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A summary of the geology, geochemistry and tin occurrences in the Black Range, New Mexico

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A SUMMARY OF THE GEOLOGY, GEOCHEMISTRY, AND TIN OCCURRENCES IN THE BLACK RANGE, NEW MEXICO

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Abstract—Tin deposits in the Black Range occur in Tertiary topaz-rhyolite lavas known as the Taylor Creek Rhyolite. The deposits consist of hematite–cassiterite–wood-tin veinlets near exteriors of the host rhyolite domes. Fluid inclusions in cassiterite and associated topaz and quartz are large vapor inclusions and unique five-phase inclusions consisting of glass, vapor, and three daughter minerals at room temperature. At about 350°C the glass melts to form liquid-vapor inclusions that homogenize to a liquid at about 680°C. Quartz associated with tin mineralization has an oxygen-isotopic composition of +7.5 permil. Fluid inclusions in gangue minerals which include quartz, calcite, fluorite, and a number of fluoroarsenates homogenize at 130–300°C and have salinities of about 0.5 equivalent wt% NaCl. Spatially and temporally associated zones of intense vapor-phase recrystallization in the host rhyolite have $\delta^{18}\text{O}$ values of 8 permil.

The Taylor Creek Rhyolite is enriched in SiO_2 , F, Rb, and lithophile elements and depleted in TiO_2 , CaO, Fe_2O_3 , Sr, Ba, and V. Chondrite-normalized rare-earth-element patterns are flat, with large negative Eu anomalies. Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are 0.708 and 0.710.

These data indicate that tin mineralization was deposited in a fumarolic environment from high-temperature magmatic fluids in response to extreme thermal gradients. Quartz, calcite, and fluorite gangue minerals were deposited from a short-lived, meteoric-water-dominated hydrothermal system at much lower temperatures. The mineralizing fluids originated from the host rhyolites due to extreme differentiation in a shallow magma chamber. This period of extreme differentiation is responsible for concentrating tin in the fluid phase of the rhyolite magma. The magmas originated in either the upper mantle or lower crust.

INTRODUCTION

Tin was discovered in the Black Range of southern New Mexico in 1918 (Hill 1921; Fig. 1). For a brief time, the region was the focus of intense prospecting activity. Little tin was found and interest in the region soon dwindled. During World War II, the region was again the focus of attention since Southeast Asian supplies of tin were not available. A small mill was erected near the Taylor Creek discovery, but the grade and tonnage of the area were not sufficient to sustain the mill and the region lapsed into inactivity (Harrington 1943a, b). Only sporadic exploration activity has occurred since then. Production from placer deposits has amounted to several tens of tons of concentrate that averaged 60–70% Sn (Maxwell et al. in this guidebook). No production has been reported from the lode deposits.

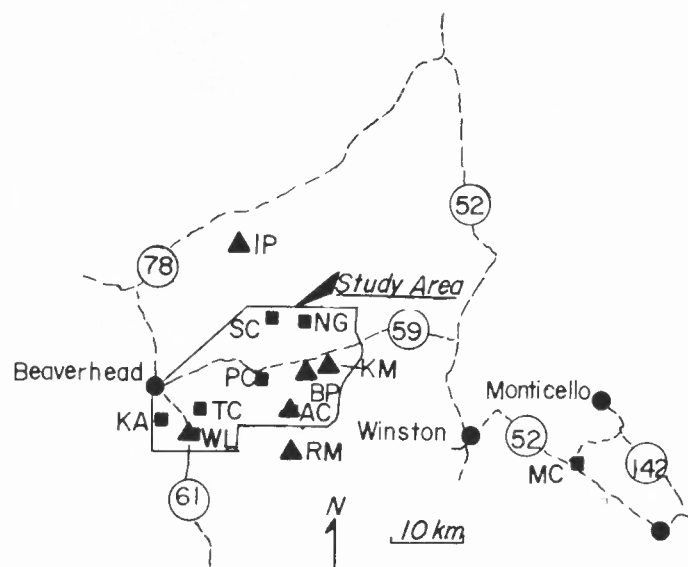


FIGURE 1—Location map of study area. Geographic features (triangles): IP=Indian Peaks, KM=Kline Mountain, BP=Boiler Peak, AC=Alexander Cienega, RM=Round Mountain, WL=Wall Lake. Tin occurrences (squares): SC=Squaw Creek, NG=Nugget Gulch, PC=Paramount Canyon, TC=Taylor Creek, KA=Kemp Mesa, MC=Monticello Cutoff.

This report summarizes results of a detailed study of the tin mineralization and petrology of the Taylor Creek Rhyolite which is host for the tin. The objective of the study was to ascertain the origin of the tin mineralization and to determine if it has any economic potential. The region was mapped at a scale of 1:24,000 and geochemical samples were analyzed for major, trace, and rare-earth elements as well as oxygen and strontium isotopic compositions. Microthermometric studies of fluid inclusions in mineralized rock constrain the temperatures and salinities of the mineralizing fluids.

GEOLOGY

The tin-bearing Taylor Creek Rhyolite is near the top of the Tertiary volcanic section in the central part of the Mogollon–Datil volcanic field (Fig. 2). The geology of the region is described in the first-day road log of this guidebook and will not be repeated here. The Taylor Creek Rhyolite consists of as much as 300–400 m of white, flow-banded, crystal-rich, rhyolite lava. The unit consists of a number of discrete rhyolite domes that locally coalesce to form eruptive centers as much as 15 km across (Fig. 3). With the exception of the rhyolite domes comprising the Taylor Creek eruptive center, the Taylor Creek Rhyolite consists of about 15–20% of quartz and sanidine phenocrysts in subequal proportions. Biotite, plagioclase, zircon, and opaque minerals are present in trace quantities. The rhyolite domes of the Taylor Creek eruptive center consist of about 40% phenocrysts as much as 1 cm long of quartz and sanidine in subequal proportions. Sphene is an important accessory. The groundmass texture in all the domes is fine to coarse granophyric depending on the intensity of the vapor-phase recrystallization.

Carapace breccias mantle the domes and consist of vitric to lithoidal blocks of rhyolite in a microbreccia of rhyolite. Vitric rhyolite (hydrated) is locally preserved as blocks in these breccias. Pyroclastic deposits consisting of thin, poorly welded ignimbrites with minor surge and subaerial fallout deposits commonly mantle the carapace breccia. The mineralogy and aerial distribution of these deposits suggest that they result from eruptions contemporaneous with dome emplacement. The ignimbrites are locally welded. The total thickness of these deposits is in excess of 50 m. Kyle et al. (this guidebook) describe these deposits in detail.

Vapor-phase recrystallization (VPR) is responsible for bleaching the rock and for deposition of numerous secondary minerals, including

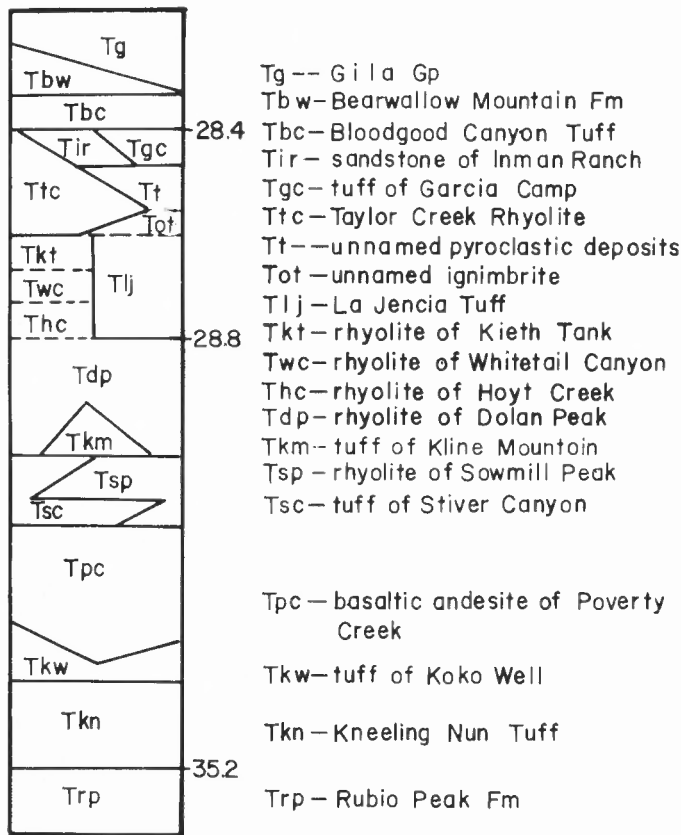


FIGURE 2—Generalized stratigraphic column for northern Black Range. Ages (in my) are from McIntosh et al. (this guidebook). See first-day road log for descriptions of units.

cassiterite. An additional effect of VPR is recrystallization of the groundmass. Typically, the granophyric groundmass of rhyolite exhibiting mild VPR consists of crystals that are less than 0.1 mm in diameter. In zones of intense VPR, the groundmass crystals are as large as 0.5–0.8 mm. Overgrowths on quartz phenocrysts locally double the size of the phenocrysts. The boundary between the original phenocryst and the overgrowth is marked by innumerable small inclusions, some of which may be fluid inclusions.

Tin occurrences are associated with zones of intense VPR and are never found more than a few hundred meters from such a zone (Fig. 4). The caprock above these zones is frequently lithophysal and the lithophysae have drusy linings consisting of euhedral crystals of hematite, quartz, pseudobrookite, bixbyite, and rarely topaz and red beryl. At Round Mountain, south of the study area, each lithophysae contains a single topaz crystal as much as 3 cm in length. The topaz contains inclusions of quartz, hematite, and pseudobrookite. The rim of Paramount Canyon is the only reported occurrence of red beryl. The best vertical exposure of an intense VPR zone is in Paramount Canyon. At this locality the intense VPR, which is exposed vertically for about 100 m, is capped by a zone of lithophysal rhyolite. A hematite–cassiterite veinlet is exposed about 20 m above the base of the lithophysal caprock. This general relationship is present in all the tin occurrences in the study area. Although tin occurrences are near zones of intense VPR, all zones of intense VPR do not have tin occurrences presently exposed.

Timing of tin deposition is constrained by the fact that lavas overlying the tin occurrence at Paramount Canyon are vitric rather than vapor-phase recrystallized. This observation indicates that VPR and tin mineralization were complete prior to emplacement of the overlying lava.

Sr-ISOTOPE DATA

Isochrons calculated from Rb–Sr isotopic data (Fig. 5) yield ages of 28.5–30 my which are consistent with constraints imposed by strati-

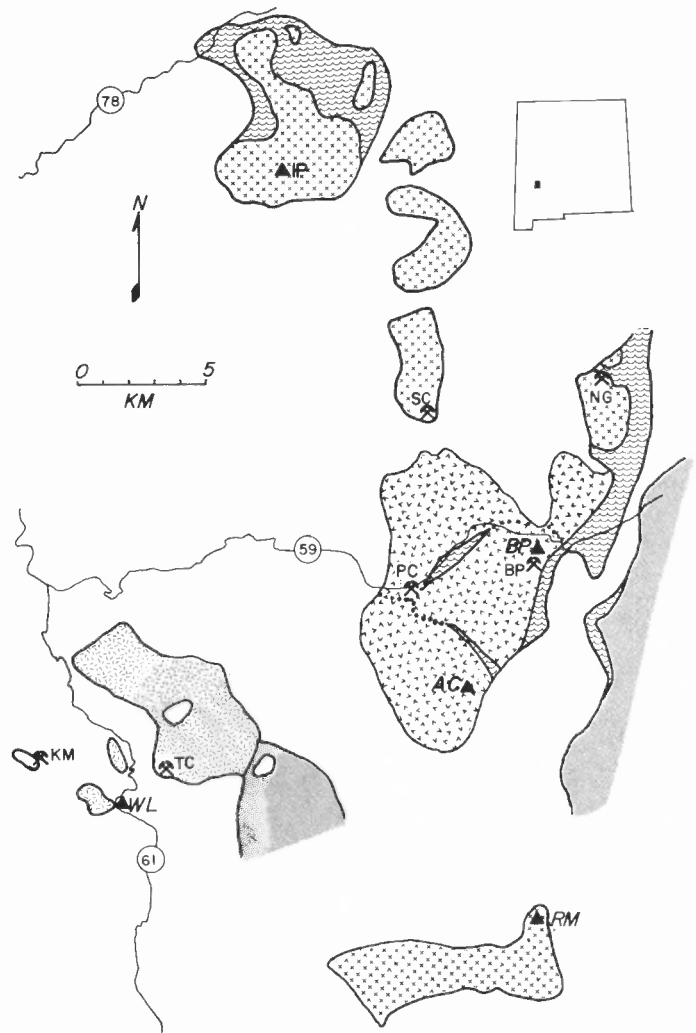


FIGURE 3—Generalized geology for Taylor Creek tin district. Geographic locations (triangles): IP=Indian Peaks, BP=Boiler Peak, AC=Alexander Cienega, RM=Round Mountain, WL=Wall Lake. Tin occurrences (pick and shovel): SC=Squaw Creek, NG=Nugget Gulch, BP=Boiler Peak, PC=Paramount Canyon, TC=Taylor Creek, KM=Kemp Mesa. Geology as follows: screen pattern=rocks older than Taylor Creek Rhyolite, wave pattern=pyroclastic rocks associated with Taylor Creek Rhyolite, white=rocks younger than Taylor Creek Rhyolite. X pattern indicates rhyolite domes that are not part of an effusive center. Random v pattern is the Boiler Peak–Paramount Canyon effusive center and consists of four domes. Random hachured pattern is the Taylor Creek effusive center which consists of at least four domes.

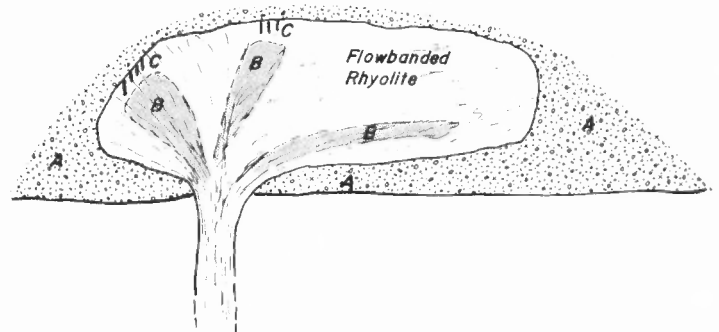


FIGURE 4—Schematic cross section of a flow-banded Taylor Creek Rhyolite dome. No scale is shown, but domes are as much as 300 m high. A=carapace breccia, B=zones of intense vapor-phase recrystallization, C=tin veinlets.

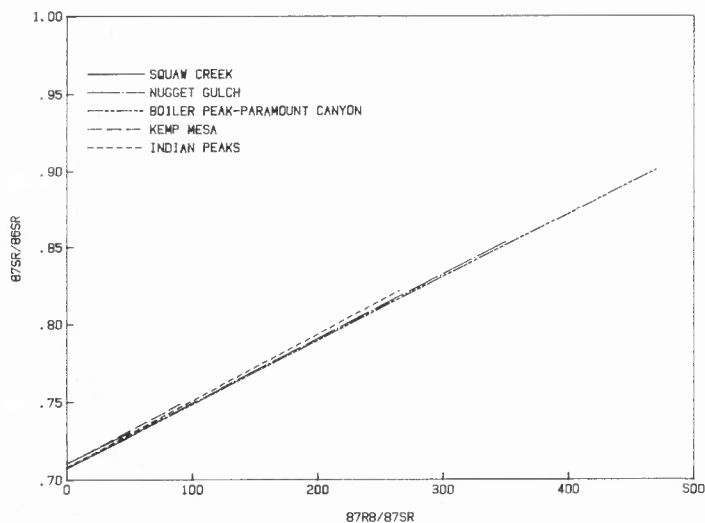


FIGURE 5—Rb/Sr isochron diagram for various Taylor Creek Rhyolite domes. Isochron ages of domes are: Squaw Creek, 28.2 ± 0.7 my; Nugget Gulch, 29 ± 0.2 my; Boiler Peak—Paramount Canyon, 29.4 ± 0.4 my; Kemp Mesa, 29.8 ± 0.6 my; Indian Peaks, 30.2 ± 0.1 my.

graphic considerations (McIntosh et al. in this guidebook). These data suggest that the domes in the Taylor Creek eruptive center are the oldest of the Taylor Creek Rhyolite domes in the study area.

Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the rhyolites fall into two groups, one at 0.7083, the other at 0.7104. The initial ratios of domes within a single eruptive center are identical. However, the initial ratios of the domes in the region exhibit no obvious pattern.

TIN MINERALIZATION

Tin is found in both lode and placer deposits in the northern Black Range. The placer deposits consist of both alluvial and residual placers. The alluvial placers are located in the valley bottoms and consist of Recent alluvium. The residual placers are on gentle hillsides underlain by mineralized rhyolite host rocks. In the placer deposits, wood tin, the cryptocrystalline, botryoidal form of cassiterite, is the dominant tin mineral. Hematite is the dominant heavy mineral in the placers.

Lode deposits consist of coarsely crystalline cassiterite and wood tin and specular hematite in veinlets typically a few meters long and high and 0.5–5 cm wide. The average crystal size in the coarsely crystalline cassiterite is about 1–2 mm, with rare crystals as large as 2–3 mm. At all the localities except Squaw Creek, hematite dominates over cassiterite. Wood tin is found in outcrop only at Nugget Gulch. This occurrence is located only a few meters below the carapace of the host rhyolite dome and consists of veinlets of opaline silica surrounding botryoidal wood-tin masses as much as 3 cm in diameter. Hematite and coarse cassiterite are absent from the veinlet, but are found in a parallel veinlet about 2 m away. Gangue minerals associated with the lode deposits include quartz, calcite, fluorite, topaz, various zeolites, cristobalite, and a number of fluoroarsenates (Foord et al. 1985).

Hematite, cassiterite, and wood tin are generally banded, and several cycles of hematite, wood tin, and cassiterite are typical in even the smallest grains. The bands are less than 0.2 mm wide. Hematite and cassiterite occur as pseudomorphs of each other and are always intergrown. Hematite occurs as euhedral crystal mats that have grown on massive hematite, on cassiterite, and on wood tin. Early hematite has locally pseudomorphed earlier magnetite. Cassiterite inclusions in hematite and hematite inclusions in cassiterite are common. These textures indicate that the hematite, cassiterite, and wood tin were deposited simultaneously, although a single phase will be predominant over the other two in any single growth band.

In the northern Black Range, tin is associated with all of the Taylor Creek Rhyolite domes. See Fries & Butler (1943) for locations of all known lode and placer deposits. Fig. 4 schematically depicts the lo-

cation of the veinlets in relation to the rhyolite dome that hosts the veinlet. Tin-bearing veinlets occur within a few tens of meters of the carapace of the rhyolite domes that host the deposits, usually immediately below the base of the carapace breccia.

FLUID INCLUSIONS

Fluid inclusions in cassiterite, quartz, calcite, and topaz were studied to determine the temperature of homogenization (T_h) and the salinity (in equivalent wt% NaCl) of the mineralizing fluids. The T_h of cassiterite is in excess of 600°C , the upper temperature limit of the heating stage used for the study. These high-temperature inclusions are unique in that at temperatures below about 350°C they are generally five-phase inclusions consisting of glass, vapor, and three daughter phases. The vapor phase is difficult to see at temperatures below 350°C because it is deformed by the glass phase. A liquid phase is sometimes present in very minute quantities, but, like the vapor phase, is very difficult to see because of the glass phase. The glass phase melts at about 350°C to a yellowish liquid. At that point the vapor bubble is round and the daughter minerals are obvious. Two appear to be salts and dissolve as the temperature is increased. The other is an opaque mineral, possibly hematite. Two of these inclusions have been heated above 600°C and homogenization to a liquid occurred at 670 – 690°C . The two salt-like daughter minerals dissolved at about 630°C . Harvey (1985) mistook the melting of the glass at about 350°C for homogenization and development of an immiscible liquid. The immiscible liquid is in fact the vapor bubble and homogenization to a liquid takes place at much higher temperatures.

T_h for gangue minerals is generally below 300°C , but temperatures as high as 400°C have been measured locally. Freezing-point depressions of fluids in inclusions in the gangue minerals are on the order of 0.1 – 0.5°C , so the salinities are very low, 0.2–1 equivalent wt% NaCl.

PARAGENESIS

The paragenesis (Fig. 6) is a composite for the district, as at no locality was the entire paragenesis observed. Note the overlap of the cassiterite and wood tin. Although wood tin is only rarely preserved in its primary veinlets, fragments recovered from placer deposits show interlayered wood tin and cassiterite. The earliest phase is typically cassiterite. T_h measured on cassiterite sandwiched between wood-tin layers is similar to cassiterite deposited without significant wood tin, suggesting that wood tin was deposited at the same temperature as cassiterite.

OXYGEN-ISOTOPE DATA

The oxygen-isotopic compositions of a number of whole-rock samples of the host rhyolite as well as of gangue quartz were determined. The isotopic composition of the whole-rock samples was about 8.5 permil (SMOW). Quartz from lithophysae in the host rhyolite domes has an oxygen-isotopic composition of about 7.5 permil, as do samples from zones of intense VPR. Quartz in the lithophysae and the VPR are interpreted to be the result of magmatic fluids. This contention is supported by fluid-inclusion temperatures. Quartz from quartz–fluorite veinlets has oxygen compositions between 6 and 11 permil (SMOW). Fluids in equilibrium with this quartz would have a $\delta^{18}\text{O}$ of about -5 to $+3$ permil (Bottinga & Javoy 1973).

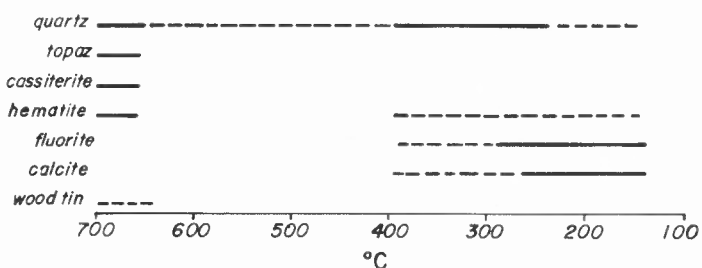


FIGURE 6—Paragenesis of tin veinlets plotted against temperature of formation as deduced from homogenization temperature of fluid inclusions in various minerals except hematite and wood tin.

Analyses of quartz and sanidine phenocrysts indicate that the primary magmatic $\delta^{18}\text{O}$ of the rhyolite was about +8.5 permil. Whole-rock analyses of the least vapor-phase recrystallized material available yield similar values which are typical of crustally derived felsic magmas (Taylor 1976).

PETROCHEMISTRY

The Taylor Creek Rhyolite consists of a number of rhyolite domes with very uniform, essentially identical, chemical compositions. The Taylor Creek Rhyolite is a high-silica topaz rhyolite in the nomenclature of Burt & Sheridan (1981). SiO_2 is typically greater than 76%. Relative to average rhyolite (Le Maitre 1976), the Taylor Creek is enriched in SiO_2 , K_2O , and Na_2O and depleted in TiO_2 , Al_2O_3 , and CaO (Fig. 7). The other major oxides have analytical uncertainties at the concentration levels present in the Taylor Creek that render comparisons of this type meaningless. Relative to the low-Ca granite of Turekian & Wedepohl (1961), the Taylor Creek is depleted in Sc and the light rare-earth elements, and dramatically depleted in Ba, Sr, V, and Eu. Trace-element enrichments include Rb, Nb, Cl, F, Th, U, Y, and the heavy rare-earth elements. The chondrite-normalized rare-earth-element patterns for the Taylor Creek (Fig. 8) are flat, with slight enrichment of the light rare-earth elements.

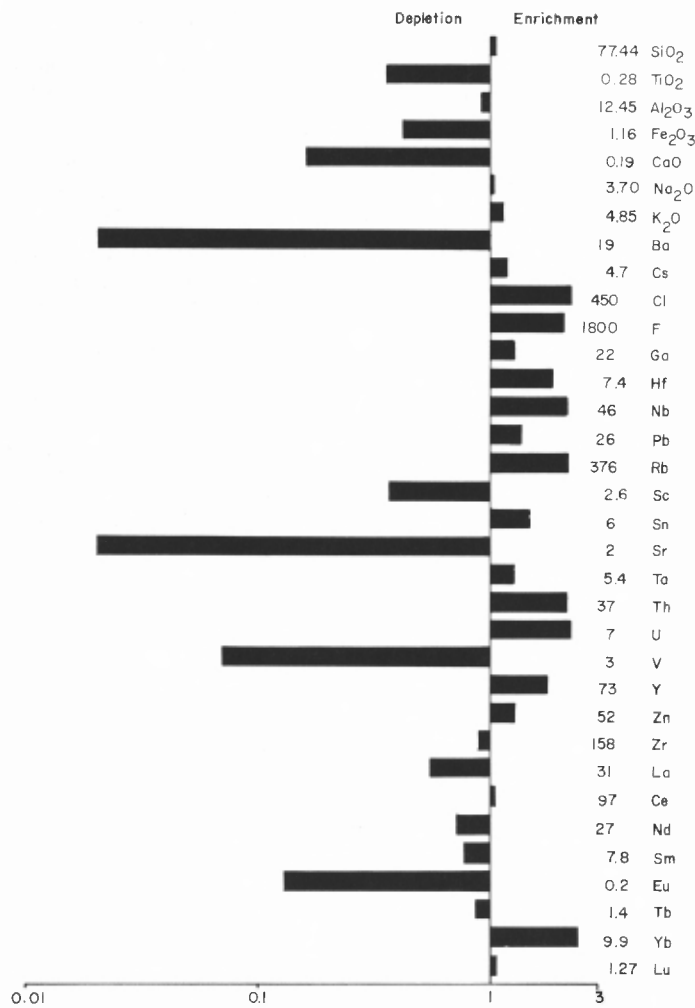


FIGURE 7—Enrichment-depletion diagram comparing Taylor Creek Rhyolite to major-element composition of average rhyolite of Le Maitre (1976) and to trace-element composition of low-Ca granite of Turekian & Wedepohl (1961). MnO, MgO, and P_2O_5 are not given because analytical uncertainty at the levels present in the Taylor Creek Rhyolite makes this type of comparison meaningless.

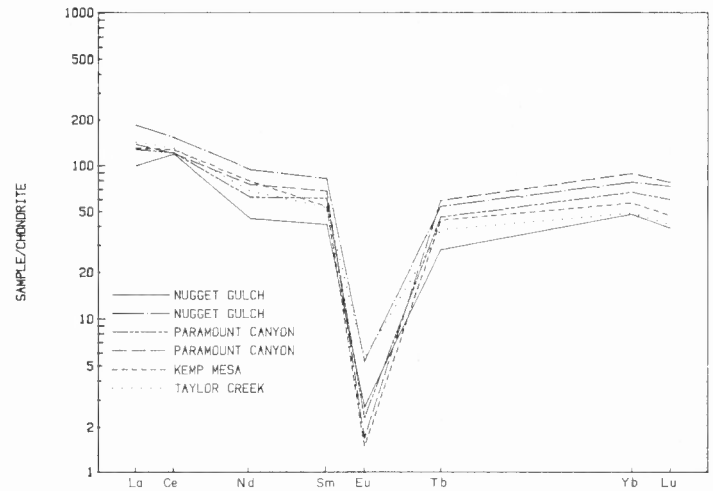


FIGURE 8—Chondrite-normalized rare-earth-element plot for several domes that comprise the Taylor Creek Rhyolite.

DISCUSSION

Tin mineralization

The data presented indicate that tin mineralization in the Taylor Creek district was deposited in high-temperature fumaroles that formed on rhyolite domes while the domes were cooling. Studies of fluid inclusions in cassiterite, quartz, and topaz indicate that these minerals formed at temperatures in excess of 600°C and homogenization-temperature data on two inclusions indicate that the temperature of formation was in fact near 700°C . These very high temperatures demand that the fluids be heated to magmatic temperatures prior to deposition of the contained metals. The $\delta^{18}\text{O}$ of the quartz formed at these temperatures is about +8 permil (Bottinga & Javoy 1973). Water in equilibrium with quartz at 700°C will have a $\delta^{18}\text{O}$ of about +8 permil. This composition places the water squarely in the magmatic-water box (Taylor 1976).

Fluid-inclusion temperatures of between 200 and 400°C and oxygen-isotopic compositions of 3–5 permil in the quartz gangue, as well as the 130 – 400°C temperatures and low salinities (less than 1 equivalent wt% NaCl) in calcite gangue, suggest that fluids that deposited these minerals were probably not entirely magmatic in origin. Water in oxygen-isotopic equilibrium with the quartz at the indicated temperatures would have had a $\delta^{18}\text{O}$ of between -8 and $+3$ permil depending upon the temperature. These values suggest that the fluid was enriched in $\delta^{18}\text{O}$ relative to meteoric water. The enrichment may be due to mixing of meteoric water with water from another source that was already enriched relative to meteoric water or interaction of heated meteoric water with rock with a high $\delta^{18}\text{O}$ such as limestone. The very low salinity of the fluid indicates that the water that produced the gangue minerals did not mix significantly with magmatic water which can have very high salinities (Kilinc & Burnham 1972). Mixing with metamorphic fluids would be similarly limited.

Enrichment due to interaction of meteoric water with rock enriched in $\delta^{18}\text{O}$ relative to the water is the most likely process. At 200°C , meteoric water ($\delta^{18}\text{O} = -10$ permil) in equilibrium with rock ($\delta^{18}\text{O} = +8$ permil) will be enriched to about +1.5 permil. This process would result in area of rock depleted in $\delta^{18}\text{O}$. Such an area has not been discovered in this study, but if the water-rock ratios were very small, the effect would not be easily recognized. Additionally, the high level of exposure prevents access to deeper portions of the system where $\delta^{18}\text{O}$ depleted rock would presumably be.

Pan (1974) suggested that wood tin in similar rhyolite-hosted tin deposits in Mexico was formed at very low temperatures (less than 150°C). No fluid-inclusion data on wood tin were obtained during this study, but since wood tin is intimately intergrown with cassiterite and hematite, and temperatures in cassiterite fractions of a millimeter from wood-tin bands were in excess of 600°C , we have concluded that the

deposition of wood tin versus coarsely crystalline cassiterite was not controlled entirely by the temperature of the mineralizing fluid. The process that controlled the deposition was probably the rate of fluid flow. Rapid fluid flow favored wood tin which was deposited somewhat closer to the outside of the dome than was the coarse cassiterite. Rapid flow rates would quickly bring the high-temperature fluid to the surface where thermal gradients would be extreme, leading to supersaturation and rapid deposition of wood tin. Quiescent fluid flow favored cassiterite.

Petrology

Enrichments of SiO_2 , K_2O , Rb, and other lithophile elements, as well as depletions of CaO, Sr, Ba, V, Eu, and light rare-earth elements, are typical of highly differentiated rhyolite magmas (Hildreth 1979). Similar enrichments and depletions are reported in Mo porphyry systems and in many high-silica ignimbrites (Mutschler et al. 1981). The Bishop Tuff is an example of an ignimbrite with similar chemistry and is postulated to be the highly differentiated cap on a zoned magma chamber (Hildreth 1979).

Two groups of initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios suggest that the source for the magmas was heterogeneous and that at least two different parental materials were present. Unfortunately, the data provide few constraints on the parental materials. Obviously, most Precambrian granites cannot be the parent because of their generally high present-day $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (Faure 1977). Models can be envisioned that allow nearly any lower-crust or upper-mantle rock to be the parent of the Taylor Creek Rhyolite.

CONCLUSIONS

1. The tin deposits are spatially and temporally associated with rhyolite lavas that host the tin deposits. The tin was deposited near margins of the cooling rhyolite domes.

2. Correlation of tin occurrences and zones of intense VPR indicates that VPR is related to the tin occurrences.

3. Fluid-inclusion data indicate that the tin mineralization was deposited at magmatic temperatures, and oxygen-isotopic data indicate that the fluids were indeed magmatic. This is consistent with derivation of the fluids from rhyolite lavas that formed the Taylor Creek Rhyolite.

4. Short-lived hydrothermal events followed deposition of the tin mineralization. These events are marked by quartz-fluorite-calcite gangue. These gangue minerals have fluid-inclusion homogenization temperatures of between 130 and 380°C and low salinities. Oxygen-isotopic compositions in the late quartz suggest that the gangue was deposited from meteoric-water-dominated hydrothermal fluids.

5. Extreme differentiation is necessary to produce the depletions of Sr, Ba, and V observed in the rhyolites. Sr-isotope data indicate that the magmas were derived from lower-crust or upper-mantle sources.

ACKNOWLEDGMENTS

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REFERENCES

- Bottinga Y. & Javoy M. 1973. Comments on oxygen isotope geothermometry.—*Earth & Planetary Science Letters*, 20: 250–265.
- Burt D.M. & Sheridan M.F. 1981. Model for the formation of uranium/lithophile element deposits in fluorine-rich volcanic rocks.—*American Association of Petroleum Geologists, Studies in Geology*, no. 13: 99–109.
- Faure G. 1977. *Principles of isotope geology*.—John Wiley & Sons, New York, 464 pp.
- Food E.E., Oatman M.R. & Maxwell C.H. 1985. Durangite from the Black Range, New Mexico, and new data on durangite from Durango and Cornwall.—*Canadian Mineralogist*, 23: 241–246.
- Fries C. Jr. & Butler A.P. 1943. Geologic map of the Black Range tin district, New Mexico.—U.S. Geological Survey, Open-file map.
- Harrington E.R. 1943a. Tin in New Mexico.—*Mines Magazine*, 33: 123, 130.
- Harrington, E.R. 1943b. Here's your tin (in Catron and Sierra Cos.).—*New Mexico Magazine*, 21: 7–9.
- Harvey D.B. 1985. Cassiterite mineralization in the Black Range tin district, Sierra and Catron Counties, New Mexico (M.S. thesis).—University of Texas at El Paso, 147 pp.
- Hildreth W. 1979. The Bishop Tuff: evidence for the origin of compositional zonation in silicic magma chambers: Geological Society of America, Special Paper 180: 43–75.
- Hill J.M. 1921. The Taylor Creek tin deposits, New Mexico.—U.S. Geological Survey, Bulletin 725: 347–359.
- Kilinc J.A. & Burnham C.W. 1972. Partitioning of chloride between a silicate melt and coexisting aqueous phase from 2 to 8 kilobars.—*Economic Geology*, 67: 231–235.
- Kyle P.R., Eggleston T.L., McIntosh W.C., Dunbar N., Hammond C.M., Johnson W.D., Knoper M. & Moore J. 1986. Pyroclastic rocks associated with the Taylor Creek Rhyolite, Scales Canyon, New Mexico.—This guidebook.
- Le Maitre R.W. 1976. The chemical variability of some common igneous rocks.—*Journal of Petrology*, 17: 589–637.
- McIntosh W.C., Sutter J.L., Chapin C.E. & Osburn G.R. 1986. A stratigraphic framework for the eastern Mogollon–Datil volcanic field based on paleomagnetism and high-precision $^{40}\text{Ar}/^{39}\text{Ar}$ dating of ignimbrites—a progress report.—This guidebook.
- Mutschler F.E., Wright E.G., Luddington S. & Abbott J.T. 1981. Granite molybdenite systems.—*Economic Geology*, 76: 874–897.
- Pan Y.-S. 1974. The genesis of the Mexican type tin deposits in acidic volcanics (Ph.D. dissertation).—Columbia University, New York, 286 pp.
- Taylor H.P. Jr. 1976. Oxygen and hydrogen isotope relationships in hydrothermal mineral deposits. *In* Barnes H.L. (ed.), *Geochemistry of hydrothermal ore deposits*.—John Wiley & Sons, New York, pp. 236–277.
- Turekian K.K. & Wedepohl K.H. 1961. Distribution of the elements in some major units of the earth's crust.—*Geological Society of America, Bulletin*, 72: 175–192.



Hauling sacked ore from a Black Range mine 1880's style. Photo courtesy of Geronimo Springs Museum.



Hillsboro stage ca 1890. Photo courtesy of Geronimo Springs Museum.