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RADIOMETRIC AND CHEMICAL DATA FOR ROCKS OF THE TORTOLITA MOUNTAINS 15′ QUADRANGLE, PINAL COUNTY, ARIZONA

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Reconnaissance geologic mapping by members of the U.S. Geological Survey and University of Arizona indicate that the Tortolita Mountains quadrangle is underlain predominantly by Precambrain-Y Oracle Granite of Peterson (1938), Tertiary volcanic and sedimentary rocks, at least one metamorphic core complex, and a variety of unconsolidated Quaternary sedimentary deposits (fig. 1). The Oracle Granite contains pendants of Precambrain-X Pinal Schist and is cut by tourmaline-bearing pegmatite dikes, thought to be related to the granite, and by Precambrian-Y diabase dikes. The pegmatite and diabase also cut quartz diorite in the central part of the quadrangle. The quartz diorite is petrographically similar to some varieties of the Precambrain Madera Diortie (1630-1660 m.y.; Damon, Livingston, and Erickson, 1962; Damon, 1968; Banks and others, 1972), but a contact between the main facies of Oracle Granite and the quartz diorite was not observed. A K-Ar age on biotite from a sample of the quartz diorite collected 1.5 km from the nearest outcrop of granite yielded a K-Ar age of 1438 ± 10 m.y. (sample TMN-93) and does not aid in determining the chronologic relation between the two igneous rocks because the age is indistinguishable from that of the Oracle Granite (1420–1460 m.y.; Giletti and Damon, 1961; Damon, Livingston, and Erickson, 1962; Livingston and others, 1967; Livingston and Damon, 1968; Silver, 1968). This age suggests two possible interpretations: (1) the quartz diorite is a large pendant of Madera or similar diorite that was reheated to several hundred degrees Centigrade during intrusion of the granite or (2) the quartz diorite may be a pluton of Oracle Granite age. The age has additional significance in that the sample site has not been appreciably affected by heat from the metamorphic core complex 6 km to the south, which yields rather uniform middle Tertiary ages, or from similar-appearing metamorphic rock in the Suizo Mountains 4 km to the northwest.

A series of intricately faulted and broadly folded Tertiary volcanic and clastic deposits overlie the Precambrian basement in the northern two-thirds of the quadrangle. Facies changes, basal paleotopography, and the faulting and folding precluded a precise description of the Tertiary column from the data gathered during reconnaissance mapping. A generalized section, however, was established by Banks and others (1977) and is shown in figure 2. Basal clastic units are 0–65 m thick with cobbles and pebbles of rocks similar to those in nearby or underlying basement exposures. The basal 150 m of volcanic rock is dominated by gray, olive-black, and grayish-red, dense to amygdaloidal basalt or trachyandesite flows, and the overlying 800 or more meters is dominated by flows and flow breccias of rose-gray, pale-gray, grayish-purple, brownish-gray and maroon to dusky-red, phenocryst-poor quartz latite, rhyodacite, and possibly rhyolite, dacite, and trachyte. Radiometric ages were determined for two samples of this volcanic sequence: (1) hornblende and biotite from a sample of quartz latite (TMN-62) from a hill named The Huerfano, which is surrounded by Quaternary deposits, and (2) a biotite age from a typical sample (TMN-92) of the flows at and south of Chief Butte (fig. 1). The Huerfano sample yielded slightly discordant ages with the hornblende older (25.1 ± 0.4 m.y.) than the biotite (23.5 ± 0.4 m.y.). This discordance may reflect heating associated with an extensive middle Tertiary thermal, metamorphic, and plutonic event near the sample site (Banks and others, 1977; Banks, 1978). The other sample yielded a slightly older age (26.7 ± 0.5 m.y.) than The Huerfano sample and was collected (with due allowances for faulting) slightly above the middle of the volcanic section. Chemical analysis (TMN-56, table 1) of a sample that is petrographically identical to sample TMN-92, but comes from Owl Head Buttes a few kilometers to the west, suggests that the flows might be at least in part trachytes or potassic quartz latites. However, devitrification of the groundmass, presence of clay minerals and sericite in the groundmass and phenocrysts, and a chemical analysis indicating normal calc-alkaline rhyodacite flows of the same age 50 km to the west (Banks and others, 1978) indicate that regional generalizations of the chemical data should be made with caution.

At least 900 m of middle Tertiary clastic deposits overlie the volcanic sequence. Clasts in the basal 100–300 m are dominated by cobbles and boulders of the underlying volcanic rocks; granitic and metamorphic rocks form the dominant clasts in the upper several hundred meters. Several thin flows of alkali basalt dated at 21.0 ± 0.5 m.y. (Jennison, 1976) occur about 700–800 meters above the base of the clastic deposits. Trachyte, trachyandesite, rhyodacite, and quartz latite flows and flow breccias that are similar to the alkali basalt in age and stratigraphic placement occur between Picacho Peak (12 km to the west of the quadrangle; Shafiqullah and others, 1976) and the Vaca Hills (50 km south of Picacho Peak; Banks and Dockter, 1976; Banks and others, 1978). However, this western volcanic sequence is much thicker than the alkali basalt dated by Jennsion (1976), and the clastic deposits underlying them do not

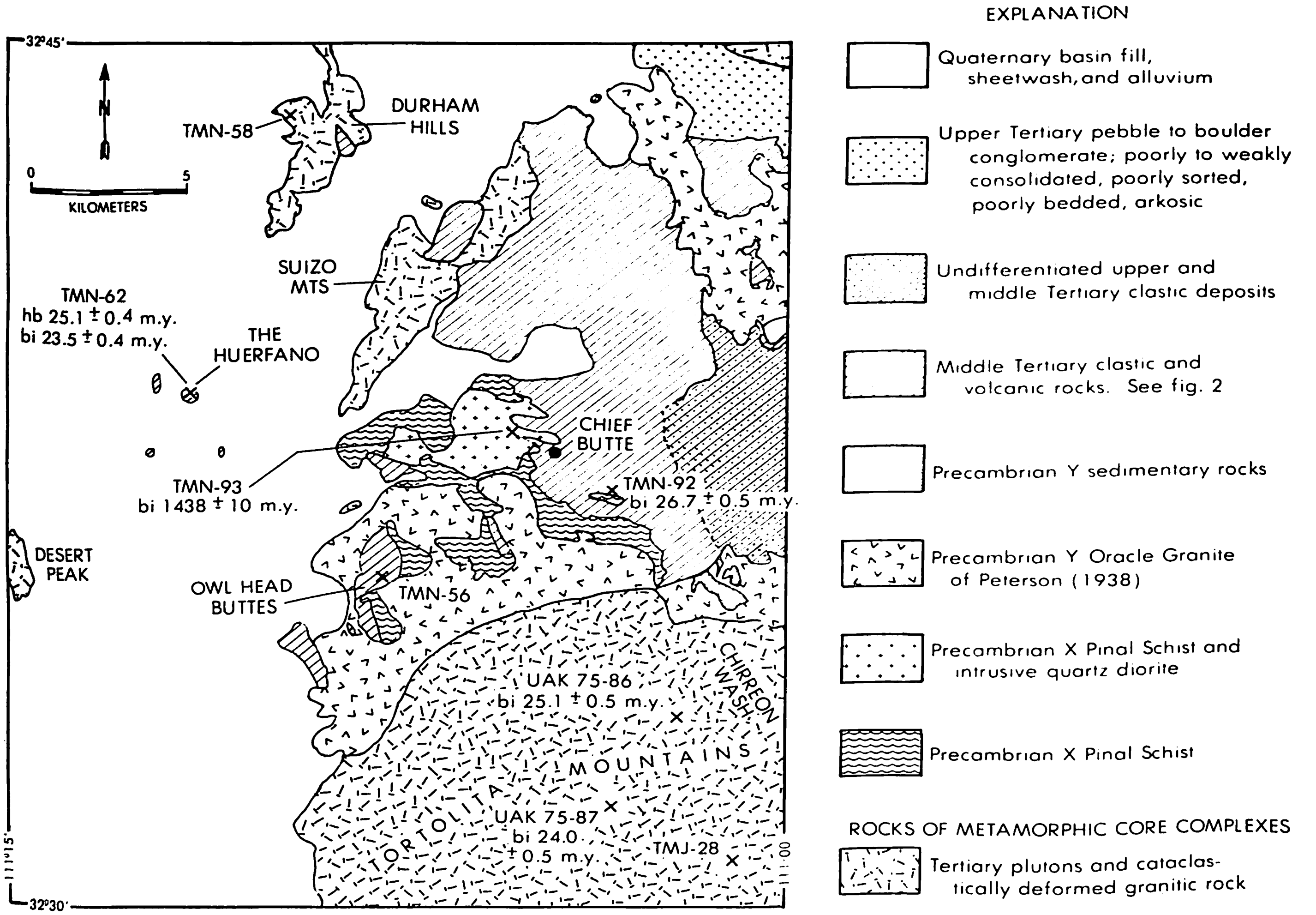
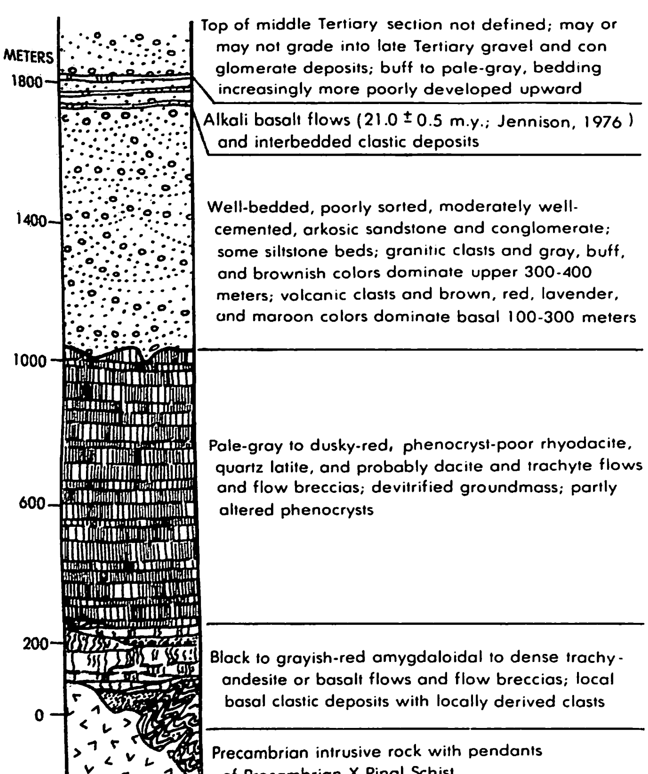


FIGURE 1. (above) Generalized geologic map of the Tortolita Mountains quadrangle, Pinal County, Arizona (simplified from Banks and others, 1977).



appear to be underlain in turn by older (≈25 m.y.) volcanic rocks correlative to those in the Tortolita Mountains quadrangle. Older and younger middle Tertiary volcanic rocks occur south of the quadrangle in the Tucson Mountains, but with much less intervening clastic material (Bikerman and Damon, 1966; Damon, 1968). Creasey (1967), Krieger and others (1974), and Creasey and Krieger (1978) describe age equivalent clastic and volcanic deposits to the north and east of the quadrangle.

Two new radiometric ages were determined for rocks exposed in a metamorphic core complex in and to the south of the southeast quarter of the quadrangle. Petrographically similar, as yet undated, rocks occur in Desert Peak, Durham Hills, Suizo Mountains, and the northeast corner of the quadrangle (fig. 1). An age of 25.1 ± 0.5 m.y. for biotite was obtained on a slightly foliated sample (UAK 75-86) of sphene-bearing porphyritic granodiorite (pluton of Chirreon Wash), which is the oldest pluton involved in the cataclastic metamorphism of the complex. The pluton has a widespread mafic border facies that may

FIGURE 2. (at left) Generalized middle Tertiary stratigraphy, Tortolita Mountains quadrangle, Pinal County, Arizona (after Banks and others, 1977).

Table 1. Chemical and normative data, rocks from Tortolita Mountains quadrangle, Pinal County, Arizona

Field number	TMN-56	TMN-83E	TMN-93	TMJ-28	TMN-58
Lab number	W192450	W192453	W192451	W192452	W192454
Latitude N.	32°35.6′	32°31.9′	32°38.0′	32°30.7′	32°43.7′
Longitude W.	111°07.3′	111°03.5′	111°04.9′	111°00.7′	111°09.3′
RAPID-ROCK ANALYSES					
SiO_2	69.1	75.3	67.1	49.2	49.5
Al_2O_3	15.6	13.4	15.9	17.4	16.0
Fe_2O_3	2.0	.79	1.7	1.9	2.4
FeO	.12	.24	1.5	6.1	5.1
MgO	.30	.22	1.5	5.5	8.1
CaO	.83	.85	2.7	7.7	7.9
Na_2O	2.8	3.4	4.4	3.3	3.5
K_2O	7.7	4.8	1.8	2.8	2.2
H_2O^+	.50	.25	.69	1.7	1.9
H_2O^-	.16	.14	.13	.14	.16
TiO_2	.40	.09	.34	1.6	1.2
P_2O_5	.09	.03	.07	.91	.71
MnO	.03	.03	.05	.12	.13
CO_2	.18	.01	.06	.16	.20
Σ	100–	100–	98–	99–	99–
NORMS					
Quartz	21.9	35.3	27.2	0	0
Corundum	1.8	1.2	2.2	0	0
Orthoclase	45.7	28.5	10.9	16.8	13.2
Albite	23.8	28.9	38.1	28.4	30.0
Anorthite	2.4	4.0	12.8	24.8	21.7
Wollastonite	0	0	0	2.9	5.0
Enstatite	.8	.6	3.8	3.7	4.4
Ferrosilite	0	0	.9	2.0	1.2
Magnetite	0	.6	2.5	2.8	3.5
Ilmenite	.3	.2	.7	3.1	2.3
Hematite	2.0	.4	0	0	0
Apatite	.2	.1	.2	2.2	1.7
Olivine	0	0	0	11.3	14.7
Other	.6	trace	.1	.4	.5

Analysts: Z. A. Hamlin, F. Brown

be represented chemically (table 1) by sample TMJ-28 (the sample, collected by J. A. Briskey, is correlated with the pluton of Chirreon Wash, but during map compilation the possibility arose that the sample alternately may represent a border facies of a compositionally and texturally similar younger pluton of the complex). The metamorphic rocks in the quadrangle are cut by at least three types of postfoliation dikes (Banks and others, 1977). One of these rock types is mafic (sample TMN-58 from the Durham Hills, table 1), but not quite so mafic as the alkali basalt flows in the middle Tertiary clastic deposits (Jennison, 1976). The youngest type of dike is a quartz monzonite porphyry that yielded a K-Ar age on biotite of 24.0 ± 0.5 m.y. (UAK 75-87). The small difference in age between the cataclastically deformed rock and the postmetamorphic rocks has been noted elsewhere in the Tortolita Mountains complex (Damon, 1968; Mauger and others, 1968; Creasey and others, 1977) and in the nearby larger Santa Catalina–Rincon complex to the southeast (Damon and others, 1963; Livingston and others, 1967; Mauger and others, 1968; Damon, 1968; Marvin and others, 1973; Shakel, 1974; Creasey and others, 1977).

ANALYTICAL TECHNIQUES

Rock samples were analyzed by the methods of Shapiro and Brannock (1962) and Shapiro (1975). Potassium-argon age determinations on samples TMN-93, TMN-62, and TMN-92 were done in the laboratories of the U.S. Geological Survey, Menlo Park, CA. Argon content was determined by standard isotope dilution methods (Dalrymple and Lanphere, 1969). Mass analyses were done using a Nier-type 60°-sector 15.24-cm-radius mass spectrometer operated in the static mode. Potassium was analyzed by a lithium metaborate fusion (Ingamells, 1962) flame photometer procedure with lithium as the internal standard; the analyst was G. Ambats. Samples UAK 75-86 (TMN-83) and UAK 75-87 were done by duplicate analyses in the laboratories of the University of Arizona using a mass spectrometer of similar type, also operated in the static mode. Potassium was analyzed in duplicate by atomic absorption spectrophotometry using sodium and lithium as internal standards. Support for analyses in the laboratories of the University of Arizona was provided by an Arizona Foundation grant to G. H. Davis and an NSF grant to P. E. Damon (EAR76-02590).

Constants used in calculation of the ages: $\lambda\beta = 4.963 \times 10^{-10} yr^{-1}$, $\lambda_\epsilon + \lambda_{\epsilon'} = 0.581 \times 10^{-10}/yr$, $^{40}K/\Sigma K = 1.167 \times 10^{-4}$ (mole/mole).

SAMPLE DESCRIPTIONS

1. *TMN-93* K-Ar

Quartz diorite (on low hill, S side of Parker Wash; 32° 37'58"N, 111°04'56"W; NW¼ NW¼, S23,T9S,R12E, Pinal Co., AZ). *Comments:* Quartz diorite similar to some outcrops of Precambrian Madera Diorite; includes pendants of Precambrian-X Pinal Schist and is cut by Precambrian-Y diabase and pegmatities associated with Precambrian-Y Oracle Granite of Peterson (1938). Contact with main facies of the Oracle Granite is not exposed; thus it is not known whether the Precambrian-Y age reflects reheating during intrusion of the granite or indicates that the quartz diorite is a mafic rock of Oracle Granite age (1440 ± 20 m.y., Giletti and Damon, 1961; Damon, Livingston, and Erickson, 1962; Livingston and others, 1967; Livingston and Damon, 1968; Silver, 1968). Sample is hypidiomorphic seriate and consists of 55–60 percent euhedral to subhedral, partially altered (epidote and sericite), subequant, zoned plagioclase (An_{36} cores) as much as 3 mm long, 2–5 percent interstitial microcline, 25–30 percent anhedral interstitial quartz with sutured boundaries (grains to 1 mm diameter), 8–10 percent anhedral, interstitial biotite (as much as 1 mm in diameter) that is slightly altered to chlorite and secondary sphene, approximately 1 percent euhedral to subhedral, locally twinned magnetite as much as 1/4 mm in diameter and commonly associated with the biotite, and 1/3 percent stubby apatite associated with the biotite. Sphene and zircon are accessory minerals. For sample chemistry, see table 1. *Analytical data:* K_2O = 8.99 percent, $^*Ar^{40} = 2.8458 \times 10^{-8}$ moles/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 99.1 percent. Collected by N. G. Banks; argon analysis by E. H. McKee at U.S. Geological Survey, Menlo Park, CA.

(biotite) 1438 ± 10 m.y.

2. *TMN-62* K-Ar

Porphyritic quartz latite flow (exposed on The Huerfano; 32°38'52"N, 111°11'09"W; NE¼ SW¼, S14,T9S,R11E, Pinal Co., AZ). *Comments:* Brownish-pink to rose-gray flows and local flow breccias that crop out through Quaternary basin fill and sheet wash in S14,15,22,23, T9S,R11E (see Banks and others, 1977, for location of outcrops). Phenocrysts are 30 percent only slightly altered (clay minerals) oligoclase-andesine as much as 3.5 mm long with abundant zonal inclusions of devitrified glass, 5–9 percent unaltered reddish-brown euhedral biotite as much as 3 mm in diameter, 1–2 percent unaltered euhedral yellowish-brown euhedral hornblende that is partially altered to carbonate and clay minerals, 1–2 percent euhedral to rounded magnetite as much as 1/2 mm in diameter, and 1 percent clotty aggregates of quartz as much as 1/3 mm in diameter. Groundmass is devitrified glass with poorly defined blocky microliths plus hematite and magnetite dust; makes up 60 percent of the rock. Accessory minerals are apatite, sphene, and zircon. *Analytical data:* Hornblende; K_2O = 1.022 percent; $^*Ar^{40} = 3.7177 \times 10^{-11}$ mole/gm; $^*Ar^{40}/\Sigma Ar^{40}$ = 49.9 percent. Biotite; K_2O = 8.62 percent; $^*Ar^{40} = 2.9388 \times 10^{-10}$ mole/gm; $^*Ar^{40}/\Sigma Ar^{40}$ = 59.5 percent. Collected by N. G. Banks, argon analyses by E. H. McKee at U.S. Geological Survey, Menlo Park, CA.

(hornblende) 25.1 ± 0.4 m.y.
(biotite) 23.5 ± 0.4 m.y.

3. *TMN-92* K-Ar

Porphyritic quartz latite flow (in volcanic section near Chief Butte; 32°37'15"N, 111°03'15"W; SW¼ NE¼, S25,T9S,R12E, Pinal Co., AZ). *Comments:* Rose-gray flow in upper part of volcanic sequence (Banks and others, 1977). Phenocrysts are 3–5 percent euhedral oligoclase-andesine as much as 2 mm long and locally partially altered to carbonate, sericite and clay minerals, 1–2 percent euhedral reddish-brown fresh but magnetite-dusted biotite as much as 1 mm in diameter, <1 percent euhedral to anhedral, partially glomerocrystic magnetite as much as 1/2 mm in diameter, and 1–2 percent irregular clotty aggregates of quartz. Groundmass is devitrified glass with pilotaxitic texture and vermicular to rod-shaped flow-alined crystallites (up to 10 percent of the rock) and irregularly distributed but locally abundant hematite and magnetite dust. Accessory minerals are apatite and zircon. Sample is petrographically identical to the chemically analyzed sample (TMN -56, table 1). *Analytical data:* K_2O = 8.43 percent.

$*Ar^{40}$ = 3.2636 x 10^{-10} mole/gm; $*Ar^{40}/\Sigma Ar^{40}$ = 51.4 percent. Collected by N. G. Banks, argon analysis by E. H. McKee at U.S. Geological Survey, Menlo Park, CA.

(biotite) 26.7 ± 0.5 m.y.

4. *UAK 75-86* K-Ar

Porphyritic sphene-bearing granodiorite, slightly foliated at sample site (32°32′52″N, 111°01′55″W; NW¼ SW¼ S20,T10S,R13E, Pinal Co., AZ). *Comments:* Granodioritic facies of pluton of Chirreon Wash (Banks, 1978); oldest exposed pluton of Tortolita Mountains metamorphic core complex; pluton has syenodioritic to quartz dioritic border facies and also porphyritic quartz monzonitic facies; pluton is locally cataclastically deformed and intruded by abundant pegmatite dikes. Sample is seriate porphyritic to hypidiomorphic seriate with about 40 percent euhedral to subhedral oligoclase-andesine as much as 10 mm long, 10–15 percent euhedral to anhedral K-feldspar as much as 30 mm long, 25 percent subhedral to anhedral quartz as much as 7 mm in diameter, 16 percent biotite as much as 8 mm in diameter, 4 percent hornblende as much as 4 mm long, and 1–2 percent sphene as much as 3 mm long. Chlorite and epidote replace part of the biotite and most of the hornblende; feldspars are slightly to moderately saussuritized. Accessory minerals are apatite and zircon. *Analytical data:* K_2O = 8.722 percent, $*Ar^{40}$ = 3.1675 x 10^{-10} moles/gm; $*Ar^{40}/\Sigma Ar^{40}$ = 80.9 percent. Collected by S. B. Keith, argon analysis by M. Shafiqullah and P. E. Damon at University of Arizona, Tucson, AZ.

(biotite) 25.1 ± 0.5 m.y.

5. *UAK 75-87 (TMN-83; USGS)* K-Ar

Porphyritic quartz monzonite dike with chilled selvage (in Bass Canyon; 32°31′54″N, 111°03′24″W; NW¼ SE¼ S25,T10S,R12E, Pinal Co., AZ). *Comments:* Porphyritic to equigranular quartz monzonite with gray, chilled, flow-banded selvage; dikes are *en echelon*, crosscut foliated and lineated granitic rock, but are themselves unfoliated. Dike centers are composed of 25–30 percent subhedral to anhedral zoned unaltered plagioclase (An_{40} core, An_{20} rims) as much as 3 mm long, 8–10 percent subhedral to anhedral unaltered orthoclase-microcline as much as 3 mm long, 10–12 percent subhedral to anhedral quartz as much as 3 mm in diameter, 5 percent euhedral to anhedral unaltered biotite as much as 1–1/3 mm in diameter, rare subhedral hornblende as much as 1 mm long, and as much as 1/3 percent euhedral to anhedral magnetite as much as 1/3 mm in diameter; relative to the rock, the aplitic groundmass consists of 15 percent plagioclase, 15 percent K-feldspar, 16 percent quartz, and 1 percent biotite. Accessory minerals (apatite, sphene, zircon, and allanite) are much larger and more abundant (cumulative 1–1/2 percent) in the dike center than in the dike selvage. Chemically analyzed sample is from dike selvage (TMN-83E, table 1). *Analytical data:* K_2O = 9.011 percent; $*Ar^{40}$ = 3.1290 x 10^{-10} mole/gm; $*Ar^{40}/\Sigma Ar^{40}$ = 86.6 percent. Date sample collected by S. B. Keith; chemically analysed sample collected by N. G. Banks; argon analysis by M. Shafiqullah and P. E. Damon at University of Arizona, Tucson, AZ.

(biotite) 24.0 ± 0.5 m.y.

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