Underplating Below the Western Chugach Mountains in the Southern Alaska Block Syntaxial Core Constrained by Low-Temperature Thermochronology*

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Abstract

Flat-slab subduction of the Yakutat microplate beneath south-central Alaska has played an instrumental role in the deformation of the overlying Southern Alaska Block (SAB). Terrains of the SAB are bound by arcuate fault systems that delineate regions of transpression and compression. North-verging accretion of these terrains form a prominent orogenic chain along Alaska's southern coast, comprised of the Chugach, St. Elias Mountains, and adjacent coastal regions of the Prince William Sound (PWS). Results from several low-temperature thermochronology studies show that focused exhumation is constrained to a few main regions in southern Alaska - these are mainly in the St. Elias region of southeast Alaska where collisional processes cause rapid rock uplift and in the western Chugach Mountains where underplating along the megathrust is interpreted to cause localized rock uplift. However, the localized rock uplift in the western Chugach is inferred from PWS sea level thermochronology age trends that are projected north into the high elevation, glaciated regions of the western Chugach Mountain syntaxial core where age constraints were previously lacking.

Six new apatite (U-Th)/He (AHe) ages were determined from samples in the rugged core of the sytaxial region to evaluate spatial patterns of rock uplift. Ages along a NNW transect from Harvard Glacier to Mt. Sergeant Robinson range from 6.6 ± 0.9 to 10.8 ± 1.6 Ma. Ages along an ENE transect from Inner Lake George to west of Mt. Marcus Baker range from 4.7 ± 0.9 to 7.6 ± 1.4 Ma. However, when these ages are corrected for topographic effects and projected to sea level for comparison with previous sea level ages, their sea level age range is 2 to 6 Ma, with average age 4.1 Ma. The topographically-corrected sea level ages generally decrease into the core of the range where elevations are greatest. Inferred exhumation rates range from 0.3 to 0.5 km/Ma across the syntaxial core; these exhumation rates are the same as rates determined for PWS fiord samples to the south and suggest that late Miocene to recent average exhumation rates have been spatially constant across the region between the terrain-bounding Contact and Border Ranges fault systems. The consistency of the sea level projected

ages and inferred exhumation rates across the syntaxial core supports a kinematic pattern of uniform rock uplift caused predominantly by underplating rather than crustal shortening between the terrain-bounding faults.

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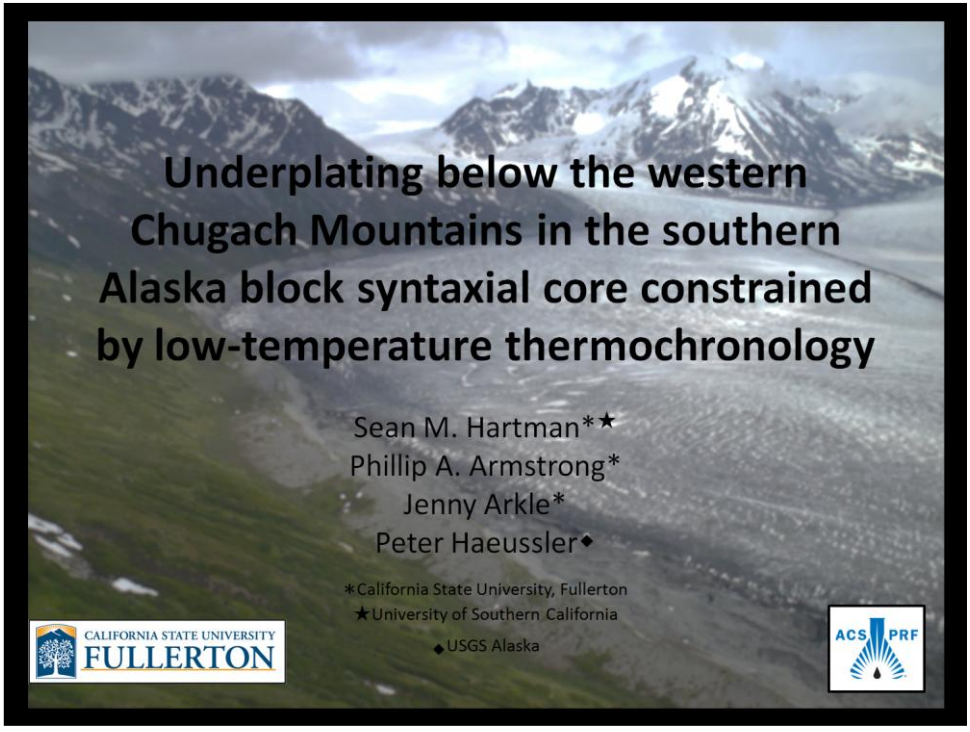
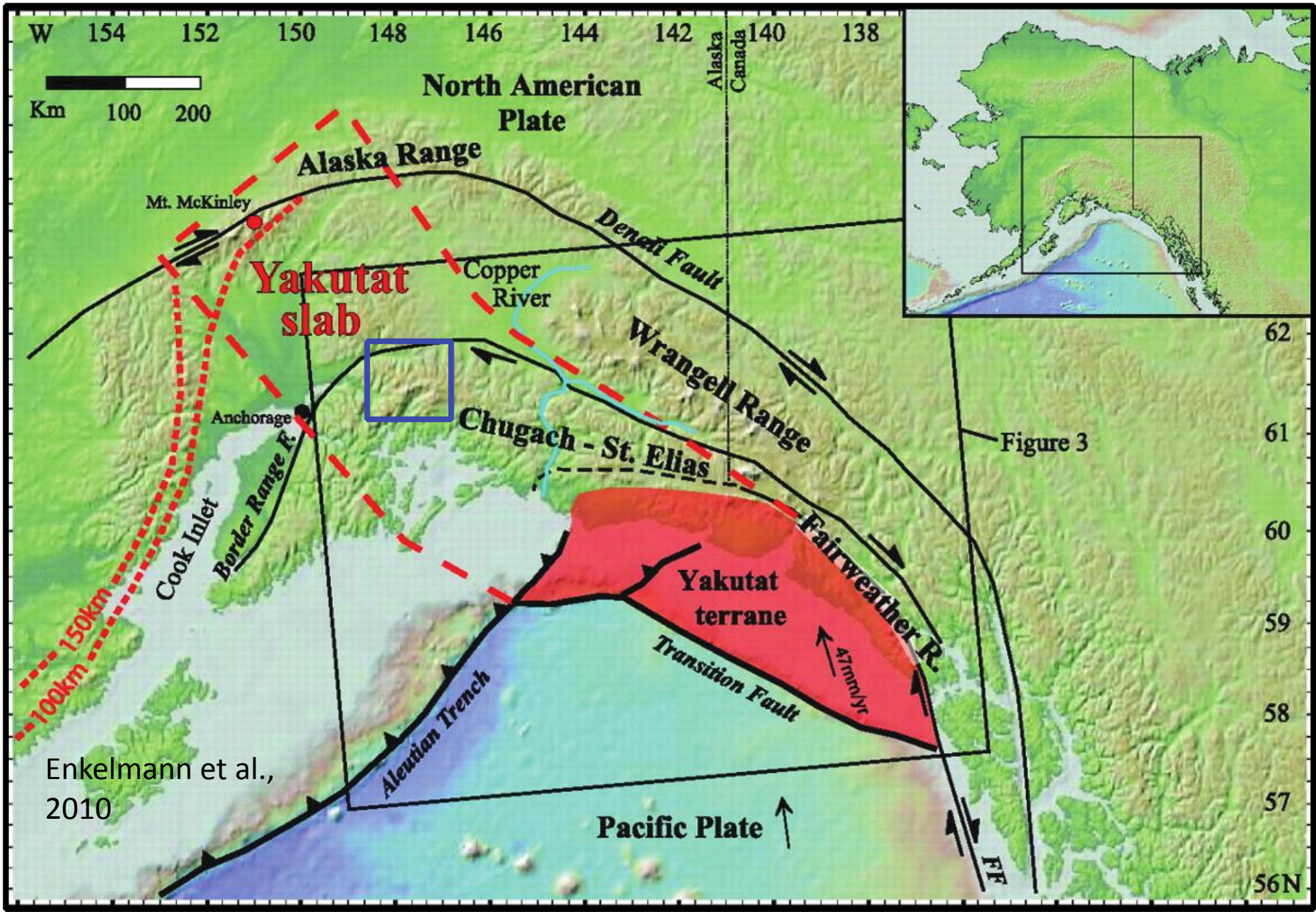


Presenter's notes: Today I want to talk about my research addressing the spatial and temporal patterns of rock uplift and exhumation in the syntaxial core of the western chugach mountains of southern alaska constrained by the apatite helium low temperature thermochronometer

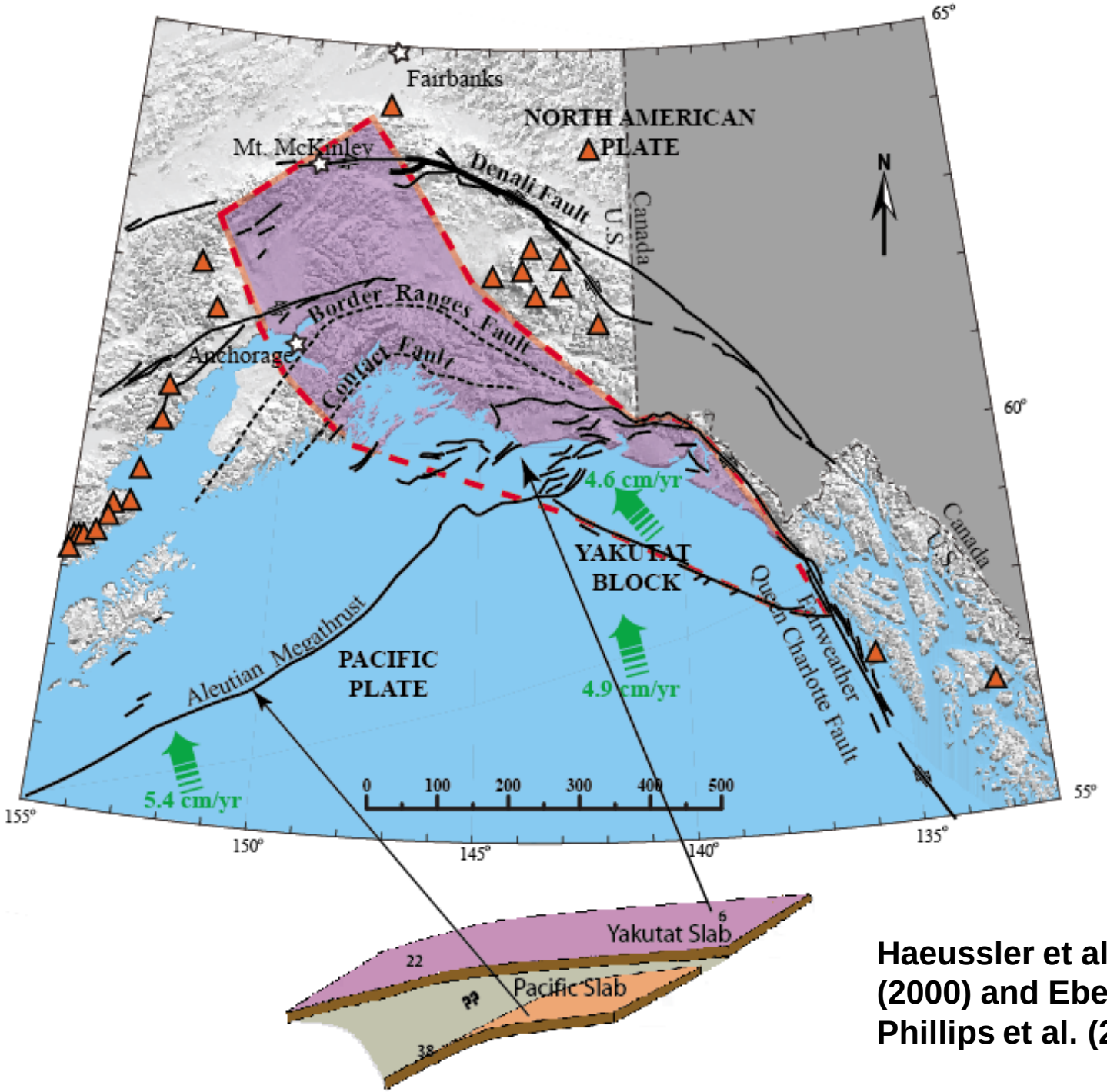
Outline

- Geological background
- Problem to be addressed
- Hypothesis
- Testing
- Results
- Interpretation
- Summary

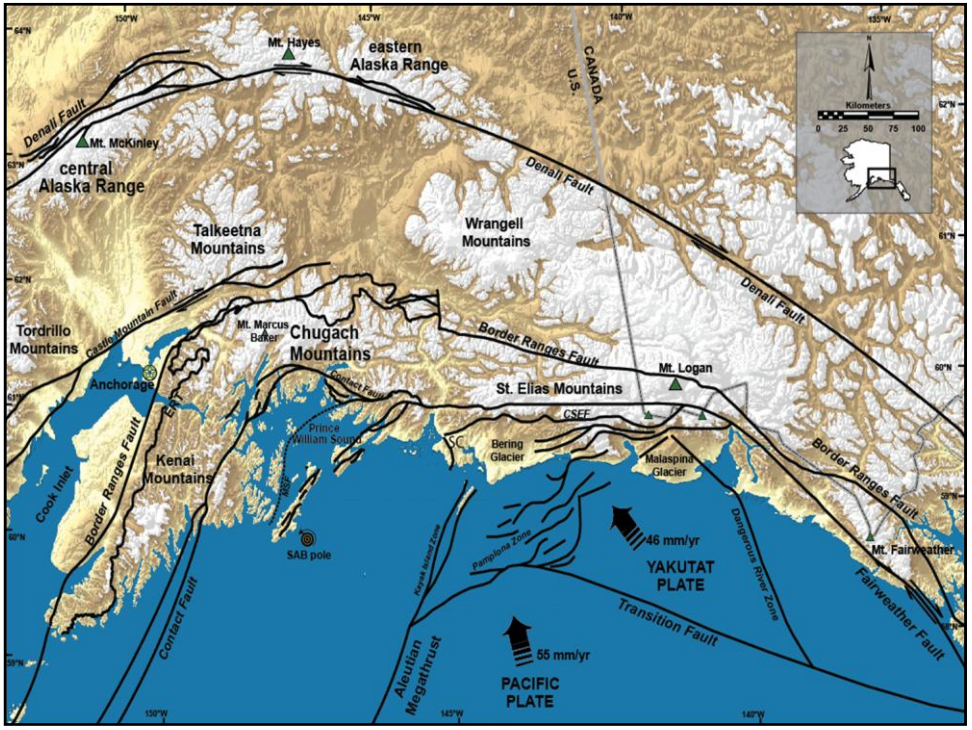
Geologic Background



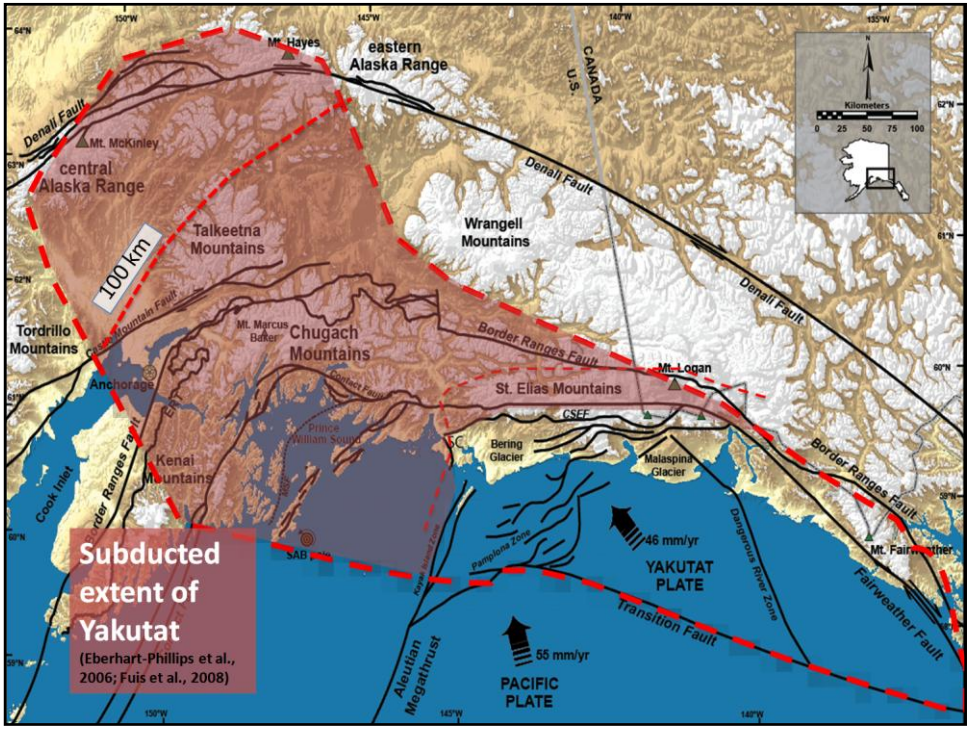
Enkelmann et al., 2010



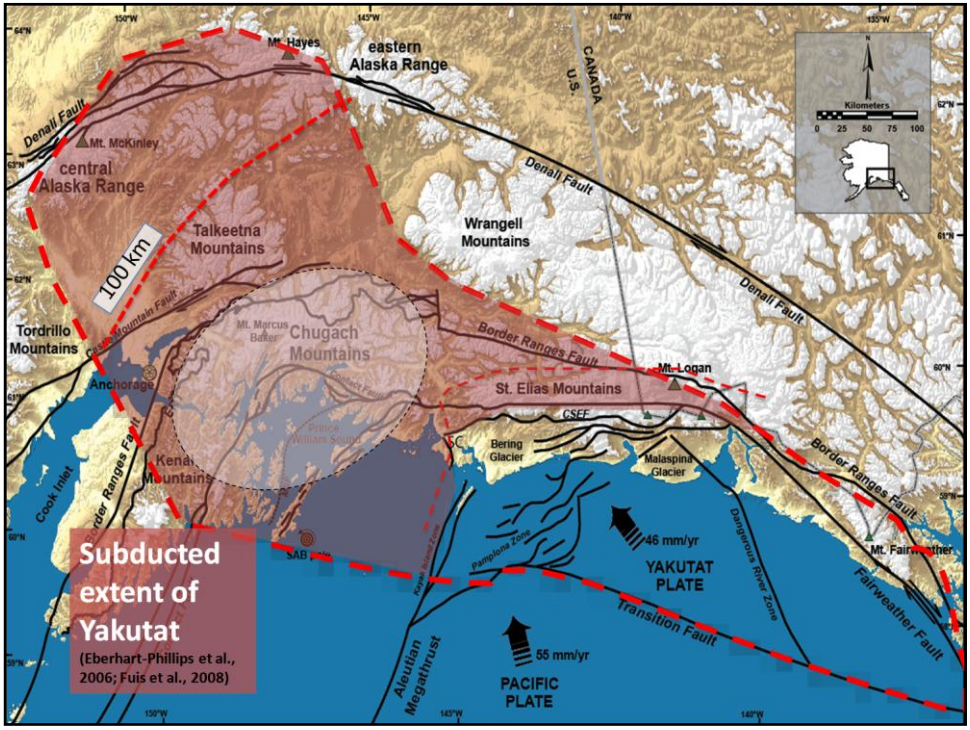
Haeussler et al. (2000) and Eberhart-Phillips et al. (2006)



Presenter's notes: Map showing major topography and faults
Main point here is that major fault systems and topographic grain make CCW bends from SE to NW
Major bends in DF at Mt Hayes area and Denali
Major bends in BRF, CSEF systems



Presenter's notes: Lateral extent based on Eberhart Phillips and Fuis (2008) – loosely constrained
Megathrust dips 6 deg
Steepens to north – show 100 km
Inboard area – but effects of Yakutat extend farther north and east
Outboard region – northward extent of the Aleutian megathrust
In between region – fault and topographic systems have maximum curvature and bend to south. 20-25 km above megathrust
NEXT SLIDE WILL BE IN BOARD REGION – NOTE LOCATION ON MAP



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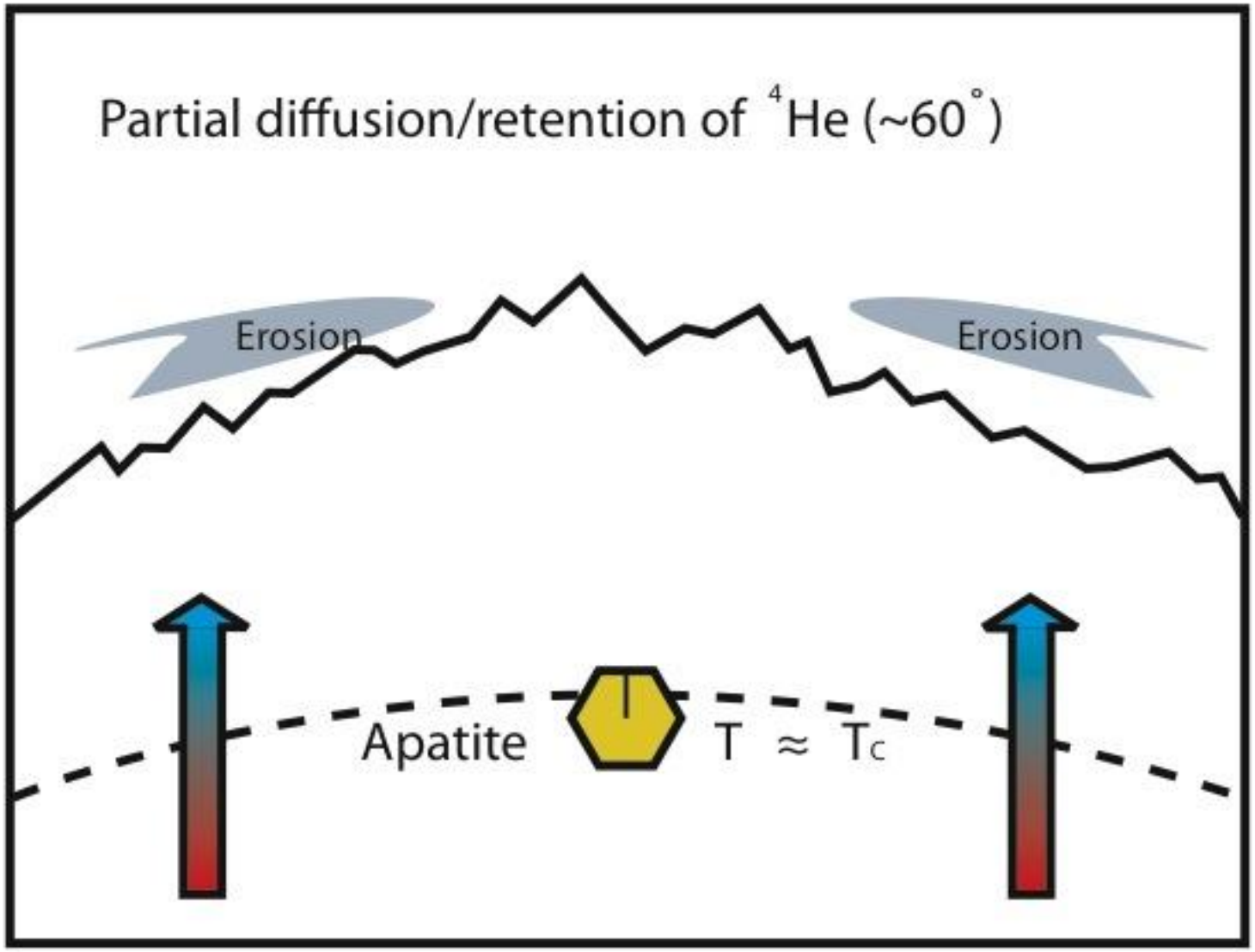
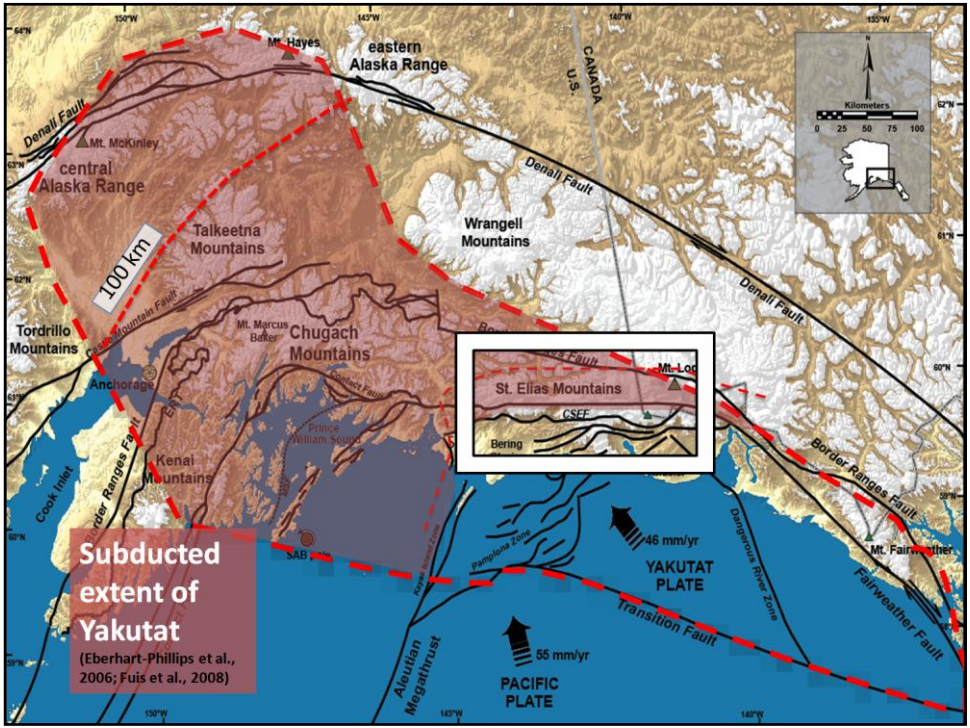

Partial diffusion/retention of ^{4}He (~60°)
Erosion
Erosion
Apatite
T ≈ Tc



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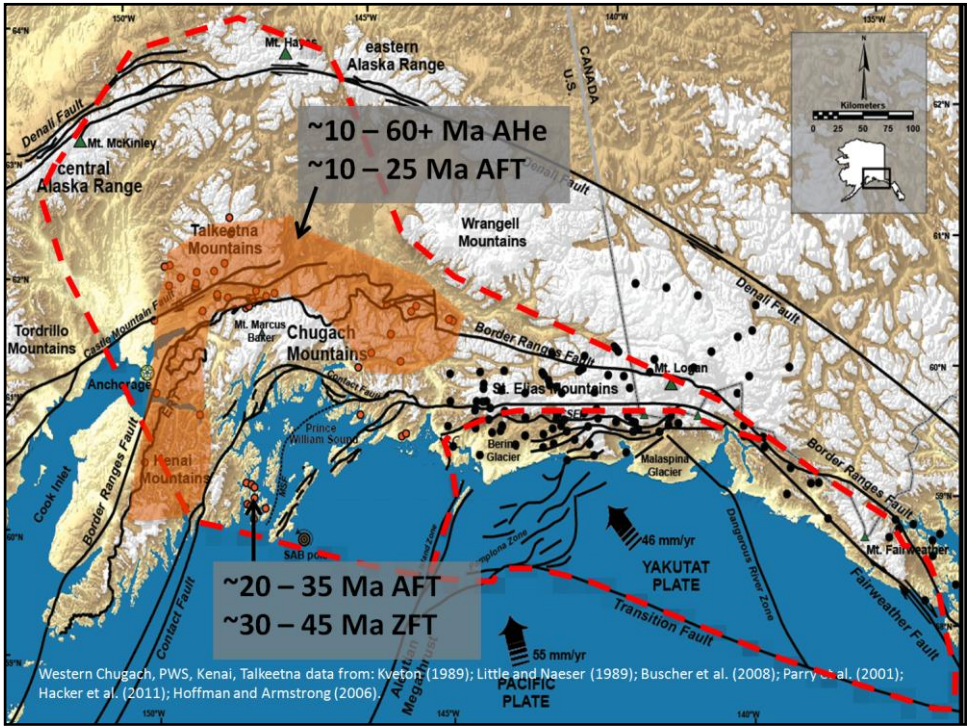
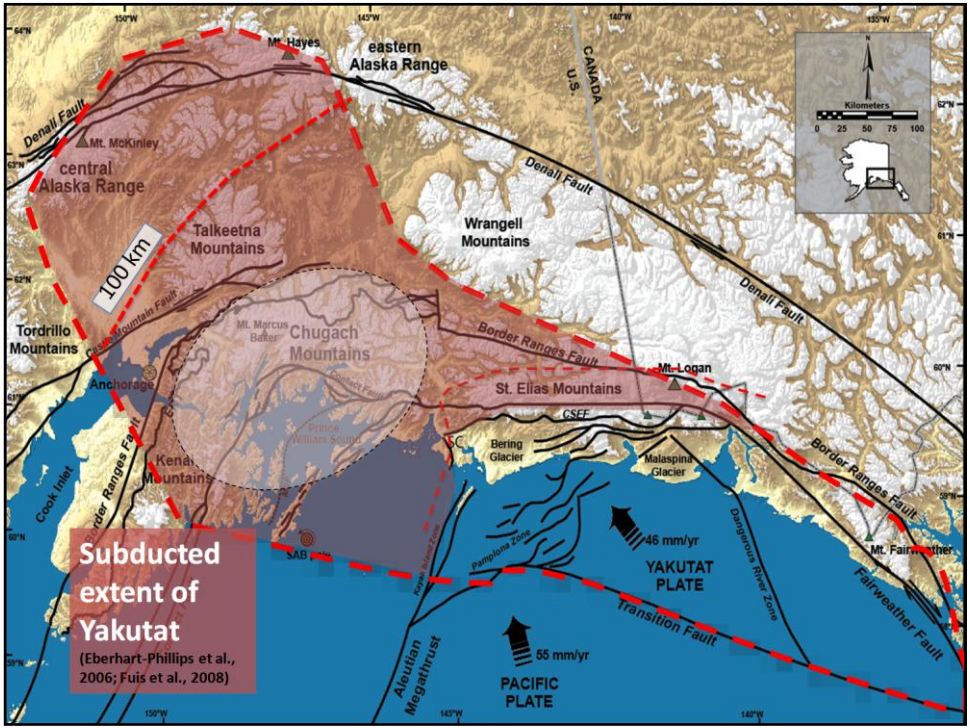


Presenter's notes: Area centered above Yakutat
Maximum curvature
Contact fault
Several thermochron studies over last couple decades, but all around the periphery of PWS – CM core as outlined by faults and topography
Ages – AFT 10 – 25 and Ahe 10-60 Ma in the bow wave around the what we call 'syntaxial' core.
Farther south, Kveton has AFT of 20-35 and ZFT of 30-45



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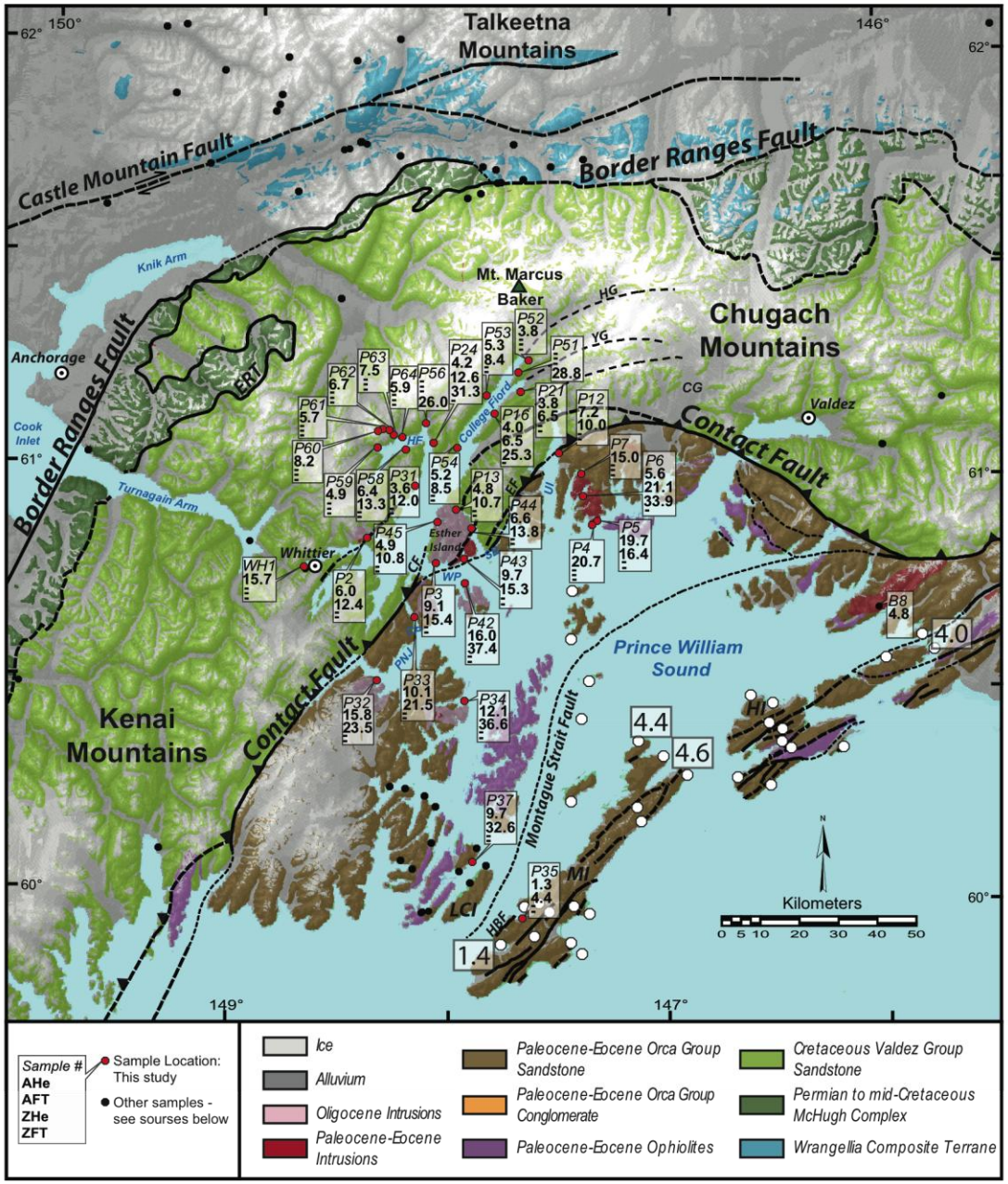
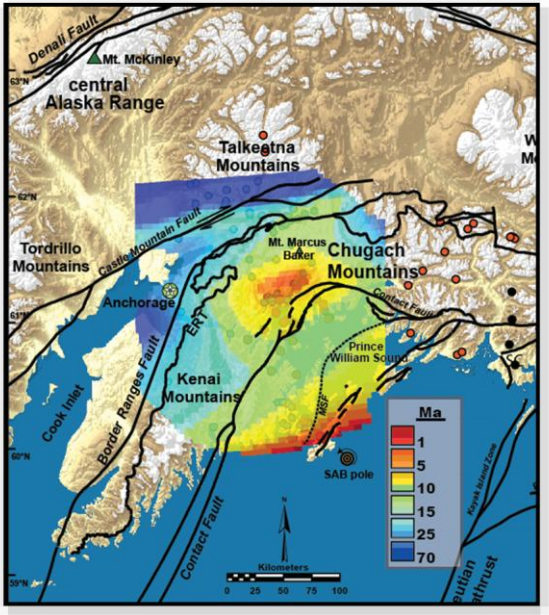
Problem to be Addressed



Hypothesis



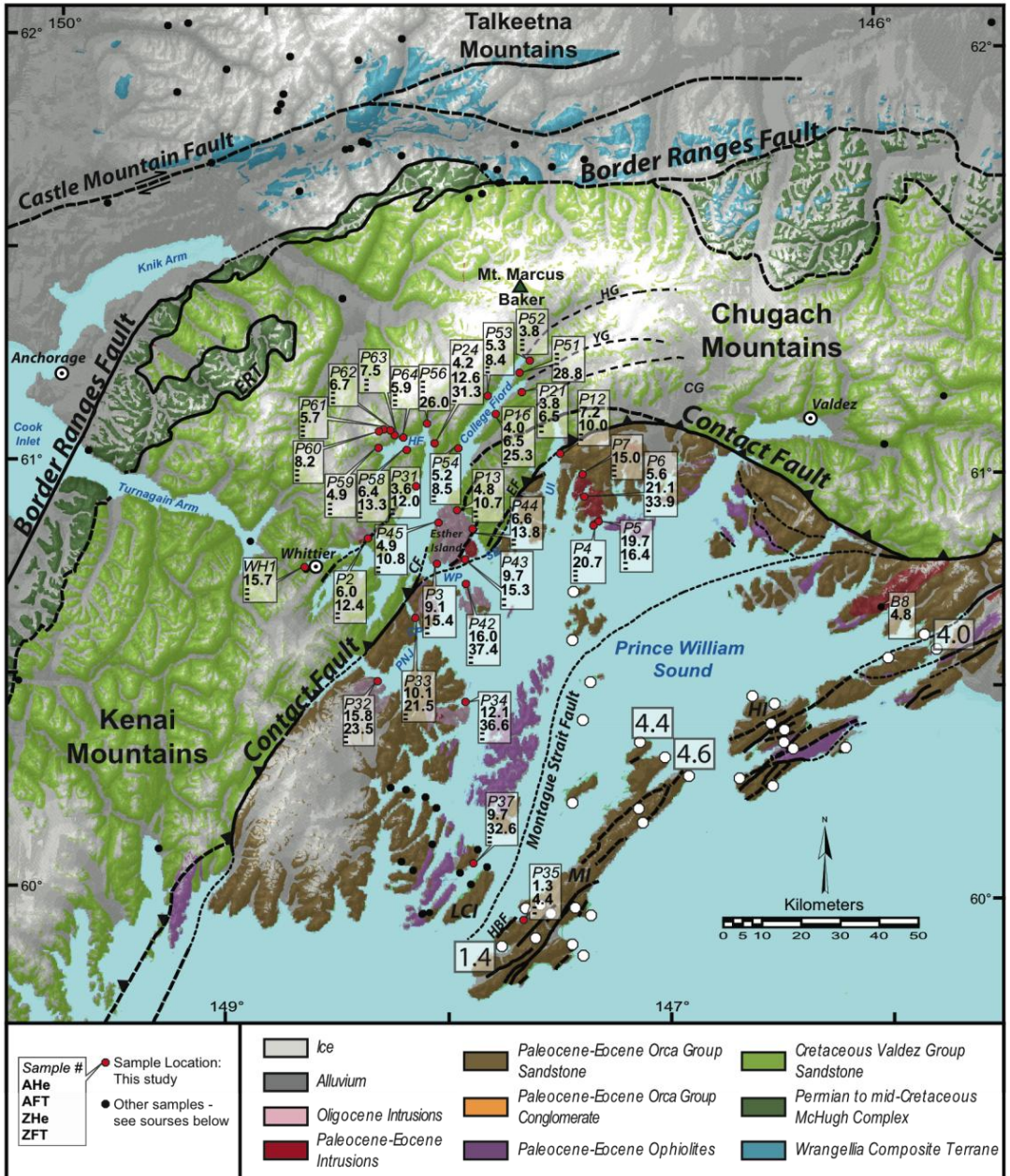
Apatite He ages

3-4 Ma in core

Increase radially outward.

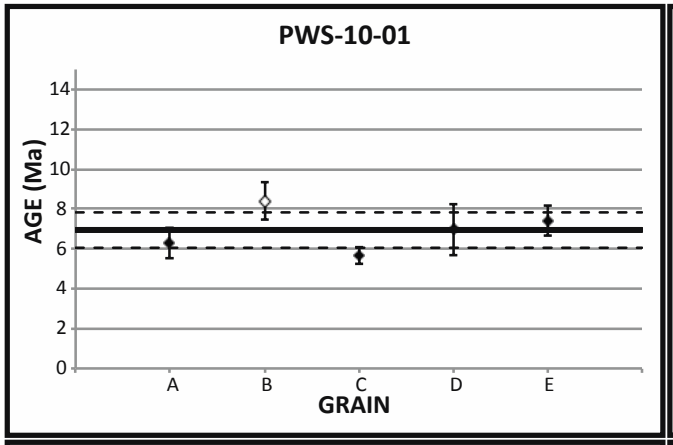
Presenter's notes: Ahe ages decrease into core of CM. But youngest ages (3-4 Ma) are concentrated on the south side of range and adjacent to CF – will be important in later plots
AFT ages show same trends

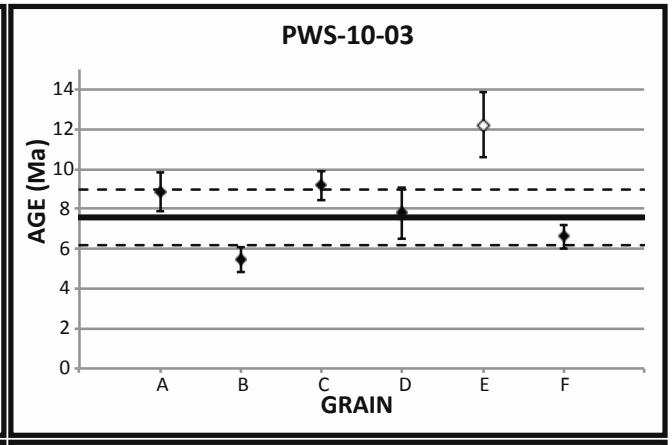
Testing


Talkeetna Mountains
Castle Mountain Fault
Border Ranges Fault
Knik Arm
Mt. Marcus Baker
Chugach Mountains
Anchorage
Cook Inlet
Turnagain Arm
Whittier
Valdez
College Fjord
Contact Fault
Kenai Mountains
Prince William Sound
Montague Strait Fault
Esther Island
Kilometers
0 5 10 20 30 40 50
Sample #
AHe
AFT
ZHe
ZFT
Sample Location: This study
Other samples - see sourses below
Ice
Alluvium
Oligocene Intrusions
Paleocene-Eocene Intrusions
Paleocene-Eocene Orca Group Sandstone
Paleocene-Eocene Orca Group Conglomerate
Paleocene-Eocene Ophiolites
Cretaceous Valdez Group Sandstone
Permian to mid-Cretaceous McHugh Complex
Wrangellia Composite Terrane


N4186Y

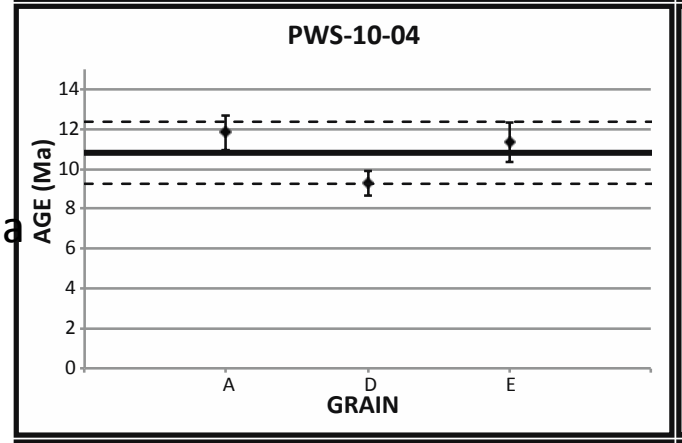
6.9 ± 0.9 Ma

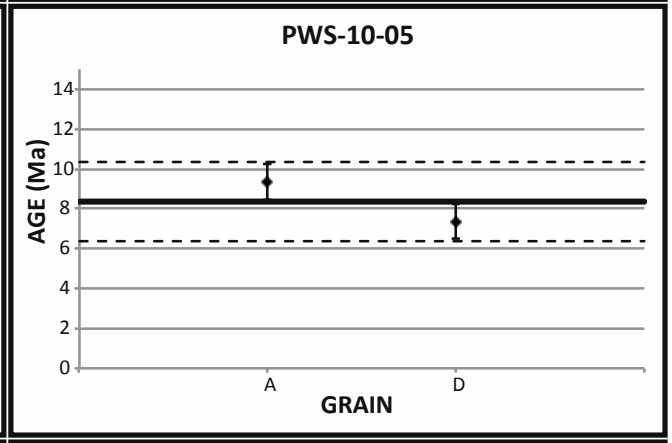




7.6 ± 1.4 Ma

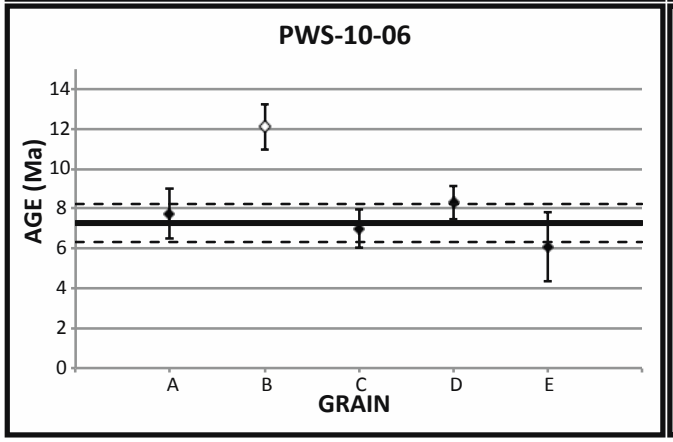
10.8 ± 1.6 Ma

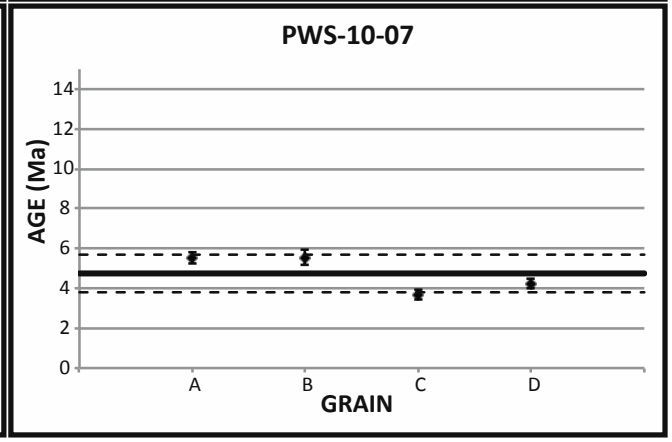




8.4 ± 2.0 Ma

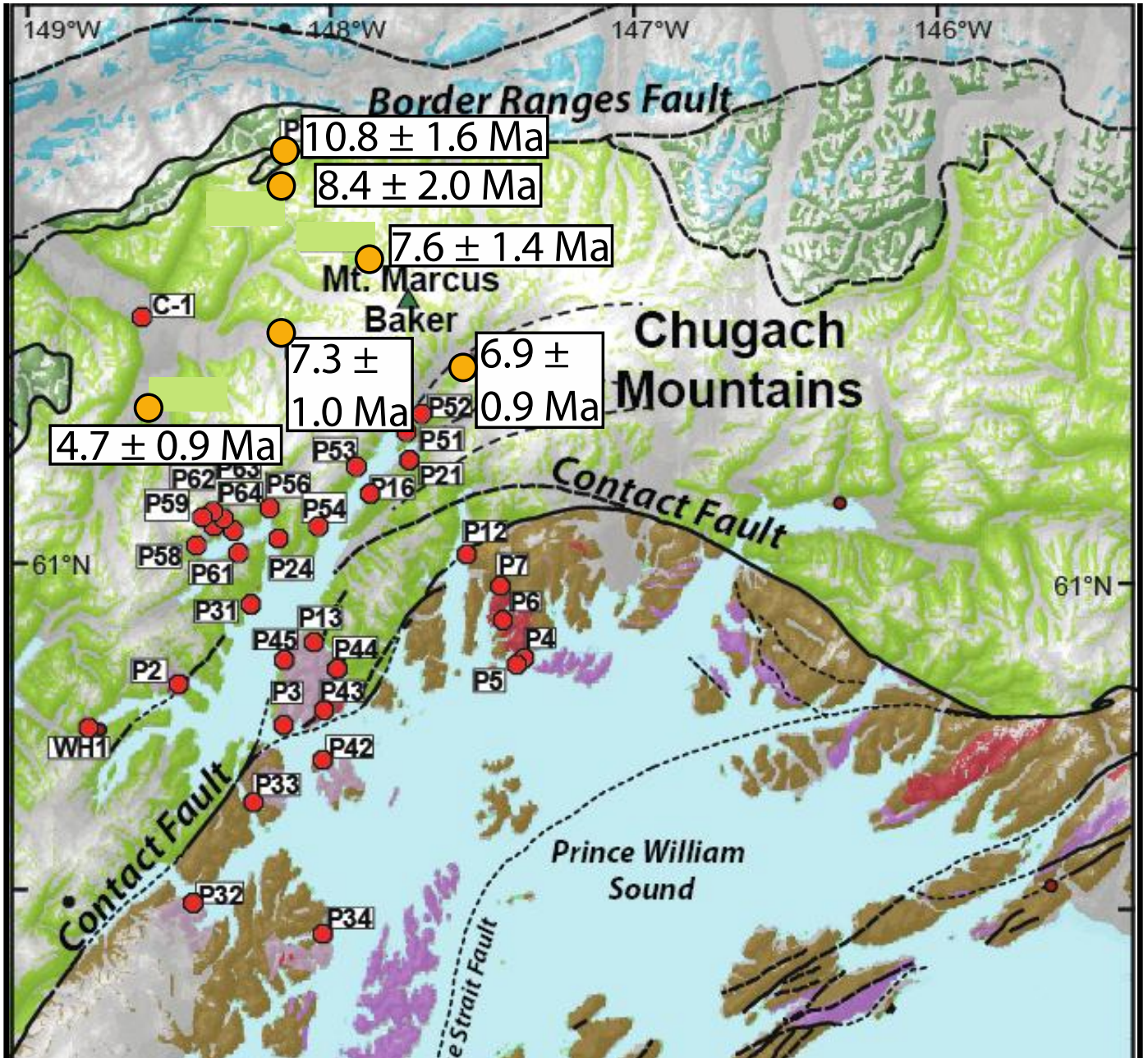
7.3 ± 1.0 Ma

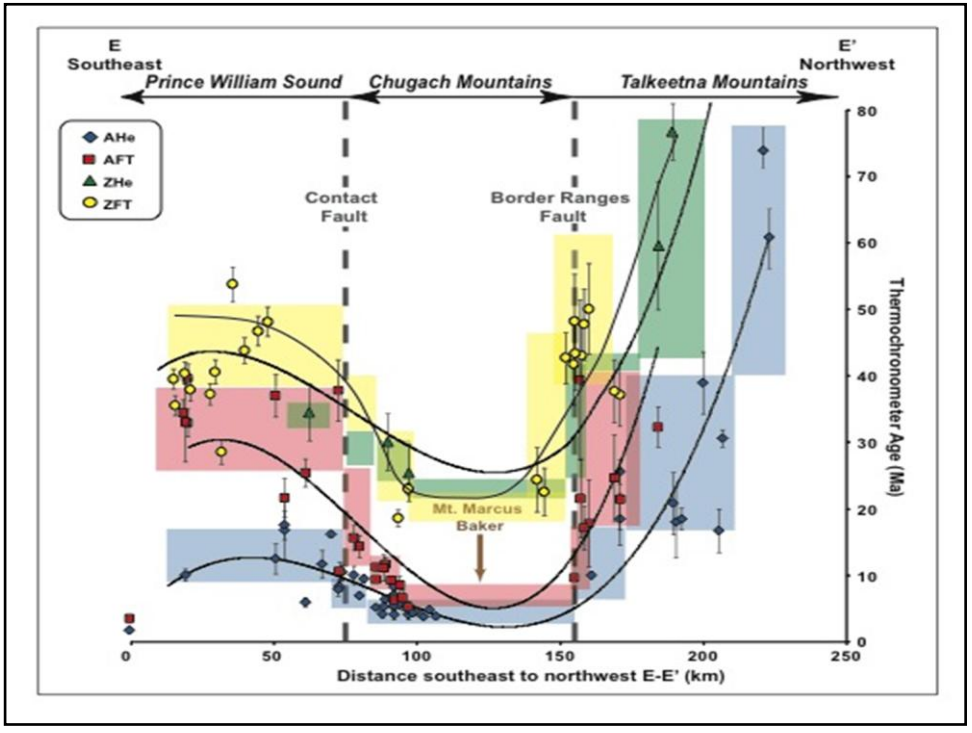




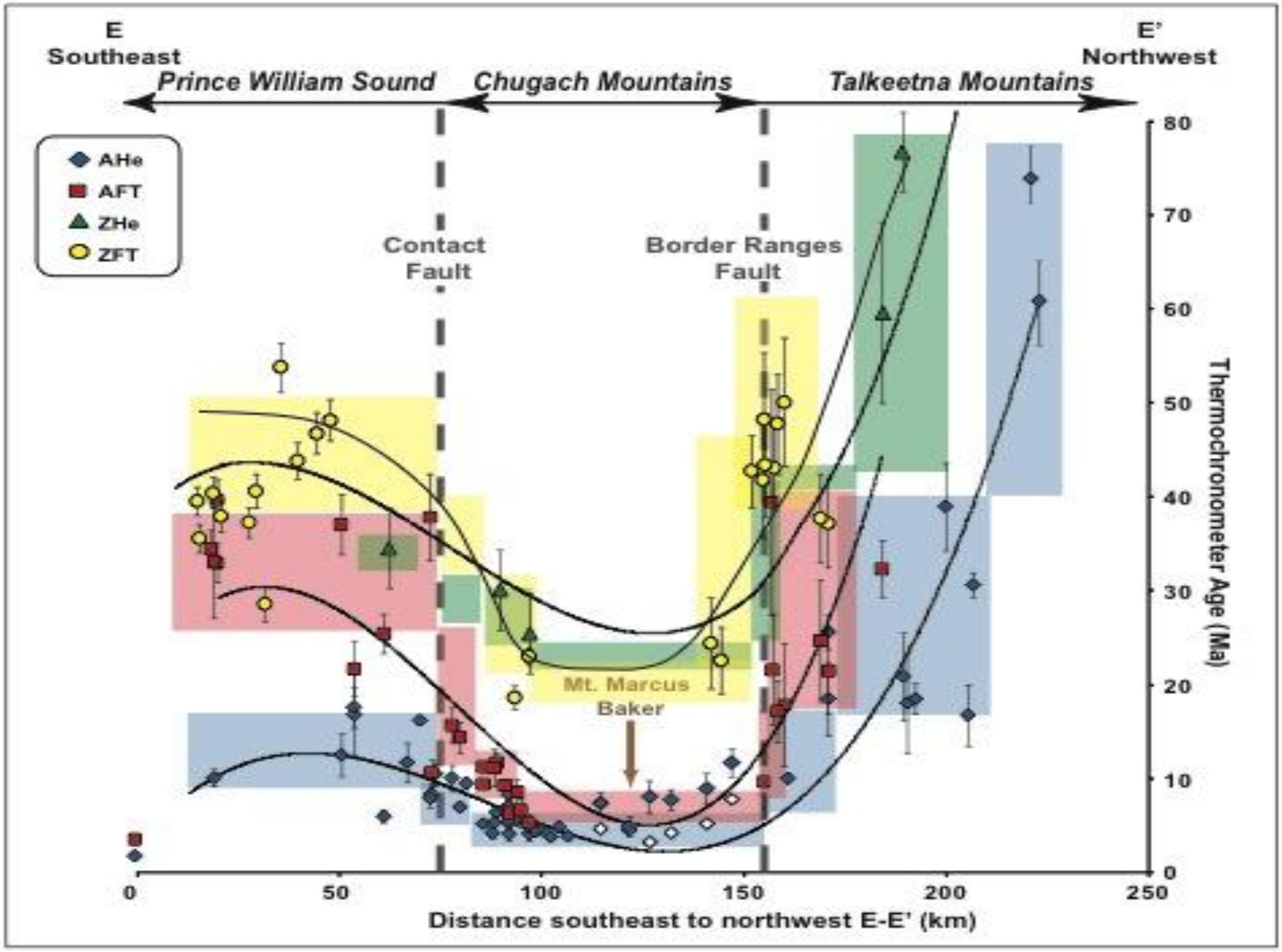
4.7 ± 0.9 Ma

Results

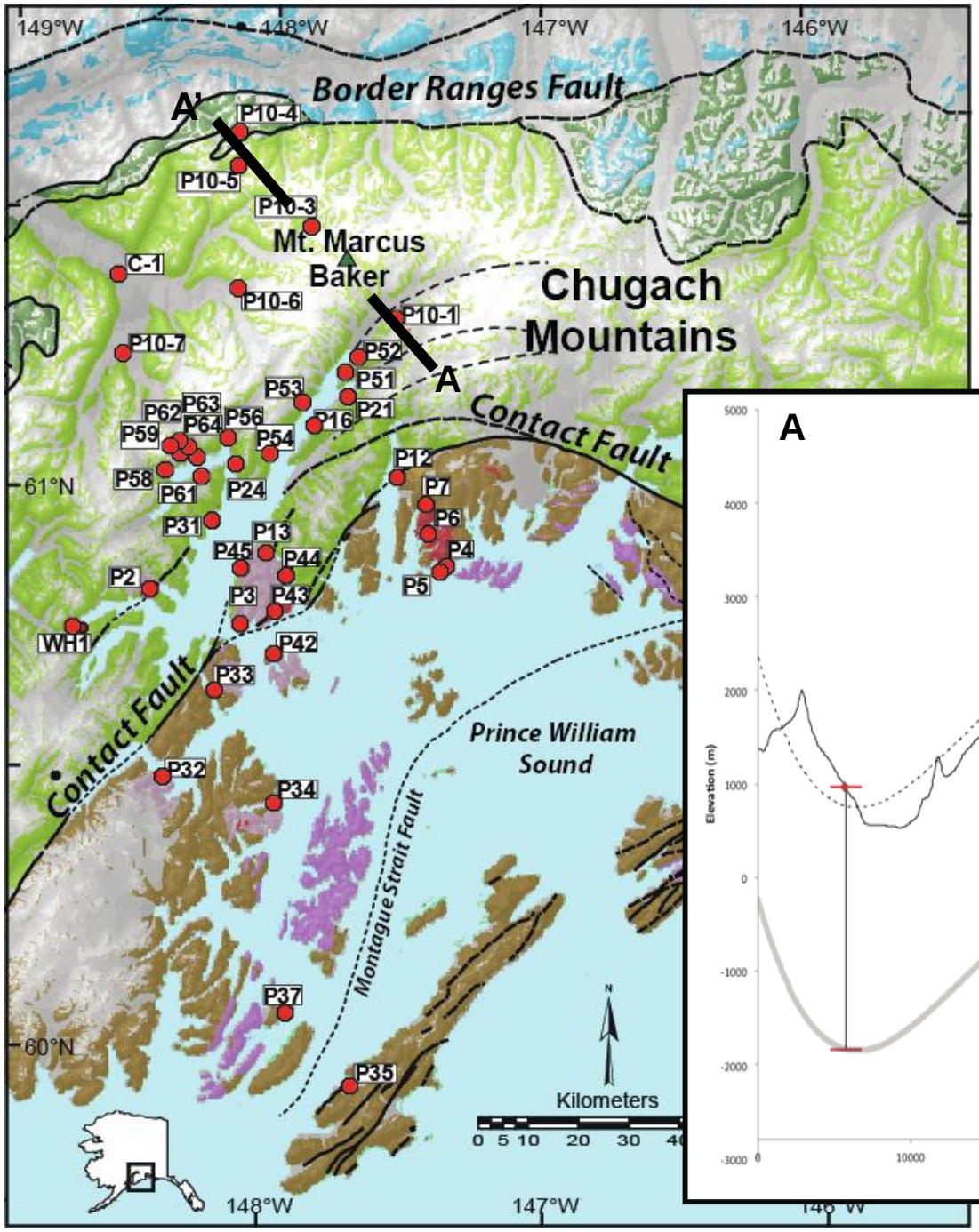

149°W
148°W
147°W
146°W
Border Ranges Fault
10.8 ± 1.6 Ma
8.4 ± 2.0 Ma
7.6 ± 1.4 Ma
Mt. Marcus Baker
Chugach Mountains
7.3 ± 1.0 Ma
6.9 ± 0.9 Ma
4.7 ± 0.9 Ma
C-1
P52
P51
P53
P21
P16
P62
P64
P56
P59
P54
P58
P61
P24
P12
P7
P6
P4
P5
P31
P13
P45
P44
P2
P3
P43
WH1
P42
P33
P32
P34
61°N
61°N
Contact Fault
Contact Fault
Prince William Sound
Strait Fault



Presenter's notes: Ages sea level


E
Southeast
E'
Northwest
Prince William Sound
Chugach Mountains
Talkeetna Mountains
AHe
AFT
ZHe
ZFT
Contact Fault
Border Ranges Fault
Mt. Marcus Baker
Thermochronometer Age (Ma)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
Distance southeast to northwest E-E' (km)

$$\text{Rate of Exhumation} = \frac{Z_{Tc}}{\text{Mean Age}}$$

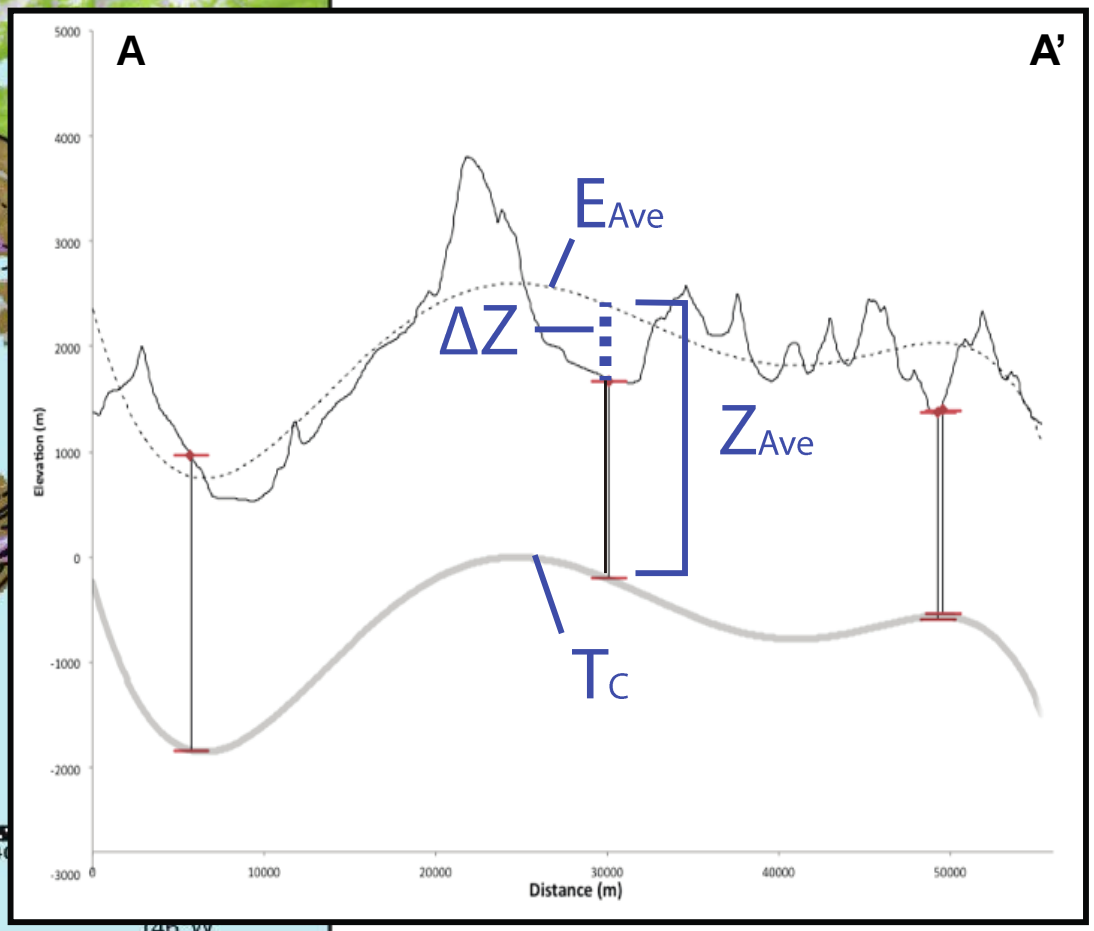


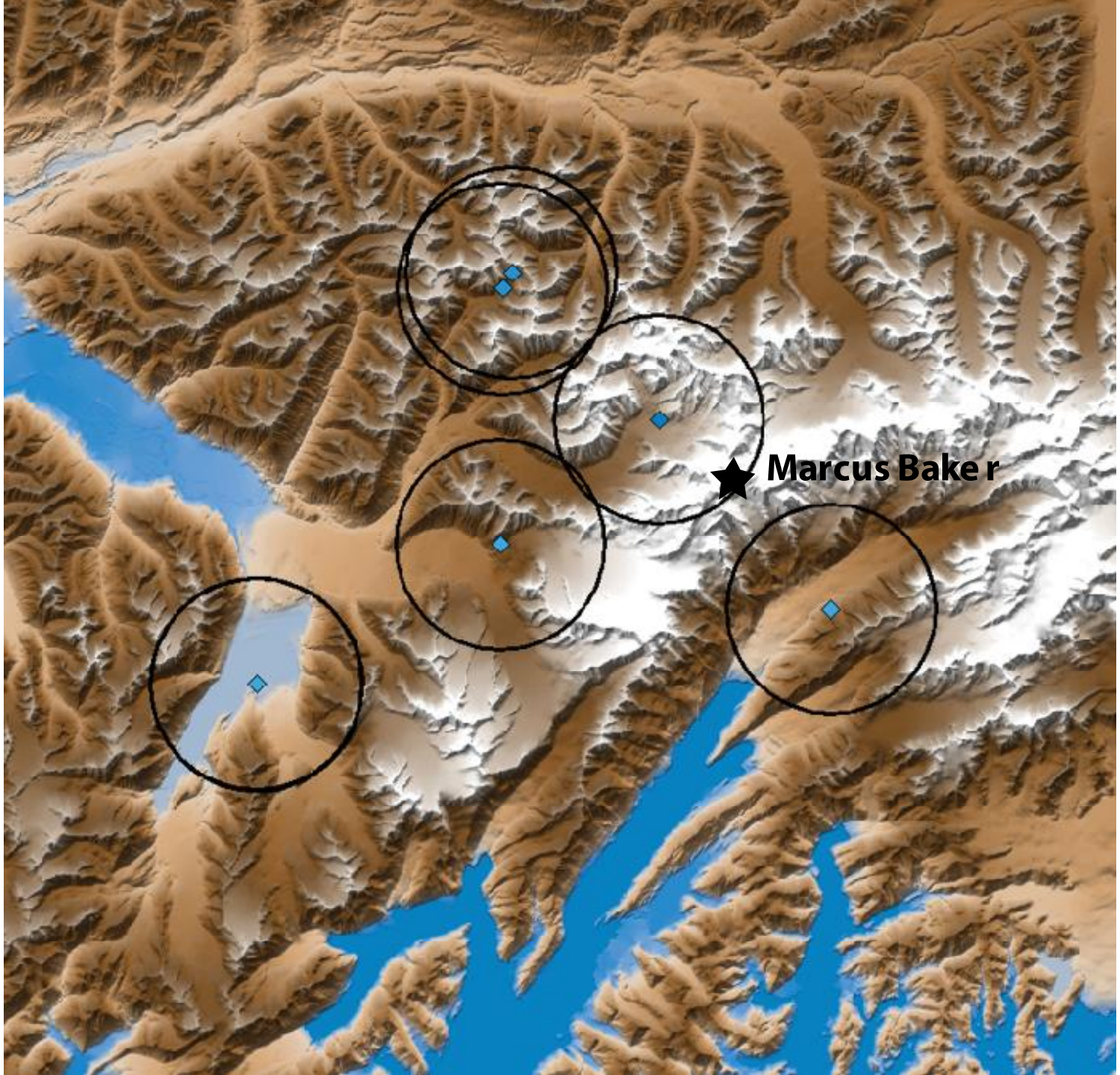
T_C = Closure T.

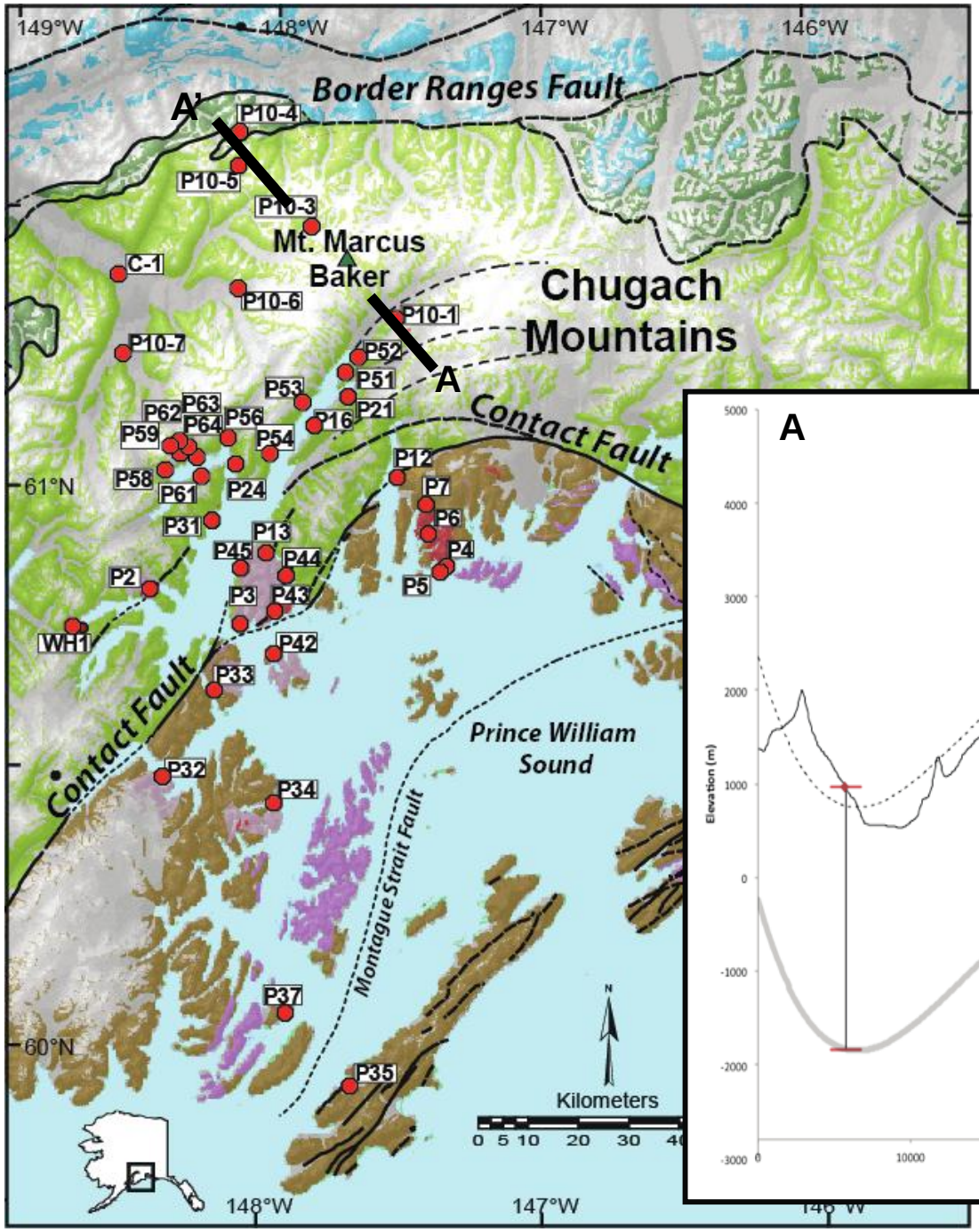
Z_{Ave} = Ave. Depth to T_C

E_{Ave} = Ave. Elevation

ΔZ = Di erence Elev.




Marcus Bake r



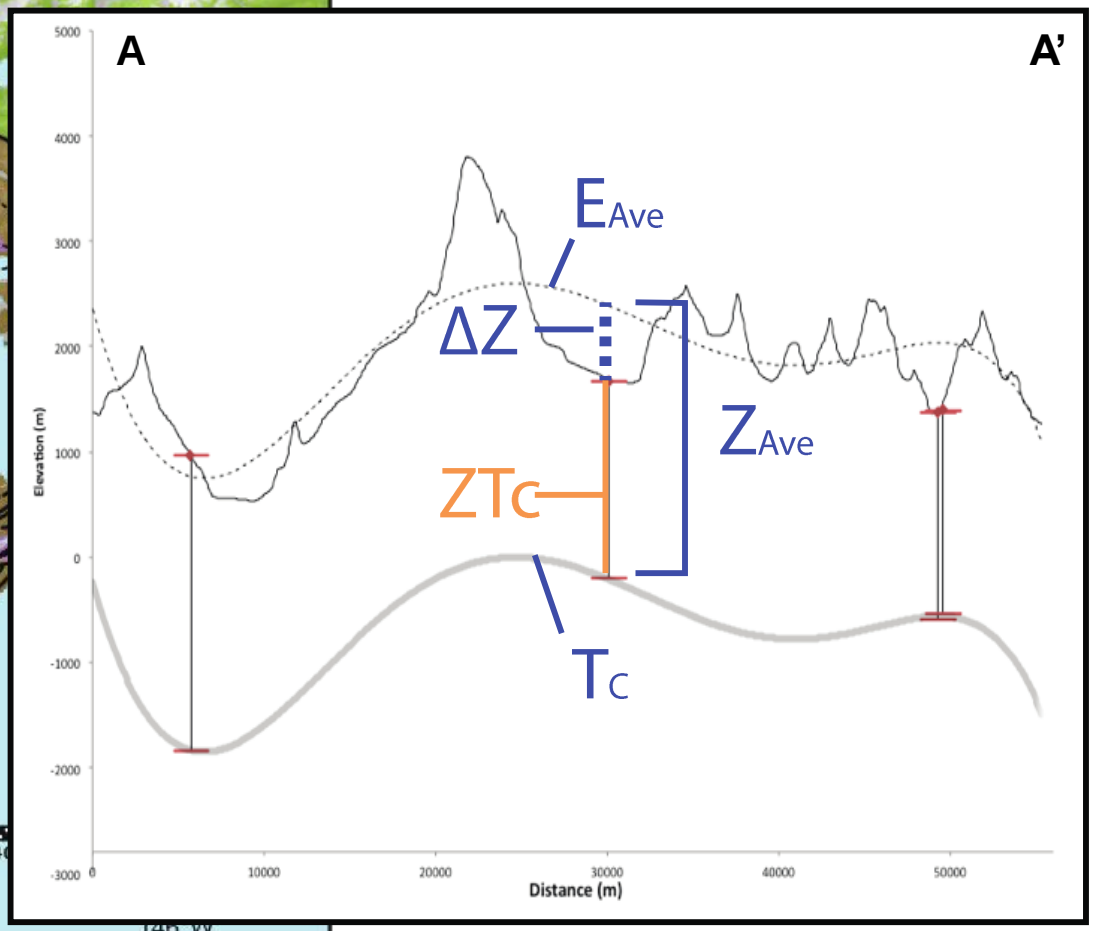
T_C = Closure T.

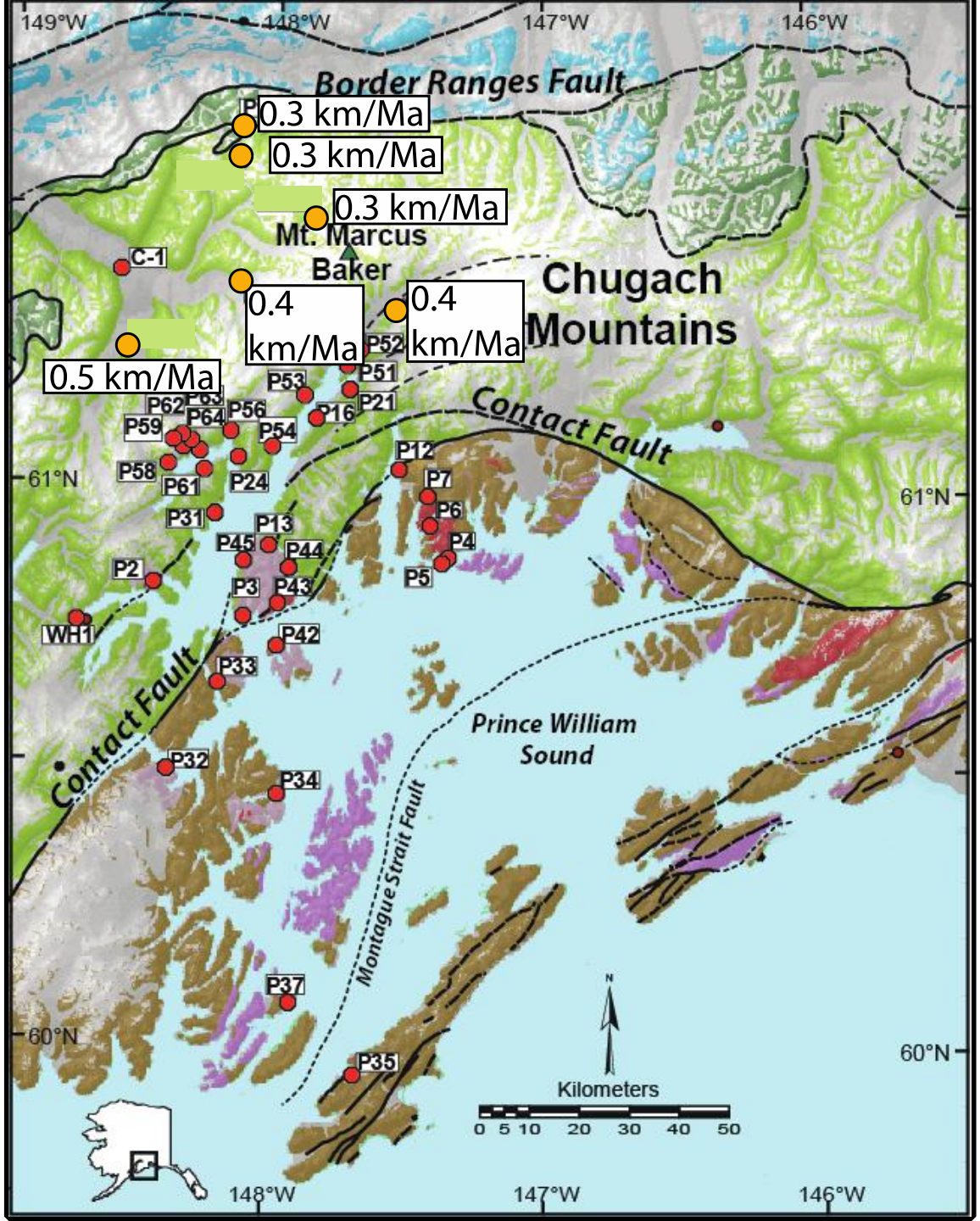
Z_{Ave} = Ave. Depth to T_C

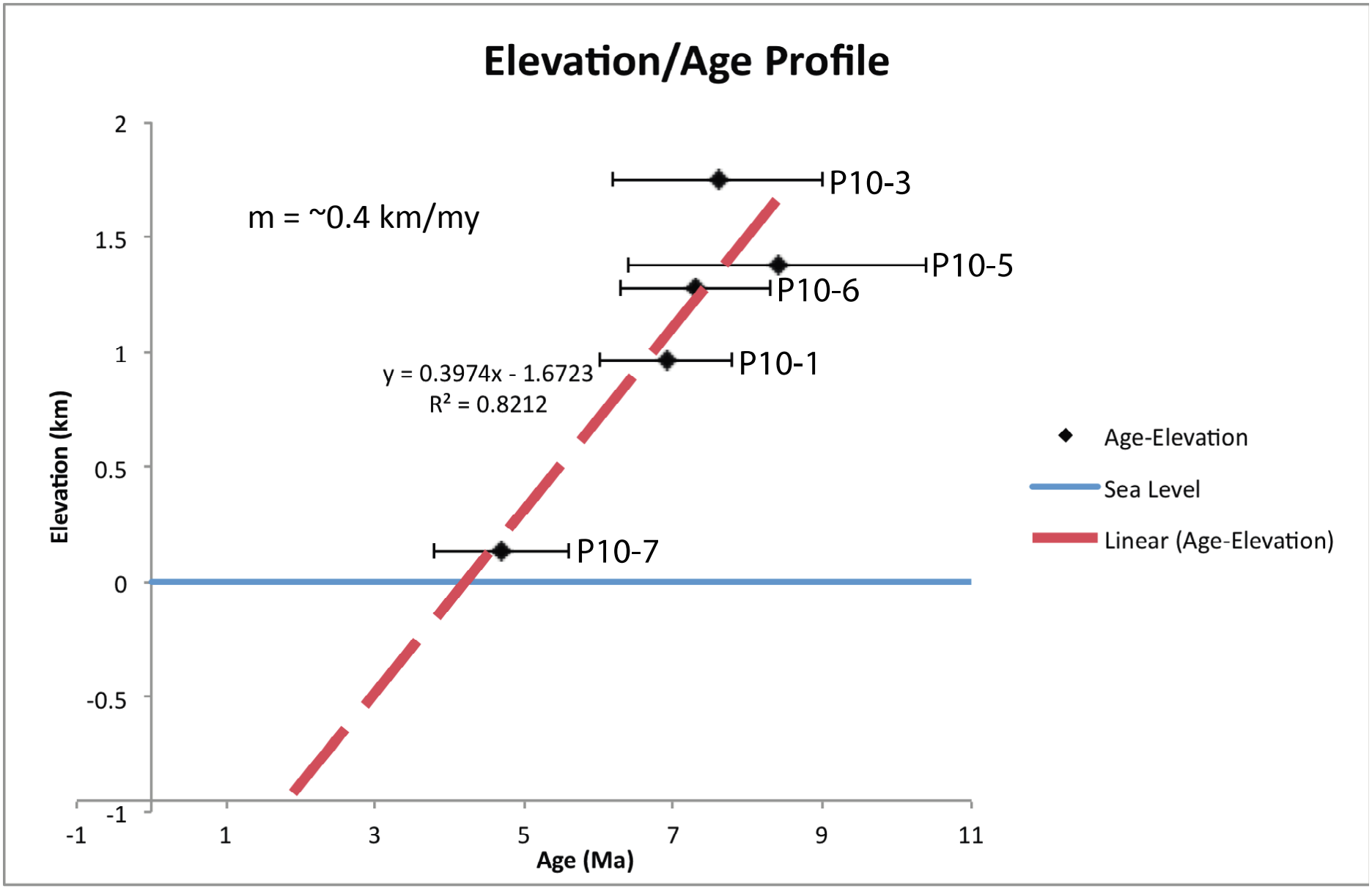
E_{Ave} = Ave. Elevation

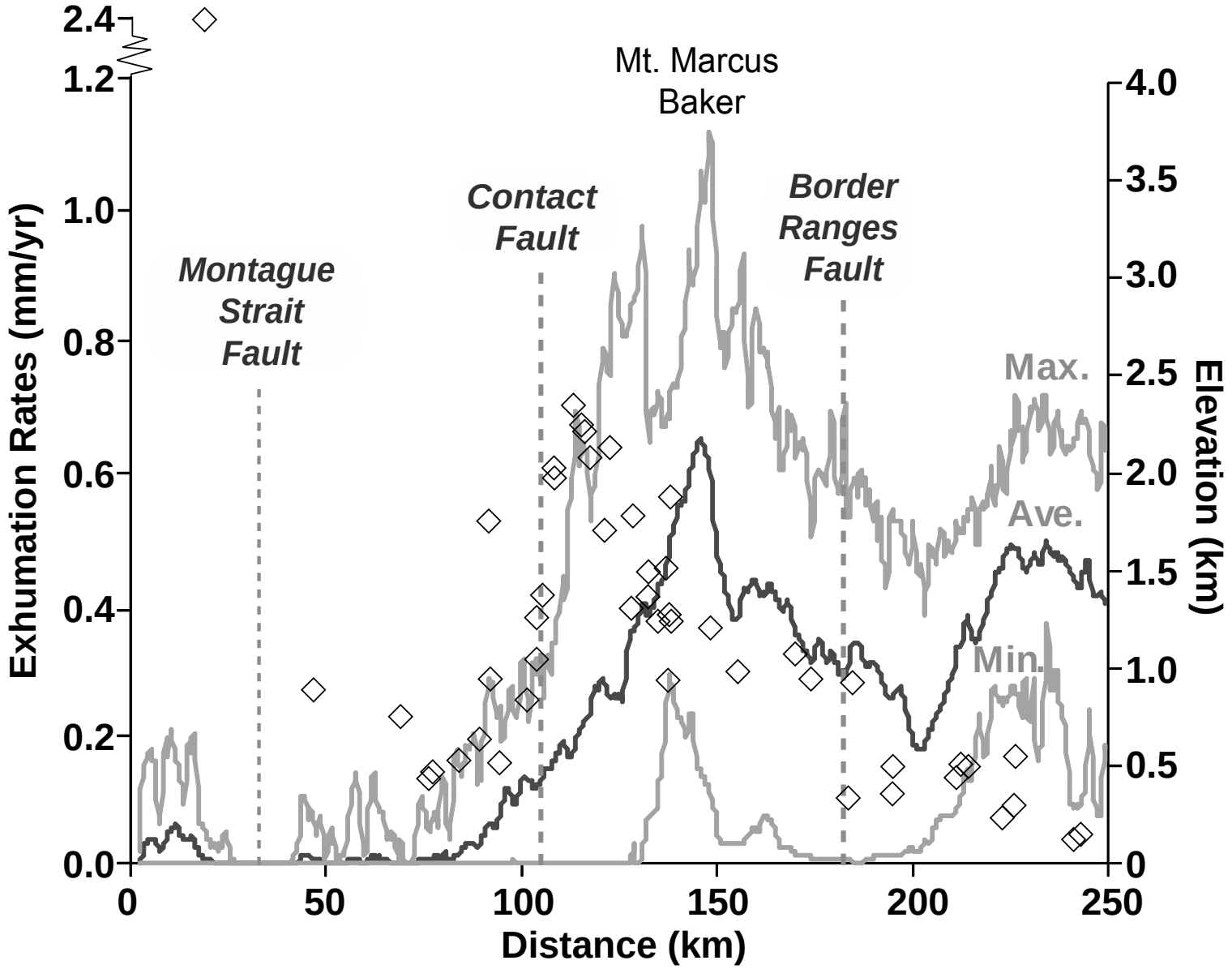
ΔZ = Di erence Elev.

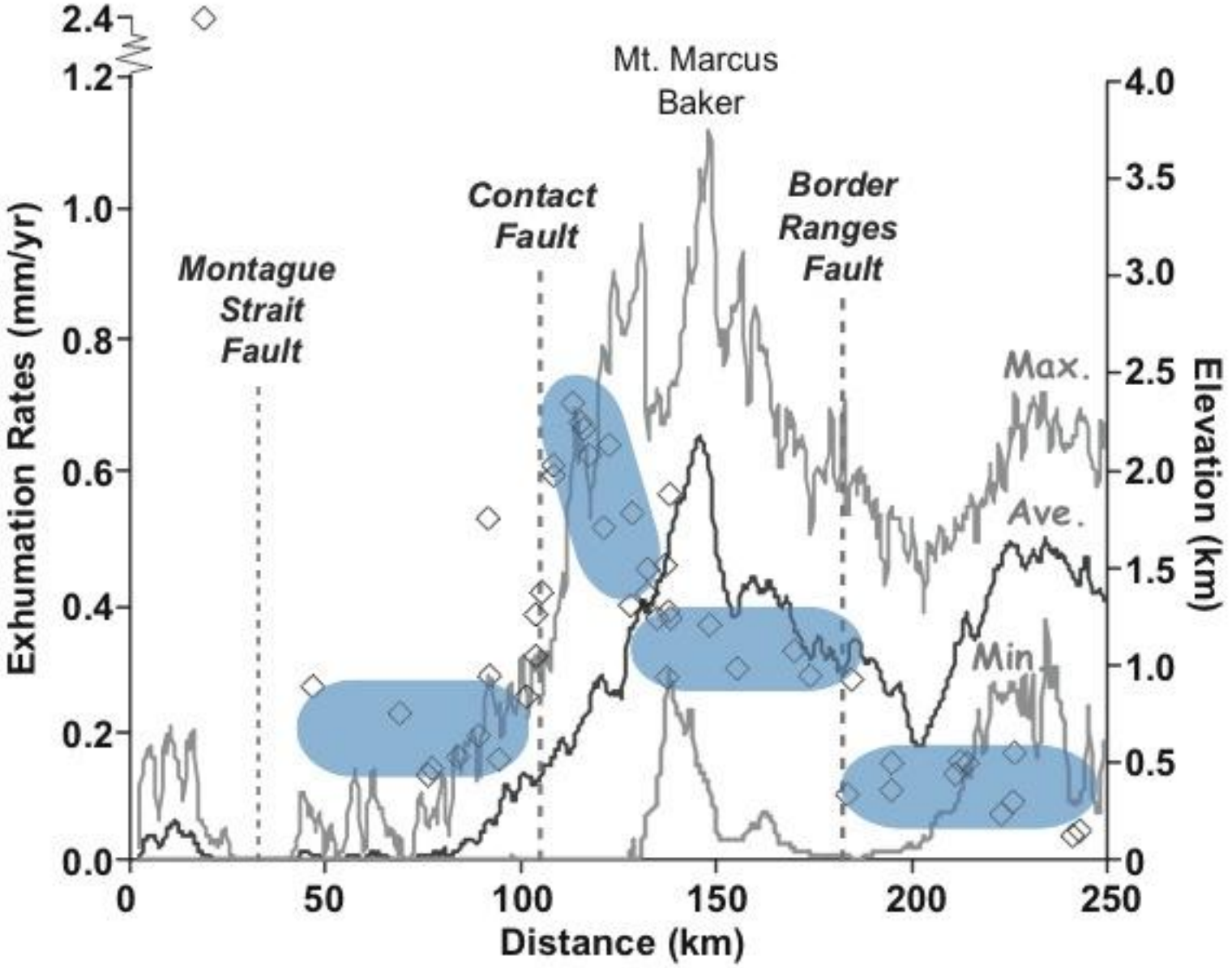
Z_{Tc} = True depth from T_C



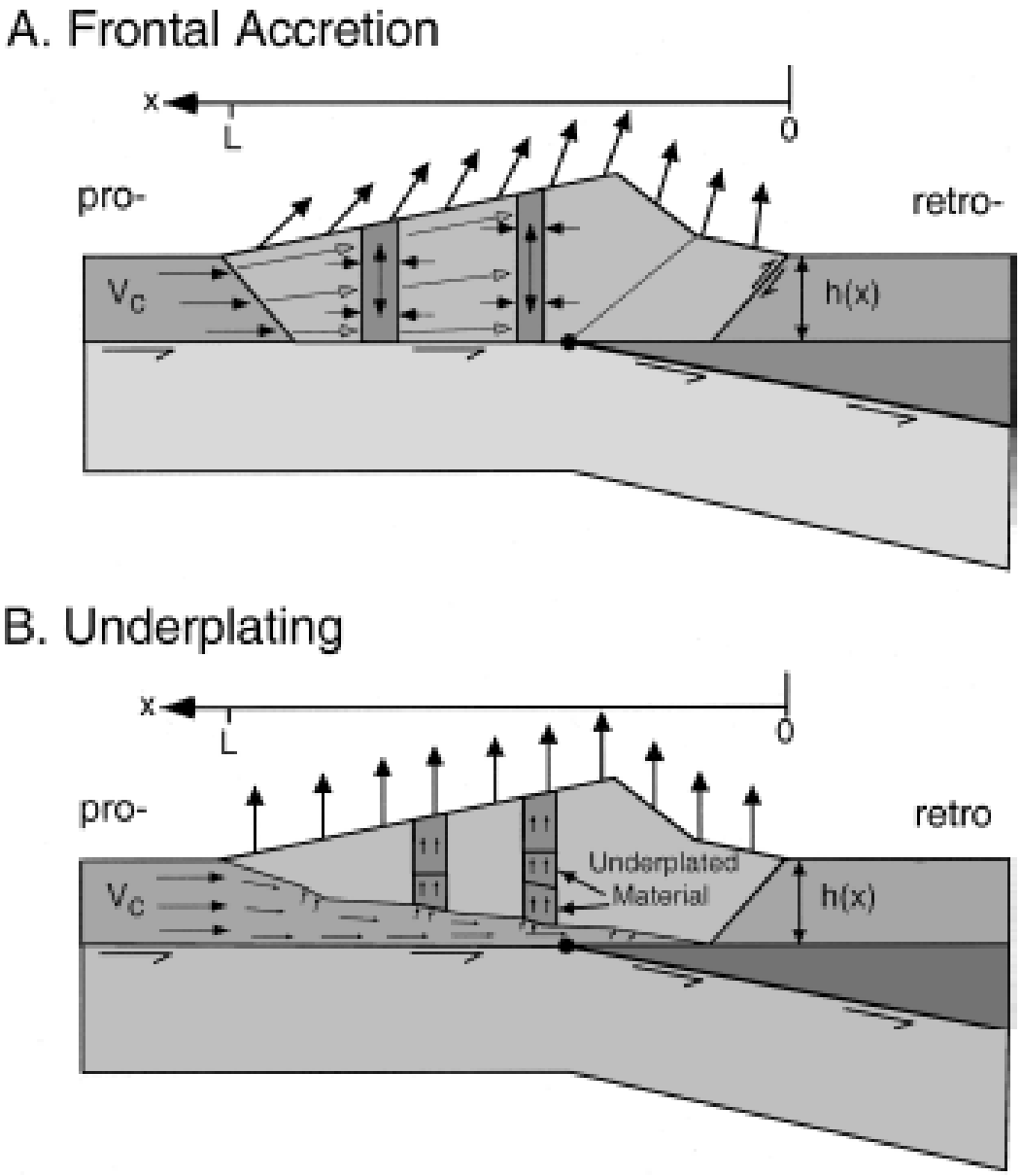

149°W
148°W
147°W
146°W
Border Ranges Fault
0.3 km/Ma
0.3 km/Ma
0.3 km/Ma
Mt. Marcus Baker
C-1
0.4 km/Ma
0.4 km/Ma
Chugach Mountains
0.5 km/Ma
P52
P51
P53
P21
P16
P62
P56
P64
P59
P54
Contact Fault
P12
P58
P61
P24
P7
61°N
P6
P31
P13
P4
P45
P44
P2
P5
P3
P43
WH1
P42
P33
Contact Fault
Prince William Sound
P32
P34
Montague Strait Fault
P37
60°N
P35
N
Kilometers
0 5 10 20 30 40 50
148°W
147°W
146°W


Elevation/Age Profile
m = ~0.4 km/my
y = 0.3974x - 1.6723
R² = 0.8212
P10-3
P10-5
P10-6
P10-1
P10-7
Elevation (km)
Age (Ma)
2
1.5
1
0.5
0
-0.5
-1
-1
1
3
5
7
9
11
Age-Elevation
Sea Level
Linear (Age-Elevation)

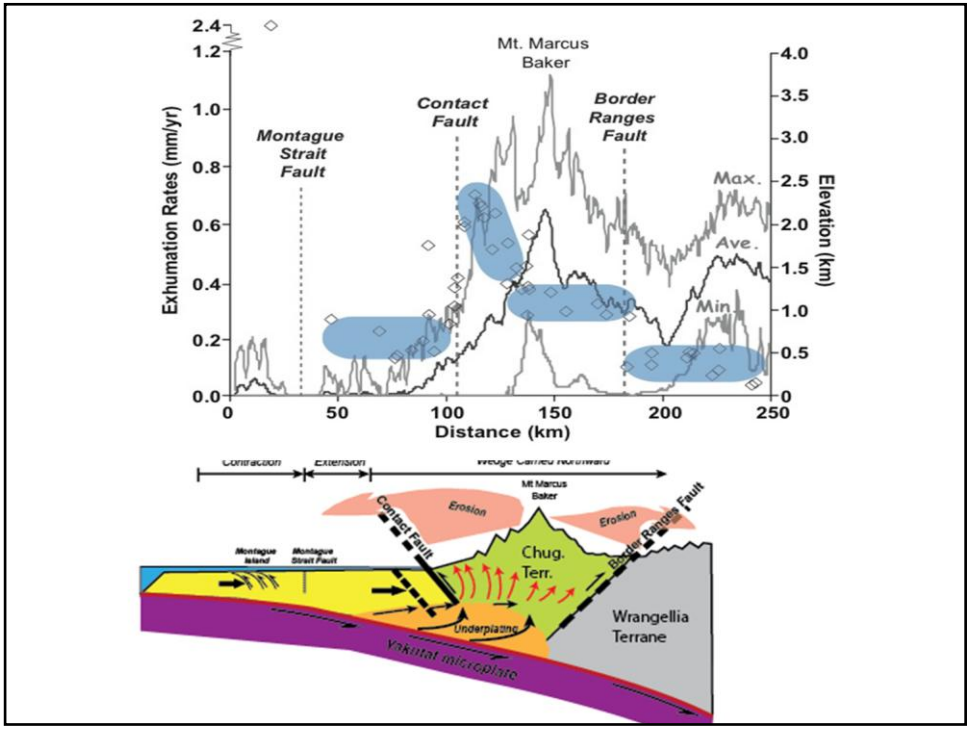

Exhumation Rates (mm/yr)
Elevation (km)
Distance (km)
Mt. Marcus Baker
Contact Fault
Border Ranges Fault
Montague Strait Fault
Max.
Ave.
Min.
2.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
0
50
100
150
200
250


Mt. Marcus Baker
Montague Strait Fault
Contact Fault
Border Ranges Fault
Max.
Ave.
Min.
Exhumation Rates (mm/yr)
Elevation (km)
Distance (km)
2.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
0
50
100
150
200
250

Interpretation

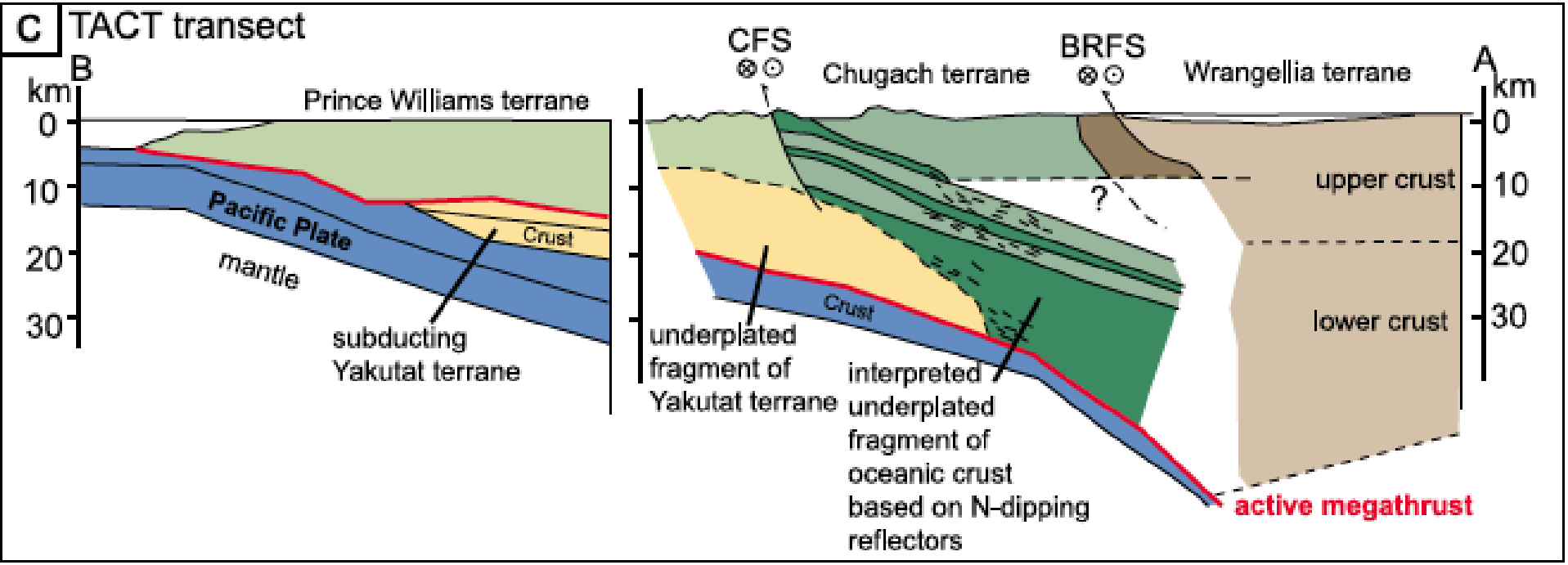


Willett et al. (2001)



Presenter's notes: Underplating
Modulated by climate/glaciers
Chugach Mnt wedge driven to north – generates extension to south along Montague strait

south north



From Fuis et al. (2008)

Summary

- Ages in the CM and NPWS decrease into syntaxial core (bulls eye in south).
- New ages fill data gap between the NPWS and BRF across CM.
- These new ages range from 10.8 to 4.7 Ma, slightly older than southern SL samples (elevation?).
- Exhumation rates relatively uniform (~0.4 mm/yr) across CM except adjacent to CF, where peak rates reach 0.8 mm/yr.
- Ages and rates consistent with underplating above flat slab subduction inboard of collision zone.
- Shortening and highest exhumation focused along southern wedge at the CF.

$$Rate\ of\ Exhumation = \frac{Z_{Tc}}{Mean\ Age}$$

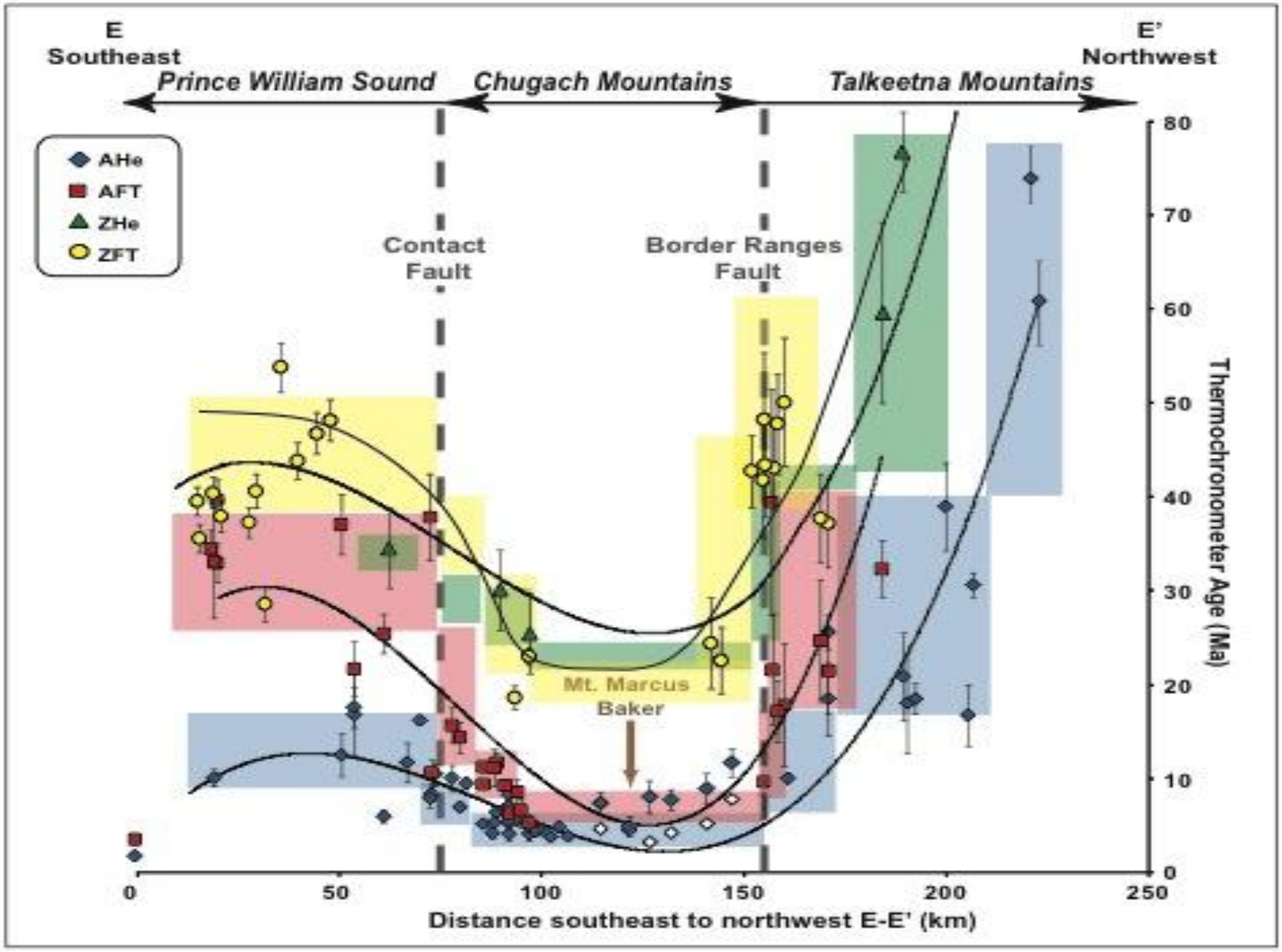
$$Z_{Tc} = Z_{Average} + \Delta Z$$

$$Z_{Average} = \frac{T_C - T_{Surface}}{\frac{dT}{dZ}}$$

$$T_{Surface} = 0°C$$ (Péwé, 1975)

$$\frac{dT}{dZ} = 22\,\frac{°C}{km}$$ (Magoon, 1986)

T_C Calculated using 'CLOSURE' from Brandon et al. (1998).


E
Southeast
E'
Northwest
Prince William Sound
Chugach Mountains
Talkeetna Mountains
AHe
AFT
ZHe
ZFT
Contact Fault
Border Ranges Fault
Mt. Marcus Baker
Thermochronometer Age (Ma)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
Distance southeast to northwest E-E' (km)