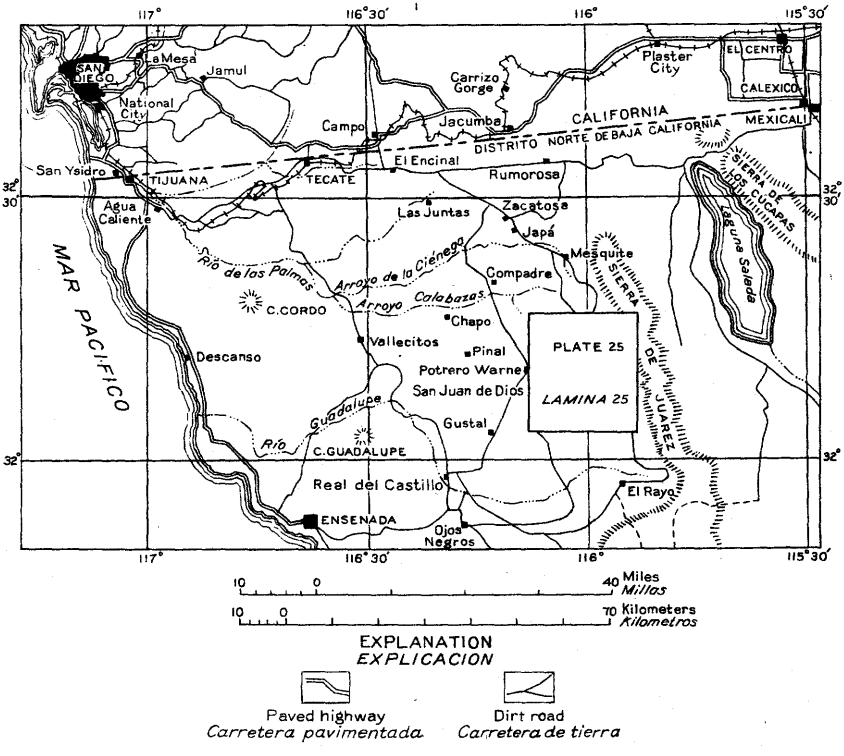

Figure 14.—Index map showing location of tungsten district studied in Lower California.

Late in 1942 the El Fenómeno company, realizing that its ore was nearly gone, intensified its search for extensions of its ore body and for other ore bodies. In the spring of 1943 the Gran Oeste company, having found its small mill unsatisfactory, began construction of a new 50-ton mill. Meanwhile the El Fenómeno company operated its mill at half capacity and purchased all the

ore available, in an effort to stimulate exploration and development by others. The Gran Oeste company carried on exploratory and development work, as well as mining, during the summer and fall of 1943, during which period it sold the ore it mined to the El Fenómeno company while it continued the building of its own mill.

Despite the stimulus created by the well-operated El Fenómeno mill, no deposit deemed rich enough or large enough to be mined commercially was found, and in August, therefore, all exploratory work by the El Fenómeno company was halted. Work on the Gran Oeste mill was halted in mid-October, and development and mining of the deposits of this company ceased in mid-November. The El Fenómeno company continued to feed its mill with ore taken from pillars and old tailings until the early part of December, when it shut down completely and prepared to sell its equipment.

It is unlikely that tungsten mining will be resumed in the region unless larger or richer deposits than these now known are found, or unless there is a marked increase in the price of tungsten. A unit of WO_3 in scheelite concentrates containing 60 percent WO_3 or more brought $22.60 in Mexico in 1943.

Field work

Early in January 1943 the senior author spent 3 days in reconnaissance in the tungsten area, and late in May he spent 5 days accompanied by the junior author in a further brief examination. He began a detailed study of the area in the first week of September and finished it late in November. In this study the senior author was assisted by Kenneth Segerstrom, Topographic Engineer of the United States Geological Survey, who supervised the topographic work. Except for a few rocks and minerals studied in the laboratories of the Instituto de Geología, in Mexico City, the rocks and ores were examined only in the field, field determinations being deemed sufficient for this preliminary report.

The elevations shown on the maps are relative to an elevation, believed to be correct within 15 meters, established by aneroid at the starting point of the survey, in the arroyo at the mill site of the Gran Oeste company. The El Fenómeno and Cerro El Topo areas were connected by a road traverse, but, owing to the pressure of other work, road traverses to the Tío Pepe, Olivia, and Pinalito deposits (see pl. 25) were not made; these deposits were located by intersection from earlier-established points.

Acknowledgments

The work leading to this report was part of a larger cooperative program carried on by the Geological Survey, U. S. Department of the Interior, and the Universidad Nacional de México, Instituto de Geología. This cooperative program is sponsored by the Interdepartmental Committee on Cultural and Scientific Cooperation under the auspices of the United States Department of State. The authors gratefully acknowledge the cooperation and aid of the Government of México in making this study possible. They are indebted to many of the owners of tungsten deposits and to local people in the region for their aid in pointing out the deposits discovered and for information on the history of those deposits. They are particularly indebted to the Cía. Minera El

Fenómeno for data on production of tungsten in the region, for results of exploratory work, and for information on the history of deposits mined by the company. The Cía. Minera del Gran Oeste supplied valuable information on the results of its mining and exploratory work and provided facilities for drafting. These two companies also kindly put living quarters at the disposal of the Geological Survey party.

Kenneth Segerstrom, of the Geological Survey, assisted in many ways during the field work and the preparation of this report, besides making the topographic base for the maps. The American Consular staff in Tijuana cooperated generously and gave valuable advice on matters relating to economic problems. The assistance of F. C. Calkins, S. E. Clabaugh, and M. E. Dorr of the Geological Survey, in critically reading the manuscript is gratefully acknowledged.

GEOLOGY

The rocks in the region are chiefly igneous but include numerous bodies of metamorphosed sediments. The original sedimentary rocks were shale interbedded with many thin beds of limestone and a few beds of sandstone, all probably of late Paleozoic age. Into these there were intruded, probably in early Mesozoic time, small bodies of dark dioritic rocks and an extensive body of light-gray quartz diorite. During the period of intrusion the sediments were strongly folded and metamorphosed to schist, hornfels, and marble. Near the end of this period all the rocks were intruded by numerous dikes of pegmatite, some of the lime beds were altered to tactite, and the tungsten deposits were formed. The rocks have since been deeply eroded, so that over much of the region only the downfolded parts of the metamorphosed sediments remain as pendants in the quartz diorite batholith.

Metamorphic rocks

The most abundant of the metamorphic rocks is a dark-gray, fairly coarse-grained schist, composed mainly of quartz, plagioclase, and biotite, with smaller quantities of muscovite and chlorite. In general the schist is strongly crenulated and contorted. At El Fenómeno this rock occupies the greater part of the western side of the area mapped (pl. 27), and near Cerro El Topo it occupies the western margin of that area (pl. 26); it also underlies much of that part of the region which was examined but not mapped in detail (pl. 25). The topography on the schist is smooth and rounded, in contrast to the rough and bouldery topography on the quartz diorite.

Within the schist are a few thin beds of fine-grained hornfels, mostly light- or dark-gray but in part pale-green to nearly white, consisting chiefly of plagioclase, pyroxene, and quartz but locally containing a little garnet, vesuvianite, and biotite. The hornfels, which generally occurs near beds of marble or between schist and marble, probably represents a somewhat more calcareous sediment than the shale that has been altered to schist. The beds of hornfels generally pinch out along their strike, forming long thin lenses. In the El Topo area (pl. 26) the hornfels crops out mainly in the belt east of the schist. It was not mapped as a separate unit.

Beds of coarse-grained white to light-gray marble occur in a few places. Only a few of these beds are more than 5 meters thick; the thickest, at El Fenómeno, is 45 meters thick. The marble beds are lenticular, even where not cut off by intrusive rocks, and in some places they form a series of lenses more or less nearly in a plane. As little definite evidence of faulting has been found it seems probable that the original beds of limestone were squeezed and separated into lenses during the formation of the schist; some beds, however, at El Fenómeno for example (pl. 27), may have been cut off by faulting, and others were cut off by intrusion of the diorite. The greater part of the marble is white, though some, containing flakes of graphite, is gray, and some has a pale-blue tint which apparently fades out on long exposure to sunlight. Most if not all of the marble consists of calcite rather than dolomite. It is highly soluble under weathering, and many small caverns occur within and alongside the beds, some extending at least as deep as 90 meters.

No pure quartzite was found in the region, but a few thin beds of quartzitic rock, apparently derived from sandy beds, were noted in the schist near the El Fenómeno mine.

Every bed of marble that was examined grades into tactite along some part of its outcrop, and almost every zone of tactite encloses remnants of marble. The tactite consists principally of lime-silicate minerals—garnet, diopside, hedenbergite, vesuvianite, axinite, tremolite, wollastonite, and epidote—with quartz, calcite, and sulfide minerals—pyrrhotite, pyrite, arsenopyrite, and chalcopyrite—and less commonly feldspar and mica. The tactite is either pale- to dark-green or pale- to dark-brown, depending upon the relative abundance of pyroxene and garnet, and is coarse-grained in some places and fine-grained in others. Its contacts with adjacent rocks are nowhere sharp; it grades into marble on one side where marble is present, and into hornfels, schist, or diorite on the other. The tactite zones range in width from a few centimeters to as much as 40 meters. The tactite was formed by a reaction of fluids from the intrusive diorite with the more calcareous beds in the intruded sediments—a reaction that involved much chemical change.

Igneous rocks

What are probably the oldest igneous rocks in the region examined are dark-gray, fine- to coarse-grained biotite and hornblende diorite. The biotite diorite is generally darker and finer-grained than the less abundant hornblende diorite, which is generally somewhat porphyritic. These rocks occur at only a few places; they are most abundant in the northeastern part of the El Topo area (pl. 26), though they occur also along the road midway between Los Gavilanes and Rosa de Castilla. They may represent an early phase of the quartz diorite intrusion. Owing to their relative unimportance, they are not distinguished in plate 26 from the schist and hornfels.

A light-gray, coarse-grained biotite-hornblende diorite near the center of the El Topo area is included in plate 26, with the main body of quartz diorite, from which it differs only in containing little or no quartz. It may have been intruded before the quartz diorite, but no actual line of division between the two rocks has been found.

The principal igneous rock in the region is a light-gray, coarse-grained diorite containing abundant quartz and a little biotite and hornblende. The feldspar is principally andesine but includes a small quantity of orthoclase. In general the smaller bodies are finer-grained and contain more quartz and biotite than the larger ones, and their foliation is more pronounced. The quartz diorite weathers to a light rusty color and produces a rugged, bouldery topography. It crops out over a larger area than any other rock in the region, extending northward into the United States, where it is well exposed along U. S. Highway 80 in the pass east of Jacumba, Calif. It is apparently the source rock of the tungsten in the region.

Pegmatite dikes from a few centimeters to as much as 4 meters wide are numerous in parts of the region, particularly in metamorphosed sediments near the borders of the larger bodies of quartz diorite. Many of these dikes contain small quantities of tourmaline and, less commonly, of garnet. Only the larger and more conspicuous of these dikes were mapped.

A fine-grained quartz-diorite (?) dike that occurs along the west side of the El Topo area (pl. 26) contains less biotite and hornblende than the typical quartz diorite and may be more closely related to granite in composition.

Structure

The areas mapped in detail were not large enough to determine the broad structural features in the Sierra de Juárez in more than a general way, but it seems evident that the rocks have been complexly folded, with major fold axes trending north-northwest. The principal structural trend in the region is N. 25°-35° W., with local deviations around embayments of sediments in the diorite, such as that near Los Gavilanes (see pl. 26). The prevailing dips of the metamorphosed sediments are between 40° and 65°, and the dip of the foliation in the schist is generally greater than 75°.

For long distances the igneous contacts are nearly parallel in dip and strike to the adjacent beds, but when followed far enough along the strike or down the dip they are found to cut gradually across the bedding. All beds of marble and tactite near an igneous contact will presumably be thus cut off downward by the igneous rock, if they do not pinch out first. This cutting off is well illustrated in the El Fenomeno mine (pl. 28), in the La Raza mine (pl. 31), and in the Los Aliados de América mine (pl. 34). As all the smaller bodies of metamorphosed sediments that could be well observed are wedgelike pendants in the biotite diorite or the quartz diorite, the larger bodies in the region probably have somewhat the same form.

No major faults were noted in the areas examined in detail, but small faults were suspected at several places, notably near the El Fenómeno mine (pl. 27). These faults are apparently older than the diorite intrusion. No faults closely associated with the ore bodies were found.

TUNGSTEN DEPOSITS

The largest known tungsten deposit in the region is th El Fenómeno, which is in the southwestern corner of the area

examined (pl. 25). The smaller deposits are most numerous near Cerro El Topo (pl. 26), where more than 25 separate deposits have been found within an area of 10 square kilometers. A group of 6 or 8 deposits has been prospected near Corte de Madera, about 10 kilometers northeast of El Fenómeno, and two other deposits a few kilometers farther north, the Pasadena and El Pinalito, have been prospected or mined. The Olivia deposit, some 15 kilometers east-northeast of El Fenómeno, has yielded a little ore. A group of four deposits on the Socorro claim, which is about 5 kilometers south of Cerro El Topo, has been slightly prospected, and work has been done on some deposits on the Tío Pepe claim, 11 kilometers east-southeast of Cerro El Topo. All these deposits were examined, but not all of them were mapped in detail.

A deposit is said to have been found some 25 kilometers by road northwest of Los Gavilanes, and some ore occurs about 15 kilometers by road farther northwest, but neither of these localities was visited. Many others undoubtedly occur in the area examined, as well as farther north and south, but prospecting has been rather hampered by the relative inaccessibility of much of the country and the prospectors' lack of familiarity with tungsten minerals.

Occurrence

Scheelite, the only tungsten mineral in the region, occurs mainly in tactite on or near contacts with quartz diorite. A scheelite-bearing zone that is mostly in tactite may extend for a short distance out into the adjacent marble, hornfels, schist, or quartz diorite, but all the commercial ore is confined to the tactite. The width of the zones rich in scheelite ranges from less than a centimeter to as much as 17 meters, but it is generally less than 2 meters. These zones rarely maintain a constant width for more than a few meters, being rather pockety or lenticular. An ore zone is generally about parallel to the walls of a body of tactite, which may form an ill-defined sheet between marble and quartz diorite or may replace irregularly a part or all of a bed of marble. In some deposits the ore zone is on the marble side of the body of tactite, in others on the diorite side, and in still others wholly within the tactite. There is no constant relation between the width of the tactite zone and the width of the scheelite-bearing zone. Many bodies of tactite are barren or nearly so.

The ore bodies generally have dips of 45° to 65°, being roughly conformable to the enclosing marble beds or to contacts between quartz diorite and marble. Where exploratory work has fully outlined the ore bodies, they seem to narrow downward, having profiles like that of a half-opened fan. In the El Fenómeno deposit (pl. 28), the sides converge toward a point somewhat more than 93 meters below the outcrop, and in the El Topo deposit (pl. 35) they apparently converge toward a point about 30 meters below the outcrop. In some other deposits, including the Los Aliados de América (pl. 34) and the La Raza (pl. 31), the ore bodies are cut off at depths of 10 to 20 meters by the underlying intrusive rock. It is to be expected that most of the other deposits in the region, when they are thoroughly explored, will likewise be found to taper downward or to be cut off by the diorite. The maximum depth to which a deposit may be expected to extend is apparently somewhat less than the length of its outcrop.

Prospecting is most likely to be successful on and near contacts between the quartz diorite and moderately large bodies of metamorphic rock. Small pendants, even if they contain good ore, can hardly yield any considerable tonnage. Large beds of marble should be sought, and they should be searched for tactite and scheelite. Most of the beds of marble in the areas examined in detail are so small that they cannot contain sufficient ore to support commercial mining operations.

Mineralogy

The scheelite ($CaWO_4$) in this region forms small equidimensional crystals, which are white in fresh rock but pale-yellow in strongly weathered rock, where they are coated with thin films of secondary tungstic oxide. The fluorescence color of the scheelite is bright blue-white, indicating that the mineral contains little or no molybdenum, and a low molybdenum content is more definitely shown by chemical and spectrographic analyses.

The most abundant of the minerals that accompany the scheelite in the best-explored deposits are light- to dark-brown garnet, brownish-green vesuvianite, dark-green diopside and hedenbergite, quartz, calcite, and gray to pale-violet axinite. The relative proportions of these minerals vary from one deposit to another and from place to place in each deposit. In a few deposits other lime-silicate minerals, such as white tremolite and wollastonite and dark-green epidote, are more abundant than those named above. Sulfides occur in all the ores below the zone of weathering, which generally extends to a depth of at least 5 meters. The principal sulfide mineral is pyrrhotite (magnetic iron sulfide); pyrite is second in abundance, and chalcopyrite and arsenopyrite are generally scarce. Small quantities of magnetite and hematite are present in all the deposits and at least traces of gold have been found in most of the ores.

Preliminary table concentrates of ores in the region consist mainly of scheelite and garnet, though they contain small quantities of other heavy lime-silicate minerals and of iron oxides and sulfides. An assay 1/ of table concentrates from ore from the El Topo deposit gave the following percentages: 34.66 WO_3, 0.76 S, 0.16 As, 0.14 P, 0.02 Cu, and a trace of Sn. A spectrogram made at the same time gave the following results:

Major metallic elements: W, Ca, Si, and Al.

Intermediate metallic elements: Mg and Fe.

Minor metallic elements:

	Percent		Percent		Percent
Ti.....	1.0	Cu.....	0.05	Co.....	0.005
Mn.....	.1	Zr.....	.05	Cr.....	.001
Bi.....	.1	Sn.....	.01	Ni.....	.001
As.....	.1	V.....	.01	Ba.....	.001
Mo.....	.05	Sr.....	.005	Ag.....	Present

Most of the non-metallic and metallic minerals in the table concentrates can readily be separated from the scheelite in an electro-magnetic separator, leaving high-grade concentrates that

---

1/ Assay by Smith, Emery & Co., Los Angeles, for the Cía. Minera El Fenómeno.

contain from 60 to 70 percent WO_3. A 30-ton shipment in May 1943 of concentrates after electro-magnetic separation gave the following assay:2/

	Percent
WO_3	66.90
As	.13
S	.06
Cu	.02
Sn	.00

Another 30-ton lot shipped in July gave the following:

	Percent
WO_3	68.03
S	.08
As	.04
Cu	.00
Sn	.00

Origin

The tungsten deposits in the region are of the pyrometasomatic or replacement type. They were formed adjacent to intrusive quartz diorite, in chemically favorable beds that were for the most part highly calcareous, by reaction of fluids from the diorite with calcium carbonate. The movement of the fluids was undoubtedly directed in part by fractures, which caused some beds to be replaced while others were not, but no commercial ore was formed where calcareous beds, chiefly marble, were not present. In general the larger bodies of calcareous rock contain the larger bodies of tungsten ore, but there are exceptions to that rule, and a large calcareous body does not necessarily contain a proportionately large deposit of scheelite.

Intrusion of the quartz diorite was accompanied by metamorphism of the sedimentary rocks to schist, hornfels, and marble. After the intrusive rock had consolidated sufficiently to fracture, numerous pegmatite dikes were injected into it and the adjacent metamorphic rock. Partly, perhaps, during the emplacement of the pegmatite, but certainly in part after its emplacement, fluids escaping from the crystallizing magma reacted with the calcareous beds to form tactite, as shown by a weak replacement by tactite minerals of some of the pegmatite that cuts the tactite bodies. The scheelite probably was deposited during and immediately after the formation of the tactite, in which it generally forms euhedral crystals. As a little scheelite occurs in the outer borders of the pegmatite dikes that cut through ore bodies, it apparently was deposited after the pegmatite was emplaced. The size and richness of the tungsten deposits are clearly independent of the presence or absence of pegmatite dikes. The tungsten-bearing fluids contained considerable quantities of silica, for irregular masses and abundant small crystals of quartz occur in the largest and richest ore bodies.

PRODUCTION AND RESERVES

The production of tungsten from this region during World War I is not known but is roughly estimated at about 4,000 units

2/ Assay by Ledoux & Co., New York, for the Cía. Minera El Fenómeno.

of WO_3. The production between 1937 and December 1943, when mining ceased, amounted to about 60,000 units of WO_3, in concentrates averaging roughly 65 percent WO_3. All but 3,300 units was produced from the El Fenómeno deposit, the rest having been mined during 1943 from nine other deposits in the region. All the final concentrates were produced in the El Fenómeno mill; about 4 tons of low-grade concentrates produced in the first mill of the Cía. Minera del Gran Oeste was sold to the El Fenómeno company and reconcentrated. An itemized account of the sources of the tungsten is given in the following table:

Sources of tungsten produced in Lower California

Deposit	Period	Tons of ore milled	Average percent WO_3 in ore milled	Units of WO_3 recovered in concentrates
El Fenómeno....	1917-19	5,000*	0.9*	4,000*
El Fenómeno....	1937-43	100,000*	0.7*	56,700*
La Raza.....	1943	1,480*	1.3*	1,650*
El Audaz.....	1943	300*	0.9*	220*
El Topo.....	1943	250*	1.75*	350*
Los Aliados de América.....	1943	703	1.48	835
El Dieciséis de Septiembre	1943	121	0.91	96
La Esperanza...	1943	86	0.80	58
Cienpiés.....	1943	58	0.55	29
Olivia.....	1943	36	1.33	43
El Pinalito....	1943	26	0.83	19
		108,060		64,000

* Estimated

It has been virtually impossible to explore and measure the ore bodies in advance of mining, because of their pockety, lenticular forms and the unpredictable downward courses of the intrusive contacts, which have sharply cut off some ore bodies that were expected to continue to greater depth. As the shape, size, and tenor of a deposit have never been accurately known until the deposit was mined out, estimates of reserves must necessarily be very rough. The tonnage and grade of the remaining ore can be estimated only from what is recorded concerning ore already mined and from general geologic evidence.

The El Fenómeno deposit yielded from the upper levels more than 70,000 tons of ore, averaging 0.7 percent WO_3 or more, but ore from the two lower levels, mined during 1943, averaged less than 0.4 percent, and much of that last mined contained less than 0.2 percent. Both sides of the body of commercial ore—material containing at least 0.4 percent of WO_3—have approached the shaft in the bottom levels, as if converging toward a point just below the bottom of the shaft (see pl. 28). The bottom of the ore body thus appears to have been nearly reached, and it is estimated that only 600 or 700 tons of ore containing 0.4 or 0.5 percent WO_3, remains in the mine.

Two other deposits in the region have been virtually mined out, having been cut off by intrusive rocks. One of these, the Los Aliados de América, produced 703 tons of ore averaging 1.48 percent WO_3, and about the same tonnage of rock containing little or no scheelite was discarded under ultraviolet light. The other deposit, the La Raza, produced about 1,500 tons of ore averaging 1.3 percent WO_3, and probably not more than 150 or 200 tons of

ore of the same grade remains in the mine. This ore also was carefully sorted under ultraviolet light, somewhat more rock being discarded than was milled. With the exception of the El Fenomeno deposit, these two have yielded larger tonnages of high-grade ore than any of the other deposits in the region. Yet the aggregate cost of exploration, road construction, mining, transportation, milling, and taxes was greater than the value of the ore recovered. These deposits did, indeed, come close to paying for themselves, but all the others mined in the region, except the El Fenómeno, have caused considerable loss to the owners.

The geology of all the other deposits examined in the region, again excepting the El Fenómeno deposit, is similar to that of the La Raza and Los Aliados de América deposits. None seems to hold much promise of being significantly larger, and, moreover, the ore bodies exposed are lower in grade than those mined. Although a deposit of ore containing as little as 0.4 percent WO_3 was generally considered commercial at the 1943 price of tungsten if it was fairly large, the small size of the unmined deposits would prevent them, in the writers' opinion, from being profitably mined even though they were found to contain some high-grade ore. Where ore must be hauled to a mill more than a few kilometers away, a deposit containing less than 2,000 tons generally cannot be considered commercial unless the ore averages better than 0.8 percent WO_3. No deposit with more than 100 tons of ore as rich as this is known to remain unmined in the region, except the El Fenómeno and La Raza deposits, which contain in all somewhat less than 1,000 tons.

The tonnage and grade of tungsten-bearing rock estimated to remain in each of the deposits that have been explored are given in the table on the next page, which does not include the indicated ore in the El Fenómeno and La Raza deposits. If the data in this table are correct, none of these deposits can be mined commercially at the 1943 price of tungsten.

MINES AND PROSPECTS

Deposits mapped in detail

El Fenómeno

The El Fenómeno mine is in the southwestern corner of the area examined (pl. 25). In 1943 it was under lease to the Cía. Minera El Fenómeno, by which it was being operated.

Geology.—The El Fenómeno deposit extends along an intrusive contact between quartz diorite and metamorphosed sediments (see pls. 27 and 28). The quartz diorite, the main body of which occupies the eastern part of the area, has been intruded into a series of sediments consisting chiefly of shale but including beds of limestone and impure sandstone, and has metamorphosed them to schist, phyllite, hornfels, marble, and impure quartzite. West of the main body there are three small areas of the quartz diorite. The marble forms two principal belts, the largest of which extends continuously along the main intrusive contact for 330 meters and has a maximum thickness of about 45 meters. A second, smaller belt lies a few meters farther west. The marble is white, light-gray, or pale-blue and is coarsely crystalline. It is rather soluble and contains caverns and wide fissures that extend as deep as the deepest workings, 93 meters below the surface.

Tactite, consisting mainly of garnet and diopside, occurs around the edges of the marble at many places and also forms irregular masses within the marble. A few pegmatite dikes cut through all the rocks, being especially numerous in the metamorphic rocks near the diorite contact. In some places they contain small quantities of tourmaline and garnet; in other places they consist mainly of quartz.

Tungsten-bearing rock in explored deposits

Name of deposit	Average mining width in meters	Estimated tonnage	Percent WO_3
El Audaz.....	1.3	2,000	0.3 -0.4
El Dieciséis de Septiembre.....	1.2	4,000	.1 - .2
Pearl Harbor.....	1.2	6,000	.2 - .3
El Topo.....	1.2	6,000	.2 - .3
El Pinalito.....	1.2	500	.2 - .3
Cienpiés.....	4.0	2,000	.3 - .4
Olivia.....	1.2	3,000	.3 - .4
Pasadena.....	1.2	2,500	.3 - .4
TOTAL.....		26,000	0.25-0.3

The metamorphic rocks strike northwest. The beds of marble dip, on the average, 65° SW., but the foliation of the schist is everywhere nearly vertical. The larger belt of marble is cut off at both ends by the diorite, and exposures of the contact in the underground workings indicate, also, that the marble terminates downward against diorite. The smaller belt of marble pinches out at the south end and is probably cut off by a fault at the north end, and it may be cut off at shallow depth by the diorite (see pl. 28). The diorite contact is rather irregular in both strike and dip. Its dip, though locally a little steeper than the bedding of the sediments, is generally somewhat flatter. At two places west of the main body the diorite has invaded the metamorphic rocks and has separated most of the marble from the rest of the metamorphic rocks, so that wedges of marble pinch out downward in the diorite. The marble beds are apparently cut off just north of the center of the area shown in plate 28, by a fault, which, as it does not affect the main diorite contact, is presumably older than the diorite. Some of the principal pegmatite dikes are parallel, and the others about perpendicular, to the strike of the metamorphic rocks.

Ore deposit.—Virtually all the tungsten is in the mineral scheelite, which is almost everywhere accompanied by garnet but is not constantly associated with any other mineral. Garnet predominates in most of the ore, but locally vesuvianite, axinite, diopside, quartz, or calcite predominates. A small percentage of the ore has a gangue of quartz diorite, with a scattering of lime-silicate minerals. Minor quantities of iron oxides and secondary copper minerals occur in the weathered part of the ore body, and sulfide minerals (pyrite, pyrrhotite, chalcopyrite, and arsenopyrite) occur in the fresh rock. In ore near the surface and along caverns and open fissures in the marble, where the rock is strongly weathered, the scheelite is so friable that there is considerable loss by sliming in the mill, but in fresh rock the scheelite is firmer and more easily recovered.

Although in some parts of the deposit the entire zone of tactite between the marble and the quartz diorite is commercial ore,

668013 O - 45 - 2

that is not usually the case. In general most of the best ore is on the marble side of the tactite zone, but at some places the tactite near the marble is barren and that near the diorite is good ore. The few pegmatite dikes that cut through the ore body are barren except where they come in contact with the ore body; there they contain a few crystals of scheelite in their outer borders.

The main ore body is in the zone of tactite between the large mass of marble and the main body of diorite (see pl. 28). The full length of the scheelite-bearing zone at the surface is 185 meters, but the length of the commercial ore body is only 120 meters. The ore body has a profile somewhat like that of a fan, and the shaft has by chance been placed in the center (see pl. 28). The sides appear to be converging toward a point just below the bottom of the shaft, which has reached a depth of 93 meters, for at that depth the ore is only 4 or 5 meters long and about 3 meters wide. Its width in the upper part of the deposit has varied from 0.2 to 17 meters, averaging about 4 meters. Much of the best ore was in large pockets or thick lenses. Some ore has been mined from irregular veinlike masses of tactite extending from the main body into the marble, as shown at the south end of the tunnel and on the 250-foot level (see pl. 28).

The middle part of the northwestward extension of the 200-foot level is in rock containing less than 0.2 percent WO_3, but the rock is somewhat richer near the end of the drift, just beyond which the marble and tactite are cut off by the diorite. There may be another, though smaller, fanlike ore body in the north end of the mine, where some ore has been stoped from above the 200-foot level, but that ore was so narrow (generally less than 1 meter wide) that much barren rock had to be removed and mining was not profitable. Owing to this fact and to the presence of deep, broad fissures along the marble, which further tended to increase mining costs, no exploratory drifts were run at lower levels.

In the crosscut leading to the mill, traces of scheelite occur at three places west of the main ore body, but as these zones are narrow and contain less than 0.1 percent WO_3, they have not been explored. Where the first zone was cut, opposite the shaft on the 200- and 300-foot levels, it is less than 0.3 of a meter wide. Outcrops of scheelite-bearing rock separate from the principal ore body occur at two other places in the area. The larger outcrop is in the tactite zone west of the main bed of marble, just south of the center of the area shown in plate 28, and near a quartzose part of a pegmatite dike. As the outcrop is not extensive and the rock not of commercial grade, no exploratory work has been done. A somewhat smaller outcrop is explored by the westernmost trench, just west of the center of the area, but no commercial ore was uncovered. Trenches on the diorite contact at three places north of the north end of the mine (see pl. 27) revealed no trace of tactite or scheelite.

Mill practice.—The mill at the El Fenómeno mine comprises two nearly identical units, which together can mill about 200 tons a day (see pl. 29). After passing over a 3/4-inch grizzly, the ore is put through a jaw crusher and sent to a 16-mesh vibrating screen, where it is mixed with water. The oversize from the screen goes to a 4- by 4-foot center-discharge ball mill, whose discharge returns to the screen. The undersize is separated in a rake classifier into sands and slimes, the sands going to Overstrom tables and the slimes to a Wilfley table. The concentrates from the tables go to a storage bin; the tails to a

thickener, where water is recovered and the solids are discharged to the dump; and the middlings go to another set of Overstrom tables. The concentrates and tails from these tables are treated like those from the primary tables, and the middlings go to a third set of Overstrom tables. From these tables the tails are discharged to the thickener, and the concentrates and middlings go back to the first set of tables. The concentrates from the storage bin are retabled on a small Overstrom table, from which the concentrates go to another storage bin for magnetic separation. The middlings and tails go back to the first set of tables. The final table concentrates, which consist mainly of scheelite and garnet but include sulfides, iron oxides, and several heavy lime-silicate minerals, contain from 25 to 35 percent WO_3.

These final table concentrates are dried in an oil-heated rotary drier and fed to a magnetic separator, where three magnets of successively higher intensity pull out the iron-bearing minerals. The non-magnetic concentrate is returned to the drier and roasted, after which it is again put through the separator. The final non-magnetic concentrate is nearly pure scheelite and contains from 65 to 70 percent WO_3. A middlings product taken at the second and third magnets and at the non-magnetic discharge is sent back to the vibrating screen. The rest of the material pulled out by the magnetic separator is stored separately and is periodically returned to the mill circuit. Thus the only scheelite lost is that carried away in the main tailings discharge.

Tailings from hard fresh ore have assayed 0.05 to 0.08 percent in WO_3, averaging a little less than 0.07 percent. As calculated from assays of the tailings and the amount of WO_3 recovered in the final concentrates, mill recovery has varied from 75 to a little better than 90 percent and averaged about 85 percent. Recovery largely depends, of course, upon the tungsten content of the ore milled, being better from high-grade than from low-grade ore. It also depends upon physical condition: soft weathered scheelite slimes readily, which causes a loss of tungsten, tailings from small runs having assayed as high as 0.15 percent WO_3; but, since nearly all the weathered ore milled in the past year contained more than 0.8 percent WO_3, final recovery was better than 80 percent.

Production and reserves.—Production from the El Fenómeno deposit during World War I is not known, but it is estimated to have been, very roughly, 4,000 units of WO_3. Between the time the deposit was reopened in 1937 and December 1943, when mining ceased, about 60,000 units of WO_3 was produced in concentrates averaging about 65 percent WO_3. During the first two or three years of renewed mining the average WO_3 content of the ore varied from 0.8 to 1.0 percent, but later it dropped to about 0.7 percent. After the middle of 1942, when the enlarged mill was put in service, leaner ore was mined, so that the WO_3 content dropped rather abruptly, until in February 1943 it was less than 0.2 percent.

Between the beginning of October 1942 and the end of February 1943, 21,590 tons of ore, averaging 0.30 percent WO_3, was mined and milled. From February until late in July, when systematic mining ceased, the ore probably did not carry more than 0.3 percent of WO_3, even though production was cut in half and an effort was made to mine only the best ore available in the lower part of the deposit. The mill heads, however, were kept somewhat higher by admixture of higher-grade ore from other deposits. Between October and December the company milled all old tailings from earlier operations, all dumps containing 0.25 percent WO_3 or

more, and all slabs and pillars of high-grade ore that could safely be taken from the mine. About 500 units in concentrates was produced during this clean-up period. Mining and milling ceased early in December 1943.

More than 1,000 tons of ore containing at least 0.6 percent WO_3 remains in pillars in the mine, but this ore cannot safely be removed. The results of past mining operations indicate that 600 or 700 tons of ore containing 0.4 or 0.5 percent WO_3 remain in the bottom of the mine. Without the aid of extensive exploratory work, there can be no basis for believing that there is a larger tonnage. Some ore may possibly remain at deeper levels in the north part of the mine, and there may be ore along one of the diorite contacts west of the main contact and below the bottom of the mine, but the chance of finding other ore bodies is hardly good enough to warrant the expense of exploration by means of crosscuts and drifts. Diamond drilling seems to be the only feasible method of exploration, and mining should not be resumed until drilling has revealed sufficient ore to justify it.

El Audaz

The El Audaz mine (pl. 30) is located just across the arroyo from Los Gavilanes, in the northeastern corner of the El Topo area (pl. 26). The deposit is controlled and was operated by the Cía. Minera del Grand Oeste. It is in a small pendant of marble and tactite, 90 meters long and 15 to 50 meters wide, in schist intruded by dark-gray fine-grained biotite diorite, about 120 meters northwest of the main body of quartz diorite. On the surface the pendant is cut off at both ends by biotite diorite, which probably cuts it off underground, also, at relatively shallow depth. Small irregular masses of quartz diorite crop out just east of the center of the tactite body, and presumably the diorite increases in abundance downward.

The entire pendant may originally have been a single bed of limestone, most of which was altered to tactite after intrusion of the quartz diorite. Several small dikes of pegmatite, the largest of which are shown on the map (pl. 30), cut all the rocks.

The marble is white to light-gray, and most of it is coarsely crystalline. Its contacts with the tactite are irregular, though in general nearly parallel to the bedding, which strikes northeast and dips 50° to 60° NW. The tactite consists mainly of light-gray to pale-green pyroxene but everywhere contains garnet; in places it also contains abundant quartz, calcite, and vesuvianite. Sulfide minerals, though weathered to oxides near the surface, occur in fresh rock in the deepest workings. The scheelite, general forming very small white grains, occurs in dense fine-grained tactite, more abundantly in the green tactite than in the brown.

The workings include four pits and two adits, one of which is connected with the surface by an incline shaft and has a 10-meter winze. Four nearly parallel scheelite-bearing zones of tactite are exposed, each on the southeast side of a marble bed. Only one of the scheelite-bearing zones found thus far is wide enough and rich enough to be regarded as possible commercial ore. This zone crops out farthest south and is exposed in the drift and winze in the largest workings (see sections and map of adit on pl. 30). The maximum length of this zone at the surface appears

to be about 35 meters, and its width in the part explored varies from a few centimeters to 2 meters, averaging about 1 meter. In one place this zone has been followed for a distance of 28 meters down the dip. At that depth the ore-bearing zone is about 0.7 of a meter wide. Two pegmatite dikes that cut through the ore body are barren.

About 300 tons of ore, averaging roughly 0.9 percent WO_3, has been selected from the rock mined and has been milled at El Fenómeno. The last hundred tons or so of selected ore averaged somewhat less than 0.8 percent WO_3, but the grade could have been raised a little by more careful selection. About 200 or 250 tons of rock was mined from the winze, which was sunk on the ore body, and about 60 tons of this rock has been selected for milling. Probably this selected material does not contain more than 0.4 percent WO_3 and would have to be re-sorted before shipping. Although most loose waste rock had to be removed because of the cavernous nature of the material in the winze, it is doubtful whether the ore body could have been mined at a profit even if the rock had been solid.

Assuming that the ore body is mined at a minimum width (1.3 meters or less), the maximum tonnage that might be expected from the deposit is estimated to be about 2,000 tons of rock averaging 0.3 or 0.4 percent WO_3. By careful selection under ultraviolet light a somewhat smaller tonnage of higher-grade ore could be sorted out. As the production cost of the ore already mined has been several times its value, it is highly improbable that this deposit could be mined commercially even at the present stage of development. Without further exploration it cannot be presumed that this pendant contains any other body of ore.

La Raza

The La Raza mine, which is controlled by the Cía. Minera del Gran Oeste, is 600 meters west of Los Gavilanes, in the northeastern corner of the El Topo area (pl. 26). It is in a small pendant of metamorphic rock, 21 meters long, 13 meters wide, and 16 meters deep, in quartz diorite and biotite diorite (see pl. 31). On the east side the pendant is cut off by the dark diorite, and on the other sides and the bottom it is cut off by the quartz diorite, which also cuts off the darker biotite diorite. This pendant consists mainly of garnet-diopside tactite but contains hornfels and schist. The tactite probably was formed by complete replacement of thin beds of limestone.

Three other larger pendants, composed mainly of hornfels and schist, near the La Raza mine are wholly or partly included in the area shown in plate 31. They strike northeast and dip about 50° NW. Two of these contain thin lenses of tactite, which because of their discontinuity and poor outcrops were not mapped separately. Pegmatite dikes, which trend north-northeast, are more numerous near the La Raza mine than at any other place in the region. The intrusive contacts are steeper than the bedding in some places and less steep in others.

Scheelite occurs in the pendants at six or seven places. In the southernmost exploratory workings in the long southeast pendant, the scheelite is associated with hornfels, but elsewhere it is associated with tactite. More of it is associated with the green diopside tactite than with the brown garnet tactite, though high-grade ore occurs in both. The fresh rock in the deepest

workings contains sulfide minerals. In general the tactite and scheelite are fine-grained, but in places they are coarsely crystalline, and the richest ore is in the coarse-grained rock.

Scheelite-bearing rock has been explored in six places by means of pits, trenches, adits, and shafts. The adit in the southeast pendant (see pl. 31) cuts two scheelite-bearing zones in hornfels, and one of the zones is also cut in the two pits just north of the adit, but scheelite is extremely scarce in all these exposures. Tactite containing a little scheelite is exposed in the pit near the center of the same pendant, but it is much too narrow and low-grade to be mined. Just north of this pit a 6-meter shaft, from the bottom of which a 4-meter crosscut has been driven, was put down on the outcrop of a narrow zone of tactite, which contained scheelite along its contact with quartz diorite. The tactite and scheelite seem to pinch out at a depth of 2 meters, but they may dip at a low angle toward the northwest. The crosscut may not have reached the extension of the scheelite zone; it should have been driven northwestward instead of westward. The zone may, however, have been cut off by the quartz diorite before reaching that depth. At best it gives little promise of yielding commercial ore, for it is little more than half a meter wide at the surface.

Two zones of scheelite-bearing tactite crop out in the small pendant just east of the principal workings, north of the center of the area shown in plate 31. The eastern zone is less than half a meter wide and contains very little scheelite at the surface; the western zone is still narrower and contains even less scheelite.

The principal deposit in the La Raza property has been explored by means of a small glory hole and 70 meters of underground workings, which include a vertical shaft, an incline shaft, and some short drifts and crosscuts. At the level of the open cut, scheelite occurs in tactite in two parallel zones which join at the north end against the intrusive contact with the dark diorite (see section and mine level maps in pl. 31). The eastern zone was not explored below the bottom of the incline shaft, which is at nearly the same level as the bottom of the open cut, the ore having been considered too lean to be worth mining. Most of the western zone has been mined, with the exception of some ore that could not be removed without destroying the shaft. At 2 meters below the first level the metamorphic rocks, and consequently the ore body, are cut off by the quartz diorite. This deposit has been sufficiently explored to locate the limits of the ore body rather definitely.

The La Raza deposit has yielded about 1,480 tons of ore, which averaged roughly 1.3 percent WO_3. Except for the lower end of the vertical shaft, not much dead development work has been done. Most of the rock mined was regarded as ore, though it had to be very carefully selected under ultraviolet light to maintain a tungstic oxide content of more than 1.0 percent. The larger part of the ore came from the small glory hole in the southwest corner of the open pit, but all the ore there seems to have been removed. Past mining operations indicate that 150 or 200 tons of ore containing 1.2 or 1.3 percent WO_3 can still be obtained by careful selection from the rock around the north end of the vertical shaft, though removing this ore would of course destroy the shaft.

El Dieciséis de Septiembre

The El Dieciséis de Septiembre deposit is 450 meters southwest of Los Gavilanes (see pl. 26). It is controlled by the Cía. Minera del Gran Oeste. The scheelite is in a small pendant 20 meters wide and somewhat more than 85 meters long, cut off on all sides and probably at shallow depth by the dark biotite diorite (see pl. 32). A small mass of quartz diorite is intruded into the pendant and into the dark diorite just south of the shaft; the contact of the main body of quartz diorite is 260 meters southeast of the deposit. The pendant consists mainly of hornfels, but near the north end it contains a body of marble, which has been replaced by tactite at three or four places along the bedding planes. The bedding in the metamorphic rocks strikes about N. 70° E. and dips 45° to 70° NW. Foliation in the diorite strikes northeast and dips more steeply than the beds in the pendant. The southeast intrusive contact of the pendant is less steep than the bedding, and the northwest contact somewhat steeper, so that the pendant wedges out downward. Pegmatite dikes are numerous in the deposit. The principal dike extends from within the outcrops of the main body of quartz diorite northwestward through the La Raza open cut (see pl. 26).

Scheelite occurs in narrow zones of tactite in and around the marble. The gangue is chiefly garnet. It replaces the borders of the pegmatite dikes where they cut the ore bodies; elsewhere the pegmatite is completely barren. The best ore is in the most coarsely crystalline tactite. At the surface three principal zones of scheelite-bearing rock crop out, but in the adit five zones are exposed (see map of adit in pl. 32). Apparently only the three principal zones contain ore that is near commercial grade. The maximum length of the northernmost zone is 40 meters, that of the second 25 meters, and that of the third about 35 meters. The zones vary in width from 0.1 to 2 meters, averaging little more than half a meter. As in all the other deposits, the ore bodies are lenticular and pockety. Assuming that they are similar in form to the El Fenómeno deposit, their maximum depth would be less than 35 meters.

The El Dieciséis de Septiembre deposit has yielded 121 tons of ore, averaging 0.91 percent WO_3, and 30 or 35 tons of ore of nearly the same grade has been sorted out into piles on the dumps. Out of some 250 or 300 tons of rock excavated from the 22.6-meter shaft, only 8 or 10 tons of ore, averaging 0.9 or 1.0 percent WO_3, has been obtained. The open cuts have represented much dead work, and even the rock removed from the adit was in large part barren. Even without counting in the expense of building the road to ship the ore, the value of the tungsten in the ore sold has not paid the cost of mining. At best, the deposit may contain roughly 2,500 tons of ore averaging 0.3 or 0.4 percent WO_3, from which perhaps 1,000 tons of ore containing 0.8 or 0.9 percent WO_3 might be sorted. But, owing to the narrowness of the ore bodies, so much barren rock would have to be mined that the total amount of rock to be removed would be about 4,000 tons, and its average WO_3 content would not exceed 0.2 percent. That is of course too low to permit profitable mining.

Pearl Harbor

The Pearl Harbor deposit is near the center of the El Topo area, near the middle of cross section line B-B' in plate 26.

The tungsten is in a long pendantlike extension, 20 meters wide, of a fairly large body of metamorphic rock. The pendant is in contact on both sides with intrusive diorite, which probably cuts it off at shallow depth (see pl. 33). The pendant consists mainly of hornfels and schist, but it includes, in a north-northeast-trending zone, five separate bodies of marble, and the tungsten deposit is in the middle body. The marble at the principal workings forms two parallel beds, striking N. 15° E. and dipping 65° to 70° W., both of which are cut off by the diorite. The western bed is 45 meters long and 2 to 3 meters wide, and the eastern one 60 meters long and 7 meters wide. Sheets of tactite from 0.5 to 2 meters wide extend along the east side of the marble. The tactite and marble in the western bed may be cut off by the diorite at a depth of 35 meters or less; the eastern bed may extend somewhat deeper.

Scheelite occurs in some of the tactite along the east side of each of the two beds of marble. Its gangue is chiefly garnet in the eastern tactite zone but contains much epidote in the western one. The best ore exposed in the eastern zone is in coarsely crystalline rock composed of garnet, vesuvianite, calcite, quartz, and axinite. The ore body is from 0.2 to 1 meter wide and apparently extends throughout the length of the tactite zone, which is about 60 meters. It is explored by an open pit and a 3-meter adit. The western ore body, which is 0.1 to 0.5 of a meter wide and about 40 meters long, is explored by a trench 7 meters long, 1.5 meters wide, and 1.5 meters deep. The adit was begun with the object of cutting the western ore body but was not driven far enough to reach it.

About 15 tons of ore, containing 0.5 to 0.7 percent WO_3, has been sorted out in the course of the exploratory work, but none has been shipped. By comparison with other deposits mined, it is inferred that the maximum tonnage of ore in the eastern zone is about 3,000 tons averaging roughly 0.5 percent WO_3, which, owing to the narrowness of the ore zones, could be obtained only by mining a nearly equal amount of barren rock. Similarly, the tonnage of ore of the same grade in the western zone is estimated to be about 500 tons, but that could be obtained only by mining about twice its weight of barren rock. About 7,000 tons of rock would thus have to be mined to obtain the ore, which makes the overall WO_3 content 0.2 or 0.3 percent. At 1943 prices, it would not pay to mine ore of that grade.

Los Aliados de América

The Los Aliados de América mine, the easternmost tungsten deposit on the claim of that name, lies near the center of the El Topo area. It is crossed by the eastern part of cross section line B-B' in plate 26. The deposit was mined by the Cía. Minera El Fenómeno. The tungsten ore is in a small pendant of hornfels, tactite, and marble in dark biotite diorite, 80 meters northwest of the contact with the main body of quartz diorite. A smaller body of quartz diorite lies 60 meters west of the deposit, and other masses too small and irregular to be shown on the map (pl. 34) occur in and around the pendant. The main pendant, not counting a tail of metamorphic rock, is 20 meters long and 10 meters wide, and it has been sufficiently explored to prove that it is completely cut off by the biotite diorite at a depth of 6 meters. A remnant of marble 15 meters long and 3 meters wide extends along the south side of the pendant. North of the marble are three zones of tactite separated by zones of hornfels,

and a narrow zone of tactite extends along the south side of the marble between it and the biotite diorite. An inclusion of hornfels and tactite a few meters long lies in the quartz diorite across the arroyo from the mine.

The main workings consist of an open pit connected by a short incline with an adit 17 meters long. Several shallow trenches explore the bedrock around the pit, and a small cut was made in the small inclusion just mentioned. Scheelite occurs in most of the tactite and rarely in the hornfels. Most of it is associated with garnet-pyroxene tactite in the open pit, but some good ore has contained abundant epidote, calcite, and quartz, and less commonly vesuvianite and axinite. Most of the rich ore was coarsely crystalline. The greater part of the ore mined was on the north side of the marble and around the west end. The tactite zone on the south side of the marble averages barely half a meter in width, and moreover, it contains little scheelite. The adit and incline, though extending under the outcrop of the pendant, are wholly in diorite, and the lowest part of the open pit, near the west end, has reached the diorite under the pendant. The small inclusion east of open pit contains a little scheelite-bearing tactite, but it is of low grade and not worth prospecting further. The pit in the inclusion on the west side of the arroyo is mainly in hornfels; the narrow zone of tactite exposed in the pit contains very little scheelite.

The mine has yielded 703 tons of ore, which averaged 1.48 percent WO_3. The ore was carefully selected under ultraviolet light, and a nearly equal amount of lean or barren rock was discarded. Probably no more than 50 tons of ore containing as much as 1.0 percent WO_3 could be gotten from the rock remaining in the deposit, and, as it would be necessary to mine much waste, the over-all tenor would be a good deal less than 1 percent. The deposit can therefore be regarded as mined out. The small tonnage of ore that was obtained did not pay expenses, which included the cost of making a road and of hauling the ore to the mill, 20 miles away. This deposit should nevertheless be closely examined by those interested in tungsten in the region, because it is one of the best of the known small deposits and illustrates the form that many of the others would be found to have if they were developed.

El Topo

The El Topo deposit lies south of the center of the El Topo area, in the southern part of the El Topo claim. It is near the middle of cross section line C-C' in plate 26. The claim is controlled and was explored by the Cía. Minera El Fenómeno. The scheelite occurs along the east side of a moderately large pendant in the quartz diorite. The pendant is a little more than a kilometer long and has a maximum width of 270 meters, but, being rather deeply invaded by the quartz diorite at three places, it probably does not extend to as great a depth as its length might suggest. A small tungsten deposit, the La Esperanza, occurs at the north end of the pendant, and a smaller deposit occurs near the south end, in the El Topo No. 2 claim. The rock along the west side of the pendant is mainly schist and that along the east side interbedded hornfels and schist. Three nearly parallel beds of marble occur east of the center of the pendant, and there is a small lenticular bed near the south end. The north tip of the pendant consists of tactite without marble.

The El Topo deposit (pl. 35) extends along the easternmost bed of marble, which is cut off at both ends by the quartz diorite. The bed is 85 meters long and has a maximum width of 13 meters. It strikes northwest and dips 45° to 55° SW. The schist west of the marble has very nearly the same strike but dips much more steeply. A narrow zone of tactite lies northeast of the marble, along its contact with the quartz diorite, which at the incline shaft has the same dip as the marble. The other marble beds contain smaller, less regular masses of tactite.

Scheelite is associated only with the tactite along the main quartz diorite contact. The tactite there contains less garnet than most of the deposits, and more diopside, hedenbergite, and quartz. Although some of the ore contains a high proportion of garnet, the highest-grade ore has been green rock containing pyrrhotite (magnetic iron sulfide) and little or no garnet. The scheelite-bearing zone is 70 meters long and 0.5 to 2 meters wide, averaging about 1 meter where exposed. It has been explored for 27 meters down the dip by an incline shaft, from the bottom of which two drifts extend 3 meters to the northwest and southeast. Near the bottom of the incline there is a narrow zone of schist between the quartz diorite and the tactite. As the ore zone there narrows to a width of less than 1 meter, being less than half a meter wide at the ends of the drifts, the bottom of the ore body may have been nearly reached. This is not certain, however, for the diorite contact probably will flatten and cut into the marble again at a slightly greater depth, and in that case the width of the tactite and of the scheelite zone may increase downward. Owing to the irregular dip of the contact, a vertical shaft to serve for removing the ore was begun 40 meters southwest of the incline. This shaft was discontinued at a depth of 25 meters, when it was decided that the ore body could not be profitably mined.

About 250 tons of ore, averaging nearly 1.75 percent WO_3, was sorted out of the rock mined from the incline shaft and was milled at El Fenómeno, but about twice as much was mined. The cost of exploring and developing this deposit considerably exceeded the value of the tungsten in the ore milled. On the assumption that the ore body is 60 meters long, has a maximum depth of 30 meters, and averages a meter in width, and that it has a fanlike profile, it is roughly estimated that the deposit contains about 3,000 tons of ore. The rock exposed in the two trenches southeast of the shaft is much leaner than that in the shaft, and the same may be true of other parts of the deposit, so that the ore body as a whole may not average more than 0.5 percent in WO_3. Moreover, as the ore body is of less than minable width, considerable barren rock would have to be removed; in order to obtain the ore, therefore, about 6,000 tons in all would have to be mined, which probably would not average more than 0.3 percent WO_3. Apparently, then, it would not pay to mine the deposit.

Tío Pepe

The Tío Pepe deposit lies 12 kilometers east-southeast of Los Gavilanes (see pl. 25) from which it is reached by a roundabout road 25 kilometers long, the last part of which leads northward from the Laguna Hánson road, and a 2-kilometer trail. The deposit is in an area of metamorphic rocks irregularly intruded by the quartz diorite, large bodies of which crop out at short distances east, north, and west of the deposit. On the Tío Pepe claim there are two small pendants, composed of hornfels

interbedded with nearly parallel thin layers of marble and tactite (see pl. 36). The contacts between the diorite and the metamorphic rocks are not as regular as they appear on the map in plate 36, but because of poor outcrops they could not everywhere be accurately located. The pendant seems to be pervaded by tiny dikelets of diorite and pegmatite, only the largest of which are shown on the map. Seven beds of marble, ranging in width from 0.5 to 4 meters, cross the pendant and are cut off at the ends by the diorite. They strike northwest and dip 70° to 80° SW.

Each of these beds is replaced by tactite at one or more places along its outcrop, principally on the under or northeast side. A fault that is apparently older than the diorite displaces the beds in the northwestern part of the small area mapped. Scheelite occurs in some of the tactite, mainly in the second and third beds counting from the west, and to a lesser extent in the fourth and fifth beds. Like the tactite, it is mainly on the northeast sides of the beds. The gangue of the ore is mainly garnet and diopside. The best ore is in coarsely crystalline rock. The pendant has been explored by eight trenches and pits, but scheelite occurs in only five of these openings, and in four of them it is very scarce. The main opening is a shaft 4.5 meters deep, sunk on the best showing of ore, which is shown on cross section line A-A', just west of the center of the area shown in plate 36. The scheelite-bearing zone varies from 0.3 to 1.0 meter in width, averaging barely half a meter, and although the marble-tactite bed is 45 meters long at the surface, the scheelite-bearing zone may be no more than 30 meters long.

No ore from the Tío Pepe deposit has been milled. Ten or 15 tons, containing 0.4 or 0.6 percent WO_3, has been sorted out in a pile at the shaft, but it would have to be re-sorted to pay the cost of hauling to the El Fenómeno mill. Even the best ore body is evidently too lean to be mined commercially. The amount of ore to be expected from the deposit is too small to repay the cost of mining and of the road improvements that would be required.

El Pinalito

The El Pinalito deposit lies 13 kilometers southwest of Los Gavilanes (see pl. 25). It is reached by a road, about 7 kilometers long, that leaves the main road between the El Fenómeno and El Topo areas at a point about midway between the two. The tungsten is in a bed of tactite and hornfels in a small pendant in the quartz diorite (see pl. 37, A). The pendant consists mainly of schist, which strikes east and has a steep dip to the north. Its maximum width is 40 meters, and its length is somewhat more than 100 meters. A bed of tactite and hornfels 3 to 4 meters wide extends throughout the length of the pendant, being cut off at both ends by the quartz diorite. Quartz diorite invades the pendant in at least two places, as shown in plate 37, A, and probably, to judge from float, in several other places not indicated on the map.

Scheelite occurs in the tactite, mostly in the more coarsely crystalline rock. As the tactite exposed in all the pits is near the middle of the bed, it presumably was formed by replacement of a thin bed of marble, though no remnant of marble appears in the outcrops or the workings. The scheelite-bearing zone has been explored by four pits 1 to 3 meters deep. The pit farthest west exposes the greatest width of ore—about 1 meter.

By careful selection, 26 tons of ore averaging 0.83 percent WO_3 has been sorted out and milled at El Fenómeno. In addition, 15 or 20 tons of ore averaging 0.7 or 0.8 percent WO_3 has been sorted out and piled at the deposit. As all this ore came out of the westernmost pit and constitutes about one-fourth of the rock that had to be mined, a minable width of rock at that place would presumably average about 0.2 percent WO_3. Probably no more than 500 tons of even this low grade is obtainable from the deposit, and consequently there is little incentive for further mining or development. The value of the scheelite recovered was considerably less than the cost of obtaining it.

Cienpiés

The Cienpiés deposit is one of a group of six or seven lying 7 kilometers airline and 11 kilometers by road northeast of Rosa de Castilla (see pl. 25). The tungsten is in a small pendant of tactite and hornfels in the quartz diorite, near the edge of a fairly large body of metamorphic rock. The pendant is 22 meters long and has a maximum width of 18 meters (see pl. 37, B). A few meters east of it is a smaller one, 18 meters long and 2 to 3 meters wide. The pendants consist mainly of tactite, the smaller one includes a thin bed of hornfels striking N. 10° W. and dipping 65° E. No remnants of marble have yet been found in the workings.

Scheelite is scattered irregularly through the central part of the outcrop of the larger pendant, in a gangue that consists mainly of garnet and a dark-green mineral that appears to be an amphibole. The weathered rock is deeply stained with black manganese oxide, no more than a trace of which was noted in any of the other deposits examined. Two pits 1.5 meters deep have been made in the scheelite-bearing rock. The limits of the deposit are not well established, but it may be a pocket somewhat like the Los Aliados de América.

Production from the deposit amounted to 58 tons of ore, averaging 0.55 percent WO_3, which was milled at El Fenómeno; 15 or 20 tons of ore of the same grade has been piled at the deposit. As the selected ore constitutes about two-thirds of the rock mined, the average WO_3 content of all the rock removed was about 0.4 percent. The tonnage minable from this deposit probably does not exceed 2,000 tons with an average WO_3 content of 0.3 or 0.4 percent, so that the deposit hardly warrants further development. The value of the ore thus far mined is less than the cost of mining it.

Corte de Madera

The Corte de Madera deposit lies 250 meters south of the Cienpiés, 11 kilometers by road north-northeast of Rosa de Castilla (see pl. 25). It is in a small pendant just east of a large body of quartz diorite. This pendant consists mainly of hornfels and schist, with two parallel thin beds of marble, striking northwest and dipping 65° NE., one of them 5 meters thick and the other 2 meters (see pl. 37, C). Eleven meters to the northwest is another pendant, 16 meters long and 5 meters wide, which contains the same two marble beds. Most of the marble has been irregularly replaced by tactite.

Scheelite occurs in tactite on the southwest side of the thinner bed of marble and in two zones of tactite within the larger bed. The tactite gangue consists mainly of garnet, tremolite, diopside, calcite, and quartz. The scheelite-bearing zones, where exposed in the trench that cuts across the two beds of marble, are only a few tenths of a meter wide. A few tons of ore, probably averaging less than 0.5 percent WO_3, has been sorted out, but none of it has been milled. As it seems doubtful whether rock mined at a minimum width along the scheelite-bearing zones would contain even 0.2 percent WO_3, and as the tonnage would be insignificant, no further mining or development is warranted.

Olivia

The Olivia deposit, 15 kilometers east-northeast of Rosa de Castilla, is reached by a road that leaves the Laguna Hánson road a few kilometers east of a line connecting the Olivia and Tío Pepe deposits (see pl. 25). Its distance by road from Rosa de Castilla is 49 kilometers and from Los Gavilanes 28 kilometers. The tungsten ore occurs near one end of a long, narrow pendant, composed mainly of hornfels, in the quartz diorite. Three beds of tactite, striking northeast and dipping 75° NW., occur in the southwestern part of the pendant (see pl. 38). Each is about 20 meters long and either pinches out or is cut off by the diorite. The tactite probably replaces thin beds of marble, but no marble remains in the part exposed.

Scheelite, associated mainly with garnet and diopside, occurs in each of the three zones of tactite. The deposit has been explored by two trenches, from which there extend short adits, and by a shaft 14 meters deep. The north trench exposes a scheelite-bearing zone 2 meters wide, and the south trench exposes two zones from 0.5 to 1 meter wide; both zones dip steeply to the northwest. The shaft is in hornfels, diorite, and pegmatite that contain no tactite or scheelite.

Production from the Olivia deposit has amounted to 36 tons of ore, averaging 1.33 percent WO_3, which was milled at El Fenómeno. All the ore was mined from the northernmost trench. As very little of the rock taken out was discarded, the WO_3 content of the zone at that place is about 1.0 percent. At a rough estimate, this zone may contain 750 tons of ore averaging more than 0.5 percent WO_3 but probably less than 0.8 percent. The two zones at the south end of the pendant may contain a nearly equal tonnage of ore with a somewhat lower percentage of WO_3. In mining these two southern zones a moderately large amount of barren rock would have to be removed; about 3,000 tons in all would therefore have to be mined, and its WO_3 content would probably average less than 0.4 percent. Considering the small size of the ore bodies and the long distance the ore would have to be hauled, it does not seem possible that this deposit could be mined commercially.

Deposits examined but not mapped in detail

La Esperanza

The only deposit in the region, other than those already described, that has produced any tungsten is known as La Esperanza. This deposit lies just south of the center of the El Topo area (see pl. 26, B) and is in the north end of the pendant that

contains the El Topo deposit. The pendant is there little more than 2 meters wide and consists mainly of tactite with a little hornfels. Scheelite occurs in a zone 0.5 to 1 meter wide in garnet-diopside tactite. The ore zone has been explored by two shafts 6 meters deep and 15 meters apart. Although some pockets of fairly good ore were mined in the upper parts of the shafts, the ore zone is less than half a meter wide at the bottom of the shafts, and it there contains only a few tenths of a percent of WO_3. The deposit is probably cut off by diorite a few meters below the bottoms of the shafts.

Production from the La Esperanza deposit has amounted to 86 tons of ore, averaging 0.8 percent in WO_3, which was sold to the El Fenómeno mill. This ore was carefully picked out under ultraviolet light, and more than half of the rock was discarded; as a whole, therefore, the rock removed from the deposit averaged less than 0.4 percent WO_3. The operation was not profitable. No ore approaching commercial grade is exposed in the workings, nor does there seem to be much likelihood that any can be found.

El Fenómeno del Topo

The El Fenómeno del Topo deposit is in the northeast corner of the El Topo area (see pl. 26, B), between the El Audaz and the El Dieciséis de Septiembre deposits. The tungsten ore is in a pendant, 170 meters long and 20 meters wide, in the dark biotite diorite. The southern part consists chiefly of marble and the northern part chiefly of tactite and hornfels. The beds strike northeast and dip 70° NW. A shaft 3 meters deep excavated at the north end of the marble part of the pendant exposes a scheelite-bearing zone about half a meter wide in garnet-diopside tactite. The ore is pockety and generally of rather low grade.

The ore sorted out, of which there is between 5 and 8 tons, does not contain enough scheelite to repay the cost of recovery. As the outcrops along the zone contain very little scheelite, it is doubtful whether any ore better than that exposed in the shaft could be found, apart from small high-grade pockets. The tonnage of scheelite-bearing rock in the deposit must be small, for the zone seems to be no more than 10 meters long.

Los Pinitos, El Osado, and adjoining deposits

In a group of small deposits lying for the most part in the Los Pinitos and El Osado claims (pl. 26, B), there are some twenty pits, trenches, and adits, all of which expose tactite or hornfels that contains at least a trace of scheelite. None of the deposits offer any promise of yielding commercial ore, unless it be those in the interrupted marble-tactite bed that extends northeastward from the center of the Los Pinitos claim to the center of the Dieciséis de Septiembre claim (see pl. 26, B). From several of the excavations in this zone a few tons of ore has been sorted out, but it has not been milled. Judging, however, from the results of work done here and in other deposits nearby, it seems highly doubtful whether any of these deposits can be mined commercially. The ore that has been sorted out certainly could not be sold on the open market for enough to repay the cost of mining.

El Topo Número Tres and adjoining deposits

The El Topo Número Tres claim is in the northwestern part of the El Topo area (pl. 26, B), northwest of the Pearl Harbor deposit. Near the south end of the claim there are two separate beds of marble associated with hornfels and schist. The marble strikes northwest and dips southwestward at the unusually low angle of 25° to 40°. Of the six or seven shallow excavations in and around these beds, only the northernmost reveals more than a trace of scheelite, and even there all the scheelite seems to be in a pocket only a few tenths of a meter wide, in a slightly wider zone of tactite along the east side of the marble.

A larger bed of marble occurs in the schist and hornfels just north of the El Topo Número Tres claim. It strikes west-northwest and dips about 60° S. Narrow zones of tactite in and near the marble have been explored by three shallow pits and a shaft 3 meters deep. The pits reveal only traces of scheelite, but the shaft exposes a scheelite-bearing zone 0.4 of a meter wide, in a zone of tactite that is not much wider, between the marble and the underlying hornfels and schist. The WO_3 content of the scheelite-bearing zone is probably less than 0.4 percent. The deposit seems to offer no promise of yielding commercial ore.

Los Cinco Hermanos and adjoining deposits

The Los Cinco Hermanos claim is in the center of the El Topo area (pl. 26, B), adjoining the Los Aliados de América claim. An elongate pendant of hornfels and schist in the quartz diorite, extending southward through these claims and ending opposite the La Esperanza claim, contains four separate beds of marble with tactite, besides the beds shown in plate 34. The northernmost of these beds is the largest, having a length of 250 meters and a maximum width of 40 meters. It strikes north-northeast and dips 70° W. Tactite occurs mainly along the east side of the bed, and small irregular masses of quartz diorite invade the marble as well as the adjoining hornfels and schist. The tactite in the marble has been explored by four shallow pits and an incline shaft 6 or 7 meters deep. Only traces of scheelite have been found in the pits, but the shaft exposes a scheelite-bearing zone that varies in width from a few tenths of a meter to about 1.5 meters. The ore in this zone is low-grade, and it is doubtful whether the rock mined averaged even 0.2 percent WO_3. A few tons of ore has been sorted out, but it was considered too lean to be worth shipping to the El Fenómeno mill. The deposit gives no promise of yielding commercial ore.

A bed of tactite a few meters long with remnants of marble occurs 40 meters south of the large bed. A small shaft in this bed revealed only traces of scheelite. About 60 meters farther south is a somewhat larger one, 180 meters long and 20 meters wide. This bed is flanked by hornfels except on the east side, where it is in contact with the main body of quartz diorite. A small shaft near the center of the bed exposes a narrow zone containing a little scheelite. Although a few tons of low-grade ore has been sorted out of the rock mined, the average WO_3 content for a minable width is probably less than 0.3 percent, and the deposit is unlikely to yield any commercial ore.

Another bed of marble, 225 meters long and about 10 meters wide, crops out 180 meters south of the Los Cinco Hermanos

incline shaft. The bed strikes north and dips 65° W. Quartz diorite is intruded into it along the east side and cuts it off at both ends. At the south end, three small trenches have been excavated across a zone of scheelite-bearing tactite. This zone contains one small pocket of fair ore, 8 or 10 tons of which, averaging roughly 1.0 percent WO_3, has been sorted out, but the rock remaining in the walls of the trenches contains only traces of scheelite. The work done thus far has afforded no evidence that the deposit contains commercial ore.

V for Victory and adjoining deposits

The V for Victory claim lies west of the La Esperanza, south of the center of the El Topo area (pl. 26, B). The deposit is one of a group in and near the edge of the large body of metamorphic rocks that occupies the western part of the area mapped. Scheelite occurs along the west side of a long bed of marble and tactite that strikes north and dips 75° E. The single pit that has been made in the scheelite-bearing zone exposes a narrow zone of tactite between marble and hornfels. As the tungsten content of the zone at that place is far below any possible commercial value, there seems to be little hope that the deposit can be mined commercially.

In a belt extending north-northwestward from the V for Victory deposit, there are at least 14 small beds of marble and tactite. In one of these, at the south end of a narrow embayment of quartz diorite in the metamorphic rocks and just south of cross section line B-B' in plate 26, B, there is a shallow trench and a shaft 2 meters deep. Only traces of scheelite have been found in these openings. Although not enough exploratory work has been done in this belt to prove that it contains no commercial ore, there seems to be little chance that it contains enough to be worth mining.

El Socorro and adjoining deposits

The El Socorro deposit lies 3 kilometers south of the El Topo area and 400 meters west of the main road (see pl. 25). Scheelite occurs there in tactite without marble, in a small pendant of schist and hornfels in the quartz diorite. Three pits, 1.5 meters deep, in the tactite have revealed little scheelite. No ore of commercial grade could be sorted out of the rock mined, and the deposit does not merit further development.

In a small deposit some 800 meters southwest of the El Socorro, a pit 2 meters deep exposes scheelite-bearing tactite between marble and hornfels, a few meters from a contact with a large body of quartz diorite. The bed of marble is apparently not more than 30 meters long, and the scheelite-bearing tactite is less than half a meter wide where exposed. There is no commercial ore in sight, and it seems unlikely that the deposit can be mined commercially.

Two small pits have been dug in a deposit 500 meters northeast of the El Socorro, about 100 meters east of the road. A very little scheelite occurs there in a half-meter wide zone of tactite in schist, a few meters east of a contact with the quartz diorite. There is no marble in or near the deposit. No commercial ore is in sight, and it does not seem possible that the deposit can yield any.

Pasadena

The Pasadena deposit, 3 kilometers south of the El Pinalito (pl. 25), is connected with the nearest road by a trail 3 kilometers long. The tungsten ore is in a tactite zone about 30 meters long and 1 to 4 meters wide, in hornfels and schist, some 20 meters east of a large body of quartz diorite. The tactite consists mainly of garnet and diopside. The deposit has been explored by an adit 8 meters long, driven many years ago in a search for commercial garnet. Near its face the adit cuts through the tactite and exposes a scheelite-bearing zone about 1.5 meters wide. Assays of this zone are said to have averaged 0.5 percent WO_3, and from inspection of the outcrops under ultraviolet light, its average content was estimated to be between 0.3 and 0.5 percent WO_3. As no ore has been produced from the deposit, the tungsten content over a minable width has not been well established. Assuming that the ore body is 30 meters long, has a maximum depth of 20 meters, and averages 1 meter in width, it would contain about 2,000 tons of ore. As a road 3 kilometers long must be built to the deposit and the ore hauled to a mill at least 15 kilometers distant, it is highly doubtful whether the deposit could be profitably mined.

668013 O - 45 - 3