A Preliminary Low-Temperature Exhumation Study of the Central Aleutian Islands, Alaska

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MOTIVATION

Exhumation in continental and oceanic arc settings results in some of the highest topography and erosion rates in the world. Yet, key questions regarding subduction zone dynamics remain, as identified by two recent NSF funded initiatives (SZ4D and GeoPRISMS SCD): *1) What are the feedbacks between surface processes and subduction zone mechanics and dynamics? 2) What drives the formation and incorporation of plutons into the overriding plate? 3) What are the processes and timing associated with the creation of topography above subduction zones?* A regional thermochronology study of the Aleutian oceanic arc can help address these questions.

Studies of oceanic arcs are sparse due to poor exposure, accessibility, and thermal overprinting due to magmatism, reburial, and metamorphism. In contrast, the Aleutian arc has an unusually thick crust, exceptional subaerial exposure of plutons, and limited regional thermal overprinting[1,2], providing the ideal conditions for a systematic thermochronology study.

We will apply a multi-chronometer approach to 94 plutonic samples that span over 1400 km of the Central Aleutian Islands to constrain uplift and erosion rates over ~40 million years of Aleutian arc history. The overarching questions of this study are:

1) When were the Aleutian Islands exhumed? 2) Are there spatio-temporal exhumation trends? 3) What was the driving mechanism for the exhumation of the Aleutian Islands?

GEOLOGIC BACKGROUND

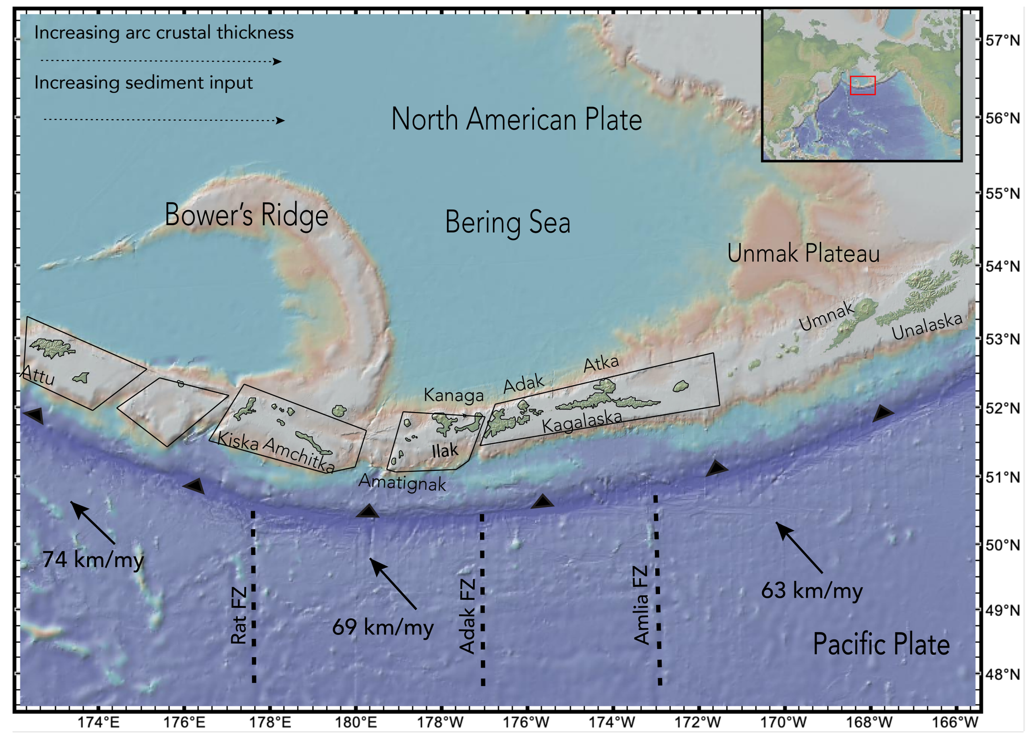

Figure 1. Regional map of the Central Aleutian Islands showing varying subduction zone dynamics. Fault bounded segmented blocks outlined. FZ= fracture zone.

- The Pacific plate began subducting beneath the North American plate at the Aleutian trench at ~55 Ma[3].
- The Central Aleutian Islands formed on North American plate oceanic crust[5].
- The Aleutian arc spans ~2200 km from the Alaska Peninsula to the Kamchatka Peninsula and is structurally segmented into various fault-controlled blocks that experienced clockwise rotation in late Cenozoic time[4,6].
- There were three main pulses (flare-ups) of Aleutian arc magmatism in the late Eocene (~39-29 Ma) and the middle (~16-11 Ma) and late Miocene (~7-5 Ma).[4,7]
- The slab dip is steeper in the central and western Aleutians (54–56°) compared to the eastern Aleutians (46°)[7].
- The Aleutian arc has eperienced 30-60 km of northward arc migration that was episodic and seems to correlate with magmatic lulls[7].

TESTABLE HYPOTHESES

Table 1. Aleutian arc proposed hypotheses to be tested

Proposed Exhumation Mechanisms	Expected Cooling Age Trend Along Arc	Reference
1) 10° clockwise change in Pacific plate motion beginning at ~6 Ma	Arc-wide exhumation would occur beginning at ~6 Ma	(Schaen et al., 2016)
2) Transition from an erosive to an accretionary margin ~5-10 Ma	Exhumation would occur first in the eastern islands and progress towards the west	(Harbert et al., 1986)
3) Pluton specific exhumation histories	Exhumation would vary locally by pluton	(Scholl et al., 1975)

METHODS

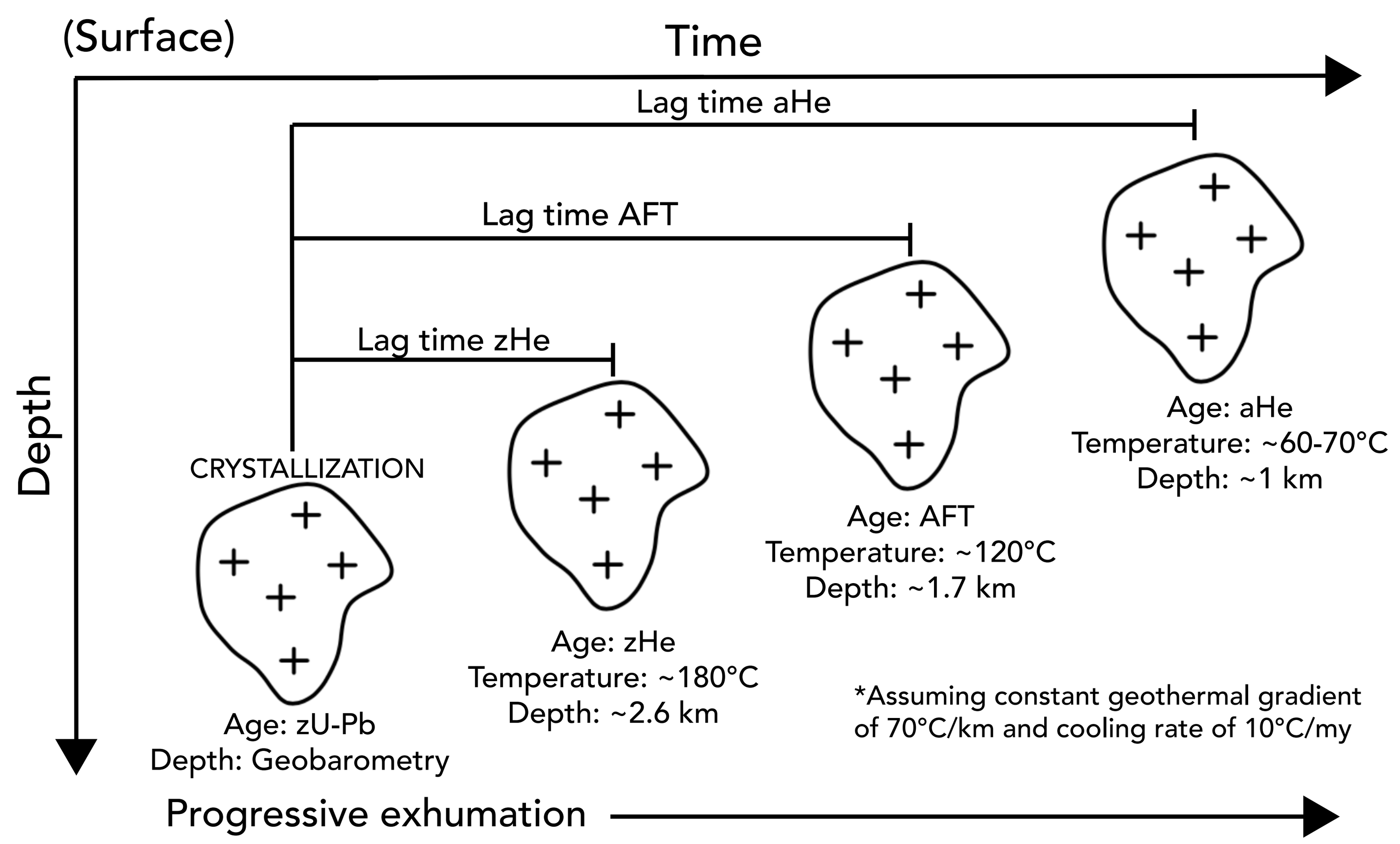

Figure 2. We will perform zircon and apatite (U-Th)/He (zHe and aHe, respectively) on each sample, and zircon U-Pb (zU-Pb) and Al-in-hornblende geobarometry on each pluton. We will perform apatite fission track (AFT) on samples that do not yield enough zircon for (U-Th)/He dating.

PRELIMINARY RESULTS

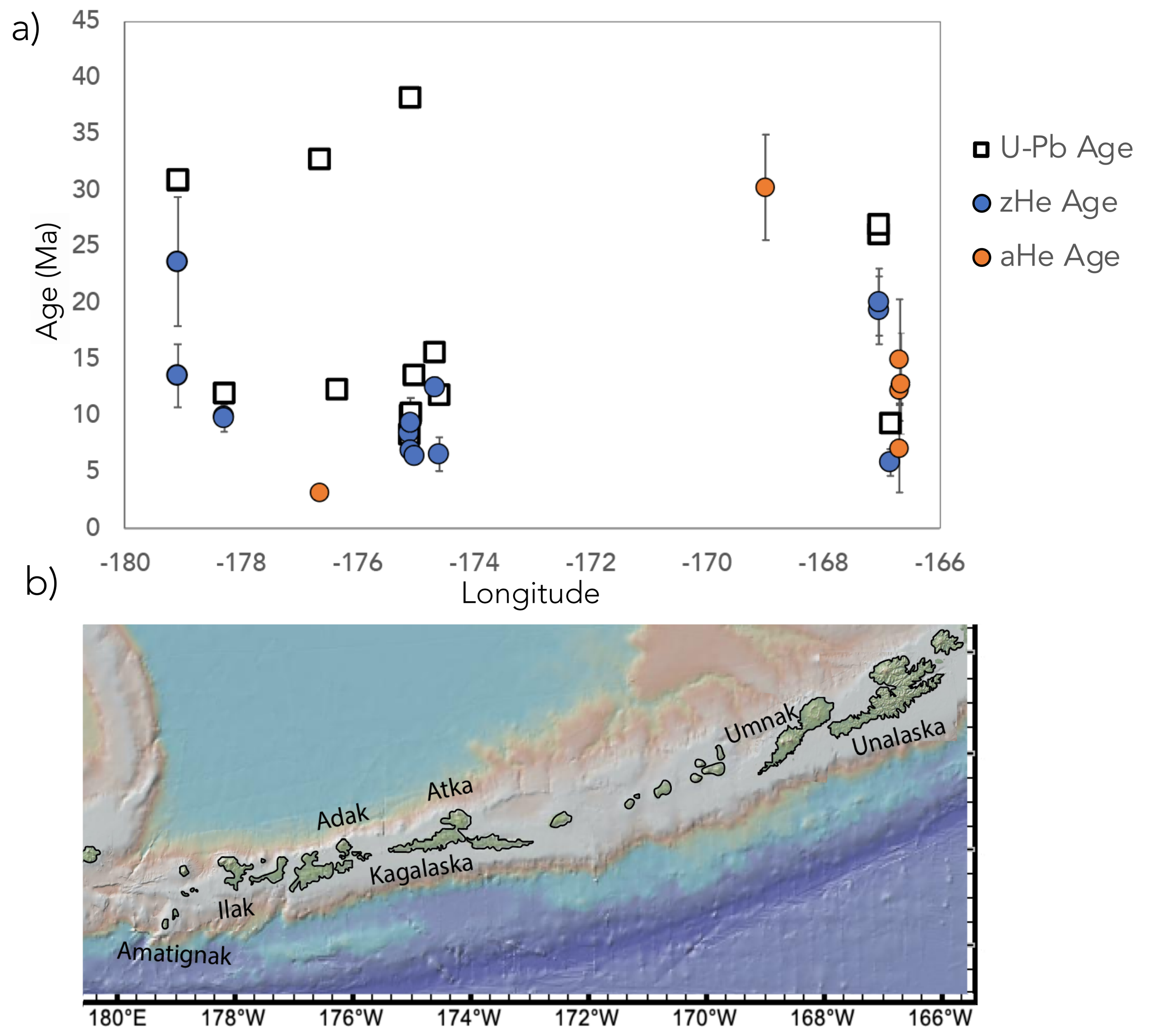

Figure 3. a) Mean zHe and aHe ages (1σ) and unpublished zU-Pb (error bars are smaller than symbol) ages against longitude. Both zHe and aHe ages show an Oligocene to Miocene spread, with a majority of the ages from both chronometers pooling at ~7-13 Ma. b) Map showing islands (named) corresponding to data in figure 3a. Note there is no apparent geographic-age trend.

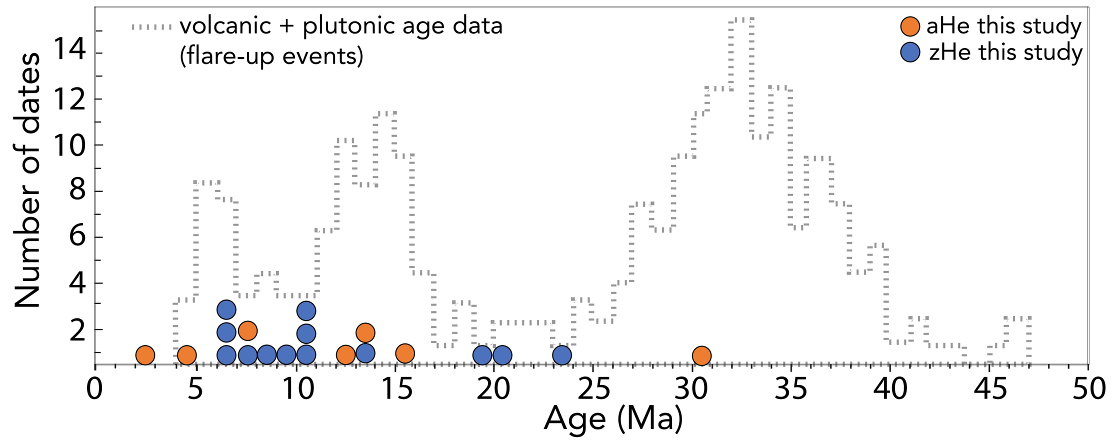

Figure 4. Histogram of published volcanic and plutonic zU-Pb ages[7] showing the three major Aleutian arc flare-up episodes (dashed line) and aHe and zHe data (circles) from this study. Most samples resulted in cooling ages that coincide with magmatic lulls.

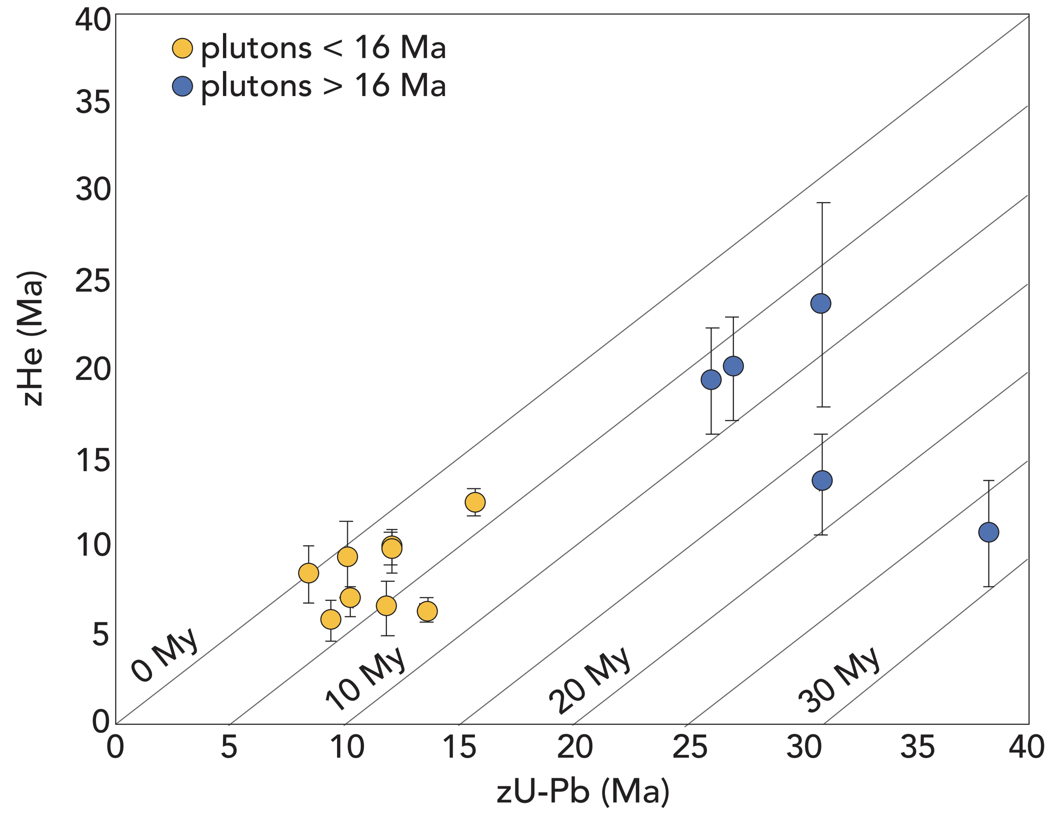

Figure 5. Mean zHe ages vs zU-Pb ages for the same sample. Contours represent lag times. Older samples correspond to older zHe cooling ages and longer lag times. Younger samples correspond to younger zHe cooling ages and shorter lag times. Average lag time for plutons <16 Ma is 3 My and for plutons >16 Ma is 13 My.

KEY TAKEAWAYS

- **Both zHe and aHe ages are mainly Oligocene-Miocene, with a majority of the ages from both chronometers pooling at ~7-13 Ma (Figure 3).**
- **These preliminary results suggest that a significant exhumation event occurred in the late Miocene, as has been observed in other circum-Pacific arcs, potentially suggesting a plate-scale exhumation mechanism such as the change in Pacific plate motion beginning at ~6 Ma.**
- **Older samples correspond to older zHe cooling ages and longer lag times and younger samples correspond to younger zHe cooling ages and shorter lag times (Figure 4).**
- **Late Miocene flare-up did not thermally reset mid-Moicene plutons.**
- **The late Miocene exhumation event coincides with the ~7-11 Ma magmatic lull and northward arc migration.**
- **Exhumation, magmatic lulls, and arc migration may be inextricably linked.**

FUTURE WORK

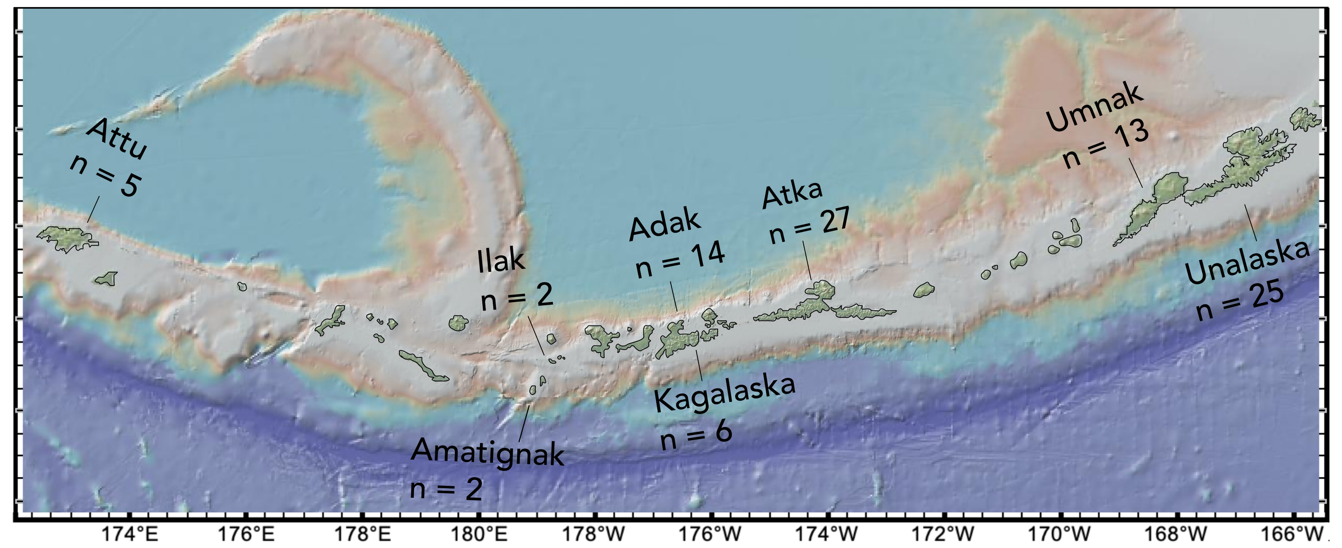

Figure 6. Regional map of the Central Aleutian Islands highlighting the islands that will be analyzed for this study and the total number of samples per islands. We will obtain depth estimates and zU-Pb ages for each pluton and zHe and aHe ages for each sample.

- Obtain pluton emplacement depths via Al-in-hornblende geobarometry and utilize alternative barometers if needed.
- Obtain zHe and aHe ages from each sample and calculate exhumation rates.
- Inverse thermal history modeling of each pluton.
- Analyze regional thermochronology dataset for geographical, temporal, and/or geochemical (calc-alkaline vs tholeiitic) exhumation trends that may shed light into potential driving mechanisms.

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ACKNOWLEDGMENTS

We thank Sue Kay, Merry Cai, and Mike Perfit for generously opening their sample collection for this project. We also thank Claire Bucholz and Odalys Callejas their collaboration on geobarometry analyses. This project is funded through a GSA student grant to AC, an NSF grant to EC (EAR-1949148), and Start-Up funds to EC from USC.