

Geochronology of the Midas Gold-Silver Deposit and its Relationship to Volcanism and Mineralization Along the Northern Nevada Rift

Ellen D. Leavitt, University of Nevada, Reno,
Patrick Goldstrand, Kirk Schmidt, Franco-Nevada Mining Co.,
Alan R. Wallace, U.S. Geological Survey, Reno, NV,
Terry Spell, University of Nevada, Las Vegas, and
Greg B. Arehart, University of Nevada, Reno

SUMMARY

Newly determined $^{40}\text{Ar}/^{39}\text{Ar}$ dates from mineralized veins and a volcanic host rock at Midas provide constraints on the timing of volcanism and hydrothermal activity along this part of the northern Nevada rift. An average of new dates for adularia from the Ken Snyder Mine area indicates an age of mineralization of about 15.3 Ma. A $^{40}\text{Ar}/^{39}\text{Ar}$ date for diabase that intrudes the Esmeralda formation (informal name), the youngest ore-bearing unit, yields an age of no more than 16.0 Ma. This date is consistent with ages of early rift-related mafic volcanic flows in the northern Shoshone Range. Constraints on the age of the Esmeralda formation imply that felsic volcanism and basin development had occurred in the Midas area by ~16 Ma. These new dates indicate that hydrothermal activity responsible for gold-rich mineralization at the Ken Snyder Mine took place considerably later than the formation of the host rocks. A younger 14.7 Ma date for basaltic andesite at Midas is similar to ages of mafic volcanism in the northern Shoshone and southwestern Sheep Creek Ranges. This magmatic episode indicates additional mafic volcanism approximately 600,000 years after mineralizing events.

INTRODUCTION

The formation of middle Miocene epithermal precious-metal deposits along the northern Nevada rift (NNR) appears to be related to crustal extension and associated magmatism (John et al., 1999). These deposits occur within a bimodal volcanic assemblage deposited along the rift. The recent discovery of the world-class Midas gold-silver deposit, located within the northern Nevada rift, has led to renewed interest in this group of deposits. However, the temporal relationship between volcanic activity, hydrothermal fluid circulation, and mineralization at Midas has not yet been documented. Detailed geochronologic studies of Midas were undertaken to improve our understanding of the relationship between metal-bearing hydrothermal systems and development of the NNR.

Geologic mapping of the Snowstorm Mountains (Wallace, 1993), Midas area (Blair, 1991), and Ken Snyder Mine (Casteel et al., 1999) delineated and characterized volcanic units that host high-grade gold deposits. Host rocks include a sequence of felsic ash-flow tuffs, flows, plugs, and interbedded tuffaceous lacustrine deposits. Numerous mafic sills and dikes intruded this sequence. Alteration and mineralization affected both the felsic units and the intrusive mafic sills and dikes. However, ore-grade mineralization was confined largely to steeply dipping veins in north-northwest-striking faults in the more felsic units. Unmineralized rhyolitic flows exposed on ridges that surround the Midas deposit overlie the youngest mineralized units.

TABLE 1. Summary of dates for volcanic rocks and mineralized veins in the Midas area.

Sample	Description	Location	Material dated	Date	Method
MKKPG-29	Diabase; intrudes Tes	1 mile E of Midas	plagioclase	16.0±0.2 Ma	⁴⁰ Ar/ ³⁹ Ar
MI-5-3	Colorado Grande Vein	Ken Snyder Mine	adularia	15.42±0.08 Ma	⁴⁰ Ar/ ³⁹ Ar
MI-5-4	Colorado Grande Vein	Ken Snyder Mine	adularia	15.31±0.08 Ma	⁴⁰ Ar/ ³⁹ Ar
DRS-9-67 ¹	Midas Canyon	2 km west of Midas	adularia	15.4±0.4 Ma	K/Ar (recalculated)
MJV-KS-1 ²	Colorado Grande Vein	Ken Snyder Mine	adularia	15.26±0.05 Ma (15.23±0.05 Ma)	⁴⁰ Ar/ ³⁹ Ar
9LH25 ³	Basaltic andesite	N end of Midas Creek	whole rock	14.7±0.5 Ma	K/Ar

¹McKee and others, 1976, recalculated to new decay constants (Steiger and Jager, 1977).

²New Mexico Geochronology Research Laboratory, recalculated to an age of 27.9 Ma for the Fish Canyon Tuff sanidine. Original age shown in parentheses.

³Wallace and McKee, 1994.

Widespread alteration of host rocks has made accurate determinations of the ages of the volcanic rocks difficult. However, newly determined ⁴⁰Ar/³⁹Ar dates of host rocks and quartz-adularia veins provide some important constraints on the timing of host-rock volcanism and mineralization. New dates were determined at the Nevada Isotope Geochronology Laboratory, Las Vegas, Nevada. These new dates, as well as dates from previous studies, are summarized in Table 1. Analytical methods and descriptions of samples are provided in the appendix.

NEW ⁴⁰AR/³⁹AR DATES

In order to constrain ages of volcanic host rocks at Midas, a diabase sill that intrudes the uppermost ore-bearing unit, the Esmeralda formation, was dated. The diabase is located approximately 2 km east-northeast of the Ken Snyder Mine. An age of this sample (MKKPG-29) provides a minimum age for the host rocks in the district. Plagioclase from the diabase produced a "U-shaped" age spectrum suggesting the presence of excess argon. A plateau age of 16.0±0.2 Ma was calculated from four contiguous steps in the middle portion of the spectrum that overlap at the 2-sigma confidence level; approximately 57% of the total gas was released from these steps. Because the sample likely contained small amounts of excess argon, this date is considered a maximum estimate of the age of intrusion.

Two dates on adularia were obtained from banded quartz-adularia material from the Colorado Grande vein, the principal vein in the deposit. Vein samples were chosen from outer (older) (MI-5-4) and inner (younger) (MI-5-3) bands within the vein from underground mine exposures. Adularia separates from both samples yielded concordant age spectra, indicative of rapidly cooled, undisturbed samples. The outer band yielded a plateau age of 15.31 ± 0.08 Ma. The inner band yielded a plateau age of 15.42 ± 0.08 Ma. The ages are identical within analytical uncertainty.

These new $^{40}\text{Ar}/^{39}\text{Ar}$ dates are summarized in bold in Table 1. Previously published dates from volcanic rocks and mineralized veins are included to present a more complete picture of geochronology of volcanism and mineralization in the Midas area. In order to directly compare results, one age determination by the New Mexico Geochronology Research Laboratory was recalculated to account for slightly different ages used for the Fish Canyon Tuff standard.

TEMPORAL RELATIONSHIP OF VOLCANISM AND MINERALIZATION

The new dates from Midas suggest that hydrothermal activity responsible for gold-silver mineralization took place considerably after the formation of the youngest known host rocks. Basalts with ages similar to that of the diabase ($\leq 16.0 \pm 0.2$ Ma) at Midas are present to the south along the NNR in the northern Shoshone Range and the southwestern Sheep Creek Range (John et al., this volume). At Mule Canyon, a coarse-grained basalt porphyry occurs near the base of a sequence of basalt to andesite lava flows and pyroclastic flows (Mule Canyon sequence). A densely welded basaltic andesite tuff near the top of the sequence yielded a whole-rock $^{40}\text{Ar}/^{39}\text{Ar}$ age of 15.85 ± 0.08 Ma (John et al., 1999). The diabase also may be equivalent to basalts in the Roberts Mountains, Cortez Range, and Simpson Park Range, where they occur primarily as north-west-trending dike swarms with minor flows related to rifting (Zoback et al., 1994). According to John et al. (1999), rift-related mafic rocks range in age from 15.85 to about 14.7 Ma.

Dates from the diabase indicate that the Esmeralda formation and underlying mineralized units are older than the 16 Ma diabase sill. Until an age can be obtained from units close to the base of the mineralized section, the age range of these host rocks remains unknown. However, intense alteration of the lowermost units thus far has precluded an age determination from the base of the section.

Deposition of lacustrine sediments in the Esmeralda formation and a thick lacustrine section exposed along Willow Creek in the Ivanhoe District may have taken place at about the same time and thus be related (Wallace, this guidebook). The Esmeralda is older than the 16.0 Ma diabase. Sedimentation within the basin along Willow Creek may have begun as early as 16.5 ± 0.5 Ma (Perkins et al., 1998), and a tuff near the base of the Willow Creek section produced an age of 15.84 ± 0.10 Ma (Wallace, this guidebook).

New dates on adularia from the Colorado Grande vein are similar to those previously determined for mineralization in the Midas area (Table 1). An average of the $^{40}\text{Ar}/^{39}\text{Ar}$ ages of the Colorado Grande vein provides a date of mineralization at Midas of 15.33 Ma, compared to the K-Ar age of 15.4 ± 0.4 Ma. This age is similar to that of other low-sulfidation gold-silver deposits along the NNR that formed from 15.6 to 15.0 Ma (John et al., 1999).

CONCLUSIONS AND FUTURE WORK

New dates on host rock and adularia from the Colorado Grande vein at the Ken Snyder Mine show a temporal gap of at least several hundred thousand years between host rock formation and mineralization. The heat source for the hydrothermal system is unknown. Magma chambers that fed felsic volcanics (unit Trt of Wallace, 1993) that overlie the Midas host rocks could have provided a heat source, and those felsic units will be dated. Continued geochronologic studies also will focus on determining the age of the lowermost host rock in the Midas District to better determine the earliest age of rifting. In addition, more dates on mafic volcanic rocks might provide a more reliable and definitive estimate of the age of the host rocks, as well as the duration of mafic volcanism in the Midas area.

REFERENCES

- Blair, K.R., 1991, Geology of the Gold Circle District, Elko County, Nevada: Tucson, University of Arizona, M.S. thesis, 85 p.
- Casteel, M.V., Schmidt, K., Goldstrand, P., Bernard, J., and Sandberg, J., 1999, Geologic setting of the Ken Snyder gold and silver mine, Elko, County, Nevada, in Kizis, J.A., Jr., (ed.), 1999 Spring Field Trip Guidebook, Low-sulfidation Gold Deposits in northern Nevada: Geological Society of Nevada Special Publication no. 29, p. 213-220.
- Cebula, G.T., Kunk, M.J., Mehnert, H.H., Naeser, C.W., Obradovich, J.D., and Sutter, J.F., 1986, The Fish Canyon Tuff, a potential standard for the $^{40}\text{Ar}/^{39}\text{Ar}$ and fission-track dating methods (abstract) *Terra Cognita* (6th International Conference on Geochronology, Cosmochronology and Isotope Geology), v. 6, p. 139.
- John, D.A., Brummer, J.E., and Saderholm, E.C., this volume, Geology of the Mule Canyon gold-silver deposits, Lander County, Nevada, in Wallace, A.R., and John, D.A., (eds.), Volcanic history, structure, and mineral deposits of the north-central northern Nevada rift: Geological Society of Nevada 2000 Symposium Field Trip Guidebook No. 8, p. 119-134.
- John, D.A., Garside, L. J., and Wallace, A.R., 1999, Magmatic and tectonic setting of late Cenozoic epithermal gold-silver deposits in northern Nevada, with an emphasis on the Pah Rah and Virginia Ranges and the northern Nevada rift: Reno, Geological Society of Nevada, 1999 Spring Field Trip Guidebook, Special Publication No. 29, p. 64-158.
- McKee, E.H., Tarshis, A.L., and Marvin, R.F., 1976, Summary of radiometric ages of Tertiary volcanic and selected plutonic rocks in Nevada; part V, northeastern Nevada: *Isochron/West*, no. 16, p. 15-27.
- Perkins, M.E., Brown, F.H., Nash, W.P., McIntosh, W., and Williams, S.K., 1998, Sequence, age, and source of silicic fall-out tuffs in middle to late Miocene basins of the northern Basin and range province: *Geological Society of America Bulletin*, v. 110, p. 344-360.
- Steiger, R.H., and Jager, E., 1977, Subcommittee of geochronology: Conventions on the use of decay constants in geo- and cosmochronology: *Earth and Planetary Science Letters*, v. 36, p. 359-362.
- Steven, T.A., Mehnert, H.H., and Obradovich, J.D., 1967, Age of volcanic activity in the San Juan Mountains, Colorado: U.S. Geological Survey Professional Paper, 575-D, p. 46-55.
- Wallace, A.R., 1993, Geologic map of the Snowstorm Mountains and vicinity, Elko and Humboldt counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-2394, scale 1:50,000.
- Wallace, A.R., this volume, Tertiary geology of the Ivanhoe District and vicinity, in Wallace, A.R., and John, D.A., (eds.), Volcanic history, structure, and mineral deposits of the north-central northern Nevada rift: Geological Society of Nevada 2000 Symposium Field Trip Guidebook No. 8, p. 135-145.
- Wallace, A.R., and McKee, E.H., 1994, Implications of Eocene through Miocene ages for volcanic rocks, Snowstorm Mountains and vicinity, northern Nevada, in Berger, B.R., (ed.), *Advances in research on mineral resources, 1994*: U.S. Geological Survey Bulletin 2081, p. 13-18.
- Zoback, M.L., McKee, E.H., Blakely, R.J., and Thompson, G.A., 1994, The northern Nevada rift: Regional tectono-magmatic relations and middle Miocene stress direction: *Geological Society of America Bulletin*, v. 106, p. 371-382.

APPENDIX

Analytical Methods and Sample Descriptions

ANALYTICAL METHODS

Mineral separates for $^{40}\text{Ar}/^{39}\text{Ar}$ analysis were prepared with help from Mike Ressel using heavy-liquid, magnetic, and hand-picking procedures at the University of Nevada, Reno. Samples were crushed to 70-140 mesh. Adularia samples were rinsed with dilute HCl to remove calcite. Adularia was then separated from other minerals using heavy liquids (Bromoform). The final separates were put through a magnetic separator (Franz) to remove any residual magnetic minerals, rinsed in dilute HF, and cleaned in distilled water and acetone. Plagioclase was separated using primarily magnetic techniques. Remaining sulfides were removed by hand-picking and heavy liquids. The final separate was rinsed in dilute HF to remove any remaining glass and cleaned in distilled water and acetone. All mineral separate samples were >99% pure. $^{40}\text{Ar}/^{39}\text{Ar}$ analyses were carried out by the Nevada Isotope Geochronology Laboratory at the University of Nevada, Las Vegas under the direction of Dr. Terry Spell. Samples were packaged with flux monitors (Fish Canyon Tuff sanidine), and they were irradiated at the Nuclear Science Center at Texas A&M University. Samples were step-heated utilizing a double vacuum resistance furnace. Argon analyses were performed by a MAP 215-50 mass spectrometer. Data reduction and calculations were carried out by T. Spell with LabVIEW software written by B. Idleman (Lehigh University). Ages for samples were calculated using an age of 27.9 Ma for the Fish Canyon Tuff sanidine flux monitor (Steven and others, 1967; Cebula and others, 1986). For each age determination, isochron analysis of apparent age spectra was carried out in order to test for the presence of excess argon. If no excess argon was indicated, a plateau age (a significant segment of the gas is released, or $\geq 50\%$, and contiguous steps or ages overlap at the 2-sigma confidence level) would be a valid calculation for the age of the sample. If excess argon was indicated, then a plateau age is considered to be a maximum estimate of the age.

SAMPLE DESCRIPTIONS

MKK-PG-29: Diabase in Squaw Creek (lat $41^{\circ}14'36''\text{N}$, long $116^{\circ}45'36''\text{W}$; Midas 7.5-minute quadrangle; Elko Co., Nevada); outcrop of diabase. Contains plagioclase that occurs primarily as 0.2 to 0.8 mm laths, commonly with subophitic pyroxene, in an intergranular texture with minor interstitial glass. Although the rock is slightly propylitically altered (minor calcite and pyrite present), the plagioclase appears fresh. A few (<1%) larger grains of plagioclase, up to 3 mm, contain inclusions of pyroxene, \pm glass and are zoned. However, no inclusions were observed in the mineral separate used for analysis.

MI-5-3: Quartz-adularia vein from Colorado Grande, Ken Snyder Mine (lat $41^{\circ}14'44''\text{N}$, long $116^{\circ}46'38''\text{W}$; Midas 7.5-minute quadrangle; Elko Co., Nevada); from inner band of vein exposed in underground mine workings (spiral 4, 5250 level, 462 ft S) Contains banded, very fine-grained quartz, adularia, calcite, selenides, and pyrite. Adularia is present in two size ranges: rhombs 0.01

to 0.05 mm in size, and locally blades up to 0.5 mm long. Bladed calcite replaced by quartz is present but was removed during sample preparation.

MI-5-4: Quartz-adularia vein from Colorado Grande, Ken Snyder Mine (lat 41°14'44"N, long 116°46'38"W; Midas 7.5-minute quadrangle; Elko Co., Nevada); from outer band of vein exposed in underground mine workings (spiral 4, 5250 level, 462 ft S). Contains banded, very fine-grained, quartz, adularia, calcite, selenides, and pyrite. Adularia is present in two size ranges: rhombs 0.01 to 0.05 mm in size, and locally blades up to 0.5 mm long. Bladed calcite replaced by quartz is present but was removed during sample preparation.