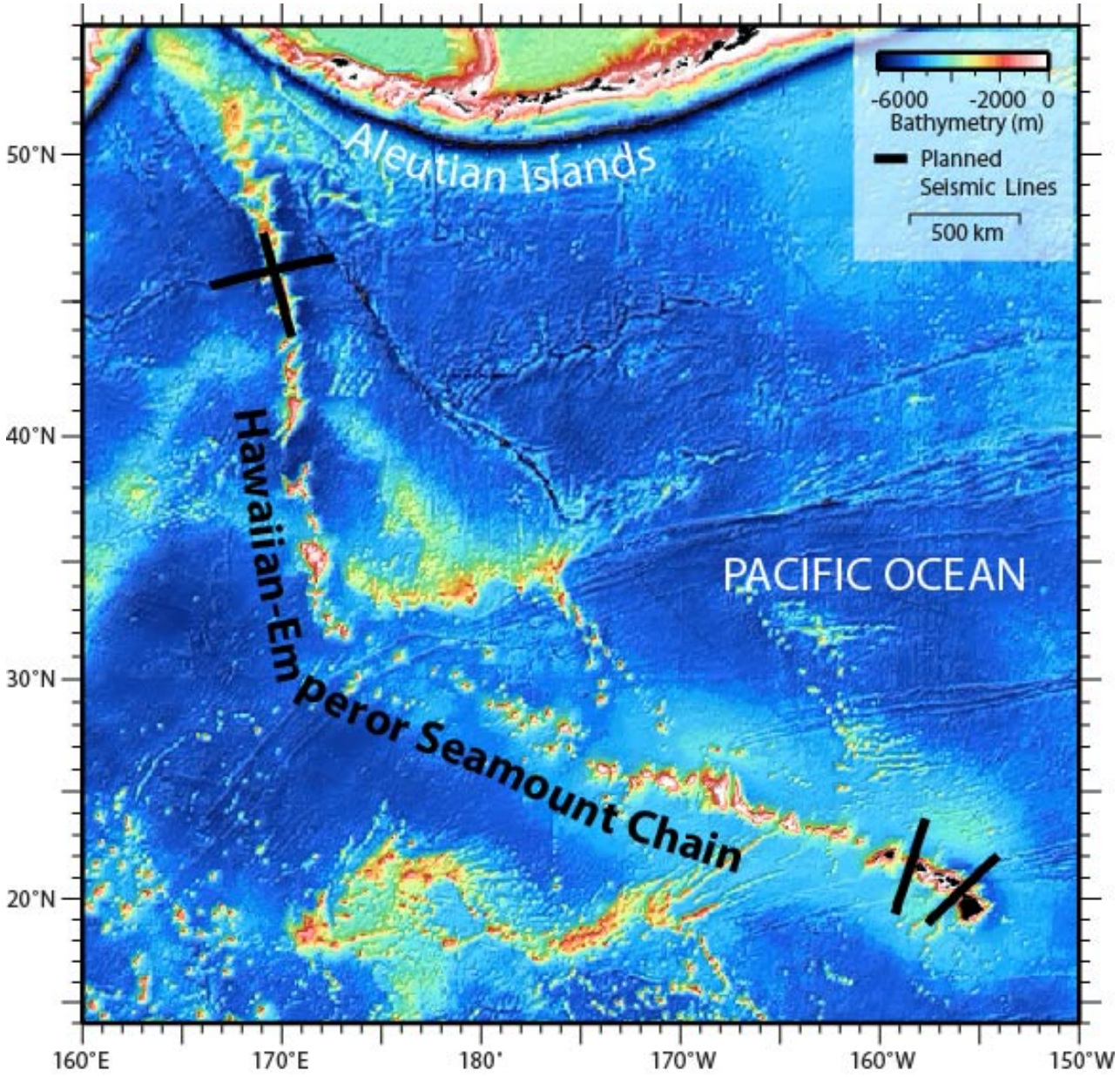
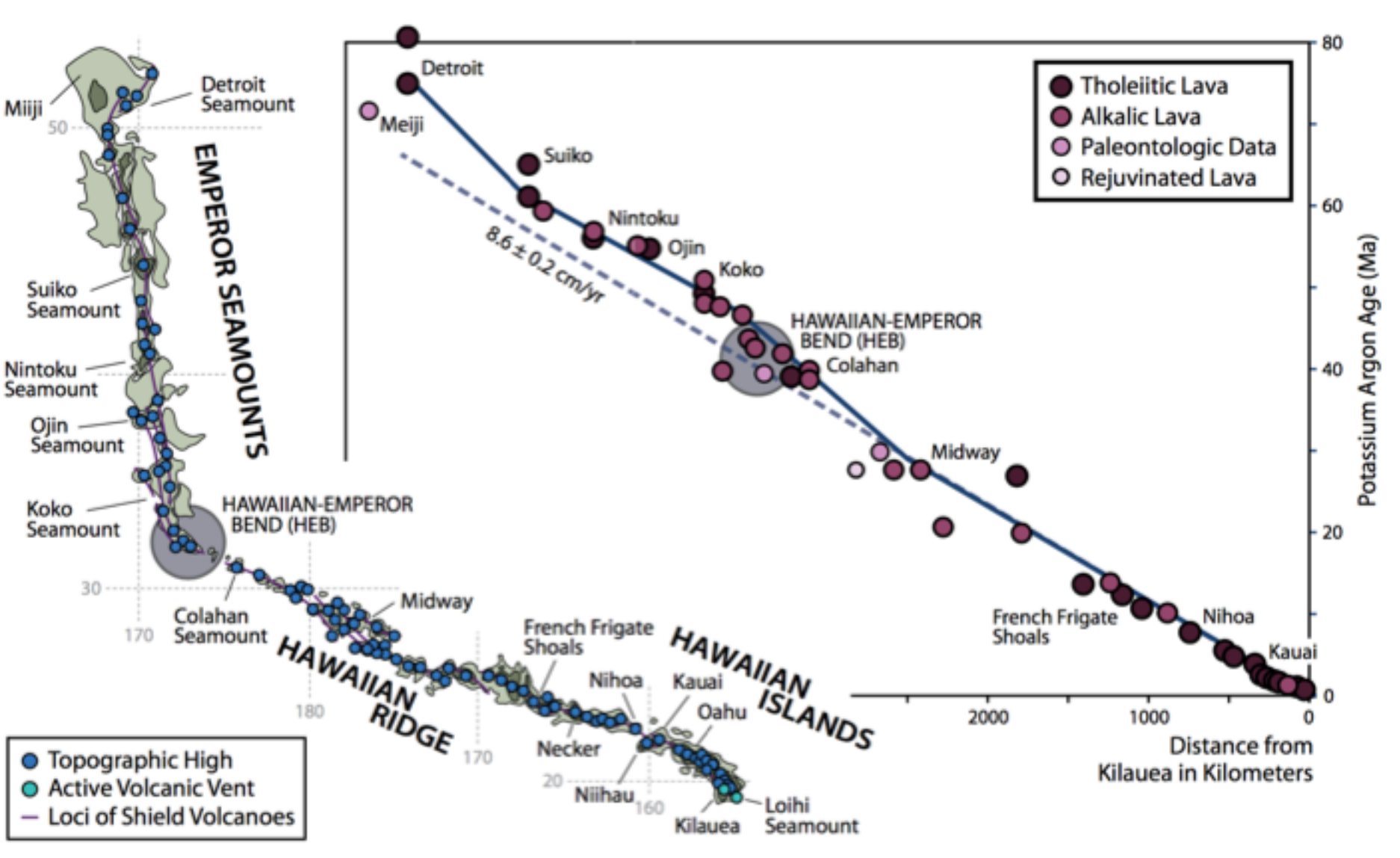


Seismic imaging of volcano construction, underplating and flexure along the Hawaiian-Emperor Seamount Chain

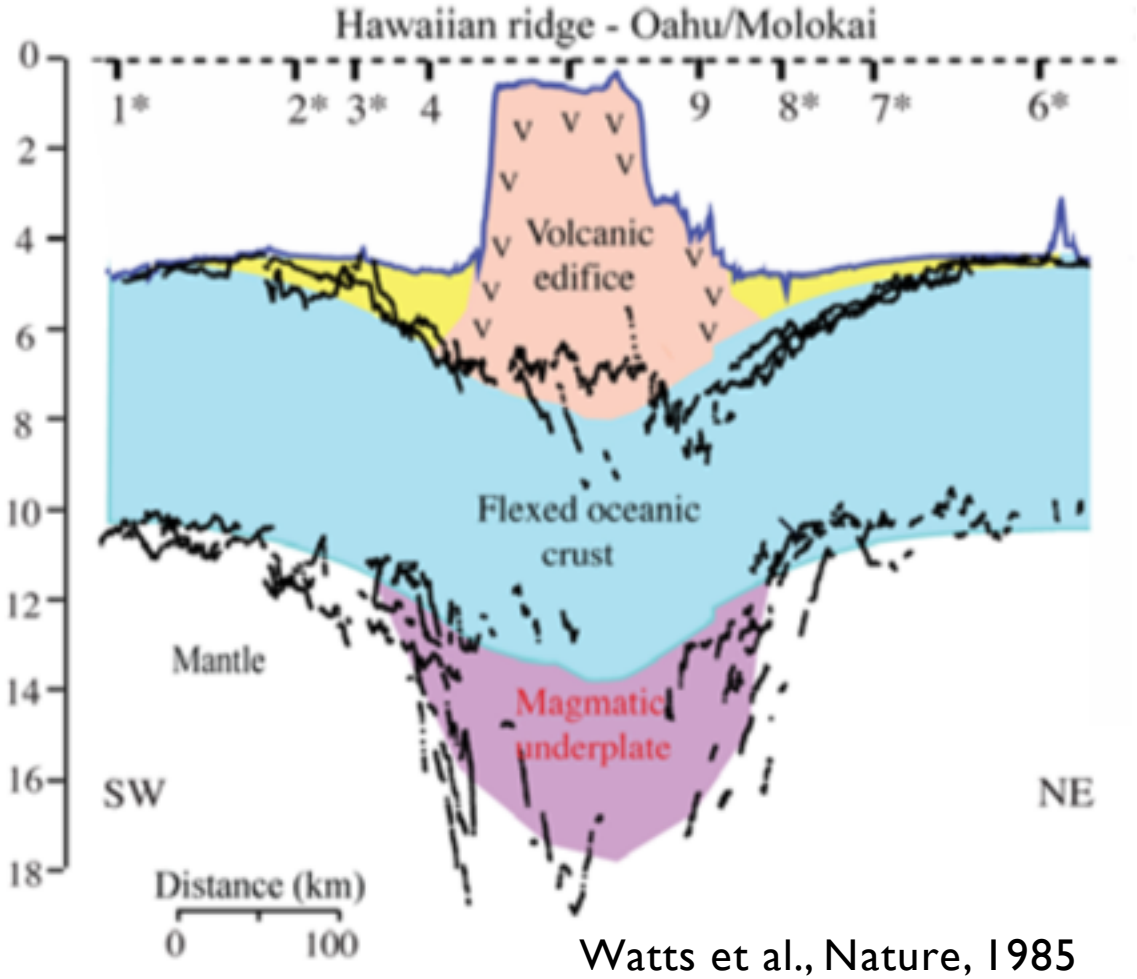
Donna J. Shillington, Lamont-Doherty Earth Observatory
Tony Watts, Oxford University
Robert Dunn, University of Hawaii
Garrett Ito, University of Hawaii
Paul Wessel, University of Hawaii
Uri ten Brink, USGS
Nathan Miller, USGS
Ingo Grevemeyer, GEOMAR

Classic seamount chain from hotspot volcanism

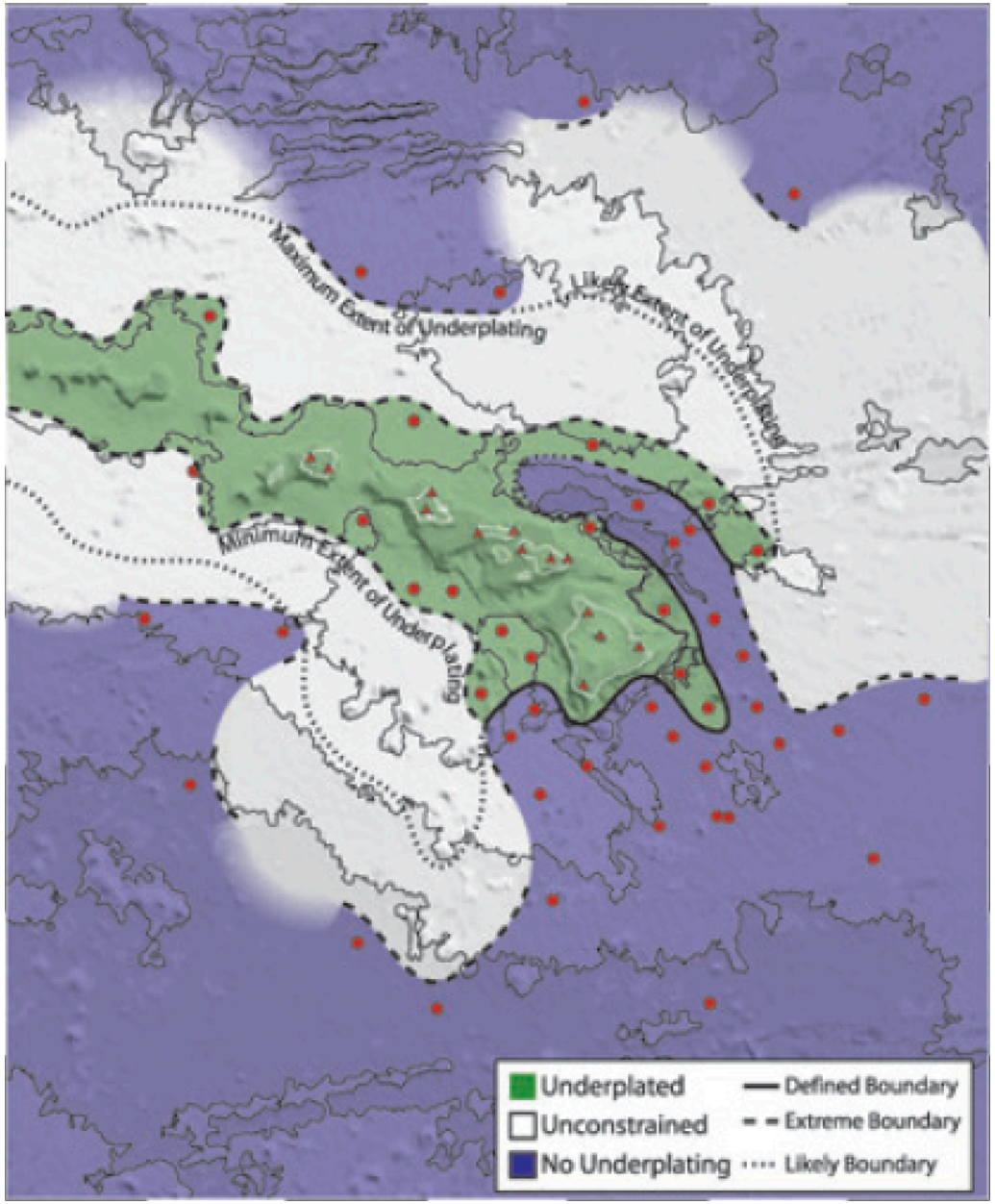


O'Connor et al, G3, 2013

What is distribution of magmatic intrusions and underplating beneath Hawaii?



Watts et al., Nature, 1985



Leahy et al. 2010

Receiver function imaging from PLUME deployment suggests more broadly distributed magmatic underplating than active source imaging

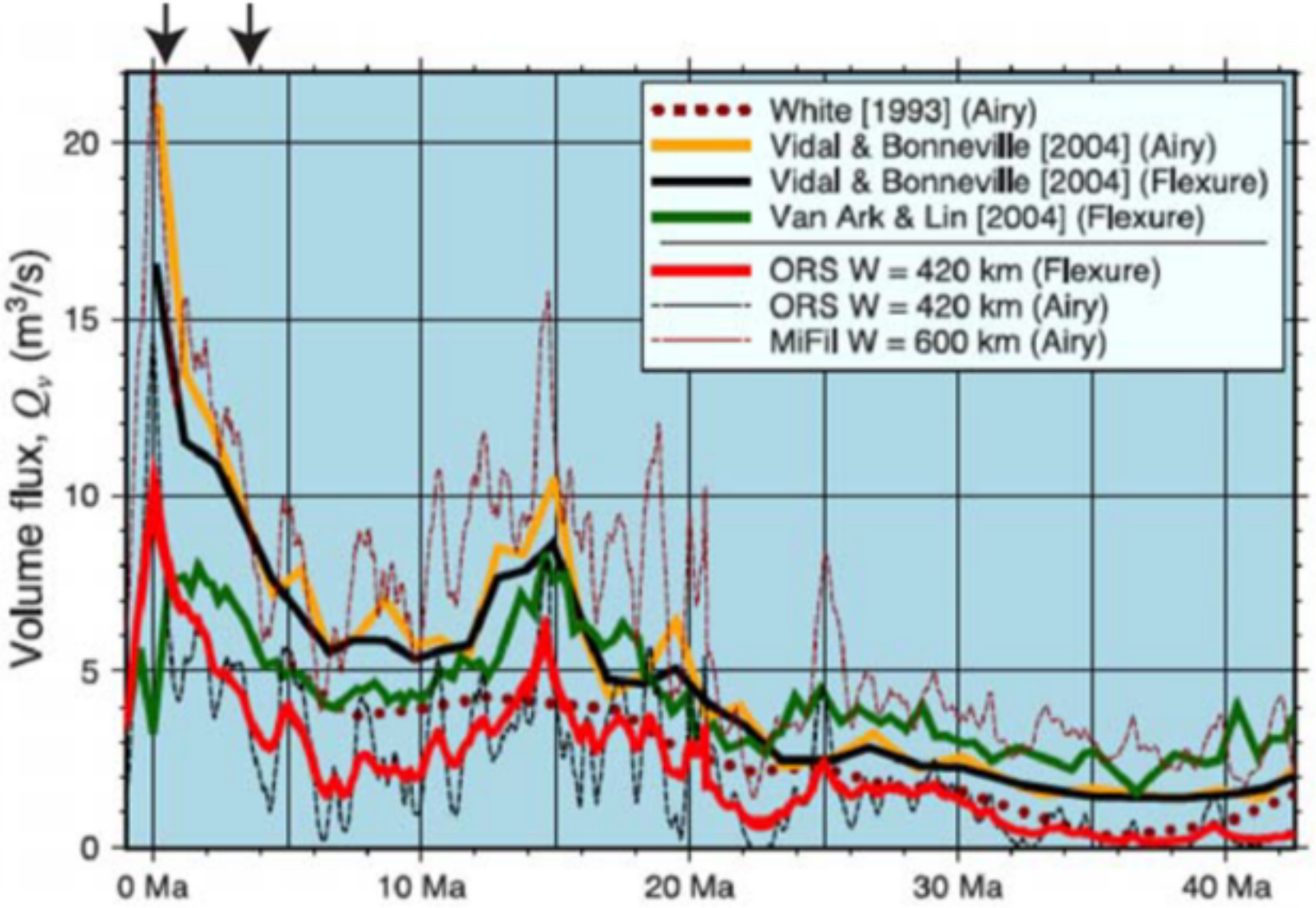
Changes in magmatic flux over time

Three superimposed scales of variation:

- Volcano to volcano
- Oscillations over 5-10 m.y.
- Recent increase in flux

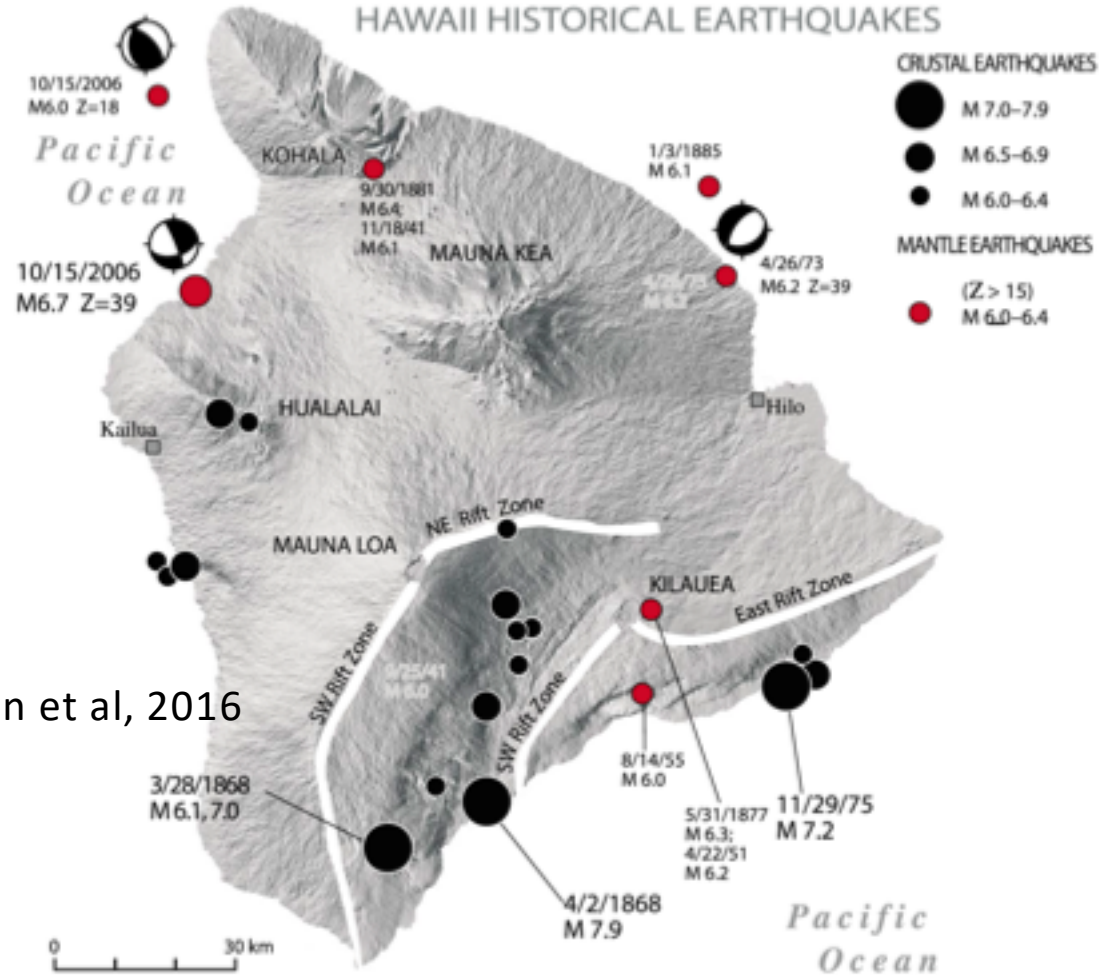
Possible explanations:

- Modulating effect of lithosphere?
- Changes in plume flux?
- Result of complex processes in thermochemical plume?

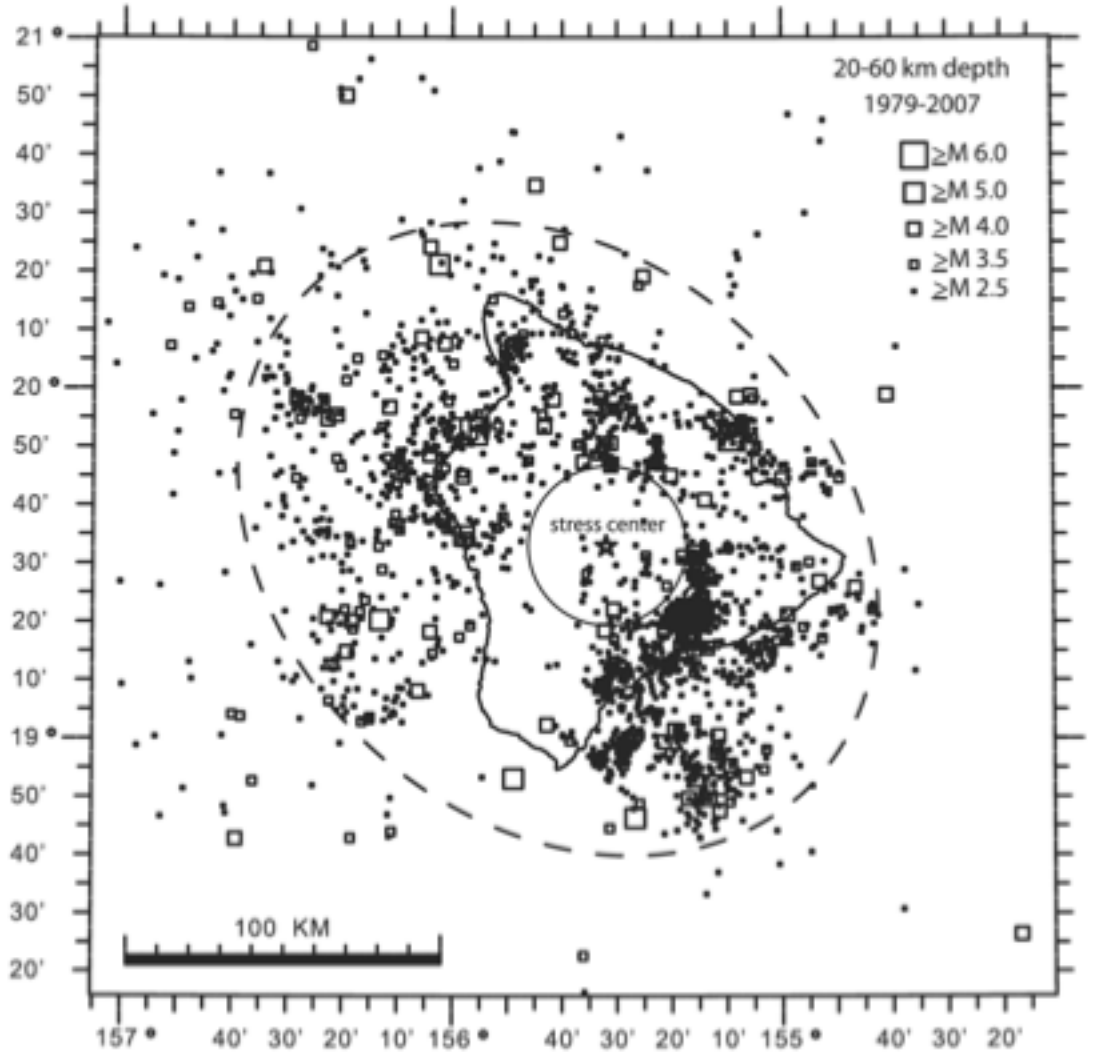


Wessel, GJI, 2016

Earthquake hazards



Klein et al, 2016



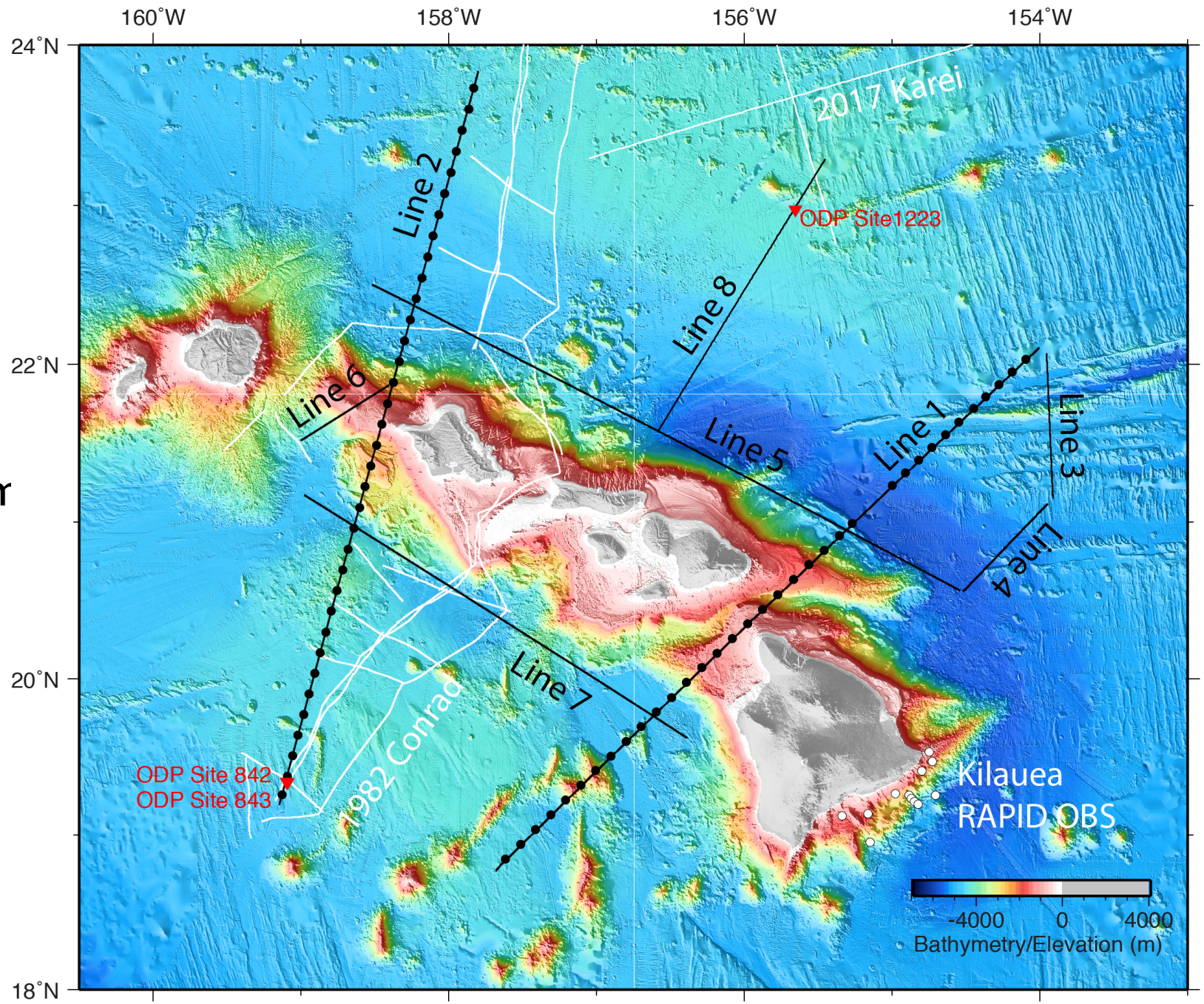
Klein, 2016

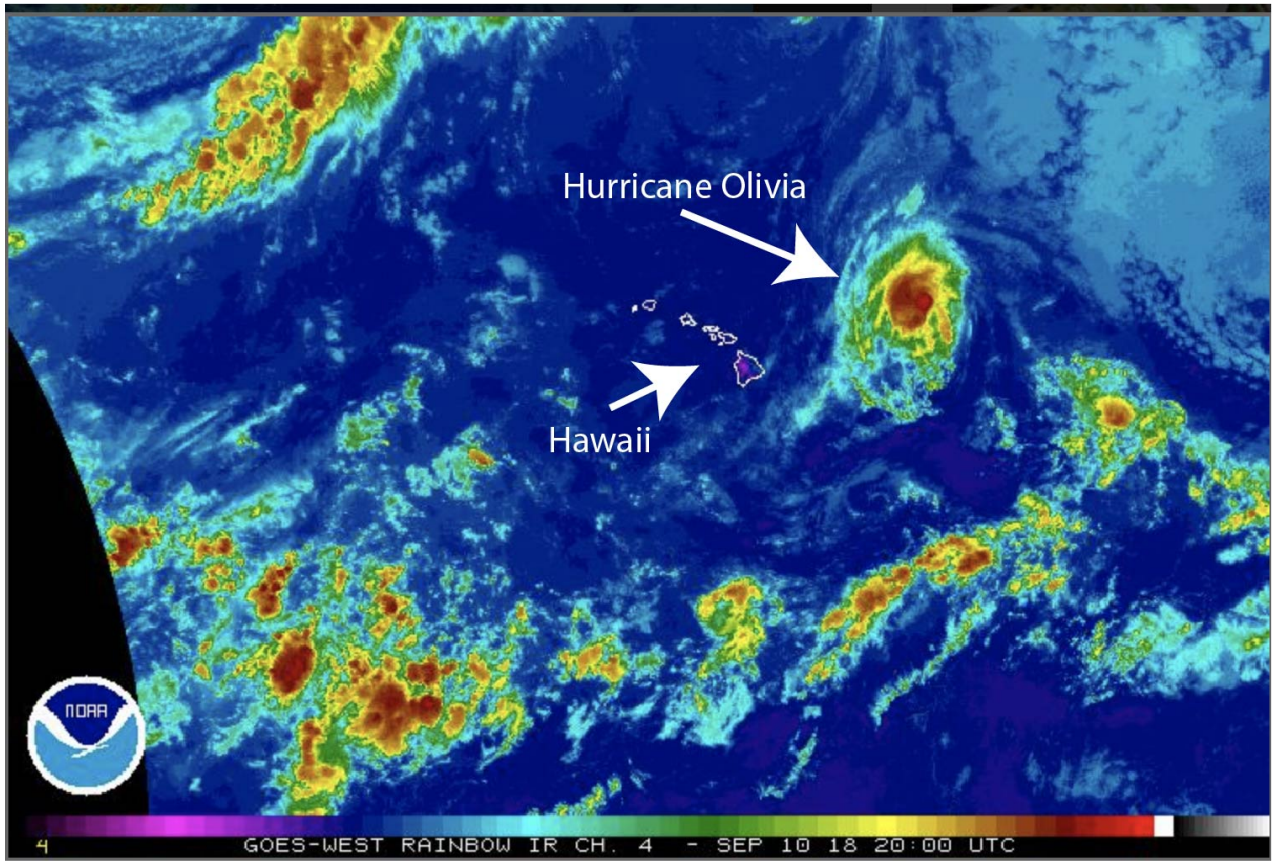
Science targets

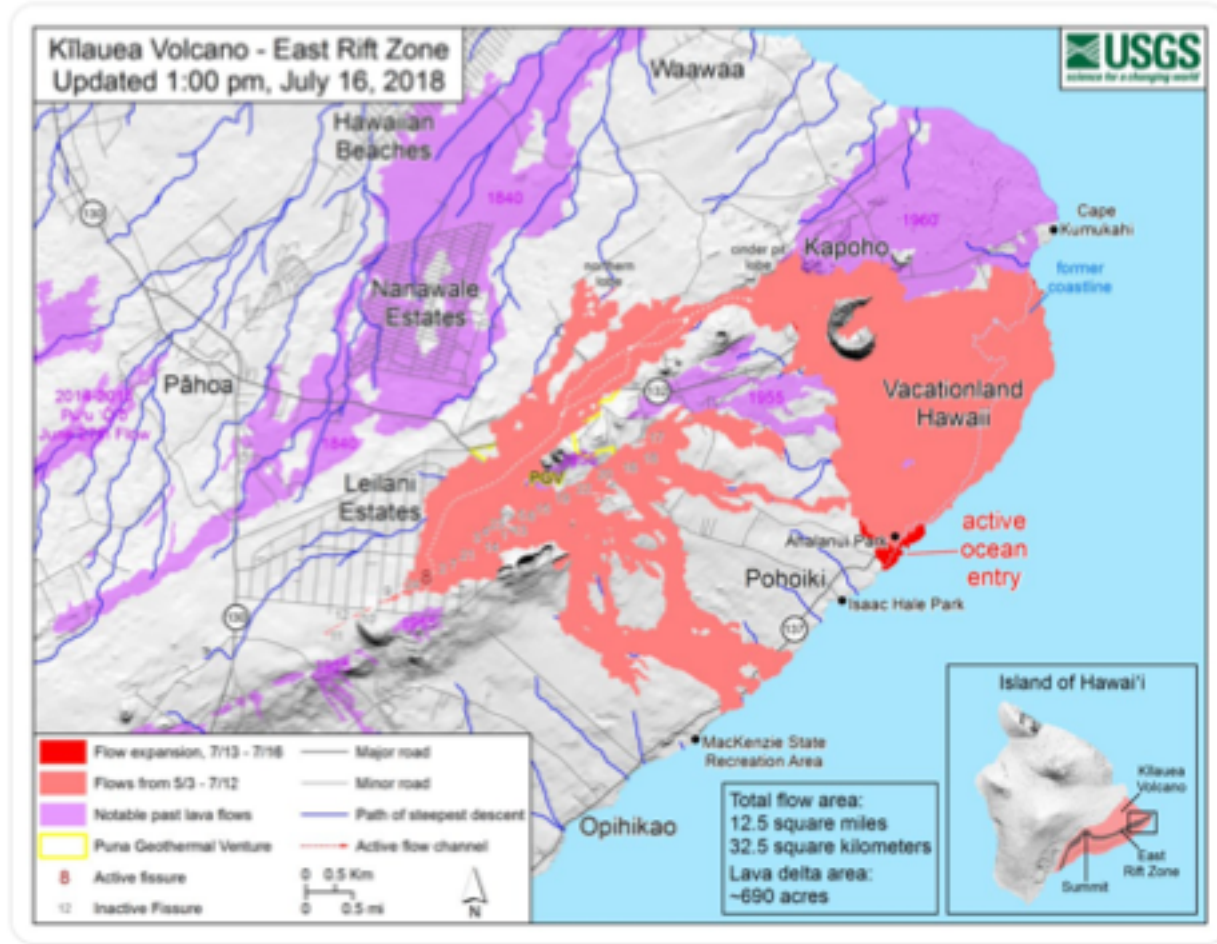
- Volume, composition and distribution of magmatic addition beneath Hawaii-Emperor Seamount Chain
- Deformation of oceanic plate in response to load and implications for faulting and hydration
- Rheology of oceanic lithosphere and its variation through time
- Origin of topographic swell around Hawaii (thermal or compositional)
- Hazards from earthquakes, landslides, tsunamis

MGL1806

- R/V *Langseth*, Sept 11 – Oct 21, 2018
- Collected >3000 km of data across and along Hawaii
- 70 OBS on the seafloor
- 15-km-long streamer
- 6600 cu in source
- Also recovered 12 OBS from RAPID response effort to Kilauea eruption

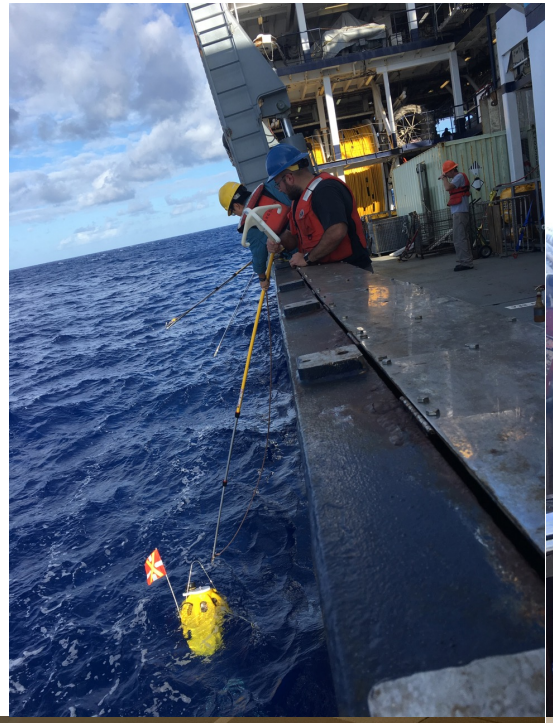


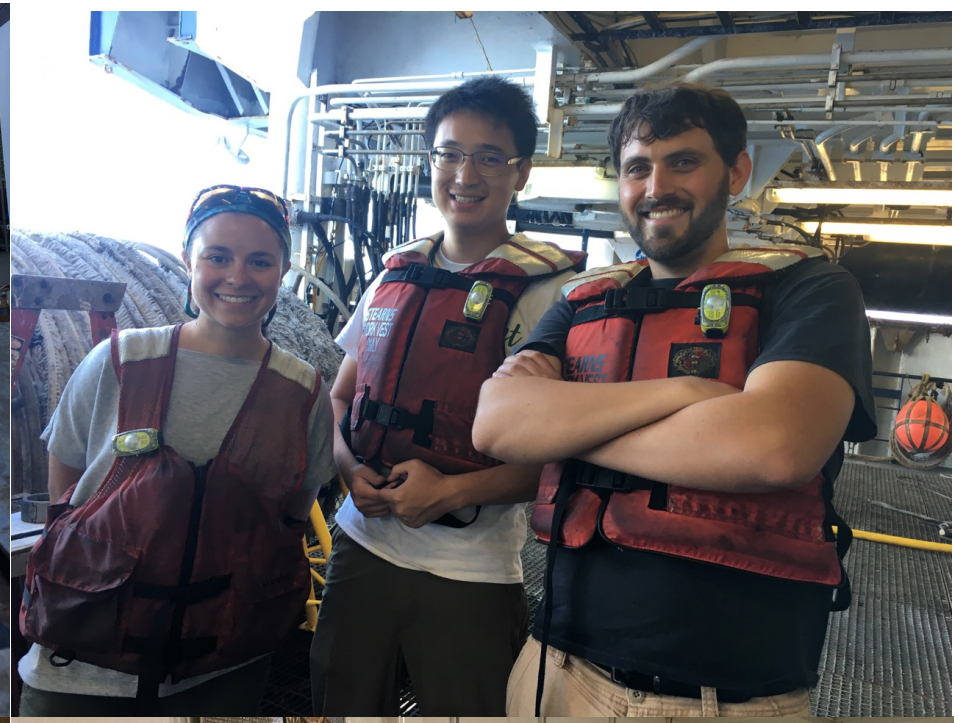

Hurricane Olivia
Hawaii
NOAA
4
GOES-WEST RAINBOW IR CH. 4 - SEP 10 18 20:00 UTC


Kīlauea Volcano - East Rift Zone
Updated 1:00 pm, July 16, 2018
USGS
Waawaa
Hawaiian Beaches
Nanawale Estates
Pāhoa
Leilani Estates
Kapoho
Cape Kumukahi
former coastline
Vacationland Hawaii
active ocean entry
Pohoiki
Isaac Hale Park
MacKenzie State Recreation Area
Opihikao
Flow expansion, 7/13 - 7/16
Flows from 5/3 - 7/12
Notable past lava flows
Puna Geothermal Venture
Active fissure
Inactive Fissure
Major road
Minor road
Path of steepest descent
Active flow channel
0 0.5 Km
0 0.5 mi
N
Total flow area:
12.5 square miles
32.5 square kilometers
Lava delta area:
~690 acres
Island of Hawai'i
Kīlauea Volcano
East Rift Zone
Summit

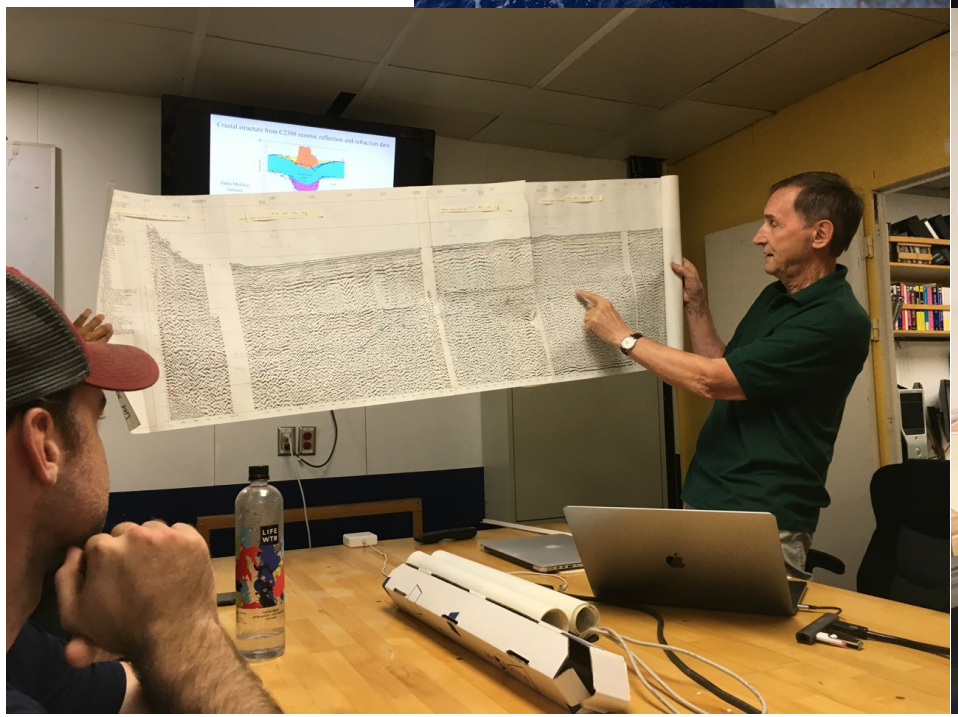
Excellent cadre of 9 early career scientists:

Bridgit Boulahanis (LDEO), Laney Hart (U. Wisc), Charu Lata (U. Hawaii), Mark McClernan (U. Alaska), Nina Nakrong (U. Hawaii), Suyapa Rodriguez (LSU), Dan Sousa (LDEO), Jingxuan Wei (TAMU), Xiaozhuo Wei (URI)





- Lectures on active-source seismic methods + other marine geophysics and background on Hawaii
- Student-led reading of passages from the seismic bible
- Presentations by students of their research
- Hands-on training in seismic reflection analysis. Everyone processed some of the new data!

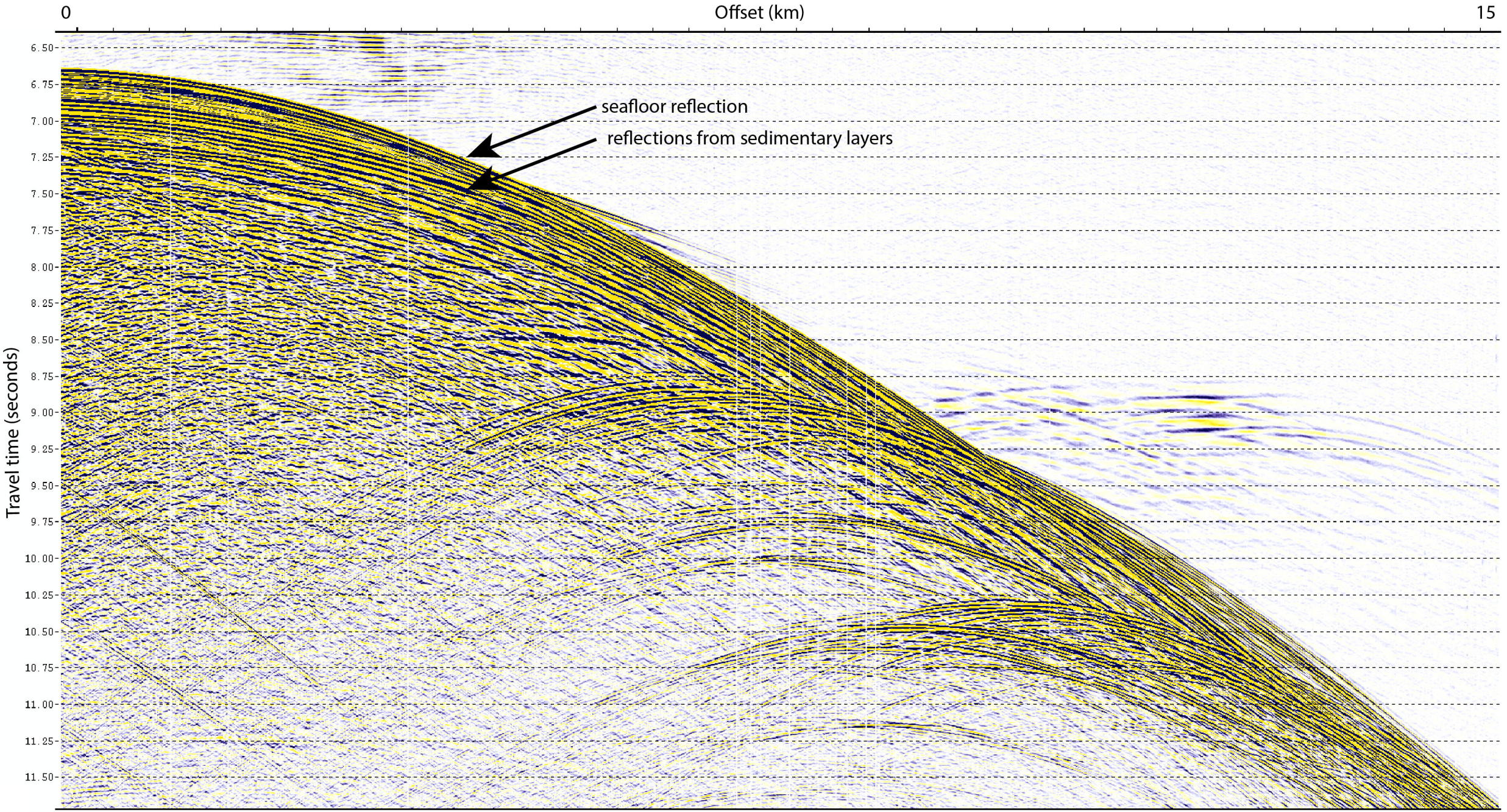


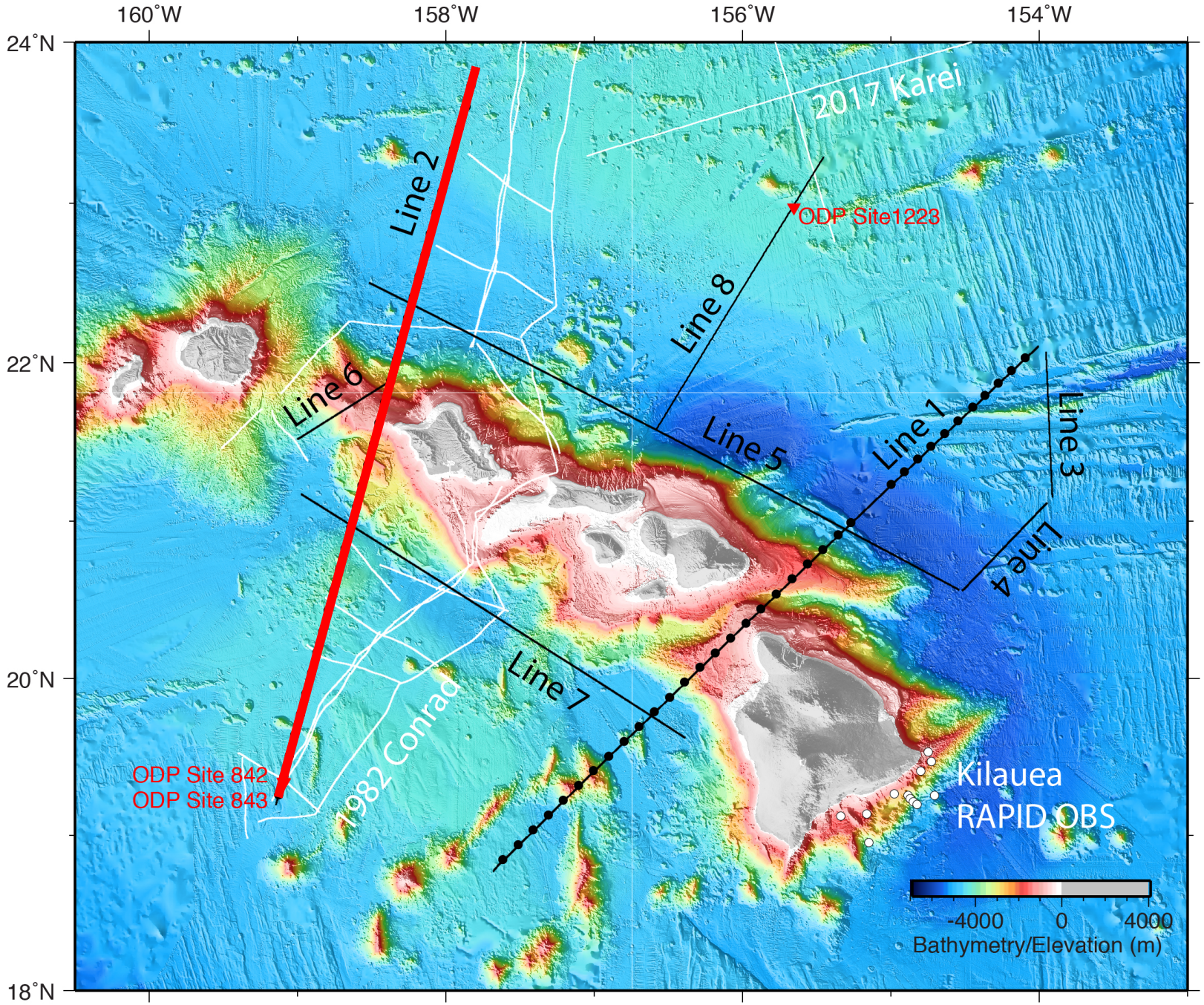
Not the first seismic cruise to the Hawaiian Islands…

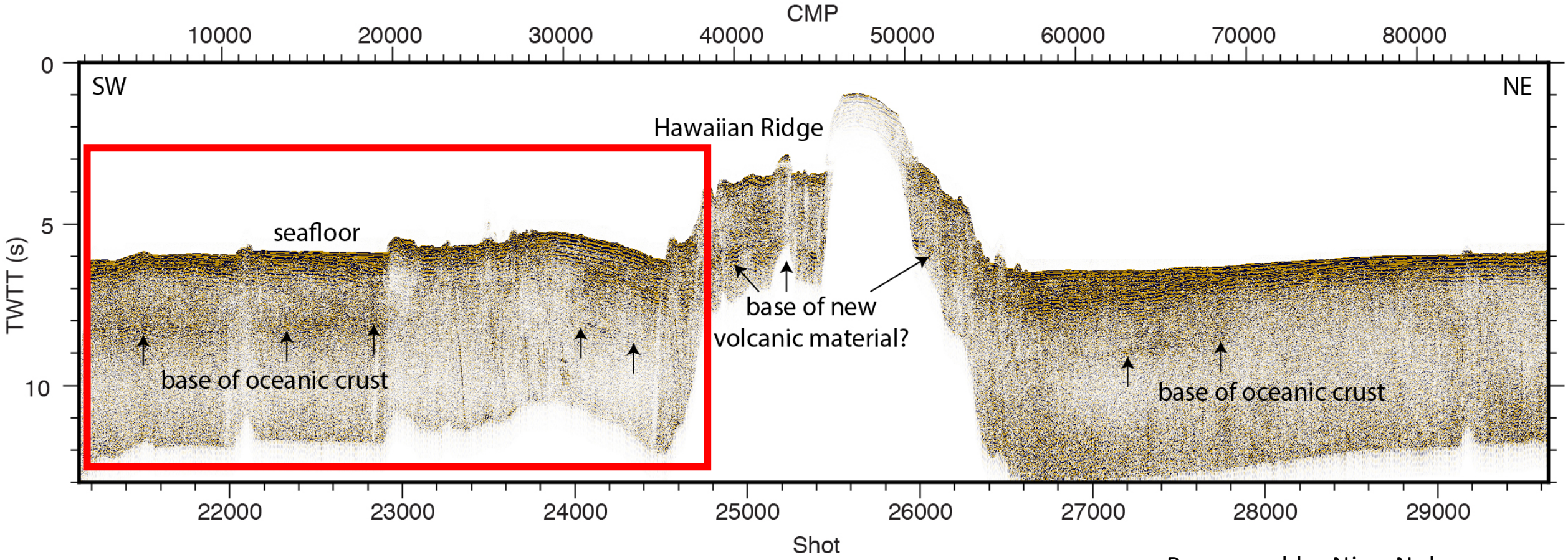
- 2-ship experiment in 1982 with R/V *Conrad* and R/V *Kana Keoki*
- Seismic sources:
  - 3-airgun arrays, including a couple of 1000-cu-in air guns!
  - 60-lb Tovex charges

One of Conrad's 1000 cu in guns on the *Langseth*!

We did not fire it…

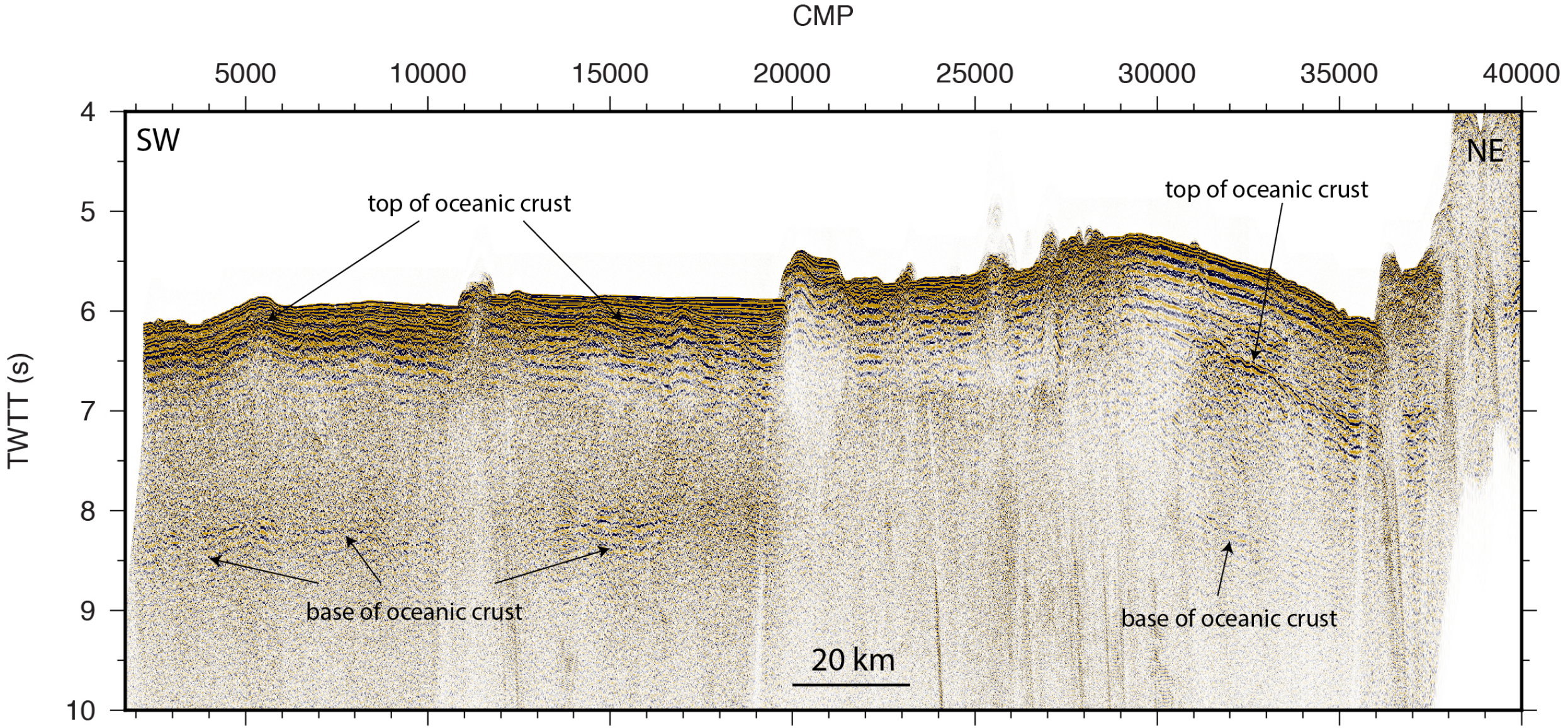

0
Offset (km)
15
Travel time (seconds)
6.50
6.75
7.00
7.25
7.50
7.75
8.00
8.25
8.50
8.75
9.00
9.25
9.50
9.75
10.00
10.25
10.50
10.75
11.00
11.25
11.50
seafloor reflection
reflections from sedimentary layers


160˚W
158˚W
156˚W
154˚W
24˚N
22˚N
20˚N
18˚N
2017 Karei
Line 2
ODP Site1223
Line 8
Line 6
Line 5
Line 1
Line 3
Line 4
Line 7
1982 Conrad
ODP Site 842
ODP Site 843
Kilauea
RAPID OBS
-4000
0
4000
Bathymetry/Elevation (m)

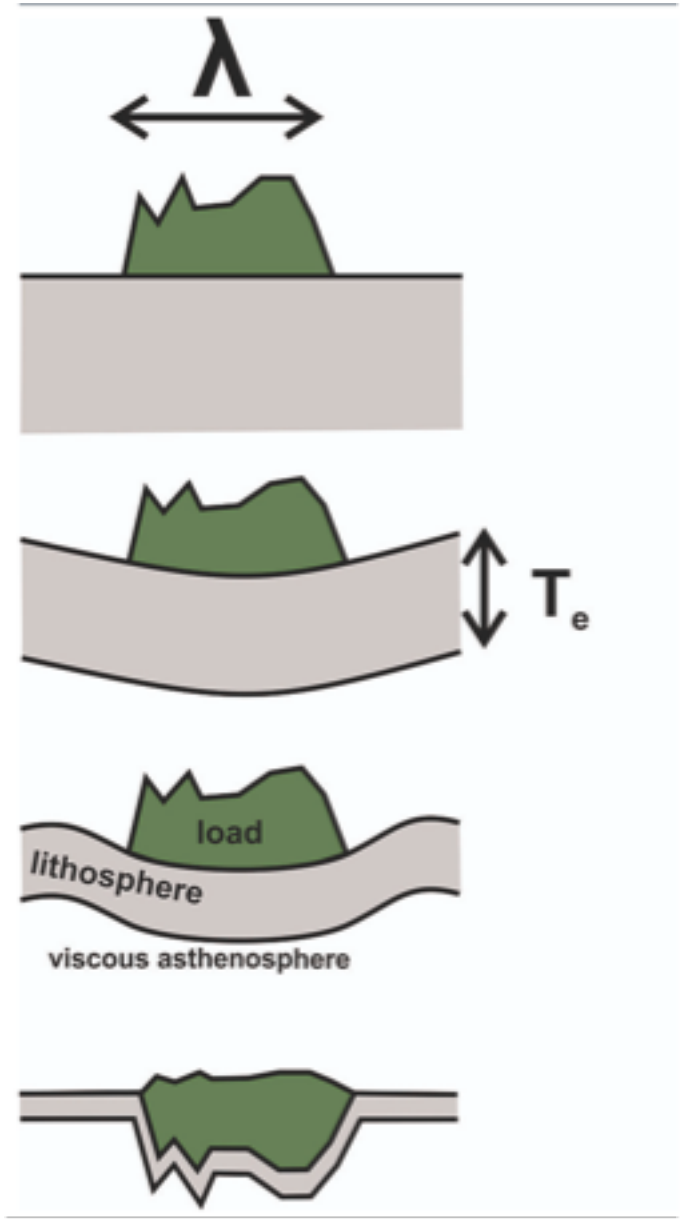


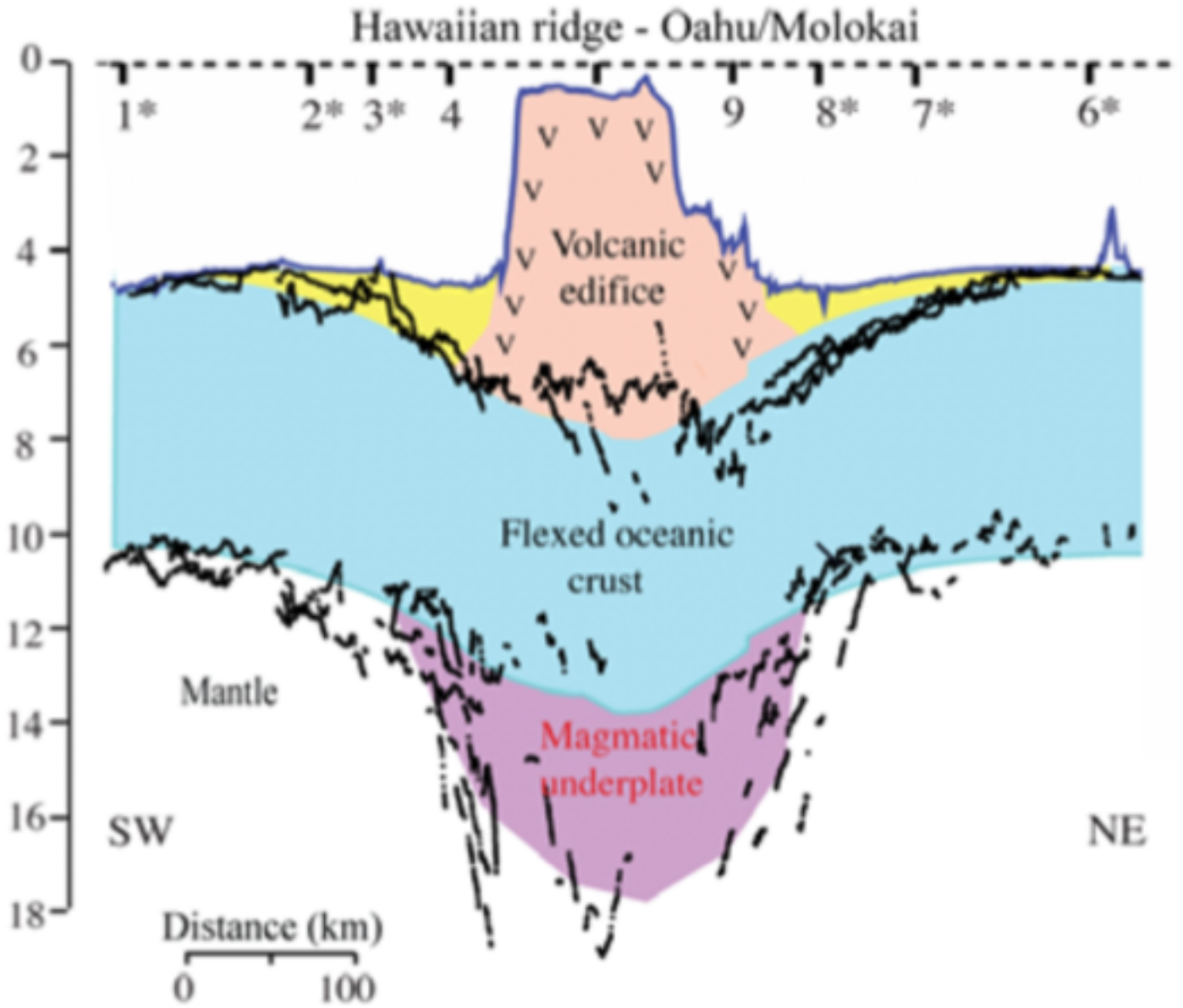
Processed by Nina Nakrong

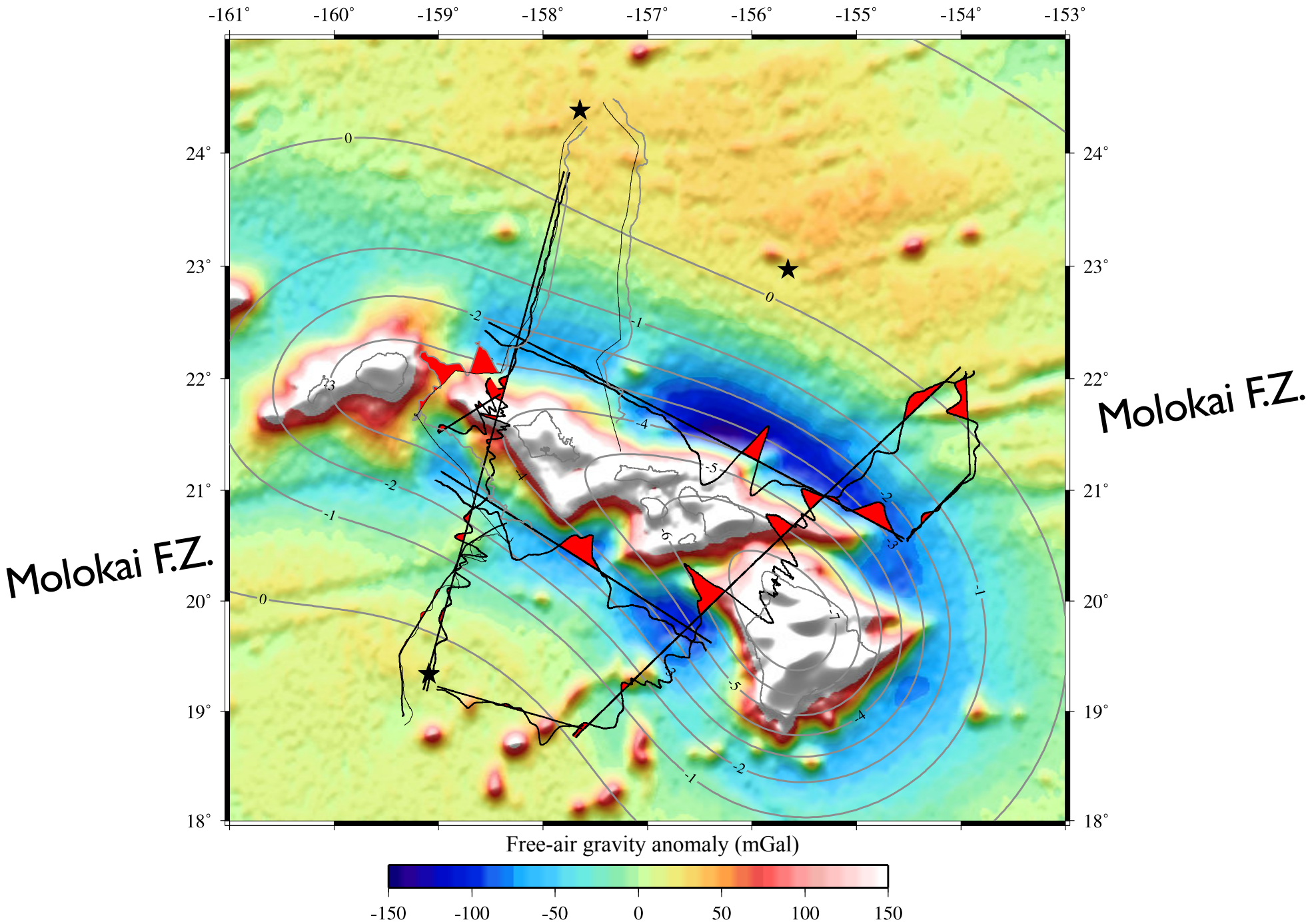
Shape of oceanic plate bending due to Hawaii volcanos



Processed by Nina Nakrong


λ
T_e
load
lithosphere
viscous asthenosphere


Hawaiian ridge - Oahu/Molokai
0
2
4
6
8
10
12
14
16
18
1*
2*
3*
4
9
8*
7*
6*
Volcanic edifice
Flexed oceanic crust
Mantle
Magmatic underplate
SW
NE
Distance (km)
0
100


-161°
-160°
-159°
-158°
-157°
-156°
-155°
-154°
-153°
24°
23°
22°
21°
20°
19°
18°
Molokai F.Z.
Molokai F.Z.
Free-air gravity anomaly (mGal)
-150
-100
-50
0
50
100
150

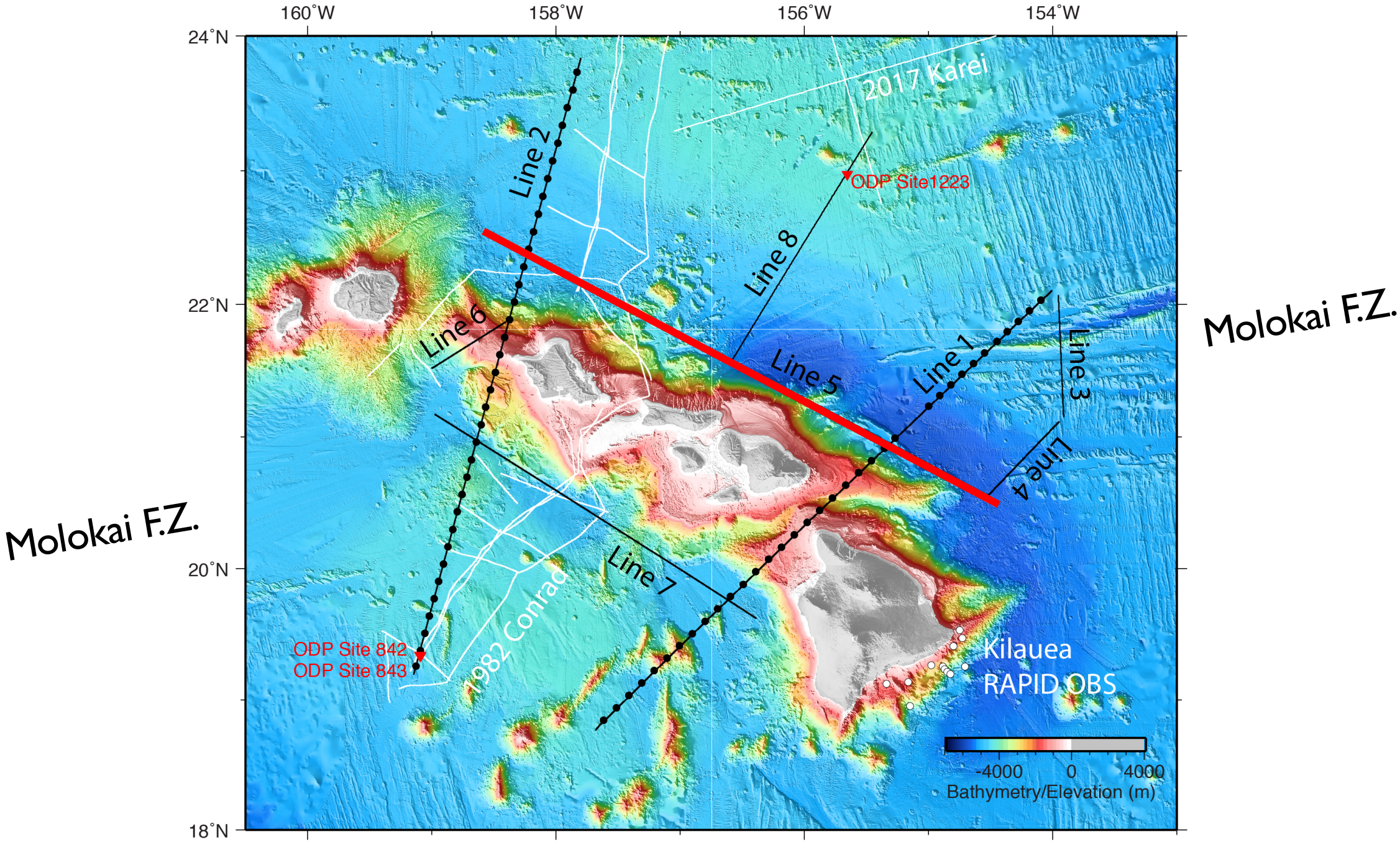
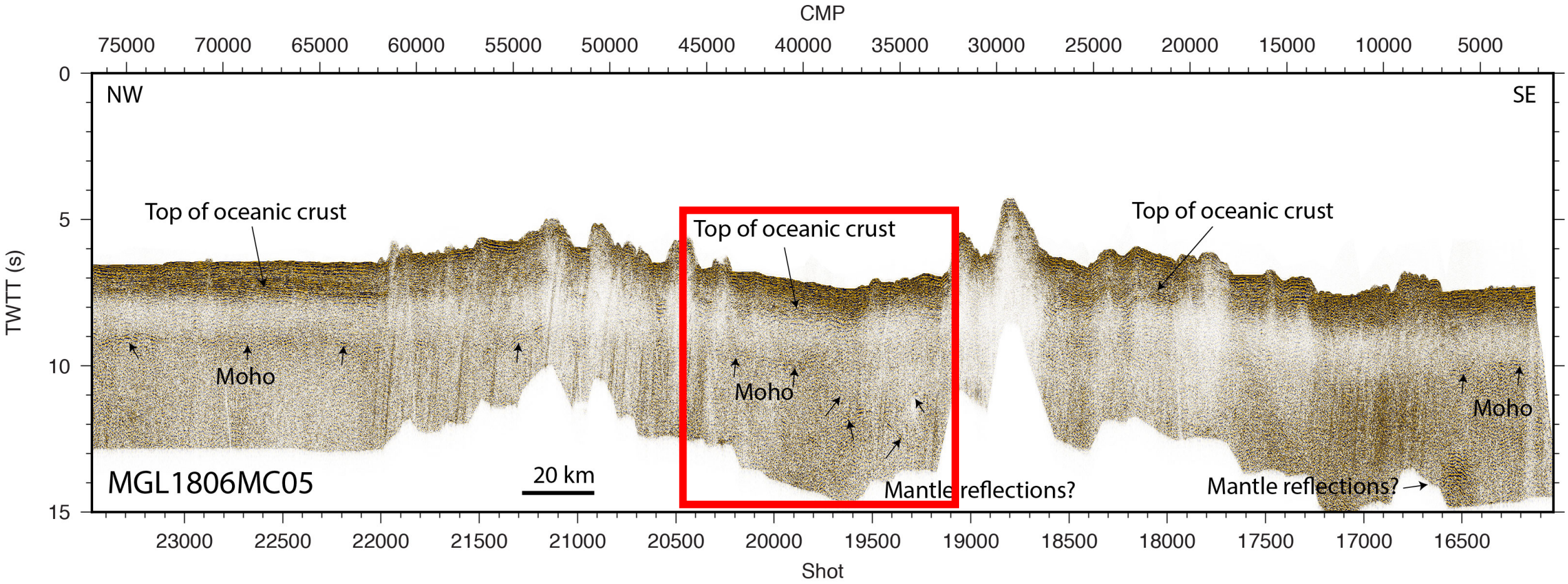
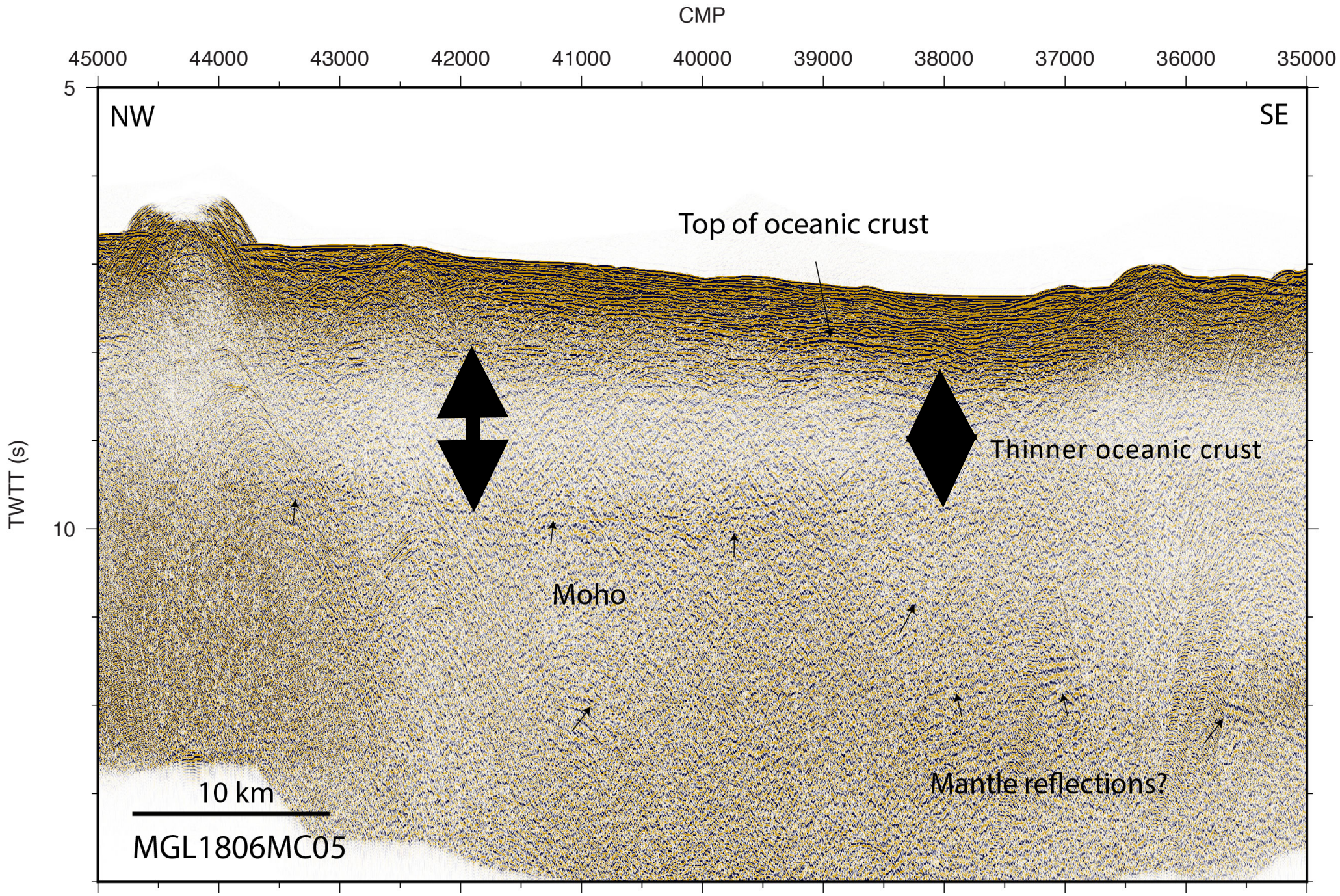
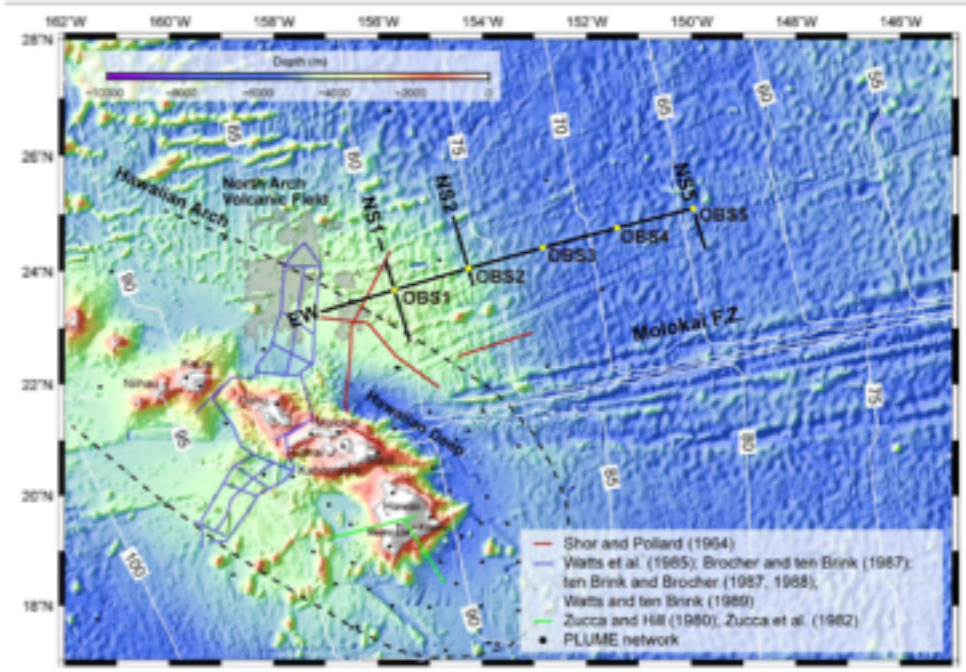

160°W
158°W
156°W
154°W
24°N
22°N
20°N
18°N
Line 2
Line 6
Line 8
Line 5
Line 1
Line 3
Line 4
Line 7
2017 Karei
1982 Conrad
ODP Site1223
ODP Site 842
ODP Site 843
Kilauea
RAPID OBS
Molokai F.Z.
Molokai F.Z.
-4000
0
4000
Bathymetry/Elevation (m)

Image the top and base of the oceanic crust around Hawaii




CMP
45000
44000
43000
42000
41000
40000
39000
38000
37000
36000
35000
5
10
TWTT (s)
NW
SE
Top of oceanic crust
Thinner oceanic crust
Moho
Mantle reflections?
10 km
MGL1806MC05

Imaging of mantle reflections farther offshore by wide-angle data acquired by R/V Karei



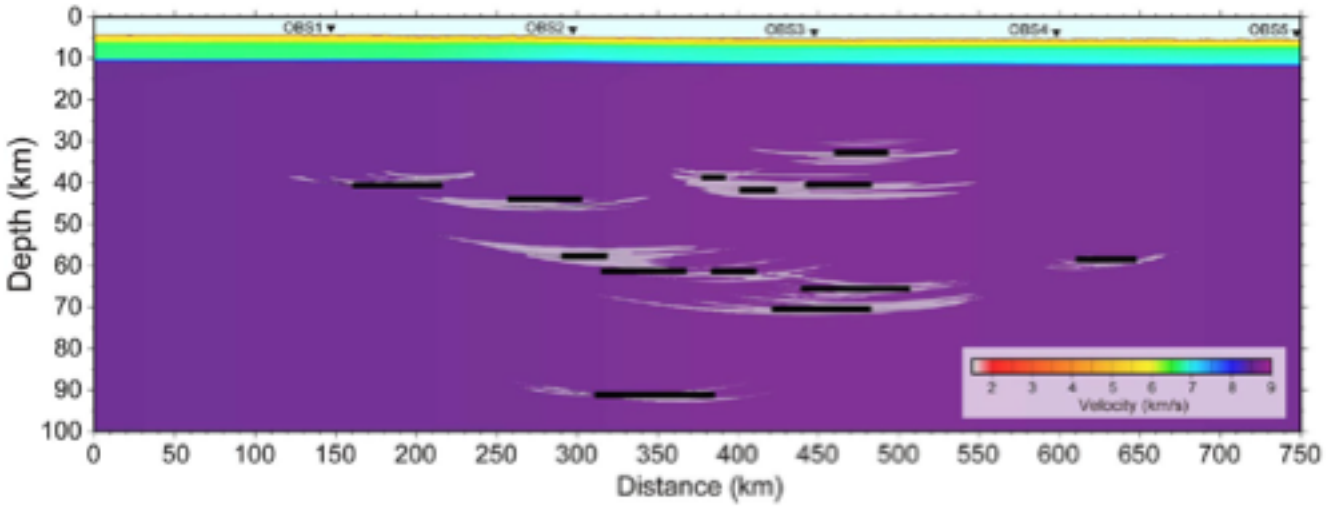
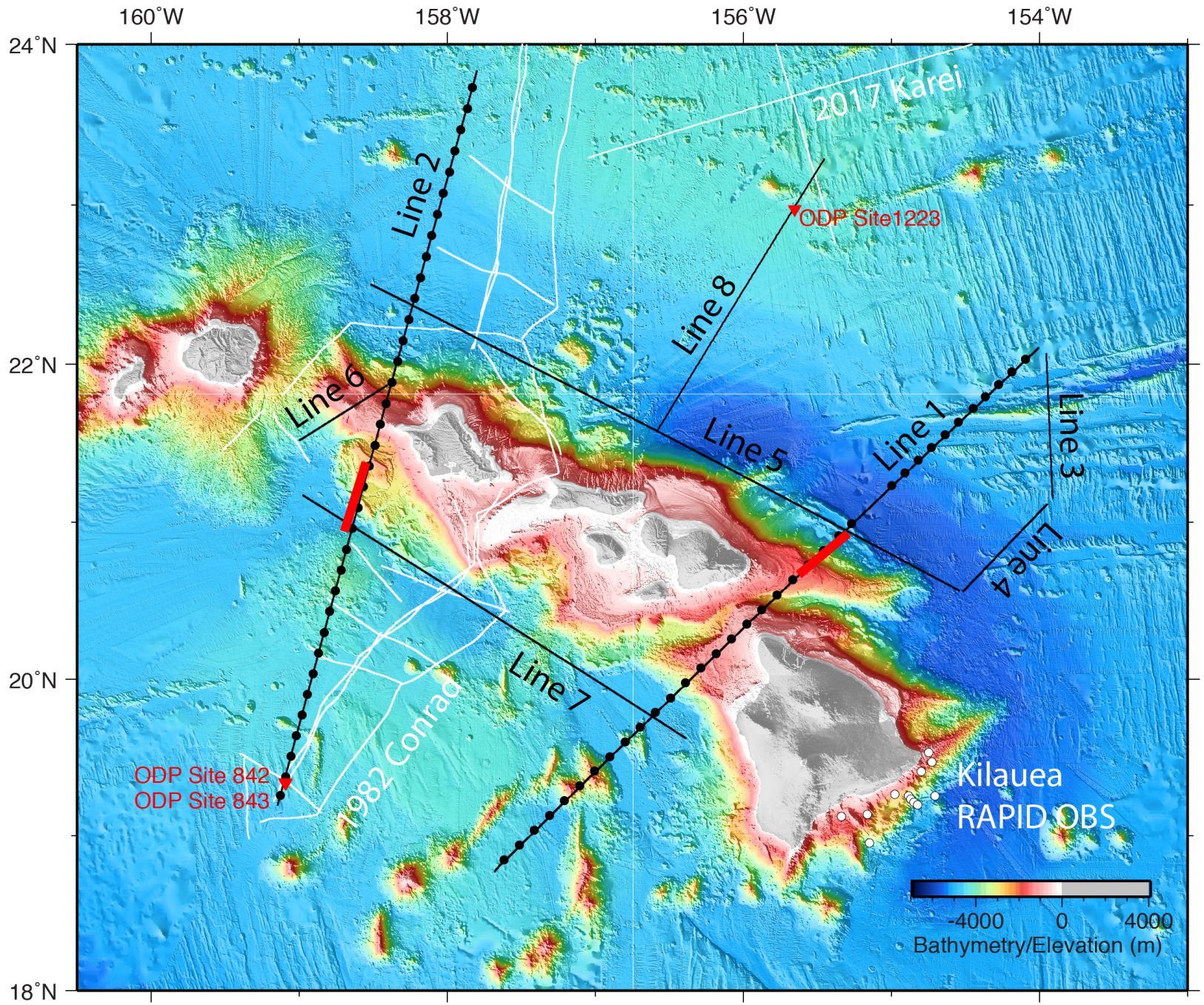
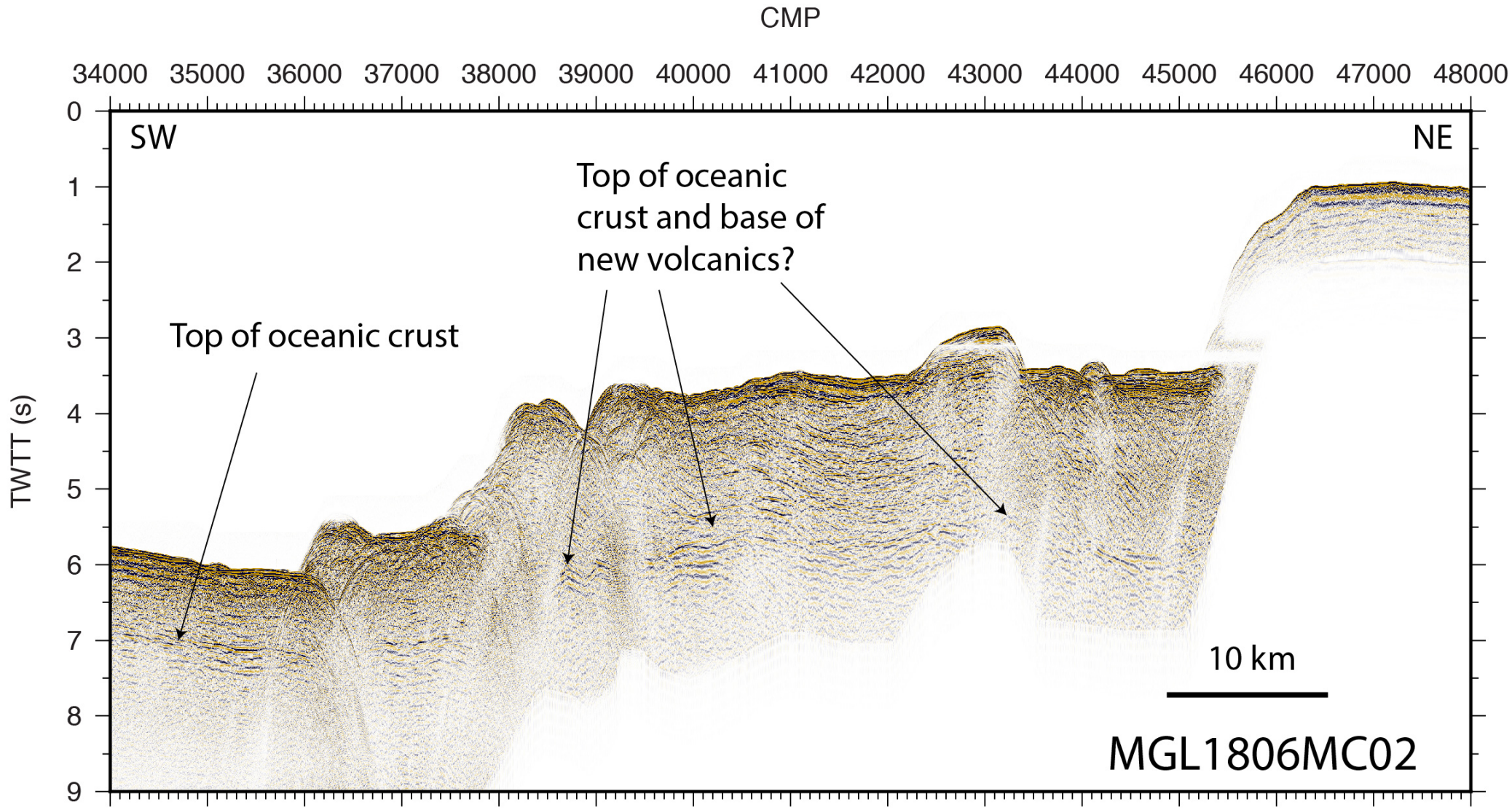


Fig. 13 Results of the travel time mapping and ray tracing for the DRs shown in Figs. 10, 11, and 12. The background *P*-wave velocity model was used to determine reflection travel time picks. Diffraction surfaces are shown as white curves. Black bars indicate reflection points for the DRs on all OBS records

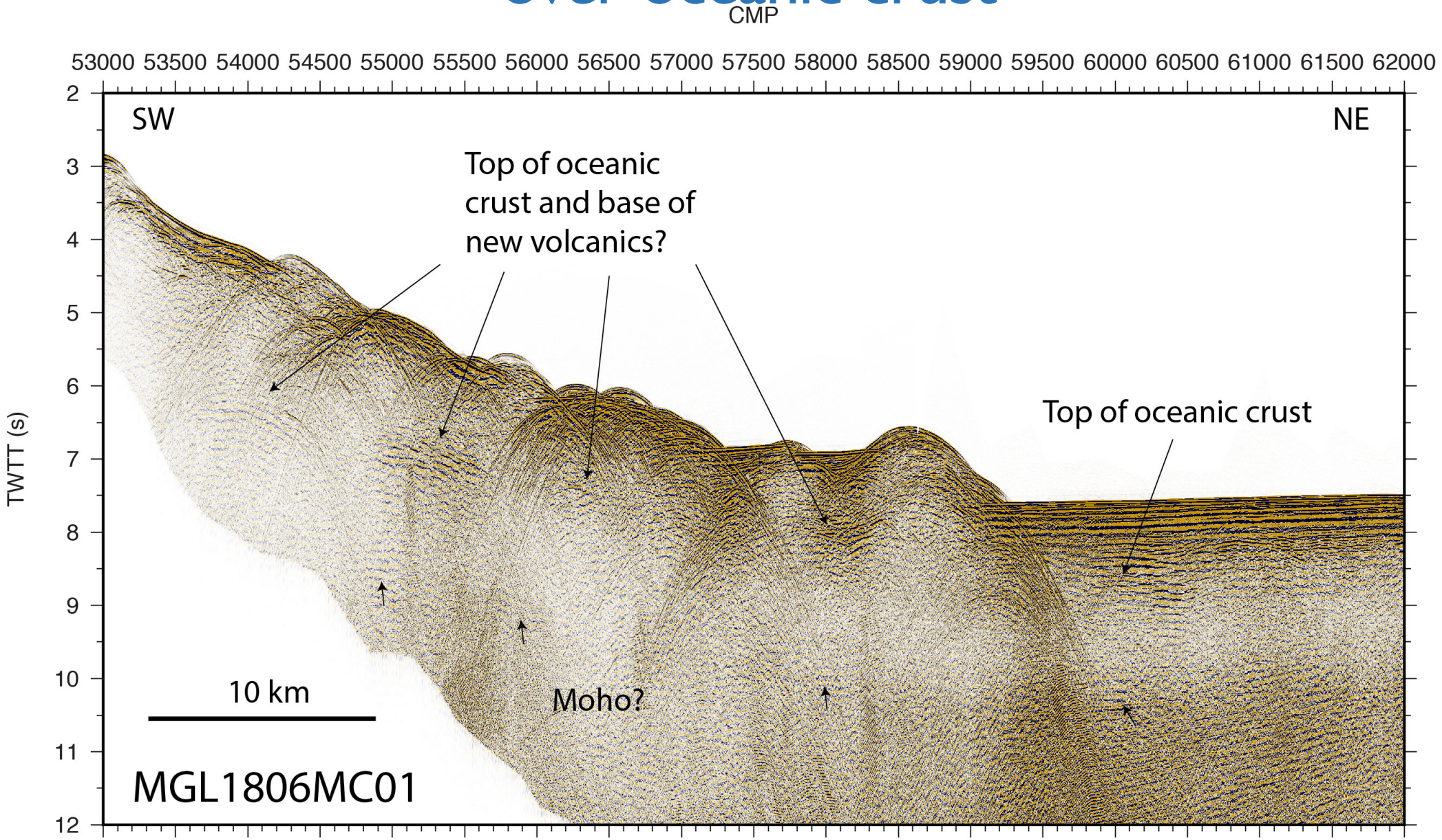
Ohira et al, 2018


160˚W
158˚W
156˚W
154˚W
24˚N
22˚N
20˚N
18˚N
2017 Karei
Line 2
ODP Site1223
Line 8
Line 6
Line 5
Line 1
Line 3
Line 4
Line 7
1982 Conrad
ODP Site 842
ODP Site 843
Kilauea
RAPID OBS
-4000
0
4000
Bathymetry/Elevation (m)

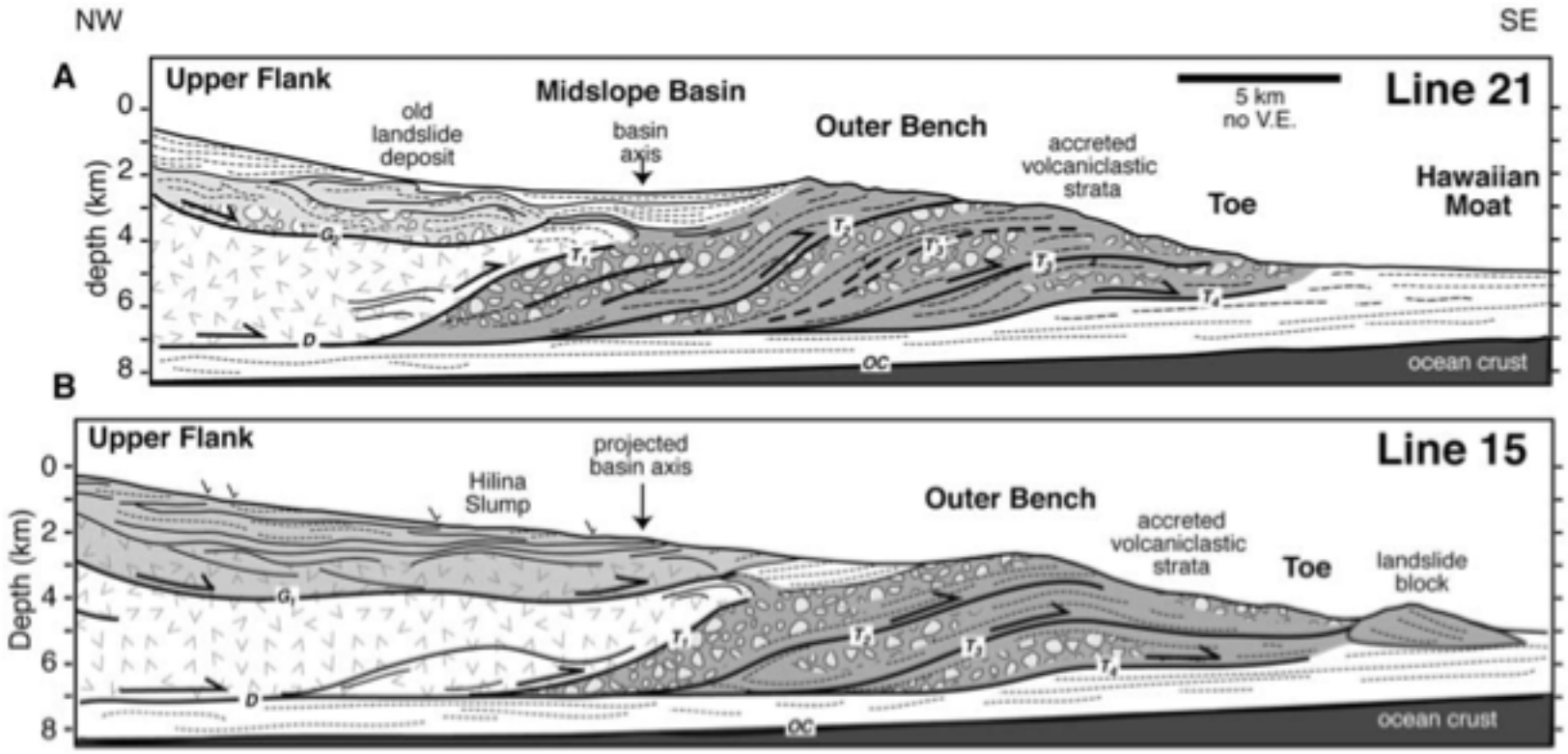
Images of decollement where volcano growing out over oceanic crust



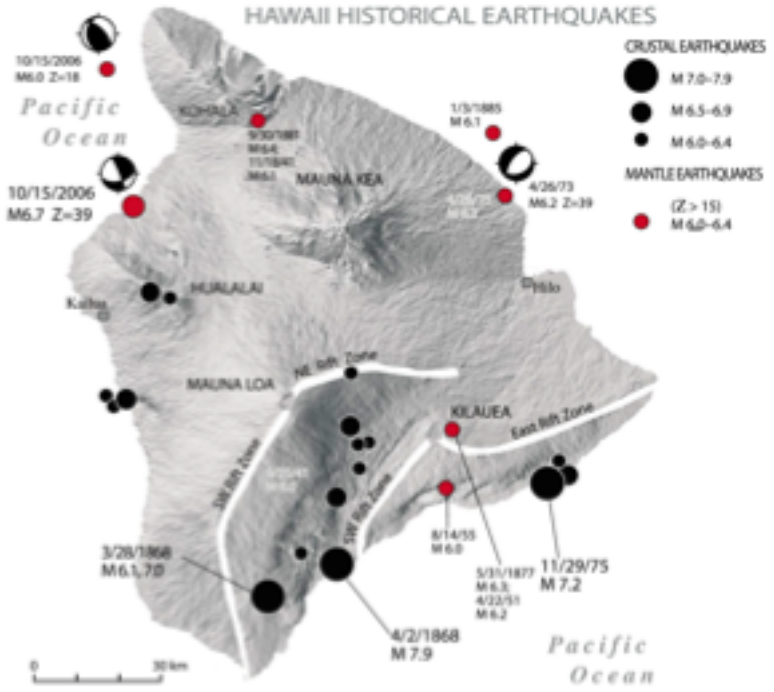
Images of decollement where volcano growing out over oceanic crust



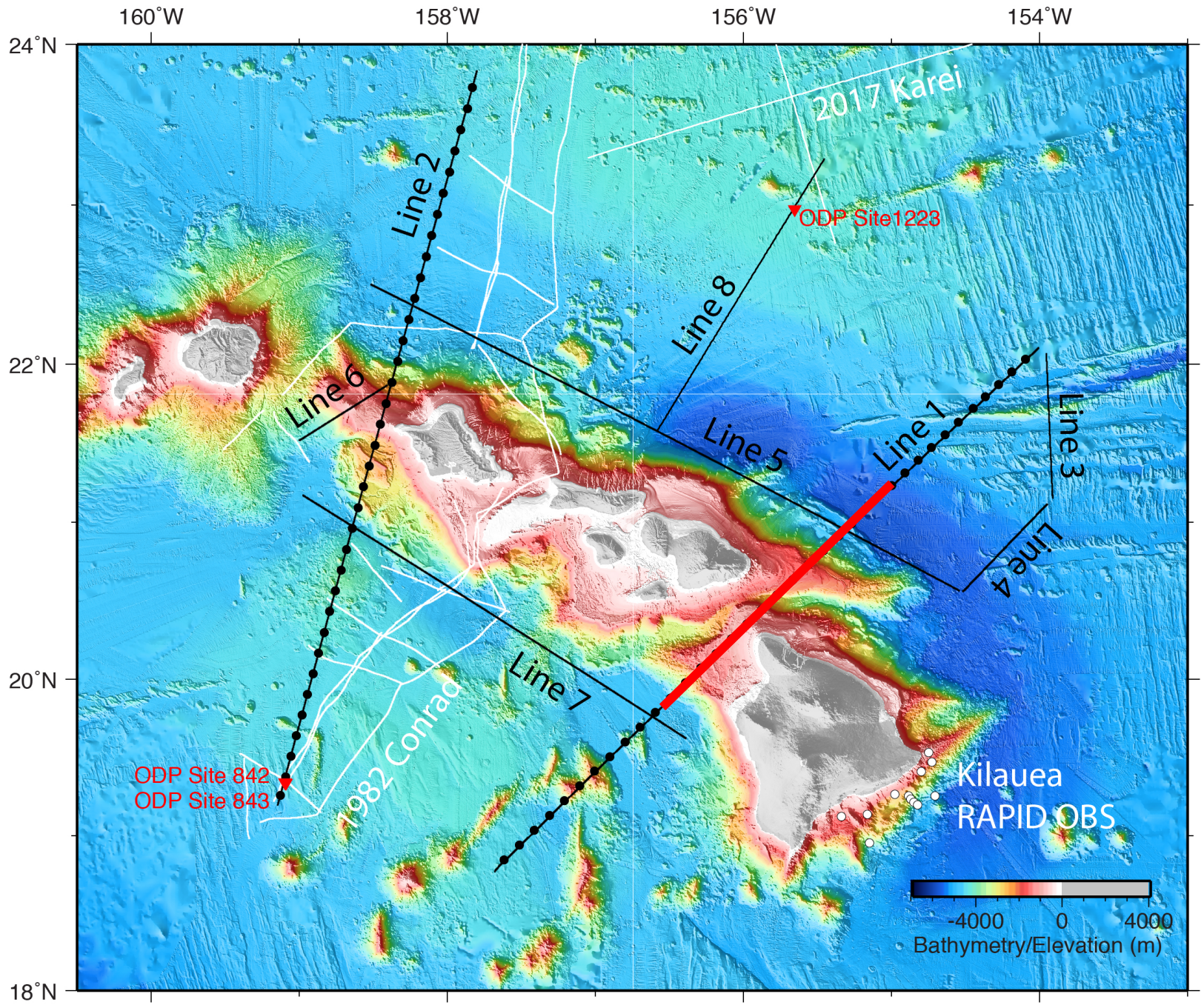
Volcanic spreading, landslides and earthquakes at edges of volcanic islands



Morgan et al., 2003



Klein, 2016


160˚W
158˚W
156˚W
154˚W
24˚N
22˚N
20˚N
18˚N
2017 Karei
Line 2
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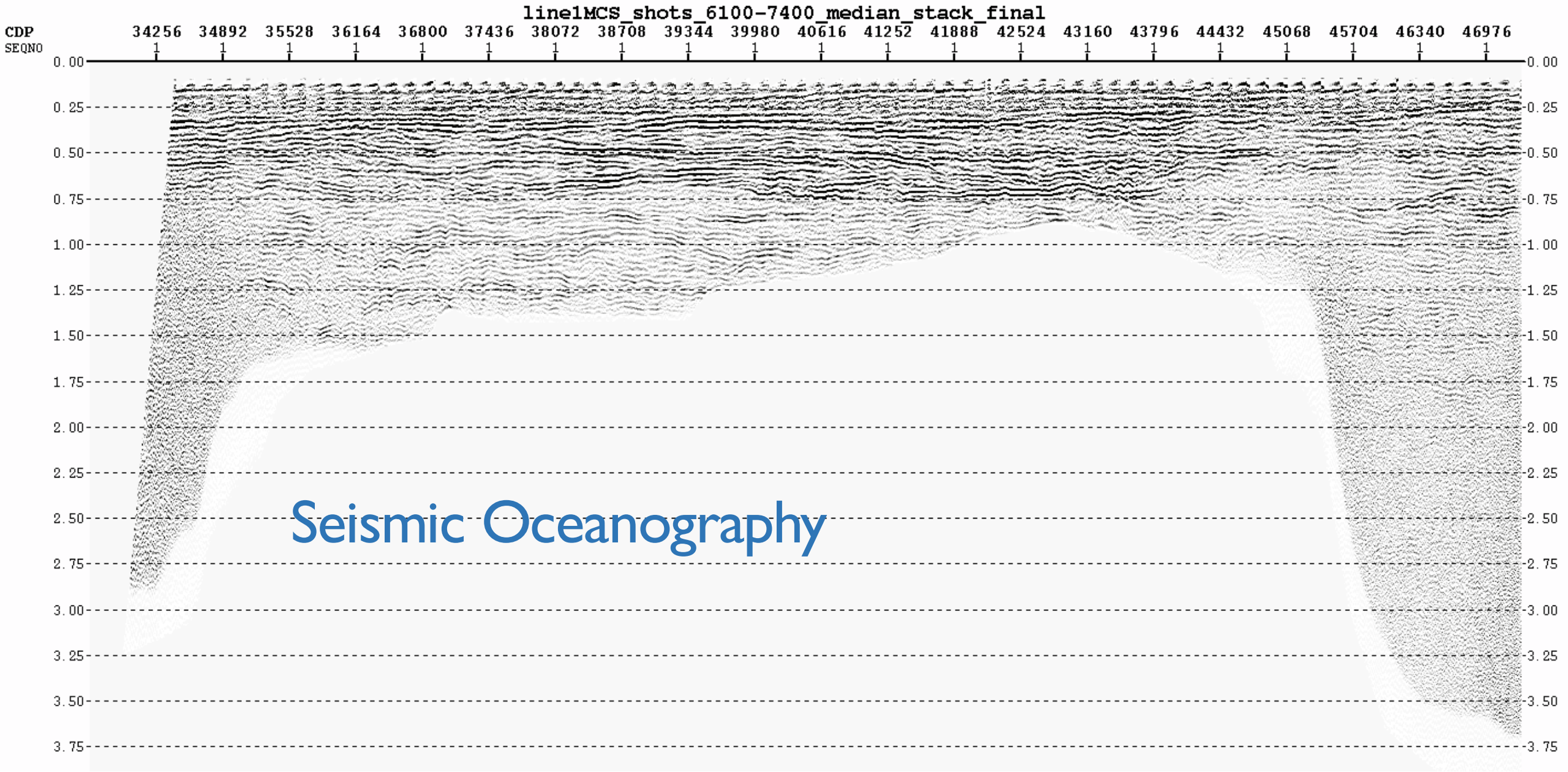
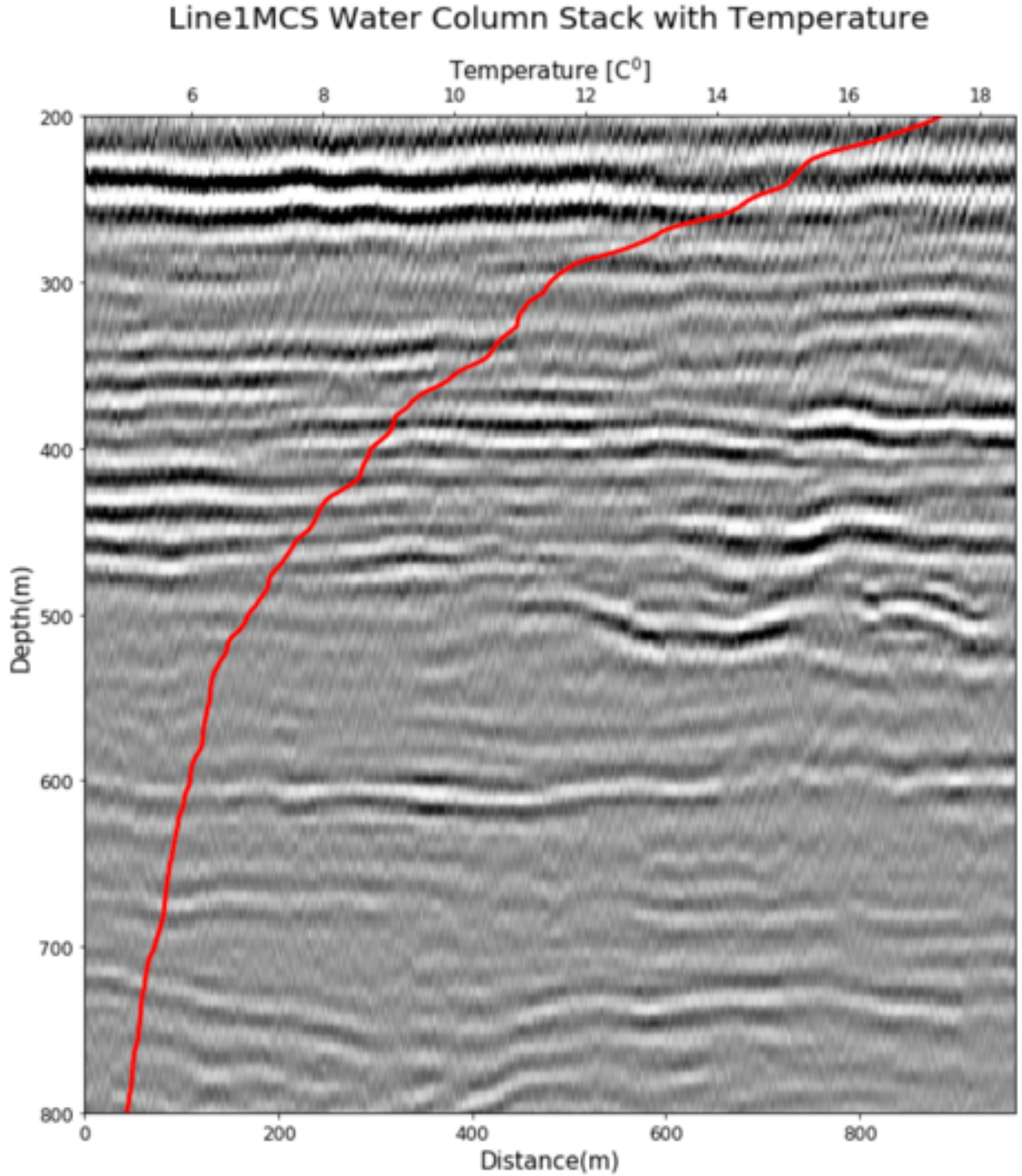
1982 Conrad
ODP Site 842
ODP Site 843
Kilauea
RAPID OBS
-4000
0
4000
Bathymetry/Elevation (m)

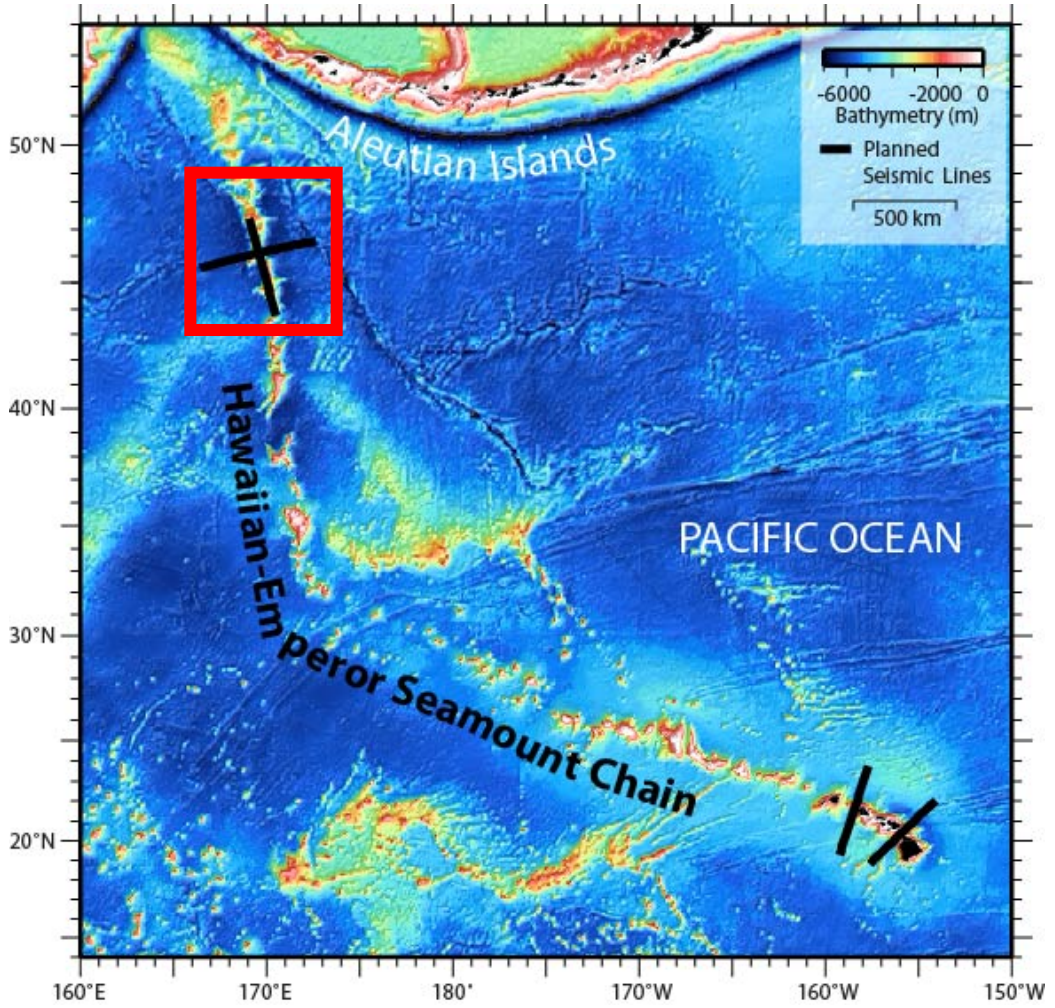


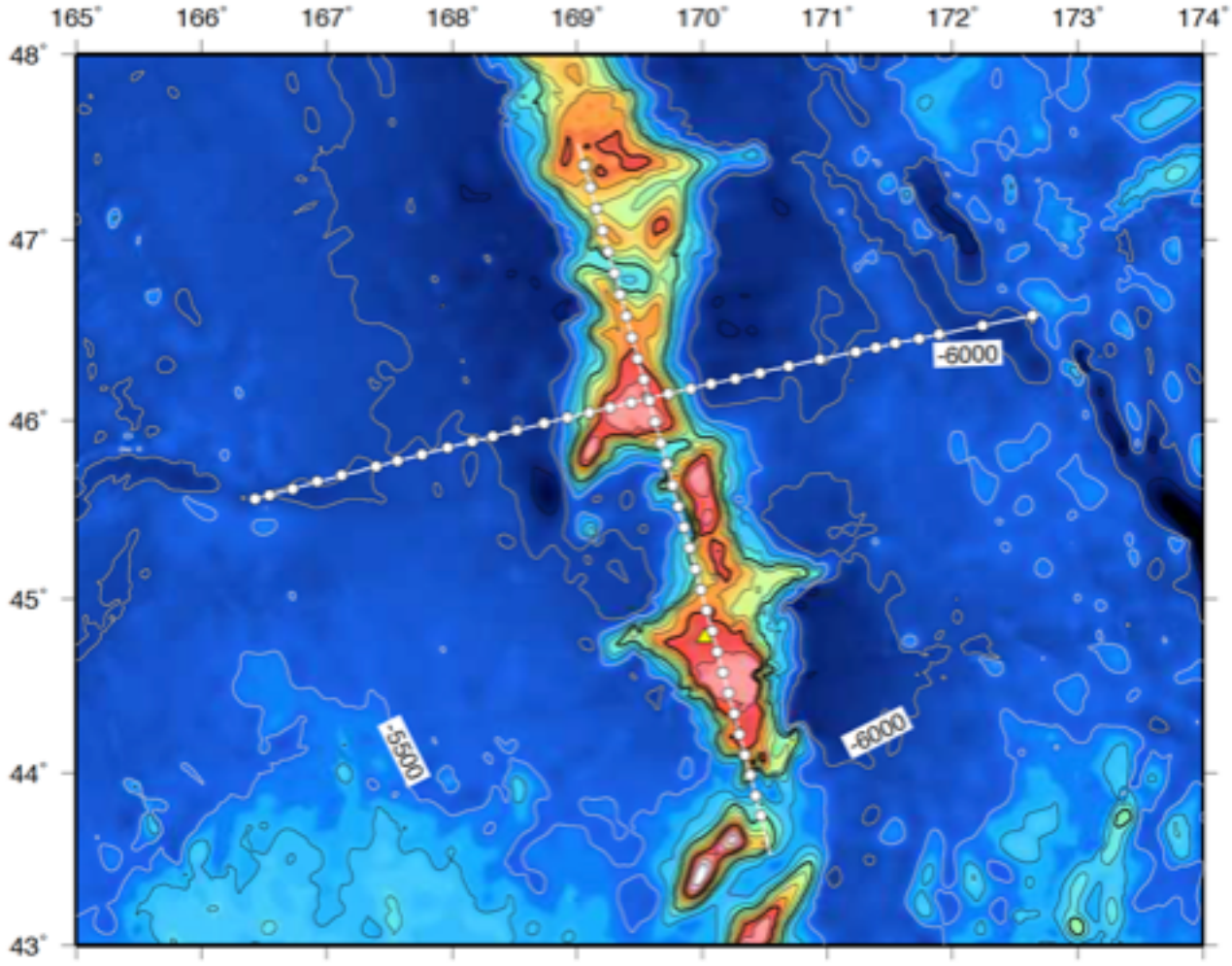
Processed by Jingxuan Wei



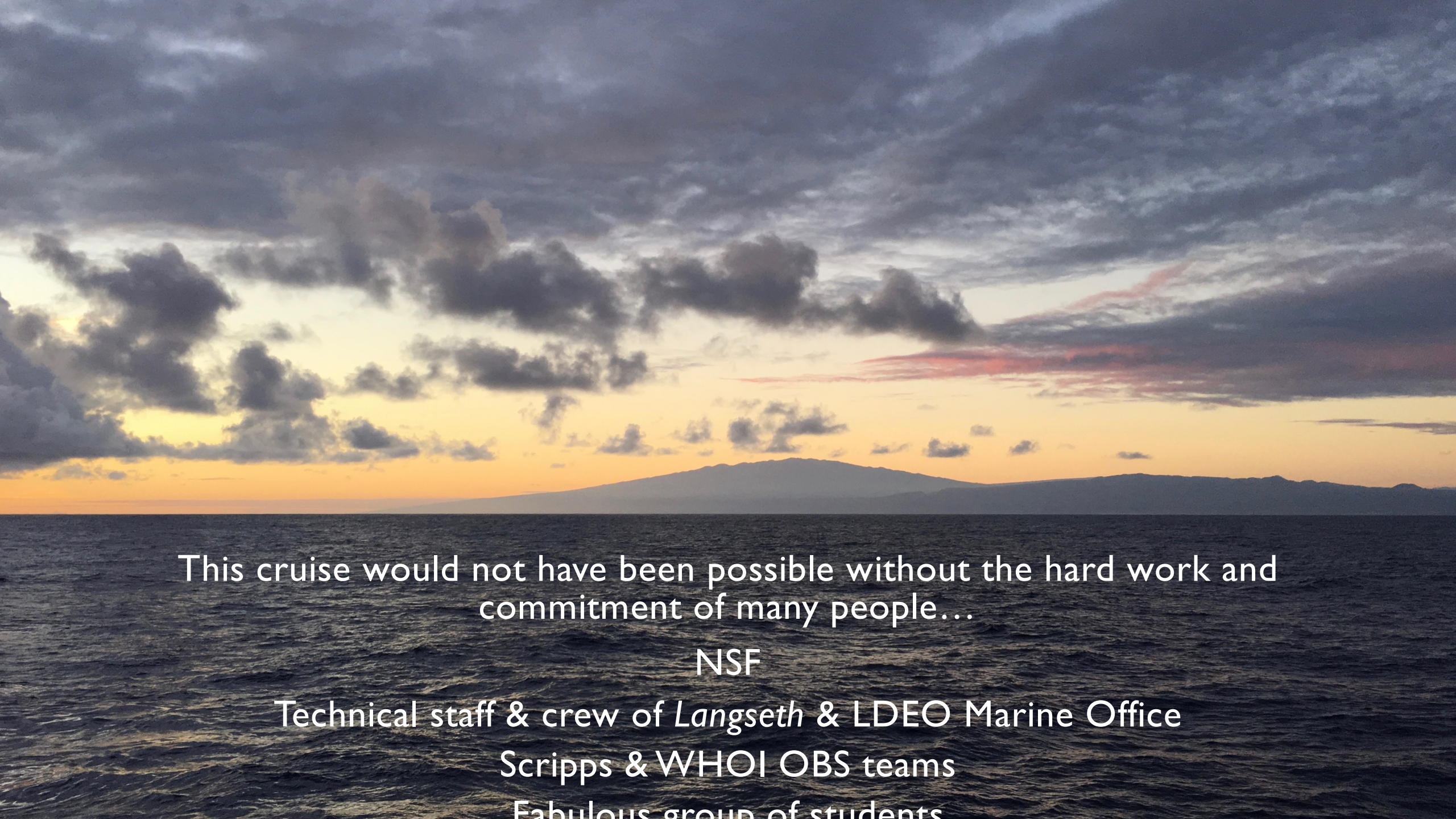
Courtesy of Jingxuan Wei

Spring 2019: Emperor Seamount Chain





Older part of the Hawaiian-Emperor Seamount Chain, where volcanoes originally formed on a plate that was much younger at the time



This cruise would not have been possible without the hard work and commitment of many people…

NSF

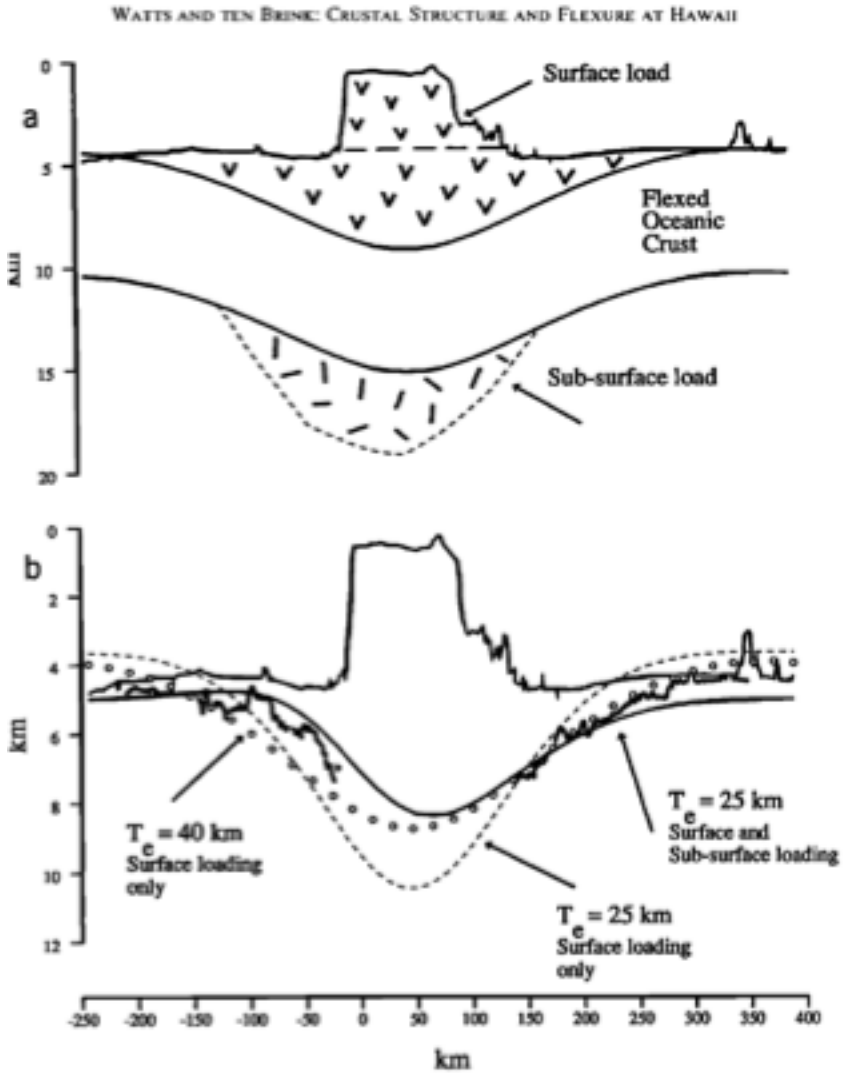
Technical staff & crew of *Langseth* & LDEO Marine Office

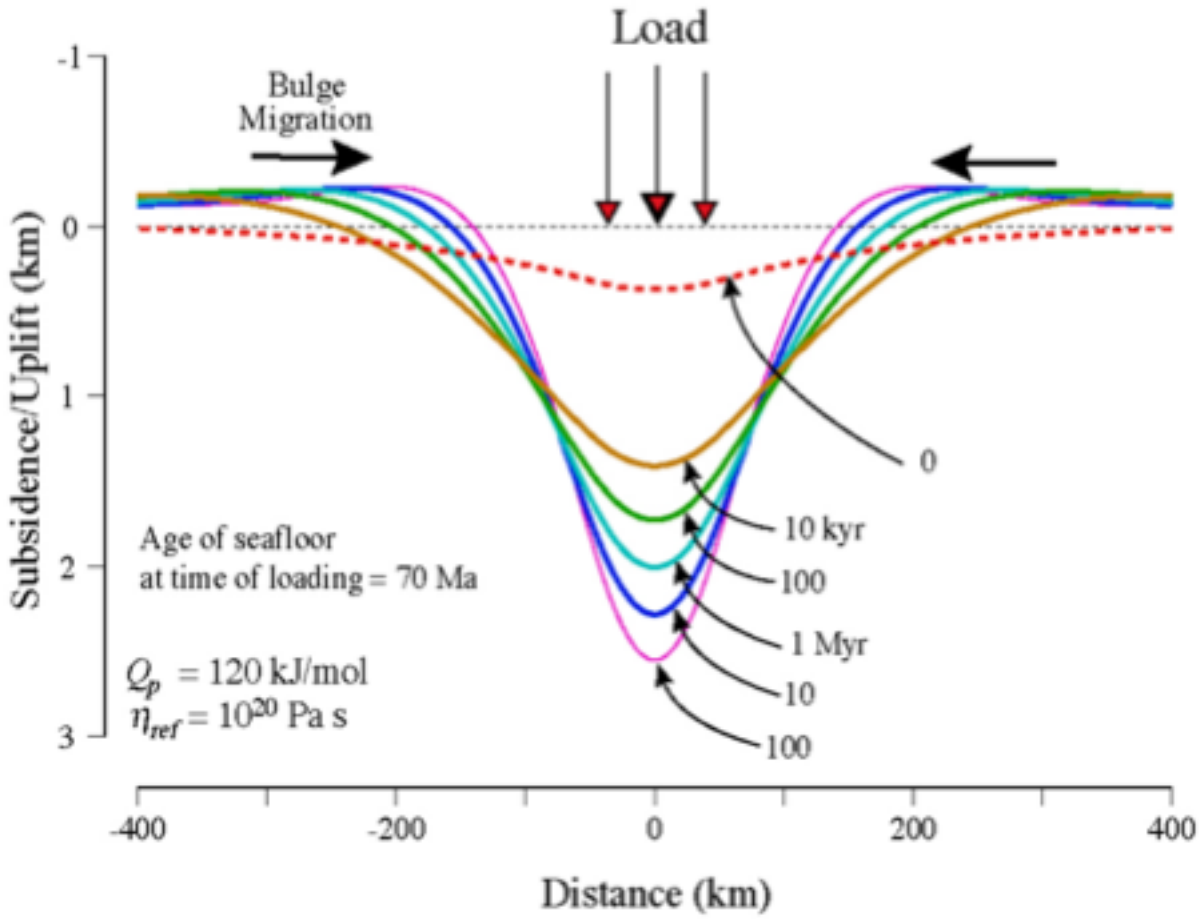
Scripps & WHOI OBS teams

Fabulous group of students

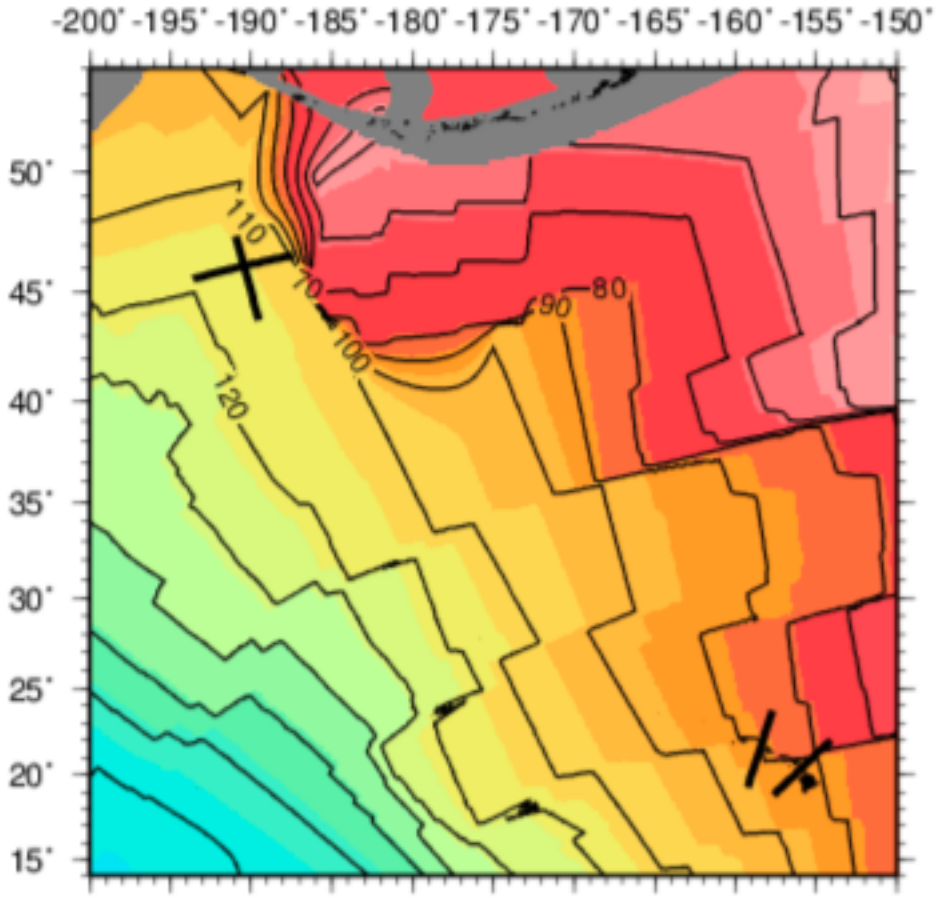
Extra slides

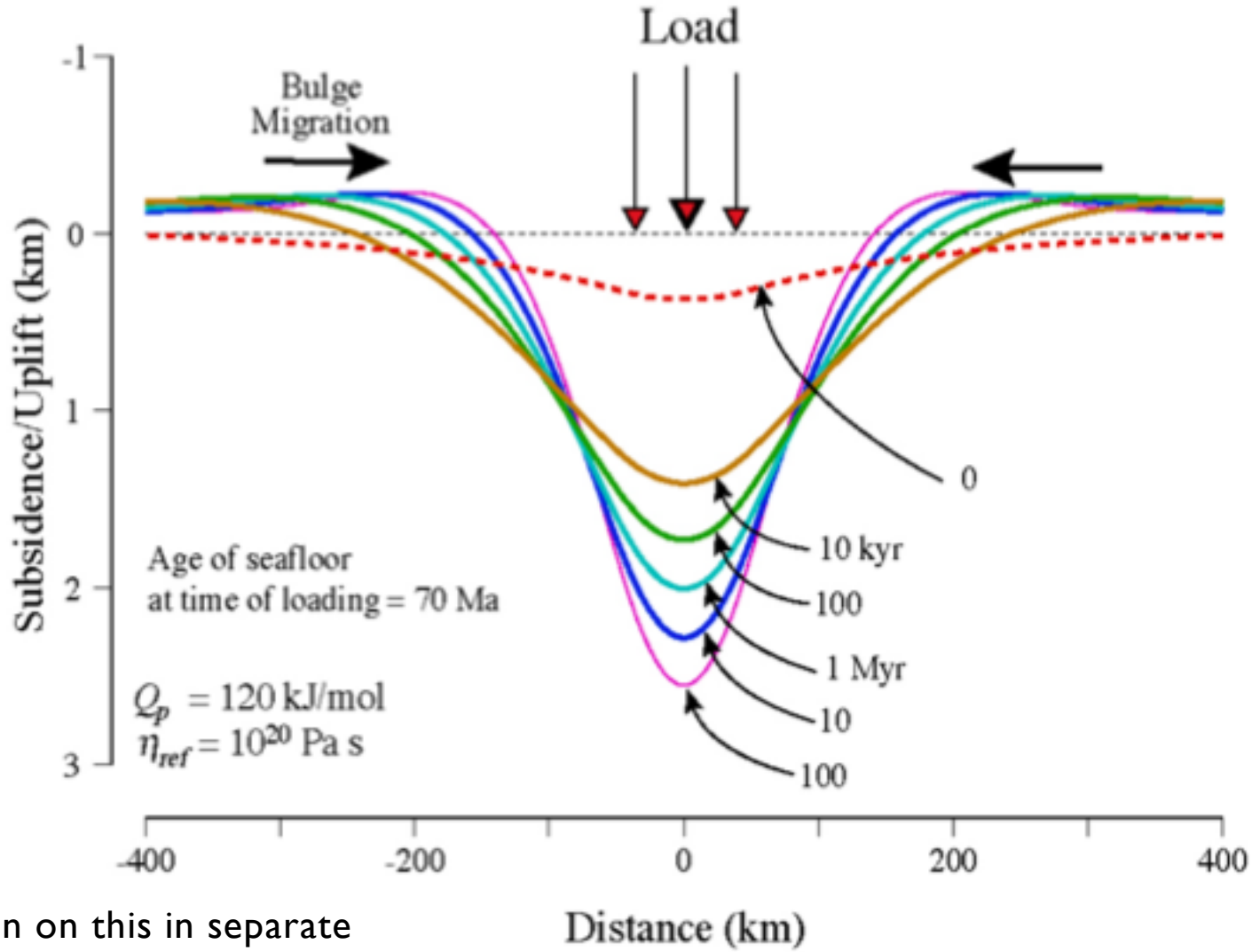
What is the strength of the lithosphere and how does it change with time?





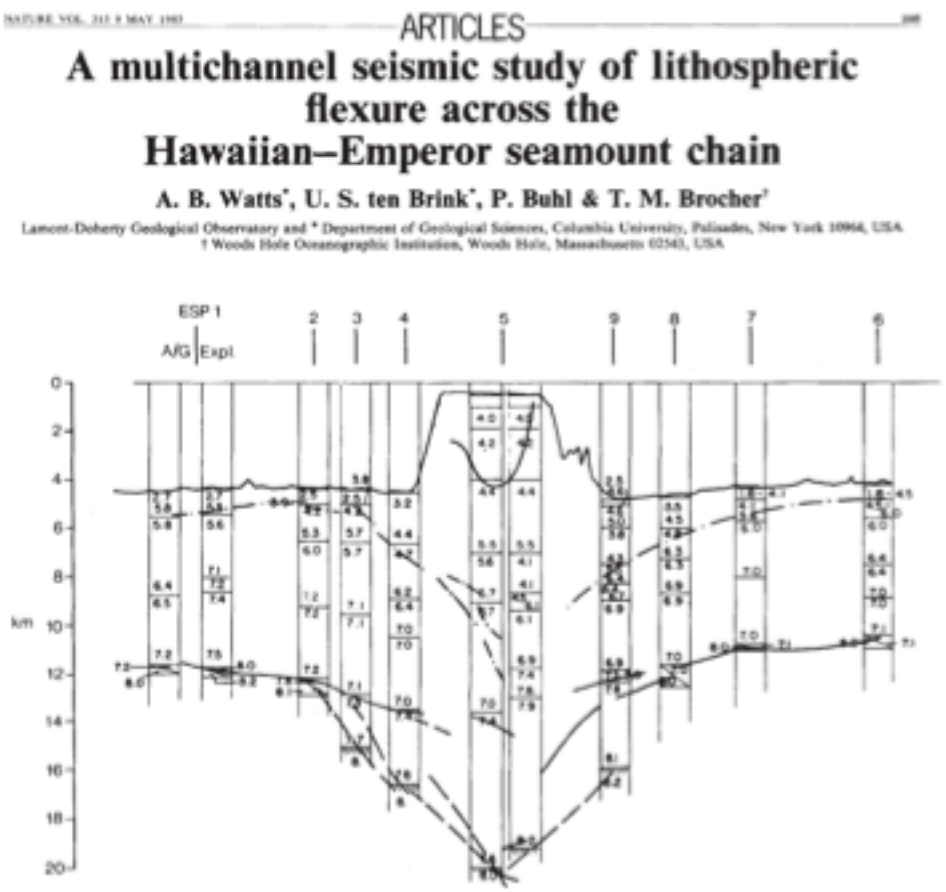
Temporal variations in lithospheric flexure beneath a load





More soon on this in separate presentation from Tony!

What is distribution of magmatic intrusions and underplating beneath Hawaii?



ARTICLES

A multichannel seismic study of lithospheric flexure across the Hawaiian–Emperor seamount chain

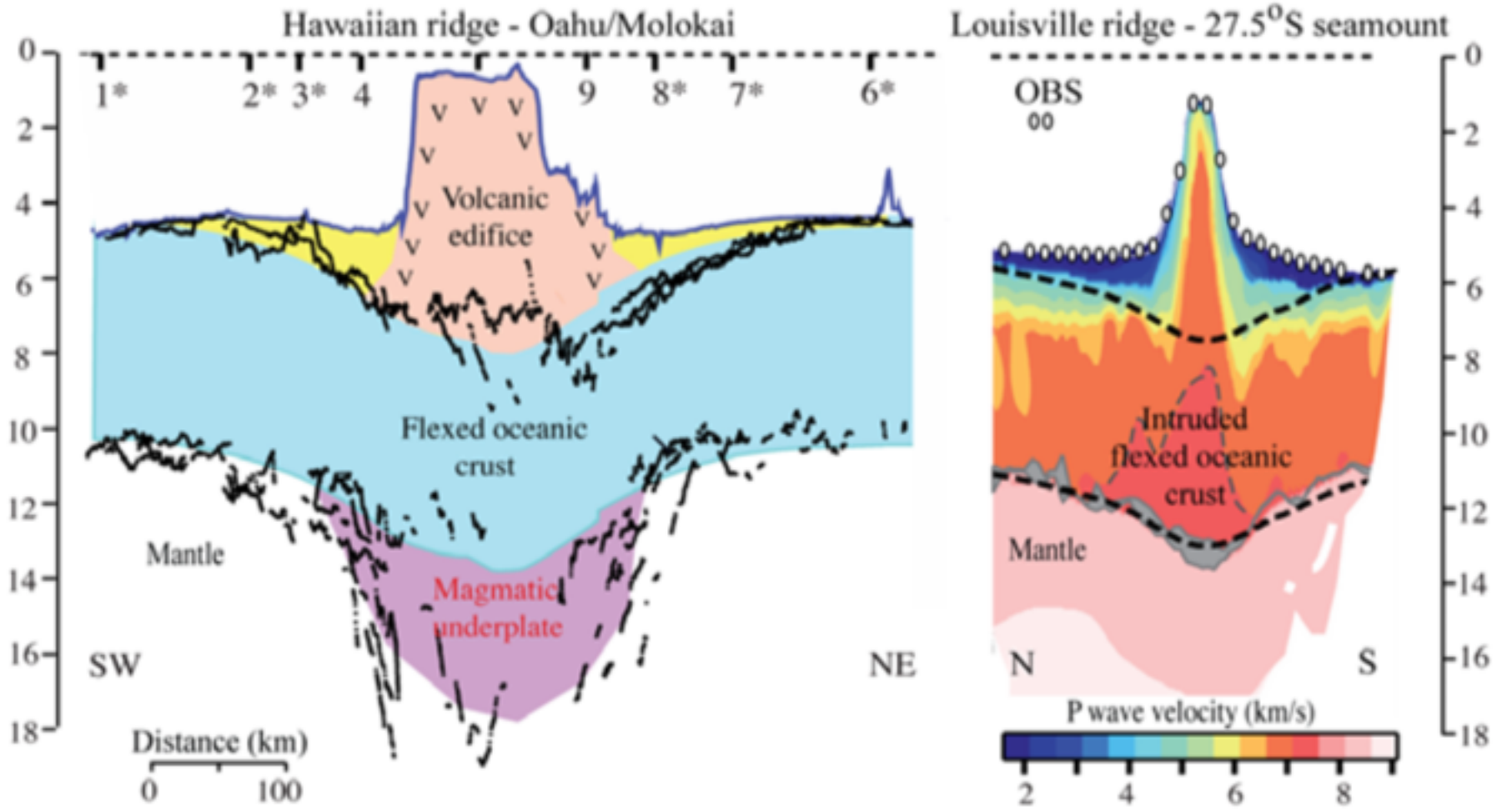
A. B. Watts*, U. S. ten Brink*, P. Buhl & T. M. Brocher†

Lamont-Doherty Geological Observatory and * Department of Geological Sciences, Columbia University, Palisades, New York 10964, USA
† Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA

Watts et al., Nature, 1985

Reflection imaging and expanding spread profiles indicate highly localized underplating beneath Hawaii volcanic chain.

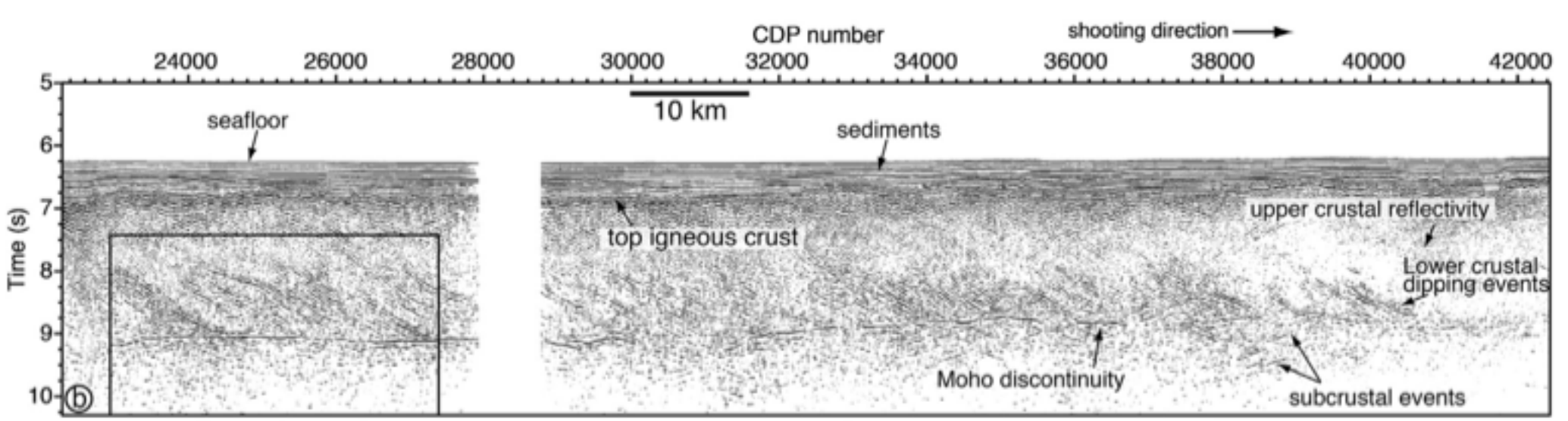
What is distribution of magmatic intrusions and underplating beneath Hawaii?



Contreras-Reyes et al., 2010

Intrusions versus underplating?

Other science targets



Bécel et al, EPSL 2015

Structure of old oceanic crust

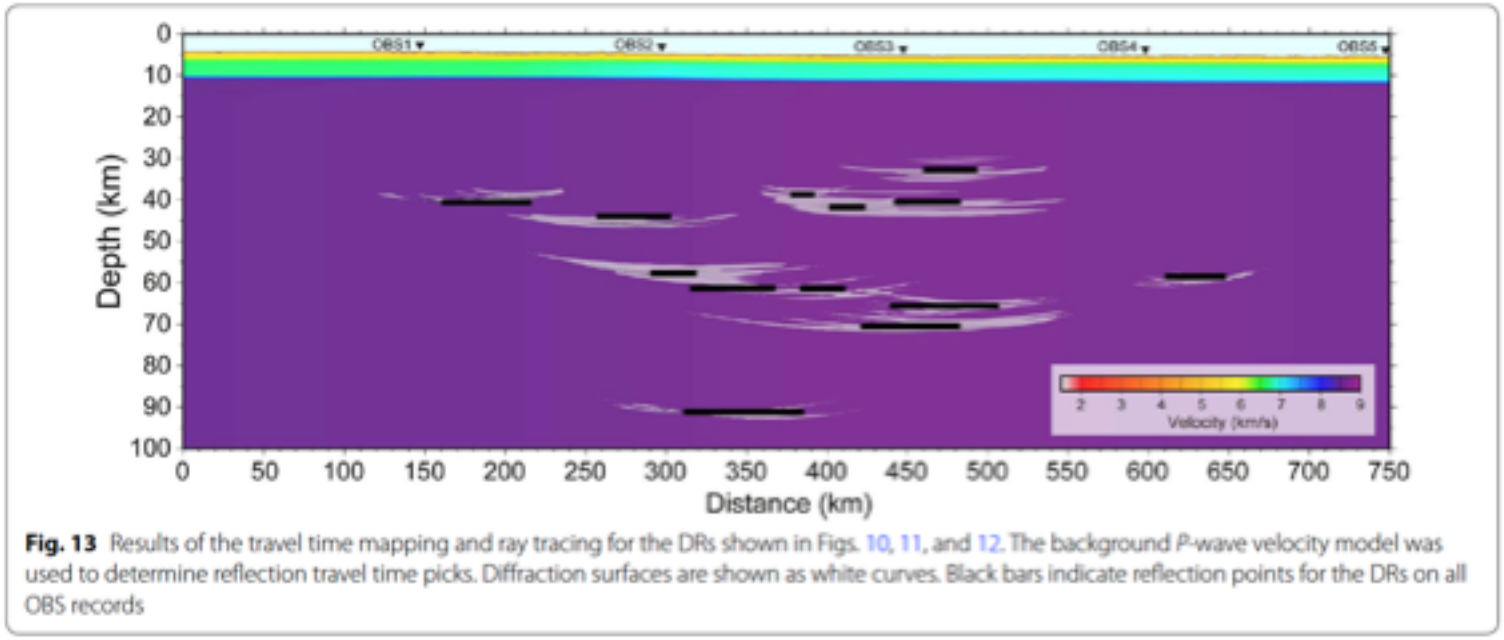
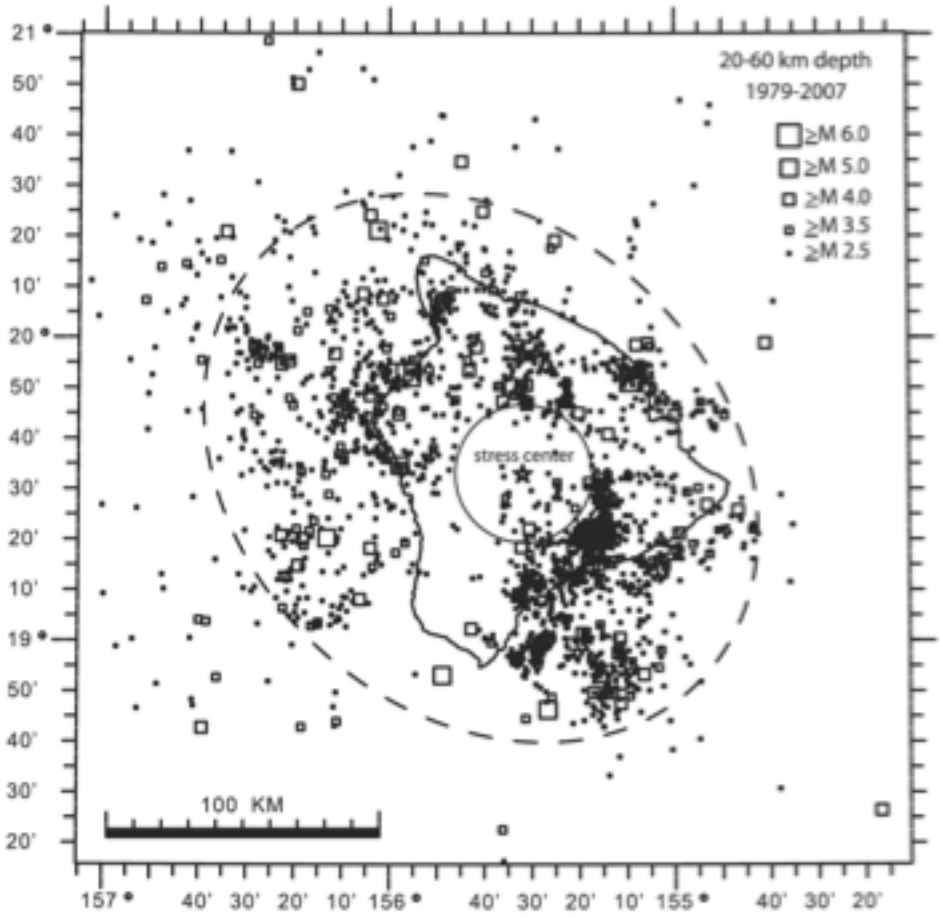


Fig. 13 Results of the travel time mapping and ray tracing for the DRs shown in Figs. 10, 11, and 12. The background *P*-wave velocity model was used to determine reflection travel time picks. Diffraction surfaces are shown as white curves. Black bars indicate reflection points for the DRs on all OBS records

Ohira et al, 2018

Reflections from within the lithosphere or from the base?

How does lithosphere bend and deform in response to load of island chain?



Klein, 2016

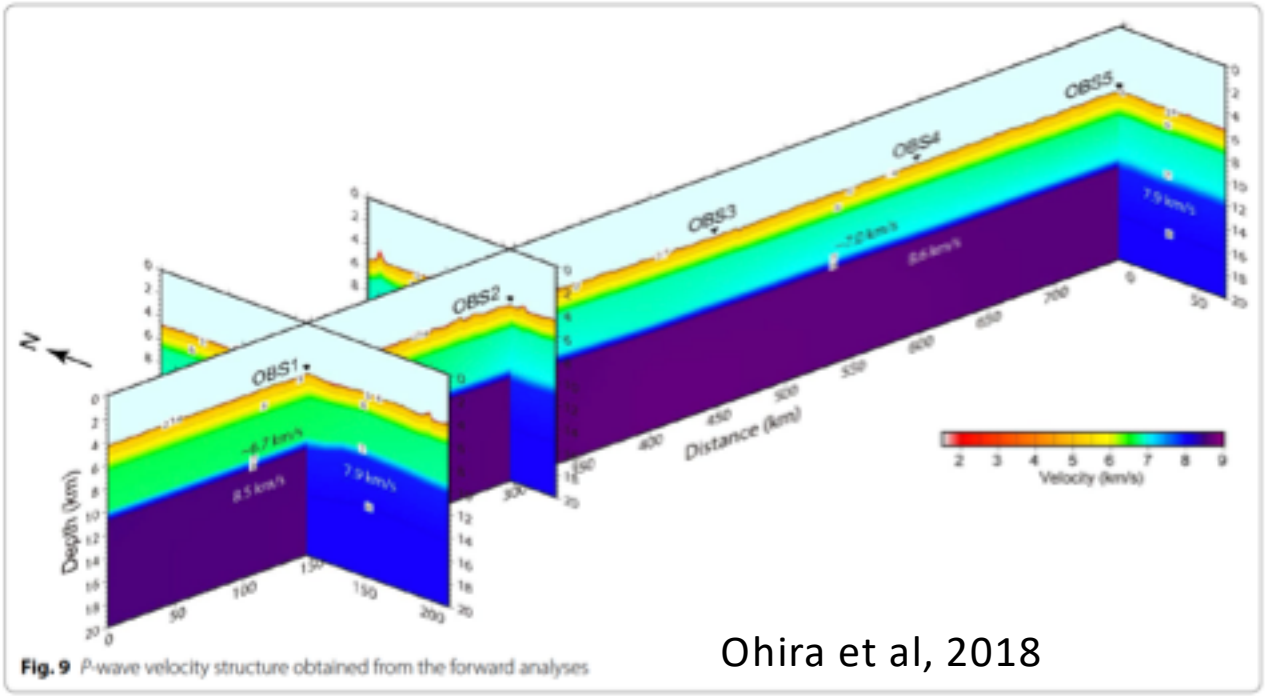
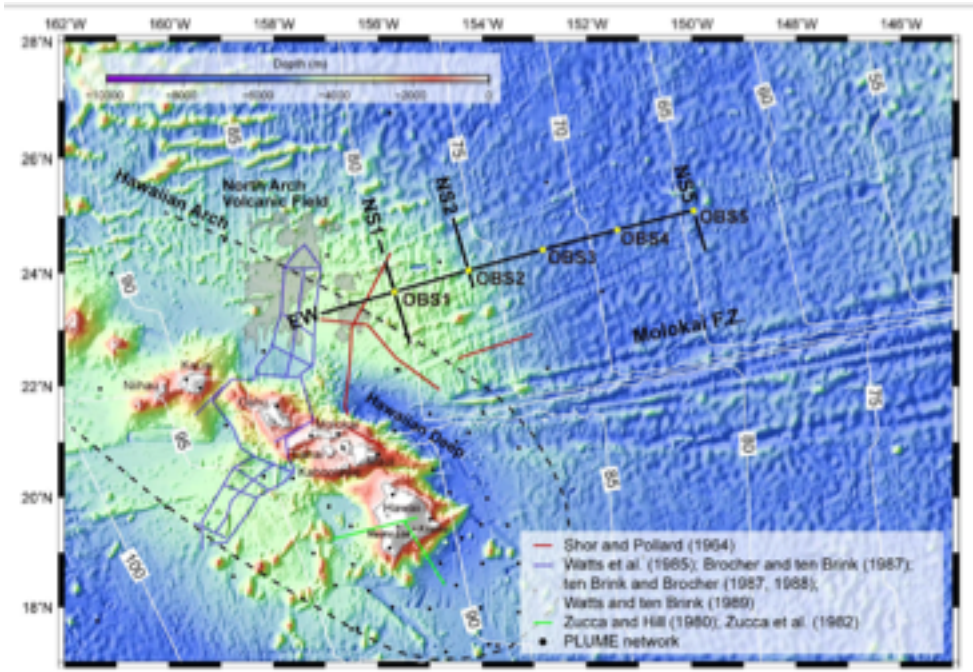
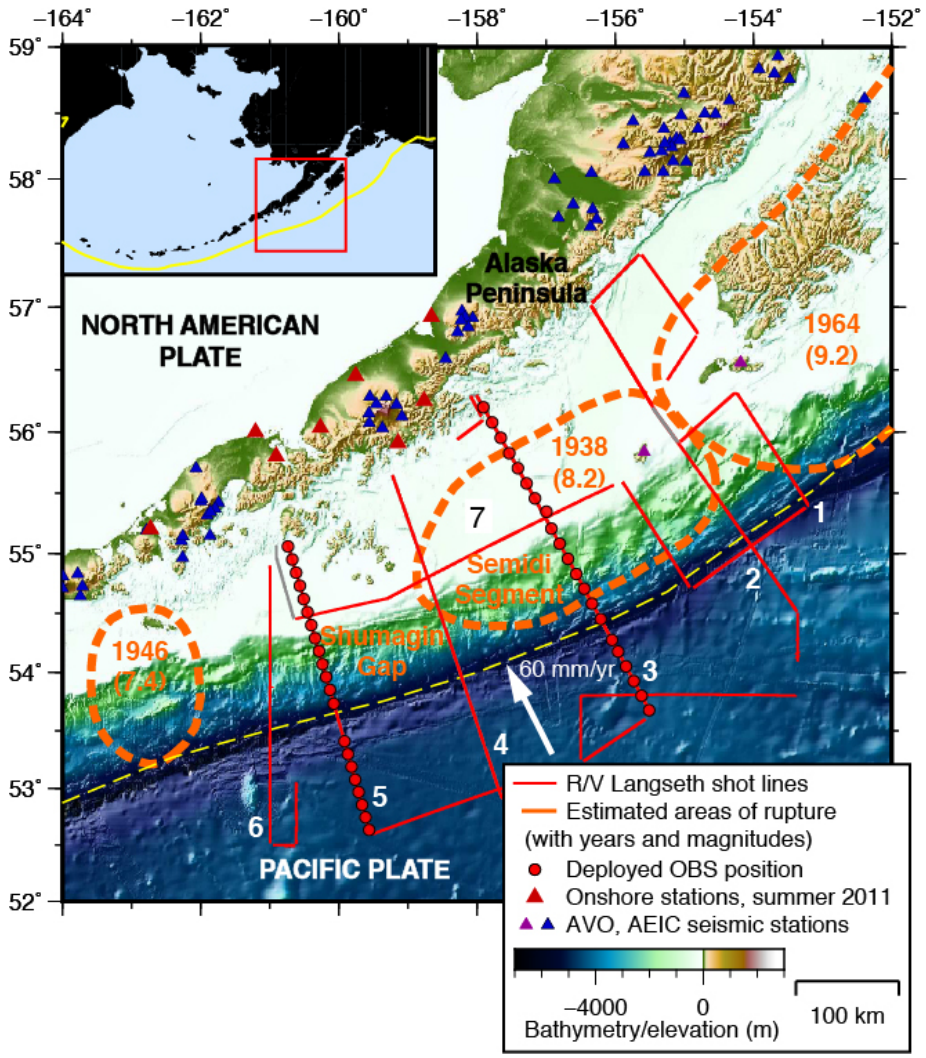


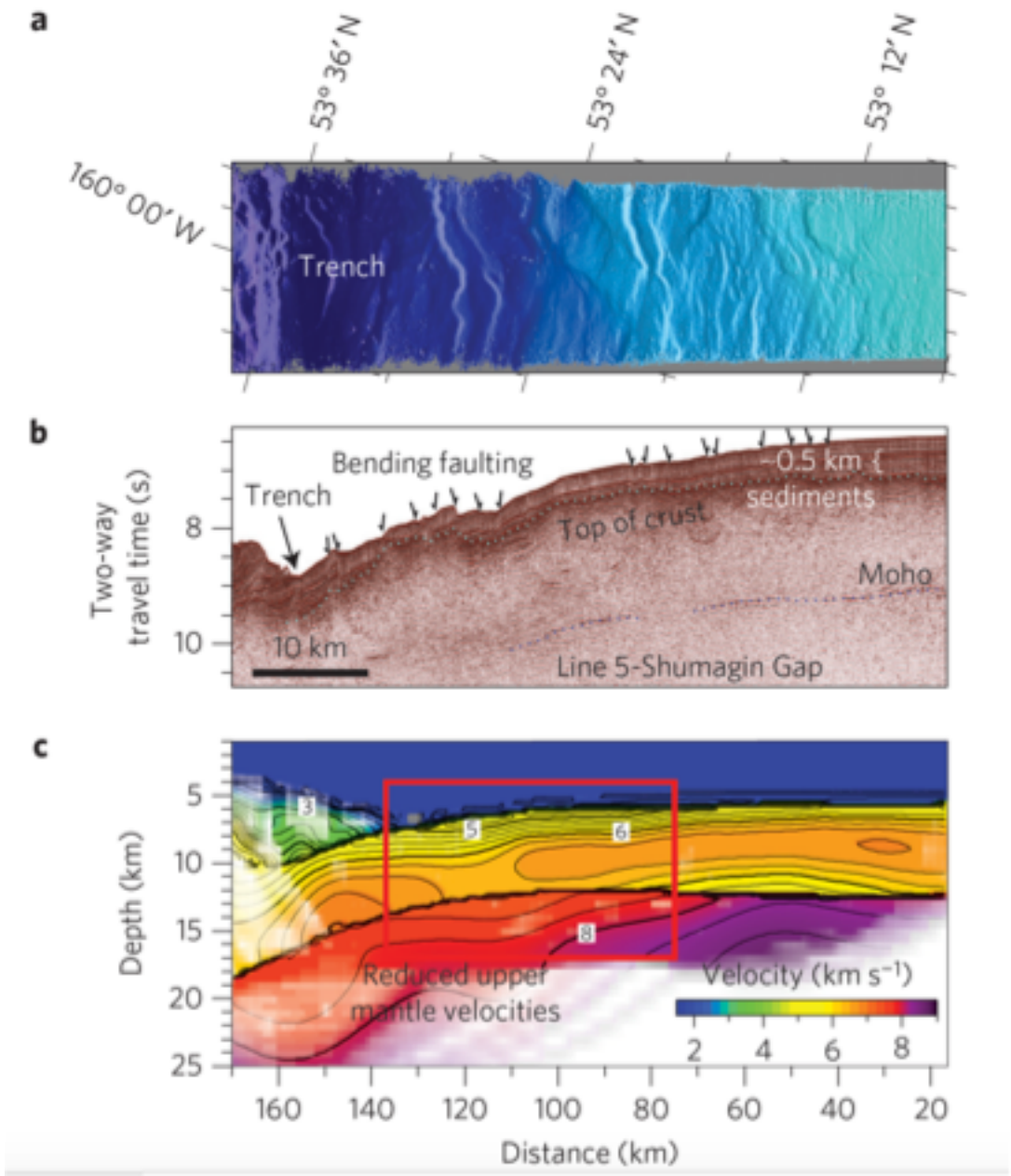
Fig. 9 *P*-wave velocity structure obtained from the forward analyses

Ohira et al, 2018



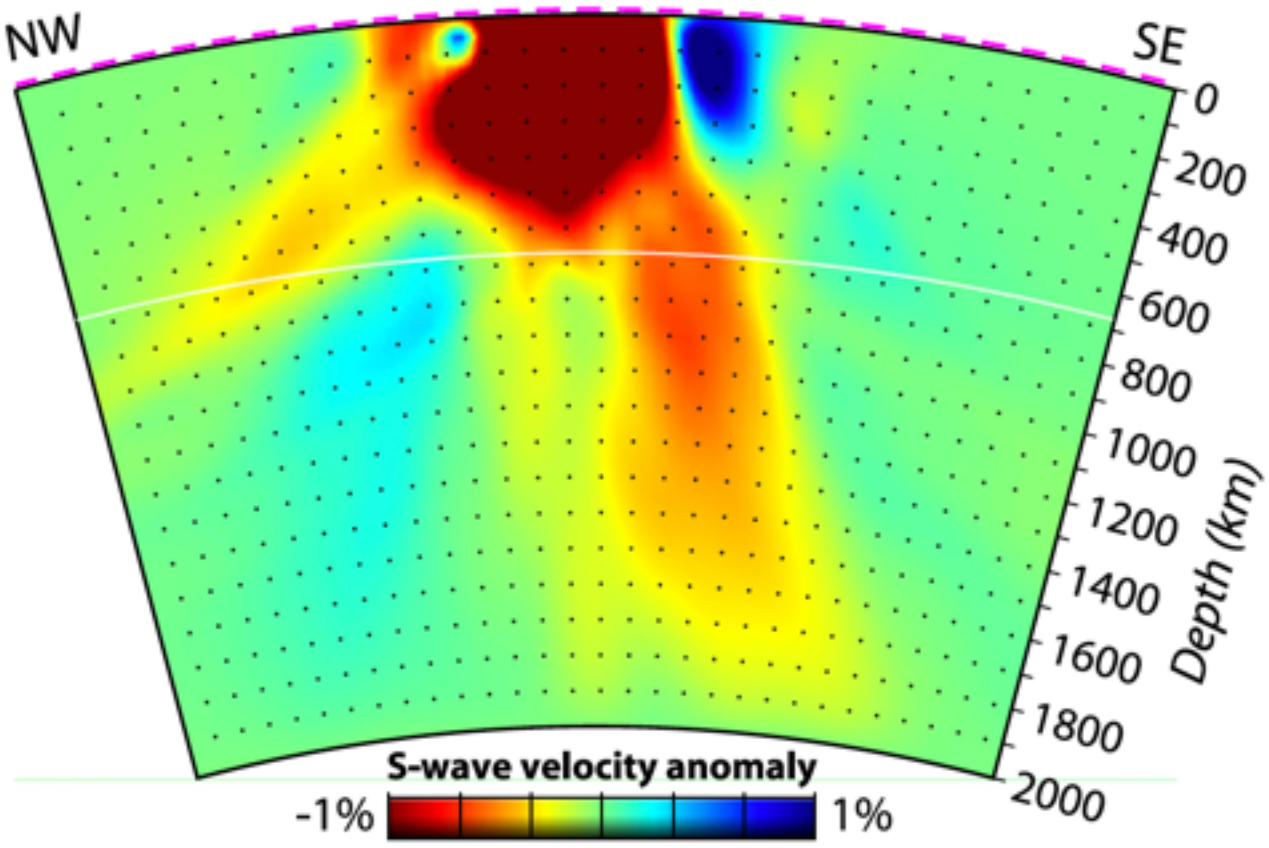
Comparison with bending/deformation of oceanic plates at subduction zones?



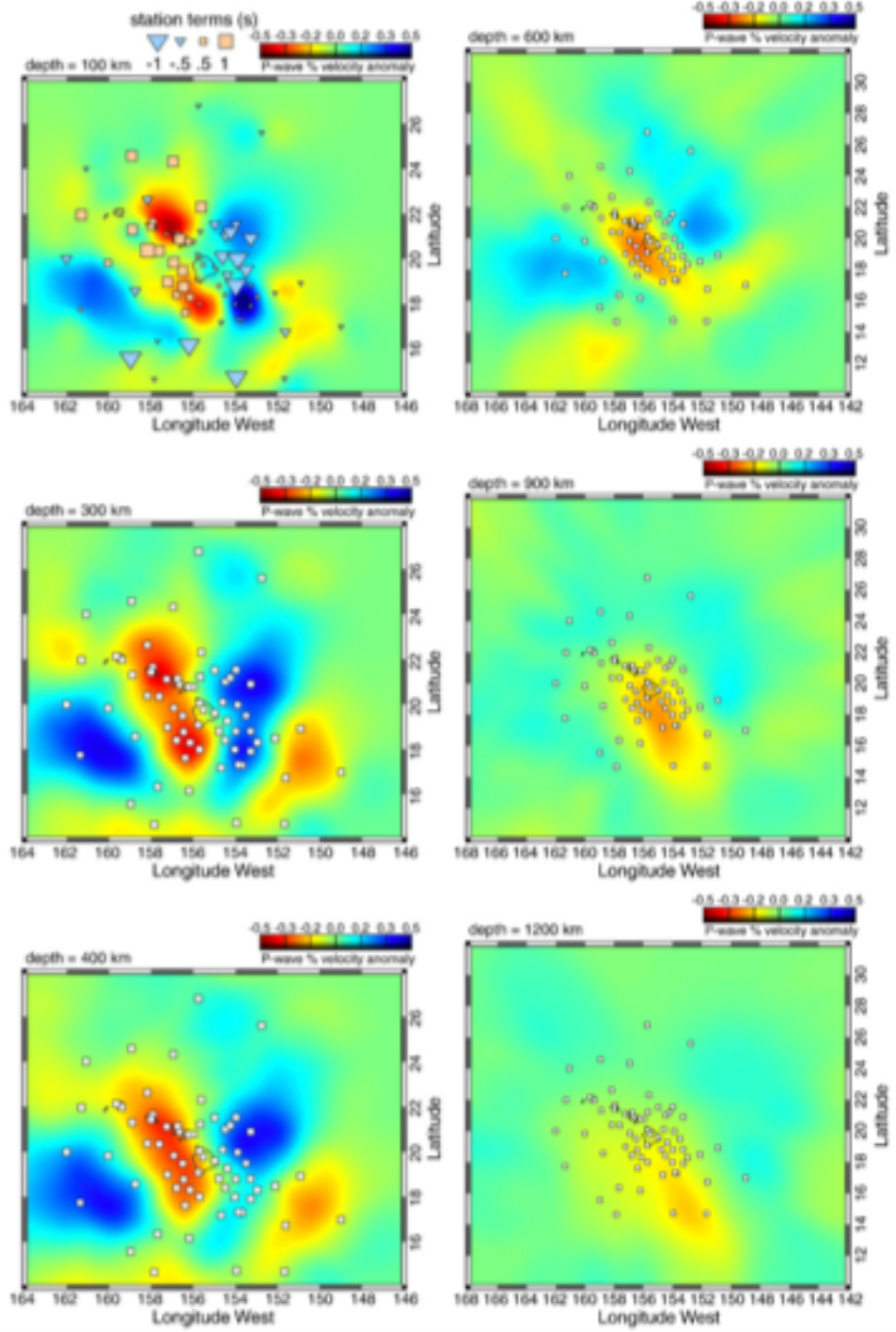


Shillington et al., Nature Geoscience, 2015

Deep imaging beneath Hawaii



Wolfe et al, Science, 2009



Wolfe et al., EPSL, 2011

Origin of topographic swell?

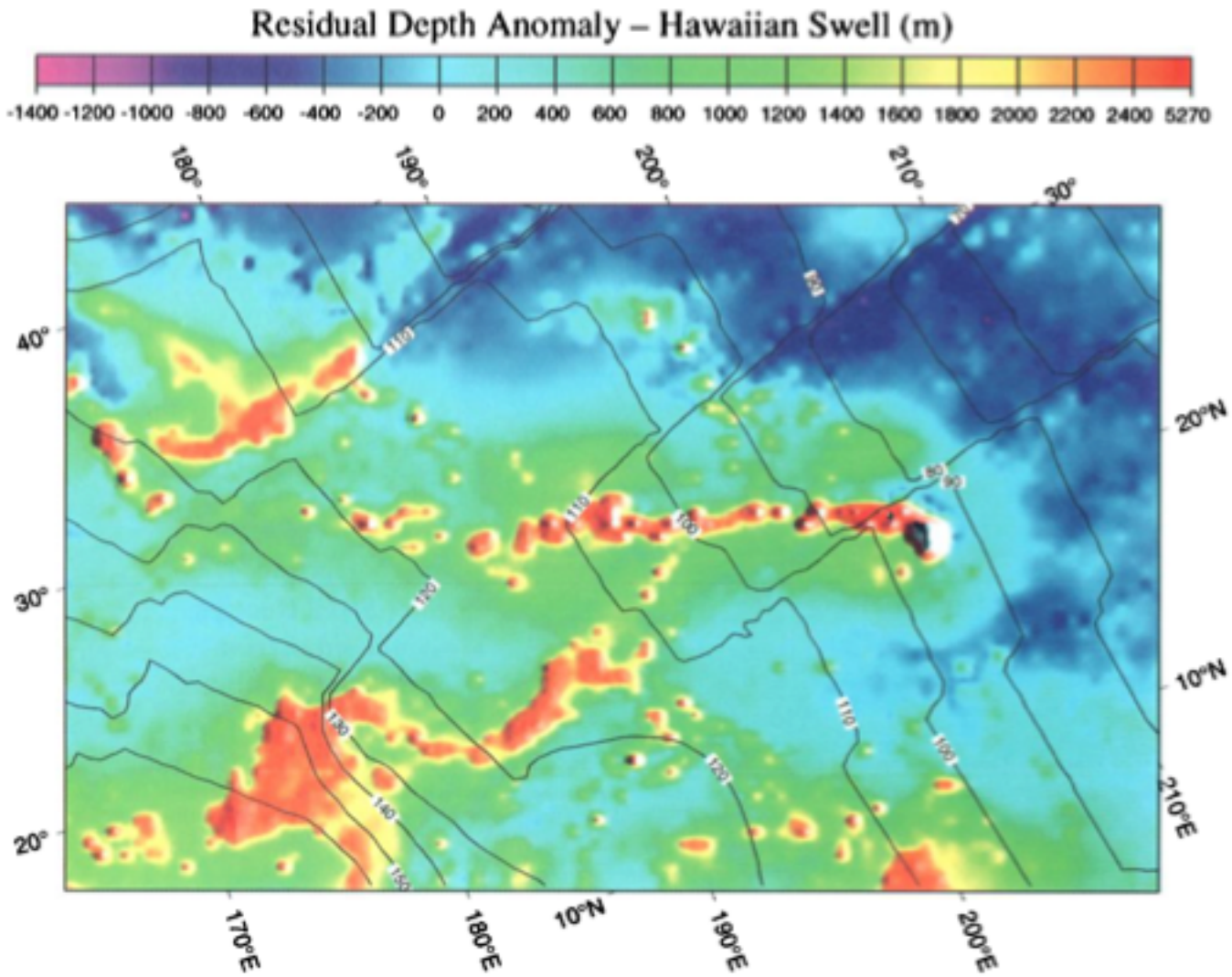
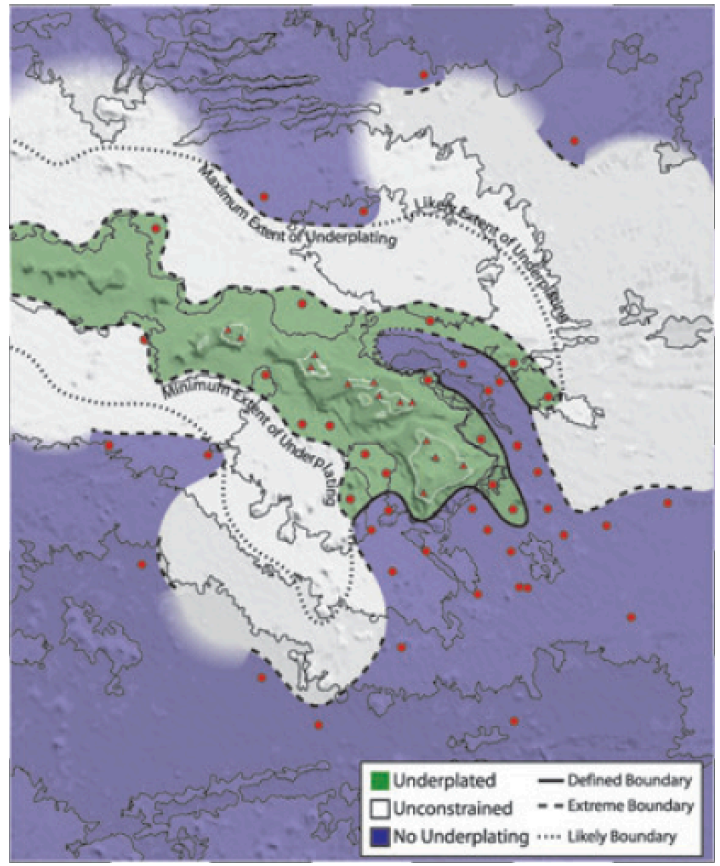


Plate 1. Age-corrected bathymetric map of the seafloor near the Hawaiian-Emperor Chain. Seafloor depths are corrected for an assumed halfspace-cooling thermal model depth $d[m] = 2650 - 300\sqrt{age[Ma]}$. Bathymetric grid is from *Wessel* [1993b]. Digital seafloor age grid from D. Muller. Current seafloor ages are shown by 10 m.y. solid contour lines.

- Rejuvenation of the lithopshere?
- Depletion associated with melting?
- Crustal underplating?



Leahy et al. 2010