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# K-Ar AND FISSION-TRACK AGES OF TUFF BEDS AT THE THREE KIDS MINE, CLARK COUNTY, NEVADA: IMPLICATIONS FOR MANGANESE MINERALIZATION

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## INTRODUCTION

The Three Kids manganese deposit occurs in clastic sedimentary rocks on the northern flank of the River Mountains in Clark County, southern Nevada (fig. 1). A large part of the River Mountains consists of a stratovolcano that formed during the middle Miocene (Anderson and others, 1972; Smith, 1982; Weber and Smith, 1987). Nonmarine Tertiary sedimentary strata exposed north of the River Mountains and around Lake Mead have been subdivided into the middle Miocene Horse Spring Formation and the overlying upper Miocene Muddy Creek Formation (Bohannon, 1984). Previous workers (Hunt and others, 1942; McKelvey and others, 1949; Van Gilder, 1963) have assigned the sedimentary rocks hosting the Three Kids deposit to the Muddy Creek Formation. Because of the stratiform nature of the manganese mineralization, the age of manganese deposition should be approximately equivalent to the age of the enclosing strata. We present K-Ar and fission-track ages of minerals separated from tuffs interbedded with the manganese-bearing sequence that indicate a middle Miocene age of tuff deposition and mineralization. This age predates the Muddy Creek Formation and indicates that manganese mineralization is temporally related to middle Miocene volcanism in the River Mountains.

## GEOLOGY

The southeast part of the River Mountains is an eroded stratovolcano dominated by alkalic andesites and dacites (Smith, 1982, 1984). Volcanic units in the northern part of the range were erupted from several domes adjacent to the stratovolcano, and consist of subalkalic dacite lava flows, subordinate flows of alkalic andesite and basalt, and thin pyroclastic beds composed of light-gray ash and pumice lapilli. This section has been named the volcanic rocks of Powerline Road by Bell and Smith (1980). The main vent for the River Mountains stratovolcano is represented by the River Mountains stock of quartz monzonite composition. Veins cutting volcanic rocks at the margins of the River Mountains stock contain barite, hematite, and Mn oxide (Smith and others, 1987).

Tertiary sedimentary units in the River Mountains consist of the manganese-bearing sedimentary rocks of the Three Kids mine area, the Muddy Creek Formation, and local fanglomerates (Bell and Smith, 1980; Smith, 1984). The Horse Spring Formation, a sequence of lacustrine and alluvial sedimentary rocks of Miocene age, is widely exposed in the region north of Lake Mead including Frenchman Mountain approximately 10 km north of the Three Kids mine (fig. 1; Bohannon, 1984).

The sedimentary sequence at the Three Kids mine lies unconformably on the volcanic rocks of Powerline Road and includes a basal conglomerate overlain by a well-bedded section of pink to dark-gray tuffaceous siltstone and sandstone and 0.1- to 2-m-thick beds of white, gray, and green tuff. The gray to dark-gray colors of tuffaceous sandstone and siltstone reflect variable amounts of manganese oxide minerals. White tuff beds in the Three Kids mine lack internal structure and are well sorted indicating an airfall origin and deposition in shallow water. Pumice lapilli and pebble- to boulder-size tuff clasts also occur in localized conglomerate facies associated with some sandstone beds. Sedimentary beds overlying the manganese-bearing strata contain gypsum and gypsum-rich sandstone and siltstone and were assigned to the Muddy Creek Formation by Bell and Smith (1980).

The River Mountains are located at the northern end of a broad zone of highly extended terrain within the Basin and Range province that extends southward along the Colorado River into southeastern California and western Arizona (fig. 1). According to Weber and Smith (1987), the River Mountains and adjacent ranges in southern

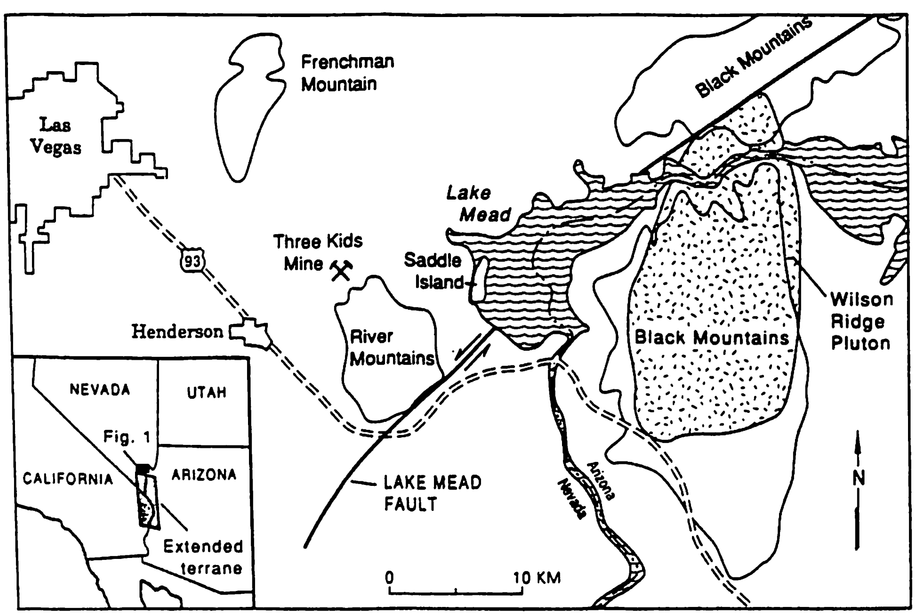


**FIGURE 1. Map showing generalized geologic and structural features and the location of the Three Kids mine in the Lake Mead region, southern Nevada. Inset shows region of highly extended terrane along the Colorado River in southeastern California and western Arizona.**

Nevada are part of a complexly deformed allochthonous block that is underlain by a regional, west-dipping detachment structure. The detachment surface is exposed at Saddle Island on the western side of Lake Mead (fig. 1). Structural and geochemical evidence indicate that the River Mountains stratovolcano has been displaced approximately 20 km southwestward from its subvolcanic source, the Wilson Ridge pluton. Anderson and others (1972) reported K-Ar ages of 15.5 ± 0.6 and 14.0 ± 0.6 Ma for rocks from the Wilson Ridge pluton.

The River Mountains are bounded on the south by the Lake Mead fault system (fig. 1; Anderson, 1973; Bohannon, 1979). The fault is left lateral and trends northeast-southwest. Major displacement on this fault system occurred between 13.5 and 12 Ma (Bohannon, 1984). Strike-slip faulting along the Lake Mead system was temporally and kinematically related to detachment and formed between blocks of differential extension in the upper plate. Low-angle normal faulting in the River Mountains allochthon resulted in approximately 40% extension, most of which occurred after the emplacement of a lamprophyre dike at 13.4 Ma (Weber and Smith, 1987).

## MANGANESE MINERALIZATION

The overall distribution of manganese at the Three Kids mine is stratiform, but in detail the deposit consists of layers and lenses of black Mn oxides in a section of medium- to thick-bedded tuffaceous siltstone and sandstone. Van Gilder (1963) calculated the average dimensions of manganese mineralization to be 12 m thick, 1,500 m long, and 1,000 m wide. In Mn-rich beds, mineralization typically consists of wad which is a mixture of colloform Mn-oxide clasts and detrital grains enclosed by Mn-oxide cement. The principal Mn-oxide minerals are pyrolusite, todorokite, coronadite, and cryptomelane; chemically, the deposits are characterized by high Mn/Fe ratio (> 10), Pb (to 4.7%), As (to 1.8%), and Sr (to 2.8%) (Bouse, 1988). The occurrence, textures, and composition of the manganese mineralization indicate a predominantly synsedimentary origin.

## ANALYTICAL PROCEDURES

Approximately 5 kg of tuff sampled at two horizons in the Three Kids mine were crushed and mineral concentrates were prepared by heavy liquid and magnetic separations. Final purification of mineral separates was achieved by removing impurities under a binocular microscope. Potassium content was measured by S. Neil using a flame photometer with a lithium internal standard. Argon analyses were performed by L. Pickthorn using standard techniques of isotope dilution. The fission-track ages were determined by R. Evarts using the external detector method for sphene and the population method for apatite as described by Naeser (1978). The thermal neutron flux was determined from counts of induced tracks recorded in a muscovite detector held in contact with NBS glass standard SRM 962 during irradiation. Ages determined on splits of the Fish Canyon Tuff FTD standard (27.8 Ma) which were included in the radiation packages are 27.0 ± 0.8 Ma (zircon) and 27.3 ± 1.6 Ma (apatite). The following constants were used. Decay constant for $^{40}K$, $\lambda_\epsilon = 0.581 \times 10^{-10}$ yr$^{-1}$, $\lambda_\epsilon = 4.963 \times 10^{-10}$ yr$^{-1}$, abundance ratio $^{40}K/K = 1.167 \times 10^{-4}$ atom percent, and fission-track decay constant for $U^{238} = 7.03 \times 10^{-17}$ yr$^{-1}$. The precision of the data, shown as the value in millions of years, is the estimated analytical uncertainly at one standard deviation.

## DISCUSSION OF RESULTS

The concordancy of the two biotite and three fission-track ages indicates that deposition of the pyroclastic deposits and, by inference, formation of the manganese deposits, occurred between 14.0 ± 0.3 and 12.4 ± 1.1 Ma. The discordant age (16.5 ± 0.4 Ma) of the hornblende in sample 486-18-1C is puzzling, but it may be spurious owing to a small amount of cognate or accidental amphibole or pyroxene in the analyzed separate. The biotite and fission-track ages presented here are comparable to three K-Ar age determinations of 13.4 ± 0.5, 12.9 ± 0.5, and 12.8 ± 0.5 Ma reported for biotite separates from the River Mountains stock (Armstrong, 1966, 1970). Anderson and others (1972) reported a K-Ar age of 12.1 ± 0.5 Ma for a basaltic andesite flow in the northern River Mountains (36°04′47″N, 114°53′47″W) approximately 1 km east of the Three Kids mine site. The ages obtained here indicate that tuff deposition and manganese mineralization are middle Miocene in age, and that these events were contemporaneous with volcanism in the River Mountains. The period in which these events occurred also overlapped with the period of maximum extension (~13.5 to ~10 Ma) associated with strike-slip, normal, and detachment faulting in the River Mountains allochthon (Bohannon, 1984; Weber and Smith, 1987).

Bohannon (1984) reported fission-track ages ranging from 16.3 ± 1.9 to 12.5 ± 0.9 Ma for zircons from airfall tuff beds in the Horse Spring Formation north of Lake Mead. The fission-track data presented by Bohannon include a 13.2 ± 0.9-Ma age for green airfall tuff and a 13.0 ± 0.8-Ma age for gray airfall tuff exposed 8 km northwest and 23 km northeast of the Three Kids mine, respectively. At Frenchman Mountain, approximately 15 km northwest of the Three Kids mine, a red sandstone that contains gypsum in its lower part separates the Horse Spring Formation from the overlying Muddy Creek Formation. Airfall tuffs from the red sandstone have zircon ages between 11.9 ± 0.9 and 10.6 ± 0.9 Ma (Bohannon, 1984). The apparent age of the red sandstone and the presence of gypsum suggest that this unit is correlative with the sedimentary sequence overlying the manganiferous strata at the Three Kids mine.

The stratigraphic relations at Frenchman Mountain indicate that the Muddy Creek Formation is younger than 10.6 ± 0.9 Ma. Although a maximum K-Ar age of 11.6 ± 0.3 Ma has been reported for the Fortification Basalt Member (Anderson and others, 1972), the uppermost member of the Muddy Creek Formation in the Lake Mead area, a more recently determined age of 5.88 ± 0.18 Ma (Damon and others, 1978) is considered to be most reliable (Bohannon, 1984). An olivine basalt flow in the middle part of the Muddy Creek section in the Black Mountains north of Lake Mead has a K-Ar age of 9.5 Ma (Thompson, 1985). No other units within the Muddy Creek Formation have yielded reliable ages, but this sequence appears to be late Miocene in age.

Based on the data presented here, the manganiferous sedimentary beds at the Three Kids mine are regarded as older than all strata heretofore ascribed to the Muddy Creek Formation, and are coeval with the Horse Spring Formation and the River Mountains stratovolcano.

## ACKNOWLEDGMENTS

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## SAMPLE DESCRIPTIONS

1. *382-20-2C* K-Ar, Fission-track
Tuff (36°04'36"N, 114°54'25"W, S35,T22S, R63E, Henderson 7.5' quad., Clark Co., NV). *Analytical data:* (biotite) $K_2O$ = 8.95%, 8.92%, 9.09%, 8.86%, 8.67%; $^{40}Ar^*$ = 1.805 × $10^{-10}$ mol/gm, 1.803 × $10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 50.1%, 36.1%; (sphene, 15 grains) Ps = 1.83 × $10^5$ tracks/cm² (229 tracks); Pi = 7.62 × $10^6$ track/cm² (476 tracks); $\phi$ = 8.87 × $10^{14}$ n/cm² (4363 tracks); r = 0.34; $P(\chi^2)$ = 71%. *Collected by:* R. Koski, J. Hein. *Comment:* Clasts of white pumice and tuff in a manganiferous sandstone bed.

**K-Ar: biotite 14.0 ± 0.3 Ma**
**Fission-track: sphene 12.8 ± 1.0 Ma**

2. *486-18-1C* K-Ar, Fission-track
Tuff (36°04'36"N, 114°54'25"W, S35,T22S, R63E, Henderson 7.5' quad., Clark Co., NV). *Analytical data:* (biotite) $K_2O$ = 8.53%, 8.64%; $^{40}Ar^*$ = 1.693 × $10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 58.1%; (hornblende) $K_2$ = 0.703%, 0.718%, 0.715%; $^{40}Ar$ = 1.636 × $10^{-11}$, 1.744 × $10^{-11}$ mol/gm; $^{40}Ar/\Sigma^{40}Ar$ = 58.9%, 40.4%; (sphene, 15 grains) Ps = 1.79 × $10^5$ tracks/cm² (205 tracks); Pi = 7.72 × $10^6$ tracks/cm² (441 tracks); $\phi$ =.8.95 × $10^{14}$ n/cm² (4363 tracks); r = 0.71; $P(\chi^2)$ = 93%; (apatite, 50 grains) Ps = 1.02 × $10^5$ tracks/cm² (192 tracks); Pi = 10.28 × $10^6$ tracks/cm² (1926 tracks); $\phi$ = 22.43 × $10^{14}$ n/cm² (4971 tracks). *Collected by:* R. Koski, J. Hein. *Comment:* From white, 0.3-m-thick tuff bed in sequence of pink tuffaceous sandstone and gray manganiferous sandstone.

**K-Ar: biotite 13.6 ± 0.4 Ma**
**hornblende 16.5 ± 0.4 Ma**
**Fission-track: sphene 12.4 ± 1.1 Ma**
**apatite 13.4 ± 1.0 Ma**

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# Geologic time chart references

The 1983 revision of this geologic time chart was prepared by the Geologic Names Committee for U.S. Geological Survey use. It supersedes the 1980 chart. Numerical ages of chronostratigraphic boundaries are subject to many uncertainties besides the analytical precision of the dating. The placement of boundary stratotypes and the achievement of international agreements on these ages is a slow process subject to much revision and review. Recent studies and revisions of the geologic time scale of especial interest are reported in *A geologic time scale,* by W. B. Harland, A. V. Cox, P. G. Llewellyn, C. A. G. Pickton, A. G. Smith, and R. Walters, 1982: Cambridge University Press, 132 p.; *The decade of North American geology 1983 geologic time scale,* by A. R. Palmer, 1983: Geology, v. 11, p. 503–504; and *The chronology of the geological record,* N. J. Snelling (ed.), 1985: Blackwell Scientific Publishers, The Geological Society, Memoir No. 10, 343 p.


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