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

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Classic seamount chain from hotspot volcanism

O’Connor et al, G3, 2013
What is distribution of magmatic intrusions and underplating beneath Hawaii?

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

Watts et al., Nature, 1985
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
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
Excellent cadre of 9 early career scientists:

Bridgit Boulahanis (LDEO), Laney Hart (U. Wis), 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...
Shape of oceanic plate bending due to Hawaii volcanos

Processed by Nina Nakrong
Image the top and base of the oceanic crust around Hawaii.
Thinner oceanic crust
Imaging of mantle reflections farther offshore by wide-angle data acquired by R/V Karei
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
Line1MCS Water Column Stack with Temperature

Depth (m) vs Distance (m)

Temperature [°C]

Courtesy of Jingxuan Wei
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!
Reflection imaging and expanding spread profiles indicate highly localized underplating beneath Hawaii volcanic chain.
What is distribution of magmatic intrusions and underplating beneath Hawaii?

Intrusions versus underplating?

Contreras-Reyes et al., 2010
Other science targets

Structure of old oceanic crust

Reflections from within the lithosphere or from the base?

Bécel et al, EPSL 2015

Ohira et al, 2018
How does lithosphere bend and deform in response to load of island chain?

Klein, 2016

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
Origin of topographic swell?

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

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 $d[m] = 2650 - 300_{\text{age}[Ma]}$. 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.

Leahy et al. 2010