Science Highlights from ALEUT (Alaska Langseth Experiment to Understand the megaThrust) MGL1110

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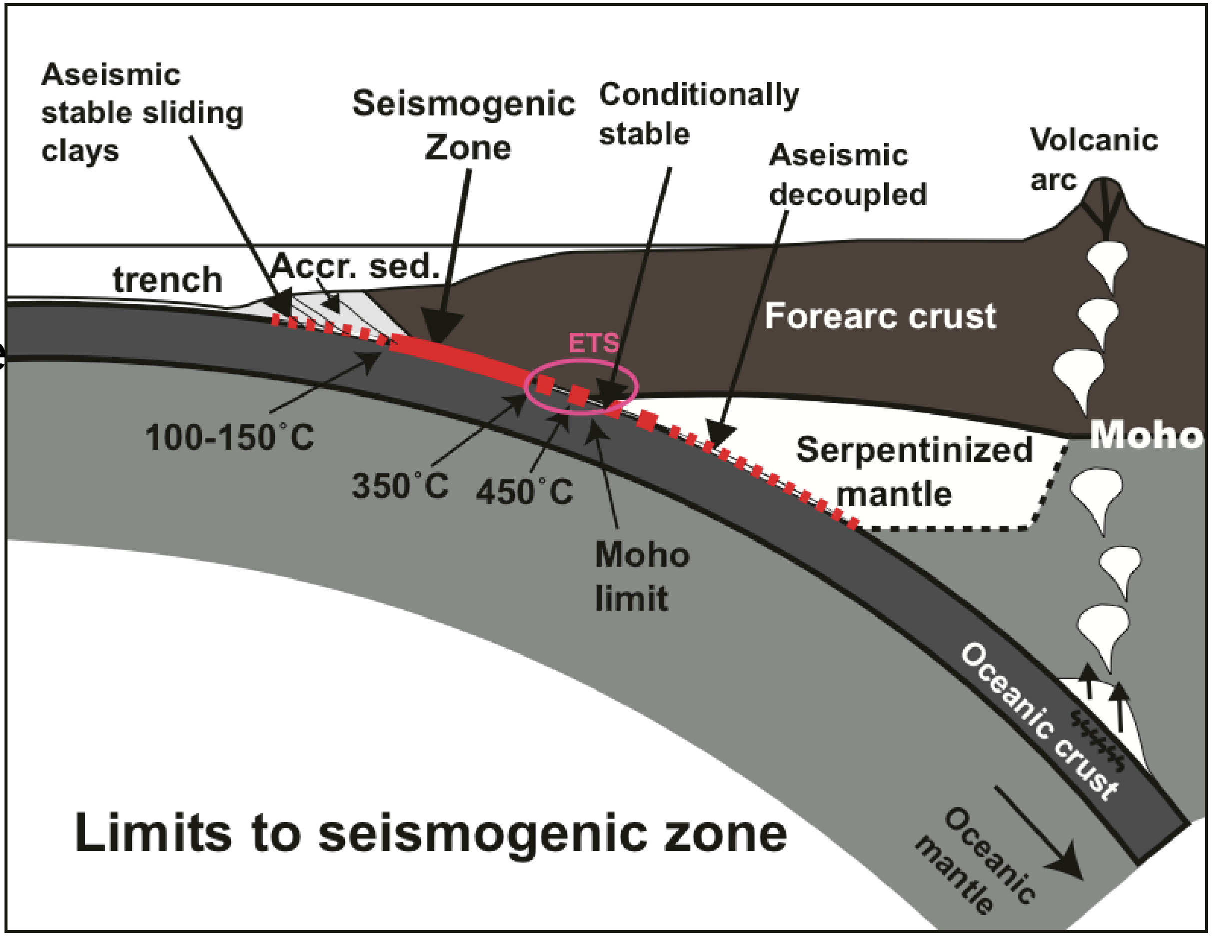
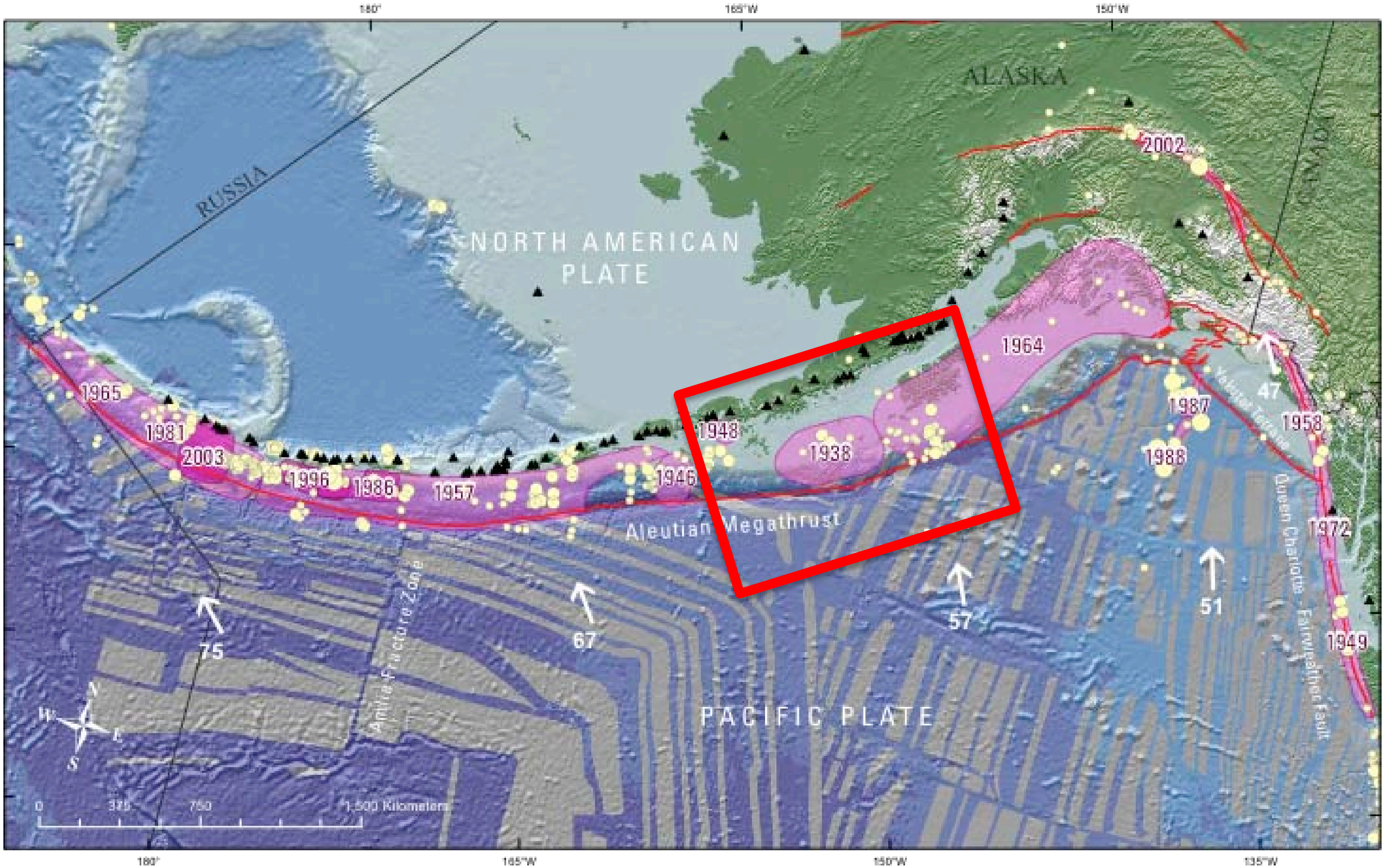
Science objectives of ALEUT

- What controls the updip and downdip limits of the locked zone on the megathrust?
- What causes along-strike variability in coupling in subduction zones?
- Are there splay faults or other structures that accommodate deformation during or between great earthquakes?



Picture modified from Oleskevich et al., 1999

Variations in earthquake rupture history along the Alaska-Aleutian subduction zone

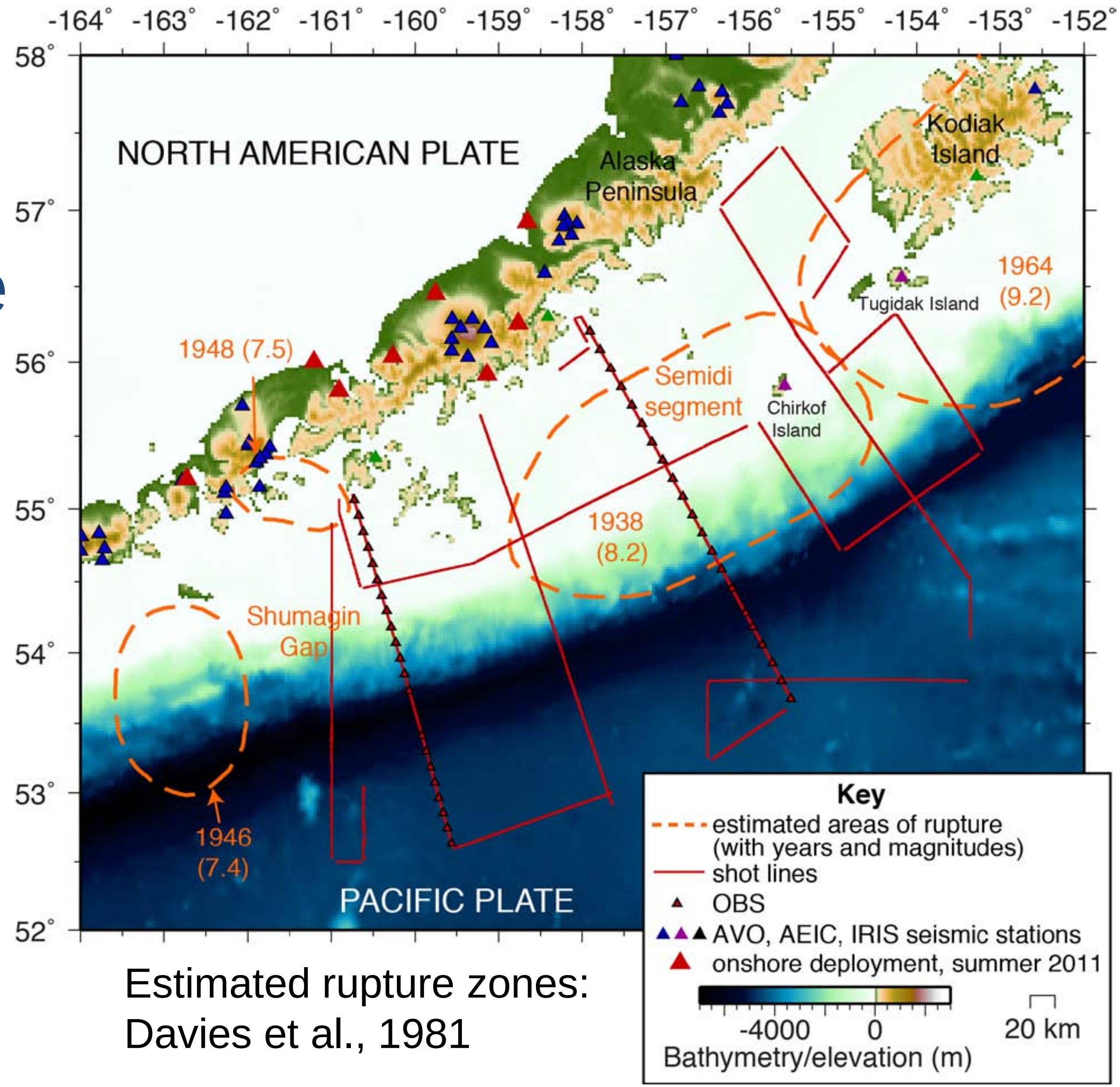


Courtesy of Peter Haeussler. Rupture patches : Davies et al., 1981

Alaska **L**angseth **E**xperiment to **U**nderstand the mega**T**hrust

Offshore program:

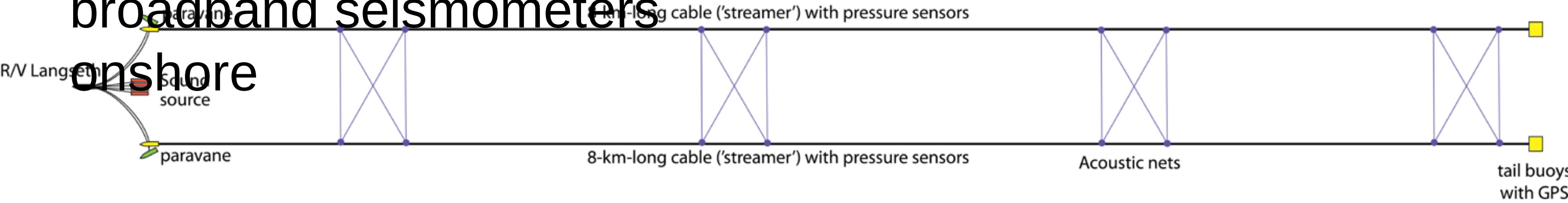
- 38-day cruise on the R/V *Langseth* (July-August 2011)
- 3700 km of MCS profiles
- 2 wide-angle seismic profiles



Estimated rupture zones: Davies et al., 1981

Data acquisition

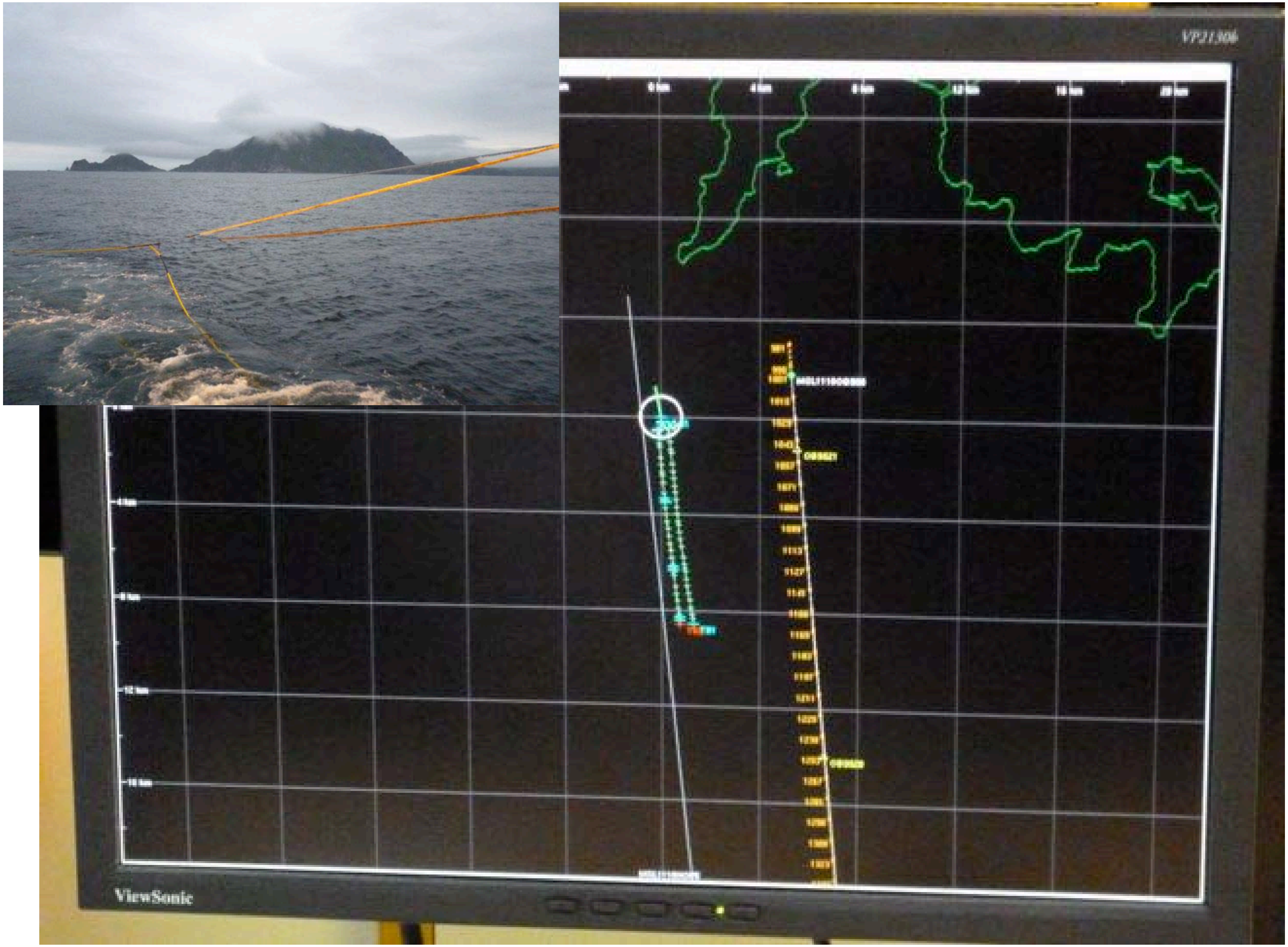
- Source: full 6600 cu in air gun array towed at 12 m
- MCS data acquired on two 8-km-long seismic streamers towed at 9 & 12 m
- Wide-angle reflection/refraction data acquired on OBS offshore and small array of shortperiod and broadband seismometers onshore



Team Diebold: CU undergraduates

- Brought 5 undergraduates to sea for the MCS portion of the cruise
- Part of a course taught by Maya Tolstoy and Donna Shillington: Seagoing Experience in Earth Science

Shallow water and close to shore

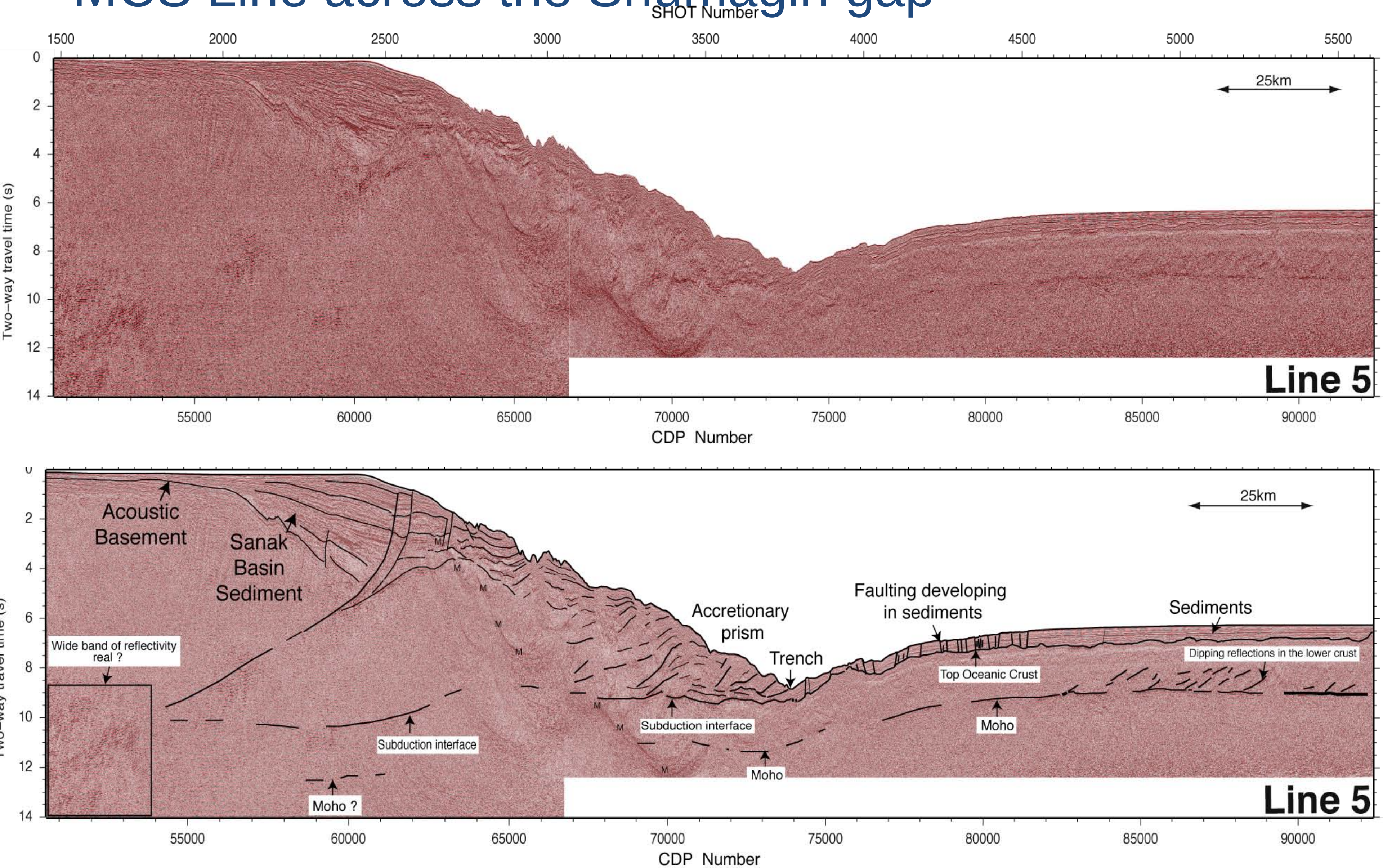


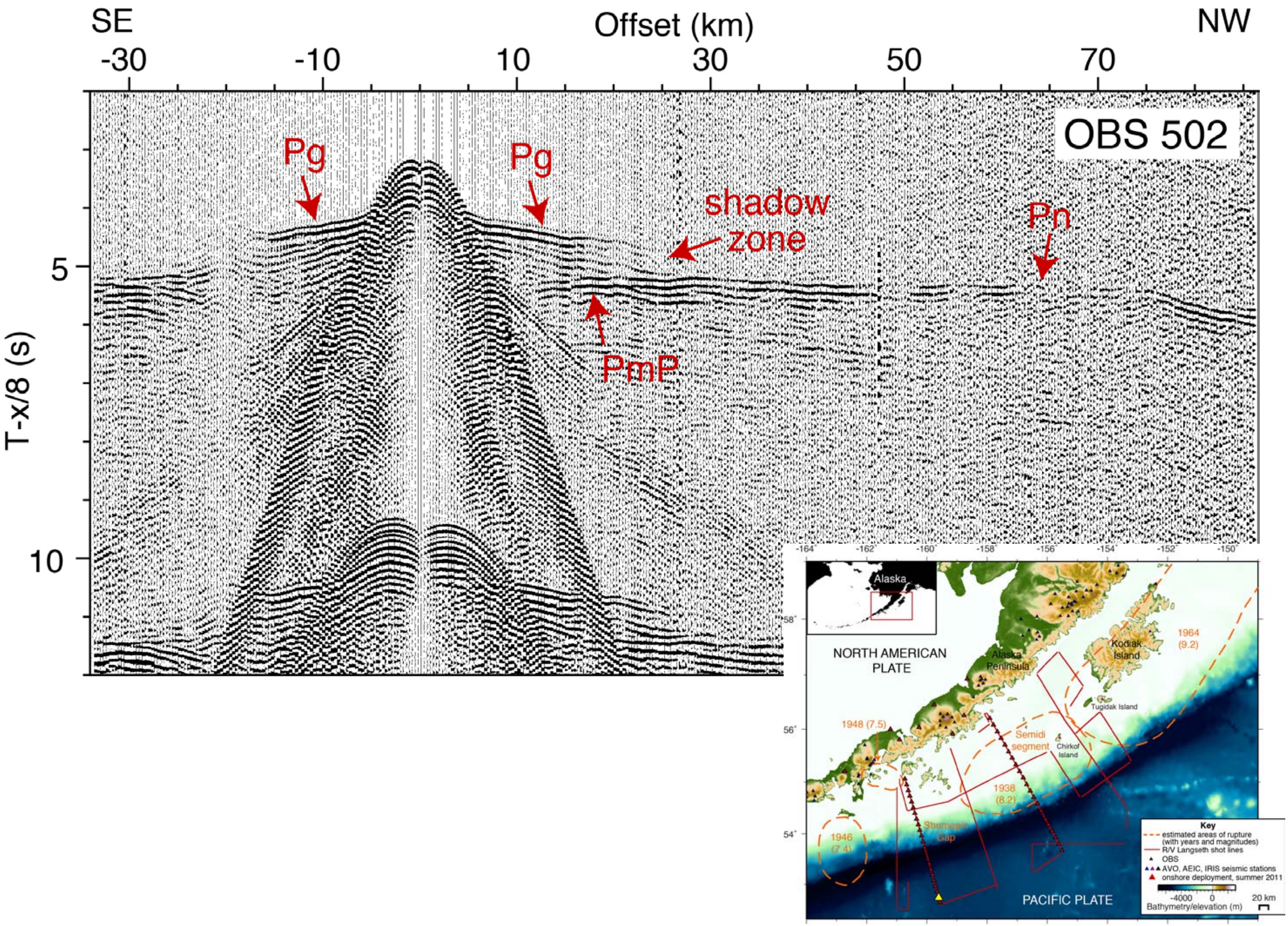
Whales

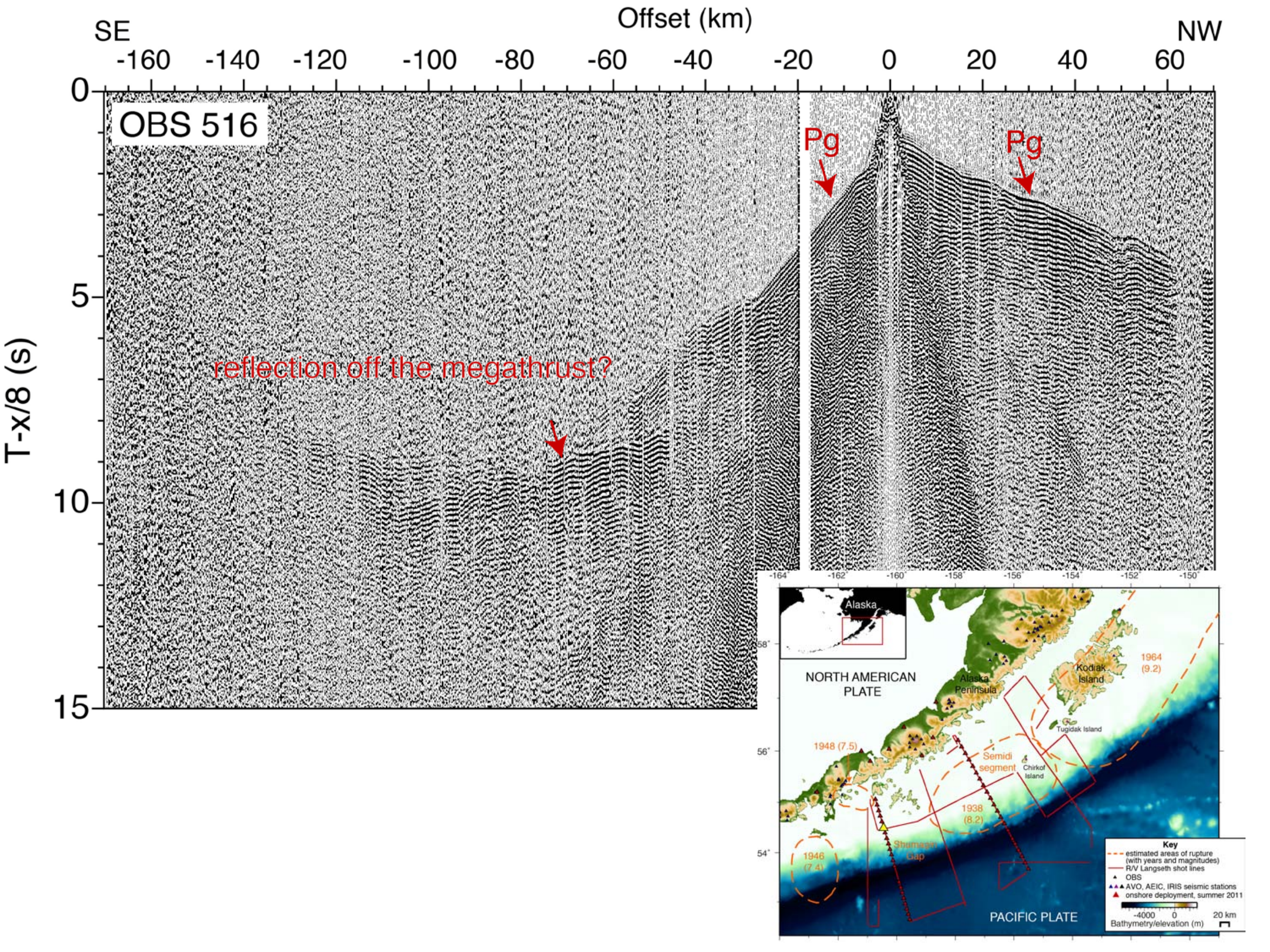
What have we seen so far?

- The hint of downdip variations in reflectivity of the megathrust
- Deeply routed structures in the overriding plate – ancient and/or active?
- Pronounced along-strike variations in bending-related faulting, sediment thickness (and hydration?)
- Intriguing features in old fast-spreading oceanic crust
- Stuck melt beneath an abandoned triple junction?

MCS Line across the Shumagin gap




SE
Offset (km)
NW
-30
-10
10
30
50
70
OBS 502
Pg
Pg
shadow zone
Pn
PmP
5
10
T-x/8 (s)
-164°
-162°
-160°
-158°
-156°
-154°
-152°
-150°
58°
56°
54°
Alaska
NORTH AMERICAN PLATE
Alaska Peninsula
Kodiak Island
1964 (9.2)
Tugidak Island
1948 (7.5)
Semidi segment
Chirikof Island
1938 (8.2)
1946 (7.4)
Shumagin Gap
PACIFIC PLATE
Key
estimated areas of rupture (with years and magnitudes)
R/V Langseth shot lines
OBS
AVO, AEIC, IRIS seismic stations
onshore deployment, summer 2011
-4000
0
Bathymetry/elevation (m)
20 km


Offset (km)
SE
NW
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
0
5
10
15
T-x/8 (s)
OBS 516
Pg
Pg
reflection off the megathrust?
Alaska
NORTH AMERICAN PLATE
Alaska Peninsula
Kodiak Island
1964 (9.2)
Tugidak Island
1948 (7.5)
Semidi segment
Chirikof Island
1938 (8.2)
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PACIFIC PLATE
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estimated areas of rupture (with years and magnitudes)
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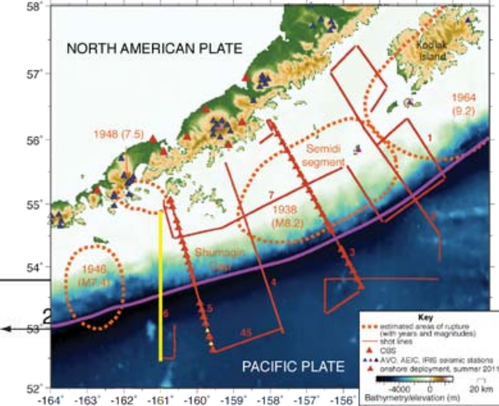
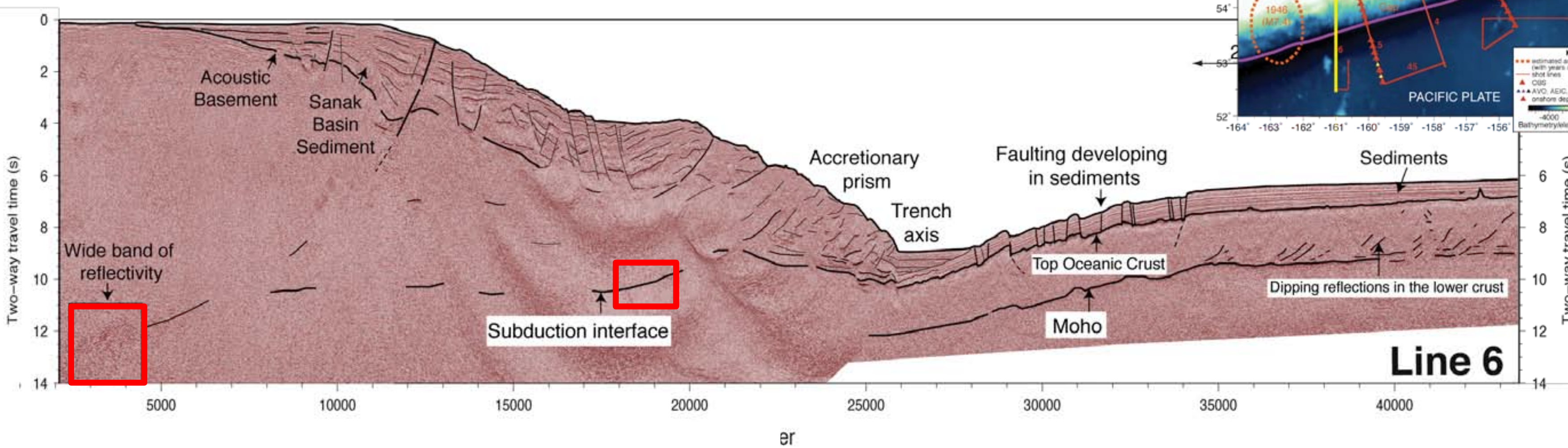
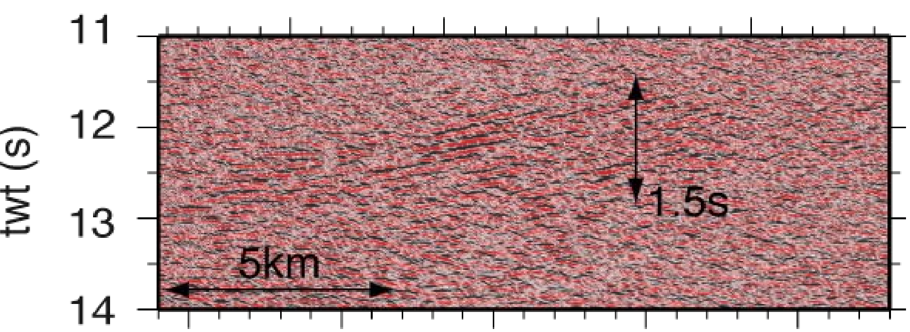
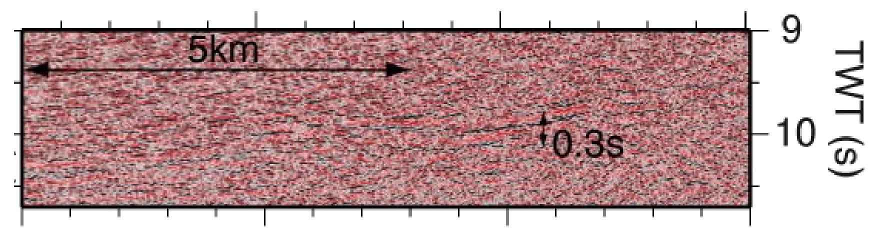
OBS
AVO, AEIC, IRIS seismic stations
onshore deployment, summer 2011
-4000
0
Bathymetry/elevation (m)
20 km

1. Downdip changes in the reflectivity of the megathrust?





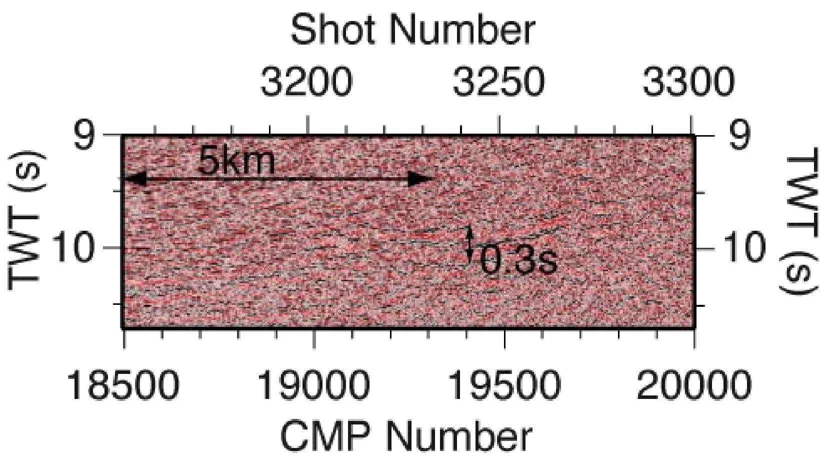


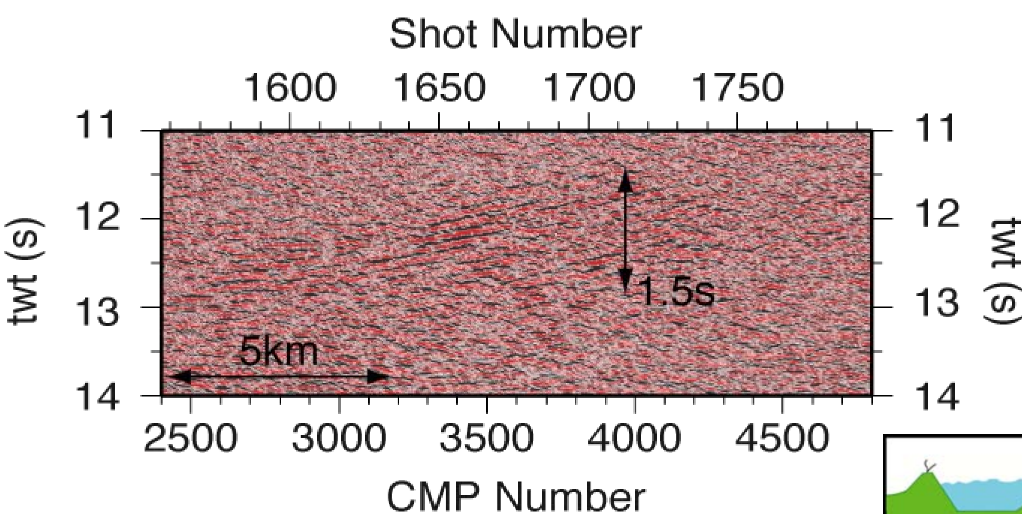


Broad reflection band (1.5s twt)

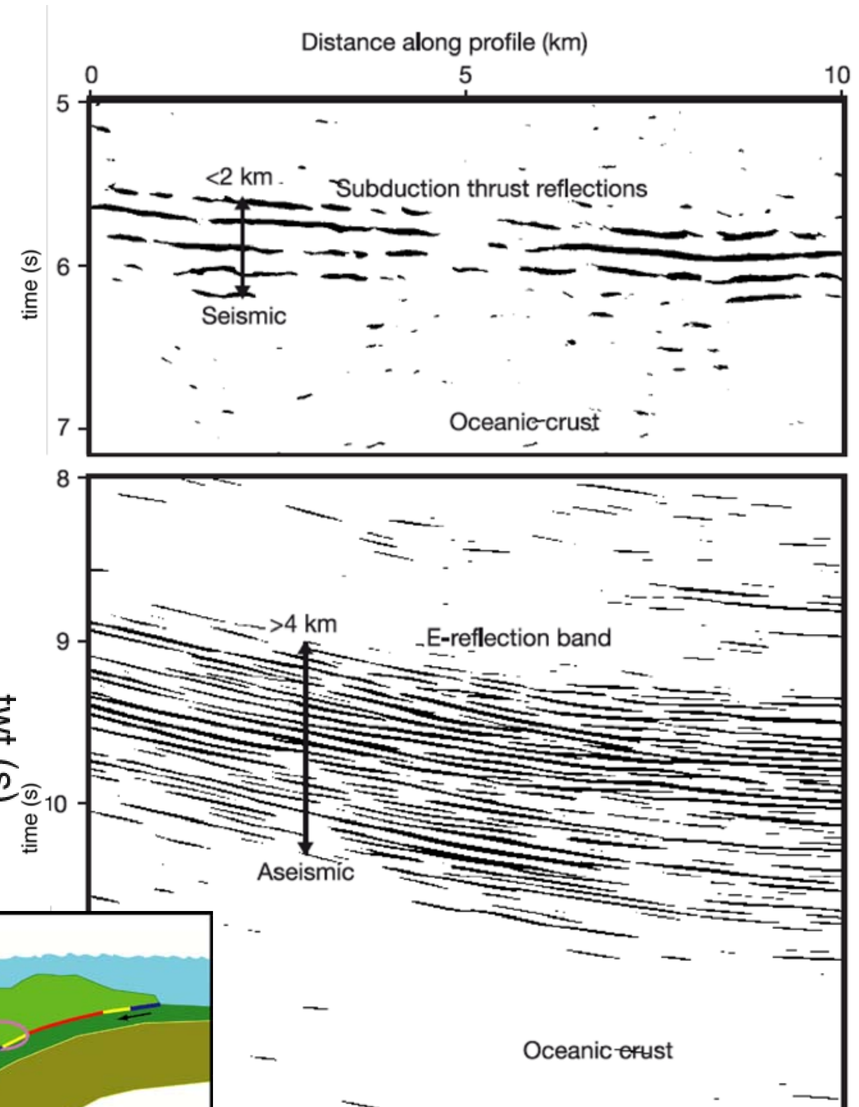
Thin sharp reflection (0.3s twt)

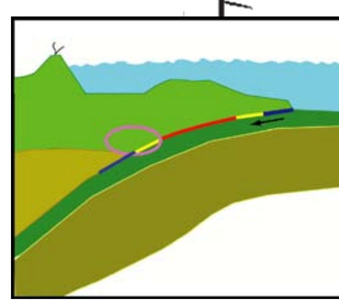
Alaska subduction Zone





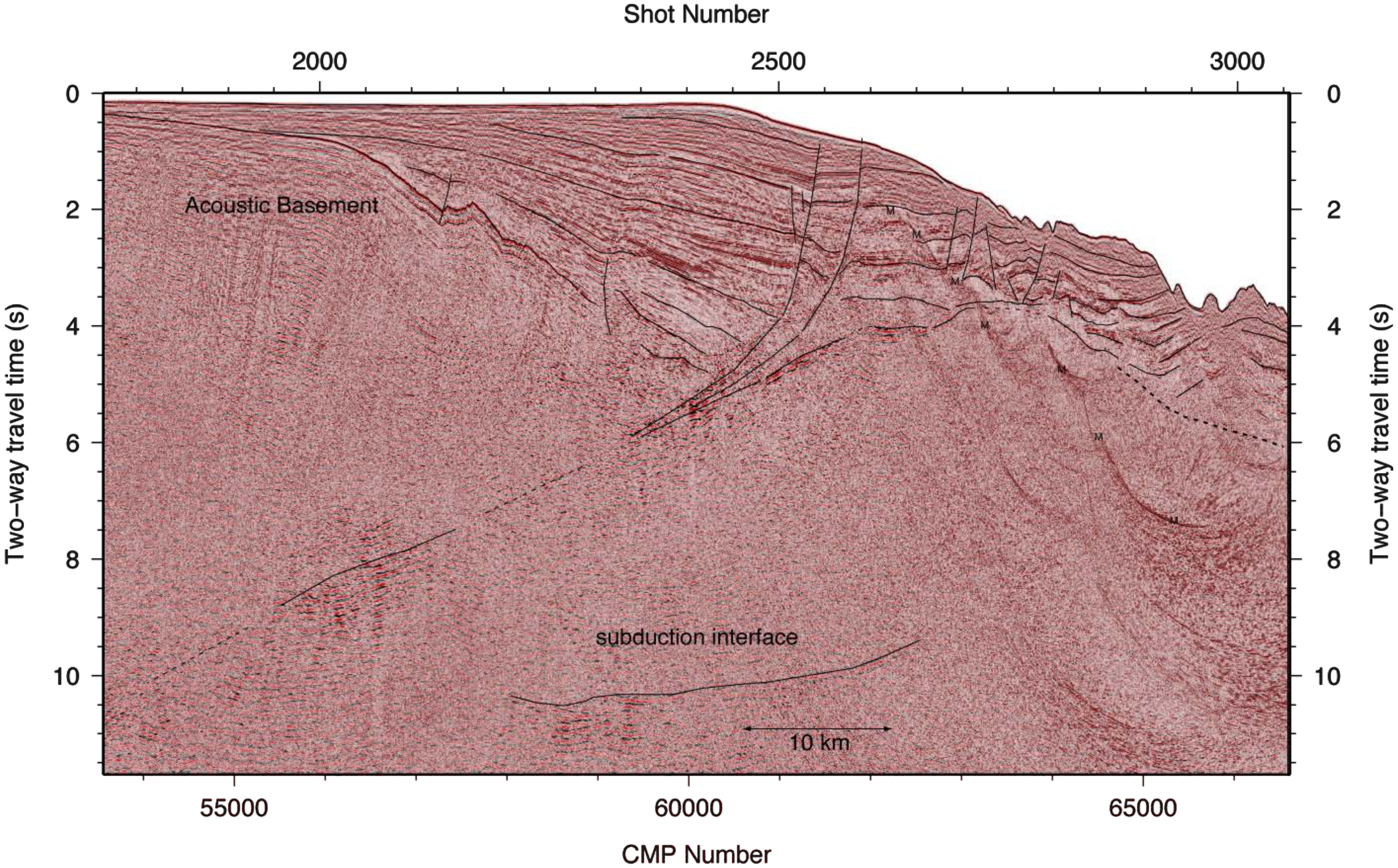
Cascadia subduction Zone



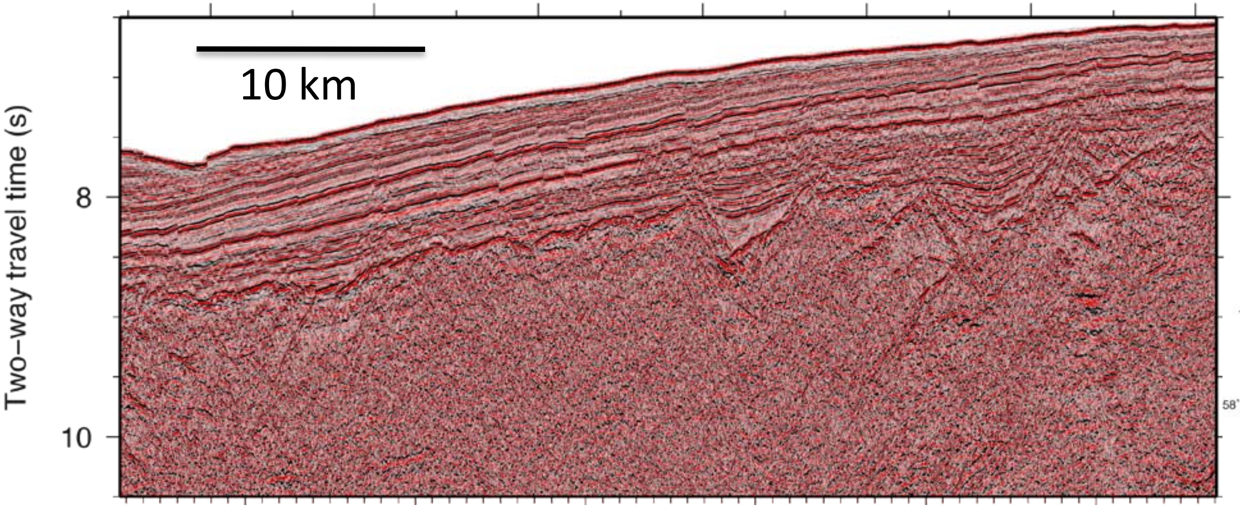


modified from Nedimović et al., Science, 2003

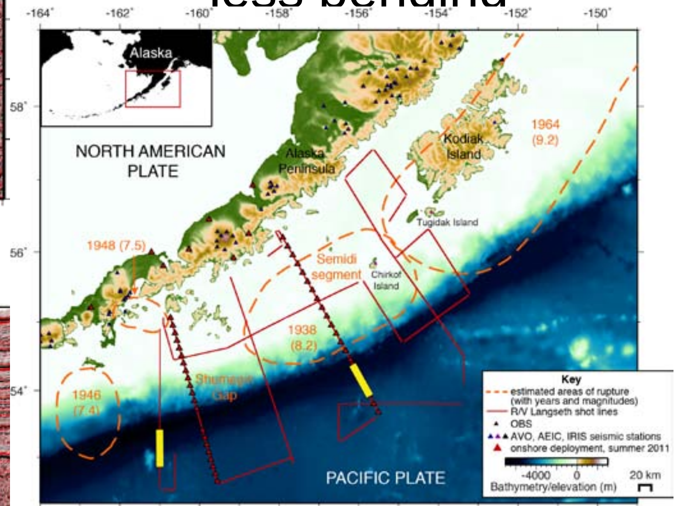
2. Deeply rooted structures in the overriding plate: ancient and/or active?

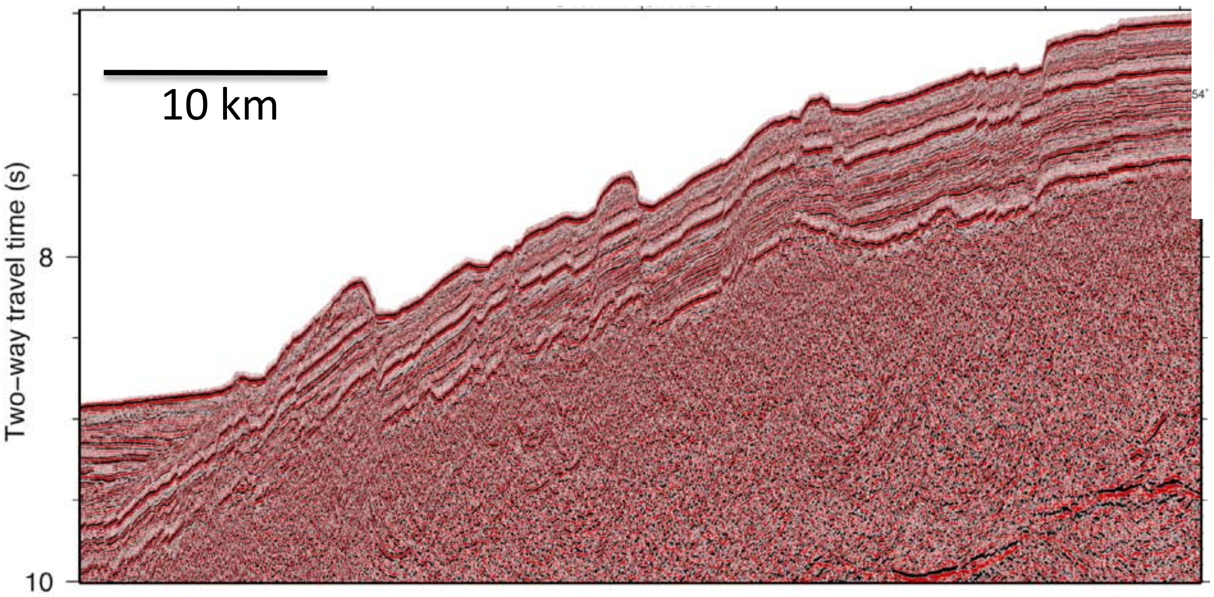


3. Along-strike variations in style and amount of bending faulting and sediment thickness



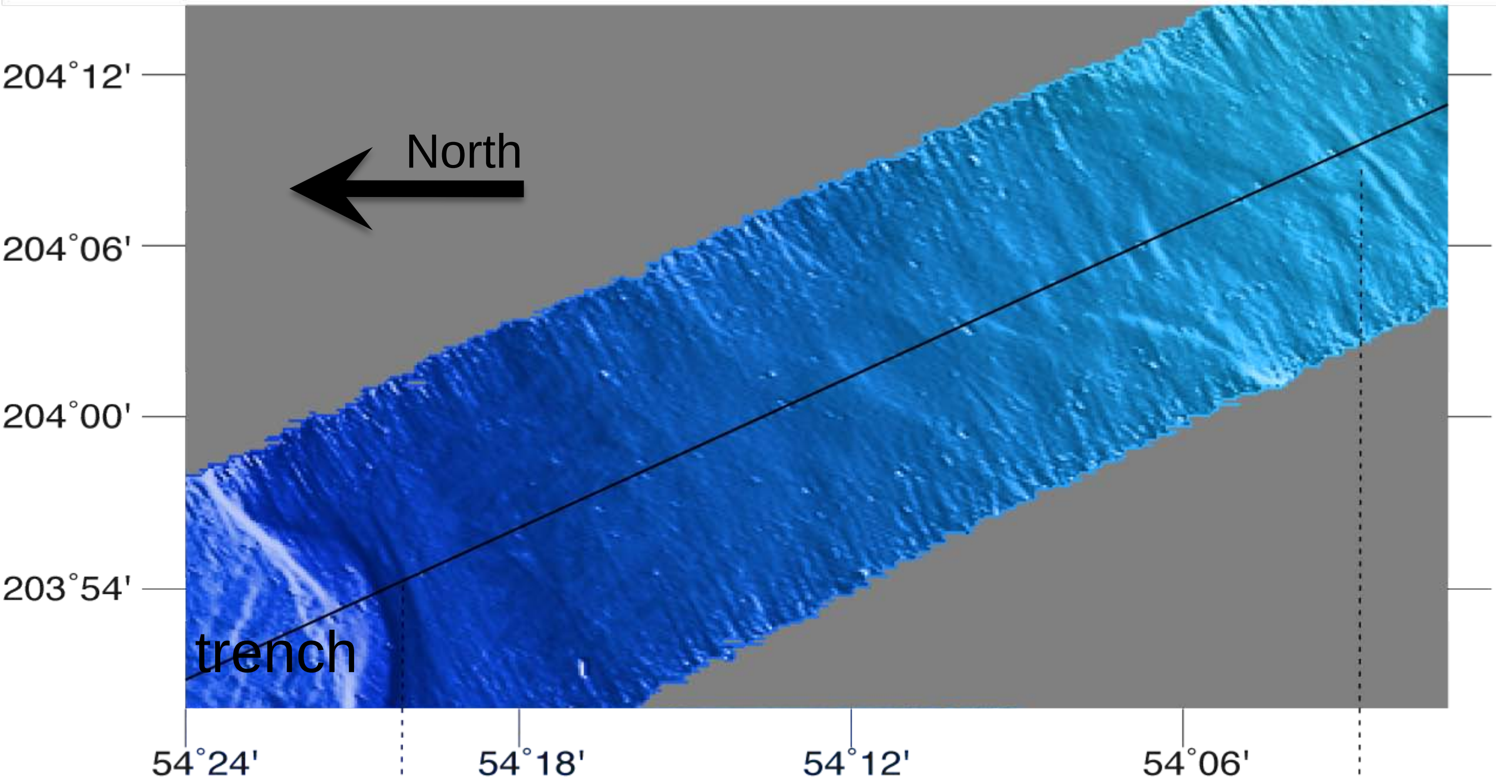
Semidi segment: Thicker sediments, less bending



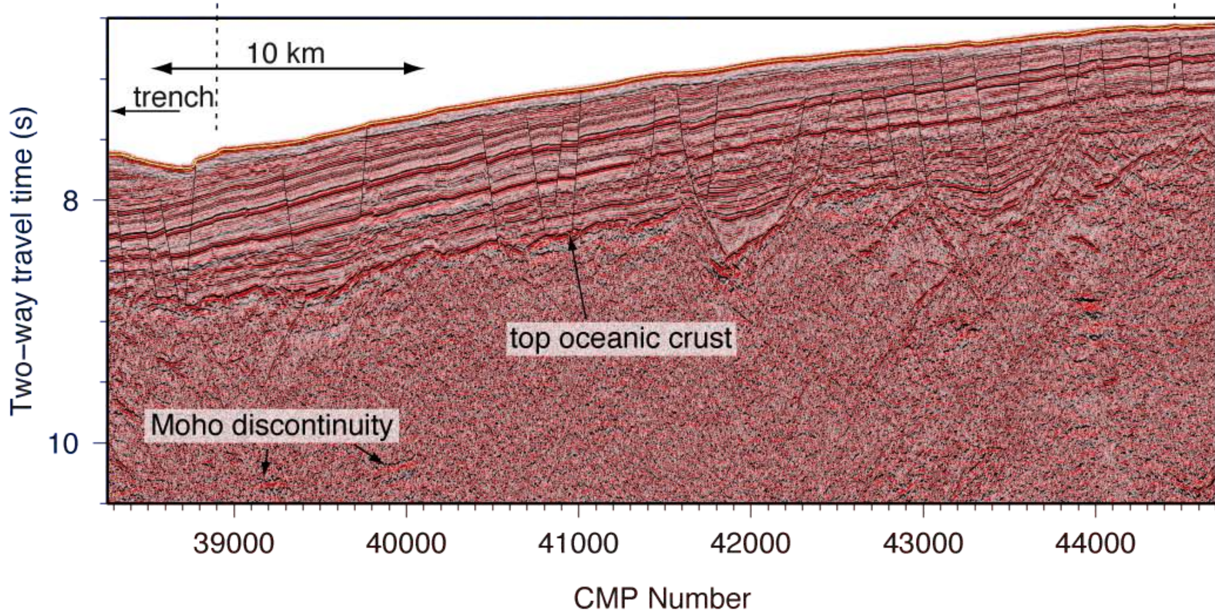


Shumagin Gap: Thinner sediments and more bending related faulting

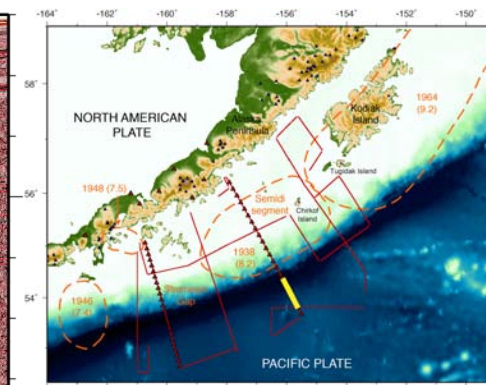
ALEUT 3



North
trench
204°12'
204°06'
204°00'
203°54'
54°24'
54°18'
54°12'
54°06'

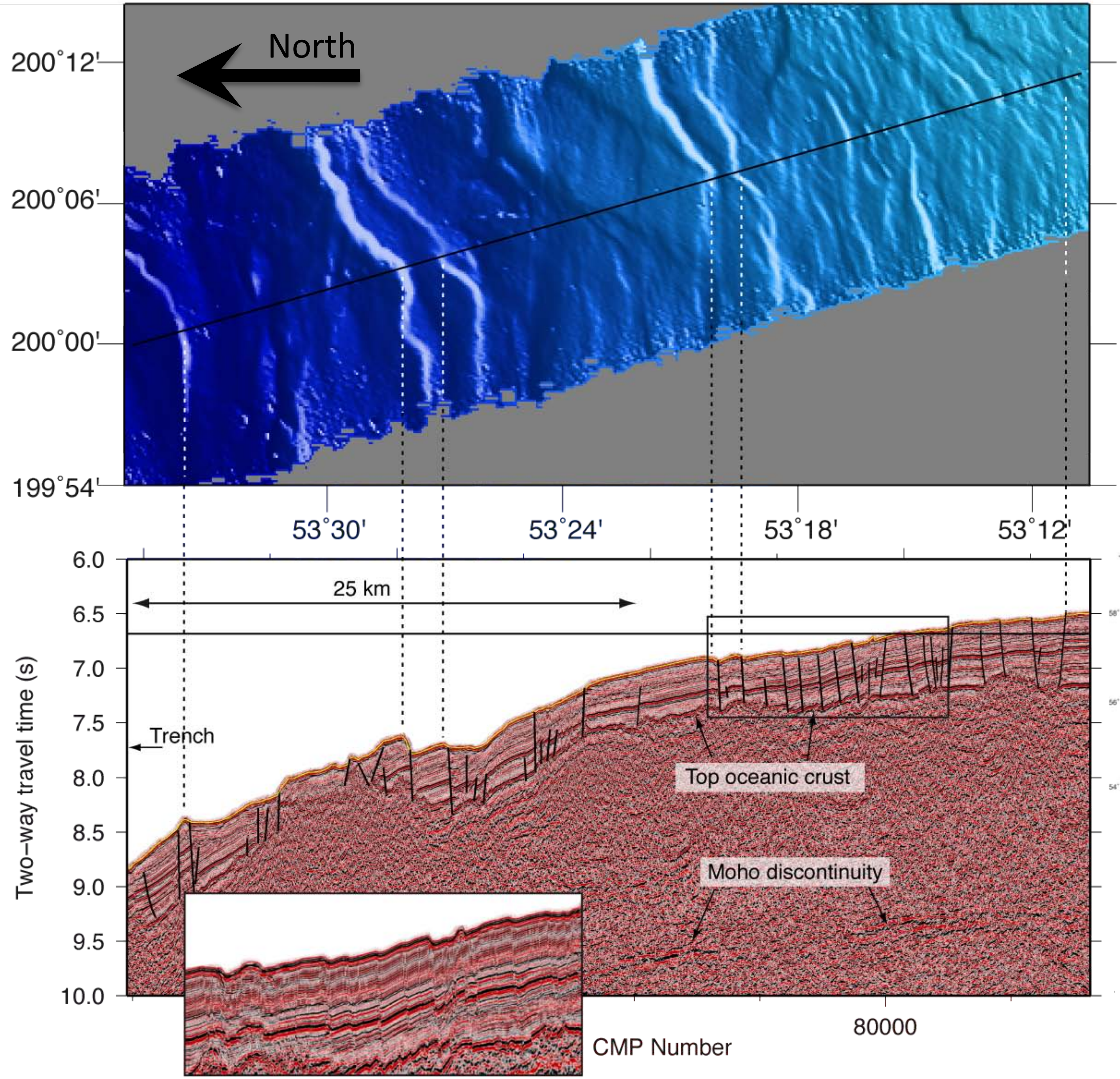


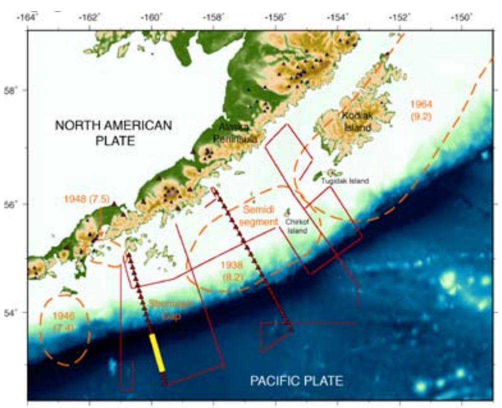
10 km
trench
top oceanic crust
Moho discontinuity
Two-way travel time (s)
8
10
39000
40000
41000
42000
43000
44000
CMP Number



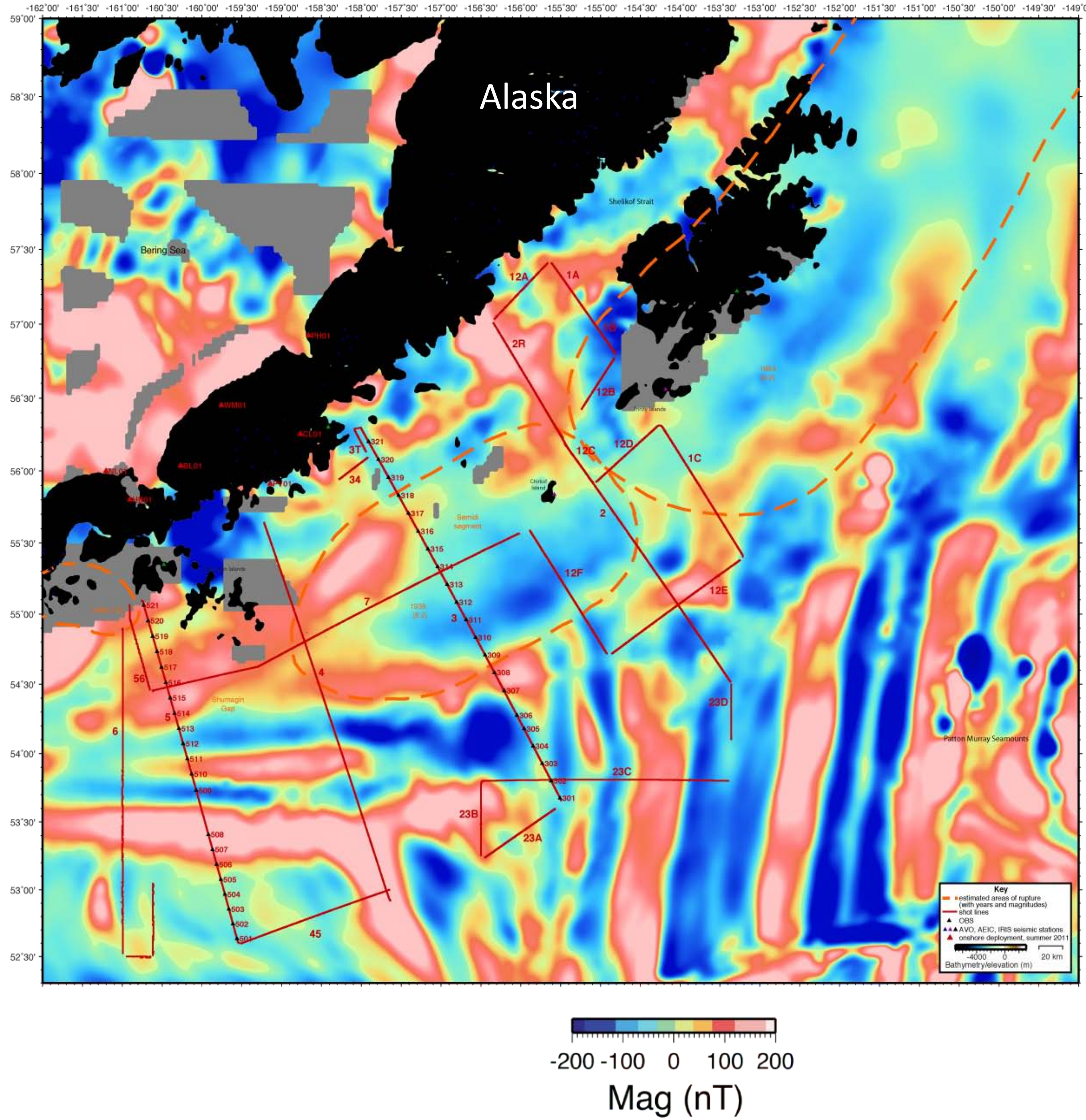
NORTH AMERICAN PLATE
PACIFIC PLATE
Kodiak Island
1964 (9.2)
1948 (7.5)
Semidi segment
1938 (8.2)

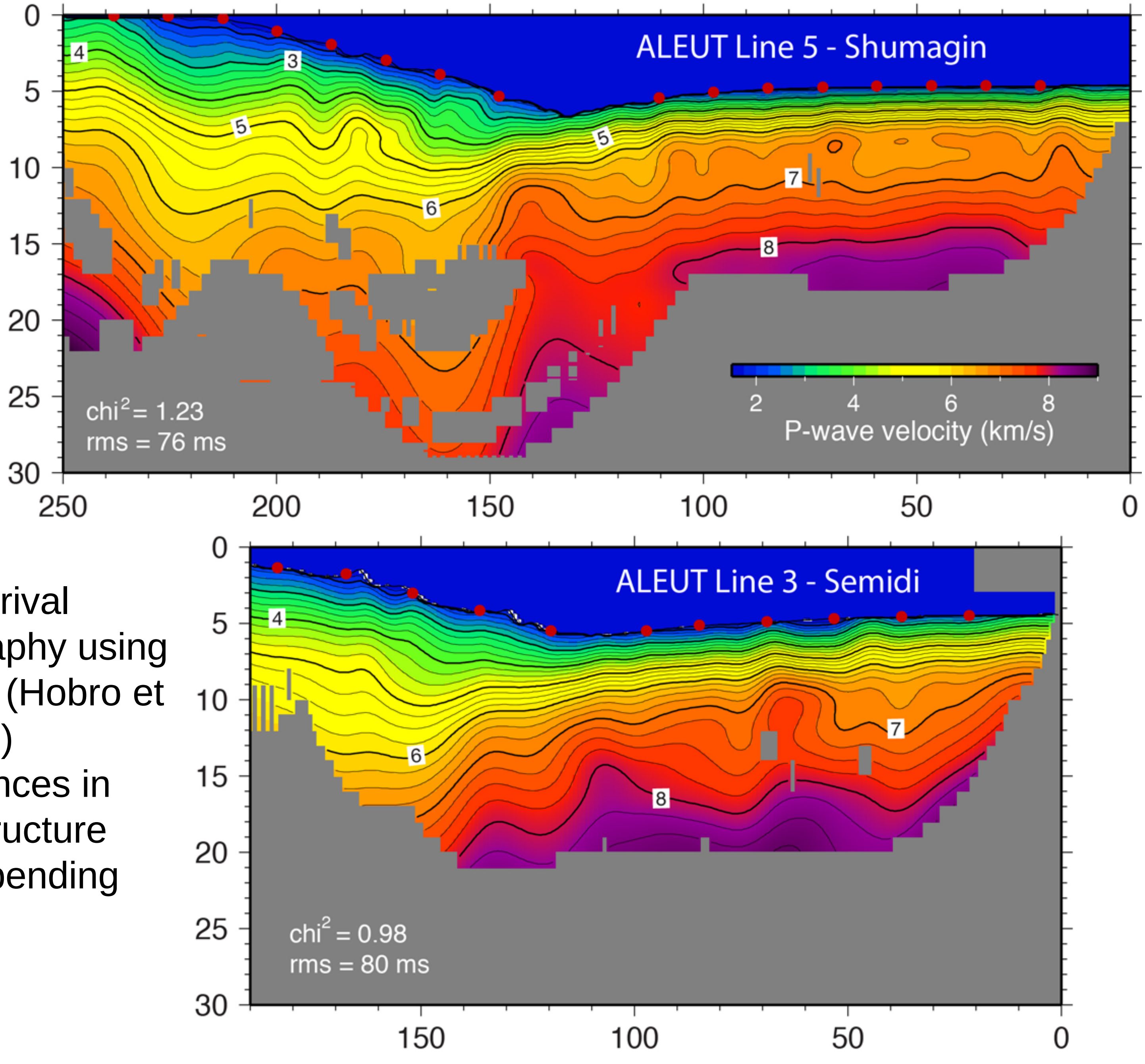
ALEUT 5


North
200°12'
200°06'
200°00'
199°54'
53°30'
53°24'
53°18'
53°12'
25 km
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
Two-way travel time (s)
Trench
Top oceanic crust
Moho discontinuity
80000
CMP Number


NORTH AMERICAN PLATE
PACIFIC PLATE
1964 (9.2)
1948 (7.5)
1938 (8.2)

Control on bending-related faulting by fabric of incoming plate?

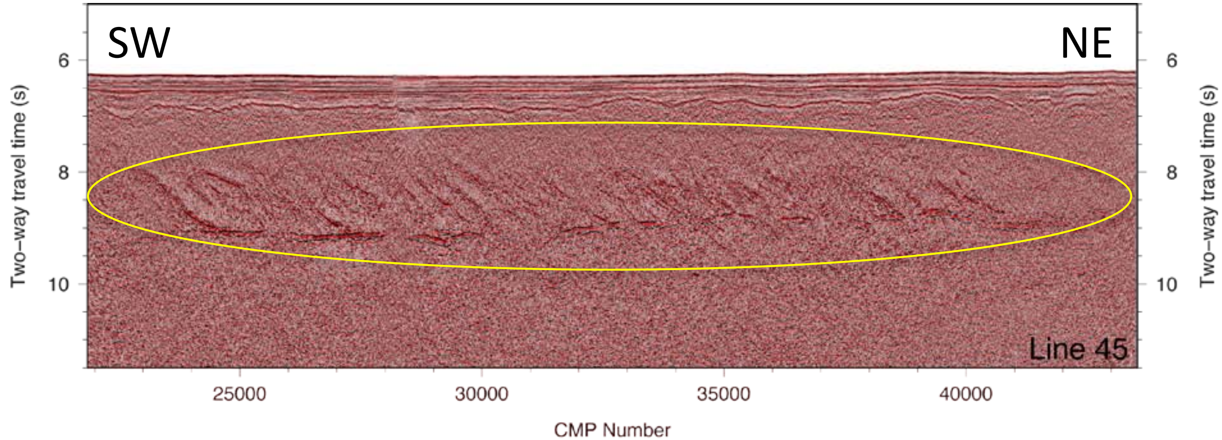


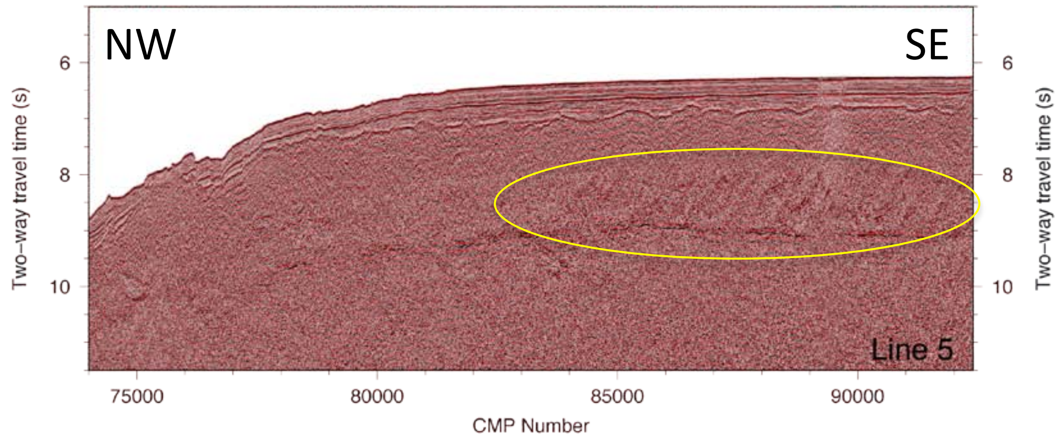


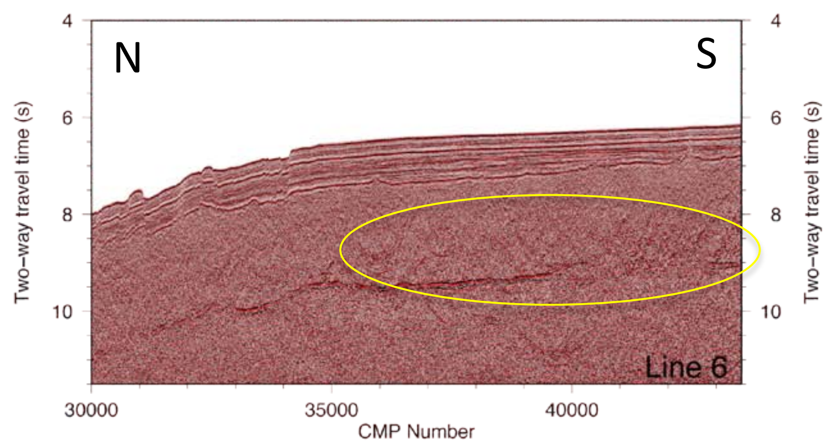
- First-arrival tomography using JIVE3D (Hobro et al, 2003)
- Differences in plate structure before bending
- D

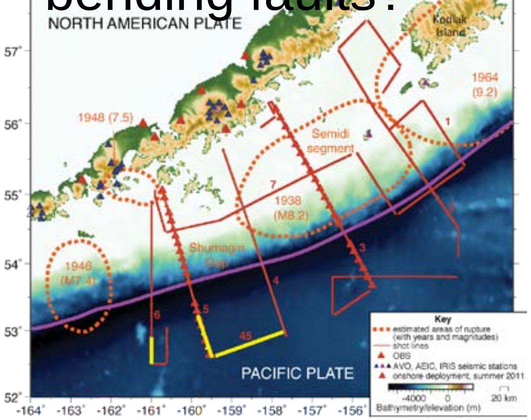
4. Structure of old, fast-spreading oceanic c

- Features observed in oceanic plate seaward of bending
- Dipping reflections in lower crust. Dip north at ~15-35º
- Appear to ‘disappear’ in bending region. Rotated to steeper angles and/or reactivated as bending faults?

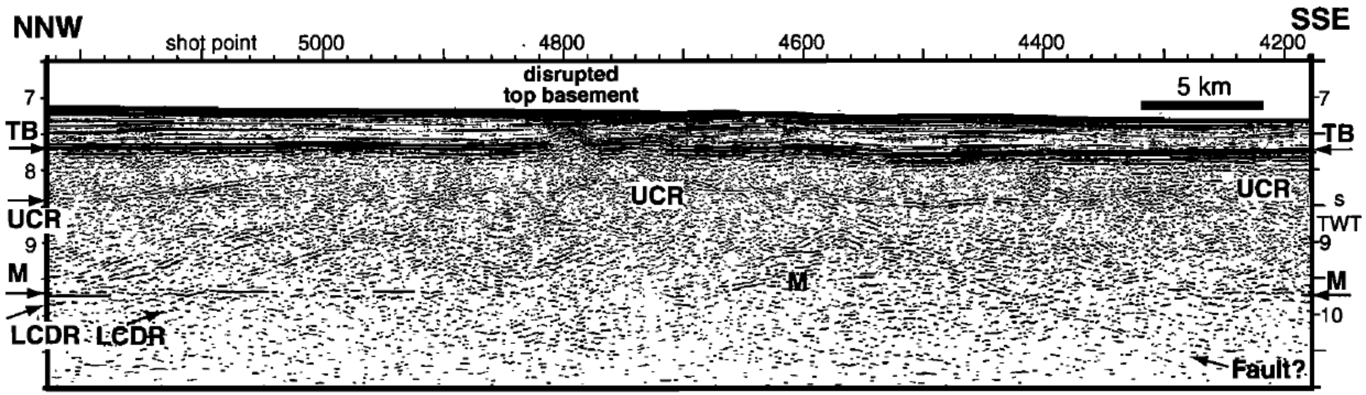








Similar features seen in other old Pacific oceanic crust



Example from ~135-125 Ma oceanic crust in the NW Pacific

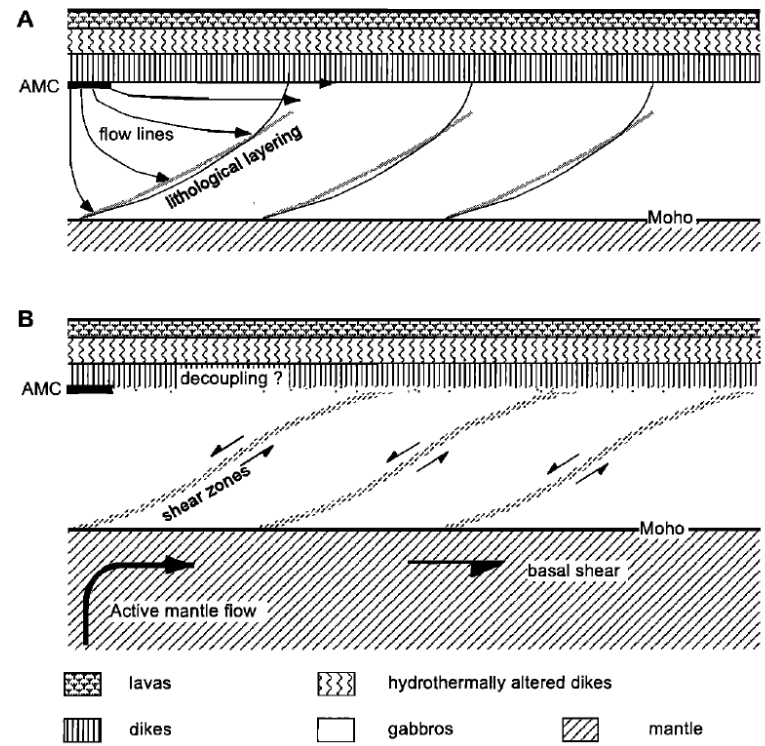
Reston et al., 1999

Published explanations:

- Lithological layering from emplacement
- Shear zones from emplacement or caused by basal shear due to active upwelling

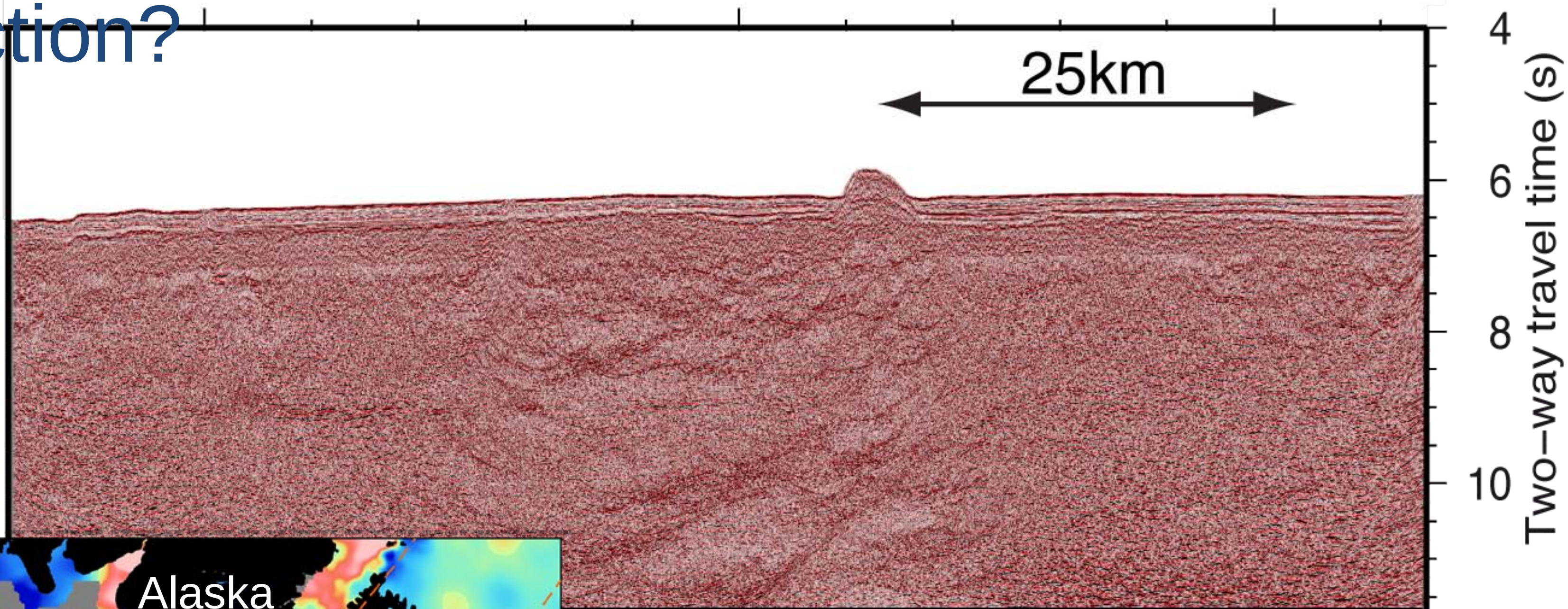
Others?

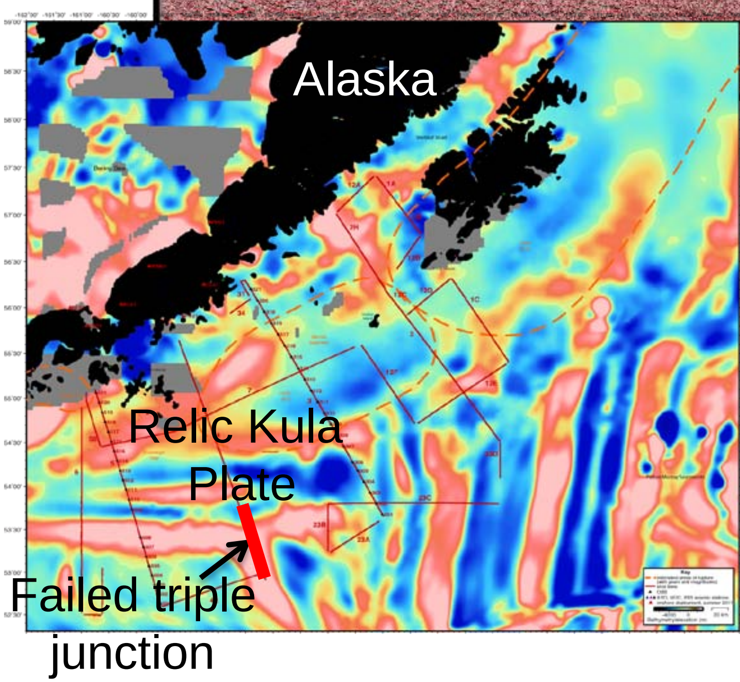
- Shear zones formed in mushy zone, including melt segregation
- Shear zones later utilized off-axis by hydrothermal circulation?



Reston et al., 1999

5. Trapped, frozen melt beneath a relic triple junction?





Deep reflections observed up to ~2 s twtt below the Moho where profile crosses a failed ridge-ridge-ridge triple junction (Lonsdale, 1988)

Frozen, retained melt?

Acknowledgements:

- The Captain, Crew, and technical staff of the R/V *Marcus G. Langseth*
- Team Diebold & Maya Tolstoy
- John Diebold
- Many other people who assisted us in planning for this cruise: Marine Office, Sean Gulick, others.
- Supported by the National Science Foundation

Questions?