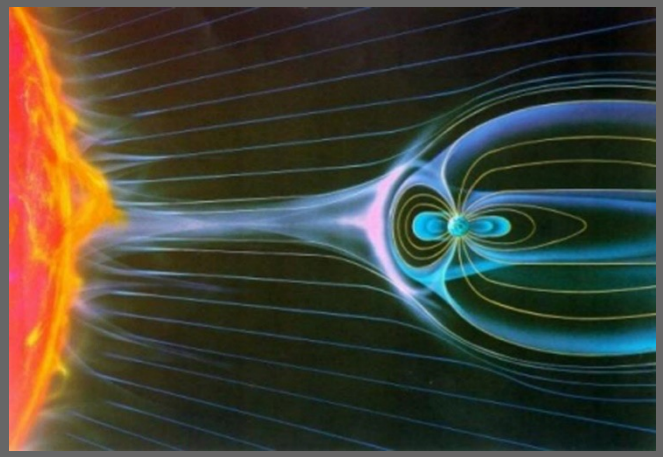
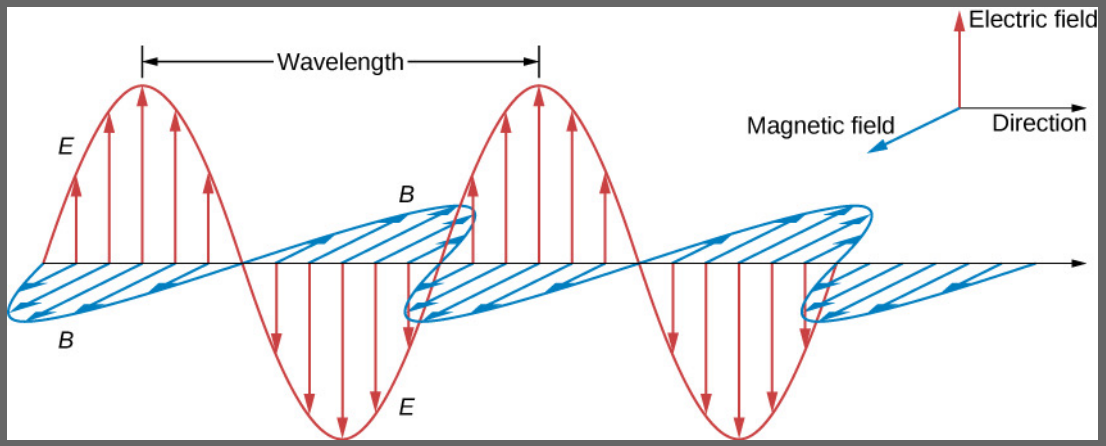
From Salt Lake City to the Roof at the Bottom of the World: Magnetotelluric studies of the Antarctic Interior

P. Wannamaker & G. Hill *et al.*

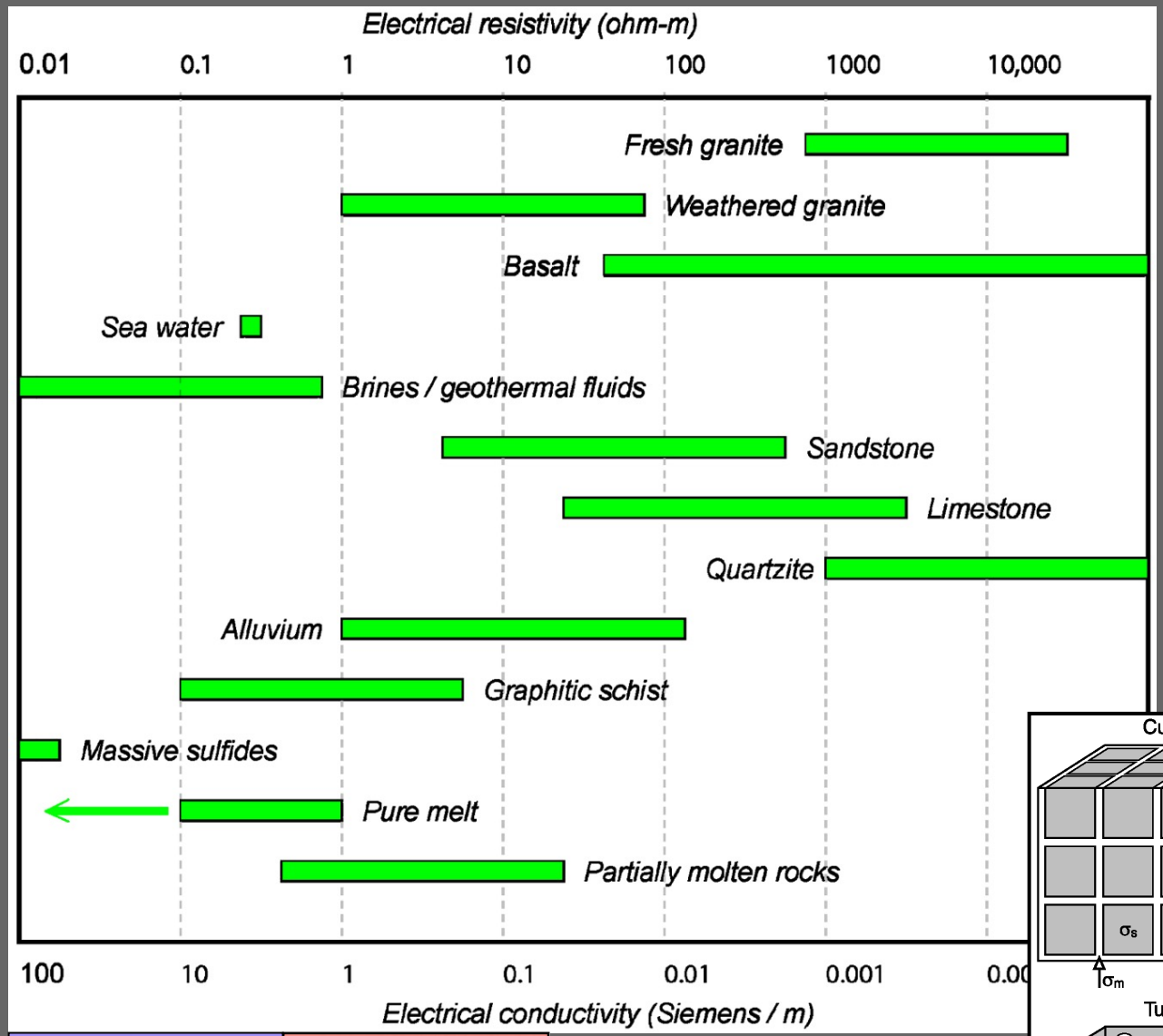
Magnetotelluric background

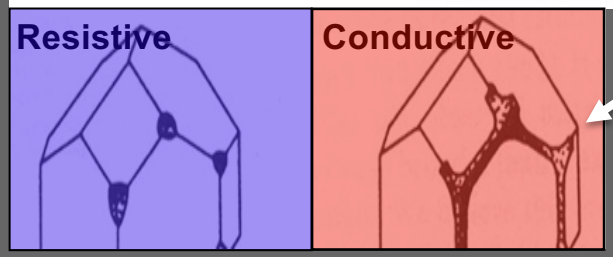
- Natural source EM induction method
- Broad range of source frequencies
  - 10000 – 0.0001 Hz / 0.0001 s – 10000 s
    - → Depths of investigation from hundreds of meters to hundreds of kilometers
- For f > 1 Hz:
  - Global lightning activity
- For f < 1Hz
  - Interactions between solar wind and magnetosphere





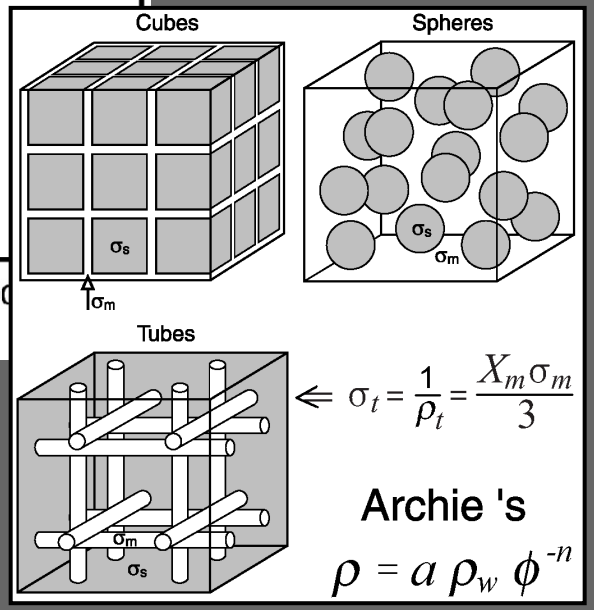
Earth Material Resistivity

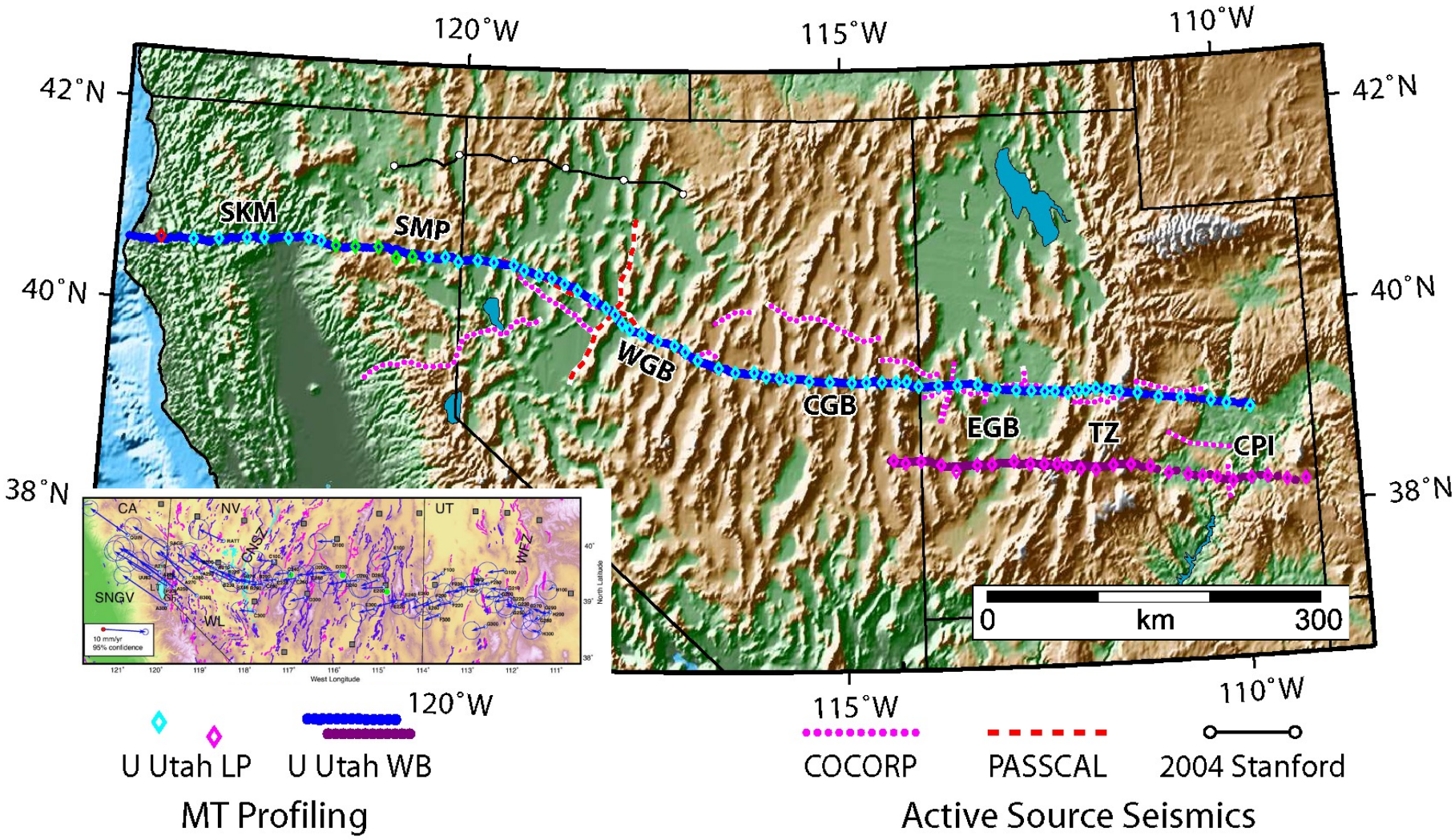




Melt and/or fluids

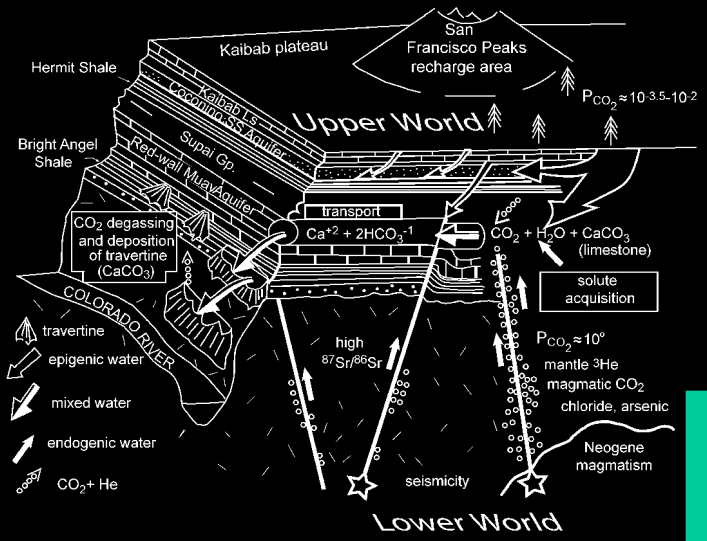
Importance of Inter-connection Texture



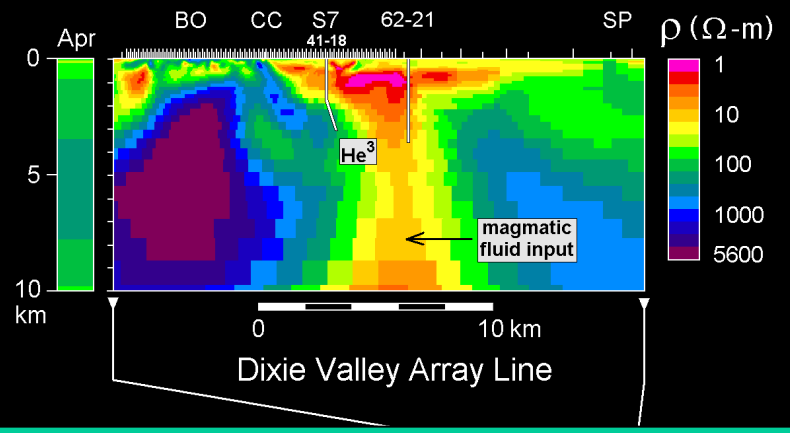


S Klamath Mtns – Great Basin – Colorado Plateau MT

Approx. coincident with COCORP, PASSCAL seismic profiling



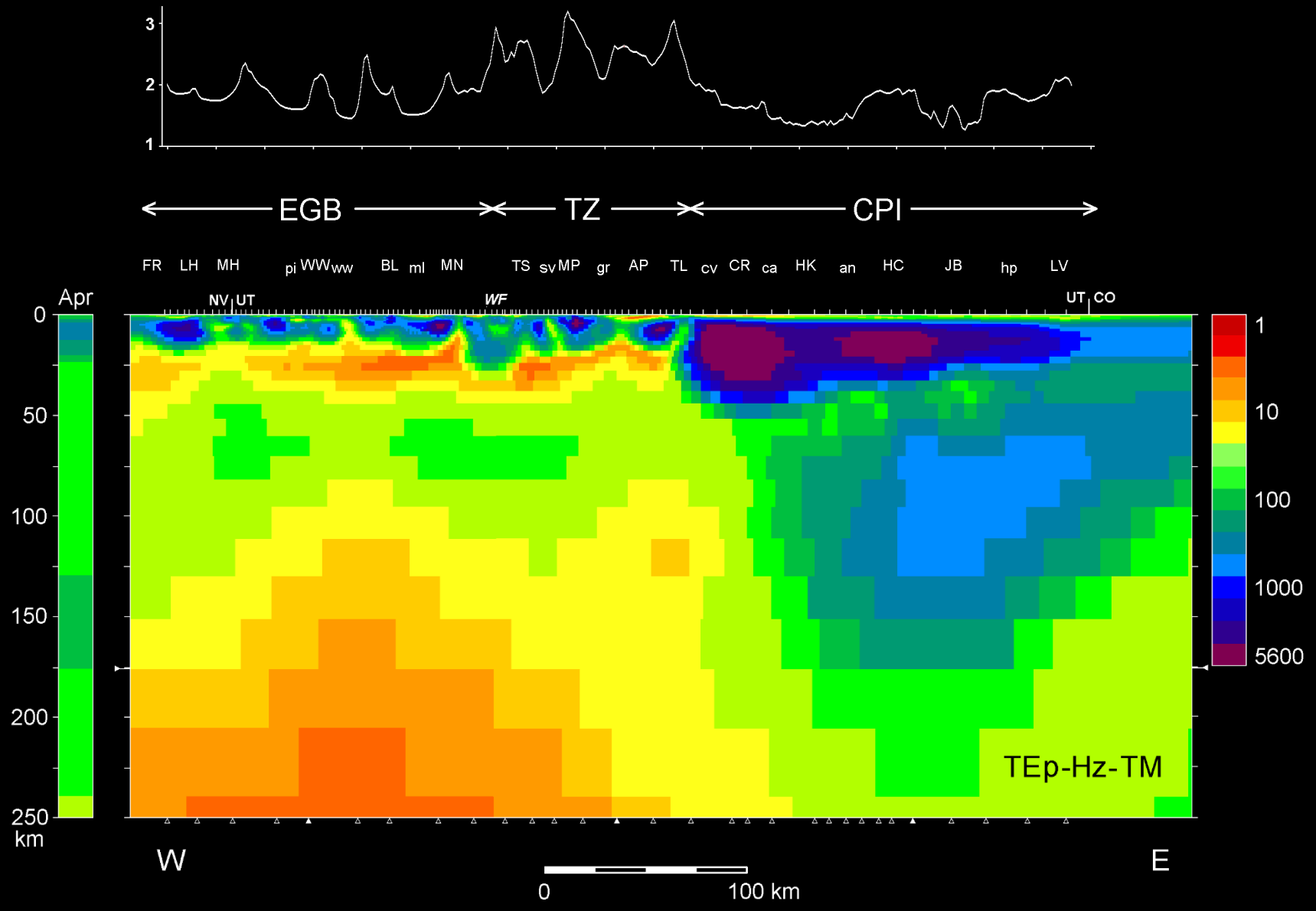
Grand Canyon Hydrol. Model
(Crossey et al., 2006)



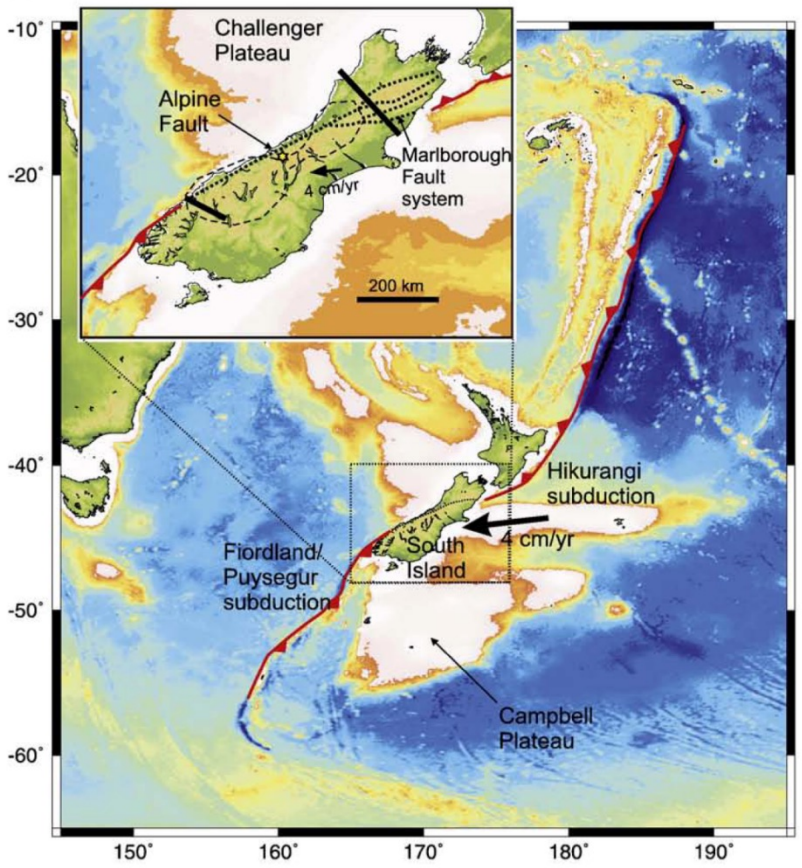
Multiscale Magmatic/
Hydrothermal Connections

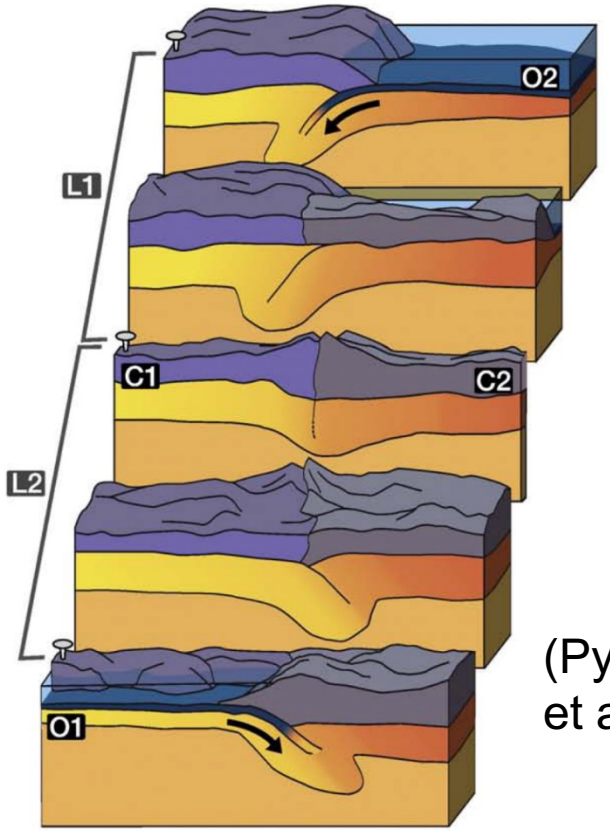
NW Great Basin MT Transect

GRC, SGP



Great Basin-Colorado Plateau MT Transect – 38.5 N

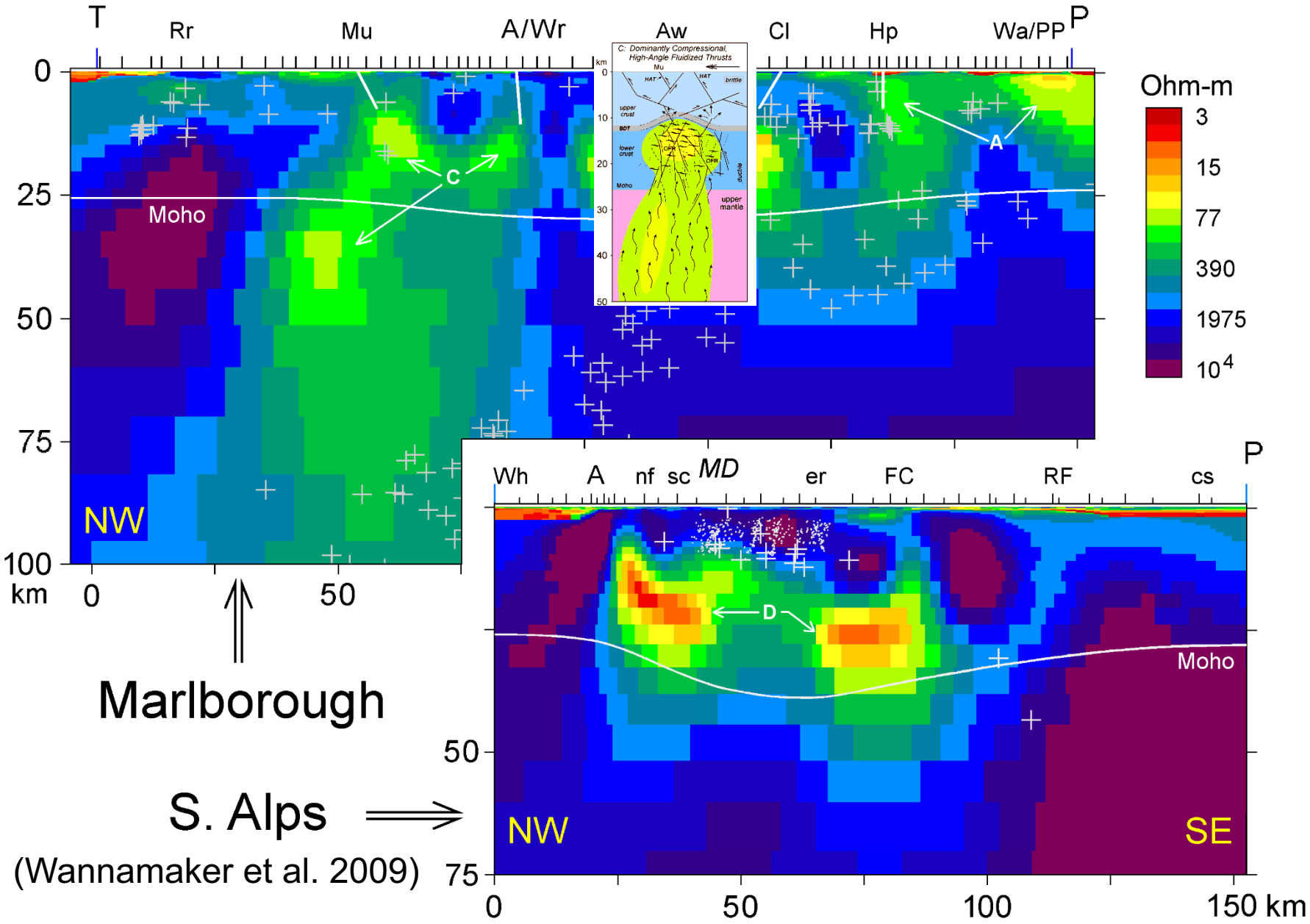




(Pysklywec et al., 2010)

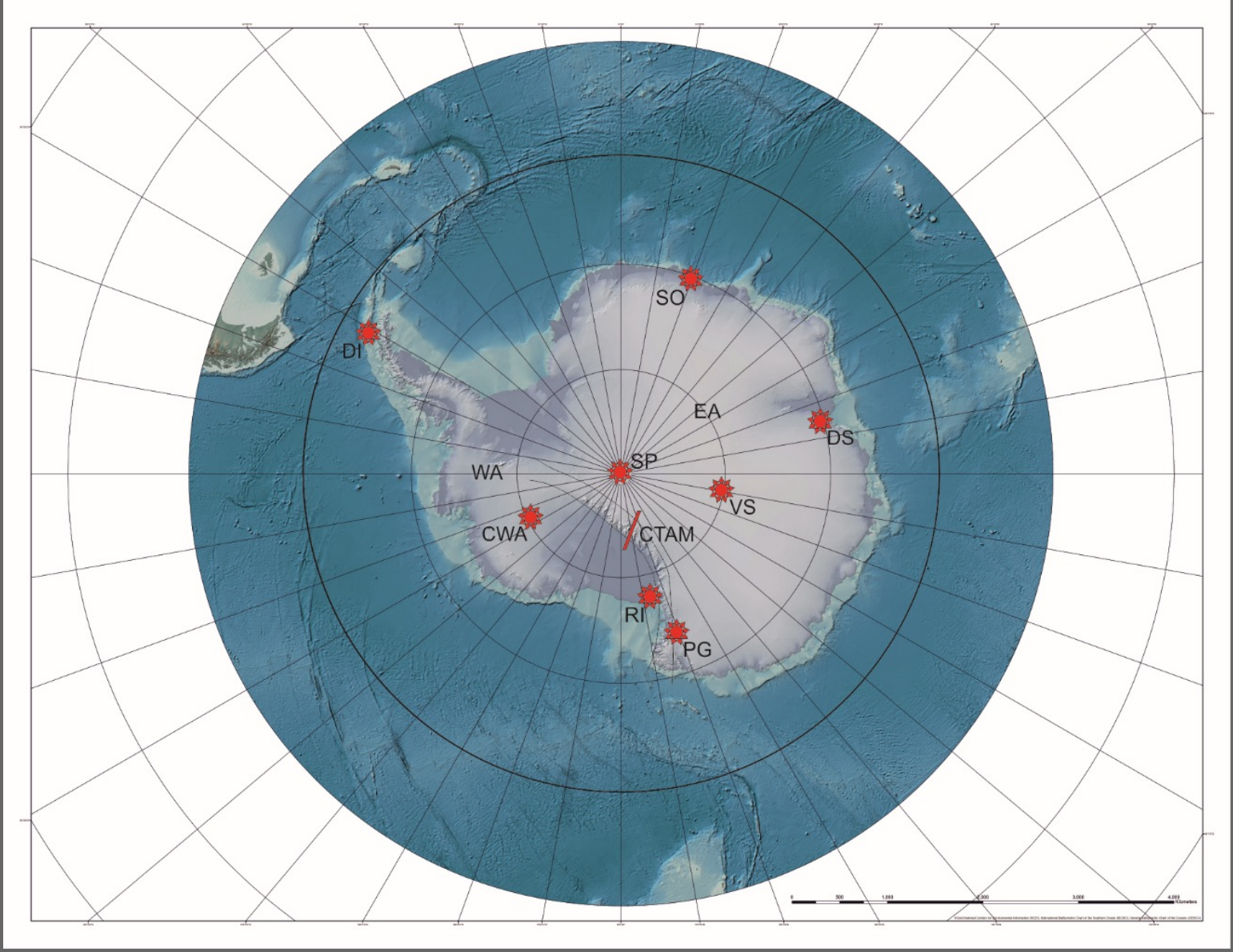
New Zealand: A Subduction Scissor

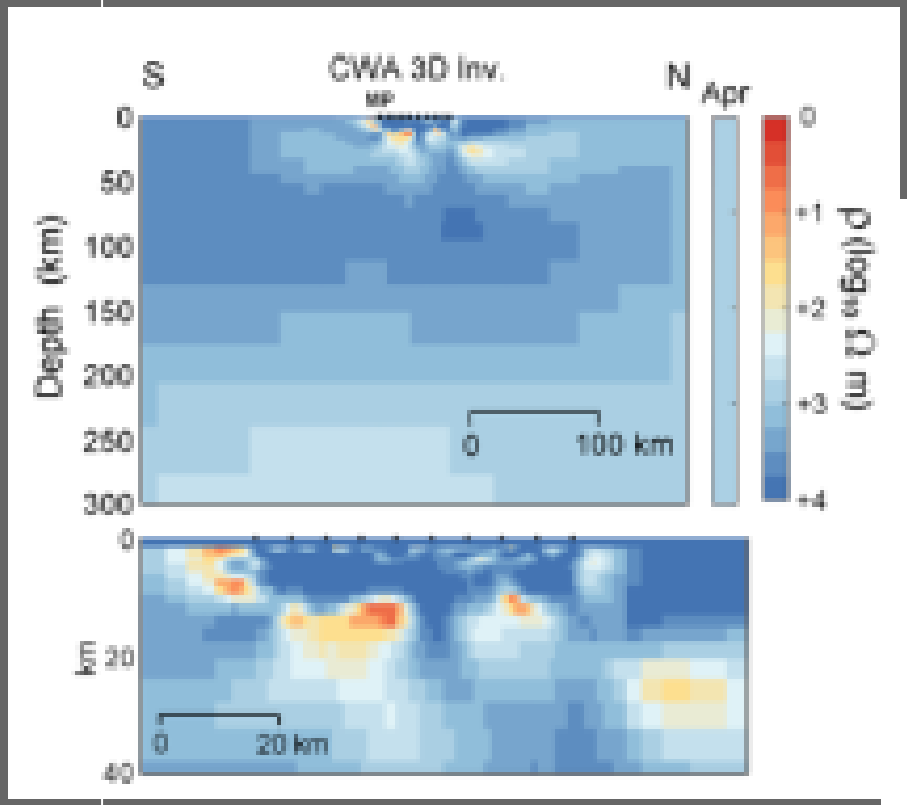
- Highly oblique convergence has induced opposing subduction zones
- Puysegur/Fiordland subduction incipient with solitary arc volcano (Sol. Is)
- Ideal to study initiation of plate eclogitization, hot mantle wedge process

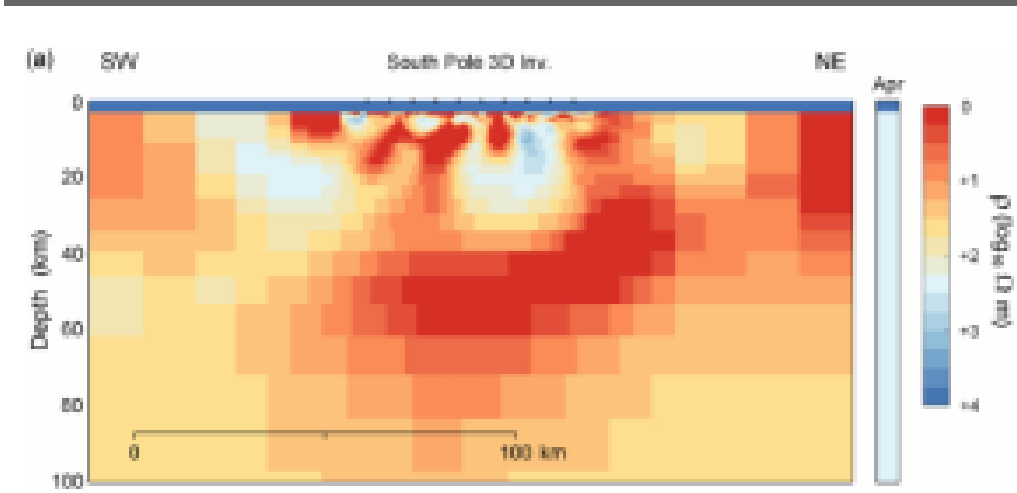


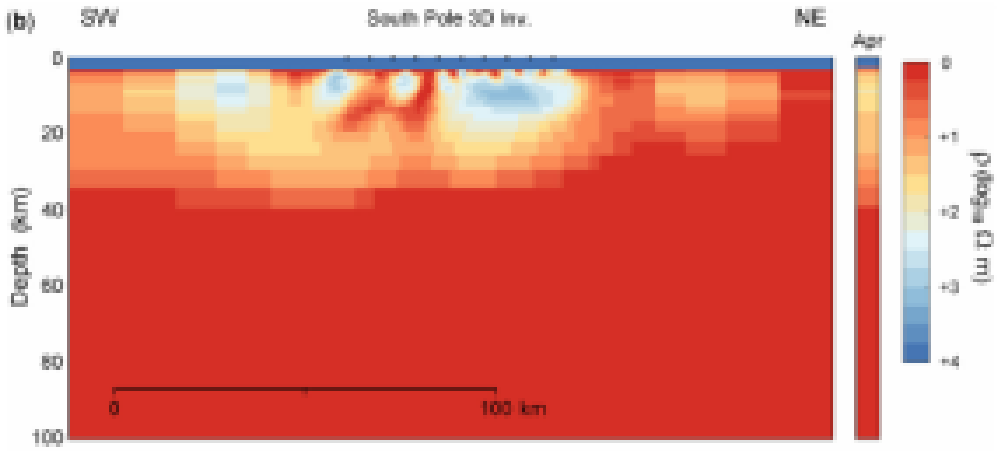
Crustal-Scale Fluid Evolution and Transport in Transpression

Magnetotelluric studies in Antarctica

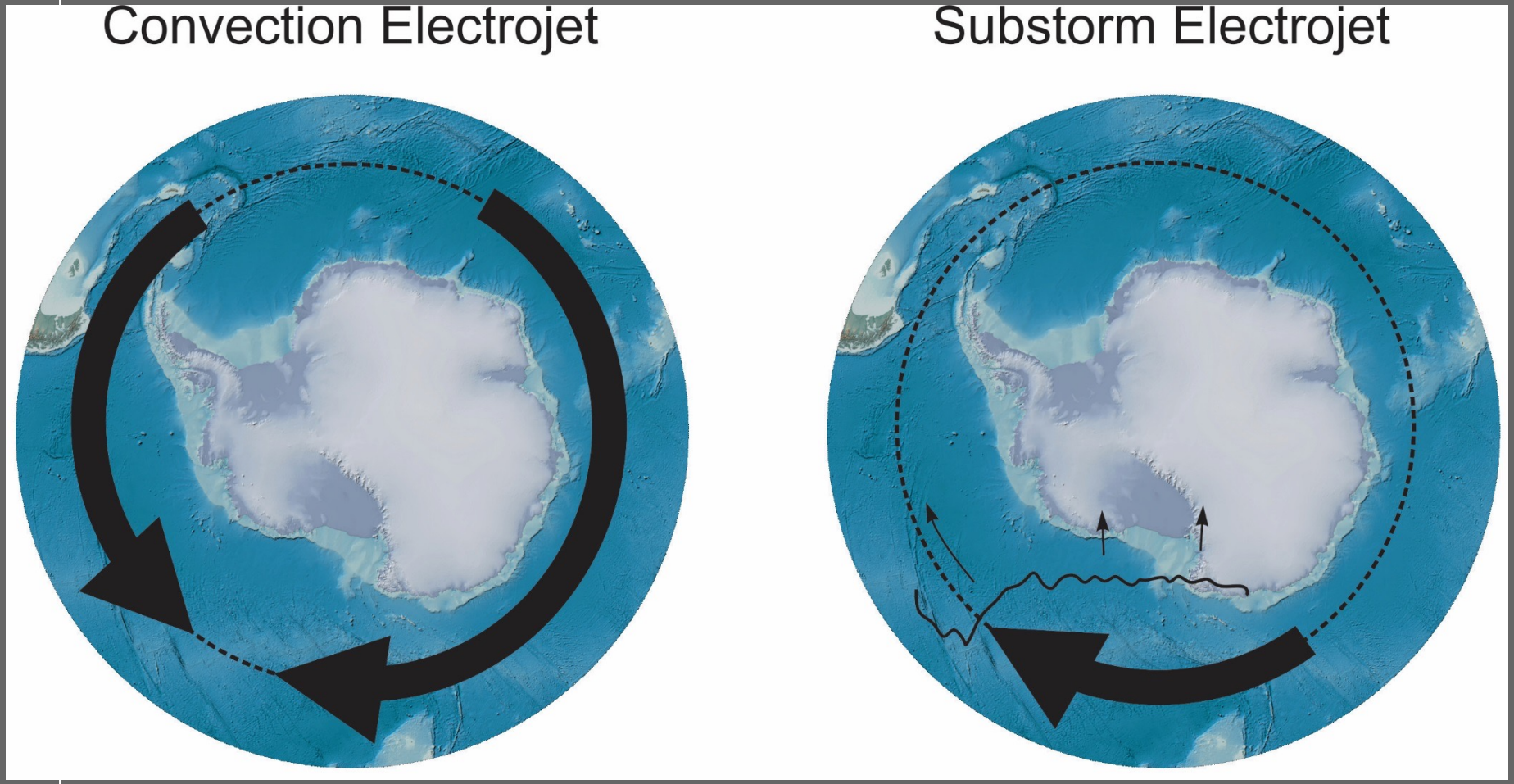



S
CWA 3D Inv.
N
Apr
MP
Depth (km)
0
50
100
150
200
250
300
0
100 km
ρ (log₁₀ Ω m)
0
+1
+2
+3
+4
km
0
20
40
0
20 km


(a)
SW
South Pole 3D Inv.
NE
Apr
Depth (km)
0
20
40
60
80
100
0
100 km
ρ (log₁₀ Ω m)
0
+1
+2
+3
+4

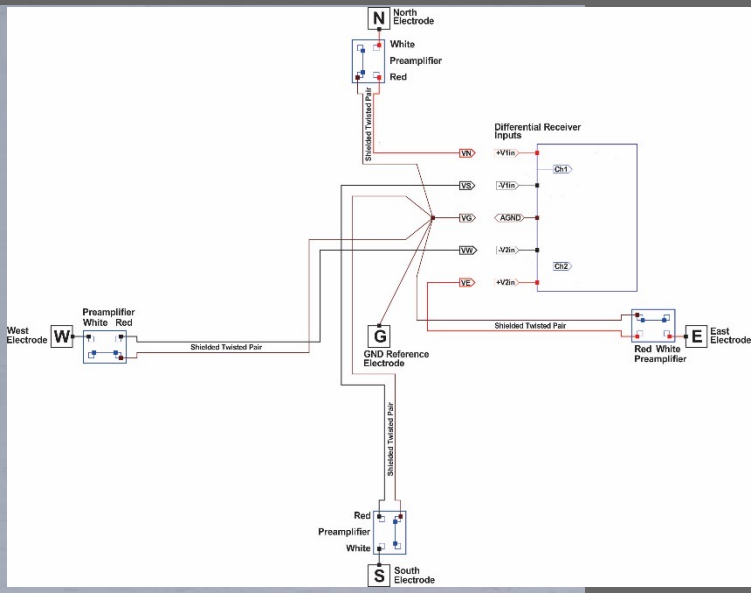

(b)
SW
South Pole 3D Inv.
NE
Apr
Depth (km)
0
20
40
60
80
100
0
100 km
ρ (log₁₀ Ω m)
0
+1
+2
+3
+4

Magnetotelluric Source Fields



After Cravens (1997)

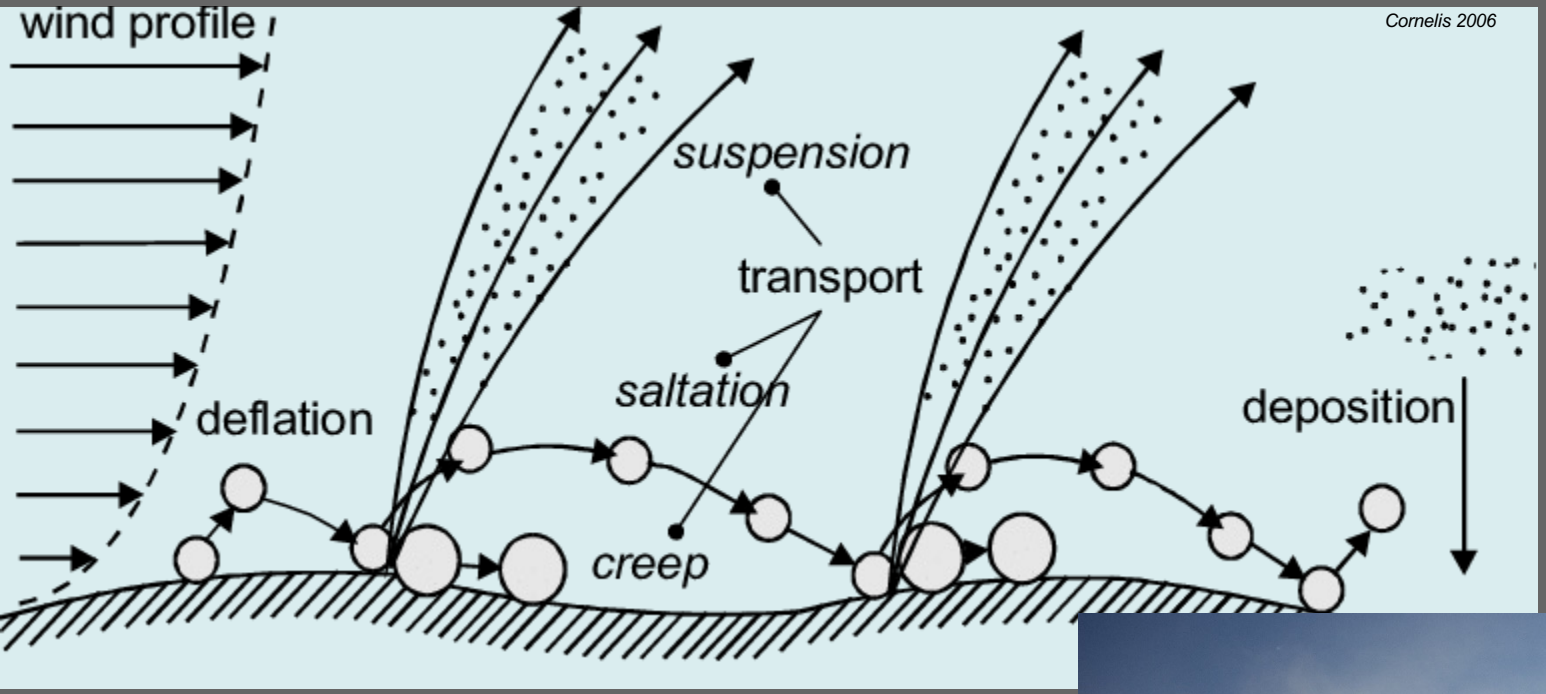
High Contact Resistance & Instrumentation



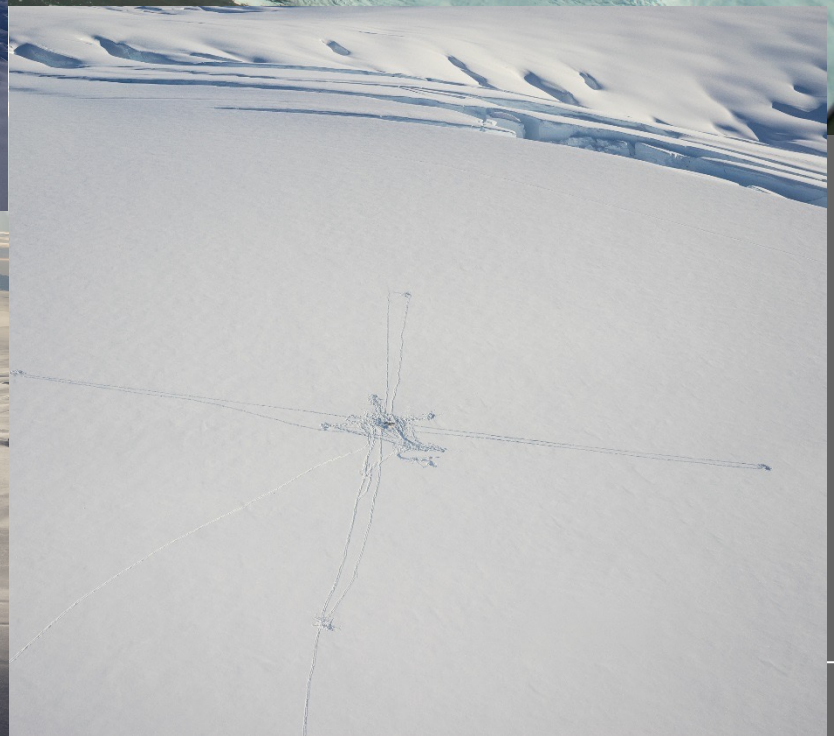
Aerial View of Setup with 3 of 4 Electrode Legs Installed

P. Wannamaker

Wind induced electrical noise

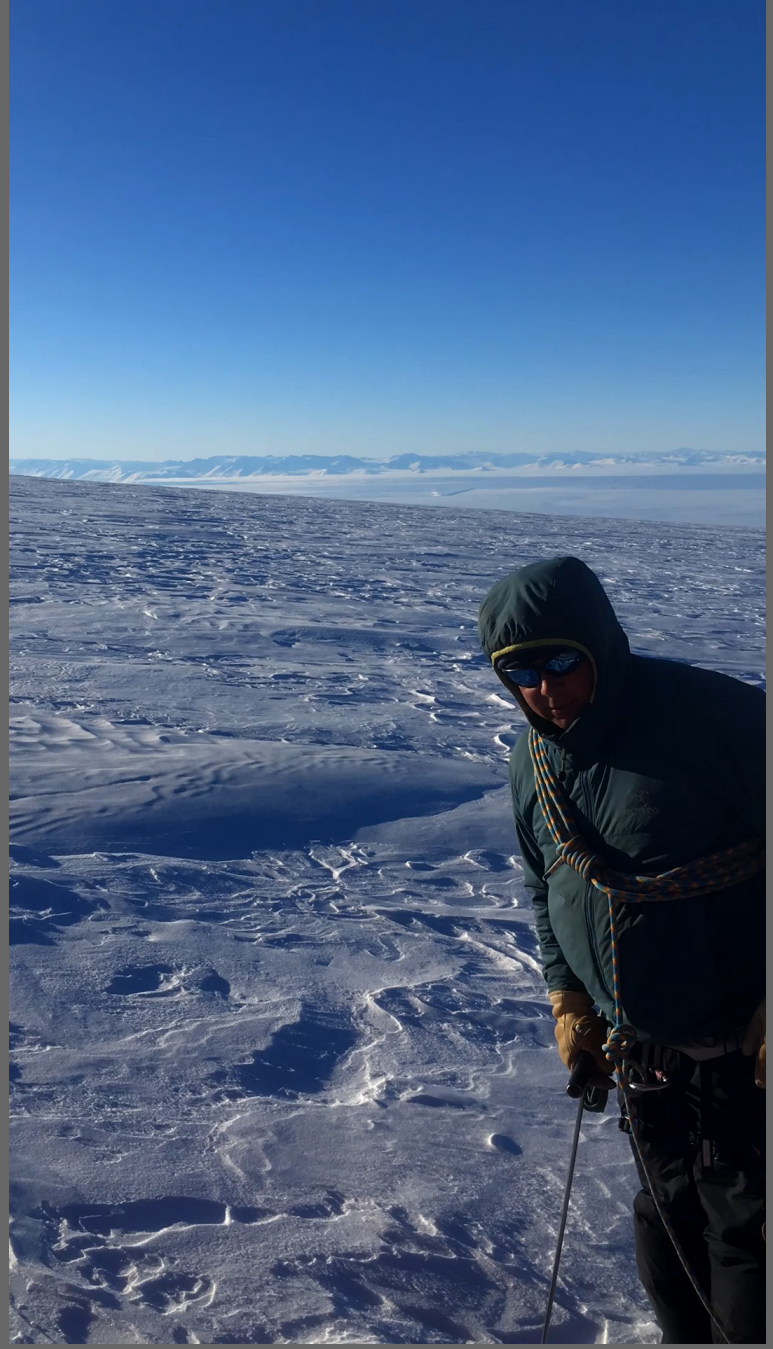


Survey Design Considerations - Terrain



Crevasses

- Crevasses



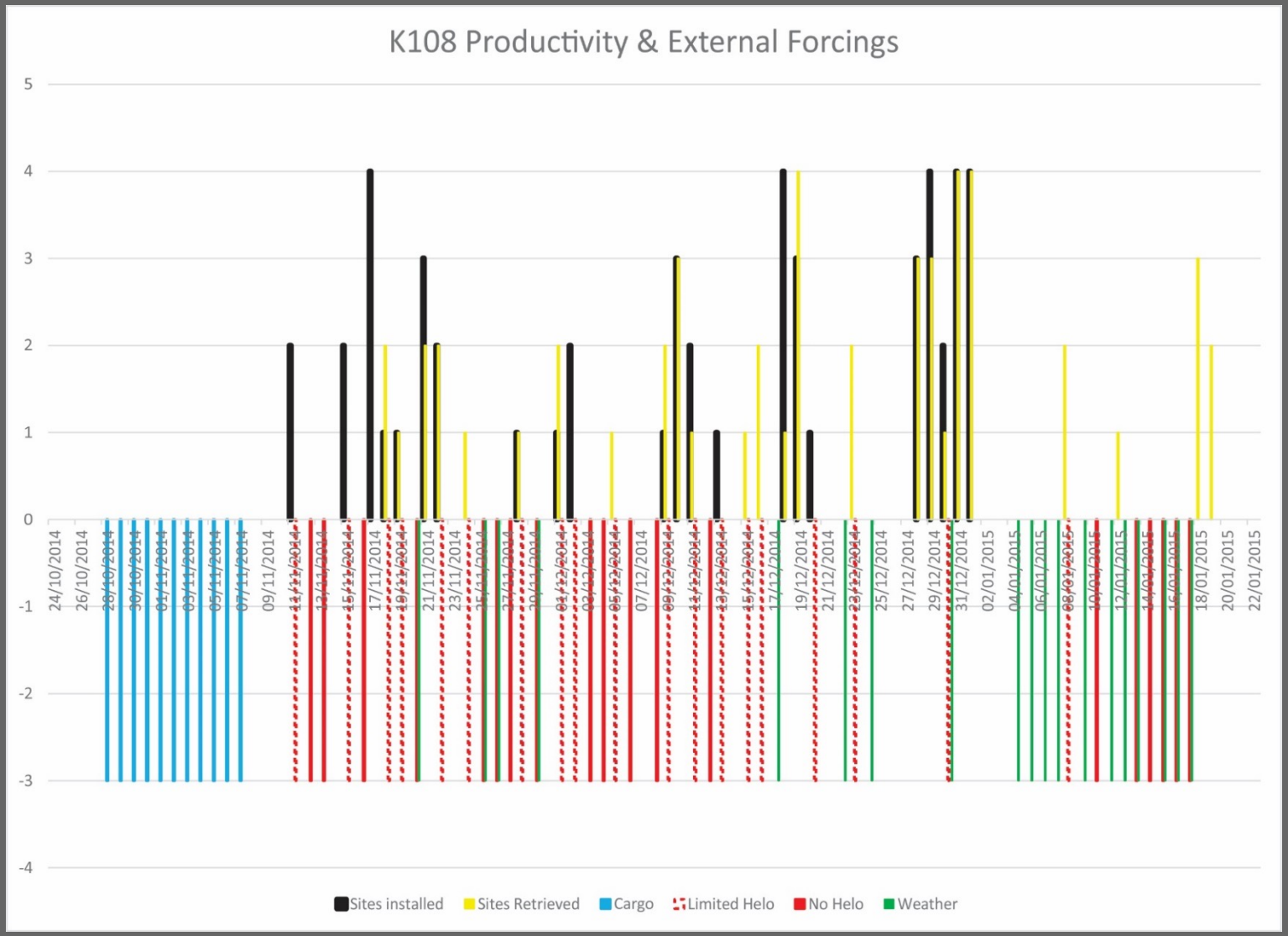
Survey Design Considerations - Terrain

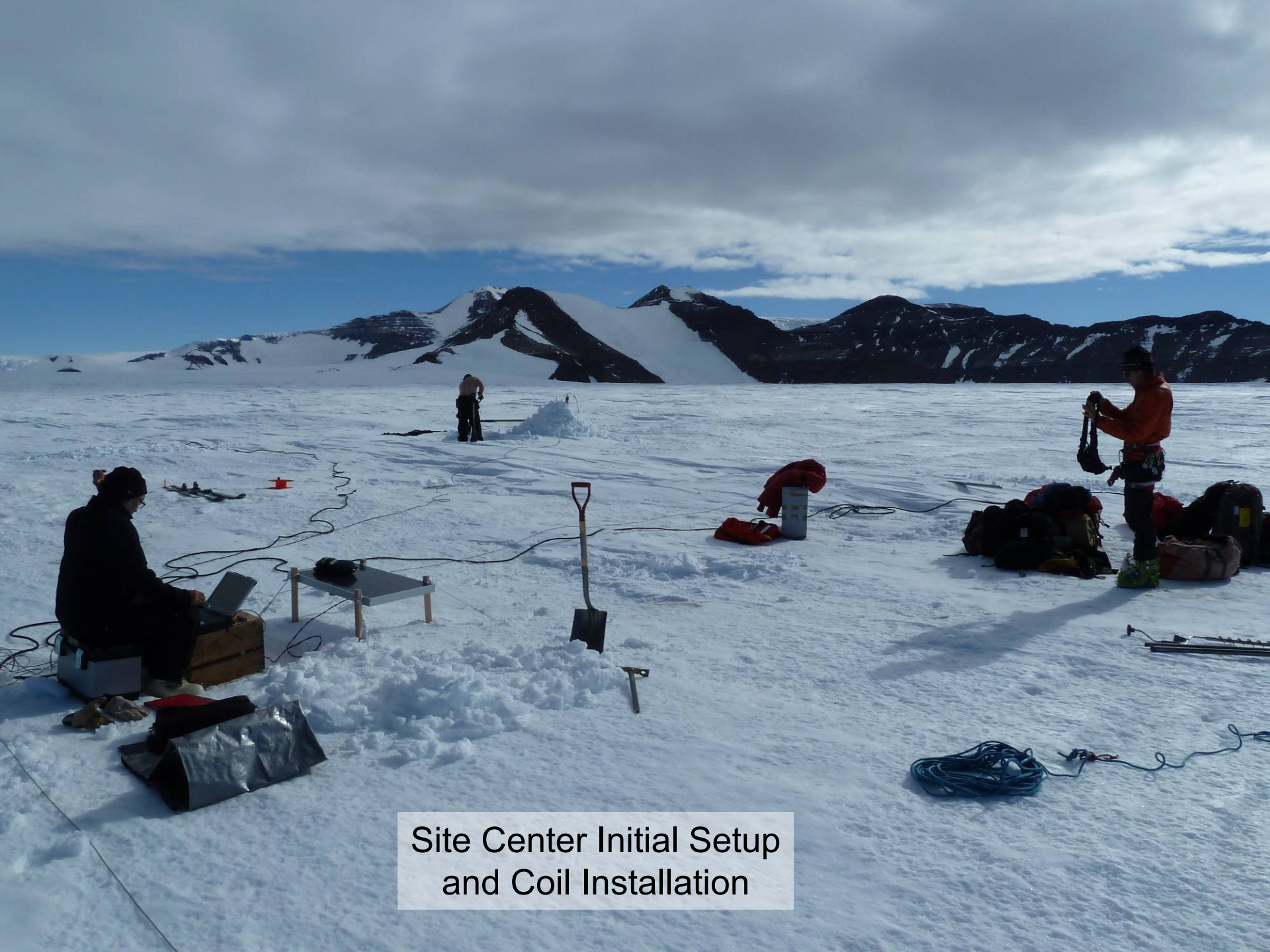
Survey Design Considerations - Terrain

Survey Design Considerations - Weather

Survey Design Considerations - Weather

Survey Design Considerations – Logistical Pressure





Site Center Initial Setup
and Coil Installation

- Site Installation

Motivations:

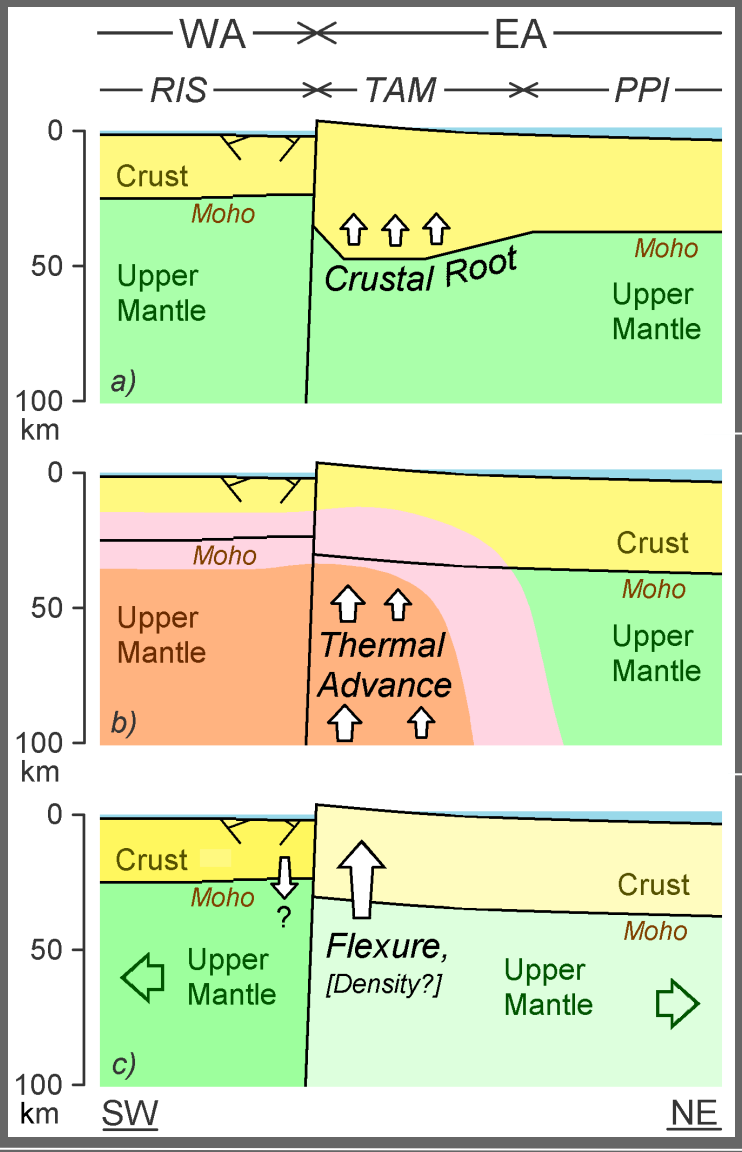
- Rifting one of 3 main modes of mountain building, volcanism.
- General goal to examine well-expressed modes worldwide.
- Rift regimes contain resources, host earthquakes.
- Understand transition between stretching and stable margins.
- What holds the TAM up?, controls decay of elevation?
- Compare to well-known Great Basin margins.
- How do CO2-dominated phonolitic rift volcanoes differ from H2O-dominated subduction volcanoes?
- What are the differentiation and staging regions for phonolites?

Approaches:

- Must understand the third dimension (depth): geophysics.
- Seismology has had limited success: coverage, sources.
- Physical property of electrical conductivity reflects melt, fluids.
- Magnetotelluric (MT) method: broadband global EM source.
- Need to adapt traditional land method to polar ice sheets.

Central Transantarctic Mountains

Central Transantarctic Mountains Uplift Models



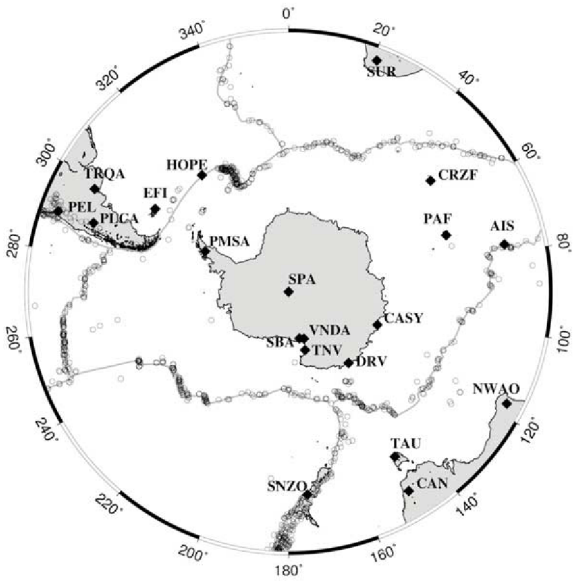
low-density crustal root – in line with isostatic models incorporating a thick East Antarctica lithosphere, a remnant of compressional over-thickening of West Antarctica (Huerta and Harry, 2007; van Vijk et al., 2008) – lack of seismic evidence along entire range

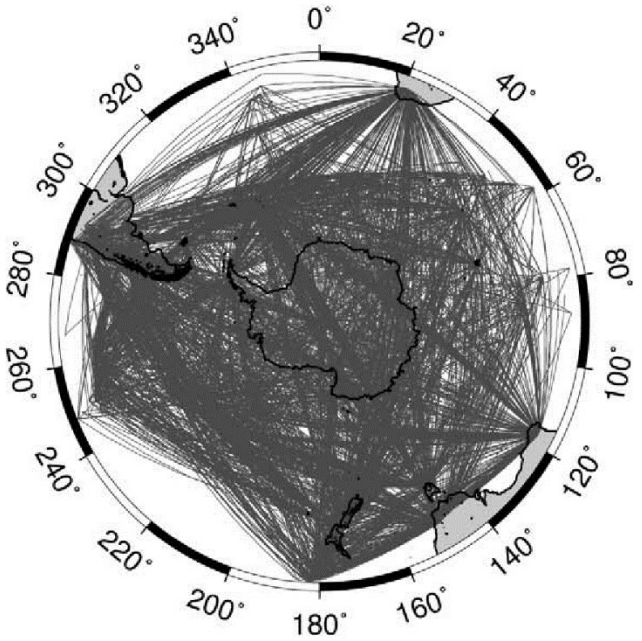
thermal buoyancy uplift processes resulting from lithospheric replacement with hot less dense asthenosphere (LeMasurier and Rex, 1991) – accepted as the support mechanism for the Great Basin in the western US and evidence of occurring in both the Northern and Southern TAM

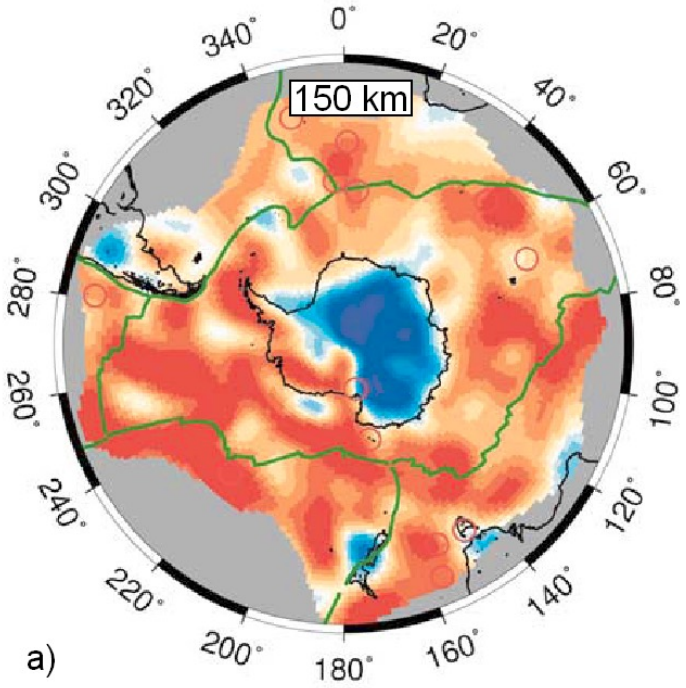
non-thermal uplift via long wave length (~500 km) cantilevered flexure (Yamasaki et al., 2008), has been proposed as an isostatic response to dipping faults without external loading – may operate in presence of other mechanisms

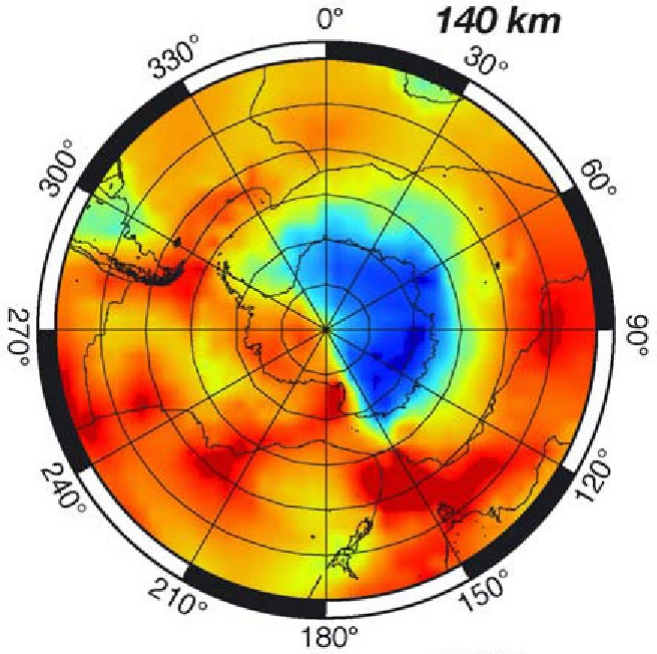
After Wannamaker et al. (2017)

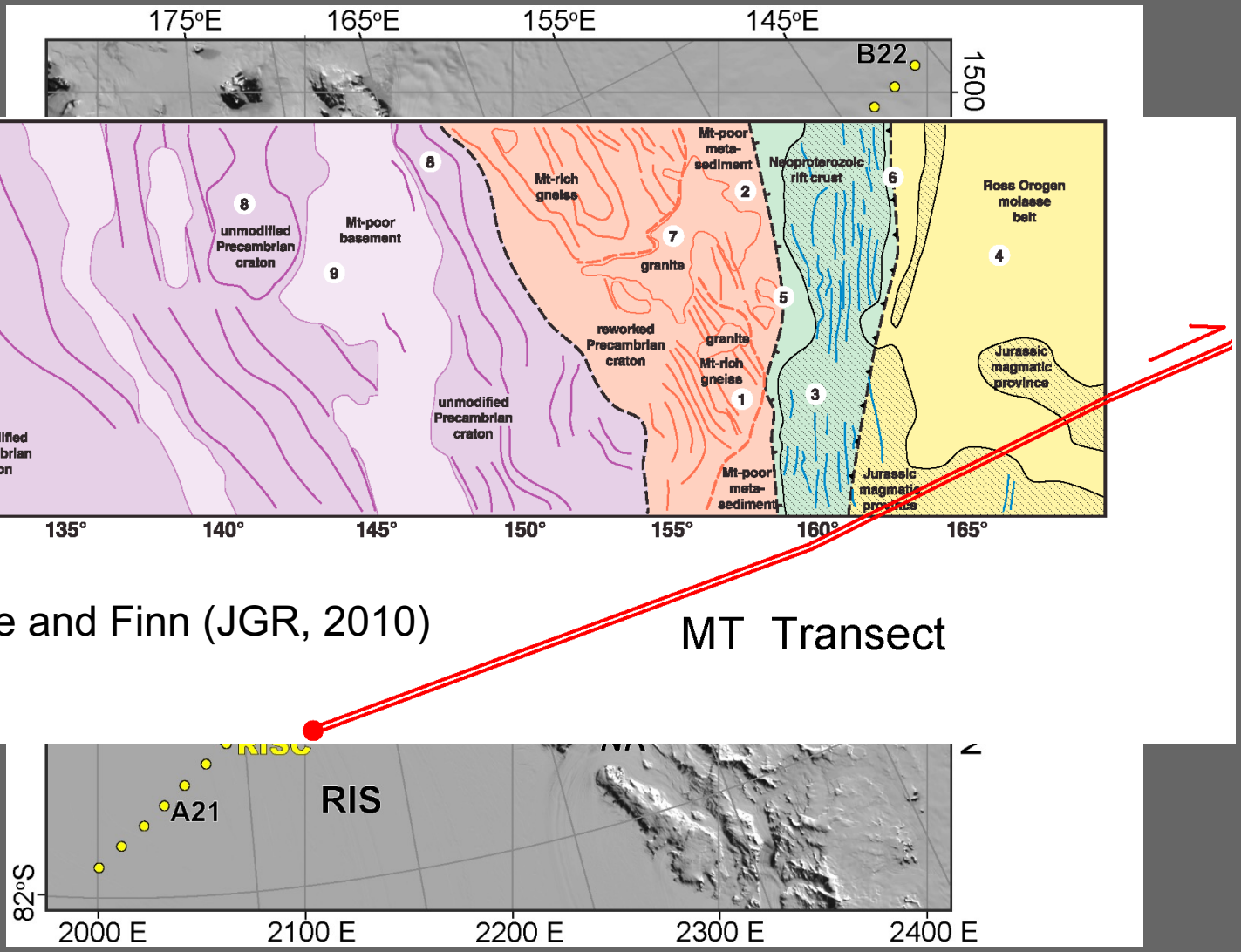
Continent-scale Seismic Tomography (Sieminski et al., Morelli & Danesi)



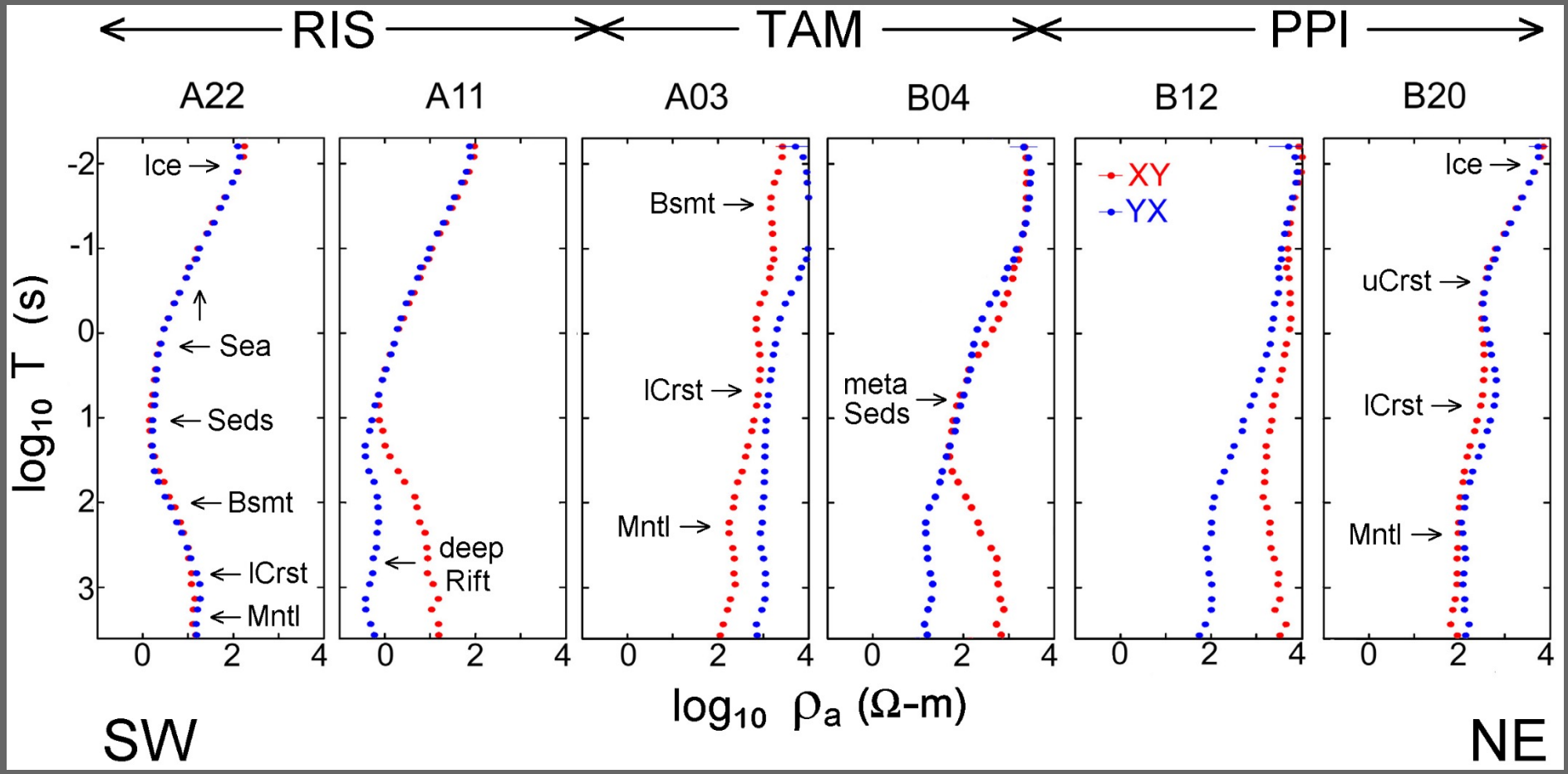






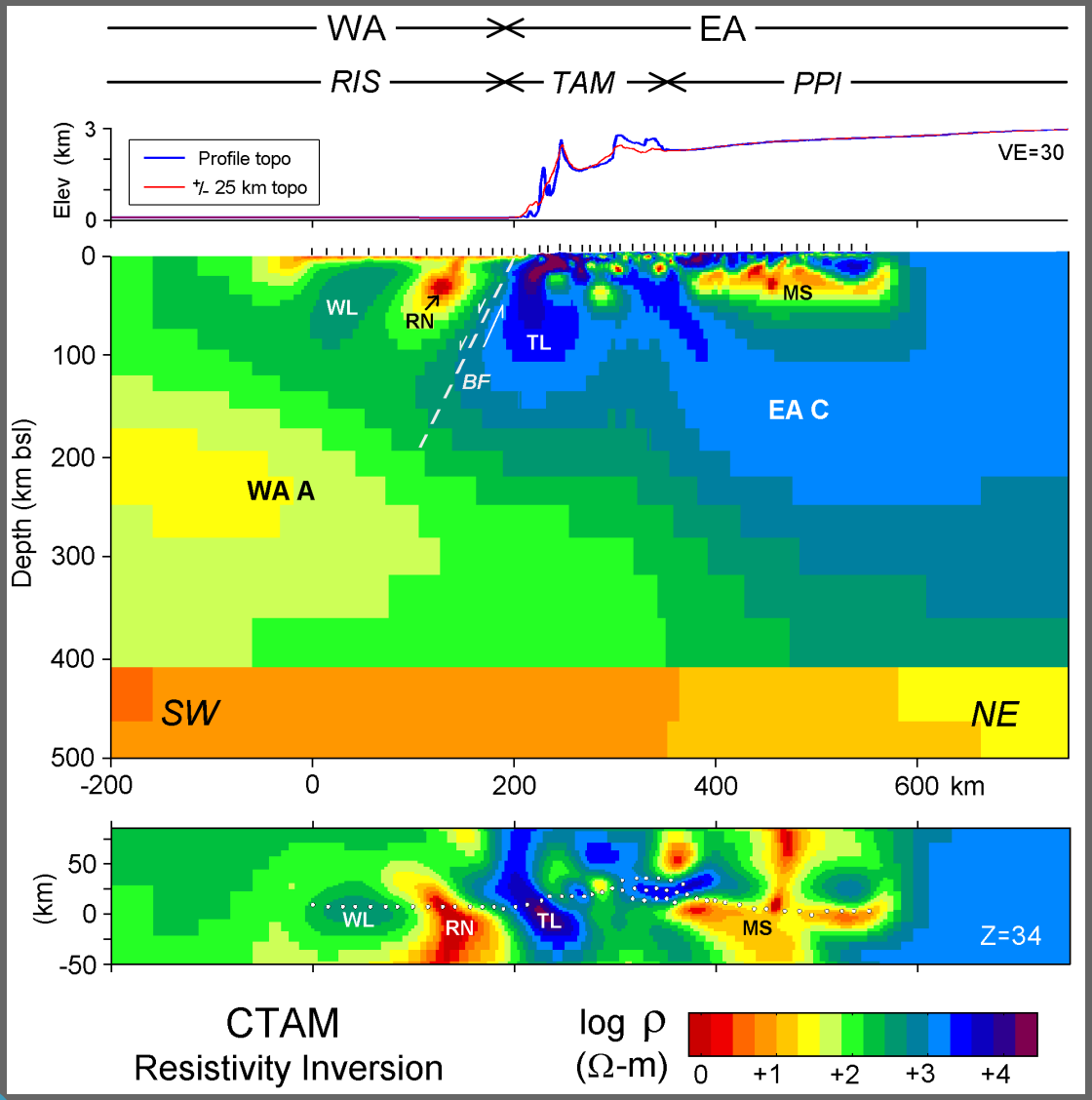


After Wannamaker et al. (2017)



After Wannamaker et al. (2017)

Central Transantarctic Mountains



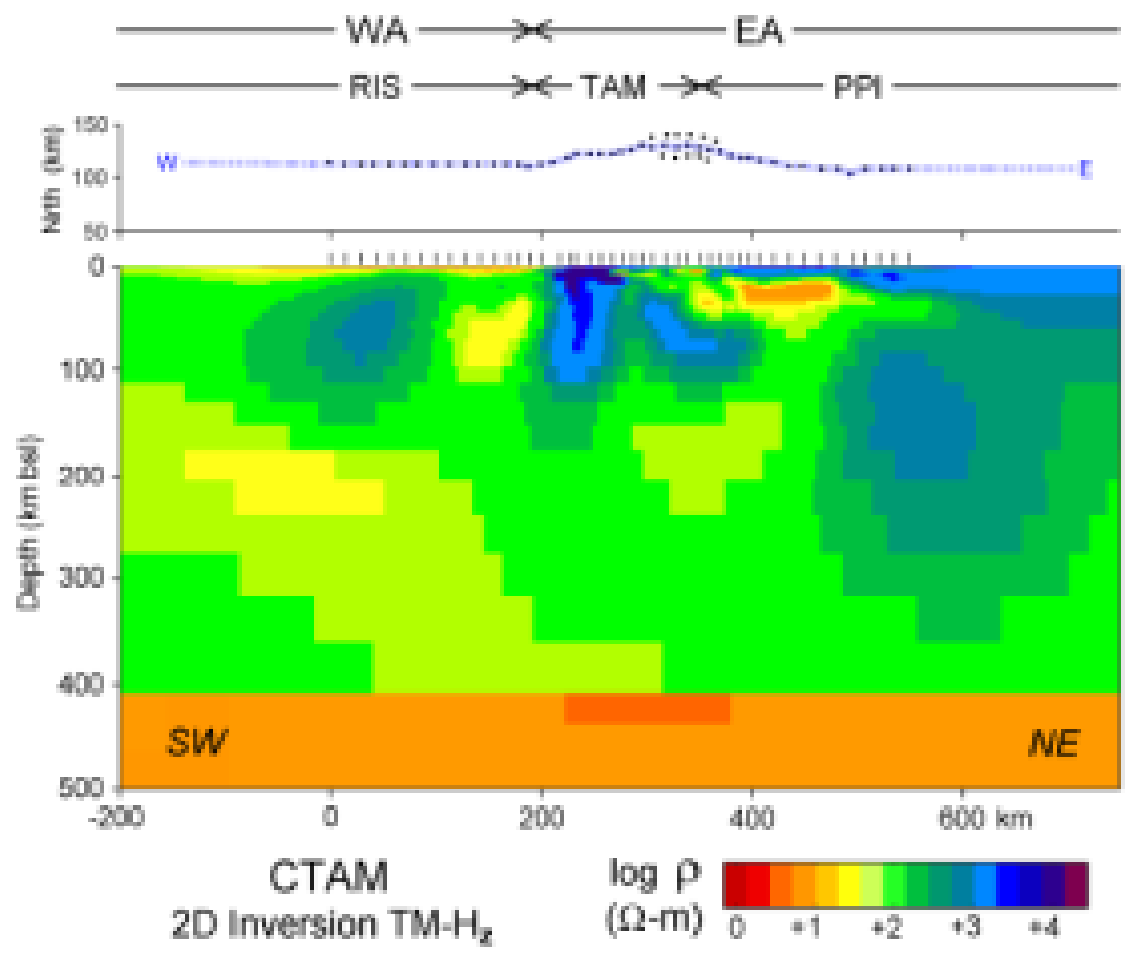
Physiographic regions
WA - West Antarctica
EA - East Antarctica
RIS - Ross Ice Shelf
TAM - Transantarctic Mountains
PPI - Polar Plateau

Interpreted model features
WL - West Antarctic lithosphere
RN - active rift necking
BF - regional boundary fault
TL - TAM lithosphere
MS - Precambrian metased basin
WA A - West Antarctic asthenosphere
EA C - East Antarctic craton

Plan view in lower panel is shown at depth of 34 km over a width of 135 km, with MT stations as white dots

After Wannamaker et al. (2017)

Central Transantarctic Mountains 2D vs 3D



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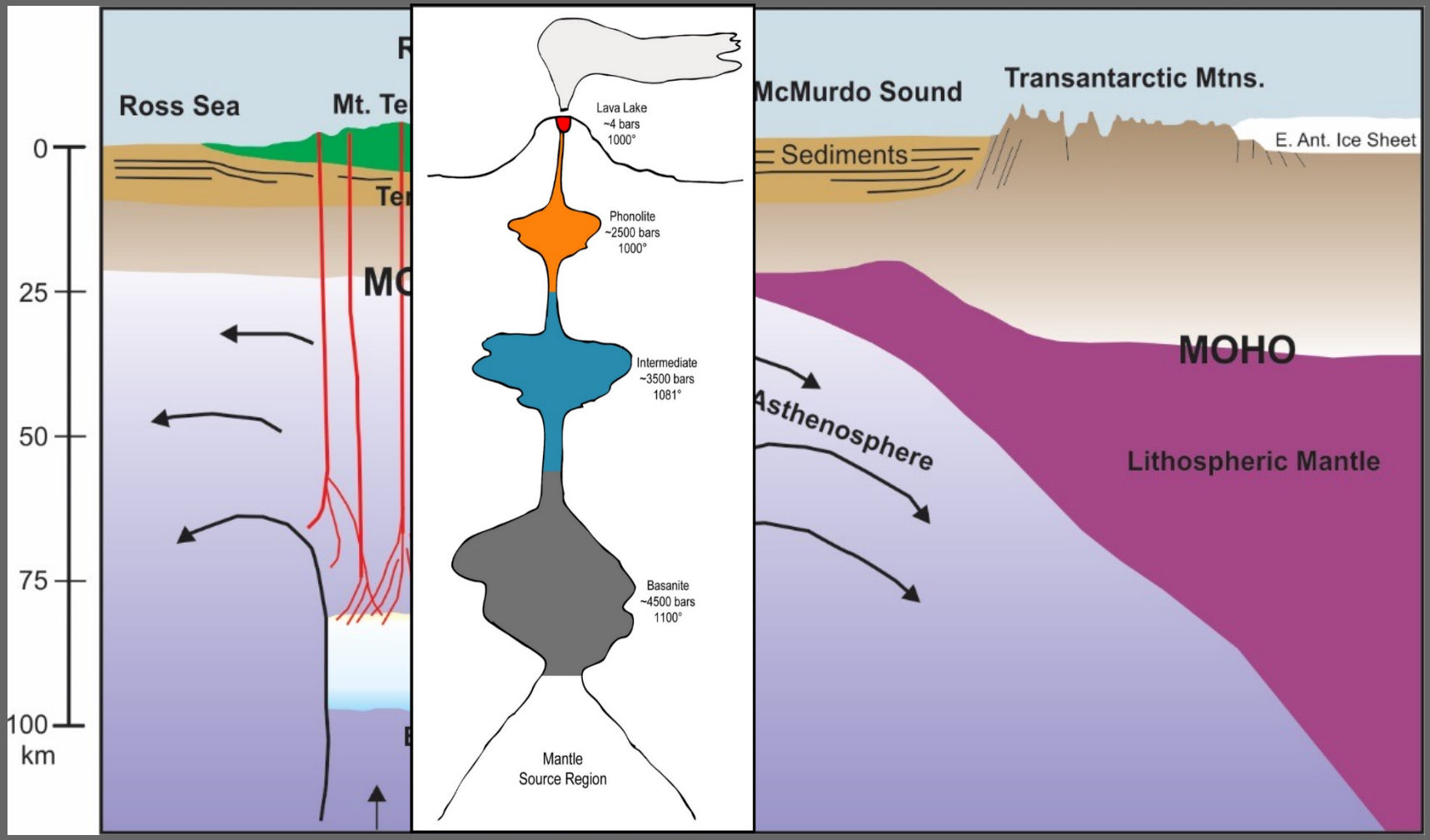
Two-dimensional inversion model of CTAM transect utilizing nominal TM (yx) mode impedance and tipper element Kzy.

After Wannamaker et al. (2017)

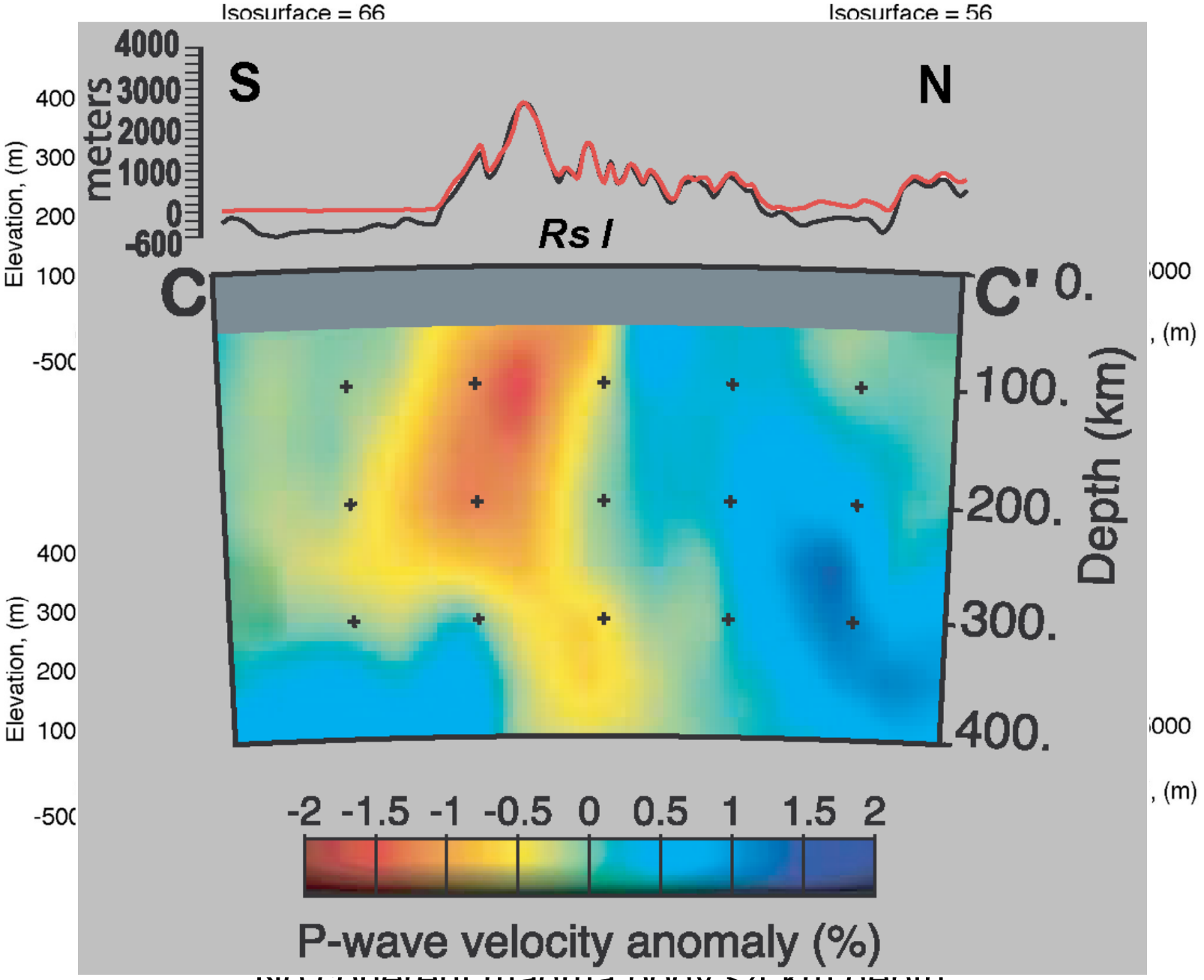
Mount Erebus, Antarctica

Mount Erebus & the Terror Rift



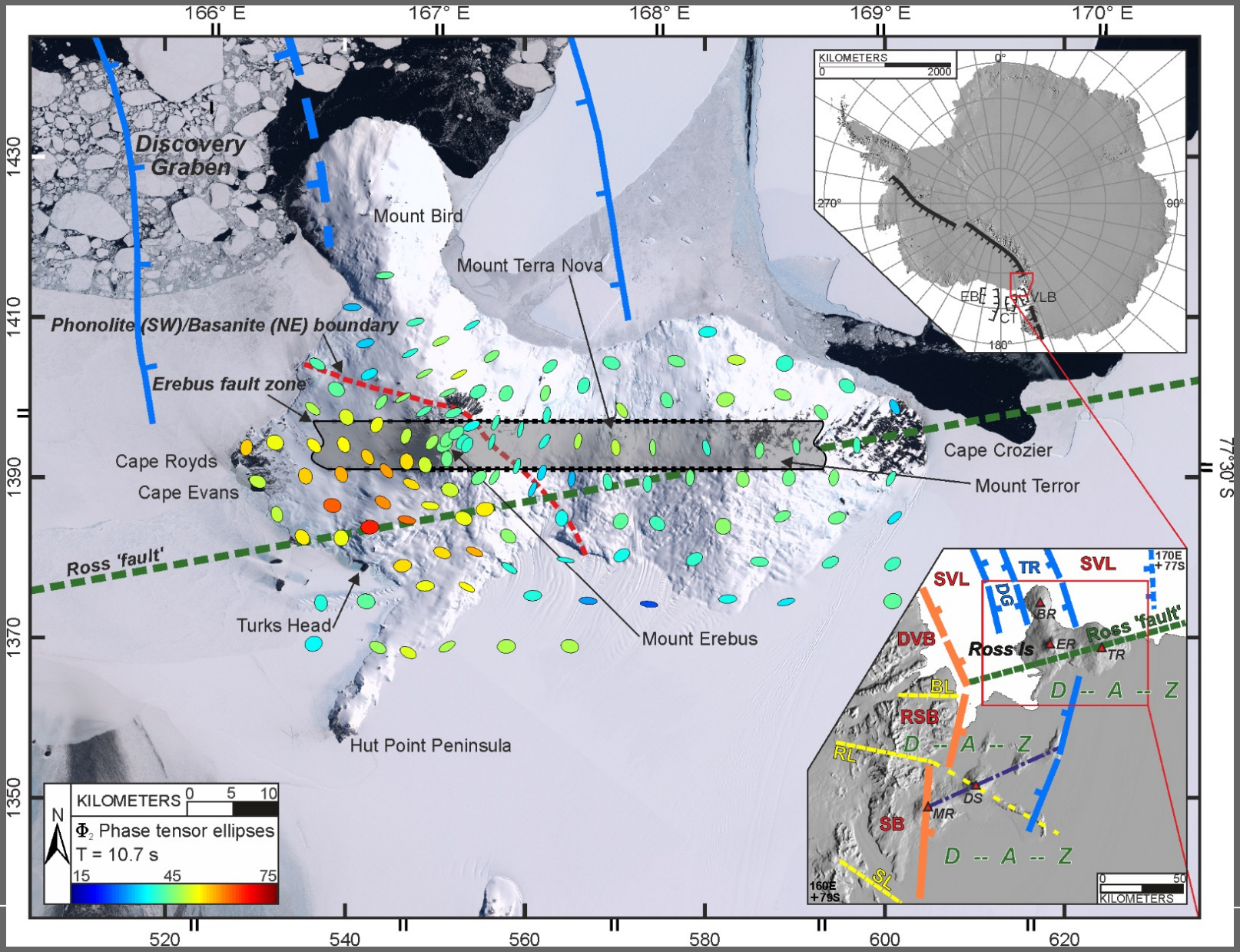
Iacovino 2015 EPSL

After Kyle et al. 1992 J. Pet

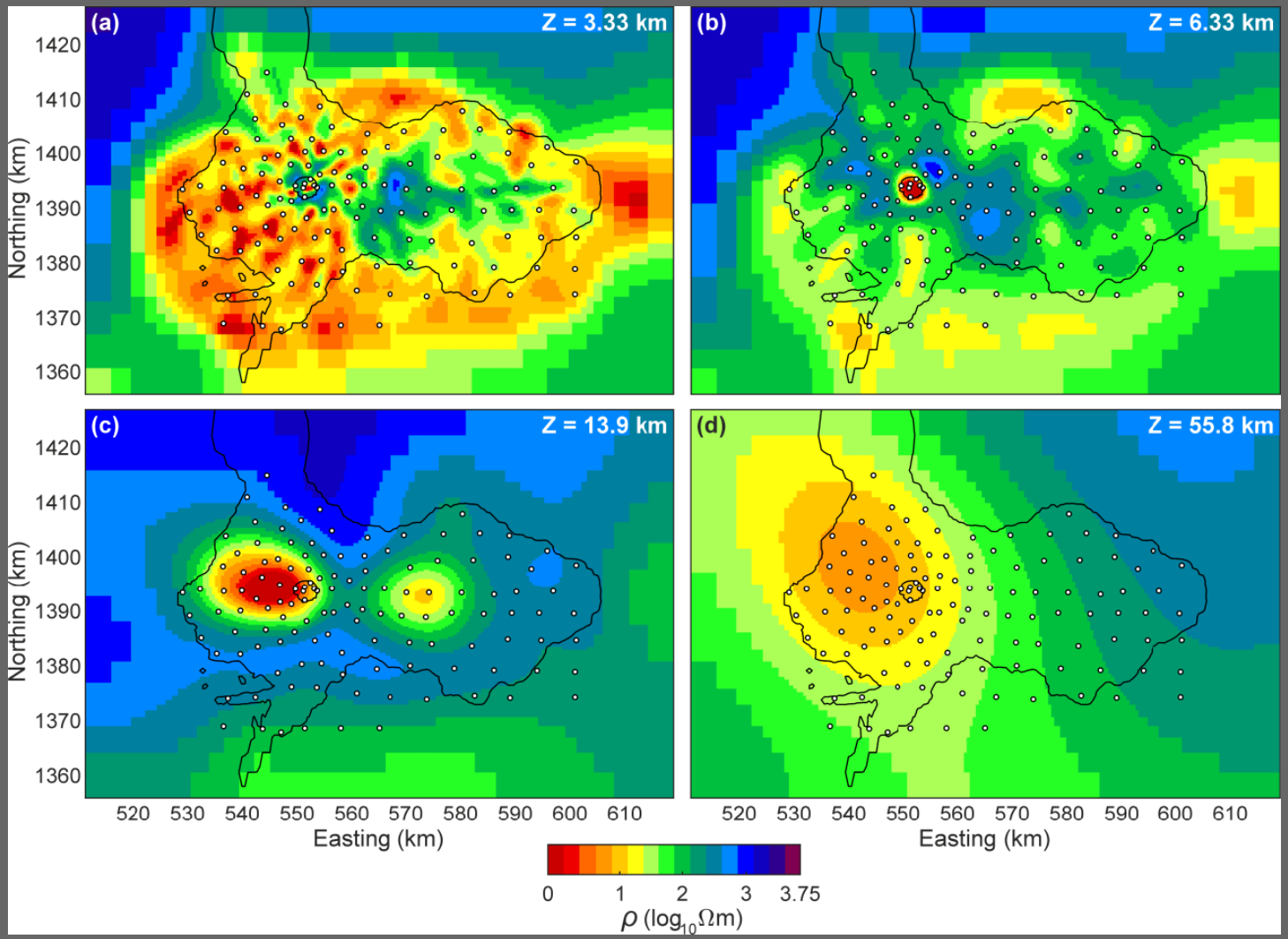


No coherent magma body <4 km depth

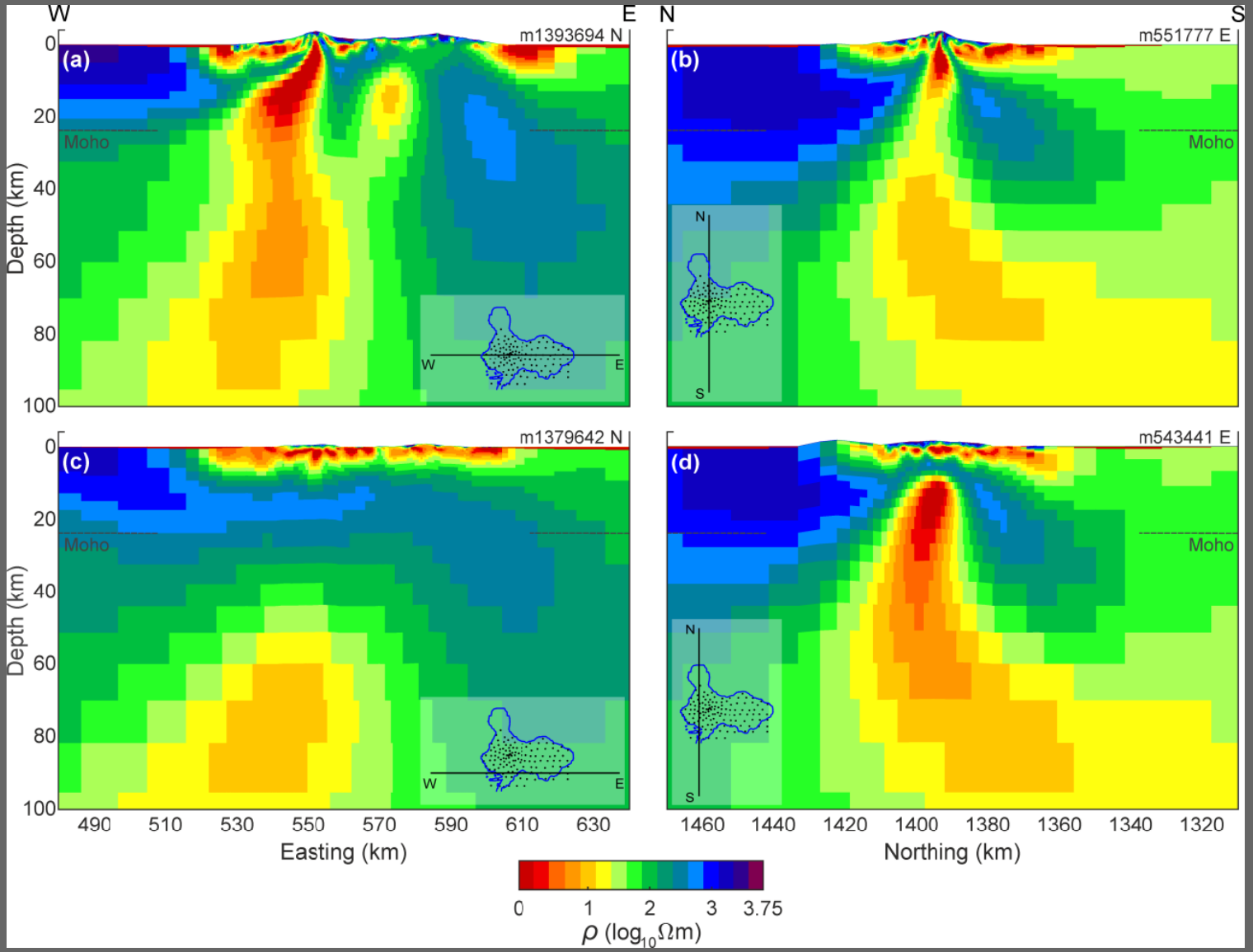
Mount Erebus & the Terror Rift

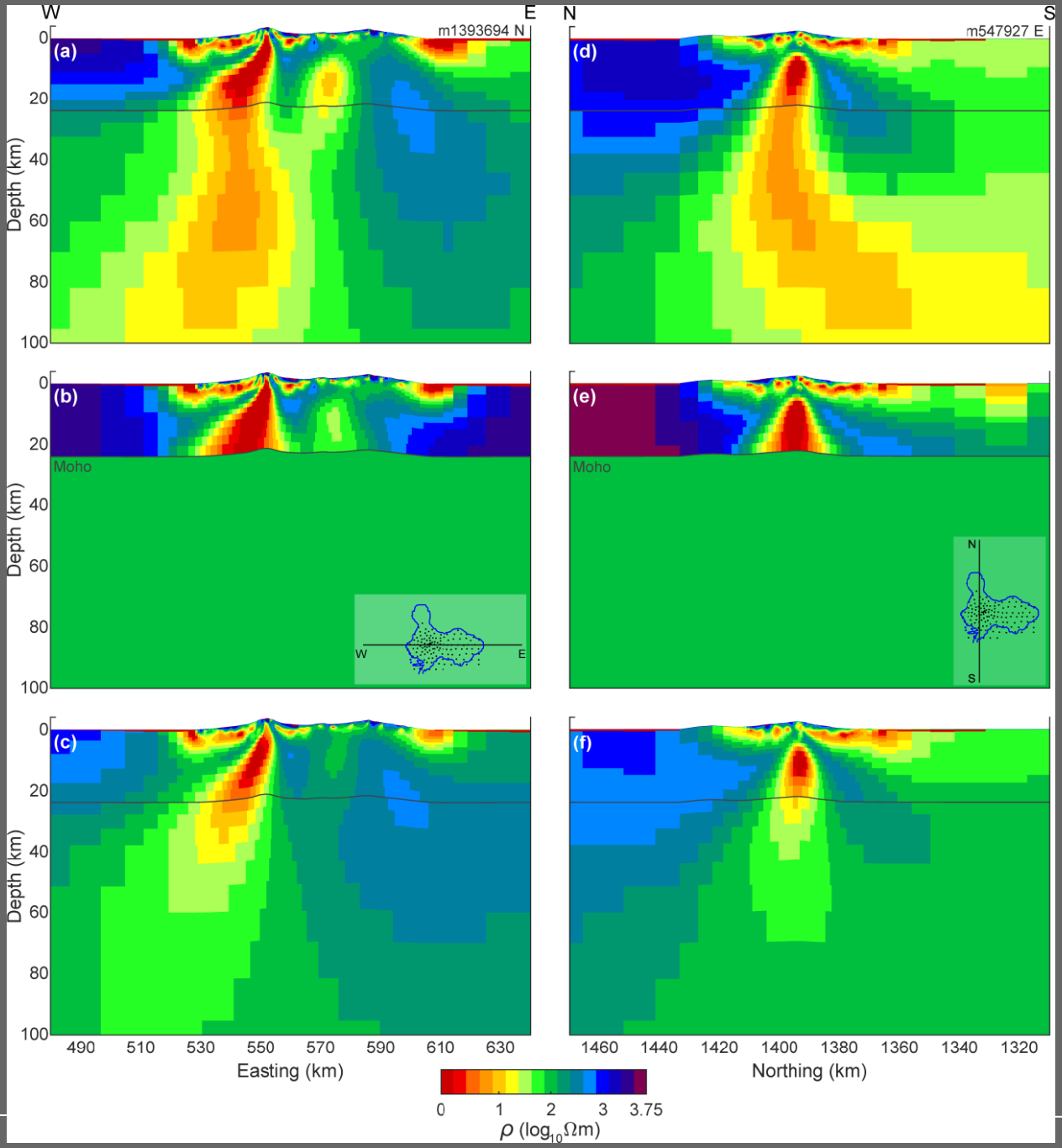


Inverse Model

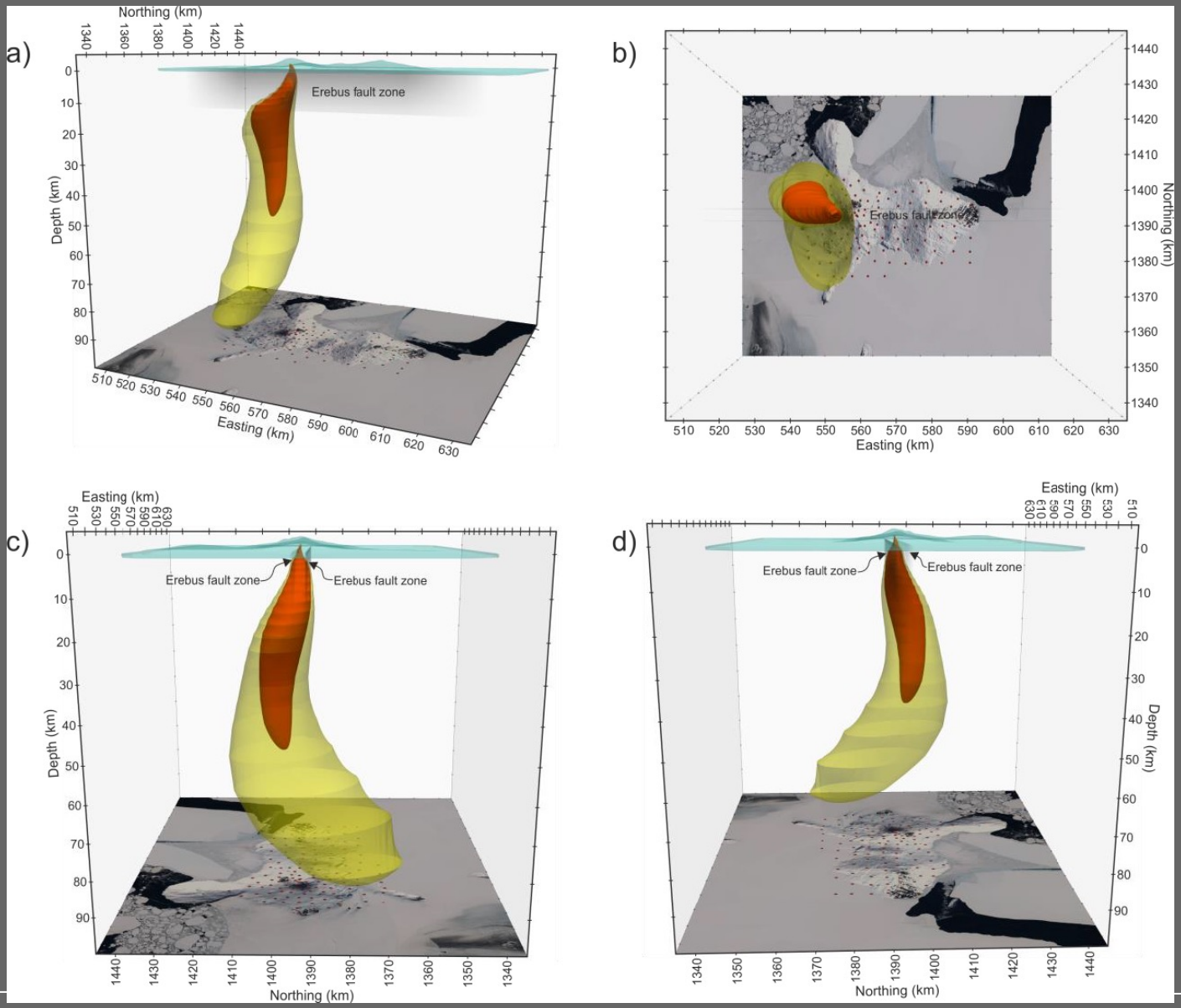


Inverse Model

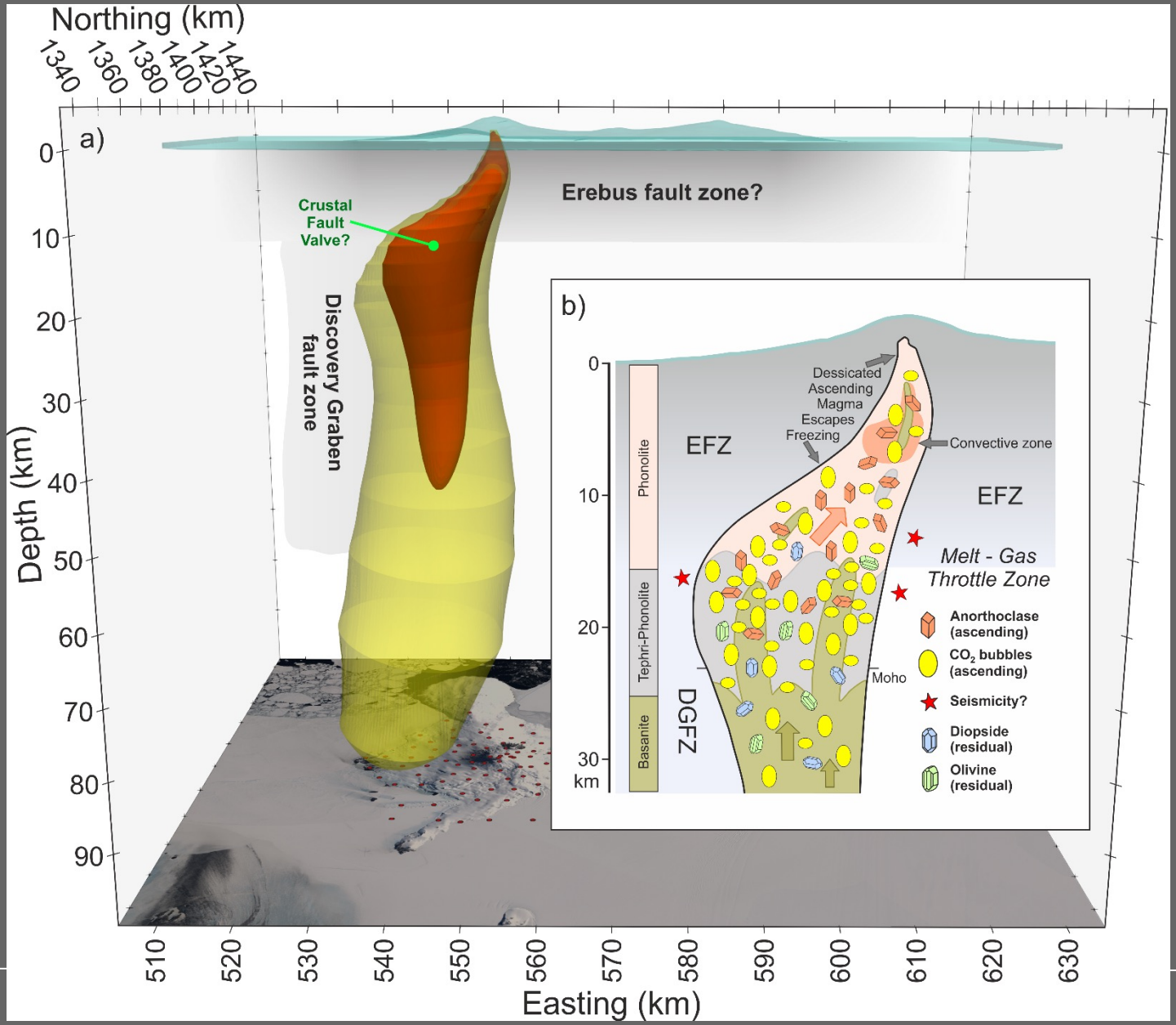



W
E
m1393694 N
(a)
(b)
(c)
N
S
m547927 E
(d)
(e)
(f)
Depth (km)
0
20
40
60
80
100
Moho
W
E
N
S
490
510
530
550
570
590
610
630
Easting (km)
1460
1440
1420
1400
1380
1360
1340
1320
Northing (km)
0
1
2
3
3.75
ρ (log10Ωm)

Inverse Model



Inverse Model



Thank You