^{40}Ar/^{39}Ar dating of the 79 AD eruption of Vesuvius: An *ab initio* basis for improved accuracy in ^{40}Ar/^{39}Ar geochronology

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^{40}Ar/^{39}Ar dating is limited in accuracy by uncertainties in decay constants (λ_ε, and λ_β), K and ^{40}Ar* concentrations in standards, and ^{40}K/K$_{tot}$. These uncertainties propagate through the age equation in such a way as to render the ^{40}Ar/^{39}Ar method accurate in an absolute sense to only $\pm$ 1–2% (1 σ). Fortunately, the age equation may be written in a form that is dependent only on the total decay constant for ^{40}K, obviating much of the (largely unacknowledged) systematic error that attends conventional formulations. Based on a standard whose age (t_0) is known *a priori,* and using intercalibration factors R^i_{i-1}, as appropriate, the age of any sample can be expressed (Renne *et al.*, 1998) as:

$$t_u = \frac{1}{\lambda}\ln\left[(e^{\lambda t_0} - 1)\prod_{i=1}^{n} R^i_{i-1} + 1\right]$$

and the propagation of errors in t_0, λ, and the R^i_{i-1}, in the absence of covariance between the R^i_{i-1} leads to an expression for the variance

$$\sigma^2_{tu} \approx \left\{\frac{\left(-t_u + t_0 e^{\lambda(t_0-t_u)}\prod_{i=1}^{n} R^i_{i-1}\right)}{\lambda}\right\}^2 \sigma^2_\lambda + \left\{e^{\lambda(t_0-t_u)}\prod_{i=1}^{n} R^i_{i-1}\right\}^2 \sigma^2_{t_0} + \sum_{j=1}^{n}\left\{\frac{(e^{\lambda t_0}-1)\prod_{i=1}^{n} R^i_{i-1}}{\lambda e^{\lambda t_u} R^j_{j-1}}\right\}^2 \sigma^2_{R^j_{j-1}}$$

which reduces dependence on decay constant uncertainties, eliminates errors in K-Ar data for standards and greatly reduces dependence on the value of ^{40}K/K$_{tot}$ to its relatively small impact on decay constant determinations. In terms of true accuracy, this approach represents an advantage over the conventional K-Ar basis for ^{40}Ar/^{39}Ar dating if t_0 and R^0_1 (the ^{40}Ar*/^{39}Ar$_K$ ratio of a fluence monitor relative to that of the *ab initio* standard) can be improved to better than about $\pm$ 1%.

The 79 AD eruption of Vesuvius represents a viable *ab initio* standard, as its 1919 year age is young enough to be well-constrained by historical records, yet old enough and sufficiently potassic to be conceivably useful for the purpose. Using a defocussed CO_2 laser and integrator lens, with strict attention to mass discrimination, (^{40}Ar/^{39}Ar)$_K$, and irradiation times, it has been possible (i.e. Renne *et al.*, 1997) to efficiently separate radiogenic from nonradiogenic "Ar through incremental heating of *c.* 40–90 mg aliquots of sanidine. Three data sets have now been generated with different neutron fluence doses relative to the Alder Creek sanidine (ACs) monitor (Turrin *et al.*, 1994). Isochrons corresponding to these three data sets yield the parameters shown in Table 1.

Ages in Table 1 are relative to an updated age of 1.194 Ma for ACs (Renne *et al.*, 1998), and uncertainties (1σ) do not include errors in decay constants, ^{40}K/K$_{tot}$ or K-Ar data for the primary standard, all of which are small compared with analytical and regression errors. The age of the sample from irradiation 186 (Renne *et al.*, 1997) is corrected for the elapsed year since analysis and publication. The new data from irradiations 206B and 206C confirm the previous conclusions (Renne *et al.*, 1997) about excess ^{40}Ar in this sample, and generally reinforce the feasibility of dating sanidine as young

TABLE 1.

Irrad. No.	N	Age (years)	$\left(\frac{^{40}Ar}{^{36}Ar}\right)_0$	MSWD
186	46	1926$\pm$94	307$\pm$1	0.51
206B	59	1889$\pm$132	309$\pm$4	0.71
206C	37	1936$\pm$207	308$\pm$7	0.40

as 2 ka with reasonable precision. Larger errors in the two new data sets than were previously obtained are due mainly to larger corrections for mass discrhnination, and analysis of *c*. 50% larger samples, apparently exceeding a threshhold for uniform heating with the laser thereby reducing isochron spread. The reproducibility ($\pm$ 14 years standard error) of the age is better than would be expected from the errors estimated for individual isochrons, suggesting that the individual isochron error estimates are pessimistic. MSWD values consistently <l imply that errors for individual analyses are also overestimated.

Combining the three results above yields a mean value of $R_1^0 = 623.1 \pm 5.0$, which combined with the intercalibration data presented by Renne *et al.* (1998) is equivalent to an age of 28.04 $\pm$ 0.23 Ma (including decay constant error) for Fish Canyon sanidine. This result compares favourably with the age of 28.02 $\pm$ 0.28 Ma (including all systematic errors).based on the conventional basis relative to the GA-1550 biotite standard (Renne *et al.*, 1998. Further work (in progress) can be expected to further refine the basis for this approach.

References

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