$^{40}Ar/^{39}Ar$ Thermochronometry of Deformed Muscovite from the Zanskar Shear Zone, NW India

John W. Sommerfeld[1], Forrest M. Horton[1], William C. Hassett[1], and Mary L. Leech[1]

[1] Department of Geosciences, San Francisco State University, San Francisco, CA 94132, U.S.A., jsommerf@sfsu.edu

$^{40}Ar/^{39}Ar$ thermochronometry can provide time constraints for the ductile activity along the Zanskar Shear Zone (ZSZ), the western segment of the South Tibetan Detachment system that extends across the entire Himalayan orogen (Herren, 1987). This northeast-dipping lithotectonic contact separates the underlying high-grade metamorphic rocks of the Greater Himalayan Sequence (GHS) from the overlying low-grade metamorphic rocks of the Tethyan Himalayan Sequence (THS, Fig. 1). Patel and others (1993) show that the rocks exposed in the ZSZ possess multiple generations of fabric development that indicate a complex strain history for the ZSZ. A snowball garnet (Fig. 2a) from the ZSZ shows an earlier top-to-the-SW sense-of-shear indicating that the ZSZ initiated as a thrust fault, consistent with Patel and others (1993). A later top-to-the-NE sense-of-shear (Fig. 2b) overprints evidence of thrust motion, due to gravitational collapse along the ZSZ (Herren, 1987; Patel and others, 1993). 100 km southeast of Padum, Dezes and others (1999) concluded that ductile extension along the ZSZ was active from 22.2 to 19.8 Ma, but the timing of ductile extension along the ZSZ in NW Zanskar is poorly constrained due to limited thermochronological data. Rb-Sr muscovite ages suggest that ductile extension started ~26 Ma (Inger, 1998). Kumar and others (1995) plotted the age of apatitie fission track ages vs. elevation from the ZSZ near Padum and concluded that the ZSZ was inactive by 11.7-8.0 Ma, and so ductile extension must have ended sometime prior to ~12 Ma. Searle and others (1992) reported 22 K-Ar dates from hornblende, muscovite, and biotite, and five $^{40}Ar/^{39}Ar$ dates from hornblende and biotite from the Suru and Nun-Kun Valleys. The spread in ages from K-Ar samples (e.g., 30-23 Ma for muscovite from one location) and the $^{40}Ar/^{39}Ar$ inverse isochron plot of their hornblende sample SVR 18 indicate the presence of excess argon. Lovera and others (2002) also reported five K-feldspar

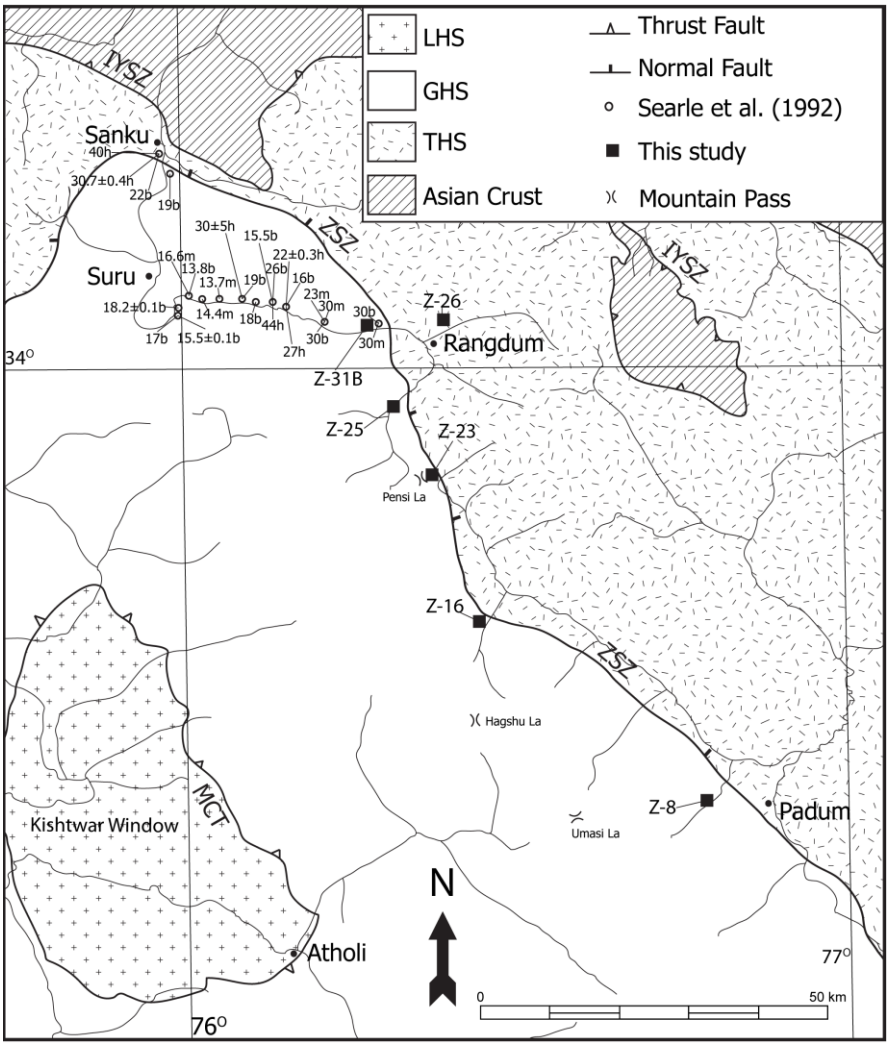

Fig. 1. Geologic map of NW Zanskar, India. Notice the widespread in K-Ar ages even from the same minerals and samples suggesting the presence of excess argon or argon loss. All ages are in Ma. Ages without 2σ errors are K-Ar; 2σ errors are approximately 1-3 Ma. Ages with 2σ error reported are $^{40}Ar/^{39}Ar$ ages. Dated minerals: hbl, hornblende; ms, muscovite; bt, biotite. Modified from Steck (2003).

$^{40}Ar/^{39}Ar$ spectra from the ZSZ that show the presence of both low-temperature and high-temperature excess argon. The presence of excess argon is an irresolvable problem for K-Ar dating, and any such dates are inherently unreliable. Muscovite $^{40}Ar/^{39}Ar$ dating has the potential to resolve this problem due to the $^{40}Ar/^{39}Ar$ technique advantages and because muscovite tends to incorporate less excess argon than biotite (McDougall and Harrison, 1999). In-situ $^{40}Ar/^{39}Ar$ dating of muscovite "fish" that show top-to-the-NE sense-of-shear (Fig. 2b) will constrain the timing of end-stage ductile deformation along the ZSZ (Mulch and others, 2005) providing valuable thermochronological data for NW Zanskar, and will be done at Stanford University in late 2010.

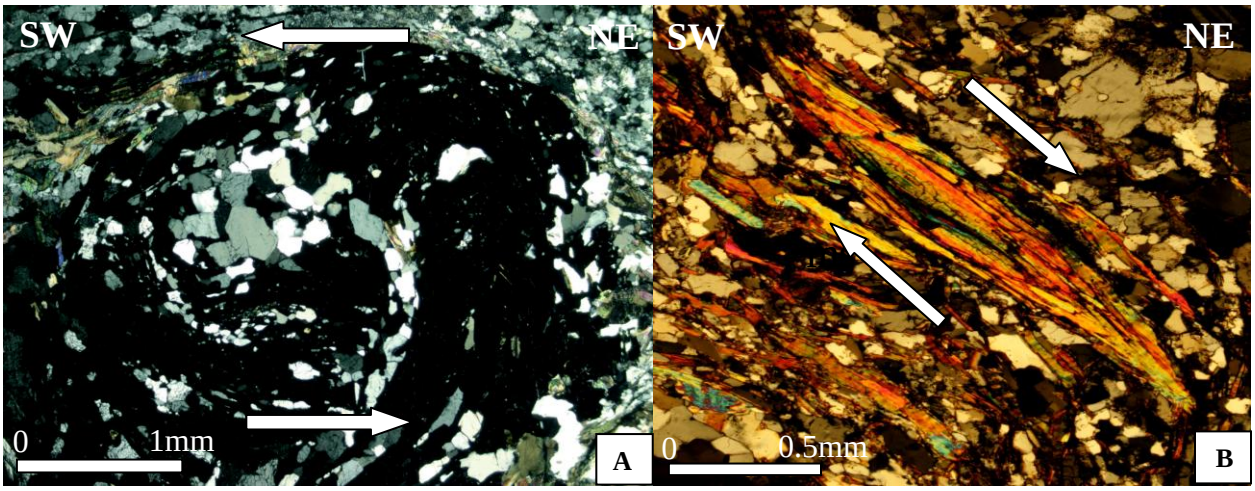

Figure 2. Photomicrographs of samples from the Zanskar Shear Zone. a) Snowball garnet in gneiss. The syn-tectonic garnet indicates a top-to-the-SW thrusting that preceded overprinting by top-to-the-NE shear in the Zanskar shear zone. XPL b) Deformed muscovite fish in gneiss. Muscovite shows top-to-the-NE sense-of-shear. XPL. Arrows show sense-of-shear direction.

References

Dezes, P.J., Vannay, J.-C., Steck, A., Bussy, F. and Cosca, M., 1999, Synorogenic extension: quantitative constraints on the age and displacement of the Zanskar shear zone (northwest Himalaya), GSA Bulletin, 111, 364-374.

Herren, E., 1987, Zanskar shear zone: northeast-southwest extension within the Higher Himalayas (Ladakh, India), Geology, 15, 409-413.

Inger, S., 1998, Timing of an extensional detachment during convergent orogeny: new Rb-Sr geochronological data from the Zanskar shear zone, northwestern Himalaya, Geology, 26, 223-226.

Kumar, A., Lal, N., Jain, A.K. and Sorkhabi, R.B., 1995, Late Cenozoic-Quaternary thermo-tectonic history of Higher Himalayan Crystalline (HHC) in Kishtwar-Padar-Zanskar region, NW Himalaya: evidence from fission track ages, Journal of the Geological Society of India, 45, 375-391.

Lovera, O.M., Grove, M. and Harrison, T.M., 2002, Systematic analysis of K-feldspar 40Ar/39Ar step heating results II: relevance of laboratory argon diffusion properties to nature, Geochim. Cosmochim. Acta, 66, 1,237-1,255.

McDougall, I. and Harrison, T.M., 1999, Geochronology and thermochronology by the $^{40}Ar/^{39}Ar$ method, Oxford University Press.

Mulch, A., Cosca, M., Andresen, A. and Fiebig, J., 2005, Time scales of deformation and exhumation in extensional detachment systems determined by high-spatial resolution in situ UV-laser 40Ar/39Ar dating, Earth and Planetary Science Letters, 233, 375-390.

Patel, R.C., Singh, S., Asokan, A., Manickavasagam, R.M. and Jain, A.K., Extensional tectonics in the Himalayan orogen, Zanskar, NW India, *in* Treloar, P.J. and Searle, M.P., eds., Himalayan Tectonics, Geological Society Special Publications, 74, 445-459.

Searle, M.P., Waters, D.J., Rex, D.C. and Wilson, R.N., 1992, Pressure, temperature and time constraints on Himalayan metamorphism from eastern Kashmir and western Zanskar, Journal of the Geol. Soc. London, 149, 753-773.

Steck, A., 2003, Geology of the NW Indian Himalaya, Eclogae Geologicae Helvetiae, 96, 147-196.

Cite as: Sommerfeld, J.W., Horton, F.M., Hassett, W.C. and Leech, M.L., 2010, $^{40}Ar/^{39}Ar$ thermochronometry of deformed muscovite from the Zanskar Shear Zone, NW India, *in* Leech, M.L., and others, eds., Proceedings for the 25th Himalaya-Karakoram-Tibet Workshop: U.S. Geological Survey, Open-File Report 2010-1099, 2 p. [http://pubs.usgs.gov/of/2010/1099/sommerfeld/].