

# Miocene Exhumation of the Karakul Basin, NE Tajikistan

William H. Amidon<sup>1</sup>, Scott A. Hynek<sup>2</sup>

1. California Institute of Technology, GPS Division,  
2. University of Utah, Department of Geology and Geophysics



## Geologic Background and Research Questions:

The Pamir mountains of eastern Tajikistan are comprised of a series of Paleozoic to Mesozoic suture zones and accreted oceanic terranes which were deflected northward during the Cenozoic India-Asia collision. Crustal thickening during this time culminated in the creation of a high plateau (> 4000 m), sitting immediately south of > 7000 m peaks. Today, north-south convergence and thickening continues as these peaks are thrust over the Eurasian margin at a rate of up to 20 mm/yr.

To the south of the high Pamir, the interior of the plateau is currently undergoing extension as evidenced by ubiquitous quaternary fault scarps and many small grabens. The clearest example of this extension is Lake Karakul, an internally drained lake basin created by extensional normal faulting in a WNW-ESE direction. The Karakul graben is related in morphology, and probably in tectonic history to several larger structural features in SW China including the Muji Graben, Kongur Shan extensional system, and the Tashkurgan graben. Although these structures are known to be undergoing active extension today, several first order questions remain:

### 1) When did extension begin?

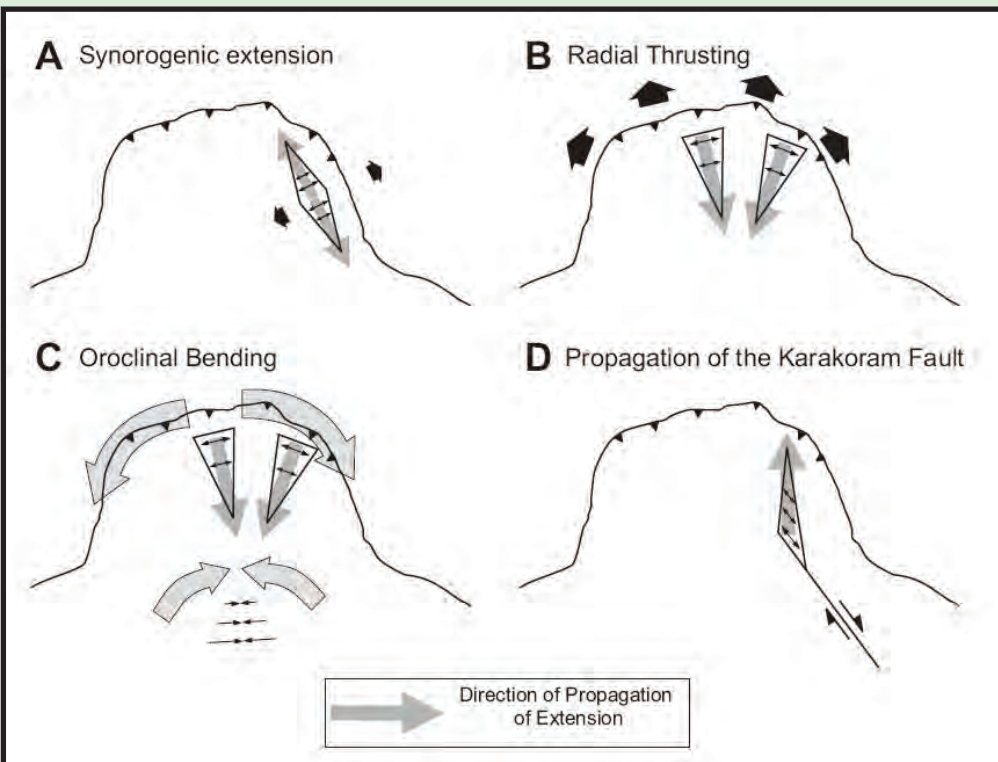
- Robinson et al. (2004 and 2007) show that the Kongur Shan extensional system reached peak temperatures ~8 Ma at depth of ~8 Kbar.
- Rifting of the Tibetan Plateau began between 14-18 Ma.

### 2) Cause of extension? Relation to regional tectonics?

Several models are summarized in Robinson et al. (2004):

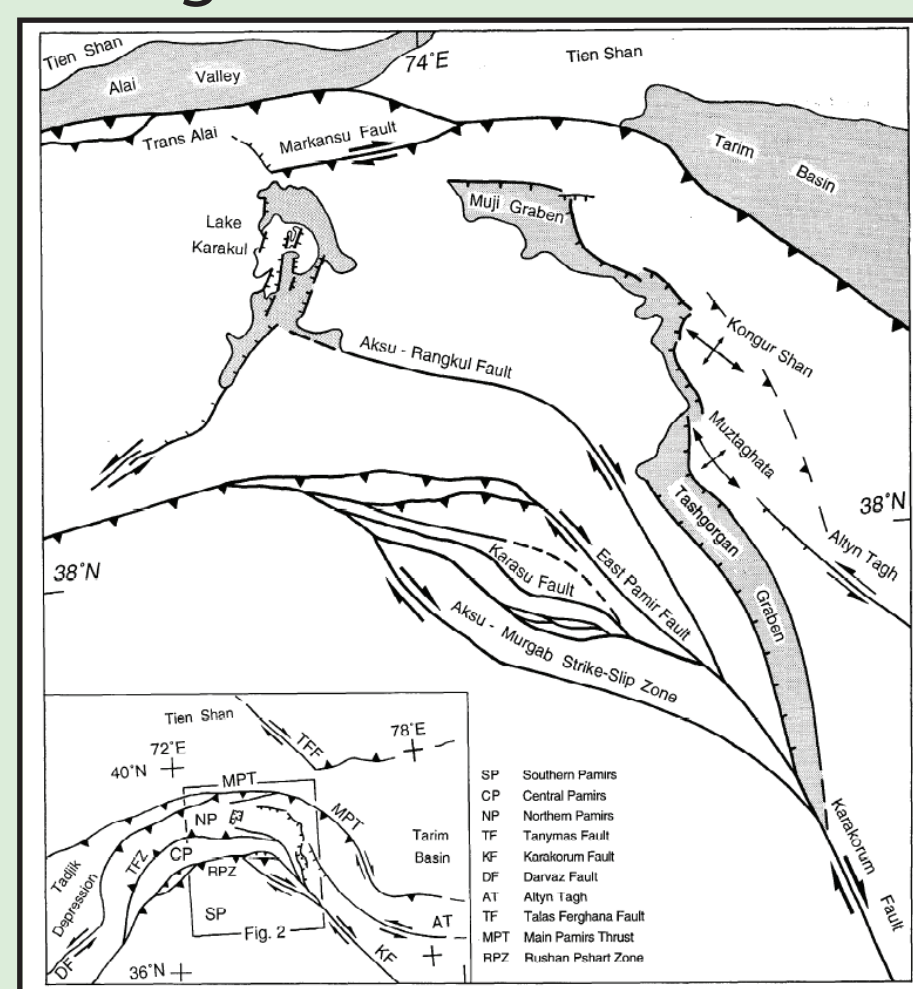
- Karakoram SS fault is lithospheric in scale and transfers large amounts of strain to normal faults in eastern Pamir.
- Gravitational instability of thickened crust (synorogenic extension)
- Wedge shaped extension due to oroclinal bending/radial thrusting

### Models of extension



Robinson et al. (2004)

### Regional Overview



Strecker et al. (1995)

## Field Work and Geochronology

- Field work in the fall of 2007: recon field mapping and sample collection  
- Divided time between Karakul area and SS region south of Murghab

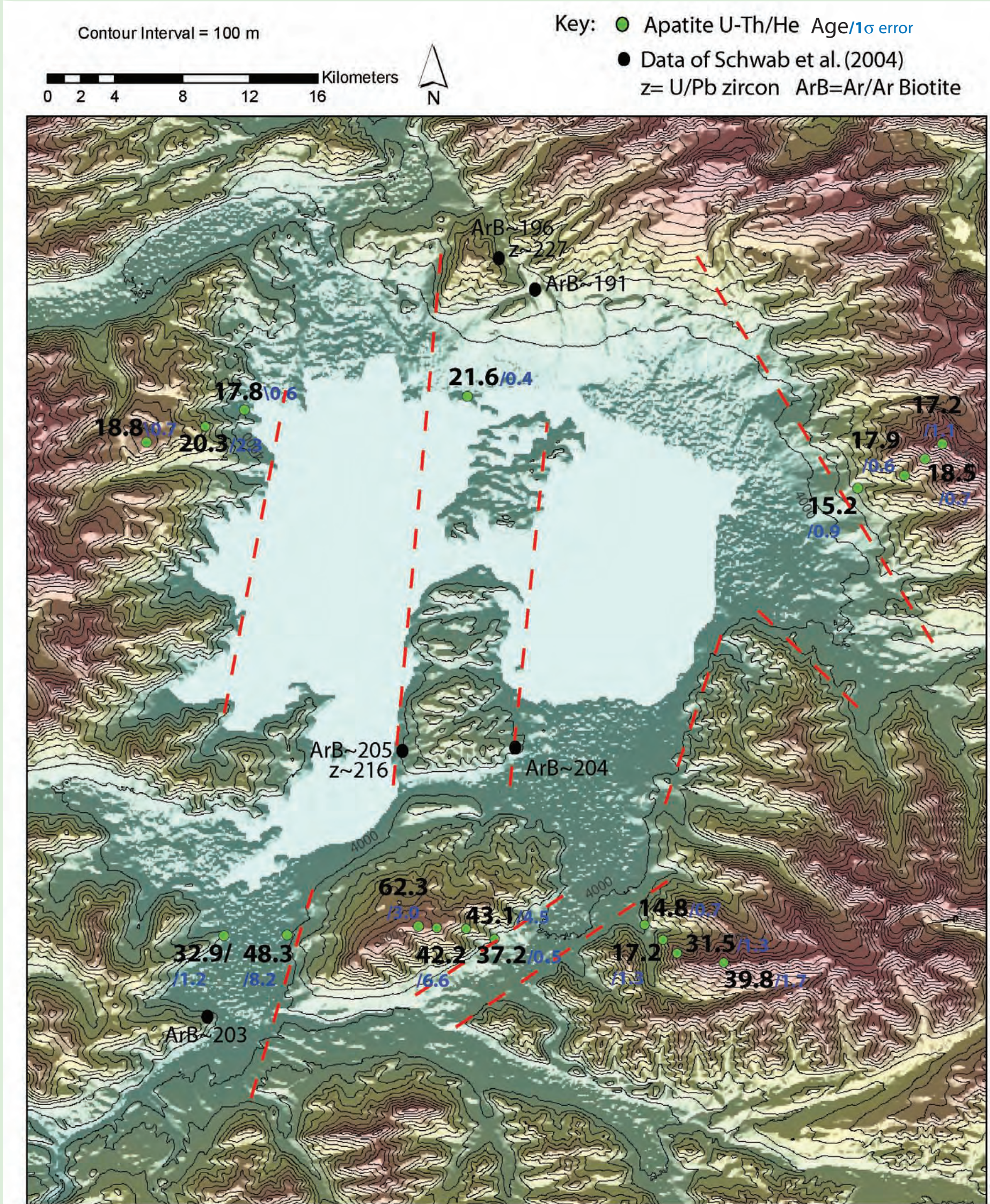
- Collected four vertical transects (1000-1600 m each) and three other sites

- Samples collected only from granodiorite plutons, yield beautiful apatites!!

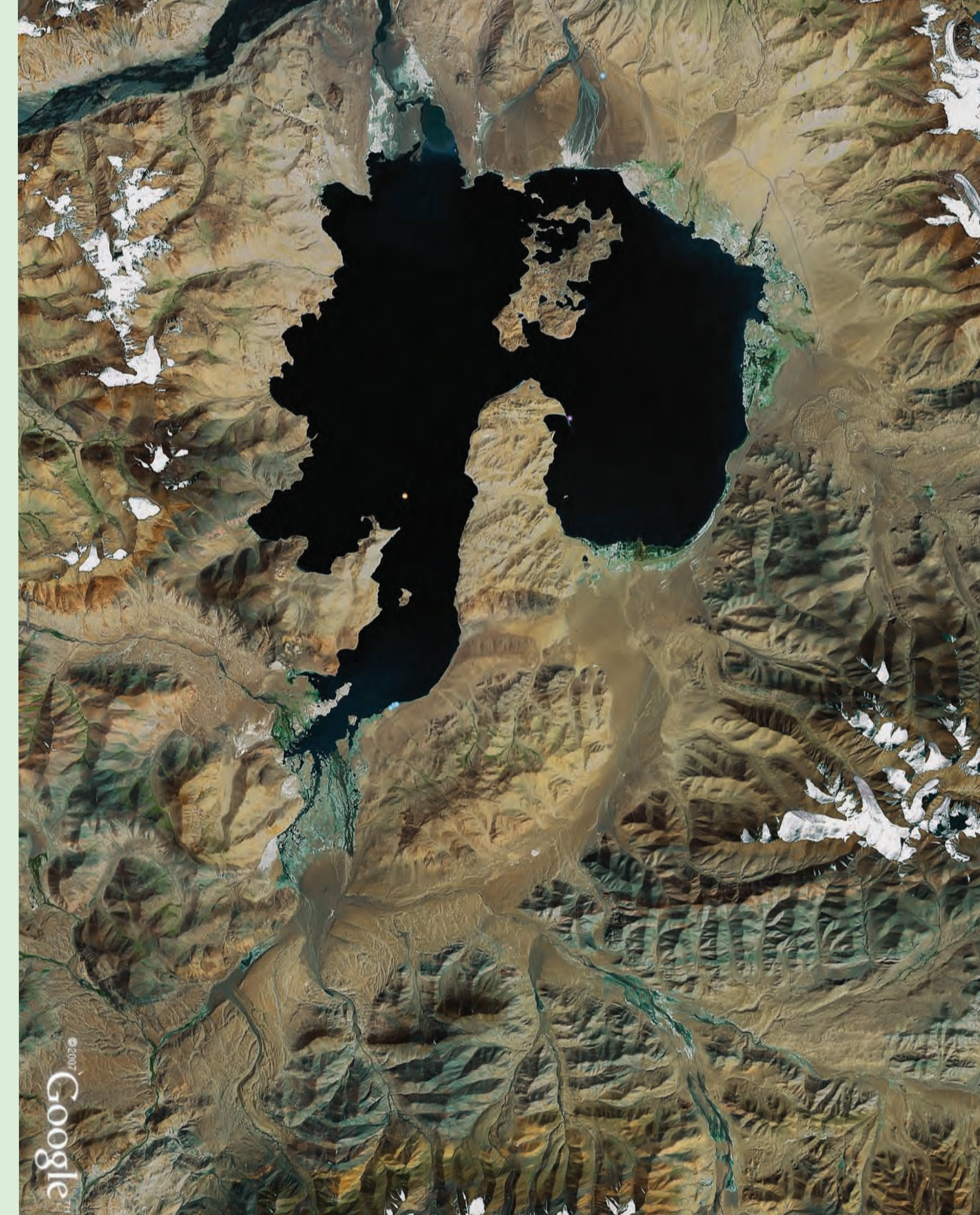
- Apatite U-Th/He dating of 3-8 apatites per samples in noble gas lab at California Institute of Technology following House et al. (2001)



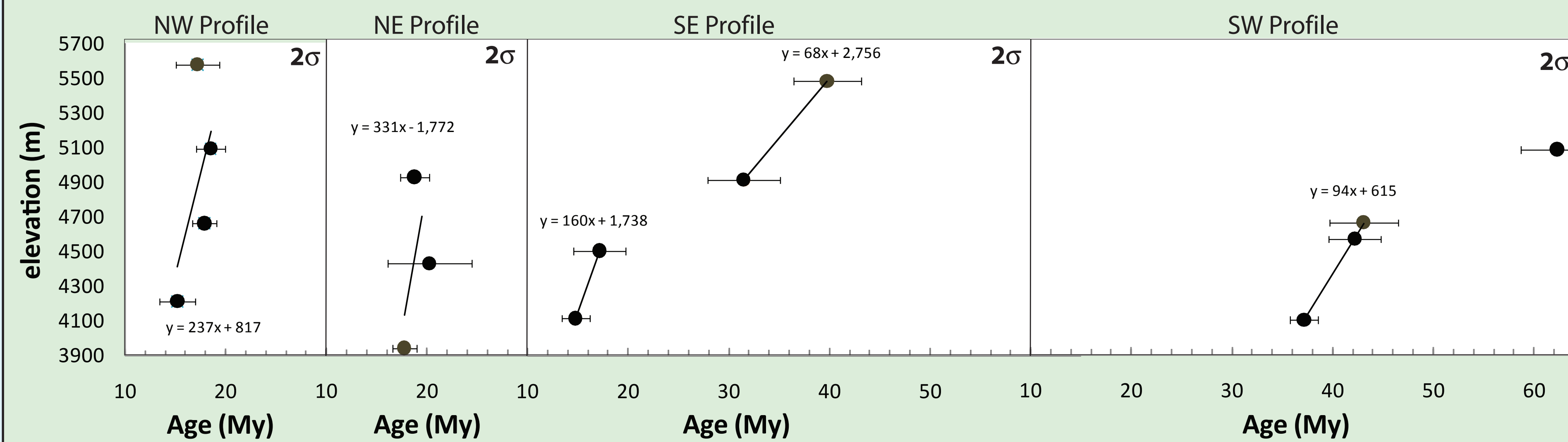
## Geochronology and schematic structure



## ASTER image



## Apatite U-Th/He Results



## Interpretation of U-Th/He ages

- Accelerated exhumation between 14-18 Ma (0.16-0.33 mm/yr).

- Onset of extension at this time?
- Exhumed PAZ due to onset of extension at ~ 8 Ma?
- Accelerated erosion due to climate change

- Accelerated exhumation between 30-44 Ma (0.07-0.1 mm/yr)?

- India-Asia collision? Crustal Thickening? Plateau Uplift?
- Same as long-term rate inferred from Ar/Ar age of 200 Ma?

- Low magnitude of extension as compared to Kongur Shan system

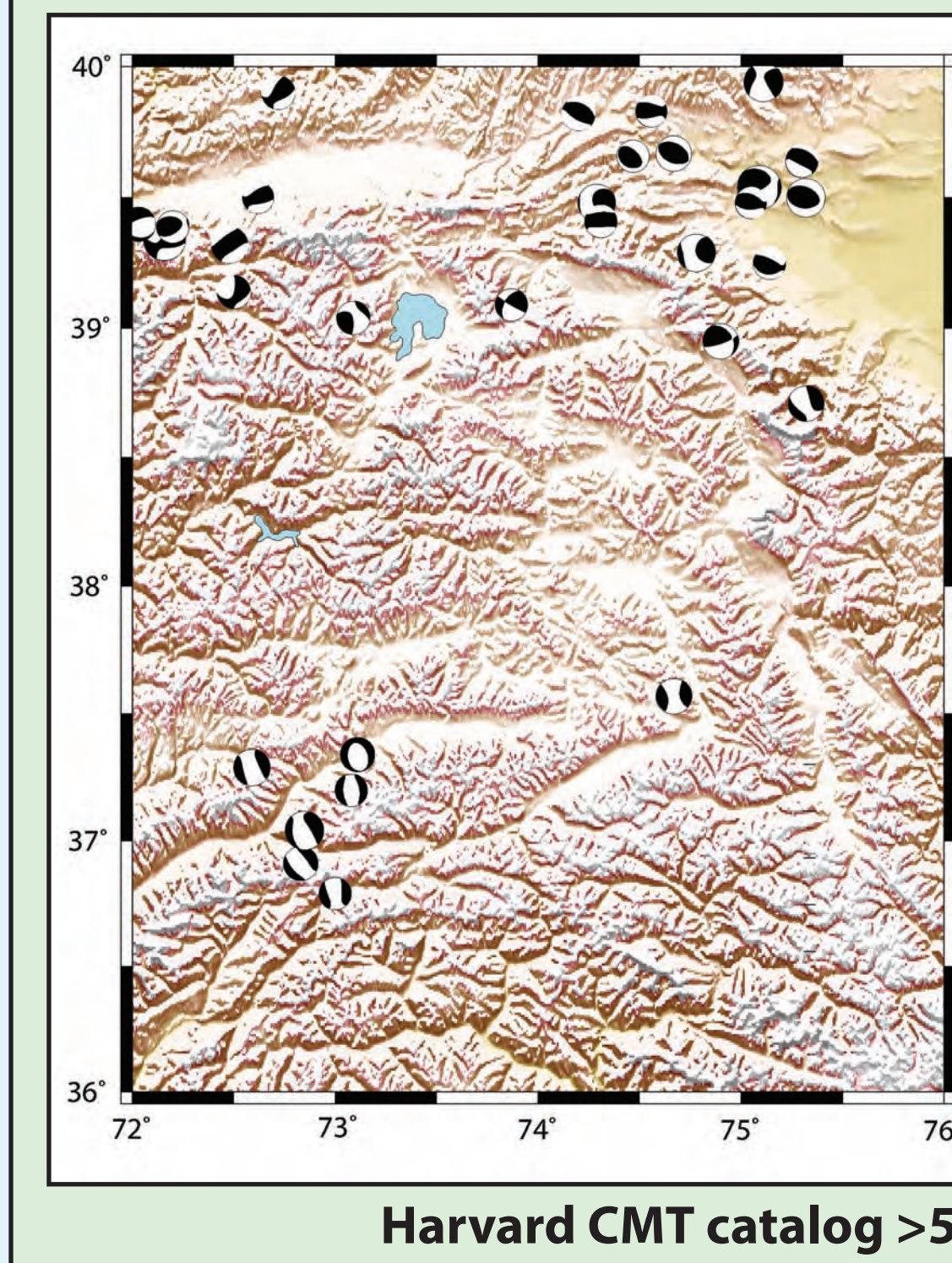
## Conclusions:

- If we interpret onset of extension at ~15 Ma...
  - Earlier than Kongur Shan, comparable to Tibet.
  - Orogen wide extension during middle miocene, before "unzipping" and massive extensional collapse along Kongur Shan system?
- If we interpret as an exhumed PAZ...
  - Onset of extension could match Kongur Shan well...

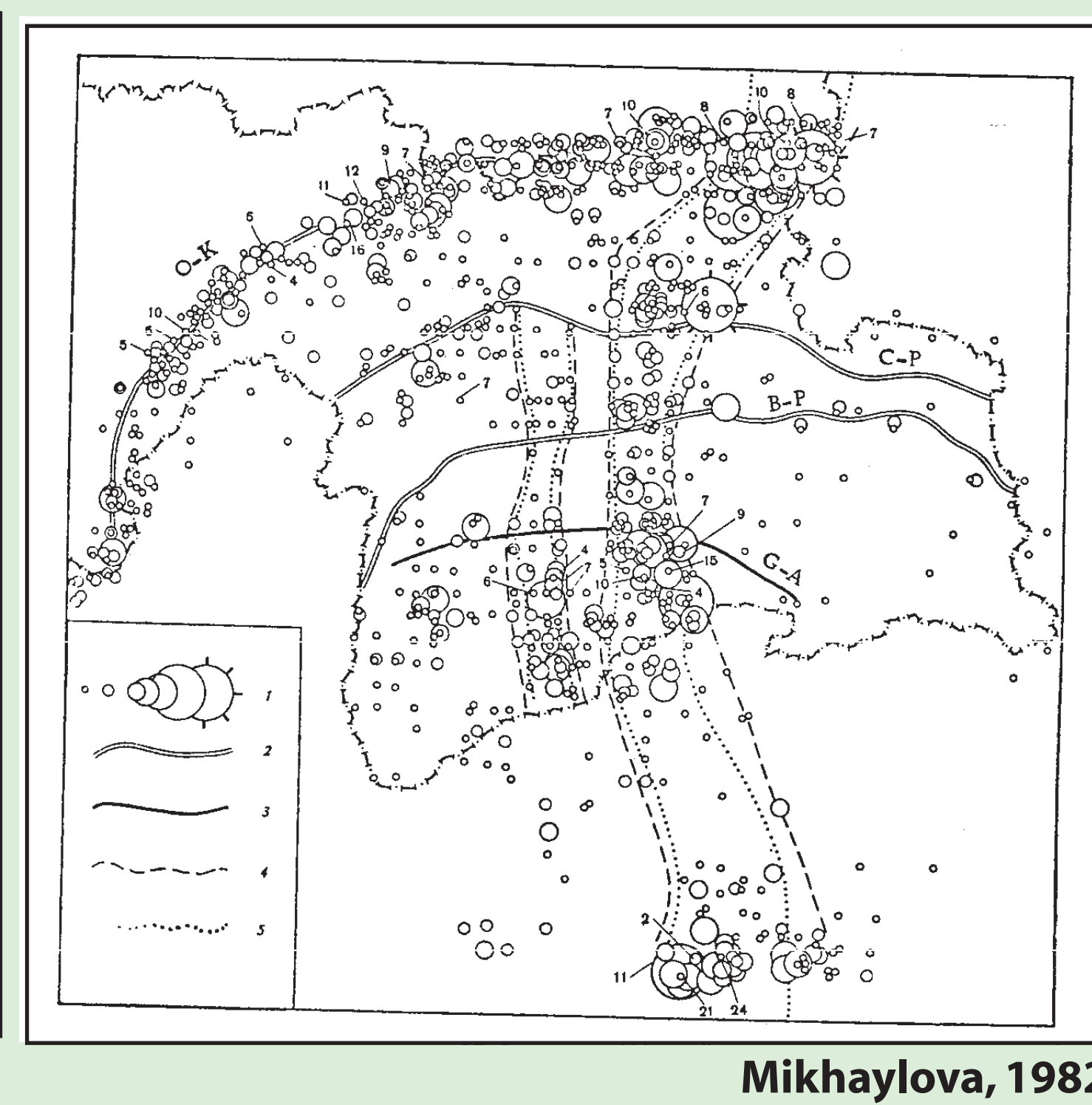
## Future Work:

- U-Th/He dating of zircon for pre-Miocene exhumation rates
- <sup>3</sup>He/<sup>4</sup>He thermochronology for lower temperature history
- Detailed field work to locate shear zones/ kinematics

## Observed Seismicity



Harvard CMT catalog >5.0



Mikheylova, 1982

## An Attempt at Thermobarometry

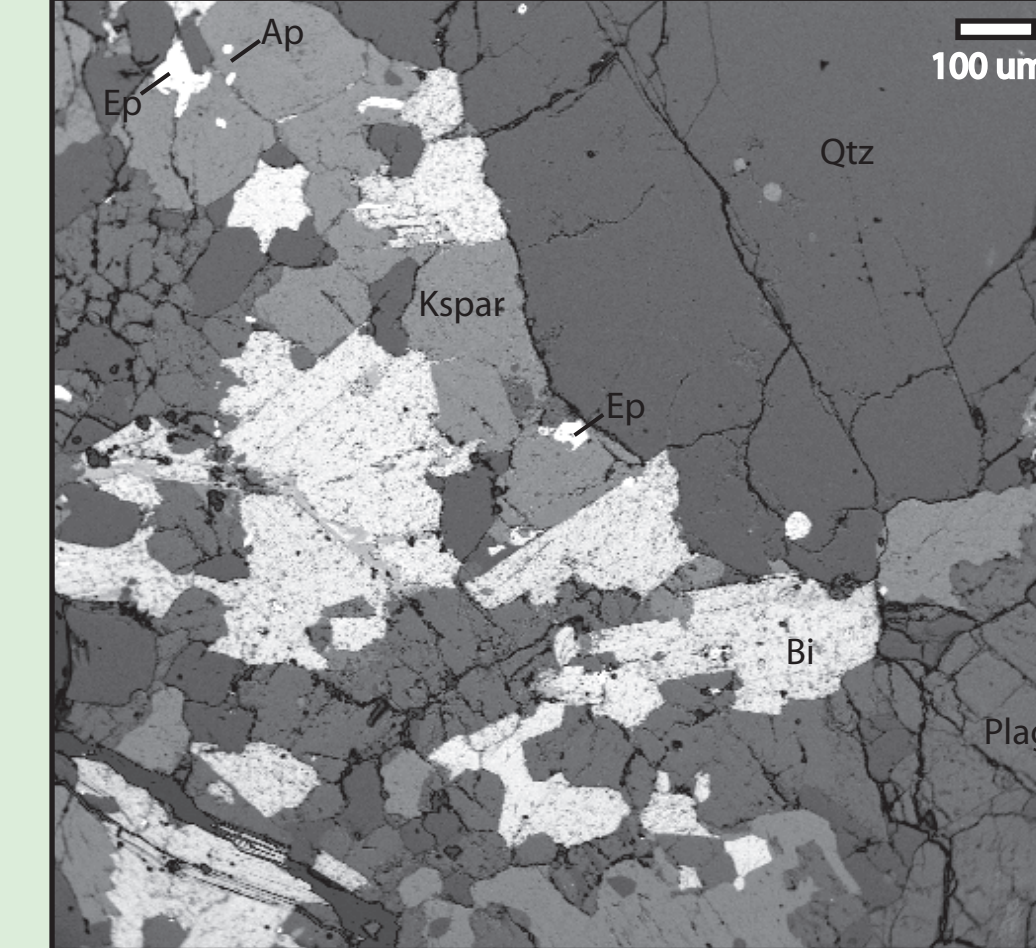
- **Thermometry:** Adjacent igneous garent and biotite

- High Mn rims indicate retrograde diffusive exchange
- Different calibrations yield range of ~650-800 °C

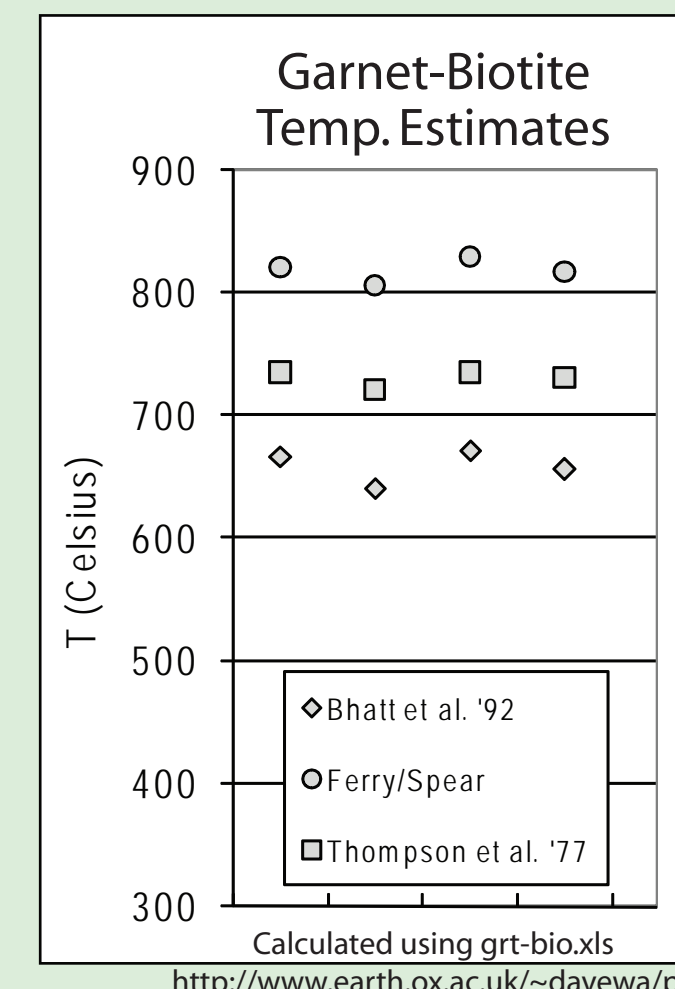
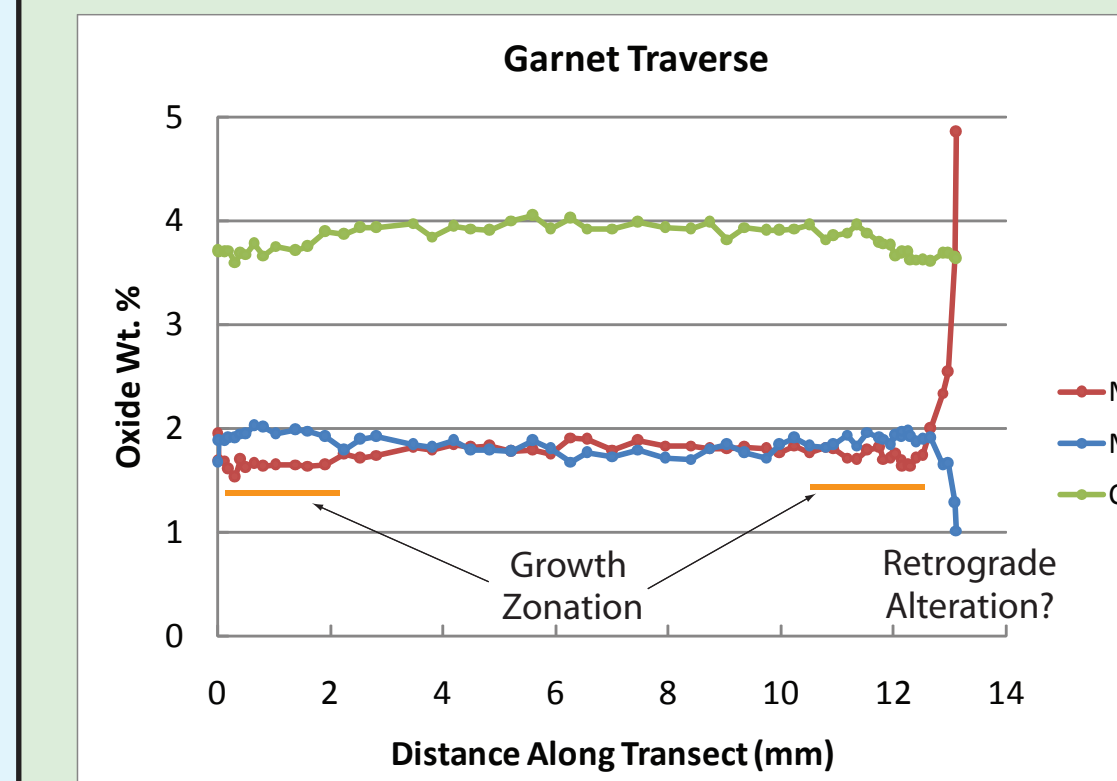
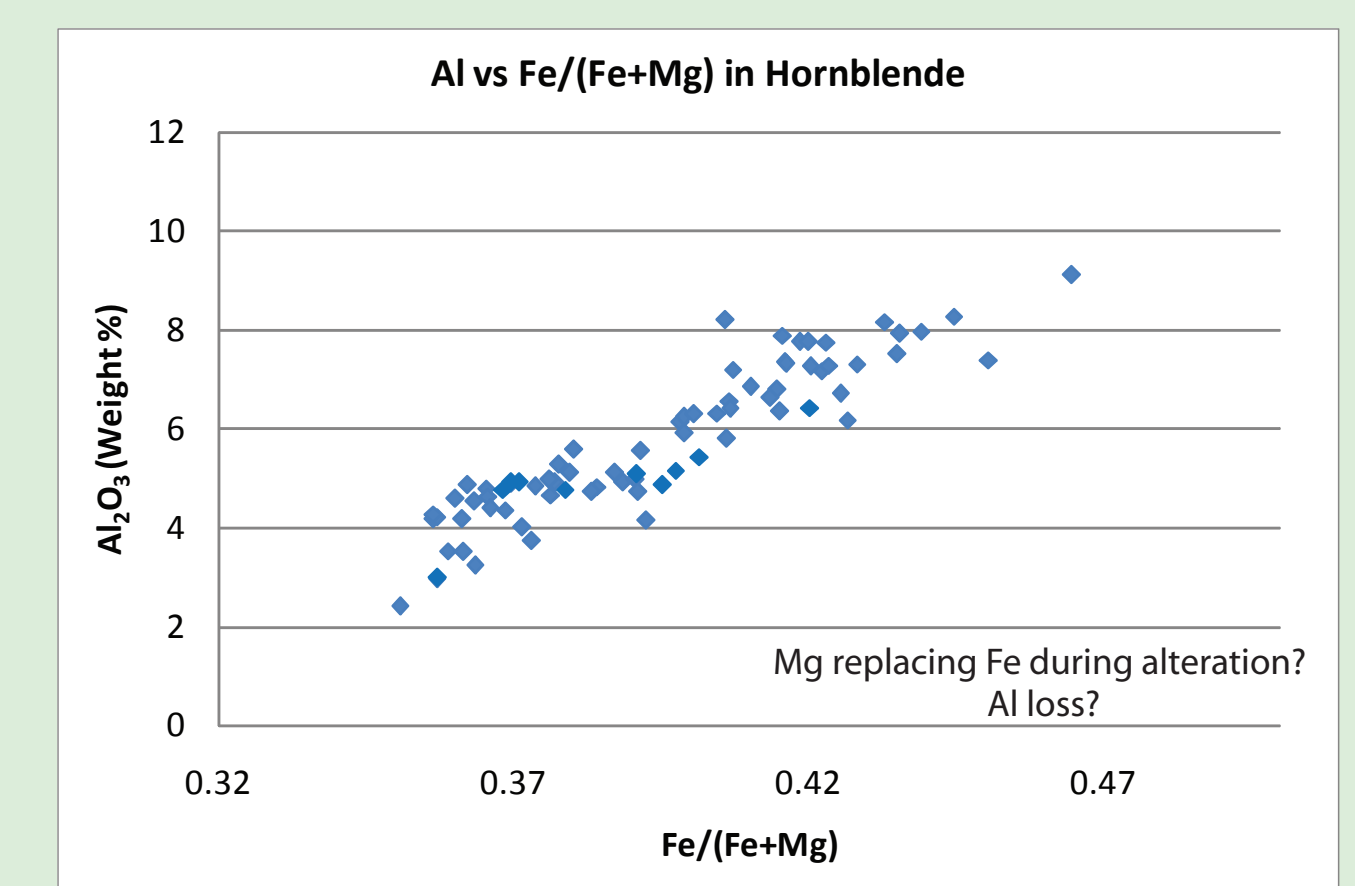
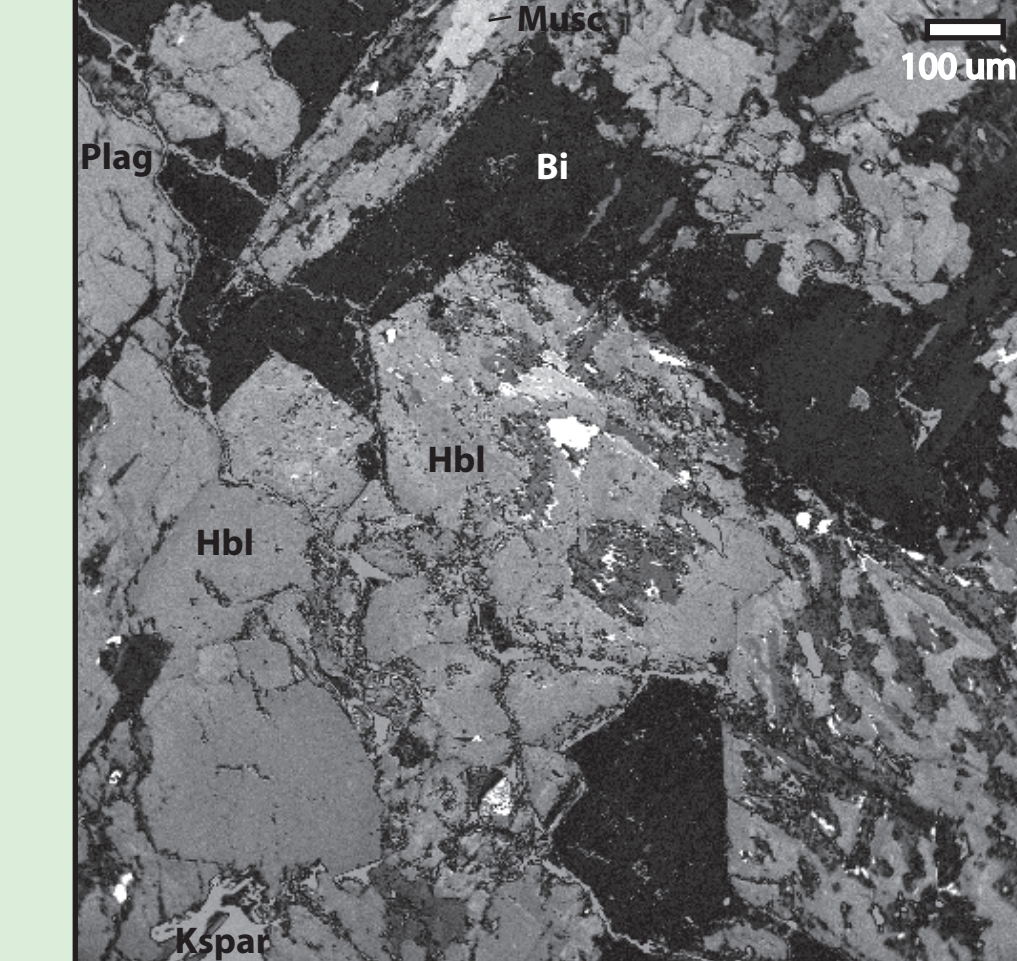
- **Barometry:** Coexisting Hbl + Plag + Kspar + Bi + Ep + Tit

- Fe/(Fe+Mg) vs Al<sup>IV</sup> correlation suggests alteration
- Pressure estimates are too low (2-3 Kbar). Al loss?

### TAJ-102



### TAJ-93



Calibration Dataset	P (Kb)
Hammarstrom & Zen '86	2.3
Hollister et al. '87	2.2
Johnson & Rutherford '89	1.8
Schmidt '92	2.9

Calculated using gtr.bio.ols  
<http://www.earth.ox.ac.uk/~davewa/pt/>

## Acknowledgments

**People:** Ken Farley Anatoli Ischuk Mars Toktogonov Kanatbek Adrahmatov Doug Burbank  
**Funding:** GSA SG&T division California Mineralogical Society Sigma Xi student GIAR Louise McCarren Foundation

## Selected References

Hollister, L.S., Grissom, G.C., Peters, E.K., Stowell, H.H., Sisson, V.B., 1987. Confirmation of the empirical correlation of Al in hornblende with pressure of solidification of calc-alkaline plutons. *American Mineralogist* 72, 231-239.

Johnson, M.C., Rutherford, M.J., 1989. Experimental calibration of the aluminum-in-hornblende geobarometer with application to Long Valley Caldera volcanic rocks. *Geology* 17, 837-841.

Robinson, A.C., Yin, A., Manning, C.E., Harrison, T.M., Zhang, S.H., Wang, X.F., 2004. Tectonic evolution of the northeastern Pamir: Constraints from the northern portion of the Cenozoic Kongur Shan extensional system, western China. *Tectonics* 23, 293-313.

Robinson, A.C., Yin, A., Manning, C.E., Harrison, T.M., Zhang, S.H., Wang, X.F., 2007. Cenozoic evolution of the eastern Pamir: Implications for strain accommodation mechanisms at the western end of the Himalayan-Tibetan orogen. *Geological Society of America Bulletin* 119, 882-896.

Strecker, M., Frisch, W., Hamburger, M.W., Ratschbacher, L., Semiletin, A., Zamoruyev, A., Sturchio, N., 1995. Quaternary deformation in the Eastern Pamirs, Tajikistan and Kyrgyzstan. *Tectonics* 14, 1061-1079.

Thompson, A.B., R.J., Lytle, P.T., 1977. Prograde reaction histories deduced from compositional zonation and mineral inclusions in garnet from Gassetts schist, Vermont. *AMERICAN JOURNAL OF SCIENCE* 277, 1152-1167.

Zen, E., Hammarstrom, J.M., 1988. Plumbing the depths of plutons by magmatic epidote hornblende association. *Geological Society of America Bulletin* 20, 475-476.