Thermal Regime, Legacy Structures, Upper Mantle Hydration and Lithospheric-Scale Magmatic Processes of the Antarctic Interior from Regional-Scale Electrical Properties

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Abstract

Large-scale electrical resistivity investigations of the Antarctic crust and upper mantle utilizing the magnetotelluric method (MT) are limited in number compared to temperate regions, but provide physical insights difficult to obtain with other techniques. Key to the method's success in polar environments are instrumentation advances that allow micro-volt level measurements of the MT electric field in the face of mega-ohm contact resistances. In this presentation, we analyze MT data from four campaigns over the Antarctic interior using modern 3D non-linear inversion analysis and offer additional geophysical conclusions and context beyond the original studies. A profile of MT soundings over transitional Ellsworth-Whitmore block in central West Antarctica implies near-cratonic lithospheric geothermal conditions with interpreted graphite-sulphide horizons deformed along margins of high-grade silicate lithologic blocks. Data across South Pole soundings confirms large-scale low resistivity spanning Moho depths that is consistent with limited seismic tomography and elevated crustal thermal regime inferences. Upper mantle under a presumed adiabatic thermal gradient below the Ross Ice Shelf region of West Antarctica appears to be of a moderately hydrated state but not sufficient so as to induce melting. The degree of hydration there is comparable to that below the north-central Great Basin extensional province of the western U.S. Comprehensive 3D coverage of Mount Erebus and Ross Island reveals unprecedented views of the magmatic plumbing feeding the phonolitic volcanic system. This includes a lower middle crustal staging area for episodic magmatic replenishment of the upper middle crustal chamber hosting phonolitic differentiation, which in turn is fed from an upper mantle source region of the parental basanite.

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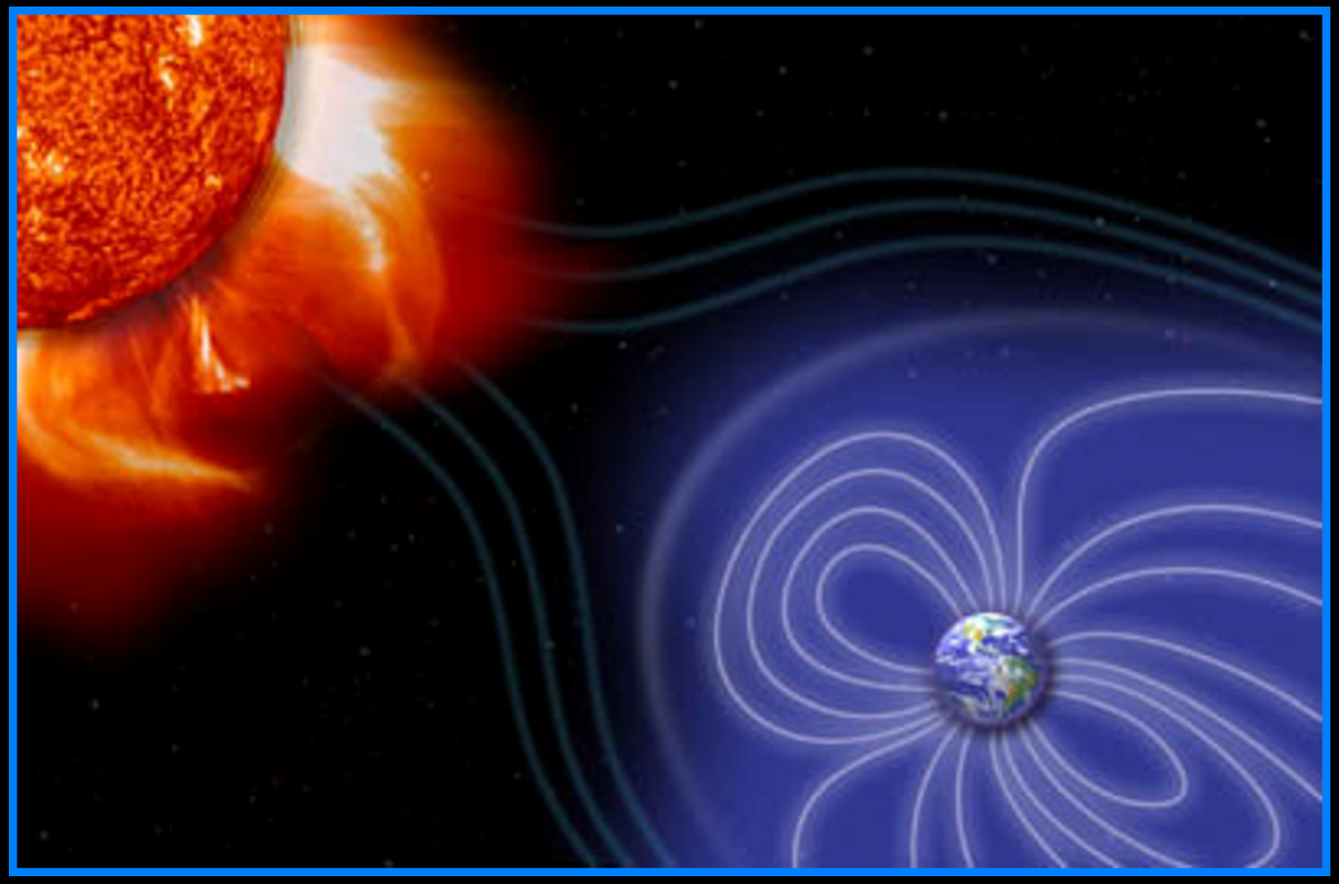
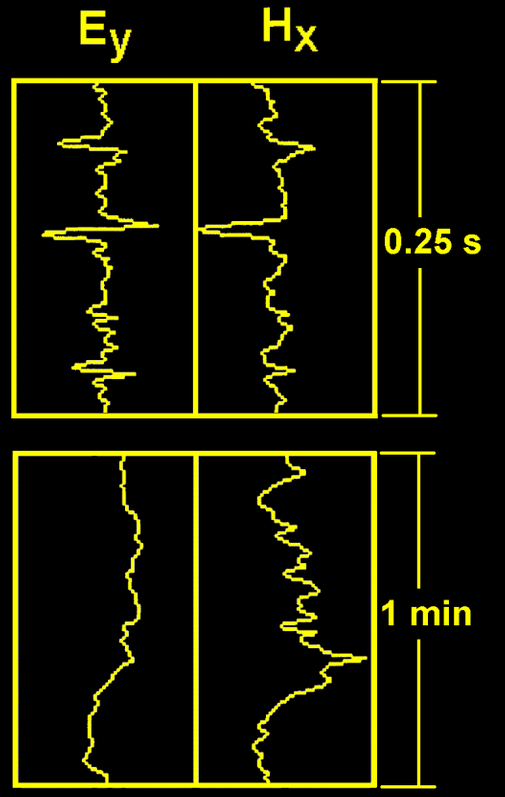
U.S. National Science Foundation, U.S. Department of Energy, Royal Society of New Zealand

Source Fields for the Magnetotelluric Method



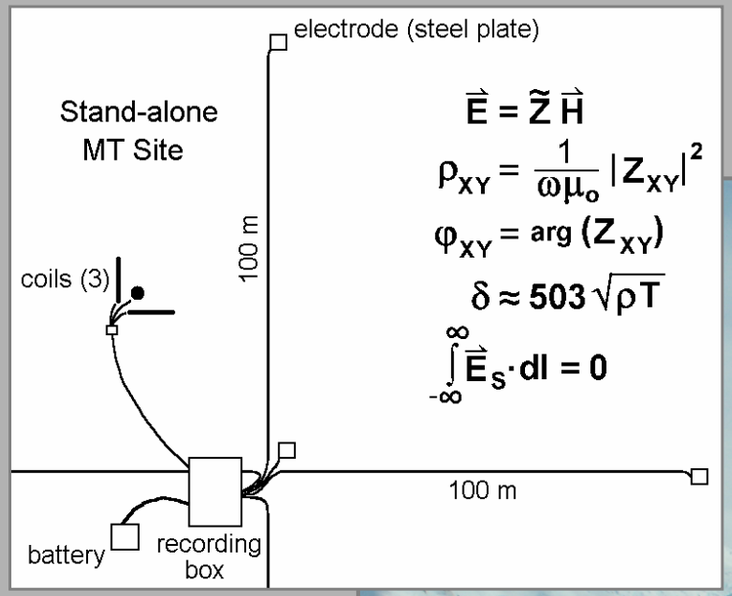


Regional and Global Lightning Activity for f > 1 Hz
Solar Wind-Magnetospheric Interactions for f < 1 Hz

MT Recording Components For Polar Deployment

Induction Coil (Solenoid)

Ti Electrode w/ High-Z Preamp



$$\vec{E} = \tilde{Z}\,\vec{H}$$

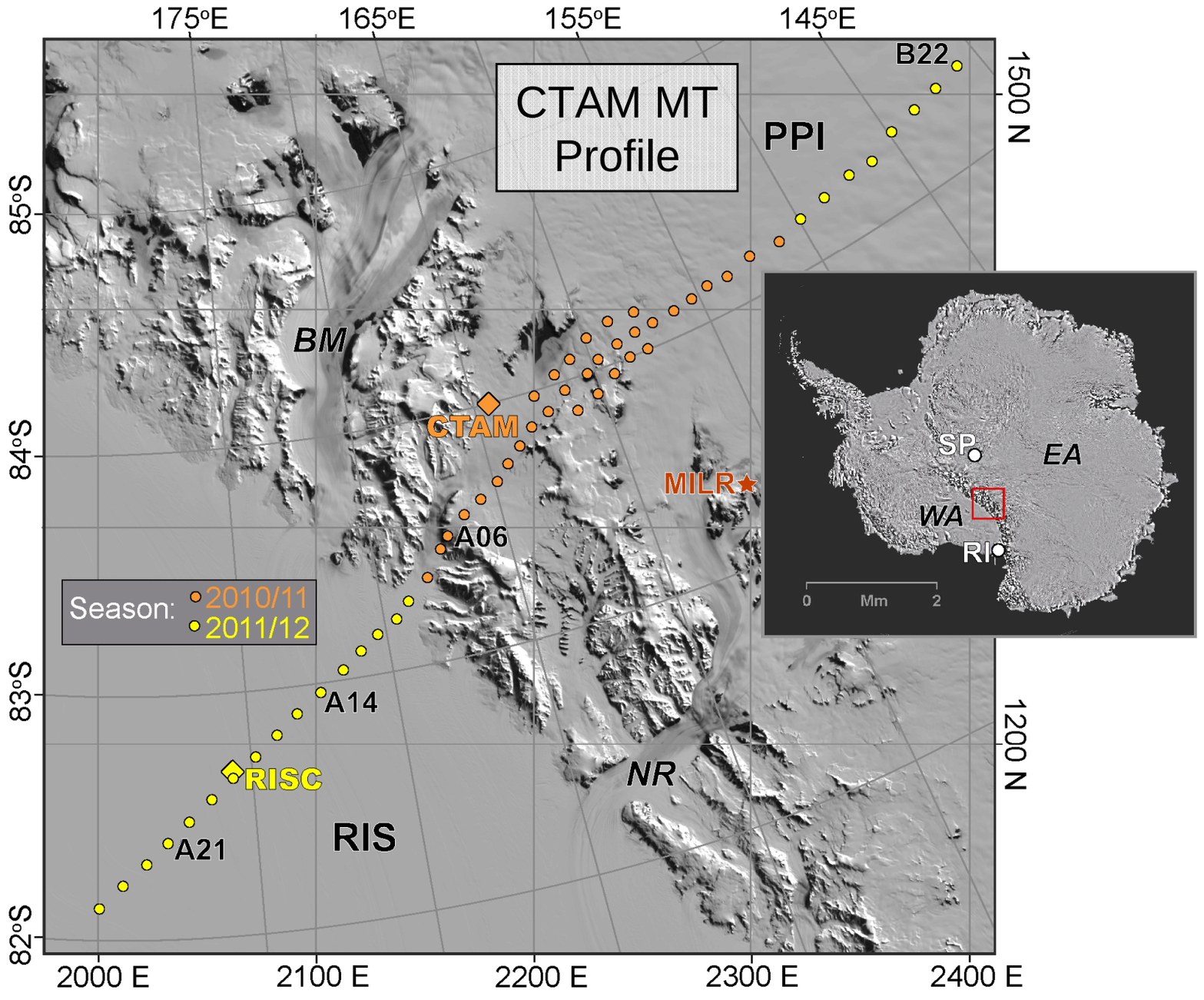
$$\rho_{XY} = \frac{1}{\omega\mu_o}\,|Z_{XY}|^2$$

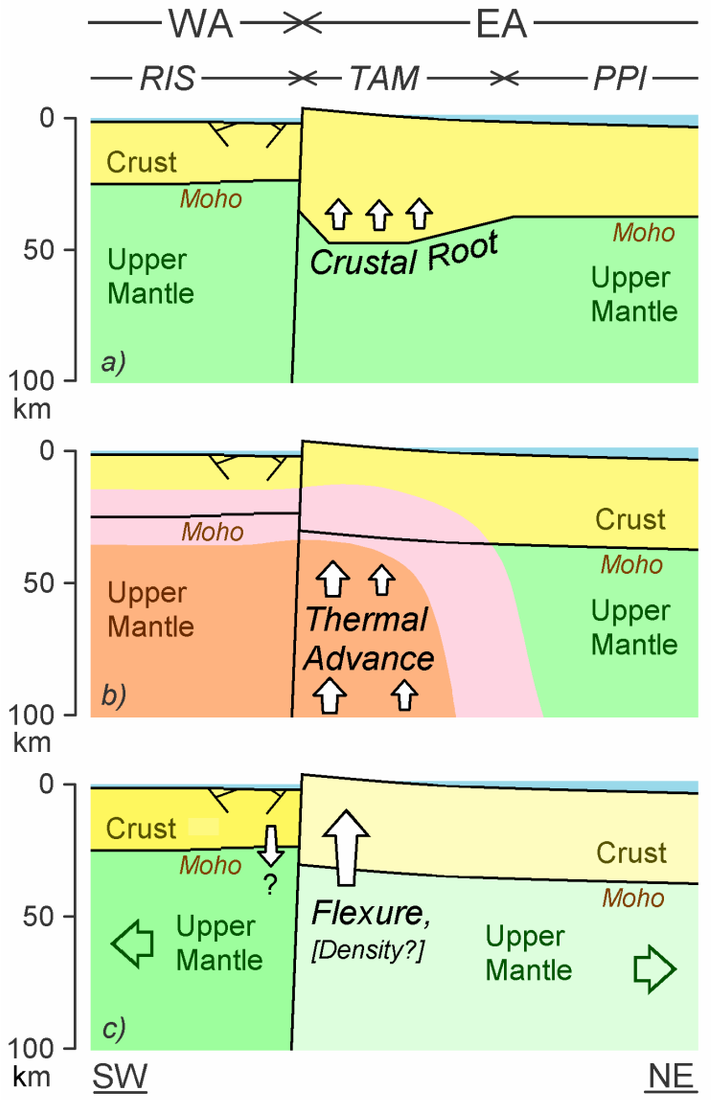
$$\varphi_{XY} = \arg\,(Z_{XY})$$

$$\delta \approx 503\sqrt{\rho T}$$

$$\int_{-\infty}^{\infty} \vec{E}_S \cdot d\mathbf{l} = 0$$

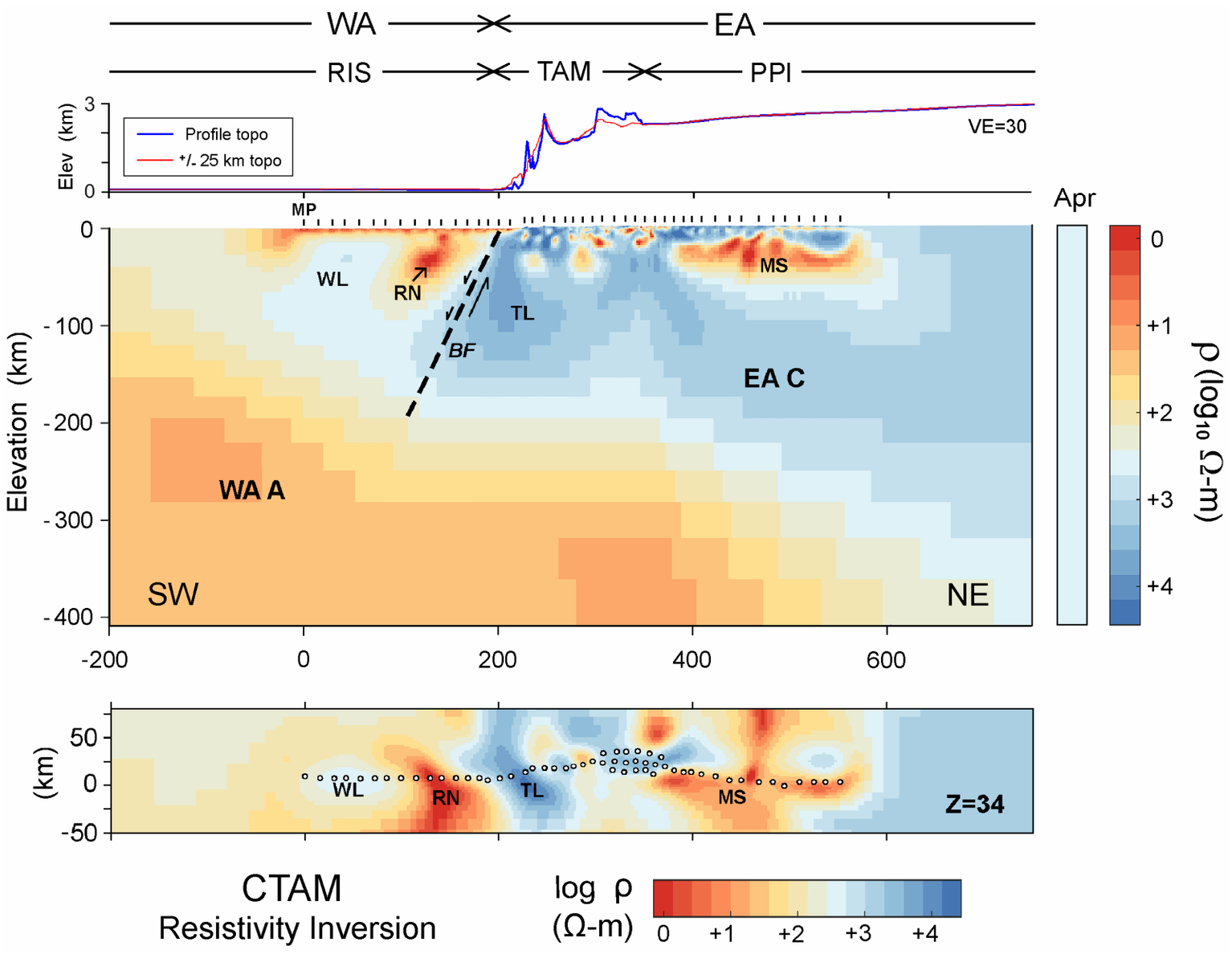
Sync'd MT recorders

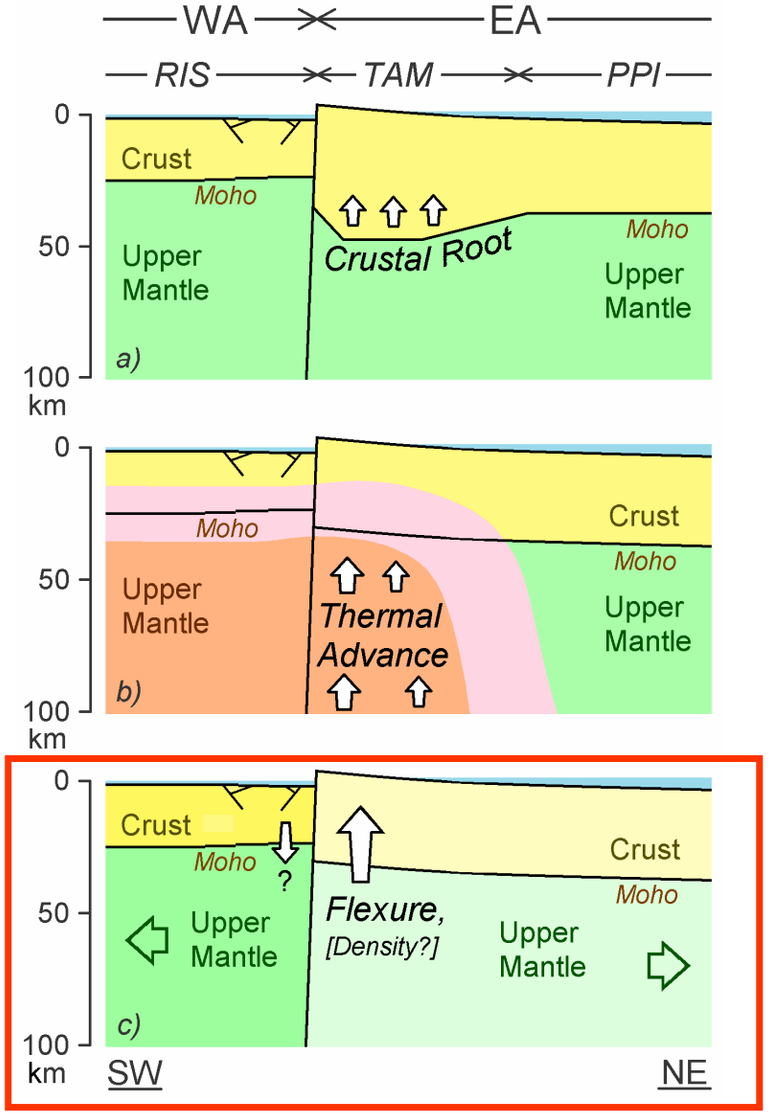




Hypotheses for TAM Uplift

(Wannamaker et al., 2017, Nat Comms)





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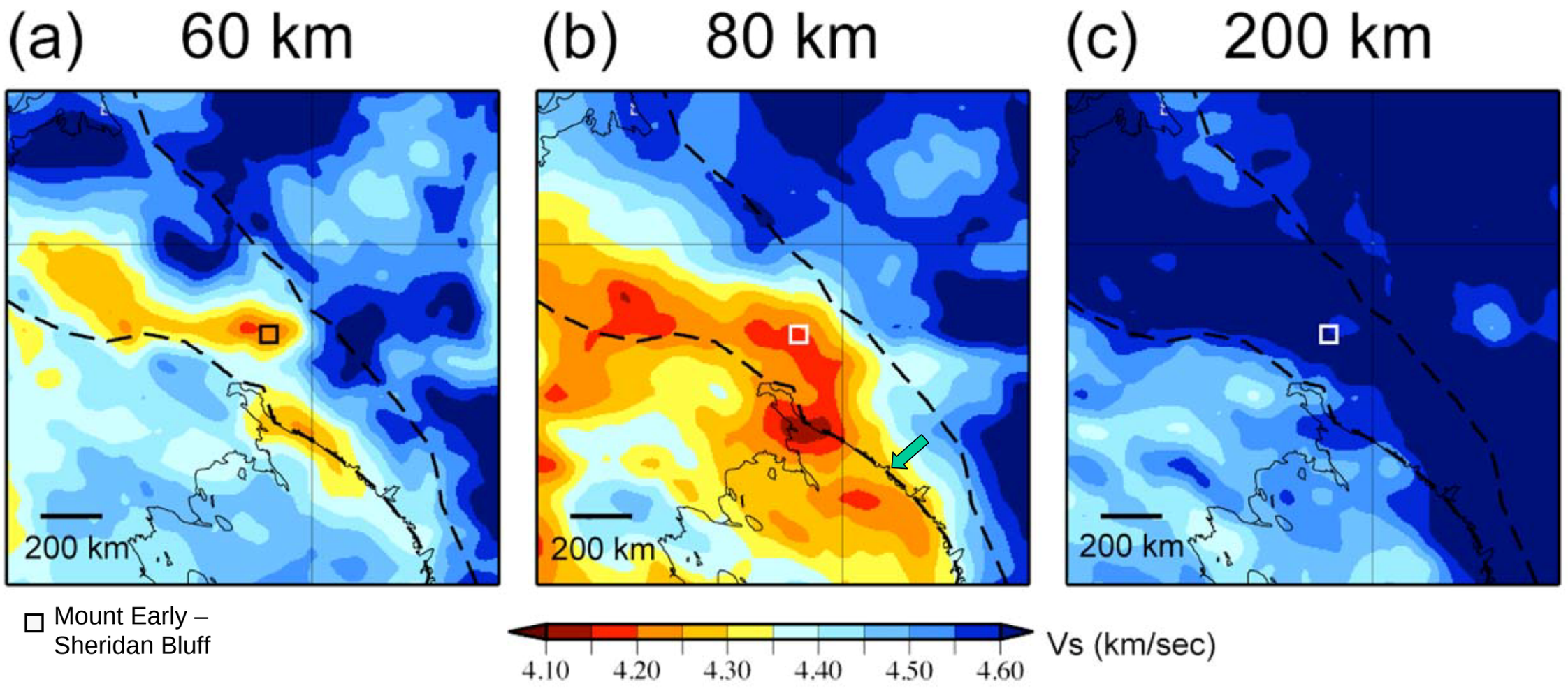
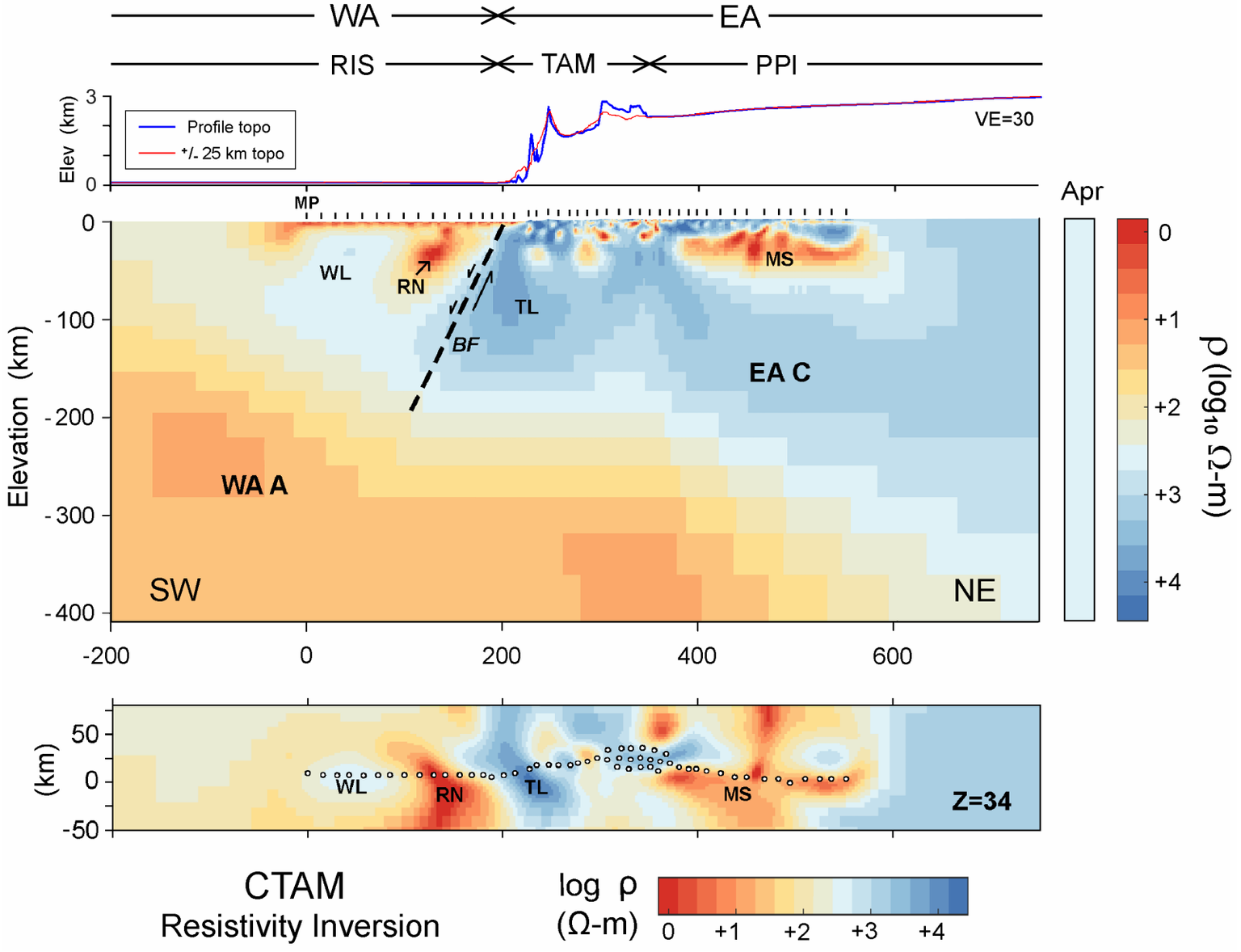
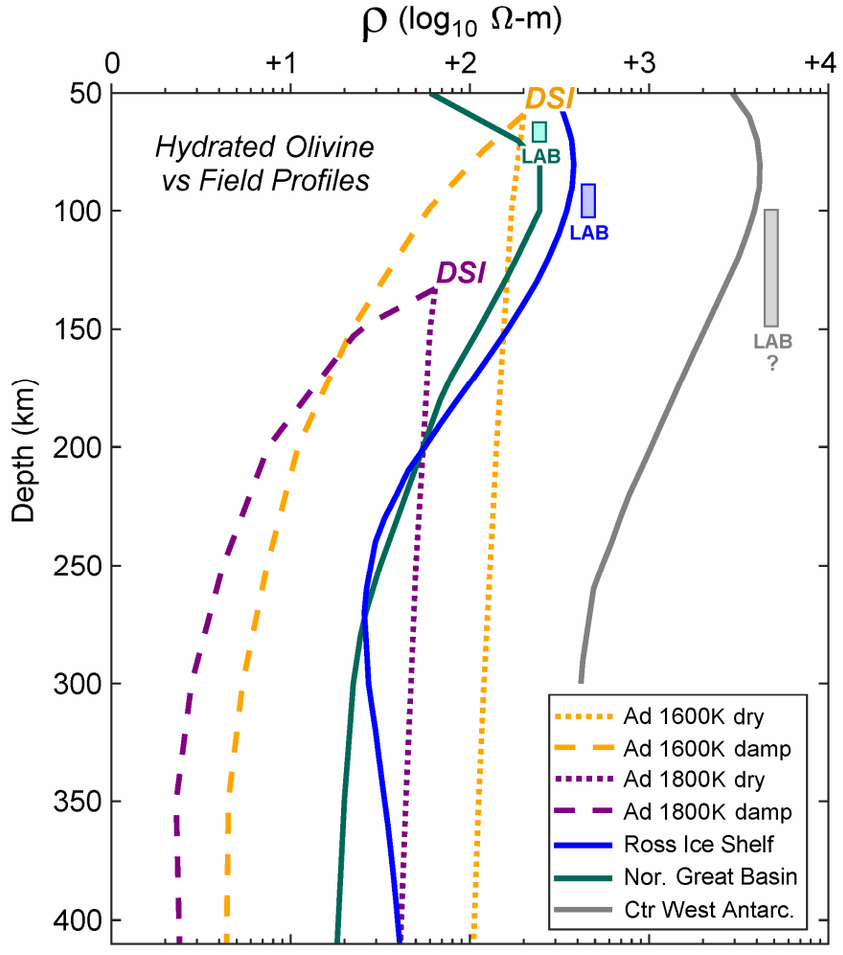


Absolute Shear Wave Speeds
Southern Transantarctic Mountains
(Shen et al., 2017)

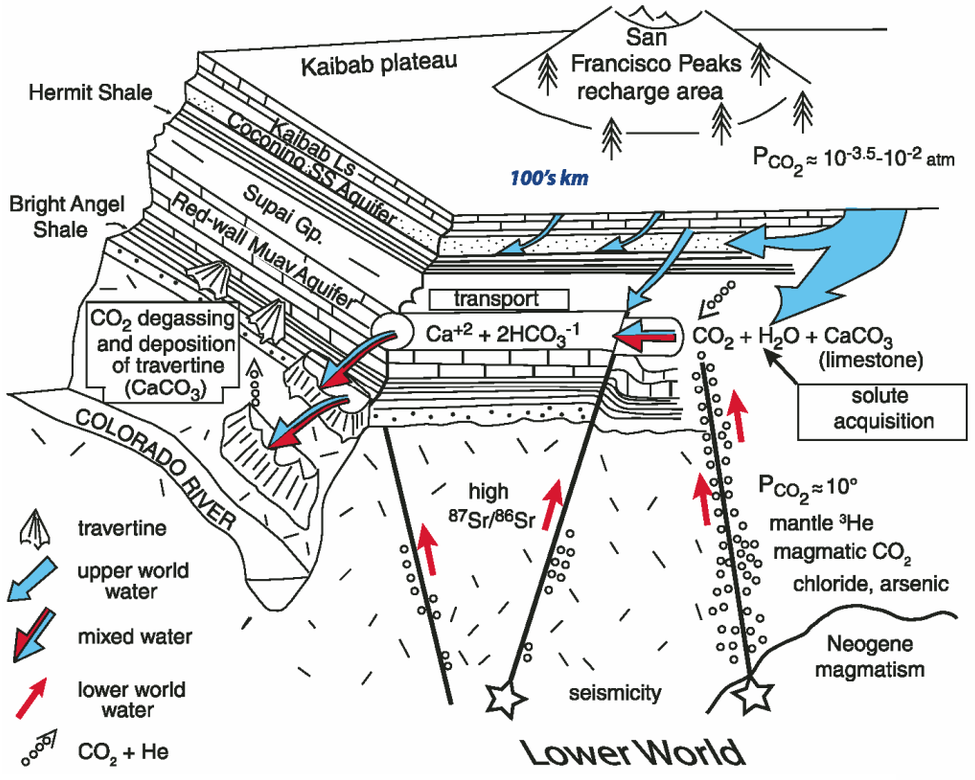




Upper Mantle NAMs Hydration

(West Antarctica, Great Basin)

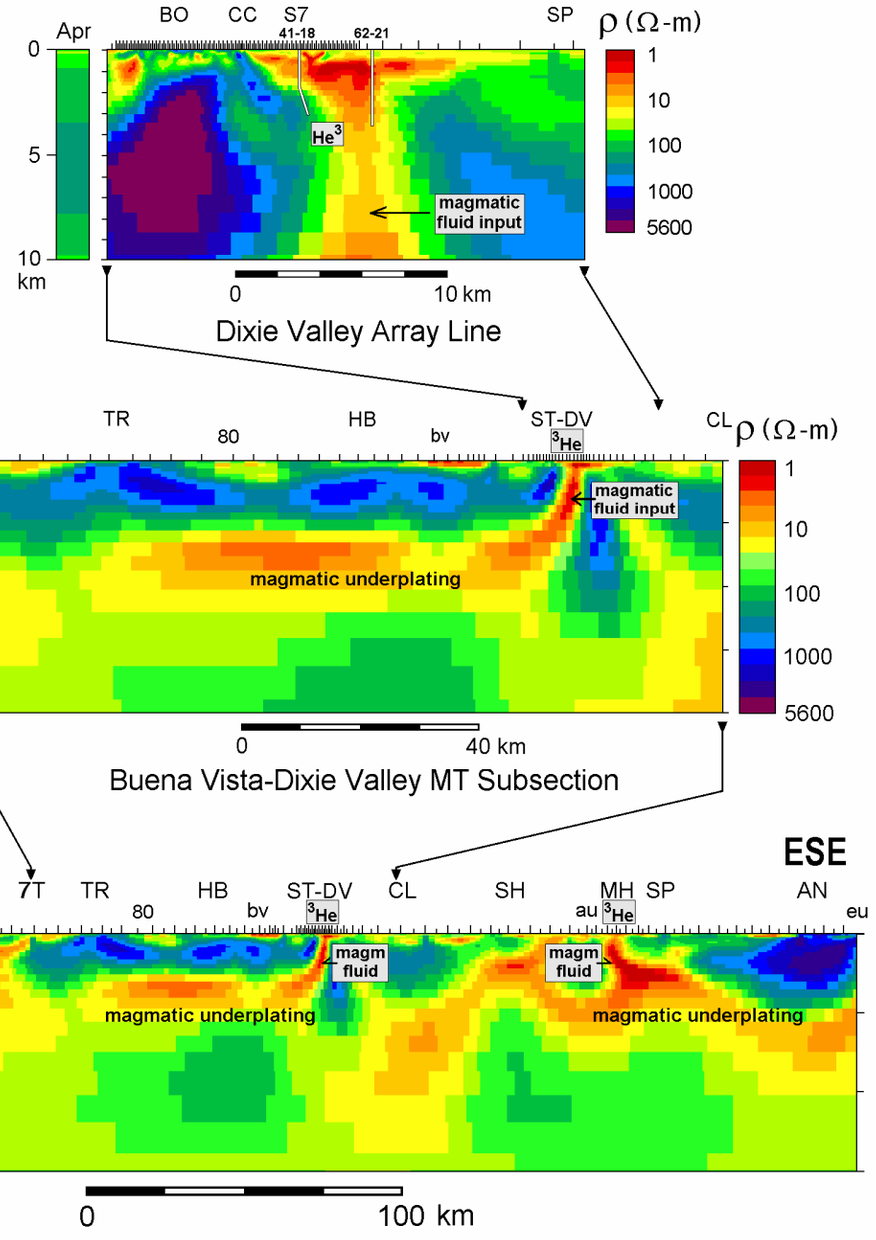
(Wannamaker et al., 2020, GSL Mem.)



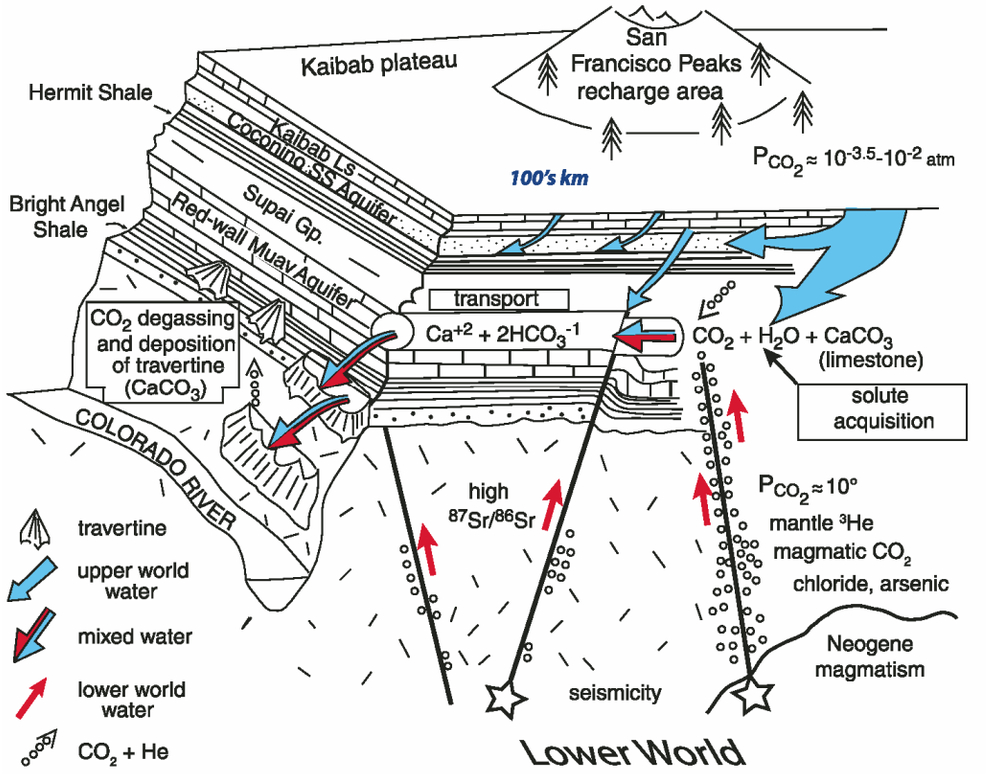
Multiscale Magmatic/ Hydrothermal Connections

Grand Canyon Hydrol. Model

(Crossey and Karlstrom, 2012)



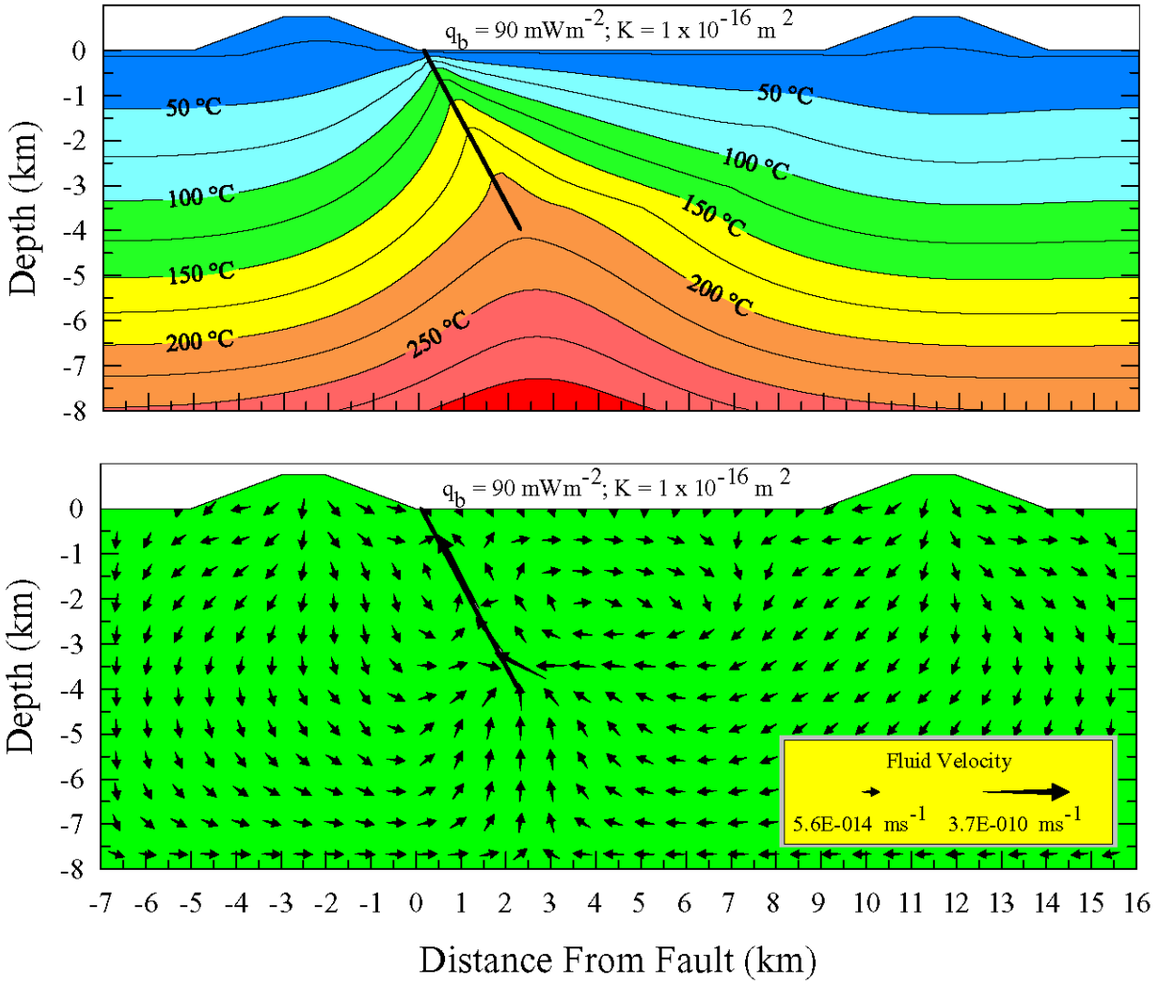
Wannamaker et al, 2007, 2008, 2011; Siler et al., 2014

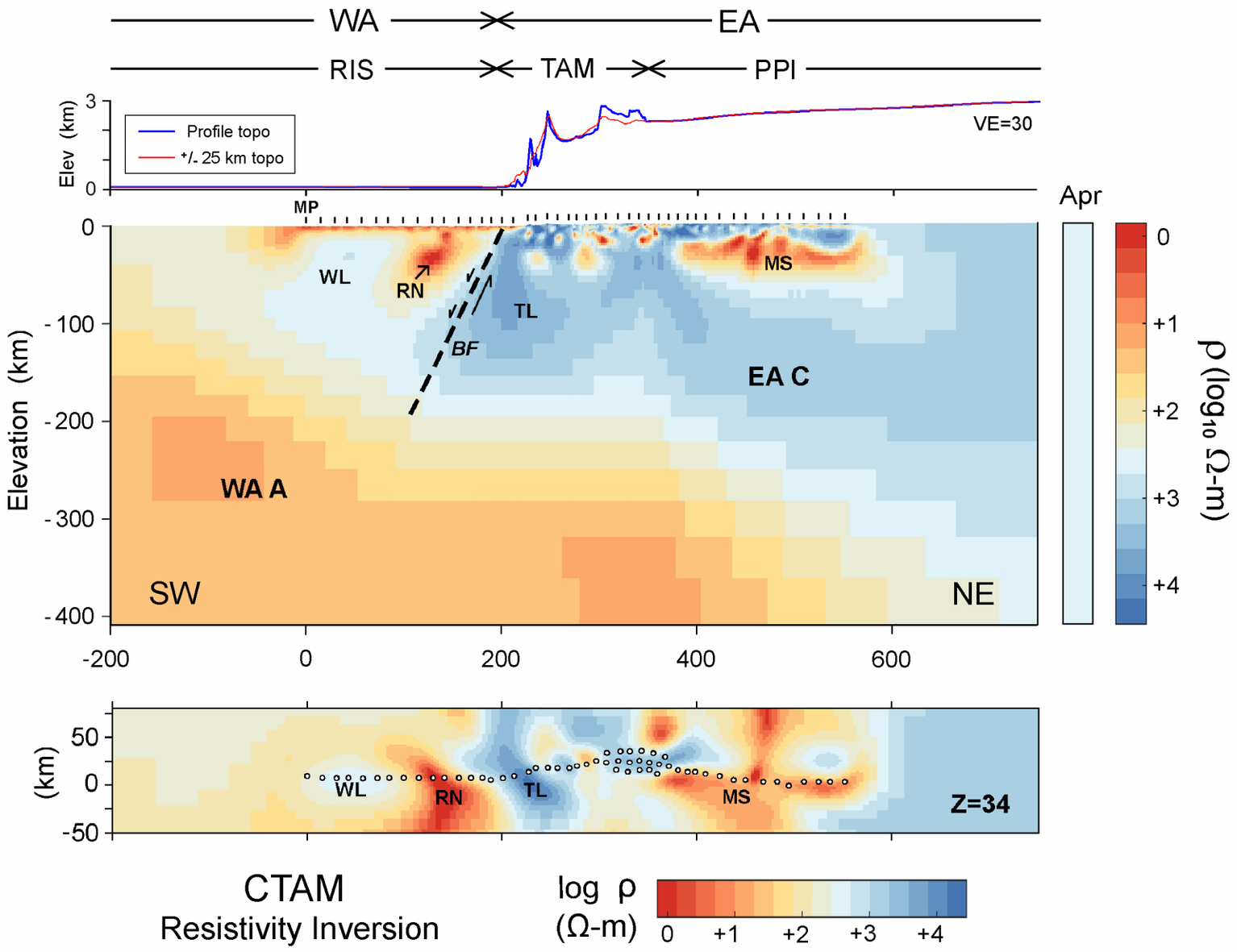


Multiscale Magmatic/
Hydrothermal Connections

Grand Canyon Hydrol. Model
(Crossey and Karlstrom, 2012)

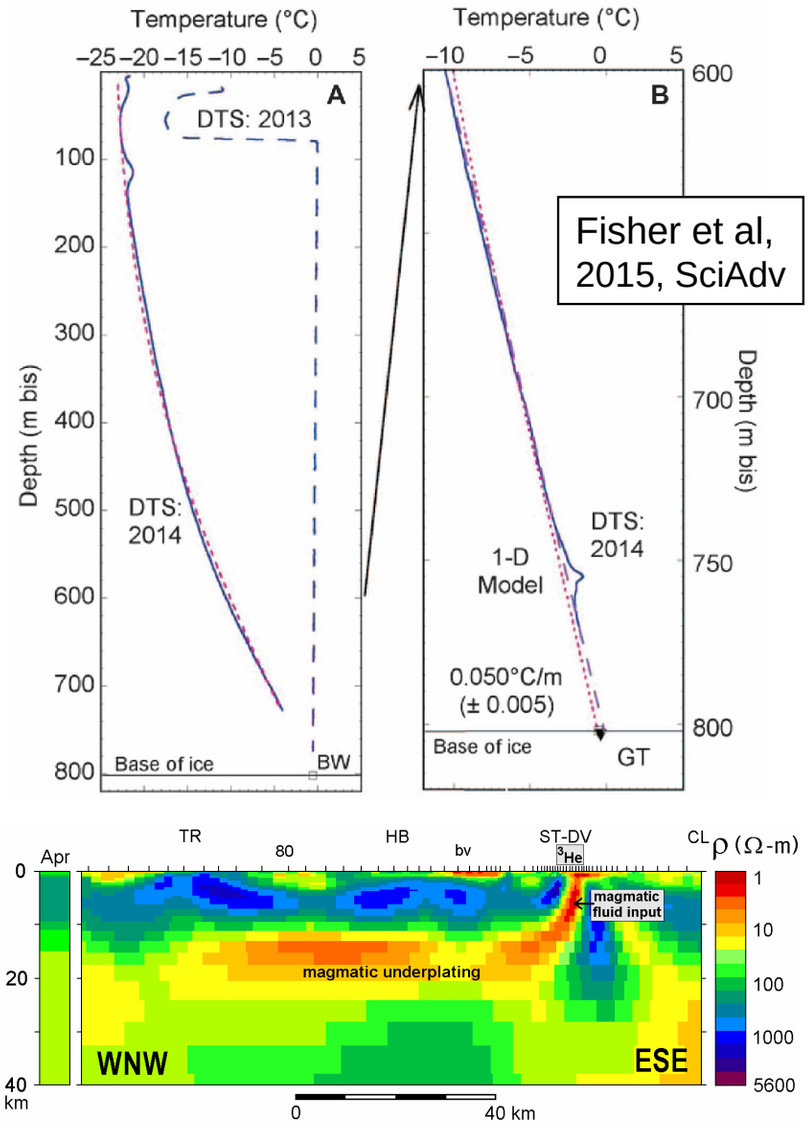
Dixie Valley NV ConvectiveThermal Model
(McKenna and Blackwell, 2004)





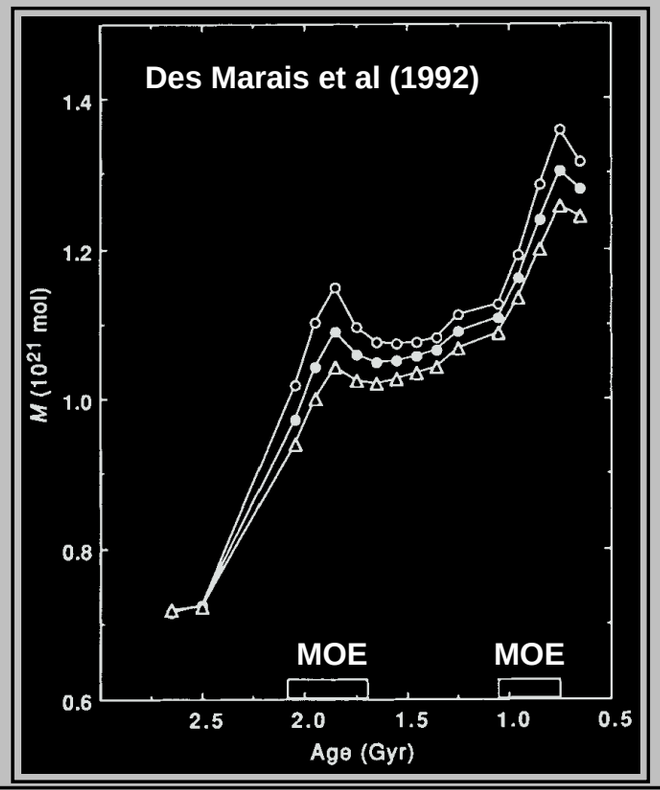
Subglacial Lake Whillans

heat flux 285 ± 80 mW/m²

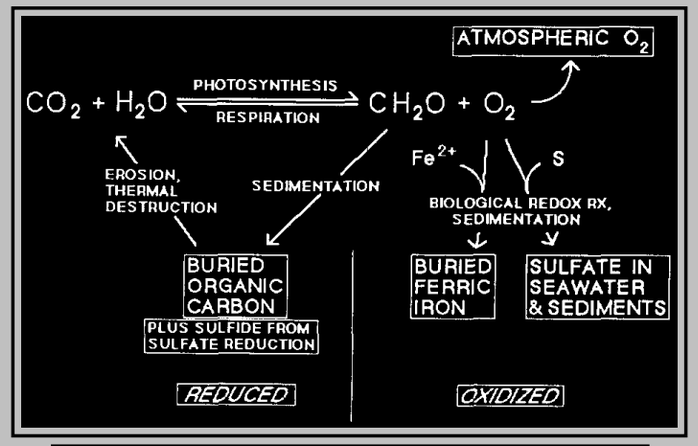


Wannamaker et al (2007) – Western NV

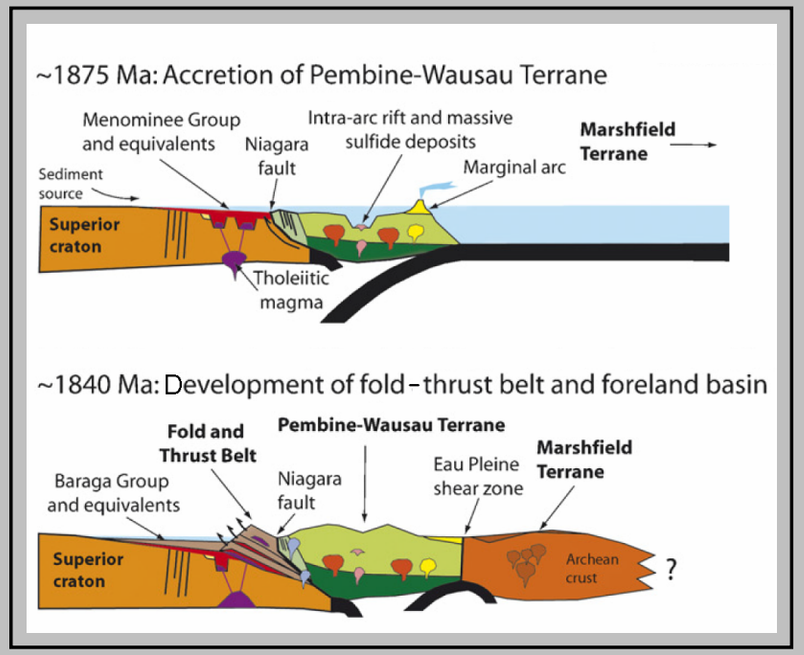
Rift Necking and Thermal Focus



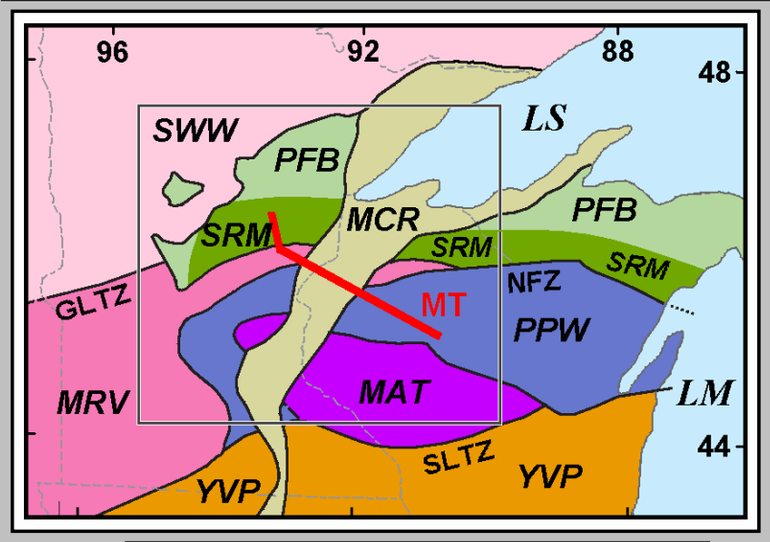
oC-Sd global primary production



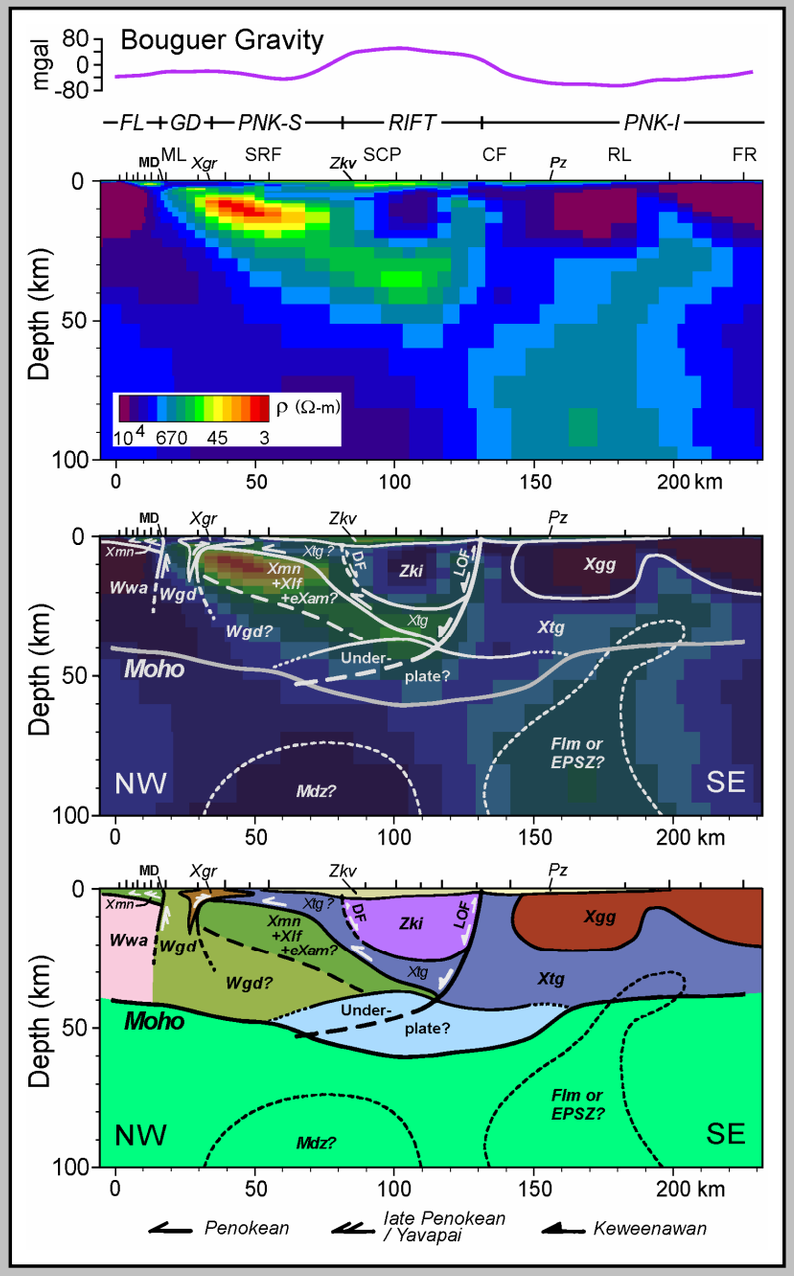
Cyanobacterial oC-Sd sequ.



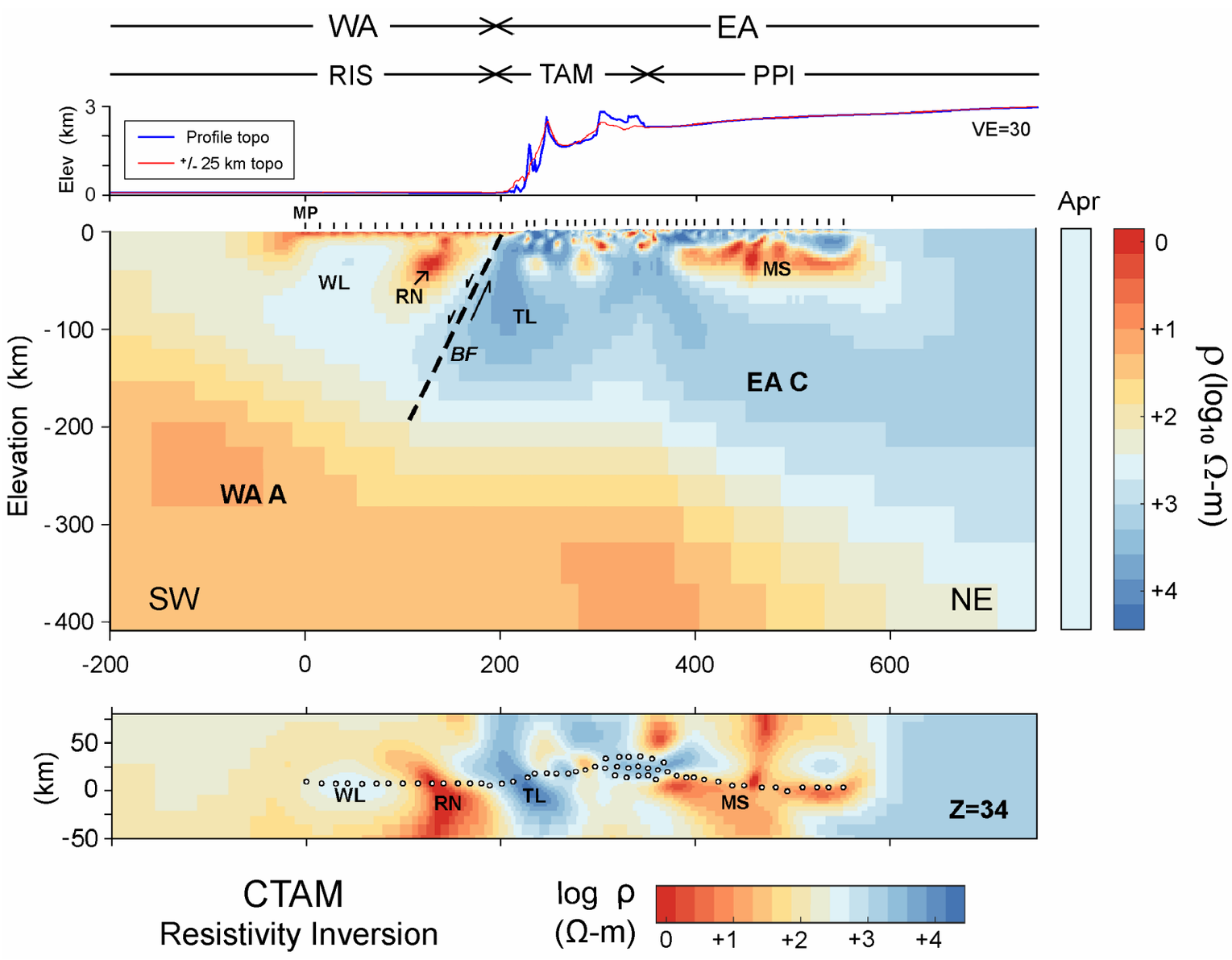
Mod from Schulz and Cannon (2007)

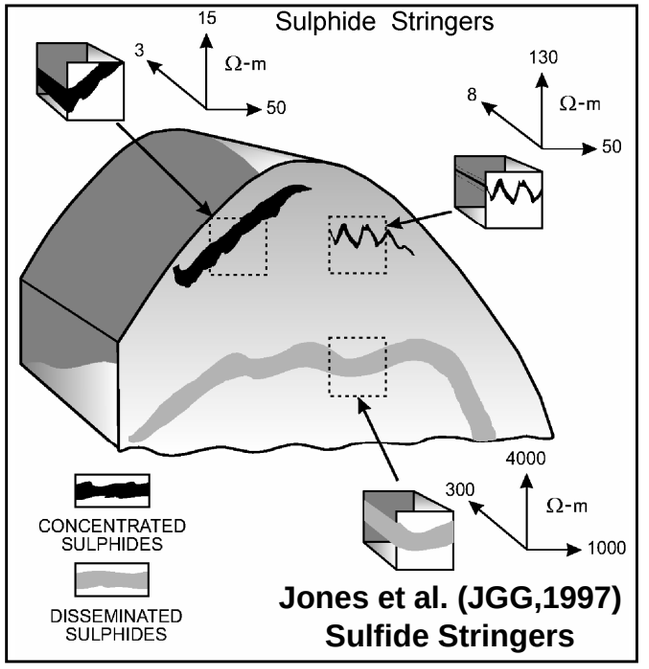


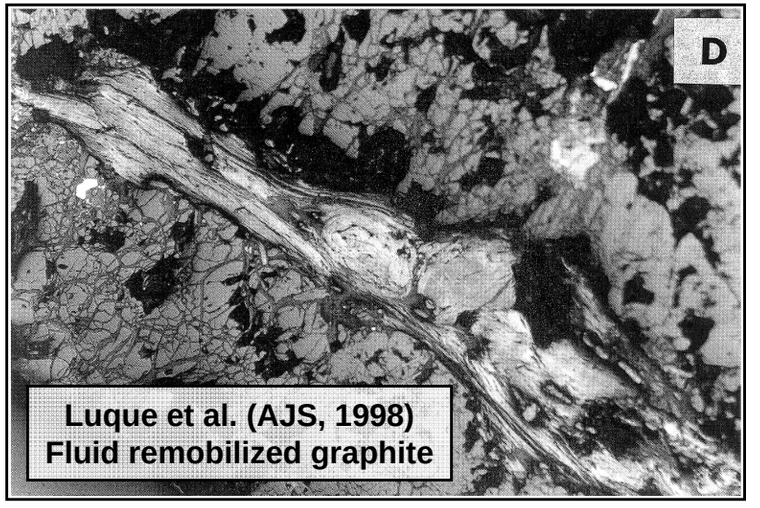
Mod from Southwick (2014)



Wunderman et al. (2018)

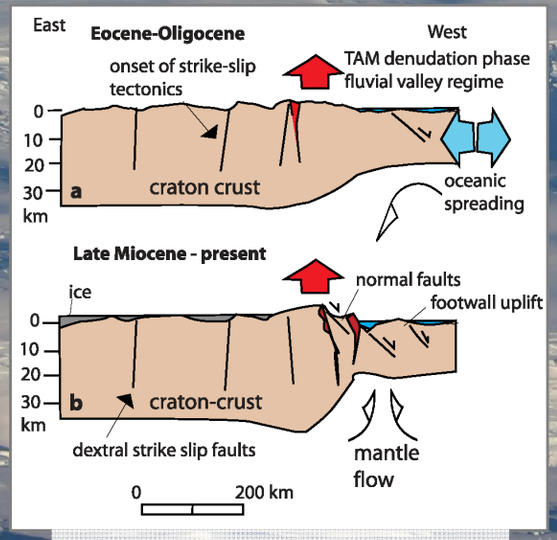




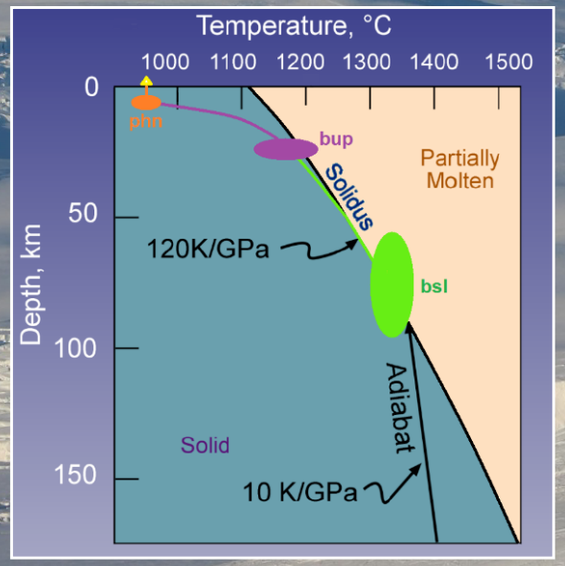


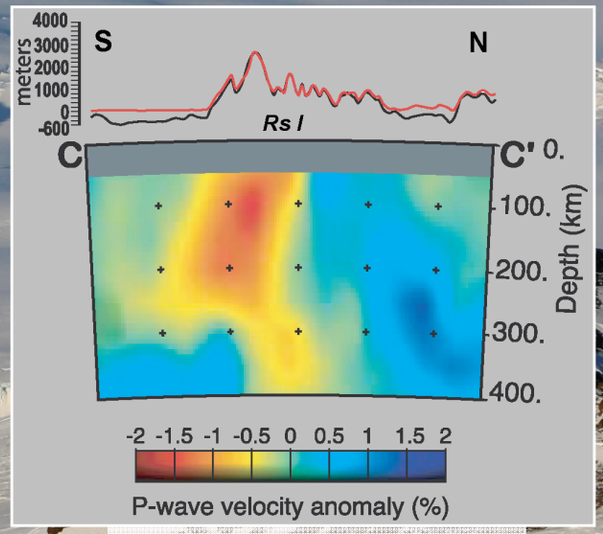
Graphite-sulfide textures in crustal-scale conductors

Mount Erebus, Ross Island
Active Phonolite Volcano

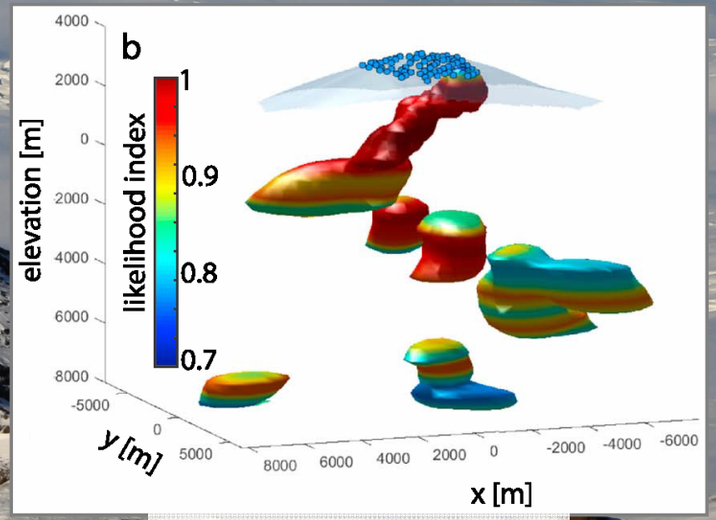


Faccenna et al., 2008

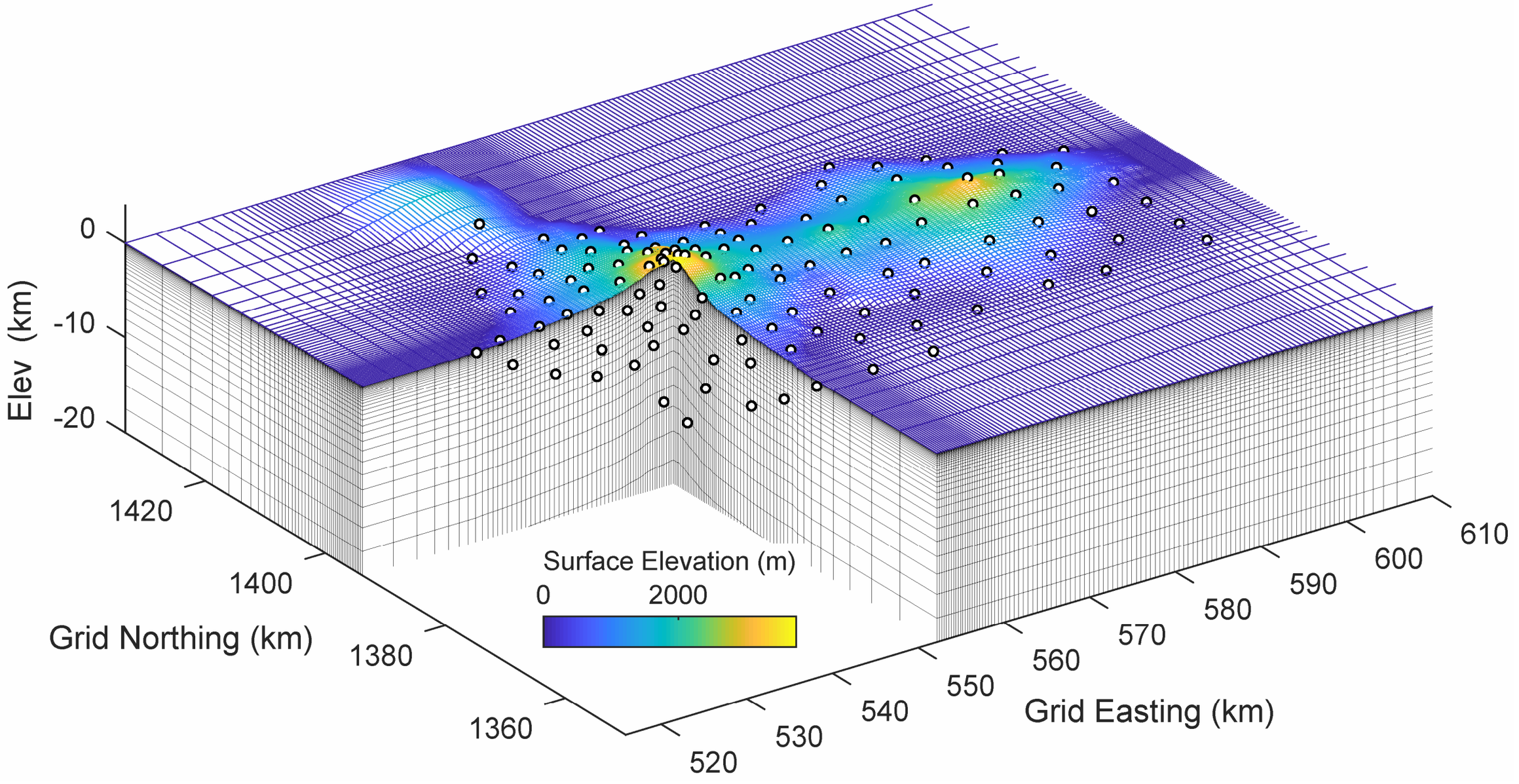




Watson et al (2006)

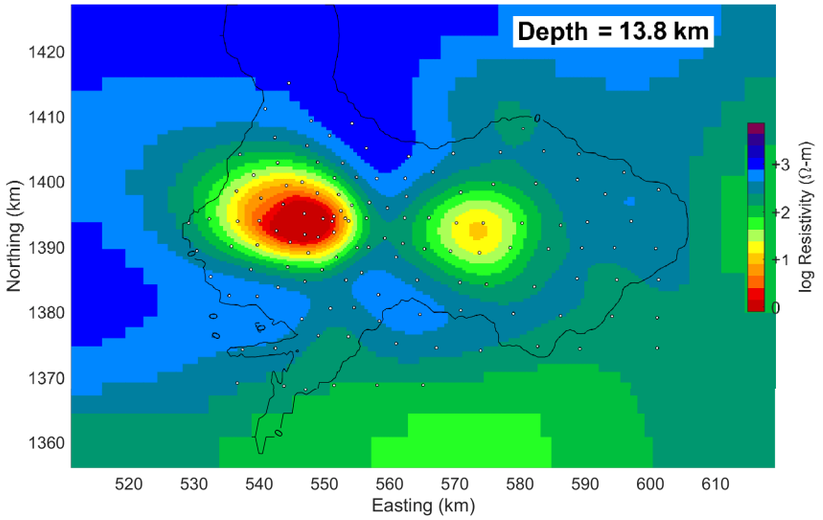


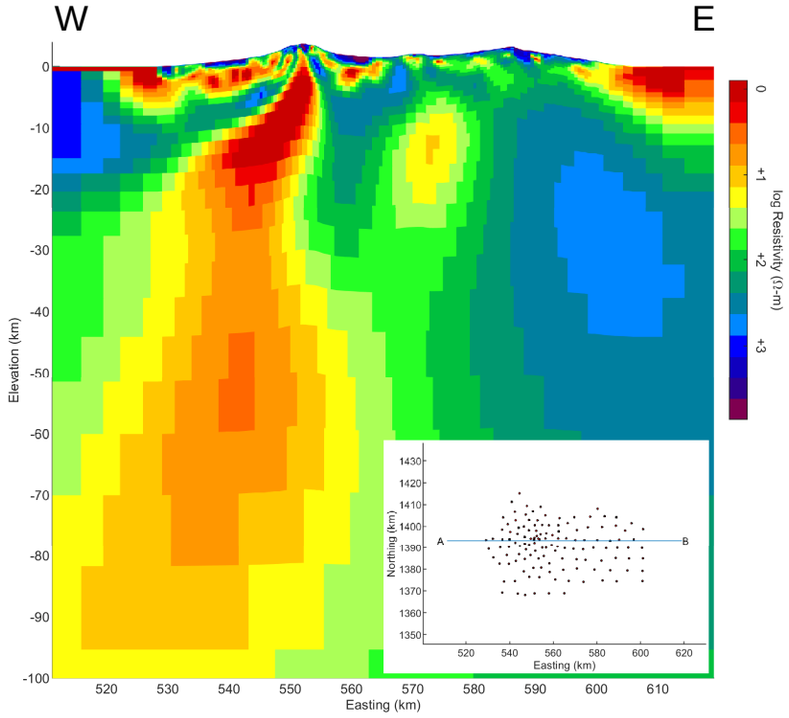
Blondel et al (2018)



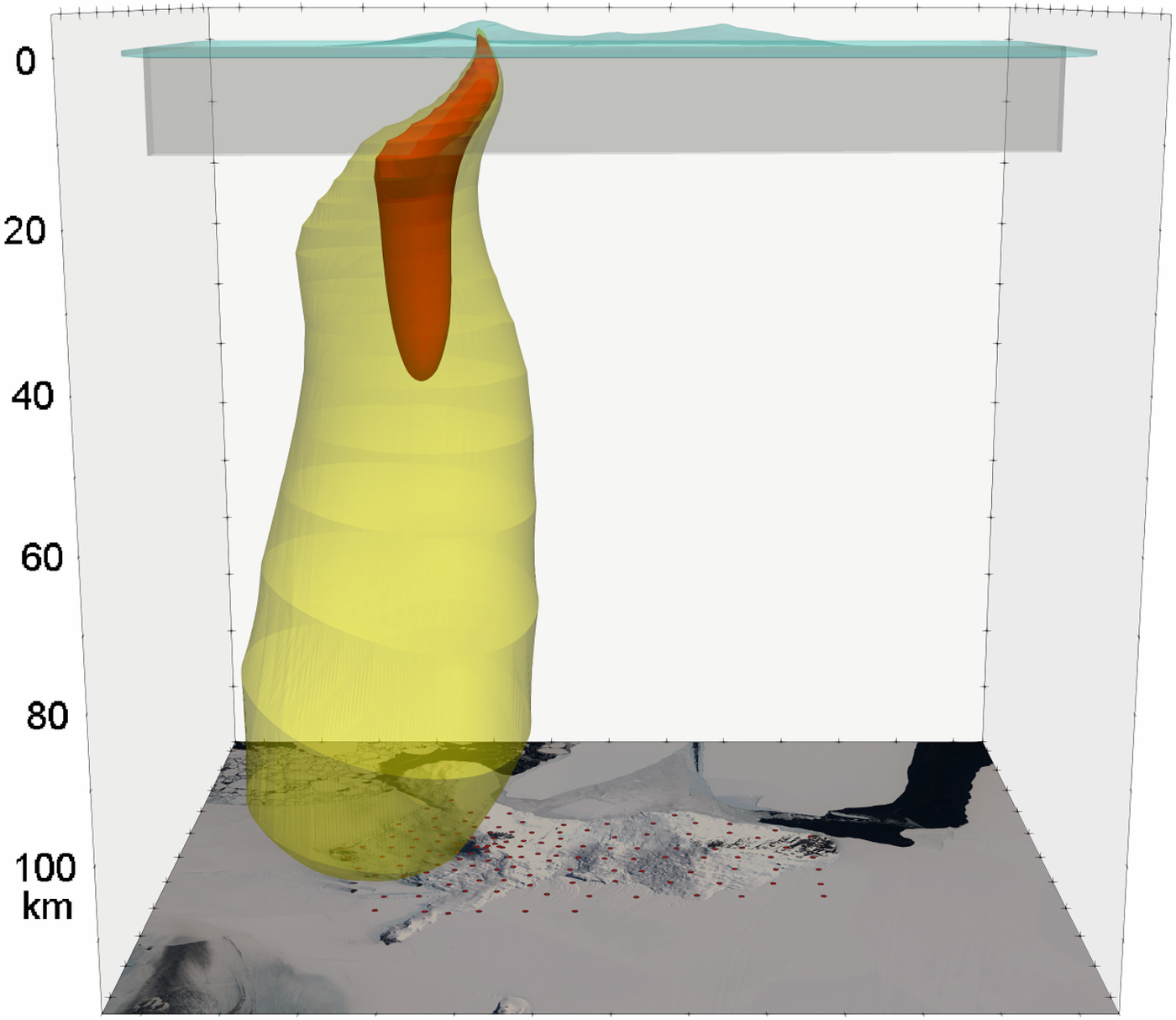
Mt Erebus/Ross Is Finite Element Mesh for 3D Non-Linear MT Inversion

(Kordy, Wannamaker et al, 2016a,b)

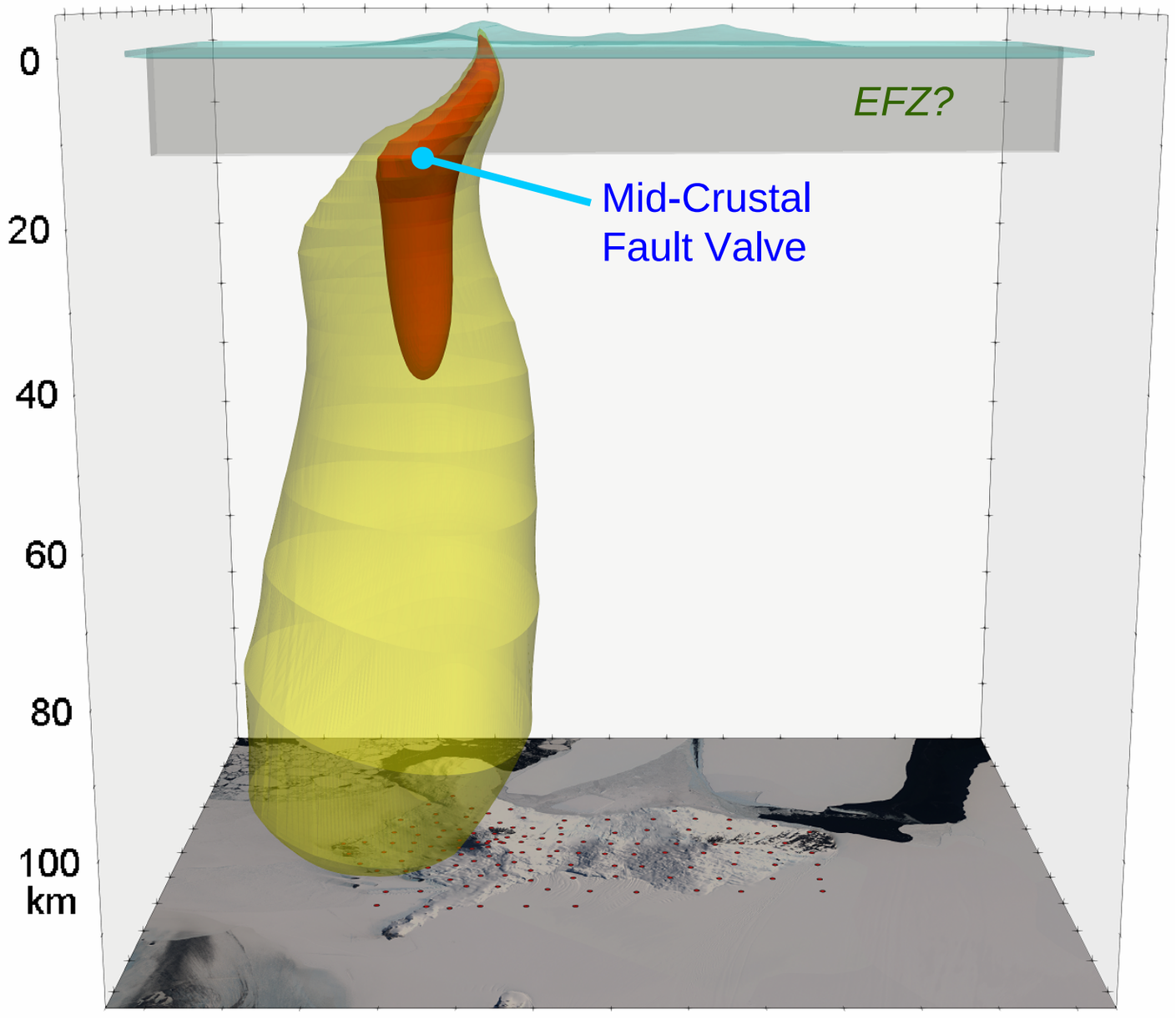




Mount Erebus MT Sections



Mount Erebus Paraview
(5, 20 ohm-m)



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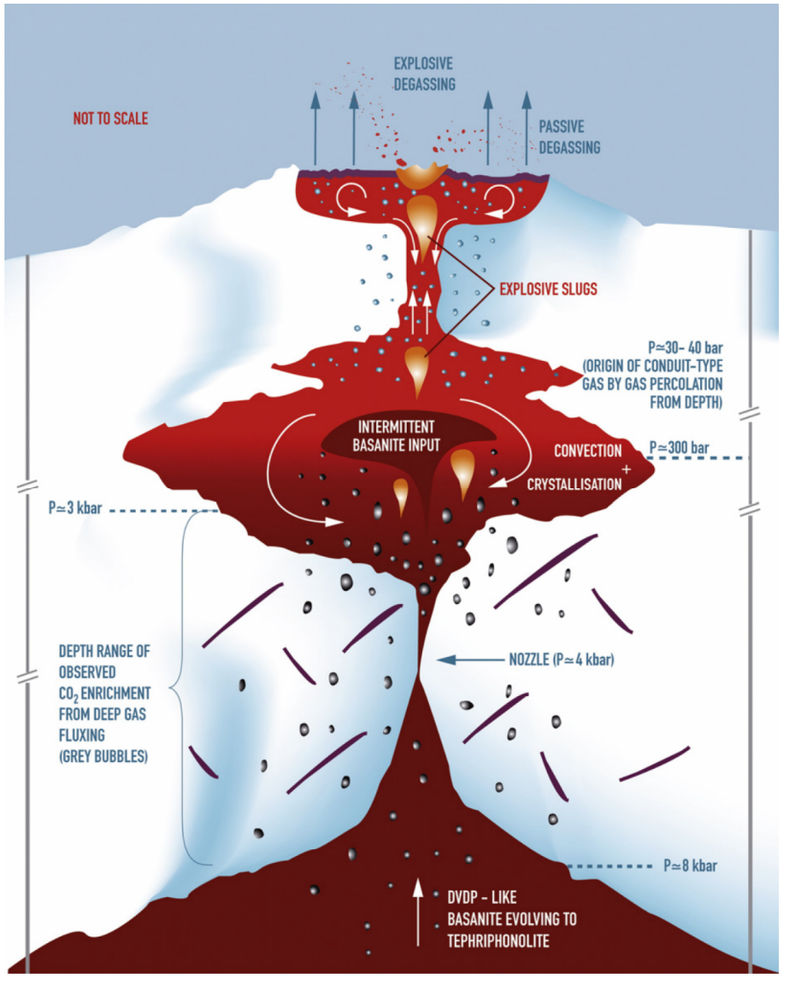

Schematic Mount Erebus magmatic plumbing (Oppenheimer et al., 2011). *“Nozzle” interpreted at ~4 kbar for periodic basanite replenishment.*

The End!

U.S. National Science Foundation, U.S. Department of Energy, Royal Society of New Zealand