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Reevaluation of the Central Colorado Plateau Laccoliths in the Light of New Age Determinations

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This report summarizes the work of Nelson, Heizler, and Davidson (1992) and of Nelson, Davidson, and Sullivan (1992). It has been included in this volume to provide a complete record of the proceedings of the laccolith conference. The new $^{40}Ar/^{39}Ar$ ages presented here for the laccoliths of the Henry and La Sal Mountains (fig. 1; table 1) give much tighter constraints on the age of magmatism. Also, the new $^{40}Ar/^{39}Ar$ data allow the assessment of processes that disturb apparent K-Ar systematics.

K-Ar (Stern and others, 1965; Armstrong, 1969; Dubiel and others, 1990) and fission-track (Sullivan and others, 1991) ages for laccoliths of the Henry and La Sal Mountains appear to be contradictory (Fig. 1). The K-Ar ages are bimodal (41–56 and 24–29 Ma), although the fission-track ages range exclusively from 20 to 30 Ma. It appears that either some fission-track ages are too young, some K-Ar ages are too old, or a sampling problem exists.

The Eocene K-Ar ages imply an episode of magmatism at 40–56 Ma during Laramide deformation and

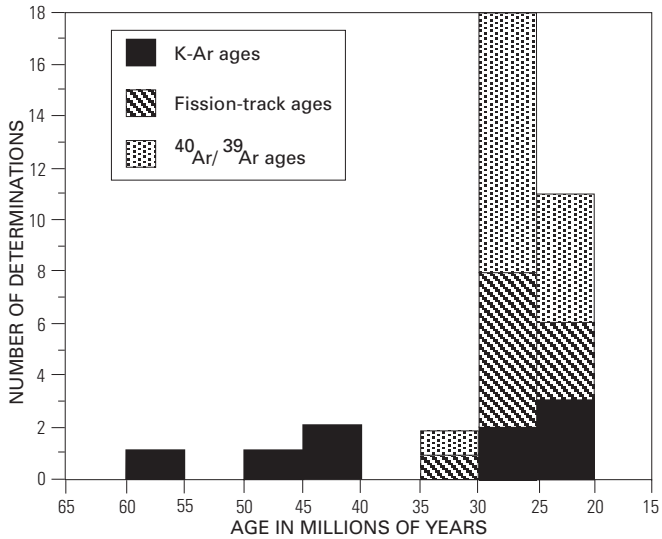

Figure 1. Histogram of age determinations for intrusive rocks of the Henry and La Sal Mountains, Utah. Fission-track data include sphene and zircon age determinations where available from the same sample. The 40- to 60-Ma ages, all determined by the K-Ar method, are interpreted to be the result of excess argon and partially outgassed hornblende xenocrysts in samples that are actually 20–30 Ma.

[1] Woodward-Clyde Federal Services, 101 Convention Center Drive, Suite P110, MS 423, Las Vegas, NV 89109.

Table 1. $^{40}Ar/^{39}Ar$ age determinations from the Henry and La Sal Mountains intrusions, Utah.

[n.d., not determined. See Nelson, Heizler, and Davidson (1992) for further details of age determinations]

Intrusive center	Sample	North latitude	West longitude	$^{40}Ar/^{36}Ar$	$^{40}Ar/^{39}Ar$	J[1]	MSWD[2]	Age (Ma) ± 1 s.d.[3]	Sample type[4]	Lithology[5]	Comments
Henry Mountains											
Mount Ellen	BULL–1	38°9'6"	110°44'23"	n.d.	n.d.	0.0050261	n.d.	<31.9±0.4	HB	PHP	Xenocryst contamination: Fission-track age of 28.6±1.2 Ma is considered best estimate of crystallization age.
	ELLN–4	38°4'39"	110°45'21"	n.d.	n.d.	0.0050319	n.d.	<39.0±0.7	HB	PHP	Xenocryst contamination.
	ELLN–10 [6]	38°4'29"	110°45'26"	320±15	3.30863 ± 0.03171	0.0049700	173	29.4±0.3	HB	PHP	
	ELLN–7	38°0'10"	110°47'36"	n.d.	n.d.	0.0047909	n.d.	<28.4±0.5	HB	PHP	Xenocryst contamination.
				302.3±2.2	2.70879 ± 0.02869	0.0047909	0.75	23.3±0.2	HB	PHP	Results from laser fusions.
Mount Pennell	PENL–14	37°57'58"	110°45'33"	690±51	2.61151 ± 0.23623	0.0048134	148	22.5±1.9	HB	PHP	Age of PENL–14 must be greater than about 25 Ma based on crosscutting relationships. This is concordant within analytical error.
	PENL–13 [6]	37°57'0"	110°46'11"	293.1±1.7	2.82955 ± 0.00656	0.0049043	7.5	24.9±0.1	HB	PHP	
	PENL–12 [6]	37°57'1"	110°47'50"	283±12	2.72196 ± 0.05494	0.0050004	9.7	24.4±0.5	HB	SP	
	PENL–9 [6]	37°57'13"	110°47'50"	305.5±3.3	2.79397 ± 0.00445	0.0050738	10.8	25.4±0.1	AF	SP	
	PENL–3 [6]	37°56'54"	110°46'44"	300.4±4.8	2.74228 ± 0.02704	0.0050156	36	24.6±0.2	HB	SP	
Mount Hillers	HILL–10KRS	37°51'26"	110°42'10"	464±11	3.44632 ± 0.03944	0.00480005	0.64	29.6±0.4	HB	PHP	Two sets of data are reported because of two distinct trapped excess argon components in the sample. Interpreted age is 29.35±0.33 Ma.
				316.8±9.9	3.28337 ± 0.03468	0.0048005	7.3	29.1±0.3	HB	PHP	
Mount Ellsworth	ELL–1KRS	37°44'50"	110°37'19"	310.8±2.4	3.44058 ± 0.11118	0.0050770	6.97	31.2±1.0	HB	PHP	Excess argon.
La Sal Mountains											
North Mountain	MW–13	38°32'34"	109°14'5"	n.d.	n.d.	0.0049390	n.d.	27.9–31.5	HB	PHP	Xenocryst contamination. Age constrained by crosscutting relationships with MW–2 and MW–17.
				n.d.	n.d.	n.d.	n.d.	27.5±1.4	HB	PHP	Results from laser fusions. Mean of three Oligocene ages.
	MW–2 [6]	38°32'19"	109°14'46"	302±10	3.08077 ± 0.02991	0.0050530	2.3	27.9±0.3	AF	SP	
	MW–17 [6]	38°31'19"	109°13'29"	296.7±4.9	2.13906 ± 0.00122	0.007287	0.9	27.9±0.03	AF	SP	
Middle Mountain	TUK–1 [6]	38°27'23"	109°15'57"	285±5.9	2.94181 ± 0.01607	0.0050676	3.7	26.7±0.2	AF	SP	
	TUK–2	38°28'25"	109°16'5"	n.d.	n.d.	0.0048854	n.d.	<62.9±2.7	HB	PHP	Xenocryst contamination.
				n.d.	n.d.	n.d.	n.d.	25.1±4.1	HB	PHP	Results from laser fusions. Mean of nine Oligocene ages.
South Mountain	TUK–6	38°24'51"	109°15'45"	n.d.	n.d.	0.0049223	n.d.	<56.5±0.3	HB	PHP	Xenocryst contamination.
				n.d.	n.d.	n.d.	n.d.	26.0±2.4	HB	PHP	Results from laser fusions. Mean of two Oligocene ages.

[1]Irradiation parameter J.
[2]Mean square of weighted deviations.
[3]Ages determined by weighted linear regression (York, 1969) of inverse correlation data.
[4]HB = hornblende; AF = alkali feldspar.
[5]PHP = plagioclase-hornblende porphyry; SP = syenite porphyry.
[6]Samples with flat age spectra and well-correlated inverse correlation plots.

accompanying flat subduction (as suggested by Bird, 1988, Hamilton, 1988). However, Oligocene-Miocene igneous activity in the Henry and La Sal Mountains could be related regionally to contemporaneous voluminous calc-alkaline magmatism of the ignimbrite flareup. Therefore, it is important to determine the true age of magmatism in order to understand the laccoliths in their tectonic context.

The results reported here indicate that igneous activity in the Henry and La Sal Mountains was exclusively middle to late Oligocene (fig. 1; table 1). Magmatism was contemporaneous and appears to have spanned several million years in the Henry (31.2–23.3 Ma) and La Sal (27.9–25.1 Ma) Mountains. About half of the samples make up a well-correlated data set: they define a linear array on inverse correlation diagrams, give flat age spectra, and have a trapped component of argon that is atmospheric in composition. Many of the other samples, however, are disturbed as a result of either excess ^{40}Ar or contamination by xenocrysts. Both processes result in the incorporation of ^{40}Ar that does not result from the in situ decay of ^{40}K in the sample, thereby increasing the sample's apparent age.

Excess ^{40}Ar is easily recognized by the $^{40}Ar/^{39}Ar$ inverse correlation technique (Heizler and Harrison, 1988). Moreover, the $^{40}Ar/^{39}Ar$ method could also be a powerful tool in identifying late-stage xenocrystic contamination of magmas by just a few weight percent, especially if the xenocrysts are much older than their host, and provided they retain a modest proportion of their radiogenic ^{40}Ar. Xenocrysts were identified by single-crystal laser fusion analysis and by electron microprobe analysis of hornblendes from the laccoliths. Mixing calculations based upon the known K content of igneous and xenocrystic hornblende and the age of the basement rocks (~1,800 Ma) indicate that only a small proportion of xenocrysts (1–4 percent) is required to increase the apparent age of the sample from Oligocene to Eocene, even if the xenocrysts are outgassed by 75 percent. Greater age, greater K concentration, and a smaller degree of degassing of the xenocrysts all tend to maximize the effect of contamination. Calculations for diffusion over short length scales (80µm) indicate that at magmatic temperatures of 850°–900°C, xenocrysts could retain as much as 10 percent of their radiogenic ^{40}Ar after 25–100 yr. Therefore, it is not unreasonable to expect hornblende xenocrysts to have retained some radiogenic ^{40}Ar, given their inherent retentivity and the fact that diffusion rates would have decreased exponentially as the laccoliths began to cool. All mineral separates exhibiting xenocryst contamination were sampled near the upper surface of the laccoliths, increasing the likelihood of Ar retention.

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