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Report Cover

Subject OCCURANCE OF TUNGSTEN IN THE SOUTHWESTERN U.S.

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PLATES

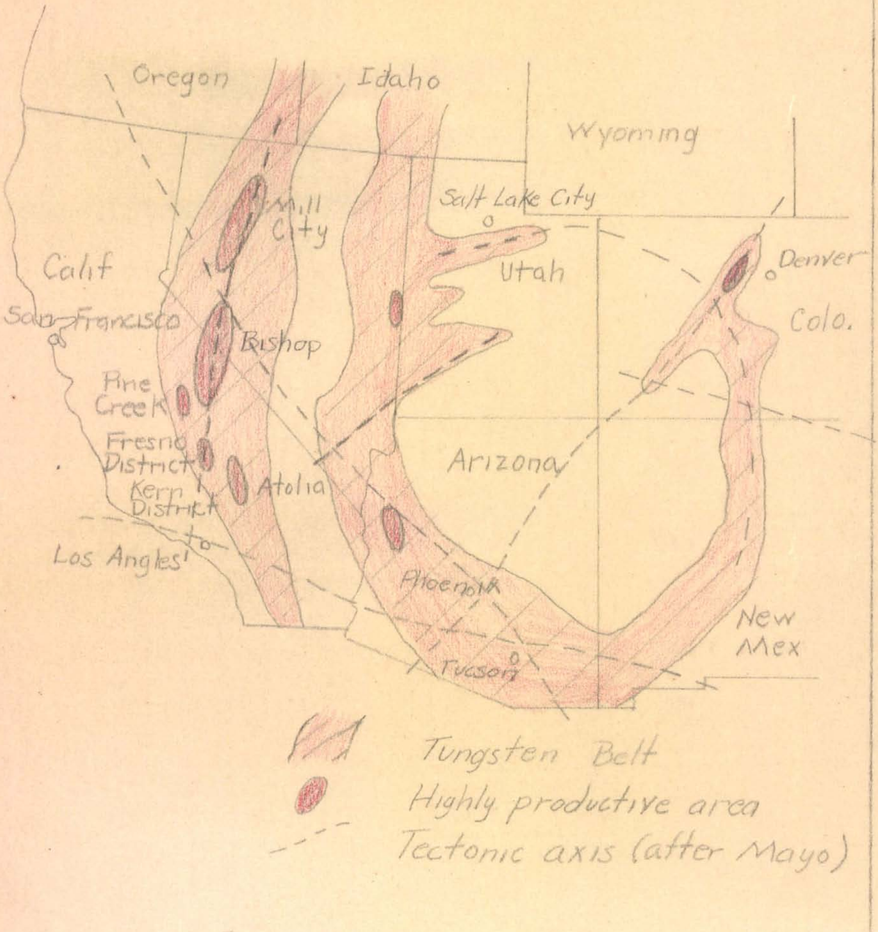
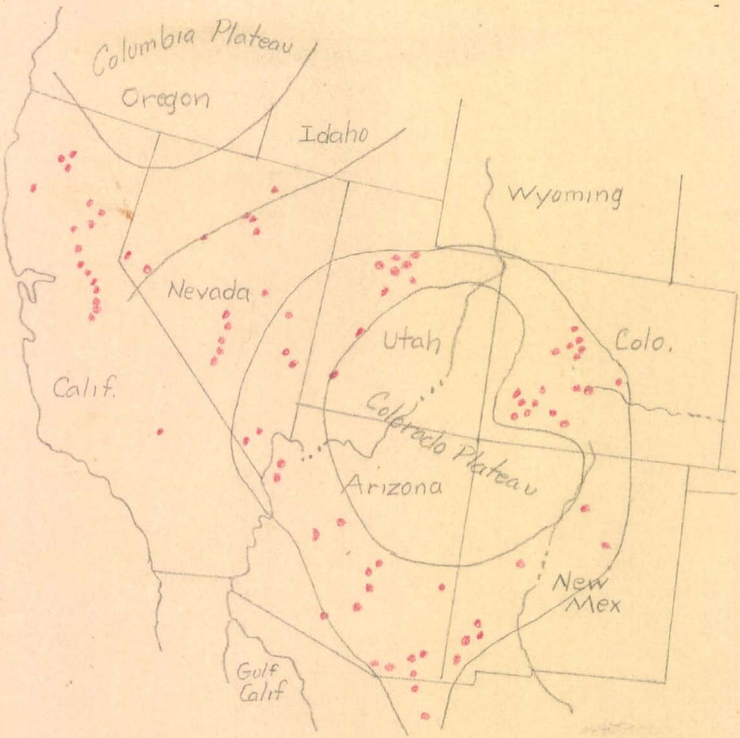


PLATE 1.

TUNGSTEN BELTS OF THE SOUTHWESTERN UNITED STATES (after Kerr, 1946).



Outline of positive & negative area
Ore district

PLATE 2.

DISTRIBUTION OF THE PRINCIPAL

ORE DISTRICTS OF THE S.W. U.S. (After Butler, 1933).

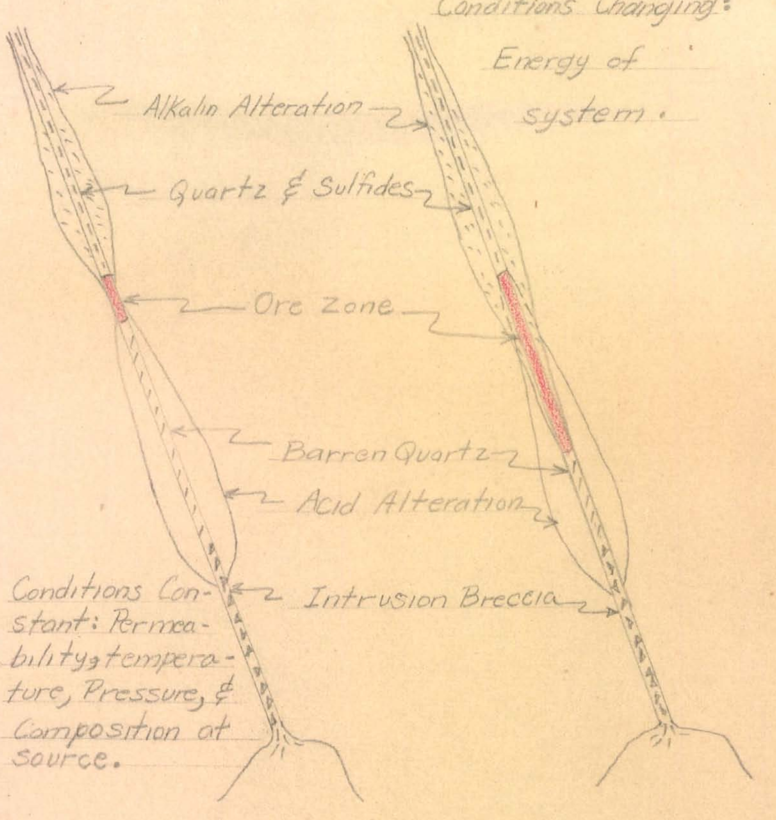


PLATE 3.
CONDITIONS OF MINERALIZATION AT BOULDER COUNTY, COLORADO

OCCURRENCE OF TUNGSTEN IN THE SOUTHWESTERN UNITED STATES

by

John E. Kinnison

Tucson, Arizona
December 20, 1952

C O N T E N T S

I L L U S T R A T I O N S

OCCURRENCE OF TUNGSTEN IN THE SOUTHWESTERN UNITED STATES

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ABSTRACT

Tungsten mineralization in the southwestern United States occurs in three northerly trending belts, apparently controlled by regional structural patterns. The western belt produces principally scheelite, and the central and eastern belts produce scheelite and wolframite.

The two most productive types of deposits are veins and contact-metamorphic deposits. The veins have yielded both wolframite and scheelite, whereas the principal mineral of the contact deposits is scheelite.

The tungsten-bearing solutions appear to have deposited the tungsten under alkaline conditions at relatively high temperatures. Most tungsten deposits are closely related to granitic intrusives, and the mineralizing solutions apparently emanated from these intrusives.

Secondary enrichment of tungsten deposits, if occurring at all, has not been economically important.

OCCURRENCE OF TUNGSTEN IN THE SOUTHWESTERN UNITED STATES

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STRUCTURAL CONTROL

Kerr (1946) has shown that tungsten deposits of the Western United States occur in three northerly trending belts (Plate 1). The eastern and central belts border the Colorado Plateau and merge below the Plateau in Arizona. The western belt, in general, follows the Sierra Nevada batholith.

The deposits of the eastern belt consist almost entirely of quartz veins with iron-manganese tungstates (wolframite, hubnerite, and ferberite). The extension of the eastern belt north of the Front Range of Colorado is not readily apparent.

The central belt contains both scheelite and the wolframites. Most of the deposits are in veins as contrasted to the scheelite replacement deposits of the western belt. The central and western belts, which join in southern Arizona, probably continue into Sonora, Mexico, but information is not sufficient to indicate any trends.

The western belt contains primarily scheelite replacement and contact-metamorphic deposits. The distinction between the western and central belts becomes vague when only location of deposits is considered, and the division was based partly on age. Those deposits assigned to the western belt appear related to the Sierra Nevada batholith, hence Nevadian (Jurassic (?)) in age, whereas those of the central and eastern belts appear related to the Laramide revolution (late Cretaceous-early Tertiary) (Kerr, 1946).

These tungsten belts lie in the Cordilleran region of the United States, and are comparable to the distribution of other minerals. Butler (1933) points out that the mineralized areas of the western United States are grouped around the Colorado Plateau. A comparison of the tungsten belts with the distribution of other western metal districts (Plate 2) leads to the conclusion that their regional structural control is related.

Mayo (Mayo, E. B., personal communication) has suggested that ore districts tend to occur near intersections of tectonic axes. The most probable location of the major axes of the southern Cordilleran is shown in Plate 1. Each axis represents a broad, and sometimes vague, belt following the alignment of prominent structural features. The location of these axes is based primarily on structural features illustrated by the tectonic map of the United States (1944). This same concept, on a smaller scale, might apply to ore centers within a district. Mayo has shown that four tectonic directions are apparent in the Sierra Nevada. The major districts of the Mother Lode gold belt and the principal tungsten producing districts (Bishop, Pine Creek, and others) appear to lie at intersections of all four tectonic directions.

TYPES OF DEPOSITS

General Statement

Hess (1917) recognized six types of deposits--veins, contact-metamorphic deposits, replacement deposits, placers, pegmatite vein deposits, and magmatic segregation deposits.

The first two types have been the most productive. Replacement deposits at Silver Dyke, Nevada, and Yellow Pine, Idaho (Bateman, 1950) are replacements associated with veins (Kerr, 1946) and might be considered as vein deposits. Kerr (1946) does not recognize replacements as a separate type of deposit. Pegmatite veins have yielded minor production. Placer deposits have been successfully exploited in a few places. The only segregation deposit recognized in the United States occurs in the Whetstone Mountains, Arizona (Hess, 1917). Wilson (1941) states that field evidence indicates metasomatic replacement.

Vein deposits

Vein deposits are more common in the eastern and central tungsten belts. They may carry either the wolframites or scheelite, or both, and almost always contain free quartz (Kerr, 1946).

Vein deposits of the wolframites occur more frequently in granitic rocks, schist, or gneiss. The wolframite veins of the Front Range, Colorado occur in a pre-Cambrian complex of schist, gneiss, and granite (Lovering and Goddard, 1950). Granite, however, was apparently a more favorable host rock than either schist or gneiss. At the Clyde mine in Boulder County, Colorado, ferberite occurs in a quartz vein in the Boulder Creek granite. Where the quartz vein passes from the Boulder Creek granite into the underlying Idaho Springs formation (schist and gneiss), the tungsten mineralization terminates rather abruptly (Lovering and Goddard, 1950). At Boriana, Arizona, scheelite and wolframite occur in quartz veins in schist (Hobbs, 1943). Wolframite veinlets occur in a wide sheeted zone in granite near Bagdad, Arizona.

High-grade scheelite in a quartz vein has been mined from quartz monzonite at Atolia, California (Lemmon & Dorr, 1940). The quartz monzonite is probably of late Jurassic age, and the mineralization probably occurred during Miocene (Lemmon & Dorr, 1940). In view of the occurrence of the Atolia deposits in a region which was heavily mineralized with tungsten during the Jurassic (?), and the lack of conclusive evidences favoring a Miocene origin for the Atolia deposits, it seems to the writer that a Jurassic (?) age is worthy of consideration.

The gangue minerals associated with tungsten veins are many. Some of the more common are: quartz, calcite, dolomite, ankerite, siderite, feldspar, muscovite, chlorite, tourmaline, topaz, and fluorite.

Contact-Metamorphic Deposits

General Statement

The contact-metamorphic deposits are perhaps the most important economically (Kerr, 1946), and occur primarily in the western belt (Plate 1). Contact deposits occur in the eastern ~~arc~~ belt at Hachita, New Mexico and in the central belt at Johnson Camp, Arizona. The contact deposits of the western belt include Bishop, Pine Creek, Benton, Fresno district, Kern district, California; and Mill City, Nevada.

The host rocks for the contact deposits are nearly all limestones or dolomites, possibly intercalated with other sediments (Hess and Larsen, 1921).

Hess (and Larsen, 1921) describes these deposits as occurring near an intrusive, within the zone of contact metamorphism. The associated minerals are mostly high-temperature lime-silicates, including garnet, diopside, epidote, vesuvianite, and hornblende. These dark-colored silicates are collectively called tactite. The predominant tungsten mineral is scheelite, the wolframites being noticeably absent.

The size and shape of the contact deposits is contingent upon many factors. Structure of the host rock, the nature of the beds and their susceptability to replacement, the nature and size of fissures, and the amount of metallizing solutions would be of major significance.

Metamorphic Zones

Hess (and Larsen, 1921) recognize three zones of metamorphism: the zone of dark silicates (tactite), the zone of light-colored silicates, and the zone of marbelized country rock.

The tactite zone is nearest the intrusive. The contact between the tactite zone and the zone of light-colored silicates is usually sharp. The marble zone is farthest from the intrusive, and is gradational with the light-colored silicate zone.

The iron content of the tactite zone is generally moderate. Garnet is usually the dominant mineral, although epidote may be dominant. Dark green hornblende and a pyroxene between diopside and hedenbergite are common. Calcite and quartz are plentiful in all zones.

The light-colored silicate zone is quite variable in extent, and grades into the zone of marble which forms the outermost part of the contact-metamorphic aureole. The two most common silicates are tremolite and wollastonite, often accompanied by colorless diopside, scapolite, alkali feldspar, quartz, and vesuvianite. There is a tendency for these minerals to have an elongation at right angles to the tactite zone or to a bedding plane in the limestone.

The zone of marble represents the zone of least intense metamorphism. The process of marbleization is one of recrystallization due to heat and pressure alone. Light-colored silicates are usually disseminated throughout the marble, indicating some addition of material by solution.

Stages of Matamorphism

Kerr (1946) outlines five stages of metamorphism in the formation of the contact deposits. The three zones of Hess (and Larsen, 1921) are the product of progressive metamorphism as described by Kerr.

(1) Original limestone. Limestone or dolomite of varying degrees of purity may be metamorphosed and be the host of a contact deposit, with no great difference in contact minerals.

(2) Marmorization. The first step in the recrystallization of limestone to a marble has been described as marmorization, and is so used by (Kerr, 1946). Often a grey or blue limestone is changed to a white marble by this process. Addition of silica and magnesium has been noted. If the pressure is sufficient to prohibit the escape of CO_2 gas, limestones may recrystallize without decomposition. This zone, possibly coupled with zone (3), appears to form the marble zone described by Hess (and Larsen, 1921).

(3) Initial Metamorphism. Pink or cream colored garnet, fibrous wollastonite (occasionally tremolite), and vesuvianite, accompanied by recrystallization of calcite, forms during the initial stage of contact metamorphism. This stage forms the zone of light-colored silicates described by Hess (and Larsen, 1921). Initial metamorphism appears to be low in tungsten content.

(4). Advanced replacement. "Where scheelite is most abundant, advanced replacement of limestone appears to form masses which consist largely of a mixture of epidote, quartz, and scheelite." (Kerr, 1946). This stage probably forms the tactite zone of Hess (and Larsen, 1921). Presumably the more advanced replacement requires more heat, and occurs nearer the intrusive. It should be pointed out that the tactite zone is not synonomous with the scheelite zone. An examination of mine maps shows that large areas of tactite are barren of scheelite.

(5) Regressive effects. Widespread silicification is frequently superimposed upon the advanced contact metamorphism.

The metallic sulfides may inaugurate the regressive effects. The sulfides, however, are not generally abundant in the contact deposits, and usually consist of pyrite, pyrrhotite, molybdenite, chalcopyrite, and sphalerite.

NATURE OF THE TUNGSTEN-BEARING SOLUTIONS

Most information available points toward deposition of tungsten minerals from high-temperature solutions. Referring to tungsten veins in Arizona, Wilson (1941) states that the wall rock alterations and associated minerals indicates deposition at a high-temperature. Hess (and Larsen, 1921) infer that contact-metamorphic deposits are a high-temperature type. Emmons (1924) lists 16 ore zones progressing outward from an intrusive; tungsten is in the second zone.

Edwards (1947) states that wolframite forms above 500 degrees Centigrade, along with such minerals as cassiterite, molybdenite, magnetite, hematite, pyrrhotite, tourmaline, topaz, garnet, and beta-quartz.

Both Hess (and Larsen, 1921) and Kerr (1946) agree that tungsten precedes most of the sulfides. Edwards (1947) gives a generalized paragenesis of hydrothermal ores; the first three groups as follows:

1. Magnetite, ilmenite, chromite, hematite.*
2. Cassiterite, tantalite, wolframite, molybdenite.
3. Pyrrhotite, pentlandite, arsenopyrite, pyrite, cobalt and nickel arsenides.

*minerals in each group in approximate order.

Edwards (1947) gives the following paragenesis of the ore at Renison Bell in Tasmania:

1. Cassiterite, wolframite, tourmaline, topaz, and quartz (the quartz continuing).
2. Pyrite, arsenopyrite, and gold.
3. Pyrrhotite, chalcopyrite, stannite, native bismuth.
4. Zinc, lead, and silver sulfides, and sulfo salts.
5. Carbonates.

Judging from Edwards' work, it appears that wolframite, at least, is a high-temperature mineral, forming long before the medium-temperature sulfides of lead and zinc.

Lemmon (1942) states that the minerals near Bishop, California formed in the following order: garnet, diopside, hornblende, idocrase, quartz and scheelite, sulfides, and veins of quartz and calcite.

Hobbs (1943) recognized at Boriana, Arizona the following sequence of mineralization.

1. Wolframite.
2. Scheelite and most of the sulfides (chalcopyrite with some pyrite and molybdenite).
3. Some late sulfides.

The proportion of wolframite to scheelite increases towards a nearby granitic stock, suggesting a zonal arrangement.

Lovering (1933) points out that some wolframite-bearing pegmatites may be traced into hypothermal quartz veins along both strike and dip.

Judging from wall rock alteration and laboratory data, the tungsten most probably was deposited from alkalin solutions. Kerr (1946) points out that solutions contains WO_3 are alkalin in reaction, and that addition of acid precipitates tungstic acid. According to Lovering (1943), the tungsten deposits of Boulder County, Colorado are generally surrounded by an outer casing of alkalin alteration and an inner casing of acid altertion. Lovering concludes that the tungsten was depositing when the solutions changed from an alkalin to an acid nature (Plate 3).

insert this pp between last pp "Nature Tungsten sol." and "Relation to Granitic intrusives".

Lovering (1933) continues, saying that tungsten may be both mesothermal and epithermal: "Minor amounts of scheelite, hubnerite, and wolframite are not uncommon in veins mined chiefly for gold, silver, or the base metals." This relation is certainly valid, but does not mean that the tungsten did not form first, or form later due to renewed activity of the metallizing solutions. Epithermal tungsten-bearing veins from Boulder County, Colorado, are described by Lovering (1933). This classification is based on association of minerals which ordinarily form at a low temperature and shallow depth. However, he points out that the tungsten may be of higher temperature than ordinarily associated with epithermal deposits. Later he states that the tungsten of Boulder County probably formed between 200 and 300 degrees Centigrade, under a pressure of about 100 atmospheres (Lovering, 1940).

Lovering (and Goddard, 1950) slightly revised his 1940 opinion when he placed the tungsten deposits of Boulder County within the "xenothermal" range (deposits formed between 300 and 500 degrees Centigrade at moderate to shallow depth) described by Buddington (1935).

RELATION TO GRANITIC INTRUSIVES

Tungsten deposits are almost always related directly to a granitic intrusive, usually a granite and often a quartz monzonite. So far as is known, tungsten is not associated with intrusives which contain no free quartz. Hess (1917) points out that the relation to a granite is usually obvious. Even where granite is not observed at the surface, field evidence usually indicates a granite at no great depth below.

Wolframite is often found with pegmatite dikes which emanated from a granitic magma.

Possibly the most intimate association between tungsten and granite is represented by the contact deposits in the Sierra Nevada. Here the tungsten frequently occurs in vertically elongated roof pendants, enclosed on all sides by granite (Kerr, 1946). The tungsten bearing solutions could hardly have come from any source other than the granite magma.

Kerr (1946) notes an association of aplite dikes and tungsten. These dikes, which are end-stage products of granitic intrusion, may have allowed the mineralizing solutions to pass along their contacts, or may have carried the tungsten during injection into the wall rock.

OXIDATION AND ENRICHMENT

Emmons (1917) states that ferberite, wolframite, and hubnerite are probably of primary origin in all deposits, and scheelite is almost always primary. In the Black Hills botryoidal masses of scheelite one millimeter thick incrust wolframite.

Tungstite (WO_3) is secondary. Stolzite ($PbWO_4$) is of uncertain origin but is probably secondary (Emmons, 1917).

General agreement among those who have worked with tungsten deposits is that the tungsten minerals may oxidize, or even be carried downward in solution, but secondary enrichment of economic value does not occur.

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