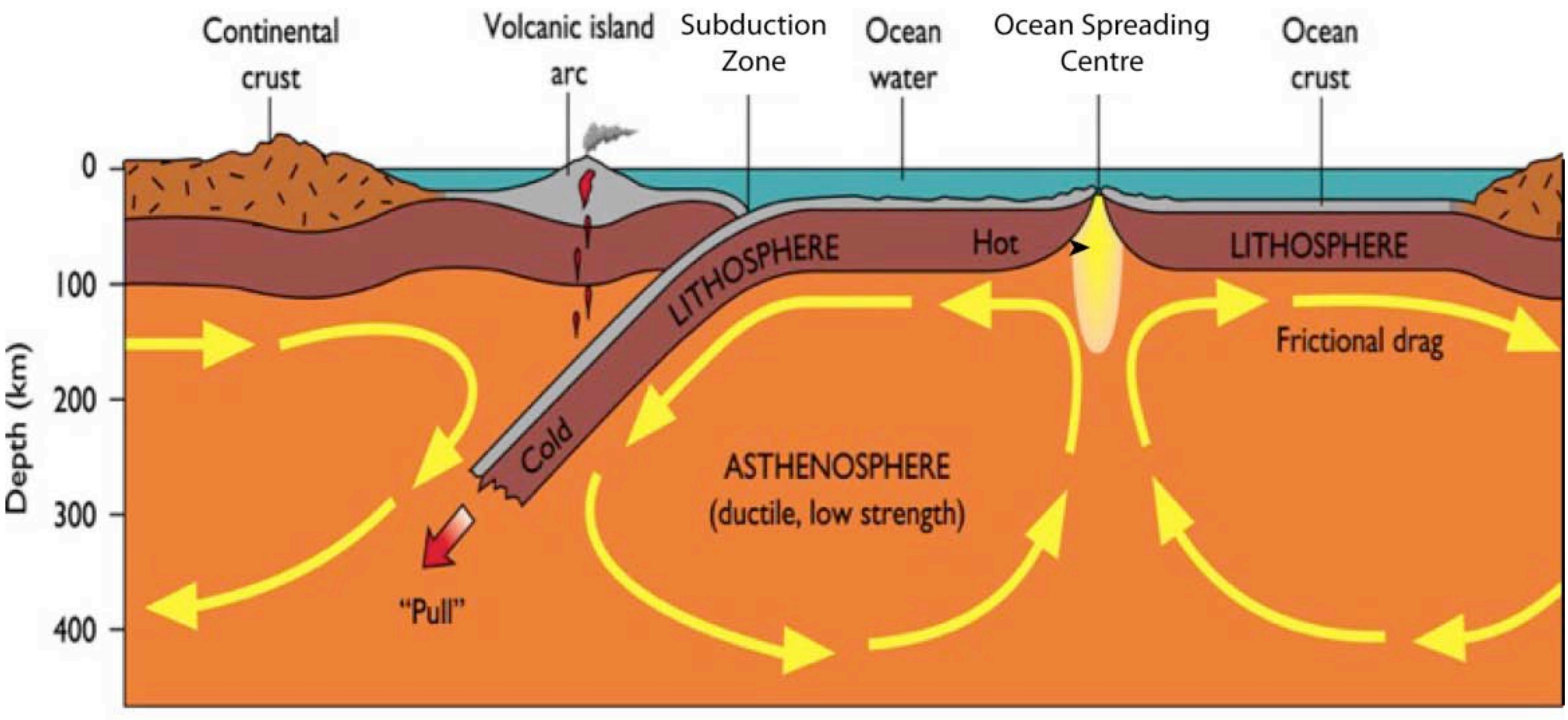
Trans-Atlantic iLab

Trans-Atlantic imaging of Lithosphere-asthenosphere boundary

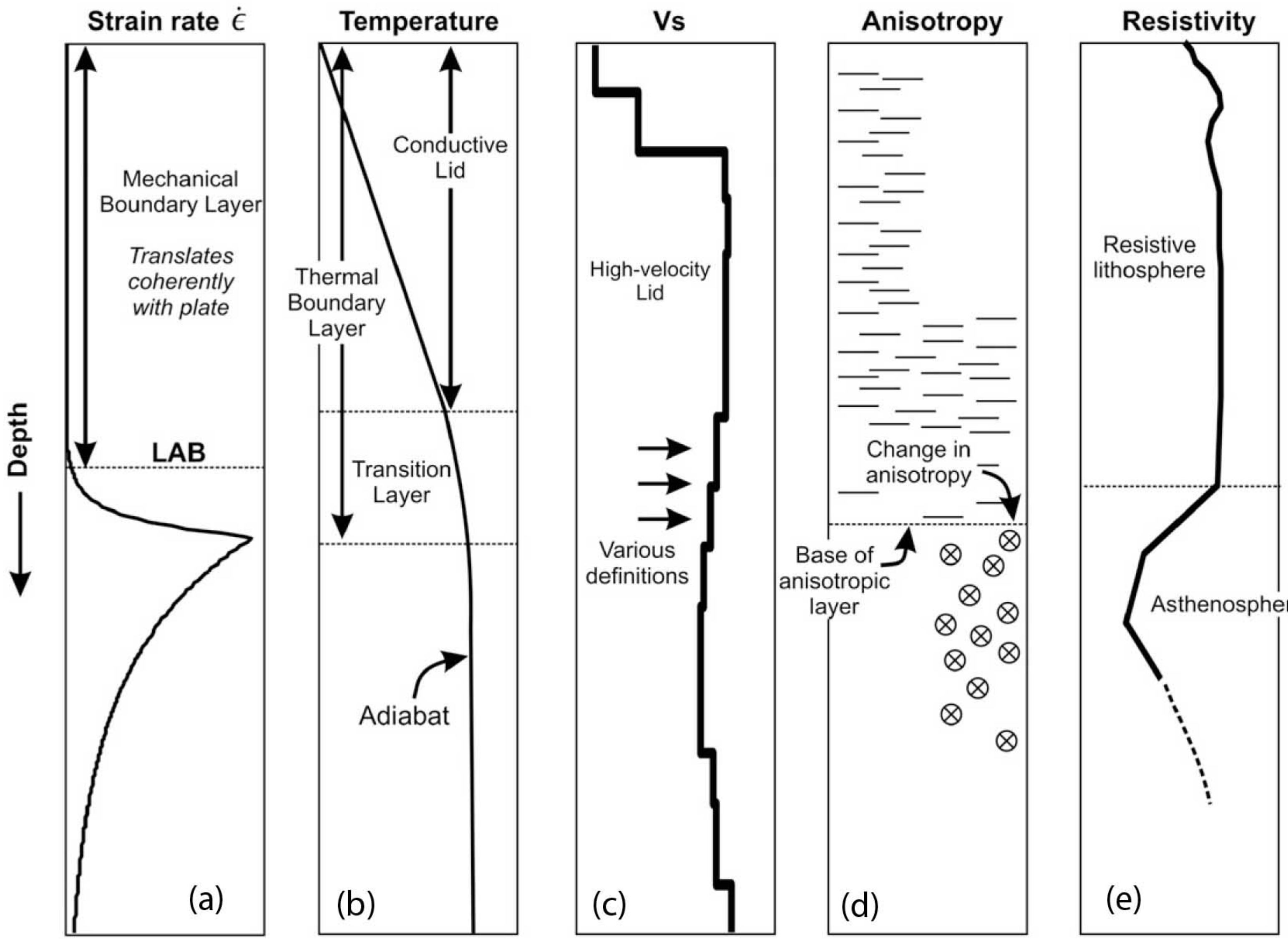
Satish Singh IPG Paris

Plate Tectonics

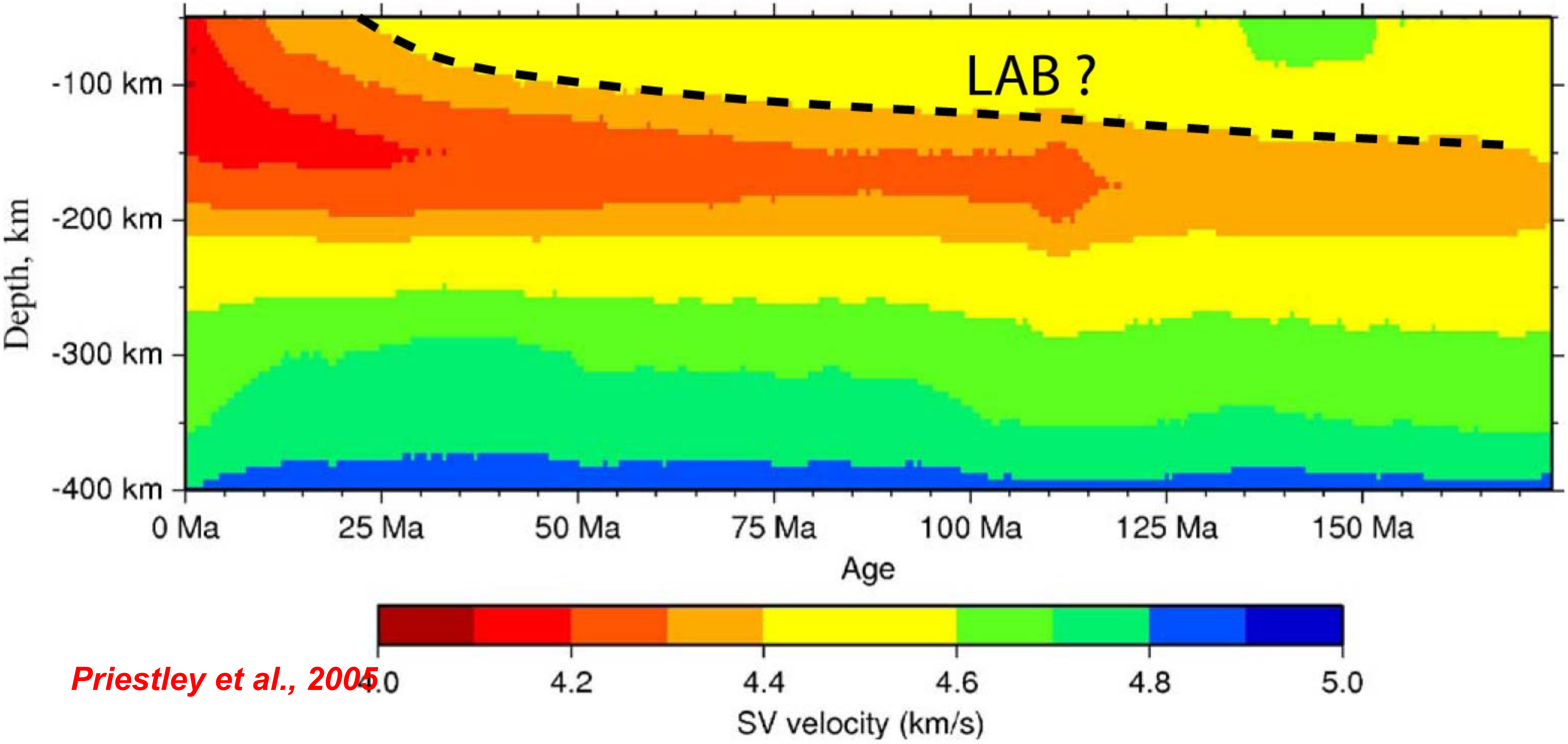
LAB is the lower plate boundary



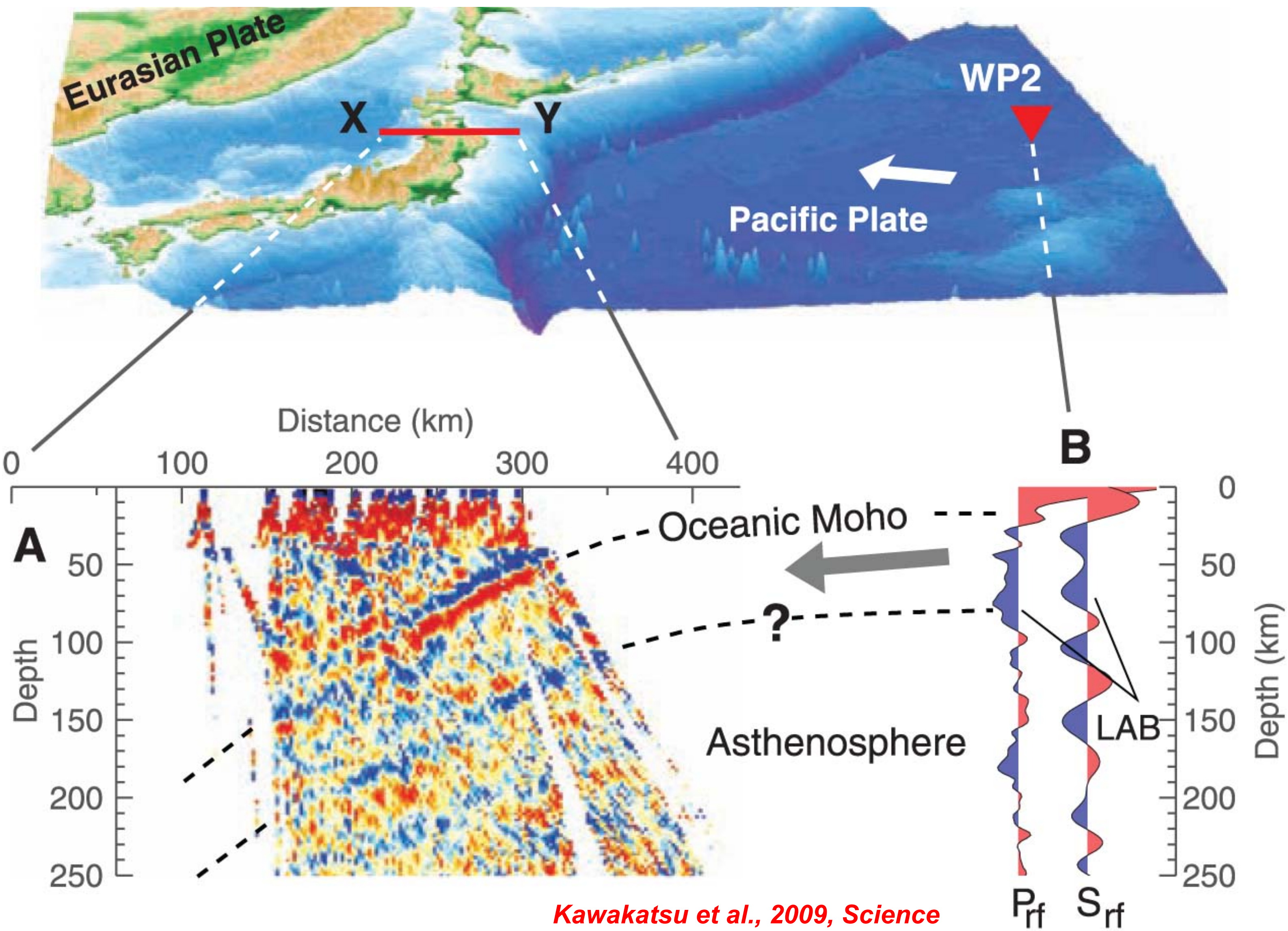
Different definitions of LAB



20-30 km transition zone

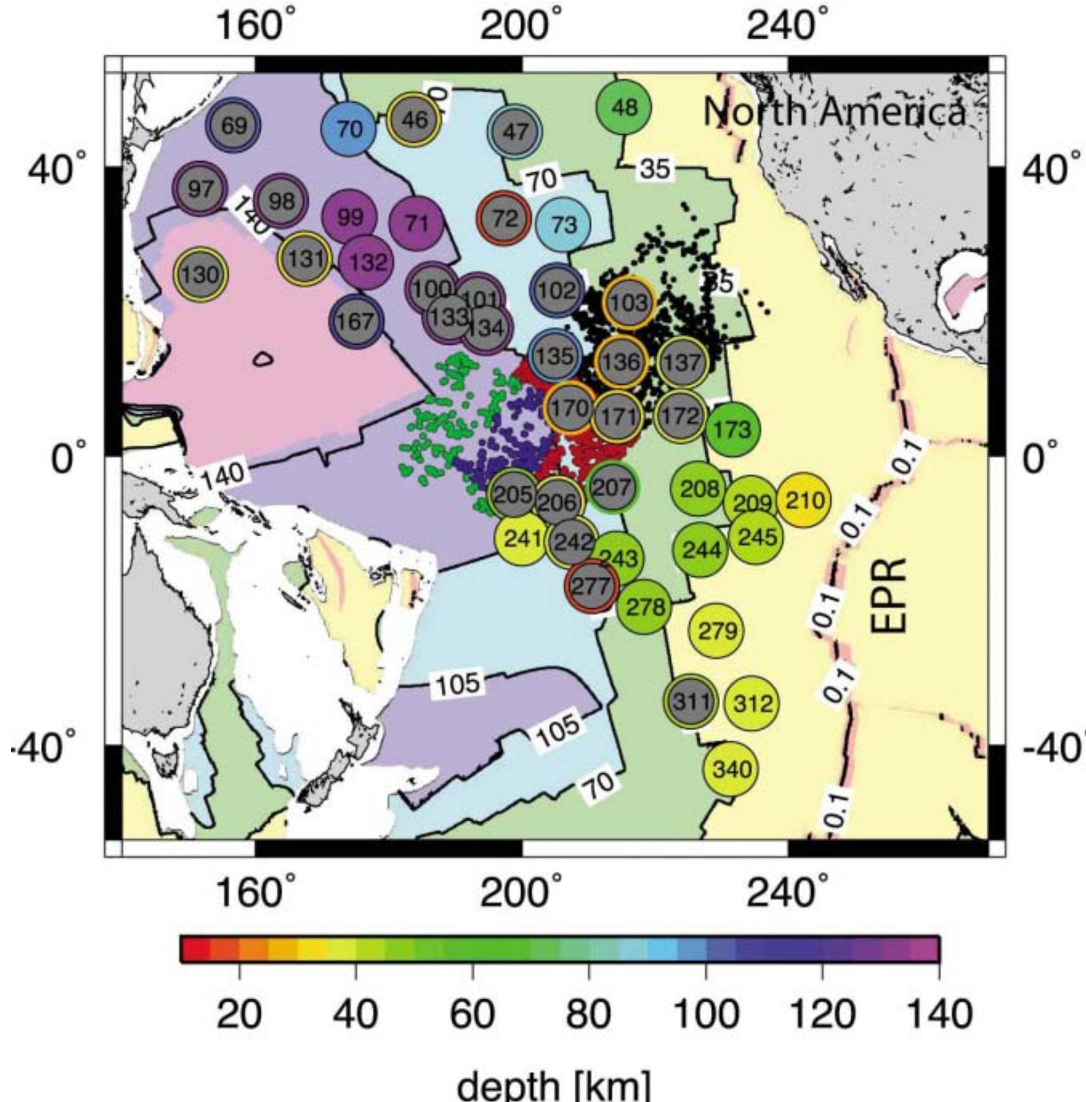


Priestley et al., 2005

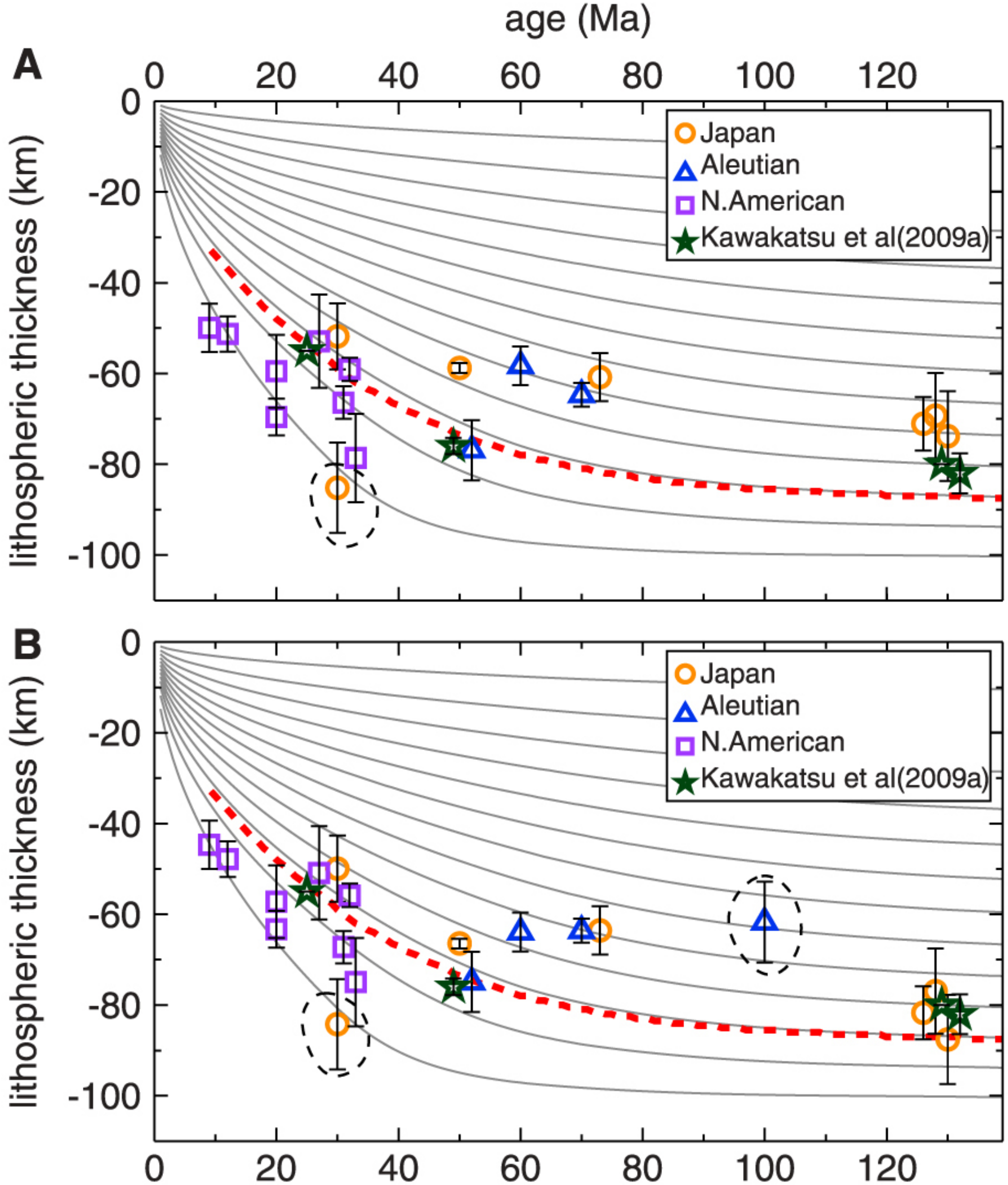


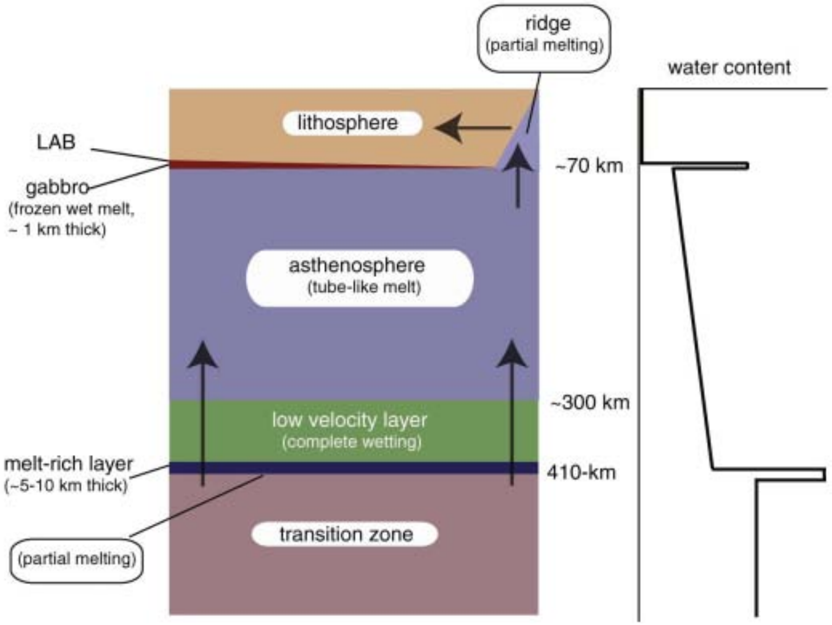
Kawakatsu et al., 2009, Science

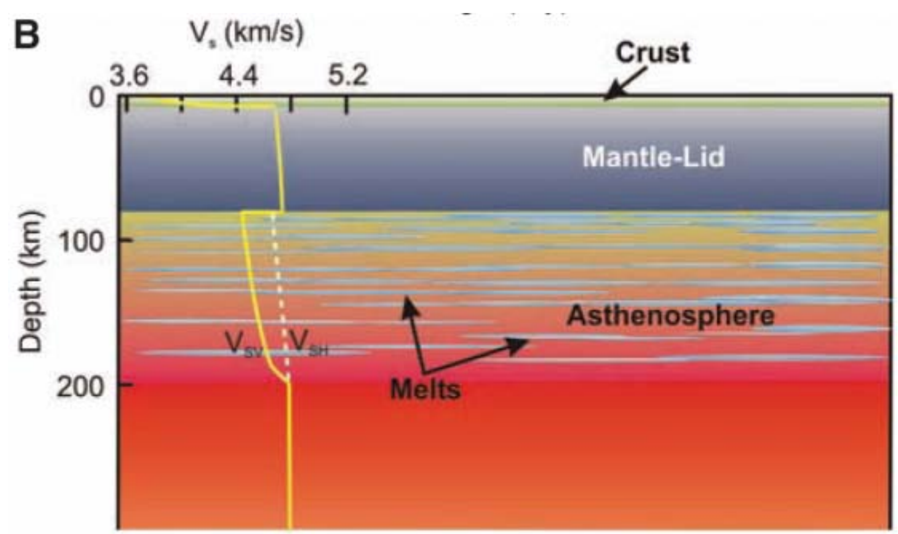
Bounce points



LAB versus age







LAB depth is constant (70 km)

Karate , 2012

LAB depth varies with age of the lithosphere from 0-100 km

Kawakatsu et al., 2008

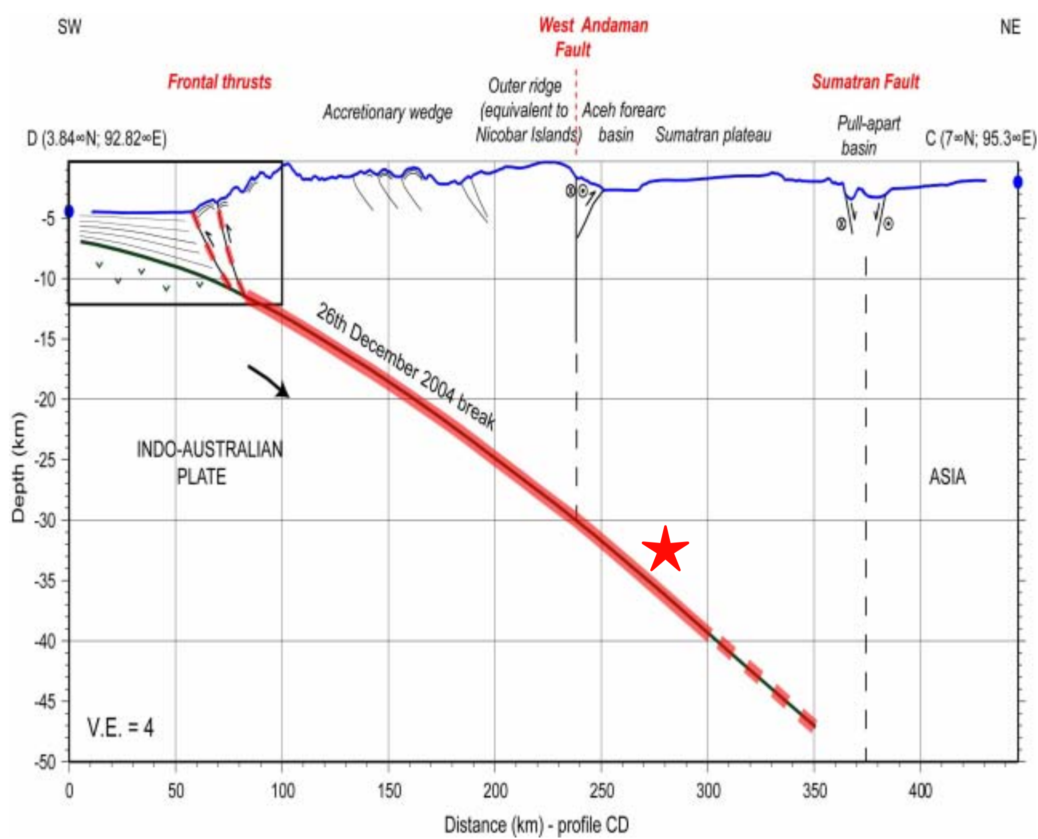
Our experience from Sumatra

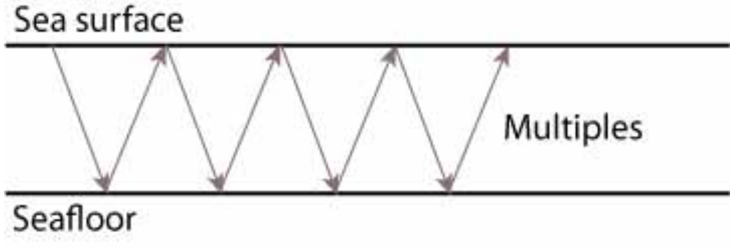
- Five earthquakes of Mw> 8 in the last seven years
- We carried out deep seismic survey with the support of WesternGeco and CGGVeritas
- We want to use these experience to do ultra-deep seismic profiling to image the LAB down to 100 km depth

Big question: What is the nature of the earthquake rupture zone: Rupture initiation to seafloor

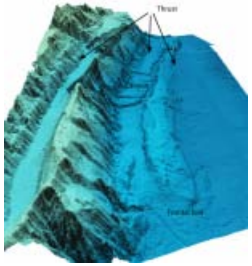
- Earthquake initiates at 30-40 km depth
- Tsunami initiates on the seafloor
- How do you get image of the complete structure?

Earthquake: 10-20 km resolution
Refraction: 1-5 km resolution: 20 km depth
Reflection: 100 m resolution, 10-12 km depth?

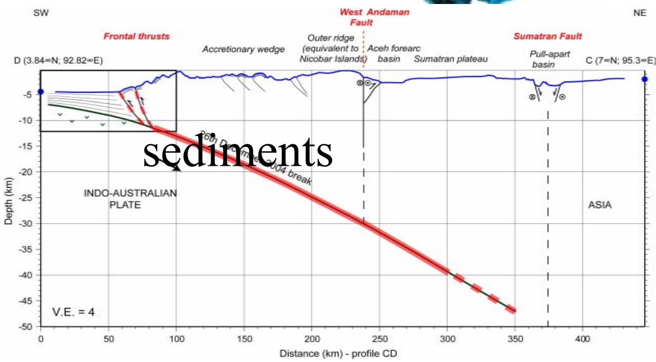




Reflection: Problems



- Multiples (water depth varies from 100 m to 6 km)
- Seafloor scattering (slope up to 30 degrees)
- Poor penetration of seismic energy in 15-20 km thick deformed sediments
- Academic streamers: 3 km



Solutions

- Long offset (12-15 km)for multiple removal
- Large low frequency source for deep penetration

But Expensive

Industry-Academic Partnership

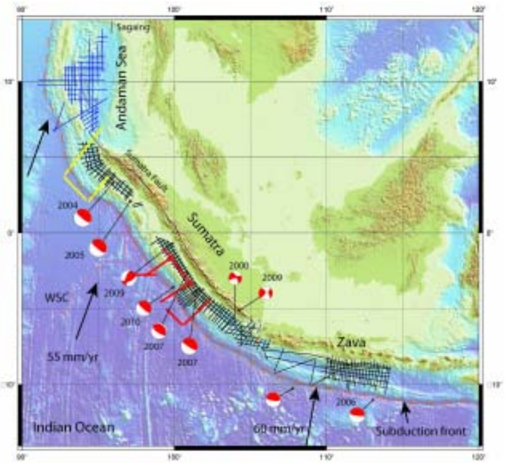
- Schlumberger (WesternGeco): 2006

  12 km streamer

In 2004 earthquake rupture zone

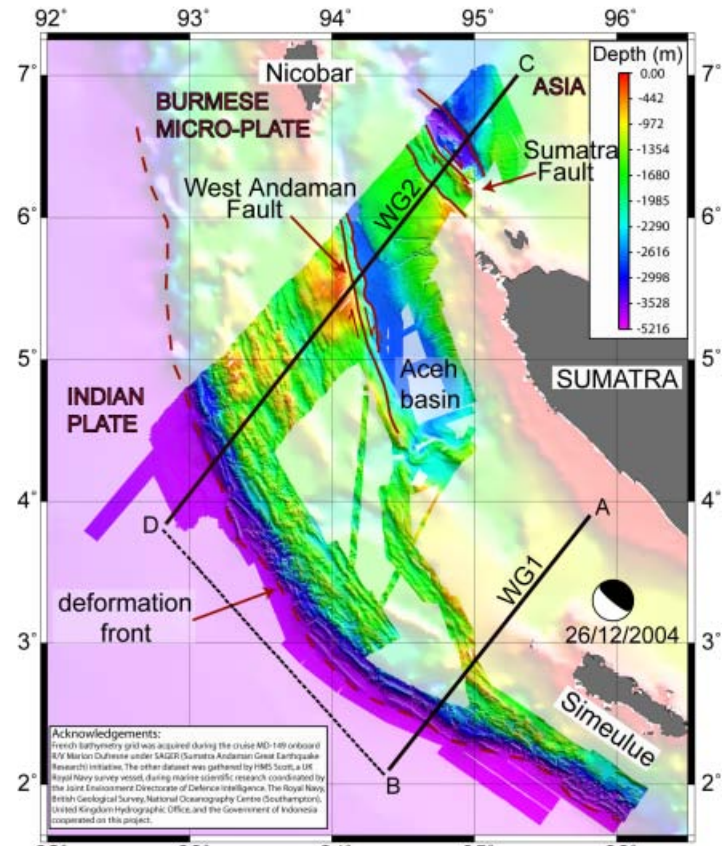
- CGGVeritas: 2009: 15 km streamer

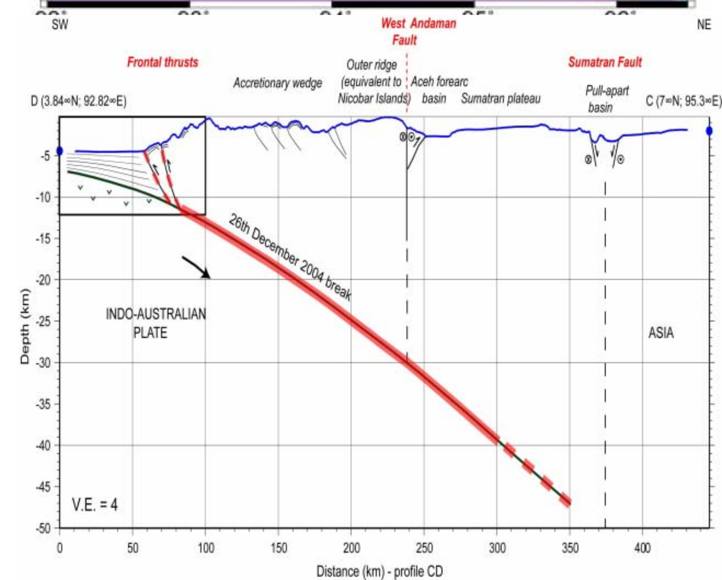
In the locked zone



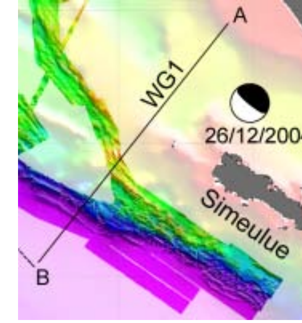
Schlumberger survey Tsunami

- 10700 cubic inch source towed at 15 m
- 12 km long Q-Marine streamer at towed 15 m
- 5.5 km Q-Marine streamer at 7.5 m
- 3 profiles, 950 km deep seismic reflection data
- Geco Searcher
- Coincident OBS data:56 OBS
- WG1- close to 2004 epicenter
- WG2- largest slip crossing the whole subduction system

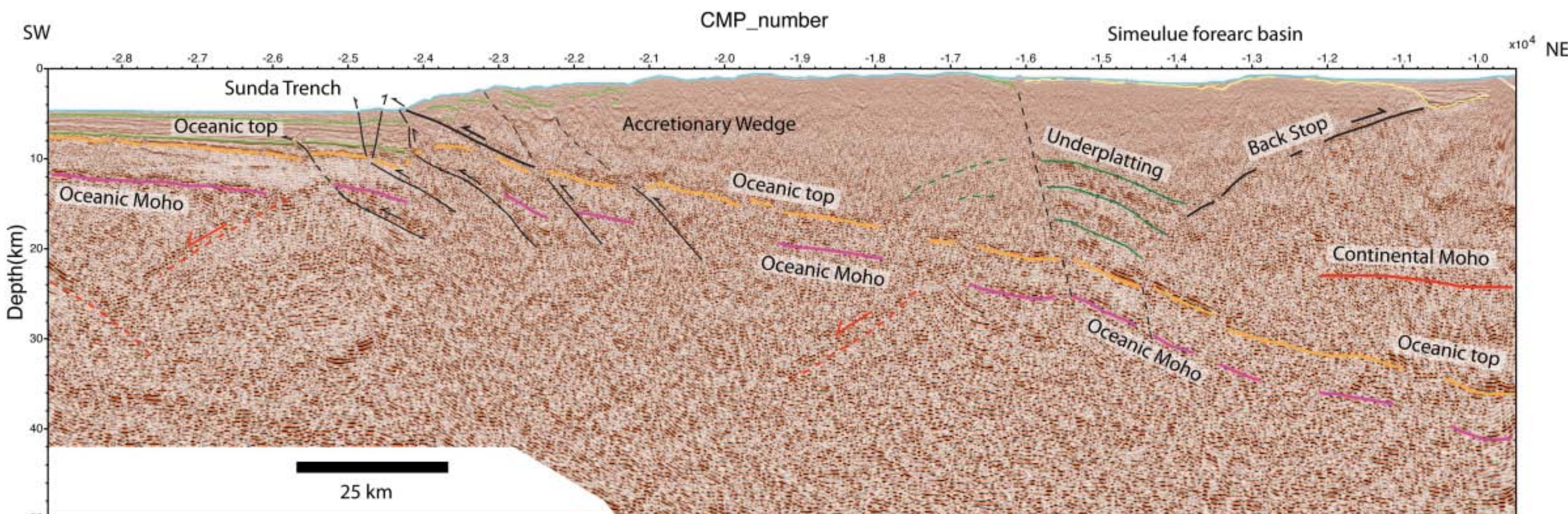




Seismic image of downgoing plate

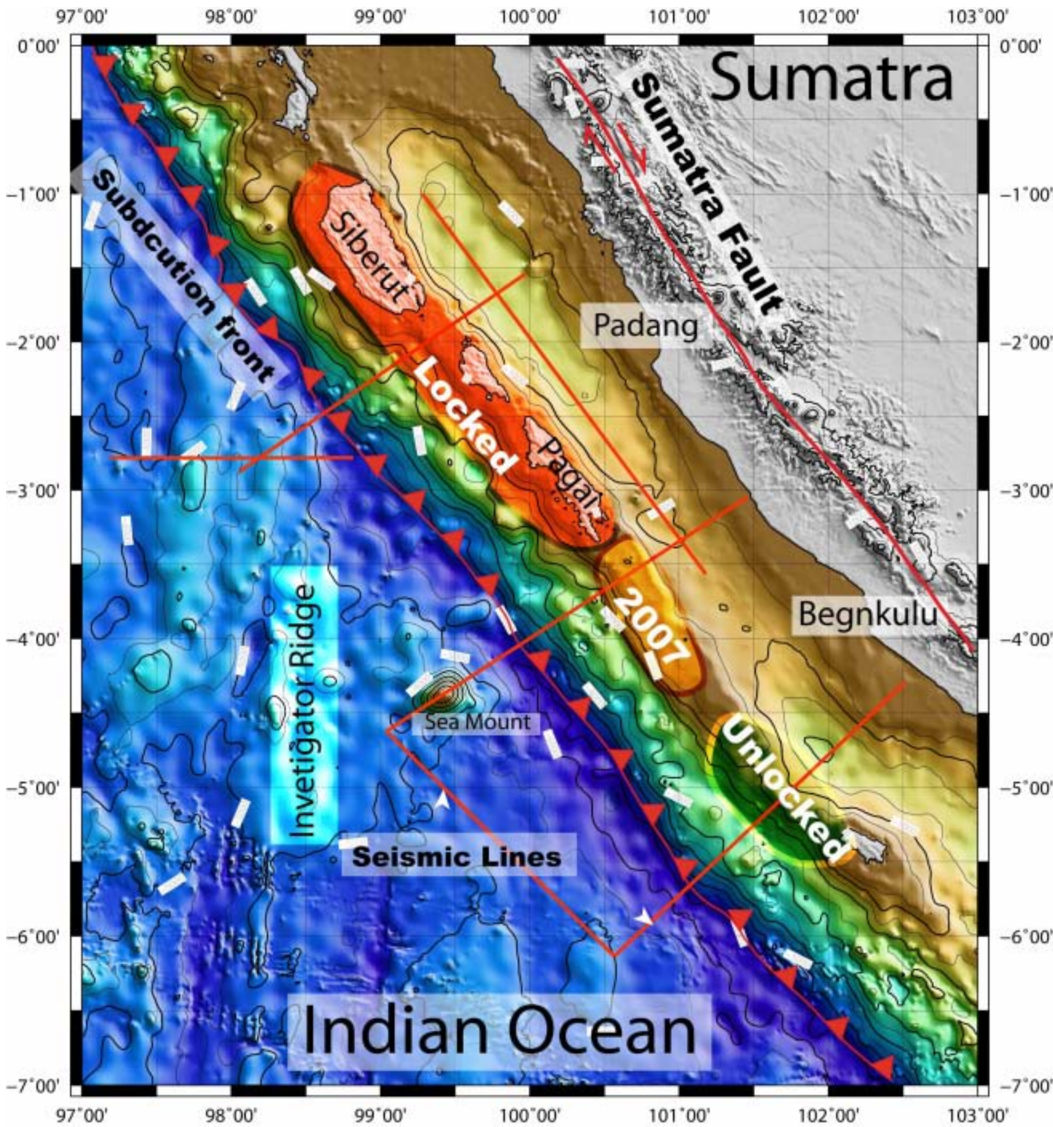


- Downgoing plate is sliced at 5 locations
- Re-activated faults
- Under platting of accretionary sediments at 10-20 km depth
- Megathrust arriving near the subduction front



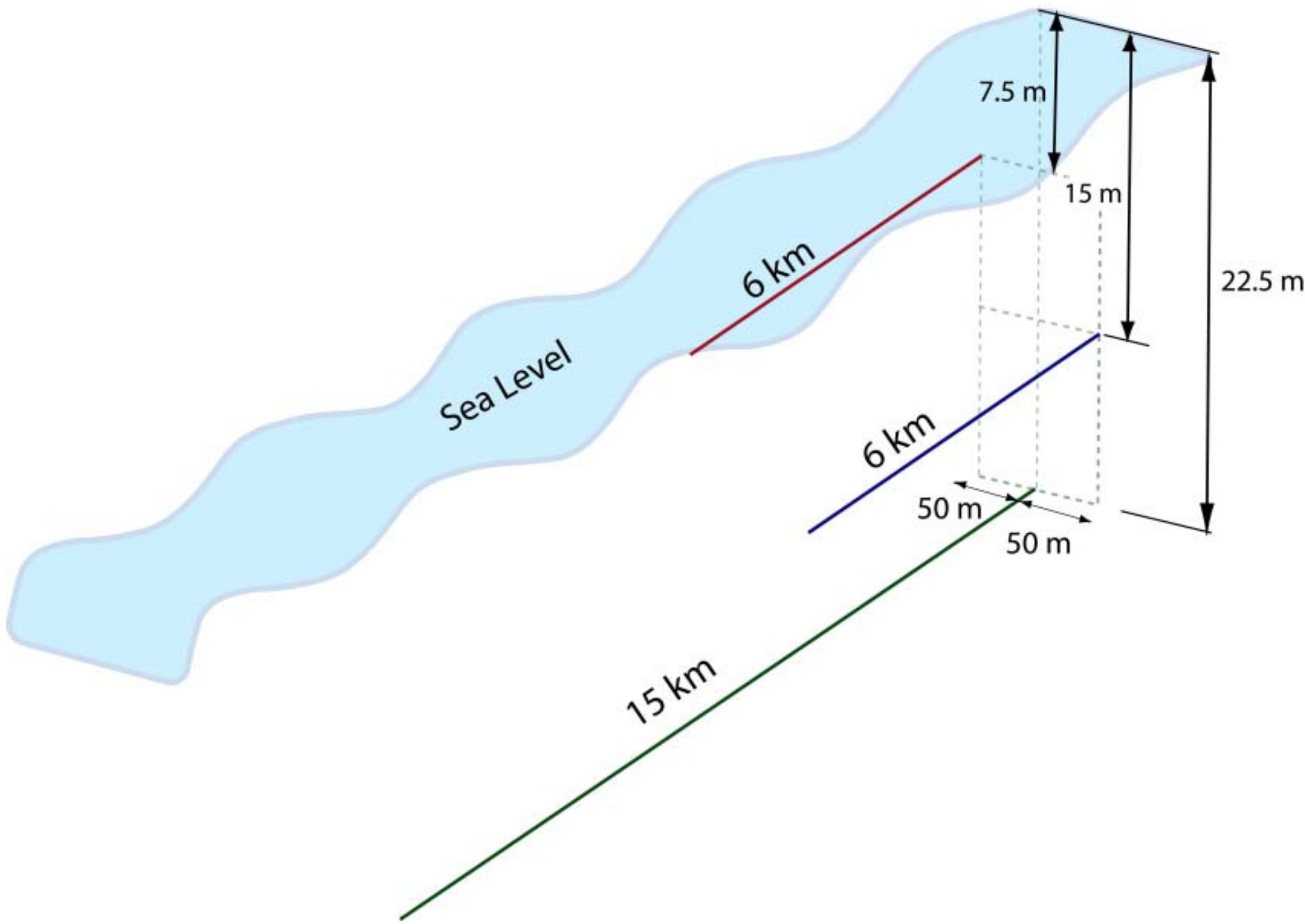
CGGVeritas: TIDES Survey: May 2009

- Low frequency source (9600 cubic inch)
- Long streamer (15 km) (22.5 m)
- Two short streamers (6 km) (7.5 and 15 m)
- Shot interval 50 m
- Record time 20 s
- Water depth: 100 to 6000 m
- Six profiles: 2007 epicenter zone, locked zone and unlocked zone

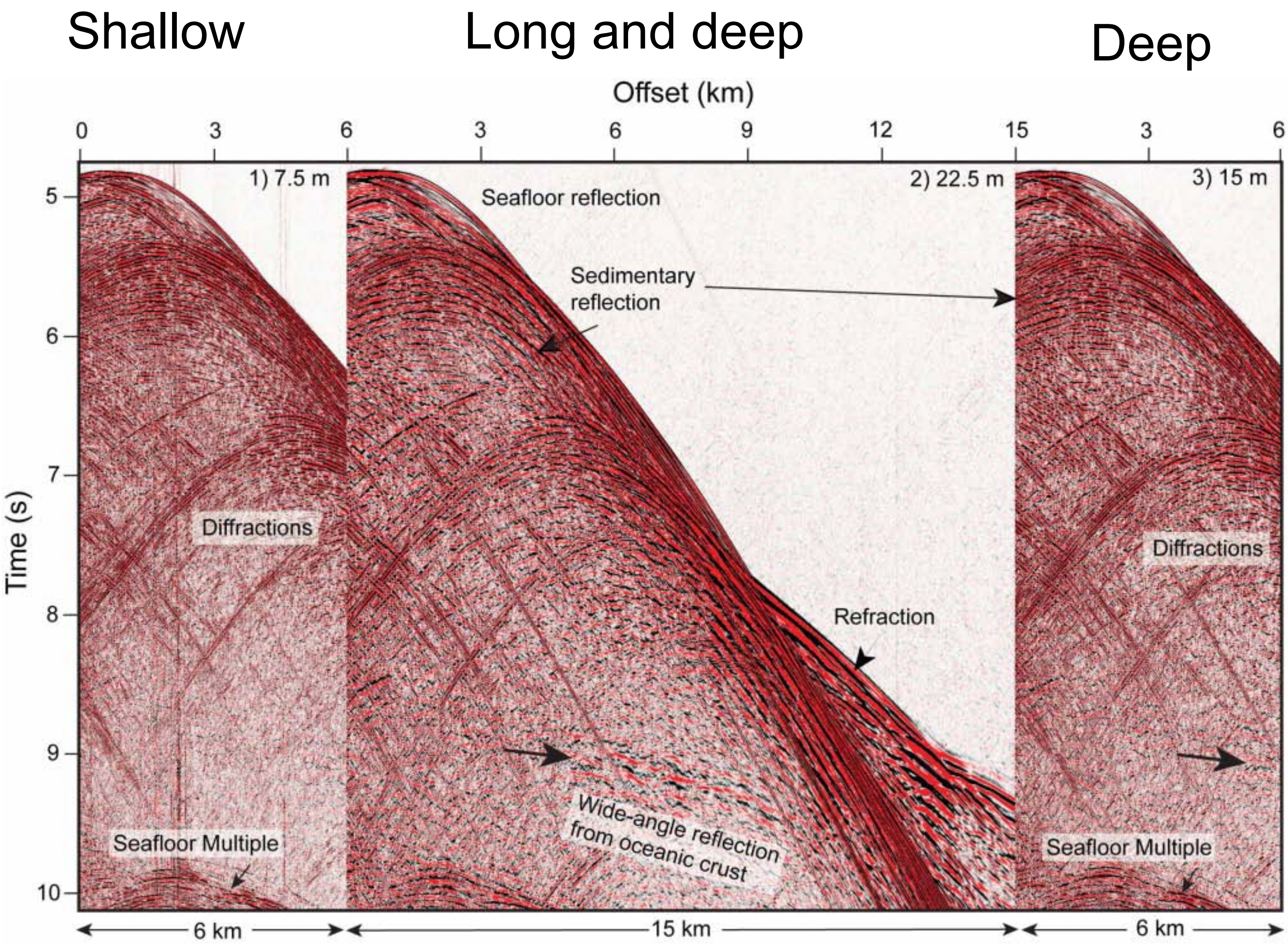


Streamer configuration

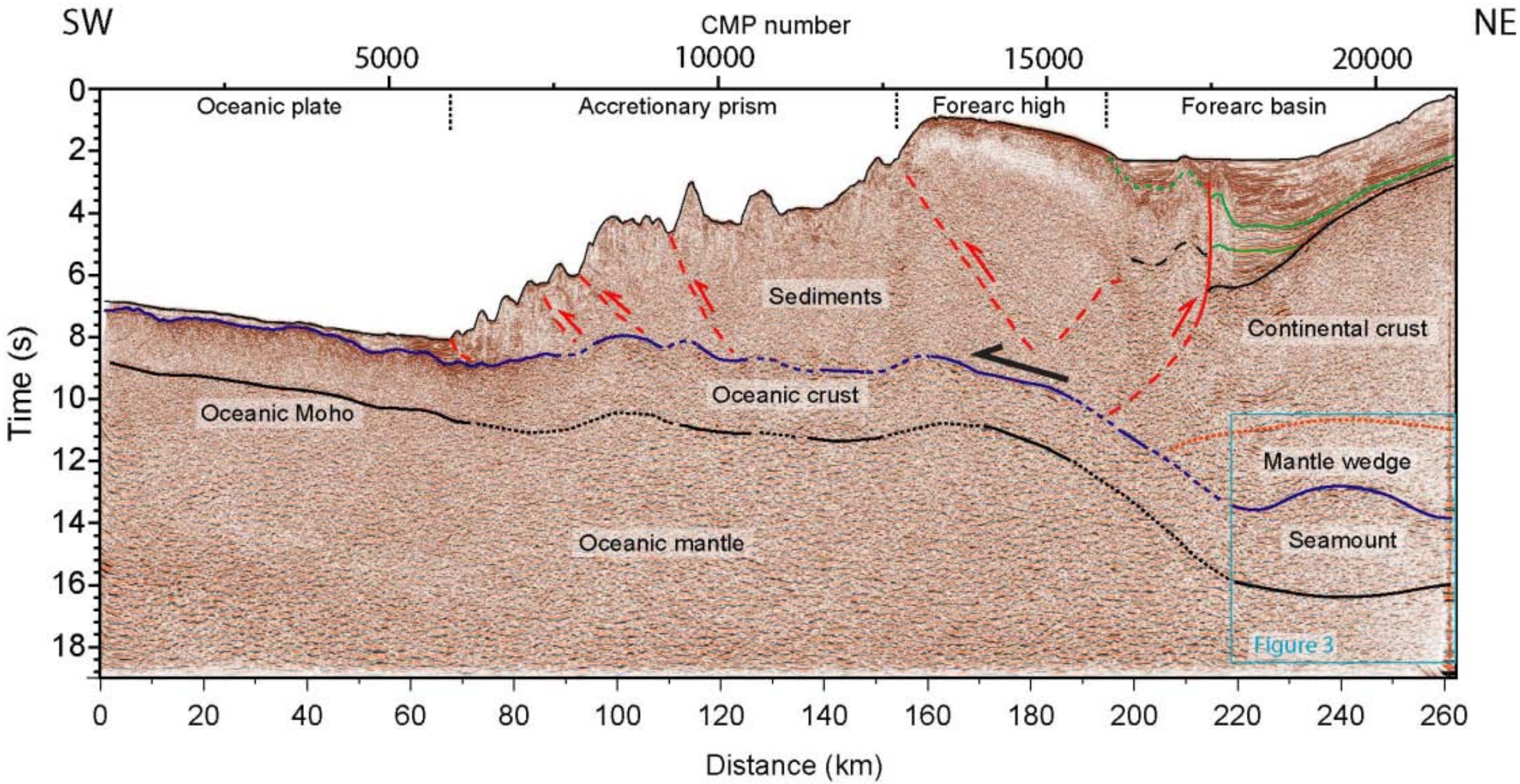
- 3 streamers
- One 15 km long
- Two 6 km long
- Over/under configuration



Shot gathers



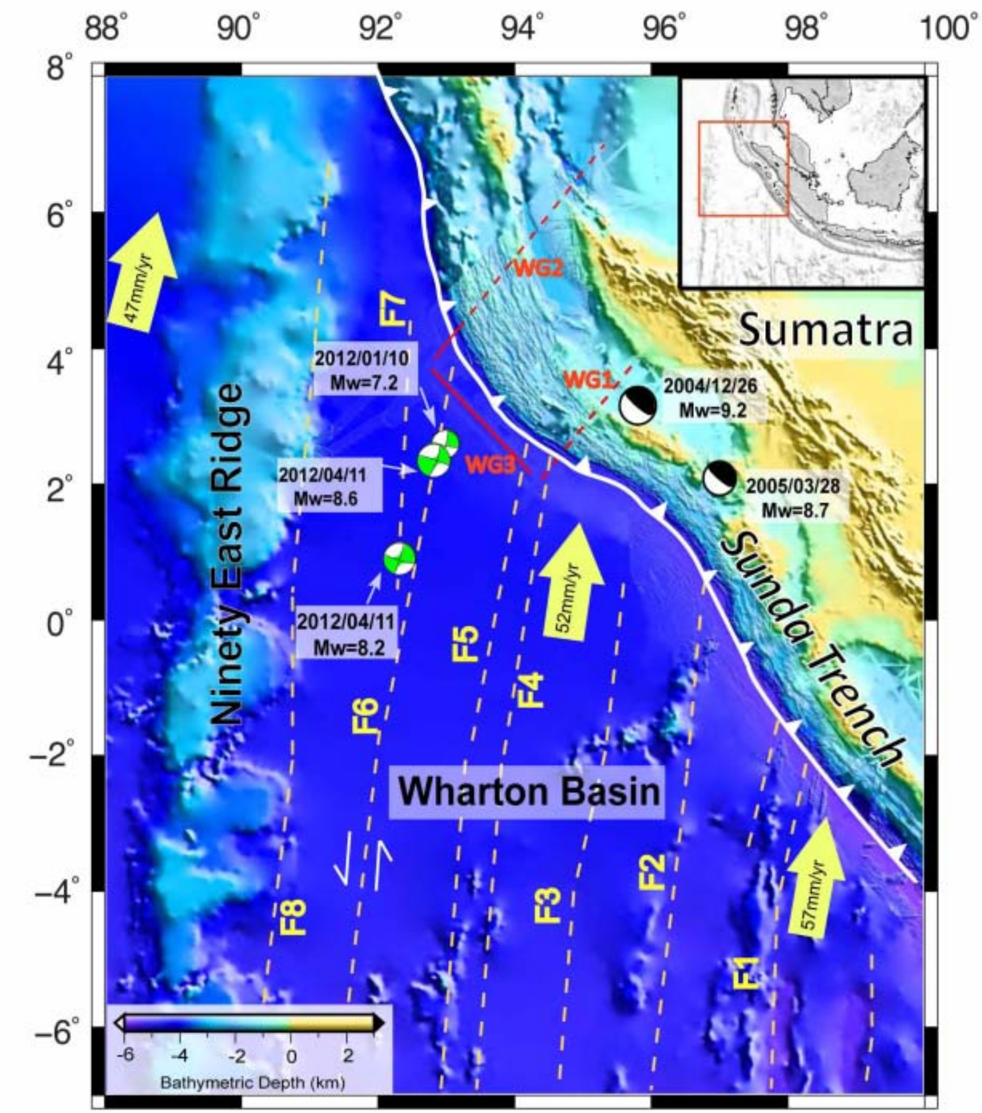
Discovery of a Deep Subducted seamount



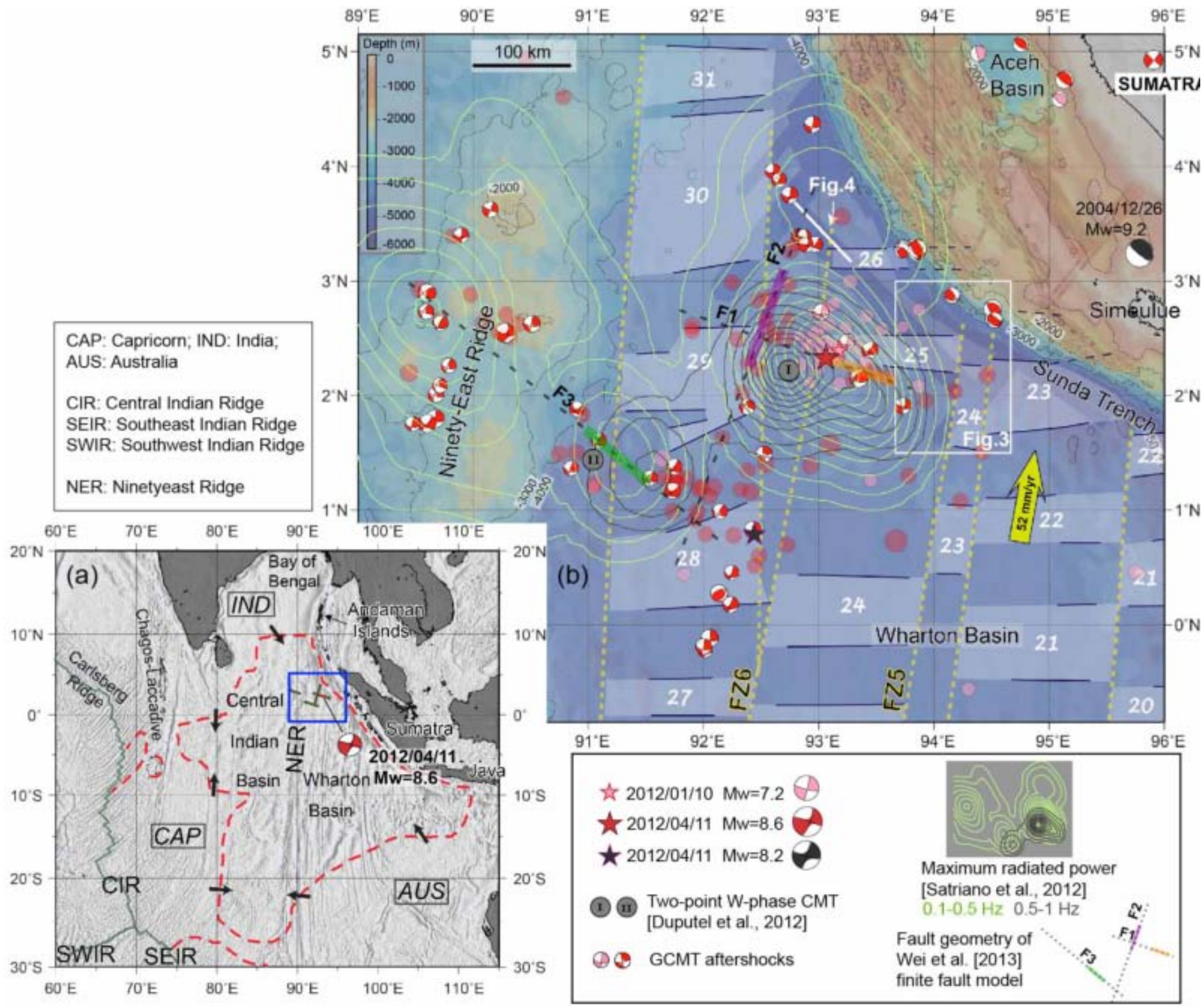
Singh et al, Nature Geoscience, 2011b

Figure 2 Singh et al.

Imaging of oceanic lithosphere

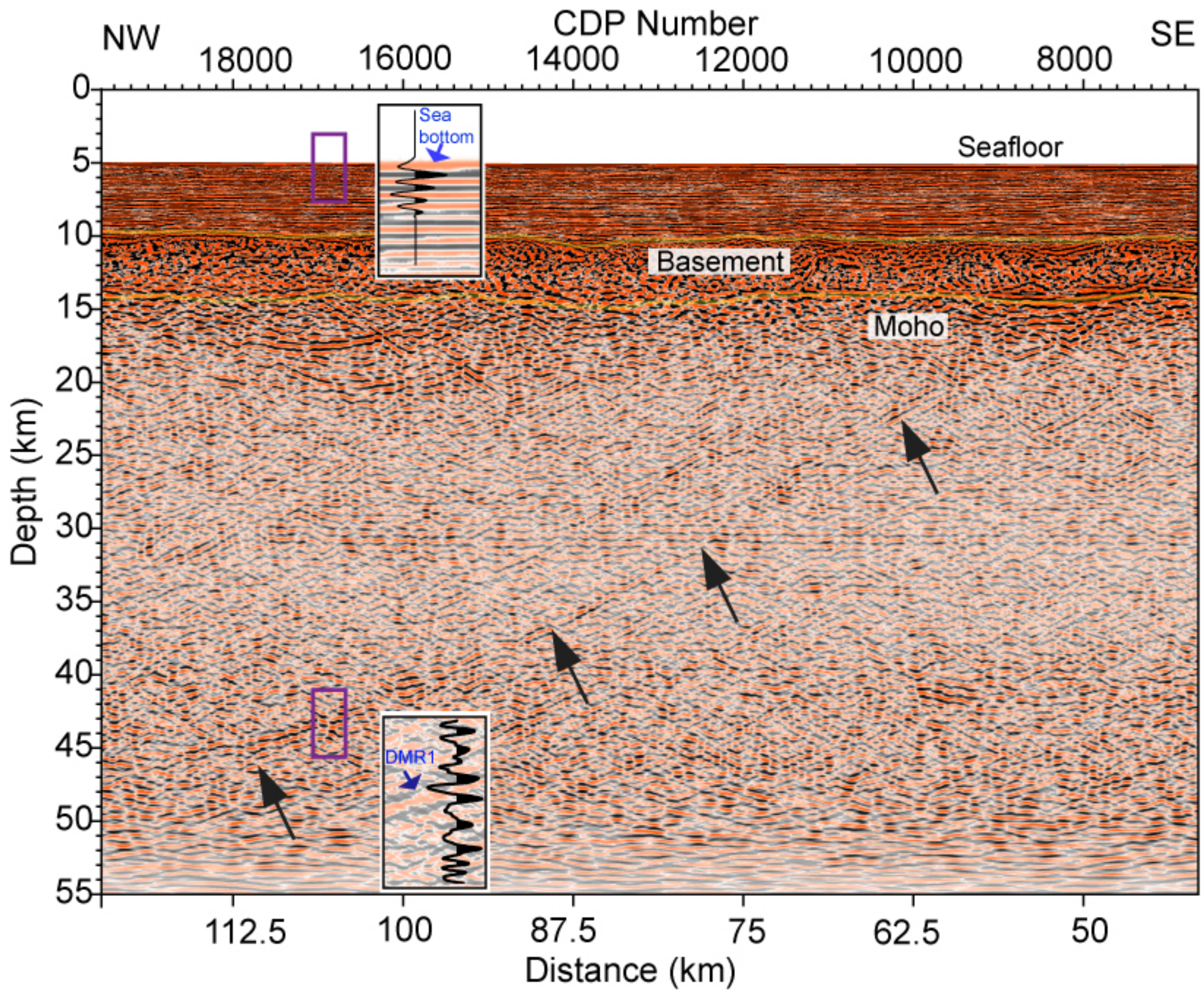


2012 Wharton Basin Earthquakes

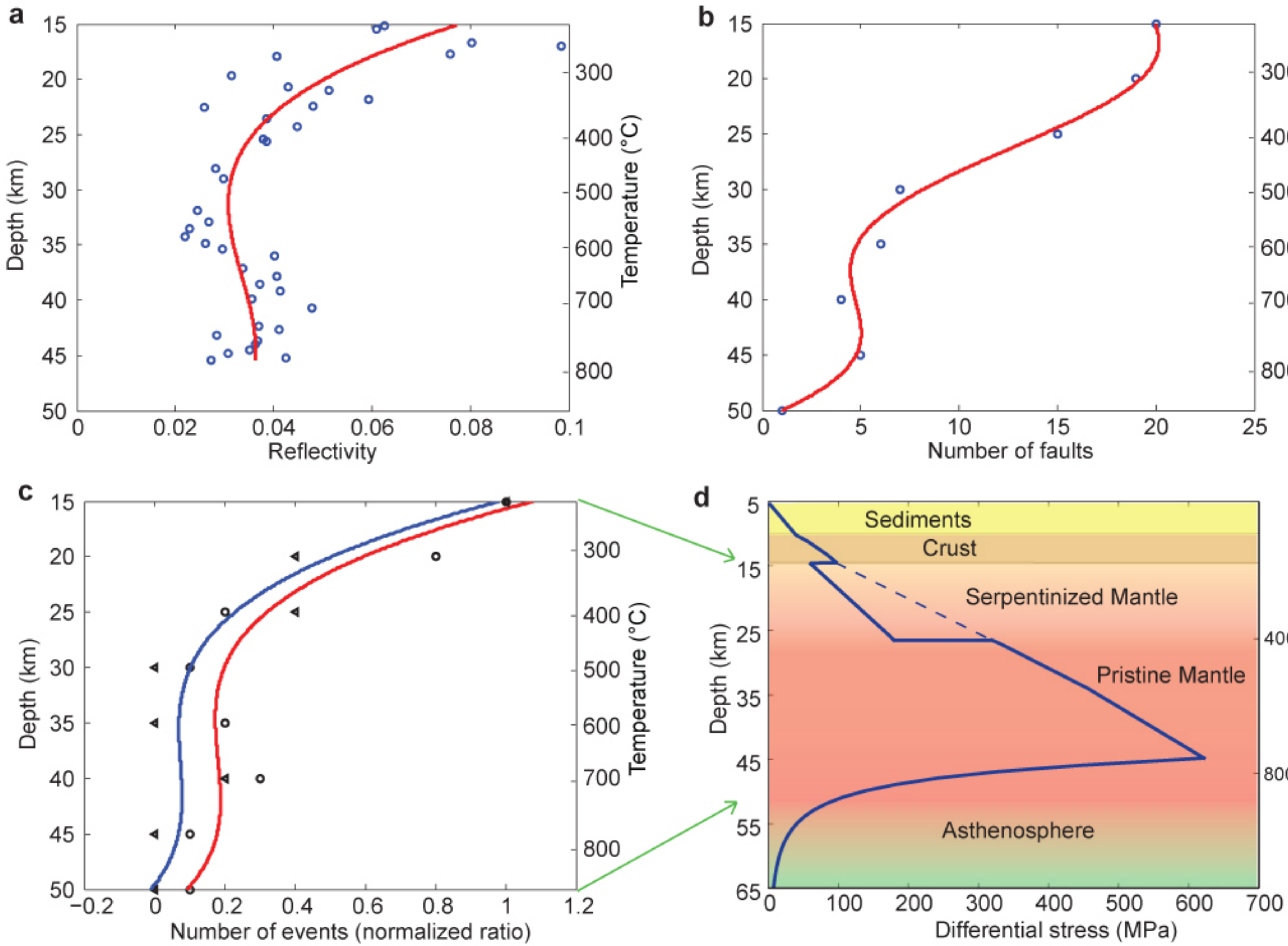


How deep faults penetrate?

Negative polarity

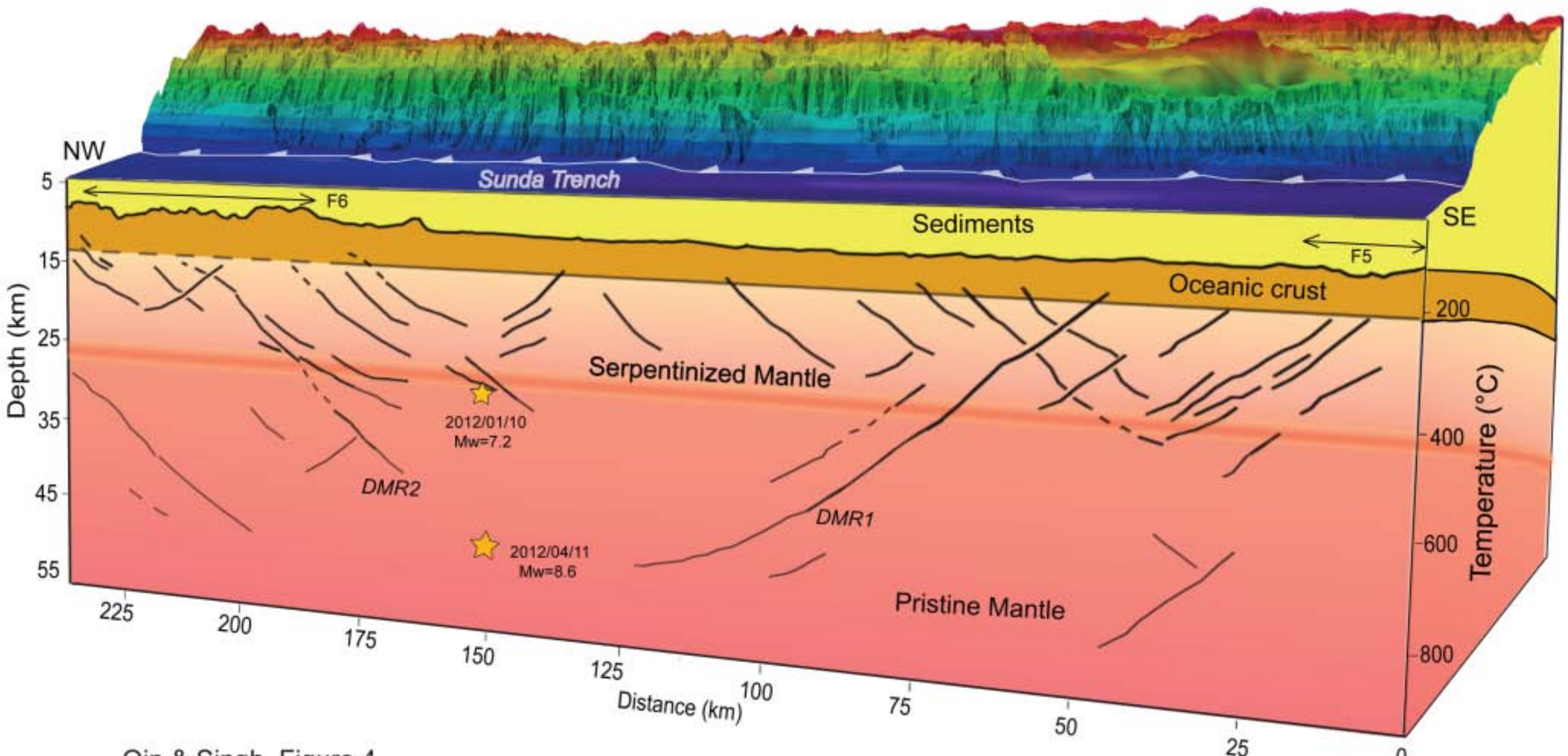


Qin & Singh, Figure 2



Qin & Singh, Figure 3

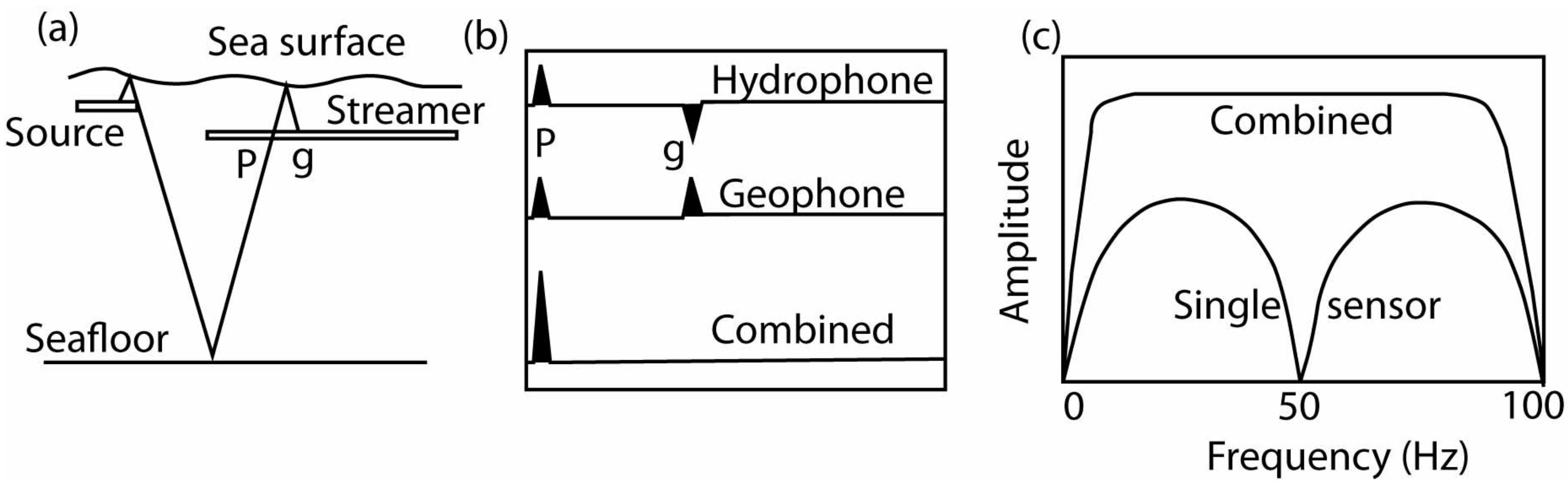
3D View



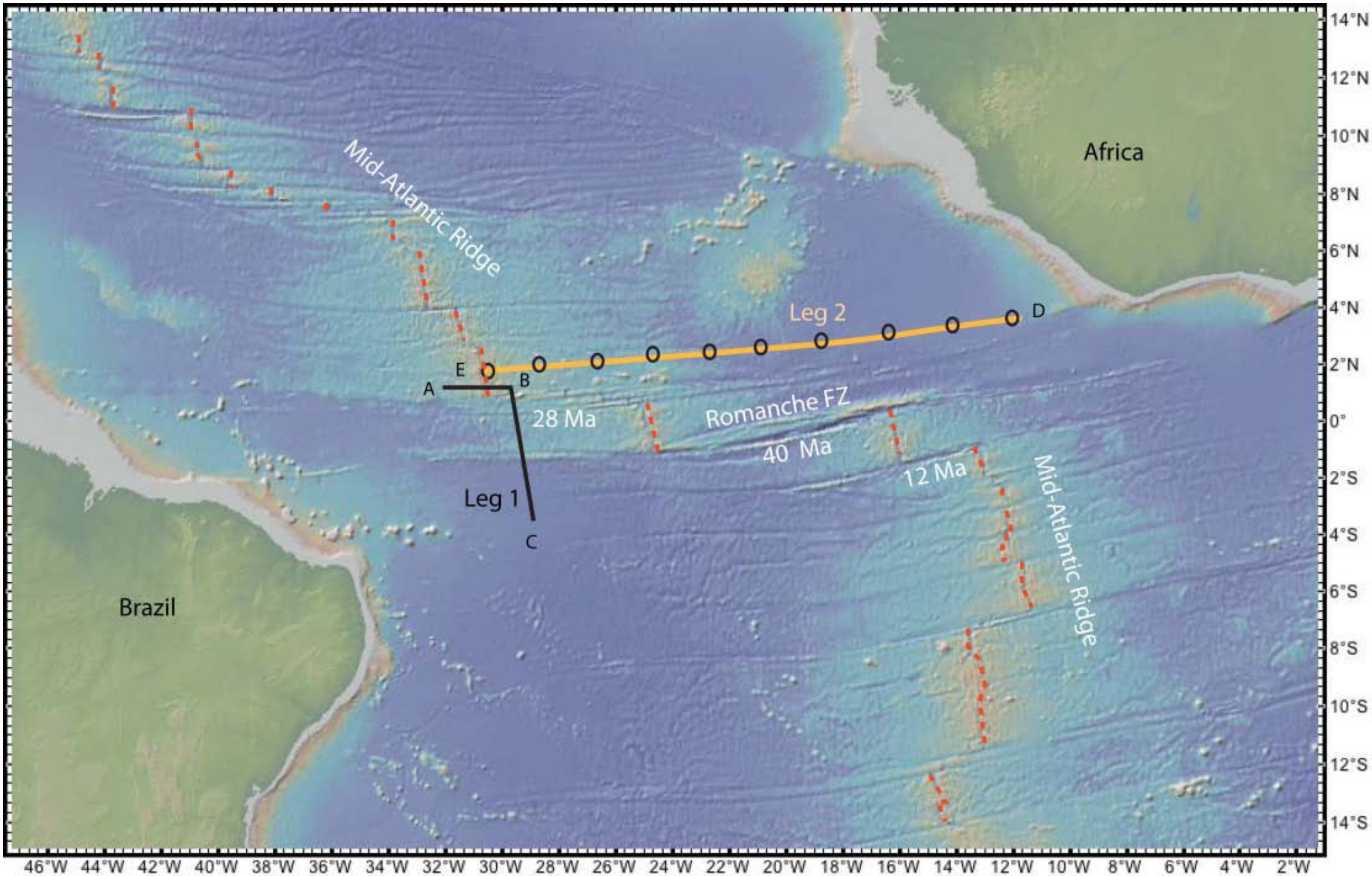
Qin & Singh, Figure 4

LAB Imaging: Challenge

- Low frequency (2 Hz) for deep penetration (100 km)
- Multiples
- ISOMETRIX Streamer



Where: On the way to Brazil

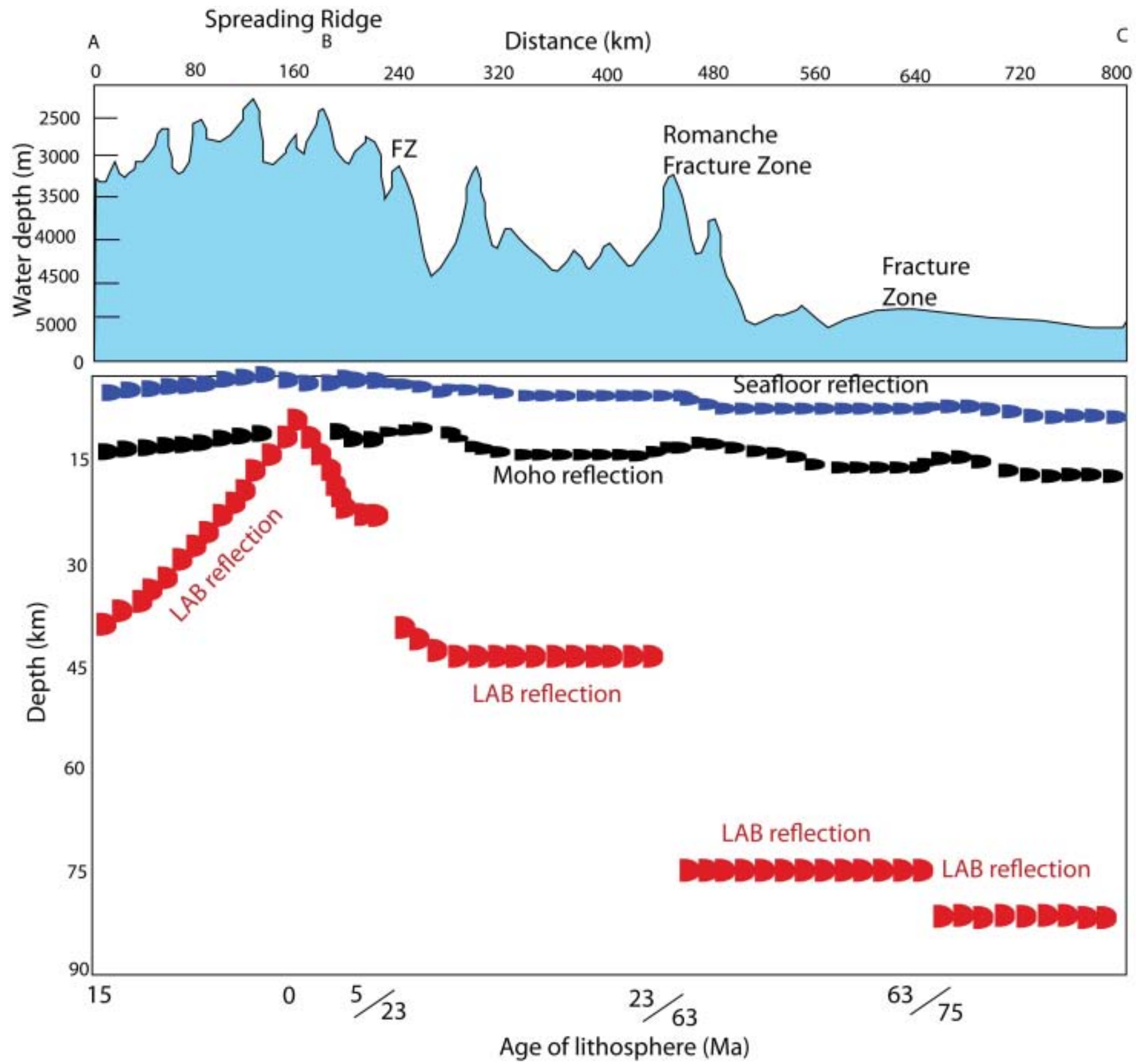


Short profile across fracture zones

0-15 Ma across spreading centre

Three Fracture zones with age contrasts of 28 Ma, 40 Ma, and 12 Ma

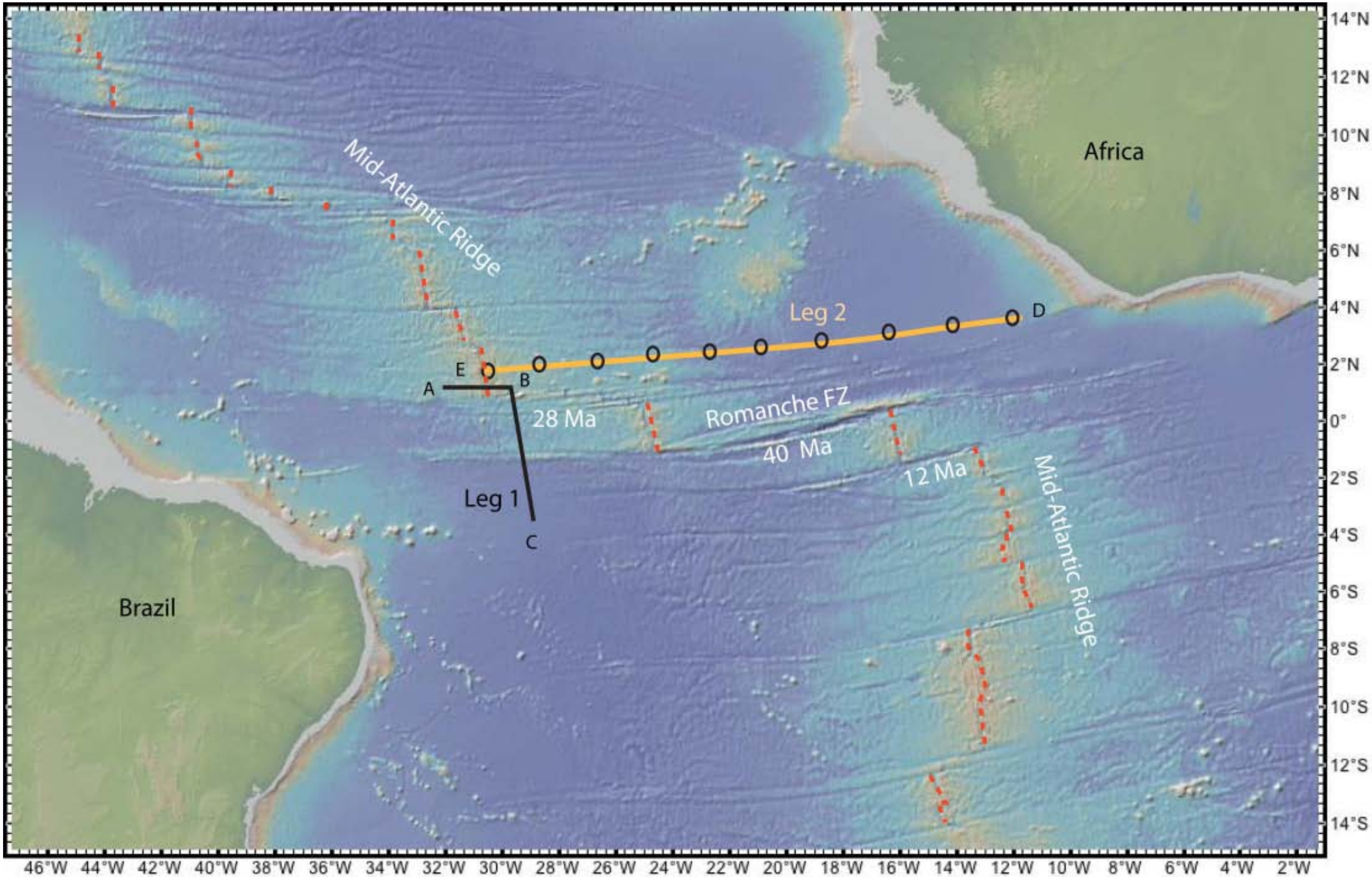
Cover 0-75 Ma lithosphere by shooting 800 km long profile

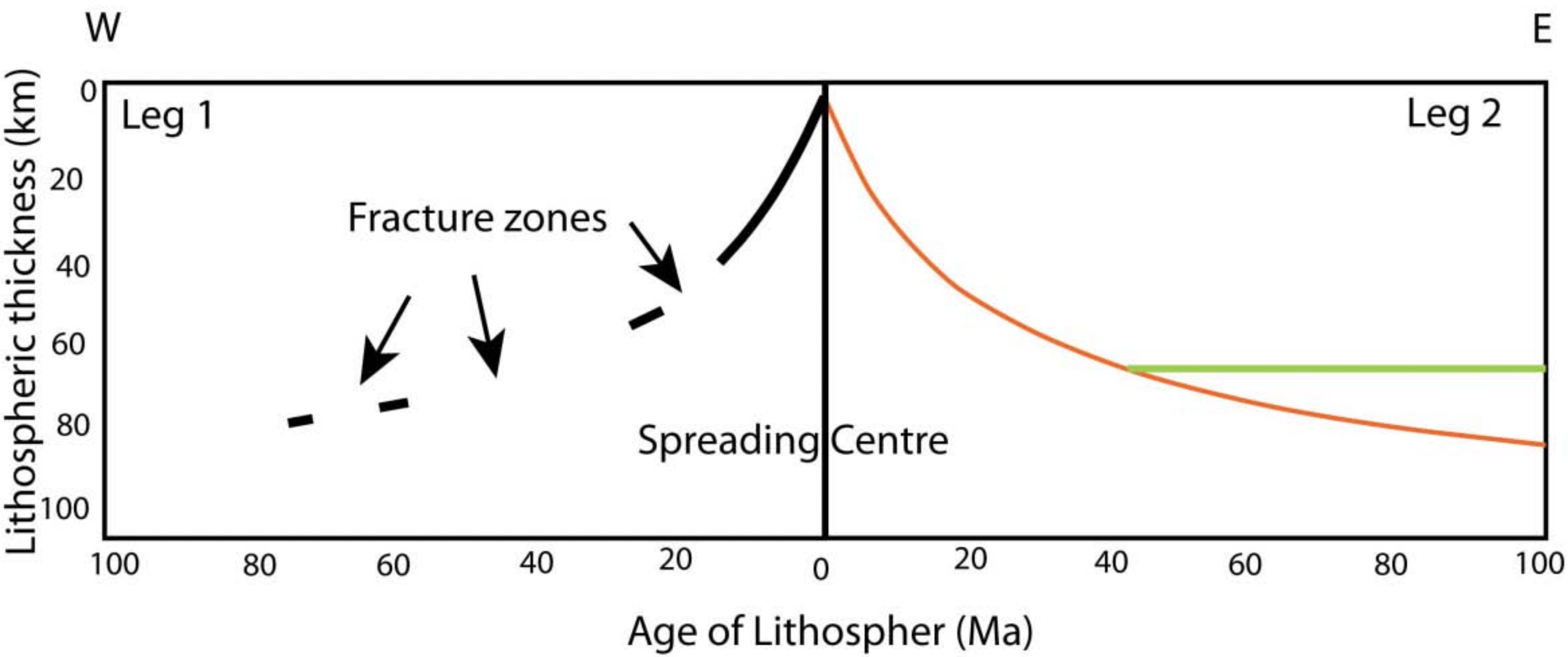


Survey design

- Streamer: 12-15 km long
- Tow at 30 m water depth
- Source: 10000-15000 cubic inch
- At 2000 psi tow at 20 m depth
- Shot interval: 40 s
- Record length 40 s (120 km)
- 5 days to shoot the profile

Trans-Atlantic Transect




W
E
Lithospheric thickness (km)
0
20
40
60
80
100
Leg 1
Leg 2
Fracture zones
Spreading Centre
100
80
60
40
20
0
20
40
60
80
100
Age of Lithospher (Ma)

Other scientific outcomes

- Images of melt lenses in the mantle near the ridge axis
- Images of frozen melt lenses away from the ridge axis
- Images of deep penetrating faults due to cooling of the lithosphere
- Crustal structure variation with age
- Hydration of upper mantle with age

4-5 Cruises

- Cruise 1: 500 km long short profile traversing MAR and Romanche Fracture zone (-5 to 65 Ma)
- Cruise 2: 2200 km long profile covering 0-100 Ma
- Cruise 3: Refraction profile (60-70 OBS) anong long profile (Ingo Grevemeyer, Wayne Crawford)
- Cruise 4: 46 MT deployment (Steve Constable)
- Cruise 4/5: 30 BBOBS along long profile (Nick Harmon, Kate Rychert)
- Funded through ERC Advanced Grant: 2014-2019