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TUNGSTEN DEPOSITS OF ARIZONA

By Eldred D. Wilson

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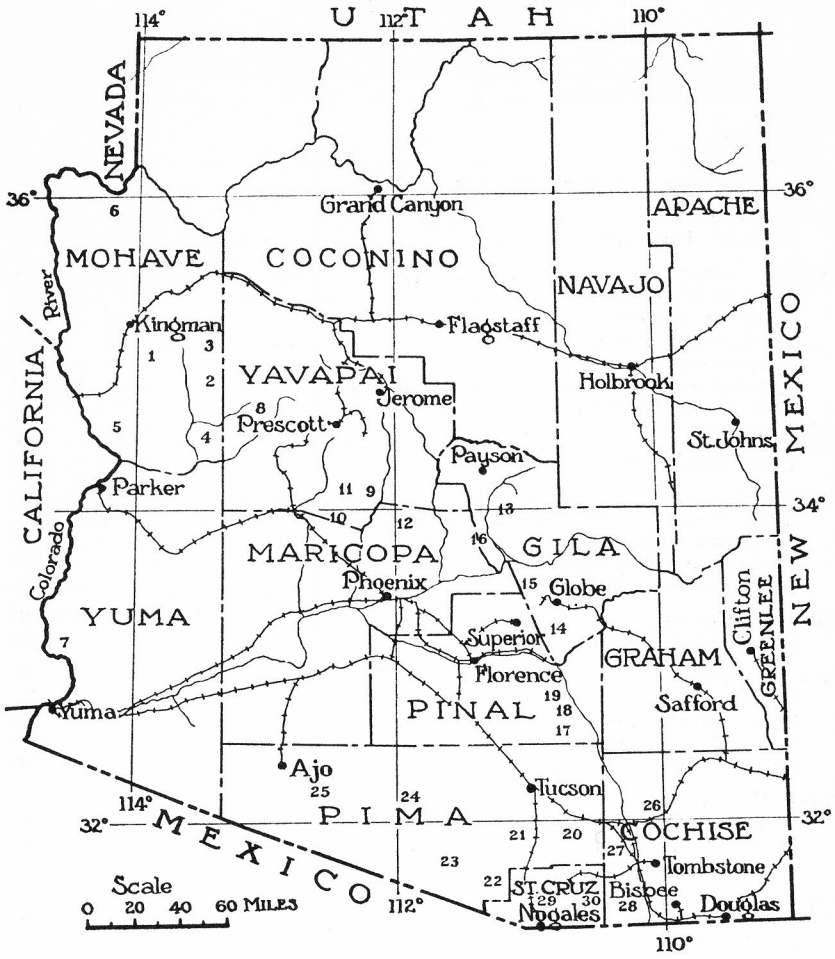

Figure 1.—Index map showing general distribution of tungsten deposits in Arizona.

1. Hualpai Mountains
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TUNGSTEN DEPOSITS OF ARIZONA

By Eldred D. Wilson[1]

INTRODUCTION

DEFINITION OF TUNGSTEN

Tungsten is a metallic element that occurs in nature only as a constituent of certain minerals; it is never found in free or metallic form.

USES

The chief use of tungsten is in the production of alloy steels. In this field the most important single use is as a component of high-speed tool steels. Other important uses for tungsten steels are in the manufacture of drills, dies, valves, taps, and permanent magnets.

A substantial proportion of the total consumption of tungsten is in the form of metallic tungsten used in the manufacture of electric light filaments.

Minor quantities of tungsten are used for stellite, a nonferrous alloy, and for dyes, ceramics, fireproof cloth, fabrics, and X-ray screens.

MINERALS[2]

GENERAL STATEMENT

The principal tungsten minerals found in Arizona are the wolframites (ferberite, wolframite, and huebnerite); scheelite; powellite; cuprotungstite; and tungstite. Only the wolframites and scheelite have been of commercial importance.

THE WOLFRAMITES

The wolframite series includes the dark tungsten minerals, ferberite, wolframite, and huebnerite, which as a rule are distinguishable from one another only by chemical analyses.

Ferberite is an iron tungstate ($FeWO_4$) containing not more than 20 per cent manganese tungstate ($MnWO_4$). *Wolframite* is an iron-manganese tungstate containing not less than 20 per cent nor more than 80 per cent of either iron or manganese tungstates. *Huebnerite* is a manganese tungstate containing not more than 20 per cent iron tungstate.

Pure minerals of the wolframite series contain 76.3 to 76.6 per cent tungsten trioxide (WO_3). Massive to crystalline. Cleavage perfect in one direction. Luster metallic. Very brittle. Hardness about 5 (easily scratched with knife). Specific gravity 7.1 to

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[1]Geologist, Arizona Bureau of Mines.

[2]See also F. L. Hess, Tungsten minerals and deposits: U.S. Geol. Survey Bull. 652 (1917); Colorado ferberite and the wolframite series: U.S. Geol Survey Bull. 583 (1914).

7.5. Color dark gray, reddish brown, black. Streak dark brown to black for ferberite and wolframite, brown to greenish yellow for huebnerite. Opaque; ferberite and huebnerite may be weakly translucent in very thin fragments. May be weakly magnetic.

SCHEELITE

Calcium tungstate ($CaWO_4$). Pure mineral contains 80.6 per cent WO_3. Generally contains molybdenum (up to 8 per cent). Massive and granular. Cleavage good in four directions. Color white, gray, pale yellow, brown. Streak white. Luster oily to resinous. Transparent to translucent. Hardness 4.5 to 5. Brittle. Specific gravity 5.4 to 6.1. Fluoresces pale horizon blue under short-wave ultraviolet light.

POWELLITE

Calcium molybdate with calcium tungstate, containing up to 10 per cent WO_3. Crystalline to massive. Cleavable in one direction. Color yellowish. Luster shiny. Hardness 3.5. Specific gravity 4.3. Fluoresces cream to yellow under short-wave ultraviolet light.

HOLLANDITE

Essentially a barium manganate containing variable amounts of WO_3 and ferric iron. Silvery gray to dark bluish or black. Hardness 4.5 to 6. Specific gravity 4.7 to 5.0. Analyses of pure mineral[3] have shown as much as 0.63 per cent WO_3.

CUPROTUNGSTITE

Hydrous copper tungstate. Massive to fibrous. Bright yellowish green. Cleavable in four directions. Hardness 4.5. An alteration product of scheelite in which the calcium has been replaced by copper. "Cuproscheelite" is a mixture of scheelite with cuprotungstite.

TUNGSTITE

Hydrous tungsten trioxide. Bright yellow. Powdery. An alteration product of scheelite and the wolframites.

FERRITUNGSTITE

Hydrous ferric tungstate. Pale yellow to brownish yellow. Friable or powdery microscopic hexagonal plates. An alteration product of wolframite. Not reported from Arizona.

TUNGSTENITE

Tungsten sulphide (probably WS_2). Earthy or foliated. Color and streak dark lead gray. Hardness 2.5. Specific gravity 7.4. Not known to occur in Arizona.

STOLZITE

Lead tungstate ($PbWO_4$). Tabular tetragonal crystals. Green to gray or brown. Hardness 3. Specific gravity 7.87 to 8.13. A rare mineral, not described from Arizona.

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[3]S. G. Lasky, U.S. Geol. Survey, oral communication.

RASPITE

Lead tungstate ($PbWO_4$). Small tabular monoclinic crystals. Brownish yellow. Hardness 2.5. A very rare mineral, not known to occur in Arizona.

CHILLAGITE

Lead molybdotungstate. Tabular tetragonal crystals. Yellow to brownish. Hardness 3.5. Specific gravity 7.5. A rare mineral, not known to occur in Arizona.

THOROTUNGSTITE

Essentially tungstic and thorium oxides. Massive and as microscopic crystals.

TESTS FOR TUNGSTEN MINERALS

The well-known chemical tests for tungsten minerals are described by Fansett[4] and by Hess.[5]

Under the short-wave ultraviolet lamp, scheelite fluoresces pale horizon blue, and powellite fluoresces cream to yellow. This fluorescence test should be checked by a chemical test or by an assay.

Pure wolframites and most cuprotungstite and "cuproscheelite" do not fluoresce.

MARKETING

Tungsten concentrates are sold either to agents or directly to consumers. A list of buyers is given at the end of this bulletin.

The standard minimum grade of tungsten concentrates in the United States is 60 per cent WO_3, and the price quoted is for units of WO_3.

UNIT

A unit, as applied to tungsten ore quotations, is equivalent to 1 per cent of a short ton or 20 pounds. For example, if the ore contains 60 per cent WO_3 and is quoted at $21 per unit, its value exclusive of penalties is 60 multiplied by $21 or $1,260 per ton.

PRICE HISTORY

Tungsten became an important commodity in 1900, after the discovery of its use in high-speed tool steels, and prior to 1915 its price was relatively low.

Prices[6] of concentrates containing 60 per cent WO_3, per unit, are as follows:

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[4]G. R. Fansett, Field tests for the common metals: Univ. Ariz., Ariz. Bureau of Mines Bull. 147, pp. 37-38 (1940).

[5]F. L. Hess, U.S. Geol. Survey Bull. 652, p. 67 (1917).

[6]U.S. Geol. Survey, Mineral Resources of the U.S.; also U.S. Bureau of Mines, Minerals Yearbooks.

Year	Av.	Year	Av.	Year	Av.
1900	$ 2.75	1914	$ 7.32	1928	$10.81
1901	2.58	1915	29.30	1929	14.76
1902	2.75	1916	33.98[7]	1930	13.40
1903	2.49	1917	20.85	1931	11.45
1904	7.25	1918	23.24	1932	10.51
1905	5.57	1919	8.69	1933	11.36
1906	6.26	1920	7.26	1934	16.70
1907	9.04	1921	3.15[8]	1935	16.00
1908	5.71	1922	4.02	1936	15.46
1909	6.32	1923	8.33	1937	21.79[9]
1910	7.68	1924	8.51	1938	17.31
1911	5.97	1925	11.07	1939	17.11
1912	6.27	1926	11.23	1940	20.61
1913	7.24	1927	10.70	1941	23.50[10]

TARIFF HISTORY

Prior to 1909, duty free; 1909-13, 10 per cent ad valorem; 1913-22, duty free; 1922-30, 45 cents per pound on metallic tungsten content; since 1930, 50 cents per pound on metallic tungsten content, which amounts to $7.93 per unit of WO_3.

SPECIFICATIONS

The penalties imposed for various impurities are exemplified by the following schedule furnished by Fernstrom & Company of Tucson, Arizona, on April 3, 1941:

Penalties of 25 cents for each 0.1 per cent excess of the following allowable impurities:

	Per cent		Per cent
Copper	0.05	Molybdenum	0.25
Phosphorous	0.06	Tin	0.10
Arsenic	0.10	Sulphur	0.50
Antimony	0.10	Lead	0.10
Bismuth	0.10	Manganese	1.00

(No penalties imposed if grade is 70 per cent or more of WO_3)

CONCENTRATION OF TUNGSTEN ORES[11]

The type of treatment required depends primarily upon the size to which the ore must be crushed to unlock the tungsten minerals from the associated gangue, and upon the characteristics and composition of the gangue minerals.

In some ores, notably the massive wolframites, liberation is obtained at relatively coarse sizes. In these cases, concentration may be effected by preliminary hand sorting and hand cobbing of the coarser pieces, followed by jigging of the intermediate sizes and tabling of the fines. Usually there is a middling product from

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[7]Maximum for the year was $93.50.
[8]Minimum for the year was $1.50.
[9]Maximum for the year was $35.00.
[10]First 5 months of year.
[11]By E. H. Crabtree, Jr., Metallurgist, Arizona Bureau of Mines.

both the jigs and tables which needs to be further ground and either put back in the same circuit or treated separately. In all crushing or grinding operations it is imperative that the production of slimes be minimized in order to avoid losses of fine tungsten minerals in the slime product. This is accomplished most adequately by stage crushing in rolls working in closed circuit with screens.

Minerals associated with the tungsten minerals may include, principally, magnetite, hematite, garnet, epidote, muscovite, pyrite, chalcopyrite, molybdenite, calcite, fluorite, and quartz. Separation of these not effected in the preliminary gravity concentration may be obtained by magnetic concentration before or after roasting or by flotation.

Treatment of finely disseminated scheelite ores requires special methods dependent upon the associated gangue minerals. When sulphide minerals are present, they may be floated prior to the scheelite flotation. Separation by flotation of scheelite and the silicates is relatively easy; when calcite or fluorite is present the problem becomes more difficult. In one plant the calcite is removed from the scheelite flotation concentrate by leaching.

Almost each tungsten ore presents its own individual problem of treatment, but it is probably good practice in all cases to concentrate the mineral at the coarsest size at which any appreciable degree of liberation is obtained, at the same time producing middling products for further grinding and subsequent treatment.

ARIZONA DEPOSITS

GENERAL FEATURES

Most of Arizona's tungsten production has come from lode deposits. A few placers, as in the Little Dragoon and Camp Wood areas, for example, have yielded notable amounts.

LODES

The lodes consist of tungsten-bearing quartz veins and shear zones in rocks that have been invaded by granite, granodiorite, pegmatite, or latite of presumed Mesozoic-Tertiary age. Their host rocks may be of almost any type but are most commonly granitic, metamorphic, or sedimentary. The vein walls generally show strong sericitization. Gangue and associate minerals may include the following: quartz, calcite, dolomite, ankerite, siderite, feldspar, muscovite, chlorite, tourmaline, topaz, fluorspar, hematite, copper carbonates, pyrite, chalcopyrite, chalcocite, galena, molybdenite, stibnite, arsenopyrite, silver minerals, gold, bismuth, columbium and tantalum minerals, and (rarely) cinnabar.

The veins are of primary (hypogene) origin and genetically connected with the upper and outer portions of granitoid stocks. As indicated by their mineral association and wall-rock alteration, they are of high-temperature type. Like other lode deposits the localization and continuity of their ore shoots are contingent upon structural features.

REPLACEMENTS

Disseminated scheelite and powellite replacement deposits have been found in many contact metamorphic zones. This type of deposit has been described by Hess and Larsen,[12] who show that, although the scheelite tends to form along the periphery of limestone or dolomite inclusions and pendants in the intrusive, the localization and extent of such deposits are determined by geologic details. Associated minerals of the contact zone, collectively termed *tactite,* include garnet, epidote, vesuvianite, diopside, hornblende, and many others. Important deposits of this type occur near Bishop, California, and Mill City, Nevada.

Dr. Larsen discovered scheelite in the deposits at Johnson, Arizona, in 1918 and recommended that other contact deposits in the state be carefully examined for this mineral. Recently, prospectors equipped with short-wave ultraviolet lamps have discovered many occurrences, but in Arizona no deposits of this type have yet been worked for tungsten.

The replacement type is also exemplified in some of the vein deposits, where tungsten mineralization extends from a fraction of an inch to several feet into the wall rocks.

PEGMATITE DEPOSITS

Pegmatites may contain tungsten minerals, and some of the vein deposits closely verge upon the pegmatitic type.

SECONDARY ENRICHMENT

Tungsten minerals in outcrops are attacked to some extent by weathering and may alter to tungstite, ferritungstite, cuprotungstite, and iron oxide, but commercially important supergene or secondary enrichment of them apparently does not take place.

PRODUCTION

Wolframite was first identified in Arizona in 1896 by W. P. Blake, Territorial Geologist. Tungsten mining in the state began about 1900 but has been of relatively small importance except during the World War and since 1930. Production figures are not available for many of the years, and the total value of the ore mined can only be estimated conservatively at approximately $3,000,000.

The available production figures are shown in Table 1.

TABLE 1.—ARIZONA TUNGSTEN PRODUCTION.

(As given in the Mineral Resources of the U.S. and the Minerals Yearbooks, published by the U.S. Geological Survey and the U.S. Bureau of Mines)

Year	Tons	Value	Remarks
1900	50	?	Dragoon deposits
1901	?	?	Las Guijas
1902	?	?	None reported
1903	?	?	Dragoon
1904	?	?	Dragoon; Aquarius (Williams); Las Guijas
1905	?	?	Dragoon; Aquarius (Williams)
1906	Few	?	Dragoon; Aquarius

[12]F. L. Hess and E. S. Larsen, Contact-metamorphic tungsten deposits of the United States: U.S. Geol. Survey Bull. 725, pp. 245-309 (1921).

TABLE 1—*Continued.*

1907	?	?	Aquarius (Williams); Little Dragoon
1908	?	?	Dragoon; Las Guijas; Calabasas; Whetstone; Aquarius (Williams); Campo Bonito
1909	Few	?	Dragoon; Campo Bonito; Aquarius (Williams)
1910	17	$ 7,834	Dragoon; Campo Bonito; Aquarius (Williams)
1911	50	17,910	Dragoon; Las Guijas; Aquarius (Williams)
1912	27	10,534	Dragoon; Las Guijas; Aquarius (Williams); Campo Bonito
1913	16	6,950	Dragoon; Las Guijas; Calabasas
1914	15	6,588	Sources not stated
1915	127	223,266	Dragoon; Las Guijas; Camp Wood; Yucca; Campo Bonito; Pinal Mts.
1916	218	444,700	Many districts
1917	150	189,000	Many districts
1918	213	263,100	Yucca and Huachuca, principally
1919	50	26,070	Yucca and Huachuca, principally
1920-24	0	0	No production recorded
1925	9	5,978	Las Guijas; Camp Wood
1926	25	16,845	Dragoon; Las Guijas; Huachuca
1927	2	1,284	Dragoon; Las Guijas; Camp Wood
1928	Few	?	Tip Top; Huachuca; Globe
1929	20	17,712	Huachuca; Globe; Yucca
1930	1	804	Camp Wood, principally
1931	98	62,166	Boriana; Camp Wood; Las Guijas
1932	62	35,281	Boriana; Camp Wood; Las Guijas
1933	42	28,600	Boriana; Camp Wood; Las Guijas
1934	.....	.....	Boriana; Dragoon; Las Guijas; Huachuca; Camp Wood; Globe
1935	394	378,300	Boriana; Las Guijas; Huachuca; Dragoon; Camp Wood; Globe
1936	489	453,900	Boriana; Las Guijas; Huachuca; Dragoon
1937	349	488,000	Boriana and several others
1938	37	30,863	Many districts
1939	100	102,900	Many districts
1940	.....	.....	
Total		$2,818,585	

MOHAVE COUNTY

HUALPAI MOUNTAINS

BORIANA MINE

Introduction.—The Boriana mine, held by the Molybdenum Corporation of America, is in the Hualpai Mountains, 18 miles by road northeast from Yucca. Its property includes forty unpatented claims in T. 18 N., R. 15 and 16 W.

The following description, based upon a 2-day visit in November, 1939, includes only some of the general features. Acknowledgments are due H. L. Veatch, Manager, G. W. Irvin, and Walter Hughes, for information and for fine mineral specimens.

History and production.—This tungsten deposit, although known prior to 1908,[13] produced comparatively little until about 1915, when it was acquired by the Yucca Tungsten Mining Company, of York, Pennsylvania. During the first 2 years of development work by this company, the ore was crushed and hand-jigged. A mill of 50 tons daily capacity was built in 1917 and operated until the decline of tungsten prices late in 1919. During 1918 the mine was the largest single producer of tungsten in Arizona and paid a dividend.[14] It also produced some copper flotation concentrates in 1919.

In 1929 the property was acquired by the Boriana Mining

[13]U.S. Geol. Survey, Mineral Resources of the U.S., 1908, pt. 1, p. 725 (1909).
[14]W. H. Weed, The Mines Handbook, vol. 14, pp. 264-65 (1920).

Company, a subsidiary of the Stoody Company, of Whittier, California. During 1929-30 this company further developed the mine and built a mill which in 1931 made wolframite concentrates carrying 66 per cent WO_3 and chalcopyrite concentrates containing 17 per cent copper and about 9 oz. of silver per ton.

In 1932 the Boriana Mining Company carried on development work and shipped 11 tons of concentrates containing 66.36 per cent WO_3 that had been mined in 1931.[15] Control of the property passed to J. P. Sievers and associates.

During 1933-37, the Boriana mine was the leading tungsten producer in Arizona and probably the second in the United States; for the 2-year period, 1936-37, its output of ore averaged about 3,000 tons per month.

The Molybdenum Corporation of America took over the property early in 1937. Late in that year the mill was destroyed by fire. A new gravity-flotation mill of 150 tons daily capacity[16] was built in 1938, and operations were resumed in October, 1939. A transmission line, bringing Boulder Dam electric power to the plant, was completed in May, 1941. Water is obtained from a shaft downstream from the camp.

From 1915 to 1939 the Boriana mine produced approximately 80,000 units.[17]

Topography and geology.—Boriana camp is near the head of a southwestward-flowing canyon in the Hualpai Mountains at an altitude of approximately 5,000 feet. The property extends northeastward over the crest of the range into the head of Cane Springs Canyon. North of this divide is Pine Flat, a well-wooded and watered hanging valley indicative of Quaternary uplift of the range.

The Boriana mine is in a belt of schist, locally ¼ to ½ mile wide, that strikes N. 30° to 40° E., dips from about 75° SE. to vertically and extends for several miles across the range. In the vicinity of the mine, this schist is a thinly laminated to blocky gray slate with some sandy phases; abundant fine-grained sericite and chlorite mark its parting planes.

The schist belt is intruded on both sides by coarse-grained biotite granite which grades into gneiss near its contacts. Dikes of aplite and pegmatite cut both the gneiss and schist.

A short distance northeast of the divide the schist and granite are intruded by a stock of medium-grained granitic rock consisting essentially of white feldspar, abundant glassy gray quartz, and biotite; provisionally, it may be classed as a granodiorite or sodic granite. Along its borders it has effected strong silicification and sericitization of the schist and gneiss. Locally, veinlets of quartz and purple fluorite occur in the adjacent gneiss. Here a narrow belt of "greisen," consisting of a foliated fine-grained ag-

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[15]U.S. Bureau of Mines, Minerals Yearbook, 1932-33, p. 274 (1933).
[16]Flow sheet given in Mining World, vol. 3, no. 4 (1941).
[17]Oral communication from H. L. Veatch.

gregate of quartz, sericite, and muscovite, parallels the schist and is traceable intermittently for several thousand feet; apparently it represents a shear zone affected by intense hydrothermal alteration. In places this greisen contains sparse tiny veinlets of chalcopyrite and disseminated particles of wolframite, up to ½ inch in diameter, encased by thin layers of scheelite. It has been explored by a short adit with some 60 feet of drifts, but apparently these workings did not find the tungsten mineralization to be of commercial grade. Other similar greisen zones are found in the granodiorite.

The formations of the Boriana area have been cut by numerous faults, most of which strike northeastward and dip from low angles to almost vertically southeastward. Some of the faults, occupied by veins or affected by primary mineralization, are premineral, but many show postmineral movement. The latter commonly occur at intervals of 100 to 200 feet, displacing the veins by reverse steps a few feet in magnitude. Some of the workings show closely spaced, intersecting postmineral faults of small displacement.

Veins.—The Boriana quartz veins in general strike N. 30° to 40° E. and dip from 75° SE. to vertically, paralleling the schist in which they occur. The veins now worked are near the middle of the schist belt, but others that have not been prospected crop out less conspicuously a few hundred feet farther southeast. Surface prospecting here is somewhat handicapped by brush and talus.

As exposed in the mine, the veins are lodes of composite type, made up of two to ten or even twenty parallel quartz veins and stringers, separated by schist, within widths of a few feet to 20 or more feet. Many of them consist of two veins from 4 to 10 inches, or exceptionally 4 feet, wide with narrower veins or stringers in schist between. At least four of the composite lodes have been encountered in the mine within a width of 200 feet.

Most of the production has come from the West lode, but considerable has been made in recent years from the East lode, which is approximately 95 to 140 feet farther southeast.

Up to June 15, 1941, the principal ore shoot on the West lode had been mined from the surface to the seventh level, with a stope length of 8,700 feet. Apparently it is echelon in plan and plunges steeply northeastward, but the structural factors that determine its localization and form have not been determined.

On the East lode an ore shoot with a stope length of 1,000 to 1,100 feet had been mined from above the third level to the seventh level. It, also, apparently plunges northeastward.

Ore.—Ore minerals in the Boriana veins consist of wolframite, scheelite, and chalcopyrite, together with hematite and a little gold and silver in unknown form. Associated with them, particularly in the northeast workings, are some arsenopyrite and pyrite and inconsequential amounts of molybdenite. Cuprotungstite is reported to have been found near the surface.

The gangue is principally coarse-grained, glassy, gray quartz with minor amounts of calcite and fluorite. Coarse flaky sericite has been formed in the vein walls.

Texturally, the ore minerals range from tiny veinlets and scattered grains to masses weighing many pounds. Their order of deposition was wolframite, followed by scheelite and chalcopyrite; the relative order between the last two minerals has not yet been definitely determined. The scheelite tends to form veinlets and irregular masses traversing and surrounding wolframite. Chalcopyrite veinlets also cut the wolframite.

For some parts of the mine the proportion of wolframite to scheelite is 3:1, but for other parts it is 1:3.

In 1939 the mill heads were reported to average 1.45 per cent WO_3 and 0.75 per cent copper. Because of dilution in mining, a composite lode, containing less than 1.25 per cent WO_3 and less than 8 inches wide, could not be regarded as ore unless at least 6 inches of its width were solid quartz.

Mine workings.—Workings of the Boriana mine total approximately 16,000 feet, with seven levels of drifts of which the fifth level is a main haulage adit.

CLAIMS NORTHEAST OF BORIANA

The Boriana schist belt extends northeastward across the Hualpai Range into the upper portions of Cane Springs Canyon, where it contains tungsten-bearing quartz veins, structurally and mineralogically similar to the Boriana. Here, on ground held by the Molybdenum Corporation of America, considerable relatively shallow mining has been done by small operators and lessees who concentrated their ore by hand sorting and with small gravity mills.

PLACERS

During the World War, according to local reports, some placer wolframite and scheelite were produced from upper Cane Springs Canyon and from the gulch below the Boriana mine.

TELLURIDE CHIEF AREA

The Telluride Chief mine is in the northeastern part of the Hualpai Mountains, 20 miles from Kingman via the Sandy and Democrat roads.

This mine was prospected for gold, silver, and molybdenum during 1916-18 by the Telluride Chief Company and the Standard Minerals Company, which sank a 450-foot shaft, did some drifting, and built a gravity-flotation mill of 100 tons daily capacity to treat gold-silver-molybdenite ores.[18] Eight of the claims, now held by W. Meyers, F. C. Walker, J. M. Cochrane, and W. E. Little, were relocated in 1935. The present owners have done considerable underground work and surface prospecting, and shipped some gold-silver-copper ore.

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[18]Historical information furnished by W. Meyers.

In this vicinity the prevailing rock is medium-grained granite, intruded by dikes of aplite and pegmatite. The granite has been broken by rather extensive fissures marked by iron-stained outcrops and coarse flaky sericitic alteration. Many of them contain quartz veins of which two systems are readily evident. Those of the more prominent system strike N. 30° W. and dip steeply southwestward. For the other system the prevailing strike is northeastward, and the dip steep southeastward. Both systems show local variations in strike and dip, particularly in the vicinity of intersections.

The vein filling consists of coarsely crystalline dull-white quartz with outcrops locally honeycombed after pyrite and stained with oxides of iron, molybdenum, and tungsten. In places it contains pyrite and molybdenite; in other places pyrite and scattered particles or small masses of wolframite and scheelite. The tungsten minerals occur in both the vein systems but apparently most abundantly in and near the intersections of the northeast veins.

LAXTON AREA

The Laxton property of fourteen unpatented claims, held in 1940 by George Laxton, is in the northeastern portion of the Hualpai Mountains, in the rugged upper drainage area of Wheeler Wash. It is accessible by a few miles of trail from Odle ranch, which is 22 miles from Kingman via the Sandy and Democrat roads.

Here the prevailing rock is medium-grained granite, intruded by a large stock of granitoid rock and associated aplite dikes.

About ½ mile east of Laxton's camp, the stock is cut by a persistent vein from 2 to 6 inches wide that strikes northward and dips 70° E. Its filling consists of coarsely crystalline iron-stained, dull-white quartz, locally with scattered small particles of wolframite and scheelite. Only a little shallow work has been done here.

On the steep slope west of camp are several pyritic quartz veins up to 2 feet wide that strike N. 60° E., and dip steeply southwest. In places they contain a little molybdenite.

Farther up this slope is a vein that strikes N. to N. 30° W., dips 80° E., and is traceable on the surface for a length of some 3,000 feet. Its filling consists of coarsely crystalline, banded, iron-stained, dull-white quartz, in places 2 to 4 feet wide. Much of its outcrop shows cavities after pyrite. As exposed in a few shallow pits and short adits, some portions of this vein contain abundant crystals of wolframite, generally near the hanging wall.

At the time of visit, no production of tungsten had been made from the property.

A small production is reported to have been made from similar veins on the Moon claims, about ½ mile northwest of the Odle ranch.

AQUARIUS REGION

TOPOGRAPHY AND GEOLOGY

The Aquarius region, of southeastern Mohave County, extends from the Big Sandy Valley on the west to the Mohon Mountains on the east, and from Trout Creek on the north to Burro Creek on the south. Its western front, termed the Aquarius Cliffs, is a probable fault-line scarp whose steeply dissected slopes culminate in a ridge nearly 6,000 feet above sea level or 3,000 feet above the Big Sandy. This ridge consists essentially of pre-Cambrian and later granitic rocks, overlapped on the east and south by a thick series of Tertiary volcanic, chiefly basaltic, flows whose mesas cover more than 1,000 square miles.

The granite shows considerable fracturing of northerly trend and contains numerous dikes of aplite and pegmatite. Quartz veins are associated with many of these dikes.

BONER CANYON DEPOSITS

The Boner Canyon area is in the southwestern portion of the region, in T. 16½ and 17 N., R. 11 and 12 E.

Here Boner Creek, a southwestward-flowing tributary of the Big Sandy, has carved a deep canyon between the Aquarius granitic ridge on the northwest and basalt mesas on the east and south. Intruding the pre-Cambrian granite in the western part of this area is a mass of medium to fine-grained gray granite with an irregular outcrop of less than ½ square mile. Much of this younger granite shows modifications to pegmatite and to greisen; possibly it represents a stock related to the aplite and pegmatite dikes of the district.

In addition to regional north-south fractures, the older granite here is broken by numerous fissures that strike in various directions and dip prevailingly northeast to northward. Many of them, as on the Williams, Short, Berger, Phillips, Hubbard, and Boner claims, are occupied by pegmatite dikes and related quartz veins with tungsten deposits.

WILLIAMS MINE

The Williams group of twelve unpatented claims is accessible from Kingman by 72 miles of road that crosses the Big Sandy east of Trout Creek store.

Some of these claims were located in 1902 by the late Ed. Williams, Sr., and they were worked on a small scale during 1904-12. The mine was operated by the Tungsten Mines Company during 1915-17, after which it remained essentially inactive until 1939. In that year, according to Ed. Williams, Jr., high-grade sorted ore from the property was milled in a small gravity plant and yielded 3¾ tons of concentrates containing 67 per cent WO_3. In 1940 the Continental Mining Corporation, operating under a bond and lease, built a jigging mill of 75 tons daily capacity, did considerable underground development, and improved the road to the property. Its production up to June, 1941, amounted to several hundred units of concentrates.

The principal vein occurs in a fault fissure that cuts the granite with a strike of N. 65° W. and a dip of 25° NE. A sheared aplite dike about 6 feet thick follows its hanging wall. Prior to the writer's visit in March, 1940, this vein had been opened from the eastern slope by an upper adit tunnel, approximately 150 feet long, connected by stopes and raises with a 500-foot adit some 160 feet farther down the dip. As shown by these workings, the vein ranges in width from less than a foot to about 2 feet. It consists of coarse-grained, glassy, gray quartz, locally with intergrowths of pale-green muscovite which forms fine-grained scaly masses adjacent to the vein walls and coarse rosettes within the vein. Wolframite and relatively sparse scheelite occur as fine-grained to coarse particles and aggregates associated with this muscovite, particularly adjacent to the hanging wall. Pyrite is fairly abundant in some portions of the vein. As indicated by old stopes, the ore shoots are of irregular length along the strike but fairly continuous down the dip. The structural features responsible for their localization are obscure. The vein walls show strong alterations to flaky sericite.

During 1940-41 the Continental Mining Corporation ran an adit approximately 1,400 feet long, connecting with a 350-foot winze below the old lower tunnel level. Two stopes, one approximately 40 feet long by 40 feet high and the other 30 by 60 feet, were mined.[19]

DEPOSITS ON WESTERN SLOPE

On the western slope of the ridge, opposite the Williams mine, tungsten-bearing veins mineralogically similar to the Williams occur on several claims which are accessible by trail. Most of them have produced a little tungsten ore from limited, shallow workings.

Bordering the Williams group on the northwest is the Louise group, held by H. R. Phillips. West of the Louise group are claims held by H. W. Berger and H. R. Phillips. North of them are claims held by Al Short and by Paul Hubbard. Claims held by the Boner Brothers are west of the Short claims.

The granite ridge west of Williams camp is extensively invaded by pegmatite. On the White Dike claim a quartz outcrop 15 feet wide by 30 feet long yielded a few tons of wolframite during the World War. On the No. 10 claim some rich wolframite ore has been mined from a vertical quartz vein of westward strike and 8 to 10 inches wide; apparently its ore shoot plunged below the shallow workings.

In the western part of the Williams group is a vertical vein of N. 65° W. strike and 8 to 14 inches wide which produced fairly well from a 15-foot adit. Here another quartz vein, which strikes N. 50° W., dips 50° NE., and is 18 to 24 inches wide, shows a little wolframite associated with pale-green muscovite.

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[19]Oral communication from R. S. Sanford, of the U.S. Bureau of Mines.

The Cliff vein, on the trail west of camp, strikes northward, dips 25° E., and is 1 to 2 feet wide. It shows abundant iron stain, and pale-green muscovite along its margins and center line. Wolframite occurs associated with this muscovite, mainly near the hanging wall. High-grade pockets have been mined from this vein for more than 200 feet along the strike.

The principal workings on the Short claims, as seen in March, 1940, consisted of a short tunnel on a lenticular quartz vein 18 inches in maximum width, which strikes N. 75° W. and dips 70° NE. This vein shows much iron stain and pale-green muscovite with associated wolframite.

On the Berger claims the principal vein strikes N. 77° W., dips almost vertically, and cuts medium-grained diorite. As exposed in a 90-foot tunnel (now largely caved) and by surface cuts scattered over a length of a few hundred feet, it is about 1 foot wide; evidently some production was made from it. Some 200 feet farther south a vein of similar strike, dip, and width, also in diorite and pegmatite, has been opened by a surface cut some 250 feet long and by a short tunnel. It shows pale-green muscovite and some wolframite, especially on its margins.

PLACERS

According to local people, small amounts of placer wolframite have been gathered from both the east and west slopes of the main ridge, below the principal veins.

COTTONWOOD REGION

GENERAL FEATURES

The Cottonwood region is west of the Cottonwood Cliffs and east of the Big Sandy, opposite Round Valley. Physiographically, it may be considered as a northern continuation of the Aquarius region, with steep-sided ridges and canyons of westward trend. The principal rocks are granite, schist, and pegmatite, overlain to the east by volcanic beds.

THREE-IN-ONE CLAIM

The Three-In-One claim, held by W. H. Hunt, R. E. Ames, and J. Daley, is accessible by ¾ mile of trail from the end of 5 miles of unimproved road that branches eastward from the Sandy road at a point 29 miles from Kingman.

Here medium-grained gray granite includes a northeastward-trending band of black schist some 150 feet wide. This band is invaded along both walls and in the middle by irregular narrow masses of pegmatite; southwest from the workings the schist band widens, and the pegmatite splitting it attains a width of several hundred feet.

Both the northwest and southeast contacts of the schist with the pegmatite contain glassy gray quartz veins, from less than 1 inch to 18 inches in width, that strike northeast, dip steeply northwest, and are traceable on the surface intermittently for several

hundred feet. In places, apparently where intersected by quartz stringers of westward strike, these veins carry scattered small masses of wolframite and some scheelite. The wall rocks show strong alteration to sericite, and in places to biotite.

Workings consist of an old shaft, recently reopened to a depth of 28 feet on the southeast contact, and an open cut 10 feet deep on the northwest contact. According to Mr. Hunt, these workings have yielded a few tons of cobbed ore during the World War and during 1937.

GREENWOOD REGION

GENERAL FEATURES

The Greenwood region is west of Greenwood Peak and east of the Big Sandy Valley, south of Burro Creek. Its surface consists of sharp ridges and canyons of westward trend, tributary to the Big Sandy. The prevailing rocks are granite, gneiss, aplite, and pegmatite, overlain in places by Tertiary volcanic rocks.

The old Greenwood mine, in the eastern part of the area, is reported to have been worked for gold and silver many years ago. Farther west, perhaps 1 to 2 miles from the Big Sandy, tungsten-bearing quartz veins occur in gneiss.

LEVAS-MADRIL CLAIMS

The Side Line claim, held by Angel Madril and Tony Levas, and the Lost Mine claim, held by Mrs. Jesus Levas, are in T. 14 N., R. 12 W., about 3½ miles by trail from the Levas ranch and N. 57° W. from Greenwood Peak.

On these claims a glassy quartz vein 1 to 1½ feet wide strikes S. 83° W., dips 60° N., and is traceable intermittently for a length of some 600 feet. Locally, at least, it strikes and dips conformably with the gneiss and has been offset minor amounts by faulting.

The principal development consists of a shallow pit with a 30-foot adit. As shown by these workings, the vein contains irregular disseminations and bunches of wolframite and straw-colored scheelite, together with sparse fine-grained chalcopyrite. Near the surface iron and copper stains are locally abundant. The wall rocks show strong sericitic alteration.

According to Mr. Madril, these workings yielded a few hundred pounds of tungsten ore during the World War and again in 1937. Recently the ground was leased for several months to the North American Tungsten Corporation.

OLEA CLAIMS

About ⅛ mile west of the Levas-Madril claims, in the NE. ¼ SW. ¼, sec. 29, T. 14 N., R. 12 W., are two claims leased by Frank Olea from the Santa Fe Railway.

Here a glassy quartz vein 1 to 2½ feet wide strikes S. 20° E. and dips 45° to 60° NE. It has been mined by an open cut to depths of 5 to 20 feet for a length of some 60 feet. Like the Levas-Madril vein it contains irregular disseminations and masses of

wolframite and scheelite and some fine-grained chalcopyrite. Much iron and some copper stain appears near the surface. The wall rocks are strongly sericitized, and in places contain abundant segregations of biotite.

According to Mr. Madril, these claims produced several tons of lode and placer tungsten ore during the World War.

MOHAVE OR CHEMEHUEVIS MOUNTAINS

DUTCH FLAT

The Dutch Flat area, about 1 mile southeast of Crossman Peak in the Mohave Mountains, is accessible by some 50 miles of unimproved road from Yucca.

This portion of the range consists essentially of deformed, highly metamorphosed, fissile biotite schist, invaded by pegmatite dikes. Narrow quartz veins containing gold, scheelite, and a little wolframite are fairly abundant.

At Dutch Flat A. V. Kamff holds twenty-three claims on five separate veins, which were located about 1917. For many years he has treated gold ore from these claims in a gravity mill of 10 tons daily capacity. As most of this ore contained some scheelite, several small lots of tungsten concentrates have been recovered and shipped.

On the Gold Crown claim, about ¾ mile northeast of Dutch Flat camp, a vein strikes northward and dips 80° E. Up to November, 1939, it had been opened by a 55-foot inclined shaft and a short adit. These workings showed the vein to consist of grayish-white quartz, generally less than a foot wide, with straw-colored scheelite occurring as a rich, narrow streak along the footwall and as disseminations in the quartz. Gold occurs associated with limonite and more or less closely with the scheelite.

Somewhat similar mineralization occurs on the Charles Bly claims, 3 miles northeast of the old Mohawk mine, and on the Jupiter claims across the mountains from Dutch Flat.

GOLD BASIN DISTRICT

O.K. MINE

The O.K. mine is in the eastern part of the White Hills, some 60 miles by road from Kingman. Its country rock is dark biotite granite.[20] The vein strikes northeastward, dips about 75° NW., and averages 18 inches in width. It is composed mainly of iron-stained gold-bearing quartz with limonite, hematite, siderite, galena, molybdenite, and wolframite.

Worked from three levels of adits, the O.K. mine produced $25,000 worth of gold from 1886 to 1906. So far as known it has made no production of tungsten.

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[20]Description abstracted from F. C. Schrader, Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs: U.S. Geol. Survey Bull. 397, pp. 121-22 (1909).

YUMA COUNTY

TRIGO MOUNTAINS

GOLD REEF CLAIMS

The Gold Reef unpatented claims, held in 1941 by H. Knowles and R. Young, are in T. 4 S., R. 22 W. in the Trigo Mountains. They are accessible by 3½ miles of trail from Knowles camp, on the Colorado River, or by a shorter trail from the Silver District road.

These mountains, although of relatively low altitude, are very rugged and arid. In the vicinity of the Gold Reef claims they are made up of brownish quartz-sericite schist, intruded by rhyolitic and aplitic dikes that may be related to a granitoid stock cropping out about a mile farther north. The schist strikes N. 35° E. and dips 30° NW.

The principal vein occurs within a fault fissure that strikes N. 55° W., dips 80° S., and is traceable on the surface intermittently for about 500 feet. As shown in shallow prospect pits, it consists of irregular masses of sheared grayish-white quartz from less than an inch to 2 feet wide. This quartz contains scattered particles of limonite, hematite, and scheelite. A little scheelite also occurs in the adjacent wall rock, which shows sericitic alteration.

YAVAPAI COUNTY

CAMP WOOD REGION (EUREKA DISTRICT)

BLACK PEARL MINE

Introduction.—The Black Pearl group includes eleven patented and five unpatented claims in secs. 7, 8, and 18, T. 15 N., R. 7 W., and in secs. 12 and 13, T. 15 N., R. 8 W. By road, it is about 60 miles from Prescott and 15 miles southwest of Camp Wood.

Acknowledgments are due Homer R. Wood, H. L. Williams, and the late Carl G. Barth, Jr., for information.

History and production.—These deposits were located in 1914 by Wm. Conners who transferred his claims to John Lawler and Homer R. Wood. The property is now held by the Lawler estate and by H. L. Williams and associates.

According to Mr. Wood, shipments from the Black Pearl mine have been as follows:

Year	Pounds	Per cent WO_3	Year	Pounds	Per cent WO_3
1915	3,401	71.13	1930	1,620	72.00
1917	3,152	70.70	1931	1,895	72.00
1917	6,830	69.90	1932	3,825	68.00
1918	3,613	70.60	1933	4,841	69.88
1918	1,482	70.81	1933	12,472	71.14
1918	1,444	71.60	1933	2,291	69.76
1919	100	68.00	1935	975	.....
1926	6,994	71.10	Misc.	4,265	.....
1929	2,900	72.45	Total	62,100	70,00 Av.

This amount is equivalent to approximately 3,622 units containing 60 per cent WO_3. About 50 units of it came from placers.

Topography and geology.—The Black Pearl group is approximately 600 feet east of Boulder Creek and on the south side of Loco Gulch, a tributary of this creek.

Loco Gulch is several hundred feet deep, with moderately steep slopes culminating on the north in extensive mesas of Tertiary volcanic flows. Dark-gray hornblende granite, invaded by pegmatite, crops out beneath these flows and forms the prevailing rock of the region southward.

Veins.—This region contains numerous tungsten-bearing quartz veins, most of which have not been adequately prospected.

The principal mining at the Black Pearl property was upon a vein that strikes S. 74° E.[21] and dips steeply SW. Stoping was carried on from short adits and shallow shafts which attained a maximum depth of 70 feet below the outcrop and, due to the topography, represented a vertical range of 225 feet. The longest adit, which was driven by the Veta Mines Company in 1936, measured 180 feet. These workings were distributed at fairly close intervals for a length of 1,900 feet along the outcrop. When seen in December, 1939, they were largely caved, and little observation of the vein and ore shoots was possible. According to Mr. Wood, the average width of vein exposed by the Veta adit was 4.2 feet.

The wall rocks show intense alteration to sericite.

Ore.—Metallic minerals in the Black Pearl veins consist chiefly of wolframite and pyrite. Some of the dumps show small amounts of molybdenite. Bismuthinite, gold, and silver are reported to be sparingly present. Oxides of iron, largely derived from weathering of pyrite, occur abundantly in the outcrop.

The gangue is coarsely crystalline grayish-white quartz, together with locally abundant masses of muscovite and some fluorite.

The wolframite occurs as particles apparently ranging from 0.10 to 1.5 inches in diameter; masses much larger have been reported. As estimated by Mr. Wood, the vein material removed in mining averaged 0.922 per cent WO_3, and the pyritic shoot opened by the 180-foot Veta adit averaged 0.784 per cent WO_3.

MARY D CLAIMS

The Mary D group of ten unpatented claims is a few miles northeast of the Black Pearl and 54 miles by road from Prescott via Camp Wood. This ground was located in 1937 by B. E. Joy and A. M. Short.

Here Conger Wash, a tributary of Kirkland Creek, has carved a deep canyon along the eastern margin of the lava mesa that lies north of Loco Creek.

Tungsten-bearing veins occur in a complex of granite and schist that has been largely replaced by coarse-textured pinkish peg-

[21]According to map of Mineral Survey No. 4186.

matite. At least twelve of these veins have been located. As indicated by limited shallow prospecting, they strike eastward, dip about 55° S., and are traceable intermittently for lengths of 2,000 to 4,000 feet across the canyon. Their filling consists of coarsely crystalline grayish-white quartz from 3 inches to 10 feet wide. In places it contains bodies of wolframite as scattered particles ranging from a fraction of an inch to more than 3 inches in diameter, associated more or less closely with pyrite. The vein walls have been strongly altered to coarse-grained sericite.

According to Mr. Joy, some of the ore from these claims had been concentrated in a small jig on Conger Creek prior to 1940.

BRADSHAW MOUNTAINS

TIP TOP DISTRICT[22]

Location.—Tip Top is in the southern foothills of the Bradshaw Mountains at an altitude of about 2,600 feet. The district is accessible by some 10 miles of road that branches westward from the Black Canyon highway at a point 42 miles north of Phoenix.

Topography and geology.—The surface has been carved into ridges separated by canyons 1,000 to 1,500 feet deep. This portion of the range consists mainly of pre-Cambrian Bradshaw granite invaded by pegmatite and long branching dikes of rhyolite porphyry. Locally the granite is gneissic and contains inclusions of schist. The rhyolite porphyry dikes strike prevailingly east to northeastward and dip northward.

Several persistent parallel veins, of which the Tip Top has been the most productive, occur in this vicinity.

Tip Top mine.—From 1875 to 1890, the Tip Top mine produced[23] approximately $2,000,000 worth of silver and $200,000 worth of gold. During the World War, some tungsten was recovered by hand sorting and by milling of the dumps and stope fills above the 200-foot level in a small gravity plant. A small production was also made in 1928. In 1936 La Bajada Exploration, Engineering, and Equipment Company built a flotation mill of 50 tons daily capacity and produced silver-gold concentrates. Since that time, a small tonnage of sorted tungsten ore has been shipped from the district.

In the vicinity of the mine the country rock consists of granite and pegmatite with local inclusions of schist. The vein strikes N. 50° to 60° E., dips 65° to 70° NW., and ranges from a tight seam to 6 feet in width. Its principal gangue is quartz, in part fine-grained and in part comb-textured. The ore minerals consist of wolframite, arsenopyrite, pyrite, sphalerite, bornite, and galena.

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[22]Mainly abstracted from W. Lindgren, Ore deposits of the Jerome and Bradshaw Mountains quadrangles, Arizona: U.S. Geol. Survey Bull. 782, pp. 179-82 (1926); J. S. Coupal, Tiptop mine: Mining Jour. (Phoenix, Ariz.), vol. 20, no. 5, pp. 3-5 (1936).

[23]M. J. Elsing and R. E. Heineman, Arizona metal production: Univ. Ariz., Ariz. Bureau of Mines Bull. 140, p. 103 (1936).

The wolframite occurs in well-crystallized crusts along the walls. In the oxidized zone, within 200 feet of the surface, cerargyrite, ruby silver, and native silver are said to have been common. The ore shoots pitch northeastward.

Mine workings include a shaft 800 feet deep on the incline, connected with an adit tunnel on the 200-foot level. Below this level the workings are filled with water. According to Coupal,[24] the major part of the ore shoot near the shaft has been stoped down to the 500-foot level.

Other veins.—According to Lindgren,[25] practically all the veins of northeast strike in this district carry wolframite. Several veins of this type occur in the vicinity of Tule Creek.

Hess[26] states that tantalum is reported to have been found in the wolframite of the Tip Top district and that specimens from the Humbug district contain microscopic crystals of topaz. Hess also mentions the occurrence of tiny specks of cinnabar in wolframite from the Tip Top district; Dr. B. Ogburn, of Phoenix, states that he collected this material in Humming Bird Basin.[27]

WICKENBURG MOUNTAINS

WHITE PICACHO DISTRICT

During recent years disseminated scheelite in schist has been discovered in the White Picacho district.

The Buena Vista, Monster, and Climax claims are in the drainage area of upper San Domingo Wash, 13 miles east of Morristown. These claims, held by M. Pachen, J. Kaler, and D. G. McMillian, were located in 1939 and 1940.

On the Buena Vista claim, schist striking east to southeastward and dipping about 45° N. is invaded on the west by medium-grained, light-gray granite and highly feldspathic pegmatite dikes. Irregular bodies of disseminated scheelite with powellite occur in bands of striped brownish garnet-epidote schist within black schist. At least six such bands, each 3 or more feet wide by some 500 feet long, crop out in an area 300 feet wide. Smaller areas of similar mineralization are traceable intermittently for some 3,000 feet eastward, across the Monster claim. When seen in December, 1940, development on these outcrops consisted of a few very shallow surface pits.

On the Climax claim, about ¾ mile north of the Buena Vista, fine-grained sericitic schist striking eastward and dipping 65° N. contains several scheelitic zones. In December, 1940, the principal outcrop, which is traceable for a length of about 100 feet, had been opened by a shallow cut and short adit. This work showed the scheelite-bearing zone to be about 6 feet wide, and more epidotitic than the material in the Buena Vista outcrops.

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[24]Work cited.
[25]Work cited.
[26]F. L. Hess, Tungsten minerals and deposits: U.S. Geol. Survey Bull. 652, pp. 55, 57 (1917).
[27]Oral communication.

The mineralogy of these deposits—garnet, epidote, quartz, specularite, scheelite, and powellite—indicates them to be of contact-metamorphic origin.

Similar deposits in schist are reported to occur on the Homestake and Eureka groups of claims in the area of Little San Domingo Wash, 8 miles east of Morristown. In late 1940 these groups were held by Messrs. Pachen, Kaler, and McMillian.

CASTLE CREEK REGION

BLACK BUTTE CLAIMS

The Black Butte group of two unpatented claims, held by W. L. Palmer, is a short distance east of Castle Creek and 27 miles by road northeast of Morristown. These claims, which were located in 1940, have been opened only by a shallow cut.

Walker Creek and other southward-flowing tributaries of Castle Creek have carved this area into shallow canyons and sharp ridges. The rocks exposed consist of andesitic flows, breccia, and tuff of prevailing northward dip, overlain on the ridges by thin soil.

The principal vein occurs within a fault fissure that strikes irregularly eastward and is traceable by float for a few hundred feet on the surface. It is intersected on the west by northward-trending fissures containing gray lime carbonate. This vein, which consists largely of black manganese oxide together with a little calcite and quartz, is 1½ to 2 feet wide where exposed. The manganese oxide shows glistening pseudomorphous cleavage faces which suggest that at least part of it was derived from manganiferous calcite. A qualitative test of the vein material by R. E. Heineman, of the Arizona Bureau of Mines, shows it to contain tungsten, and Mr. Palmer states[28] that an assay of it showed 43.8 per cent manganese, 1.23 per cent WO_3, and 15 per cent silica. The form in which this tungsten occurs is unknown, but S. G. Lasky, of the U.S. Geological Survey, suggests that at least part of it may be present as the mineral hollandite.[29]

C AND W CLAIMS

The C and W group of three unpatented claims, held by W. L. Palmer and G. A. Westerdahl, is in the southeastern part of T. 9 N., R. 2 W., about 2 miles southwest of Silver Mountain. This area is accessible by some 3 miles of trail from the end of a rough road that leads up Banty Creek for 4 miles north of Westerdahl's camp.

Since the location of these claims in 1940, G. A. Westerdahl and W. L. Palmer have worked them in a small way and produced a few hundred pounds of concentrates with a portable hand jig.

The workings are at an altitude of approximately 3,500 feet, on a saddle between Walker and Banty creeks. Here the prevailing

[28]Oral communication.
[29]Oral communication.

formation is pre-Cambrian sedimentary schist, intruded on the south by granite and invaded by large sill-like bodies of tourmaline-bearing pegmatite.

In the vicinity of the claims a prominent belt of granular dark-colored schist a few hundred feet wide strikes generally northeastward and dips about 60° NW.; it strongly affects a compass needle, indicating high content of magnetite. This belt is cut at right angles by a fault zone about 2 feet wide and marked by strong gouge in the hanging wall, which dips 80° SE. Its walls show some sericitization. When visited in June, 1941, this fault zone had been opened by a pit 25 feet long by 20 feet deep from which lenticular bodies, 1 to 2 inches wide, of quartz with massive wolframite and scheelite are reported to have been mined. No visible tungsten minerals remained in the face.

MARICOPA COUNTY

CAVE CREEK DISTRICT

GENERAL FEATURES

The Cave Creek district, of northeastern Maricopa County, is in steep, irregular mountains that consist largely of pre-Cambrian schist and granite, intruded in places by younger granite and overlain on the north by mesa-forming volcanic rocks of Tertiary or Quaternary age.

This district contains deposits of gold, silver, copper, lead, tungsten, molybdenum, and vanadium.

GOLD CLIFF MINE

The Gold Cliff property of thirteen unpatented claims, held by the Gold Cliff Mining Company, is 5 miles by road, via the Dart Ranch, north of Cave Creek post office.

The northeastern portion of this property contains quartz veins from which, for many years, gold ore has been mined intermittently and concentrated in a stamp-gravity mill.

Three claims in the southwestern portion of the group contain the principal tungsten deposits. These deposits, well-known by 1913, were worked during the World War by the Pittsburgh Tungsten Company, but figures on their production are not available. In 1936 the group was leased to Jack Lemons who has produced several tons of ferberite concentrates with the aid of a small gravity plant.

Here slaty to sericitic gray pre-Cambrian schist, which strikes northeastward and dips northwestward at moderate angles, is intruded by a granitic stock that crops out over an east-west length of about a mile and a width of ¼ to ¾ mile. This granite has been extensively invaded and altered by pegmatite. The alteration consists largely of coarse sericite and quartz.

The area has been broken by several faults of undetermined displacement. Springs, important for local water supply, are associated with some of these faults.

Two systems of fissures are prominent; one system, which strikes N. 45° E. and dips about 65° SE., is intersected by the other, which strikes N. 25° to 30° NE. and dips about 60° SE.

The N. 45° E. fissures show extensive sericitization and silicification, in places forming zones 30 feet wide. Their outcrops, relatively resistant to erosion, are easily traceable.

The N. 25° to 30° E. fissures generally contain thin veins of quartz up to 3 inches thick, together with iron oxide. Oxidized iron and copper minerals are locally abundant in the walls.

Tungsten deposits are known to occur in six of the N. 45° E. zones, of which four have been productive. The principal mineral is ferberite, locally with auriferous pyrite, chalcopyrite, fluorite, and minor molybdenite. In places near the surface, copper carbonates, iron oxides, tungstite, and cuprotungstite are abundant; Hess[30] believes that the latter mineral formed through mutual decomposition of ferberite and copper minerals. He cites one analysis which shows the ferberite to contain 2.20 per cent of columbium-tantalum oxide.

The ore shoots, of which some as much as 2 or 3 feet wide have been mined, clearly seem to be related to the intersections of the fissures, as if the N. 45° E. zones were permeable structures mineralized by the N. 25° to 30° E. fissures. Some of the N. 45° E. zones contain ferberite seams and replacements for tens of feet southwest of these intersections.

Workings include several open stopes, surface cuts, and short adits.

GILA COUNTY

SPRING CREEK REGION

ROSE TUNGSTEN OR SHOESTRING MINE

The Rose Tungsten or Shoestring property of five unpatented claims is in the drainage area of upper Spring Creek in the northern part of the Sierra Ancha. It is accessible by approximately ½ mile of trail from the end of 11 miles of rocky road that branches westward from the Globe highway at a point 9 miles south of Young.

These claims were located a few years ago by R. O'Quinn. They have been worked in a small way by Messrs. O'Quinn, J. Binkley, and others, who produced a few lots of tungsten concentrates with a small gravity plant.

At the mine, a northeastward-flowing tributary of Spring Creek has carved a canyon about 300 feet deep through flat-lying quartzite, shale, and conglomerate of the pre-Cambrian Apache series, down into older tilted rocks. These older rocks here consist of laminated, somewhat schistose, ripple-marked beds, in places chloritized and impregnated with specularite. They strike northeastward, dip about 45° NW., and have been intruded by

[30]F. L. Hess, Tungsten minerals and deposits: U.S. Geol. Survey Bull. 652, pp. 33, 64 (1917). Contains colored illustrations of tungsten minerals.

northeastward-trending sill-like bodies of fine-grained dark-gray to black rock as much as 300 feet wide. Microscopically, this dark-colored rock is seen to be a diorite porphyry that has undergone considerable silicification.

Cutting the dark-gray intrusive on the west side of the canyon are two parallel quartz veins, 17 feet apart, that strike northwestward and dip 80° to 85° SW. When seen in May, 1941, they had been opened by surface cuts, by a lower adit, and by two adits some 50 feet higher up the slope; these adits are each more than 40 feet long. As thus exposed, the veins average about 8 inches in width within the dark-gray rock but are not traceable beyond its borders. Their filling consists of coarse-grained, shiny, grayish-white quartz with minor calcite and scattered masses of tourmaline, hematite, wolframite, and sparse scheelite. A few small specks of copper stain are apparent in places. The wolframite tends to form fairly coarse particles, commonly up to an inch in diameter, surrounded by thin crusts of scheelite. The vein walls show alteration to coarse sericite.

Some 100 feet farther north, a short adit has been driven on a similar parallel vein, which appears to contain more abundant tourmaline.

On the east side of the canyon, a 30-foot adit has opened a quartz vein similar in strike and dip to those on the west side. This vein ranges in width from less than an inch to more than a foot and cuts both the dark intrusive and the tilted beds. It shows much iron stain, but nothing was learned as to its tungsten content.

Surface equipment includes a small gravity plant, a compressor, and an 800-foot aerial tramway connecting the camp with the end of the road. Water is obtained from the bed of the canyon, whose altitude here approximates 5,000 feet.

PINAL MOUNTAINS

SAMSEL CLAIMS

The Samsel group of sixteen unpatented claims is on the southwestern slope of the Pinal Mountains, 14 miles by road from Globe. In 1940 these claims were held by Frank Samsel and under lease to the Pinal Tungsten Mines, Inc.

This ground was located for gold, silver, and lead deposits many years ago. Intermittent work has been done on its tungsten deposits since about 1924, and several tons of concentrates have been produced. Equipment includes a 600-foot aerial tram and a small gravity mill. Water is obtained from a spring and a shallow well.

This part of the Pinal Mountains has been carved into steep-sided, southwestward-draining canyons tributary to Mineral Creek. Pre-Cambrian Pinal schist, intruded on the northwest by Madera diorite and granodiorite, is the prevailing formation.

The principal vein occurs in a fissure that strikes N. 25° to 30° E., dips about 80° NW., and is traceable for some 3,000 feet. It has

been complexly faulted and cuts metamorphosed sericitic schist that strikes and dips about parallel to the vein. The vein filling consists of granular, glassy, grayish-white quartz, ranging from a thin seam to 4 or 5 feet in thickness, in which tungsten occurs as rather small particles of wolframite. Other minerals in the quartz include pyrite, galena, and gold and silver in unidentified form. Oxidized iron and lead minerals are locally prominent in the outcrops. This vein has been stoped for a length of 60 feet by a depth of 20 feet from the surface.

Early in 1940 the Pinal Tungsten Mines, Inc., completed a 280-foot adit designed to cut the principal vein at a point northeast of the stope and some distance below the surface workings. This adit penetrates some thin bodies of pyritic molybdenite and terminates at a fault that strikes N. 50° E. and dips 65° to 75° NW.

WESTLAKE CLAIMS

The Westlake group of fifty unpatented claims is on the northern and southwestern slopes of the Pinal Mountains, some 10 miles by road from Globe.

Many of these claims were located long ago for silver and copper. During 1917-29, while held by the late Jerome Clark, the Del Rey Silver Mines Company and the Merged Mines, Inc., were formed to exploit them. When visited in June, 1940, the group was held by Mrs. B. H. Westlake who had acquired it in 1929. In June, 1941, it was reported to have been taken over by the Moonshine Group Mining Company.

Ranging in altitude from about 4,500 to 6,000 feet, this region is well wooded and fairly well watered. It is made up largely of pre-Cambrian Pinal schist intruded in places by Madera diorite and granodiorite.

The claims cover several veins of prevailing northeastward strike and northwestward dip. They consist principally of granular glassy grayish-white quartz, locally with bodies of pyrite, galena, chalcopyrite, chalcocite, hematite, and gold and silver in unidentified combination. Wolframite, locally with sparse scheelite, occurs at several places, particularly in the Big Boulder and Centipede veins, which are in the southwestern part of the group, and in the Moonshine area, in the eastern part.

Up to June, 1940, development of the veins had been limited to a few short adits and shallow surface openings.

OTHER DEPOSITS

Tungsten mineralization is reported to occur also in the Doak and Bobtail mine areas in the southern part of the Pinal Mountains.

PINTO CREEK REGION

WAGNER CLAIMS

The Wagner group of ten unpatented claims is on lower Pinto Creek, 23 miles by road, via Horrel's ranch, from Miami. When visited in March, 1940, these claims were held by V. E.

Wagner, who located them for tungsten in 1938. A few tons of sorted ore have been produced.

Here, Pinto Creek, a northward-flowing tributary of Salt River, has carved a canyon several hundred feet deep through pre-Cambrian Apache beds and into underlying coarse-grained granite.

This granite has undergone considerable fissuring and sheeting of northwestward trend. Some of these structures contain pegmatite and aplite dikes, and others are occupied by quartz veins. Along the vein walls it shows alteration to sericite.

This area contains numerous quartz veins of prevailing N. 25° to 45° W. strike and vertical to steep northeast dip. They commonly range from a thin seam to 12 inches, and exceptionally to 32 inches in width. Their filling consists essentially of coarse-grained, glassy, grayish-white quartz with locally abundant tourmaline, scattered particles of wolframite and scheelite, and grains of pyrite. Some of the outcrops show considerable iron oxide.

On the east side of the canyon and a few hundred feet above Pinto Creek, shallow pits or short adits have opened six veins, all generally less than a foot wide. About ½ mile farther southwest, on the west side of the canyon, a short tunnel has been driven on a vein 2 to 2½ feet wide. It shows rather abundant wolframite in places adjacent to the walls.

OTHER DEPOSITS

Tungsten mineralization is reported to occur in the drainage area of Pinto Creek at several other places, as on the S. Rose claims, 4 miles west of Horrel's ranch, and near the Superior highway.

MAZATZAL MOUNTAINS

PINE MOUNTAIN AREA

General features.—The Pine Mountain tungsten area is near the crest of the Mazatzal Mountains, 5½ miles northwest of Four Peaks. Most of the claims lie in Gila County, in the upper reaches of a drainage locally known as Sycamore Creek,[31] but some of them are on the Maricopa County side of the divide.

This area is characterized by deep canyons and steep slopes ranging from about 5,000 to 6,100 feet in altitude, with sufficient precipitation to support pine and oak timber and to supply a few springs.

Coarse-grained, pinkish-gray, pre-Cambrian granite is the predominant rock of this portion of the Mazatzal Range. In the vicinity of the tungsten deposits, it has been intruded by a northeastward-trending belt of granite porphyry about a mile wide. This porphyry is characterized by coarse phenocrysts of pink feld-

[31]Shown on the U.S. Geological Survey Roosevelt quadrangle map as Cline Creek. Unfortunately, there are at least two other Sycamore creeks, one other Pine Mountain, and a Pine Ridge, elsewhere in the Mazatzal Range.

spar within an aplitic, sugary groundmass of feldspar, quartz, and biotite.

Both the granite and granite porphyry are cut by numerous steeply dipping to vertical fissures which may be grouped according to strike as follows: N. to S., N. 20° to 25° E., N. 45° E., and N. 65° W. At many places these fissures have been intruded by aplite or pegmatite dikes, the walls of which are marked by sericitic alteration and iron stain. Some of them are occupied by tungsten-bearing quartz veins. There is considerable suggestion that the deposits of tungsten are associated with intersections of the fissures.

El Oso claims.—El Oso group of sixteen unpatented claims, held by the Harrison brothers, is accessible from the Roosevelt-Payson highway by 10 miles of trail. These claims were located in May, 1941. When visited early in July of that year, they had been developed by several shallow shafts and open cuts.

In the northern part of the group, a vein striking N. 65° W. is traceable for more than 2,000 feet. As shown by a 10-foot shaft on El Oso No. 4 claim, it dips 75° NE. and ranges from 1 to 1½ feet in width. It consists of coarsely crystalline, locally iron-stained, glassy quartz with scattered bunches of wolframite crystals which are coated with variable amounts of scheelite. Some masses of wolframite crystals several inches in diameter were found in the vein, and wolframite particles up to ½ inch wide are locally present in the footwall gouge.

A few hundred feet farther south, on El Oso and El Oso No. 1 claims, vein segments striking N. 65° W. crop out at several places. Where exposed in shallow cuts, they range from about 28 inches to 5 feet in width and dip 65° NE. The gangue consists of coarsely crystalline, glassy, grayish-white quartz together with some pink feldspar. Scattered particles of wolframite, scheelite, and pyrite are locally abundant.

A short distance northeast of the main divide, on El Oso No. 10 claim, a northeast vein, generally less than 1 foot wide, crops out at several places. This vein consists of coarsely granular to sugary, glassy quartz together with some large crystals of pink feldspar. Where opened by a shallow pit, it shows fairly abundant particles of wolframite and scheelite and also sparse pyrite.

On El Oso No. 7 claim, on the Maricopa County side of the divide, a vertical vein of northward strike crops out with a width of about 2½ feet. Early in July, 1941, this vein had been opened by a shallow shaft which showed it to consist of coarsely crystalline grayish-white quartz with fairly abundant, scattered, small masses of wolframite and scheelite.

Cline claims.—The Jolene group of five unpatented claims, held by Joe H. and John H. Cline, is about 1 mile east of the main divide and 7 miles by trail from the Roosevelt-Payson highway.

These claims were located in 1938. When visited early in July, 1941, they had been developed by a few shallow cuts and by a 20-foot shaft with a 15-foot drift.

Here, coarse-grained, pinkish-gray granite has been invaded by aplite and pegmatite. Associated more or less closely with the pegmatite are four quartz veins a few tens of feet apart, which strike N. 20° to 25° E. and dip almost vertically. As exposed, they range from a few inches to more than 2 feet in width. The 20-foot shaft was sunk on an 8-inch vein of coarsely crystalline grayish-white quartz which contains scattered particles of wolframite, scheelite, and pyrite. Its drift cuts through about 7 feet of sericitized pegmatite which contains abundant vein quartz and local areas of disseminated scheelite, fairly abundant pyrite, and some fluorite.

PINAL COUNTY

SANTA CATALINA MOUNTAINS

CAMPO BONITO TUNGSTEN MINES

The property of Campo Bonito Tungsten Mines includes twenty-nine claims which were being surveyed for patent in June, 1941. Bonito camp is accessible from the Mt. Lemmon highway by 1½ miles of road that branches southwestward at a point 5 miles from Oracle.

This ground, originally located for gold, was worked for tungsten by the Cody-Dyer Arizona Mining and Milling Company during 1908-12 and 1915-16, and by lessees. The ore was concentrated in the Campo Bonito gravity mill, which had a capacity of 1 to 2 tons per hour. According to E. J. Ewing,[32] the total production, most of which came from the Maudina mine, was equivalent to approximately 50 tons of concentrates containing 60 per cent WO_3.

The Maudina mine is about 1 mile southeast of Campo Bonito, at an altitude of approximately 5,100 feet. In this vicinity the prevailing rocks consist of eastward-dipping sandstone, quartzite, impure limestone and shale of the Apache group. Some 1,200 feet farther north is the Mogul fault which strikes west to northwest, dips steeply southward, and brings Apache and Paleozoic beds on the south in contact with pre-Cambrian granite on the north. Earlier than this fault are diorite-porphyry dikes of northward strike and eastward dip. Associated with them in the granite area are quartz veins in which scheelite has recently been found on claims held by E. J. Ewing. Other quartz veins in the granite strike west to northwest.

The principal ore shoot of the Maudina mine was found in the southern portion of a vertical fault zone that strikes parallel to the Mogul fault. As shown by a 175-foot vertical shaft, an adit tunnel, and several hundred feet of drifts, this ore shoot plunged 45° E. and ranged from 4 to 15 feet in width by 50 or more feet in stope length. It has been largely stoped from its outcrop to the 175-foot level. The ore consists of scheelite veinlets and replacement masses, generally free of gangue but locally associated with quartz. The veinlets range from a fraction of an inch to several

[32]Oral communication.

inches in width, and the masses from about ¼ inch to several inches in diameter; according to Mr. Ewing, one solid mass of scheelite weighing 90 pounds was mined. The best ore is reported to have occurred below the 100-foot level, in impure limestone beneath the sandstone and quartzite of the upper workings. Some lead carbonate and wulfenite are reported to have occurred in the upper 50 feet of this ore shoot and in its honeycombed, siliceous outcrop.

A few feet north of the main ore shoot on the 150-foot level, a body of scheelite ore approximately 20 feet long by 12 feet high and 4 feet wide was encountered. Its occurrence suggests the need for further exploration in this fault zone.

MORNING STAR CLAIM

The Morning Star patented claim is in the northern portion of the Southern Belle group, about 1 mile south of Campo Bonito or 7 miles by road south from Oracle. The writer is indebted to E. J. Ewing and Lambert Wood for information.

In 1913 this claim was worked by E. J. Ewing, who treated several hundred tons of the ore in the Campo Bonito gravity mill and produced about 5 tons of concentrates containing 67 per cent WO_3; some of this ore was of relatively high grade.

When visited in June, 1941, it was owned by Mrs. Elizabeth L. Wood and under lease to Lambert Wood and the Rivera brothers, who had produced about 8 tons of concentrates.

The mine is at an altitude of about 5,200 feet on the western flank of a northward-trending canyon that exposes thick-bedded dark-gray Paleozoic limestone underlain by pre-Cambrian granite; the limestone-granite contact appears to be a low-angle fault genetically related to the Mogul fault, which crops out 300 feet north of the mine.

Rising prominently above the limestone for a length of approximately 125 feet by a maximum width of 50 feet is a vein that strikes N. 65° W. and dips 50° SW. Its footwall is a well-defined fault fissure whose age relative to the mineralization was not determined. This vein consists of coarsely crystalline grayish-white quartz, cut by numerous branching veinlets of finer-grained white quartz. It contains irregular disseminations of scheelite, mostly as particles larger than 16 mesh in size. One small body or shoot yielded 2 tons of concentrates.

Workings at the time of visit included a haulage adit beneath a surface glory hole some 35 feet in width.

Near the abrupt western termination of the vein outcrop, the dump of a shallow shaft shows abundant galena disseminated in quartz.

In June, 1941, the scheelite ore from this property was being treated in a gravity mill of 2 tons per hour capacity, situated about 1½ miles northeast of the mine. Water for milling was obtained from a shallow well.

BEAR CAT CLAIMS

The Bear Cat group of eight unpatented claims, held by E. B. Lovejoy, is 4 miles via the Mt. Lemmon road south from Oracle. Most of this ground was located in 1939. In June, 1941, the western part of the group was under lease to Seth Langley, who had produced about 210 pounds of concentrates.[33]

The property is equipped with a gravity mill of 150 pounds per hour capacity. Water for milling is obtained from a shallow well.

The Langley workings are on the southern flank of a gulch 1 mile by road west of Lovejoy's house. Here, on the Bear Cat No. 6 claim, granite is intruded by a dike about 60 feet wide that strikes N. 10° E. and dips 45° E. This dike is a fine-grained dark rock provisionally classified as diorite porphyry. Both its east and west contacts are marked by breccia and gouge together with scheelite-bearing veins.

The east vein, as exposed by an open cut some 50 feet long by a maximum of 15 feet deep, ranges from a thin streak to about 1 foot in width. It consists of coarsely crystalline grayish-white quartz with disseminated scheelite, iron oxide, and local sparse wulfenite and vanadinite. Some masses of scheelite are reported to occur in the footwall gouge.

In June, 1941, the west quartz vein, along the footwall of the dike, had been opened by a 20-foot inclined shaft which showed its width to be 16 inches at the collar and increasing downward. It contains disseminated scheelite, iron oxide, and pyrite.

Mr. Lovejoy reports the occurrence of two narrow scheelite-bearing quartz veins between diorite and granite on the Bear Cat No. 5 claim, about ¼ mile south of camp. They have yielded a little scheelite ore from recent shallow workings.

MAMMOTH AREA

MAMMOTH MINES

According to Hess,[34] concentrates of wulfenite and vanadinite from the Mammoth mines, 21 miles south of Winkelman, contain as much as 2 per cent WO_3. In 1938 the mill concentrates were reported[35] to carry 0.4 to 0.5 per cent WO_3. No tungsten mineral has been identified in these deposits.

TARR PROPERTY

Tungsten mineralization occurs on ground held by M. G. Tarr, some 5 miles by road north of Tarr's camp and 11 miles northwest of Mammoth.

This eastern foothill portion of the Black Hills has been sharply dissected by northeastward-draining ravines. The principal

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[33]Oral communication from E. B. Lovejoy.

[34]F. L. Hess, Molybdenum deposits: U.S. Geol. Survey Bull. 761, pp. 6-7 (1924).

[35]N. P. Peterson, Geology and ore deposits of the Mammoth mining camp area, Pinal County, Arizona: Univ. Ariz., Ariz. Bureau of Mines Bull. 144, p. 43 (1938).

rock exposed is fine-grained gneissic to schistose brown porphyry that has undergone considerable hydrothermal and surface alteration. Cutting this formation are numerous north to northeast fissures, of which some contain quartz veins that range from thin seams to 6 inches in width.

When visited in March, 1940, a small production had been made from two shallow pits sunk on a brecciated zone several feet wide that strikes N. 70° E. and dips about 80° SE. Its quartz stringers carry wolframite and scheelite. A short distance farther west are six parallel stringers of almost flat dip which show a little scheelite. The possible intersection of them with the brecciated zone had not been prospected.

ANTELOPE PEAK REGION

GOLD CIRCLE CLAIMS

The Gold Circle group of six unpatented claims, held by C. Upshaw, is in the drainage area of Putnam Wash at the southern end of the Tortilla Mountains, some 16 miles by road southwest of Winkelman.

Here, the prevailing rock is porphyritic granite cut by numerous stringers and veins of quartz which in places contain a little gold and tungsten.

A short distance east of Upshaw's camp, a quartz vein that strikes N. 70° E. and dips steeply south has been opened by a shallow pit which shows it to be only a few inches wide; according to Mr. Upshaw, it yielded some high-grade wolframite ore.

About ½ mile farther northeast, a fissure zone of irregular eastward trend and steep southward dip is traceable for some 2,000 feet. Its outcrop is marked by iron stain and in places by lenticular bodies of coarsely crystalline, cellular, dull-white quartz. At one place, where this zone contains a quartz vein striking N. 75° E. and dipping 45° to 60° SE., it has been prospected by a 70-foot inclined shaft with 50 feet of drifts. As exposed by these workings, the quartz vein ranges from 6 to 12 inches in width and in places carries small particles of powellite together with irregular bunches of scheelite and some wolframite.

PIMA COUNTY

SANTA RITA MOUNTAINS

HELVETIA DISTRICT[36]

The Helvetia district, 13 miles by road southeast of Sahuarita, is well known for its contact-metamorphic deposits, formed in Paleozoic limestone that has been intruded by granite and aplite. Since the early eighties of the past century these deposits have yielded more than $3,000,000 worth of copper, besides minor silver, gold, zinc, and molybdenum.

[36]F. C. Schrader, Mineral deposits of the Santa Rita and Patagonia Mountains, Arizona: U.S. Geol. Survey Bull. 582, pp. 91-128 (1915).

In 1940 O. C. Mitchell discovered stringers of scheelite adjacent to molybdenite bodies in the Leader mine. Early in 1941, C. M. Taylor found disseminated scheelite and powellite in the garnetiferous contact zone near the Black Horse shaft. These mines are the property of the Helvetia Copper Company, whose forty-two patented claims in the district were leased to C. M. Taylor during 1941.

As no development of the scheelite bodies in this district has been undertaken, little is known of their size, grade, and extent.

EMPIRE MOUNTAINS

HILTON PROPERTY

In May, 1941, E. P. Hilton located two claims covering scheelite deposits on his ranch in the Empire Mountains. This area is accessible by 4 miles of road that branches eastward from the Sonoita highway at a point 10 miles south of Mountain View station.

Here Paleozoic beds have been intruded by a stock which, according to F. W. Galbraith, of the University of Arizona, ranges in composition from monzonite to granodiorite. This area is part of the Empire district, which from 1880 to 1930 produced more than $1,000,000 worth of lead, copper, silver, and gold.

The principal scheelite deposits so far discovered in this area occur as disseminations in marble and in garnetiferous or siliceous beds. A belt of these altered sedimentary beds, 10 to 15 feet wide and intruded by granodiorite on both sides, extends northeastward for about ¾ mile from near the Hilton ranch house. When visited in June, 1941, it had been found to contain disseminated scheelite bodies at several places along its outcrop, but not enough prospecting had been done to determine much regarding their size, extent, or grade. Similar deposits occur a few hundred feet farther northeast where the granodiorite intrudes Carboniferous limestone at the base of a long ridge.

SIERRITA MOUNTAINS

PIMA DISTRICT

General features.—The Pima district is in the eastern foothills of the Sierrita Mountains, 9 miles by road west of Sahuarita and 18 miles south of Tucson.

As stated by Ransome,[37]

> the Sierrita Mountains consist essentially of an intrusive granitic core flanked by more or less metamorphosed rocks of sedimentary and eruptive origin. On the east are rather massive gray limestones, with quartzites, shales, and altered andesitic volcanic rocks. These rocks are folded and faulted, have been invaded by granite, and in places show pronounced contact metamorphism.

During 1887-1929 the Pima district produced more than

[37] F. L. Ransome, Ore deposits of the Sierrita Mountains, Pima County, Arizona: U.S. Geol. Survey Bull. 725, pp. 407-28 (1922).

$7,535,000[38] worth of copper, silver, lead, and gold from contact-metamorphic deposits.

Contact scheelite deposits.—In 1941 C. M. Taylor discovered disseminated scheelite and powellite in the garnetiferous contact zones of this area. A little shallow prospecting of some of the zones has since been done, but very little is yet known of their tungsten content.

Scheelite-quartz veins.—Mr. Taylor also discovered disseminated scheelite in quartz veins extending southwestward from the Senator Morgan mine, which he holds under lease from the Twin Buttes Mining and Smelting Company. Here the rocks consist of southwestward-dipping quartzite and shale, more or less epidotized and in places stained brown with iron oxide. The veins occur as segments whose outcrops range from a few tens of feet to more than 50 feet in length and from about 1 foot to perhaps 9 feet in width, distributed in echelon over a length of some 625 feet; whether this outcrop pattern is original or due to faulting has not been determined.

The vein filling consists of coarsely crystalline dull-white quartz, locally iron stained on outcrops and containing irregularly disseminated particles of scheelite that range from about 60 mesh to more than ⅛ inch in diameter. These particles are scarcely visible except by means of short-wave ultraviolet light. Samples from outcrops and shallow pits contained from 0.7 to 10.0 per cent[39] WO_3.

The Senator Morgan workings are reported to be 900 feet deep, with water level at approximately 300 feet below the surface. In June, 1941, one of the shafts was being reopened in order to explore the quartz veins.

LAS GUIJAS OR ARIVACA DISTRICT

SITUATION

Las Guijas or Arivaca tungsten district is in the vicinity of Las Guijas, a small settlement some 6½ miles in air line northwest of Arivaca. This area is accessible by 7 miles of road that branches westward from the Arivaca road at the Cerro Colorado mine, 14 miles west of the Tucson-Nogales highway.

HISTORY AND PRODUCTION[40]

Part of this ground was located for silver and copper by C. Bent more than 50 years ago. H. Whitcomb and associates bought sixteen of the claims and worked the deposits extensively during the World War.

In 1930 the Tungsten Alloys Corporation acquired the principal

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[38]M. J. Elsing and R. E. Heineman, Arizona metal production: Univ. Ariz., Ariz. Bureau of Mines Bull. 140, p. 97 (1936).

[39]Oral communication from C. M. Taylor.

[40]Information from E. Fernstrom, L. G. Fernstrom, and F. W. Giroux; also from Mineral Resources of U.S. and Minerals Yearbooks.

claims and built a gravity mill of 30 tons daily capacity. During the first part of 1931, their mill heads averaged 1.5 to 2 per cent, and tailings a little over 0.2 per cent, WO_3. Their concentrates, carrying pyrite, chalcopyrite, and about 40 per cent WO_3, were sent to E. C. O'Brien and Co. at Globe, Arizona, for magnetic separation. During 1931, 60 tons of concentrates containing 64 per cent WO_3 were sold. In 1933 the Tungsten Alloys Corporation ceased operations in the district and sold its machinery.

During 1934 to 1936 the Ore Metal and Engineering Corporation and the Southwestern Ore Corporation worked the deposits and produced about 1,000 units.

In 1936 the General Electric Company acquired the Whitcomb group and several other claims in the district. Since that time, the area had yielded approximately 1,200 units, largely by lessee operations.

A gravity custom mill, operated by Fernstrom & Co., is situated at a well 2 miles east of Las Guijas.

TOPOGRAPHY AND GEOLOGY

Las Guijas Mountains form a moderately dissected range 8 miles long by 4 miles wide and 3,500 to 4,600 feet in altitude. The northern portion, which includes the principal tungsten deposits, consists of medium-grained granite bordered at the northern base by andesitic volcanic rocks. This granite has been extensively fractured, particularly in westerly and southwesterly directions. Dikes of granite porphyry, aplite, and black biotite minette occupy some of these fractures.

North of Las Guijas is a broad ridge that may be considered part of the Cerro Colorado Mountains. It is composed of an igneous complex, largely andesite and diorite.

LAS GUIJAS VEINS

The principal tungsten-bearing veins of Las Guijas Mountains crop out on the northern flank of the range, within an area some 1½ miles long by 3,000 feet wide. Most of them strike westerly (N. 65° W. to S. 80° W.) and dip 45° to 85° N., but some strike S. 65° W. and dip steeply. In places they are accompanied more or less closely by dikes of altered black minette.

There are at least six veins, of which two attain major size. They are rather persistent along the strike, and range in width from a few inches to more than 20 feet. In places they are offset by faults, at least part of which are postmineral in age. These veins consist of coarsely crystalline grayish-white quartz with wolframite, pyrite, chalcopyrite, and galena. Iron and copper stains are locally abundant near the surface. Scheelite is generally lacking except for small amounts on the Stewart claims. The wolframite ranges from small particles to masses several inches across.

The ore shoots are of irregular size and shape. The structural factors that govern their localization could not be definitely de-

termined during the present brief study. For several feet away from the ore shoots the wall rock shows alteration to coarse sericite, and local red surface stain.

General Electric group.—The General Electric property includes thirty-eight patented claims, under lease to E. and L. G. Fernstrom. It includes the Immense lode on the north, the Grand lode about 1,000 feet farther south, and some smaller veins. Developments include shallow shafts, open cuts, a 1,500-foot adit, a 1,000-foot adit, and some shorter adits. Most of this work has been done on the Grand lode where a maximum depth of 150 feet was attained, and considerable stoping over widths of 3 to 5 feet was done.

Soto group.—The Soto group of five unpatented claims is east of the General Electric group. These claims, which were part of the original Whitcomb group, have been worked by Pete Soto and associates and, in 1941, by Frank Zappia. The principal vein, which ranges from a narrow stringer to 1½ feet in width, has been opened over a length of approximately 3,000 feet by several surface cuts, a few shallow shafts, and two short adits. As indicated by these workings, the ore shoots ranged up to 25 feet in length. The vein has been offset to a minor extent by several faults.

Stewart group.—The Stewart group of twelve unpatented claims is southeast of the General Electric workings. These claims, which were worked by lessees prior to 1925 and more recently by the Cleveland Tungsten Company, are now held by L. G. Fernstrom. Here, several shallow shafts and extensive open cuts have been sunk on veins that range from thin stringers to about 18 inches in width.

Obregon claims.—Some production is said to have been made from the Manuel L. Obregon claims, of which one is between the General Electric and Soto groups, and one adjoins the General Electric group on the west.

Black Gold group.—The Black Gold group of three unpatented claims, held by E. and L. G. Fernstrom, is about 2 miles north of Las Guijas. According to L. G. Fernstrom,[41] it has been developed by a 40-foot shaft and a 70-foot adit on a branching northeast vein which, during the past 4 years, has yielded some 500 units.

Placers.—Wolframite placers on the northeast slopes of Las Guijas Mountains and in the vicinity of the Black Gold group were notably productive during the World War. Since that time they have been worked intermittently, especially after heavy rains. Placer claims in this general region are held by C. E. Udall and by M. J. Mitchell.

BABOQUIVARI MOUNTAINS

CIRCLE CLAIMS

The Circle group of three unpatented claims is in the southeastern portion of the Baboquivari Mountains, some 60 miles by

[41]Oral communication.

road from Tucson and 7 miles, via Ronstadt's gate, west of the Sasabe highway.

These claims were located in 1939 by G. T. Harford and C. E. Bent. When visited early in 1940, they had been developed by a few shallow cuts.

Here, the steep sides of Schaffer Canyon consist largely of a faulted complex of siliceous sedimentary beds and volcanic rocks, intruded by dikes of acidic and intermediate composition.

One of the open cuts exposes a vein 6 to 18 inches wide and dipping 10 to 20 degrees westward. It consists of dull-white quartz with scattered bunches of wolframite, very sparse scheelite, and some pyrite.

OTHER DEPOSITS

On the north side of the Canyon, northwest of the Circle cuts, some shallow pits were sunk on steeply dipping lenticular quartz veins that in places carry scattered masses of wolframite.

COMOBABI MOUNTAINS

COYOTE HOLE CLAIMS

The Coyote Hole group of two unpatented claims is at the northern edge of San Luis village of the Papago Indian Reservation, in the western foothills of the Comobabi Mountains, 13 miles via the Ajo highway north from Sells.

These claims were located early in 1941. When visited in May, 1941, they were held by Wm. Coplen and W. L. O'Brien, who had produced several hundred dollars' worth of tungsten ore from them.

In this area, andesitic flows have been intruded by dikes of diorite porphyry and granite porphyry.

At the time of visit the principal opening consisted of a 30-foot incline on a vein that strikes northward and dips 15° E. As exposed, this vein was of lenticular cross section, 7 inches in maximum thickness by 6 feet across the incline. It consists of coarsely crystalline grayish-white quartz with irregular seams and particles of wolframite and sparse disseminations of scheelite. Small particles of chalcopyrite occur in the footwall, and iron oxide is abundant near the surface.

Several small, locally high-grade veins of similar character occur in the immediate vicinity.

SILVER DOLLAR CLAIMS

The Silver Dollar claims are a short distance east of the San Luis village windmill and south of the Coyote Hole group.

These claims, which were relocated in 1939 by M. Kyriak and Marshall Bartlett, are reported to have yielded a small production. When visited in January, 1940, their development consisted of an open cut about 100 feet long and a shallow incline on a vein that strikes N. 60° E., dips 70° NW., and is 6 to 10 inches wide. The ore consists of coarsely crystalline grayish-white quartz with

some barite, scattered particles of wolframite, and a little scheelite.

GUNSIGHT HILLS

SUNSET LIMITED OR YELLOW ASTER CLAIMS

The Sunset Limited claims, near the Gunsight Hills, are accessible by 1.2 miles of road that branches eastward from the Walls Well road at a point 3.7 miles south of the Ajo highway.

About 1917 these claims were known as the Yellow Aster group, which was worked to some extent by A. W. Bramwell and J. J. Sullivan. According to Burt Long, of Ajo, about 1 ton of scheelite ore was produced from near the surface.

This area is a pediment of granite littered with quartz fragments. The principal veins strike N. 30° W. to N. 60° W. and dip steeply. They consist of sheer zones 3 to 4 feet wide with lenticular bodies of shattered locally iron-stained, milky quartz. According to G. Bradley, several shafts 80 to 100 feet were sunk on them; the scheelite ore was mined mainly from open cuts.

COCHISE COUNTY

LITTLE DRAGOON MOUNTAINS

GENERAL FEATURES

The Little Dragoon Mountains, of northwestern Cochise County, form a ruggedly dissected range about 10 miles long by 7 miles wide. Their northern portion is made up of pre-Cambrian schist overlain by deformed Paleozoic beds. These rocks are invaded by coarse-grained sodic granite which constitutes most of the southern half of the range. Tungsten deposits occur in this range as follows:

Quartz veins in granite; quartz veins along the granite-schist contact; veins in schist; quartz veins in Paleozoic limestone; contact-metamorphic disseminations at Johnson Camp; and placers.

VEINS IN GRANITE

The principal tungsten-bearing quartz veins in the granite occur within a belt some 1,500 feet wide that extends from the Johnson limestone-granite contact southwestward for nearly 3 miles.

In this area the granite has been extensively broken by fissures, the most prominent set of which strikes northeastward and dips steeply southeastward; another set strikes northwestward; and a third set strikes northward. It has been intruded in places by aplitic and dark basic dikes of northeast and northward trend. The quartz veins occur within the northeast fissures.

In the northeastern part of the area, on the Primos ground, dozens of parallel and intersecting veins crop out within a width of 600 feet, and a parallel, but less productive, vein system appears about 1,500 feet farther southeast.

Southwestward, on the Dragoon or Little Fanny ground, the

main productive belt is represented by a vein that crops out about 1,200 feet northwest of a minor parallel lead.

Southwest of the Little Fanny, a main structure appears on the Hawk claims, and a minor parallel lead crops out some 600 feet farther southeast, on the Hillside claims.

The veins range from thin seams to 2 or 3 feet in width. Their gangue consists of coarsely crystalline grayish-white quartz with some purple fluorite. Generally the quartz is solid, but in places it is banded or thinly laminated, and some portions contain vugs more or less filled with clear quartz crystals.

The ore consists mainly of huebnerite, although in places it may be nearly one third scheelite. Huebnerite occurs in the quartz as tabular particles or blocky masses ranging from a fraction of an inch to several inches in diameter; some masses weighing as much as 500 pounds have been reported. Scheelite is present mainly as coatings on, and veinlets within, the huebnerite, and to a minor extent as particles and crystals in the quartz. In places, particularly in the southwestern portion of the area, hematite, limonite, galena, chalcopyrite, pyrite, and oxides of lead and copper are present.

The ore shoots are of irregular size, shape, and distribution. Most of them measure only a few feet horizontally and vertically, but one mined on the Primos ground is reported to have yielded 5½ tons of huebnerite.[42] The ore shoots appear to occur where fissures of northerly strike intersect the veins. They may also be related to abrupt pinches or convergences of the vein walls. The wall rock shows marked alteration to coarse sericite and is commonly stained reddish in the vicinity of ore shoots.

Primos group.—A group of twenty-one patented claims in the northeastern portion of the belt, west of Johnson Camp road, has been held by the Primos Chemical Company since 1903 and extensively worked. A gravity mill of 5 tons per hour capacity was built in 1915 and operated during the World War.

When visited in January, 1940, developments consisted of several hundred feet of adit tunnels and numerous open cuts. Some thirty-two lessees were mining ore that was being concentrated by crushing and hand jigging. According to Mr. Walker, about 4,500 pounds of huebnerite concentrates per month were being produced.

Little Fanny group.—The Little Fanny group of fourteen unpatented claims adjoins the Primos ground on the southwest and is accessible by a road that branches north of the Benson highway at the school house near Triangle T ranch. These claims were actively worked during the World War. During 1934-38, lessees are reported to have produced 55,000 pounds of concentrates from them.[43] Development consists of extensive surface workings and also some 1,600 or more feet of adit tunnels. The

[42]Oral communication from E. C. Walker, Manager.
[43]Oral communication from the late A. H. Yaegley.

group was acquired by the Dragoon Mining Corporation in 1938. Production by this company and by lessees from June, 1937, to October, 1939, amounted to approximately 8,000 pounds of concentrates.[44]

Wien claims.—The Hawk group of five claims and the Hillside group of four claims, southwest of the Little Fanny, are accessible from the Benson highway via Triangle T ranch. When visited in January, 1940, they were held by J. J. Wien who states[45] that they were located in 1898 by Asa Walker and worked by P. M. Sebring during the World War. Developments consist of a series of shallow cuts and short adits distributed over a length of 4,500 feet. According to Mr. Wien, production from 1933 through 1939 amounted to about 5 tons of concentrates, and lessees were producing 500 pounds of concentrates per week in January, 1940.

VEINS ALONG GRANITE-SCHIST CONTACT

The Tungsten King group of twelve unpatented claims is on the western slope of the Little Dragoon Mountains, about 12 miles by road northeast of Benson, via Pomerene.

Scheelite was discovered upon this ground in 1916, and the claims located were known for a time as the Tungsten Queen group. During the World War it was developed by open cuts and short adits which, according to J. J. Wien,[46] of Benson, yielded 5 tons of high-grade scheelite concentrates. When visited in January, 1940, the Tungsten King group was owned by Gold, Silver, and Tungsten, Inc., and had been leased for some time to Miles M. Carpenter who had produced about 800 pounds of concentrates with a small gravity pilot plant.

In this vicinity pre-Cambrian schist on the east is invaded by granite on the west, which in turn is intruded by northeastward-trending aplite dikes up to about 1 foot wide.

Scheelite-bearing quartz veins crop out intermittently for some 4,000 feet along this granite-schist contact and in the adjacent schist. These veins form eastward-dipping lenticular segments from a few inches to 6 feet wide and locally several hundred feet long, which have been offset in places by faults. Their coarsely crystalline dull-white quartz contains a little pyrite, chalcopyrite, and galena and, where oxidized, sparse iron oxide, copper stain, and wulfenite. Scheelite, generally detectable only by panning or by short-wave ultraviolet light, occurs as irregularly distributed small particles at various places in the veins and to a minor extent in the adjacent walls.

On the Tungsten King No. 1 claim, a 275-foot adit has been run to the vein, which has been followed southward by more than 100 feet of drift with some stopes. The adit continues eastward for some 125 feet to a faulted segment of the vein, which Mr.

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[44]Oral communication from the late Don Douglas, Manager.
[45]Oral communication.
[46]Oral communication.

Carpenter states was followed northward by more than 100 feet of workings (now caved).

Northward, the veins have been opened by shallow shafts, adits, and open cuts. Part of the early production is reported to have come from shallow workings in the northern portion of the property.

VEINS IN SCHIST

Across the ridge southeast of the Tungsten King ground is the Homestake group of four unpatented claims. This area is accessible by a mile of trail from the end of 4 miles of rough road that branches northwestward from the Willcox highway at the school house, 15 miles east of Benson. These claims were located about 1930 by J. J. Wien and the late A. H. Yaegley. When visited in October, 1939, they were held by R. C. Wise.

Here the prevailing rock is pre-Cambrian schist of northeastward strike and steep northwestward dip, intruded about ½ mile farther south by granite.

At various places fissures parallel to the schistosity, have been mineralized for widths of a few inches to a foot with quartz, epidote, and disseminations of scheelite. A little gold and oxidized copper minerals are locally present.

These veins have been opened by a few shallow cuts, short adits, and shallow shafts.

VEINS IN PALEOZOIC LIMESTONE

The Gilbert claims, in 1940 held by the Burrell brothers and worked by B. E. Gilbert, are 1½ miles by road west of Dragoon and a short distance north of the Southern Pacific Railway.

These claims were originally located for copper. During the World War about 100 pounds of tungsten ore were shipped from an old dump on the property. Up to December, 1940, the present operator had shipped approximately $1,500 worth of hand-sorted ore.[47]

This area is a pediment, largely covered by alluvium, at the southeastern base of the Little Dragoon Mountains. A small outcrop of Paleozoic limestone is cut by narrow altered dark porphyry dikes of N. 30° E. strike and by a quartz vein that strikes N. 50° E. and dips 80° NW. The outcrop of this vein is 4 to 12 inches wide and traceable for a length of about 200 feet. When visited early in 1940, it had been opened by surface cuts, a 40-foot shaft, and some 50 feet of drifts. As shown by these workings, the vein consists of coarsely crystalline grayish-white quartz, together with some lime and iron carbonates and irregular particles or masses of straw-colored scheelite. In the western portion lead and copper sulphides and carbonates are locally abundant; here some of the scheelite has partially altered to cuprotungstite.

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[47]Oral communication from J. H. Smith, of Dragoon.

CONTACT DEPOSITS AT JOHNSON

The Johnson camp area, 7 miles by road north of Dragoon station, has yielded more than $6,000,000 worth of copper and silver ore from contact-metamorphic deposits.

Here, Paleozoic limestones northeast of the granite-schist contact have been extensively metamorphosed to tactite, consisting largely of garnet and other silicates. This tactite zone[48] has been mined for copper intermittently for more than 2 miles along the strike. Disseminated scheelite was first recognized in these deposits by Dr. Larsen, then of the U.S. Geological Survey. It appears to favor association with sphalerite. Nothing regarding the commercial possibilities of these scheelite deposits has been determined.

PLACERS

Placer deposits of tungsten occur at various localities in the Little Dragoon Mountains, from Sheep Canyon at the north to Texas Canyon at the south, and on the western foothill pediment. Prior to 1919, they were extensively worked by hand picking, jigs, rockers, long toms, and dry washers, and yielded many thousands of pounds of huebnerite as well as some scheelite.

The more important placers were derived from the veins in the granite area, from which rich fragments and boulders of float were gathered; masses weighing 15 to 20, and exceptionally as much as 500, pounds were reported during the early days.[49]

Various attempts have been made to work the placers on a large scale.

WHETSTONE MOUNTAINS

CHADWICK CLAIMS

Tungsten deposits occur in the eastern part of the Whetstone Mountains, about ¾ mile southwest of McGrew Spring or 6 miles west of San Juan, a siding on the Southern Pacific Railway. This area is accessible from the Apache Powder highway by 9 miles of road that branches westward at a point 6 miles from Benson.

These deposits were well known in 1909, prior to which time they had been worked by the Euclid Mining Company and had yielded a few tons of ore.[50] When visited in October, 1939, the claims were held by Dewey Chadwick and associates, who subsequently have installed a small gravity mill and produced some concentrates.

Here pre-Cambrian schist of northeast strike is intruded by a stock of medium-grained white muscovite granite that forms a ridge. Cropping out on the southern slope of this ridge for a length of some 600 feet is a vein of crystalline grayish-white

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[48]F. L. Hess and E. S. Larsen, U.S. Geol. Survey Bull. 725, p. 260 (1922).
[49]W. P. Blake, Huebnerite in Arizona: A.I.M.E., Trans., vol. 28, p. 544 (1898).
[50]F. L. Hess, Note on a wolframite deposit in the Whetstone Mountains, Arizona: U.S. Geol. Survey Bull. 380, pp. 164-65 (1909).

quartz 6 inches to 2 feet wide that strikes N. 60° E. and dips 80° NW. As revealed by the short-wave ultraviolet lamp, portions of it carry fairly abundant disseminated particles of scheelite. As exposed in several shallow pits, this quartz vein contains sparse crystals of wolframite, generally less than ½ inch long, together with a few small particles of iron and copper sulphides. The adjacent granite shows intense sericitic alteration and contains thin particles of wolframite up to ¼ inch long which become less abundant away from the vein; in places they form small lens-shaped bodies of relatively rich ore. Sparse, thin veinlets and tiny particles of scheelite are locally present.

Within an area approximately ½ mile long by ⅛ mile wide there are at least five other lenticular veins parallel to this quartz vein. As seen in short adits and numerous shallow pits, the tungsten mineralization is most intense near the schist contact.

Although Hess[51] believed the wolframite in this granite to be a magmatic segregation, the field evidence seems to favor metasomatic replacement.

EVENING STAR CLAIMS

The Evening Star group of five unpatented claims, held since 1937 by J. Christie, is accessible by 2 miles of road that leads west from Chadwick's claims.

This property was worked in a small way during the World War and has yielded a few thousand pounds of tungsten ore since 1937.

The principal veins are in schist on the northern flank of an eastward-draining canyon, some 400 feet above camp. This schist strikes N. 10° W., dips 80° SE., and is intruded on the southeast by granite. Trending N. 20° to 30° NE. through the granite and schist are several pegmatite dikes up to 15 or more feet wide. Quartz stringers in the pegmatite and other quartz stringers of N. 10° E. and N. 45° W. strike carry a little wolframite. Some of these stringers intersect the main vein, which strikes N. 50° E., dips 30° NW., and ranges from 5 inches to about 2 feet in thickness. This vein shows tungsten mineralization at several places within a length of 300 feet. When visited in January, 1940, it had been opened by several shallow cuts and a 32-foot incline. It consists of coarsely crystalline grayish-white quartz with small scattered particles of wolframite, iron oxide, and pyrite. Mr. Christie states that a few feet below the collar of the incline the vein contained from 1.5 to 1.9 per cent WO_3.

The wall rocks of the vein and of the quartz stringers have been strongly sericitized.

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[51]Work cited.

HUACHUCA MOUNTAINS

GENERAL FEATURES

The Huachuca Mountains form a high, rugged range in which pre-Cambrian granite and Paleozoic and Mesozoic sedimentary rocks have been complexly deformed by low-angle thrust faults and invaded by Laramide intrusives, principally granite, granite porphyry, aplite, and diorite porphyry. Scheelite-bearing quartz veins occur in the sedimentary beds and in the older granite.

BROWN CANYON DEPOSITS

James group.—The James group of three unpatented claims is in upper Brown Canyon, near the crest of the range and adjacent to the Military Reservation. It is accessible by 3 miles of steep trail from the end of 3 miles of road that branches north from the Ramsey road at a point 2 miles west of the Huachuca highway.

At this altitude of 7,200 or more feet, precipitation is sufficient to grow timber and to replenish water-catches for domestic and small-scale milling purposes.

These claims were worked during the World War by J. Kelley and associates, who milled the ore in a small gravity plant in Brown Canyon at the foot of the trail. Since 1927 the ground has been held by H. S. James who has made an intermittent production of concentrates with a small gravity plant.

The deposits consist of scheelite-bearing quartz veins in complexly deformed lower Paleozoic limestone. The principal vein crops out for a length of about 150 feet, with a width of 1½ to 10 feet, a northwestward strike, and a dip of 45° SW. to almost flat. It has been opened by a 200-foot adit, with several stopes and drifts. As shown by these workings, the ore shoots ranged up to 5 feet in thickness and more than 10 feet in length. They appear to occur at intersections of northwest and northerly fissures. Associated with the vein are caverns or watercourses 8 to 14 feet high, more or less filled with reddish-brown sandy silt or mud. The ore consists of coarsely crystalline grayish-white quartz with irregularly distributed particles of straw-colored scheelite generally more than ⅛ inch in diameter.

Quartz stringers with local rich pockets of scheelite occur in limestone at several places on these claims.

Military Reservation.—According to Mr. James,[52] scheelite-bearing quartz stringers occur in limestone on the Fort Huachuca Military Reservation, in the upper reaches of Tanner Canyon, for a distance of some 2 miles northwest of the James claims. For a short period during the World War, numerous "gambucinos" worked these deposits to shallow depths.

Lucky Strike.—The Lucky Strike property is immediately north of the end of James's road.

During 1935-38, the property was worked by Gold, Silver and Tungsten, Inc., which built a small gravity plant about 1 mile east

[52]Oral communication.

of the mouth of Carr Canyon to mill ore from this ground, and from a similar deposit in Miller Canyon.

The Lucky Strike has been developed by a few shallow pits and an inclined shaft, now caved but reported to be 90 feet deep. As indicated by these workings, the vein strikes north, dips 25° W., and cuts coarse-textured pink granite. A schistose, altered dark-green dike about a foot wide occurs in the hanging wall. None of the vein now crops out, but specimens on the dump consist of coarsely crystalline grayish-white quartz with scattered grains of pyrite and stringers of scheelite.

CARR CANYON DEPOSITS

Reef group.—The Reef group of nine patented and five unpatented claims is on the crest of the range at the head of Carr Canyon. It is accessible by 6½ miles of road that branches westward from the Huachuca highway at Bright Spot.

This ground, originally located for gold, was first worked for tungsten during the World War. In 1918 the claims of the Exposed Reef Tungsten Company were taken over by the Tungsten Reef Mining Company. Since about 1935 the group has been leased to J. J. Seeman who has produced a considerable tonnage of concentrates with a small gravity plant. In June, 1941, the U.S. Bureau of Mines completed an exploration project upon the property.

This area is at an altitude of 7,000 or more feet, with gentle northwest slopes that support a fair stand of timber. Water is piped from springs to the camp.

Here, Cambrian Bolsa quartzite and Abrigo limestone have been weakly deformed by a series of thrust drag folds of gentle northwestward plunge and broken by fractures of northwest and nortward trends.

The mineral deposits consist of quartz veins which lie near the base of the Abrigo formation and in general dip conformably with the flexed strata. There are two principal veins, from a few feet to about 12 feet apart, of which the lower ranges from less than a foot to 6 feet, and the upper from about 2 to 15 feet, in thickness. They consist of coarsely crystalline grayish-white quartz, locally with scheelite, a little gold, and sparse galena. The scheelite occurs as irregular particles ranging from about ¼ inch to several inches in diameter. In many places the veins are sheared parallel to their dip, and the shear planes show northeast striations.

These veins, particularly the upper one, extend over a large area. Development of them consists of numerous trenches, pits, open stopes, and a few adit workings. These openings have demonstrated that the veins carry small quantities of scheelite throughout much of their extent and ore shoots of commercial grade at many places. These ore shoots are of irregular shape. Some of the stopes are small, but others measure 8 feet in height by 20 or more feet across. The lower vein appears to be the richer.

There is strong suggestion that the ore shoots occur at intersections of the northwest and northerly fractures.

BEAR CANYON DEPOSITS

Harper group.—The Harper group of two patented claims is in lower Bear Canyon, 2 miles by road northeast of the Canelo road.

These claims were worked to some extent during the World War. Since about 1939 they have been leased to C. O. Stockstad and associates, who have produced concentrates with a small gravity plant. When visited in July, 1941, a new gravity mill of 2½ tons hourly capacity was being installed.

This area is at an altitude of approximately 6,000 feet and moderately rugged. The prevailing rocks are Mesozoic maroon shale and sandstone, intruded on the northeast and south by granite.

At least four scheelite-bearing quartz veins crop out on the property. These veins strike northward and dip from medium angles to almost vertical. Recent workings consist of a 140-foot drift on a vein of 55° W. dip that averages about 1½ feet in thickness and a surface cut on a steeply dipping vein, 5 or more feet thick, which crops out 12 feet east of the adit portal.

These veins consist of coarsely crystalline grayish-white quartz with scheelite and local chalcopyrite, bornite, and galena. The scheelite occurs as sparse clear crystals and as irregularly disseminated straw-colored particles generally exceeding ¼ inch in diameter.

Van Horn group.—A group of twelve unpatented claims, held by H. G. Van Horn, is a short distance southwest of the Harper property.

Here, several locally rich scheelite-bearing quartz stringers of northeastward strike cut the Mesozoic shale. Development of them consists of surface cuts which have yielded some rich ore.

MONTEZUMA CANYON DEPOSITS

Zaleski claims.—The Zaleski group of three claims is at the mouth of Montezuma Canyon, north of the Montezuma or Border ranch. When visited in June, 1941, these claims were held by J. Zaleski and S. Kudznu and leased to T. Puryear.

Several quartz veins of northwest strike and steep southwestward dip crop out in granite that has been invaded by pegmatite and aplite dikes.

In the southeastern part of the property, a short adit shows one of these veins to consist of coarsely crystalline grayish-white quartz which ranges from a thin streak to about 7 inches in width. It contains irregularly distributed particles of straw-colored scheelite and sparse galena.

Other veins farther northwest have been prospected for gold.

SANTA CRUZ COUNTY

NOGALES DISTRICT

CALABASAS AREA

According to Hill,[53] the occurrence of tungsten deposits in an area about 2½ miles south-southeast of Calabasas and 10 miles north of Nogales has been known since 1906. He states that up to 1909 these deposits had been opened by several shafts 10 to 30 feet deep from which about 1,400 pounds of ore containing more than 50 per cent WO_3 had been mined. Some production was made from them in 1913. In 1940, according to Hugo Miller,[54] the principal deposits were held by H. B. Imus. Little development of them had been done during recent years.

The following description is abstracted from Hill:

> This area, between Nogales Wash and Santa Cruz River, is made up of coarse-grained light-gray granodiorite intruded by dikes of aplite and lamprophyre. Cutting these rocks are veins of banded, comb-textured quartz with wolframite, minor scheelite, and sparse calcite. There are many veins, all striking N. 25° W. and essentially vertical, but apparently most of them are barren or of low grade. Most of them are less than 10 inches, and a few as much as 2 feet, in width. There wolframite occurs as crystals and masses in pockets and stringers, apparently more concentrated near the wall rock in the narrow portions. In some of the smaller veins, bands of wolframite ⅛ inch thick are fairly continuous; the largest pocket seen was about 4 by 3 feet in a 6-inch vein. Scheelite occurs as tiny crystals in quartz associated with the wolframite.[55]

PATAGONIA MOUNTAINS

GUAJOLOTE AREA

Red Mountain claims.—The Red Mountain claims, held by the Kino Copper Company, include the southeastern side of Guajolote Flat.

Here, granitic rock is invaded by a stock or pipe of acid porphyry about 1,200 feet in diameter. The southern border of this mass shows northerly vertical fracturing and local intense sericitic alteration. A sericite zone about 5 feet wide contains irregular particles and masses, up to several inches in diameter, of a brownish tungsten mineral of unknown identity. The adjacent wall rock also carries some particles of a similar tungsten mineral. Oxidized molybdenum compounds are abundant in this mineralized area.

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[53]J. M. Hill, Note on the occurrence of tungsten minerals near Calabasas, Arizona: U.S. Geol. Survey Bull. 430, pp. 164-66 (1910).
[54]Oral communication.
[55]Work cited.

PRODUCERS AND POTENTIAL PRODUCERS OF TUNGSTEN IN ARIZONA

Marshall Bartlett, Sells
H. W. Berger, Kingman
Chas. Bly, Yucca
Miles M. Carpenter, Tucson
Dewey Chadwick, Tombstone
Jno. Christie, 1200 E. 8th St., Tucson
J. H. Cline, Tonto Basin
Continental Min. Corp., Kingman
Dragoon Min. Corp., Benson
E. J. Ewing, 316 E. 3rd St., Tucson
C. C. Findley, 718 W. McDowell, Phoenix
Fernstrom & Co., 164 S. Main St., Tucson
B. E. Gilbert, Dragoon
E. P. Hilton, Tucson
Grady Harrison, Payson
Paul Hubbard, Kingman
L. Hudgin, Nogales
W. H. Hunt, Kingman
H. B. Imus, Nogales
Harvey James, Box 415, Bisbee
J. B. Johnston, Glendale
B. E. Joy, Prescott
A. V. Kamff, Box 123, Yucca
H. Knowles, Yuma
Sam Kudznu, Hereford
Seth Langley, Oracle
Geo. Laxton, Kingman
Jack Lemons, 1519 W. Washington, Phoenix
Mrs. Jesus Levas, Wickieup
E. B. Lovejoy, Oracle
D. G. McMillian, Morristown
Angel Madril, Wickieup
Mammoth-St. Anthony Co., Tiger
W. Meyers, Kingman
Molybdenum Corp. of America, Yucca
J. G. Moon, Kingman
W. L. O'Brien, 1333 E. Mabel St., Tucson
Manuel L. Obregon, Tucson
Frank Olea, Wickieup
M. Pachen, Morristown
W. L. Palmer, Morristown
H. R. Phillips, Kingman
Rivera Bros., Oracle
Rose Tungsten Co., Young
Mrs. F. Samsel, Globe
J. J. Seeman, Hereford
A. Short, Wickieup
C. O. Stockstad, Box 1393, Bisbee
M. G. Tarr, Mammoth
Chas. M. Taylor, Court House, Tucson
Tunqepata Mine, Arivaca
C. E. Udall, Ruby Star Rt., Tucson
Chas. Upshaw, Winkelman
H. G. Van Horn, Star Route, Patagonia
Victor E. Wagner, Box 688, Globe
E. C. Walker, Dragoon
G. A. Westerdahl, Morristown
Mrs. B. H. Westlake, Globe
J. J. Wien, Benson
H. L. Williams, Prescott
Jno. Woods, Oracle
Lambert Wood, Oracle
Joe Zaleski, Hereford
Frank Zappia, Tucson

POSSIBLE BUYERS OF TUNGSTEN CONCENTRATES[56]

Fernstrom & Co., 164 S. Main St., Tucson, Ariz.
Jas. Hollingsworth, 1518 E. 7th St., Tucson, Ariz.
E. A. Jacobs, 34 S. Main St., Tucson, Ariz.
Mrs. Nellie G. Krieger, 1124 E. Helen St., Tucson, Ariz.
Seth Langley, Box 85, Oracle, Ariz.
Hawley & Hawley, Douglas, Ariz.
Atkins Kroll & Co., 260 California St., San Francisco, Calif.
Bond Bros. & Co., Inc., 310 California St., San Francisco, Calif.
Ore, Metal & Engineering Corp., 112 Market St., San Francisco, Calif.
H. R. Rogers Chemical Co., 527 Commercial St., San Francisco, Calif.
Clifford L. Ach—Chemical Alloys, 2326 E. 8th St., Los Angeles, Calif.
H. L. Coombs, 1765 W. 25th St., Los Angeles, Calif.
O. W. Dahlmer, 1203 3rd Ave., Los Angeles, Calif.
Engineers Metallurgical Co., 1126 Santa Fe Ave., Los Angeles, Calif.
First National Co. of Nevada, 3757 Wilshire Blvd., Los Angeles, Calif.
Chas. W. Garland Co., 412 W. 6th St., Los Angeles, Calif.
J. E. Leland, 228 W. 4th St., Los Angeles, Calif.
Smith-Emery Co., 920 Santa Fe St., Los Angeles, Calif.
Trans-Oceanic Shipping Co., 6160 Santa Monica Blvd., Los Angeles, Calif.
Marcus B. Whitney, 210 W. 7th St., Los Angeles, Calif.
Los Angeles Chemical Co., 4525 Independence Ave., South Gate, Calif.
Mills Alloys Co., 11320 So. Alameda, Compton, Calif.
Thos. Marden, 604 W. Commonwealth Ave., Alhambra, Calif.
Stoody Co., Whittier, Calif.
Western Mineral Associates, 1256 Fulton St., Fresno, Calif.
Ores, 608 Security Bldg., Pasadena, Calif.
W. K. Thompson, 5153 Earl Drive, Box 581, La Canada, Calif.
U.S. Vanadium Corp., Scheelite, Calif.
Wm. Loach, Wolf Tongue Min. Co., Boulder, Colo.
A. M. Riedesel, 523 Mining Exch. Bldg., Denver, Colo.
S. W. Shattuck Chemical Co., 1807 S. Bannock St., Denver, Colo.
A. Daigger & Co., 161 W. Kinzie St., Chicago, Ill.
Fansteele Metallurgical Corp., 40 West 22nd St., North Chicago, Ill.
Hiland's, 117 Warren Ave., Boston, Mass.
Raytheon Production Corp., 53 Chapel St., Newton, Mass.
Carboloy Co., Inc., 2481 East Grand Blvd., Detroit, Mich.
J. T. Baker Chemical Co., Phillipsburg, N.J.
Eisler Electric Corp., 754 S. 13th St., Newark, N.J.
Sirian Wire & Contact Co., 260 Sherman Ave., Newark, N.J.
Callite Products Co., 542 39th St., Union City, N.J.
Westinghouse Lamp Co., Bloomfield, N.J., and 420 S. San Pedro St., Los Angeles, Calif.
Associated Metals & Minerals Corp., 40 Rector St., New York, N.Y.
Barth Metals, Inc., 15 Park Row, New York, N.Y.
China Commercial Co., Ltd., 225 Fifth Ave., New York, N.Y.
H. Cross, Ores and Minerals, 15 Beekman St., New York, N.Y.
Crucible Steel Co. of America, 405 Lexington Ave., New York, N.Y.
C. A. Friz, 55 W. 42nd St., New York, N.Y.
Chas. Gitlan & Co., New York, N.Y.
W. R. Grace & Co., Ore & Metal Dept., 7 Hanover Square, New York, N.Y.
Chas. Hardy Inc., 415 Lexington Ave., New York, N.Y.
H. J. Lier, Continental Ore Corp., 500 Fifth Ave., New York, N.Y.
A. D. Mackay, 198 Broadway, New York, N.Y.
Metal & Ore Corp., Woolworth Bldg., New York, N.Y.
Metal & Thermit Corp., 120 Broadway, New York, N.Y.
Metal Traders, Inc., 67 Wall St., New York, N.Y.
Molybdenum Corp. of America, 500 5th Ave., New York, N.Y.

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[56]Names furnished in part by U.S. Bureau of Mines.

Ore & Chemical Corp., 80 Broad St., New York, N.Y.
Overseas Metal & Ore Corp., 29 Broadway, New York, N.Y.
Philipp Bros. Inc., 70 Pine St., New York, N.Y.
Josef Radnai, 36 Fulton St., New York, N.Y.
J. A. Samuel & Co., 220 Broadway, New York, N.Y.
David Taylor Co., Inc., 52 Broadway, New York, N.Y.
C. Tennant Sons & Co. of New York, 19 West 44th St., New York, N.Y.
George Uhe Co., 102 Maiden Lane, New York, N.Y.
Vanadium Corp. of America, 120 Broadway, New York, N.Y.
J. R. Van Fleet, 30 E. 42nd St., New York, N.Y.
Varlacoid Chemical Co., 116 Broad St., New York, N.Y.
Wah Chang Trading Corp., 233 Broadway, New York, N.Y.
Watson, Glach & Co., Inc., 57 William St., New York, N.Y.
Cecil M. Atkinson, 141 W. Ostrander Ave., Syracuse, N.Y.
General Electric Co., 1 River Road, Schenectady, N.Y.
Simonds Saw & Steel Co., Lockport, N.Y.
Ludlum Steel Co., Watervliet, N.Y.
Harshaw Chemical Co., 1933 E. 97th St., Cleveland, Ohio.
Allegheny-Ludlum Steel Corp., Brackenridge, Pa.
Braeburn Alloy Steel Corp., Braeburn, Pa.
Vulcan Crucible Steel Co., Aliquippa, Pa.
Electric Steel Co., Latrobe, Pa.
Vanadium-Alloys Steel Co., Latrobe, Pa.
Firth Sterling Steel Co., McKeesport, Pa.
North Metal & Chemical Co., York, Pa.
York Metal and Alloys Co., York, Pa.
Sterling Products Co., Easton, Pa.
Universal Steel Co., Bridgeville, Pa.
Colonial Steel Co., 324 Fourth Ave., Pittsburgh, Pa.
Westinghouse Electric Mfg. Co., 35 Cable Ave., E. Pittsburgh, Pa.
Foote Mineral Co., Inc., 1610 Summer St., Philadelphia, Pa.
E. J. Lavino Co., 1528 Walnut St., Philadelphia, Pa.
Metallurgical Products Co., Philadelphia, Pa.
Rohn & Haas Co., 222 West Washington Square, Philadelphia, Pa.
E. V. Oberdick, 91 West Jackson St., Tucson, Ariz.
Cleveland Tungsten, Inc., 10200 Meech Ave., Cleveland, Ohio.

INDEX TO PROPERTIES