# (U-Th)/He Studies of the Exhumational History of the Colorado Plateau Transition Zone

Janet Harvey, Brian Wernicke and Ken Farley

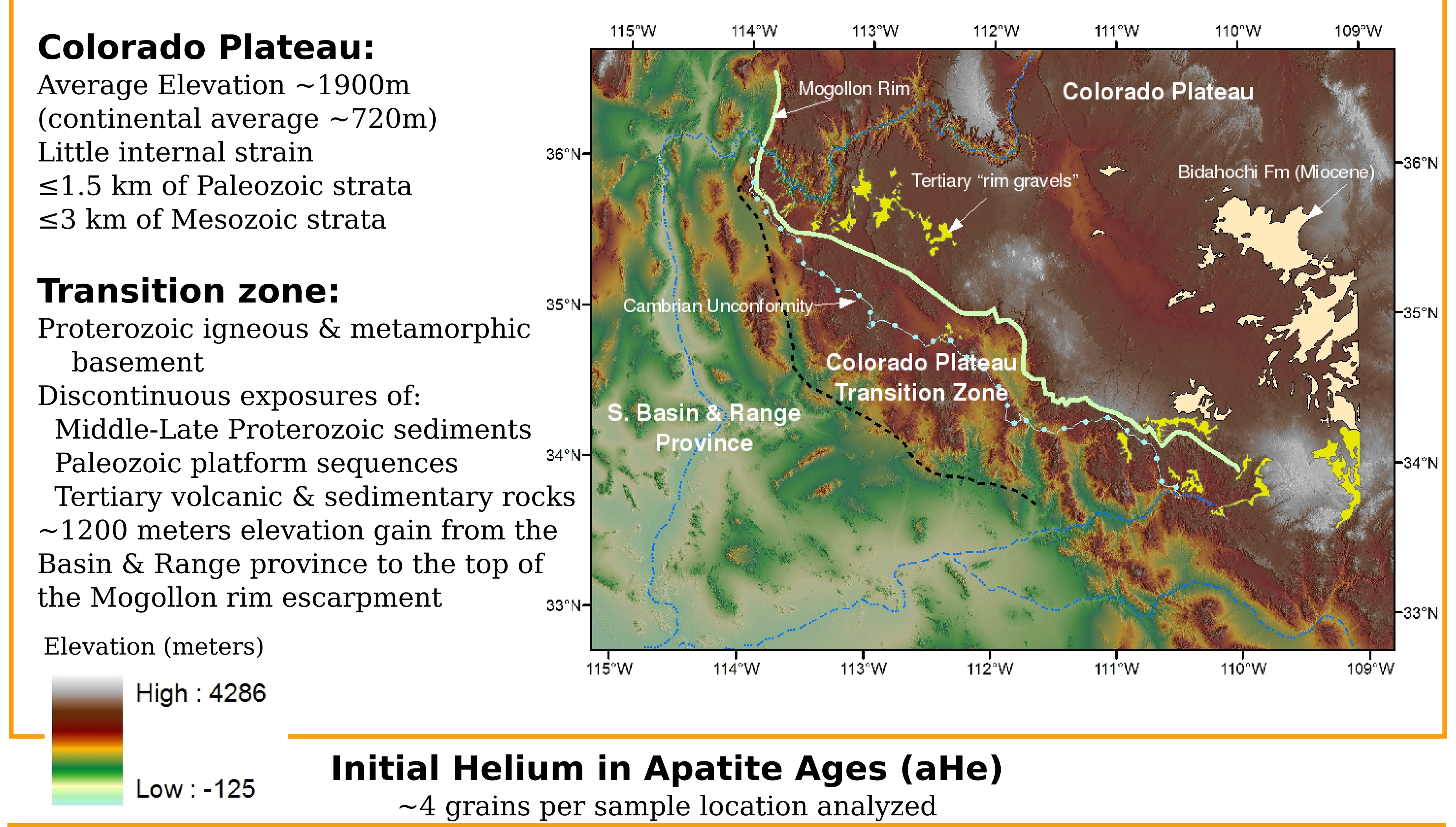
## Introduction

The project goal is to combine helium in apatite ages ( aHe: closure temperature ~75 °C) and helium in zircon ages (zHe: closure temperature~190 °C), in conjuction with existing apatite and zircon fission track data, to determine the spatial and temporal pattern of unroofing in the Colorado Plateau transition zone. Combined with previous work on the unroofing history of the Colorado Plateau itself, this should help determine the buoyancy source, or sources driving the relief development of this significant continental plateau and should give fundamental insights into continental dynamics.

## Geologic Setting of the Colorado Plateau & Transition Zone

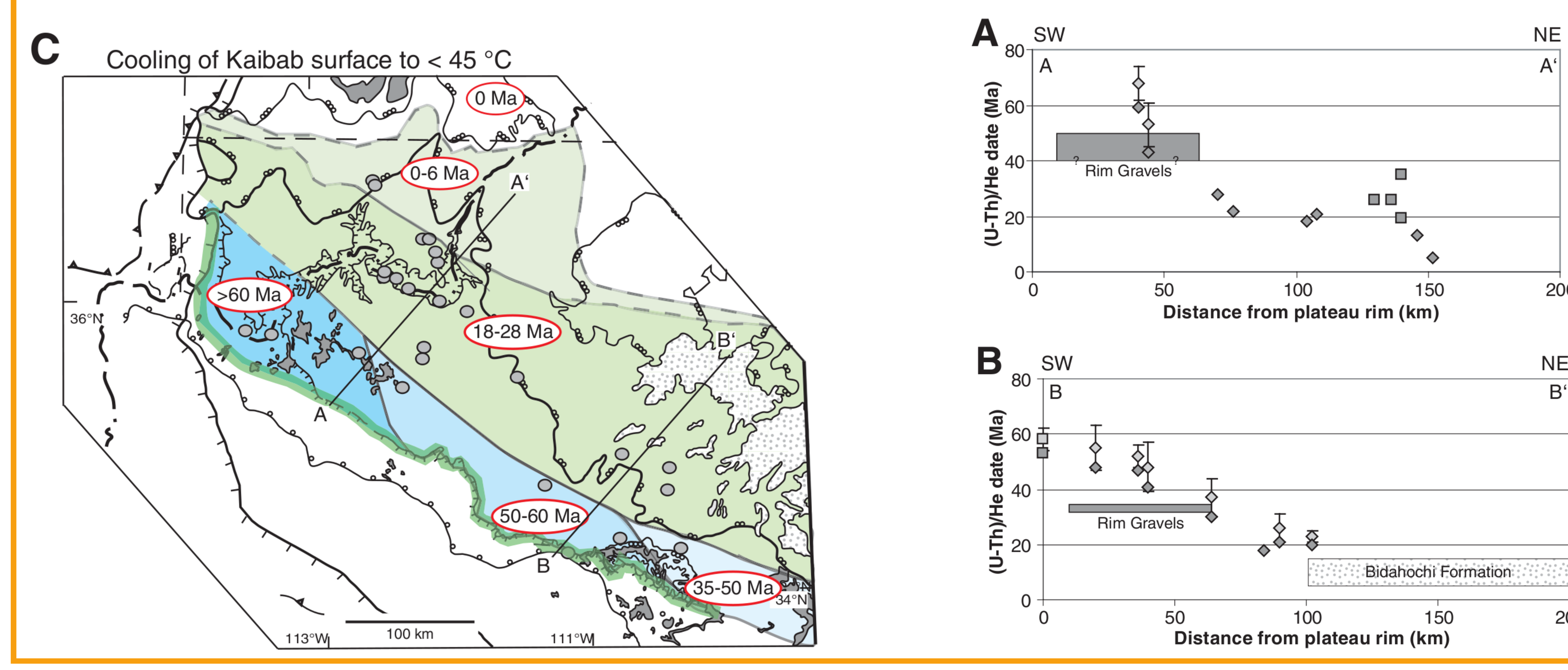
**Colorado Plateau:**
Average Elevation ~1900m
(continental average ~720m)
Little internal strain
≤1.5 km of Paleozoic strata
≤3 km of Mesozoic strata

**Transition zone:**
Proterozoic igneous & metamorphic basement
Discontinuous exposures of:
Middle-Late Proterozoic sediments
Paleozoic platform sequences
Tertiary volcanic & sedimentary rocks
~1200 meters elevation gain from the Basin & Range province to the top of the Mogollon rim escarpment

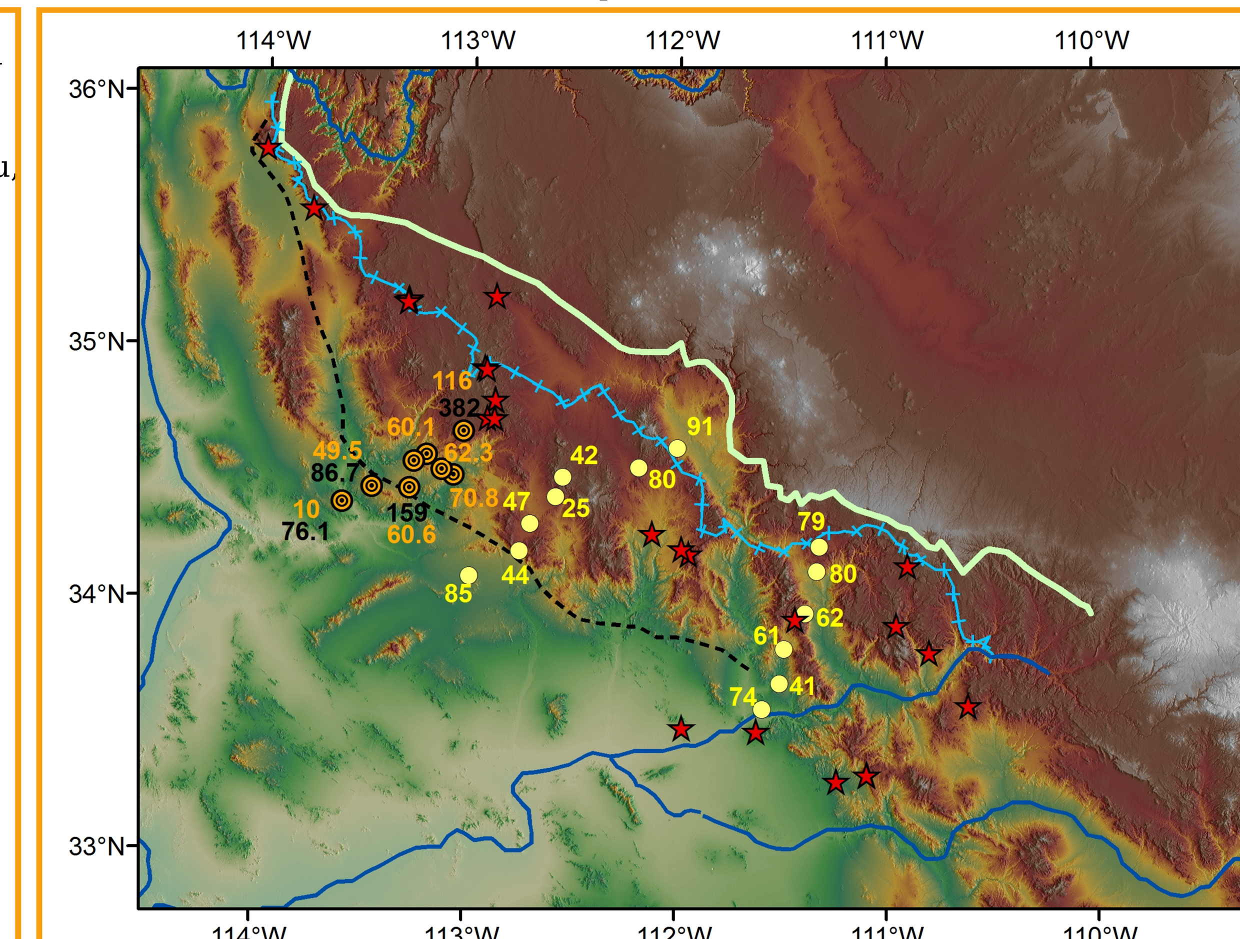



## Prior Work on the Colorado Plateau

Flowers et al., (2008)[1] have shown that substantial unroofing and the development of high relief began at the southwestern plateau margin during the Sevier Laramide orogony (80-50 Ma) progressing to the south east along the plateau margin through ~35 Ma, followed by denudation progressing to the north east from ~28 Ma through ~5 Ma. They conclude that the later stage of exhumation can be explained solely by enhanced denudation due to rifting to the south west of the plateau, and thus the ~80-50 Ma exhumation has the most relevance for understanding the mechanisms by which the Colorado Plateau uplift occurred.



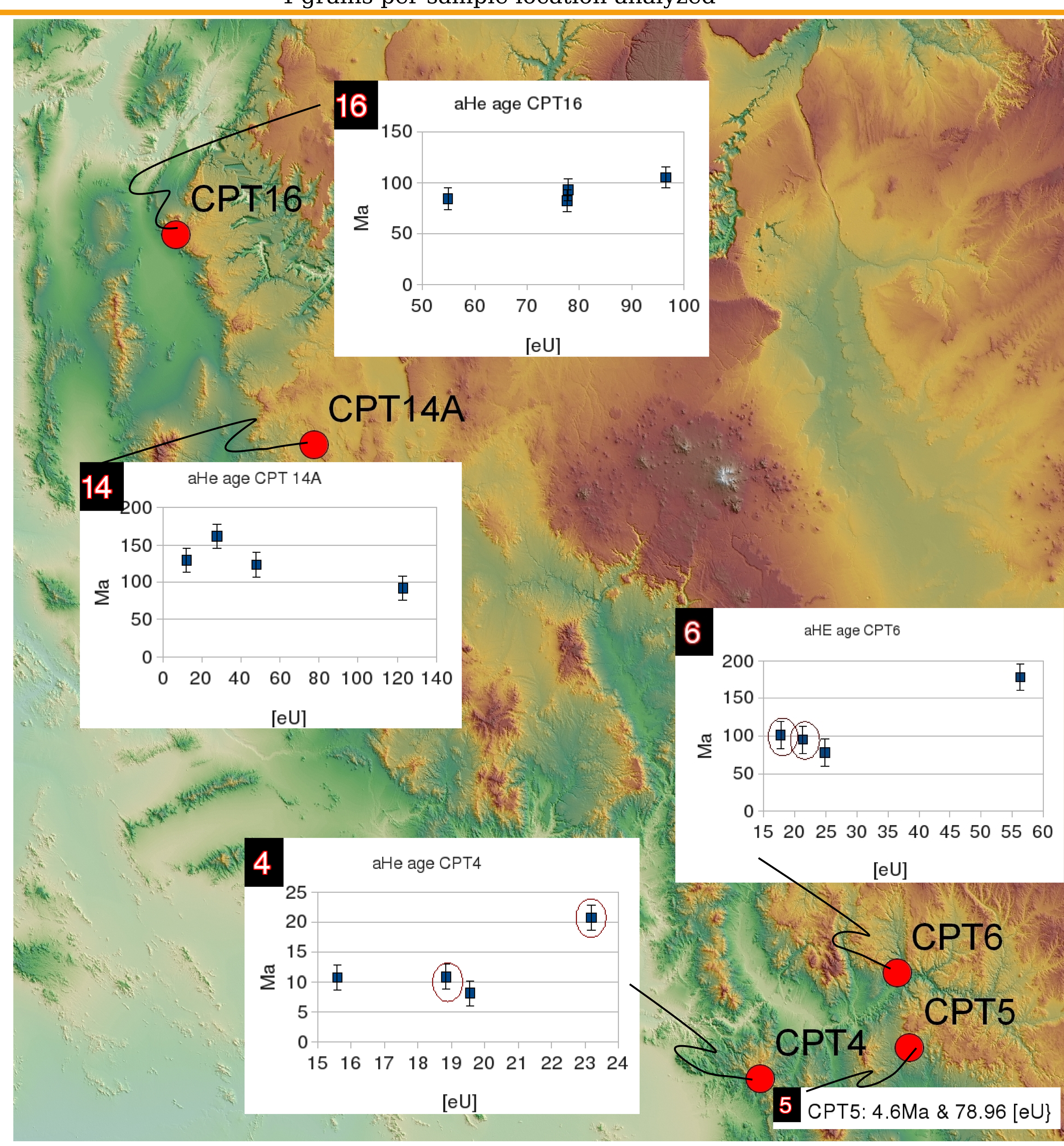

## Sample Locations for Transition Zone Study



Samples collected July 2008, to be analzed for apatite & zircon helium ages
Samples to be acquired, to be analzed for apatite & zircon helium ages
Existing apatite fission track age – 80 (Ma)
Samples to be acquired, to be analzed for apatite & zircon helium ages
Existing apatite fission track age 116 (Ma)
Existing zircon fission track age 382 (Ma)
a few ages not shown for simplicity

## Initial Helium in Apatite Ages (aHe)

~4 grains per sample location analyzed




[eU]= effective uranium concentration=[U]+(.235+[Th]): indicator for radiation damage potential

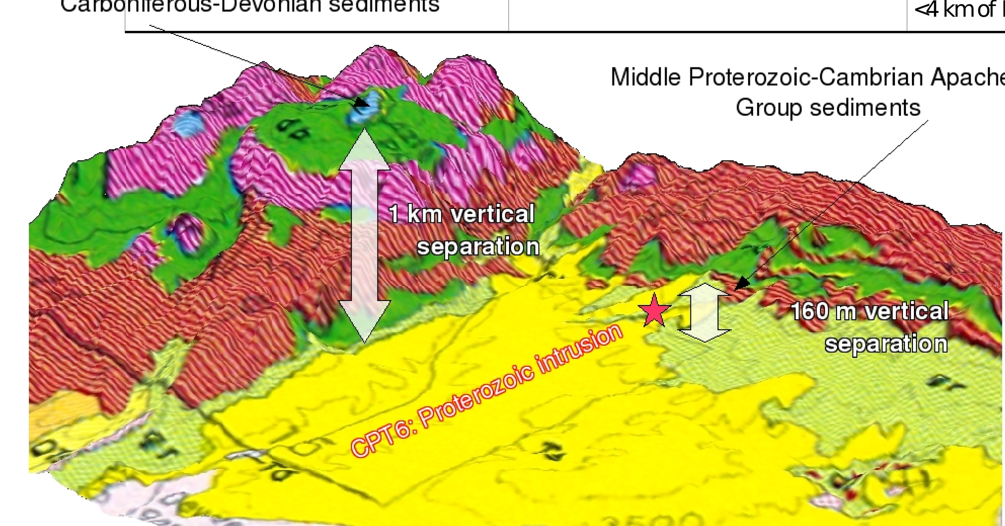
## Radiation Damage Model for Apatite Helium Ages[4]

Increasing radiation damage w/in apatite crystals increases helium retentivity.
Radiation damage is a function of [eU], and thus varies among a heterogeneous apatite population
Diffusion coefficients & closure temperatures are a function of radiation damage and thus evolve over time as radiation damage accumulates.[5]

Use the geologic history of the sample & HeFTy to model this process.

### Modeling Constraints by sample location

| Sample | Distance below nonconformity/unconformity | Modeling constraint (assuming 25° C/km geotherm unless otherwise stated) |
|---|---|---|
| CPT4: Cretaceous tonalite intruding Precambrian schists and Middle Proterozoic to Precambrian Apache Group | NA | Initial T~800 ° C at ~120Ma, followed by a monotonic cooling path |
| CPT5 fine: Aplitic dike w/in coarse Proterozoic granitoid | <60 m below Middle Proterozoic Apache group sediments | Near surface conditions <1,150 Ma (age of diabase sills which intrude the Apache group) |
| | | <6 km of Neoproterozoic through Cretaceous sedimentation |
| CPT6: Coarse Proterozoic granite or quartz syenite | <160 m below Middle Proterozoic Apache group sediments | Near surface conditions <1,150 Ma (age of diabase sills which intrude the Apache group) |
| | ~1000 meters below the nearest outcrop of Carboniferous to Devonian sediments | ~417 290 Ma, this rock reached near surface temperatures of ~45 ° Celsius, (assuming for simplicity, little tilting here) |
| | | 4 5 km of Paleozoic through Cretaceous sedimentation |
| CPT14A: Granite gneiss, Proterozoic protolith | ~217 m below the Tonto Group[3] | ~550 515 Ma, reached near surface temperatures |
| | ~220 m below Redwall and Martin limestones | ~360 300 Ma, reached near surface temperatures |
| | | <4 km of Paleozoic through Cretaceous sedimentation, up to 30 ° C/km geotherm |
| CPT16: Coarse Proterozoic syenite or quartz syenite, | ~500 m below the Tonto Group | ~550 515 Ma, reached near surface temperatures |
| | ~226 m below Redwall and Martin limestones | ~360 300 Ma, reached near surface temperatures |
| | | <4 km of Paleozoic through Cretaceous sedimentation |




**Geologic Histories derived from Arizona County Geologic Maps**

## Results of HeFTy Modeling

**Conclusions**:
Preliminary results from the aHe ages from the first 5 location show that exhumation appears to coincide with, or lead, early Sevier-Laramide deformation.
Much different Cenezoic exhumation rates north and south of Salt Creek
Significant Basin & Range extension is not recognized @ CPT 4 and CPT5 sites and Basin & Range extension <10 Ma would be unusual there
Possible non tectonic exhumation south of Salt Creek?

**Future Work:**
12 additional personal samples + Foster & Bryant samples still to analyze


References:

3 Bryant, B, Neser, C, & Fryxell, J. (1991). Implications of low-temperature cooling history of a transect across the Colorado Plateau-Basin and Range boundary, west central Arizona. Journal of geophysical research, 96(b7), 12375-.

2 Foster, DA, Gleadow, AA, Reynolds, S, et al. (1993). Denudation of metamorphic core complexes and the reconstruction of the transition zone, west central Arizona; constraints from apatite fission track thermochronology. Journal of geophysical research, 98(b2), 2167-2185.

1 Flowers, RM , Wernicke, BP, Farley, KA. Unroofing, incision, and uplift history of the southwestern Colorado Plateau from apatite (U-Th)/He thermochronometry. GEOLOGICAL SOCIETY OF AMERICA BULLETIN, 120 (5-6): 571-587 MAY-JUN 2008

5 Ketcham, Richard A. Forward and Inverse Modeling of Low-Temperature Thermochronometry Data. Reviews in Mineralogy and Geochemistry 2005 58: 275-314

4 Shuster, D.L., Flowers, R.M. & Farley, K.A. 2006, "Radiation damage and helium diffusion kinetics in apatite; Abstracts of the 16th annual V. M. Goldschmidt conference", Geochimica et Cosmochimica Acta, vol. 70, no. 18S, pp. A590