USGS Coastal and Marine Geology high-resolution marine seismic capabilities

Maureen L. Walton, USGS Mendenhall Postdoc (Santa Cruz, CA)

MSROC pre-AGU meeting, 10 December 2017

USGS Coastal and Marine Geology (CMG)

Three science centers

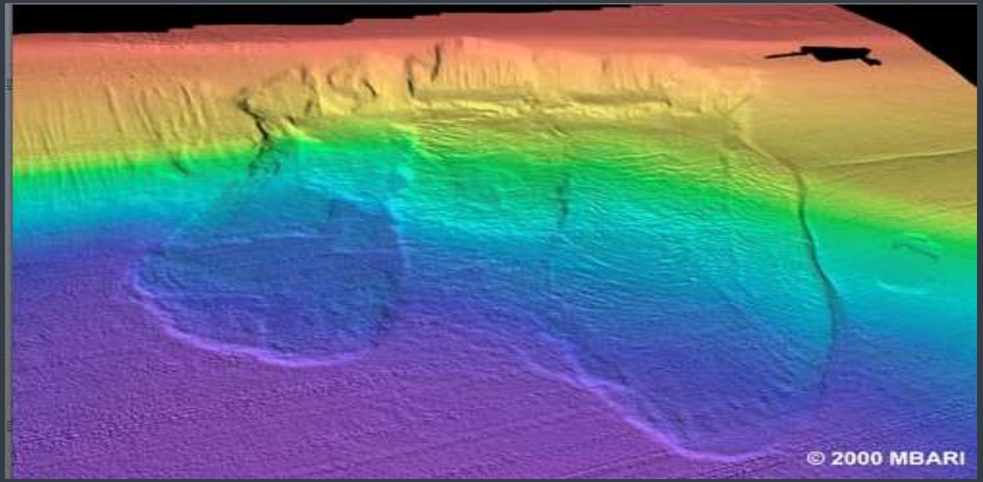
- Santa Cruz, CA; St. Petersburg, FL; Woods Hole, MA
- Marine seismic research: Santa Cruz and Woods Hole
- *marine.usgs.gov*

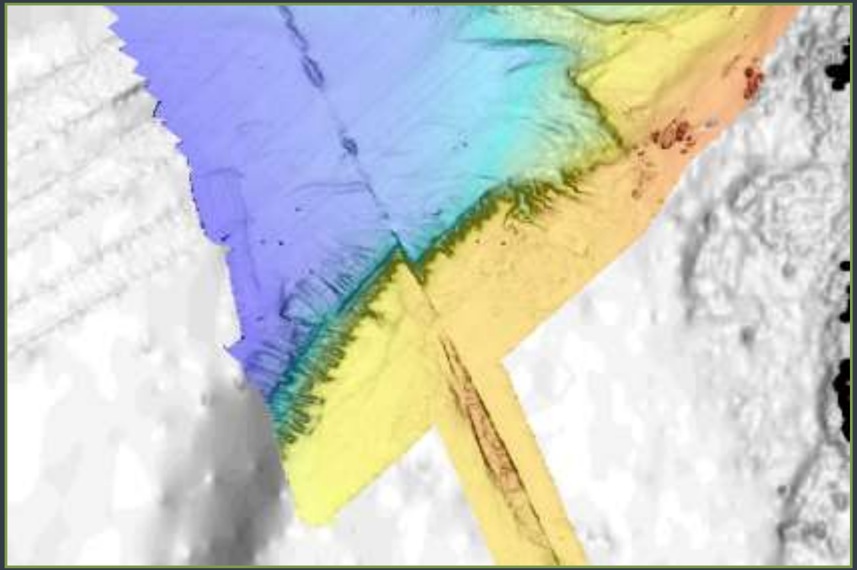
USGS Natural Hazards Mission Area

- Driving force is society's need to assess the probability and severity of future events
- Sudden and extreme geologic events that affect coastal areas and seabed infrastructure… e.g., earthquakes, submarine landslides, tsunamis, volcanic eruptions

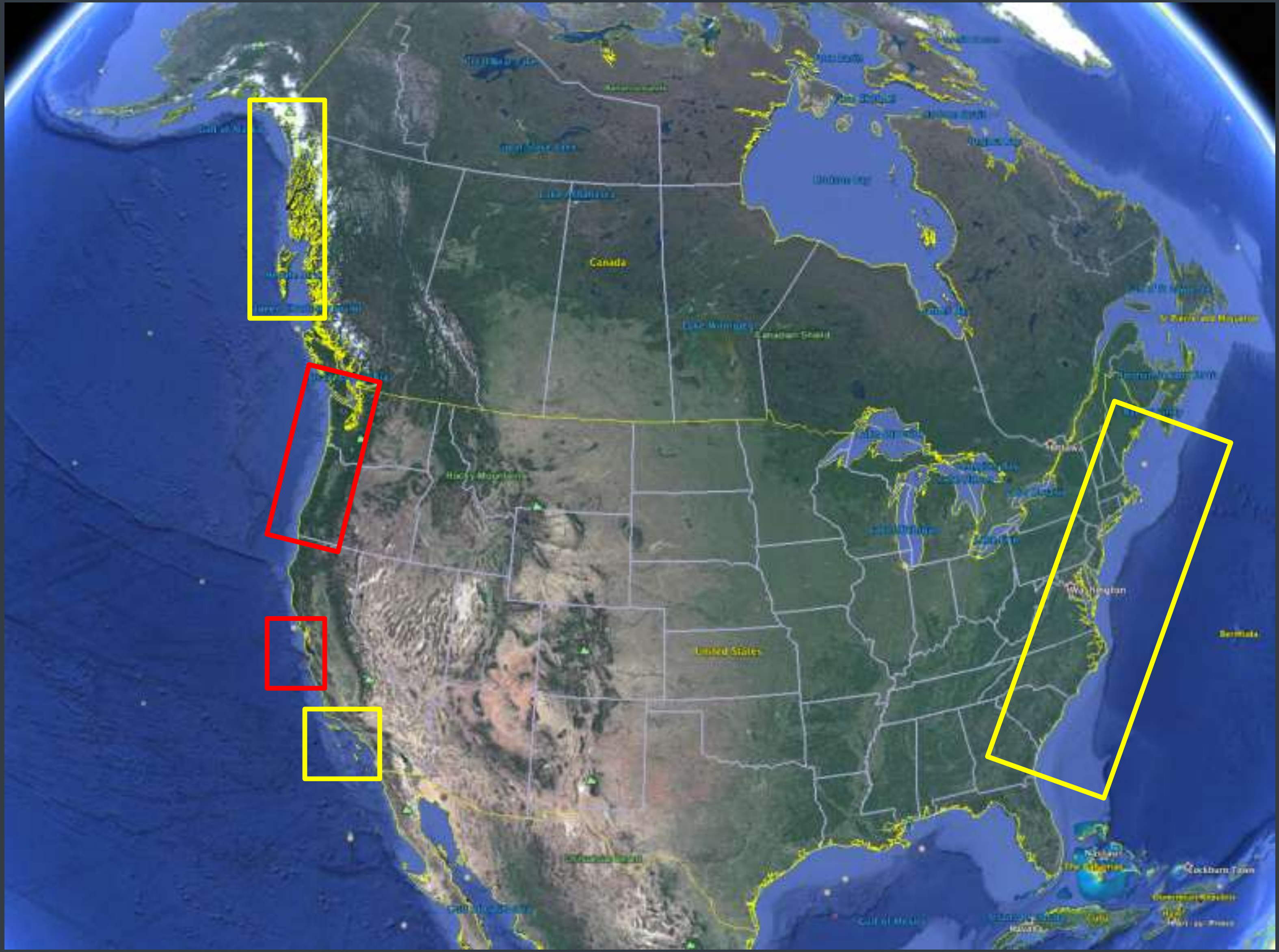
Overarching Research Goals:

- Understand the structure, kinematics, and rates of deformation along submerged fault systems (e.g., marine paleoseismology and tectonic geomorphology)
- Understand the causes and consequences of submarine landslides





Current USGS marine seismic research targets



Southeastern Alaska: Queen Charlotte Fault tectonics, earthquake, landslide, and tsunami studies

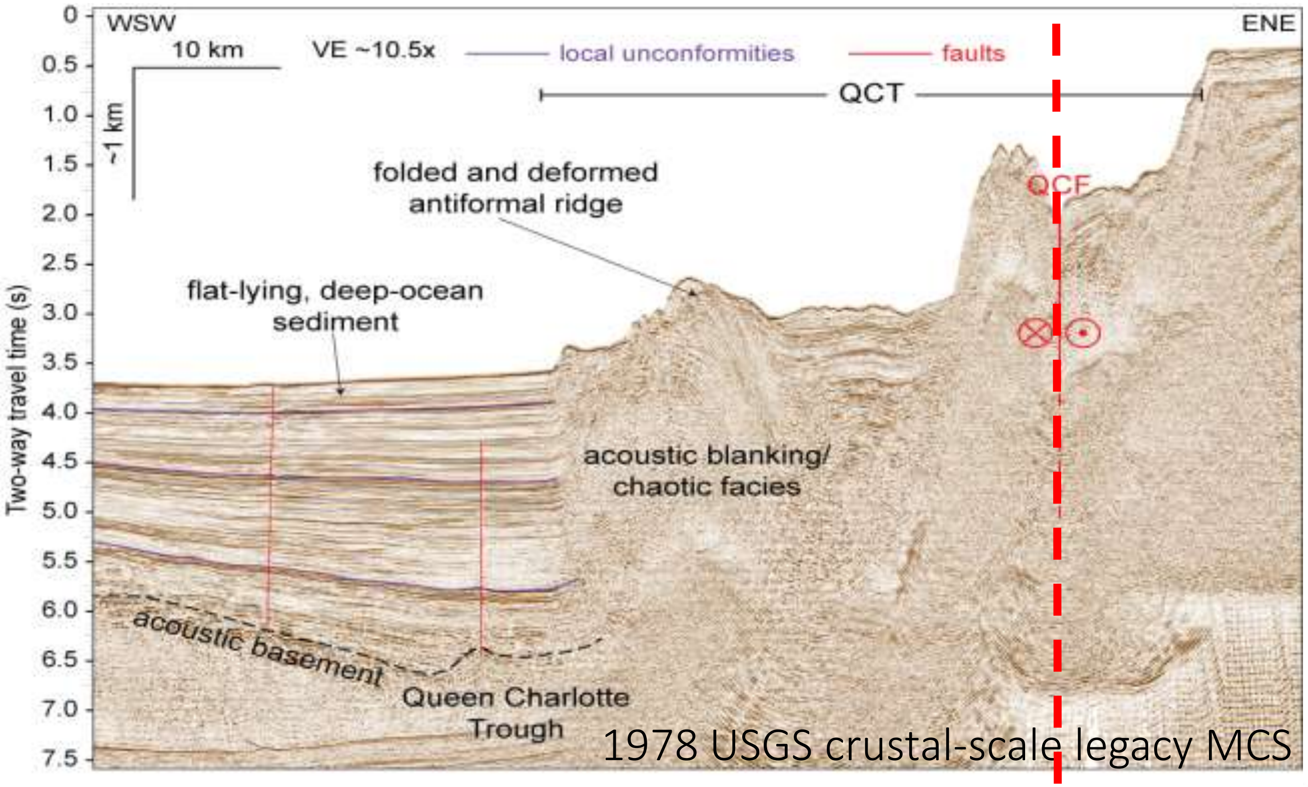
Southern California: Inner Continental Borderland fault structure and and submarine landslide hazards

U.S. Atlantic margin: landslide studies

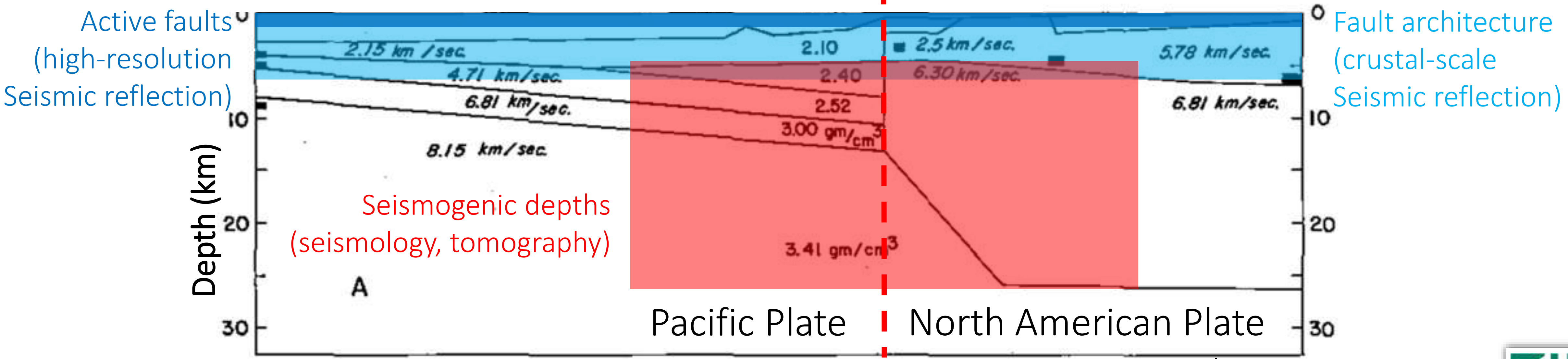
[Central California: active faults, sediment transport, and slope stability studies]

[Cascadia: subduction zone science]

Resolution differences



<-- reprocessed legacy data – come see poster T51G-0558 Friday morning!

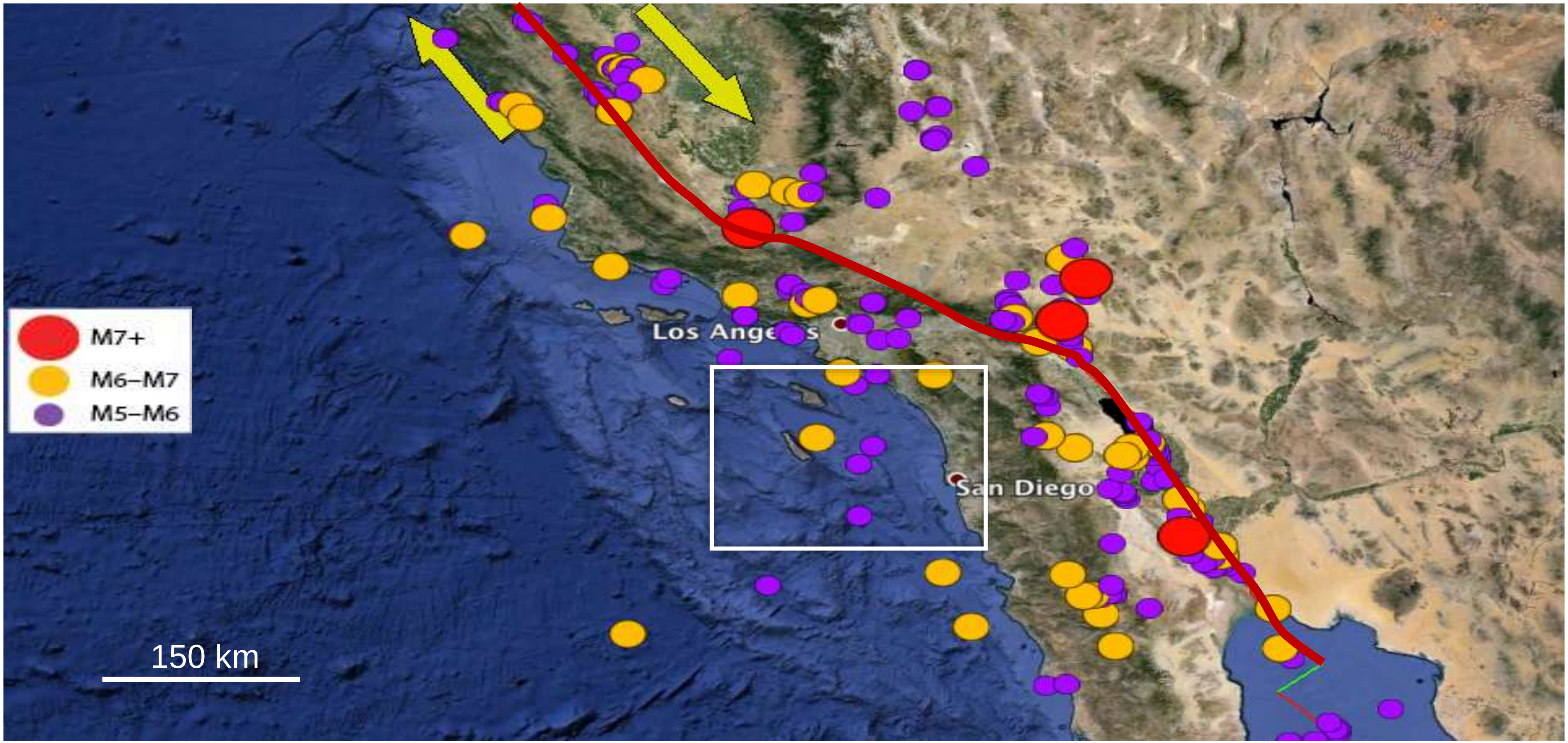


von Huene et al., 1979






Southern California



Earthquakes M5+ since 1870

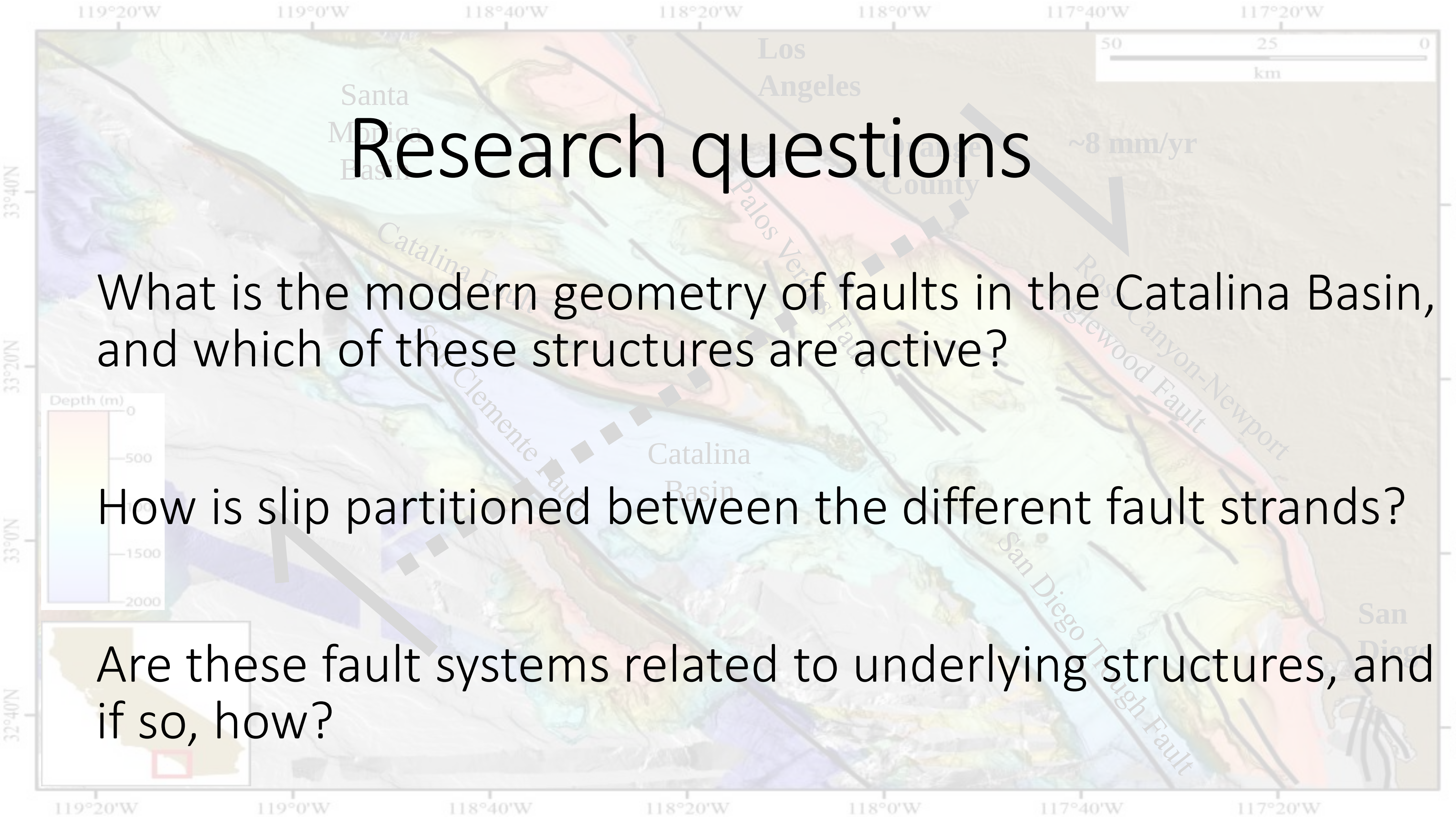
Distributed plate boundary deformation

Research questions

What is the modern geometry of faults in the Catalina Basin, and which of these structures are active?

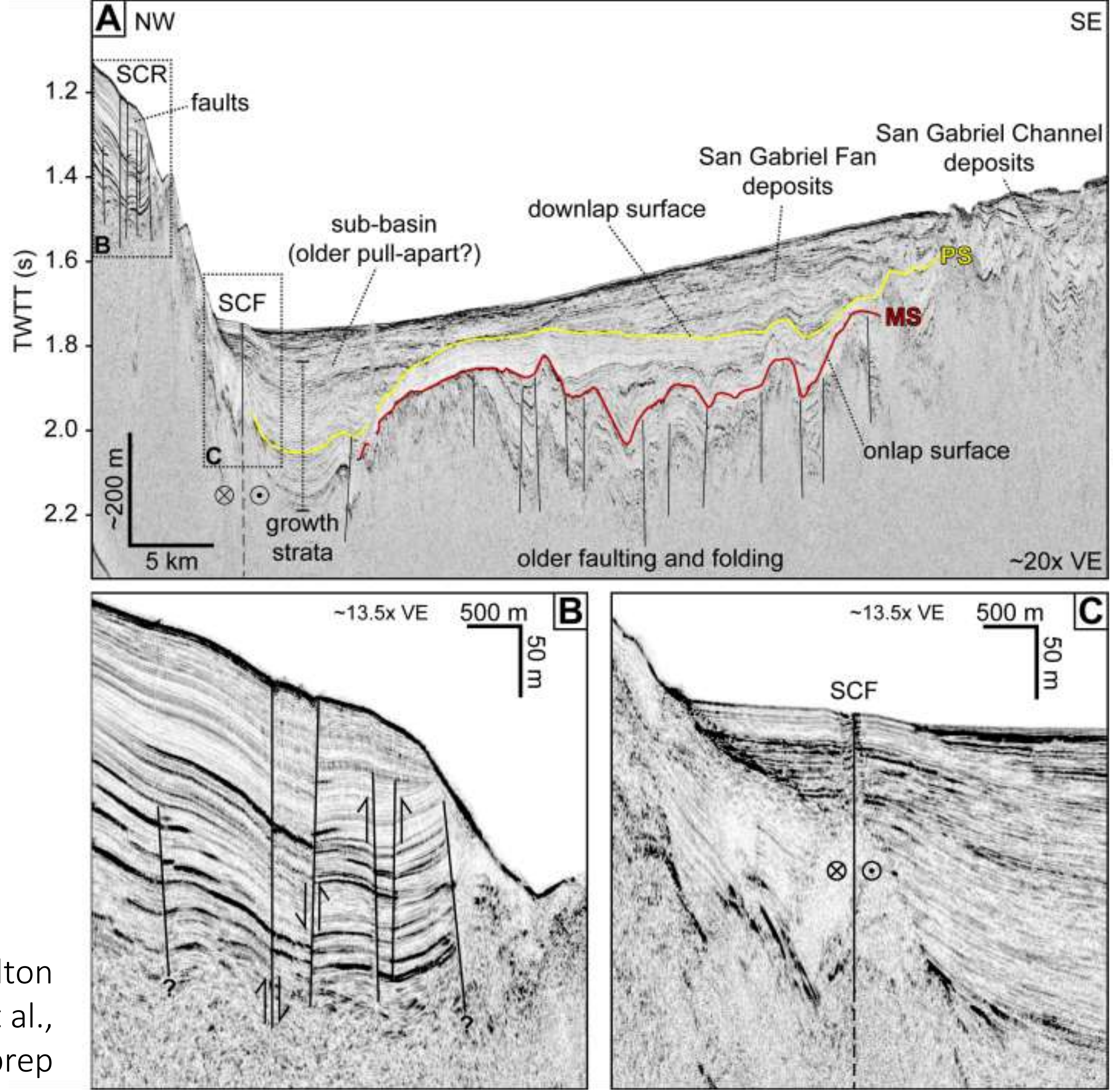
How is slip partitioned between the different fault strands?

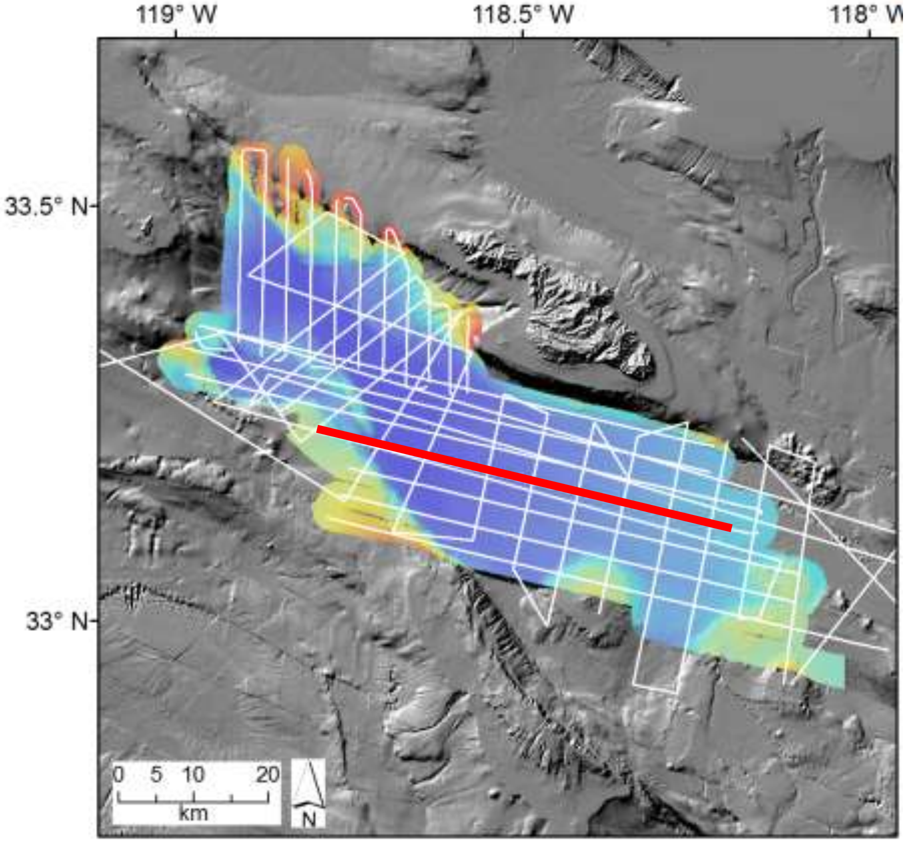
Are these fault systems related to underlying structures, and if so, how?



Dartnell, P., E. C. Roland, N. A. Raineault, C. M. Castillo, J. E. Conrad, R. R. Kane, D. S. Brothers, J. W. Kluesner, and M. A. L. Walton (2017), Multibeam bathymetry and acoustic-backscatter data collected in 2016 in Catalina Basin, southern California and merged multibeam bathymetry datasets of the northern portion of the Southern California Continental Borderland, *USGS data release*, U.S. Geological Survey, Santa Cruz, CA.

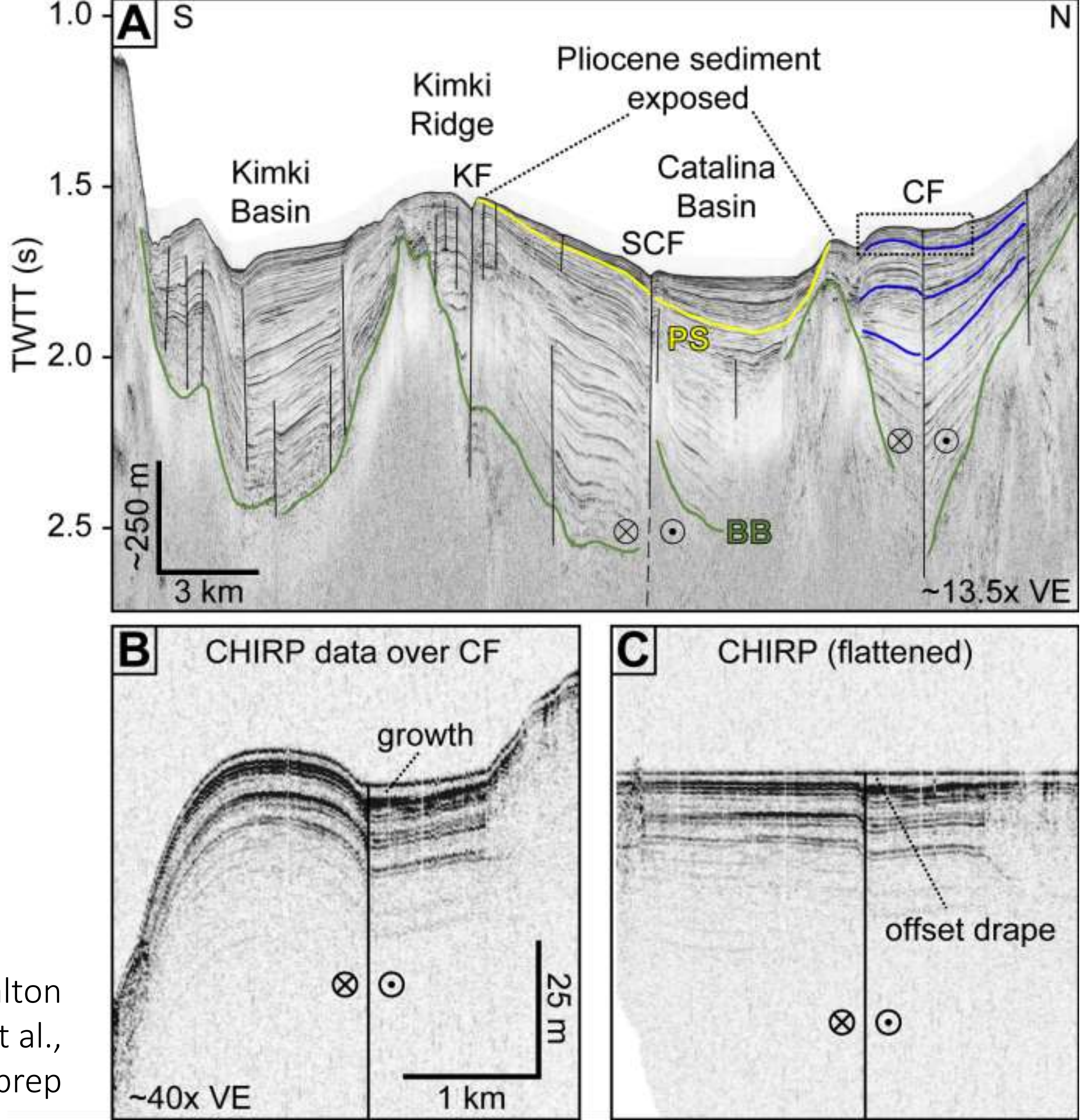
Faults

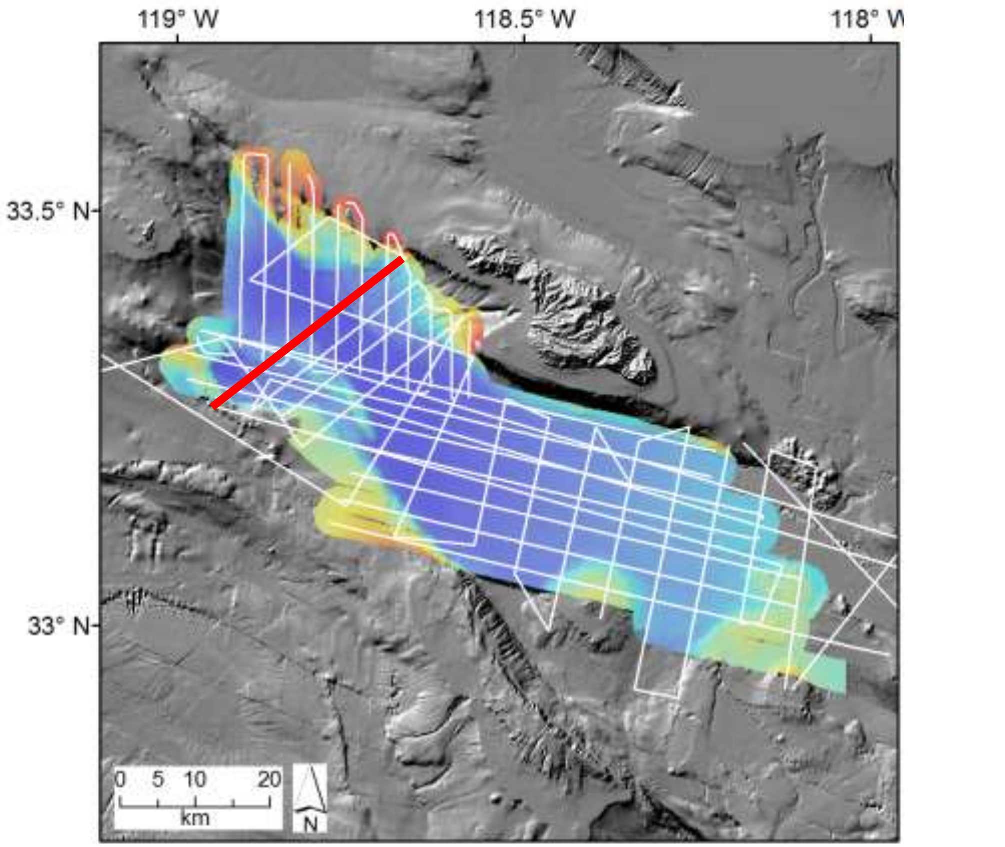




Walton et al., in prep

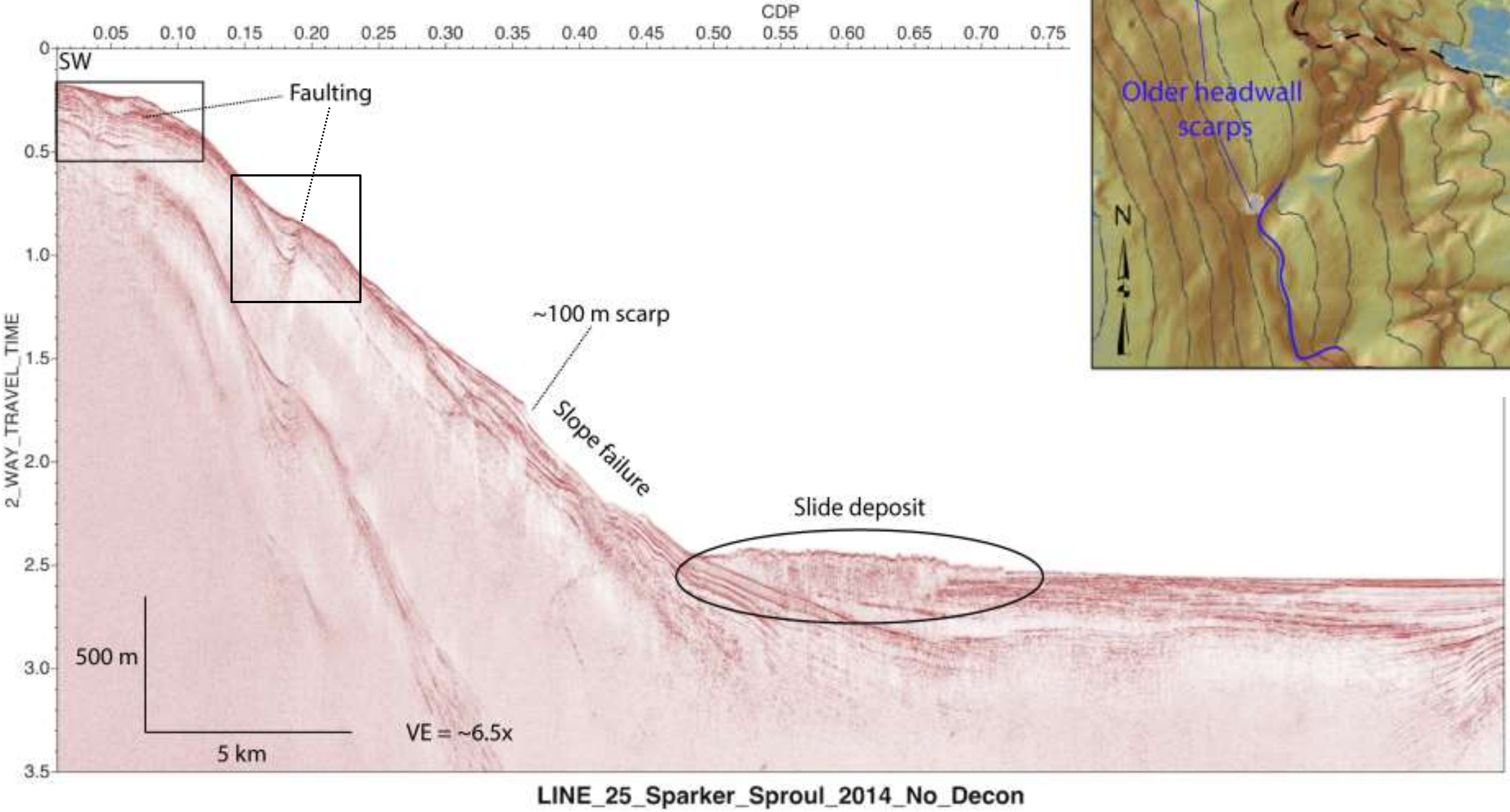
Faults

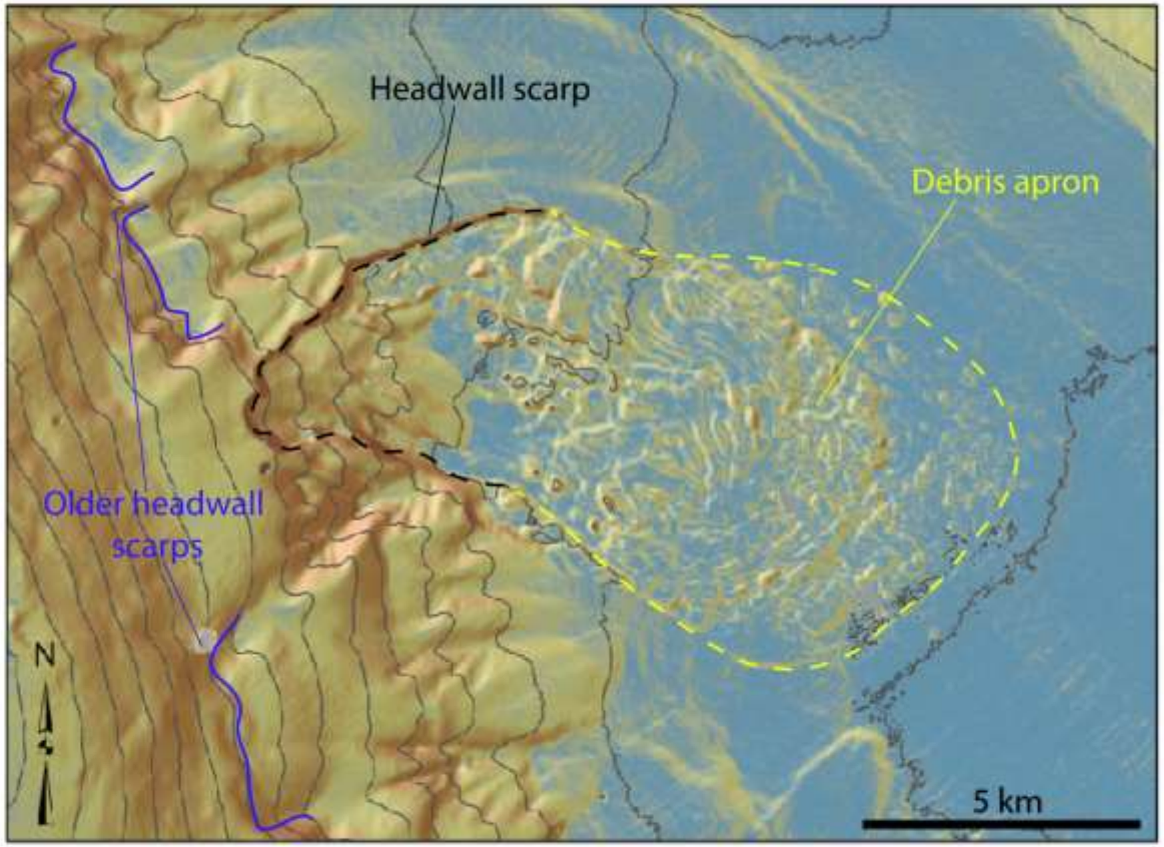




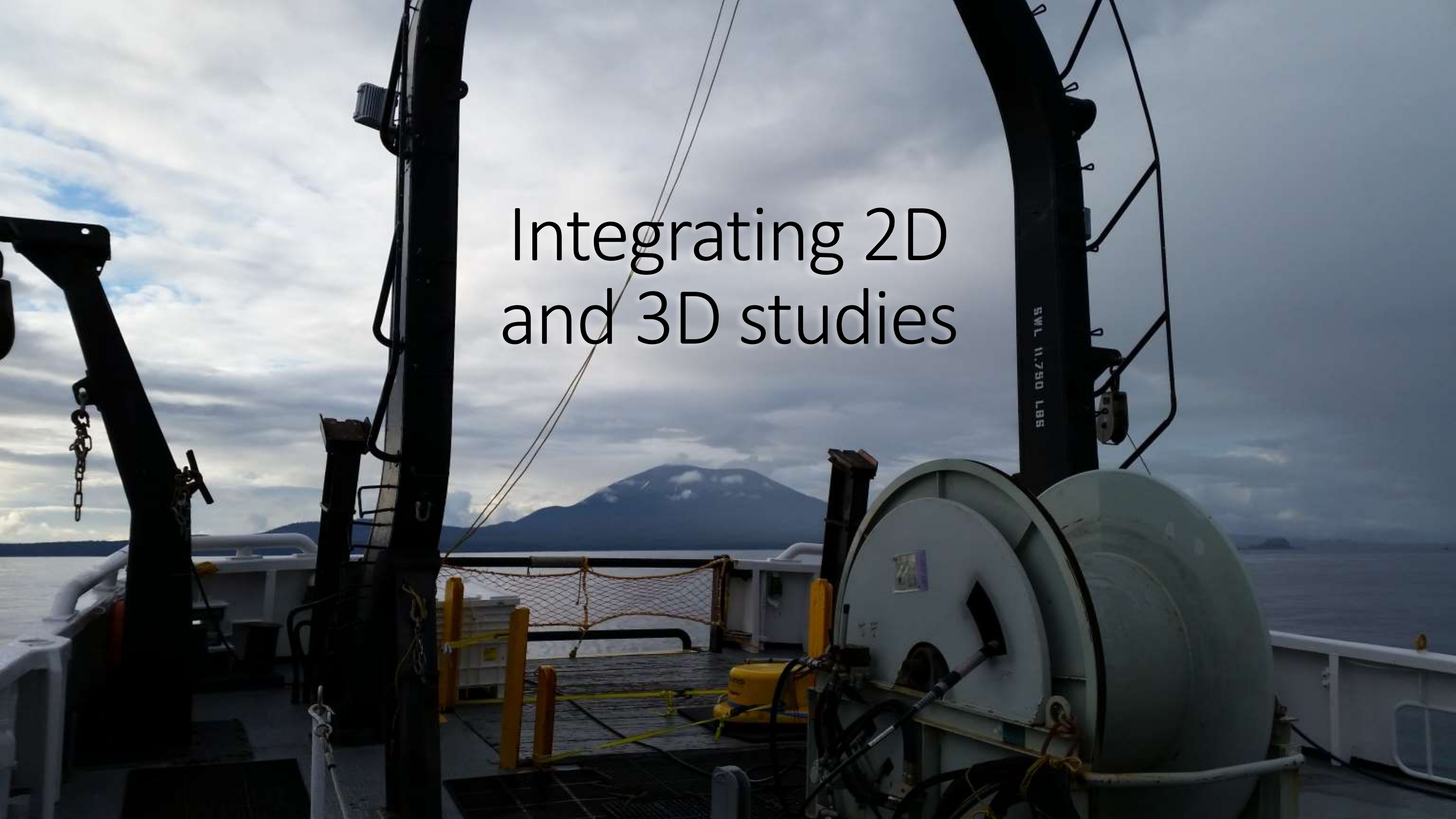
Walton et al., in prep

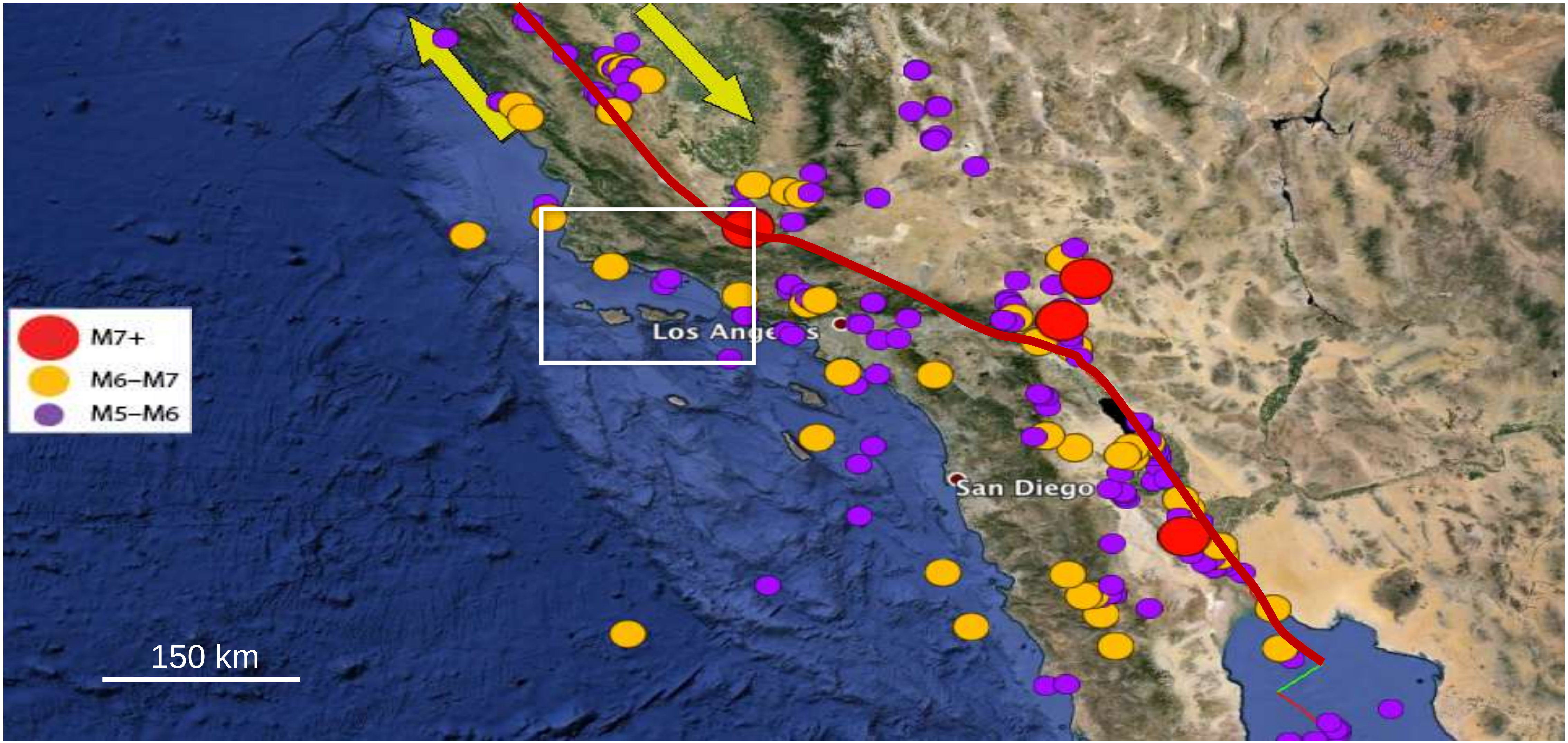
Submarine landslides





Integrating 2D and 3D studies

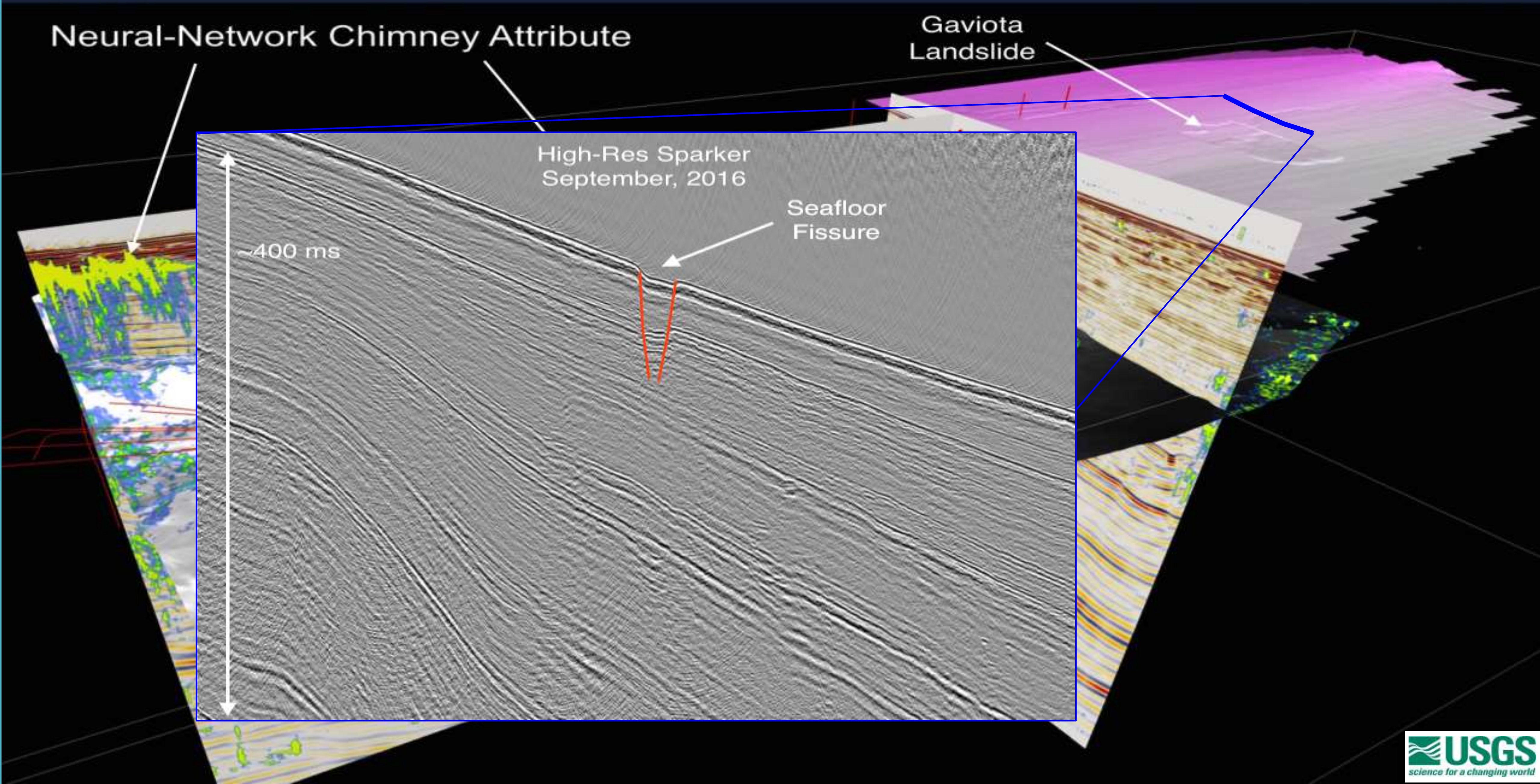




Earthquakes M5+ since 1870

Distributed plate boundary deformation

Santa Barbara Channel 3D



Developing 3D capabilities

Advanced fault mapping

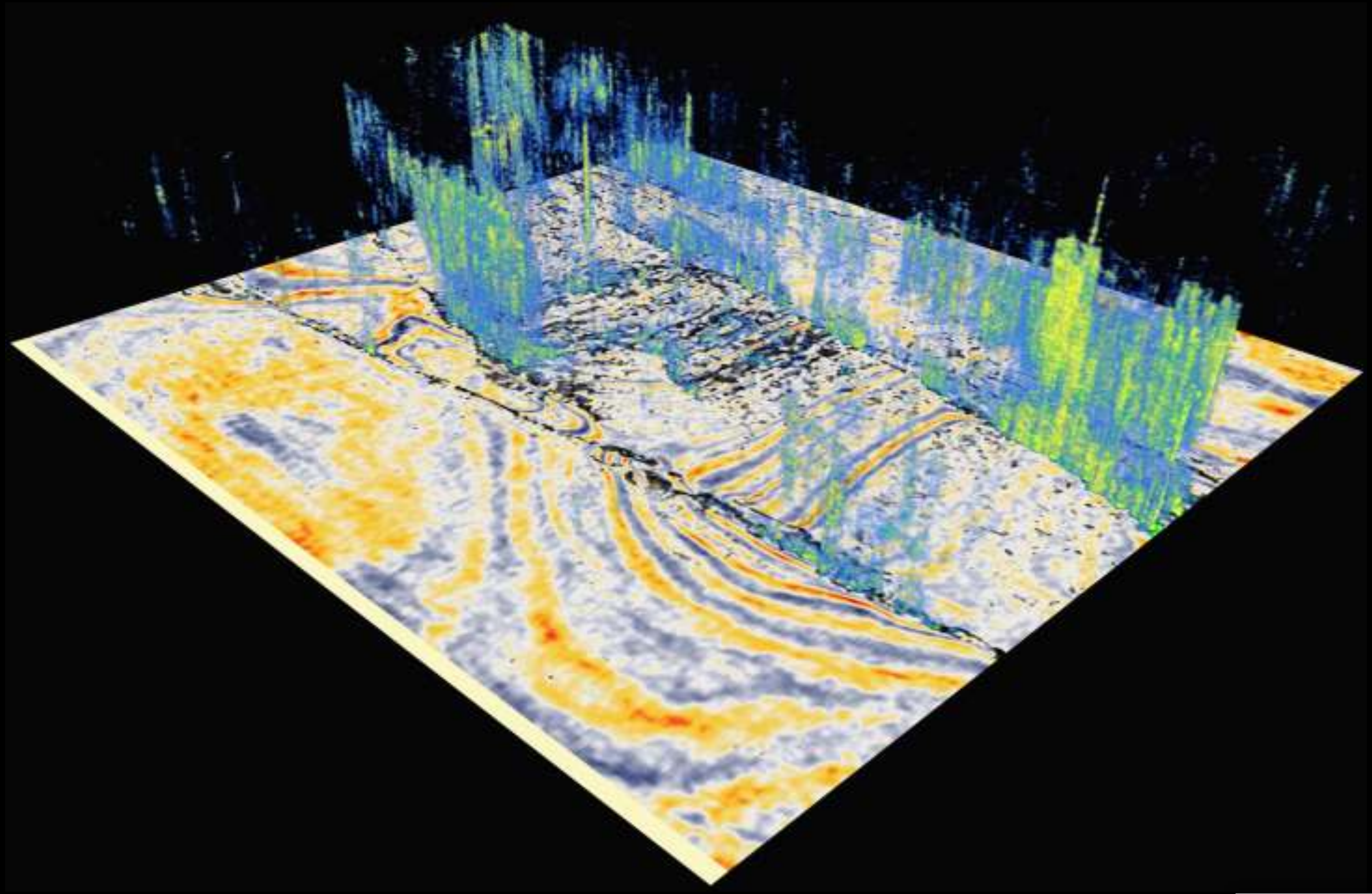
3D horizon mapping

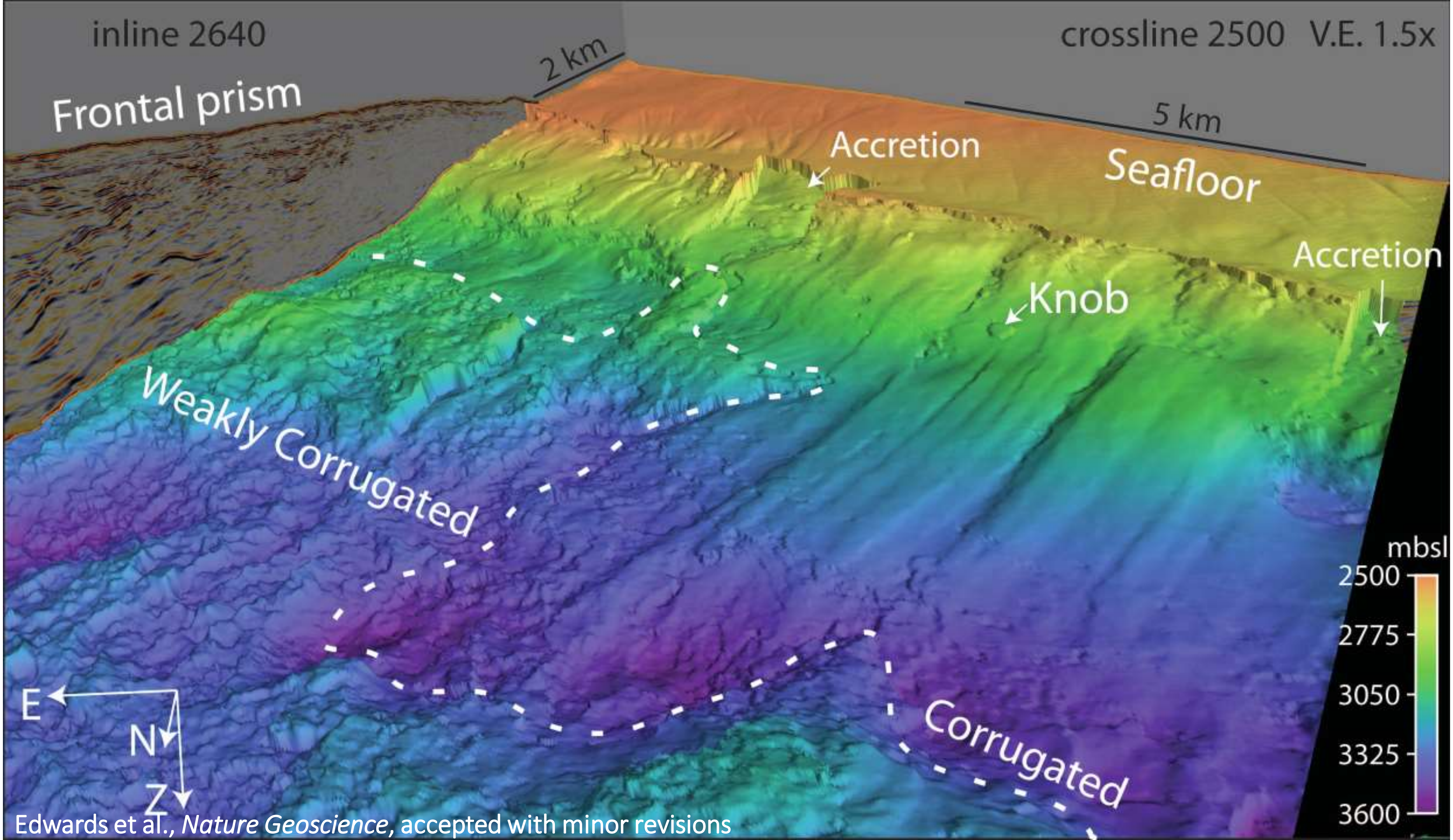
Fluid-flow analysis

Fault, chimney attributes

Hosgri 3D study (Kluesner and Brothers, 2016; right image)

Santa Barbara Channel 3D (Wright et al., in prep)



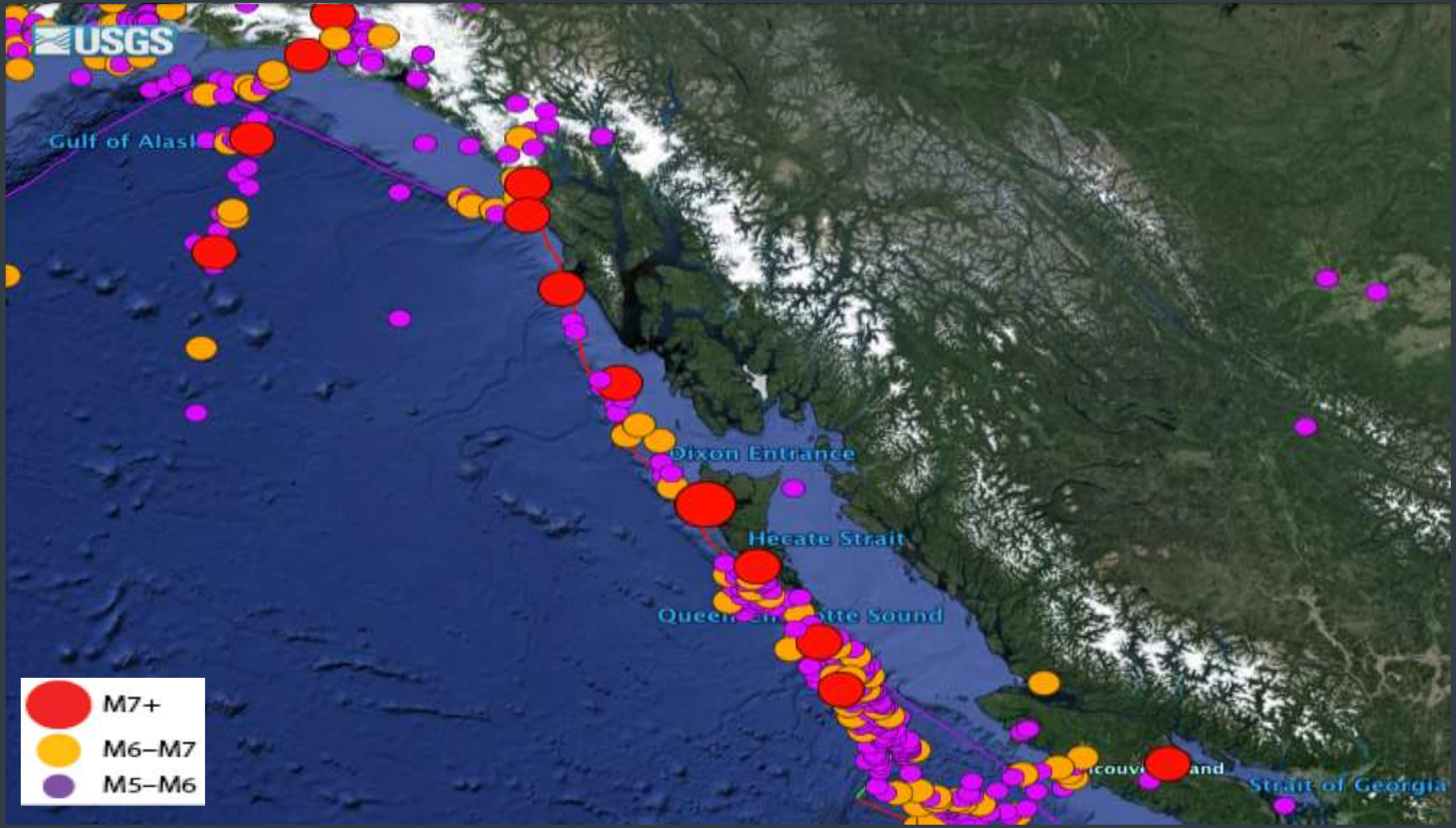


Edwards et al., *Nature Geoscience*, accepted with minor revisions


Alaska

Queen Charlotte-Fairweather Fault

- 1,200 km-long right-lateral transform boundary
- Very remote and difficult to map: 920 km located offshore, another 200 km covered by glaciers
- Few-to-no constraints on strain partitioning, fault segmentation, earthquake recurrence, etc.
- 7 magnitude 7 and greater earthquakes since 1900. Canada's largest earthquake ever recorded (1949 M8.1).
- Recent earthquakes: 2012 M7.8 Haida Gwaii and 2013 M7.5 Craig: motive for better understanding



2015-2017 Alaska field campaign

2015–2017: 150+ days in the field, 116 days at sea (!)

R/V Solstice (20 day MBES & MCS)

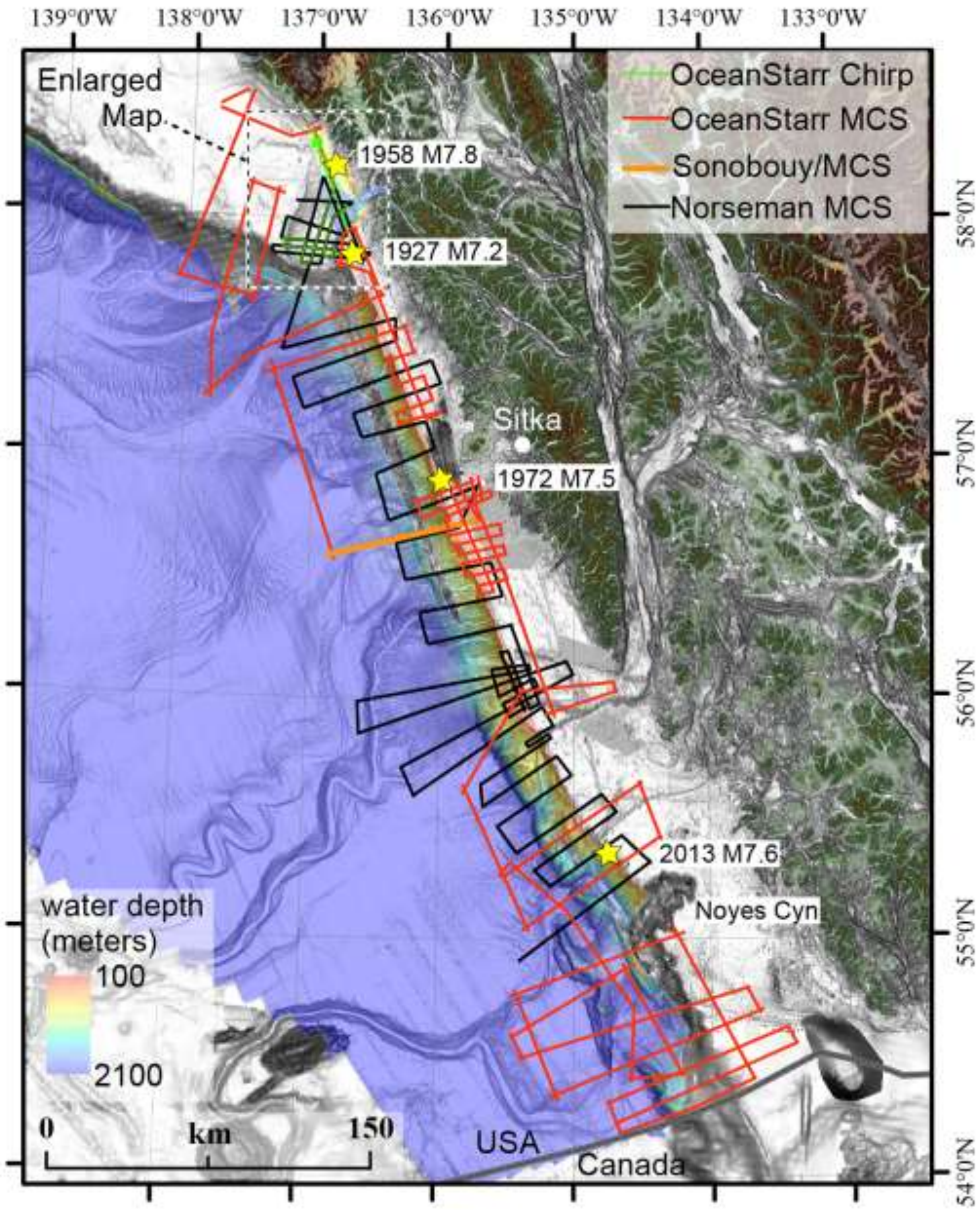
R/V Alaskan Gyre (11 day Chirp & MCS)

R/V Medeia (27 day MBES and MCS)

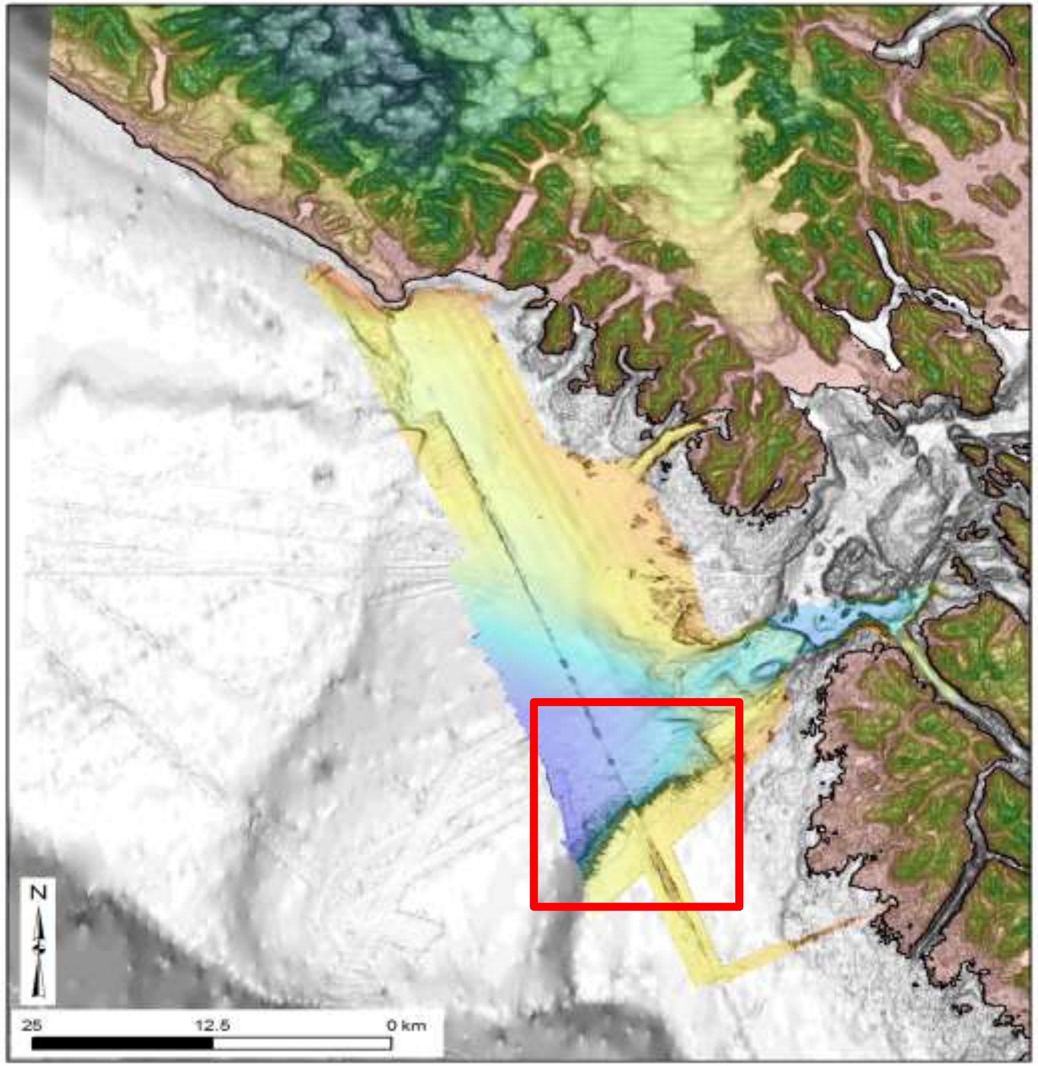
R/V Norseman (17 day MCS)

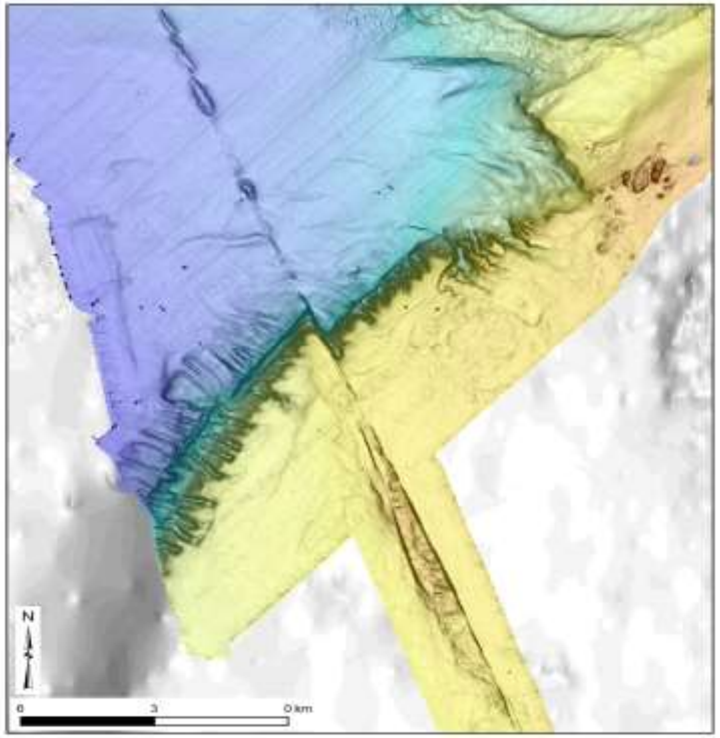
R/V Ocean Starr (22 day Chirp & MCS)

R/V Tully (19 day piston coring, video, and sampling)



Queen Charlotte Fault





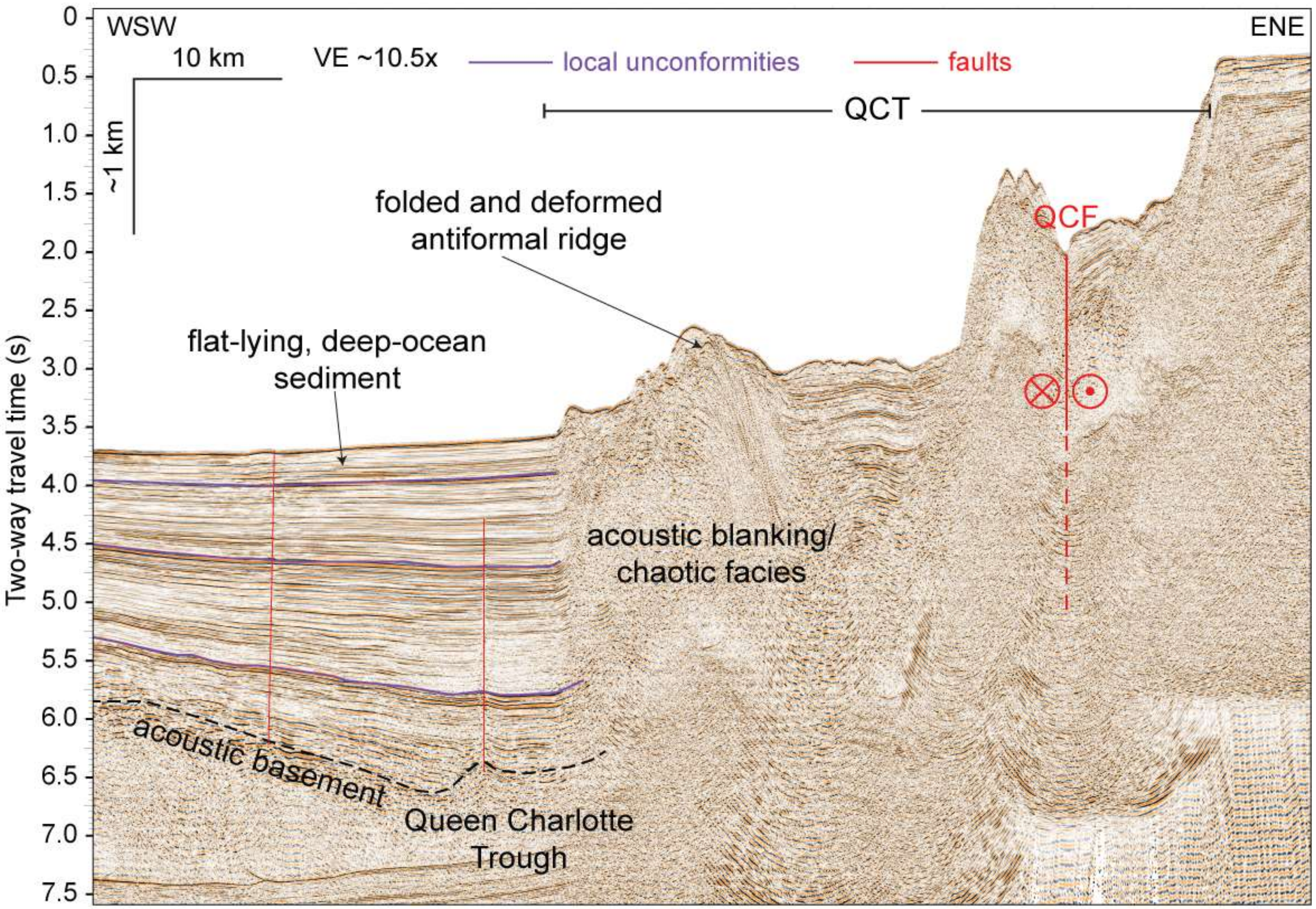
Offset glacial sea valley (and a number of other piercing points)

925 + 25 m displacement since glacial retreat ~17 Ka

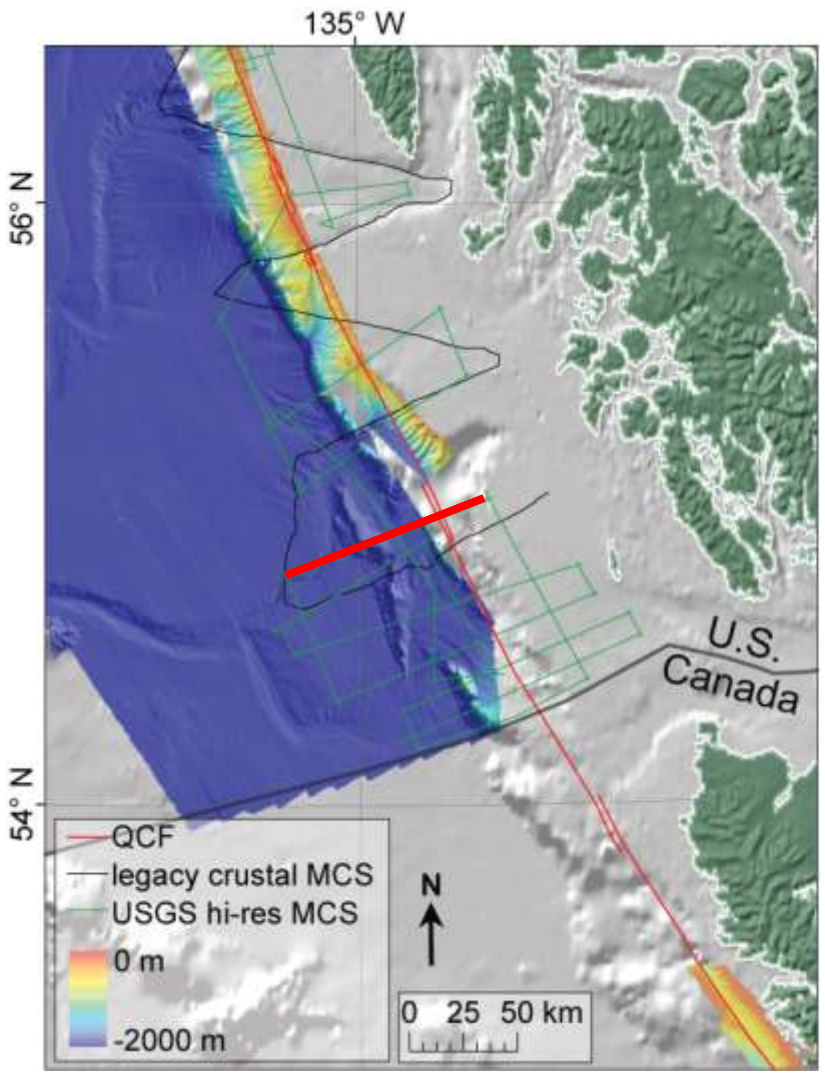
Slip rates calculated: ~53-56 mm/yr… entire plate boundary displacement on a single fault?

Recent (2017) core data will help constrain timing of glacial retreat

Queen Charlotte Fault

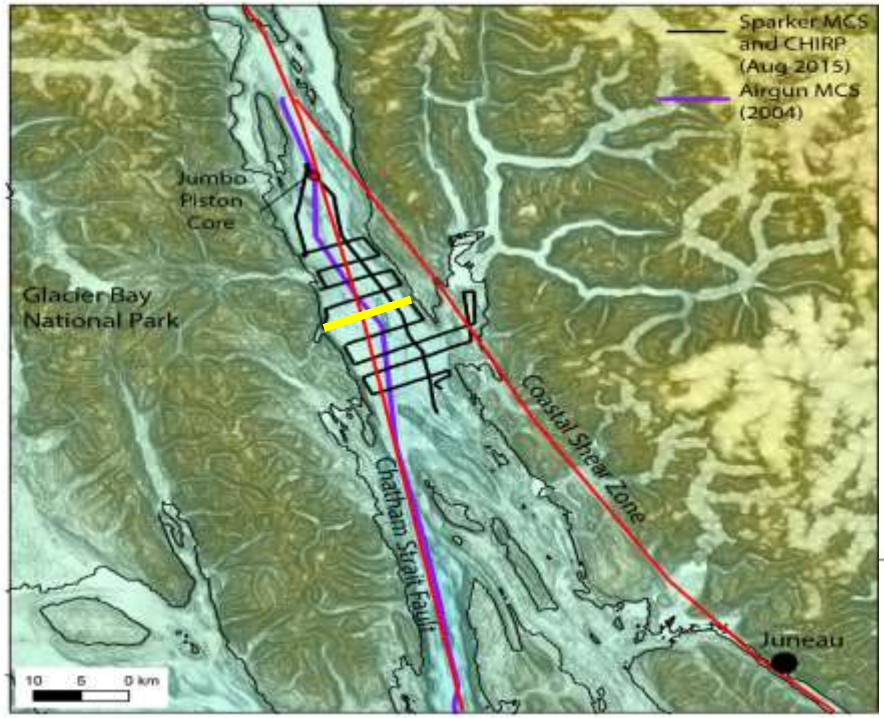


1978 USGS crustal-scale legacy MCS (reprocessed)



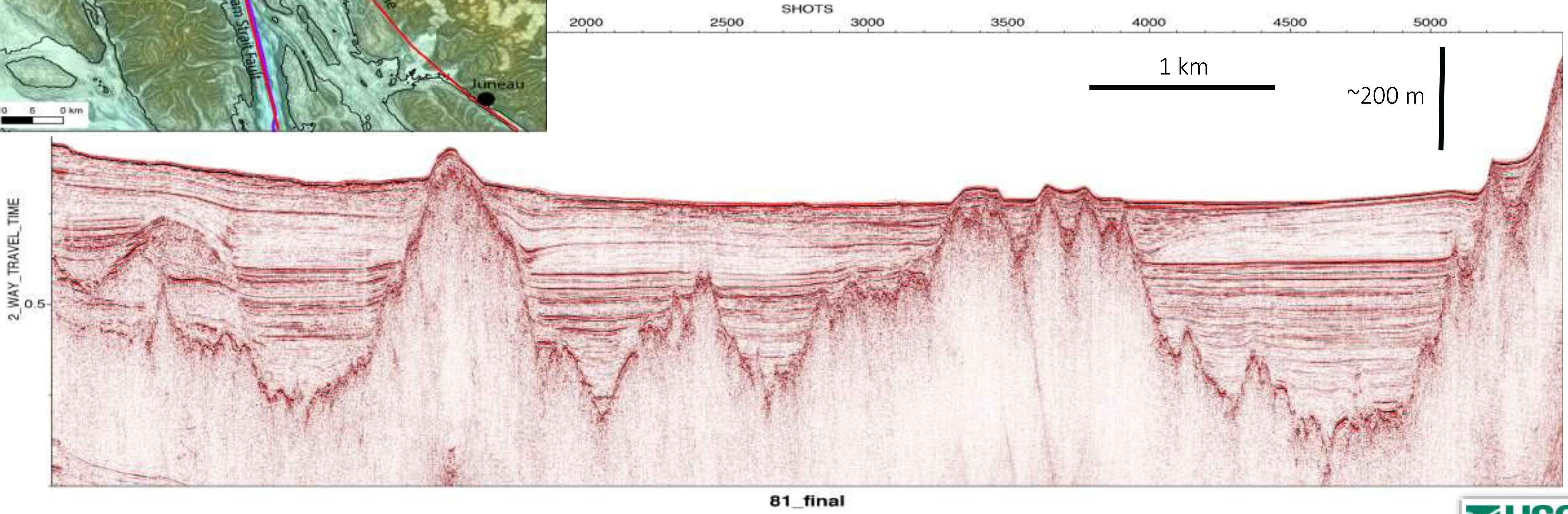
New evidence for Quaternary deformation (another shameless plug for poster T51G-0558 Friday morning)

Chatham Strait Fault



Beautiful, mostly continuous record of glacimarine sedimentation since Last Glacial Maximum

Not much evidence for active faulting



Improving high-resolution imaging

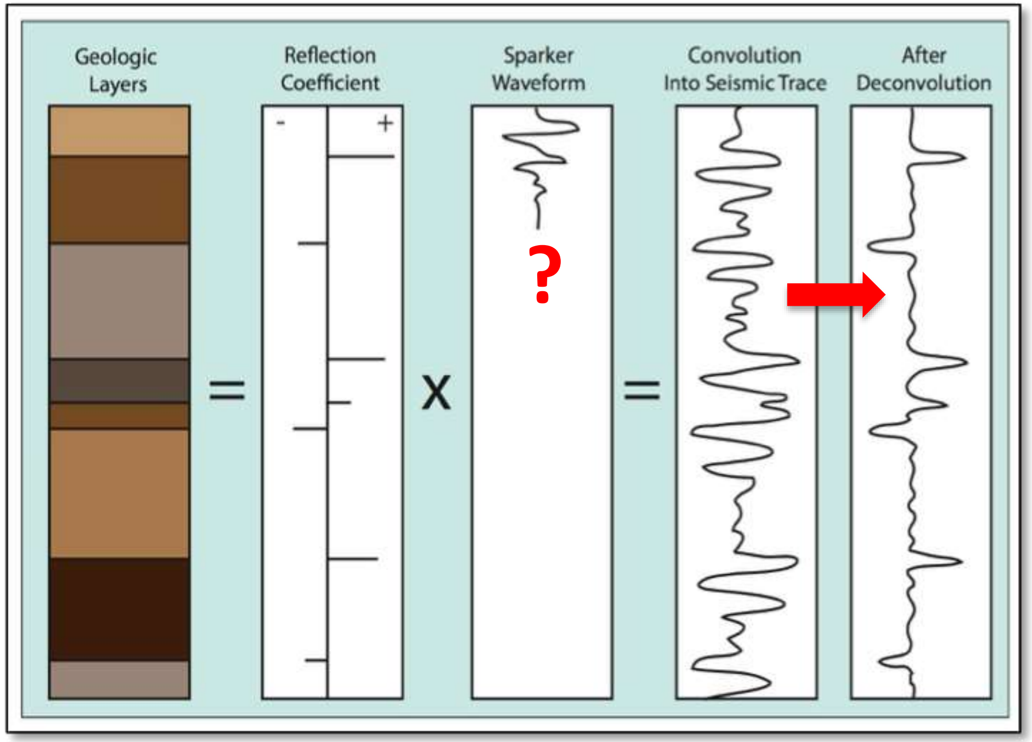
Isolating the Earth's response

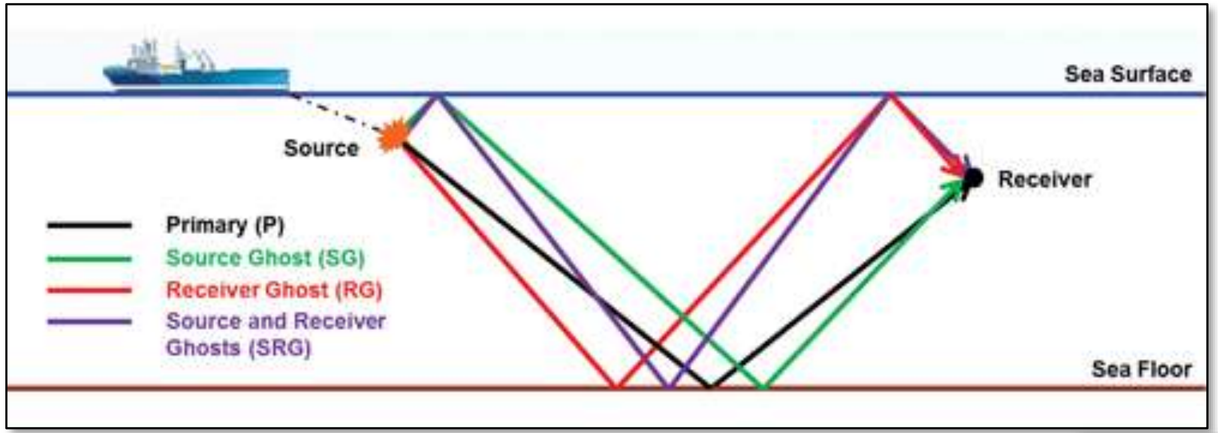
<u>Resolution</u>—the ability to discern fine-scale features below the seafloor—is severely limited by the complex nature of the outgoing sound pulse. This affects the quality of the data and a scientist's ability to interpret it.

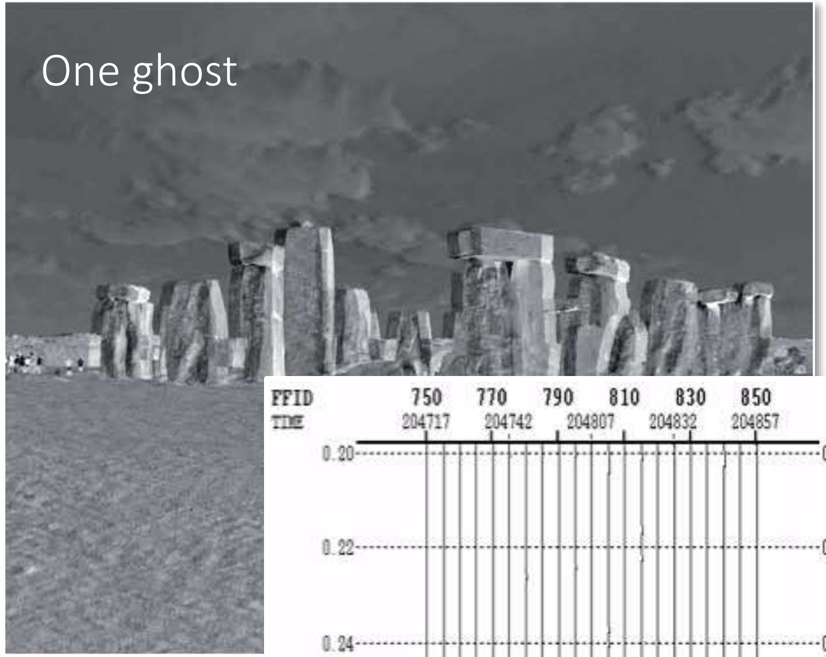
Imagery can be greatly improved and greater information garnered if each outgoing sound pulse could be completely characterized and removed from recorded data using deconvolution.

<u>Two deconvolution approaches:</u>
Estimated (predictive; easier and commonly used)
Deterministic (known; more difficult and less commonly used)

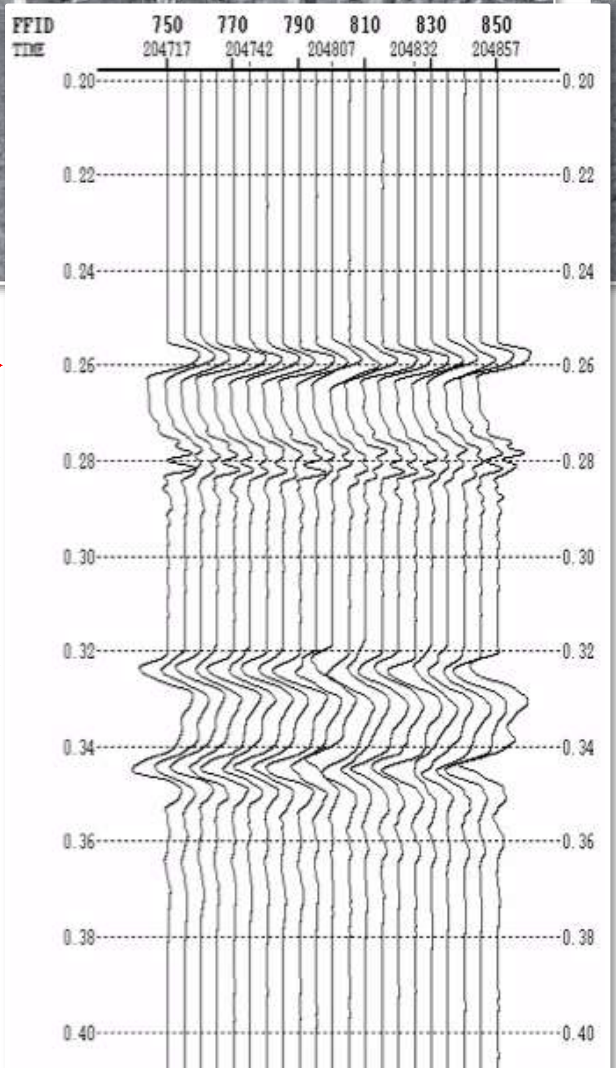
Significant problem with high-resolution seismic is the <u>ghost</u> – a reflection at the air/water interface.





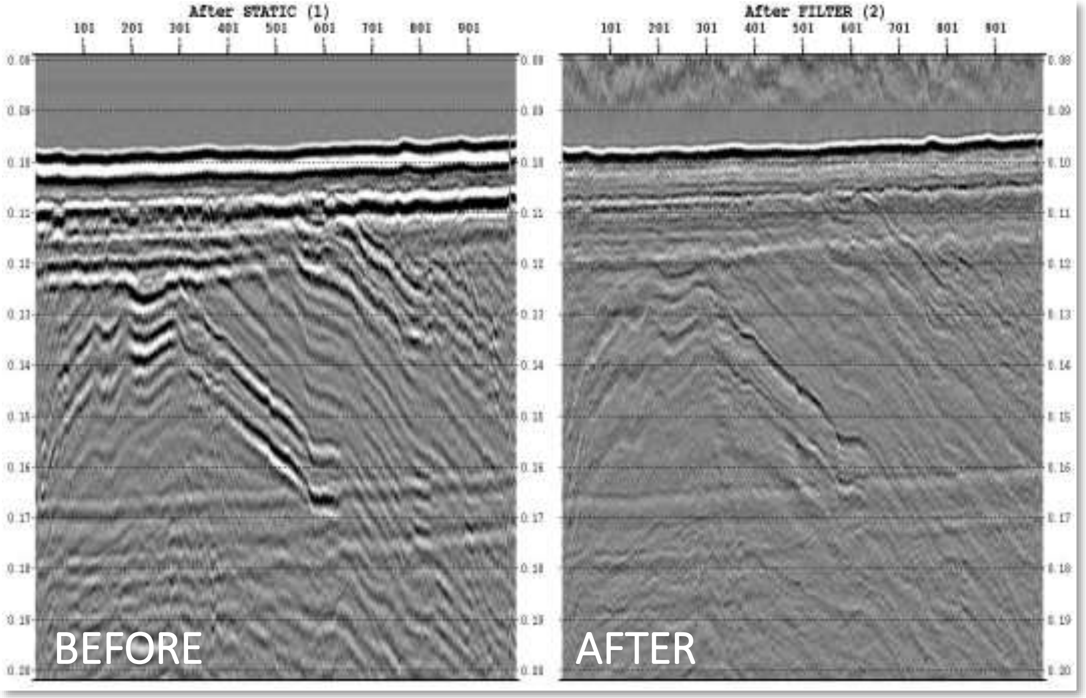


modified from Parkes and Hegna, 2011)



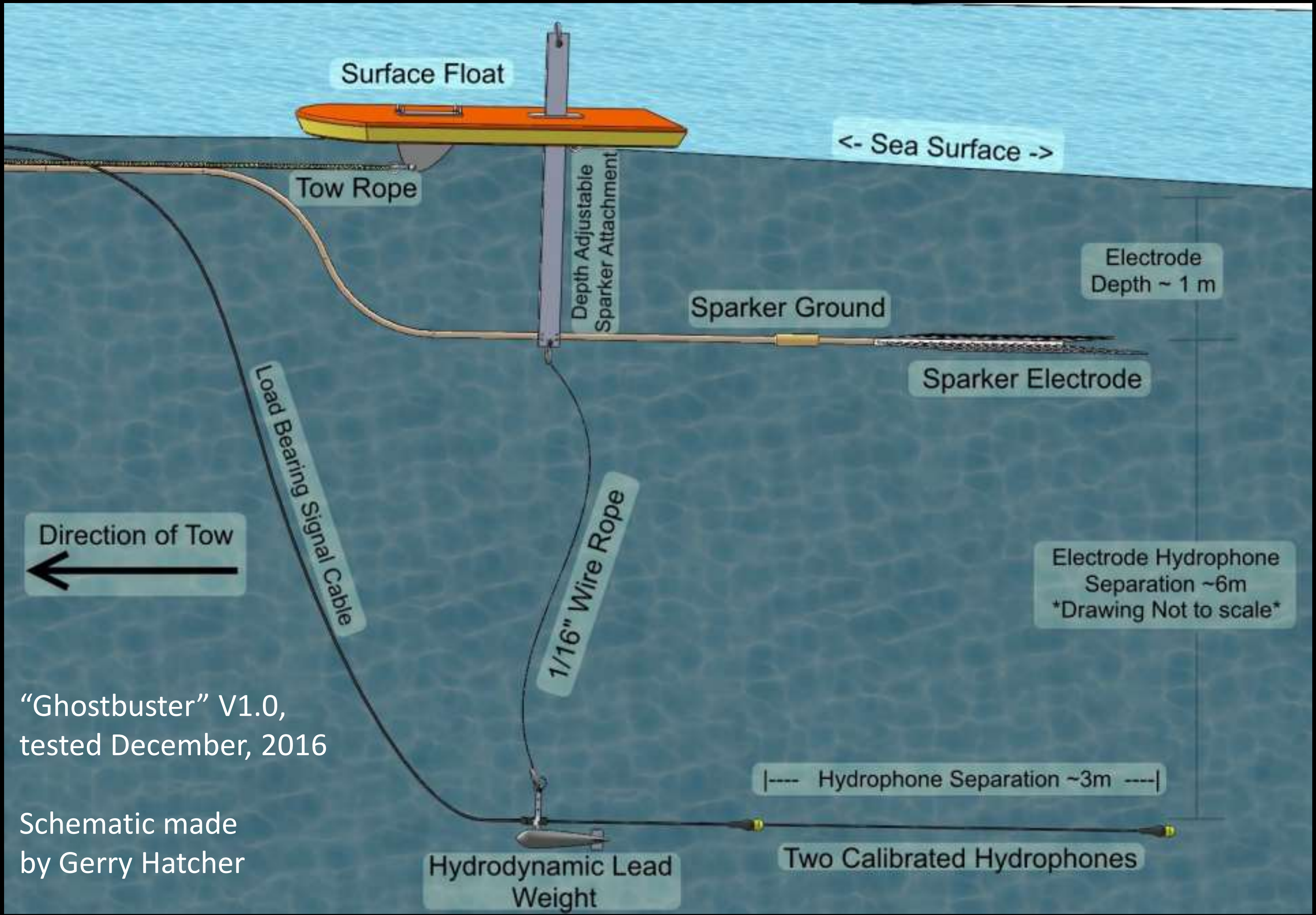
Processing/acquisition goals

- Deflect and/or scatter ghost
- Characterize every outgoing shot and resulting complex waveform
- Remove unwanted waveforms from data with deterministic deconvolution



Who you gonna call?

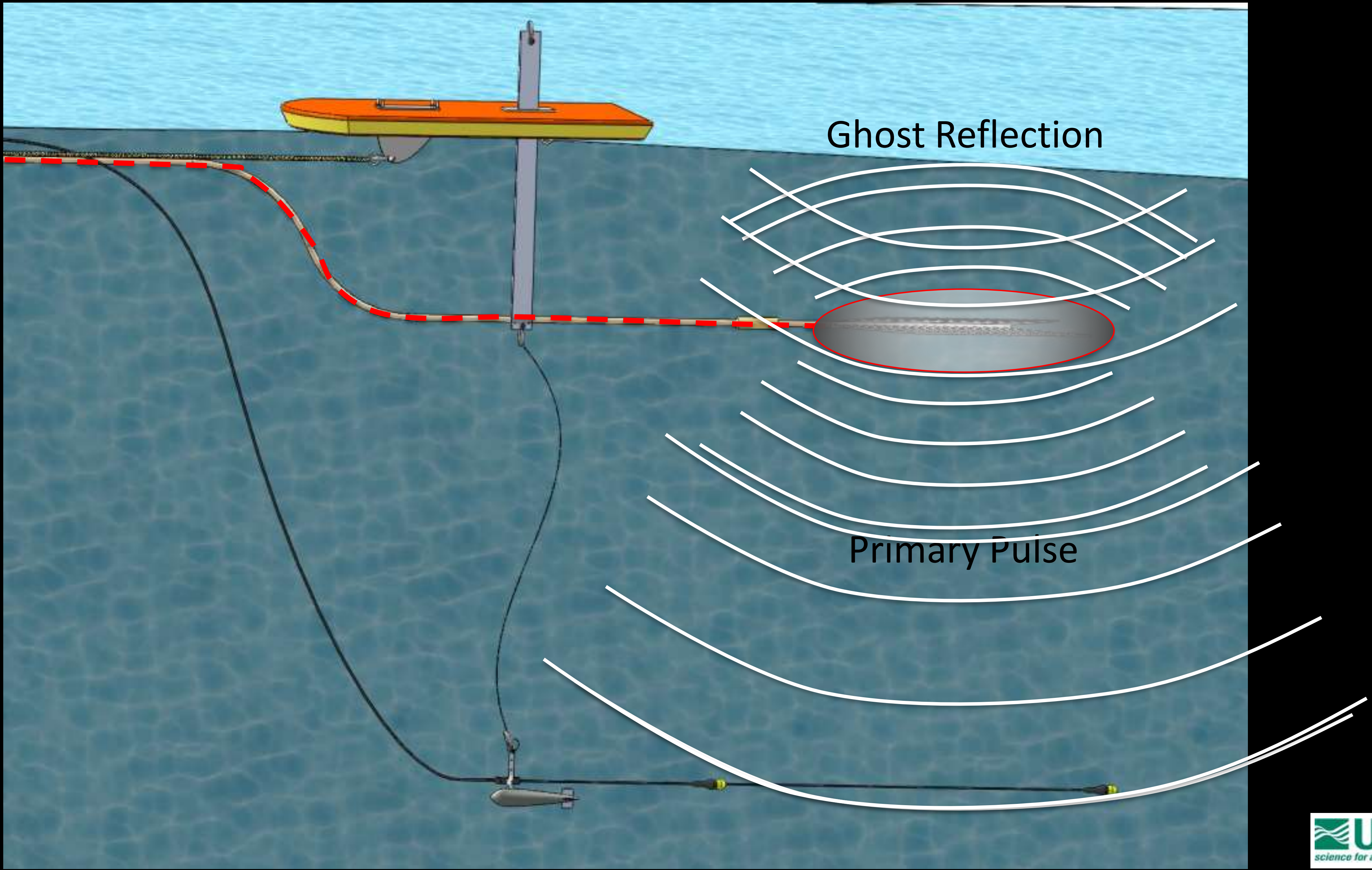
“Ghostbuster” deterministic deconvolution (in development)



“Ghostbuster” V1.0, tested December, 2016

Schematic made by Gerry Hatcher

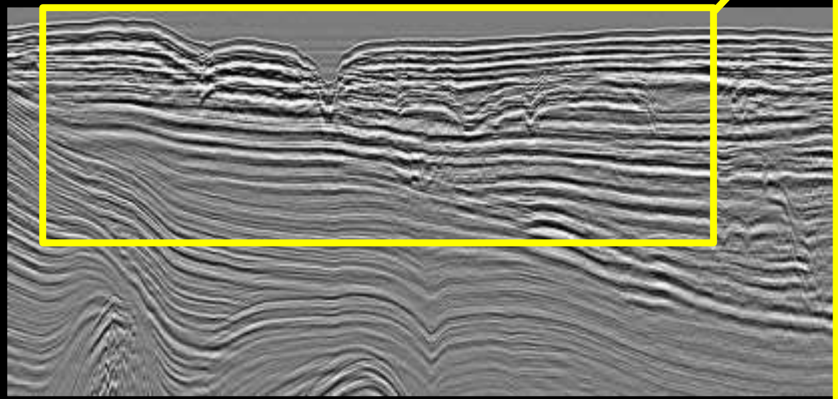
“Ghostbuster” V1.0 design, tested December, 2016

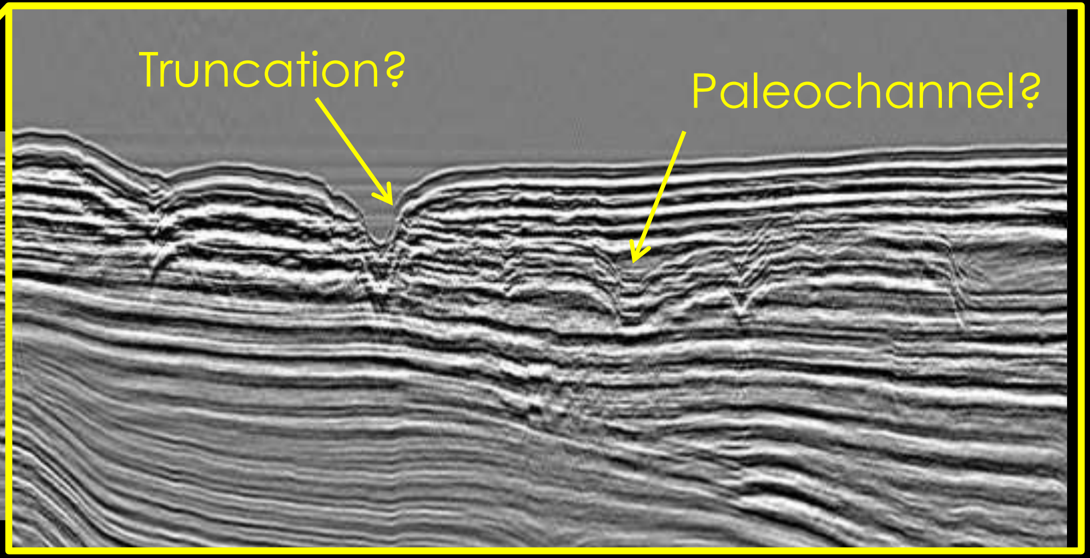


Examples of Sparker Wavelet Processing

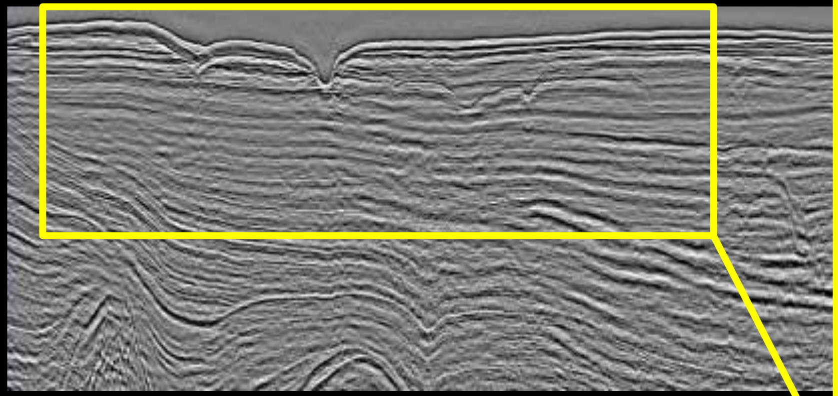
2014 Southern California Sparker MCS (~6 kJ and 48 channels)

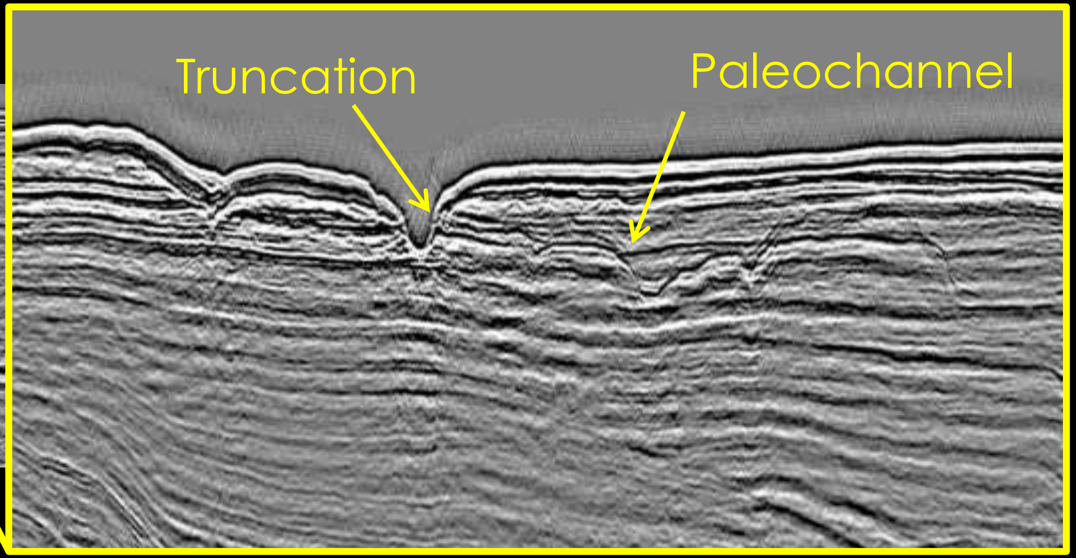
Without wavelet processing





With approximated wavelet processing



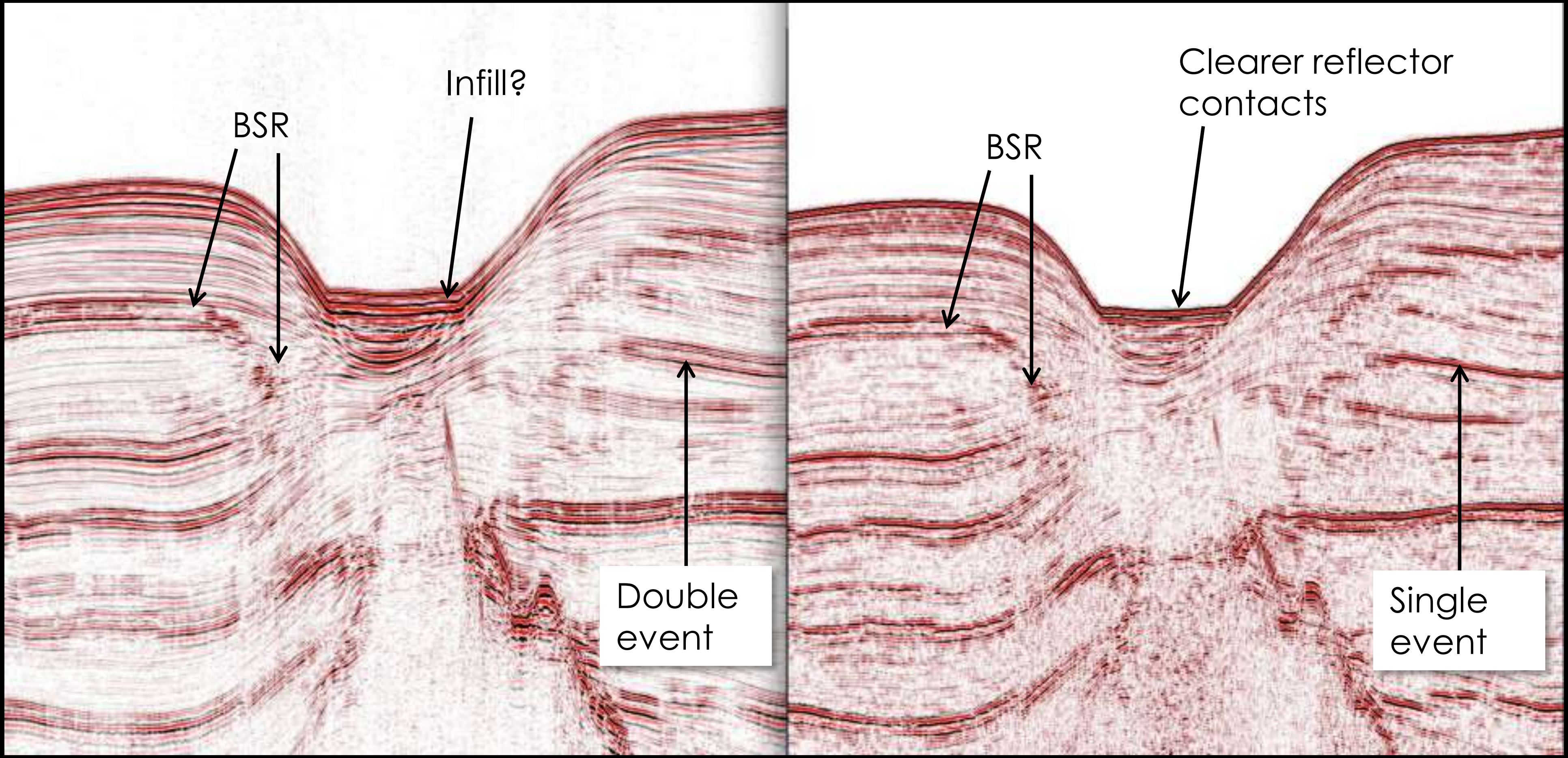


USGS
science for a changing world

Examples of Sparker Wavelet Processing

2014 Southern California Mini-Sparker MCS (~700 J and 48 channels)

Without wavelet processing | Wavelet processing

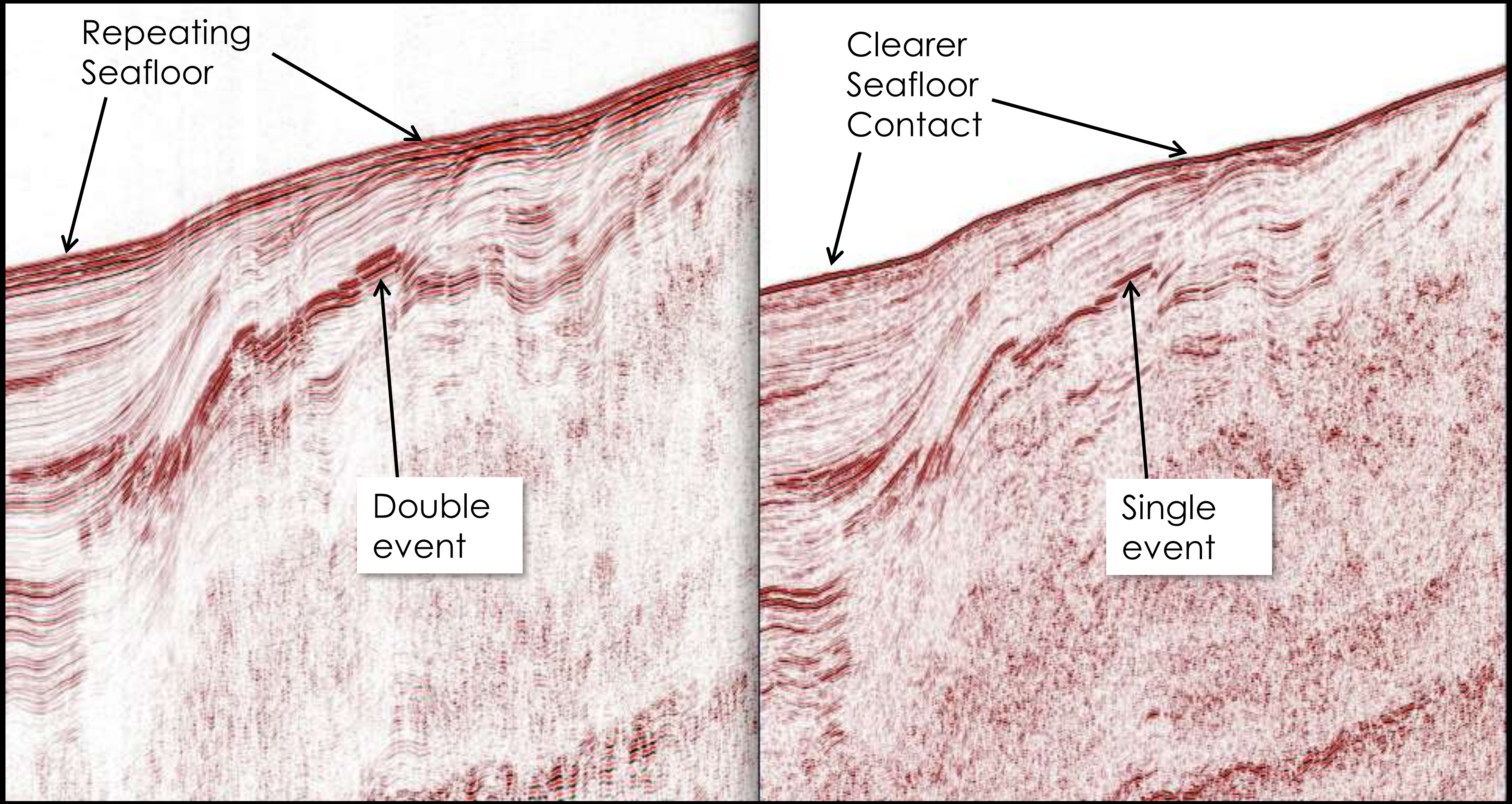


Examples of Sparker Wavelet Processing

2014 Southern California Mini-Sparker MCS (~700 J and 48 channels)

Without wavelet processing

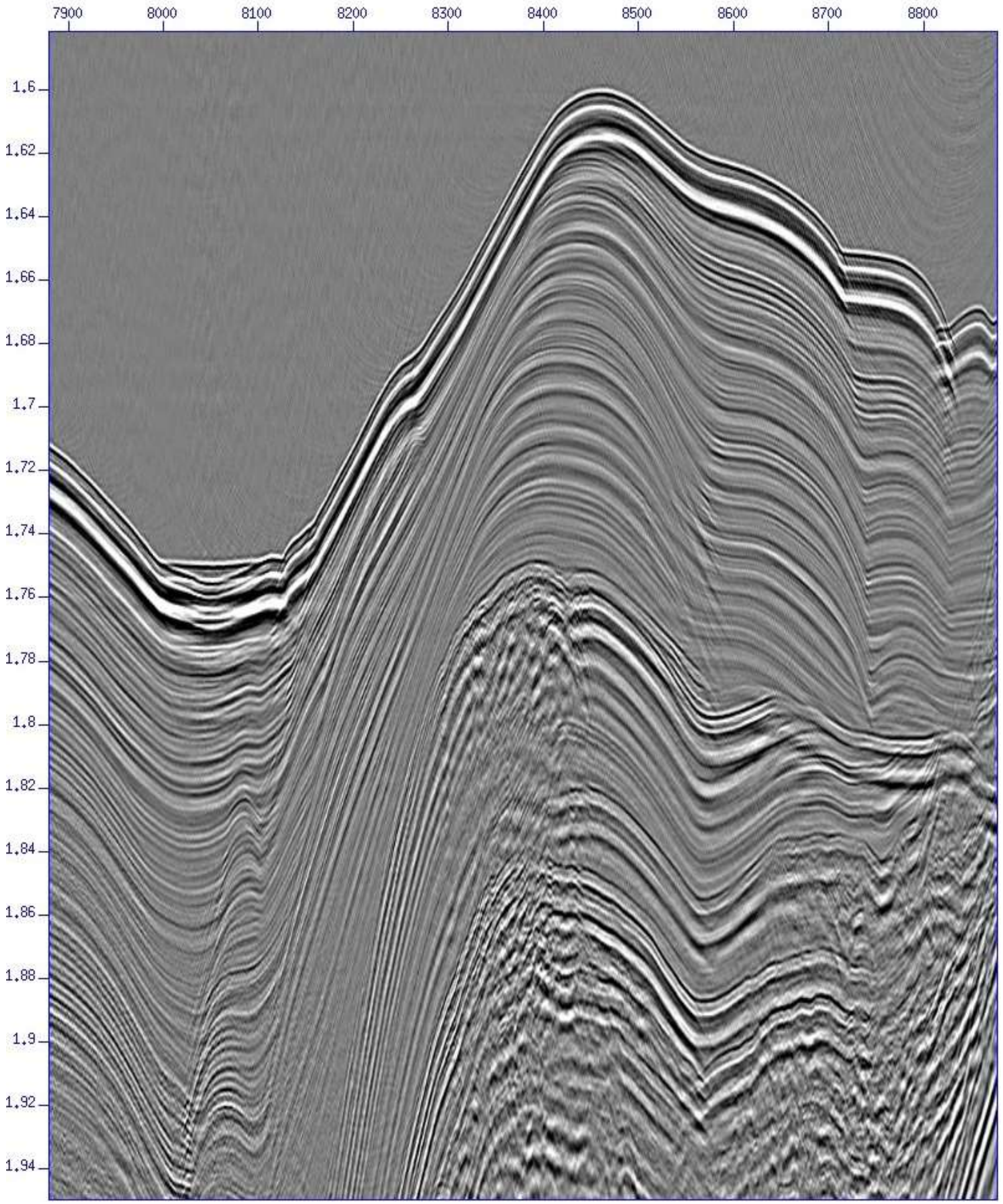
Wavelet processing

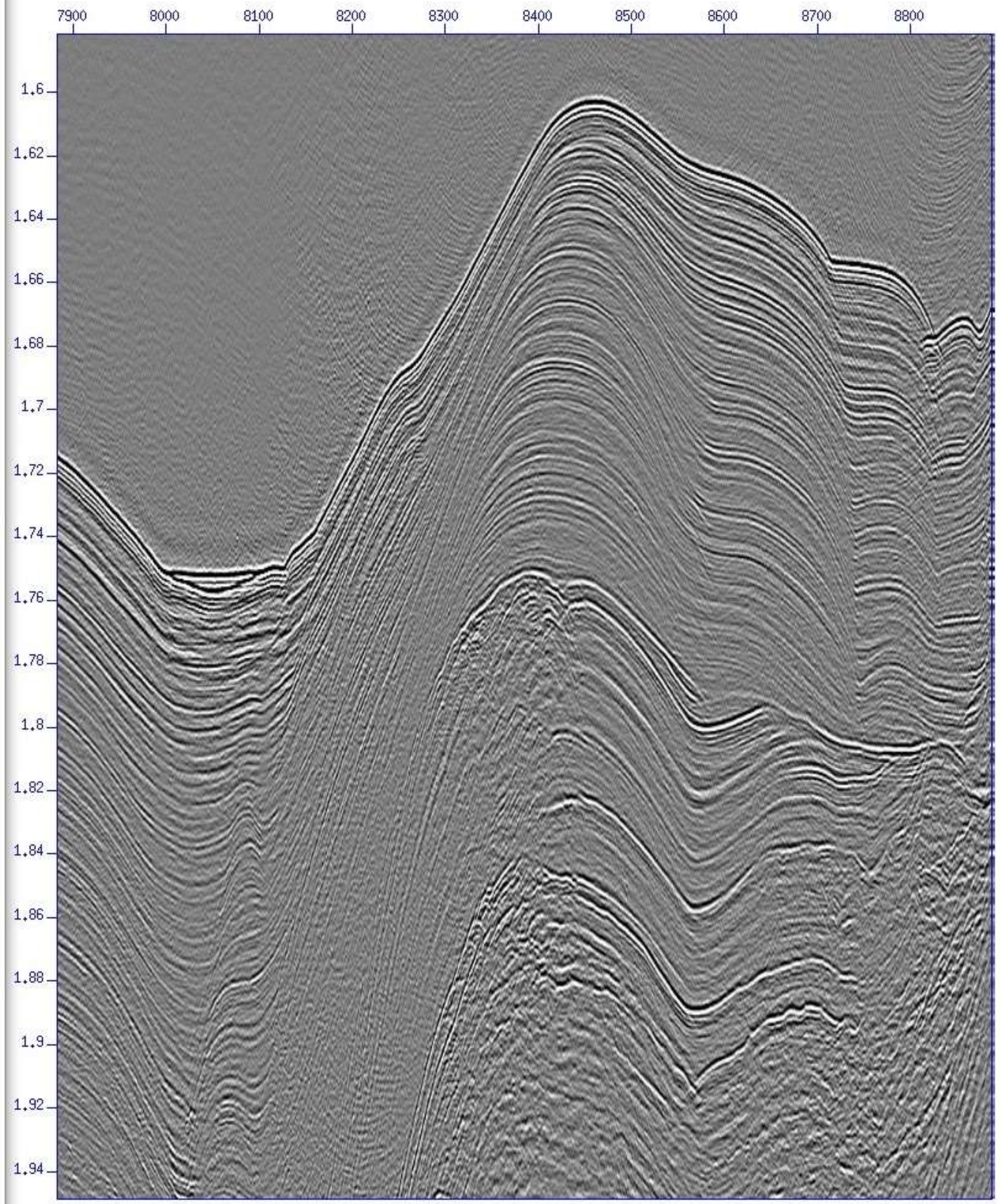


Thank you!

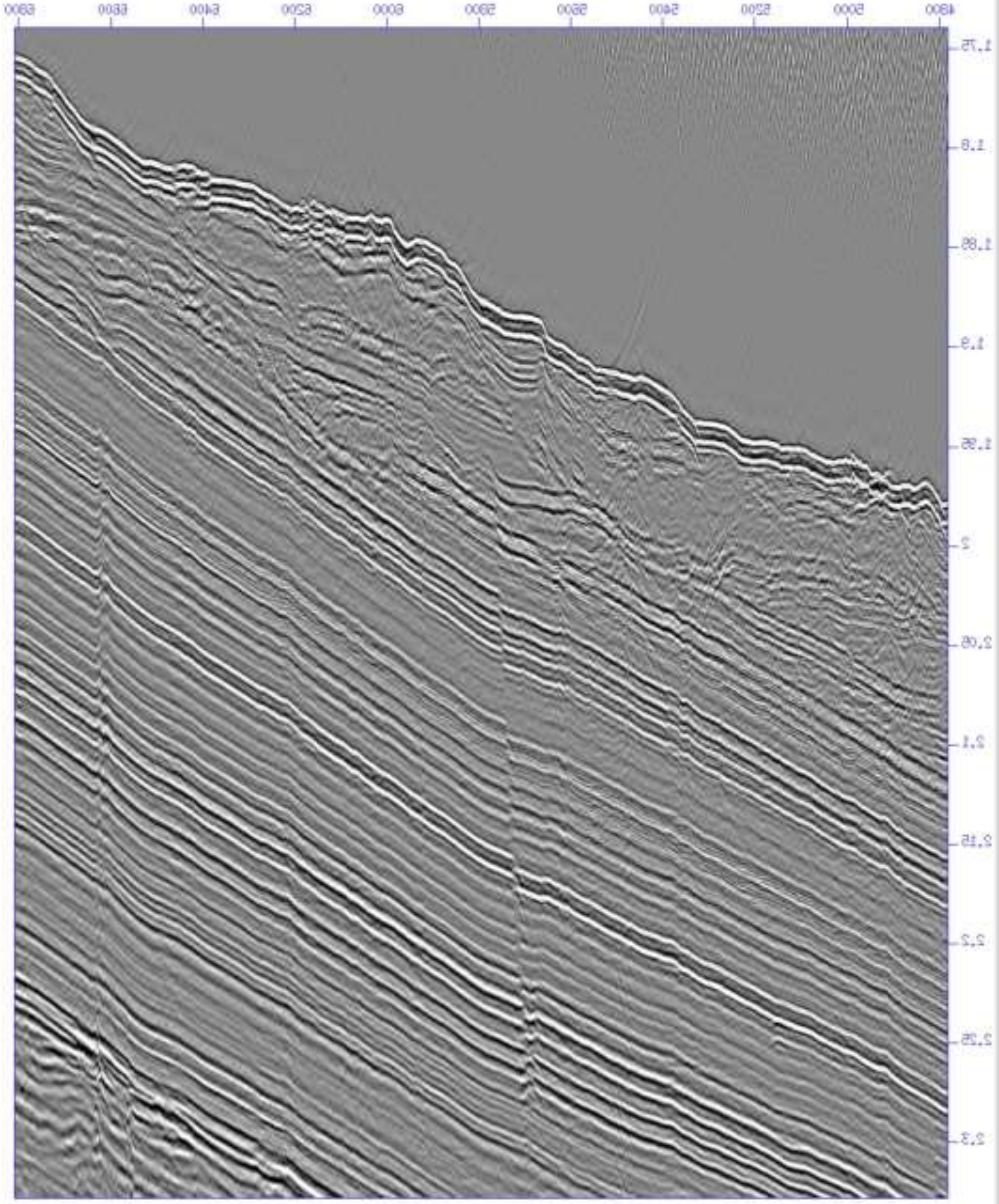
Acknowledgements: Alicia Balster-Gee, Danny Brothers, Jamie Conrad, Pete Dartnell, Joel Edwards, Pat Hart, Daniel Kennedy, Jared Kluesner, Ray Sliter, Alexis Wright, and many others who assisted with fieldwork and data!

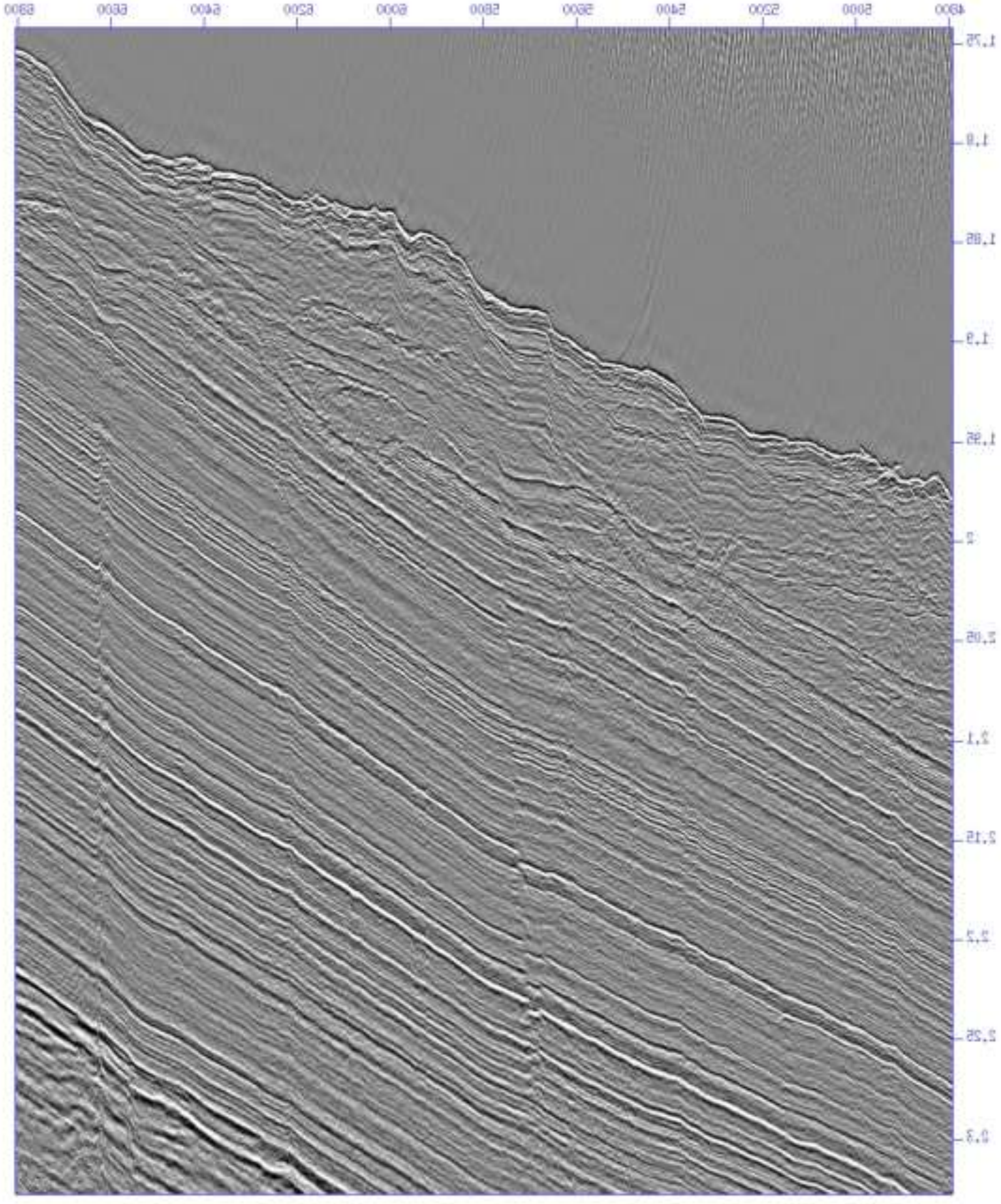
Sparker seismic stratigraphy



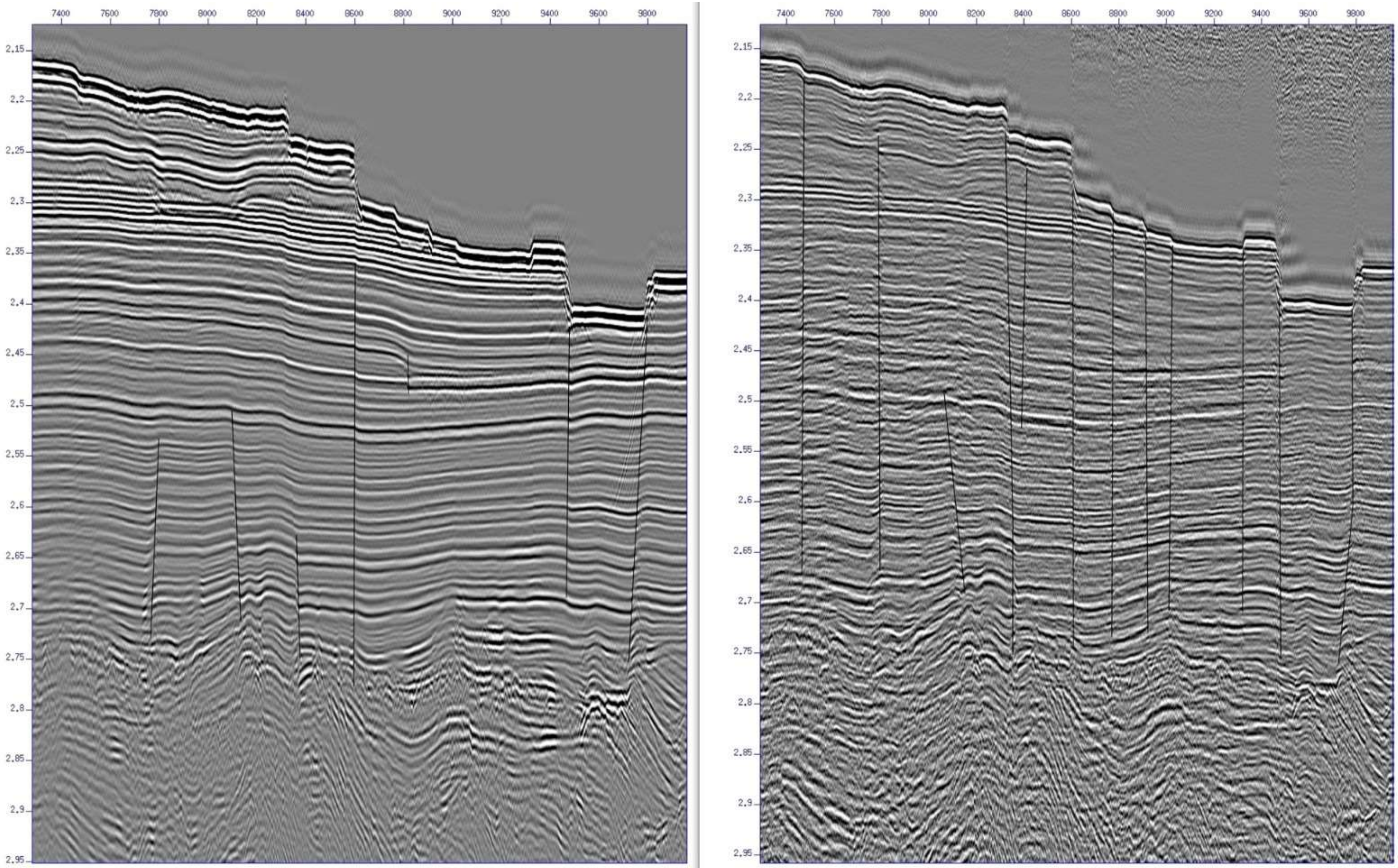


Sparker landslide structures





Sparker fault mapping



Atlantic margin