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The Age of Porphyry-Type Copper Mineralization in the Bingham Mining District, Utah—A Refined Estimate [1]

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Abstract

Hydrothermal biotite that crystallized contemporaneously with bornite, chalcopyrite, and molybdenite in the disseminated ore zone at Bingham, Utah, has a potassium-argon age of 35.8 m.y. This and other age measurements indicate that the time difference between plutonism, mineralization, and volcanism at Bingham can be resolved.

Introduction

The common occurrence of sulfide veinlets and sulfide fracture coatings in porphyry copper ore bodies is textural evidence indicating that at least a part of the mineralization episode postdated crystallization of the igneous host rocks. Radiometric ages have been measured on many porphyry copper deposits of North America, in part to determine the time interval between magmatism and mineralization. Damon and Mauger (1966) concluded that the difference in age between late Mesozoic to early Tertiary (Laramide) magmatism and associated mineralization cannot be detected within the precision of the potassium-argon dating method. However, at Bingham, Utah, in a porphyry copper deposit of middle-Tertiary age, the time difference between magmatism and mineralization can be resolved using potassium-argon age measurements.

Magmatic activity at Bingham, including post-mineralization rhyolitic volcanism, spanned a 7 m.y. interval between 39 m.y. and 32 m.y. ago (Moore and others, 1968). Furthermore the age measurements indicated that mineralization began within 1 m.y. of final emplacement of the Bingham stock, a composite intrusion composed of equigranular and porphyritic quartz monzonite cut by latitic dikes. This conclusion was based on the difference in average age between pervasively altered samples from each of the three rock units (36.5 m.y.) and their unaltered equivalents (37.3 m.y.). Moore and others (1968) suggested, however, that dates for mineralization based on recrystallized magmatic biotite (or a mixture of magmatic and hydrothermal biotite) could be in error if argon loss had been incomplete. In other words, dates for biotite separated from altered rock samples would approach, but perhaps not equal, the date of mineralization.

We have determined a potassium-argon age of 35.8 m.y. for a hydrothermal biotite sample that crystallized contemporaneously with bornite, chalcopyrite, and molybdenite on fracture surfaces in the altered porphyritic host rock of the disseminated ore zone. This date is consistent with previous data indicating a short but measurable time interval between emplacement of the igneous host rocks and fracture-controlled mineralization.

Sample Description

Two small pieces of altered igneous rock with quartz-biotite fracture coatings were discovered among samples at the University of Utah collected at Bingham by the late Bronson Stringham and described by him in an earlier report (Stringham, 1953). This particular biotite occurrence apparently was distinctive enough to warrant a brief description on his sample location map. The samples were collected in 1948 in the west-central part of the ore zone at an elevation of 6,090 feet, or about 500 feet vertically above the projected location today.

The hand samples are altered porphyritic quartz monzonite (Stringham's "Granite Porphyry") and are typical of the major porphyritic host rock exposed in the open pit. Phenocrysts of plagioclase are replaced extensively by sericite and, in addition, are rimmed or replaced by clear K-feldspar. Microperthitic K-feldspar phenocrysts as much as 1.5 cm long are less abundant than plagioclase phenocrysts. Pale-brown magmatic biotite, the only remaining mafic silicate in the rock, occurs in fine-grained recrystallized aggregates or in millimeter-sized rectangular plates with ragged edges, and is similar to that separated previously for dating. The phenocryst minerals and biotite aggregates are set in a microgranular groundmass composed of K-feldspar and quartz. Sulfide minerals, including bornite with minor chalcopyrite and molybdenite, are scattered throughout the rock and associated with milky quartz in hairline veinlets.

The bronze-colored hydrothermal biotite separated for analysis occurs in books and flaky aggregates intergrown with, and coating, vitreous quartz on

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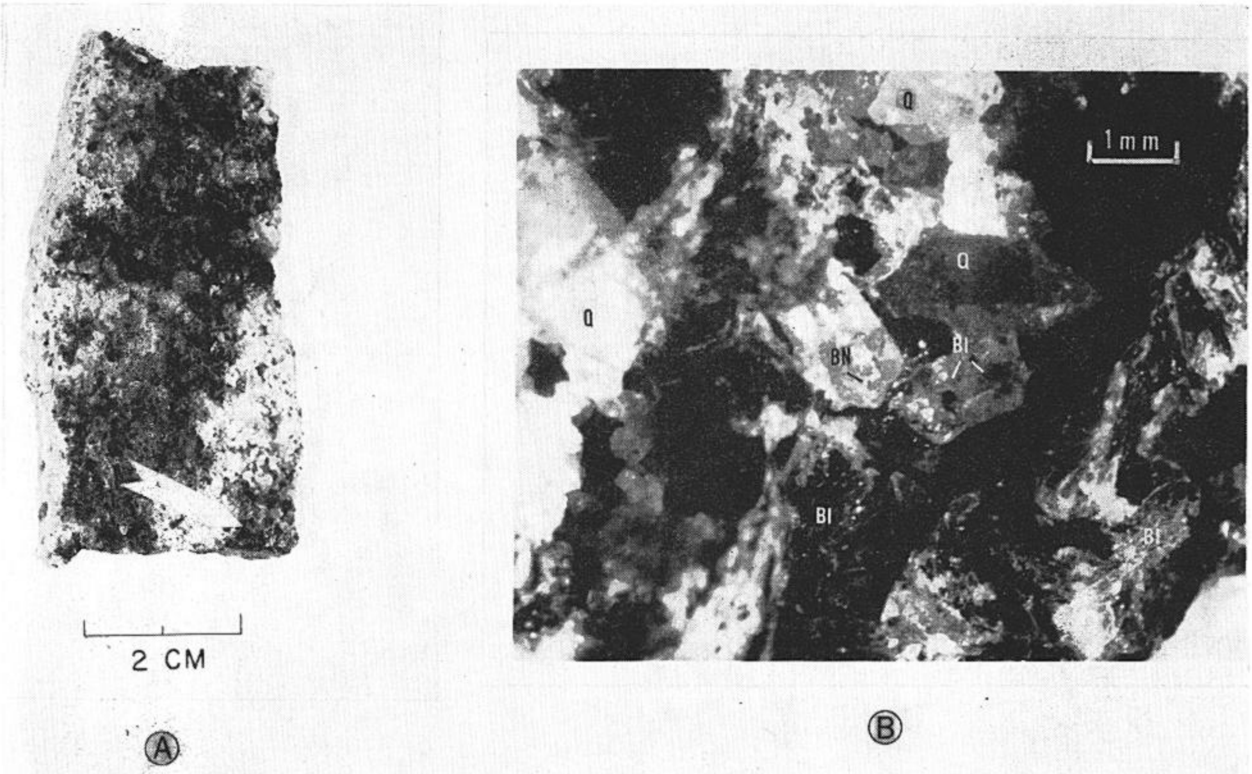

FIG. 1. Photographs illustrating textural relations of flaky hydrothermal biotite and sulfide minerals. A, Hand specimen showing biotite-quartz intergrowth on fracture surface of mineralized and altered porphyritic quartz monzonite; general area of Fig. 1B indicated by arrow. B, Macrophotograph showing terminated vitreous quartz crystals (Q) with inclusions of hydrothermal biotite (BI) and bornite (BN).

fracture surfaces cutting the porphyry (Fig. 1A). Under a binocular microscope inclusions of bornite and biotite are visible in the quartz crystals (Fig. 1B). Hexagonal plates of molybdenite and scattered grains of chalcopyrite are intergrown with the biotite and quartz; pyrite is absent. Thus, textural relations indicate clearly that the biotite crystallized contemporaneously with quartz and the sulfide minerals. Biotite scraped from the fracture coatings was purified for analysis by heavy liquid and magnetic methods.

Results and Discussion of Analytical Precision

Duplicate potassium-argon determinations for the hydrothermal biotite (sample No. 26) agree within 0.3 m.y. and give an average age of 35.8 m.y. The

Table 1

Potassium-argon ages and analytical data for samples from Bingham, Utah

Columns 3 and 5 include estimates of analytical precision at the 68 percent level of confidence

Sample No.	K_2O analyses (percent)	Ar^{40} (10^{-10} moles per gm)	$Ar^{40}_{rad}/Ar^{40}_{total}$	Calculated age (m.y.)
26	10.08, 10.03	5.364 ± 0.054	0.68	$35.8 \pm 0.2_3$
		5.405 ± 0.043	0.74	
20B'	8.82, 8.82	4.695	0.73	35.7 ± 0.3

Decay constants for K^{40}: $\lambda_\varepsilon = 0.585 \times 10^{-10}$/yr.

$x_\beta = 4.72 \times 10^{-10}$/yr.

Atomic abundance of K^{40} $= 1.19 \times 10^{-4}$

Potassium measurements: L. B. Schlocker

Argon measurements: J. B. Von Essen and M. A. Lanphere

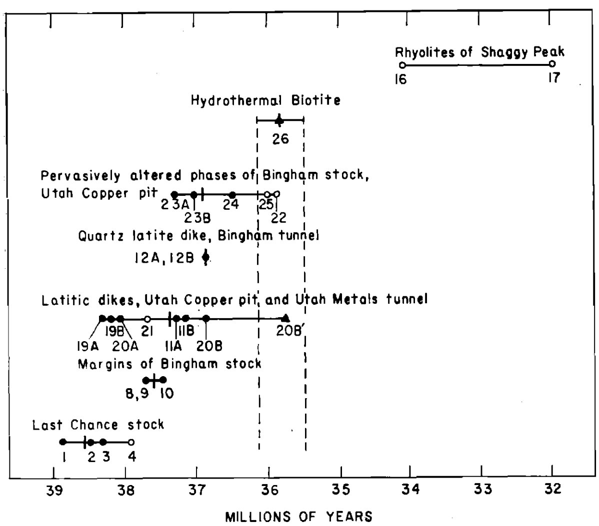

FIG. 2. Potassium-argon dates for igneous rocks in the Bingham mining district, Utah (Figure, including sample numbers, adapted from Moore and others, 1968, Fig. 2). All dates for biotite except No. 11A (phlogopite) and No. 12B (hornblende). Circles are dates from Moore and others (1968), triangles are new dates from Table 1, this paper. Filled symbols are replicate determinations of various types described in text; heavy bar denotes mean age for given rock unit. Dashed lines drawn at one standard deviation (s) from results for sample 26.

analytical data are summarized in Table 1, and the results are compared with previous dates for Bingham rocks in Figure 2.

The standard deviation of analytical precision for a single date reported previously was ± 1.2 m.y. This value includes uncertainties in the isotopic composition and concentration of the Ar^{38} tracers and in the concentrations of the flame photometer standards. These factors are constant in a given laboratory and need not be considered when evaluating the internal precision of a body of data obtained in that laboratory. For the Bingham data reported previously, each measurement was treated as a single age determination. Many of these ages, however, represent replicate measurements of various types, such as (1) different samples from the same rock unit, (2) two size fractions of biotite from the same sample, or (3) coexisting minerals from the same sample, that may be pooled in order to obtain a refined estimate of precision. This estimate may then be used to determine whether the ages of various magmatic events at Bingham can be resolved.

The largest difference in replicate measurements was between different biotite size fractions of sample 20, from a latitic dike that cuts the Bingham stock. These separates were exhausted, but additional biotite was concentrated from the remaining -80 mesh mafic mineral fraction of the original sample. This new biotite sample (No. 20B′) has a relatively low specific gravity (2.85–2.90) and may contain a larger proportion of recrystallized magnesian biotite than did the original sample 20B. The new biotite separate yielded an age of 35.7 m.y., which indicates that the difference in measured ages between samples 20A and 20B is real and is not merely analytical scatter.

Mean ages for the various rock units at Bingham, based on replicate dates, are given in Table 2 and indicated by heavy bars in Figure 2. The plus-or-minus values (Table 2) are standard deviations of analytical precision that were calculated from the measured ages for rock units for which there are three or more replicate dates, or estimated from individual measurements for rock units for which there are less than three dates. The ages for individual samples within rock units pooled in Table 2 group very well, except those for latitic dikes in the Utah Copper pit and the Utah Metals tunnel. This scatter may reflect the imprecision of petrographic criteria (biotite textures, degree of sericitization of plagioclase phenocrysts) used to establish the extent of alteration in these dikes. The low age of sample 20B′ (Table 1), apparently in agreement with that of the hydrothermal biotite, illustrates this problem.

The data in Table 2 indicate a precision of better that ± 0.5 m.y. for the mean age of the rock units studied at Bingham, and it is clear that short time intervals can be resolved in this intrusive sequence. The enhanced precision is attributed largely to two factors. First, all mineral separates were prepared by one person and, consequently, uniform standards of sample purity were maintained throughout the study. Second, the analyses were performed in one laboratory, thereby eliminating potential discrepancies due to interlaboratory bias.

Table 2

Mean ages and pooled estimates of precision for samples from Bingham, Utah

Rock unit	Samples*	Mean K-Ar age (m.y.)
Last Chance stock	1,2,3	$38.6 \pm 0.1_8$
Margins of Bingham stock	8,9,10	$37.6 \pm 0.0_7$
Quartz latite dike, Bingham tunnel	12	$36.9 \pm 0.2_6$
Latitic dikes, Utah copper pit and Utah metals tunnel	11,19,20	$37.4 \pm 0.3_5$
Pervasively altered phases of Bingham stock, Utah copper pit	23,24	$36.9 \pm 0.2_3$
Hydrothermal biotite	26	$35.8 \pm 0.2_3$

*Data from Table 3 of Moore and others (1968) and Table 1 of this paper.

Table 3

Critical Value Test for samples from Bingham, Utah

Rock unit	Difference in mean age for hydrothermal biotite and rock unit (in m.y.)	Critical Value (in m.y.)	Is difference in age between hydrothermal biotite and rock unit real?
Last Chance stock	2.8	0.48	yes
Bingham stock	1.8	0.39	yes
Quartz latite dike, Bingham tunnel	1.1	0.57	yes
Latitic dikes, Utah copper pit and Utah metals tunnel	1.6	0.69	yes
Pervasively altered phases of Bingham stock, Utah copper pit	1.1	0.53	yes

Conclusions Concerning the Age of Porphyry-Type Copper Mineralization at Bingham

The main conclusion drawn from this study is that porphyry copper mineralization at Bingham was not strictly contemporaneous with emplacement of the composite Bingham stock. The dates suggest that a short but measurable time interval separated crystallization of the igneous host rocks and subsequent hydrothermal events. None of the mean ages for unaltered rocks falls within the limits of analytical uncertainty for the hydrothermal biotite that crystallized contemporaneously with copper and molybdenum sulfides. The mean age for biotite from the altered rocks approaches the age of mineralization, but the scatter in individual ages indicates that accumulated radiogenic argon was, in fact, not completely expelled from the original biotites at the time of hydrothermal recrystallization.

In order to claim, at 95-percent confidence, that there is a real difference between the calculated ages of two rocks, the difference in age must exceed the Critical Value (McIntyre, 1963). The results of this test (Table 3) show that there is a real difference between the age of the hydrothermal biotite and the mean age of the other rock units.

Laughlin and others (1969) state that potassium-argon mineral ages at the Questa Mine, New Mexico, support the general conclusion that magmatism and mineralization are indistinguishable in time. Their data, however, consist of single determinations on biotite from the granitic host rock (22.3 m.y.) and on biotite from a quartz-molybdenite-biotite vein (23.5 m.y.). We do not consider the dating study at Questa or earlier studies reported by Damon and Mauger (1966) to be detailed enough to justify their general conclusion that magmatism and mineralization are indistinguishable in age. At least in the Bingham mining district, where 25 potassium-argon ages have been measured, the times between plutonism, mineralization and volcanism can be resolved.

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U. S. Geological Survey,

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