$^{40}Ar/^{39}Ar$ ages of igneous rocks in the Railroad Valley, to Pioche Transect

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$^{40}Ar/^{39}Ar$ AGES OF IGNEOUS ROCKS IN THE RAILROAD VALLEY TO PIOCHE TRANSECT

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We present here 14 new $^{40}Ar/^{39}Ar$ dates from tuffs, flow rocks and a stock in the region between Pioche and Railroad Valley in east-central Nevada (fig. 1). These dates establish the ages of previously undated units or test rock-unit correlations between ranges. The significance of individual ages is discussed in the sample descriptions. However, we will discuss further the regional significance of some ages elsewhere in conjunction with complete descriptions of the geology.

The principal purpose of this paper is to provide complete analytical data (table 1 and appendix A) and evaluate the data quality. The data are sufficiently good that a credible age can be deduced for every sample dated.

METHODS

Samples were crushed and sieved to uniform grain sizes and a size range was selected that yielded the largest possible individual (not composite) grains. Standard physical methods were used to extract mineral separates of biotite, sanidine, hornblende, and plagioclase with an estimated purity of >99.9%. The physical separations were performed at the mineral separation facility at the University of Utah.

The whole rock samples were prepared by crushing, grinding and then washing them with a dilute solution of $HN0_3$. This material was then ground with a mortar and pestle and sieved to insure a limited fragment size range.

The mineral separates and whole rocks were encapsulated in tin foil, sealed in silica vials, and irradiated in the nuclear reactor at the Phoenix Memorial Laboratory at the University of Michigan. An intralaboratory standard, SBG-7, was used as an irradiation monitor. It was calibrated to a widely accepted mineral standard, MMhb-1 (Alexander and others, 1978). Irradiation packages were heavily monitored with a monitor at the top and bottom of each vial and internal monitors every 1 or 2 samples.

Isotope measurements were made at the University of Maine. Procedures used in the isotope analyses are described by Hubacher and Lux (1987). Individual ages and errors, calculated using equations from Dalrymple and others (1981), are 2σ plus 0.5% uncertainty in the **J** value (measure of the neutron fluence). This method of calculating uncertainty easily permits the data presented here to be directly compared with data collected at other laboratories. The IUGS decay constants and the recommended isotopic compositions of **K** were used in the date calculations (Steiger and Jäger, 1977).

Total gas, plateau and isochron ages are reported. A plateau age is the mean of ages from increments that are considered concordant. The criteria used for determining plateaus are from Fleck and others (1977). The critical value test (Dalrymple and Lanphere, 1969) was used to test concordance between successive increments using only analytical uncertainties. The plateau age was considered reliable if the plateau contained >50% of the total gas released, consisted of four or more increments, and the plateau date was consistent with the isochron date. The last criterion is an independent check that the only source of nonradiogenic ^{40}Ar in the sample was atmospheric Ar in which $^{40}Ar/^{36}Ar$ = 295.5. The isochron age was computed from gas increments in the sample by the isotope correlation method. $^{40}Ar/^{36}Ar$ values between 285 and 305 were considered acceptable. The total gas age is a weighted average based on the total amount of ^{39}Ar in each increment.

SAMPLE DESCRIPTION AND DISCUSSION

Samples 5.385 and 5.385-II

Plateau age: 32.38 ± 1.21

This mafic flow rock is intercalated with conglomerate and freshwater limestone that lies at the base of the Tertiary sequence in the North Pahroc Range, Lincoln County, Nevada (fig. 2). This assemblage of conglomerate and limestone is informally called the formation of Rattlesnake Spring (Taylor and others, 1989; Taylor, 1990; Taylor and Bartley, 1992). The flow rock is dark gray to black, weathers gray to brown and contains blocky plagioclase, pyroxene and olivine phenocrysts. Locally, it is vesicular, autobrecciated or flow banded.

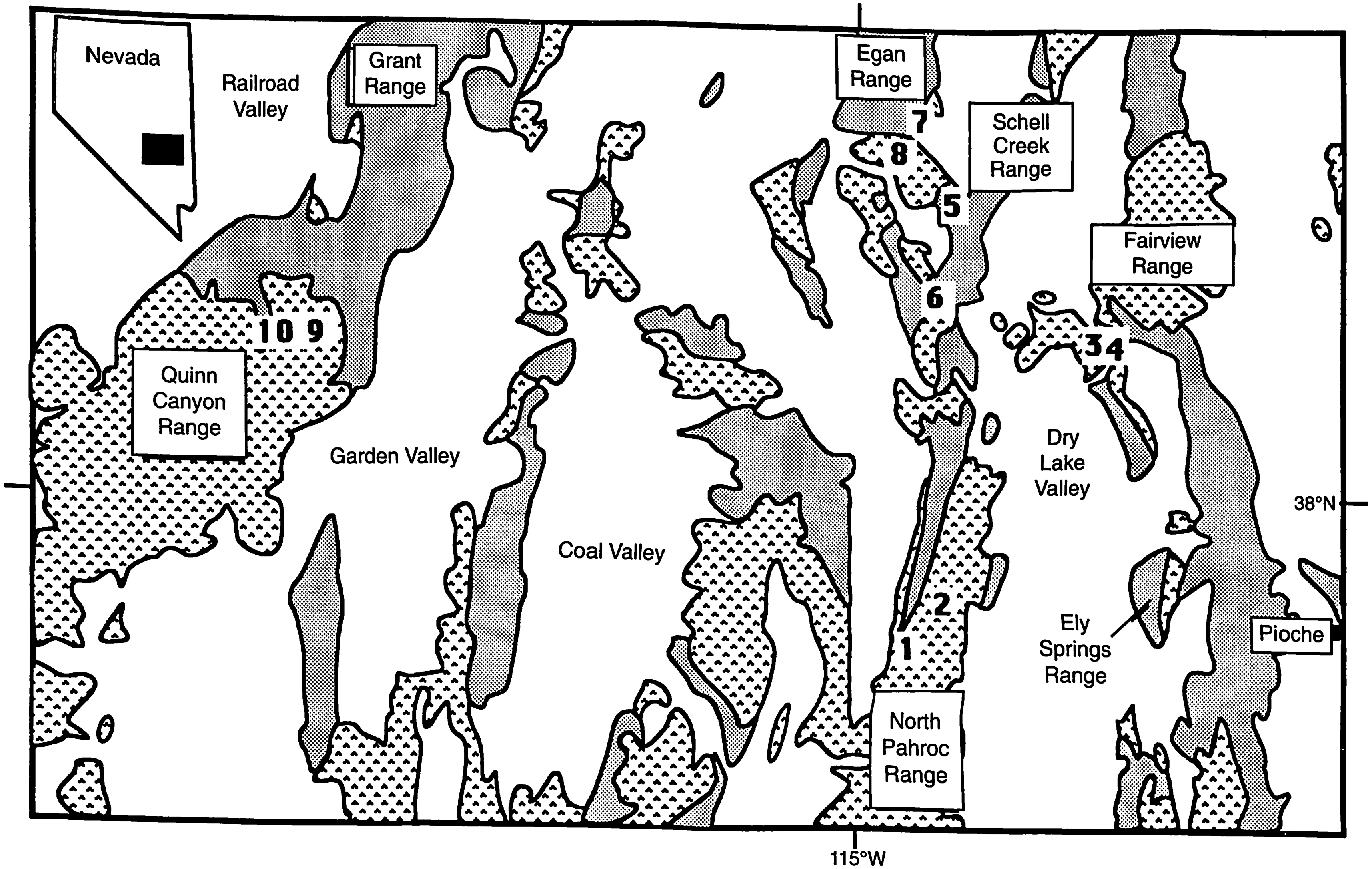

FIGURE 1. Map showing generalized location of samples for which dates are reported here. Numbers show approximate locations of samples: 1 = 5.385, 2 = 4.139-659, 3 = FVW25.1, 4 = FVW26.1, 5 = SKS, 6 = SK4.7, 7 = SEG3.2, 8 = SEG1.1, 9 = QC1.1,10 = QC44.1. Inverted v's = Tertiary volcanic rocks, stipple = Paleozoic rocks, white = Quaternary sedimentary deposits.

TABLE 1. Rock units, locations and dates.

Sample no.	Rock type	Unit name	Location	Latitude ° ′ ″N	Longitude ° ′ ″W	Material dated	Plateau age (Ma)	Isochron age (Ma)	$^{40}Ar/^{36}Ar$	Total gas age (Ma)	Sample no.
5.385	mafic flow rock	formation of Rattlesnake Spring	North Pahroc Range	37 49 51	114 57 02	whole rock	32.38 ± 1.21	32.2 ± 1.21	297.3 ± 1.2	31.98 ± 0.75	5.385
5.385-II	mafic flow rock	formation of Rattlesnake Spring	North Pahroc Range	37 49 51	114 57 02	whole rock	no plateau	32.8 ± 0.8	291.0 ± 11.5	32.17 ± 0.45	5.385-II
4.139-659	ash-flow tuff	tuff of Deadman Spring	North Pahroc Range	37 54 52	114 55 09	sanidine	29.90 ± 0.25	29.8 ± 0.2	283.8 ± 2.2	29.62 ± 0.46	4.139-659
4.139-659	ash-flow tuff	tuff of Deadman Spring	North Pahroc Range	37 54 52	114 55 09	biotite	31.9 ± 0.5	33.4 ± 0.5	254.7 ± 9.5	29.58 ± 0.43	4.139-659
FVW25.1	ash-flow tuff	tuff of Deadman Spring	Fairview Range	38 09 28	114 43 41	sanidine	30.22 ± 0.28	30.2 ± 0.3	285.6 ± 2.8	30.12 ± 1.13	FVW25.1
FVW26.1	ash-flow tuff	tuff of Silverhorn Wash	Fairview Range	38 08 59	114 42 28	sanidine	31.83 ± 0.29	31.8 ± 0.3	281.7 ± 5.8	31.74 ± 0.35	FVW26.1
FVW26.1	ash-flow tuff	tuff of Silverhorn Wash	Fairview Range	38 08 59	114 42 28	biotite	31.60 ± 0.41	31.7 ± 0.4	272.4 ± 7.5	31.38 ± 0.43	FVW26.1
SKS	granite porphyry	Silver King stock	southern Schell Creek Range	38 16	114 53 30	hornblende	33.52 ± 0.49	33.7 ± 0.3	290.0 ± 1.9	33.45 ± 1.92	SKS
SK4.7	rhyolite	Burnit Peak rhyolite	southern Schell Creek Range	38 10 45	114 55 30	plagioclase (~OR5)	21.58 ± 1.52	21.9 ± 0.8	297.9 ± 11.6	22.39 ± 1.40	SK4.7
SEG3.2	ash-flow tuff	unnamed vitrophyric dacitic tuff	southern Egan Range	38 21 25	114 55 30	sanidine	29.74 ± 0.54	29.6 ± 0.4	295.4 ± 8.4	29.71 ± 0.49	SEG3.2
SEG1.1	ash-flow tuff	rhyolitic tuff of Shingle Pass type	southern Egan Range	38 19 30	114 58 06	sanidine	27.09 ± 0.22	27.09 ± 0.19	294.9 ± 2.6	27.09 ± 0.32	SEG1.1
QC1.1	ash-flow tuff	tuff of Cherry Creek	Quinn Canyon Range	38 10 5	115 36 24	biotite	26.94 ± 0.32	26.7 ± 0.3	294.2 ± 0.3	26.75 ± 1.10	QC1.1
QC44.1	rhyolite	unnamed	Quinn Canyon Range	38 09 15	115 38 29	plagioclase (~OR5)	no plateau	23.0 ± 0.8	294.4 ± 25.7	24.07 ± 0.89	QC44.1

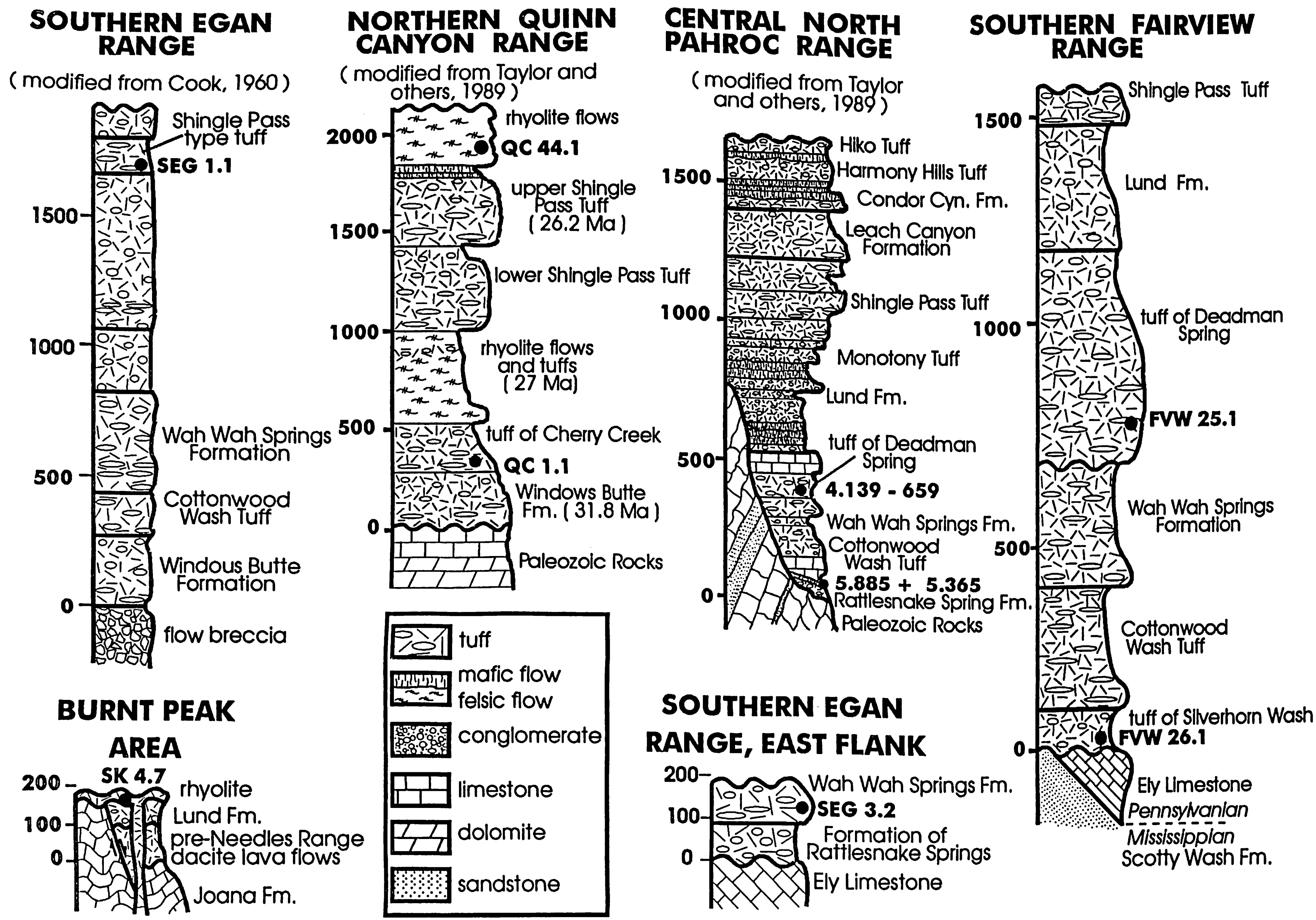

FIGURE 2. Stratigraphic columns showing approximate positions of samples. *Reported dates are $^{40}Ar/^{39}Ar$ dates from Taylor and others (1989).*

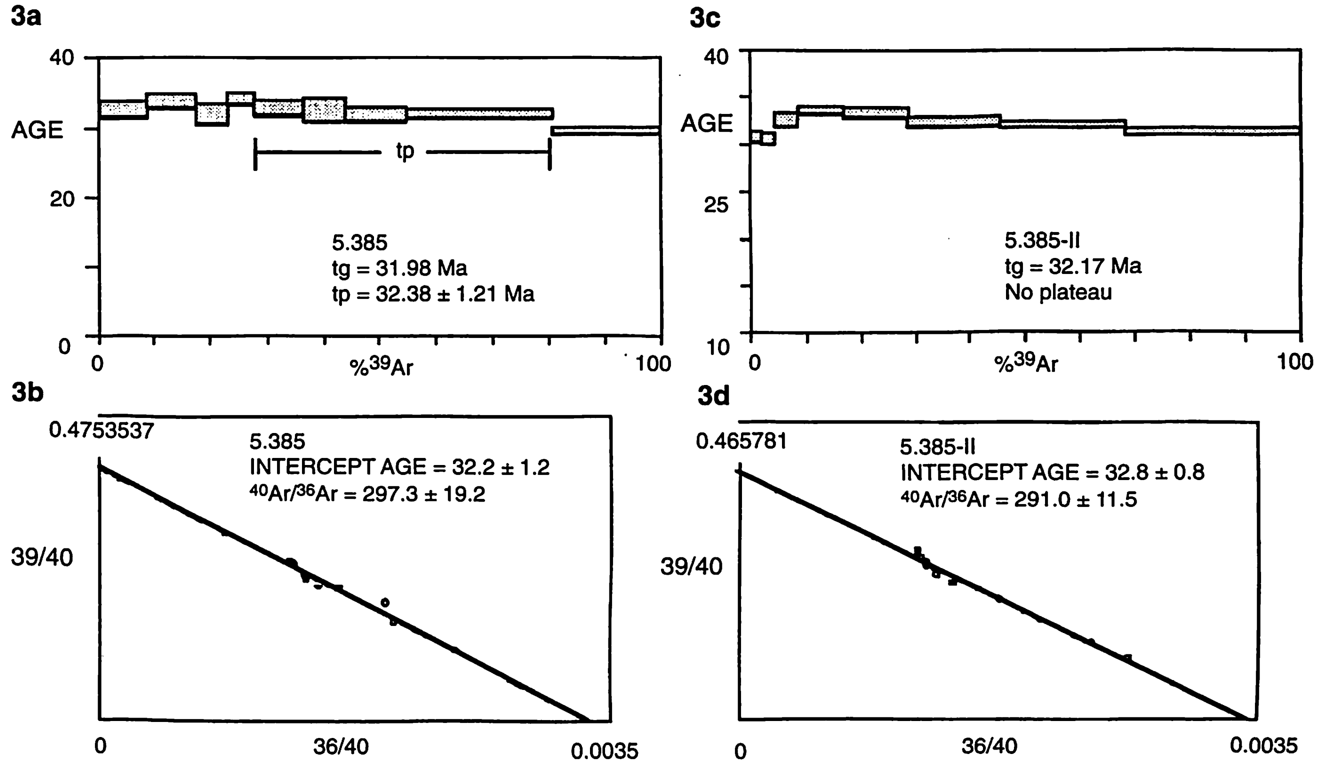

FIGURE 3. (a) Incremental release spectrum from whole rock sample of 5.385. (b) Correlation diagram for sample 5.385. (c) Incremental release spectrum for sample 5.385-II. (d) Correlation diagram for sample 5.385-II. tp = plateau age, tg = total gas age.

Two specimens were dated from the same sample. One yielded a 32.38 ± 1.21 Ma plateau age that agrees within uncertainty with the isochron age, 32.2 ± 1.2, from that sample (table 1; figs. 3a and 3b). The other yielded no plateau and a 32.8 ± 0.8 Ma isochron age (figs. 3c and 3d). The $^{40}Ar/^{36}Ar$ for both specimens matched the radiogenic value within uncertainty. The weighted average of the three values is 32.6 ± 0.34 Ma and the weighted average of the isochron ages is 32.61 ± 0.44 Ma. Therefore, 32.6 Ma is accepted as the age of the flow rock.

This age indicates that the formation of Rattlesnake Spring is Oligocene in age, consistent with Oligocene to Miocene pollen reported from the associated freshwater limestone by Tschanz and Pampeyan (1970). Therefore, the normal fault bounded basin in which the formation was deposited most likely also formed in the Oligocene, as previously suggested by Taylor 1990; Taylor and Bartley, 1992; Axen and others, 1993. Taylor and Bartley (1992) further interpreted the normal fault that bounds this Oligocene basin, the Seaman breakaway, to form the western margin of a regional-scale, premiddle Oligocene extensional detachment system. This new age reinforces the early Oligocene age of the oldest known Cenozoic crustal extension in the area of the North Pahroc Range.

Sample 4.139-659

Plateau ages: 29.90 ± 1.21 Ma and 31.9 ± 0.5 Ma

This sample was collected in the North Pahroc Range from a unit informally called the tuff of Deadman Spring (table 1; figs. 1 and 2) (Taylor, 1990). The unit is a pink-, gray- or tan-weathering pink-gray to tan, lightly to moderately welded rhyolitic ash-flow tuff with volcanic and sandstone lithic fragments. This tuff exhibits significant vertical variation in percent phenocrysts, percent pumice and ratios of phenocryst types. Near the middle of the unit the phenocryst mode is 44% purple or gray quartz up to 3.2 mm in diameter, but which average 2 mm in diameter; 33% alkali feldspar up to 3 mm across; 19% plagioclase up to 0.4 mm across; 4% biotite up to 0.8 mm across (rare near the top); and trace oxides up to 0.6 mm across. Modal quartz and alkali feldspar increase toward the top and the base of the unit. Both the quartz and the feldspar crystals are terminated and locally the quartz is a darker color than the alkali feldspar.

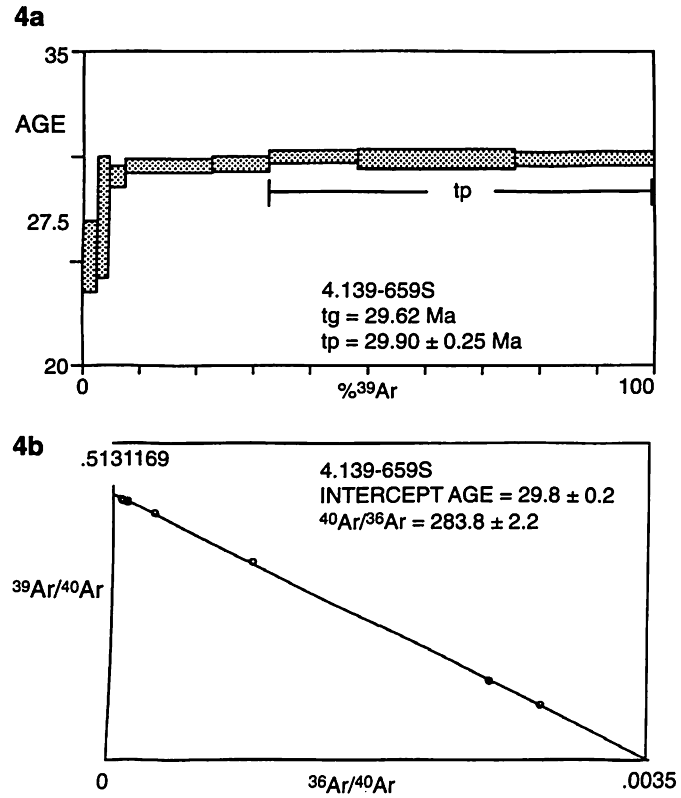

FIGURE 4. (a) Incremental release spectrum and (b) isotope correlation diagram for the sanidine mineral separate from sample 4.139-659. tp = plateau age, tg = total gas age.

The plateau ages of 29.90 ± 0.25 Ma on sanidine and 31.9 ± 0.5 Ma on biotite do not agree within uncertainty (table 1; figs. 4 and 5). We accept the sanidine plateau age (29.90 Ma) as the best age for this unit because sanidine dates are more reliable than biotite dates due to the common alteration of biotite to chlorite, the $^{40}Ar/^{36}Ar$ ratio is unreasonably low for the biotite separate (table 1) and because the sanidine plateau age agrees within uncertainty with the sanidine isochron age 29.8 ± 0.2 Ma (fig. 4).

Mapping by Taylor (1990) showed that this felsic tuff lies stratigraphically below the Lund Tuff and higher than the Wah Wah Springs Formation, which both are regionally recognized ignimbrites of the Needles Range Group (Best and others, 1973; Best and Grant, 1987). Best and Grant (1987) assigned an age of 29.5 Ma age to the Wah Wah Springs Formation, but our data from the overlying tuff of Rattlesnake Spring suggest a minimum age nearer 29.9 Ma. The published age of the Wah Wah Springs Formation was based on averaging a number of analyses, many of which are old conventional K/Ar ages. We consider our $^{40}Ar/^{39}Ar$ results to be more reliable, and therefore suggest that the age of the Wah Wah Springs Formation may need to be revised upward by a few hundred thousand years.

Sample FVW25.1

Plateau age: 30.22 ± 0.28 Ma

This sample was collected in the Fairview Range from a unit correlated in the field with the tuff of Deadman Spring, based on outcrop appearance, hand sample attributes, phenocryst assemblage, and stratigraphic position between the Wah Wah Springs Formation and the Lund Tuff (figs. 1 and 2). However, in the Fairview Range the tuff of Deadman Spring is thicker (at least 300 m) and more densely welded than in the North Pahroc Range (Bartley, unpublished mapping).

The sanidine mineral separate yielded a plateau age of 30.22 ± 0.28 Ma and an isochron age of 30.2 ± 0.2 Ma (table 1, fig. 6). The plateau contains >80% of the gas, and the plateau age and isochron age are essentially identical. The $^{40}Ar/^{36}Ar$ is somewhat below the atmospheric value but, given the otherwise consistent results, the date is considered reasonable.

An age of 30.2 ± 0.2 Ma agrees within uncertainty with the age of sample 4.139-659 and therefore corroborates our field correlation of this unit from the North Pahroc to the Fairview Range. Our new ages indicate

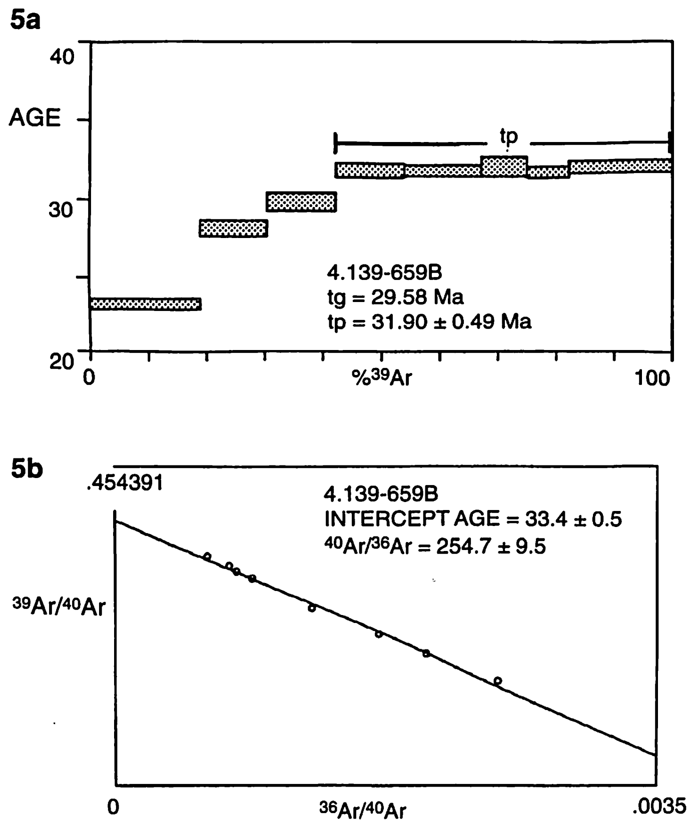

FIGURE 5. (a) release spectrum and (b) correlation diagram for the biotite separate from sample 4.139-659. tp = plateau age, tg = total gas age.

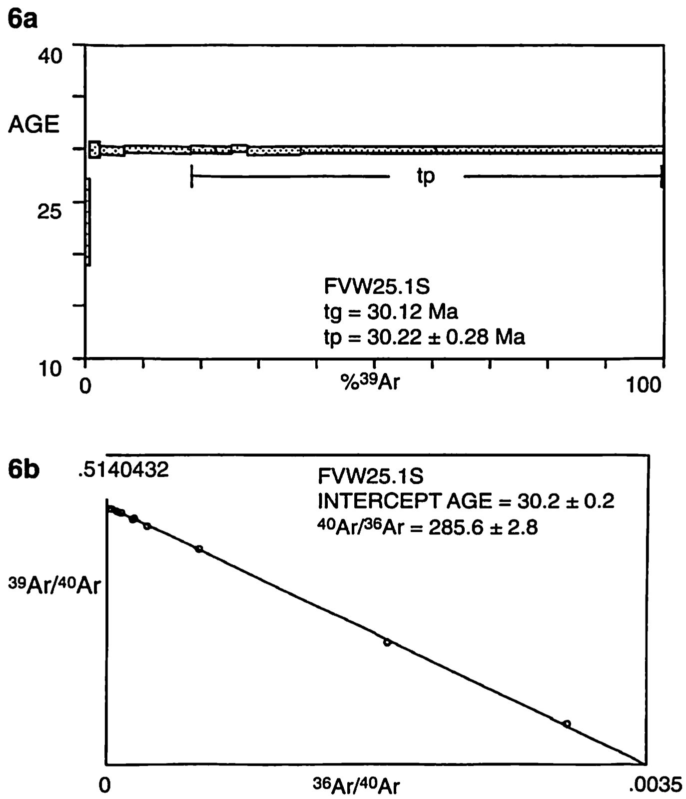

FIGURE 6. (a) Incremental release spectrum and (b) correlation diagram for the sanidine mineral separate from sample FVW25.1. tp = plateau age, tg = total gas age.

that this unit is Oligocene, not Miocene as has been previously assumed (cf., Ekren and others, 1977).

As yet, no similar tuff was observed at this stratigraphic level in any other range in the region. The increase in thickness and degree of welding from the North Pahroc Range to the Fairview Range, which lies at the western end of the Indian Peak caldera complex (source of the Needles Range Group ignimbrites; Best and others, 1989), and its stratigraphic position among Needles Range Group tuffs, suggest that the tuff of Deadman Spring also may have been erupted from the Indian Peak caldera complex. If so, the tuff of Deadman Spring would appear to be a new formation in the Needles Range Group.

Sample FVW26.1

Plateau ages: 31.83 ± 0.29 and 31.60 ± 0.41 Ma

This unit is here informally called the tuff of Silverhorn Wash, for exposures in Silverhorn Wash in the Fairview Range from which this sample was collected (table 1, figs. 1 and 2). The unit is a rhyolitic or rhyodacitic ash-flow tuff that contains 20-30% phenocrysts including, in order of decreasing abundance, plagioclase, quartz, sanidine, and biotite. This tuff is the basal ignimbrite in the Tertiary section in this location and therefore marks the onset of pyroclastic volcanism in the area. The tuff of Silverhorn Wash underlies the regionally widespread Cottonwood Wash Tuff, which was assigned an age of 30.6 Ma by Best and Grant (1987).

The plateau ages determined on biotite, 31.60 ± 0.41 Ma, and sanidine, 31.83 ± 0.29 Ma, agree within uncertainty (figs. 7 and 8). Although the $^{40}Ar/^{36}Ar$ for biotite is slightly low, the isochron ages on biotite, 31.7 ± 0.4 Ma, and sanidine, 31.8 ± 0.3 Ma, agree within uncertainty (figs. 7 and 8) both with each other and with the plateau ages. This internal consistency indicates an age for the tuff of Silverhorn Wash of 31.7 Ma, consistent with its stratigraphic position.

This sample was analyzed in part to test lithologic correlation of the tuff of Silverhorn Wash with a similar, unnamed ignimbrite at the base of the Tertiary section in the Ely Springs Range (fig. 1). The basal ignimbrite in the Ely Springs Range yielded an $^{40}Ar/^{39}Ar$ plateau age on biotite of 31.3 ± 0.4 Ma (sample 4109-2B of Taylor and others, 1989), which agrees within uncertainty with the age reported here. Therefore, we suggest that the basal tuff in the Ely Springs Range probably is equivalent to the tuff of Silverhorn Wash.

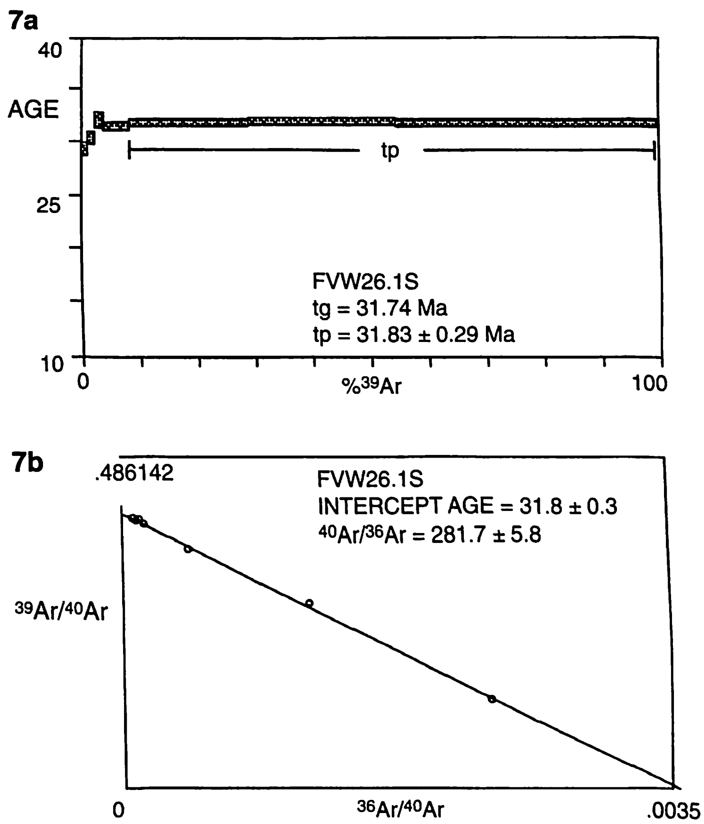

FIGURE 7. (a) Incremental release spectrum and (b) correlation diagram for the sanidine mineral separate from sample FVW26.1. tp = plateau age, tg = total gas age.

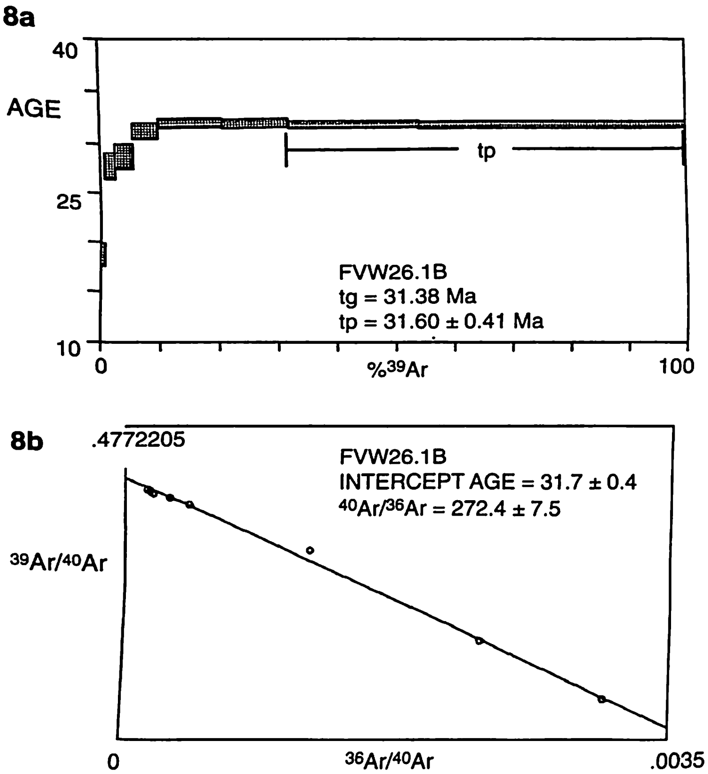

FIGURE 8. (a) Incremental release spectrum and (b) correlation diagram for the biotite mineral separate from sample FVW26.1. tp = plateau age, tg = total gas age.

Sample SKS

Plateau age: 33.52 ± 0.49 Ma

The Silver King stock, located in the southern Schell Creek Range, is composed of porphyritic granite containing phenocrysts of plagioclase, quartz, orthoclase, biotite, hornblende, and chlorite up to 5 mm in diameter (fig. 1). Quartz and feldspar form the largest grains. Glomerocrysts of plagioclase, hornblende or plagioclase and biotite are common. Many of the plagioclase phenocrysts are zoned and/or poikolitic. The hornblende is somewhat altered to actinolite. The groundmass consists mainly of plagioclase, orthoclase, quartz, and hornblende crystals that are typically 0.1 to 0.05 mm across. Some of the groundmass orthoclase has a radiating and fibrous habit.

Hornblende from the Silver King stock yielded a plateau age 33.52 ± 0.49 Ma that agrees within uncertainty with the isochron age, 33.7 ± 0.3 Ma (table 1, fig. 9). This agreement, combined with a reasonable $^{40}Ar/^{36}Ar$ value, lead us to accept an age of 33.5 Ma. This is slightly older than the biotite K/Ar age from the stock of 32.9 reported by Armstrong (1970; corrected to IUGS constants). Both the rock textures and the agreement between hornblende and biotite ages imply rapid cooling, suggesting that the stock crystallized near 33.5 Ma.

This is a geologically plausible age for the stock because of its proximity to the Indian Peak caldera complex, to which the stock could be genetically related.

Sample SK4.7

Plateau age: 21.58 ± 1.52 Ma

This sample was collected from a small lava flow (area <1 km^2) erupted from a small volcanic plug located 2 km northwest of a larger but otherwise similar rhyolite plug in the southern Schell Creek Range that forms Burnt Peak (figs. 1 and 2). The dated sample is flow-banded vitrophyre that contains about 10% phenocrysts including, in order of decreasing abundance, plagioclase (approximately $Ab_{60}An_{35}Or_5$, determined by microprobe analyses at the University of Utah), green clinopyroxene, and opaque minerals. All phenocrysts are euhedral to subhedral and occur in places as glomerocrysts. Plagioclase phenocrysts range up to 2 mm across; some of the larger crystals are sieved with glass inclusions, but most are inclusion-free and unaltered.

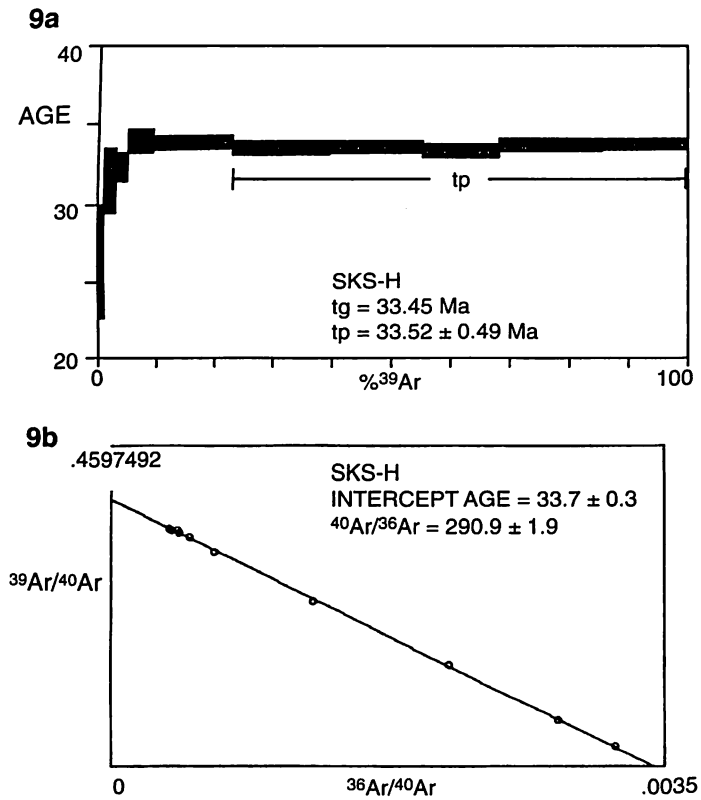

FIGURE 9. (a) Incremental release spectrum and (b) correlation diagram for the hornblende mineral separate from sample SKS. tp = plateau age, tg = total gas age.

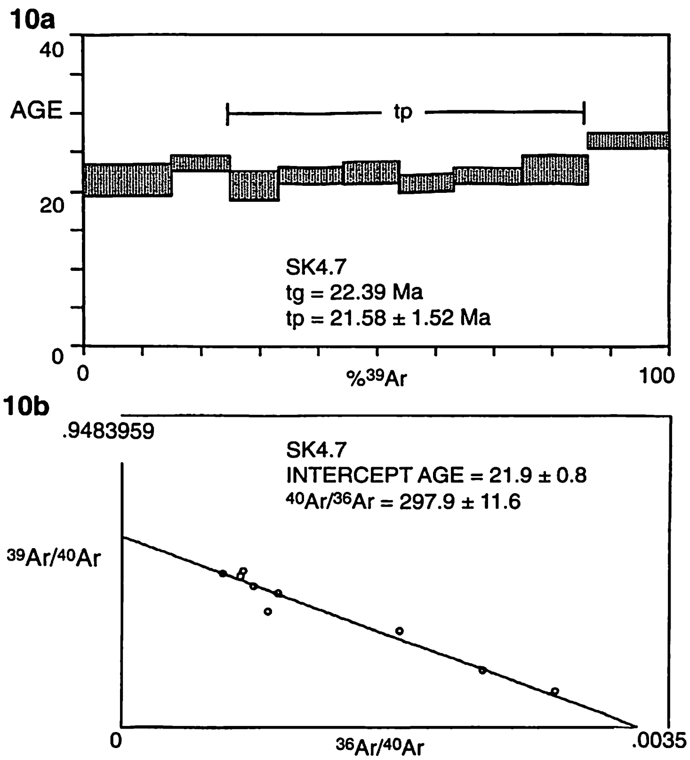

FIGURE 10. (a) Incremental release spectrum from plagioclase mineral separate of sample SK4.7 (b) Correlation diagram from the same separate. tp = plateau age, tg = total gas age.

Analysis of a plagioclase separate yielded plateau and isochron ages that agree within uncertainties (21.58 ± 1.52 Ma and 21.9 ± 0.8 Ma, respectively; table 1, fig. 10). The $^{40}Ar/^{36}Ar$ value of 297.9 ± 11.6 matches the atmospheric value. Therefore, we accept an age for this flow rock of about 22 Ma.

We interpret this date probably to resemble those of other rhyolitic lava flows and plugs, including Burnt Peak, in the southern Schell Creek Range. The dated flow and several similar flows overlap early normal faults (Bartley, unpublished mapping), indicating that extension began prior to 21.6 Ma in the southern Schell Creek Range.

Sample SEG 3.2

Plateau age: 29.74 ± 0.54 Ma

This sample of pale gray, vitrophyric dacitic tuff was collected from exposures on the eastern flank of the southern Egan Range (figs. 1 and 2). The sample contains approximately 25% phenocrysts of, in order of decreasing abundance, plagioclase, biotite, hornblende, quartz, sanidine, and clinopyroxene.

Only sanidine was analyzed and yielded a plateau age on >80% of the gas of 29.74 ± 0.54 Ma (fig. 11a), in close agreement with the isochron age of 29.6 ± 0.4 Ma (fig. 11b). We accept an age for this unit of 29.74 ± 0.54 Ma.

This rock broadly resembles Needles Range Group dacitic ignimbrites, but is not a clear lithologic match for any one of them. It also generally resembles the dacitic Monotony Tuff, based on low hornblende abundance (about 2 vol.% of the rock) compared to typical Wah Wah Springs Formation, the presence of both sanidine and clinopyroxene, and the lack of modal sphene. However, the measured age clearly is too old for the Monotony Tuff (e.g., Taylor and others, 1989; Best and Christiansen, 1991). The location of the outcrop makes it more likely that this is an atypical exposure of the Wah Wah Springs Formation. The 29.7 ± 0.54 Ma age from this sample agrees well with the 29.5 Ma age assigned to the Wah Wah Springs Tuff by Best and Grant (1987) although, as noted above, the dates reported here from the tuff of Deadman Spring suggest that the actual age of the Wah Wah Springs Formation may be closer to 30 Ma, still within the permissible age range of SEG 3.2.

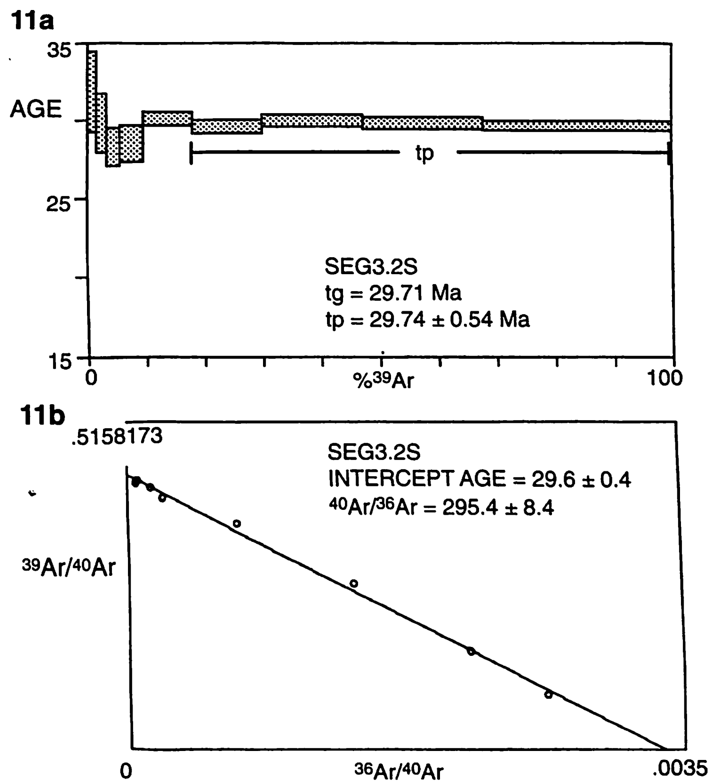

FIGURE 11. (a) Incremental release spectrum from sample SEG3.2 on sanidine mineral separate. (b) Correlation diagram from same sample. tp = plateau age, tg = total gas age.

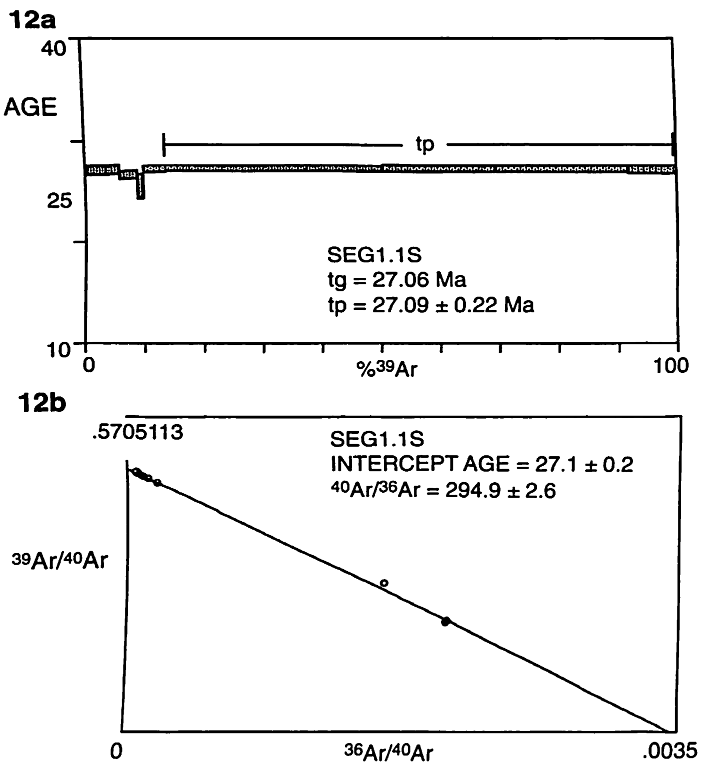

FIGURE 12. (a) Incremental release spectrum from a sanidine mineral separate from sample SEG1.1. (b) Correlation diagram from same data set. tp = plateau age, tg = total gas age.

Sample SEG 1.1

Plateau age: 27.09 ± 0.22 Ma

This sample was collected in the southern Egan Range from a densely welded, devitrified rhyolite ignimbrite that in outcrop and hand specimen resembles the Shingle Pass Tuff (figs. 1 and 2). This tuff contains about 15% phenocrysts, more than 95% of which are sanidine and plagioclase in a roughly 3:1 ratio. The remaining phenocrysts include minor quartz and anhedral fayalite that is locally intergrown with pale green clinopyroxene.

The plateau age from sanidine includes >85% of the ^{39}Ar gas released (fig. 12a) and gives a date of 27.09 ± 0.22 Ma (table 1). This precisely matches the 27.09 ± 0.19 Ma isochron age (fig. 12b). The $^{40}Ar/^{36}Ar$ intercept has an atmospheric value (tables 1 and 2). We therefore accept an age of 27.1 ± 0.2 Ma for this rock unit.

In spite of similar age and petrography to the Shingle Pass Tuff (Cook, 1965; Taylor and others, 1989; Taylor, 1990; Best and Christiansen, 1991), the correlation of this tuff is unclear. The outcrop sampled apparently does not carry a magnetic remanence consistent with any known cooling unit of the Shingle Pass Tuff (S. Gromme, personal communication, 1993). We therefore leave the correlation of this tuff undecided.

Sample OC1.1

Plateau ages: 26.70 ± 0.39 and 26.94 ± 0.32 Ma

This sample is from the second oldest Tertiary volcanic unit that has been mapped in the Quinn Canyon Range and southernmost Grant Range (figs. 1 and 2; see also Taylor and others, 1989, fig. 2). Bartley and Gleason (1990) informally named this -230 m thick unit the tuff of Cherry Creek. Gleason (1989) described the tuff of Cherry Creek as a yellow weathering, densely welded, lithic-crystal tuff with about 27% phenocrysts. Phenocrysts include 37% quartz, 29% plagioclase, 11% sanidine, 2% biotite, 1% amphibole and trace clinopyroxene.

Volcanic and carbonate lithic fragments make up about 10% of the rock (Gleason, 1989).

The tuff of Cherry Creek overlies the ca. 31.3 Ma Windous Butte Formation, and underlies an unnamed sequence of rhyolitic lava flows and unwelded tuffs that in turn underlie the Shingle Pass Tuff (Taylor and others, 1989, fig. 2). Biotite from a rhyolite lava flow directly

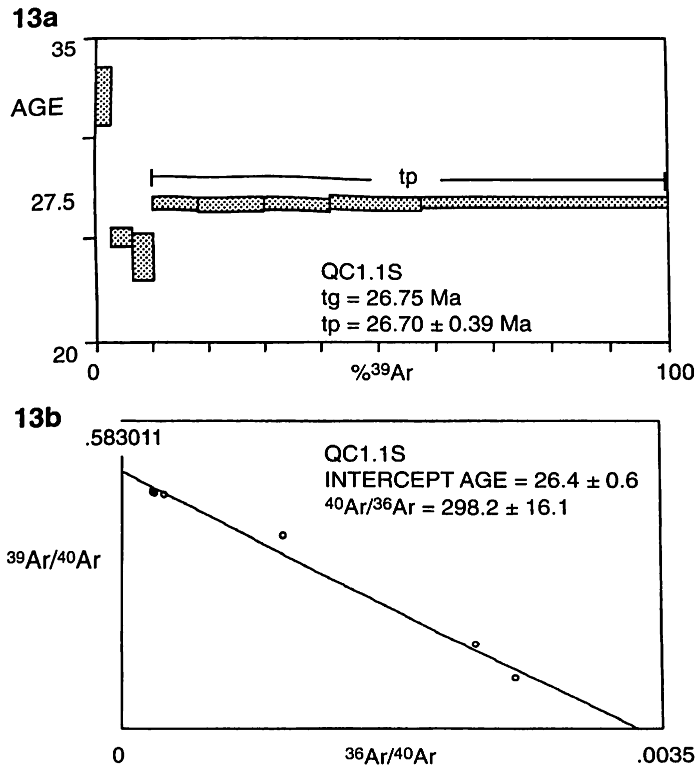

FIGURE 13. (a) Incremental release spectrum from sanidine separate from sample QC1.1. (b) Correlation diagram from same separate. tp = plateau age, tg = total gas age.

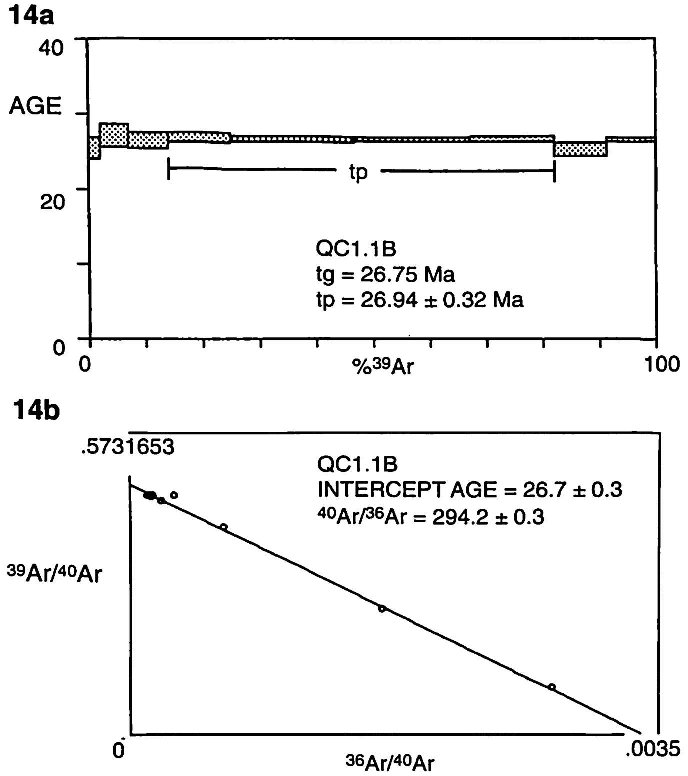

FIGURE 14. (a) Incremental release spectrum from the biotite mineral separate from sample QC1.1. (b) Correlation diagram from the same mineral separate. tp = plateau age, tg = total gas age.

overlying the tuff of Cherry Creek gave a plateau age of 27.1 ± 0.4 Ma (Taylor and others, 1989).

The plateau ages of 26.70 ± 0.39 Ma on sanidine and 26.94 ± 0.32 Ma on biotite from QC1.1 agree within uncertainty (figs. 13a and 14a). Both plateaus contain >80% of the gas released. The isochron ages are concordant with each other and with the plateau ages (figs. 13b and 14b). A weighted average of the plateau ages, 26.72 Ma, is considered the best date for the unit. This age is slightly younger than that we reported from the overlying rhyolite flow, but the two overlap within error, implying that the two rock units are very close in age. As the oldest known volcanic rock units in this area that are locally derived, the ages indicate that volcanism began at about 27 Ma at the large, but as yet poorly known, caldera complex in the Quinn Canyon Range (Ekren and others, 1977; Taylor and others, 1989).

Sample OC44.1

Intercept age: 23.0 ± 0.8 Ma

This sample was collected from an unnamed rhyolite flow in the Quinn Canyon Range (figs. 1 and 2; table 1). The flow lies above the Shingle Pass Tuff and belongs to the highest stratigraphic unit recognized in the northern Quinn Canyon Range (Taylor and others, 1989, fig. 2), and therefore is the youngest known product of the Quinn Canyon volcanic center. The dated sample is a flow-banded vitrophyre containing plagioclase microlites aligned in the glassy matrix and about 5% phenocrysts. The phenocrysts are 90% euhedral to subhedral plagioclase ($Ab_{60}An_{35}Or_5$ by microprobe) ranging up to 2 mm diameter, and 10% anhedral to subhedral green clinopyroxene. The plagioclase is unaltered and free of inclusions.

The incremental-release spectrum from the plagioclase separate does not define a plateau. The monotonic increase of apparent age with temperature suggests diffusive argon loss after crystallization (fig. 15a). The oldest increment age is 26.1 ± 0.3 Ma. The isochron age is 23.0 ± 0.8 Ma with an $^{40}Ar/^{36}Ar$ that matches the atmospheric value. However, the scatter on the correlation diagram is fairly large (table 1, fig. 15).

We consider two alternative interpretations of these data. If the incremental-release spectrum records Ar loss, then the maximum age increment,

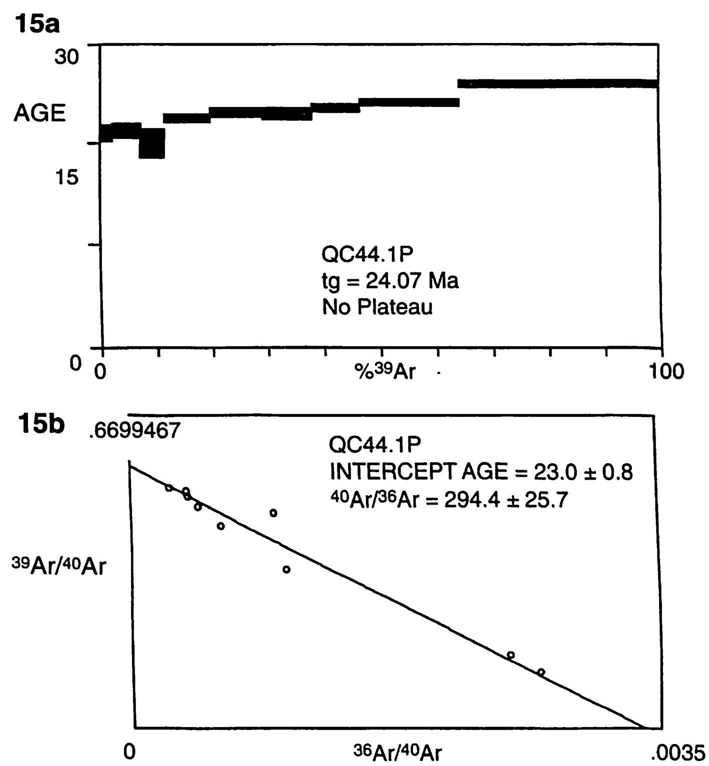

FIGURE 15. (a) Incremental release spectrum from plagioclase mineral separate from sample QC44.1. Age of oldest increment, #9, is 26.1 ± 0.3 Ma. (b) Correlation diagram from the same separate. tg = total gas age.

26.1 Ma, is a minimum age for the rock. This interpretation is stratigraphically permissible because the youngest dated underlying rock unit is the upper cooling unit of the Shingle Pass Tuff, dated in this immediate vicinity at 26.2 ± 0.5 Ma (Taylor and others, 1989). However, in that the oldest known locally derived volcanic rock is dated at about 27 Ma (see above), this requires that the entire volcanic section in the northern Quinn Canyon Range derived from the Quinn Canyon caldera accumulated in about 1 Ma. The other alternative interpretation is that the discordant incremental-release spectrum reflects not Ar loss but internal redistribution of radiogenic Ar within the plagioclase grains. In this case, the isochron age of 23.0 Ma probably is a more accurate age estimate for the rock. This alternative also is stratigraphically permissible, and is favored by close petrographic resemblance of this rock to the rhyolite flow in the southern Schell Creek Range dated here at about 22 Ma (SK4.7). However, we presently have no conclusive way to distinguish between these alternatives.

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APPENDIX A. Analytical data.

TEMP	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	Moles ^{39}Ar	Total (%)	% Radiogenic	K/Ca	Age (Ma)	Uncertainty
Sample #5.385					**J = .007134**				
500	9.12	0.3007	0.0222	148.8	9.0	28.1	1.629	32.74	1.07
550	6.42	0.3308	0.0128	145.7	8.8	41.1	1.481	33.70	1.12
620	4.83	0.4471	0.0079	87.6	5.3	51.9	1.096	31.96	1.27
690	4.80	0.4490	0.0072	78.5	4.8	55.9	1.091	34.21	0.75
760	4.42	0.5700	0.0063	138.5	8.4	58.3	0.859	32.91	1.05
800	4.34	0.5815	0.0061	109.7	6.6	59.1	0.842	32.73	1.58
900	4.04	0.8273	0.0054	201.1	12.2	61.7	0.592	31.84	0.65
1000	4.10	0.9106	0.0056	423.5	25.7	61.1	0.538	32.02	0.37
FUSE	5.44	1.2893	0.0108	317.6	19.2	42.7	0.380	29.65	0.46
TOTAL			1651.0	100.0				31.98	0.75
PLATEAU AGE								32.38	1.21
Sample # 5.385-II					**J = .007117**				
500	10.59	0.2958	0.0277	116.8	1.6	22.8	1.656	30.79	0.72
560	8.23	0.2880	0.0197	169.6	2.4	29.2	1.701	30.63	0.63
680	5.33	0.3557	0.0094	315.2	4.4	48.0	1.377	32.62	0.71
760	4.64	0.4509	0.0068	572.4	8.1	57.1	1.086	33.69	0.42
830	4.35	0.5479	0.0059	819.2	11.6	60.4	0.894	33.44	0.40
930	4.09	0.7093	0.0053	1224.0	17.3	62.4	0.690	32.55	0.49
1030	3.97	0.8110	0.0051	1626.4	22.9	63.6	0.604	32.17	0.42
FUSE	3.81	1.0033	0.0048	2244.4	31.7	64.3	0.488	31.23	0.33
TOTAL			7088.0	100.0				32.17	0.45
No Plateau									
Sample #4.139-659S					**J = .007119**				
650	11.603	0.086	0.0325	36.1	2.5	17.0	5.70	25.21	1.69
730	7.920	0.084	0.0196	29.8	2.0	26.8	5.81	27.09	2.92
810	3.154	0.081	0.0029	39.6	2.7	72.3	6.05	29.06	0.51
950	2.532	0.056	0.0007	225.0	15.4	91.6	8.71	29.53	0.33
1050	2.407	0.030	0.0002	144.5	9.9	96.6	16.10	29.62	0.36
1100	2.414	0.026	0.0002	228.6	15.6	97.4	18.85	29.96	0.31
1170	2.427	0.018	0.0002	403.4	27.5	96.7	27.09	29.88	0.47
FUSE	2.399	0.012	0.0001	357.9	24.4	97.7	40.49	29.87	0.31
TOTAL			1465.0	100.0				29.62	0.46
PLATEAU AGE								29.90	0.25

continued

APPENDIX A. Analytical data (continued).

TEMP	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	Moles ^{39}Ar	Total (%)	% Radiogenic	K/Ca	Age (Ma)	Uncertainty
Sample #4.139-659B					**J = .007068**				
700	6.783	0.014	0.0167	439.6	19.0	27.0	34.71	23.19	0.36
760	5.467	0.015	0.0109	268.1	11.6	40.7	33.68	28.13	0.46
820	4.758	0.014	0.0081	269.9	11.7	49.6	35.08	29.86	0.58
890	4.048	0.013	0.0051	271.7	11.7	62.1	36.60	31.78	0.45
970	3.432	0.025	0.0030	305.3	13.2	73.4	19.63	31.82	0.35
1050	3.326	0.025	0.0026	179.1	7.7	76.4	19.30	32.09	0.61
1130	3.229	0.023	0.0024	169.9	7.3	77.8	21.16	31.75	0.35
FUSE	3.096	0.037	0.0018	409.7	17.7	82.0	13.22	32.07	0.39
TOTAL			2313.4	100.0				29.58	0.43
PLATEAU AGE								31.86	0.47
Sample #FVW25.1S					**J = .007241**				
650	15.286	0.122	0.0457	29.2	0.7	11.6	4.01	23.07	4.13
730	5.016	0.058	0.0091	76.3	1.8	46.1	8.45	29.95	0.69
820	2.820	0.049	0.0017	184.2	4.3	81.8	10.10	29.89	0.36
950	2.464	0.024	0.0004	494.0	11.6	94.1	20.39	30.03	0.30
1050	2.396	0.020	0.0002	180.5	4.2	97.4	24.22	30.23	0.31
1110	2.368	0.022	0.0001	114.2	2.7	98.5	22.22	30.23	0.31
1160	2.371	0.020	0.0001	112.1	2.6	98.7	24.24	30.31	0.33
1190	2.404	0.015	0.0002	398.7	9.3	96.7	31.92	30.11	0.39
1250	2.470	0.012	0.0004	988.6	23.2	94.4	41.50	30.22	0.36
FUSE	2.543	0.011	0.0007	1688.9	39.6	91.7	44.49	30.22	0.35
TOTAL			4266.6	100.0				30.12	1.13
PLATEAU AGE								30.22	0.28
Sample #FVW26.1S					**J = .007208**				
650	7.453	0.020	0.0175	61.9	1.1	30.4	24.91	29.22	0.60
730	3.655	0.017	0.0044	73.5	1.3	64.4	28.94	30.36	0.59
820	2.854	0.016	0.0012	74.7	1.3	87.1	31.56	32.04	0.74
950	2.540	0.012	0.0003	265.5	4.6	96.1	39.82	31.45	0.38
1000	2.533	0.010	0.0002	424.2	7.4	97.4	47.04	31.80	0.35
1110	2.537	0.009	0.0002	758.9	13.2	97.3	56.70	31.81	0.34
1160	2.535	0.009	0.0002	433.2	7.5	97.5	57.47	31.87	0.33
1190	2.563	0.008	0.0002	1035.5	18.0	96.6	63.93	31.91	0.34
FUSE	2.588	0.007	0.0004	2617.0	45.6	95.2	68.73	31.74	0.34
TOTAL			5744.5	100.0				31.74	0.35
PLATEAU AGE								31.83	0.29

APPENDIX A. Analytical data (continued).

TEMP	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	Moles ^{39}Ar	Total (%)	% Radiogenic	K/Ca	Age (Ma)	Uncertainty
Sample #FVW26.1B					**J = .007042**				
690	16.324	0.112	0.0502	24.6	0.8	9.1	4.38	18.72	1.15
770	6.740	0.060	0.0153	47.6	1.6	32.7	7.53	27.77	1.33
840	3.512	0.028	0.0041	89.4	3.0	64.9	17.44	28.71	1.29
900	2.831	0.015	0.0011	130.8	4.4	87.7	32.35	31.26	0.69
970	2.691	0.012	0.0005	325.9	10.9	94.3	40.79	31.96	0.38
1030	2.653	0.017	0.0004	335.2	11.2	95.4	29.61	31.87	0.40
1100	2.660	0.024	0.0004	668.0	22.2	94.6	20.42	31.69	0.34
FUSE	2.745	0.053	0.0008	1382.2	46.0	91.2	9.26	31.52	0.36
TOTAL			3003.7	100.0				31.38	0.43
PLATEAU AGE								31.60	0.41
Sample #SKS-H					**J = .007222**				
700	35.66	0.3785	0.1138	22.3	1.0	5.7	1.294	26.29	3.68
830	15.14	0.3165	0.0430	41.0	1.9	16.1	1.548	31.46	2.03
920	6.89	0.3039	0.0149	43.1	2.0	36.3	1.612	32.33	0.88
1030	4.28	1.8915	0.0061	91.8	4.3	61.3	0.259	33.96	0.72
1090	3.27	3.5927	0.0032	287.4	13.4	79.9	0.136	33.83	0.41
1110	3.05	3.8783	0.0026	358.0	16.7	84.7	0.126	33.48	0.38
1140	2.99	3.9445	0.0024	335.5	15.6	86.7	0.124	33.53	0.36
1170	2.96	4.0078	0.0024	278.9	13.0	86.9	0.122	33.28	0.41
1200	2.96	4.1893	0.0023	374.1	17.4	87.8	0.117	33.64	0.40
FUSE	2.94	4.5514	0.0023	312.7	14.68	8.6	0.107	33.69	0.40
TOTAL			2145.0	100.0				33.45	1.92
PLATEAU AGE								33.52	0.49
Sample #SK4.7					**J = .007132**				
650	9.23	0.5615	0.0257	127.2	14.9	18.1	0.872	21.35	2.04
720	5.78	1.1234	0.0136	85.6	10.0	31.8	0.436	23.49	0.95
790	3.42	2.2528	0.0067	71.2	8.4	47.3	0.217	20.73	1.84
920	2.45	3.2768	0.0033	92.8	10.9	69.9	0.149	22.00	1.10
1000	2.16	3.6283	0.0024	81.6	9.6	80.3	0.135	22.20	1.45
1050	2.11	3.7192	0.0026	77.6	9.1	76.6	0.131	20.74	1.17
1100	2.18	3.6123	0.0026	100.8	11.8	77.0	0.135	21.50	1.01
1150	2.33	3.0960	0.0028	96.8	11.4	74.7	0.158	22.30	1.84
FUSE	2.83	2.2228	0.0032	118.4	13.9	72.0	0.220	26.07	1.08
TOTAL			852.0	100.0				22.39	1.40
PLATEAU AGE								21.58	1.52

continued

APPENDIX A. Analytical data (continued).

TEMP	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	Moles ^{39}Ar	Total (%)	% Radiogenic	K/Ca	Age (Ma)	Uncertainty
Sample #SEG3.2S					**J = .007104**				
650	11.38	0.2798	0.0300	18.3	1.5	22.0	1.751	31.85	2.63
750	6.52	0.3673	0.0142	22.6	1.9	36.0	1.334	29.80	1.94
820	3.85	0.6030	0.0056	26.2	2.2	57.6	0.812	28.23	1.25
950	2.83	0.8235	0.0022	49.5	4.1	79.2	0.595	28.47	1.16
1050	2.55	0.8435	0.0008	102.0	8.4	92.9	0.581	30.12	0.47
1110	2.45	0.7569	0.0006	146.6	12.1	95.0	0.647	29.60	0.44
1160	2.41	0.6483	0.0003	207.6	17.1	97.8	0.755	30.00	0.41
1190	2.39	0.5265	0.0003	249.8	20.6	97.8	0.930	29.78	0.40
FUSE	2.39	0.3790	0.0003	390.5	32.2	97.3	1.292	29.59	0.31
TOTAL			1213.1	100.0				29.71	0.49
PLATEAU AGE								29.74	0.54
Sample #SEG1.1S					**J = .007189**				
650	5.216	0.116	0.0105	191.1	5.7	40.4	4.21	27.12	0.45
730	5.136	0.118	0.0104	103.0	3.0	40.1	4.16	26.49	0.40
820	3.809	0.128	0.0062	34.0	1.0	51.7	3.84	25.36	1.16
950	2.238	0.119	0.0005	125.0	3.7	93.7	4.13	27.00	0.39
1050	2.179	0.106	0.0002	326.6	9.7	96.5	4.62	27.06	0.31
1110	2.170	0.097	0.0002	485.4	14.4	97.0	5.04	27.09	0.28
1160	2.153	0.087	0.0001	434.2	12.8	97.6	5.65	27.04	0.29
1190	2.159	0.079	0.0001	643.0	19.0	97.7	6.17	27.14	0.29
1250	2.159	0.070	0.0001	760.4	22.5	97.6	6.98	27.13	0.31
FUSE	2.202	0.058	0.0003	278.4	8.2	95.6	8.42	27.10	0.37
TOTAL			3381.1	100.0				27.09	0.32
PLATEAU AGE								27.09	0.22
Sample # QC1.1S					**J = .00715**				
650	10.529	0.264	0.0272	74.9	2.8	23.8	1.86	32.04	1.47
730	6.237	0.395	0.0145	98.9	3.7	31.3	1.24	25.04	0.43
820	2.760	0.523	0.0031	97.4	3.7	67.9	0.94	24.04	1.13
950	2.278	0.582	0.0008	214.8	8.1	91.2	0.84	26.60	0.30
1050	2.228	0.541	0.0006	310.0	11.7	93.1	0.91	26.59	0.32
1110	2.231	0.447	0.0006	302.5	11.4	93.1	1.10	26.61	0.30
1170	2.246	0.346	0.0006	425.0	16.1	93.2	1.42	26.80	0.32
FUSE	2.257	0.225	0.0005	1122.3	42.4	92.9	2.18	26.87	0.29
TOTAL			2645.8	100.0				26.75	0.74
PLATEAU AGE								26.70	0.39

APPENDIX A. Analytical data (continued).

TEMP	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	Moles ^{39}Ar	Total (%)	% Radiogenic	K/Ca	Age (Ma)	Uncertainty
Sample #QC1.1B					**J = .007125**				
690	11.379	0.011	0.0317	42.9	1.9	17.6	43.69	25.49	1.42
760	4.204	0.004	0.0070	114.1	5.1	50.6	135.59	27.15	1.49
820	2.548	0.005	0.0016	157.7	7.0	81.4	97.10	26.45	1.10
880	2.264	0.002	0.0005	247.2	11.0	93.4	249.89	26.98	0.64
940	2.215	0.045	0.0003	485.7	21.6	94.9	10.95	26.81	0.30
1000	2.209	0.062	0.0003	457.5	20.4	95.5	7.88	26.93	0.33
1050	2.206	0.068	0.0003	334.1	14.9	96.0	7.24	27.02	0.34
1100	2.207	0.070	0.0006	212.3	9.5	90.9	6.95	25.60	0.92
FUSE	2.218	0.062	0.0003	194.1	8.6	95.2	7.91	26.95	0.34
TOTAL			2245.6	100.0				26.75	0.55
PLATEAU AGE								26.94	0.32
Sample # QC44.1S					**J = .007154**				
650	8.176	0.548	0.0222	29.0	2.2	20.0	0.89	20.95	0.87
730	6.403	0.703	0.0162	67.0	5.1	25.9	0.70	21.27	0.71
820	2.182	1.689	0.0025	53.9	4.1	71.2	0.29	19.97	1.44
950	1.986	2.479	0.0014	110.3	8.4	88.3	0.20	22.53	0.41
1050	1.963	2.692	0.0012	125.1	9.5	91.6	0.18	23.11	0.49
1110	2.035	2.515	0.0015	114.7	8.7	88.0	0.19	23.02	0.60
1160	2.131	2.270	0.0016	110.0	8.4	86.3	0.22	23.60	0.43
1190	2.310	1.869	0.0019	232.4	17.7	81.7	0.26	24.21	0.32
FUSE	2.937	0.882	0.0033	469.1	35.8	69.2	0.56	26.05	0.31
TOTAL			1311.4	100.0				24.07	0.45
No Plateau									

TEMP = temperature. Temperatures are approximate.