Development and Applications of a Novel Mass Spectrometer System For Laser $^{40}Ar/^{39}Ar$ Geochronology

Dr. Bill Hames[1] and Dr. Andreas Illies[2],
Auburn University.
[1]Department of Geology and Geography;
[2]Department of Chemistry and Biochemistry

Presentation Outline

- Commercial Noble Gas Spectrometers
- Motivation For Building a Spectrometer
- Construction
- Characteristics
- Performance
- Applications

Instruments that enable precise analysis with smaller sample quantities lead to scientific advances.

Commercial Instruments For $^{40}Ar/^{39}Ar$ Dating

- **Nu Instruments**

  Noblesse *http://www.nu-ins.com/nobledetail.html*

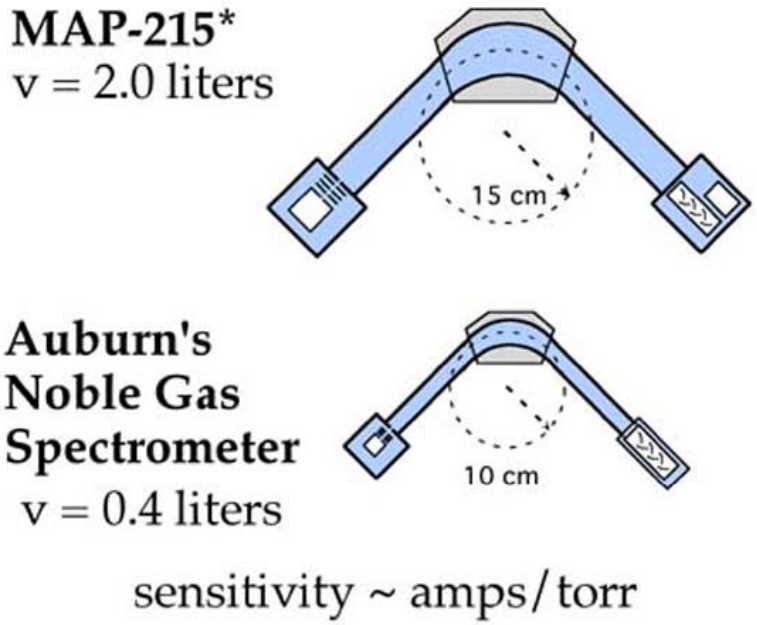
  Aurora *http://www.nu-ins.com/auroradetail.html*

- **GV Instruments**

  Argus *http://www.gvinstruments.co.uk/Noble_Gas_MS.htm*

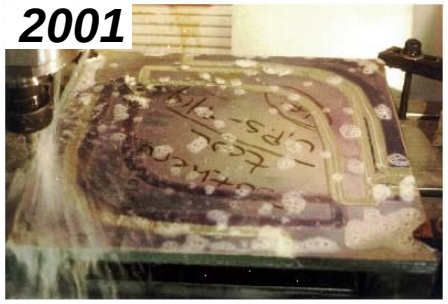
Motivations for Building an Instrument

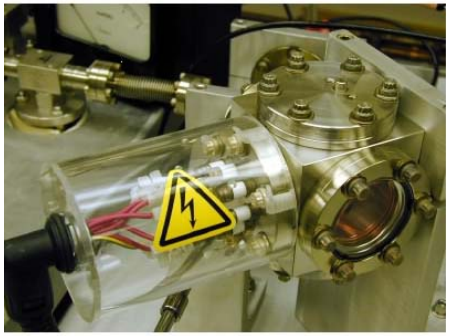
- Higher sensitivity and lower blank for argon isotopes;
- Greater efficiency (in time and facilities);
- Compatibility with standard hardware;
- Lower cost of operation.

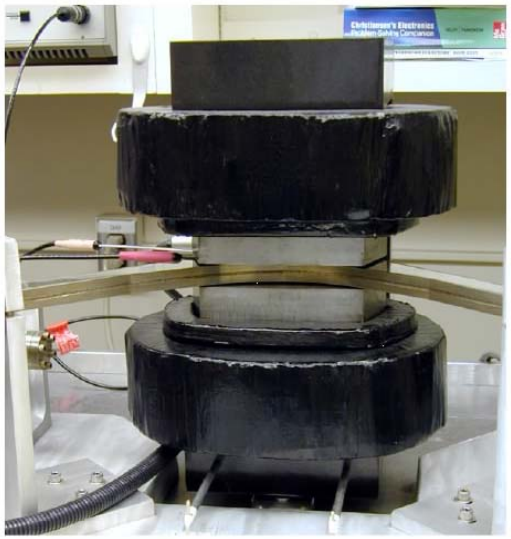


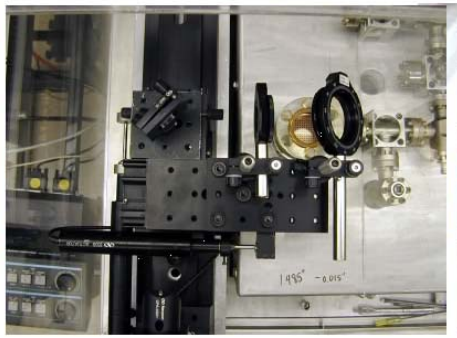
Construction:

The time from conception of the instrument to routine analysis was approximately six years.

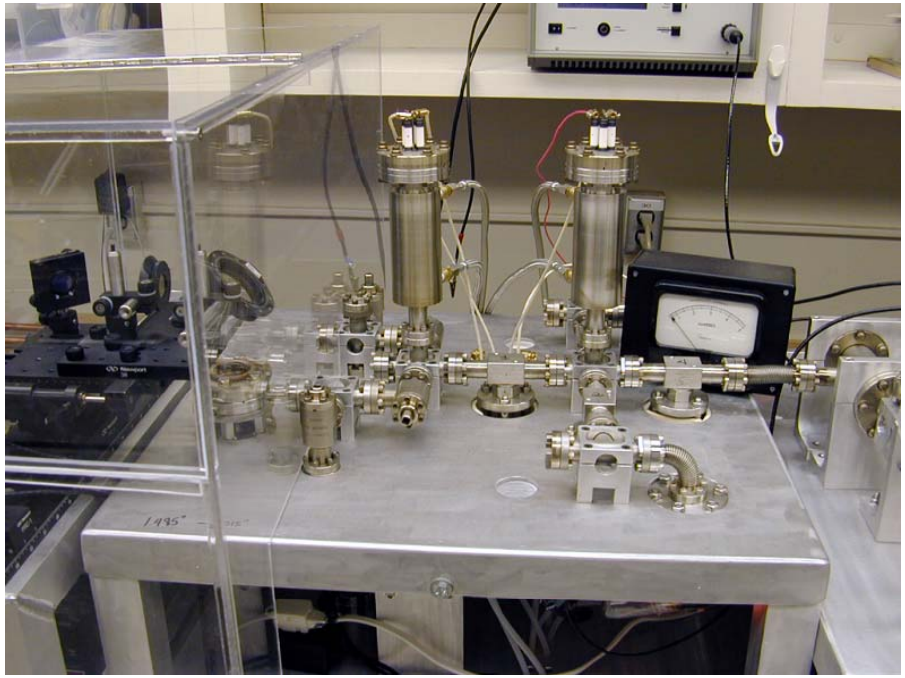


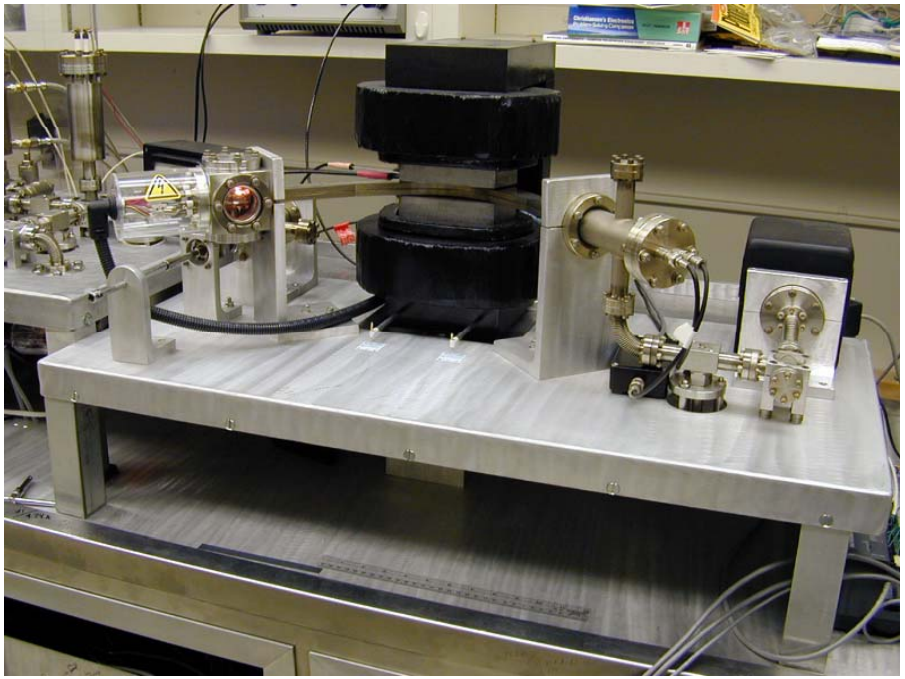




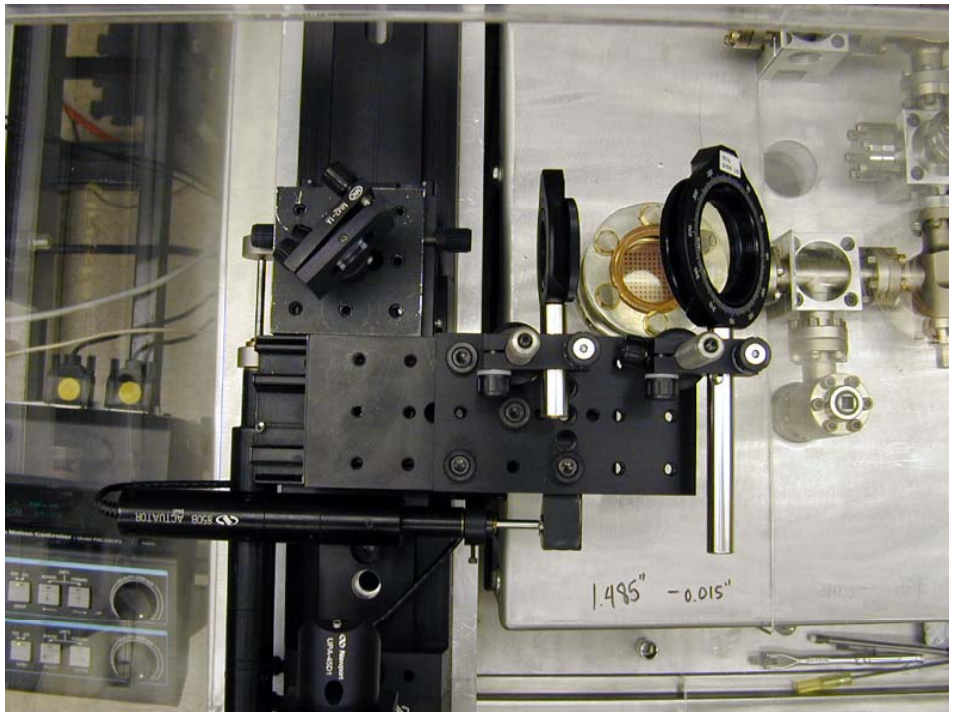


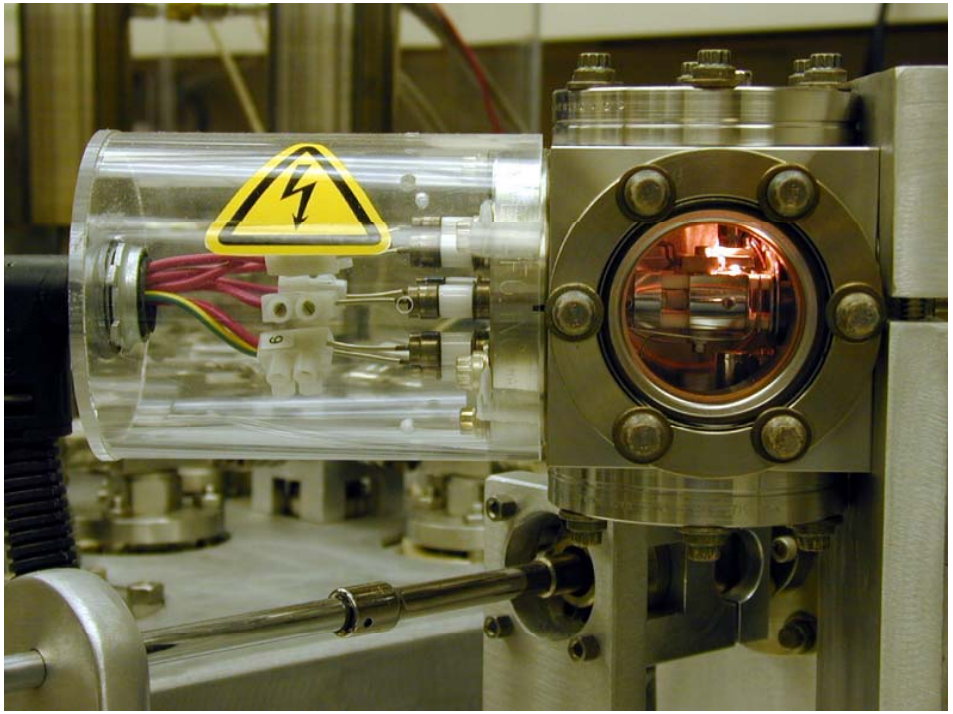
Construction





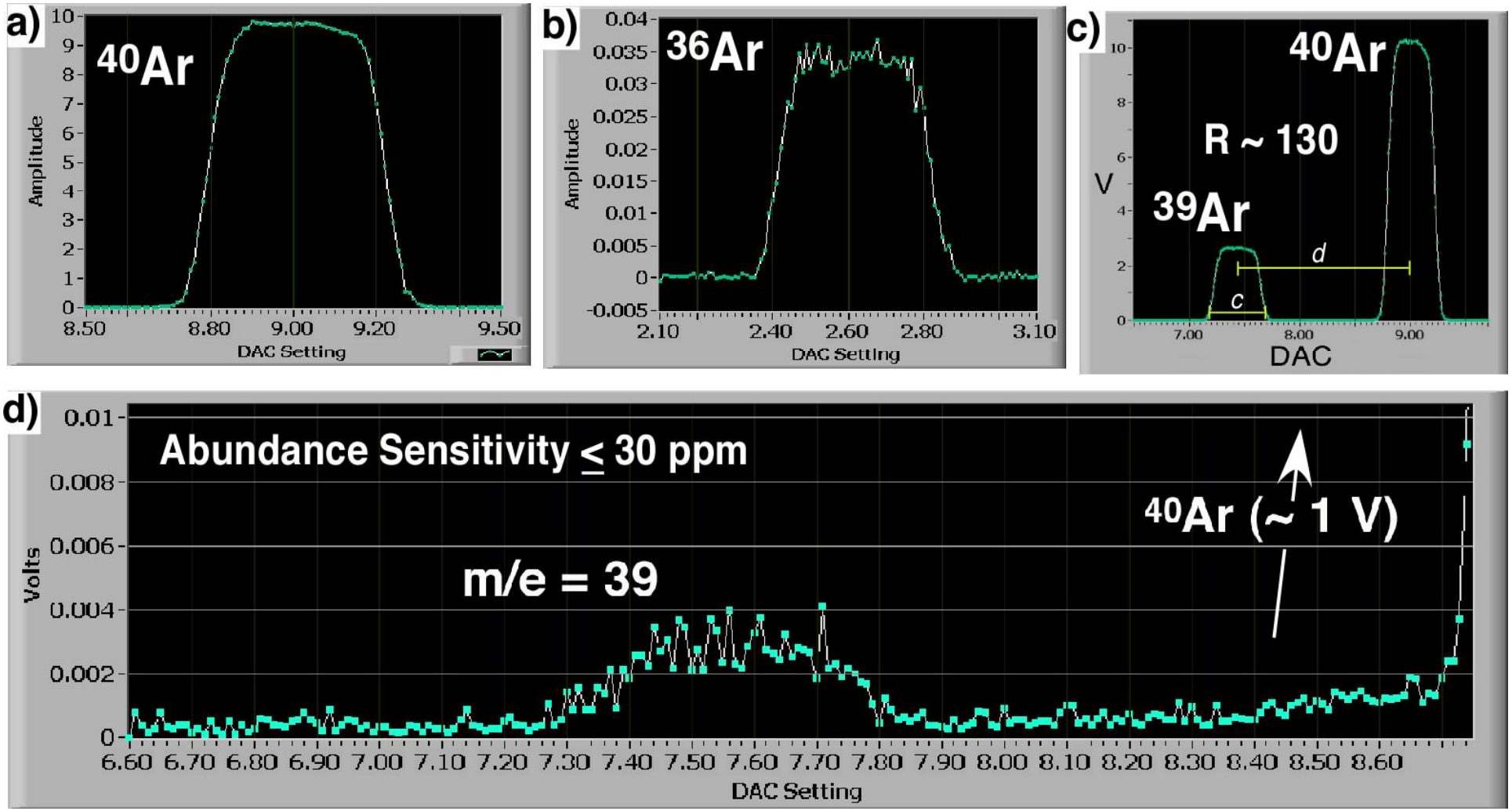
Construction





ANIMAL: Auburn Noble Isotope Mass Analysis Laboratory

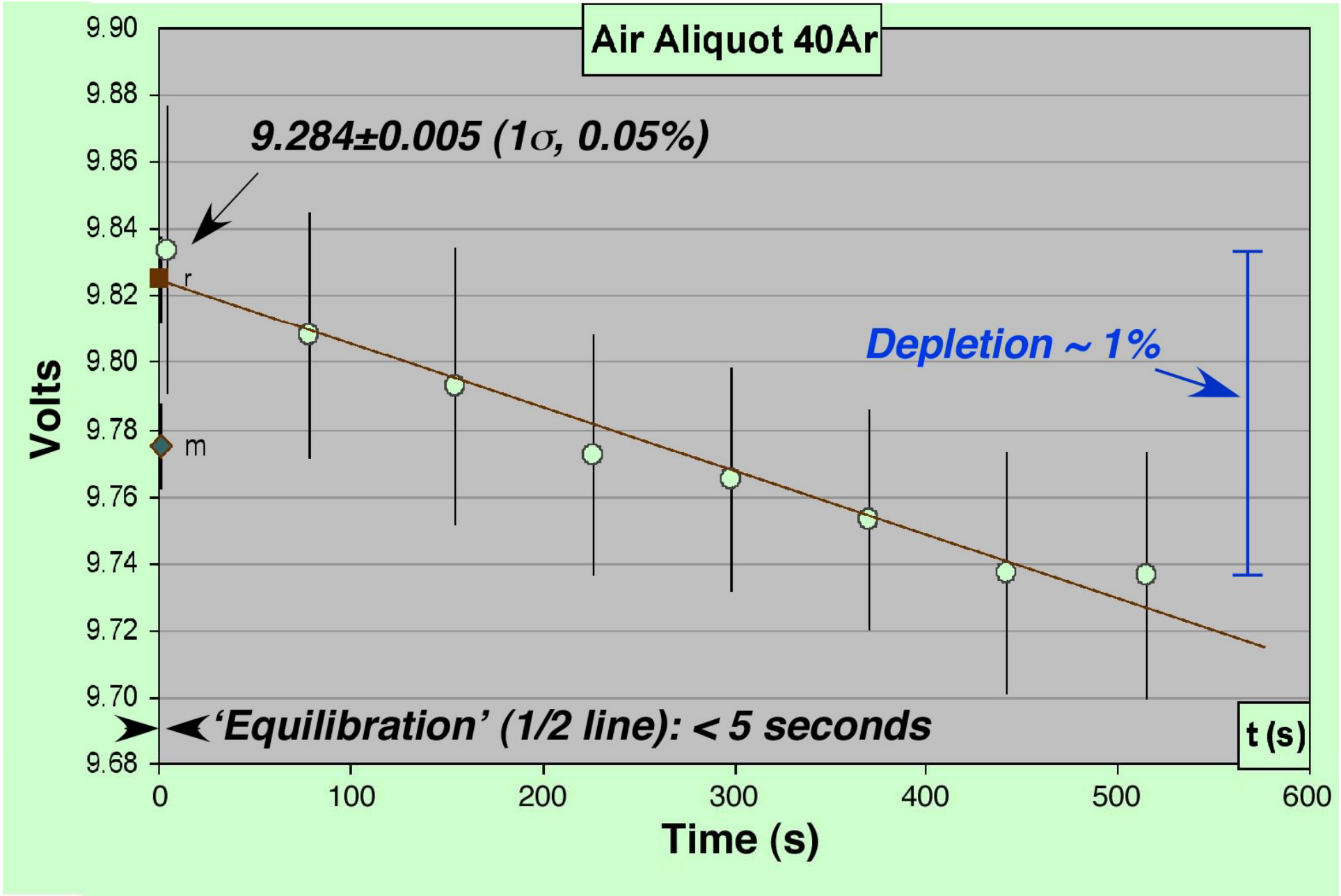
Characteristics

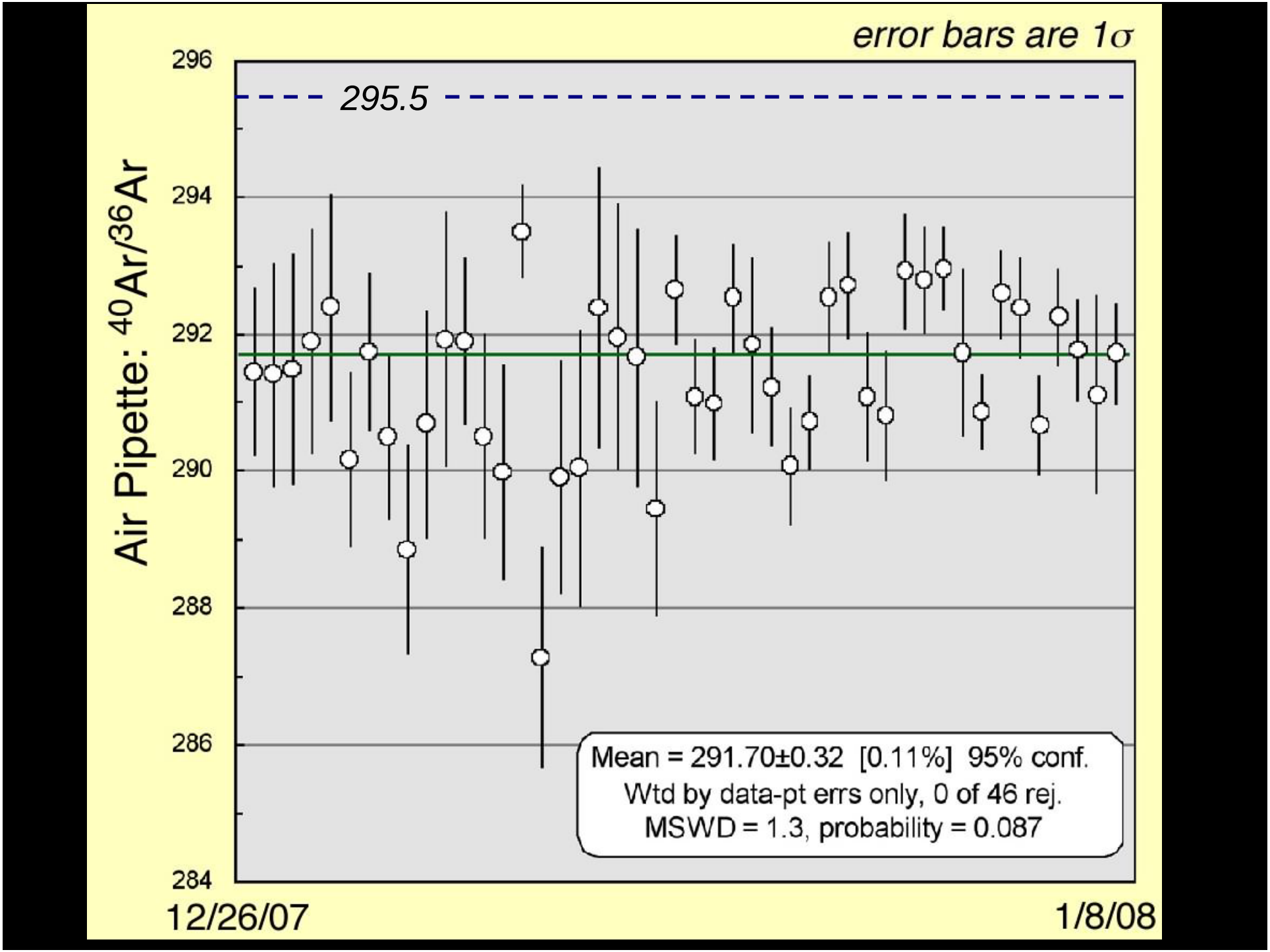


$$t_{age} = 1/\lambda \cdot \ln\left[{}^{40}Ar^{*}/{}^{39}Ar_{K} \cdot J + 1\right]$$

$$^{40}Ar^{*} = (^{40}Ar_{meas}) - (295.5 \cdot {}^{36}Ar)$$

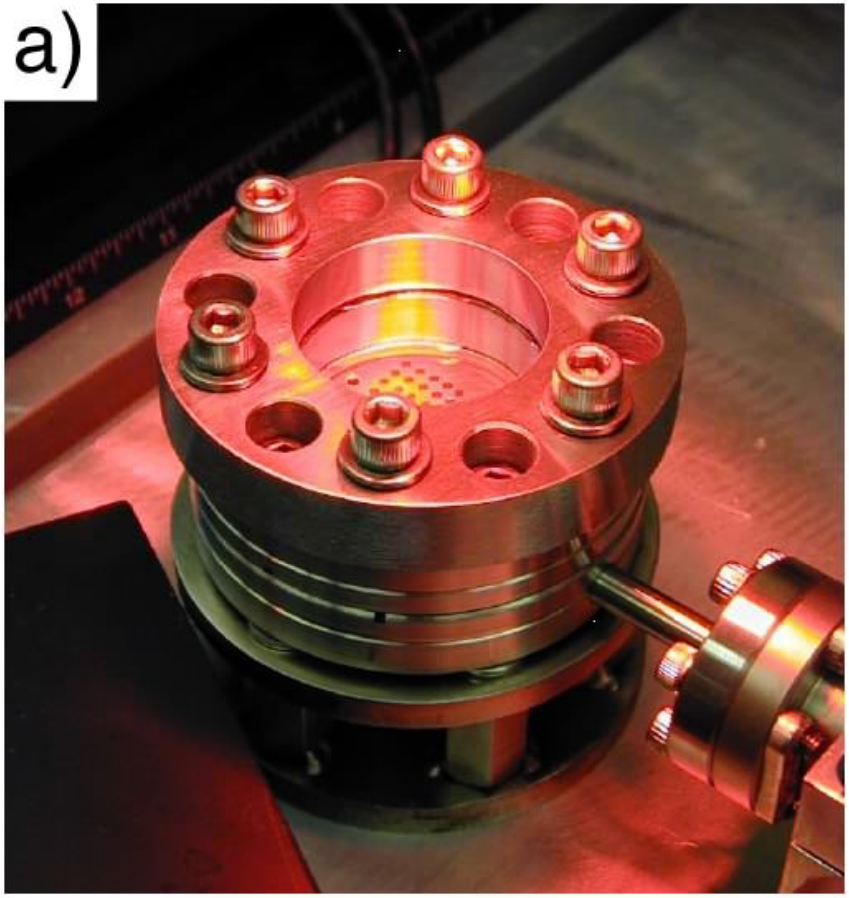
Characteristics

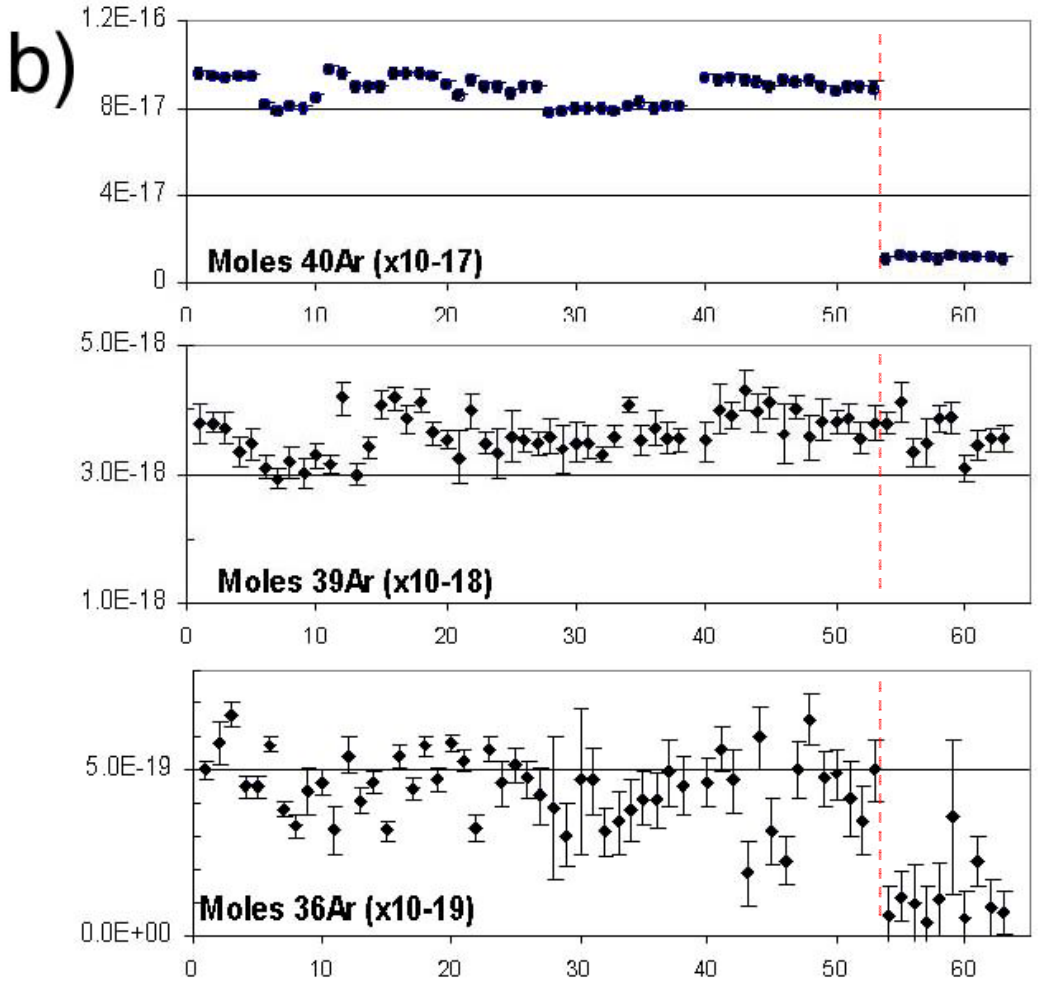



error bars are 1σ
296
295.5
294
292
290
288
286
284
Air Pipette: $^{40}Ar/^{36}Ar$
Mean = 291.70±0.32 [0.11%] 95% conf.
Wtd by data-pt errs only, 0 of 46 rej.
MSWD = 1.3, probability = 0.087
12/26/07
1/8/08

Testing

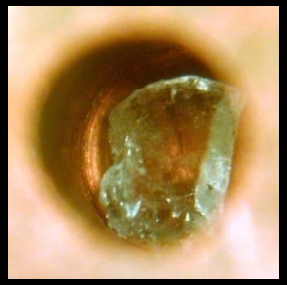
No s.c.



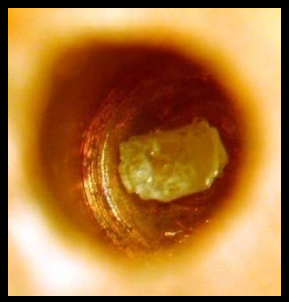


- Blanks for m/e=40 are ~ 1-2 x10^{-16} mol (4 minute)

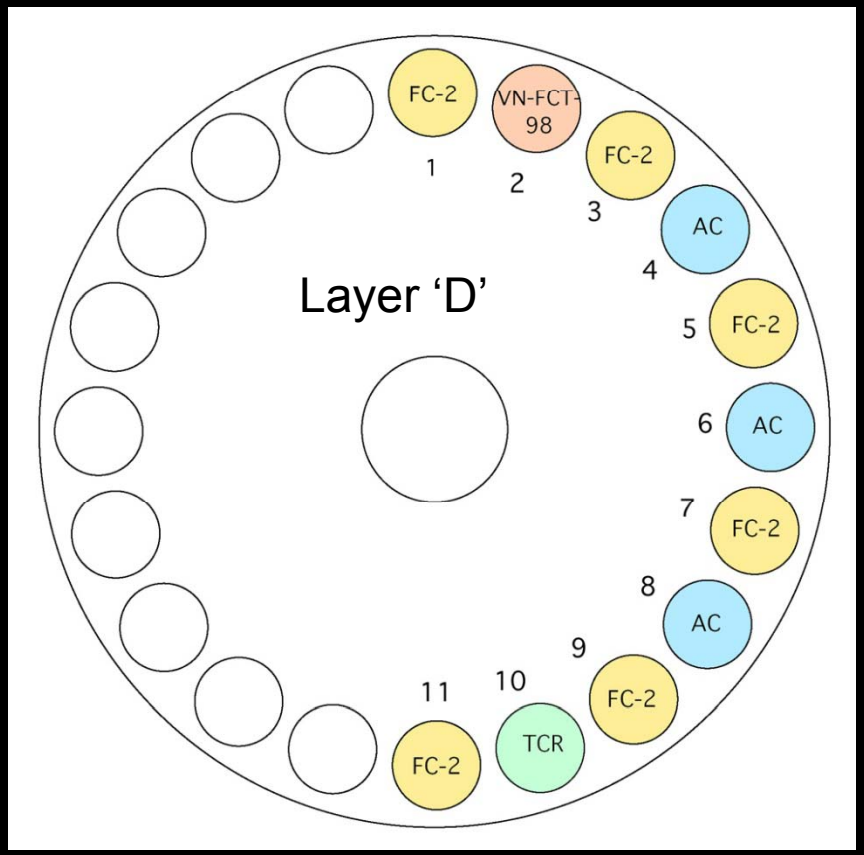
Performance: Earthtime Standards

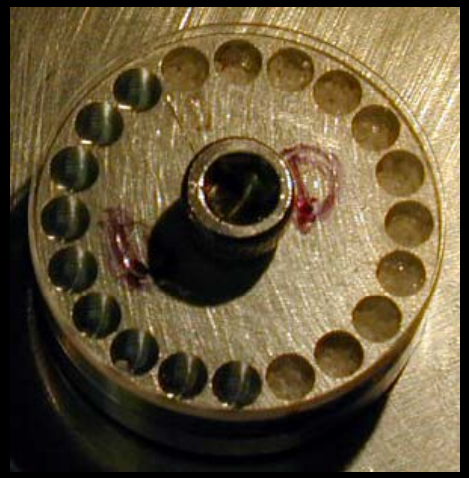


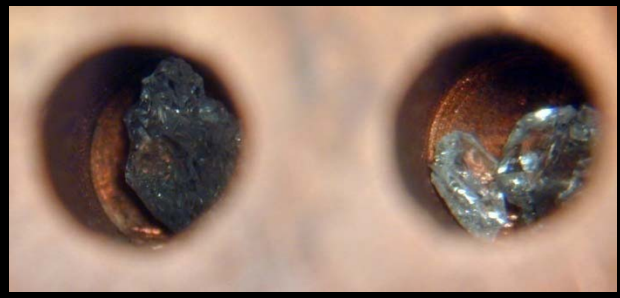
FC2-NMT
(VN-FC-98)



TCR-USGS





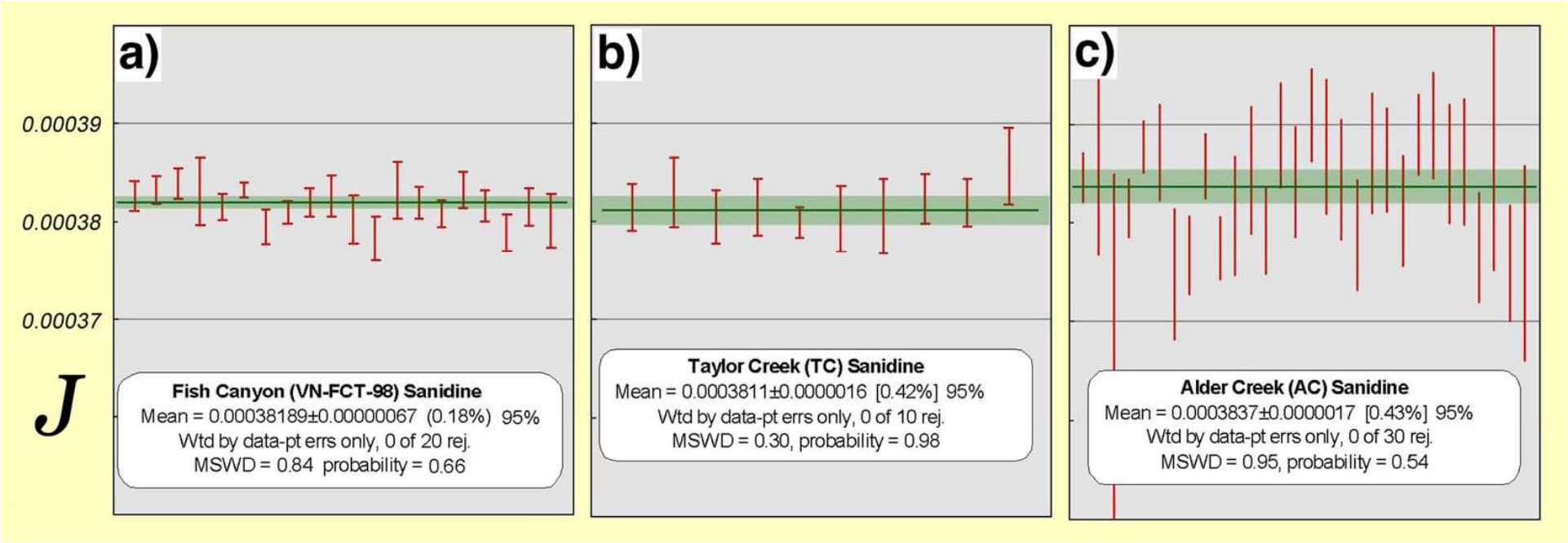


ACS-BGC

Twenty international laboratories are participants in Earthtime $^{40}Ar/^{39}Ar$ dating.

Performance: Earthtime Standards

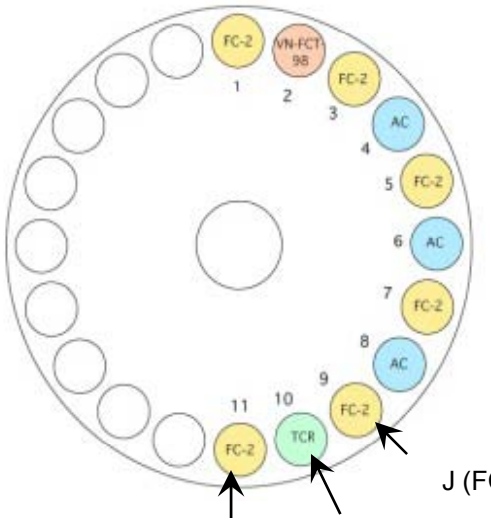
t=28.02 Ma *t=28.34 Ma* *t=1.193 Ma*



$$t_{age} = 1/\lambda \cdot \ln\left[\frac{^{40}Ar^*}{^{39}Ar_K} \cdot J + 1\right] \qquad ^{40}Ar^* = (^{40}Ar_{meas}) - (295.5 \cdot ^{36}Ar)$$

Assigned ages for standards based on Renne et al., 1998, and Nomade et al., 2005

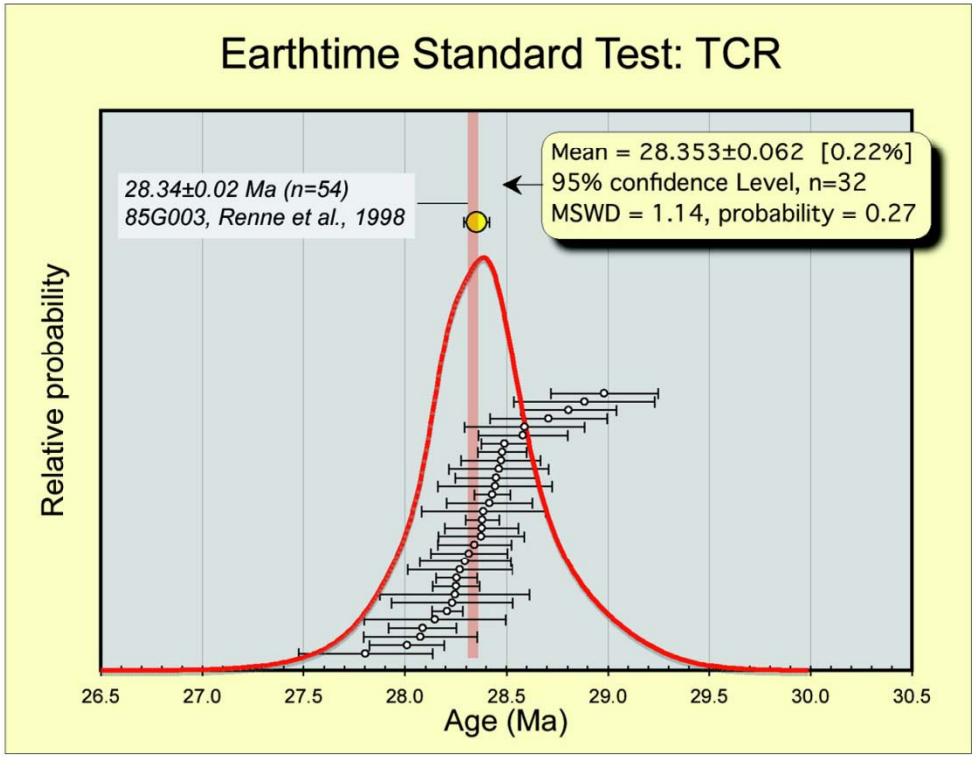
Performance: Taylor Creek Rhyolite



J (FC2 @ 28.02 Ma)

J (FC2 @ 28.02 Ma)

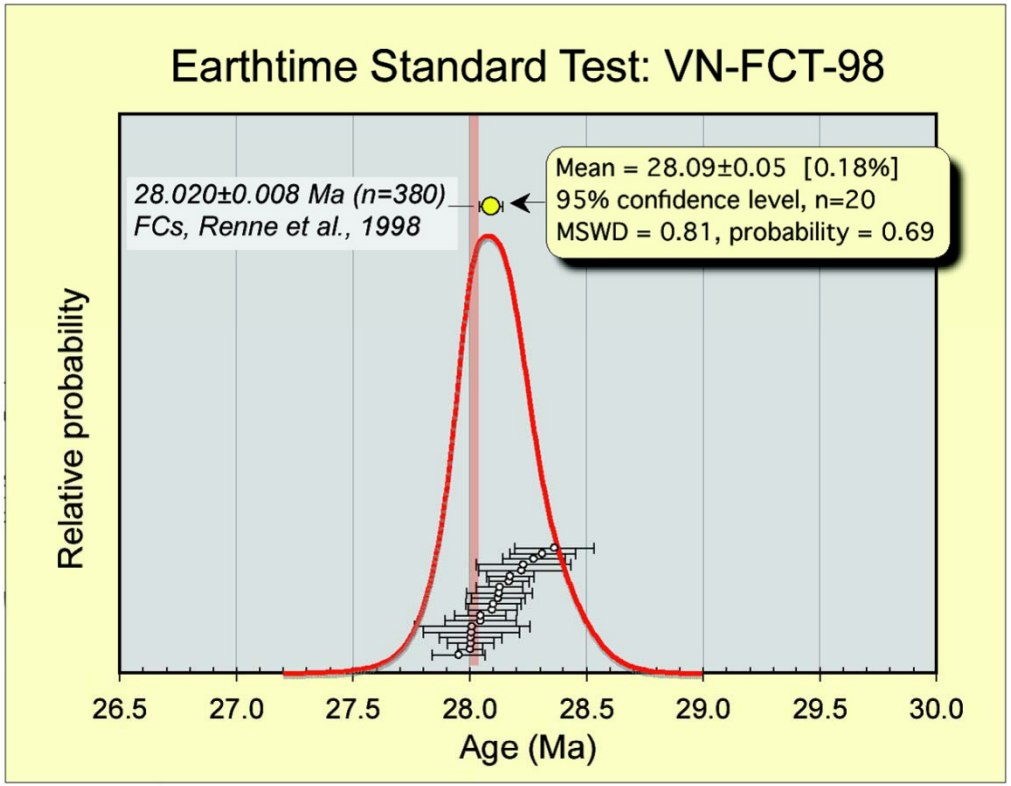
J-TCR



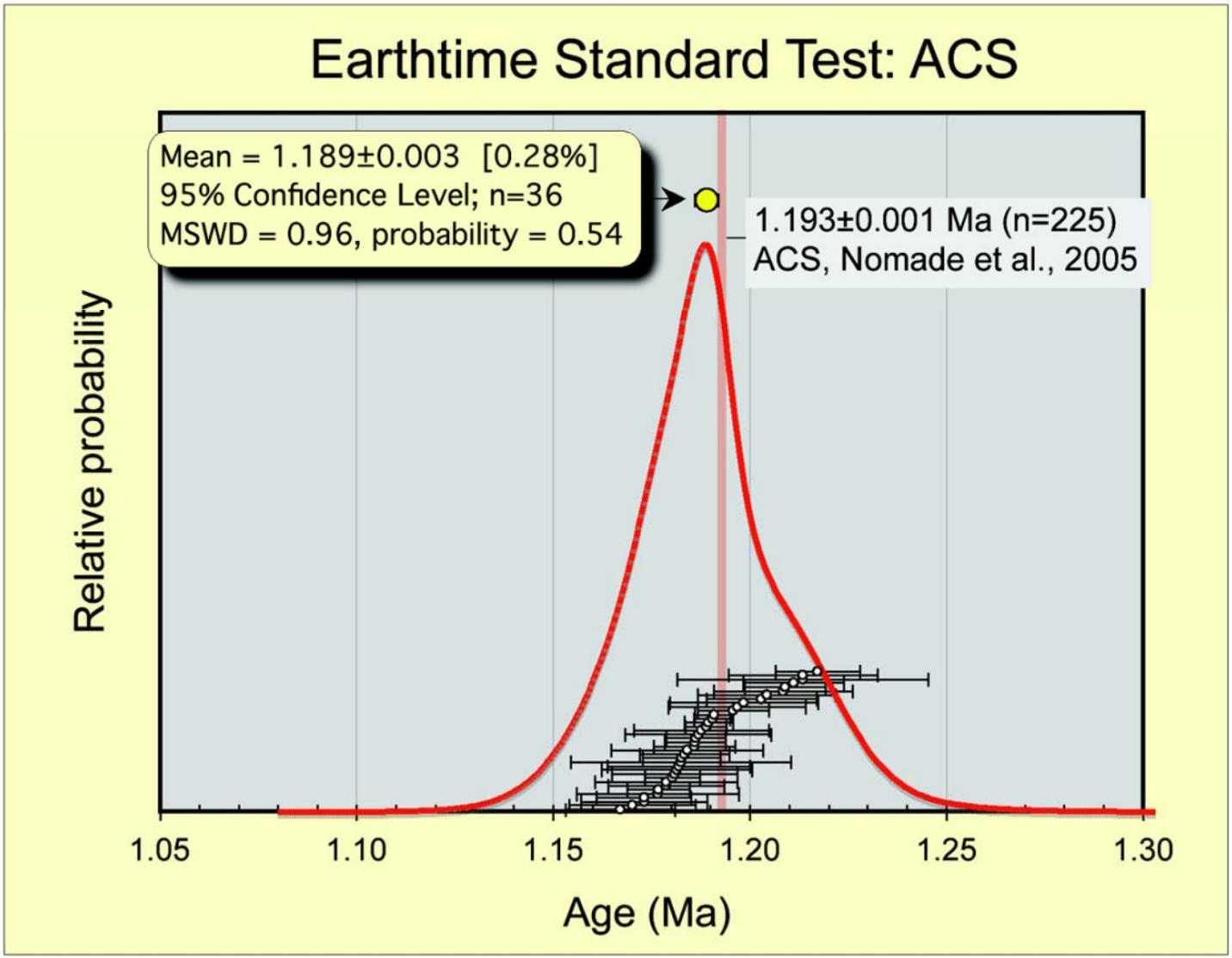
Performance: VN-FCT-98

~ 0.5 mm

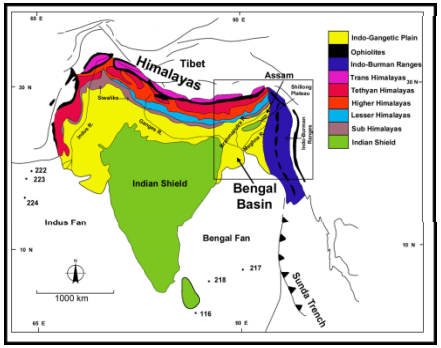
Crystals analyzed included some with melt inclusions.

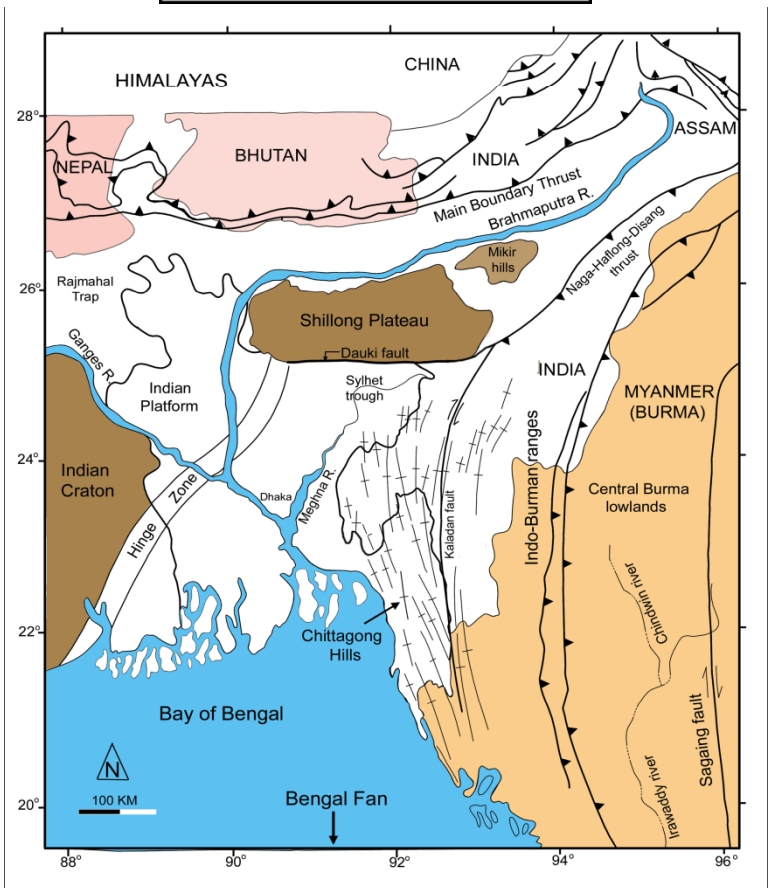


Performance: Alder Creek Sanidine

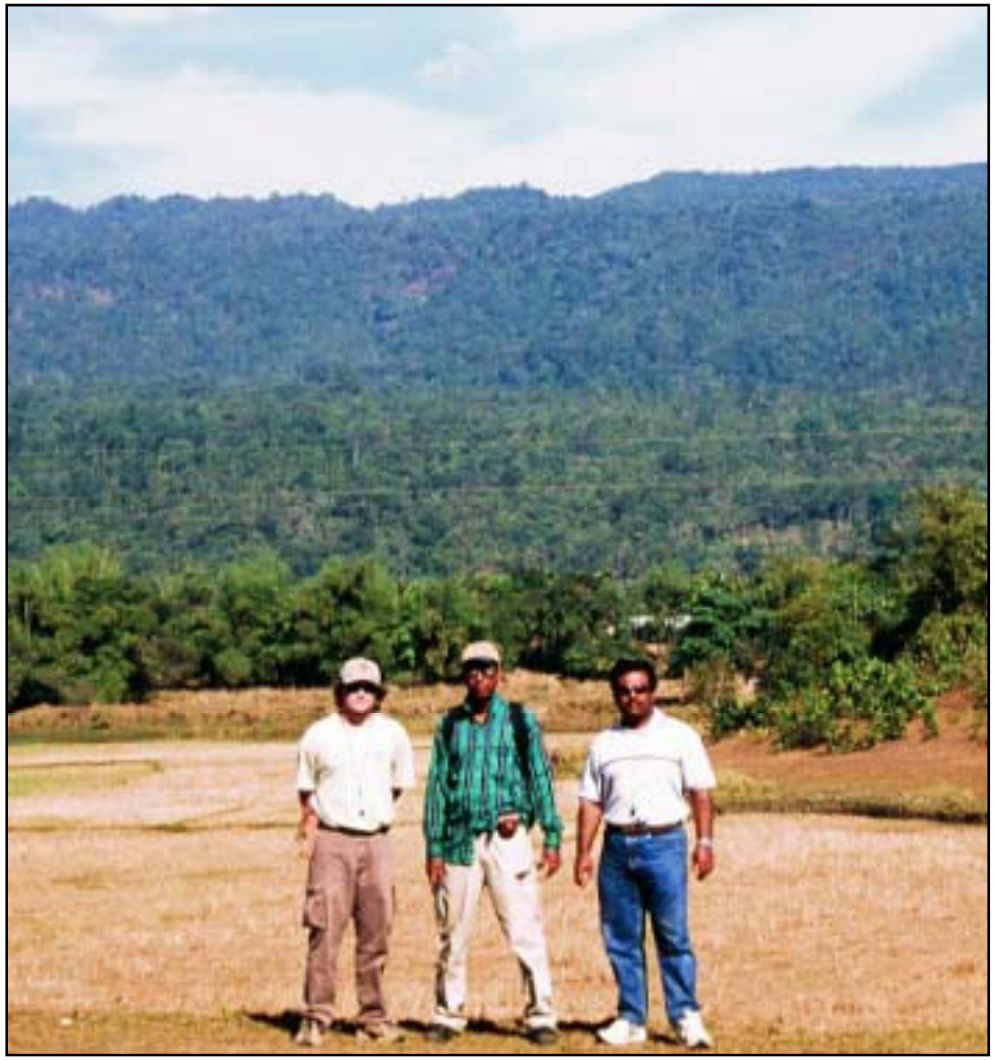


Application: Himalayan Sedimentation

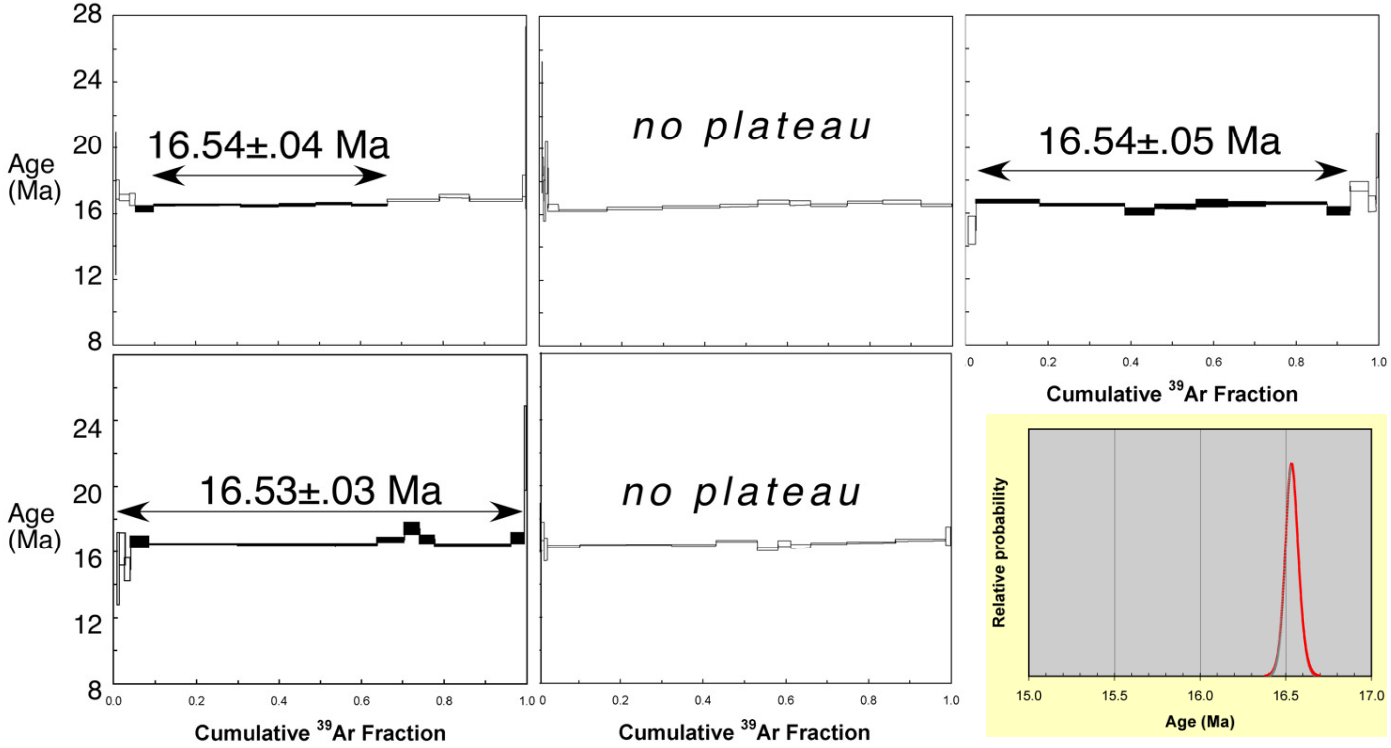


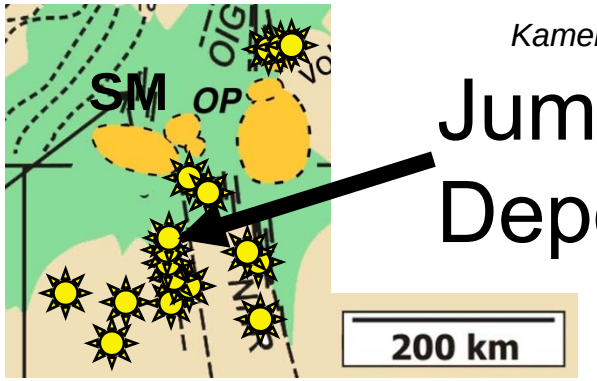


Dr. A. Uddin and AU Graduate Students



Application: Metallogeny and Magmatism in the Early Yellowstone Hotspot





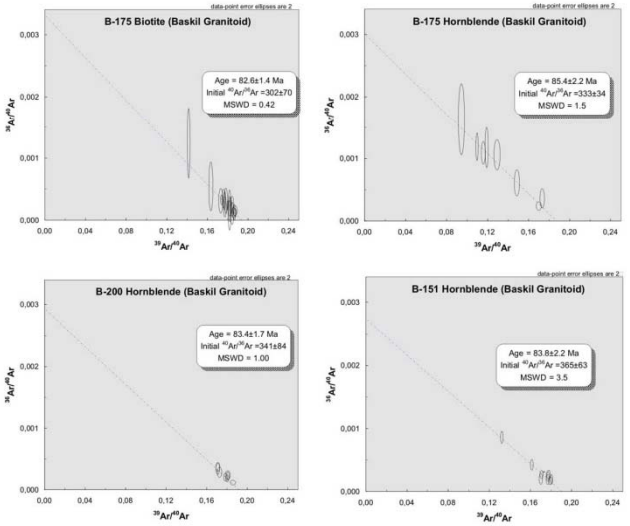
Jumbo Deposit

Kamenov et al., in press; Saunders et al., in prep.; Hames et al., in prep.

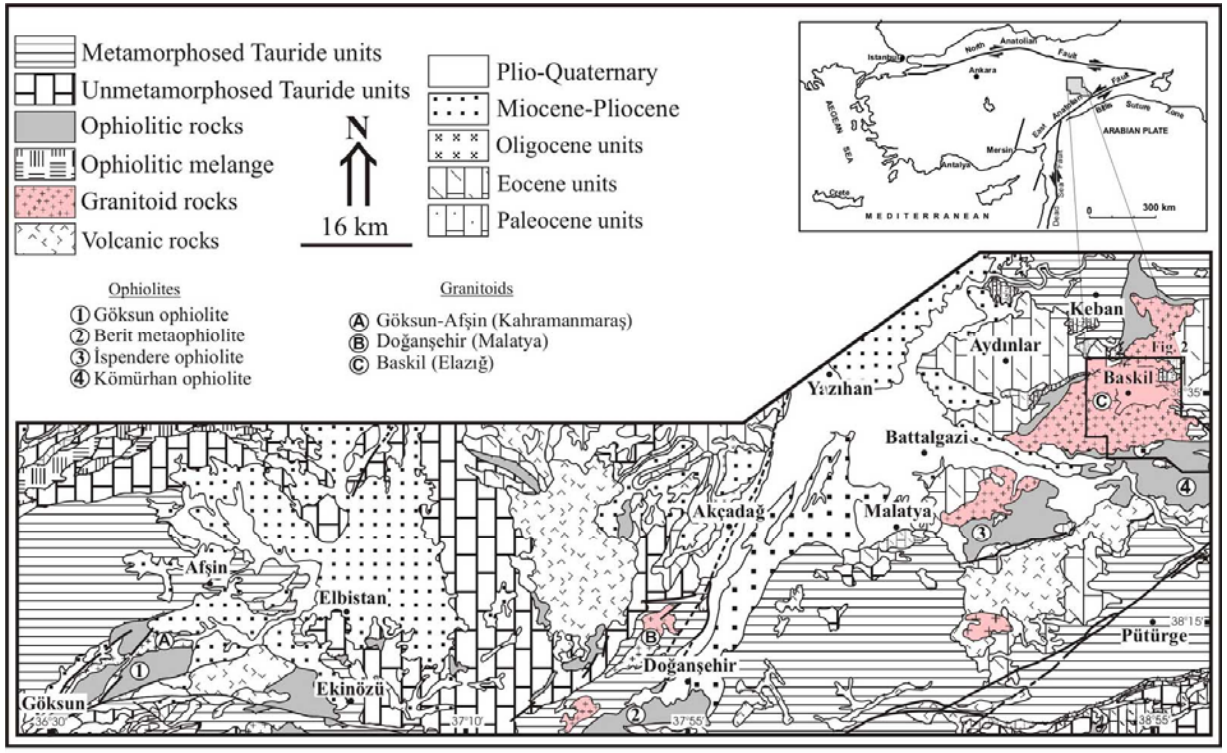
The weighted average of three analyses for adularia of Jumbo is 16.54±0.04 (95% confidence level). Two crystals exhibit extraneous, non-atmospheric argon.

Application: Tectonics of the Eastern Anatolian Suture

Rızaoğlu et al., in press.



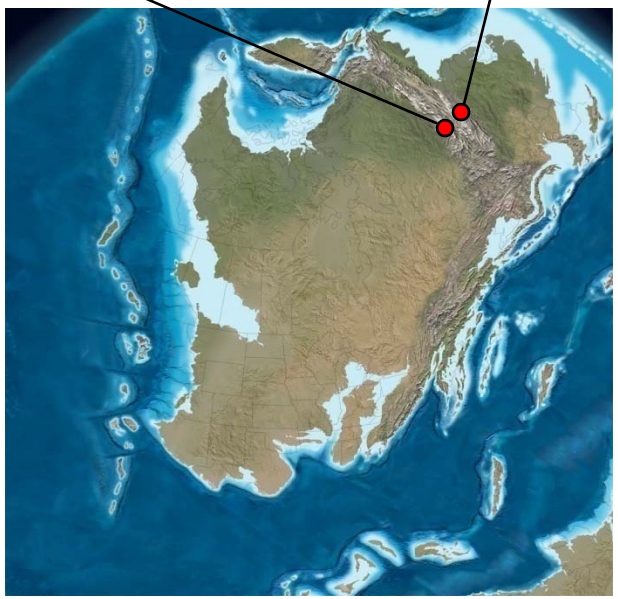
L-R: Dr. O. Parlak, W. Hames, Z. Billor



Hornblende from post-emplacement granitoids in ophiolites in the Eastern Anatolian Shear Zone yield laser single-crystal $^{40}Ar/^{39}Ar$ ages of 84-85 Ma.

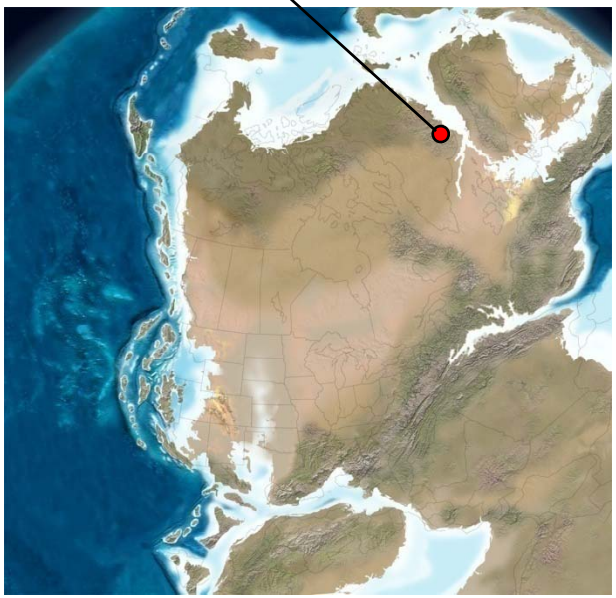
Application: Tectonics of the Scandinavian Caledonides

Students directed by Dr. M. Steltenpohl



Ca. 400 Ma

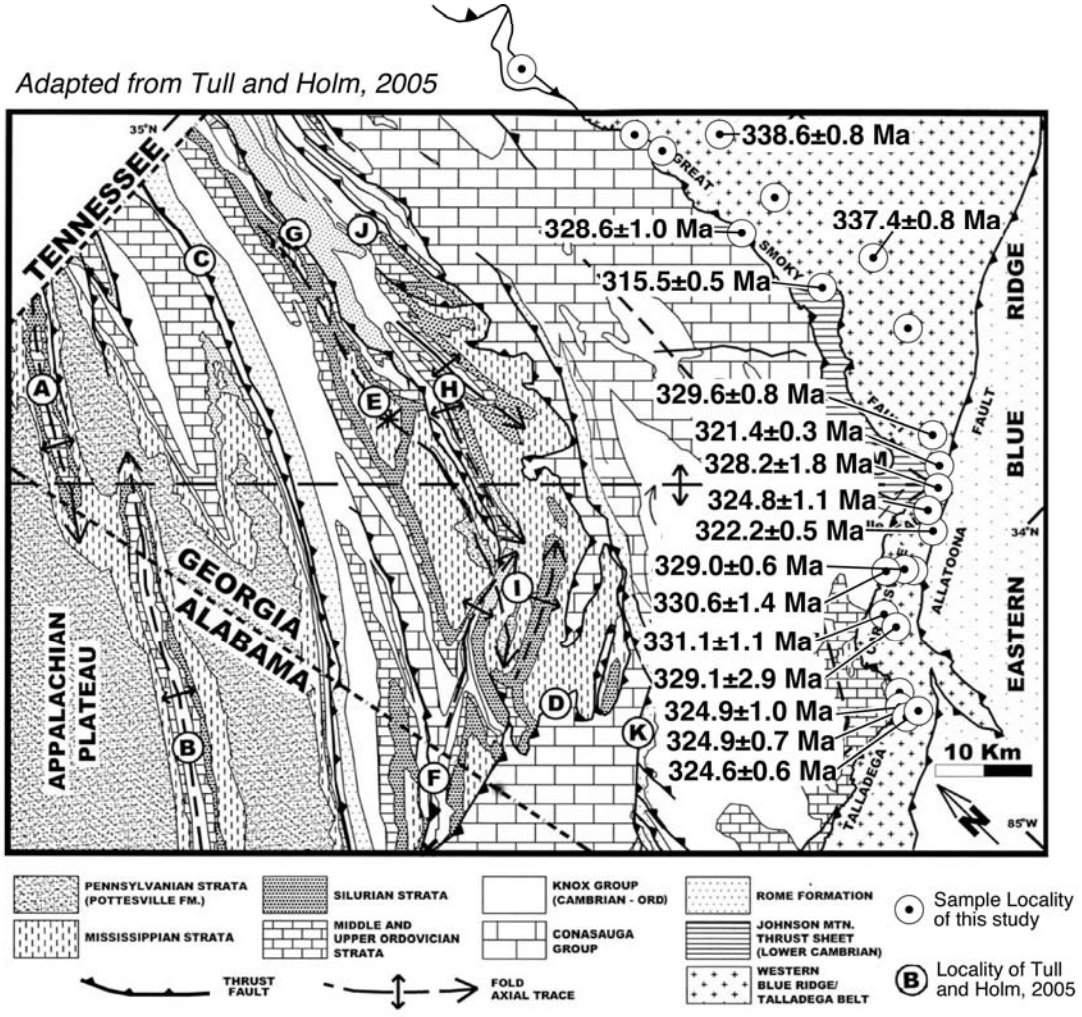
Lamprophyre dikes: 262±1 Ma

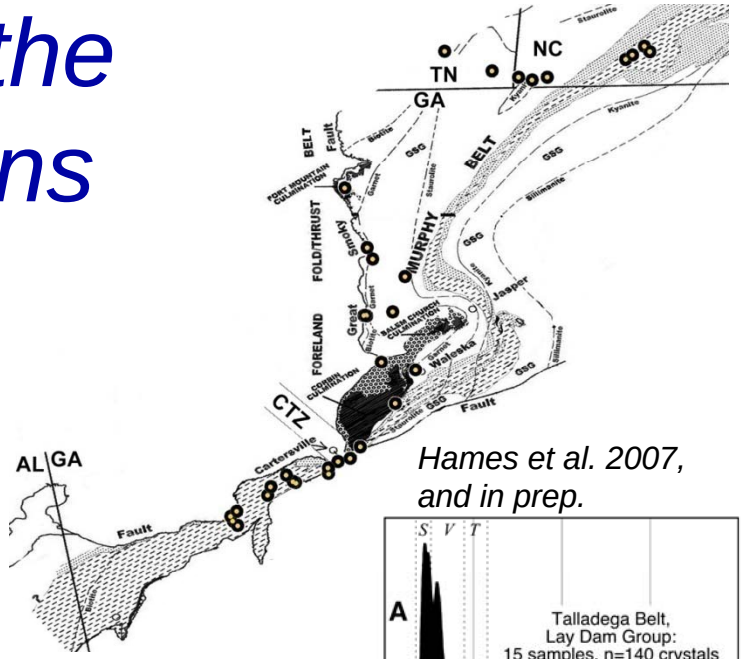


Ca. 260 Ma

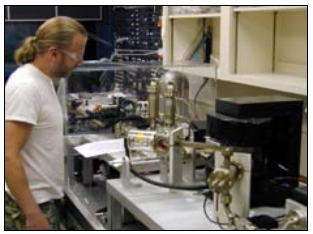
Tectonic Reconstructions: Dr. Ron Blakey, Northern Arizona University

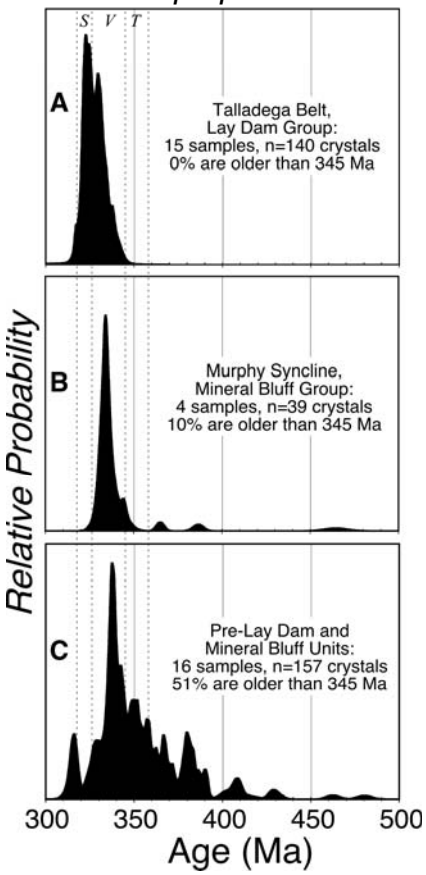
Application: Tectonics of the Southeastern Appalachians





Hames et al. 2007, and in prep.





Refinements:

- Computer monitoring and control of electronics;
- Web-based instrument control and real-time viewing of experiments;
- Changes in vacuum system to permit ~5×10^{-17} mol ^{40}Ar in a typical blank (lower by 50%);

Adaptation and Future Construction:

- A specialized system can be constructed for $^{40}Ar/^{39}Ar$ dating with UV-laser ablation;
- A specialized system can be constructed for quantitative helium measurements in (U-Th)/He dating.

Goals for Teaching and Training

- ANIMAL will become a regional center supporting a diverse array of geochronologic research activities;
- Experiments in ANIMAL will become a routine part of the Auburn University core science and humanities curriculum (Physical and Historical Geology, Concepts of Science, Human Odyssey);
- ANIMAL will continue to provide students with the unique perspective of designing, building and using an instrument for advanced geochronologic research.

Conclusions

- The characteristics and test data for ANIMAL compare favorably with results of established geochronologic laboratories;
- ANIMAL can be a viable Center at Auburn University that supports state-of-the-art research activities;
- Instrumentation developed at Auburn University can help promote noble gas mass spectrometry and geochronology.