Fission-track ages of Tertiary intrusive rocks in the Manhattan Mining District, northern Front Range, Colorado

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FISSION-TRACK AGES OF TERTIARY INTRUSIVE ROCKS IN THE MANHATTAN MINING DISTRICT, NORTHERN FRONT RANGE, COLORADO

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Nine intrusive bodies in the Manhattan Mining District of northern Colorado were sampled for fission-track analysis. Zircon and/or apatite concentrates were obtained from seven dikes, a plug, and a breccia pipe associated with the sampled plug. Grain mounts were prepared for etching by the method described by Naeser and Dodge (1969) and etched in the manner described by Naeser and McKee (1970).

The decay constant for the spontaneous fission of ^{238}U used in the age calculations is 6.85×10^{-17} yr^{-1} (Fleischer and Price, 1964). The amount of neutron radiation was determined by counting the induced fission tracks present in a piece of muscovite which covered a standard glass during irradiation. Zircon ages reflect a 95% confidence level (2σ) whereas apatite values reflect a confidence level of 68% (σ). Analyses were performed by C. W. Naeser, U. S. Geological Survey, Denver, Colorado.

Abbreviations used: P_s, fossil track density (tracks/cm^2), number of tracks counted in parenthesis;
P_i, induced track density (tracks/cm^2), number of tracks counted in parenthesis;
ϕ, neutron radiation (n/cm^2)

GEOLOGIC DISCUSSION

Tertiary igneous intrusive rocks form a northeast-trending belt which extends from the Rabbit Ears Range northeastward to the Manhattan Mining District, in the northern Front Range (fig. 1). Prominent intrusive centers are located at Poison Ridge, Haystack Mountain, Parkview Mountain, Radial Mountain, Mt. Richthofen (Never Summer stock), and the Manhattan district. The intrusives in this belt are similar in general composition to those of the Colorado Mineral Belt to the south, and have been considered to be similar in age by some workers (e.g., Lovering and Goddard, 1950, p. 285; Ogden Tweto, personal communication). Both belts are characterized by prominent gravimetric and magnetic lows (Popenoe and others, 1970; Tweto and Case, 1972).

The Manhattan Mining District is at the eastern end of the northern Colorado intrusive belt. Porphyries and porphyritic rocks (dominantly dacitic to rhyodacitic) occur in small elongate to irregular-shaped stocks, plugs and dikes (some lens-like) concentrated in an area in excess of 30 square mi. Dikes and tabular bodies are most abundant, and these range from a few feet to nearly 200 ft wide and in excess of a mile long. One large plug consists of flow-banded rhyolite with steep dips. The plug is roughly hourglass shaped and is approximately 2700 ft long and 1000 ft wide, narrowing to 400 ft wide at a central constriction zone. Two small breccia zones or "pipes" (less than 200 ft across) occupy marginal locations near the constriction zone and reflect the latest intrusive activity. Intrusion of these hypabyssal bodies was predominantly controlled by prominent faults and joint sets in the host Precambrian crystalline rocks.

Based on stratigraphic control, Kinney and others (1968) suggested a probable Oligocene age for intrusives at Poison Ridge, at the west end of the northern Colorado intrusive belt. Fission-track ages by Naeser and others (1973) indicated that igneous activity commenced in the late Oligocene and continued into the early Miocene. Quartz latite porphyries of the Poison Ridge stock, Haystack Mountain stock, and a dike near Parkview Mountain gave zircon fission-track ages of 22.8±1.8, 27.7±3.8, and 26.1±2.2 m.y. respectively. Roughly comparable biotite K/Ar ages of 24.4 m.y., from the Haystack stock (Marvin and others, 1974, item no. 55) and 28±3 m.y., from the Never Summer stock, Mt. Richthofen area (Corbett, 1966, p. 8) were obtained to further substantiate this Oligocene-Miocene igneous activity for the northern Colorado intrusive belt. By inference, it was generally assumed that the Manhattan district intrusives would be of similar age. However, a K/Ar analysis of hornblende by Bole (1971)

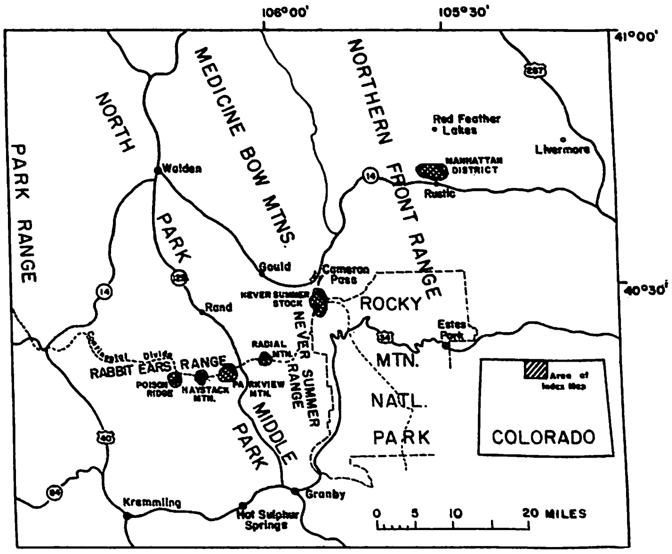

FIGURE 1 – Tertiary intrusive centers of the northern Colorado intrusive belt (centers indicated by cross-hatched pattern).

from a hornblende dacite dike gave a Paleocene age of 54.6±1.1 m.y. An early Tertiary age for most of the intrusive activity in the Manhattan district was confirmed by our study. Seven zircon fission-track ages for dacite, rhyodacite, and quartz latite dikes range from 53.6 m.y. (sample 73N5) to 60.2 m.y. (sample 73N2). Fission-track ages for three coexisting apatites fall in the same range: 56 (sample 73N5), 58 (sample 73N3), and 58 (sample 73N4) m.y. Apatites from two dikes (samples 73N1 and 73N2) near fault zones gave appreciably lower ages (47.5 m.y. and 33.6 m.y. as compared to 57.9 m.y. and 60.2 m.y., respectively for zircons) that probably reflect thermal annealing of apatite associated with later Tertiary tectonic activity. The rhyolite plug with associated breccia zones is rather similar to rhyolitic plugs and breccia pipes described in the Colorado Mineral Belt (Emmons and others, 1927; Tweto and Case, 1972). Fission track ages of 36 m.y. (apatite, sample 73N6) and 33.3 m.y. (zircon, sample 5-39A) for the rhyolite plug also establish an episode of Oligocene rhyolite intrusion for the Manhattan district.

Confirmation of Paleocene igneous activity for a portion of the northern Colorado intrusive belt suggests that igneous activity in the Colorado Mineral Belt and the northern Colorado intrusive belt may be related. Dating of porphyries in the Colorado Mineral Belt has shown that most igneous intrusive activity occurred either during Late Cretaceous–early Tertiary (Paleocene) times or during the middle Tertiary (Oligocene) (Marvin and others, 1974). This activity in the Colorado Mineral Belt seemed to foreshadow activity in the northern Colorado intrusive belt where activity occurred during either the Paleocene or late Oligocene–early Miocene.

SAMPLE DESCRIPTIONS

1. USGS (D) – 73N1 — Fission track

Porphyritic rhyodacite dike (40°41′35″N., 105°31′08″W.; NE¼NE¼ sec. 1, unsurveyed T. 8 N., R. 73 W.; 100 yards SW. of Colorado Highway 14 near western picnic area, Poudre Canyon; Larimer Co., CO). Analytical data: (zircon) 260 ppm U, $P_s = 8.31 \times 10^6$ (1385), $P_i = 9.20 \times 10^6$ (767), $\phi = 1.05 \times 10^{15}$; (apatite) 1.8 ppm U, $P_s = 4.66 \times 10^4$ (97), $P_i = 9.94 \times 10^4$ (207), $\phi = 1.66 \times 10^{15}$. Comments: Buff to gray porphyritic rock with abundant phenocrysts (to 1 cm) of complexly zoned and twinned plagioclase (sodic andesine to calcic oligoclase) and sparse phenocrysts of sanidine, quartz, and ragged biotite. Plagioclase and biotite phenocrysts are commonly partially to completely altered. Microcrystalline (felsiphyric to orthophyric) groundmass consists mainly of K-feldspar (sanidine?) with interlocking grains of oligoclase and quartz.

(zircon) 57.9±5.2 m.y.
(apatite) 47.5±5 m.y.

2. USGS (D) – 73N2 — Fission track

Dacite porphyry dike (40°42′54″N., 105°35′49″W.; central part sec. 1, T. 9 N., R. 73 W.; 200 yards NE. of Sevenmile Creek; Larimer Co., CO). Analytical data: (zircon) 240 ppm U, $P_s = 8.11 \times 10^6$ (1765), $P_i = 8.55 \times 10^6$ (930), $\phi = 1.04 \times 10^{15}$; (apatite) 1.3 ppm U, $P_s = 2.35 \times 10^4$ (49), $P_i = 7.06 \times 10^4$ (147), $\phi = 1.65 \times 10^{15}$. Comments: Gray porphyry with abundant phenocrysts of plagioclase (sodic andesine to calcic oligoclase, average 4-6 mm), less quartz, minor hornblende and biotite (to 3 mm), and prominent but minor orthoclase (to 3 cm). Plagioclase phenocrysts are commonly complexly zoned and twinned and cores of some crystals are intensely strained or polygonized (twinning destroyed), whereas rims, where not intensely altered, are generally unstrained. Some initially formed plagioclase phenocrysts were apparently strained during emplacement and were rimmed by more sodic oligoclase during final crystallization. Prominent orthoclase phenocrysts are typically euhedral, and strongly zoned with cores commonly rounded. Orthoclase crystals characteristically are strongly poikilitic, containing abundant inclusions of quartz and lesser amounts of magnetite and altered biotite and amphibole. Hornblende and biotite phenocrysts are locally abundant and are generally propylitized. The microcrystalline orthophyric matrix consists mainly of K-feldspar and oligoclase with interstital quartz, magnetite, apatite, and abundant chlorite, sericite, calcite and other alteration products.

(zircon) 60.2±4.9 m.y.
(apatite) 33.6±6 m.y.

3. USGS (D) – 73N3 — Fission track

Porphyritic rhyodacite to quartz latite dike (40°43′02″N., 105°35′22″W.; SE¼NE¼ sec. 29, T. 9 N., R. 73 W.; exposed in roadcut about 1½ miles N. of Rustic; Larimer Co., CO). Analytical data: (zircon) 210 ppm U, $P_s = 6.70 \times 10^6$ (1396), $P_i = 7.47 \times 10^6$ (778), $\phi = 1.03 \times 10^{15}$; (apatite) 2.0 ppm U, $P_s = 6.53 \times 10^4$ (136), $P_i = 1.14 \times 10^5$ (?), $\phi = 1.65 \times 10^{15}$. Comments: Buff to gray, deuterically altered rock with abundant complexly zoned and twinned phenocrysts (to 8 mm) of plagioclase (oligoclase-andesine) and strongly propylitized phenocrysts of hornblende (abundant magnetite in "propylite"). Phenocrysts (to 4 mm) of altered biotite and rare quartz are also present. Many plagioclase phenocrysts have strained and polygonized cores similar to those described in sample 73N2. Microcrystalline orthophyric matrix consists primarily of K-feldspar with subordinate amounts of oligoclase(?) and quartz.

(zircon) 56.4±5.0 m.y.
(apatite) 58±5 m.y.

4. USGS (D) – 73N4 Fission track
Sodic quartz-rich dacite porphyry dike (40°43′35″N., 105°34′54″W.; NE¼SW¼ sec. 21, T. 9 N., R. 73 W.; exposure at intersection of jeep trail with road about 0.6 mi S. of Goodell Corner; Larimer Co., CO). Analytical data: (zircon) 190 ppm U, $P_s = 5.74 \times 10^6$ (1436), $P_i = 6.55 \times 10^6$ (819), $\phi = 1.01 \times 10^{15}$; (apatite) 1.1 ppm U, $P_s = 3.55 \times 10^4$ (74), $P_i = 6.10 \times 10^4$ (127), $\phi = 1.64 \times 10^{15}$. Comments: Light-gray, typically pitted porphyry with abundant phenocrysts (to 1 cm) of plagioclase (albite-oligoclase) and quartz and minor deuterically altered hornblende and biotite. Plagioclase phenocrysts are weakly zoned, complexly twinned, and are considerably altered (particularly margin areas). Quartz phenocrysts are deeply embayed and a discoidal form after tridymite (some tridymite still preserved) is most abundant. A weak planar fabric has been developed locally by subparallel alignment of the discoidal quartz phenocrysts. The microcrystalline felsiphyric to weakly pilotaxitic matrix consists mainly of K-feldspar (sanidine?) and plagioclase (albite) with lesser amounts of quartz. Chemical analyses indicate high Na_2O/K_2O and Na_2O/CaO ratios (approximately 2:1 and 6:1 respectively) and based on normative minerals, this rock can be classified as a quartz keratophyre.
(zircon) 54.0±5.8 m.y.
(apatite) 58±9 m.y.

5. USGS (D) – 73N5 Fission track
Porphyritic hornblende dacite dike (40°44′06″N., 105° 36′11″W.; N½NW¼ sec. 20, T. 9 N., R. 73 W.; exposure along S. side of jeep trail approx. 300 yards W. of road intersection; Larimer Co., CO). Analytical data: (zircon) 190 ppm U, $P_s = 5.73 \times 10^6$ (1193), $P_i = 6.53 \times 10^6$ (680), $\phi = 1.00 \times 10^{15}$; (apatite) 1.8 ppm U, $P_s = 5.57 \times 10^4$ (116), $P_i = 9.94 \times 10^4$ (207), $\phi = 1.64 \times 10^{15}$. Comments: Dark-gray porphyritic rock with abundant phenocrysts (to 1 cm long) of prismatic, black to blackish-green hornblende. Hornblende prisms establish a weak to locally pronounced lineation. Minor phenocrysts (to 3 mm) of blocky plagioclase (andesine), sanidine, and quartz. Quartz phenocrysts are all either strained or polygonized (recrystallized). Felsiphyric to pilotaxitic matrix of K-feldspar (sanidine?), andesine, quartz, and opaque minerals. This dike is thought to be the same one that was dated by Bole (1971).
(zircon) 53.6±5.2 m.y.
(apatite) 56±6 m.y.

6. USGS (D) – 5-43(DF-826) Fission track
Quartz-rich dacite porphyry dike (40°43′21″N., 105° 33′59″W.; SW¼SW¼ sec. 22, T. 9 N., R. 73 W.; exposed crossing jeep trail approx. 800 ft E. of SW. section corner; Larimer Co., CO) . Analytical data: (zircon) 220 ppm U, $P_s = 6.80 \times 10^6$ (1071), $P_i = 7.04 \times 10^6$ (554), $\phi = 9.70 \times 10^{14}$. Comments: Light-gray rock with abundant phenocrysts (to 1 cm) of discoidal quartz (after tridymite) and plagioclase (oligoclase-sodic andesine) with lesser hornblende (partially to completely chloritized) and minor biotite (also chloritized). A moderately well developed planar fabric is defined by the discoidal quartz which typically has rounded edges and is complexly embayed. Some smaller quartz grains are angular to well rounded and lack embayment features. This noncorroded quartz contains fewer dust trains than the discoidal variety and probably crystallized later, directly as quartz. Plagioclase phenocrysts are mostly euhedral, complexly twinned, and some are strongly zoned. Larger grains generally show about 50 percent alteration whereas smaller phenocrysts are nearly completely altered. Hornblende phenocrysts are commonly intergrown cumulophyrically. The groundmass is felsiphyric to felty and consists of fine-grained quartz, feldspar, and abundant alteration products (clay, mica, chlorite, and carbonates). Accessory opaque minerals are abundant and significant amounts of sphene, apatite and zircon are also present.
(zircon) 57.2±6.0 m.y.

7. USGS (D) – 5-44 (DF-828) Fission track
Quartz-rich dacite porphyry dike (40°43′20″N., 105° 34′15″W.; SE¼SE¼ sec. 21, T. 9 N., R. 73 W.; exposed crossing jeep trail approx. 350 ft W. of SE. section corner; Larimer Co., CO). Analytical data: (zircon) 220 ppm U, $P_s = 6.99 \times 10^6$ (1229), $P_i = 7.01 \times 10^6$ (617), $\phi = 9.65 \times 10^{14}$. Comments: Gray rock very similar to sample 5-43 except plagioclase phenocrysts are far more abundant than the discoidal quartz, and planar fabric is not well developed. Deuteric alteration is moderately extensive, particularly involving hornblende and biotite. The groundmass is felsiphyric to felty and consists of fine-grained quartz and feldspar with abundant micaceous and clayey alteration material. Small grains of opaque minerals are abundant and rutile, apatite, sphene, and zircon are present in trace amounts.
(zircon) 58.7±5.8 m.y.

8. USGS (D) – 5-39A (DF-829) Fission track
Flow-banded rhyolite in plug (40°43′32″N., 105°32′ 21″W.; SW¼SW¼ sec. 23, T. 9 N., R. 73 W.; Larimer Co., CO). Analytical data: (zircon) 870 ppm U, $P_s = 15.6 \times 10^6$ (217), $P_i = 27.5 \times 10^6$ (191), $\phi = 9.60 \times 10^{14}$. Comments: Steeply dipping (55° to 60°), pale-pink to whitish-buff, flow banded rhyolite from northern edge of a volcanic plug. The rock is predominantly very fine grained and has a strongly trachytic fabric defined by abundant microlites of plagioclase (albite?) and sanidine in a quartz-feldspar or glass-rich matrix. Microlites locally swirl around small phenocrysts (to 3 mm) of quartz, plagioclase (albite-sodic oligoclase), and sanidine. Many of the phenocrysts have been rotated and fractured and commonly are confined to "segregation" layers in the

8. (continued)
well-banded rock. Flow layering is also well defined by differences in the concentration and/or size of microlites, the glass versus quartz-feldspar content of the groundmass, and the degree of alteration of matrix constituents. Minor accessory minerals include euhedral to subhedral magnetite, biotite, zircon, and rare monazite. (zircon) 33.3±6.7 m.y.

9. USGS (D) – 73N6 Fission track
Rhyolite breccia pipe (40°43'27"N., 105°32'20"W.; SW¼SE¼ sec. 23, T. 9 N., R. 73 W.; Larimer Co., CO).
Analytical data: (apatite) 8.1 ppm U, P_s=1.62x10^5(337), P_i = 4.45 x 10^5 (927), ϕ = 1.63 x 10^{15}. Comments: Rhyolite-tuff-granite breccia from a small breccia pipe at the west edge of a constriction feature of the flow-banded rhyolite plug described under sample 5-39A above. Breccia consists of about equal amounts of angular fragments (to 15 cm) of pale-pink, layered Tertiary rhyolite and Precambrian pink granite with lesser amounts of white, punky Tertiary tuff and Precambrian biotite schist set in a microcrystalline to glassy matrix. Angular fragments (to 1 cm) of quartz, microcline, and plagioclase (albite-oligoclase) from the host Precambrian crystalline rocks are also abundant. The breccia matrix is vitrophyric to trachytic and consists mainly of subparallel feldspar microlites in pale-brown glass. Most of the mineral grains show little to no alteration, suggesting that there was no post-intrusive hydrothermal activity, and it is assumed, therefore, that the apatite age dates the episode of breccia pipe emplacement, which slightly postdated crystallization of the flow-banded rhyolite of sample 5-39A. (apatite) 36±4 m.y.

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