RESEARCH EXPERIENCES IN SOLID EARTH SCIENCE FOR STUDENTS
RESESS

Thermochronology of the McClure Mountain Syenite: Characterization of new He thermochronometers and constraints on the cooling history of the Wet Mountains, CO

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Background

The McClure Mountain Complex, located in Colorado's Wet Mountains, is a 9.1 km^2 Cambrian syenite intruded into Precambrian migmatitic gneiss (Parker and Hildebrand, 1962). Over a billion years younger than its surrounding lithologies, the McClure Mountain Complex was dated using U-Pb geochronology on chemically abraded zircons at 523.98 ± 0.12 Ma as its age of crystallization (Shoene and Bowring, 2006). The complex's capability of reproducing dates makes it a prime candidate for use as a standard and therefore is of great interest in the geo- and thermochronologic community. Thermal histories of the complex that are above ~450 °C have been thoroughly explained but no study has been conducted below that regime. Apatite and zircon data was effective at constraining upper crustal temperature ranges. Due to the unit's reliability, we were able to use other minerals such as titanite, baddeleyite, and monazite to offer potential additional constraints to the McClure Mountain Complex's thermal past.

Our goals for this study are to limit the thermal and tectonic evolution of the McClure Mountain Complex to a probable geologic past and apply that knowledge to Colorado's Wet Mountains geology. The other is the development of new ways to study thermal histories specific to (U-Th)/He thermochronology.

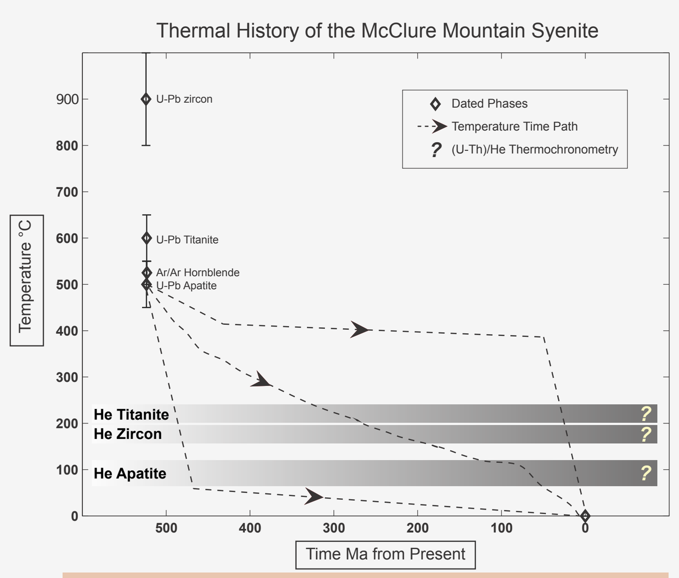


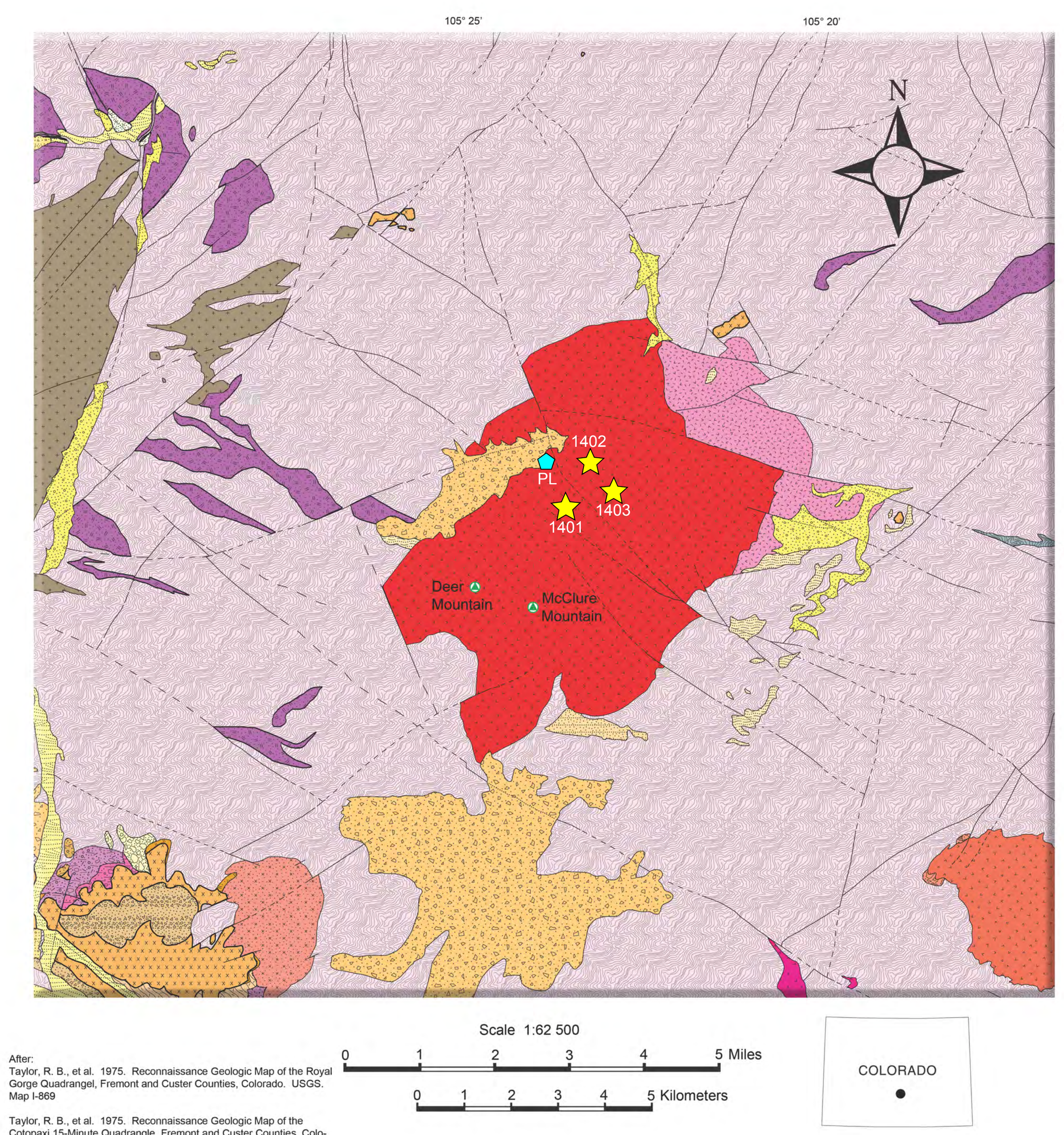
Figure 1. Model depicting possible time-temperature paths for the McClure Mountian Complex and mineral thermal data relative to their closure temperatures.

Problems:

-(U-Th)/He thermochronology restricted to low temperature thermal histories by the use of apatite and zircon. Assessment of new minerals will allow evaluation of a broader temperature regime.

-McClure Mountain Complex's low temperature thermal history is unknown, a complete thermal history can help us understand Colorado's Wet Mountains and the Ancestral Rockies for that area.

Geologic Setting



After:
Taylor, R. B., et al. 1975. Reconnaissance Geologic Map of the Royal Gorge Quadrangel, Fremont and Custer Counties, Colorado. USGS. Map I-869

Taylor, R. B., et al. 1975. Reconnaissance Geologic Map of the Cotopaxi 15-Minute Quadrangle, Fremont and Custer Counties, Colorado. USGS. Map I-900

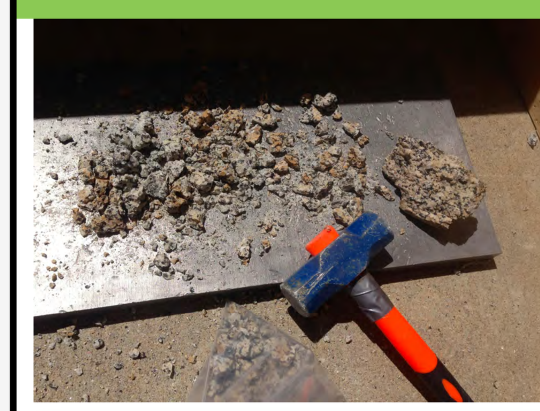
Figure 2. Digitally constructed geologic map depicting the McClure Mountain Complex and its surrounding lithologies. Each yellow star indicates a particular sample outcrop location (MMhb_1401, MMhb_1402, MMhb_1403) while the blue pentagon shows the location of the parking lot bolder used as a standard..

- Qp — Piney Creek alluvium (upper Holocene)
- Qls — Landslide deposits (Holocene and Pleistocene)
- Qpo — Outwash (?)
- Ts — Santa Fe(?) Formation (Pliocene toMiocene)
- Tsu — Upper part (alluvium) (Pliocene and Miocene)
- Taha — Med-grained hornblende-pyroxene andesite (Miocene)
- Tgp — Gibbles Park Tuff (Oligocene)
- Cms — McClure Mountain Complex (Cambrian)
- Ꞓmm — Mafic-Ultramafic Complex at Iron Mountain (Cambrian)
- Ꞓqs — Syenite Complex at Democratic Creek (Cambrian)
- Ꞓgp — Gem Park Complex (Cambrian)
- Ꞓsy — Syenite (Cambrian)
- Ygm — Quartz monzonite of Silver Plume age (Precambrian)
- Xgd — Granodiorite (Precambrian)
- Xg — Metagabbro (Precambrian)
- Xgm — Migmatitic Gneiss (Precambrian)

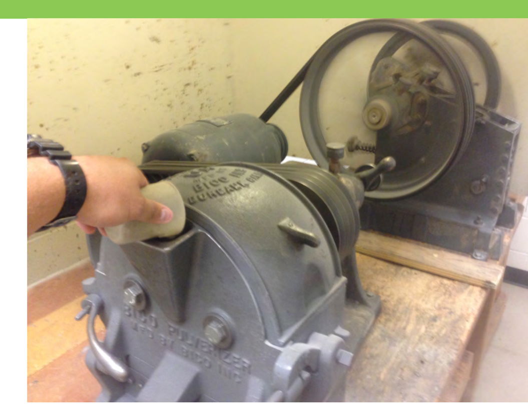
Sampling MM syenite with Deer Mtn and Sangre de Cristo's Range in background; James Metcalf (left), Wesley Weisberg (right)-photo by Aisha Morris

MM Syenite from parkinglot boulder

Methods



Step 1.
Hand crush samples with a rock hammer.

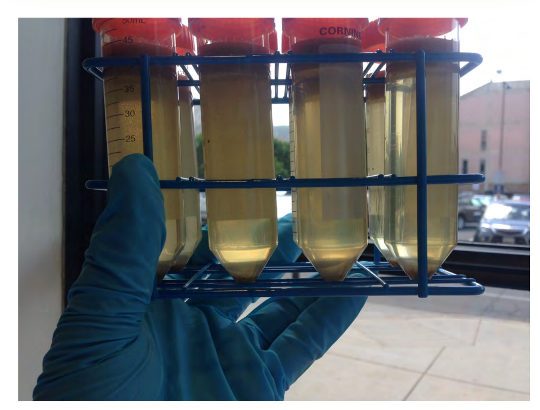


Step 2.
Pulverize sample in rock crushing lab and classify with sivs.

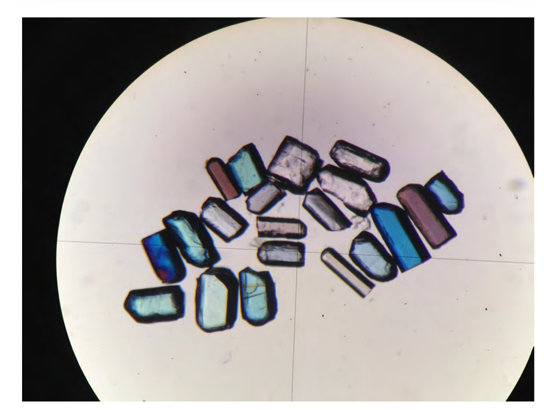
Step 3.
Utilize Wilfley table to separate light material from the heavies. Removal of micas, quartz and feldspars.

Step 4.
Dry sample and begin hand magnetic separation.

Step 5.
Induce magnetism on mineral grains by use of the Franz magnetic separator.
a. 0.35 A, 20 ° tilt
b. 0.60 A, 20 ° tilt
c. 0.80 A, 20 ° tilt
d. 1.00 A, 20 ° tilt



Step 6.
Heavy liquids, lithium-metatungsate (LMT), with use in centrifuge to further separate materials.



Step 7.
Hand separation under microscopes. Determine suitable grains, document visual character, and pack in Niobium tube.

Steps 8-10.
Use Alphachron to degas grains to measure amount of He. Dissolve in acid, measure U-Th content by ICP-MS. Apply data to HeFTy for analysis.

HeFTy Modeling

ABOUT:
HeFTy is a program that models different time temperature paths (t-T) and determines "good" and "acceptable" paths based off date, eU, and radius of the grain (Ketcham, 2013).

A "good" fit correlates to a value of ≥ 0.5 and shows that the (*t*-T) is supported by the data. This means the model has not failed a null hypothesis test and passed the minimum goodness-of-fit (GOF) of 1/(N+1) where N = the number of GOF statistics (Ketcham, 2013)

An "acceptable" fit is where a value of ≥ 0.05 is needed and shows that the (*t*-T) is not ruled out by the data (Ketcham, 2013).

Apatite was modeled using RDAAM calibration for apatite He retentivity (Flowers et al., 2009).

Zircon was modeled using Guenthner (zircon) calibration for zircon He retentivity (Guenthner et al., 2013).

Pathways: 10,000
Constraints:
1.) 500-523 Ma / 400-450 °C 5Ev
2.) 350-500 Ma / 65-450 °C 5Ev
3.) 100-350 Ma / 0-250 °C 2Gc
4.) 0-100 Ma / 0-110 °C 5Ev

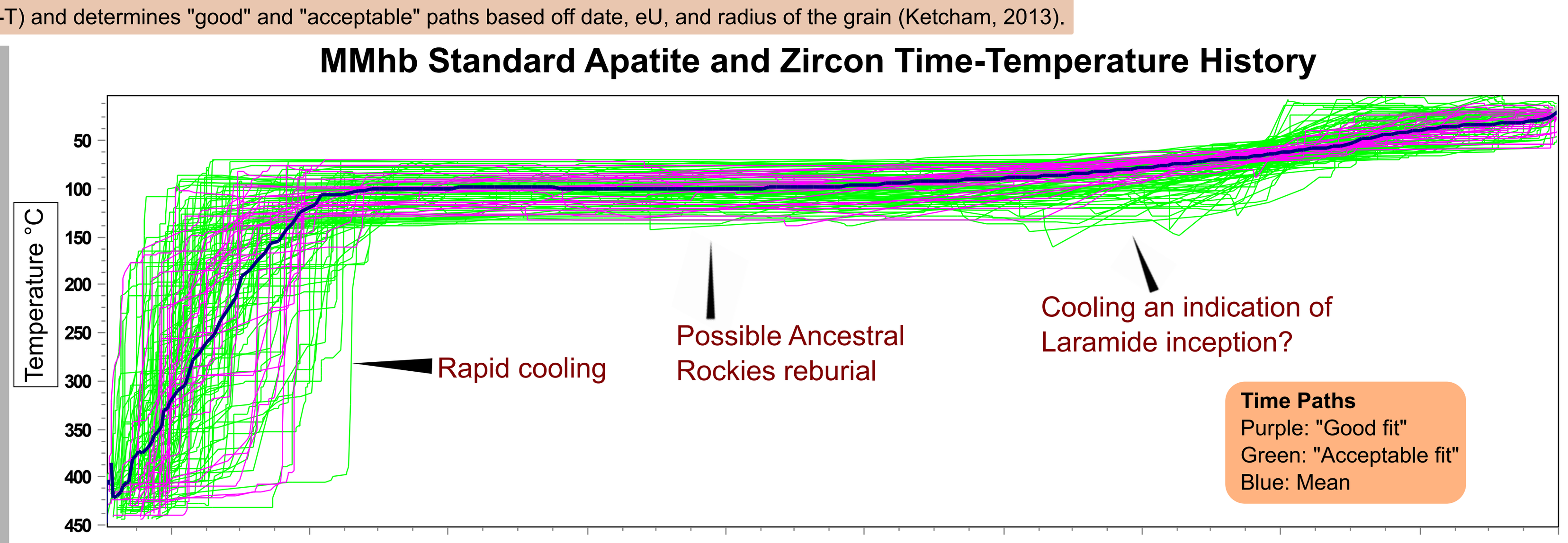


Figure 3. Quanitification of fig. 3a, 3b, 3c to derive tT path depecting MM syenite thermal history.

High eU	rs (µm)	U (ppm)	Th (ppm)	Sm (ppm)	Date (corr) (Ma)
MMhb_ap04	76.53	15.53	49.15	9.12	139.32
MMhb_ap03	121.54	16.25	45.28	5.00	144.01
MM_ap08	83.53	15.89	52.64	12.71	111.05
MM_ap07	88.52	16.19	50.84	8.77	99.03
Avg	**92.53**	**15.96**	**49.48**	**8.90**	**123.35**
StDev	19.96	0.33	3.14	3.15	21.79

Figure 3a.

Low eU	rs (µm)	U (ppm)	Th (ppm)	Sm (ppm)	Date (corr) (Ma)
MM_ap10	61.97	8.47	22.80	10.36	93.34
MM_ap06	85.13	8.79	25.37	6.01	88.28
MMhb_ap01	90.75	8.67	23.80	7.85	67.97
Avg	**79.28**	**8.64**	**23.99**	**8.08**	**83.20**
StDev	15.25	0.16	1.30	2.19	13.43

Figure 3b.

Zircon	rs (µm)	U (ppm)	Th (ppm)	Sm (ppm)	Date (corr) (Ma)
MM_zrn03	82.55	41.48	593.40	xxxxxx	474.90
MM_zrn01	114.57	46.97	464.26	xxxxxx	466.20
MM_zrn02	109.19	50.97	550.82	xxxxxx	436.20
Avg	**102.09**	**46.47**	**537.36**	xxxxxx	**459.10**
StDev	17.146	4.76446	65.8063		**20.3**

Figure 3c.

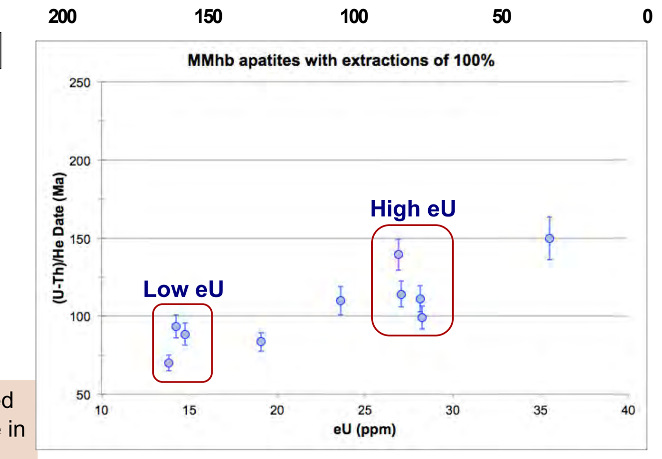


Figure 4. Modeled radiation damage in apatites. eU.

Results

Polarized binocular scope images of standard MM apatite and zircon.

-Dates from MMhb standard apatite, zircon, baddeleyite, and titanite reflect highly reproducible ages (1σ sample standard deviation).

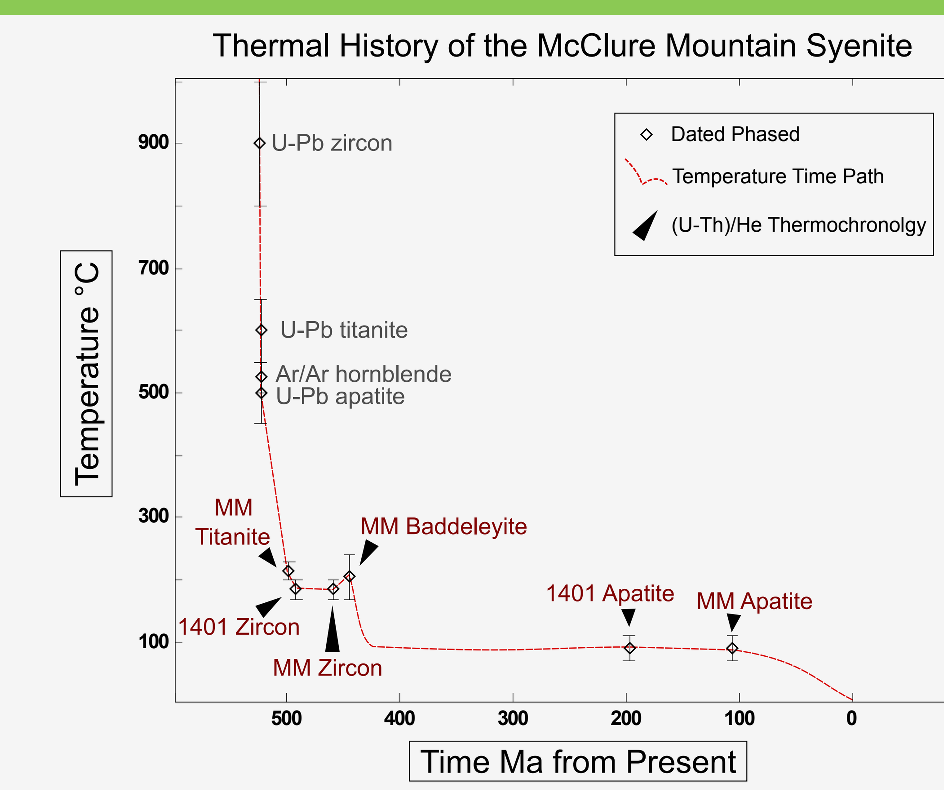
Full Sample Name	Dim Mass (µg)	U (ppm)	Th (ppm)	eU	Th/U	Date to use	Raw/Corr	±
Standard boulder								
Baddeleyite								
MM_Bdy01	11.50	985.04	12.43	988.0	0.013	**539.7**	corr	7.50
MM_Bdy02	6.17	339.65	6.65	341.2	0.020	**548.6**	corr	5.25
MM_Bdy03	6.06	309.50	3.56	310.3	0.012	**539.9**	corr	3.83
					avg	**542.7**		
					std	**5.1**		
Titanite								
MMhb_Ttn01	49.77	4.89	4.08	5.8	0.834	**501.7**	raw	9.98
MMhb_Ttn02	17.45	16.98	40.76	26.6	2.401	**488.3**	raw	10.59
MMhb_Ttn03	19.05	16.25	46.42	27.2	2.856	**505.1**	raw	8.14
					avg	**498.3**		
					std	**8.9**		
Zircon								
MM_zrn01	60.81	46.97	464.26	156.1	9.884	**466.2**	corr	4.00
MM_zrn02	45.01	50.97	550.82	180.4	10.806	**436.2**	corr	2.29
MM_zrn03	22.22	41.48	593.40	180.9	14.305	**474.9**	corr	4.31
					avg	**459.1**		
					std	**20.3**		

MM Apatite	rs (µm)	U (ppm)	Th (ppm)	eU	U/Th	Date (corr) (Ma)
MM_ap05	3.36	20.58	63.62	35.5	3.091	149.83
MMhb_ap04	31.53	16.25	45.28	26.9	2.787	139.32
MMhb_ap03	10.42	15.53	49.15	27.1	3.165	114.01
MM_ap08	10.19	16.19	50.84	28.1	3.141	111.05
MM_ap09	6.38	13.96	41.03	23.6	2.939	109.98
MM_ap07	8.83	15.89	52.64	28.3	3.312	99.03
MM_ap10	14.61	8.67	23.80	14.3	2.746	93.34
MM_ap06	10.91	8.79	25.37	14.8	2.885	88.28
MMhb_ap02	20.41	10.98	34.49	19.1	3.141	83.37
MMhb_ap01	5.96	8.47	22.80	13.8	2.693	69.97
Avg	**12.26**	**13.53**	**40.90**	**23.14**	**2.99**	**105.82**
StDev	**8.29**	**4.11**	**13.91**	**7.35**	**0.21**	**24.7**

-Apatite He dates from MM syenite standard range from 149.83 Ma to 69.97 Ma and ages appear to be positively correlated to effective eU variations.

-MM syenite sample 1401 dates from apatite, titanite, baddeleyite, and zircon were not as reproducible as standard and warrents further investigation.

Discussion



The McClure Mountain Complex cooled from initial crystallization too close to the surface at temperatures below zircon closure temperature (170-200 °C) in only ~30 Ma. MM standard He ages of titanite and baddeleyite are significantly older possibly reflecting higher closure temperatures for these minerals. Cooling continued at a steady rate with possible correlations to Ancestral Rockies exhumation ~300 Ma and Laramide uplift from ~70 to 50 Ma.

Further Discussion:

-If the MM apatite standard and sample 1401 are from the same unit, then why are the dates separated by ~100 Ma? Could this be associated to reburial/faulting or a variation in the chemistry of the rock?

-Can we identify where the standard parking lot boulder originated from? Was it higher or lower elevation relative to our sample or even from the McClure Mountain Complex?

-Why, if this unit is a standard, was sample 1401 not able to reproduce dates as reliable as the parking lot boulder? How does grain size affect thermal analysis?

Acknowledgements

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