Geohazards and Margin Stability

GeoPRISMS TEI Early Career Workshop
26 February 2019

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Sub-Topics in Geohazards and Margin Stability

- Slow Slip Events

  Earthquakes at rifts

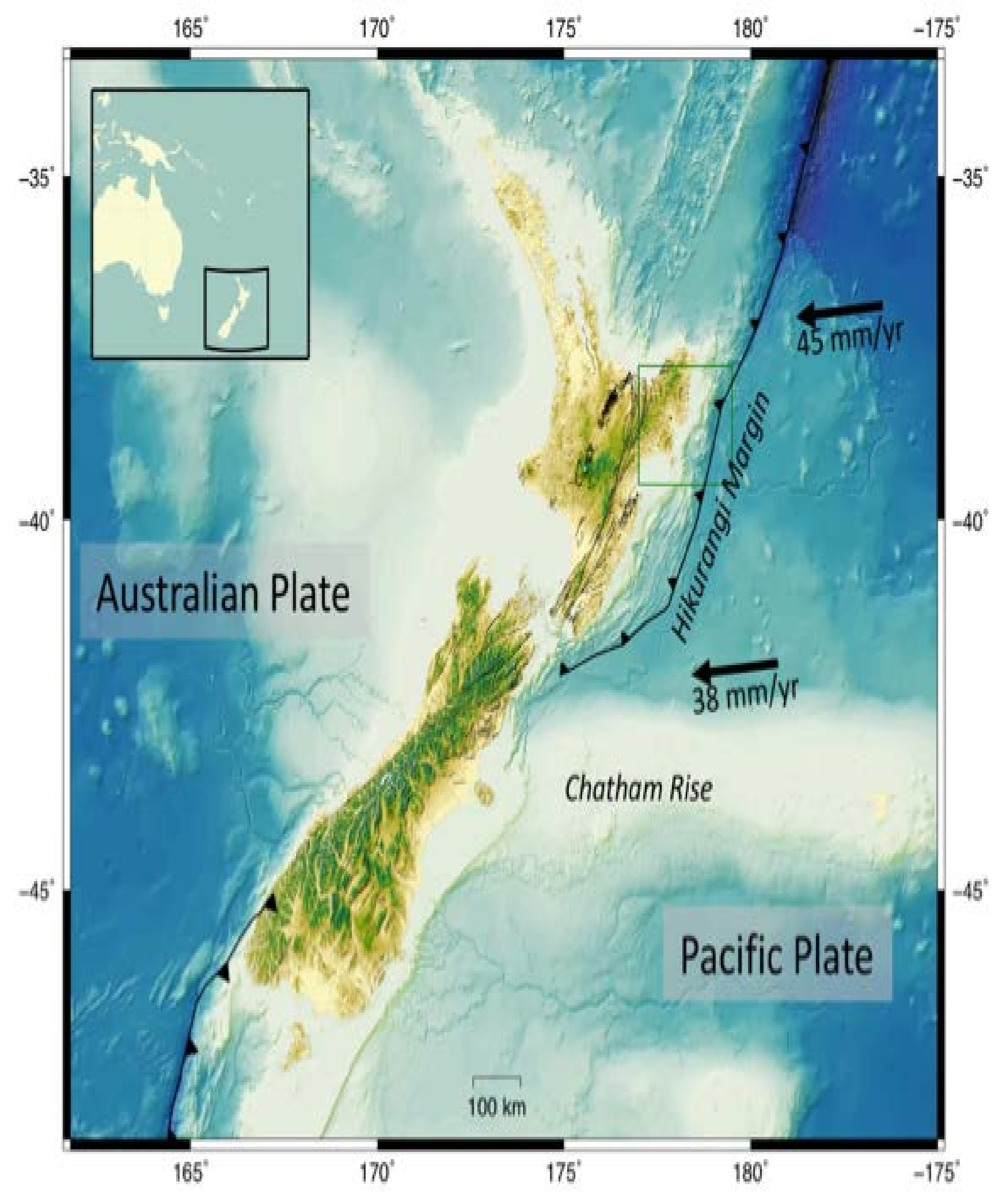
- Tsunamis

- Volcanoes and Eruptions

Slow Slip Events (SSEs)

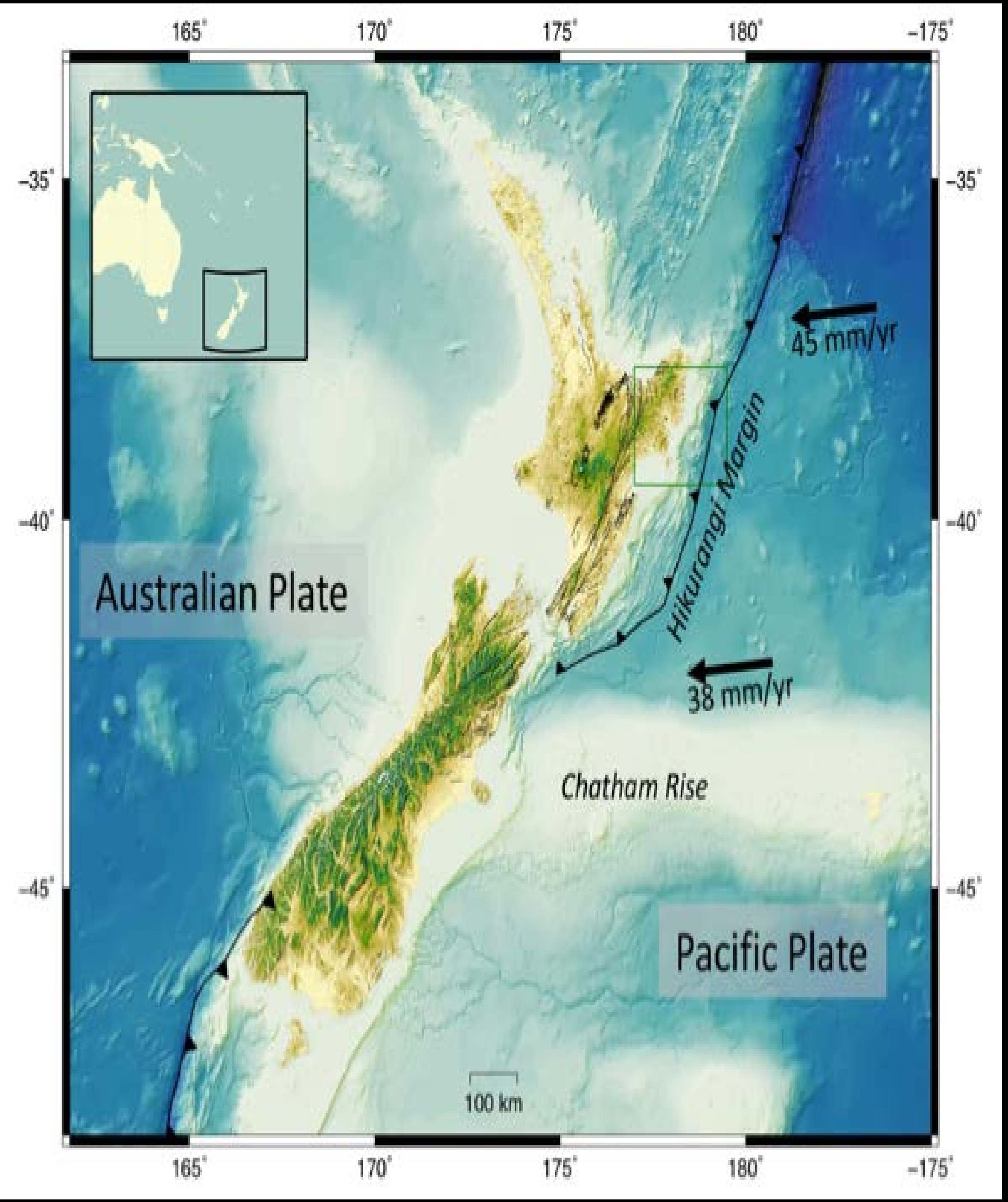
Geologic Background

- Recently discovered (~15 years)
- Not well understood
- Shallow portion of offshore plate boundaries
- Slower than earthquakes (weeks/years vs. seconds), faster than typical tectonic plate motion
- Can be quasi-periodic and last for days to months

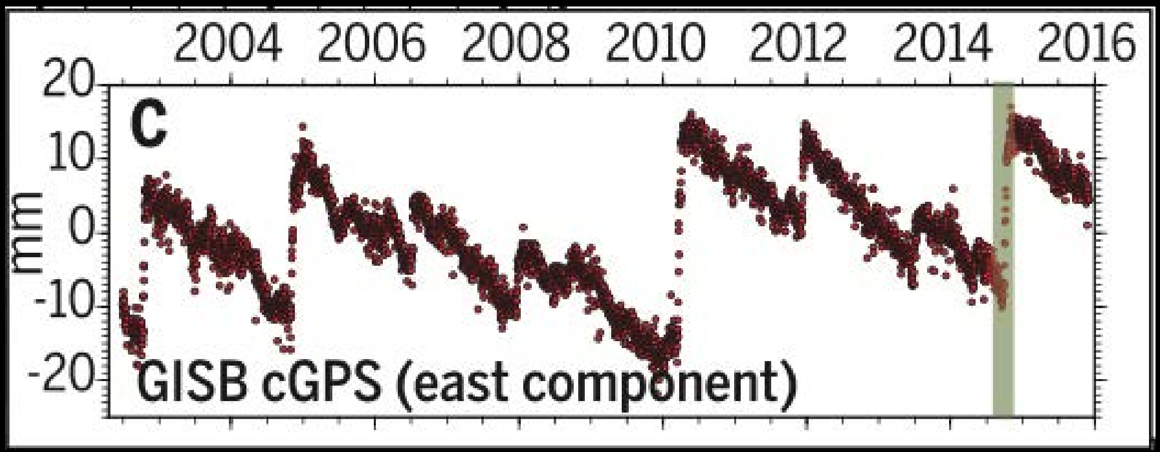


Geologic Background

- Close spatial/temporal proximity to damaging megathrust EQs
- Detected at many subduction zones, mainly in the circum-Pacific Rim:
  - Japan
  - Cascadia
  - Costa Rica
  - Southern Mexico
  - Alaska
  - New Zealand's North Island



Research Techniques



- On-shore GPS
  - Inland migration as subducting plate stresses continental plate
  - Offshore migration/jump during periods of elastic rebound

- Absolute pressure gauges (APGs)
  - Positive vertical movement during SSEs measured as decrease in hydrostatic pressure from overlying seawater

Some Overarching Questions

1. What are the physical processes and properties leading to transient slow slip behavior at subduction margins?

2. How can we better constrain SSEs using scientific methods and how can we improve these methods

- Offshore geodesy

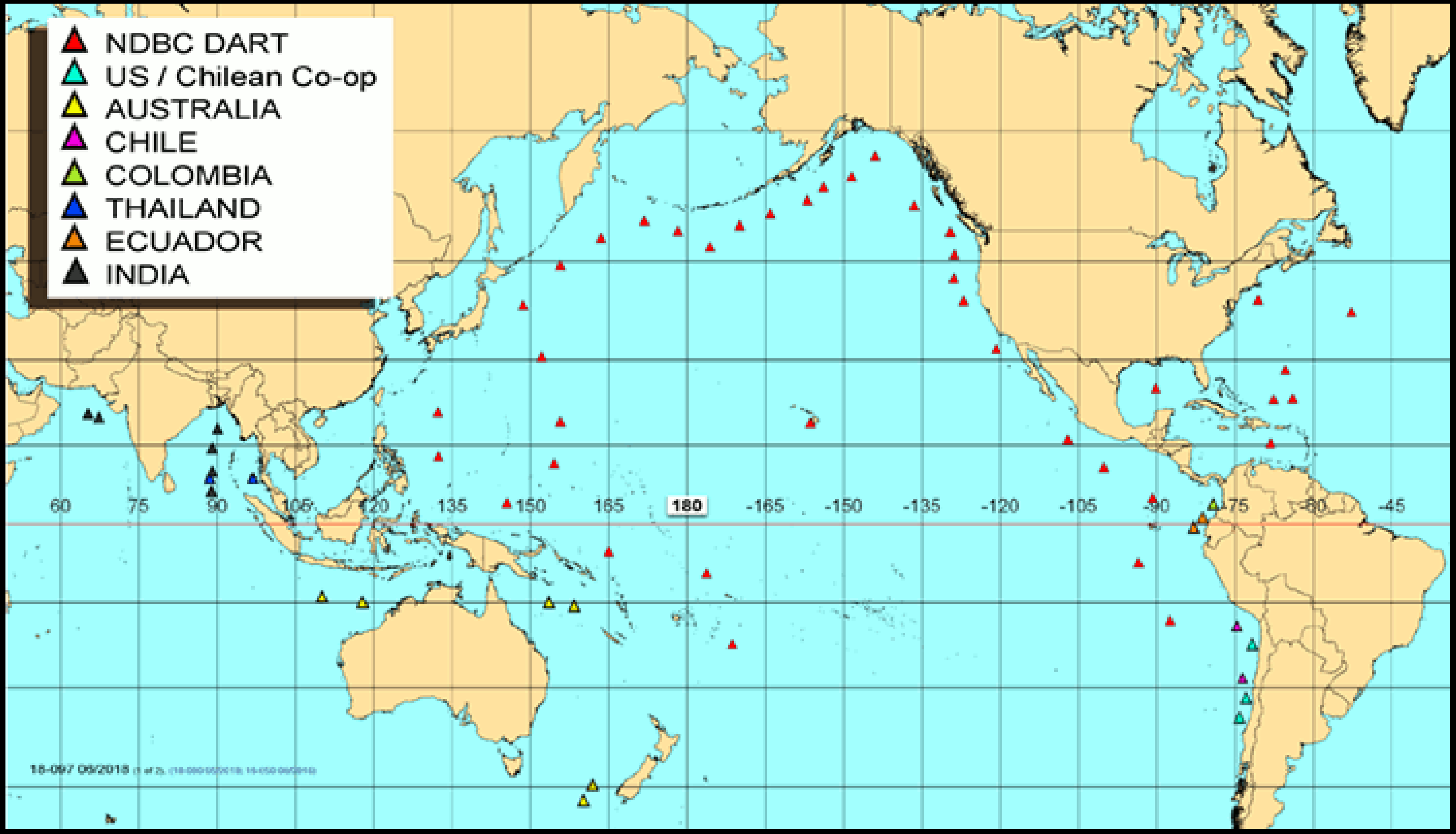
3. Can SSEs be used to predict large hazards, such as megathrust and tsunami-generating events?

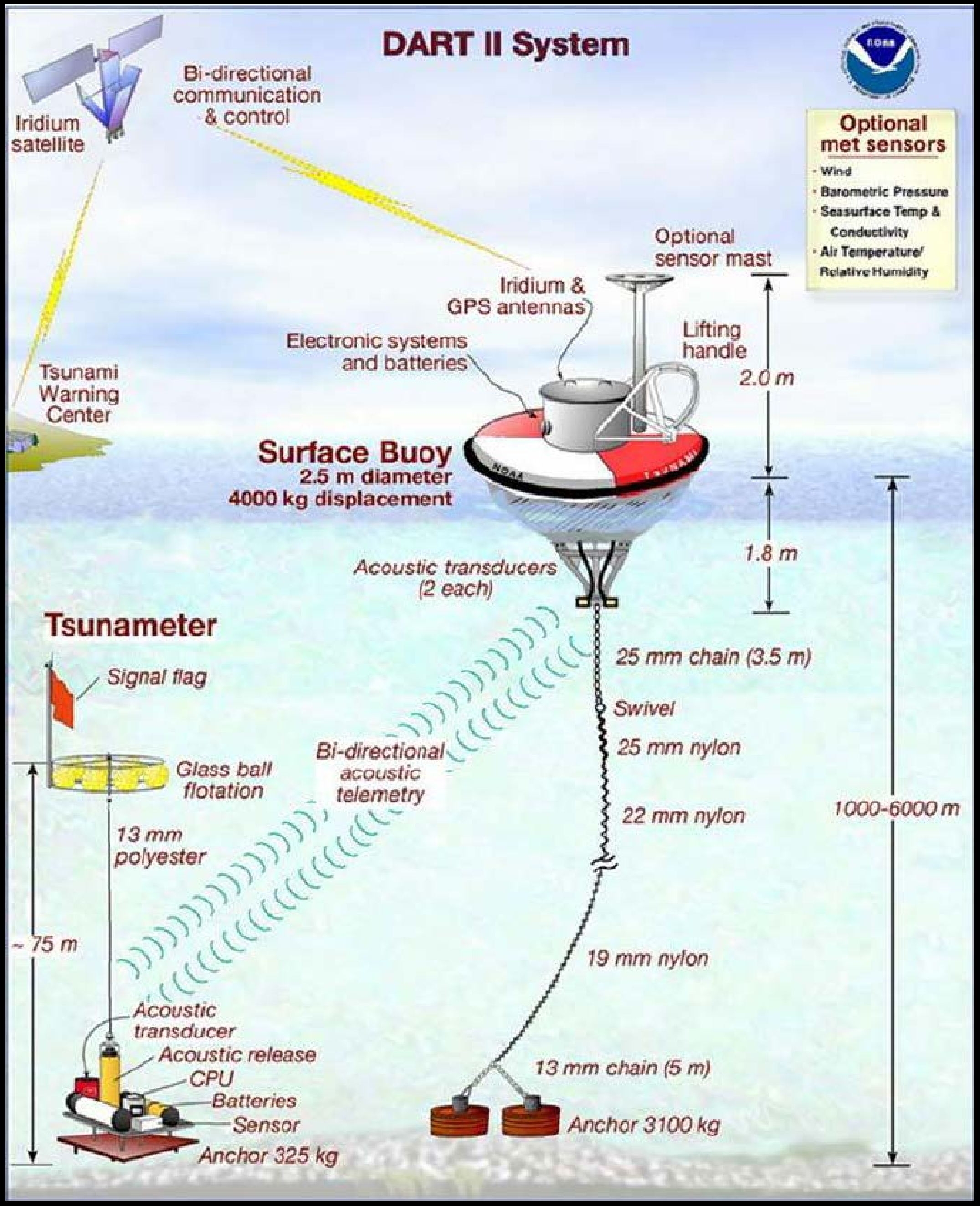
4. What role do fluids play?

   Are SSEs stimulated by subducted fluid-rich sediments increasing pore-fluid pressure at the slab interface, thereby reducing effective stress?

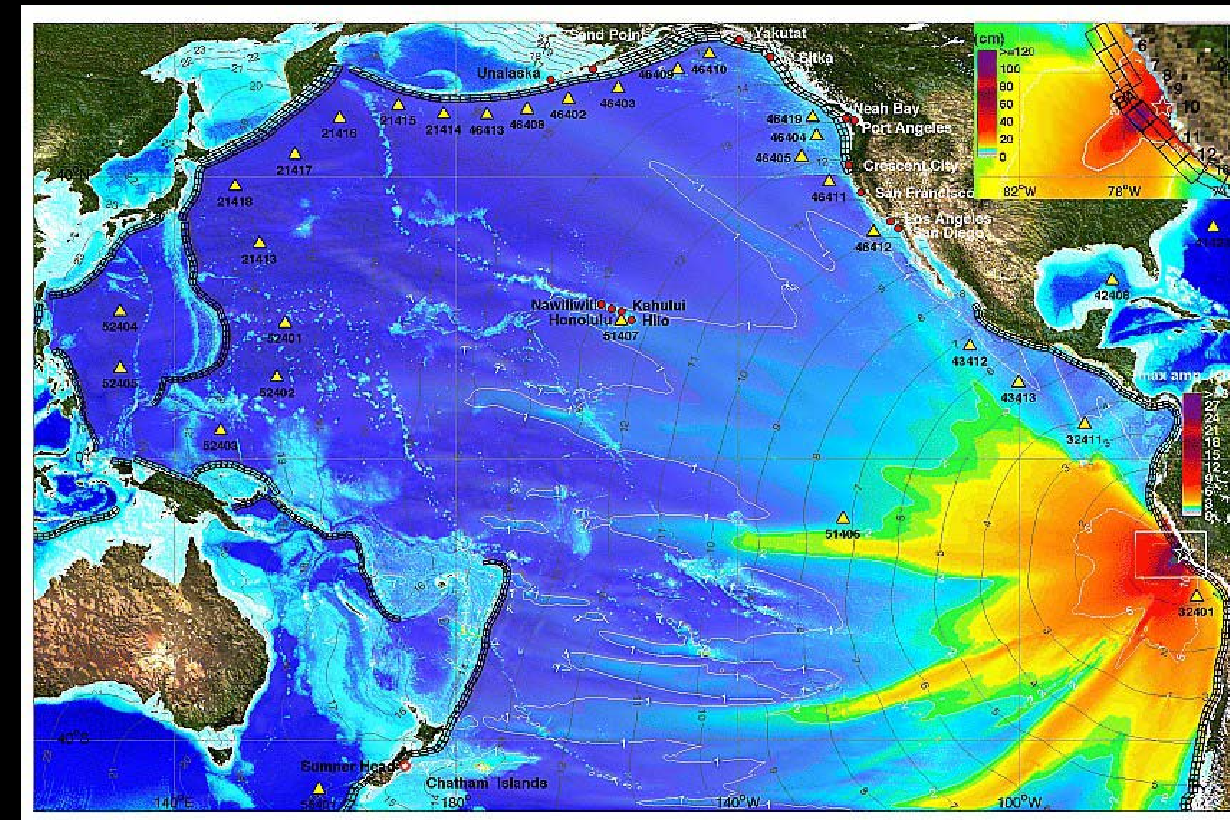
Tsunami Hazards

Tsunami warning and forecasting – DART II system

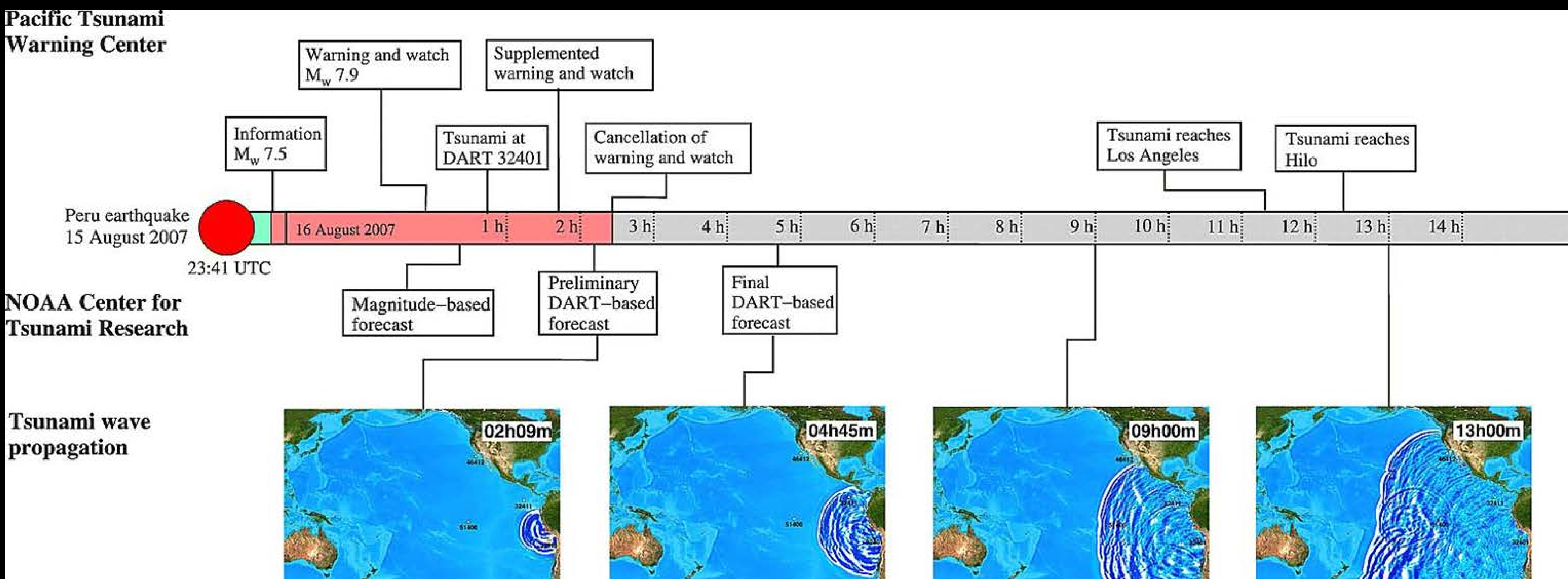




DART II system



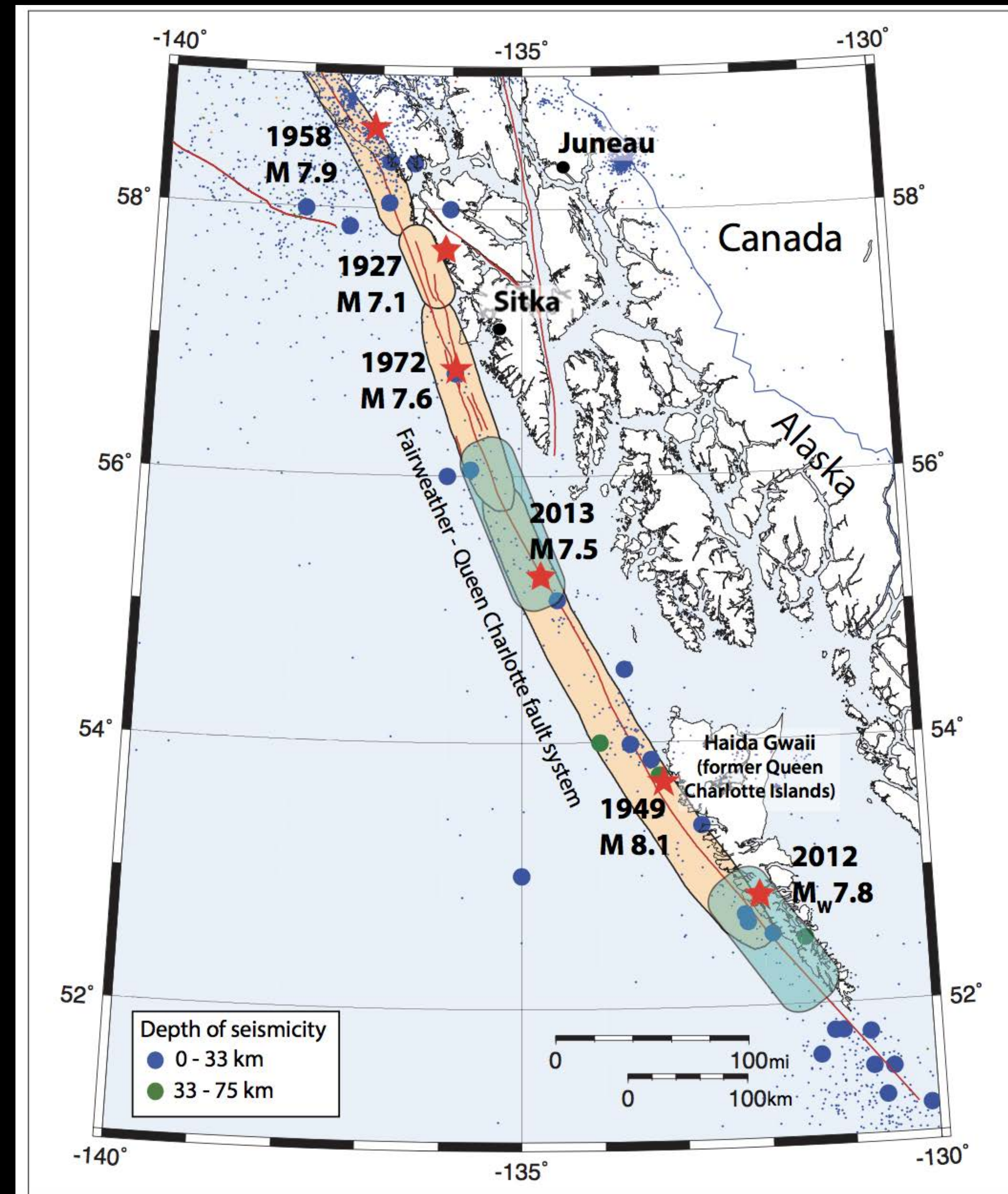
Deep-ocean Assessment and Reporting of Tsunamis



Yong, et al., 2008

Tsunami Hazard Assessment: Tectonic control and geological evidences

- How tectonic control can help rule or reduce possible earthquake displacement scenarios?
- What information we can get from geological evidence (i.e. tsunami deposits)?



Suleimani, et al., 2013

Volcanoes and Eruptions

“Grand Challenges” in Volcano Science

1.

2.

3.

“Grand Challenges” in Volcano Science

1. Forecast onset, size, duration, and hazard of eruptions

2.

3.

NASEM, 2017

"Grand Challenges" in Volcano Science

1. Forecast onset, size, duration, and hazard of eruptions

2. Quantify life cycles of global volcanoes

3.

NASEM, 2017

"Grand Challenges" in Volcano Science

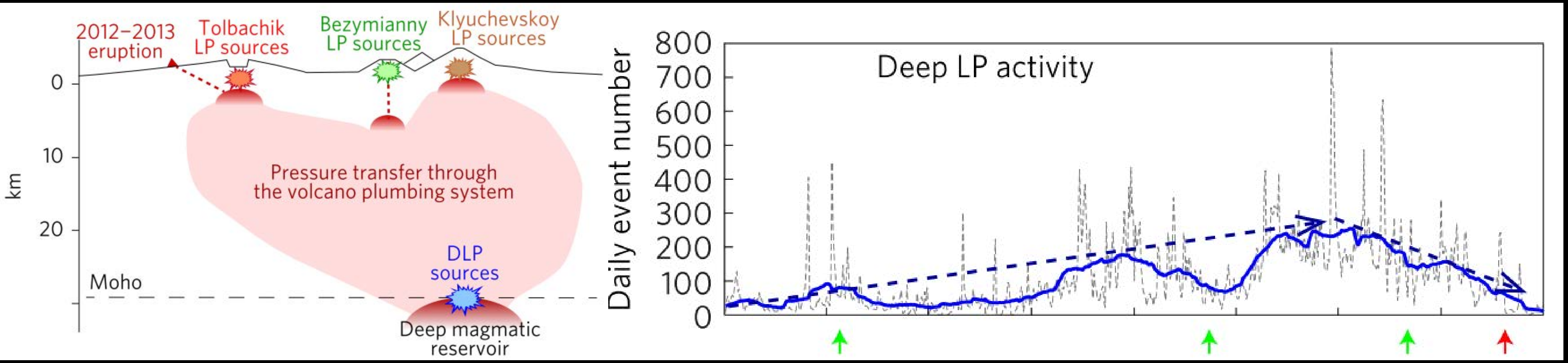
1. Forecast onset, size, duration, and hazard of eruptions

2. Quantify life cycles of global volcanoes

3. Develop organized volcano science community to improve scientific gains from volcanic events

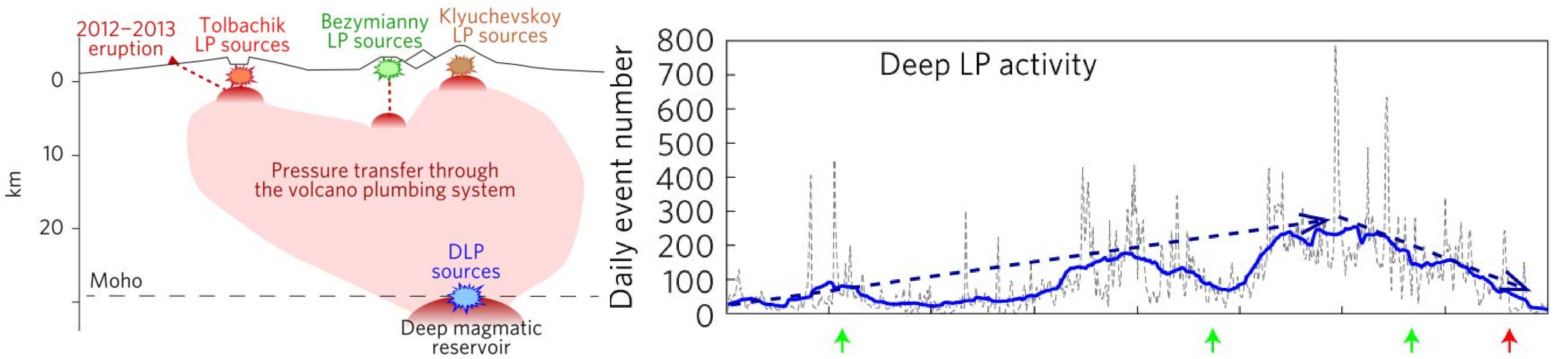
NASEM, 2017

Seismic techniques allow us to monitor volcanic unrest and to image magma chambers



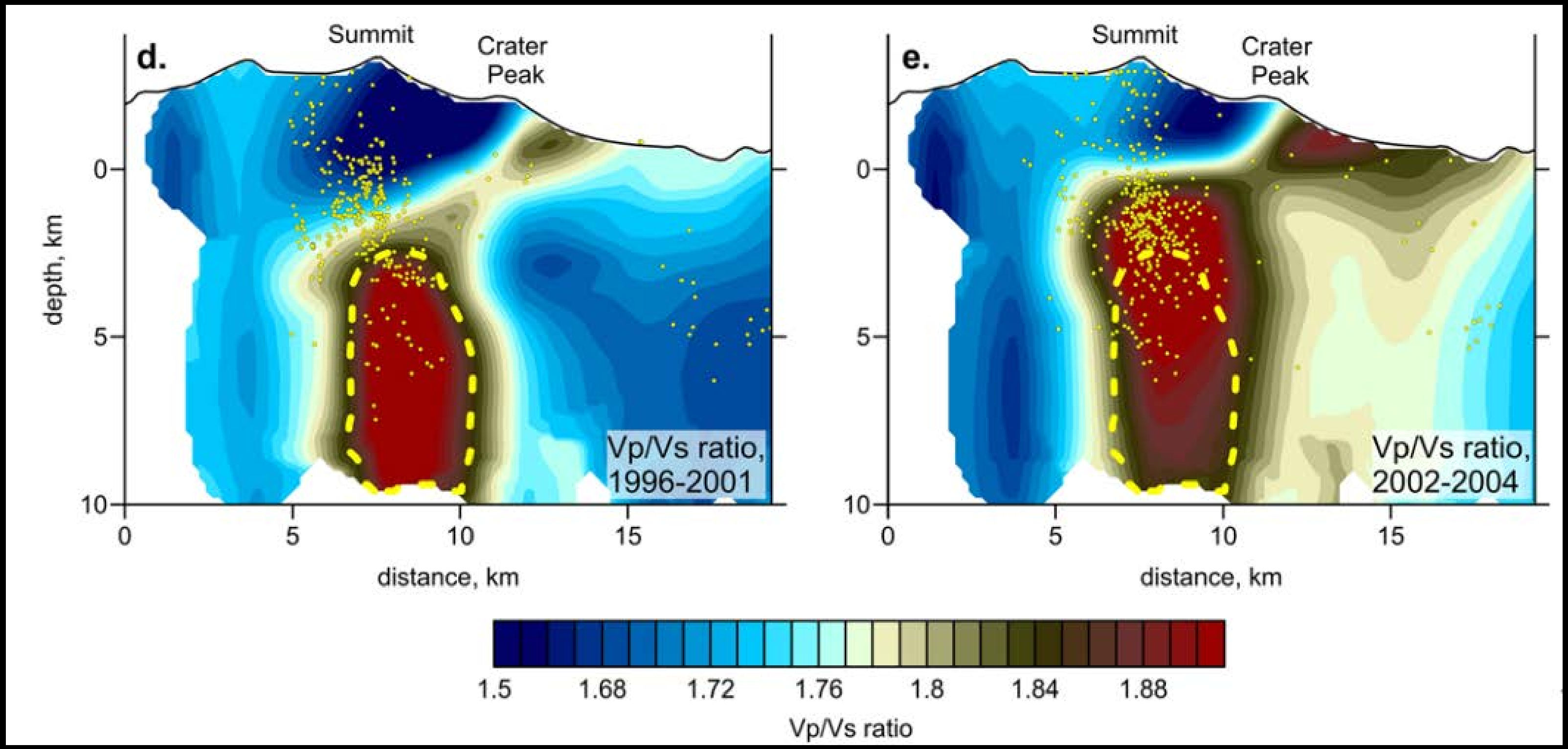
Deep, long-period seismicity as precursors to eruption **Shapiro et al. (2017)**

Seismic techniques allow us to monitor volcanic unrest and to image magma chambers

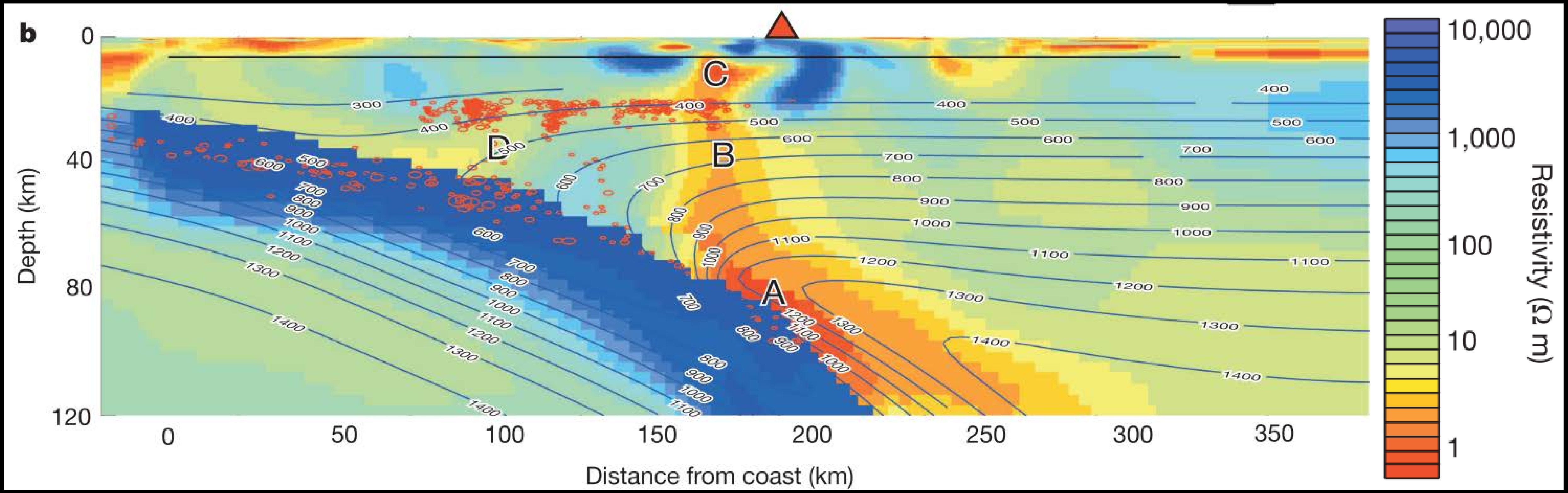


Deep, long-period seismicity as precursors to eruption
Shapiro et al. (2017)

Migration of fluids using Vp/Vs tomography
(Koulakov et al., 2018)



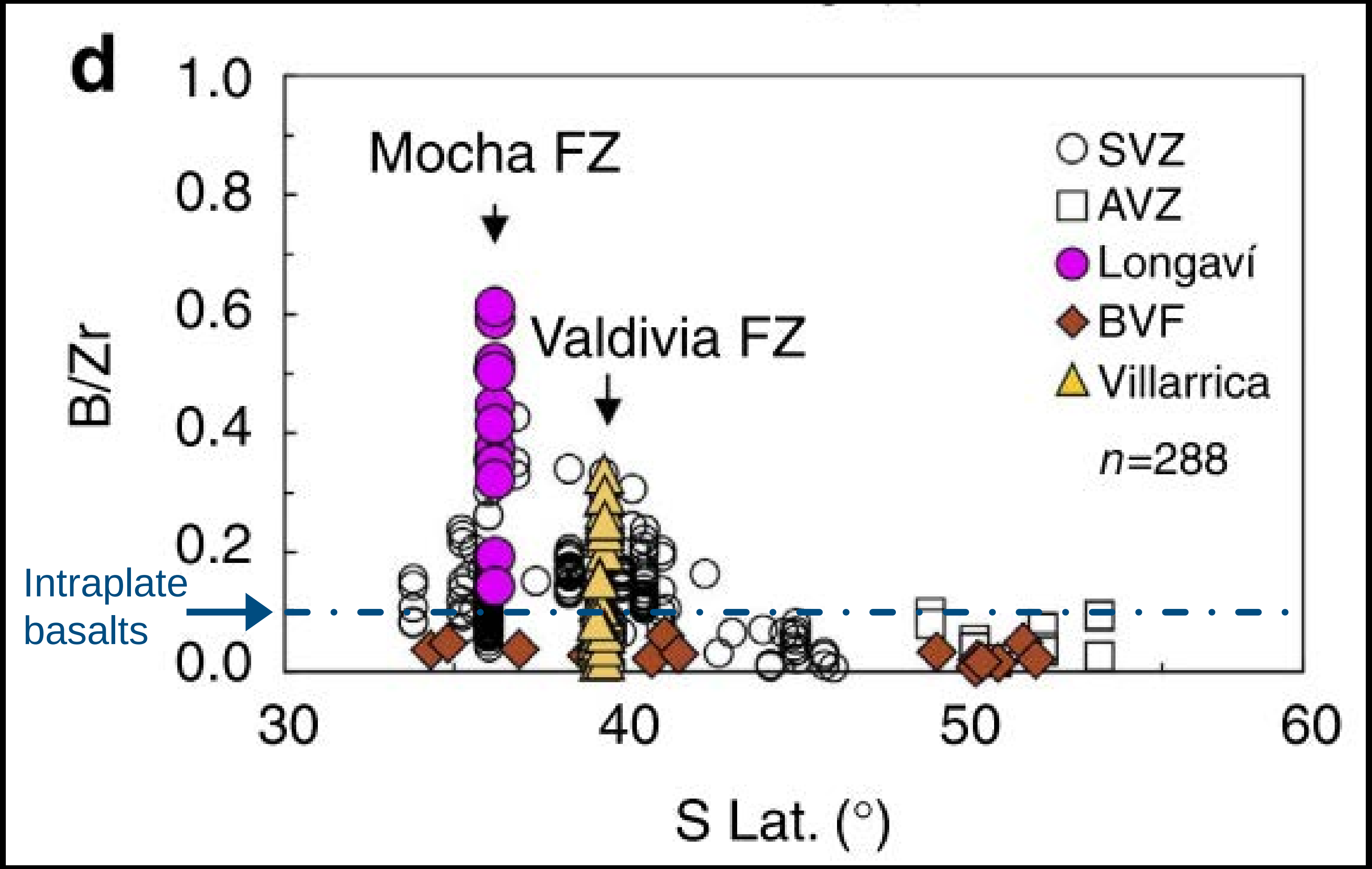
Electromagnetic data are particularly sensitive to fluids, melt, and elevated temperatures



Fluid released from subducting slab promotes mantle melting beneath Mt. Rainier
McGary et al. (2014)

Geochemistry of eruptives clues us in to the slab inputs that promote mantle melting

Elevated B/Zr ratios as proxy for infiltration of slab-derived fluids through subducted fracture zones
Manea et al. (2014)



Even more techniques!

- InSAR (Global link between deformation and volcanic eruption quantified by satellite imagery—Biggs et al., 2014)
- Infrasound (Infrasonic early warning system for explosive eruptions—Ripepe et al., 2018)

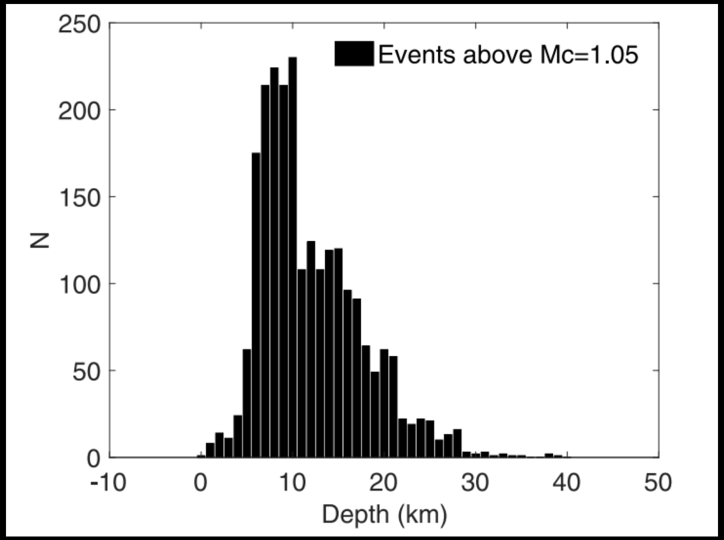
Geohazards at Rifting Margins

Along- Axis segmentation of Seismic Hazards in Continental Rift zones

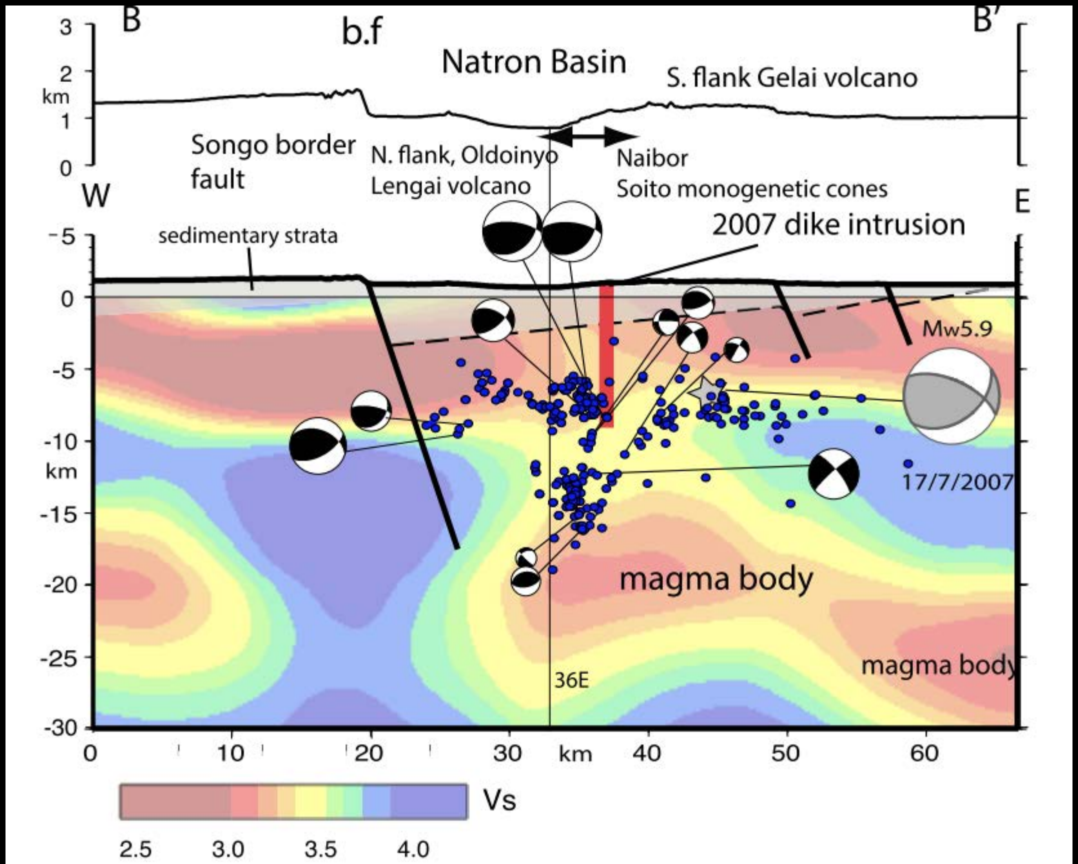
Well- developed magmatic sector

‘Creme Brulee’ rheological model, seismicity largely confined to upper 15 km

Interaction between magmatic and fault systems



Seismicity histogram from the Natron- Magadi basin (Weinstein et al. [2017])



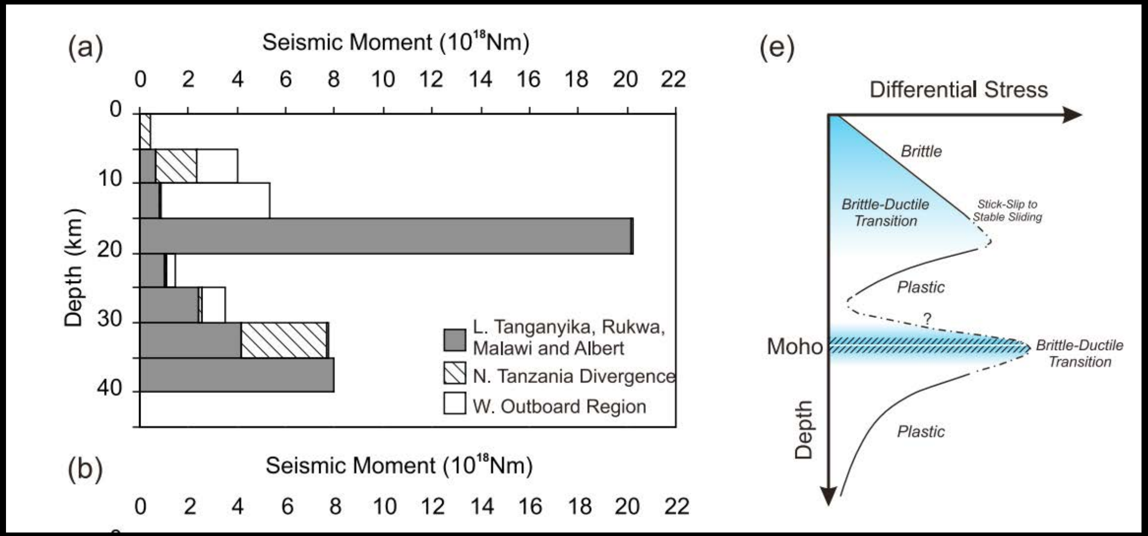
EQ relocation overlain with focal mechanisms, projections of border faults, and Vs model of Roecker et al.(2017) figure from Weinstein et al. (2017)

Along- Axis segmentation of Seismic Hazards in Continental Rift zones

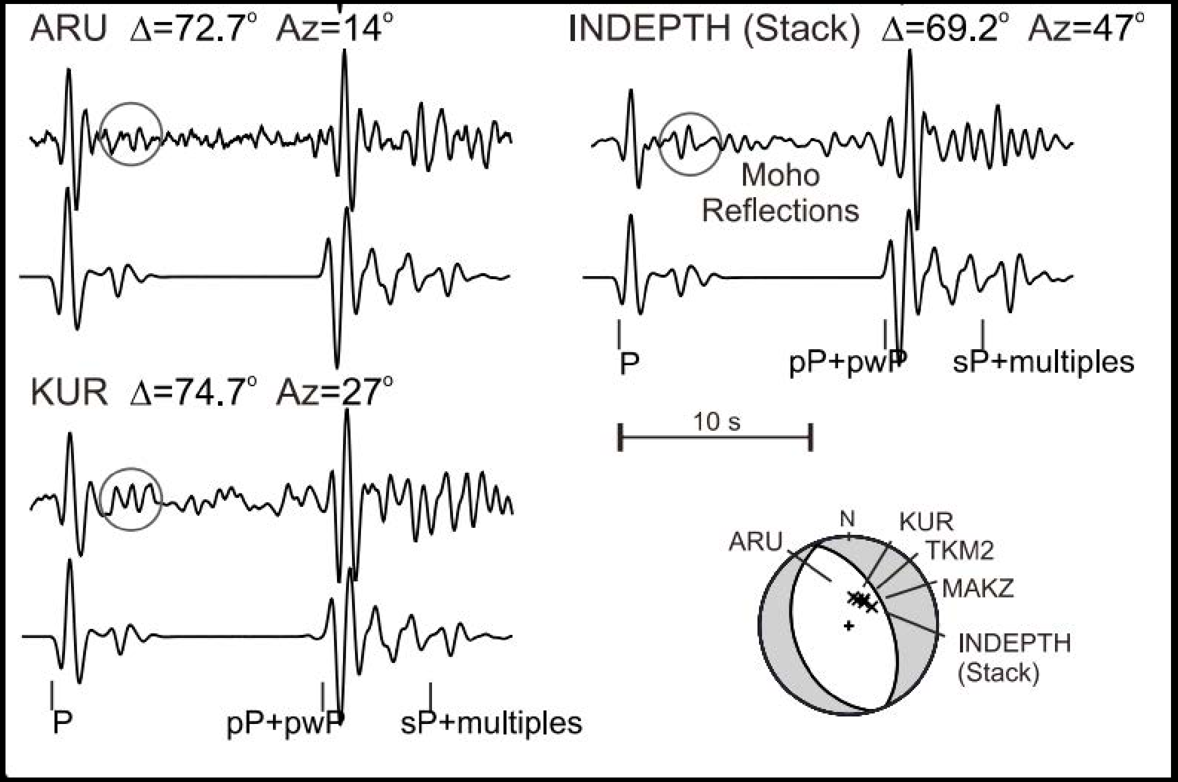
Well- developed amagmatic sector

‘Jelly Sandwich’’ rheological model

Significant and high magnitude clustering of seismicity in the upper mantle



Seismicity histogram and inferred yield stress envelope for amagmatic E African rift segments
Yang & Chen (2010)



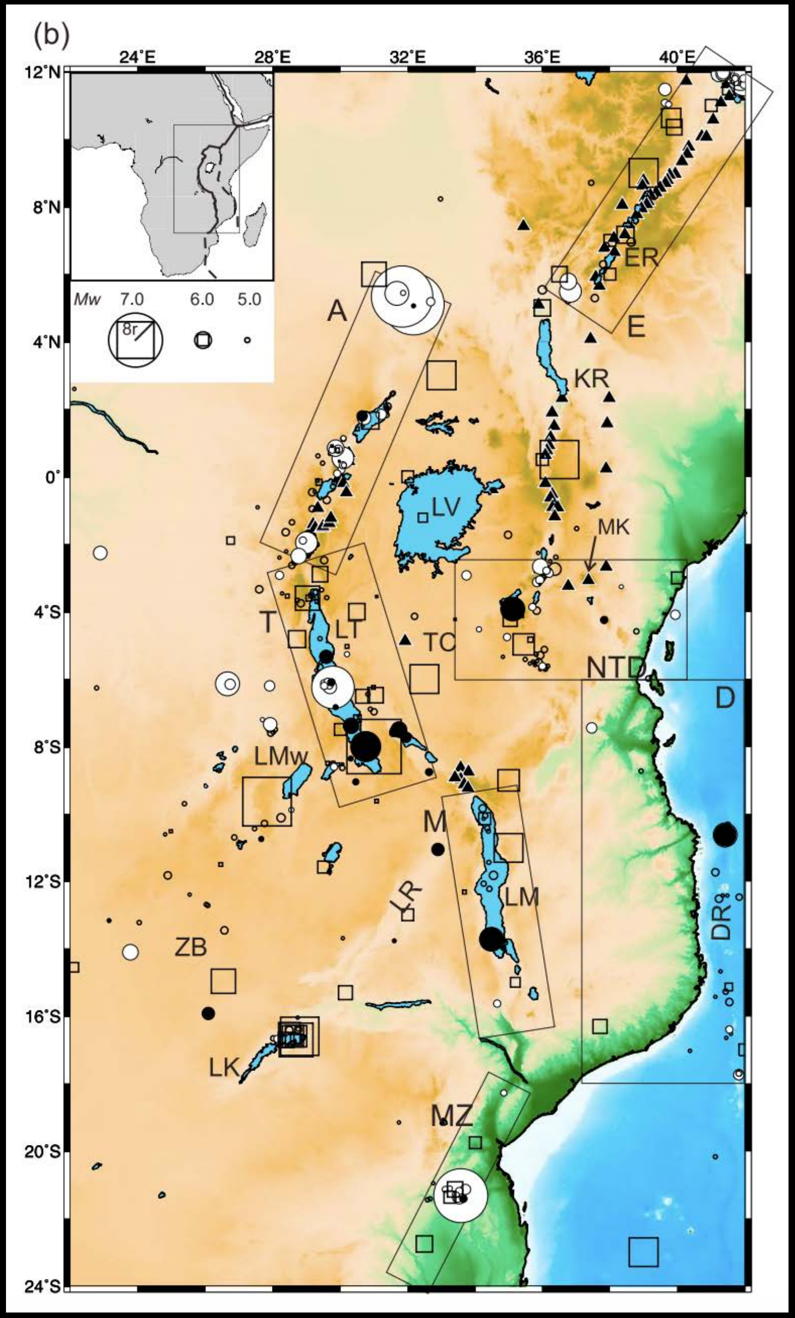
Record sections from event M3 (Z = 44 ± 4 km) in the Malawi rift. Inferred PmS underside moho phase conversion highlighted
Yang & Chen (2010)

Along- Axis segmentation of Seismic Hazards in Continental Rift zones

No surficial expression of rifting

Very large ($M_w > 7$) earthquakes in the top 15 km

Aftershocks can extend to depths of ~35 km



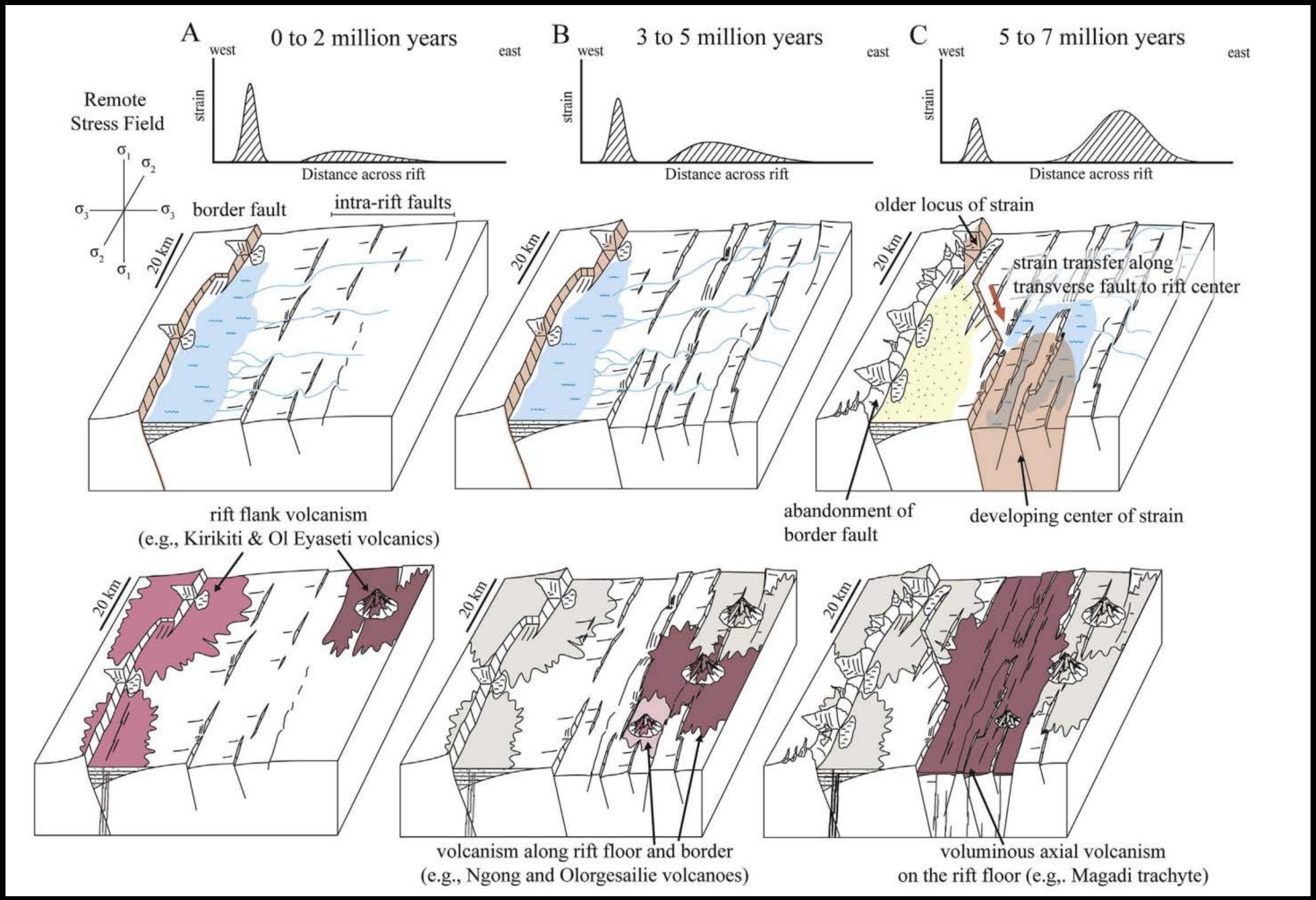
Yang & Chen (2010)

Volcanism

Clustering of volcanic activity in rift basin floor and along border flanks

Mostly effusive magmatic activity in both oceanic and continental rift settings

Volatile sources drive explosive behavior



Evolutiuon of surface volcanism and fault structure in the Magadi basin, Ethiopia
Muirhead & Kattenhorn (2018)

Overarching Questions

What factors control along-axis segmentation of seismic hazards?

- Role of inherited structure, mantle processes

What is the interplay between magmatic and seismic processes at depth?

- Implications for stress localization and magma transport

What role do volatiles play in determining rheological properties at depth?

References

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- Bell et al., 2010
- Biggs et al., 2014
- Cassidy et al., 2018
- Delahaye et al., 2009
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- Koulakov et al., 2018
- Langridge et al., 2016
- Manea et al., 2014
- McGary et al., 2014
- National Academies of Sciences, Engineering, and Medicine, 2017
- Peng & Gomberg, 2010
- Ripepe et al., 2018
- Schwartz & Rokosky, 2007
- Shapiro et al., 2017
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- Vidale et al., 2014
- Yarce et al., 2019