IMPLICATIONS OF NEW APATITE AND ZIRCON FISSION-TRACK THERMOCHRONOLOGY FOR MESOZOIC AND TERTIARY BASIN MARGIN EXHUMATION, UPPER ALASKA PENINSULA

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Slightly modified from original presentation.

Abstract

Extending ~530 km from the upper Alaska Peninsula northeastward along the western Cook Inlet basin margin (Fig. 1), the Bruin Bay fault represents a major, long-lived, tectonic boundary that has accommodated crustal-scale stresses generated by the subduction of oceanic lithosphere beneath continental North America since Middle to Late Jurassic time. The fault has exerted a fundamental control on forearc basin architecture (e.g. Fig. 2), but that extent is poorly understood. Less is known about the timing, rate, and steadiness of sediment source-rock exhumation over time and space associated with motion along the fault. Fifteen new apatite and eleven new zircon fission-track ages from samples collected at two locations across the Bruin Bay fault on the upper Alaska Peninsula (Fig. 3) span Middle Jurassic to Late Oligocene time and provide new insight into the long-term history of source area, and subsequent basin margin exhumation. Markedly different hangingwall, footwall, and along-strike cooling histories indicate episodic, diachronous exhumation of Jurassic intrusive arc rocks. Age-distance distributions can be challenging to interpret for this dataset, presumably due to faulting between samples and some igneous reheating. However, inverse modeling of AFT results helps identify periods, and estimate rates, of rapid cooling. The southwesternmost two samples collected near Becharof Lake indicate rapid Middle Jurassic cooling of granitic hangingwall rocks and slow Early Cretaceous cooling of adjacent Late Jurassic basin fill. Samples collected to the northeast along a transect in Katmai National Park reveal rapid cooling of hangingwall granitic rocks during latest Jurassic time that was partially coeval with regional arc-derived clastic sedimentation. Late Paleocene-Early Eocene footwall ZFT cooling ages are identical to the oldest hangingwall AFT ages at this location, suggesting simultaneous hangingwall and footwall cooling during Late Paleocene to Early Eocene time that was coeval with deposition of conglomerates found in both settings. Footwall rocks continued to cool independently of hangingwall rocks after ~42 Ma, suggesting footwall inversion during Early Oligocene time. Perhaps a third, poorly-defined cooling episode of involving hangingwall and footwall rocks occurred during Late Oligocene time and overlaps with coarse, arc-derived sedimentation. Early Cenozoic cooling ages from the Katmai area are nearly identical to reconnaisaince AFT results from the western margin of upper Cook Inlet. Additionally, apparent transtensional deformation occurring in both locations (after ~42 Ma in upper Cook Inlet area) may indicate changes in the regional stress field along the western Cook Inlet corridor during Paleogene time. Early Cenozoic cooling ages from the Katmai area are coeval with Kula-Farallon ridge/slab window subduction and may be related. If so, then Oligocene footwall inversion and cooling may reflect expected changes in rate and perhaps obliquity between the North American plate and the leading and trailing edges of the subducted Kula-Farallon ridge system.

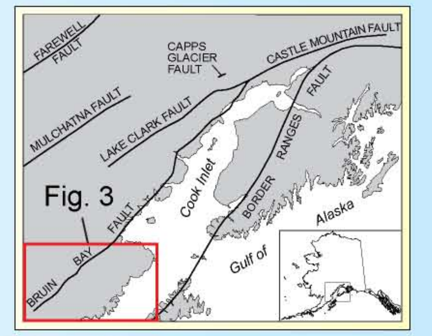


Fig. 1
Regional tectonic map of southern Alaska

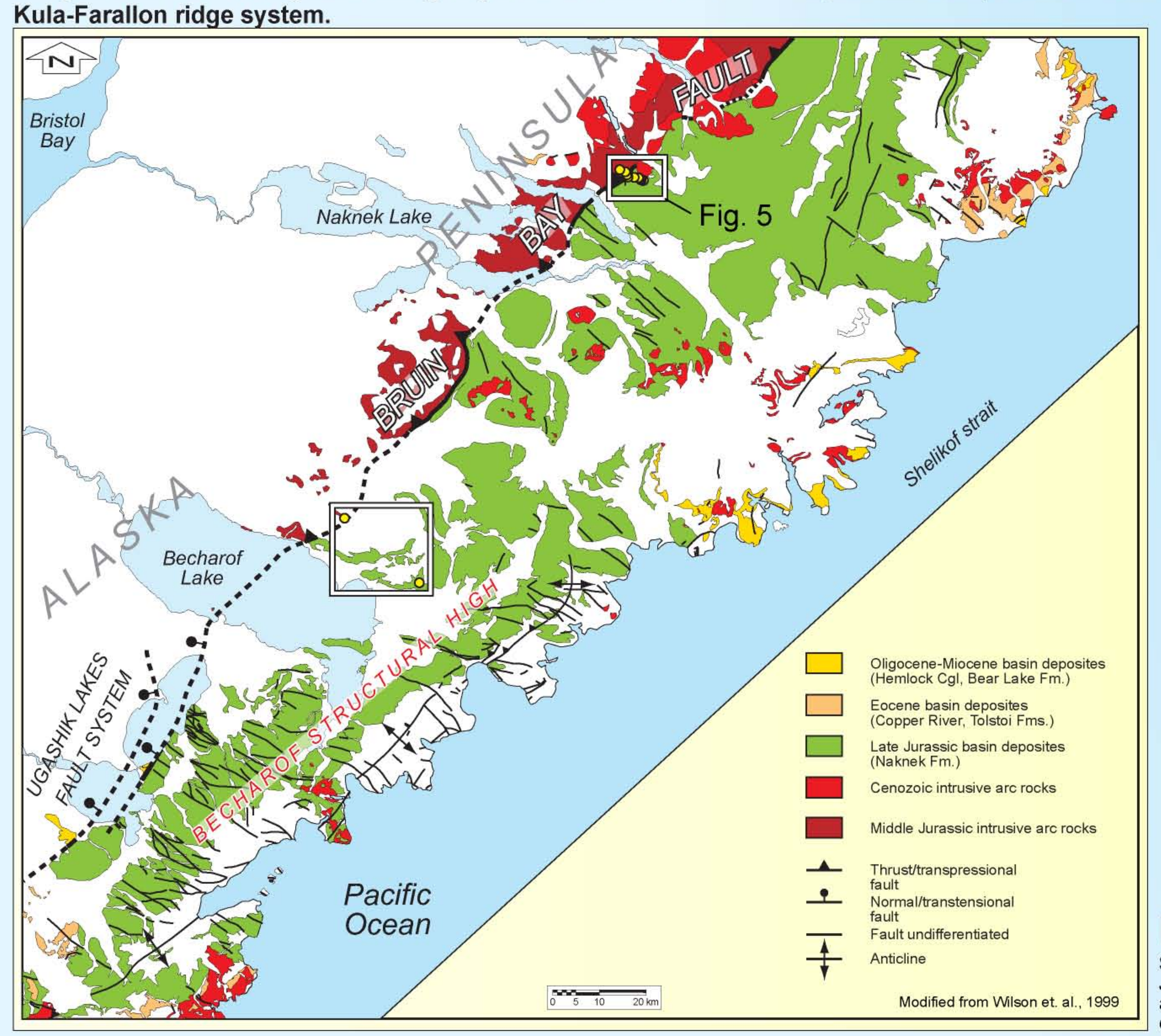


Fig. 3
Simplified geologic map of the upper Alaska Peninsula highlighting Middle Jurassic and Cenozoic sediment source-rocks derived from the intrusive-arc, and Late Jurassic and Cenozoic sedimentary units containing significant conglomeratic facies composed of granitic and volcanic clasts

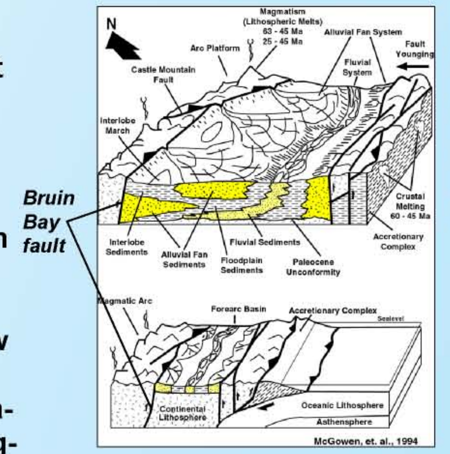
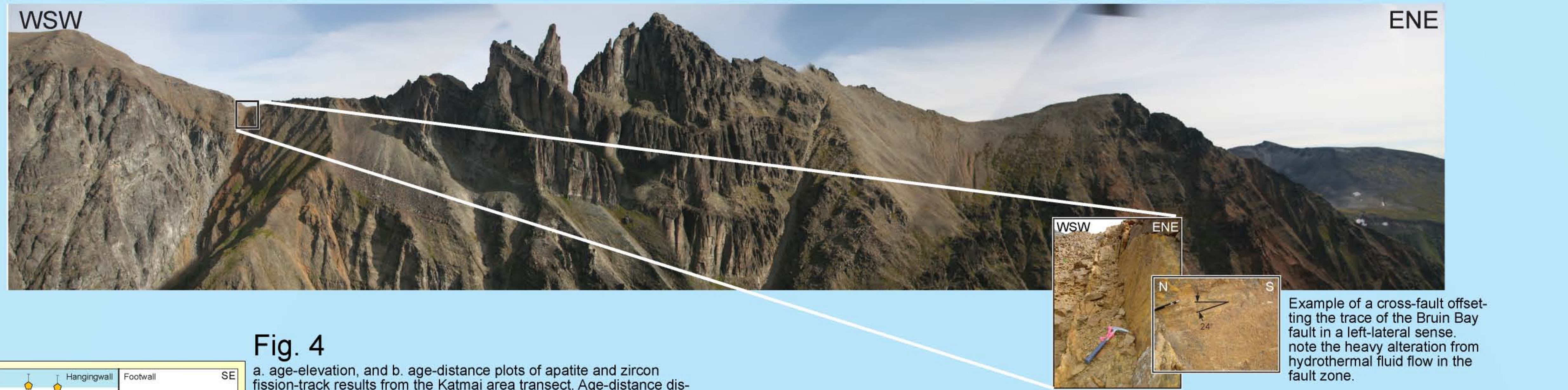
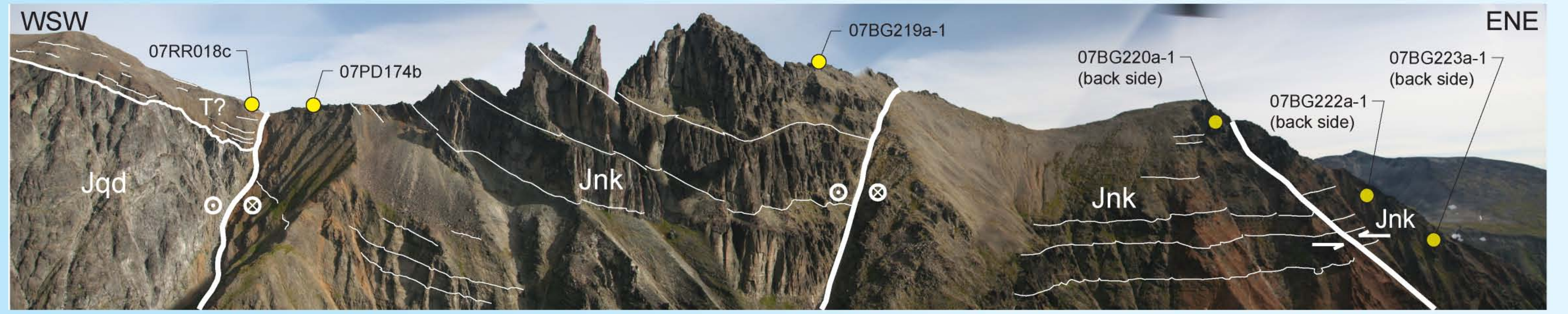


Fig. 2
Schematic representation of the Cook Inlet forearc basin showing relationship between basin-controlling structures such as the Bruin Bay fault, and forearc basin sedimentary architecture



Example of a cross-fault offsetting the trace of the Bruin Bay fault in a left-lateral sense. note the heavy alteration from hydrothermal fluid flow in the fault zone.



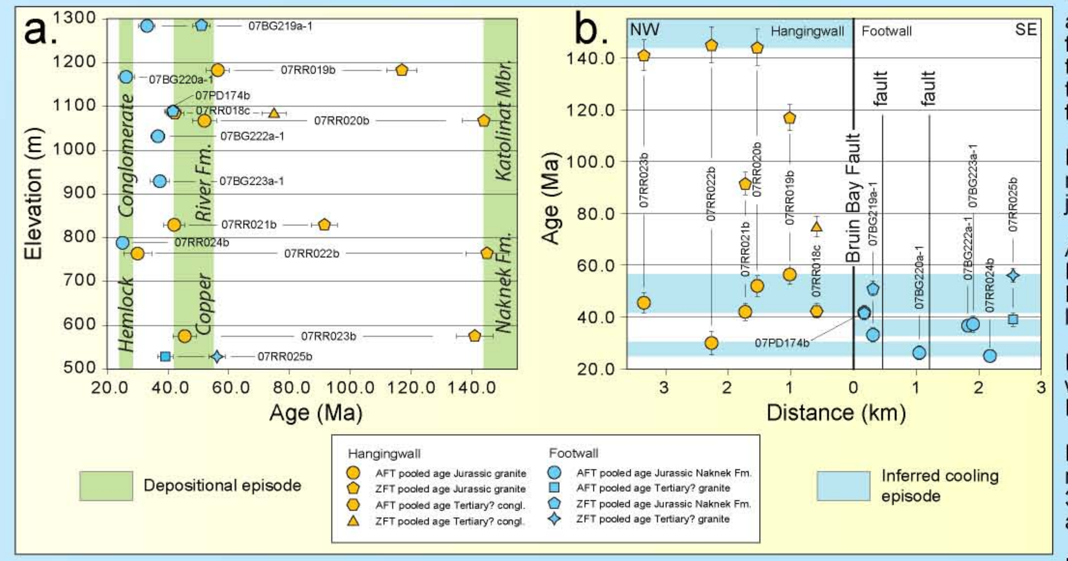


Fig. 4
a. age-elevation, and b. age-distance plots of apatite and zircon fission-track results from the Katmai area transect. Age-distance distributions (b.) highlight the markedly different cooling histories between hangingwall (HW) and footwall (FW) rocks of the Bruin Bay fault.

Plutonic HW ZFT results (a.: orange pentagons) are consistent with rapid cooling from 145-141 Ma and are coeval with deposition of adjacent Katolinat conglomerate.

A relatively concordant AFT distribution (a.: orange circles) indicates HW cooling primarily between 56.4 and 42 Ma, overlapping Copper River Fm. conglomerate deposition ~12 km to the SE at Cape Douglas.

FW ZFT cooling ages (a.: blue pentagon and star) are identical within error to the oldest HW AFT ages, suggesting simultaneous HW-FW cooling at ~56-42 Ma).

FW AFT cooling ages (blue circles) are commonly discordant with respect to elevation (a.), but indicate FW cooling between 37.3 and 33.1 Ma. Younger FW ages at the same elevations as older HW ages suggest footwall inversion after ~42 Ma.

HW and FW AFT ages (blue and orange circles) with cooling ages between 30 and 25 Ma are identical within error and may indicate a poorly-defined cooling event during a period coeval with Hemlock Conglomerate deposition.

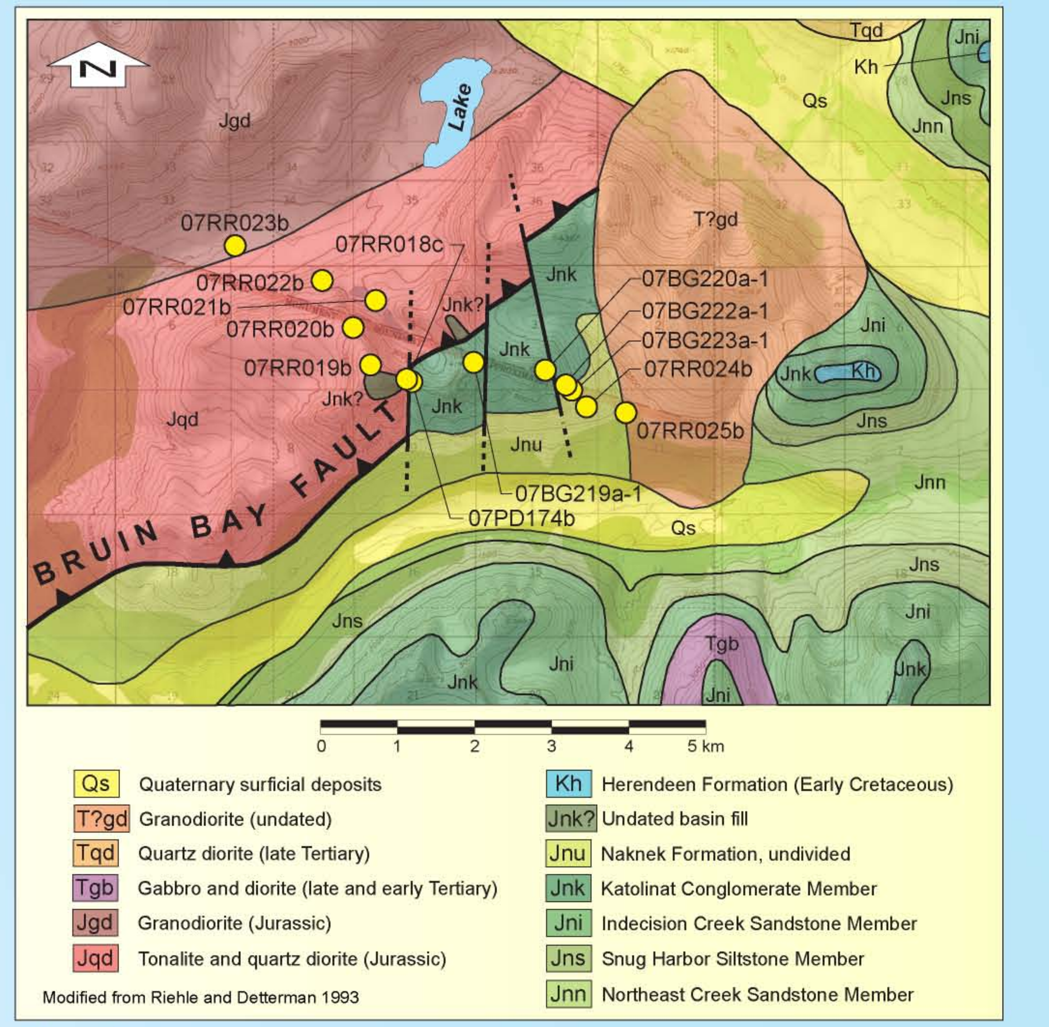


Fig. 5
Simplified geologic map near Grosvenor Lake in Katmai National Park showing sample locations (yellow circles) and oblique-slip faults offsetting the Bruin Bay fault trace in a sinistral sense. Cooling rates estimated from AFT age-elevation distributions and those derived from inverse cooling models differ by an order of magnitude, suggesting that vertical distances between samples have been condensed along unmapped faults, or the entire sample series rotated about a horizontal axis

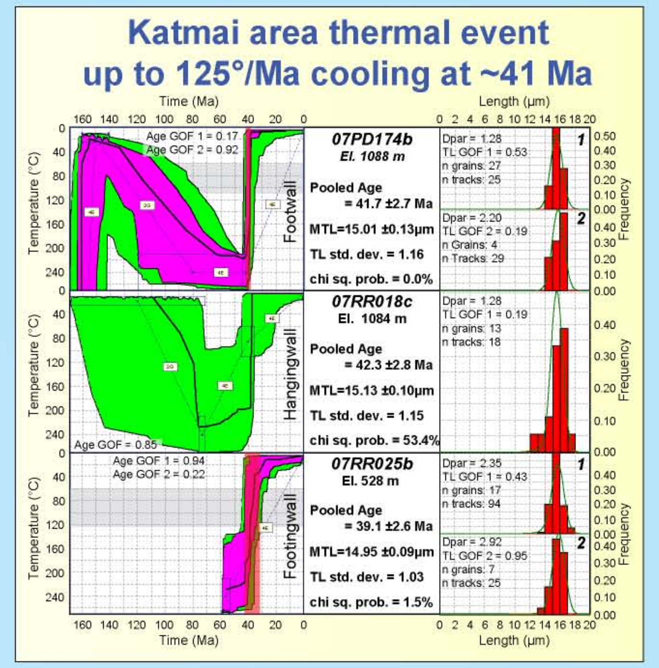


Fig. 6
Inverse thermal models of samples interpreted to reflect very rapid cooling after igneous reheating. Pooled ages are identical within error for each sample, and all three samples share the highest mean track lengths with the lowest standard deviations of all samples. The upper two samples were collected ~100 m apart at the same elevation in hangingwall and footwall settings of the Bruin Bay fault in close proximity to a hydrothermally altered cross-fault zone. The uppermost sample (07PD174b yielded identical ZFT and AFT cooling ages.

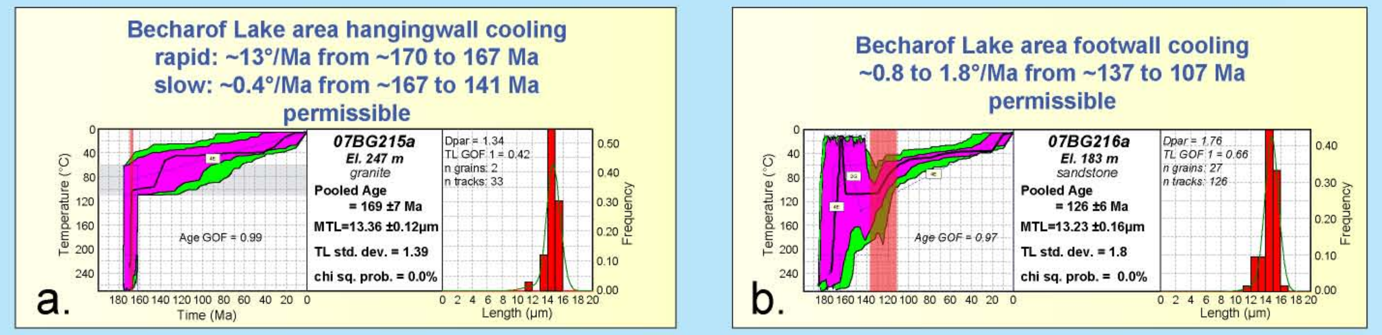


Fig. 7
AFT inverse thermal models from the Becharof Lake area. The hangingwall good-fit model envelope (a., magenta) shows initial rapid cooling during a short period in Middle Jurassic time followed by very slow, protracted cooling until earliest Cretaceous time. The results are tentatively interpreted to reflect initial primary post-emplacement cooling at a shallow crustal level followed perhaps by slower exhumation-cooling due to motion along the Bruin Bay fault. The footwall good-fit model envelope (b., magenta) shows slow post-burial exhumation of Late Jurassic Naknek Fm. strata, although the mechanism for cooling is uncertain.

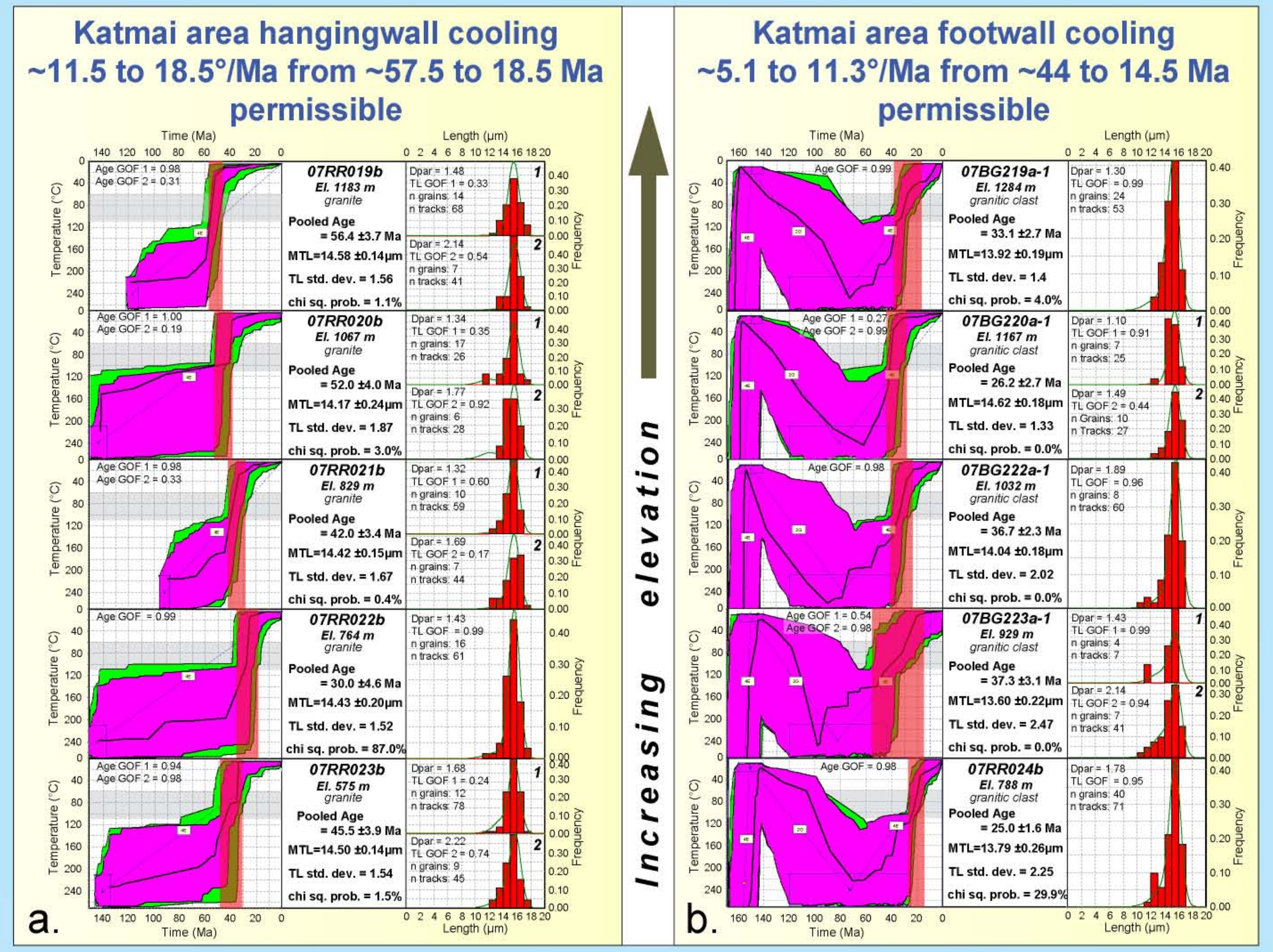


Fig. 8
AFT inverse thermal models from the Katmai area transect arranged with respect to sample elevation. Hangingwall good-fit model envelopes (a., magenta) show rapid cooling of HW samples from as early as Late Paleocene to as late as Early Oligocene times. Cooling in this setting occurred at a rate twice as fast as that estimated from footwall good-fit model envelopes (b., magenta) spanning Middle Eocene to Early Miocene times. Samples from both settings with Oligocene pooled ages exhibit some of the more rapid cooling rates for their respective settings, supporting the possibility of an Oligocene cooling event affecting hangingwall and footwall rocks.

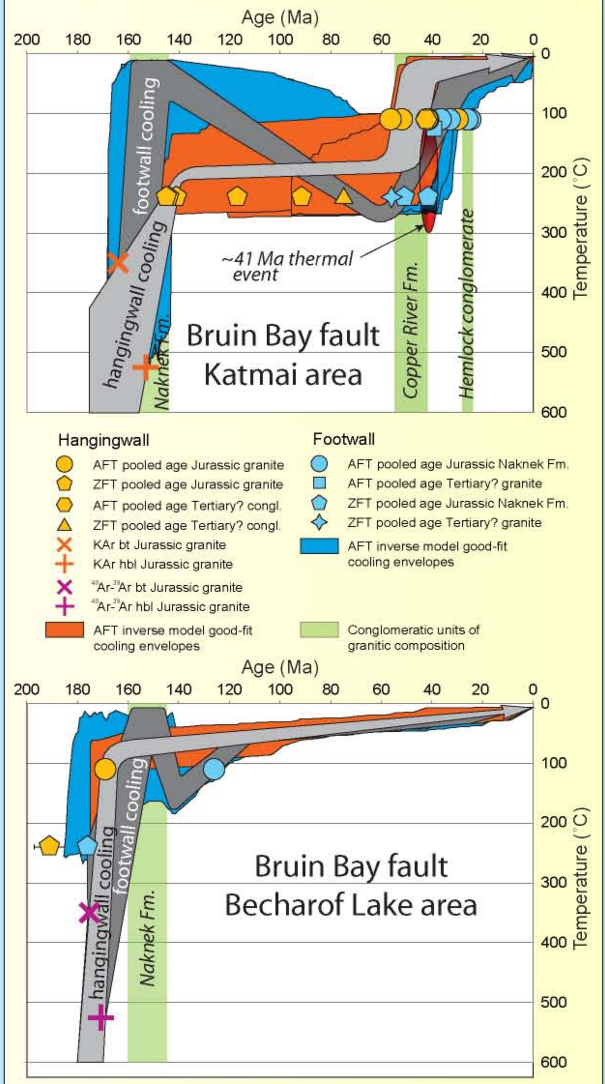


Fig. 9
Schematic representation of Katmai area (a.) and Becharof Lake area (b.) hangingwall and footwall cooling trajectories based on new AFT, ZFT, $^{40}Ar/^{39}Ar$, and existing potassium argon ages superposed over thermal modeling results.

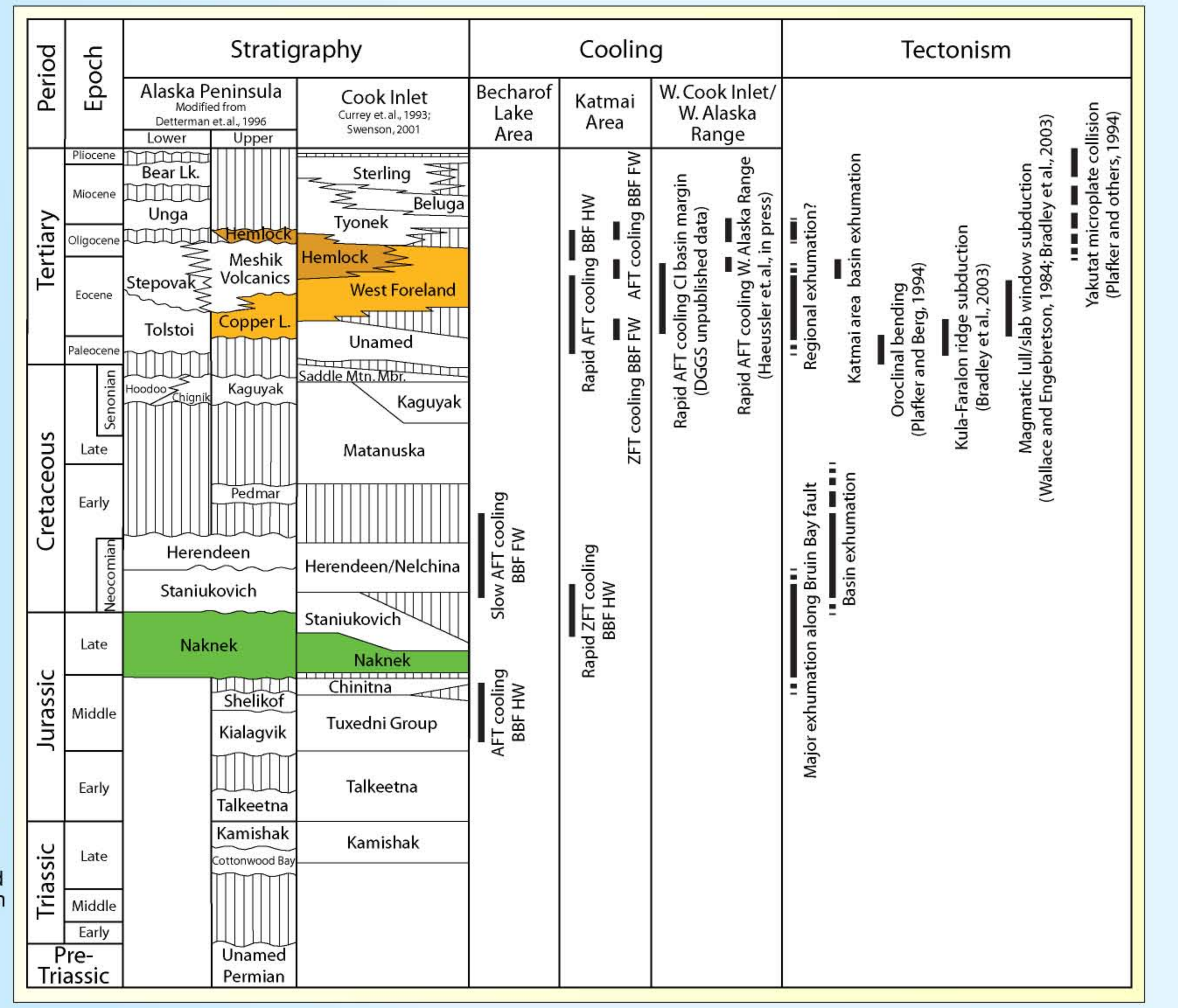


Fig. 10
Stratigraphic column of the Alaska Peninsula and Cook Inlet regions highlighting units containing significant conglomeratic facies of granitic and volcanic composition presented with respect to major tectonic events and available cooling information from this and other studies.

Conclusions

Cooling along the Bruin Bay fault was diachronous, with the earliest hangingwall cooling recorded near the southernmost mapped exposure of the fault by Becharof Lake. Rapid cooling of the intrusive arc below ~110°C in the Becharof Lake area occurred during a single episode in Middle Jurassic time, presumably from post-emplacement cooling and possibly early motion along the Bruin Bay fault. Adjacent Late Jurassic footwall basin deposits are interpreted to have been buried to AFT resetting temperature by ~140 Ma and slowly exhumed thereafter.

Rapid Jurassic hangingwall cooling in the Katmai National Park area approximately 95 km to the northeast was occurring ~26 Ma later at ~144 Ma that was likely related to rapid hangingwall exhumation resulting in deposition of the adjacent granitic boulder conglomerate of the Katolinat Member at that time. A second cooling event in the Katmai area from ~56 to 42 Ma progressed at rates up to 18.5°C/Ma and appears to have involved both hangingwall and footwall rocks. Paleogene cooling and deposition of the Early Eocene age Copper Lake Fm. in the Katmai area are broadly coeval with subduction of the Paleogene Kula-Farallon ridge and passage of a predicted slab window.

Granitic clasts from the Katolinat Member of the Naknek Fm. directly SE of the fault were completely reset above ZFT closure temperature prior to Late Paleocene time and cooled moderately rapidly during Late Eocene to Early Oligocene times. Apparent inversion of the Jurassic basin during this period may have progressed by normal or oblique reactivation of the Bruin Bay fault or along several oblique-slip cross faults cutting the Bruin Bay fault. Reasons for the apparent shift in tectonic regime is unclear, but could be related to expected changes in convergence rate and obliquity between the North American plate and the leading and trailing edges of the subducted Kula-Farallon ridge system.

Uncertainties in the paleogeothermal gradient hinder accurately estimating the magnitude of hangingwall exhumation, but using a broad range of values from hot arc to the current geothermal gradient in upper Cook Inlet yields a minimum range of 4 to 9.5 km of middle Jurassic hangingwall exhumation near Becharof Lake. In the Katmai area, 2 to 5 km of Jurassic-age exhumation was followed by an additional 2 to 4.5 km in Paleogene time.

Ongoing thermochronologic work, geologic mapping, and Tertiary basin analyses by the Alaska DGGS and DOG near the Bruin Bay fault along the western upper Cook Inlet area will improve our understanding of the Cenozoic tectonic history of the Alaska Peninsula-Cook Inlet corridor.

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