From resource exploration to tackling tectonophysics: Understanding our dynamic Earth with marine EM

Christine Chesley

MSROC pre-AGU Meeting 2023

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Email me at: christine.chesley@whoi.edu

NSF

Sunday Funday

I. Basics of Marine EM Geophysics

II. A Smattering of Recent Work

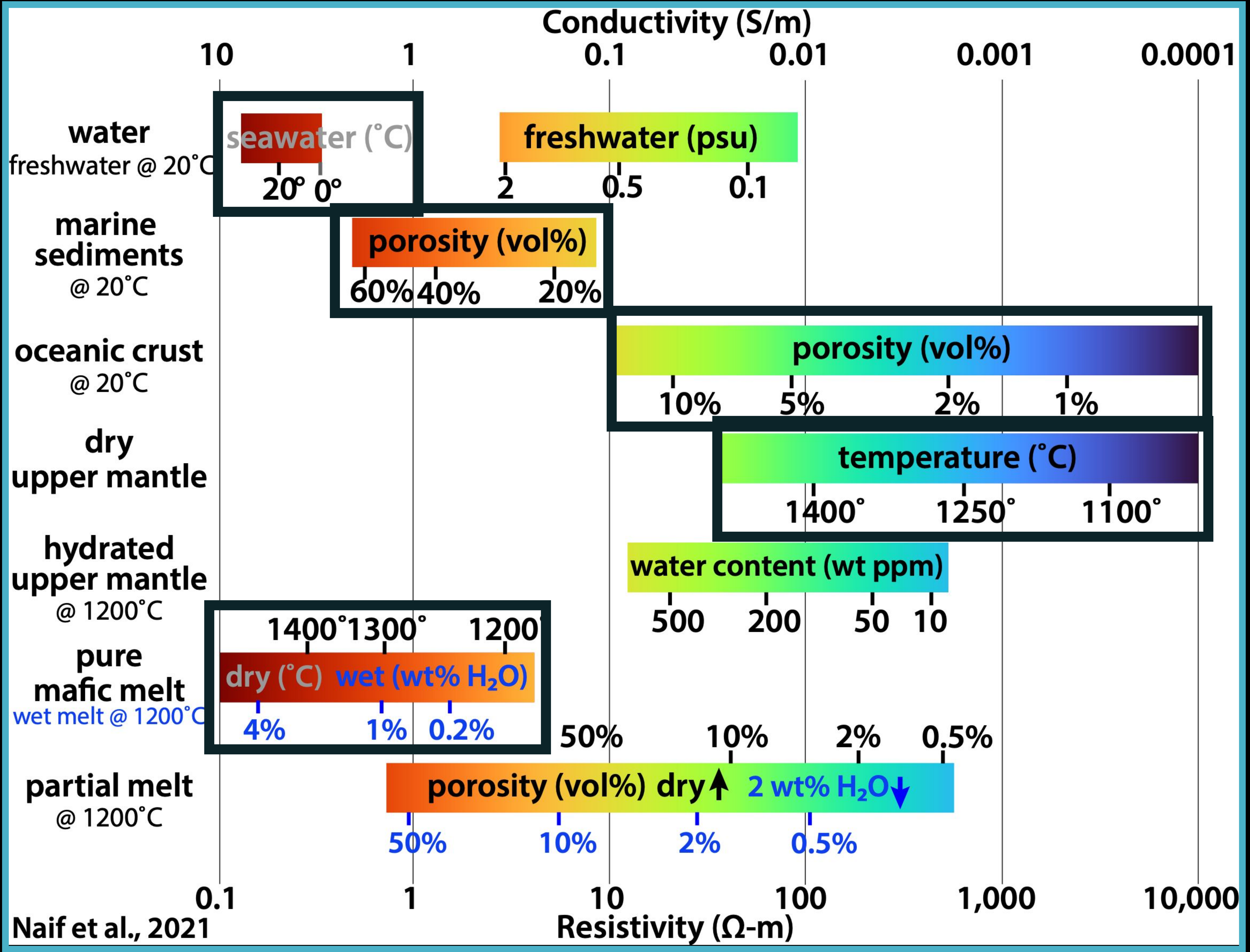
A. Resources

- Offshore freshened groundwater
- Hydrocarbons (e.g. gas and gas hydrates)

B. Tectonophysics

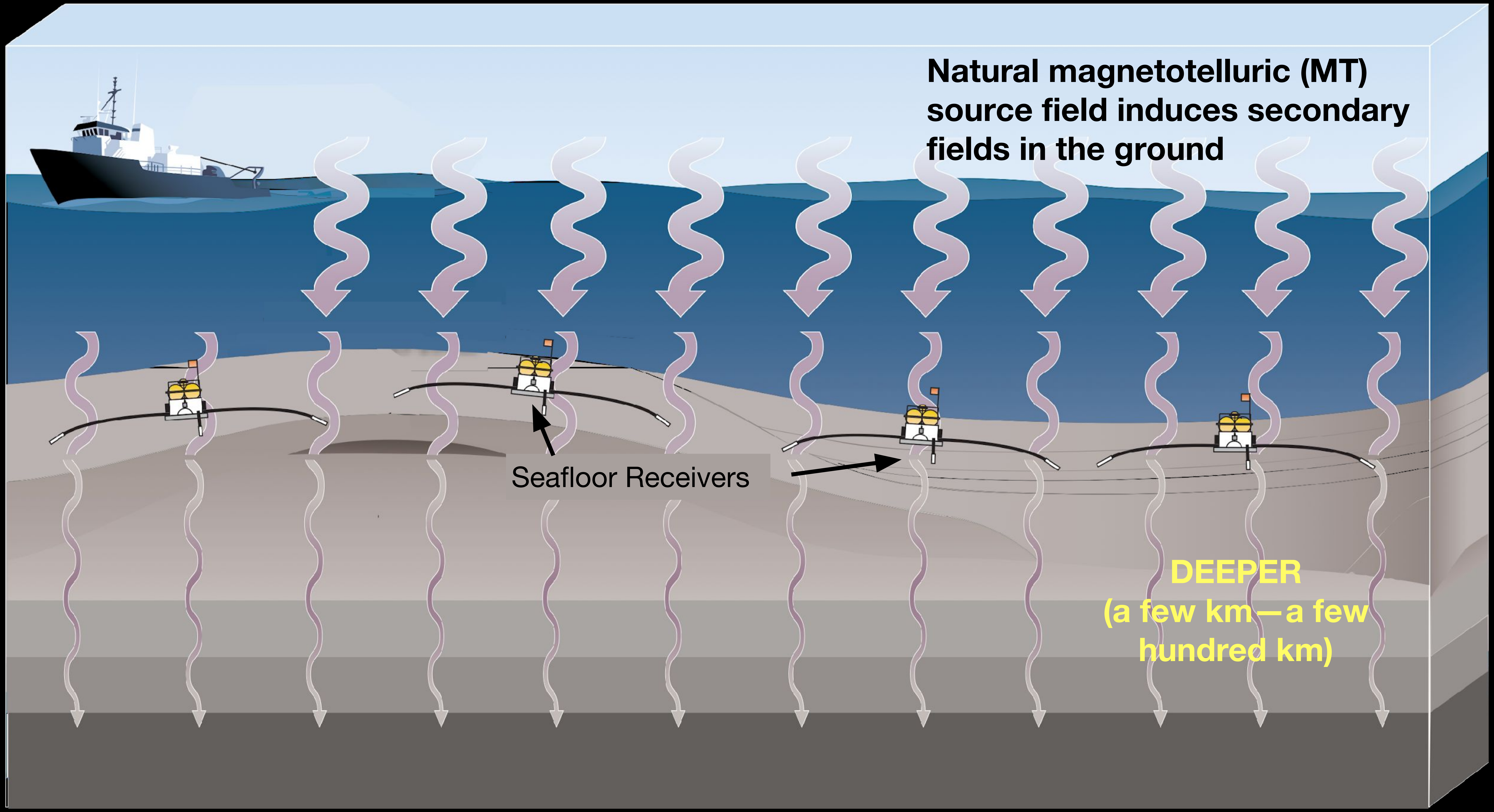
- Mid-ocean ridges
- Subduction Zones
- Gofar Oceanic Transform Fault

EM Data Constrain Electrical Resistivity

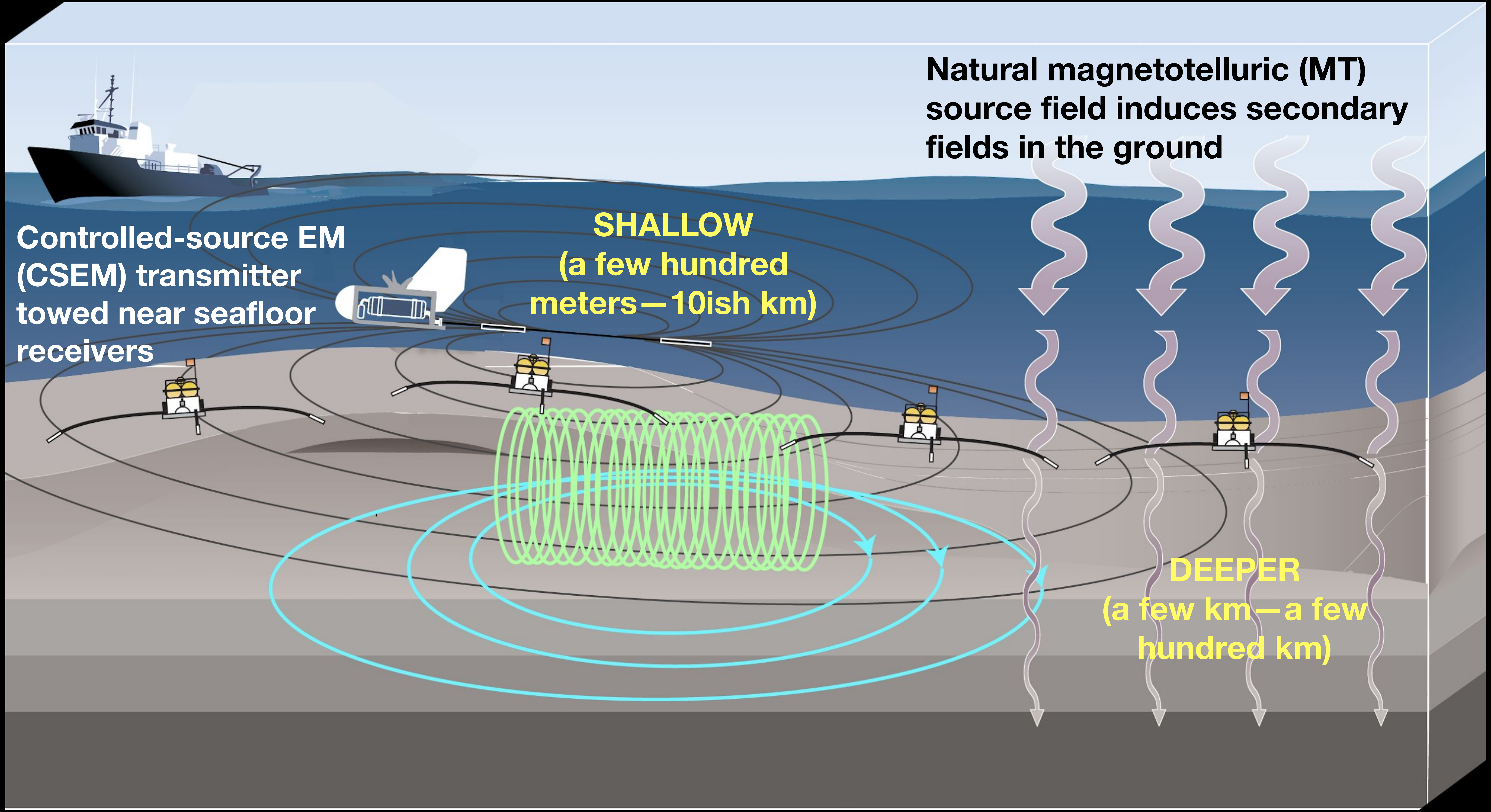


- Resistivity (1/conductivity)
- Highly sensitive to water and melt in rock
- Porosity = dominant control on resistivity of oceanic crust and marine sediments
- Complements other geophysical data

Passive Source Method—Magnetotellurics



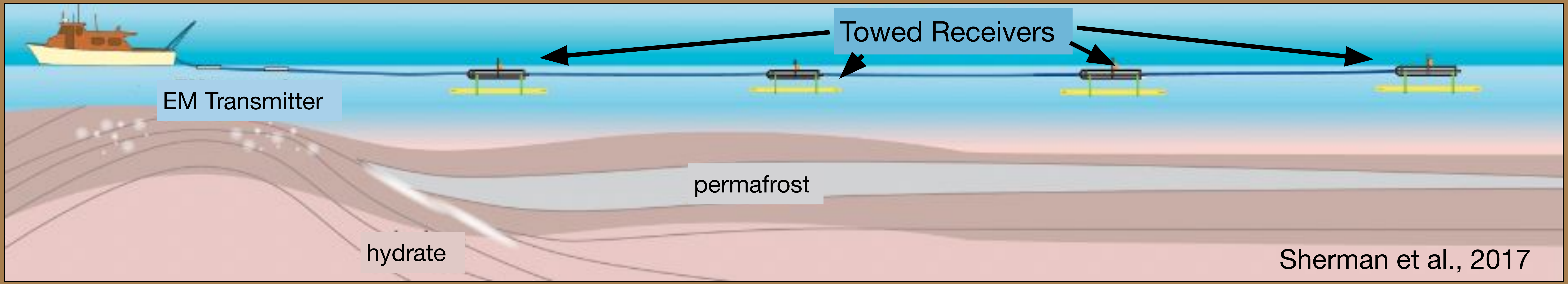
Active Source Method—Controlled-Source EM



Active Source Method—Controlled-Source EM

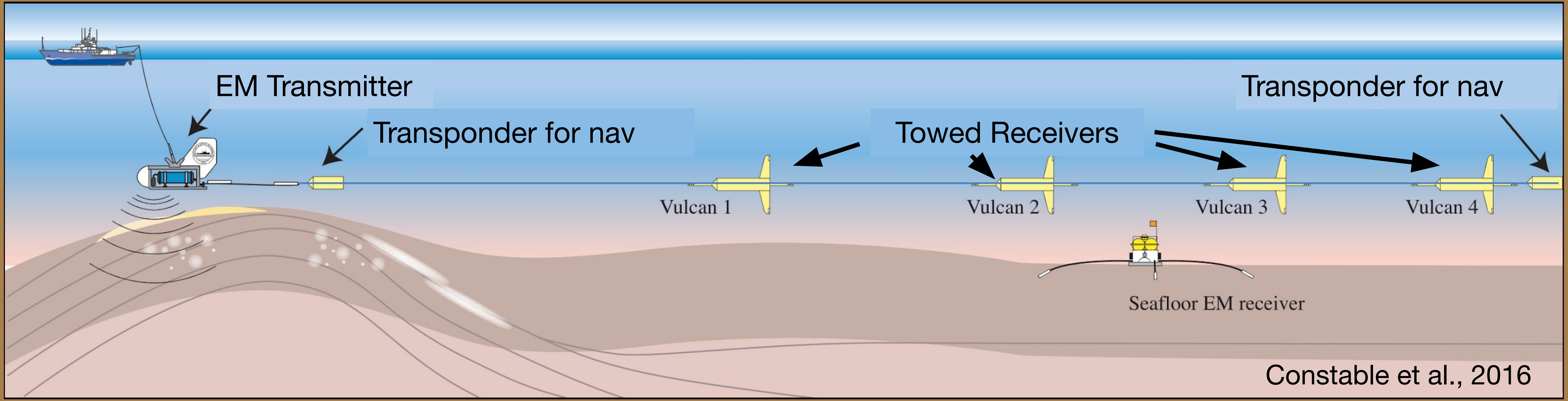
- Can also tow receivers behind source for higher resolution of sediments and very shallow subsurface (a few 10s—a few 100s of m)

Surface-towed receivers

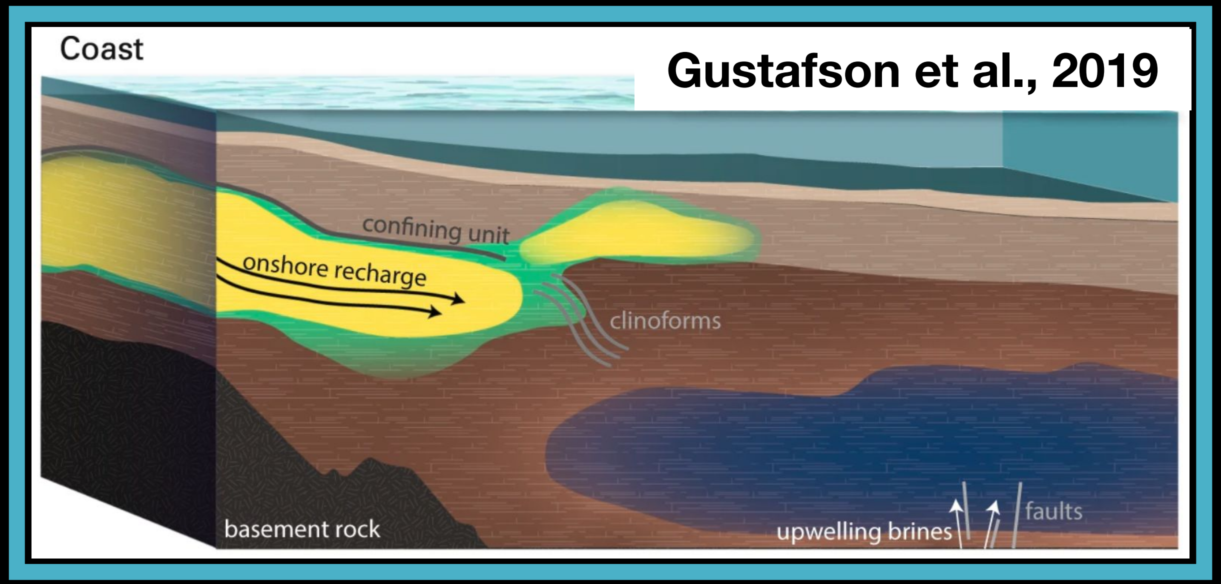


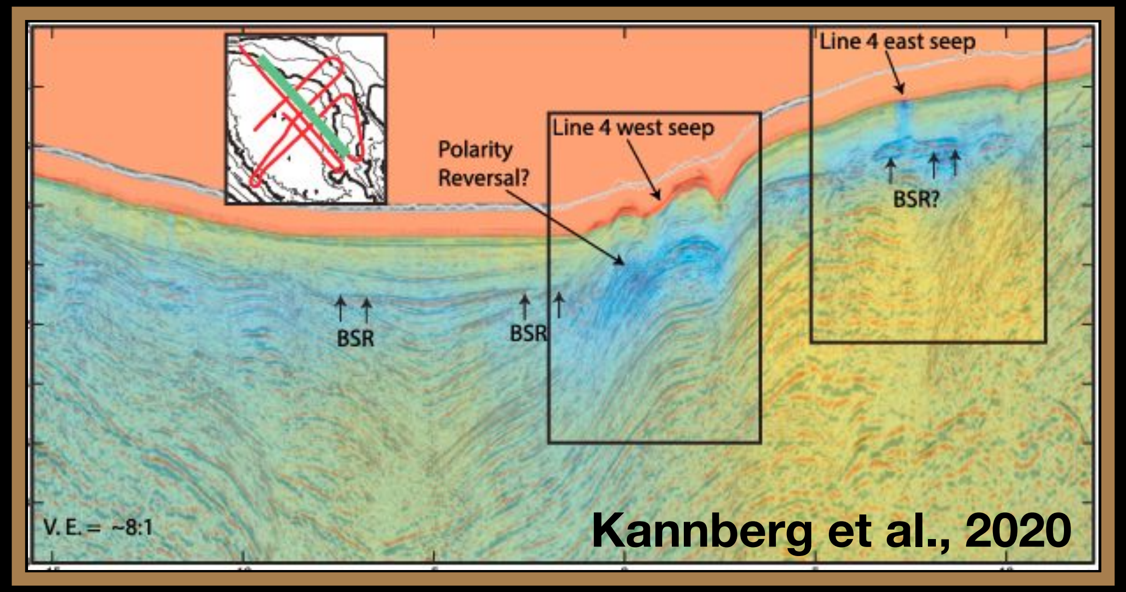
Sherman et al., 2017

Deep-towed receivers



Constable et al., 2016

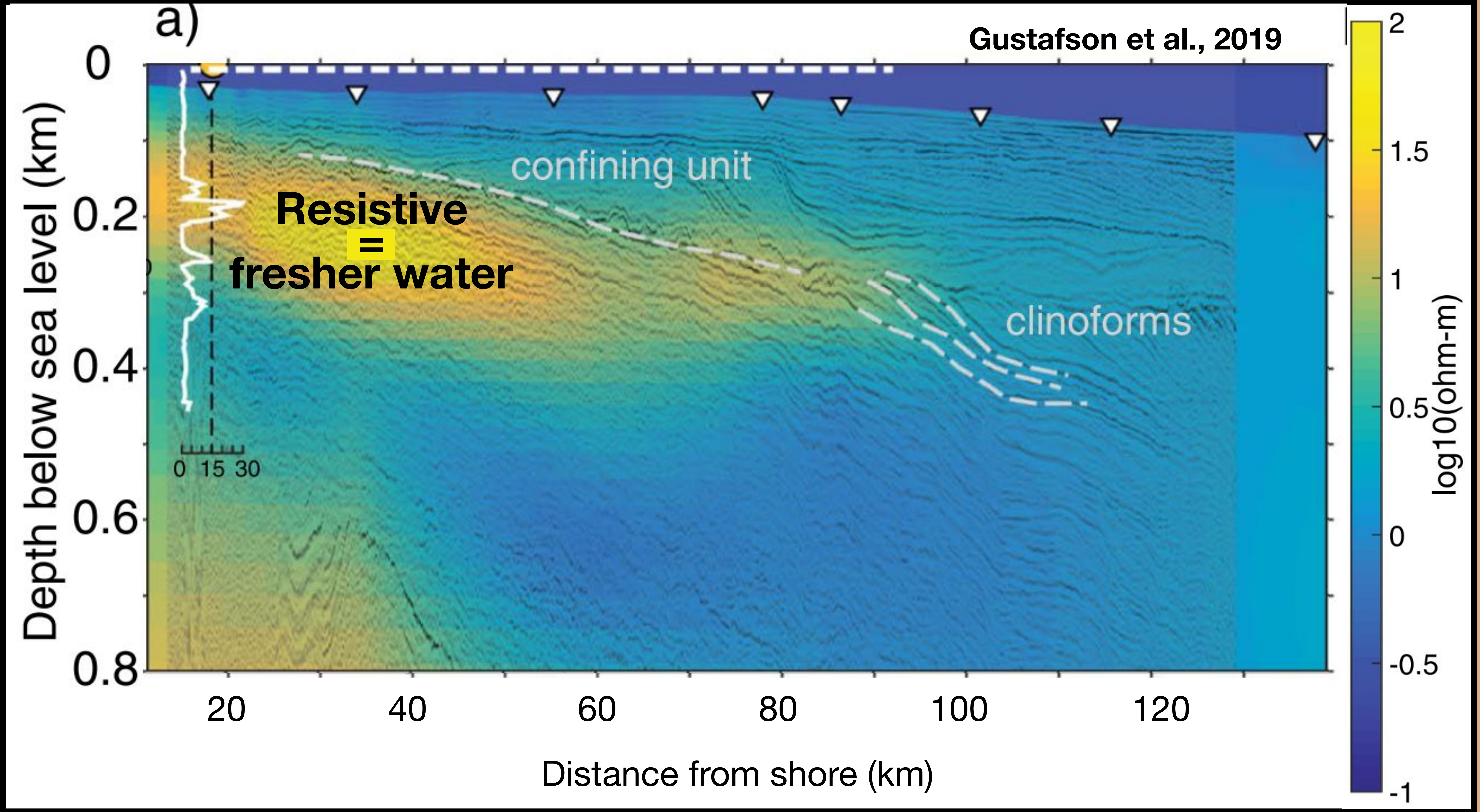


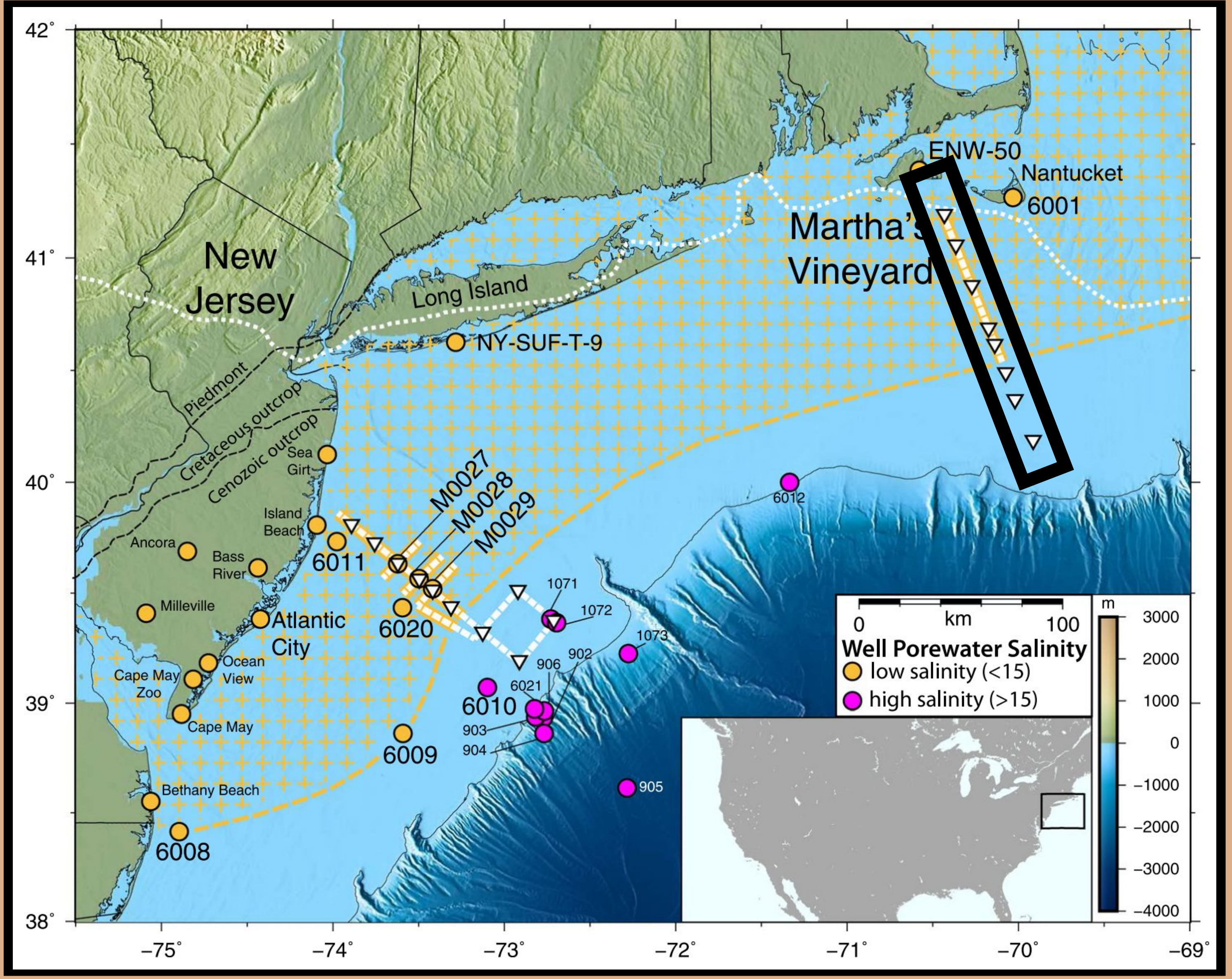


Marine EM for Resource Exploration

Offshore Freshened Groundwater

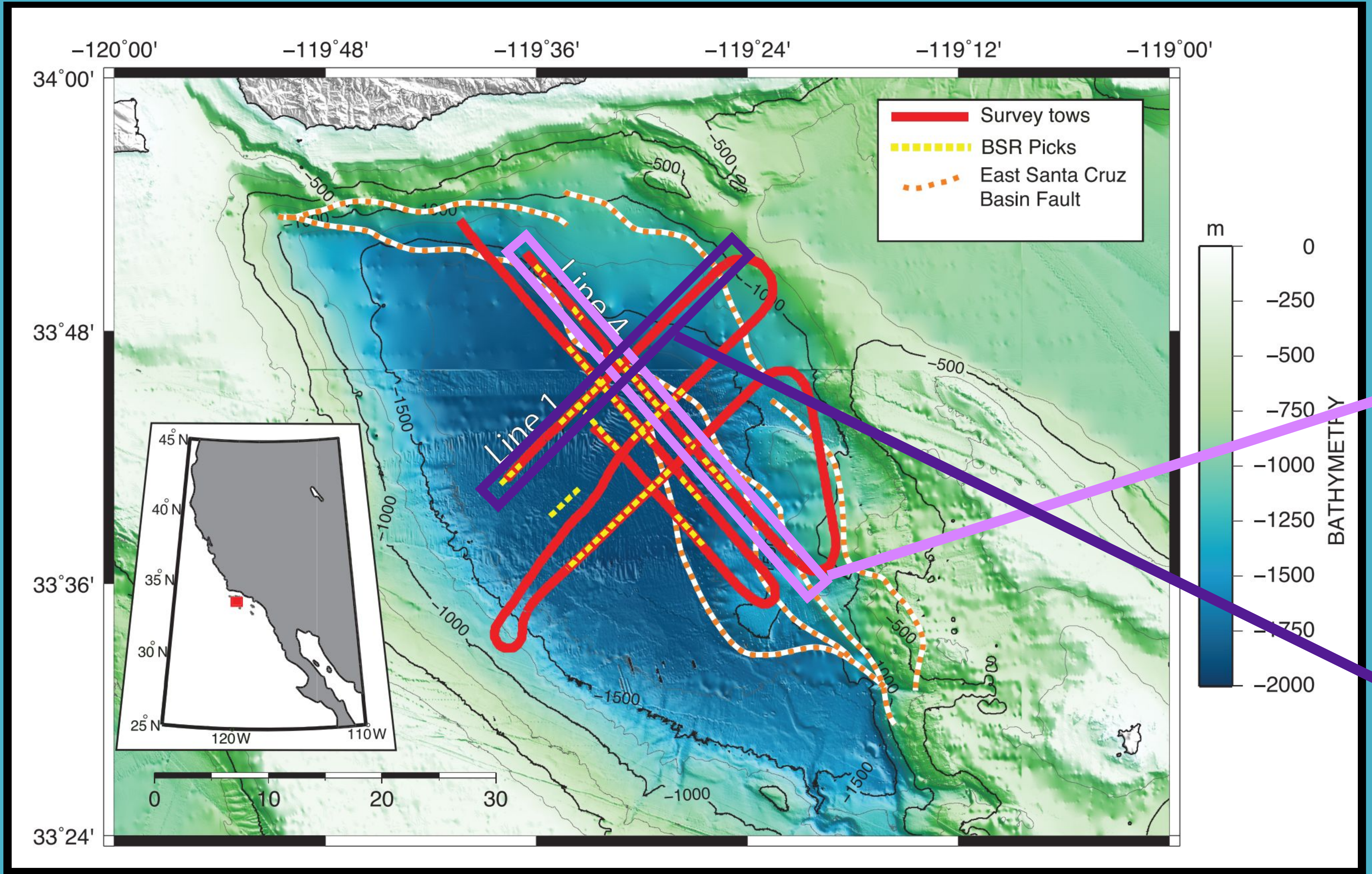
Low-Salinity Aquifer Offshore Martha's Vineyard, MA
(Note - freshwater is resistive)

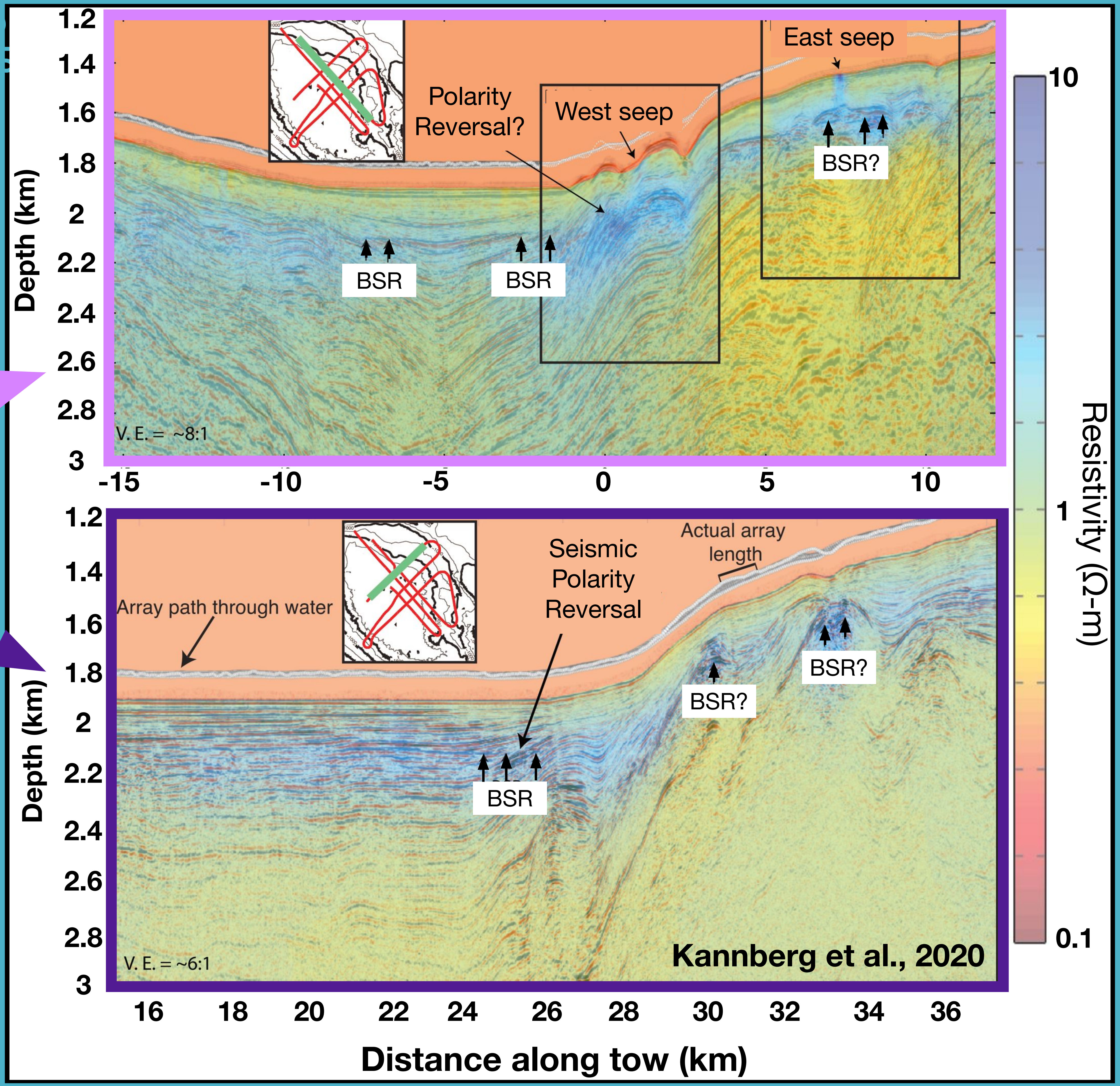




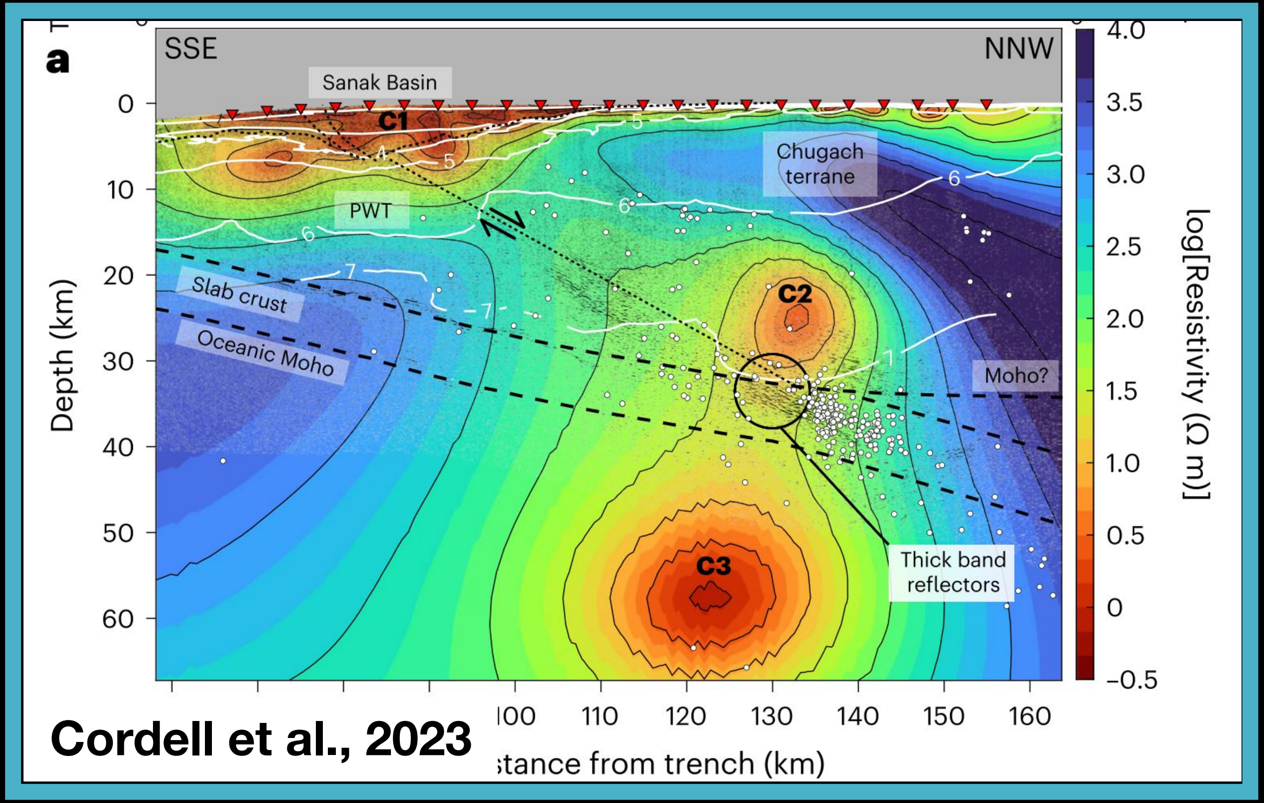
Gas Hydrate Mapping

Kannberg et al., 2020

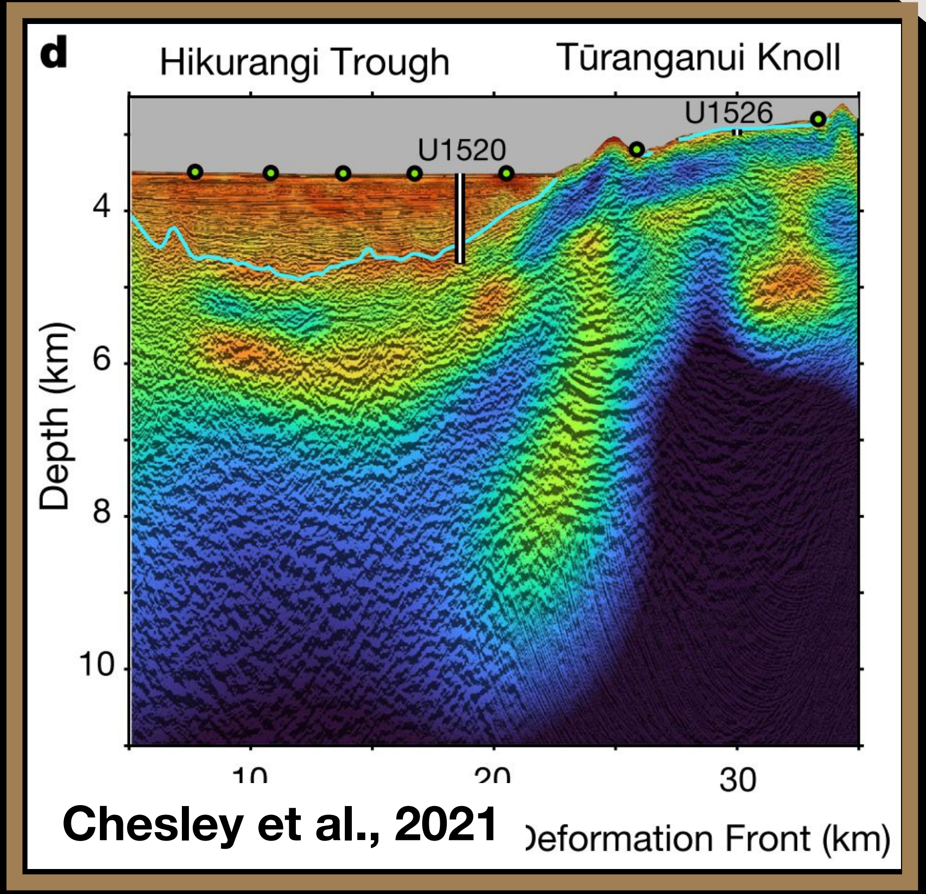




Quantifying gas hydrates and seeps in the California Borderlands (Note - gas is resistive)



Cordell et al., 2023



Chesley et al., 2021

Recent Tectonophysics Advances using Marine EM

@AGU2023:

Monday
GP11A-04 (9:02—9:12)

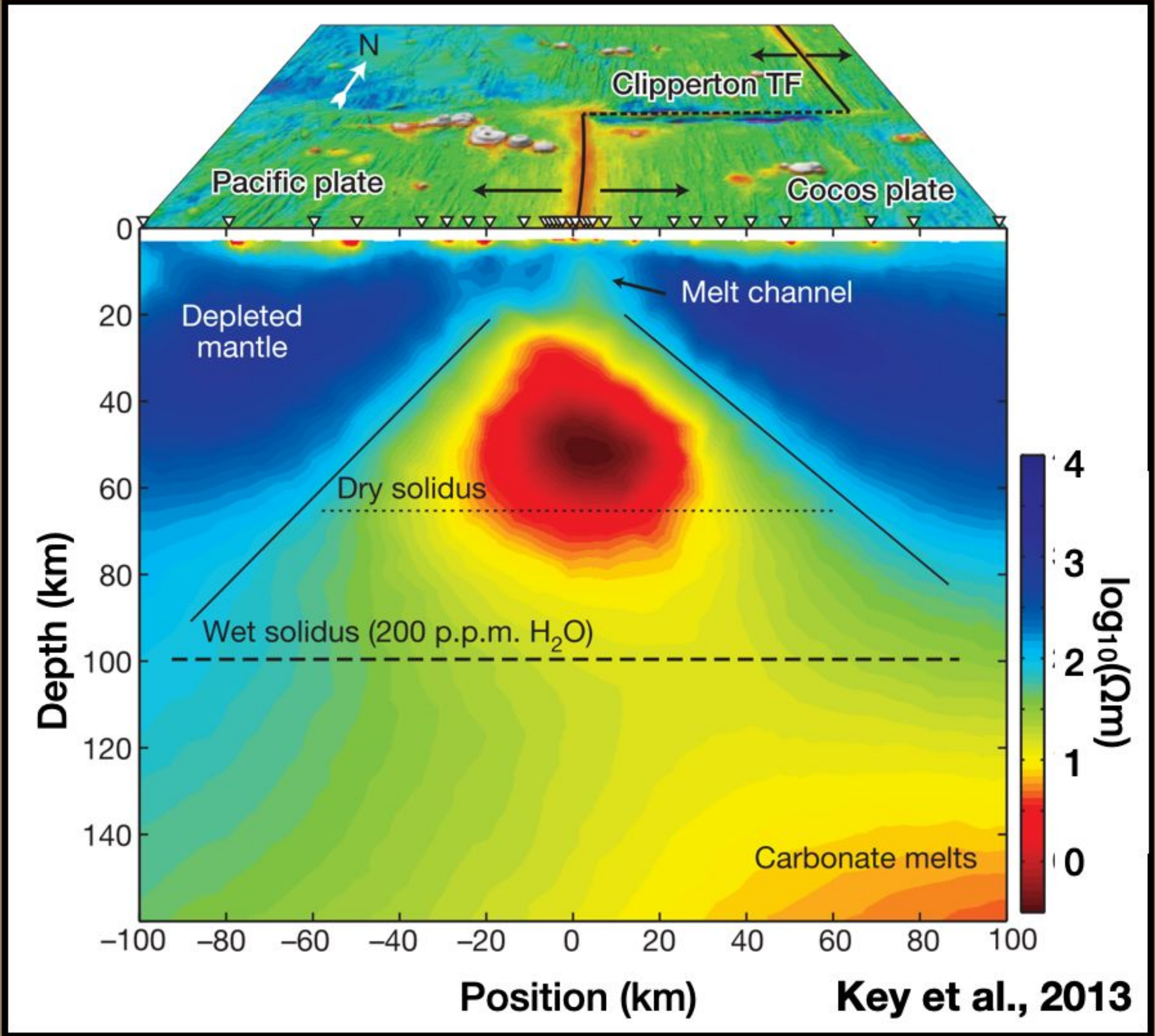
Tuesday
MR21A-07 (9:38—9:48)

Wednesday
V34A-01(16:02—16:12)

Thursday
V43B-0165 and V43B-0177
T44A-03 (16:22—16:33)

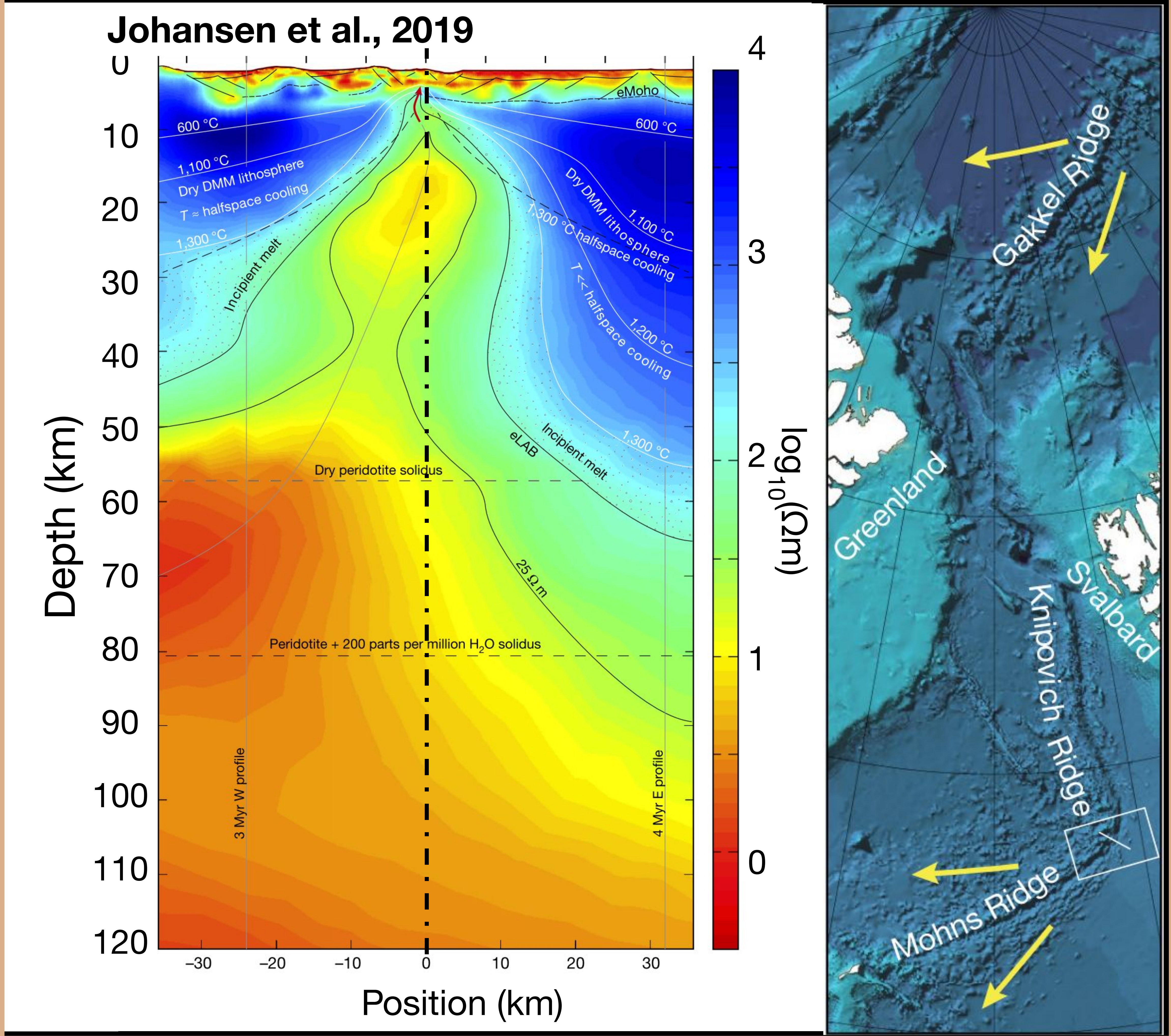
Friday

Mid-Ocean Ridge Melts

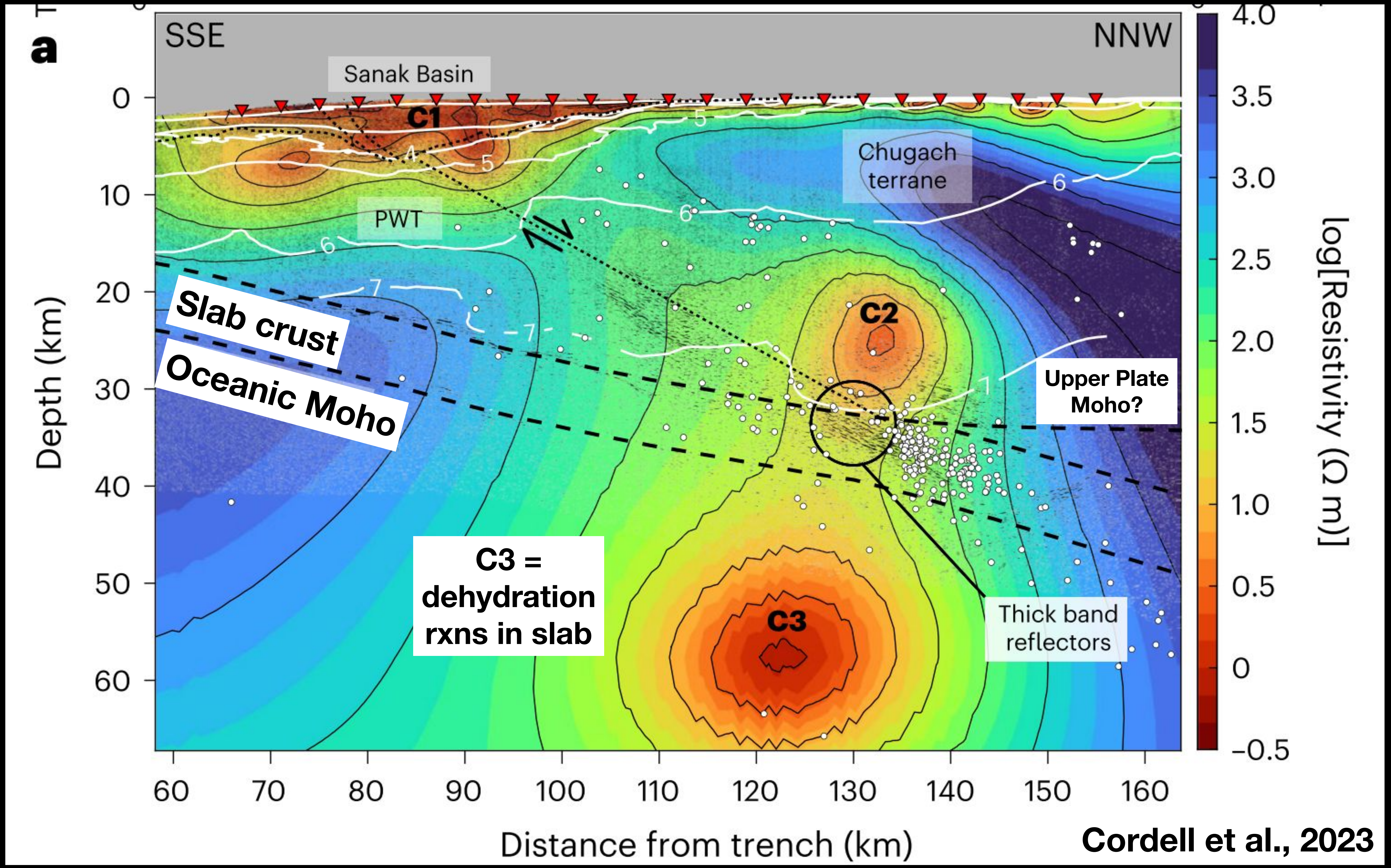


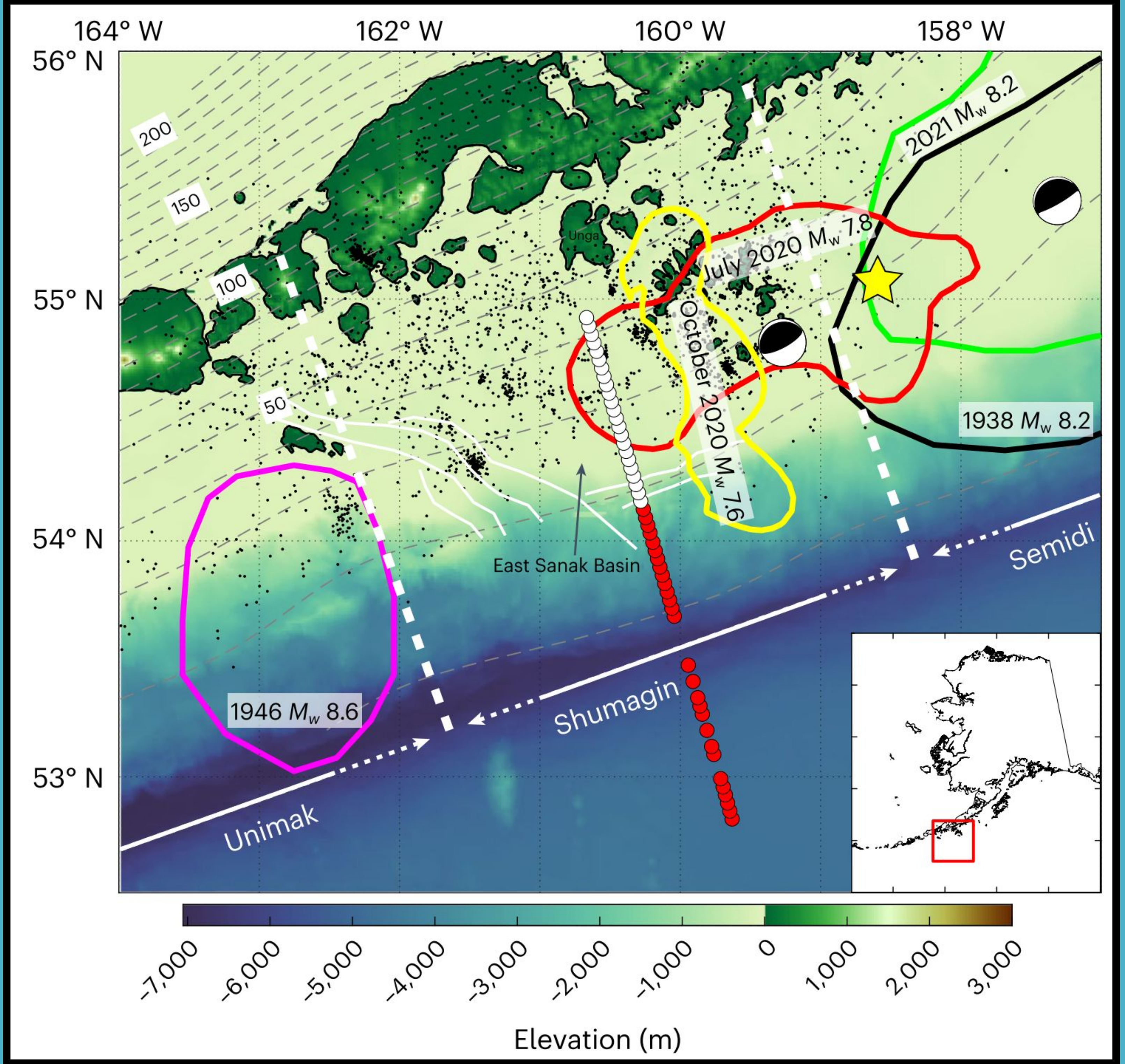
Partial Melt Chamber at the fast-spreading EPR

Deep, asymmetric mantle upwelling at the ultraslow-spreading Mohns Ridge



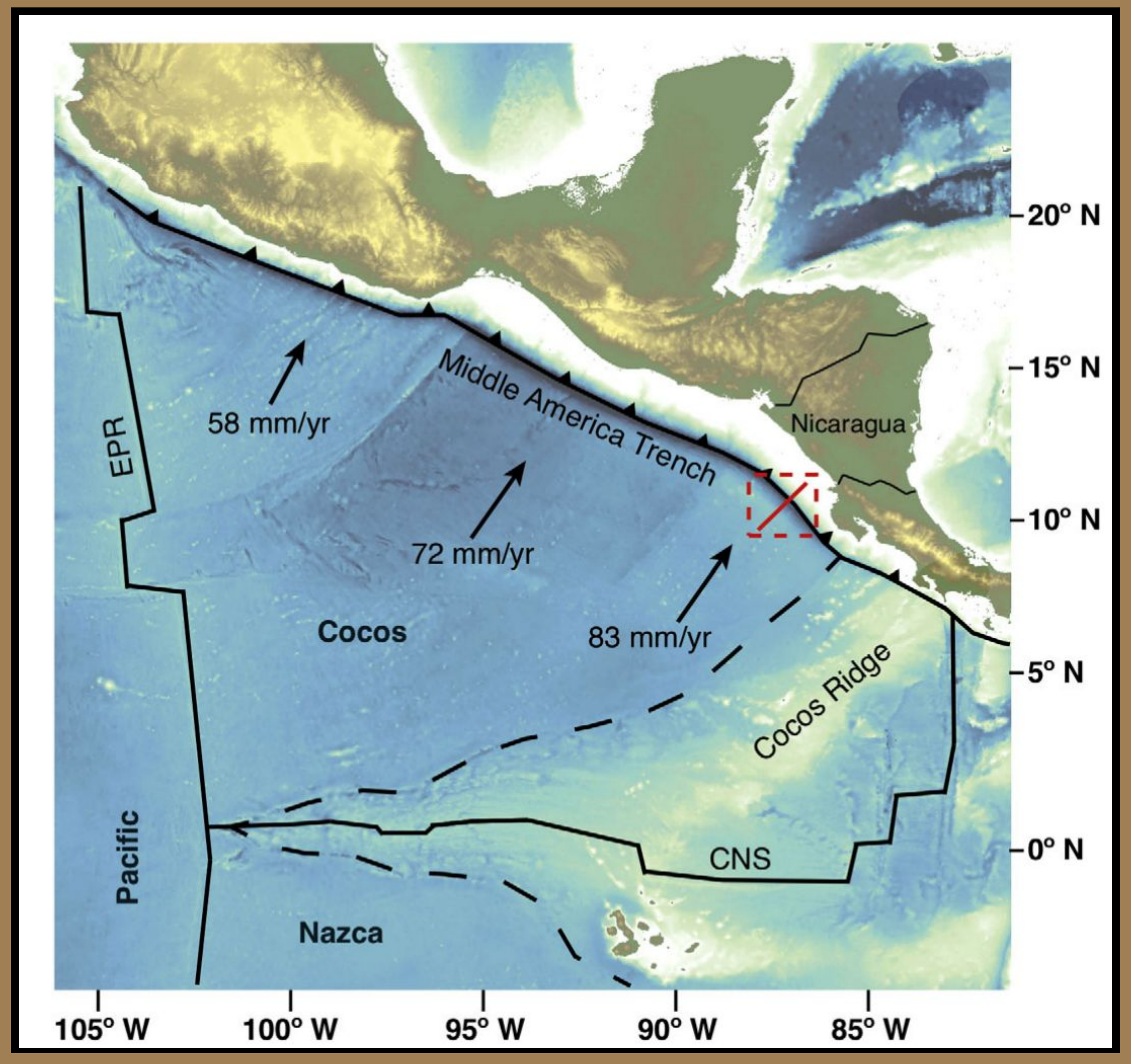
EM at Subduction Zones: Alaska-Aleutians



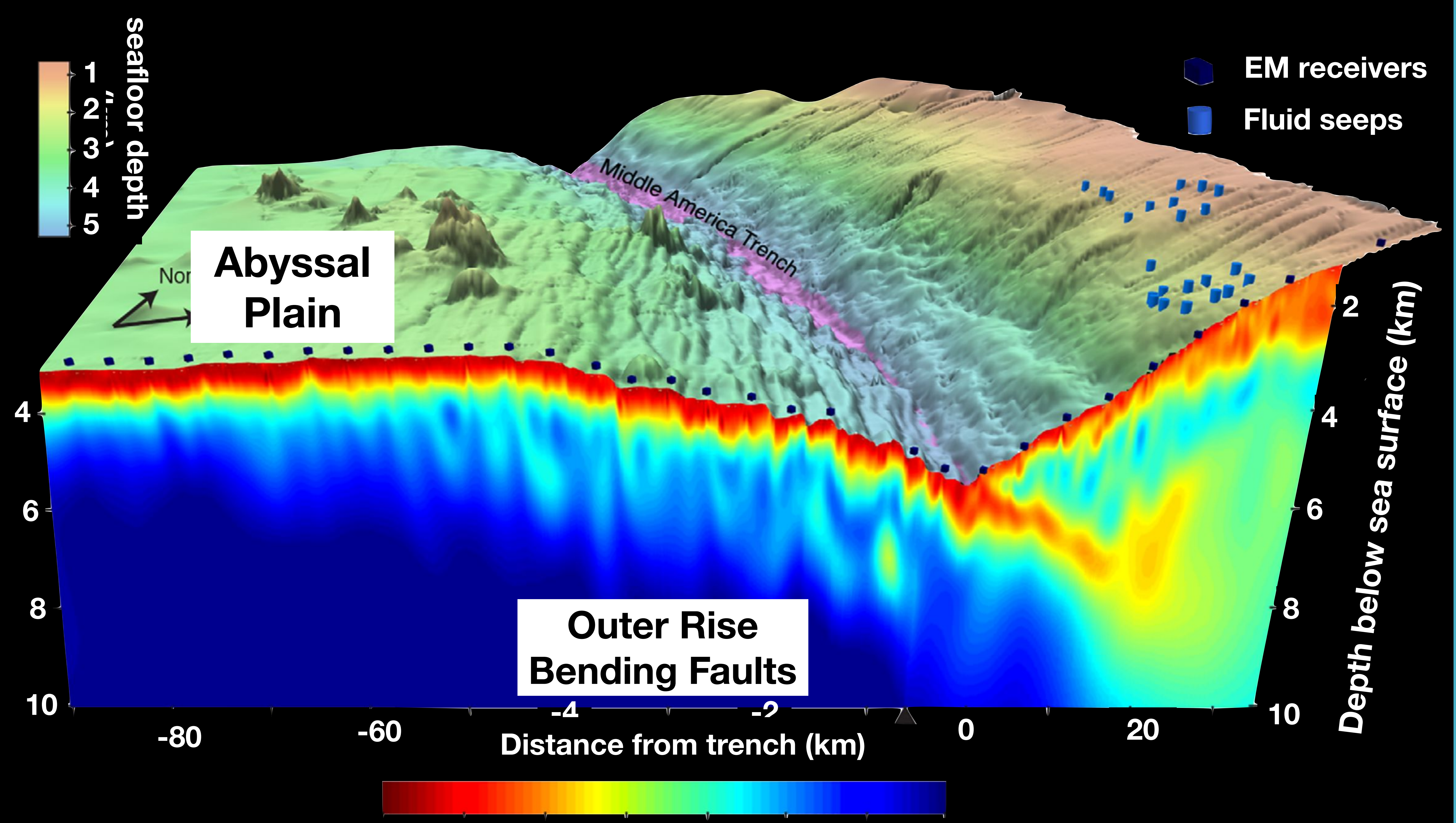


Deep hydration of slab mantle can provide fluids to forearc plate interface.

Outer rise bending faults



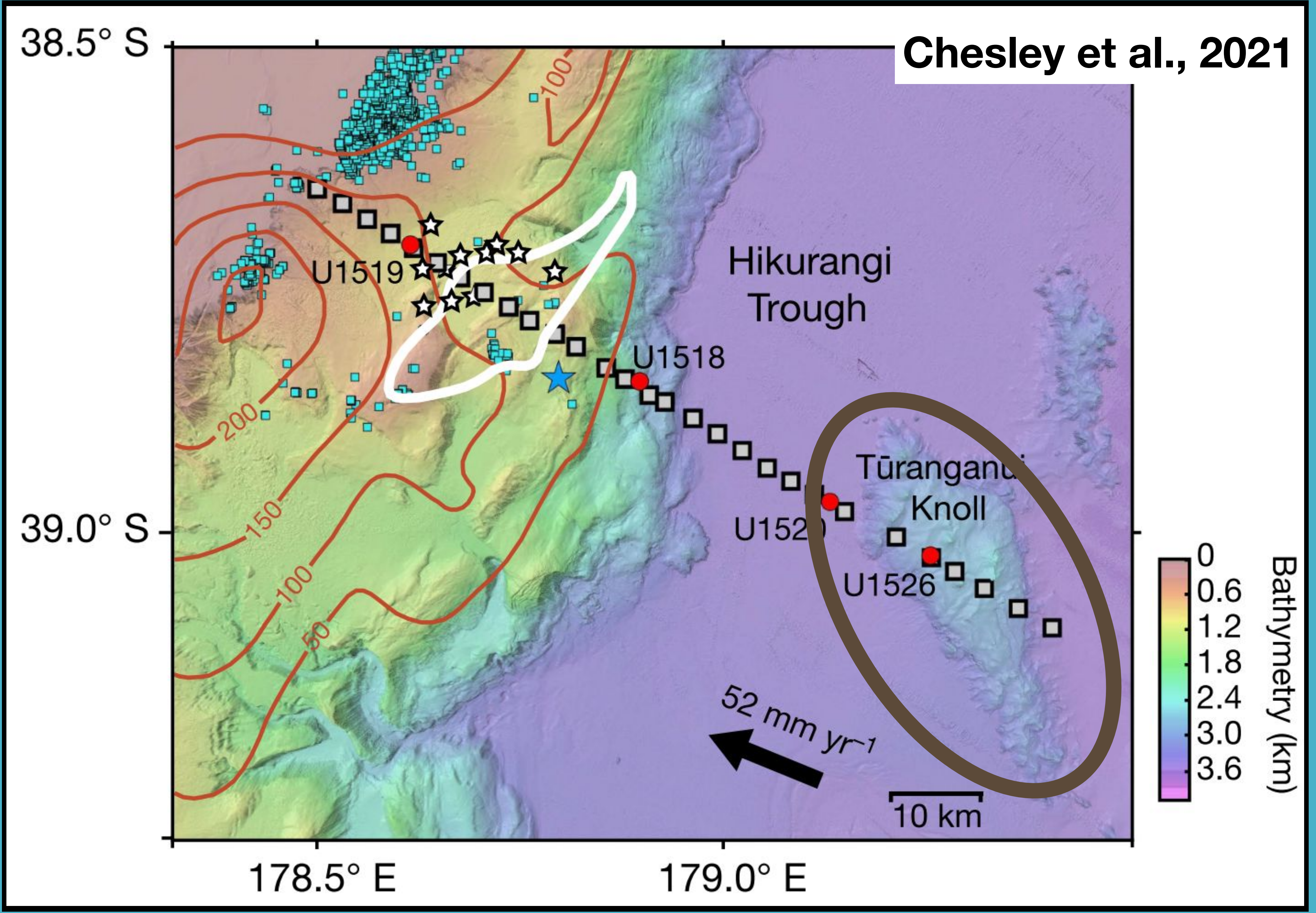
Outer rise bending faults increase crustal fluid volume

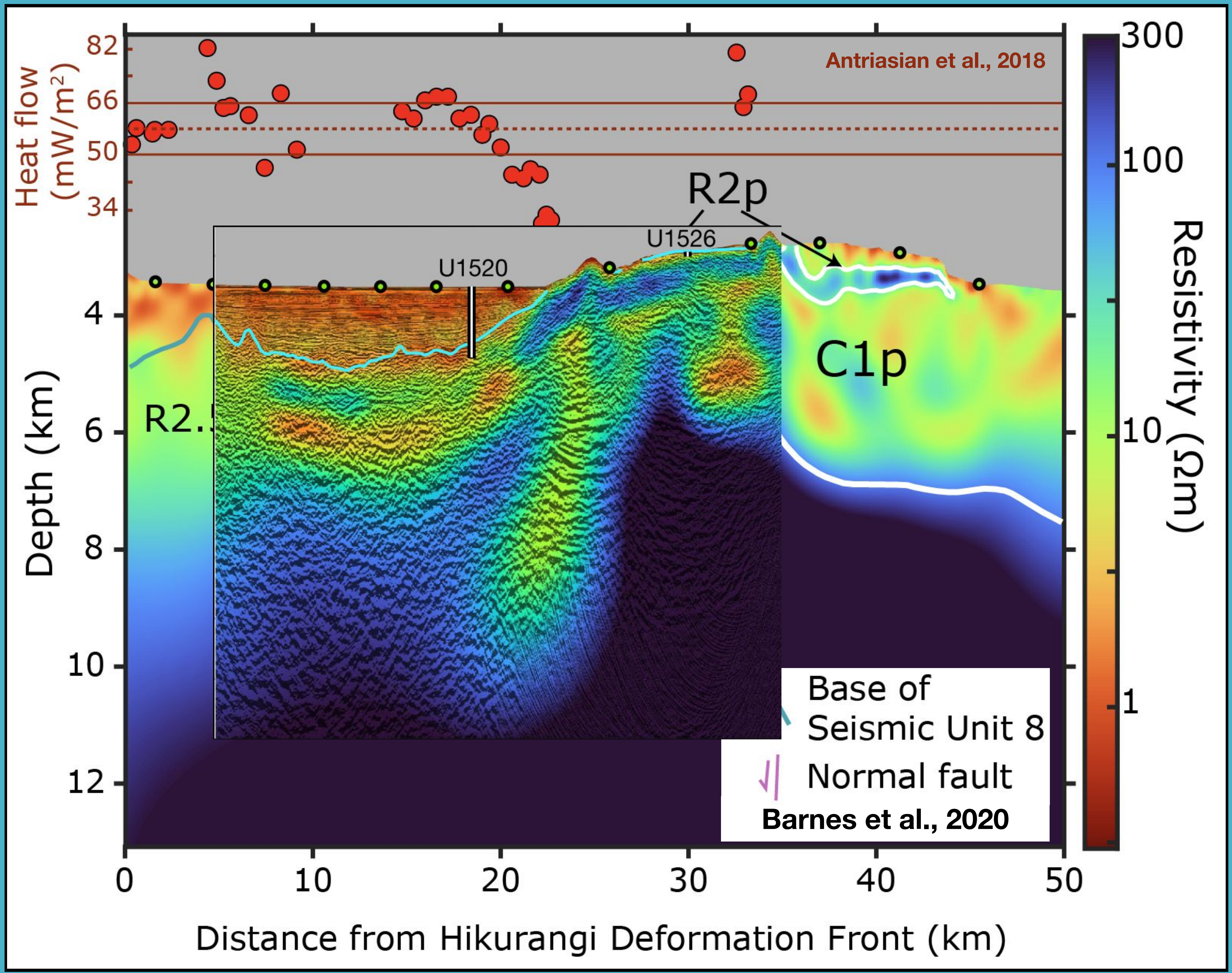


Naif et al., 2016

Seamounts are sponges

Seamounts can hold large volumes of fluid that may influence shallow slow slip events





Chesley et al., 2021

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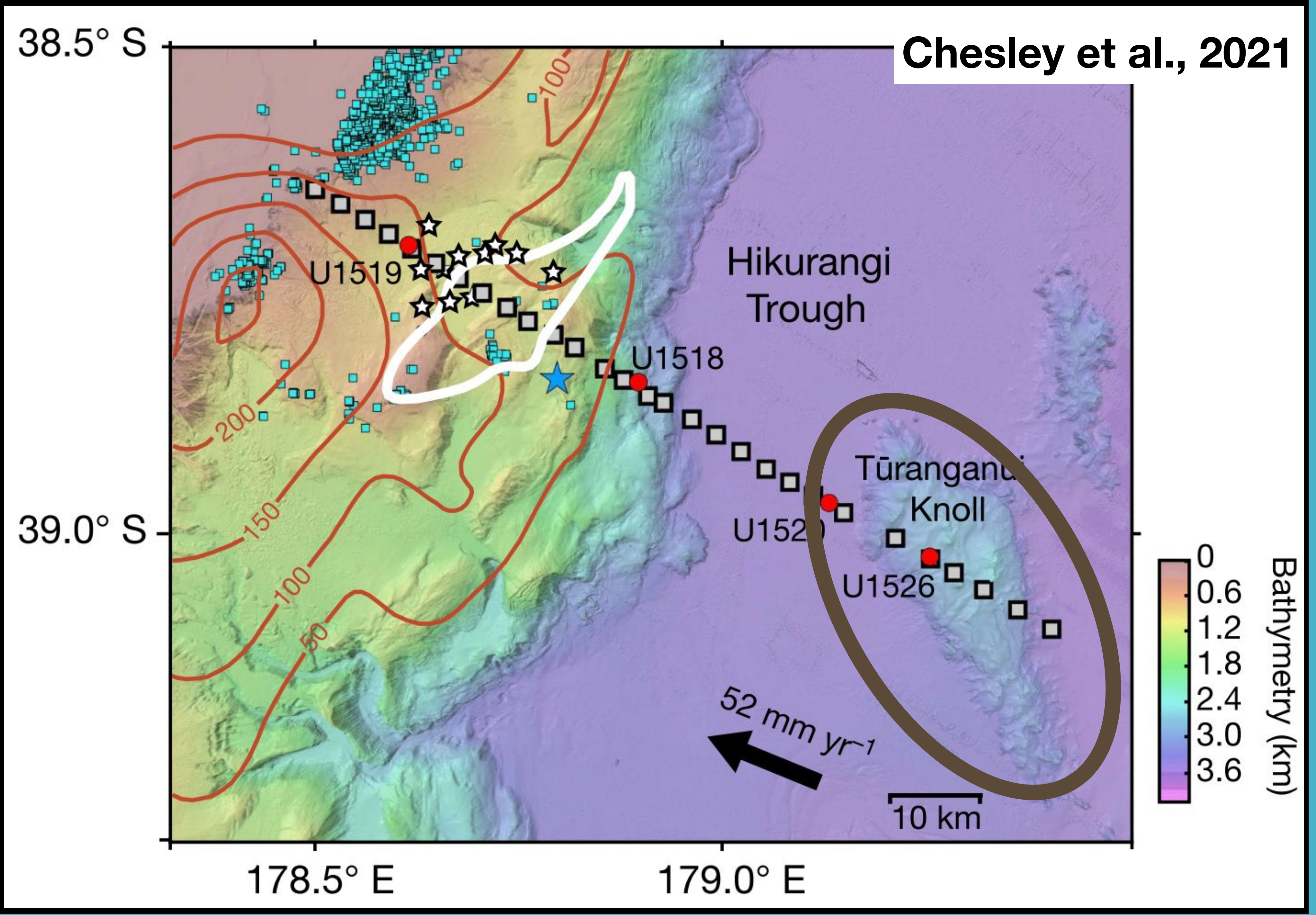
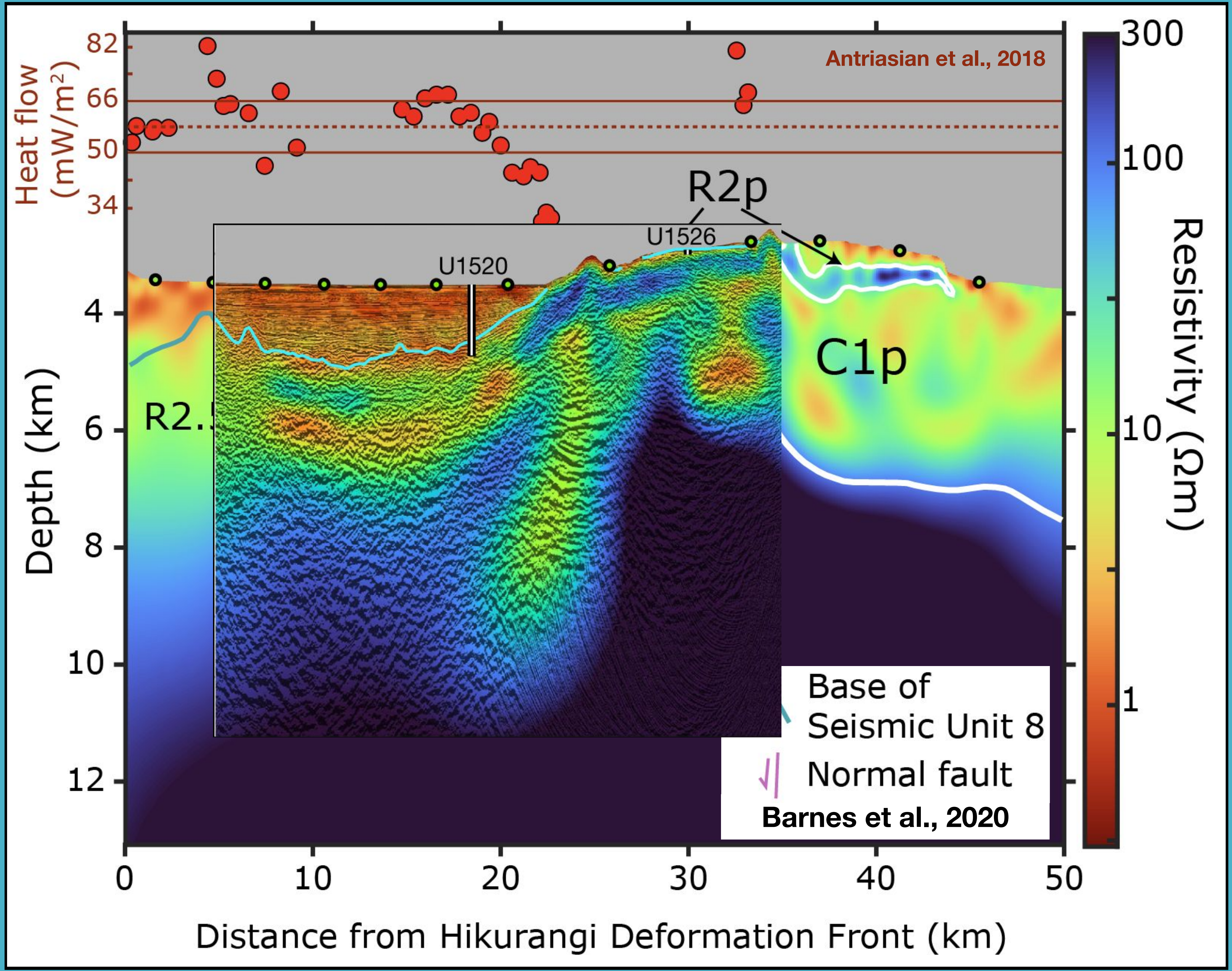
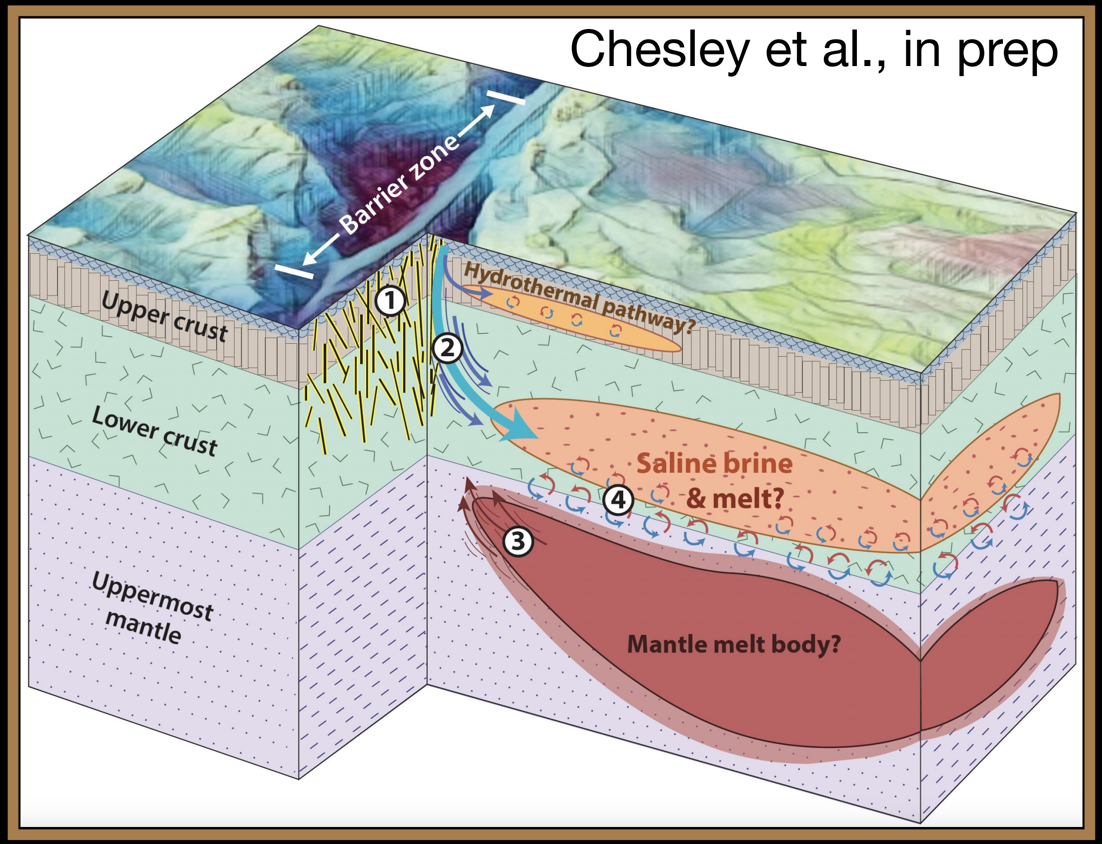




Chesley et al., 2021



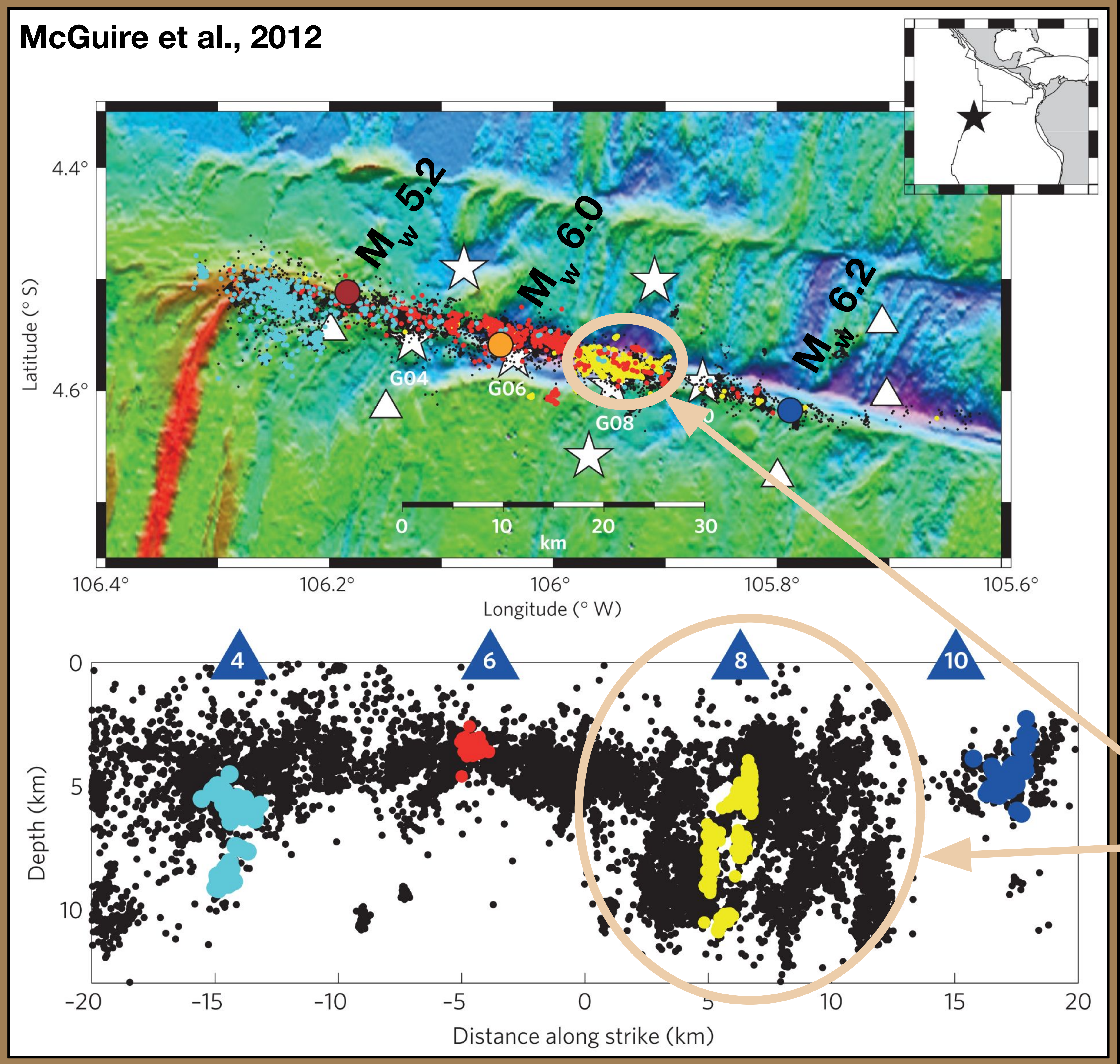
Gofar Oceanic Transform Fault

Shameless plug (Session V003):

Thursday poster hall 2:10—6:30 PM
V43B-0165 and V43B-0177

Friday talk 10:30—10:40
V52A-02

Curious Earthquake Rupture Barrier Zone at Gofar



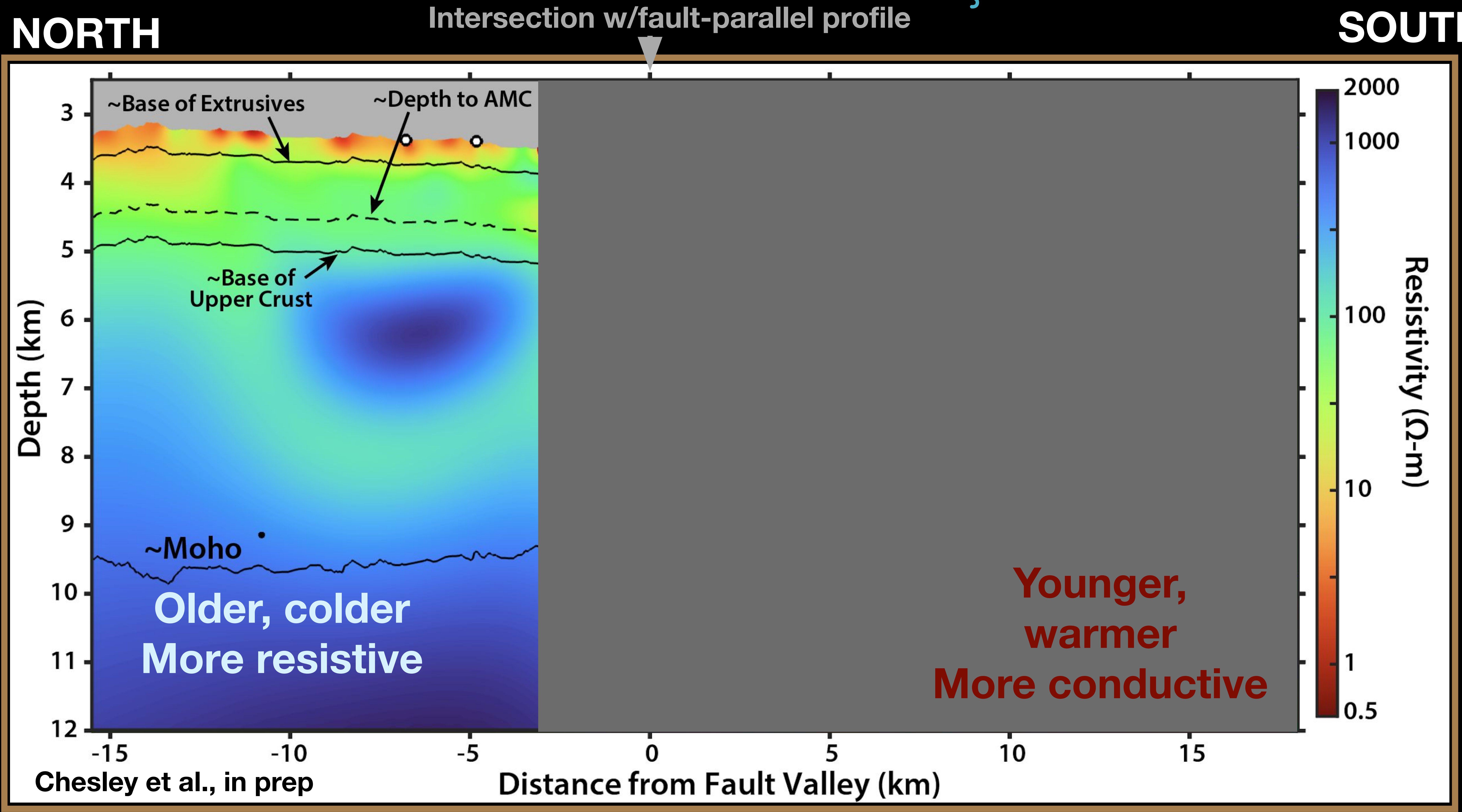
- Observations from 2008 OBS deployment revealed…
- Larger (Mw ≥ 5.0) EQs don't occur in middle segment of fault
- Lots of smaller EQs that happen abnormally deep
- Rupture propagation appears to be prevented by a "barrier zone"

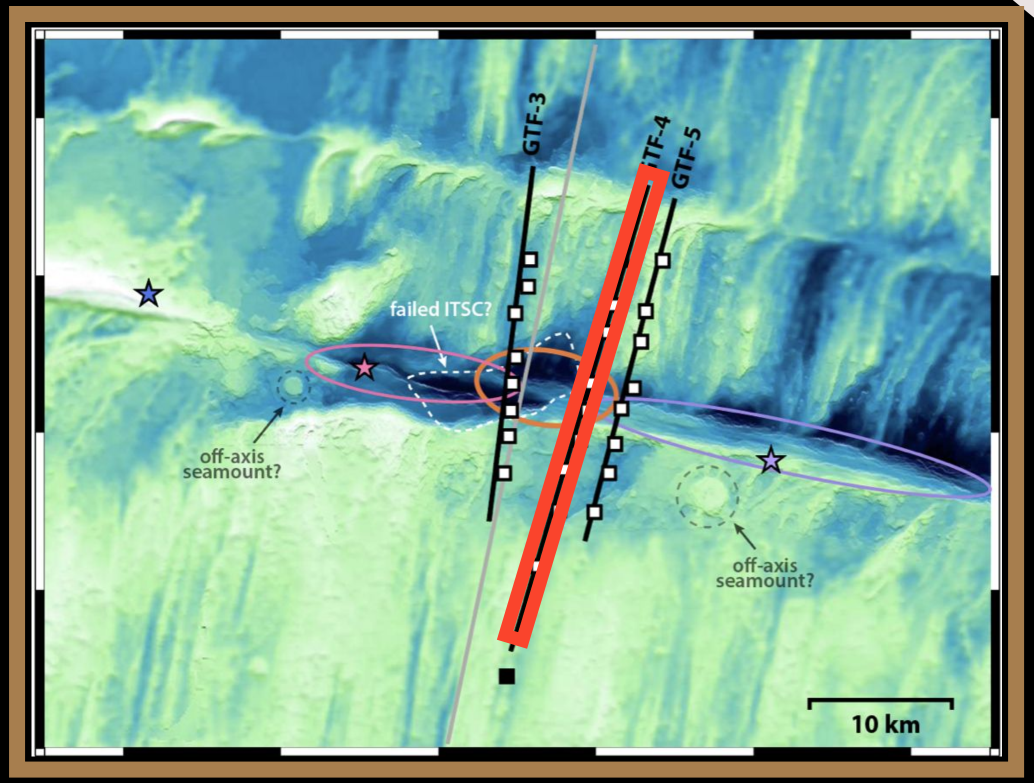
Investigating Properties of the GOFAR Fault

- 40 OBEM deployments & recoveries
- 5 CSEM tow lines
- 14 AUV Sentry dives
- 47 OBS recoveries

- mid Jan - early Mar 2022
- ~50 days on R/V Thompson

Resistivity of GTF-4





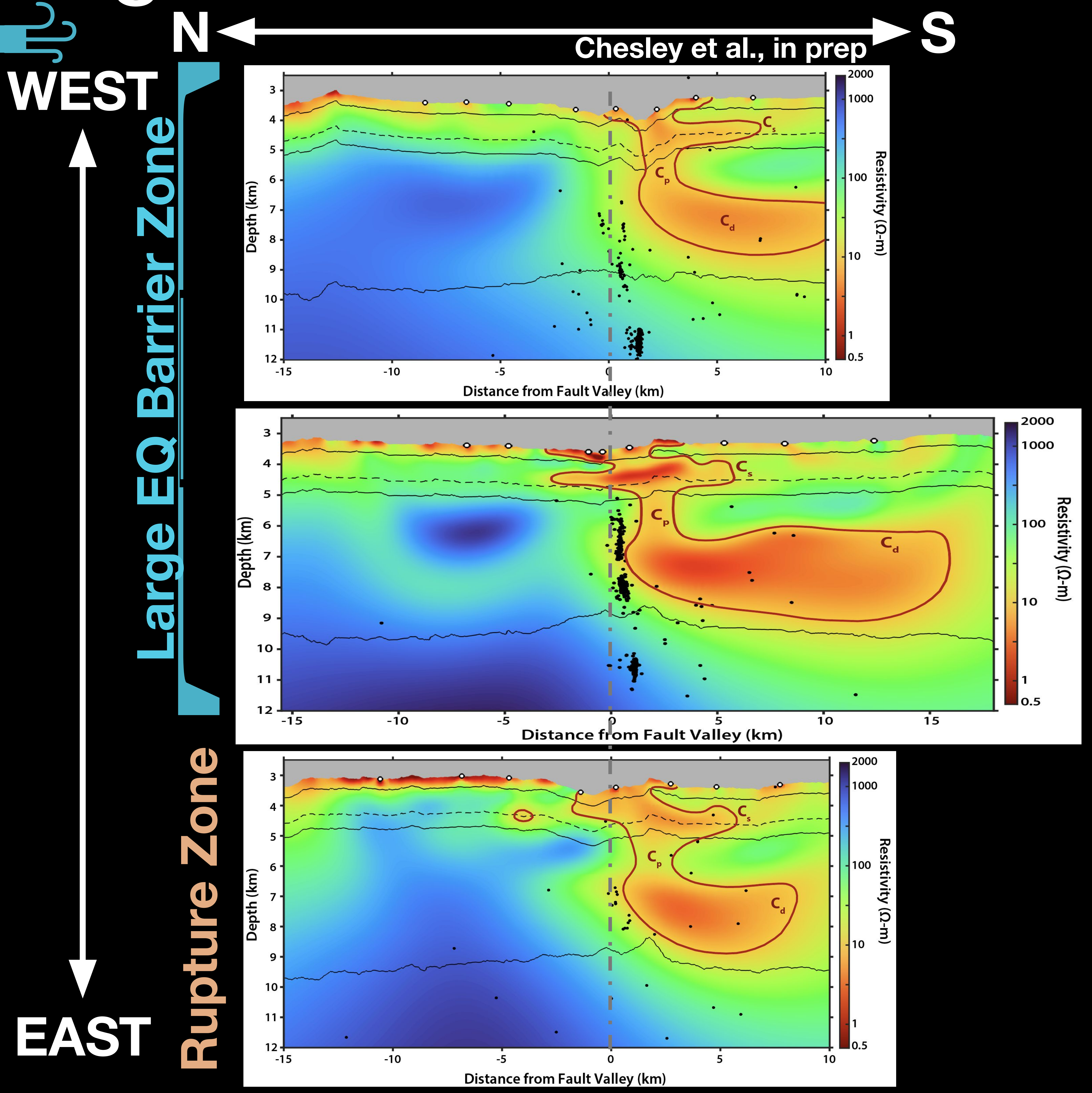
Christeson et al., 2019;
Hussenoeder et al., 2002;
Detrick et al., 1993;

- 3 conductive to south anomalies:
  - Deep (C_d)
  - Shallow (C_s)
  - Pipe-like (C_p)

- Seismicity from *Gong and Fan 2022* are relocated 2008 EQs w/in 250 m of profile

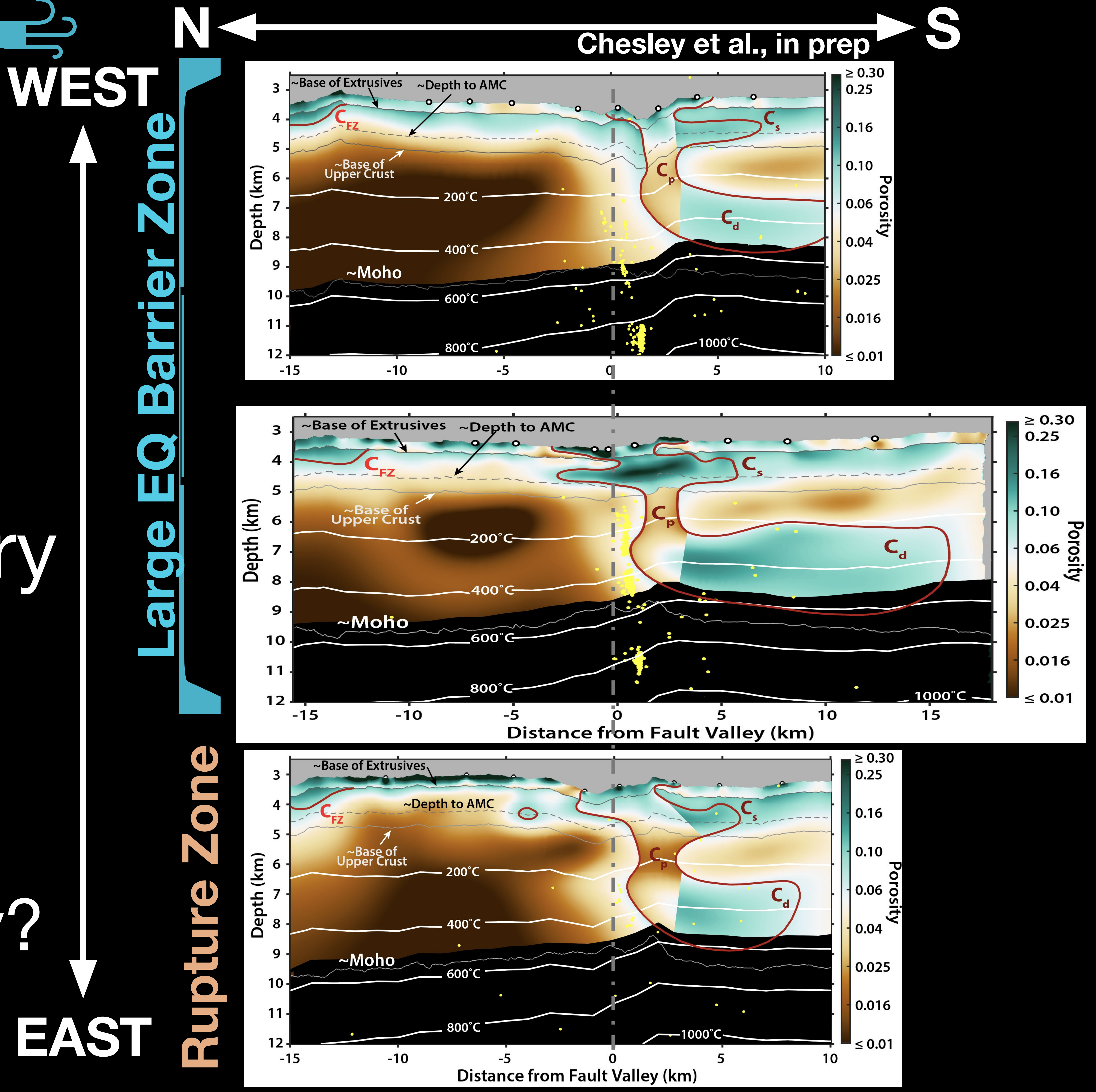
Resistivity of all Fault-Crossing Profiles

- No clear difference in resistivity structure b/w **barrier** & **rupture** zones
- North (older) side of fault is more resistive than south (younger)
- Shallow (1.5–15 Ω-m) & deep conductor (2–10 Ω-m) on younger plate



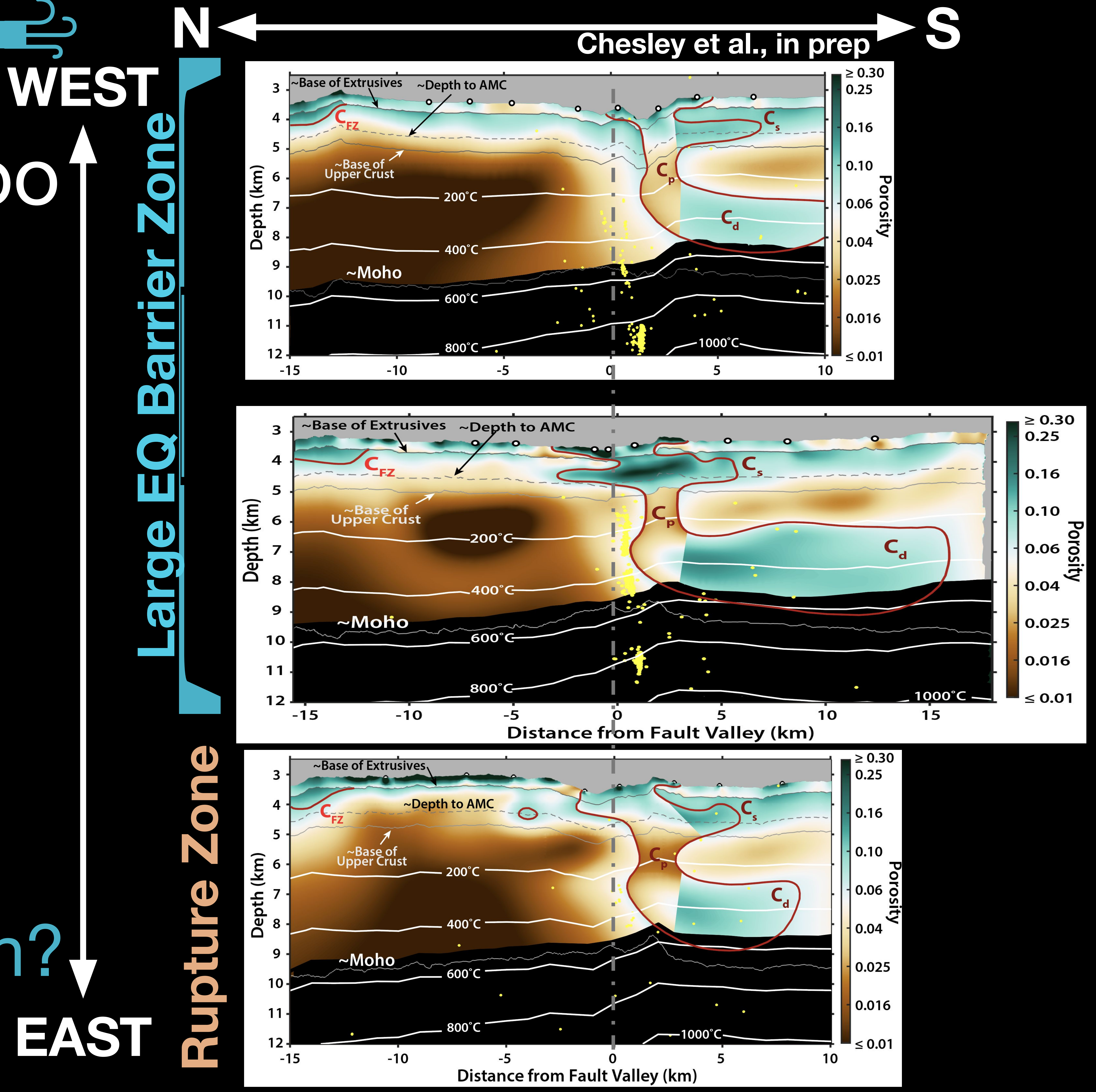
Is seawater-filling porosity realistic?

- C_p ($\phi \leq 5\%$; ave 3%) — okay
  - intense damage & fluid infiltration
- C_s ($\phi \leq 30\%$; ave 13%) — very high
  - hydrothermal circulation?
  - remnant thermal/melt anomaly?
  - heavy metal deposits?



Is seawater-filling porosity realistic? NO

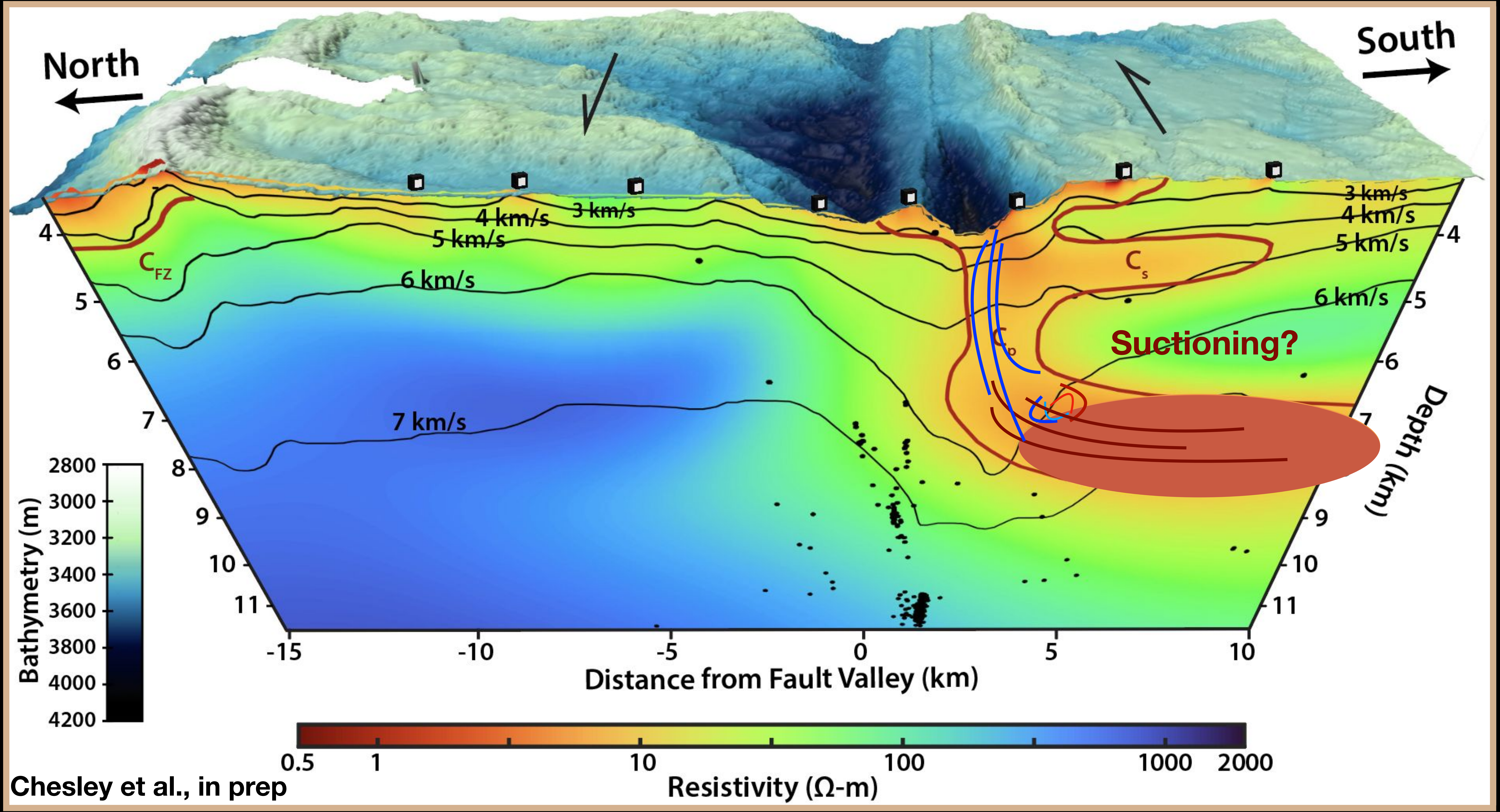
- C_d (ϕ ≤ 16%; ave 9%) — too high for lower crust
  - No corresponding LVZ (Roland et al., 2012)
  - Saline brines may be responsible
    - What would drive asymmetric brine formation?
  - MELT



Some possible interpretations for C_d

Scenario 1

- C_d = Low fraction of partial melt and saline brine
  - Suctioned from EPR or other melt source



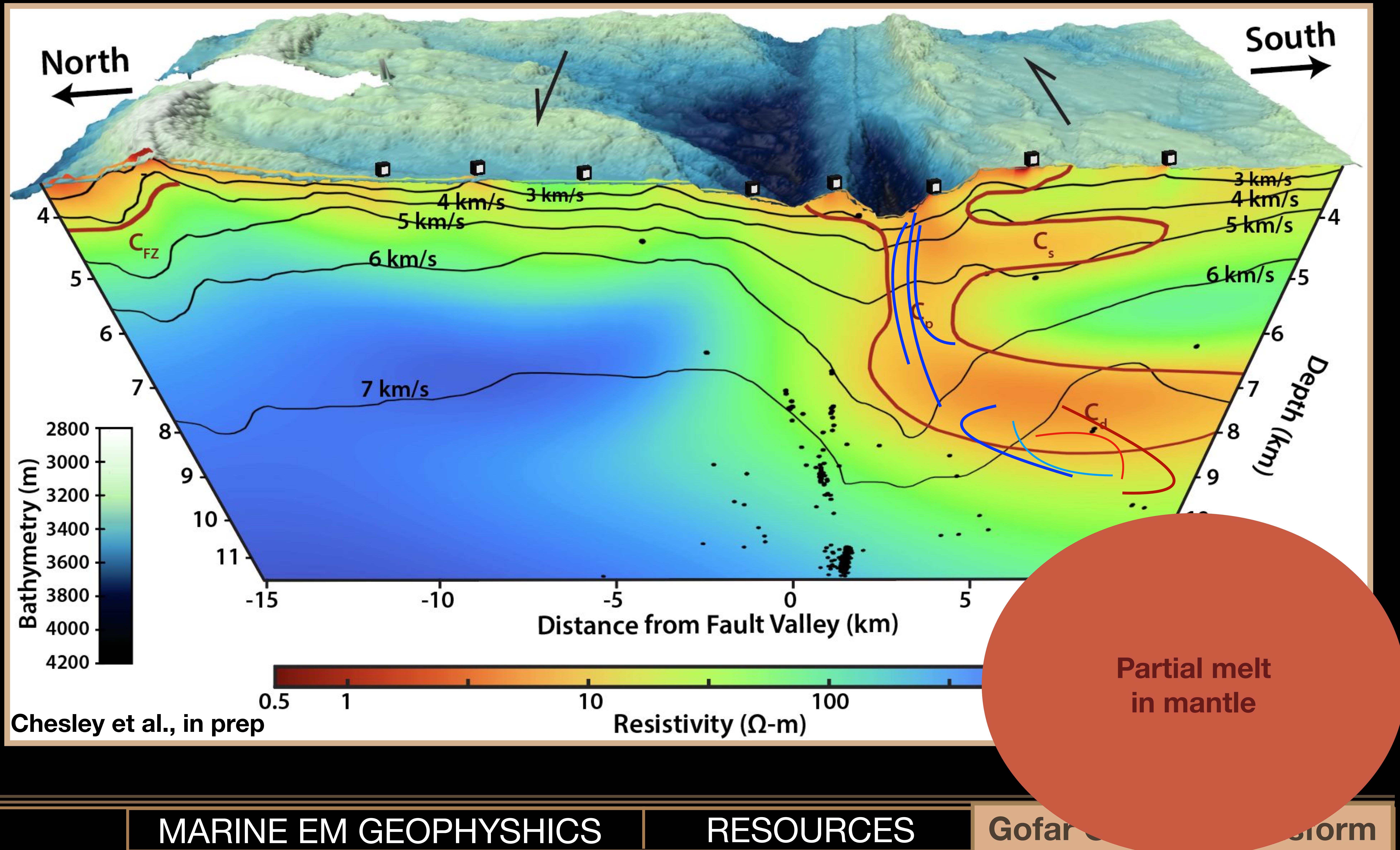
Some possible interpretations for C_d

Scenario 1

- C_d = Low fraction of partial melt and saline brine
  - Suctioned from EPR or other melt source

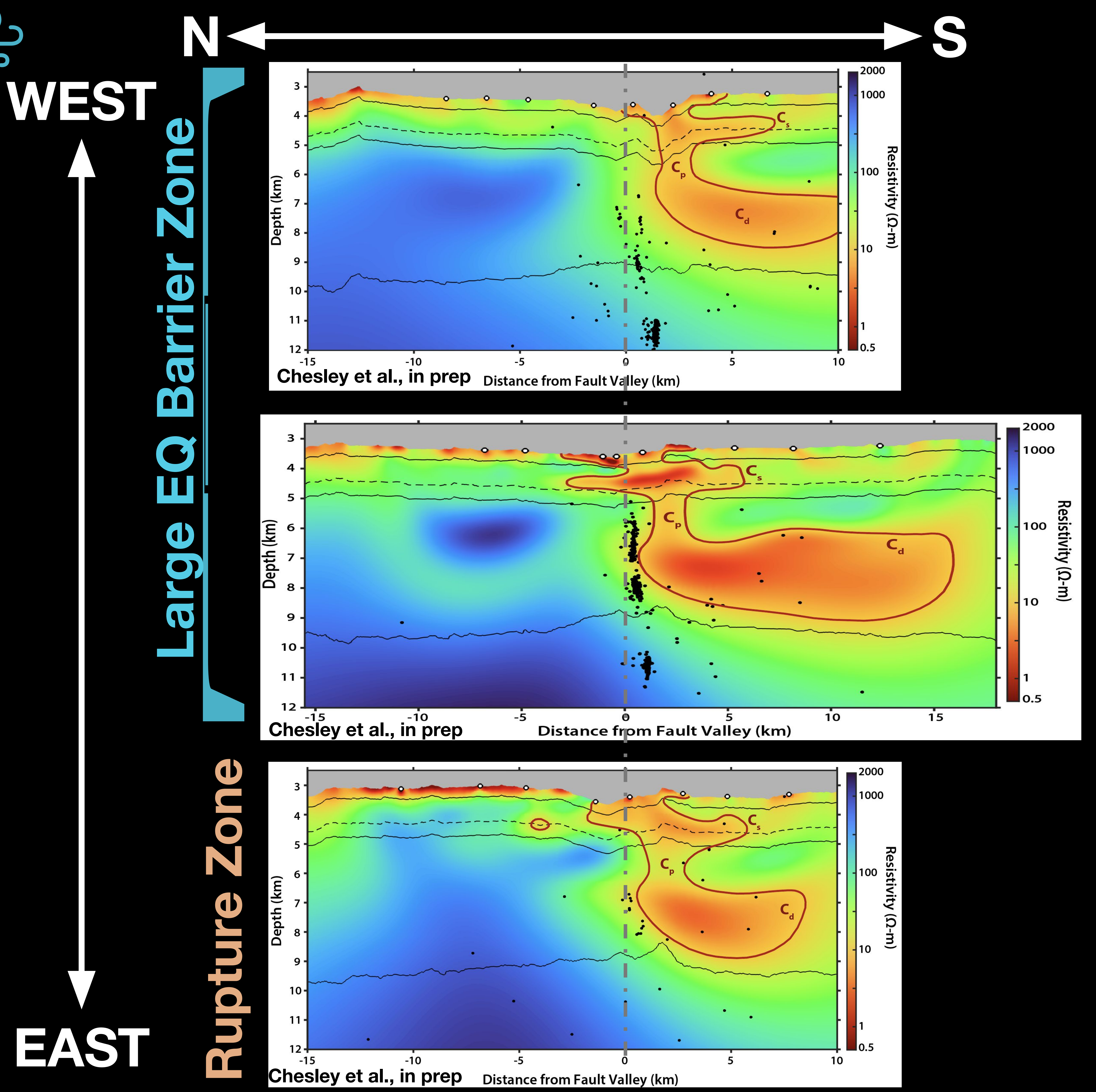
Scenario 2

- C_d = saline brine
  - Melt source in the mantle drives fluid flow



Conclusions

- Melt suctioned into OTF domain + enhanced permeability of fault drive localized, deep fluid infiltration in barrier zone
  - We image effect of this as lower crustal brines
- This may imply that some melt that doesn't escape at the ridge gets carried to transforms and influences fault rheology



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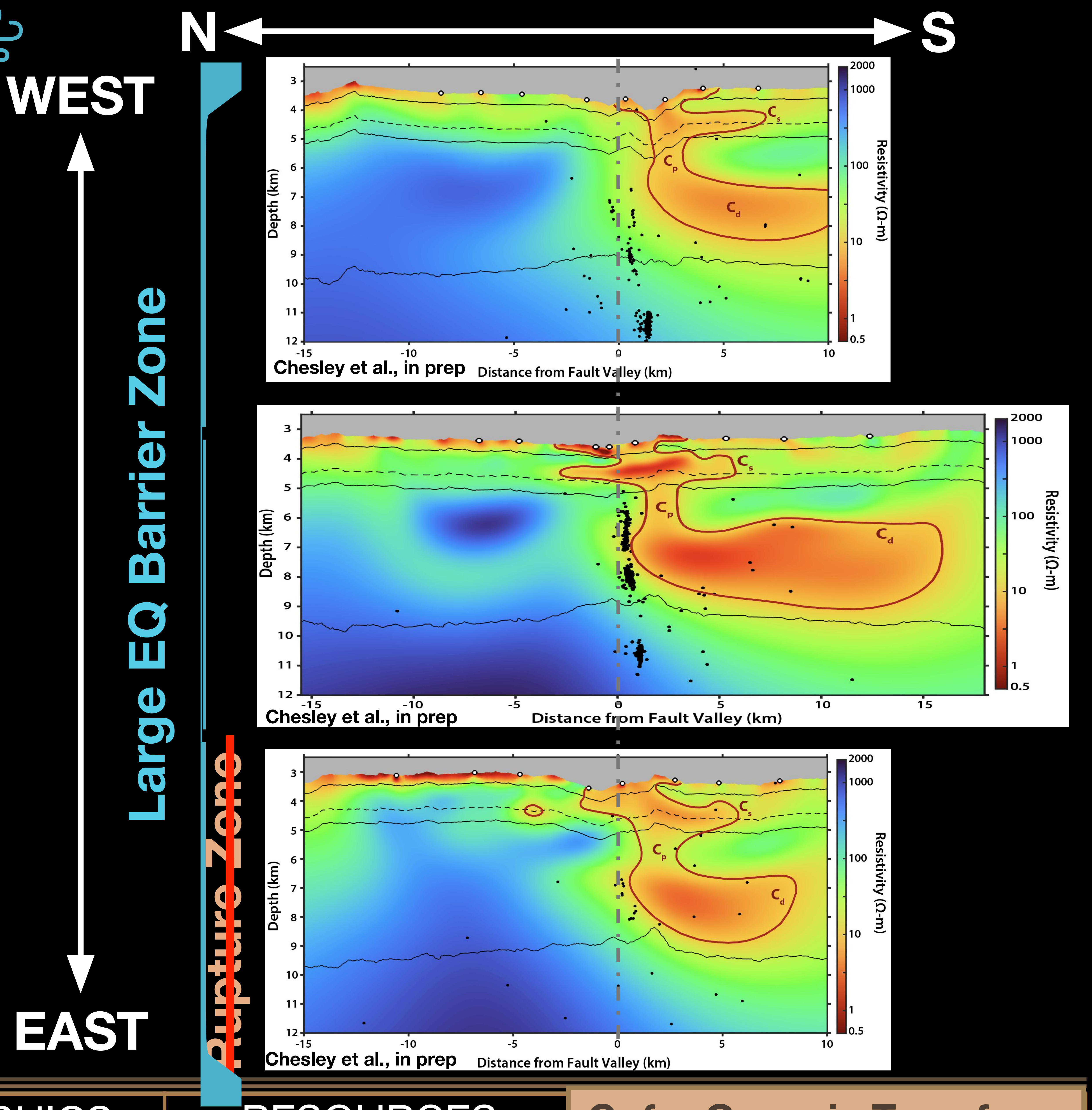
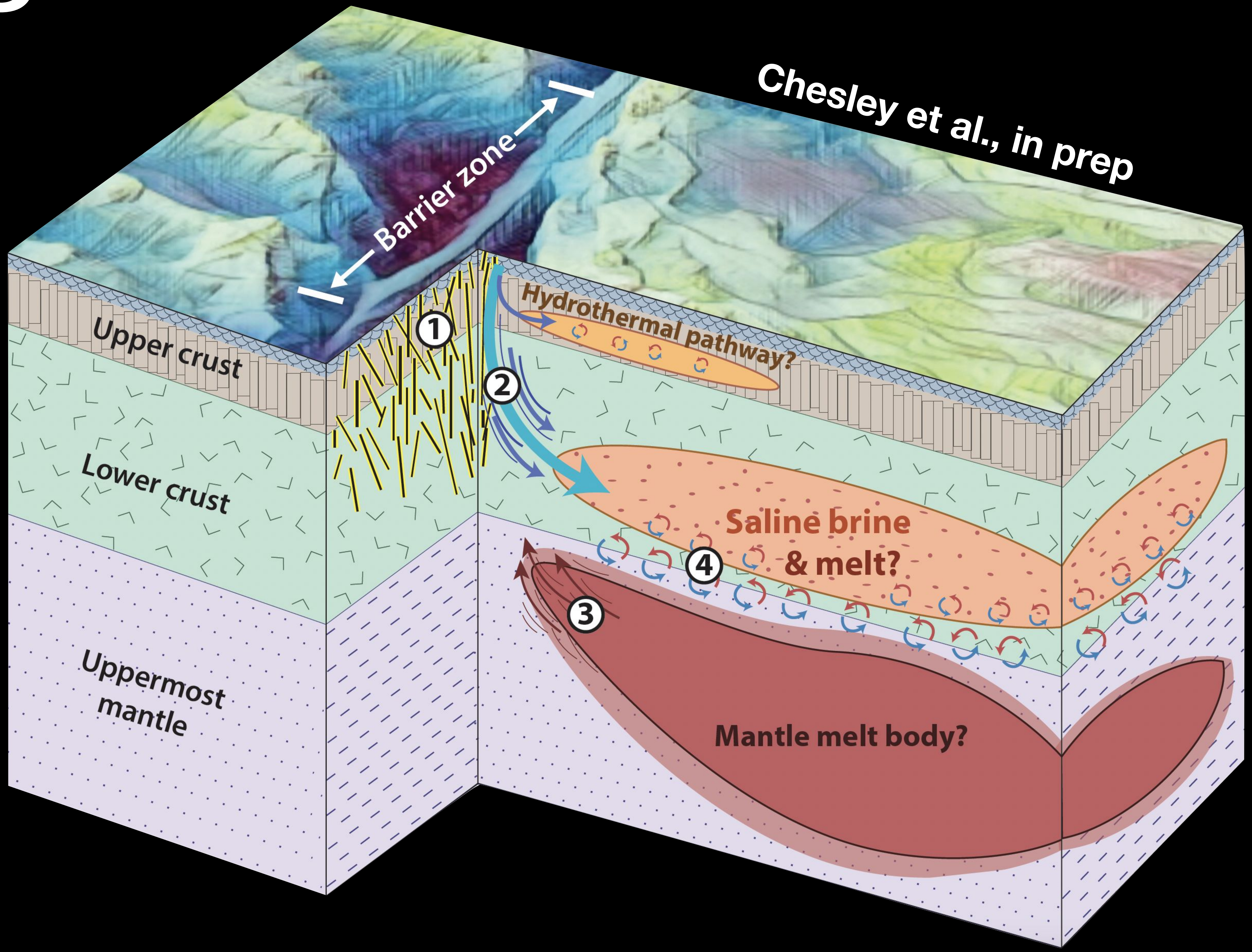


Thanks for listening!
Questions?



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