Persistent topographic development along a strike-slip fault system: The Mount McKinley restraining bend

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Abstract: The Denali Fault is a major strike-slip fault extending from British Colombia, into western Alaska. Mount McKinley, at 6,114 m, is the highest peak in North America and is located to the south of a bend in the Denali Fault (Fig.1). To the north, at the apex of the bend in the fault, Peters Dome (3,221 m) is the highest peak and north-side peak elevations rapidly decrease moving away from the bend's apex.

Topographic development is predicted to be transient along strike-slip faults as crustal blocks move through bends, which are regions where a component of horizontal slip is partitioned into a vertical component. We applied apatite fission-track thermochronology analysis (Fig. 2) to samples collected along both sides of the Mount McKinley restraining bend and part way up Peters Dome to better understand why Mount McKinley is so big and the evolution of the Mount McKinley restraining bend. The preliminary data suggests a fission-track pattern of ages decreasing to the west on both sides of the fault. As the crustal block of Mount McKinley is moving through the bend, it is likely the bend itself is also migrating-deforming to the west,

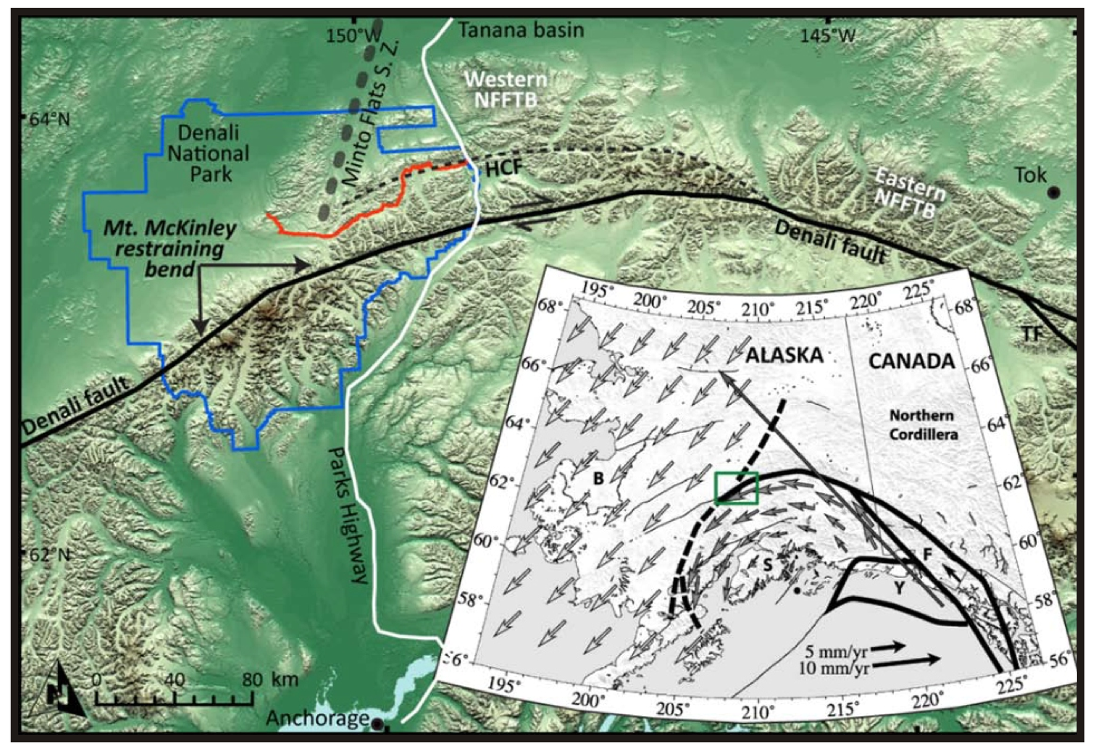

Figure 1: Regional topography, geographic features, and generalized crustal tectonics of south-central Alaska. The inset map, from Freymueller et al. (2008), shows the modeled motions for crustal blocks in Alaska. B = Bering Block, F = Fairweather Block, S = Southern Alaska Block, and Y = Yakutat Block. The green box on the inset depicts the area of Figure 4. The blue outline is the boundary of Denali National Park & Preserve, the red line is the park road, and the white line is the Parks Highway, the primary transportation corridor between Alaska's largest cities, Anchorage and Fairbanks. The dashed black line is trace of the Hines Creek fault (HCF), interpreted to be an older strand of the Denali fault system and is no longer significantly active as a right-lateral strike-slip fault.

Statement of Problem: Topographic development should be transient along a strike-slip fault system as a crustal block passes through a region of focused vertical tectonics (ex. A restraining bend) relatively quickly. Topographic development should be limited in both overall height and width along strike-slip faults assuming the above statement is true. Yet we have the massive Mount McKinley (6,000 m), which lies south of a restraining bend along the Denali Fault (Figs. 1and 3).

Methods: Fission-track dating is a radiometric dating analysis of the damage tracks left by the fission of ^{238}U which is present in certain minerals (Fig. 2; ex. apatite). Fission-tracks are produced during the spontaneous decay of ^{238}U, which sends two product nuclides traveling in opposite directions leaving a single damage trail or track. When exposed to high temperatures (~>110° C) fission-tracks will anneal and the tracks will shorten allowing for analysis of thermal evolution.
We applied apatite fission-track (AFT) thermocronology analysis to samples collected on both sides of the Denali fault to constrain the development and evolution Mount McKinley restraining bend.

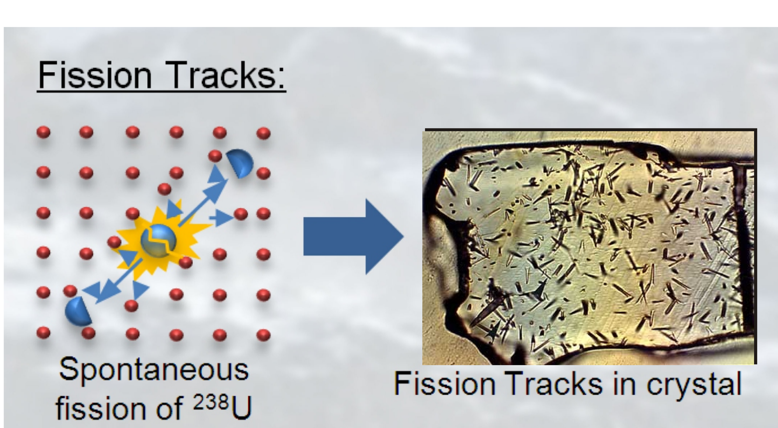

Figure 2: Spontaneous fission of 238U Produces fission tracks.

Predicted topographic development through two restraining bend evolution scenarios

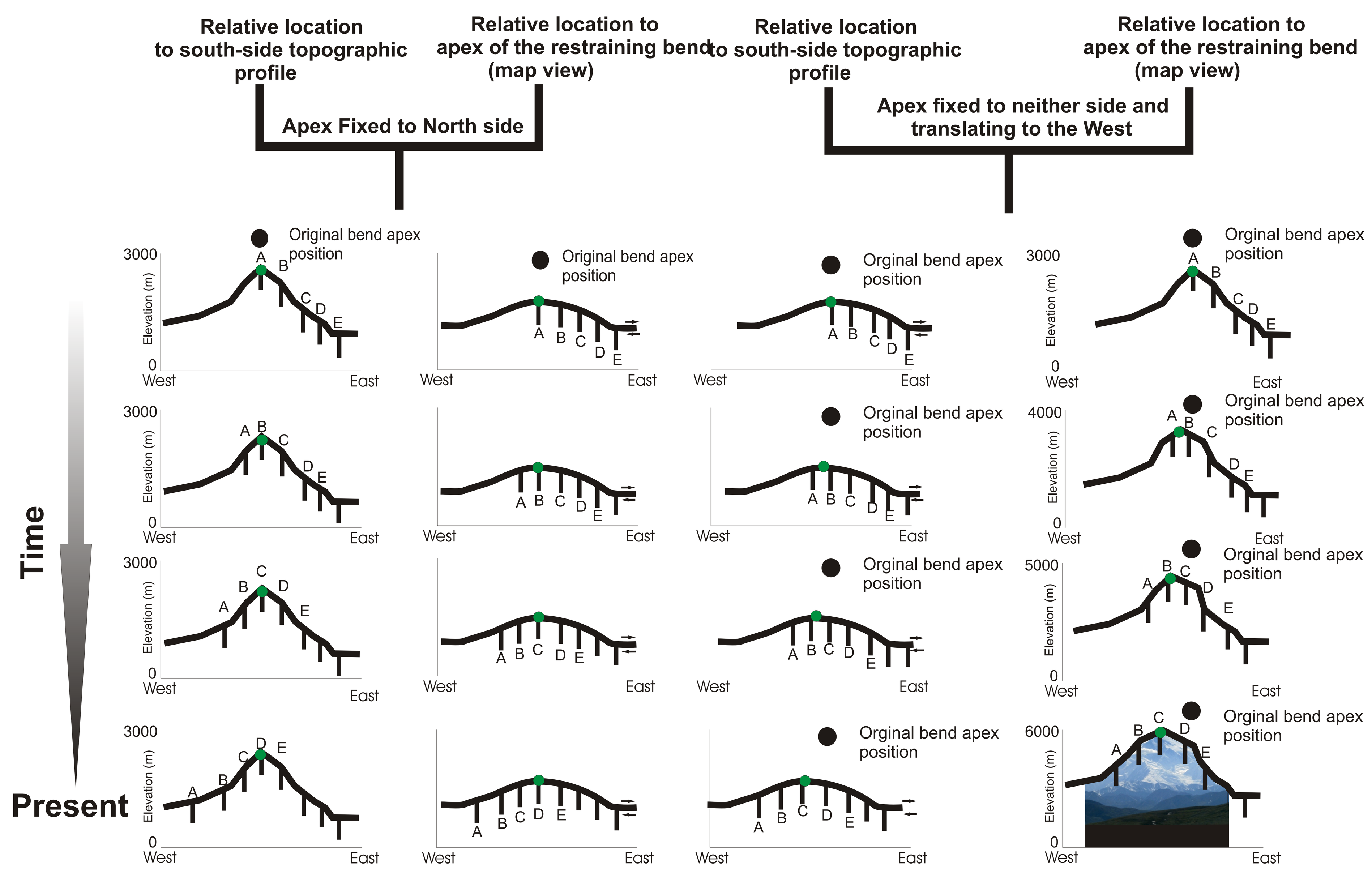

Figure 3: Predicted topographic development through two *relative position* restraining bend scenarios.

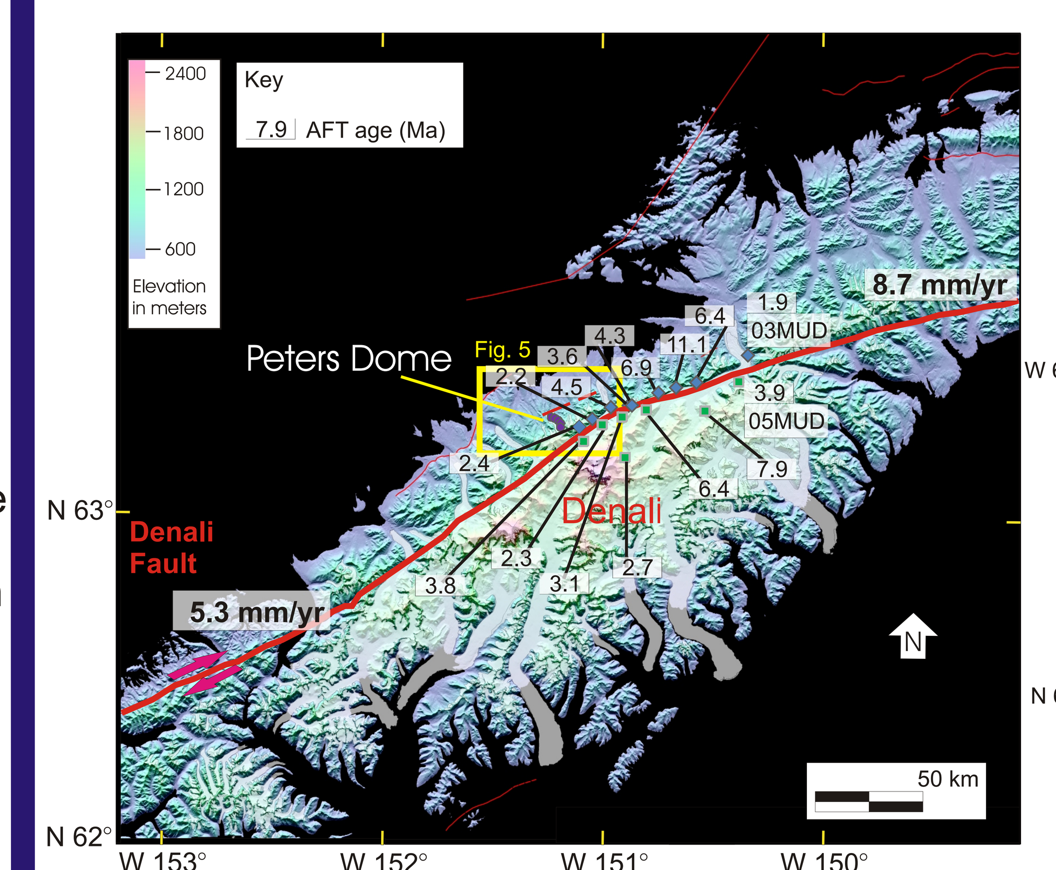

Figure 4: Digital elevation model of the Mount McKinley restraining bend region flooded to 700 meters to emphasis topography. Quaternary active faults in red from Koehler et al., 2012. Yellow box is area in Fig. 5. AFT ages are in Ma. Slip rates for the Denali fault as determined by Matmon and Haeussler (in prep.) are shown at their respective locations.

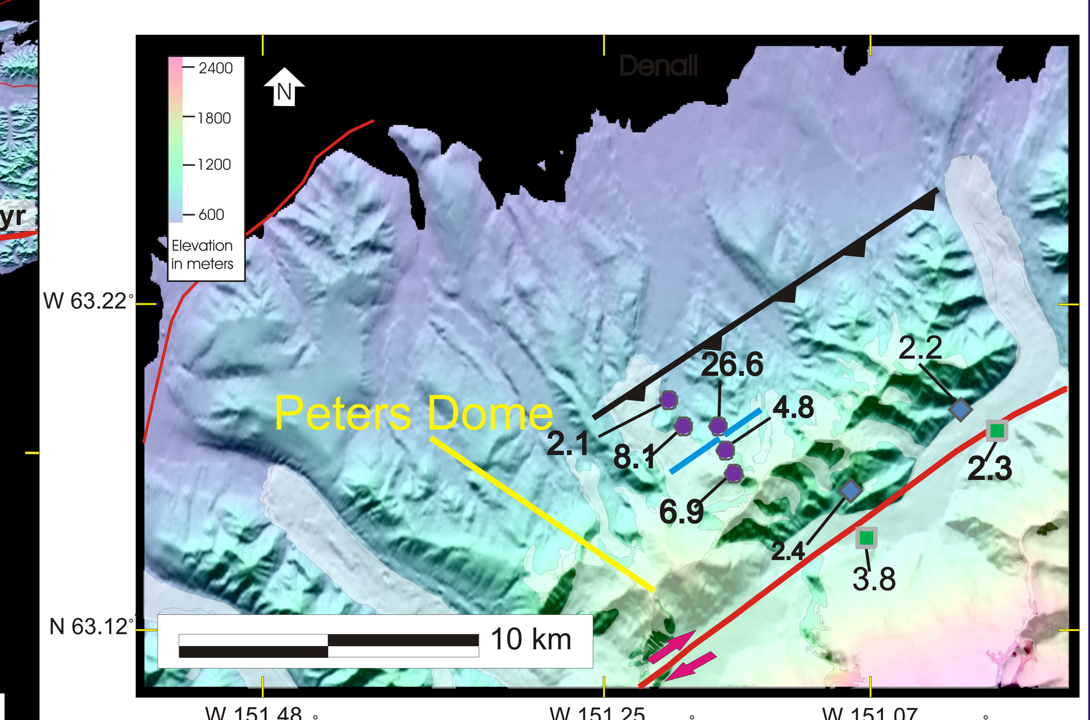

Figure 5: Digital elevation model of the Peters Dome region flooded to 700 meters to emphasize topography. AFT cooling ages (Ma) are shown in black. Quaternary active faults in red from Koehler et al. 2012 with a newly mapped thrust fault in black. The dashed blue line is for an inferred fault based on the discordant AFT age-elevation relationship (Fig. 6C) and field observations.

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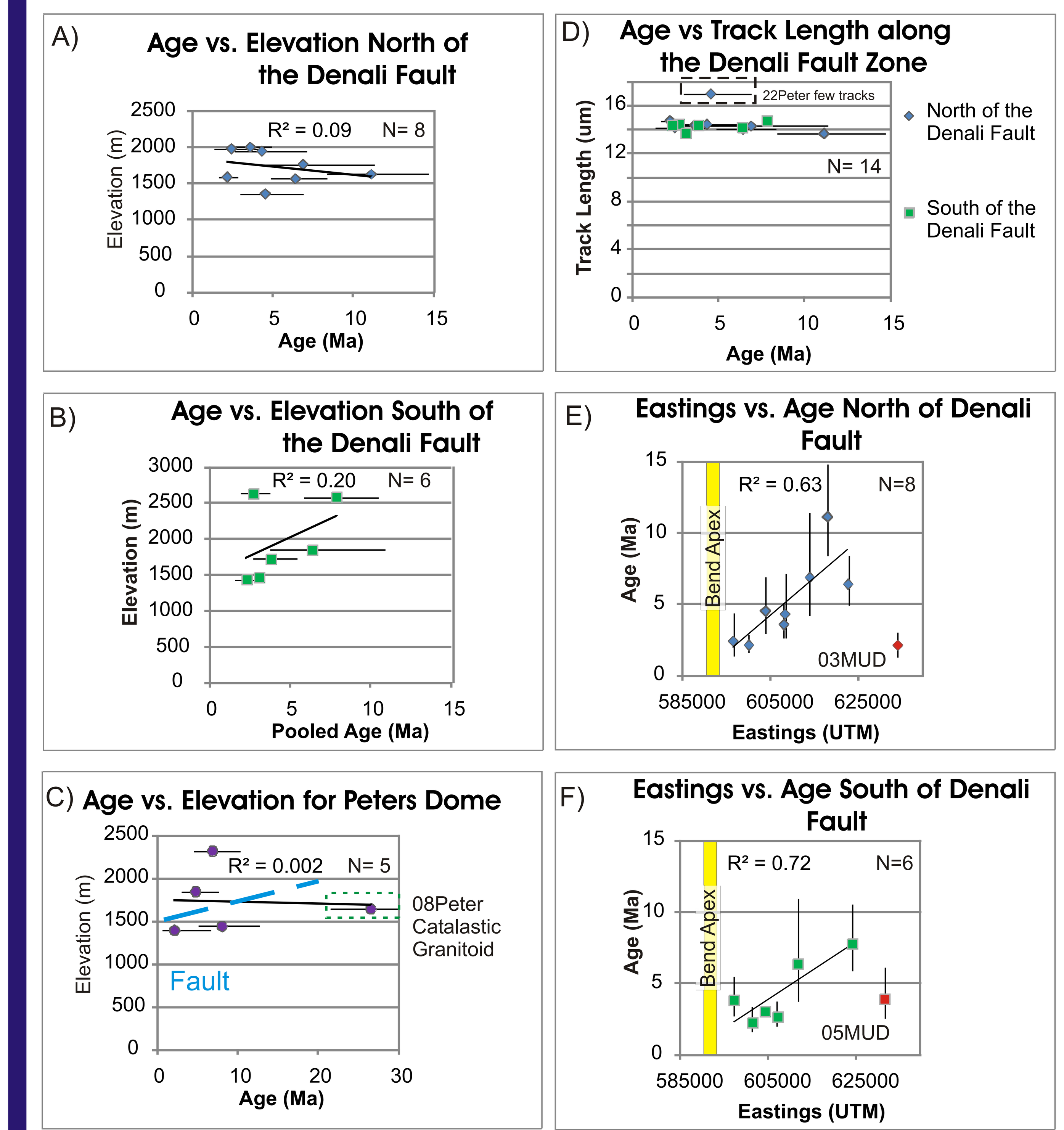

Figure 6: AFT cooling ages north and south of the Denali fault (Fig. 4) and from the Peters Dome area (Fig. 5). **1**) There is no expected age-elevation relationship (Fig. 6 A, B, C). **2)** Long average track lengths indicate all samples close to the Denali fault cooled rapidly at the time of the "closure" of the AFT system (Fig. 6 D). 3) AFT cooling ages young to the west on both sides of the Denali fault E, F). This apparent east to west time progressive trend in inferred focus of exhumation is mimicked by an increase in width of the deformation front to the west (Fig. 1). In addition, north and south side topographic development increases to the west (Figure 5). Based on these preliminary observations, we infer the evolution of the Mount McKinley restraining bend is the dominant control on exhumation patterns in the region, not variations in erosional forcing, basement faults, lithology, and rheology. The Peters Dome area is a region with young AFT cooling ages (Fig. 6) and multiple documented structures (Figs. 5 and 6C), implying the area is undergoing significant shortening to accommodate the migration of the Mount McKinley restraining bend.

Discussion: The Denali fault is a right-lateral fault with a horizontal slip rate of about ~6mm/yr. It is predicted the low angle (17°) Mount McKinley restraining bend at ~3mm/yr based on kaolin analog experiments (Cooke et al., 2013). We believe that the Mount McKinley restraining bend is not in a fixed position relative to the crustal block to the south (i.e. Mount McKinley) and that it is deforming and migrating to the west at ~4 mm/yr causing the crust north of the bend's apex to shorten (Peters Dome area). This tectonic scenario is responsible for the regionally unique elevation and broad width of Mount McKinley. The granitic lithology of the mountain and the fact that it is composed of granite plutons that are not dissected by many faults contributes to the erosional resistivity of the Mountain and hence it's large size (Wilson et al., 1998).

Continued Work: Our next step in this project is to complete collecting bedrock samples along the western limb of the Mount McKinley restraining bend. We will perform a full range of thermochronometric techniques on the new sample set.

We expect to see a pattern of older AFT cooling ages increasing away from the bend apex to the west on both sides of the Denali Fault. We predict this region cooled (eroded) at a slower rate than the crustal block now entering the bend. Completing this analysis will give us a better understanding of the evolution of the restraining bend and better insight into why Mount McKinley grew so big.