A multi-age, U-Pb and $^{40}Ar/^{39}Ar$ approach to the calibration of Fish Canyon Tuff sanidine as a flux monitor.

M. E. Villeneuve
H. A. Sandeman
W. J. Davis
Geological Survey of Canada, 601 Booth St., Ottawa, Ontario, K1A 0E8, Canada

J. K Mortensen
University of British Columbia, Vancouver, B.C., Canada

A. Dazé
J. K. W. Lee
Queens University, Kingston, Ontario K7L 3N6, Canada

The accuracy of the $^{40}Ar/^{39}Ar$ geochronological method, like all isotopic systems, requires calibration to a well characterized standard. As such, the accuracy required to make comparisons with interlaboratory data or with other isotopic systems, is primarily dependent on accurate assignment of $^{40}Ar^{*}/^{40}K$ ratio (or apparent age) of the standard.

One of the standards that has long been in widespread use for Phanerozoic $^{40}Ar/^{39}Ar$ geochronology is sanidine and biotite from the Fish Canyon Tuff (FCT) of Colorado. These minerals show a high degree of internal reproducibility, with a number of studies showing a precision of <0.7%. However, there is no consensus on the age that should be assigned to this standard. Apparent ages of 28.03 ± 0.18 Ma (sanidine, Renne *et al.*, 1994), 27.9 ± 1.2 Ma (biotite, Cebula *et al.*, 1986) and 27.55 ± 0.10 Ma (biotite, sanidine) and 27.42 ± 0.17 Ma (biotite, Lanphere and Baadsgaard, 1997) have been reported, representing a deviation of over 2%. Unfortunately, U-Pb zircon data on FCT itself is somewhat inconclusive, with ages ranging of 28.41 ± 0.05 Ma (Oberli, 1990) and 27.55 ± 0.03 Ma (Lanphere and Baadsgaard, 1997) reported. We have attempted to resolve this discrepancy by cross calibrating well constrained U/Pb ages with $^{40}Ar/^{39}Ar$ ages derived from 16 Ma to 166 Ma biotite$\pm$hornblende plutons to arrive at the best value for a common standard.

One of the tenets of $^{40}Ar/^{39}Ar$ geochronology is that step-heated samples have their crystallization ages defined by wide plateaux (as represented by >50% from overlapping, contiguous gas aliquots), barring independent evidence for complete resetting of the Ar isotopic systematics by post-crystallisation thermal events. This being the case, the benchmark for geochronological accuracy should be equivalence to co-existing U-Pb ages, the U-Pb technique being the highest precision and highest accuracy method available. Rather than comparing the precise analytical system of $^{40}Ar/^{39}Ar$ against the imprecise K-Ar system, reference should be made against precise and accurate U-Pb analyses.

As such, the ideal age for FCT should result in accurate cross-calibration of crystallization ages over a wide range of ages, not just within the FCT. For example, a $^{40}Ar/^{39}Ar$ age of 90 Ma, cross referenced to an age of 28.03 Ma on FCT, would result in a $^{40}Ar/^{39}Ar$ age of 88.5 Ma cross referenced to a age of 27.55 Ma for FCT. This difference is not only outside the limits of $^{40}Ar/^{39}Ar$ analysis (generally 1% at 2σ), but is well outside the analytical limits of U-Pb (0.1% at 2σ).

In order to place limits on the apparent age of FCT-3 biotite and FCT sanidine, we have broadened the approach by comparing the U-Pb zircon ages against those obtained from laser $^{40}Ar/^{39}Ar$ analysis on a wider range of samples. All $^{40}Ar/^{39}Ar$ ages initially reference to a 28.03 Ma FCT sanidine age of Renne *et al.* (1994). Unless otherwise noted all samples have 2σ errors = 1%.

Samples include U-Th-Pb monazite data cross calibrated against the 24.06 ± 0.17 Ma MAC-83 (Sandeman *et al.*, 1997), and 16.34 ± 0.07 Ma MAC-55b, both from the southeastern Peruvian Andes.

Other samples come from the Canadian Cordillera. Four samples (six analyses) of Emerald Lake Pluton give equivalent hornblende and biotite $^{40}Ar/^{39}Ar$ ages ranging from 93.1 to 93.8 Ma, indicating relatively quick cooling conditions. The comparative U-Pb zircon age is 92.8 ± 0.2 Ma. A sample of Patton Porphyry from the Yukon Territory gives a $^{40}Ar/^{39}Ar$ plateau age of 74.5 and a U-Pb zircon age of 73.9 ± 0.1 Ma

In the Endako area of British Columbia, Mo-porphyry mineralisation is related to intrusion of a

145.0 ± 0.3 Ma granite dated by U-Pb zircon. Corresponding ages on 3 separate samples of hydrothermally generated biotite range from 144.4 to 144.6 Ma. A porphyry dyke with a U/Pb zircon age of 147.5 ± 0.3 Ma crosscuts a quartz monzonite dated at two locations by $^{40}Ar/^{39}Ar$ biotite at 148.8 and 147.8 Ma, although both ages are affected by Eocene overprinting and need to be considered as minimum ages. Finally, a hornblende-biotite diorite dated at 165.7+2/-1 Ma by U-Pb was dated on two separate occassions by $^{40}Ar/^{39}Ar$. Biotite ages of 164.5 and 165.1 Ma are indistinguishable from hornblende ages of 166.2 and 164.6 Ma.

Bringing the $^{40}Ar/^{39}Ar$ ages into agreement with the U/Pb ages, a preferred age for FCT sanidine can be derived. The age range presented from all the samples is 27.73 to 28.15 Ma, with an average of 27.98 Ma. By recalculating at upper and lower limits of the errors for the U/Pb data, an age range of 28.11 Ma to 27.89 Ma is derived.

This age range is almost identical to that derived from the APTS calibration of Renne *et al.* (1994). Furthermore, the average age differs by more than 2% from the estimate of 27.42 ± 0.17 Ma of FCT-3 biotite of Lanphere and Baadsgaard (1997). As the database of U/Pb and $^{40}Ar/^{39}Ar$ ages continues to increase, a better estimate of the age of FCT sanidine should emerge.

References

Cebula, G.T., Kunk, M.J., Mehnert, H.H., Naeser, C.W., Obradovich, J.D. and Sutter, J.F. (1986) *Sixth International Conf. on Geochron., Cosmochron. and Isotope Geol., Terra Cognita* **6**, 139–40.

Lanphere, M.A. and Baadsgaard, H. (1997) *AGU Spring Meeting Program with Abstracts*, p.326.

Oberli, F., Fischer, H. and Meier, M. (1990) *Seventh International Conf. on Geochron., Cosmochron. and Isotope Geol., Geol. Surv. Australia*, **7**, p.74.

Renne, P.R., Deino, A.L., Walter, R.C., Turrin, B.D., Swisher, C.C., Becker, T.A., Curtis, G.H., Sharp, W.D. and Jaouni, A. (1994) *Geology*, **22**, 783–6.

Sandeman, H.A., Sasso, A.M. and Archibald, D.A. (1997) *GAC-MAC Annual Meeting, Program with Abstracts,* **22**, p. A131.