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Isochron/West, Bulletin of Isotopic Geochronology, v. 49, pp. 13-20

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ISOTOPIC AGE DETERMINATIONS, UNALTERED AND HYDROTHERMALLY ALTERED IGNEOUS ROCKS, NORTH-CENTRAL COLORADO MINERAL BELT

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Monzonite and granodiorite intrusions of the Empire district are early Tertiary (65 Ma) in age, as dated by Simmons and Hedge (1978). Monzonite and granodiorite intrusions of the Alma district have yielded isotopic ages ranging from 71 to 41 Ma (Bookstrom, in press). Monzonitic intrusions predominated 71–65 Ma ago, whereas granodioritic intrusions predominated 65–41 Ma ago.

A voluminous suite of granite-B porphyries was emplaced 45–35 Ma ago, along the north-central Colorado mineral belt from Empire to Climax. Examples are the Montezuma stock and its associated intrusions (43–35 Ma), the Swan Mountain sill (Marvin and others, 1974; Simmons and Hedge, 1978), several intrusions in the Breckenridge district (Bryant, Marvin, and others, 1981), the Humbug and Tucker Mountain stocks (Marvin and others, 1974), and a large domed sill about 8 km west of Climax. The Fe-, Cu-, Zn-, Pb-, Ag-, Au-, and Mo-bearing hydrothermal systems of Mad Creek (Empire), Georgetown-Silver Plume, Montezuma, and Breckenridge are associated with intrusions of this suite of late Eocene-early Oligocene granite-B porphyries.

Between about 33 and 20 Ma, bimodal suites of leucocratic, high-silica alkali-rich rhyolite-granite porphyries, with subordinate kersantites, were emplaced at Climax and Red Mountain. The giant porphyry molybdenum deposits of Climax and Red Mountain formed in association with rhyolite-granite porphyry intrusions of these bimodal suites. Rhyolite-A porphyries of the Alma district (34.9 Ma) and the Geneva area, near Montezuma (33.3 Ma) are compositionally similar to the rhyolite-granite porphyries of Climax and Red Mountain. They may belong to the same family of intrusions as the bimodal, Oligocene-early Miocene suites of Climax and Red Mountain.

ANALYTICAL METHODS

Five K-Ar and 27 fission-track age determinations are given here for 26 samples of igneous rocks from the north-central part of the Colorado mineral belt. Most of the samples are of either unaltered or hydrothermally-altered igneous rocks, directly or indirectly associated with molybdenite occurrences. Sample locations are shown in figure 1. Rock types are named according to the IUGS classification system (Streckeisen, 1973, 1979), on the basis of petrographic analyses by Diana Kamilli. Where necessary, K-Ar age determinations have been corrected by the method of Dalrymple (1979) to conform to current IUGS decay constants, as reported by Steiger and Jager (1977). Fission-track age determinations were done using methods described by Naeser (1976). Error estimates were made at 2 standard deviations by combining Poisson errors of fossil, induced, and neutron dosimetry counts.

This work was done as part of a cooperative study of the geochronology, igneous petrology and hydrothermal ore deposits of the Colorado mineral belt, by members of the Climax Molybdenum Division of AMAX, Inc. and the U.S. Geological Survey. K-Ar age determinations were done commercially by Geochron Laboratories, Teledyne Isotopes, and the University of Utah Research Institute. Fission-track age determinations were done in the fission-track laboratory of the U.S. Geological Survey in Denver, and at the University of Utah Research Institute. People who cooperated in this study include Mark Coolbaugh, P. A. M. Andriessen, W. H. White, R. P. Smith, R. B. Carten, W. C. Utterback, G. J. Neuerburg, Richard Winton, Brian Claybourn, Diana Kamilli, S. H. Evans, and Georgiana Piete. R. F. Marvin and P. K. Sims reviewed the manuscript.

INTRUSIVE SUITES AT ALMA-CLIMAX

Monzonites and granodiorites of the Buckskin Gulch intrusive center, in the Alma district have yielded isotopic ages ranging from 71 to 41 Ma (Bookstrom, in press). Monzonitic intrusions predominated 71–65 Ma, whereas granodioritic intrusions predominated from 65–41 Ma. Minor granite aplites are associated with some of the granodiorite intrusions. One such aplite (sample 20) gave a biotite K-Ar age of 63.6 Ma. Some Laramide granodiorites are gradational to granite-B porphyries. Biotite from a plug of rhyolite-B porphyry in the southern Mosquito Range gave a K-Ar age of 55.9 Ma.

A voluminous suite of granite-B porphyries was emplaced between 45 and 35 Ma in the north-central Colorado mineral belt. Examples are the Montezuma stock and its associated intrusions (43–35 Ma), the Swan Mountain sill (Marvin and others, 1974; Simmons and Hedge, 1978), several intrusions in the Breckenridge district (Bryan, Marvin, and others, 1981), and the Humbug and Tucker Mountain stocks (Marvin and others, 1974).

About 5 mi (8 km) west of Climax, a large domed sill of biotite rhyolite-B porphyry crystallized about 43–40 Ma ago, according to biotite and sanidine K-Ar ages. This rhyolite-B porphyry is similar in appearance to the Chalk Mountain Porphyry, a rhyolite porphyry of the intrusive suite at Climax (about 28 Ma; White and others, 1981). However, this sill probably belongs to the granite-B suite and not to the later and more differentiated rhyolite-granite suite at Climax. A zircon fission-track age of 35.5 Ma for this porphyry sill suggests a thermal event occurred about 35 Ma ago. This would correspond to the time of mineralization and alteration at Gilman to the northwest (Naeser and Cunningham, 1984), and at Tennessee Pass to the south (Beaty and others, 1986).

Between about 35 and 24 Ma, a suite of leucocratic, high-silica, alkali-rich rhyolite-granite porphyries were emplaced in the Alma and Climax districts. The oldest of these formed as a swarm of dikes of white porphyritic rhyolite-A, in the Alma district 35 Ma ago (sample 23). The youngest intrusion of this suite was a post-ore granite stock at Climax 24 Ma (sample 26).

Veins of the Alma district cut the 35 Ma dikes of white porphyritic rhyolite. Zircon fission-track ages of about 27 Ma for older intrusives (65–43 Ma) strongly suggest a last pulse of hydrothermal alteration and mineralization occurred at about 27 Ma in the Alma district.

The Climax magmatic-hydrothermal system was intermittently active between 33 and about 18 Ma (White and

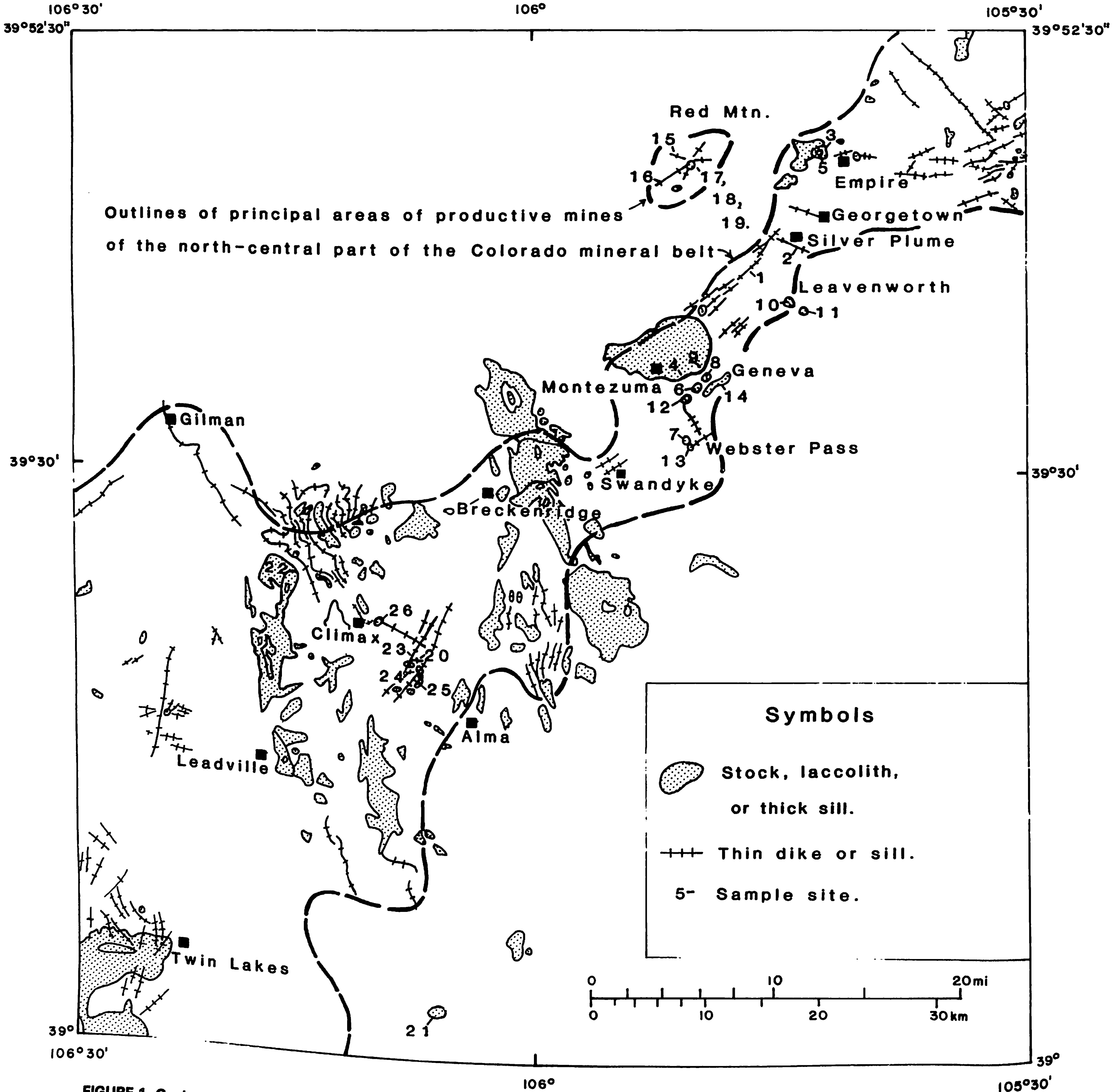

FIGURE 1. Geologic sample location map of the north-central part of the Colorado mineral belt, showing igneous intrusions of Tertiary and Late Cretaceous age. Sample site numbers correspond to item numbers given in the accompanying list of sample descriptions and age determinations. Principal sources of information for the geologic map are Tweto (1979); Tweto, Moench, and Reed (1978); and Bryant, McGrew and Wobus (1981).

others, 1981). The ages presented in this paper suggest that the adjacent Climax and Alma igneous-hydrothermal systems were active concurrently. Structural, petrologic, and geophysical evidence presented by Bookstrom (in press) shows that the highly mineralized stocks of the Climax porphyry molybdenum system represent high cupolas on the western margin of a much larger pluton of granite porphyry, centered beneath the Alma district.

Sample descriptions, analytical data, and comments for dated samples from the southern Mosquito Range, and the Alma-Climax area and western vicinity are given in items 20 to 26.

GRANITE-B SUITE OF MONTEZUMA STOCK

The Montezuma granite-B porphyry stock (about 40 Ma) is the largest outcropping pluton in a northeast-trending swarm of smaller stocks, plugs, cupolas and dikes. This swarm extends from near Breckenridge, northeastward to near Empire (fig. 1). Intrusions in this swarm are predominately rhyolite-B to granite-B porphyries.

Early latite-porphyry dikes, south of the Montezuma stock, are cut by rhyolite-B porphyry dikes and by the Montezuma stock. Many dikes of biotite rhyolite-B porphyry (43–41 Ma) crop out northeast of the Montezuma stock, near Silver Plume (samples 1 and 2). Compositionally, these dikes resemble the granite-B porphyry of the Montezuma stock, but they contain fewer and smaller phenocrysts and have microcrystalline groundmass textures.

Several cupolas and dikes of variably sericitized and/or argillized biotite rhyolite-B porphyry (39–37 Ma) crop out along the northeast-trending Montezuma shear zone that extends from Swandyke to Georgetown (Bookstrom, unpublished maps, 1979) and also along a broad fracture zone that extends south-southeastward from Montezuma through Webster Pass (Bryant, Marvin, and others, 1981). The Mad Creek stock, near Empire, and its associated ring of hydrothermal breccia also belong to this group of porphyries. These porphyries commonly are spatially and temporally associated with hydrothermal breccias, zones of hydrothermally altered rocks, and swarms of veins and/or veinlets. Relatively sparse 35-Ma old dikes and plugs of dark gray dacite porphyry (samples 12 and 13) locally cut the more common dikes and plugs of sericitized and/or argillized biotite rhyolite-B (39–37 Ma).

A thick sill of white rhyolite-A porphyry (about 33 Ma) crops out in the cirque of Geneva Gulch, southeast of the Montezuma stock. This porphyry resembles the white rhyolite-granite porphyries, which are part of the porphyry-molybdenum systems at Climax and Red Mountain, and which range in age from about 33 to 20 Ma (samples 15 to 19, and 26; and White and others, 1981).

Sample descriptions, analytical data, and comments for dated samples from the Montezuma dike swarm are given in items 1 to 14.

GRANITE-KERSANTITE SUITE AT RED MOUNTAIN

Five new age determinations, ranging from 29.6 to 20.4 Ma are presented here for samples from the granite-kersantite (lamprophyre) suite at Red Mountain and its associated Urad-Henderson porphyry molybdenum system.

Previous work gives a fission-track age of 28.7 ± 2.9 Ma for rhyolite porphyry of the Red Mountain porphyry neck (recalculated from Marvin and others, 1974, sample 86). The Red Mountain porphyry neck cuts the Urad orebody and the East Knob and Square Quartz porphyries of Wallace and others (1978). However, these older rocks give fission-track ages of 28.5 Ma (recalculated from Naeser and others, 1973, as cited in Marvin and others, 1974, items 81 and 82). This indicates that the zircons of the older rocks were thermally annealed during emplacement and cooling of the adjacent Red Mountain porphyry neck.

Sample 16 (29.6 Ma) is from a rhyolite porphyry dike of the radial dike swarm, about 1 mi (1.6 km, or 3 stock diameters) west-southwest of the Red Mountain porphyry neck. This sample location may be far enough from the Red Mountain intrusive center to have escaped thermal annealing.

Composite dikes of the radial dike swarm contain coeval components of rhyolite porphyry and kersantite (Shannon and others, 1984). Samples of rhyolite porphyry and kersantite from different dikes give essentially concordant age determinations of 29.6 ± 1.9 Ma for rhyolite porphyry (sample 16) and 28.6 ± 3.3 Ma for kersantite (sample 15).

Dikes of the radial dike swarm cut the Urad orebody, the Square quartz porphyry (of Wallace and others, 1978) and tungsten slide complex (of Wallace and others, 1978). Thus, igneous and hydrothermal activity began before 29.6 Ma at Red Mountain. Thermal activity in the Red Mountain intrusive center continued until at least 20 Ma (sample 19). Sample descriptions, analytical data and comments for dated samples from Red Mountain are given in items 15 to 19.

SAMPLE DESCRIPTIONS

1. *DF-2697* Fission-track
(MC-78-L-68-5 of M. Coolbaugh)
Biotite rhyolite-B porphyry dike, Montezuma-Silver Plume dike swarm (39°40′17″N,105°46′38″W; Clear Creek County, CO). Northeast-trending dike, 12,400 ft altitude, upper northeast slope of Ganley Mountain, about 3.8 mi (6.3 km) northeast of the Montezuma stock and 3.2 mi (5.2 km) southwest of Silver Plume. *Analytical data:* (zircon, 6 grains) Ps = 2.96 × 10^6 tracks/cm² (984 tracks counted); P_i = 4.38 × 10^6 tracks/cm² (727 tracks counted); neutron dose = 1.06 × 10^{15} N/cm². *Collected by:* M. Coolbaugh. *Counted by:* P. Andriessen.
(zircon) 42.8 ± 4.2 Ma

2. *DF-2695* Fission-track
(MC-78-SP-6 of M. Coolbaugh)
Rhyolite-B porphyry dike (39°41′48″N, 105°43′55″W; Silver Plume, Clear Creek County, CO). Northwest-trending dike. *Analytical data:* (zircon, 6 grains) P_s = 4.87 × 10^6 tracks/cm² (715 tracks counted); P_i = 7.42 × 10^6 tracks/cm² (545 tracks counted); neutron dose = 1.06 × 10^{15} N/cm². *Comment:* The rhyolite-B porphyry dikes of items 1 and 2 are similar to the granite-B porphyry of the nearby Montezuma stock. They probably represent precursor dikes, emplaced ahead of and peripheral to the rising Montezuma pluton. Dikes of this type are cut by the Pb-Zn-Ag-bearing veins of the Silver Plume district. *Collected by:* M. Coolbaugh. *Counted by:* P. Andriessen.
(zircon) 41.5 ± 4.8 Ma

3. *DF-2693* Fission-track
(CX-170-2105 of A. Bookstrom)
Explosion breccia (39°46′02″N,105°41′53″W; Mad Creek area, Empire district, Clear Creek County, CO). Drill core, hole CX 170, 2105 ft (642 m). Pyritized, sericitized, argillized hydrothermal explosion breccia containing clasts of altered leuco-monzonite, rhyolite-B

porphyry, and Silver Plume Granite, in an altered clastic matrix. A ring of such breccia surrounds a small stock of rhyolite-B porphyry (item 5), exposed east of Mad Creek. *Analytical data:* (zircon, 6 grains) $P_s = 2.78 \times 10^6$ tracks/cm² (347 tracks counted); $P_i = 4.34 \times 10^6$ tracks/cm² (271 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Collected by:* A. Bookstrom. *Counted by:* P. Andriessen.

(zircon) 40.5 ± 6.5 Ma

4. *DF-1500* Fission-track
(M-189A of A. Bookstrom)
Granite-B porphyry, Montezuma stock (39°35′12″N, 105°50′28″W; E slope of Morgan Peak, Summit County, CO). *Analytical data:* (zircon) $P_s = 4.09 \times 10^6$ tracks/cm² (853 tracks counted), $P_i = 6.27 \times 10^6$ tracks/cm² (653 tracks counted), neutron dose = 1.02×10^{15} N/cm²; (apatite) $P_s = 0.351 \times 10^6$ tracks/cm² (117 tracks counted), $P_i = 1.79 \times 10^6$ tracks/cm² (299 tracks counted), neutron dose = 3.44×10^{15} N/cm². *Comment:* The Montezuma stock is cut by sparse veins and veinlets, containing Fe-, Cu-, Zn-, Pb-, Ag- and Mo-bearing sulfides and sulfo-salt ore minerals. *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 39.8 ± 4.2 Ma
(apatite) 40.2 ± 8.8 Ma

5. *DF-2692* Fission-track
(CX-170-290 of A. Bookstrom)
Sericitized, argillized rhyolite-B porphyry (39°46′02″N, 105°41′53″W; Mad Creek area, Empire district, Clear Creek County, CO). Drill core, hole CX-170, 290 ft (88 m). *Analytical data:* (zircon, 3 grains) $P_s = 8.73 \times 10^6$ tracks/cm² (768 counted); $P_i = 14.01 \times 10^6$ tracks/cm² (616 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Comment:* Stocks of the monzonite and granodiorite suites of the Empire district are Laramide in age (about 65 Ma) (Simmons and Hedge, 1978). Renewed igneous activity during the late Eocene resulted in emplacement of the Mad Creek stock and its associated explosion breccia. The Mad Creek stock is similar in composition and age to the granite-B porphyry of the Montezuma stock. *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 39.4 ± 4.3 Ma

6. *DF-2698* Fission-track
(AB-78-G-2 of A. Bookstrom)
Biotite rhyolite-B porphyry cupola (39°34′16″N, 105°49′26″W; Geneva Creek cirque, Clear Creek County, CO). Drill core. *Analytical data:* (zircon, 6 grains) $P_s = 6.28 \times 10^6$ tracks/cm² (1120 tracks counted); $P_i = 10.10 \times 10^6$ tracks/cm² (900 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Collected by:* A. Bookstrom. *Counted by:* P. Andriessen.

(zircon) 39.4 ± 3.6 Ma

7. *DF-1498* Fission-track
(M-171A of A. Bookstrom)
Rhyolite-B porphyry plug (39°31′44″N, 105°50′13″W; Webster Pass Park and Summit Counties, CO). *Analytical data:* (zircon, six grains) $P_s = 5.10 \times 10^6$ tracks/cm² (1181 tracks counted); $P_i = 8.36 \times 10^6$ (968 tracks counted); neutron dose = 1.03×10^{15} N/cm². *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 37.5 ± 3.7 Ma

8. *AB-77-G-12A* Fission-track
Sericitized granite-B porphyry (39°34′47″N, 105°48′58″W; N slope, Geneva Creek, Clear Creek County, CO). *Analytical data:* (zircon, 6 grains) $P_s = 5.7 \times 10^6$ tracks/cm² (993 tracks counted); $P_i = 5.4 \times 10^6$ tracks/cm² (469 tracks counted); neutron dose = 5.92×10^{14} N/cm². *Comment:* The fission-track ages for samples of items 8, 9, 10, and 11 indicate emplacement of several small stocks, plugs, necks, and dikes of rhyolite-B porphyry during the late Eocene along fracture zones south of the Montezuma stock. These small intrusions were emplaced soon after crystallization of the Montezuma stock during the interval 39–37 Ma. They are thought to be cupolas connected to a much larger, hidden pluton of granite-B porphyry, south of the Montezuma stock. *Collected by:* A. Bookstrom. *Counted by:* A. Bookstrom.

(zircon) 37.4 ± 4.3 Ma

9. *DF-1528* Fission-track
(M-163A of A. Bookstrom)
Sericitized granite-B porphyry, SE margin of the Montezuma stock (39°35′31″N,105°49′37″W; E of Warden Gulch, Summit County, CO). Zone of sericitized, quartz-veined, and jarosite-stained granite-B porphyry. *Analytical data:* (zircon, 6 grains) $P_s = 5.84 \times 10^6$ tracks/cm² (1378 tracks counted); $P_i = 10.15 \times 10^6$ tracks/cm² (1198 tracks counted); neutron dose = 1.09×10^{15} N/cm². *Comment:* The Montezuma stock is 40 Ma (item 4). Thus, the zircon fission-track age of 37 Ma on this sample of sericitized granite-B porphyry from the Montezuma stock probably represents the time of hydrothermal alteration. This time of hydrothermal alteration (37 Ma) is within the range of ages of several small intrusions of hydrothermally altered rhyolite-B porphyry (39–37 Ma), (items 8, 9, 10, and 11). These intrusions are thought to be connected to a much larger hidden pluton of granite-B porphyry south of the Montezuma stock (item 11). Most of the mineralization and alteration in the Montezuma district probably formed in response to hydrothermal activity above and around apical portions of this somewhat younger, hidden pluton of granite-B porphyry, south of the Montezuma stock. *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 37.4 ± 3.0 Ma

10. *DF-1497* Fission-track
(L-1-A of A. Bookstrom)
Sericitized rhyolite-B porphyry (39°38′57″N, 105°44′25″W; Leavenworth Creek, Clear Creek County, CO). Central plug of a cluster of intrusive breccias and rhyolite-B porphyry plugs and dikes on the east side of Leavenworth Creek, about 3 mi (5 km) south of Silver Plume. *Analytical data:* (zircon, 5 grains) $P_s = 4.83 \times 10^6$ tracks/cm² (827 tracks counted); $P_i = 8.10 \times 10^6$ tracks/cm² (694 tracks counted); neutron dose = 1.04×10^{15} N/cm². *Comment:* In the Silver Plume and Georgetown areas, some important veins, such as the Pelican, Colorado Central, and Sunburst-Scepter veins, follow along the margins, and locally cut dikes of alaskite, granite porphyry, and rhyolite vitrophyre (Spurr and others, 1908; Connors, 1985). These dikes are here correlated with the rhyolite-B porphyries of Leavenworth Creek (37 Ma). This suggests that the Fe-, Cu-, Zn-, Pb-, Ag-, and Au-bearing veins of Silver Plume and Georgetown are related to subjacent intrusions of 37-Ma rhyolite/granite-B porphyry. Such

intrusions probably represent late differentiates of the granite-B porphyries of the Montezuma stock (43–37 Ma). *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 37.0 ± 4.0 Ma

11. *DF-1496* Fission-track
(CC-9A of A. Bookstrom)
Biotite rhyolite-B porphyry, (39°38′12″N, 105°43′18″W; upper Cabin Creek, Clear Creek County, CO). Funnel-shaped neck on northeast ridge of Otter Mountain, about 4 mi (6.4 km) south of Silver Plume. *Analytical data:* (zircon, 6 grains), $P_s = 5.52 \times 10^6$ tracks/cm² (664 tracks counted); $P_i = 9.35 \times 10^6$ tracks/cm² (563 tracks counted); neutron dose = 1.04×10^{15} N/cm². *Comment:* The biotite rhyolite-B porphyry of this neck resembles that of an unaltered dike that cuts the sericitized porphyries and breccias of Leavenworth Creek (sample 10). Thus, the Cabin Creek neck probably is correlative with a late dike of the Leavenworth Creek intrusive center. *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 36.6 ± 4.2 Ma

12. *DF-2699* Fission-track
(1193 of G. Neuerburg)
Hornblende-biotite dacite porphyry dike, (39°33′16″N, 105°50′07″W; E side upper Snake River, Summit County, CO). North-northwest-trending dike, south of Montezuma stock. *Analytical data:* (zircon, 6 grains) $P_s = 5.53 \times 10^6$ tracks/cm² (846 tracks counted); $P_i = 9.86 \times 10^6$ tracks/cm² (754 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Collected by:* G. Neuerberg. *Counted by:* P. Andriessen.

(zircon) 35.5 ± 3.7 Ma

13. *DF-1499* Fission-track
(M-1724 of A. Bookstrom)
Biotite dacite porphyry plug (39°31′36″N, 105°50′05″W; Handcart Gulch cirque, S side of Webster Pass, Park County, CO). *Analytical data:* (zircon, 6 grains) $P_s = 4.79 \times 10^6$ tracks/cm² (799 tracks counted); $P_i = 8.47 \times 10^6$ tracks/cm² (706 tracks counted); neutron dose = 1.03×10^{15} N/cm². *Comment:* The dacite porphyries (items 12 and 13) appear to represent the last pulse of the Montezuma magmatism. They are more mafic than the rhyolite-B porphyries, which immediately preceded them. They may represent relatively mafic magmas, tapped from deep within a body of vertically differentiated residual magma. *Collected by:* A. Bookstrom. *Counted by:* C. W. Naeser.

(zircon) 34.8 ± 3.7 Ma

14. *AB-77-G-27A* Fission-track
Rhyolite-A porphyry (39°34′34″N,105°48′08″W; Geneva Creek, Clear Creek County, CO). Thick sill in upper Geneva Creek and on the southeast slope of Revenue Mountain. *Analytical data:* (zircon, 6 grains) $P_s = 4.87 \times 10^6$ tracks/cm² (704 tracks counted); $P_i = 5.14 \times 10^6$ tracks/cm² (372 tracks counted); neutron dose = 5.90×10^{14} N/cm². *Comment:* The margins of this sill of leucocratic rhyolite-A porphyry are cut by sparse quartz-molybdenite veinlets. The composition, appearance and young (33 Ma) age of this porphyry are similar to those of high-silica, alkali-rich rhyolite-granite porphyries associated with the porphyry molybdenum deposits at Climax (33–18 Ma) and Red Mountain (30–20 Ma). This suggests that the molybdenite-bearing, white rhyolite-A porphyry of Geneva Creek may be more closely related to the rhyolite-granite suites of Climax and Red Mountain than to the granite-B suite of the Montezuma stock (43–35 Ma). *Collected by:* A. Bookstrom. *Counted by:* A. Bookstrom.

(zircon) 33.3 ± 4.3 Ma

15. *KA-82-585* Fission-track
(82-287 of Henderson Mine staff)
Kersantite dike, Red Mountain intrusive center, (39°46′09″N,105°50′55″W; Henderson Mine, 7500 level, Dailey district, Clear Creek County, CO). Microcrystalline biotite-plagioclase-magnetite lamprophyre with xenocrysts of quartz and potassic feldspar. *Analytical data:* (zircon, 8 grains) $P_s = 2.44 \times 10^6$ tracks/cm² (671 tracks counted); $P_i = 5.06 \times 10^6$ tracks/cm² (694 tracks counted); neutron dose = 9.90×10^{14} N/cm². *Comment:* Kersantite occurs as dikes containing rhyolitic inclusions and xenocrysts, as margins on composite kersantite-rhyolite porphyry dikes, and as inclusions in rhyolite porphyry dikes of the radial dike swarm. *Collected by:* J. Shannon. *Counted by:* J. Shannon (zircon fission-track).

(zircon) 28.6 ± 3.3 Ma

16. *DF-2700* Fission-track
(76-345 of the Henderson Mine staff)
Rhyolite-A porphyry dike of the radial dike swarm, Red Mountain intrusive center (39°45′10″N, 105°51′16″W; Harrison Mountain, Dailey district, Clear Creek County, CO). *Analytical data:* (zircon, 22 grains) $P_s = 2.24 \times 10^6$ tracks/cm² (2908 tracks counted); $P_i = 4.70 \times 10^6$ tracks/cm² (3046 tracks counted); neutron dose = 1.04×10^{15} N/cm². *Comment:* This sample is from a west-southwest-trending dike on Harrison Mountain, about 1 mi (1.6 km) from the outcrop area of the younger rhyolite porphyry neck of Red Mountain which is about 1700 ft (518 m) in diameter. *Collected by:* Henderson Mine staff. *Counted by:* P. Andriessen, J. Shannon, and C. Naeser.

(zircon) 29.6 ± 1.9 Ma

17. *DF-4830* Fission-track
(83-67 of Henderson Mine staff)
Granite-A porphyry of the Urad stock (of Wallace and others, 1978), Red Mountain intrusive center (39°45′49″N,105°50′37″W; Henderson Mine, 8100 level, Dailey district, Clear Creek County, CO). *Analytical data:* (zircon, 8 grains) $P_s = 2.00 \times 10^6$ tracks/cm² (673 tracks counted); $P_i = 4.36 \times 10^6$ tracks/cm² (732 tracks counted); neutron dose = 9.90×10^{14} N/cm². *Comment:* Urad porphyry is younger than the Urad molybdenum deposit but older than the Henderson molybdenum deposit. This sample was collected near the contact of Urad porphyry with its host rock, Proterozoic Silver Plume Granite. *Collected by:* R. Carten. *Counted by:* J. Shannon.

(zircon) 27.2 ± 3.1 Ma

18. *DF-4829* Fission-track
(80-180 of Henderson Mine staff)
Granite-A porphyry of the Urad stock, Red Mountain intrusive center (39°45′48″N,105°50′40″W; Henderson Mine, 7550 level, Dailey district, Clear Creek County, CO). *Analytical data:* $P_s = 1.95 \times 10^6$ tracks/cm² (515 tracks counted); $P_i = 4.58 \times 10^6$ tracks/cm² (607 tracks counted); neutron dose = 9.90×10^{14} N/cm². *Comment:* Sample collected near contact with

Proterozoic Silver Plume Granite. *Collected by:* J. Shannon. *Counted by:* J. Shannon.

(zircon) 25.1 ± 3.1 Ma

19. *DF-4831* Fissión-track
(80-181 of Henderson Mine staff)
Granite-A of the Henderson stock (of Carten and others, 1985), Red Mountain intrusive center (39°45′32″N,105°50′25″W; Henderson Mine, 7500 level, Dailey district, Clear Creek County, CO). *Analytical data:* (zircon, 7 grains) $P_s = 5.84 \times 10^6$ tracks/cm² (1124 tracks counted); $P_i = 19.64 \times 10^6$ tracks/cm² (189 tracks counted); neutron dose = 1.15×10^{14} N/cm². *Comment:* This sample is from Henderson granite near its contact with the younger stock of Seriate granite (of Carten and others, 1985). The 20.4 Ma fission-track age probably represents a thermal annealing event associated with emplacement of the younger Seriate granite stock. There are two stocks which are known to be younger than the Seriate granite (the Vasquez and Dailey stocks of Carten and others, 1985). *Collected by:* J. Shannon. *Counted by:* J. Shannon.

(zircon) 20.4 ± 3.2 Ma

20. *B-5289* K-Ar
(AB-80-BG-13A of A. Bookstrom)
Aplitic rhyolite-A porphyry dike (39°20′13″N, 106°07′37″W; upper Buckskin Gulch, Park County, CO). *Analytical data:* (biotite) K = 7.695%; $^*Ar^{40}$ = 8.63×10^{-10} mol/gm; $^*Ar^{40}$/total Ar^{40} = 78.6%. *Comment:* This minor, east-northeast-trending dike of aplitic rhyolite-A porphyry belongs to a swarm of aplitic dikes and dikelets associated with a pluton of biotite granodiorite porphyry, which cuts a stock that resembles the Lincoln Porphyry of Singewald and Butler (1941). Simmons and Hedge (1978) reported a Rb-Sr age of 67 Ma for Lincoln Porphyry from Mt. Lincoln near Buckskin Gulch. *Collected by:* A. Bookstrom and M. Clasen. *Analysis by:* Geochron Laboratories.

(biotite) 63.6 ± 2.3 Ma

21. *B-5853* K-Ar
(AB-80-LBM-2A of A. Bookstrom)
Biotite rhyolite-B porphyry (39°02′09″N,
106°06′25″W; between Rough and Tumbling Creek
and Willow Creek, SW Jones Hill 7.5′ quad., Park
County, CO). *Analytical data:* K = 6.614%; $^*Ar^{40}$ =
6.5×10^{-10} mol/gm; $^*Ar^{40}$/total Ar^{40} = 50.6%. *Com-*
ment: This plug is late Laramide in age, but it resembles
many rhyolite-B porphyries of middle Tertiary age in the
north-central Colorado mineral belt. *Collected by:*
A. Bookstrom. *Analysis by:* Geochron Laboratories.

(biotite) 55.9 ± 2.1 Ma

22. *1323-AB-82-1* K-Ar, Fission-track
Biotite rhyolite-B porphyry (39°25′09″N,
106°16′09″W; upper East Fork of the Eagle River,
Eagle County, CO). Large domed sill and smaller con-
necting bodies along the upper East Fork of the Eagle
River and on the north end of Chicago Ridge, east of
Jones Gulch (Tweto, 1974). *Analytical data:* 1. (biotite
K-Ar) K = 6.33%; $^*Ar^{40}$ = 48.294 × 10^{-11}
moles/gm; Ar^{40}/total Ar^{40} = 29%. 2. (sanidine K-Ar) K
= 9.78%; $^*Ar^{40}$ = 6.88×10^{-10} mol/gm; $^*Ar^{40}$/total
Ar^{40} = 80%. 3. (zircon fission-track, 4 grains) P_s =
3.43×10^6 tracks/cm²; $P_i = 4.17 \times 10^6$ tracks/cm²;
neutron dose = 7.24×10^{14} N/cm². *Comment:* This porphyry cuts a thick sill of Lincoln-like granodiorite porphyry (65.6 Ma, as recalculated from Pearson and others, 1962). It is leucocratic and quartz-rich, and is similar in appearance to Chalk Mountain Porphyry of White and others (1981), which give a biotite K-Ar age of 27.7 Ma (as recalculated from White and others, 1981). The age of this rhyolite porphyry is around 42 Ma (43.5 Ma—biotite; 40.2 Ma—sanidine). This age probably represents the time of crystallization. The zircon fission-track age of 35.5 Ma may signify the time of a regional thermal event that also is represented by ore deposition at Gilman, 34.0–34.5 Ma (Naeser and Cunningham, 1984) and Tennessee Pass (Beaty and others, 1986). *Collected by:* A. Bookstrom and J. Shannon. *Analyses by:* S. H. Evans, Jr., University of Utah Research Institute (biotite K-Ar and zircon fission-track age determinations); G. Piete, Teledyne Isotopes (sanidine K-Ar age determination).

(biotite) 43.5 ± 3.0 Ma
(sanidine) 40.2 ± 2.0 Ma
(zircon) 35.5 ± 3.2 Ma

23. *Bu-77-H-100* Fission-track
Porphyritic rhyolite-A dike (39°20′08″N, 106°07′47″W; upper Buckskin Gulch, Alma district, Park County, CO). Later white porphyry of Singewald and Butler (1941). *Analytical data:* (zircon, 8 grains) $P_s = 4.44 \times 10^6$ tracks/cm² (1028 tracks counted); $P_i = 4.42 \times 10^6$ tracks/cm² (512 tracks counted); neutron dose = 5.83×10^{14} N/cm². *Comment:* This dike belongs to a swarm of north-northeast-trending dikes of white, porphyritic rhyolite-A. They intrude the monzonite, granodiorite, and granite-B suites of the Alma district. These rhyolite dikes themselves are commonly sericitized and cut by veins and veinlets. Most of these contain quartz and pyrite, and some contain sphalerite, galena, tetrahedrite, molybdenite, huebnerite, fluorite, and/or rhodochrosite. The dikes of white porphyritic rhyolite-A may be precursory dikes of a large granitic pluton, related to the suite of rhyolite-granite porphyries at Climax (Bookstrom, in press). *Collected by:* W. Utterback. *Counted by:* A. Bookstrom.

(zircon) 34.9 ± 4.0 Ma

24. *DF-2702* Fission-track
(KL-1-2134 of A. Bookstrom)
Chloritized biotite granodiorite porphyry dike (39°19′40″N,106°07′47″W; upper Buckskin Gulch, near Kite Lake, Alma district, Park County, CO). Drill core from hole KL-1, 2135 ft (651 m). *Analytical data:* (zircon, 6 grains) $P_s = 2.45 \times 10^6$ tracks/cm² (666 tracks counted); $P_i = 5.62 \times 10^6$ tracks/cm² (763 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Comment:* This sample is similar to biotite granodiorite porphyry of the composite Buckskin stock which has a biotite K-Ar age of 62.4 ± 1.9 Ma (recalculated from Heidrick and Hedge, written commun., 1972). The 27.6 Ma zircon fission-track age of this sample probably represents the time of a hydrothermal event. The chlorite of the granodiorite porphyry dike and the quartz-pyrite-molybdenite-sericite veins of the Kite Lake area are probable manifestations of that hydrothermal event. *Collected by:* A. Bookstrom. *Counted by:* P. Andreissen.

(zircon) 27.6 ± 3.0 Ma

25. *BU-77-H-98* Fission-track
Porphyritic rhyolite-B dike (39°19′38″N, 106°07′14″W; upper Buckskin Gulch, Alma district,

Park County, CO). North-northeast-trending dike; porphyritic rhyolite-B is equivalent to gray rhyodacite of Kuntz (1968). *Analytical data:* (zircon, 7 of 7 grains) $P_s = 6.77 \times 10^6$ tracks/cm² (1372 tracks counted), $P_i = 6.68 \times 10^6$ tracks/cm² (677 tracks counted); (zircon, 4 of the 7 grains) $P_s = 7.44 \times 10^6$ tracks/cm² (861 tracks counted), $P_i = 5.91 \times 10^6$ tracks/cm² (342 tracks counted; (zircon, other 3 of the 7 grains) $P_s = 5.89 \times 10^6$ tracks/cm² (511 tracks counted, $P_i = 7.72 \times 10^6$ tracks/cm² (335 tracks counted); neutron dose = 5.85×10^{14} N/cm². *Comment:* The total 7-grain count yields an average age of 35.4 Ma. However, the individual grains yield ages that cluster into two distinct groups, which do not overlap. Age determinations on 4 grains cluster around 43.9 Ma, an age that may represent a time of dike emplacement and first cooling. Ages of three other grains cluster around 26.7 Ma, an age that may represent a time of partial thermal annealing of fission tracks. Such thermal annealing probably was associated with the hydrothermal event that produced the quartz-pyrite-molybdenite veins of the Kite Lake area. The 26.7 Ma age is within the age range of rhyolite-granite magmatism and hydrothermal alteration of the nearby Climax porphyry molybdenum system (33–18 Ma, White and others, 1981). *Collected by:* W. Utterback. *Counted by:* A. Bookstrom.

(zircon, 7 grains) 35.4 ± 3.3 Ma
(zircon, 4 grains) 43.9 ± 5.6 Ma
(zircon, 3 grains) 26.7 ± 4.0 Ma

26. *DF-2701* Fission-track

(Climax 78-1 of A. Bookstrom)

Seriate alkali-feldspar granite of the post-ore Traver stock, Climax intrusive center and porphyry molybdenum system (39°22'24"N,106°09'41"W; Climax Mine, 929 level, Lake County, CO). *Analytical data:* (zircon, 3 grains) $P_s = 3.66 \times 10^6$ tracks/cm² (176 tracks counted); $P_i = 9.48 \times 10^6$ tracks/cm² (228 tracks counted); neutron dose = 1.06×10^{15} N/cm². *Comment:* This sample was taken from the top of the cupola of the Traver stock. White and others (1981) reported a zircon fission-track age of 18.2 ± 0.9 Ma for a sample of seriate granite from drill core about 300 ft (90 m) deeper within the Traver stock. The 24.4 Ma age reported here may represent the time of emplacement, crystallization and first cooling of the Traver stock. The 18.2 Ma age reported by White and others (1981) may indicate a later thermal annealing event associated with a younger, deeper intrusion, not yet encountered by mining or drilling. *Collected by:* A. Bookstrom and R. Smith. *Counted by:* P. Andriessen.

(zircon) 24.4 ± 4.9 Ma

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