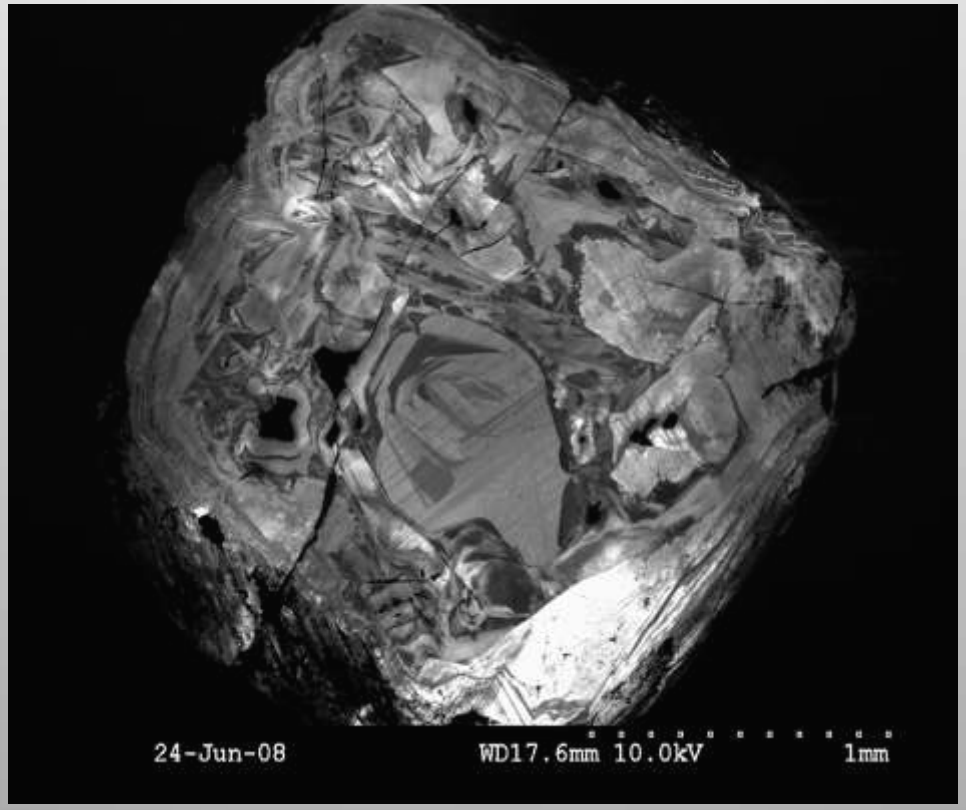
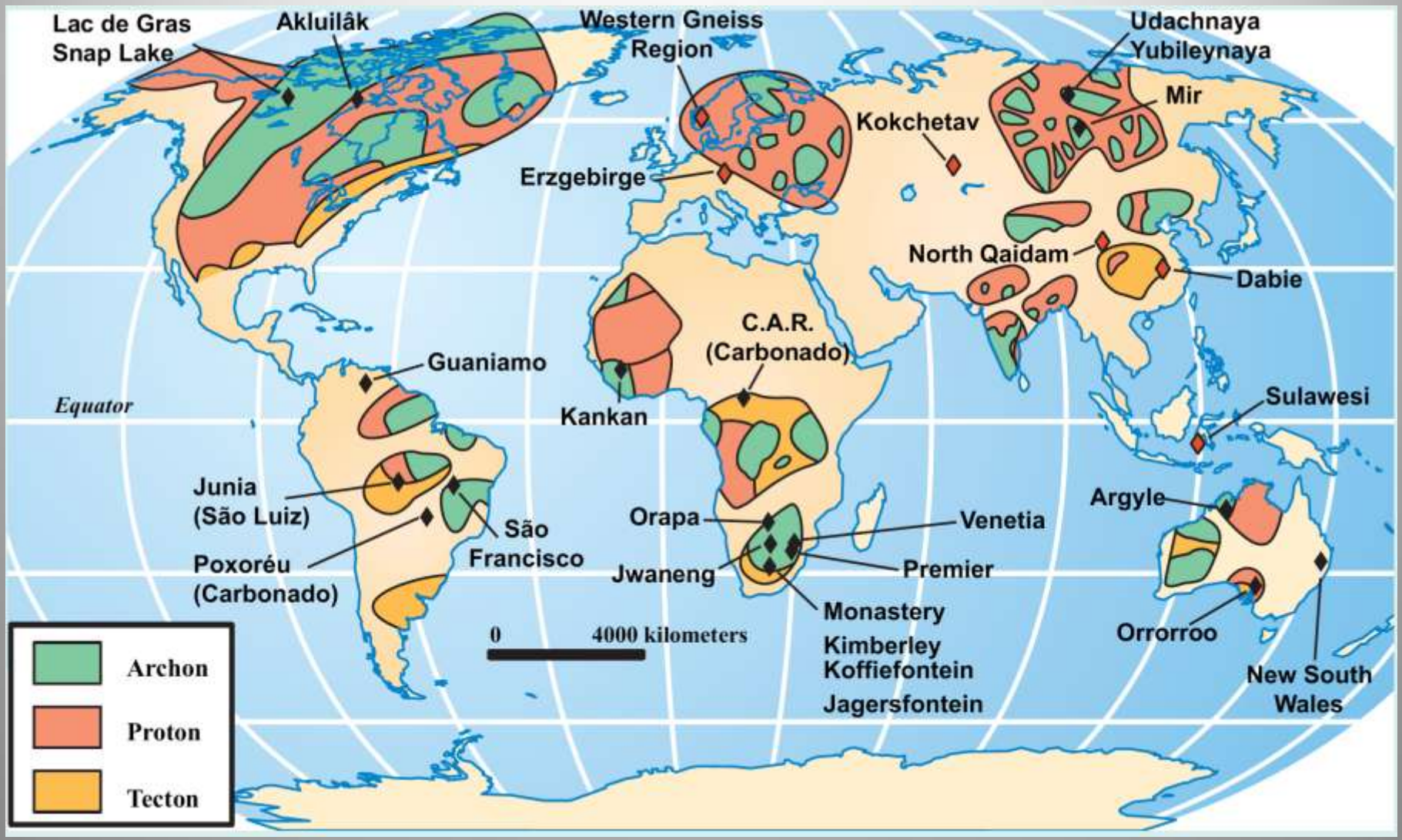
Diamonds from the L-A Boundary Beneath Brazil: Tracers of Deep Carbonated Melts



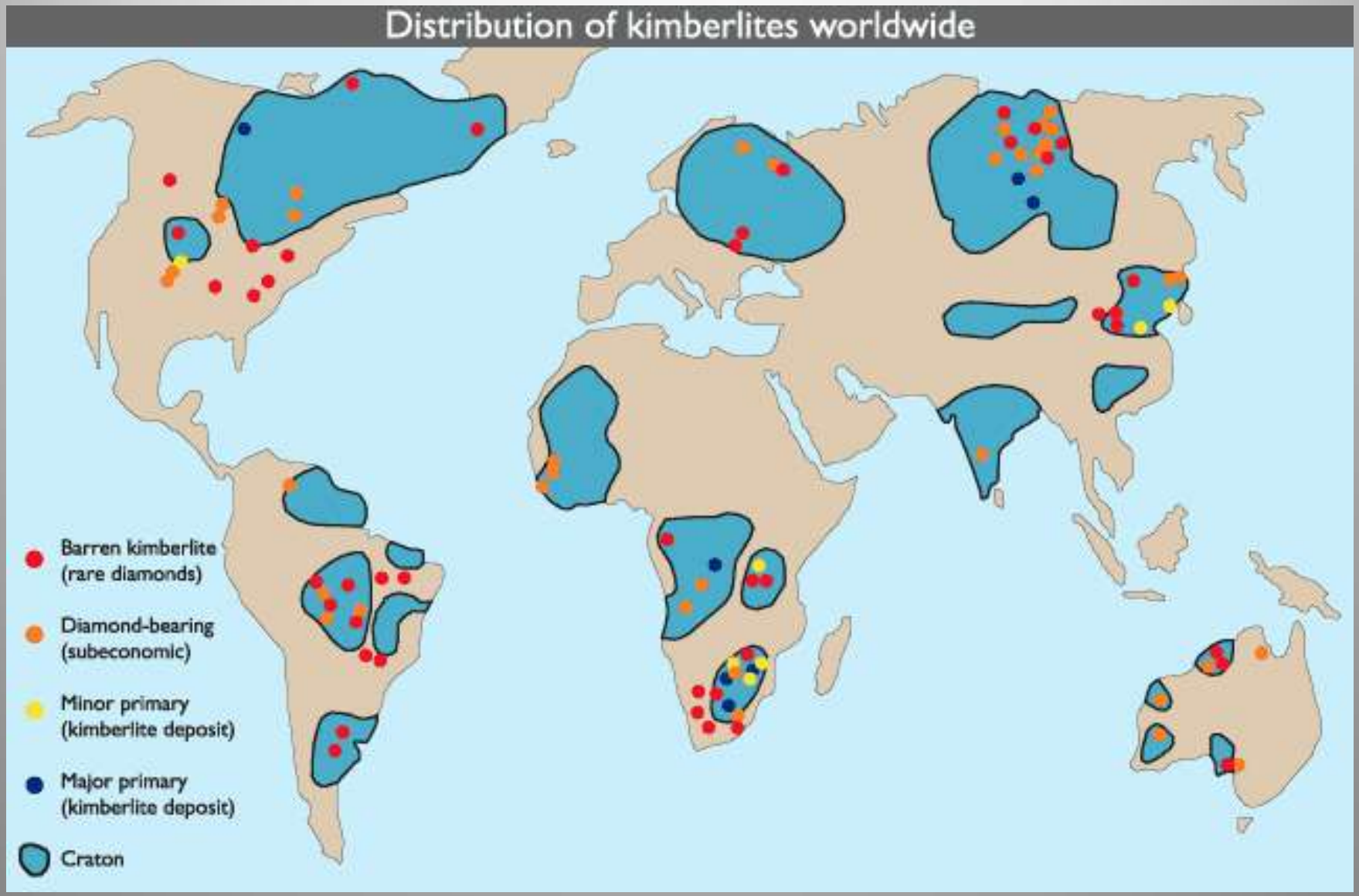
Michael Walter, A Thomson, G Bulanova, S Kohn, C Smith
University of Bristol

Where Are Diamonds Found?

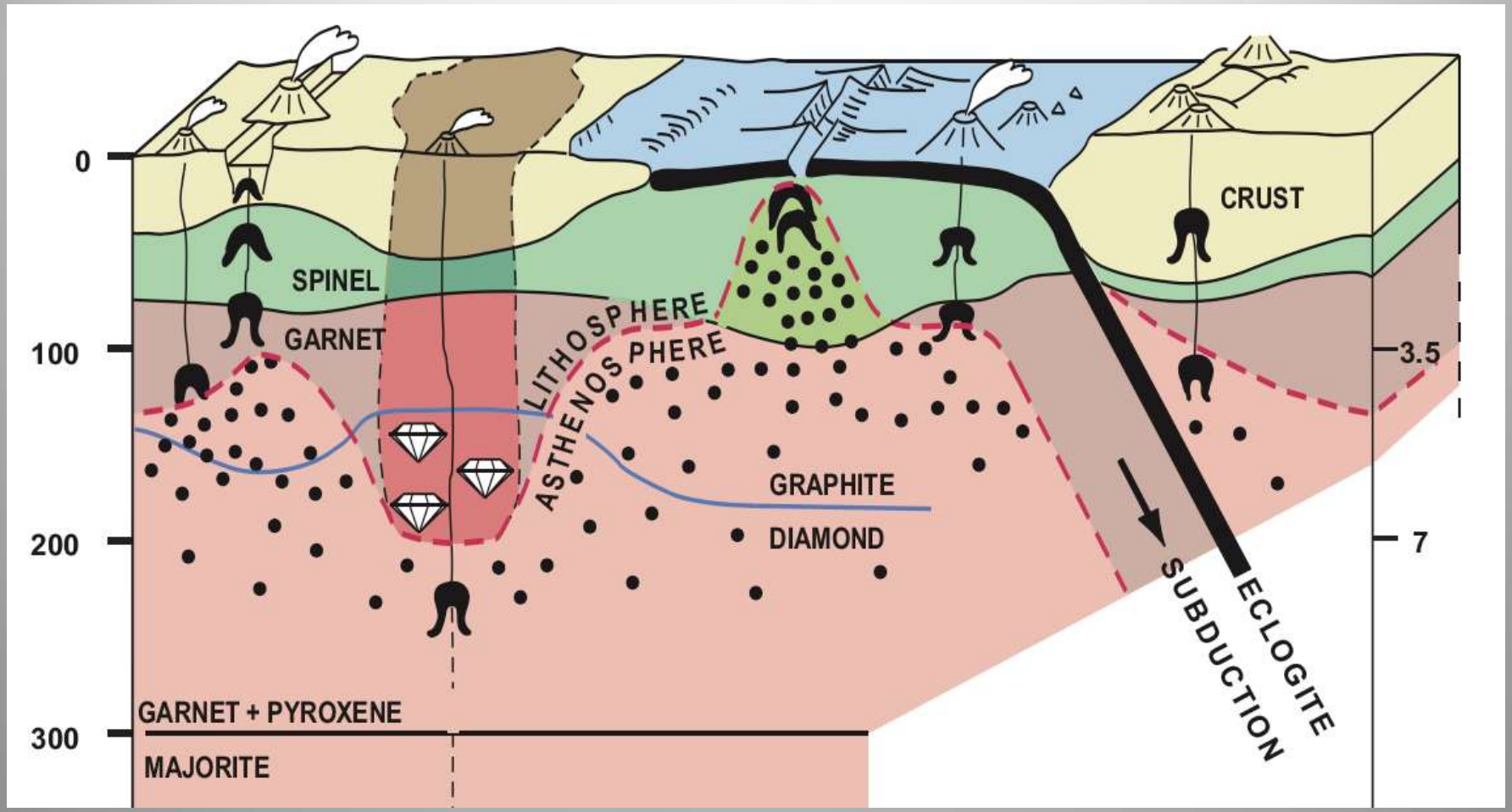


Harlow and Davies 2005

The Kimberlite Connection

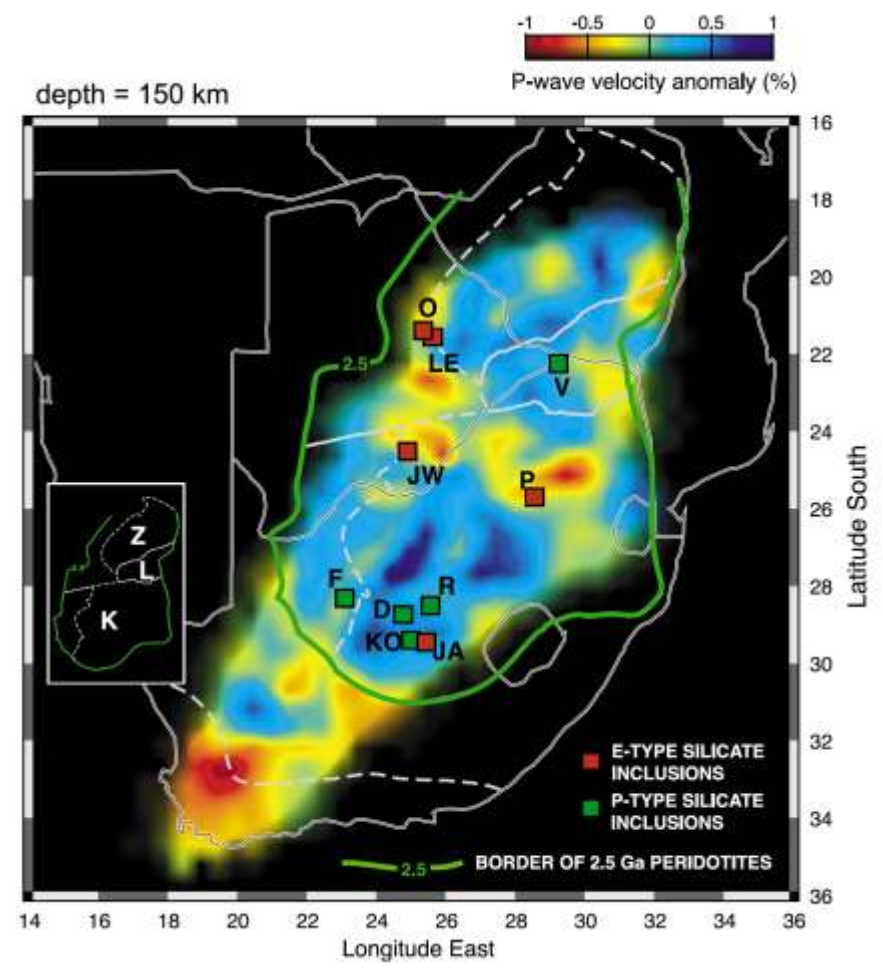


Diamond Source Regions

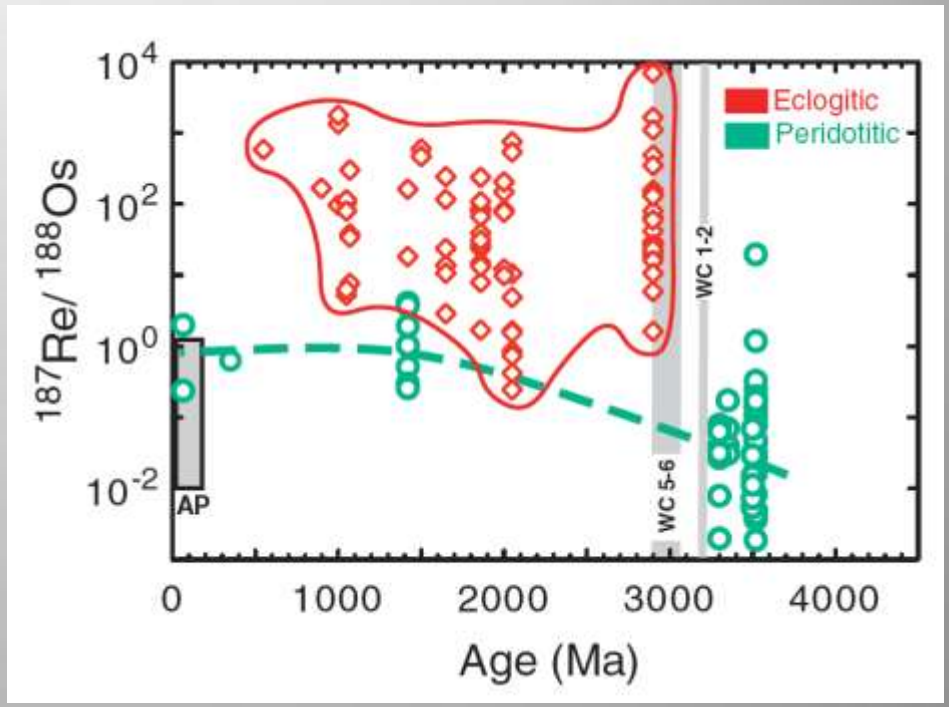


From Stachel et al 2005

Diamond – Lithospheric Probes

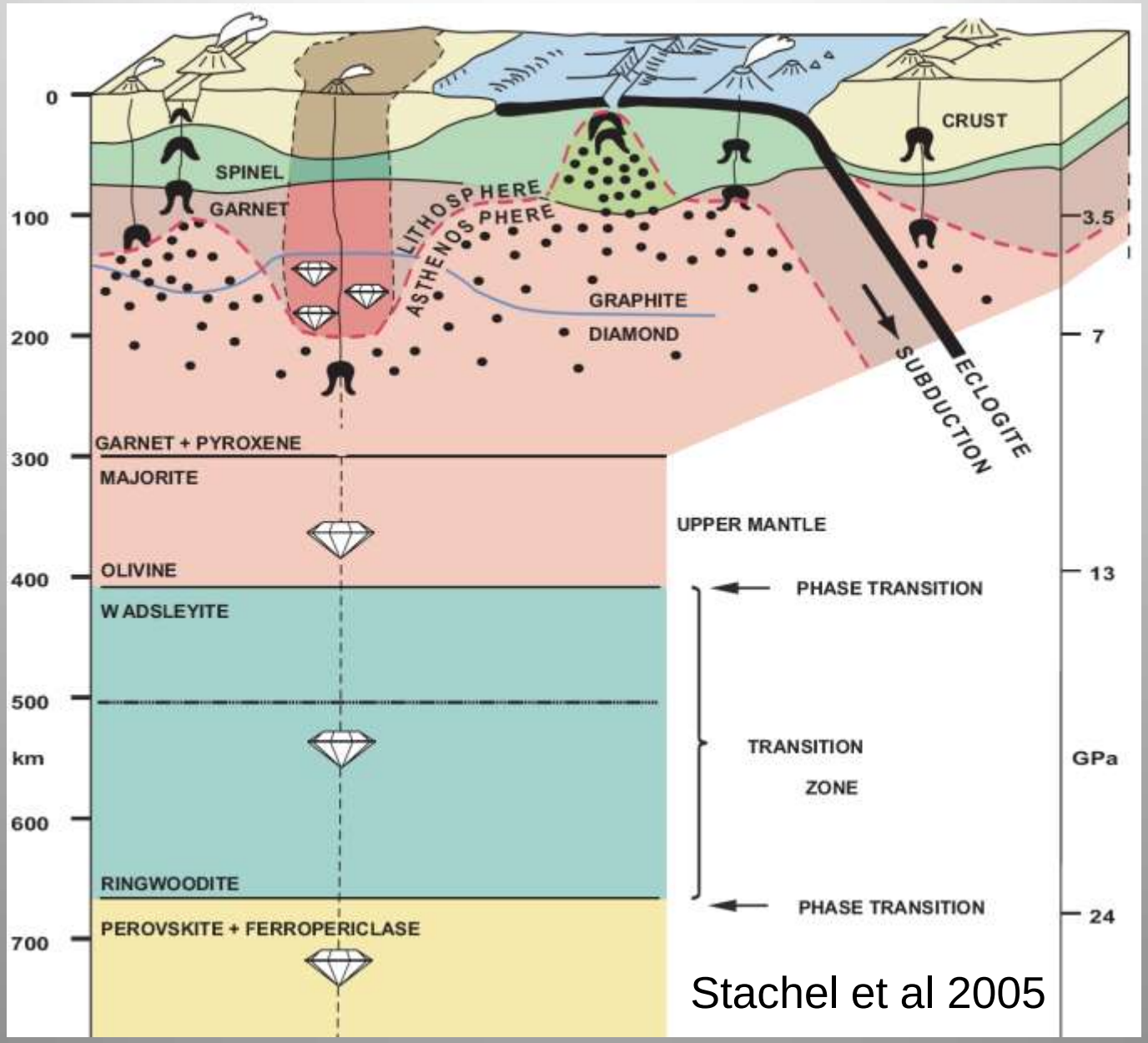


Shirey et al, 2002



Shirey & Richardson, 2011

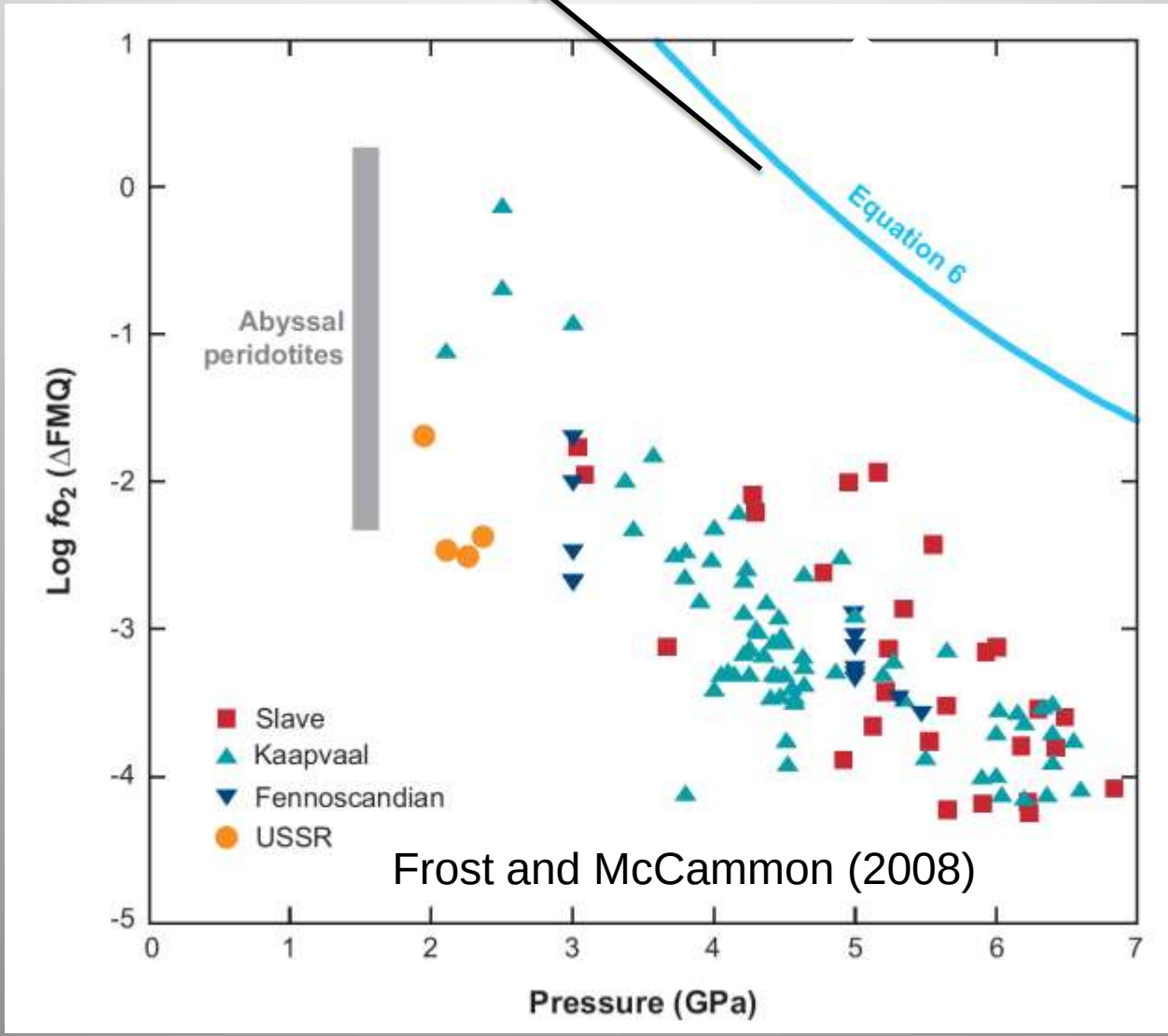
Diamond Source Regions



Stachel et al 2005

What is the mantle oxygen fugacity?

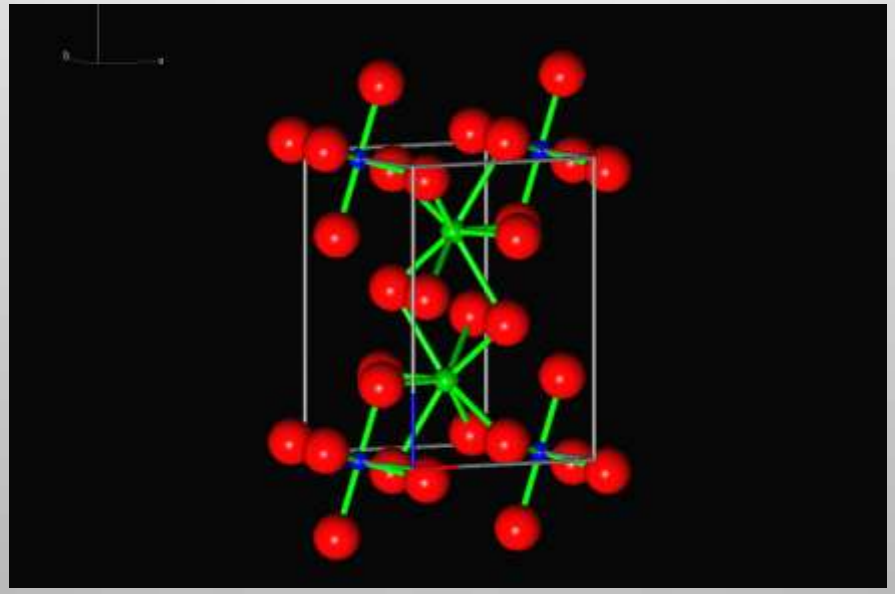
$$2\ Fe_3Fe_2Si_3O_{12} = 4\ Fe_2SiO_4 + 2FeSiO_3 + O_2$$



Frost and McCammon (2008)

Iron Disproportionation in Mg-perovskite

Perovskite Cation Substitution

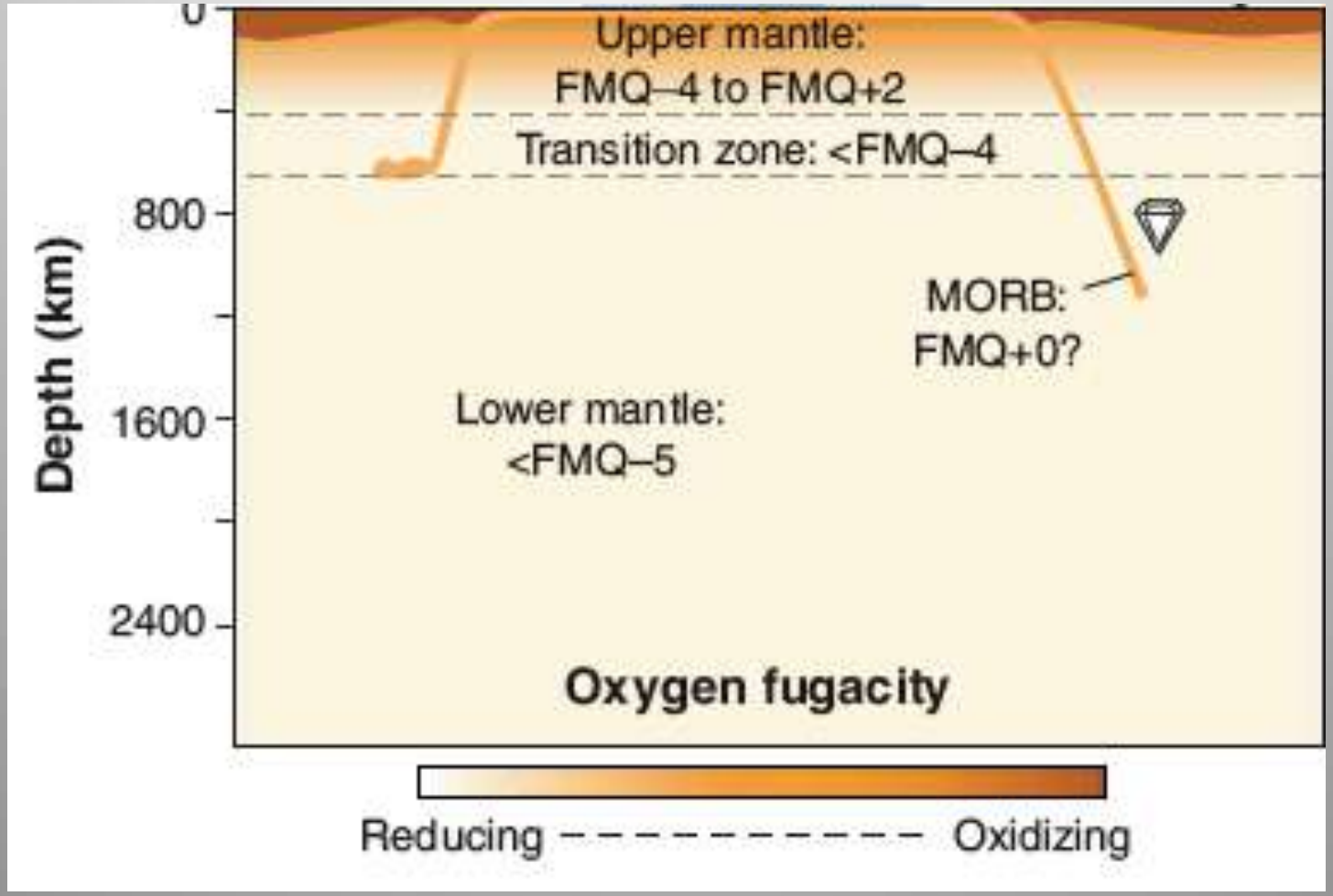


$$Fe^{3+}_{VIII} + Al^{3+}_{VI} \leftrightarrow Mg^{2+}_{VIII} + Si^{4+}_{VI}$$

$$3Fe^{2+}O \leftrightarrow Fe^{3+}_{2}O_{3,perovskite} + Fe^{o}_{metal}$$

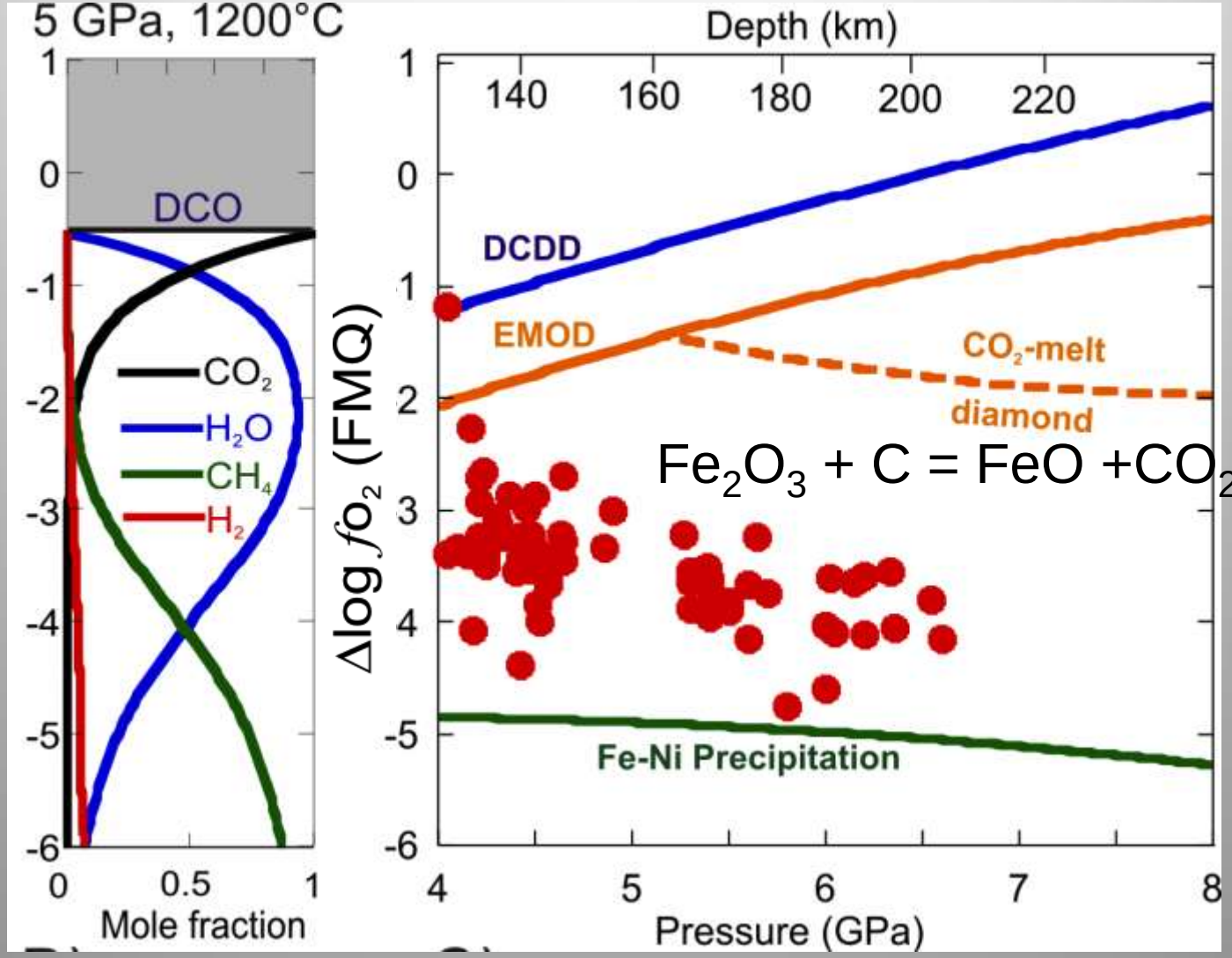
Frost et al, Nature 2004

Upper Mantle is Oxidizing
Transition Zone & Lower Mantle are likely to be Reducing



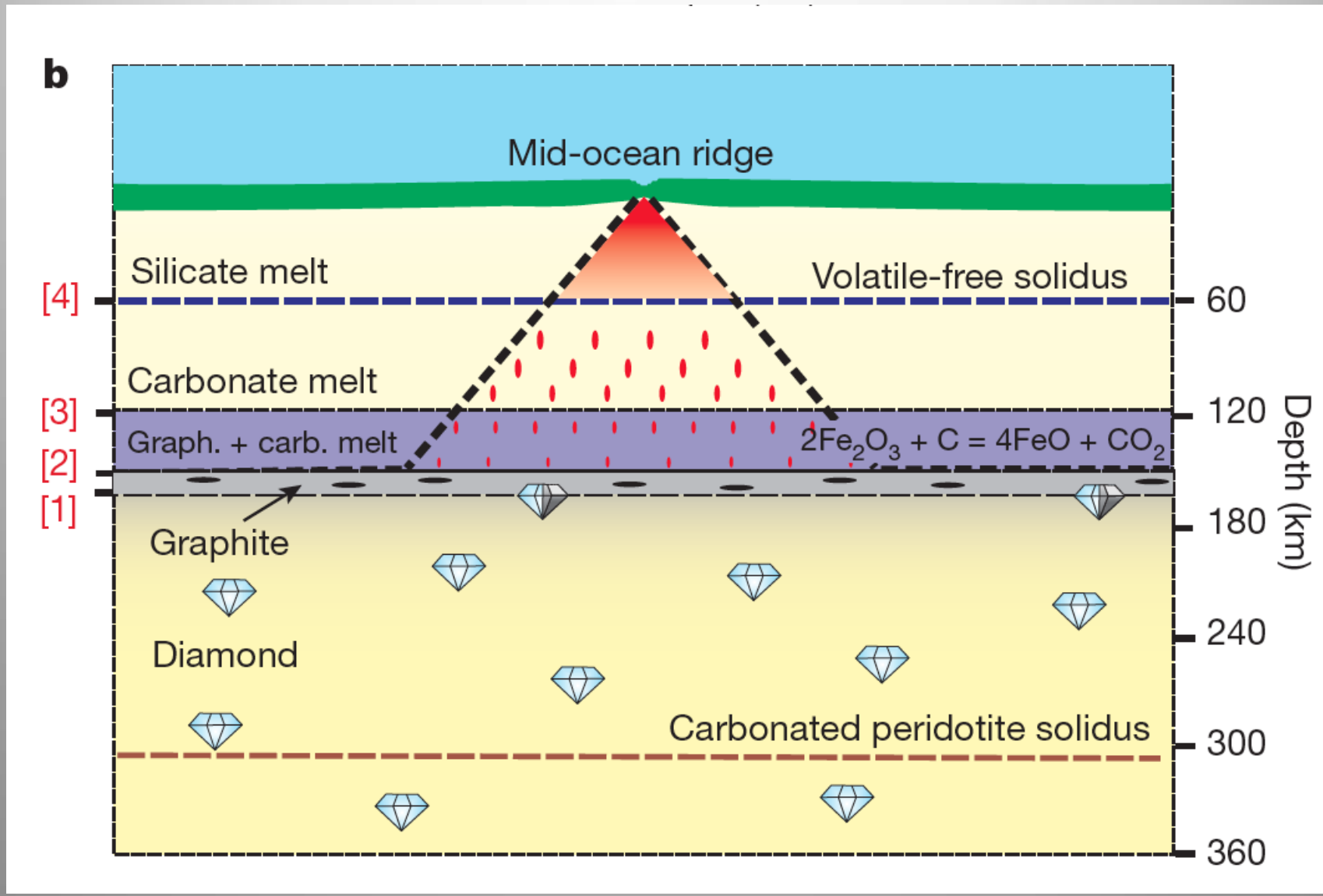
McCammon, *Science*, 2005

Carbon Speciation and Mantle Oxygen Fugacity



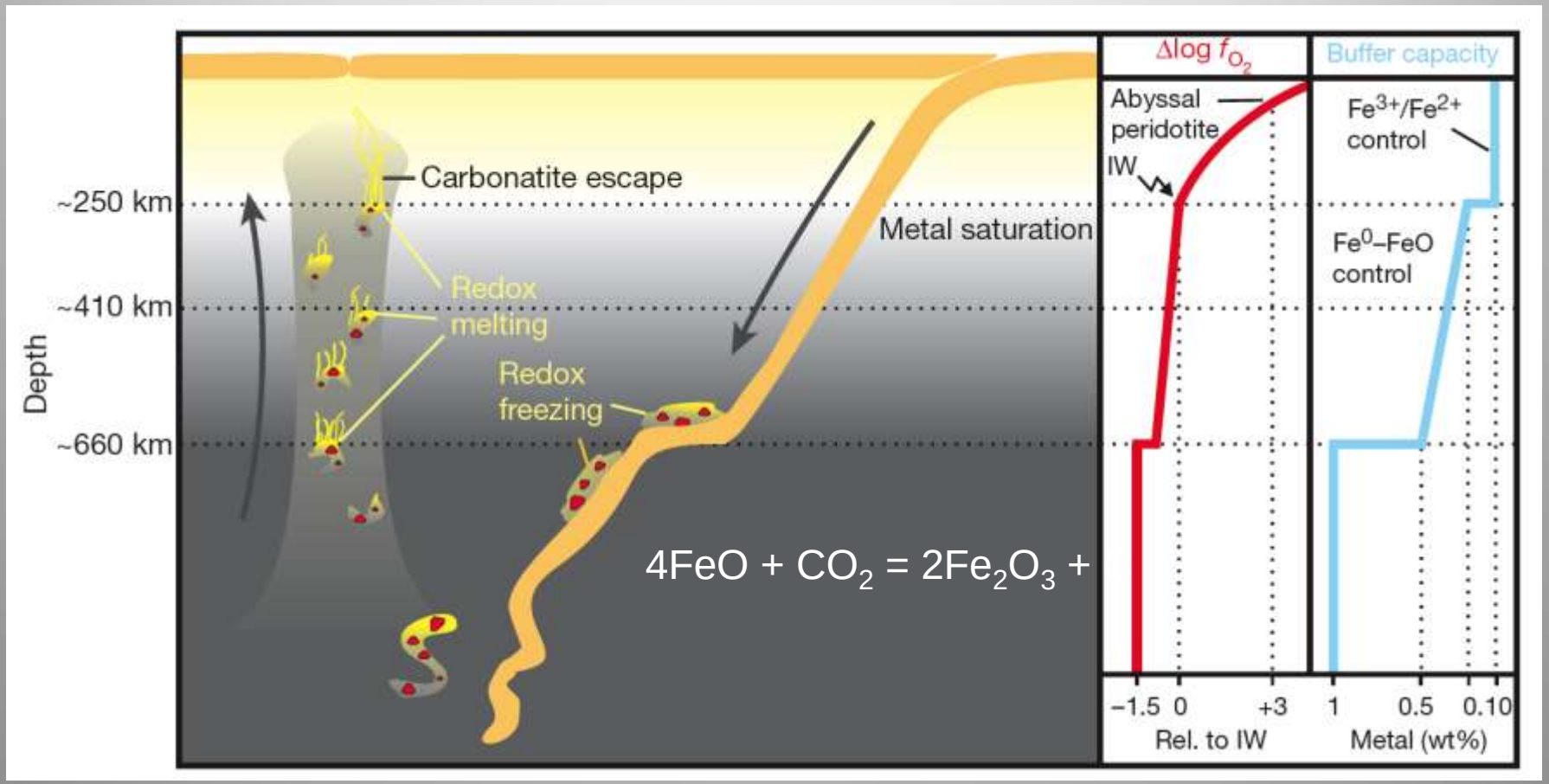
Shirey et al Reviews in Mineralogy, 2013

Redox Melting



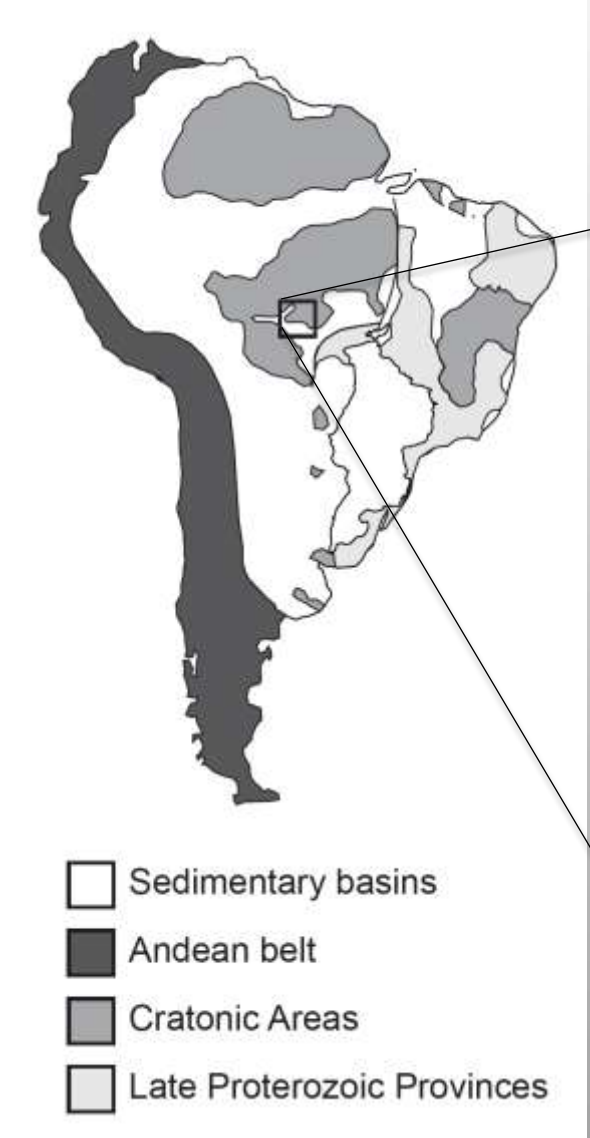
Stagno et al (2013)

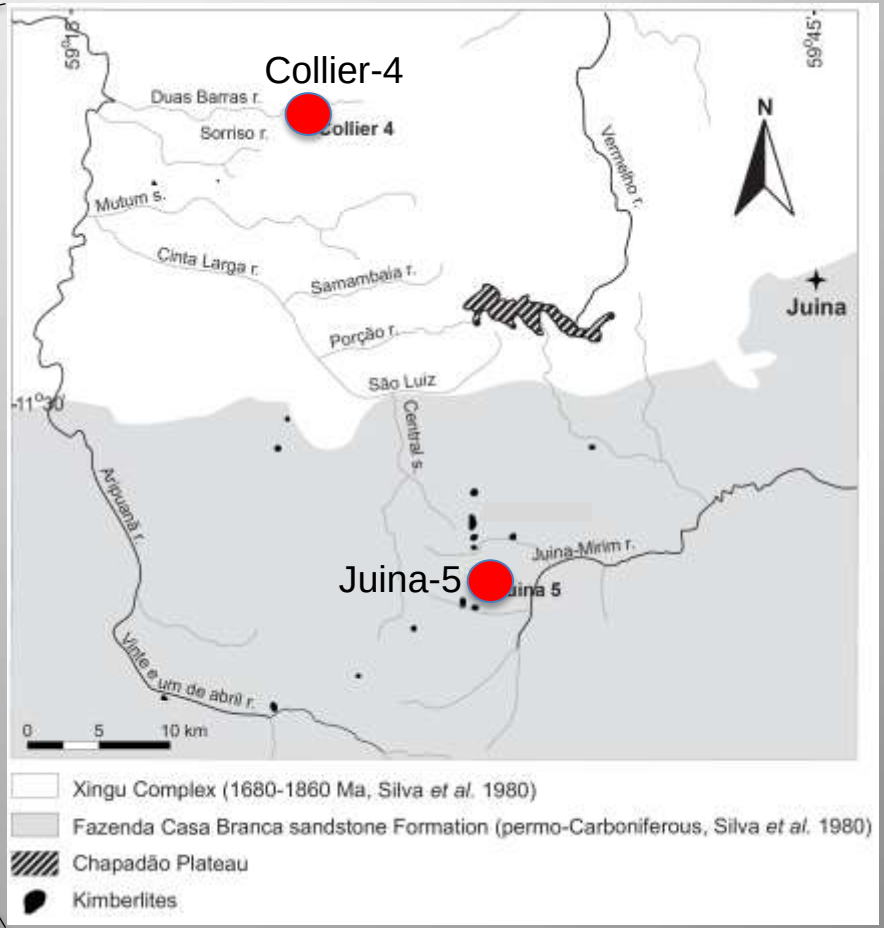
Redox Freezing



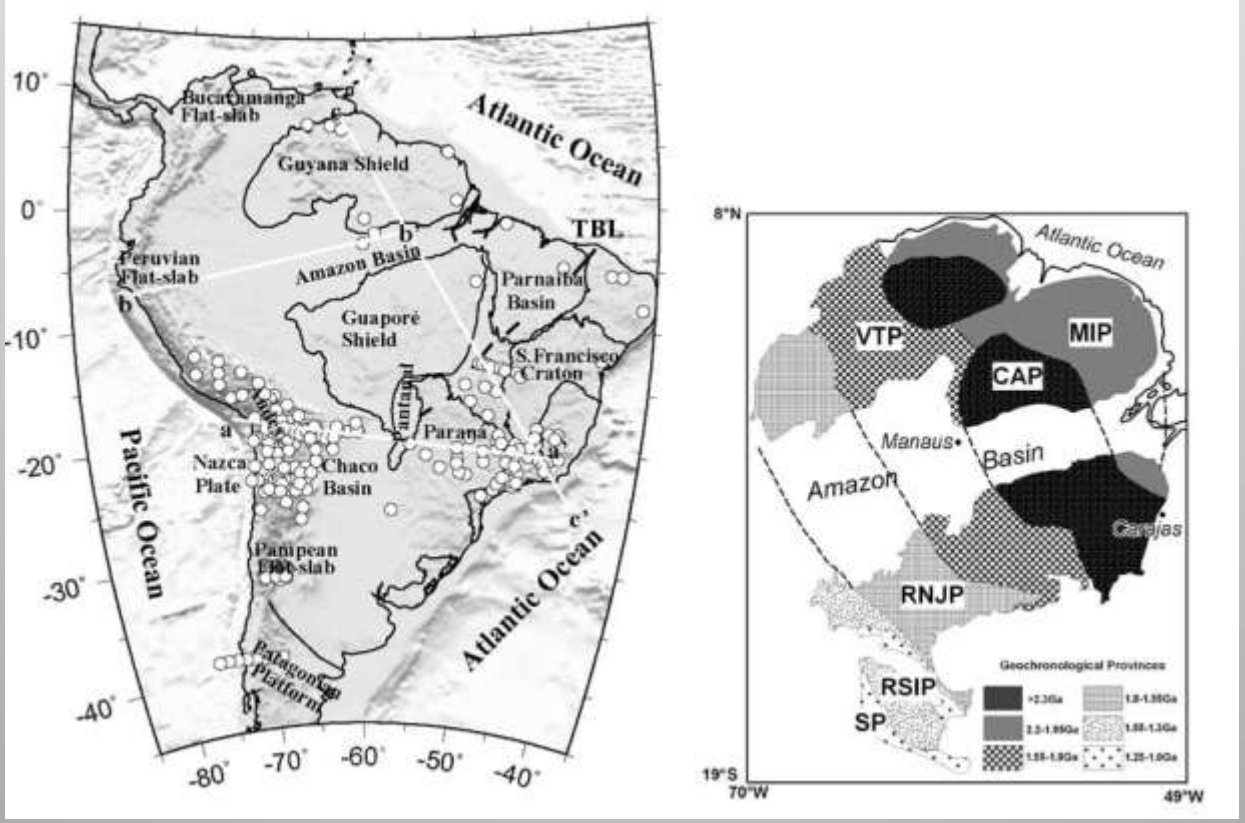
Rohrbach and Schmidt 2011

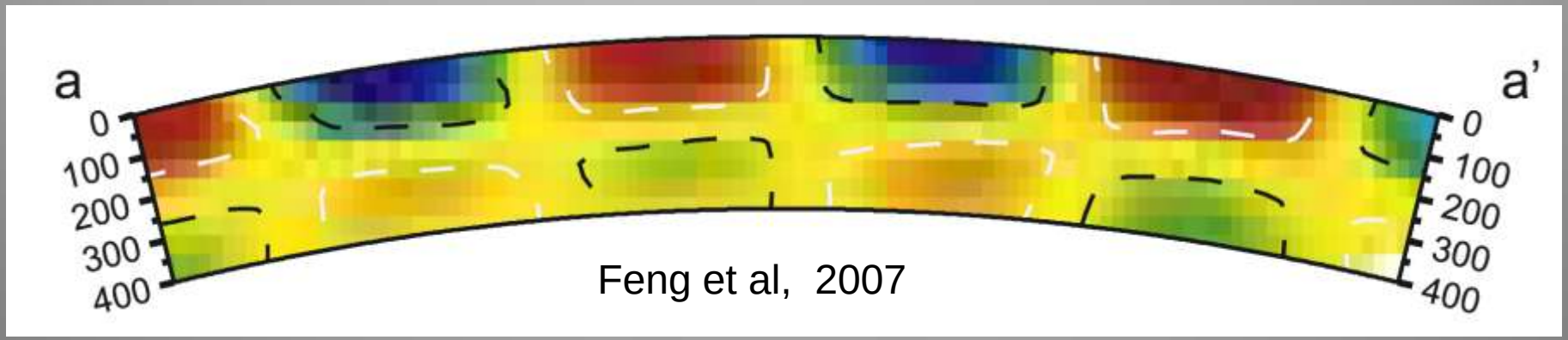
Superdeep Diamonds
Juina Region, Brazil





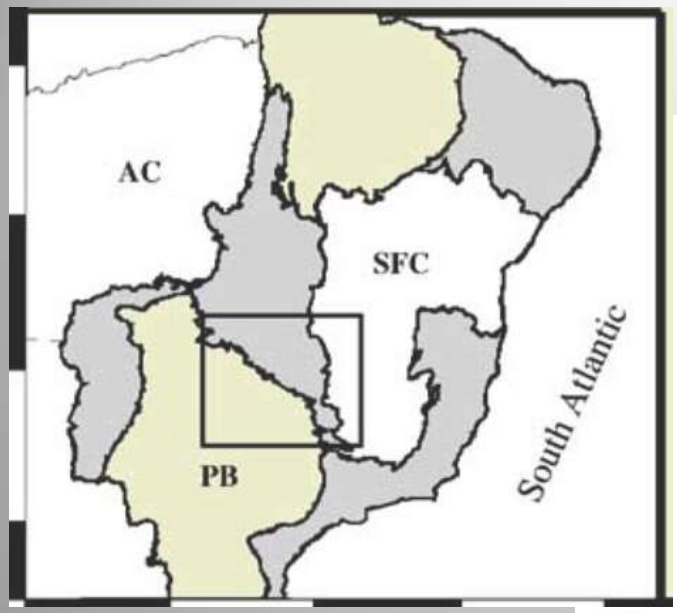
The LA Boundary – The Amazon Craton



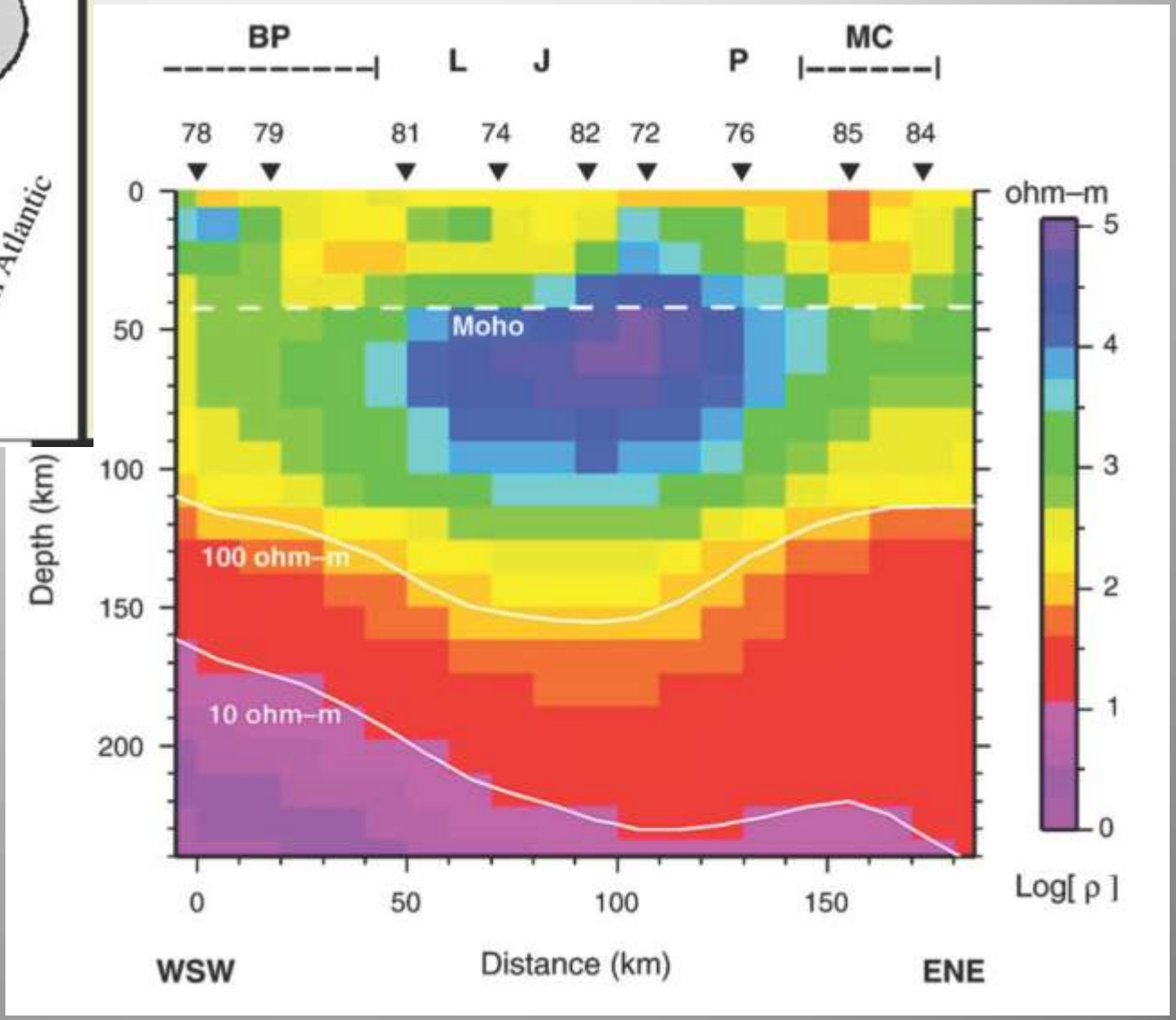


Feng et al, 2007

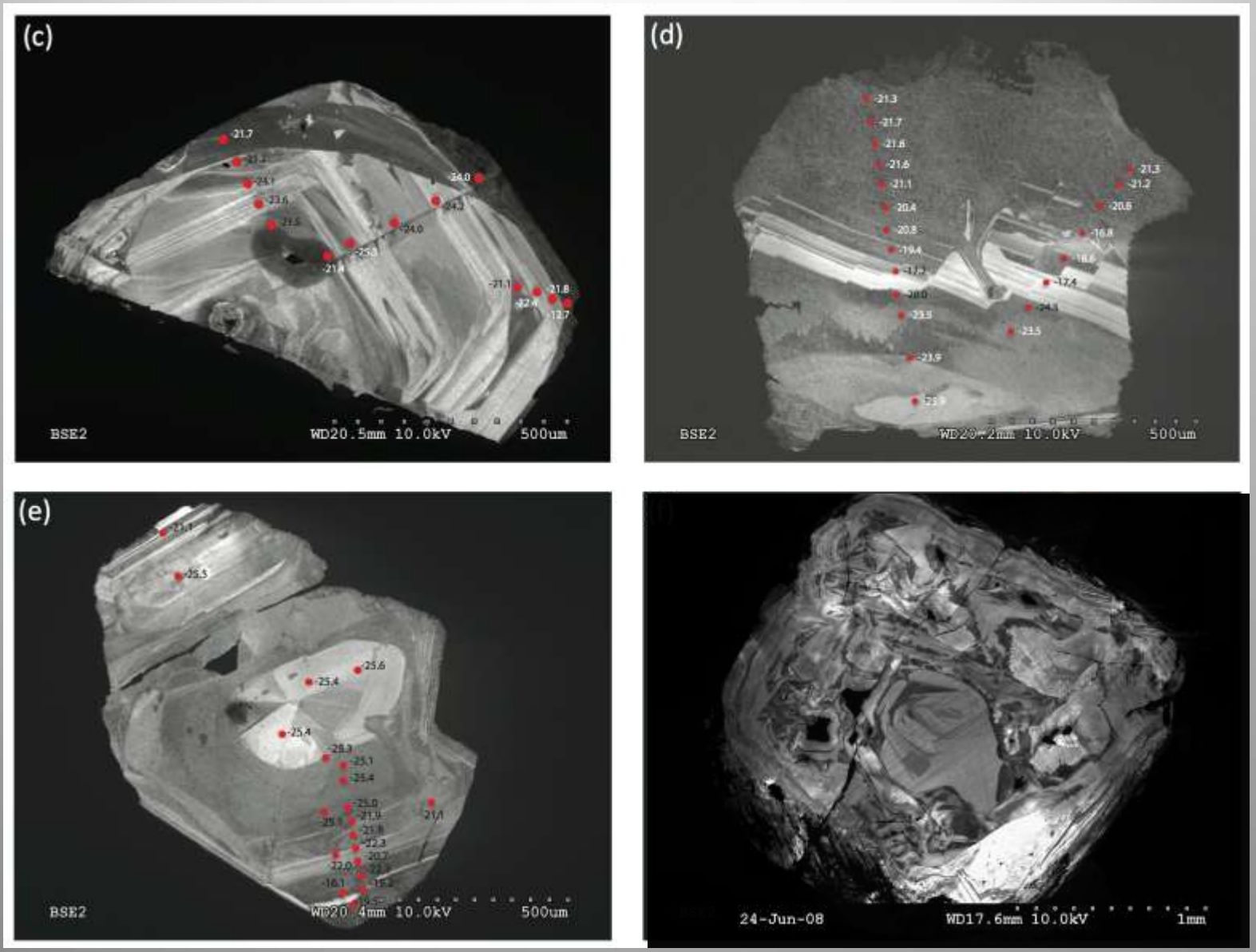
The LA Boundary - MT



Bologna et al, 2006



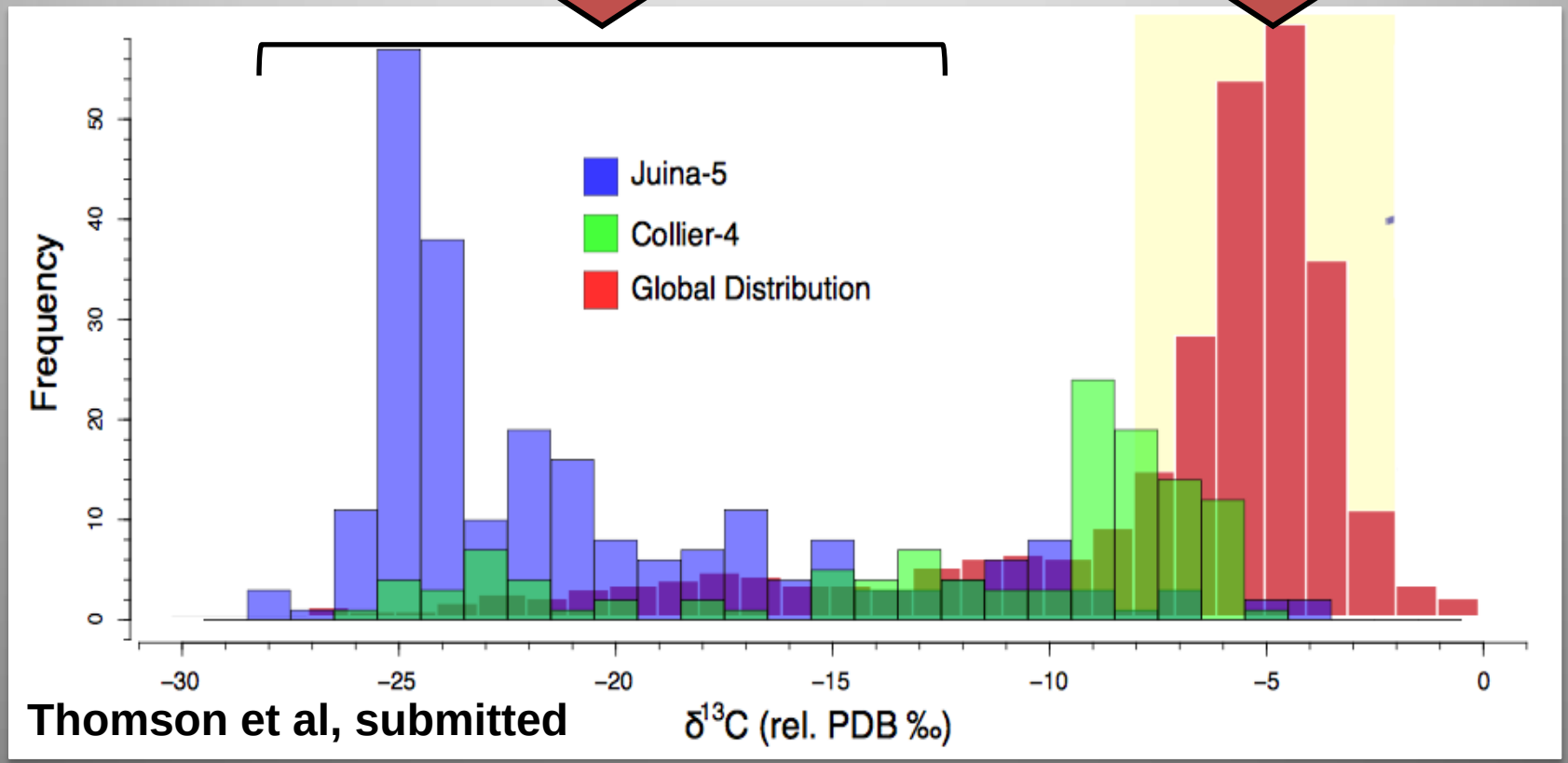
Juina Diamonds – Type II



Carbon Isotopes Suggestive of Recycled Carbon

Recycled organic carbon

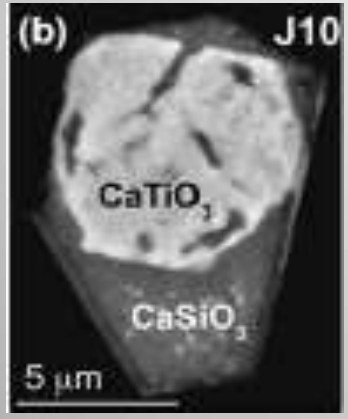
"Mantle" carbon

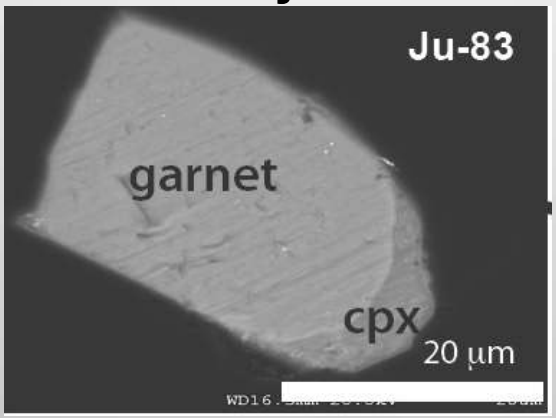


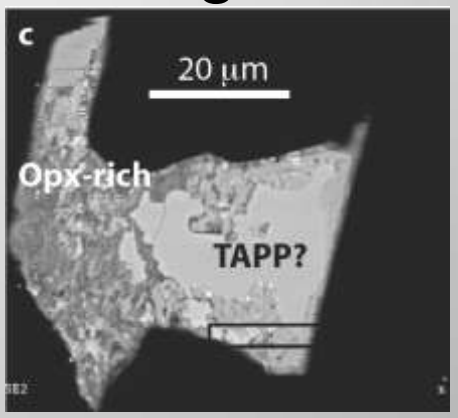
Thomson et al, submitted

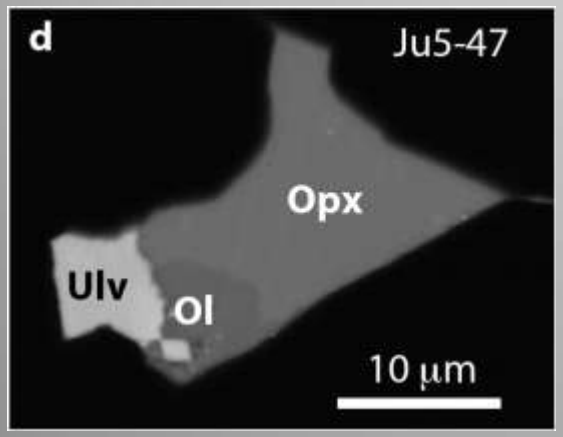
Multi-phase, Composite Inclusions Common

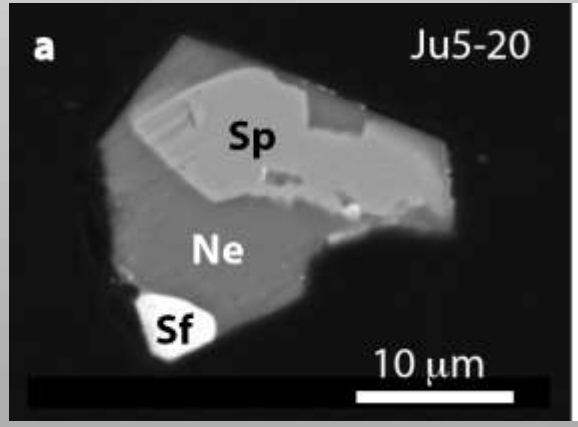
Ca-Pv majorite Mg-Pv

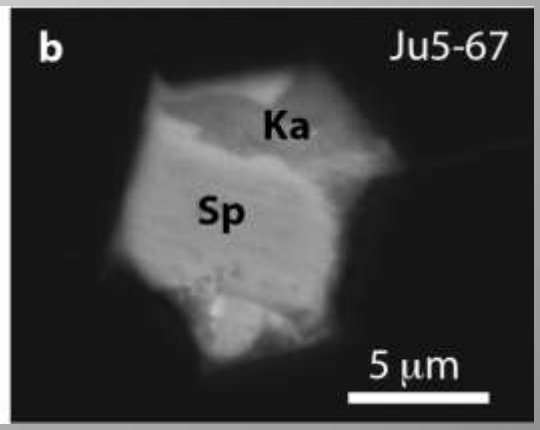








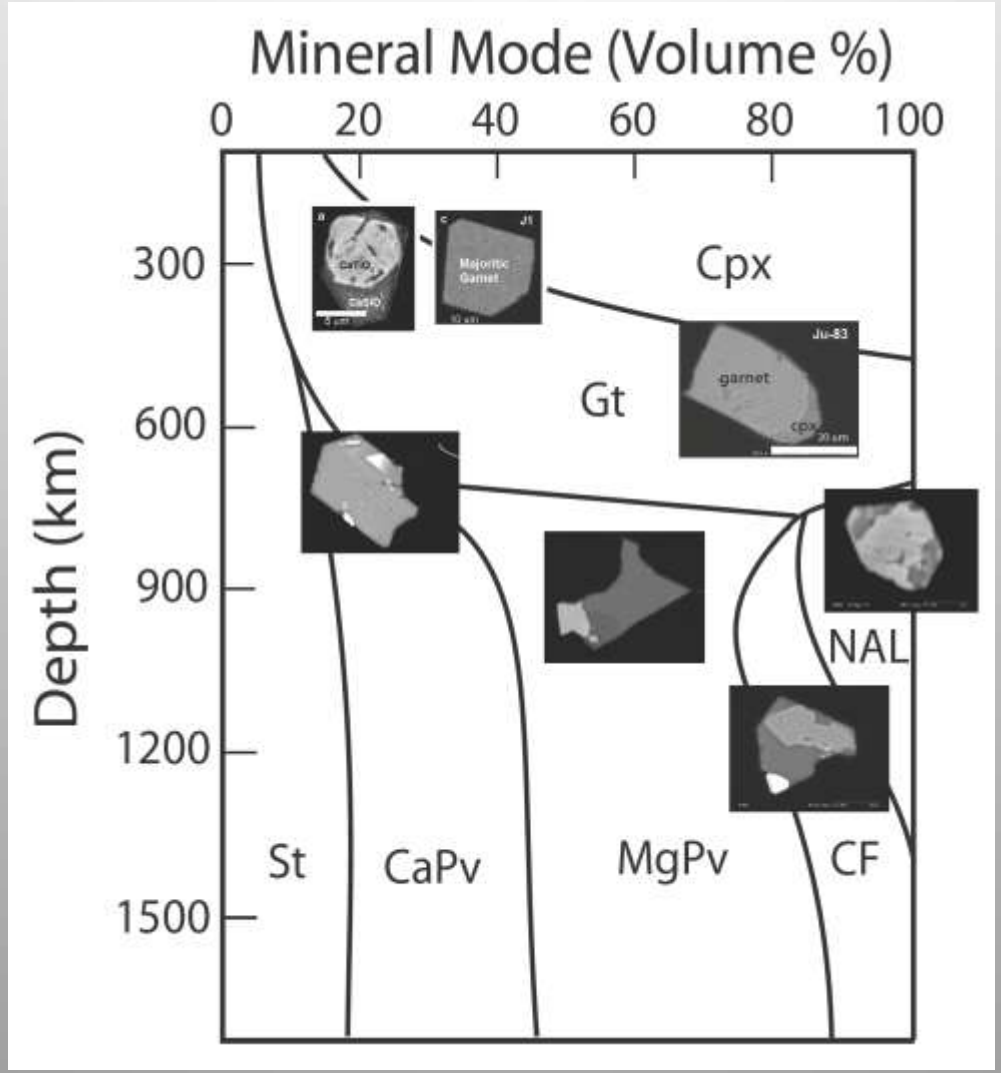




Mg-Pv CF-phase NAL-phase

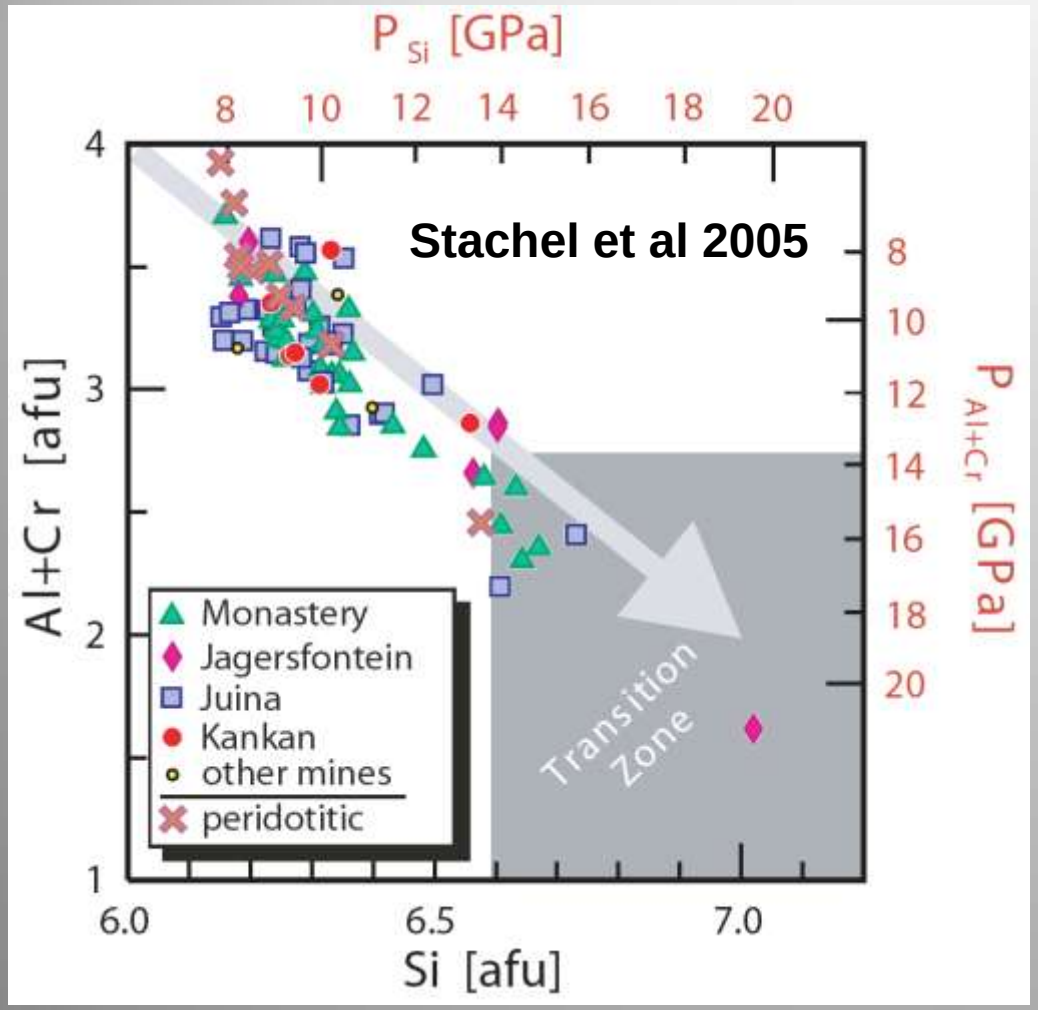
Polybaric Inclusion Crystallization

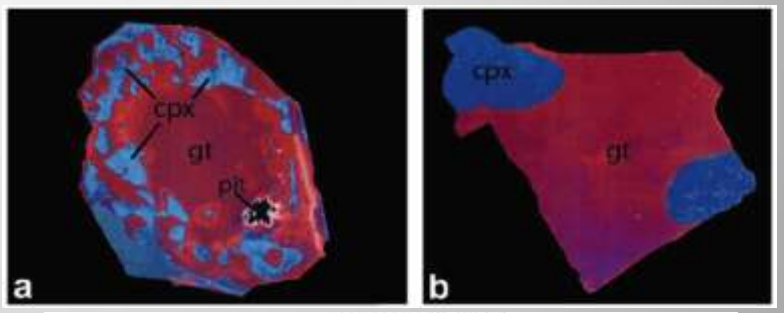
Subducted Oceanic Crust a Key Component



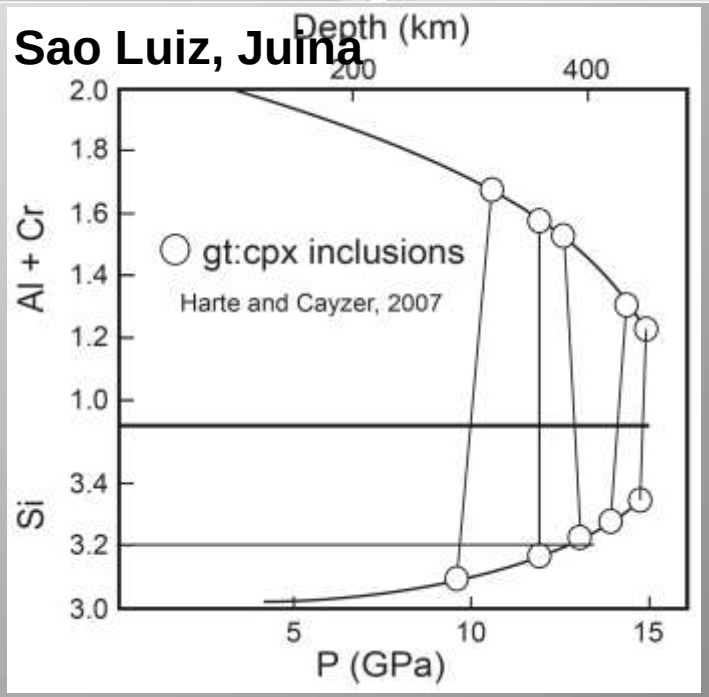
Walter et al (2011)

Majorite Garnet Barometry

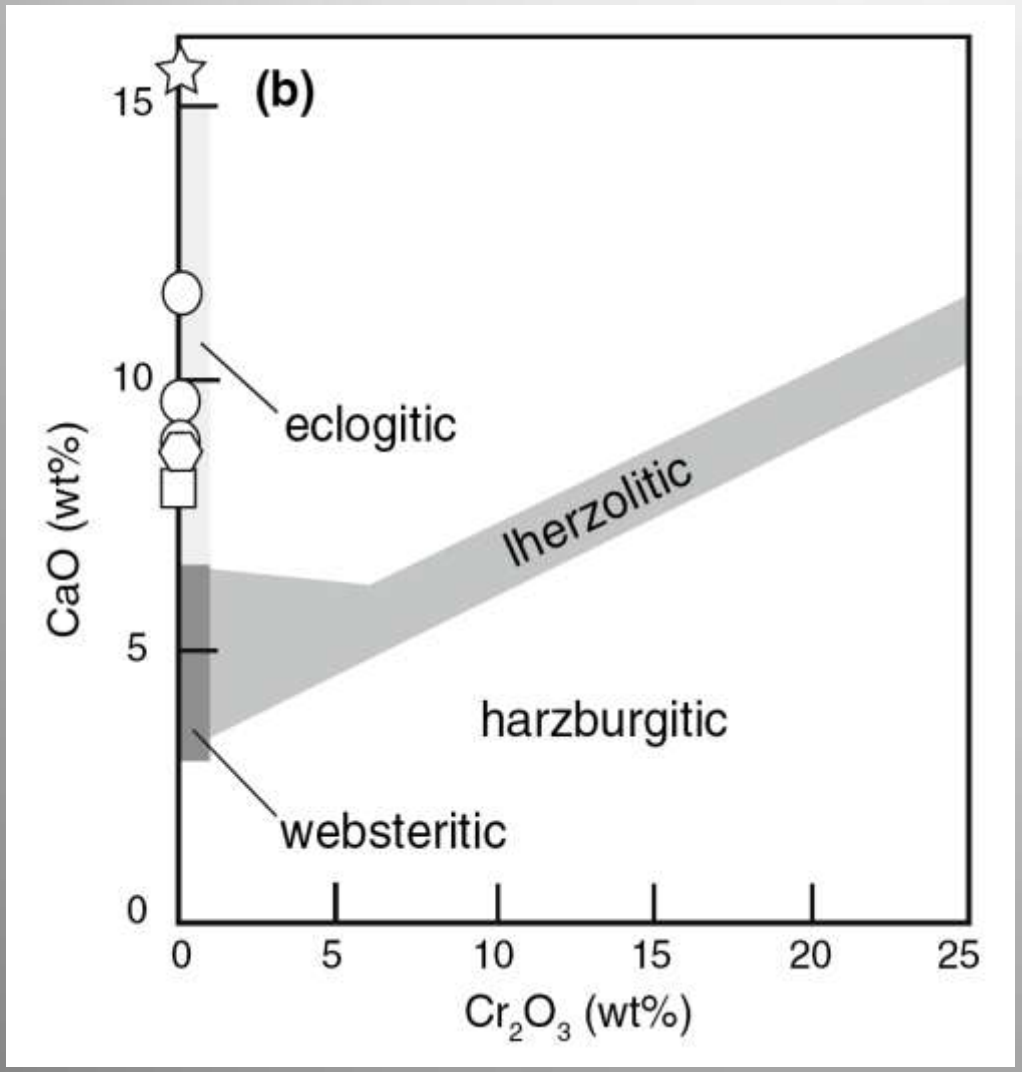


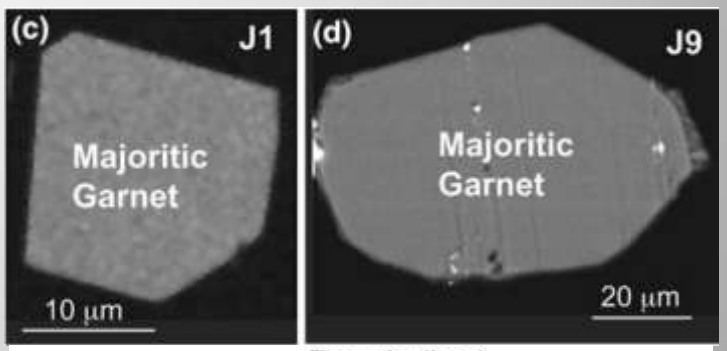


Sao Luiz, Juina

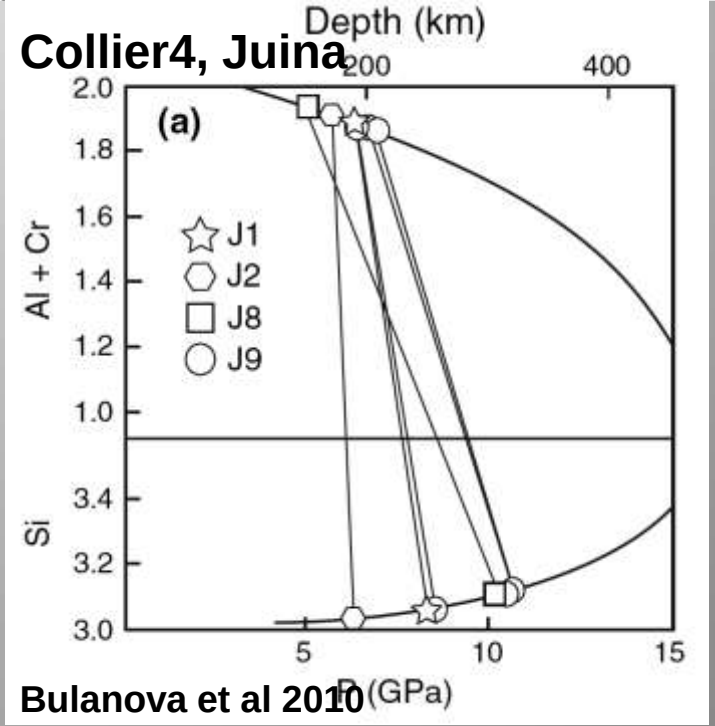


Juina Majorite Garnets are ‘Eclogitic’



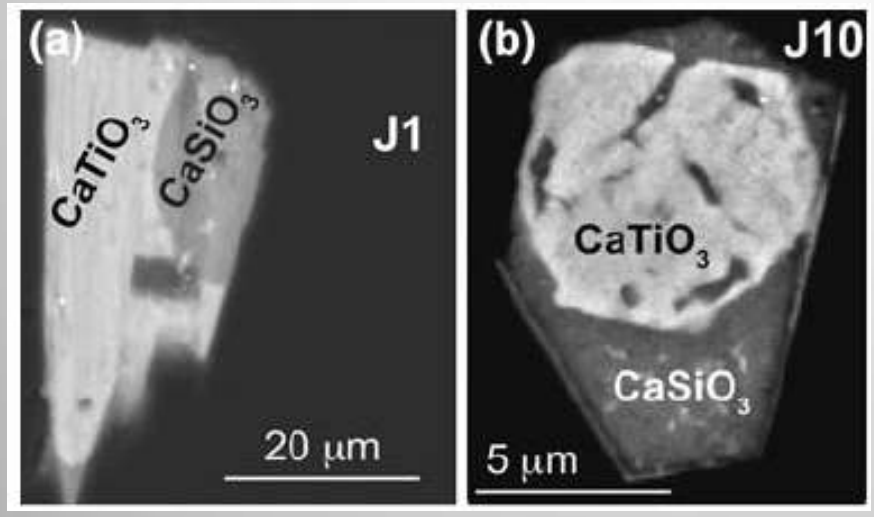


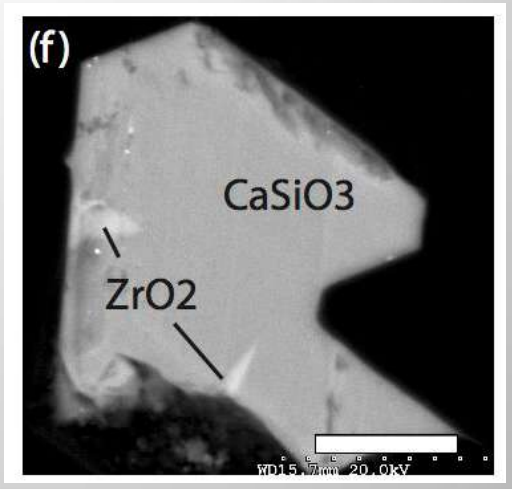
Collier4, Juina

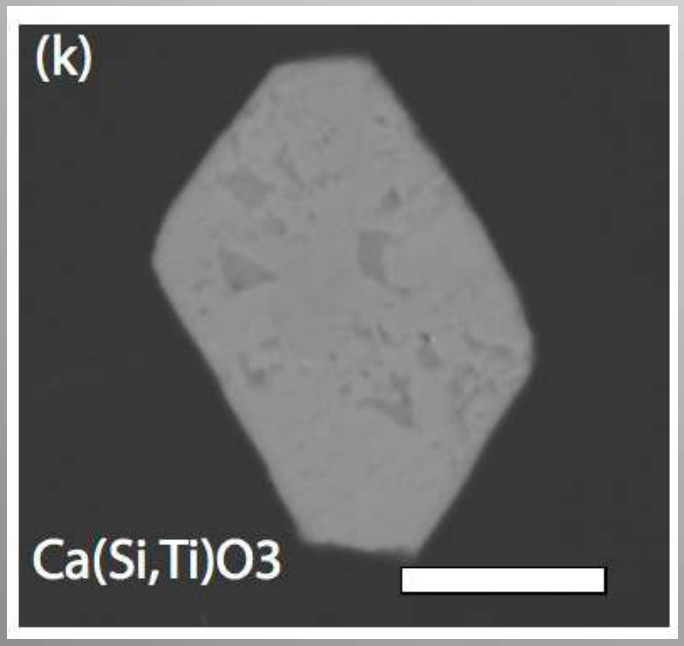


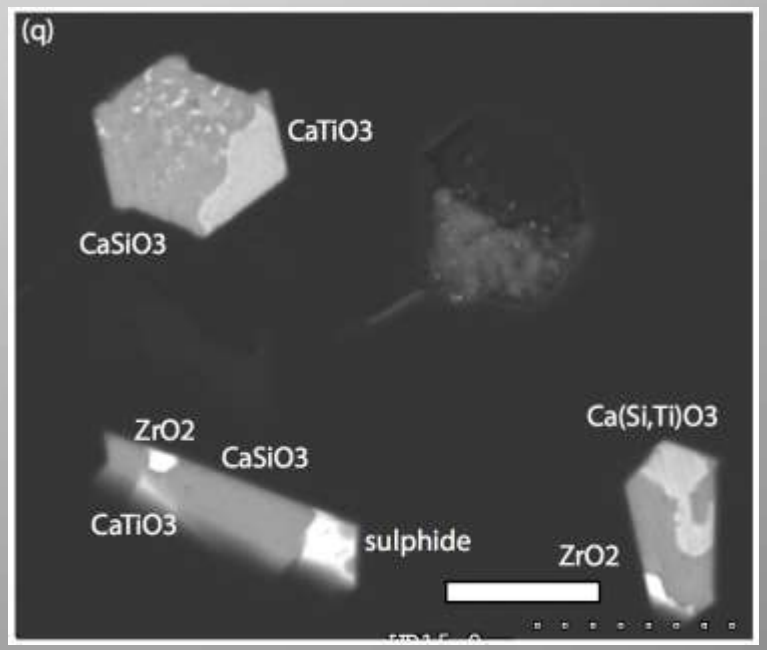
Bulanova et al 2010

Composite CaTiSi-rich (‘perovsite’) Inclusions

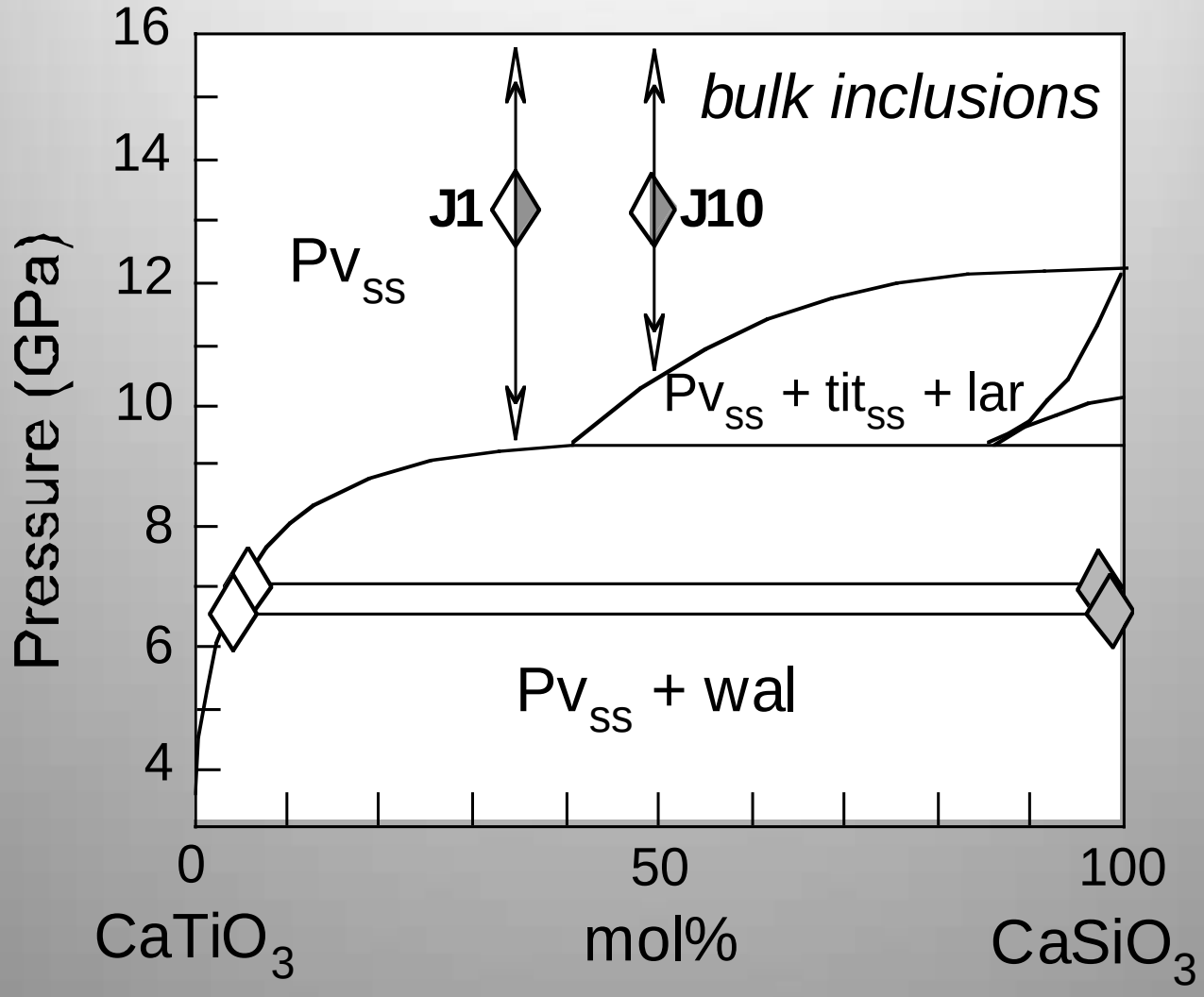






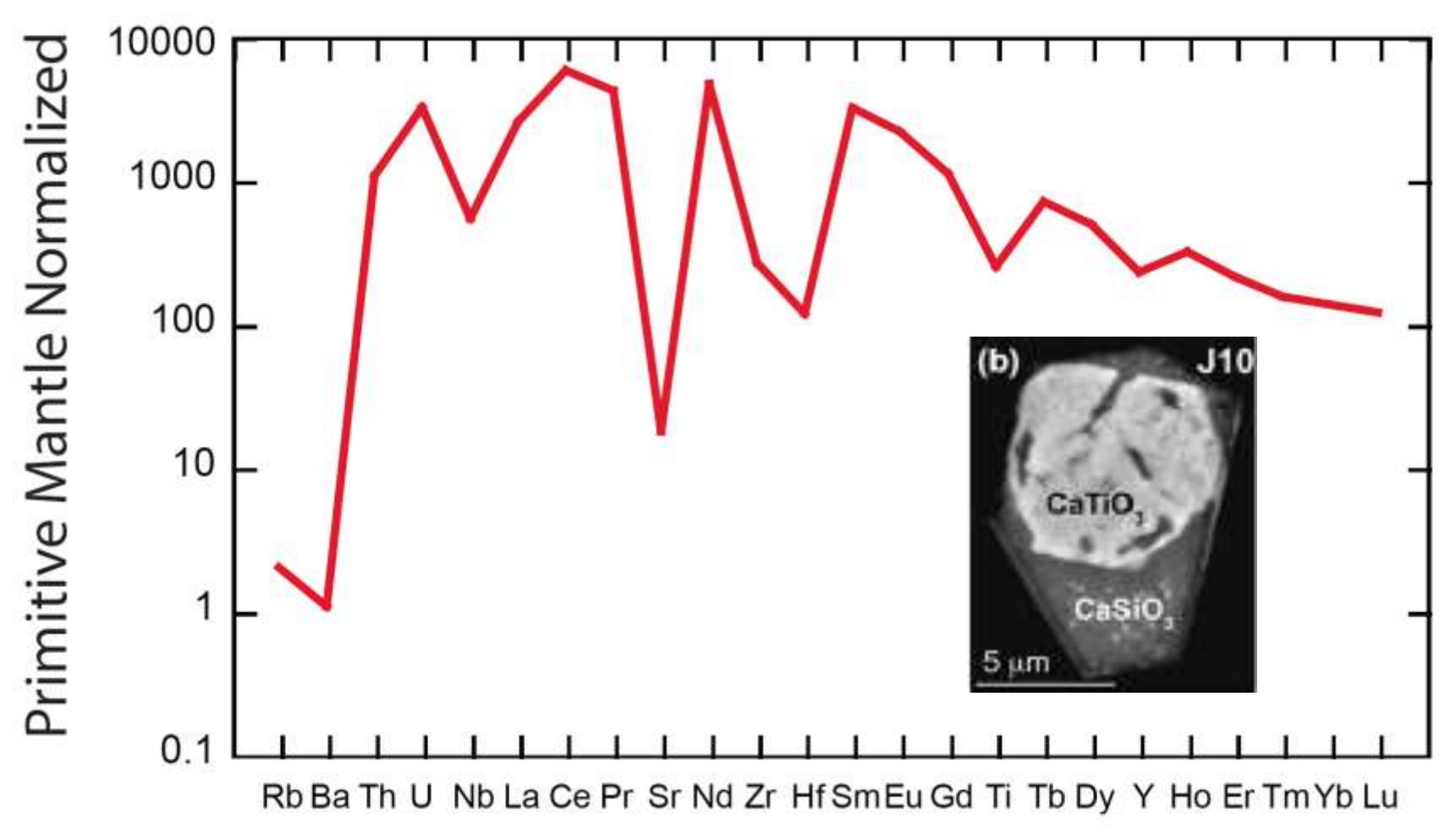


Composite CaTiSi-rich (‘perovsite’) Inclusions



Walter et al 2008

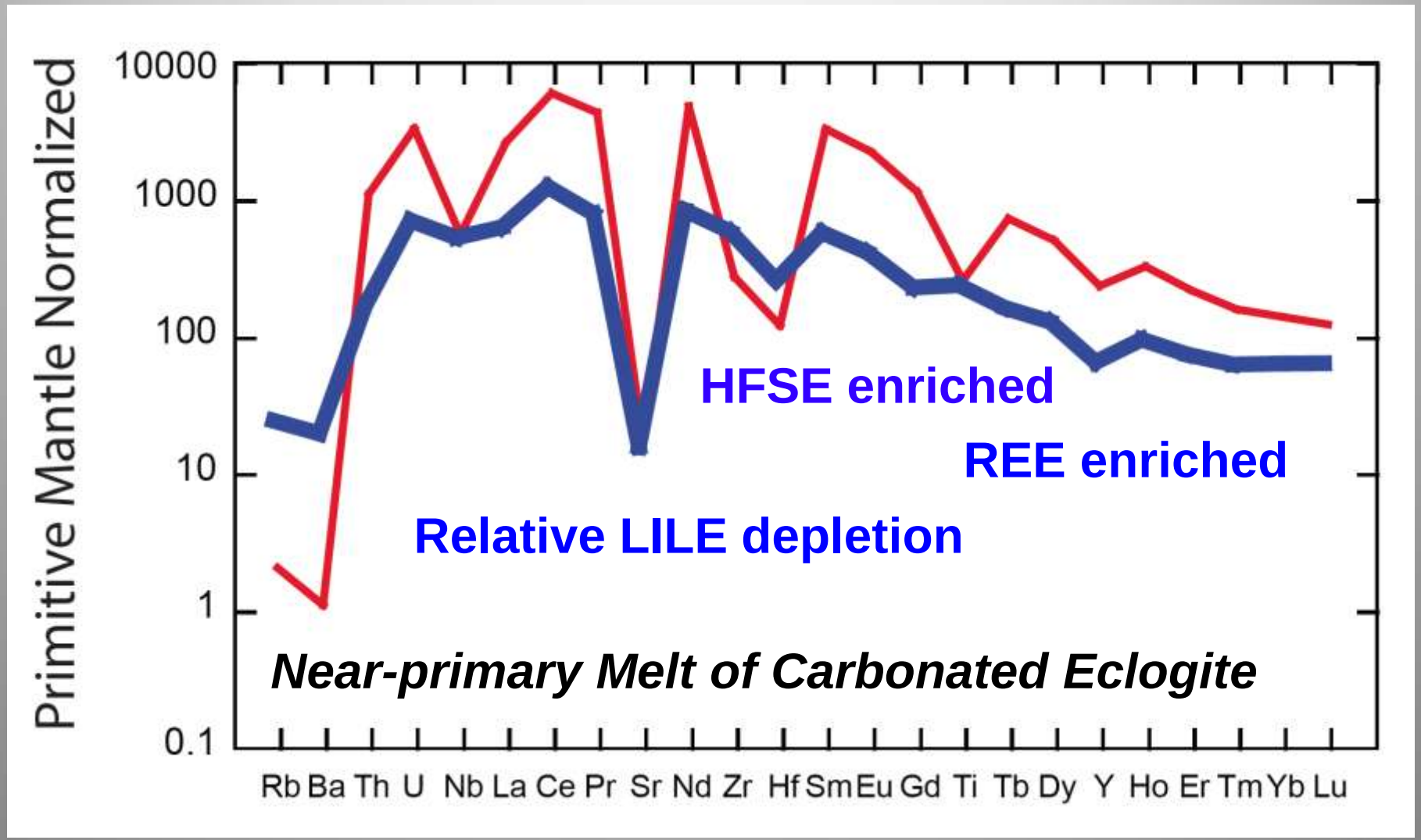
Ca-perovskite from Juina excessively enriched in trace element



Walter et al, 2008

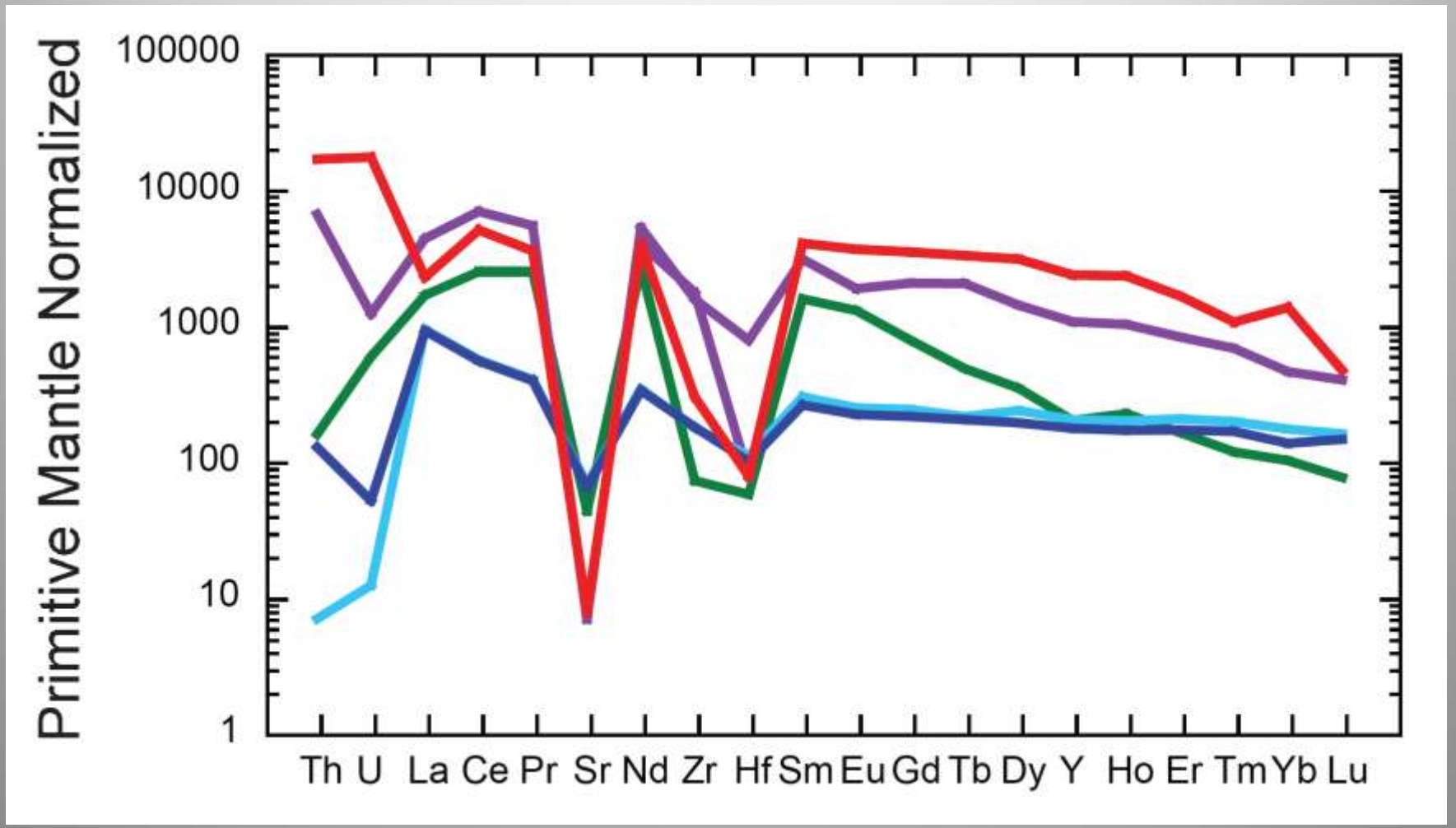
Calculated Melt Equilibrated with CaTiSi-Pv

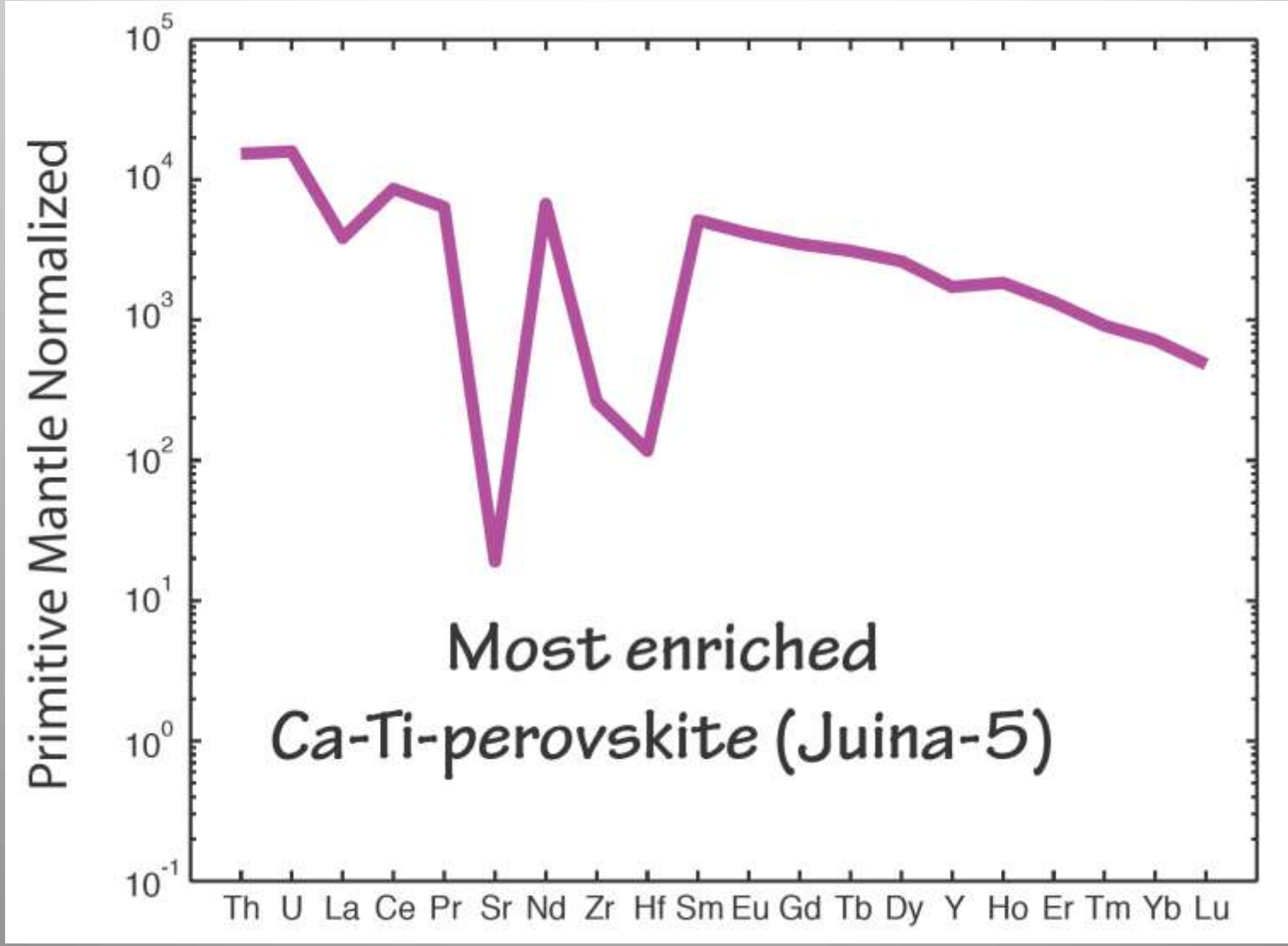
$$C^{melt} = C^{mineral} / D^{min/melt}$$

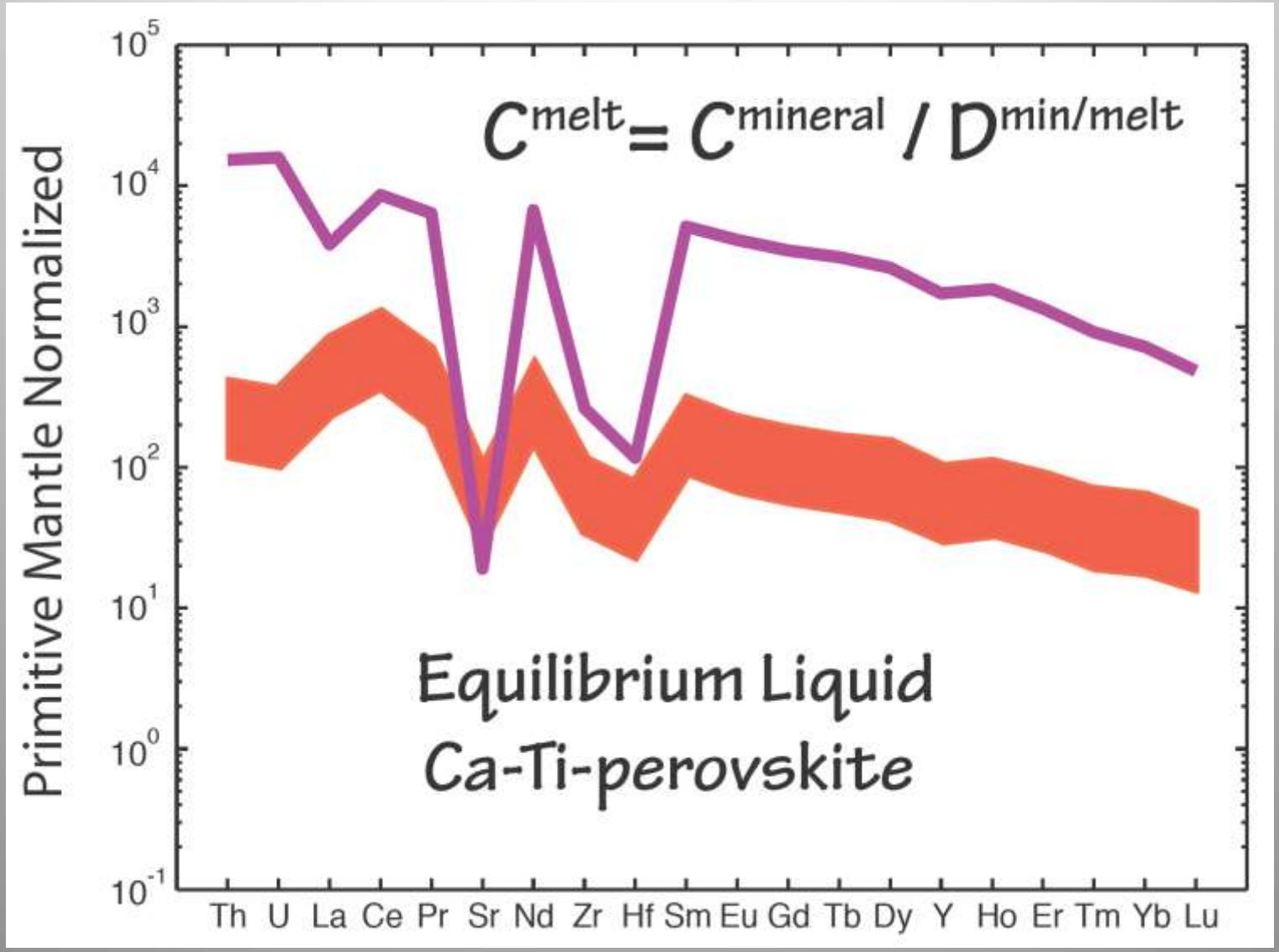


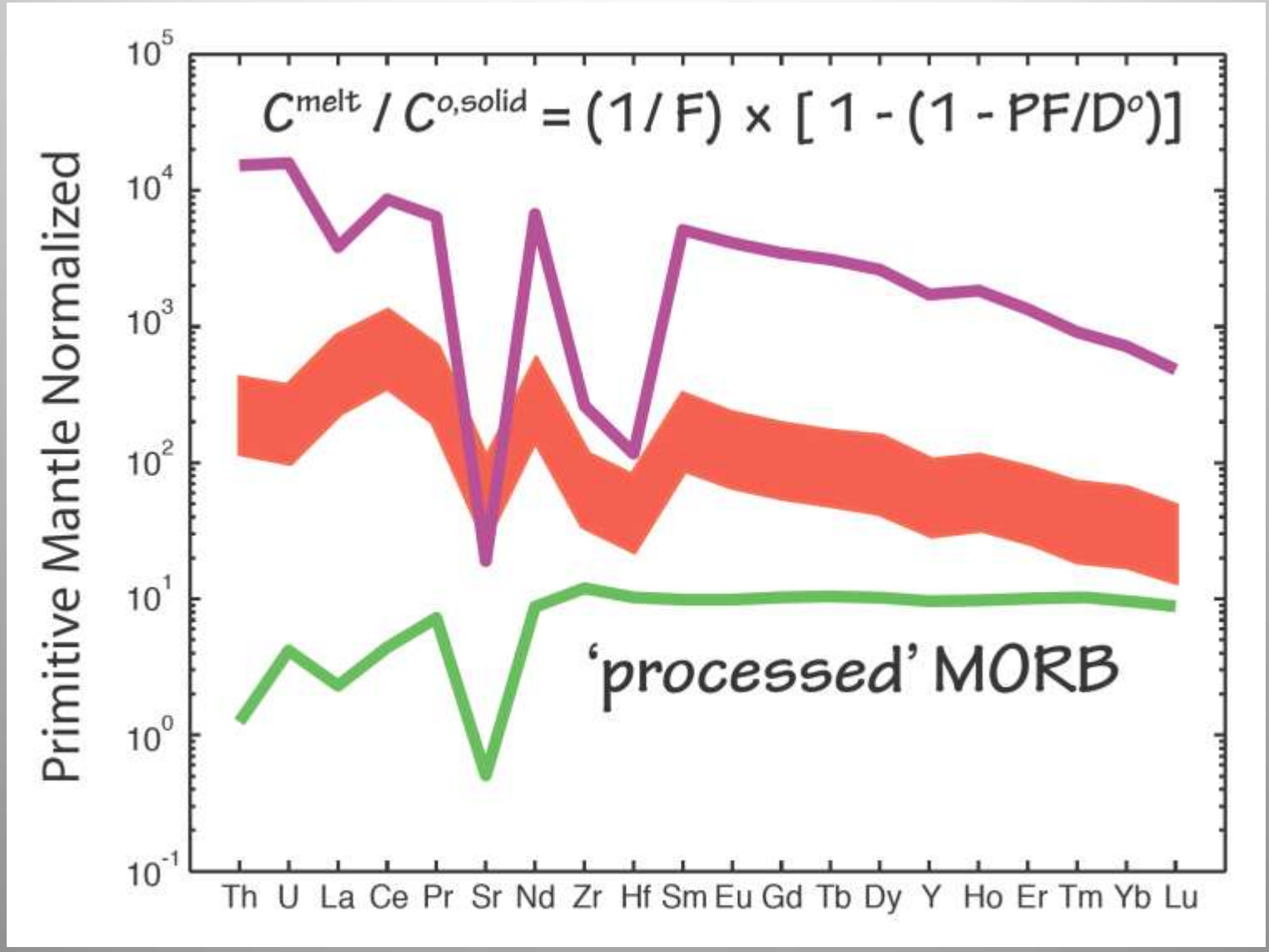
Walter et al, 2008

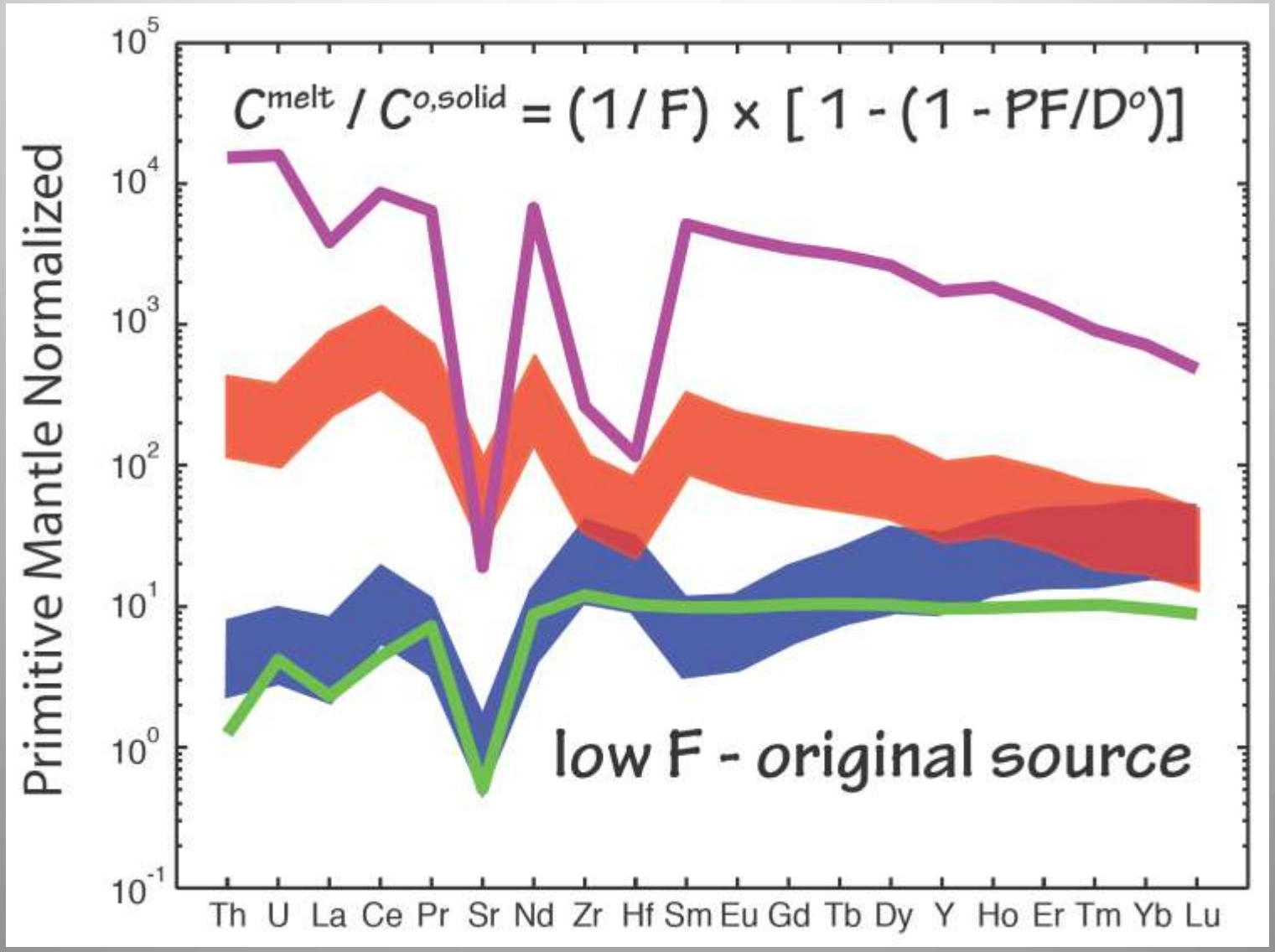
Testing the Model with CaTi-Pv from Juina-5



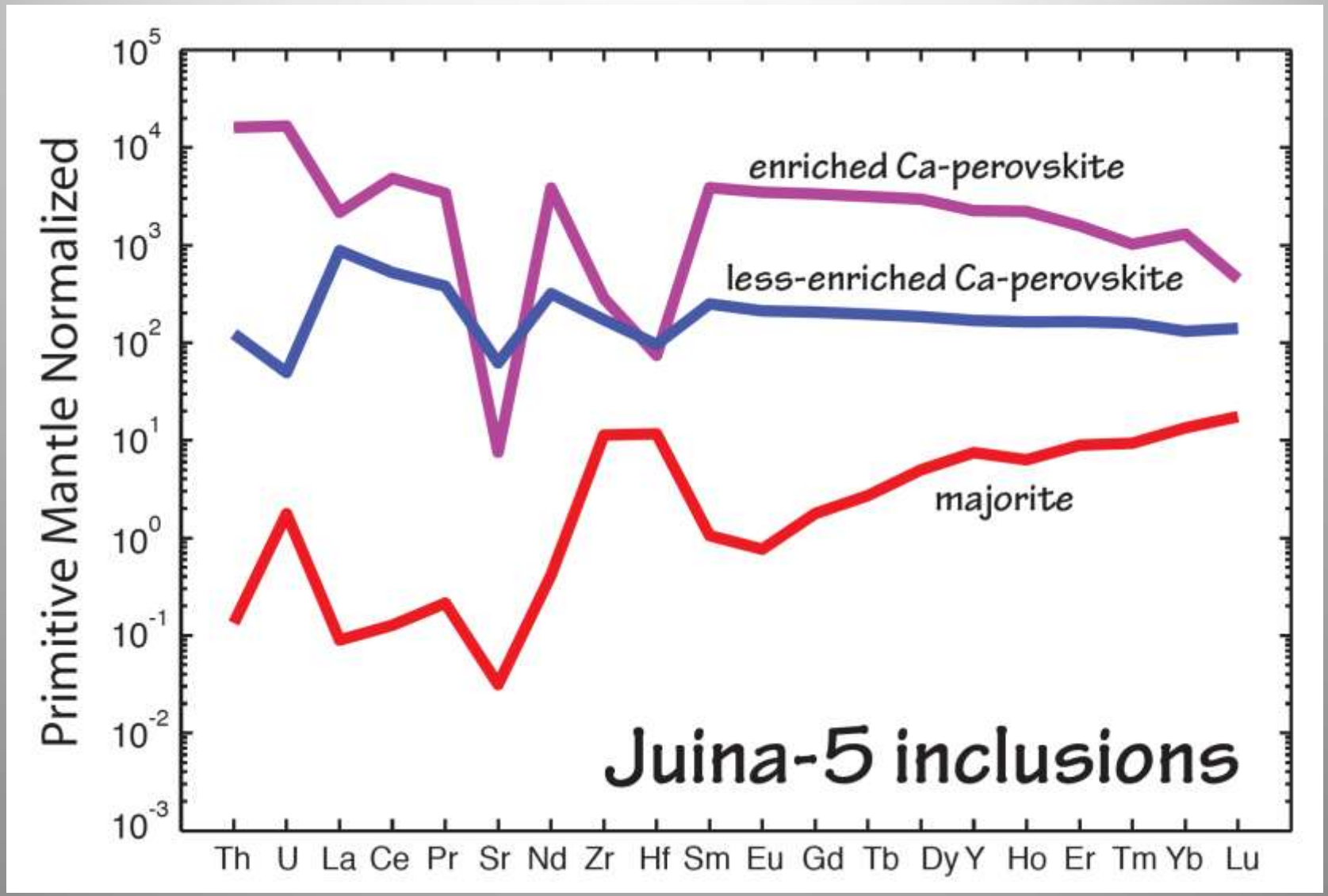

Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu
Most enriched
Ca-Ti-perovskite (Juina-5)

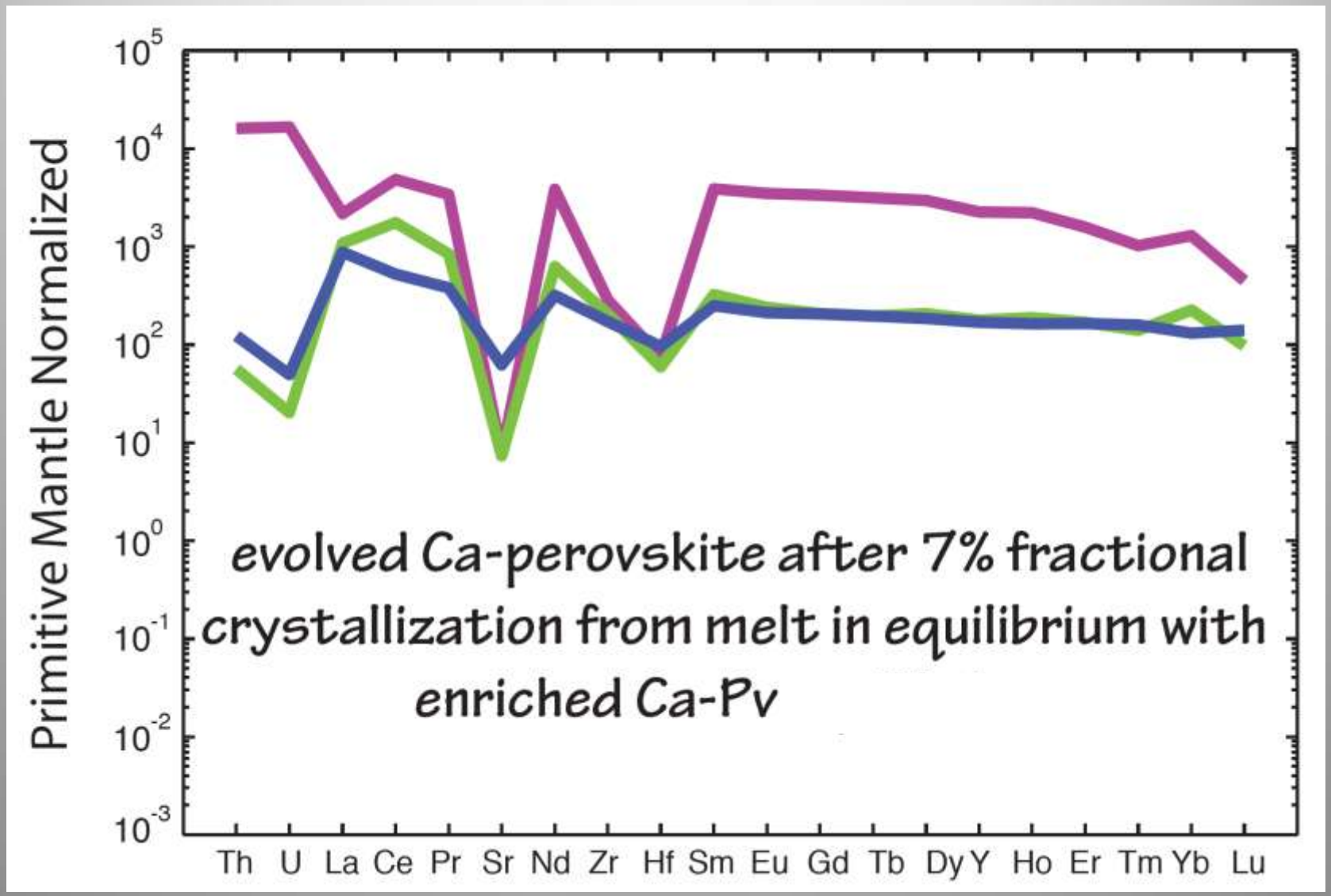

Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
$C^{melt} = C^{mineral} / D^{min/melt}$
Equilibrium Liquid
Ca-Ti-perovskite
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu

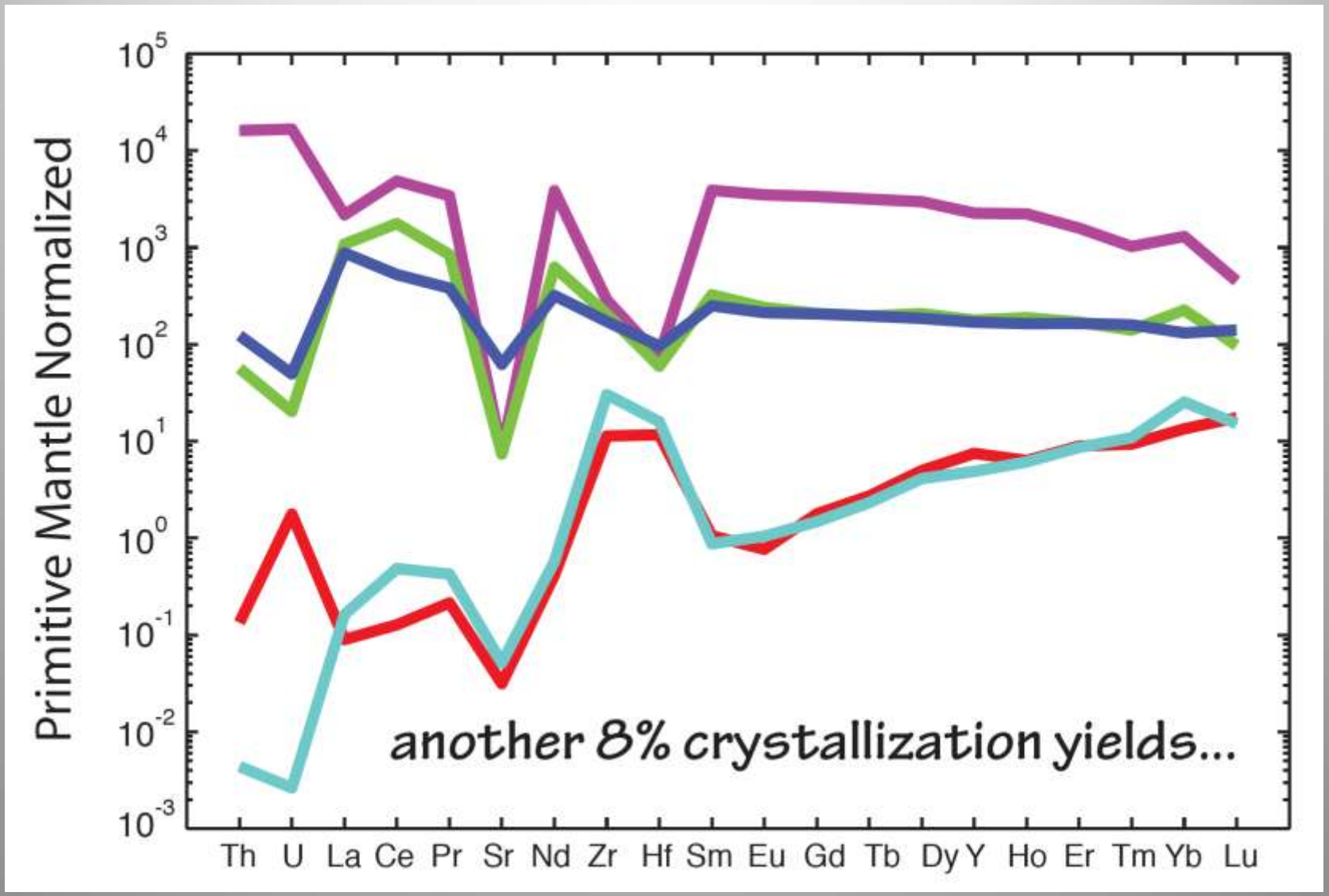

$C^{melt} / C^{o,solid} = (1/F) \times [1 - (1 - PF/D^o)]$
Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
'processed' MORB
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu


$C^{melt} / C^{o,solid} = (1/F) \times [1 - (1 - PF/D^o)]$
Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu
low F - original source

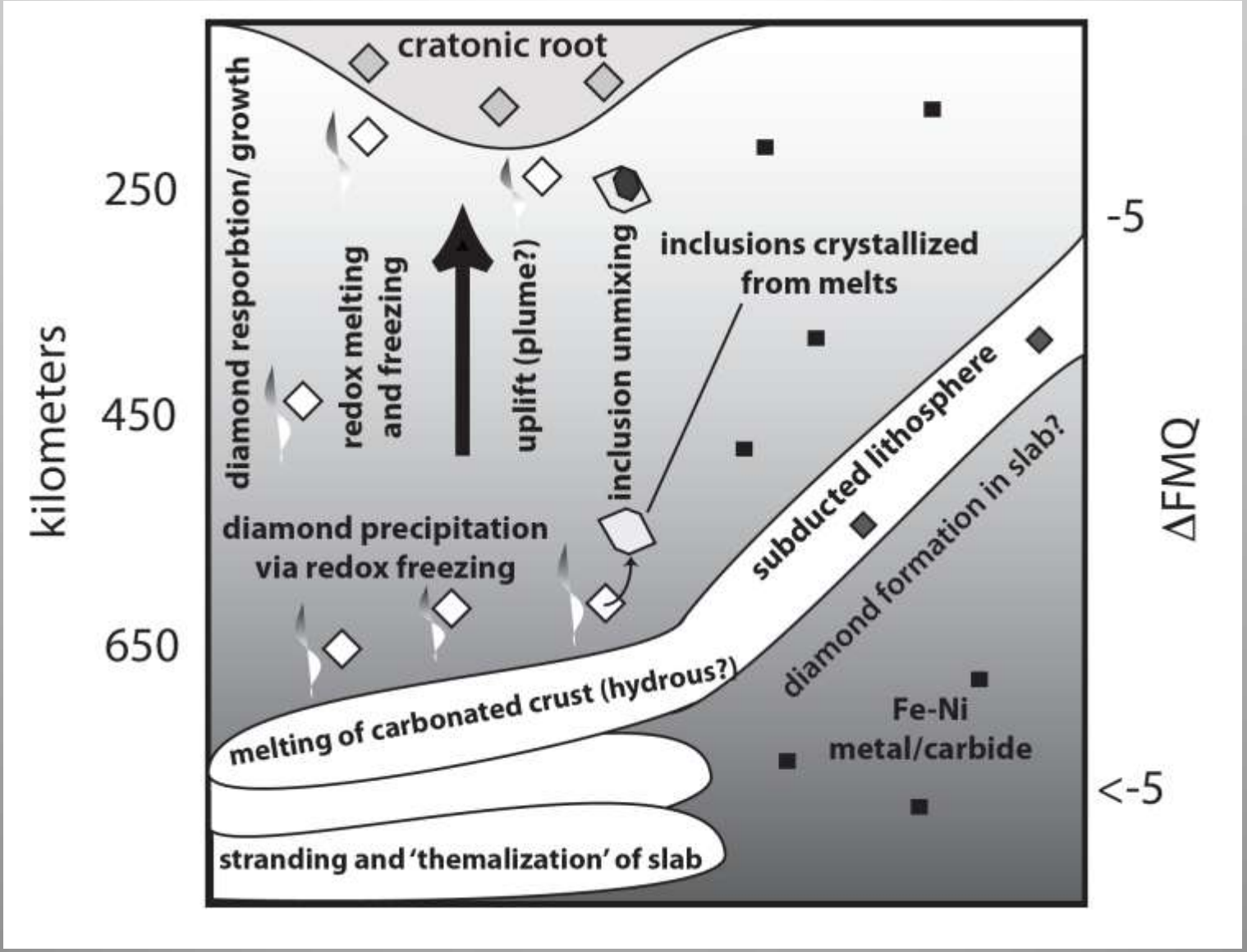
Tracking Liquid Evolution




Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
evolved Ca-perovskite after 7% fractional crystallization from melt in equilibrium with enriched Ca-Pv
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu

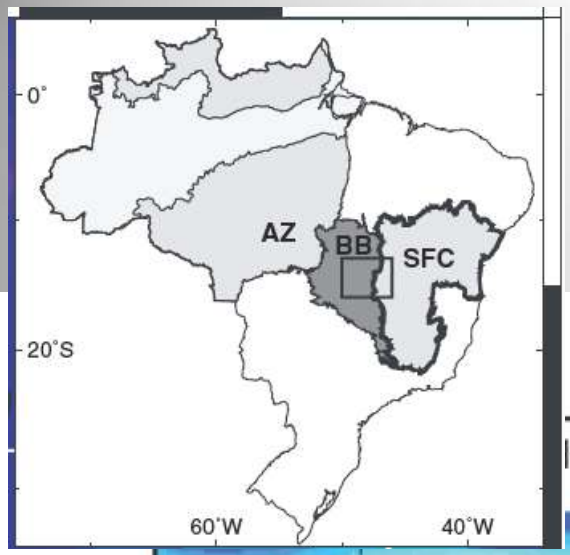

Primitive Mantle Normalized
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
Th U La Ce Pr Sr Nd Zr Hf Sm Eu Gd Tb Dy Y Ho Er Tm Yb Lu
another 8% crystallization yields...

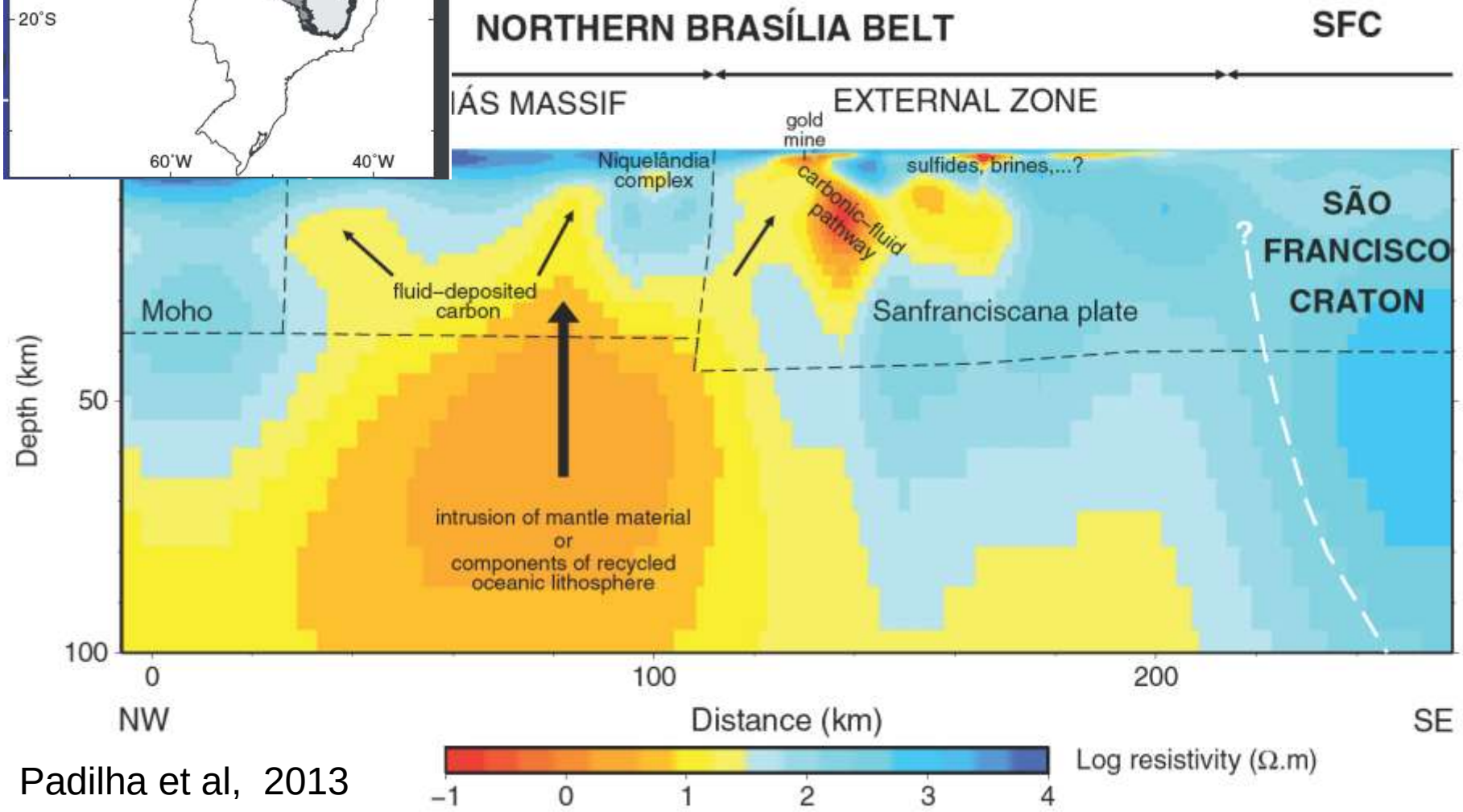
Deep Carbon Cycling



Shirey et al Reviews in Mineralogy, 2013

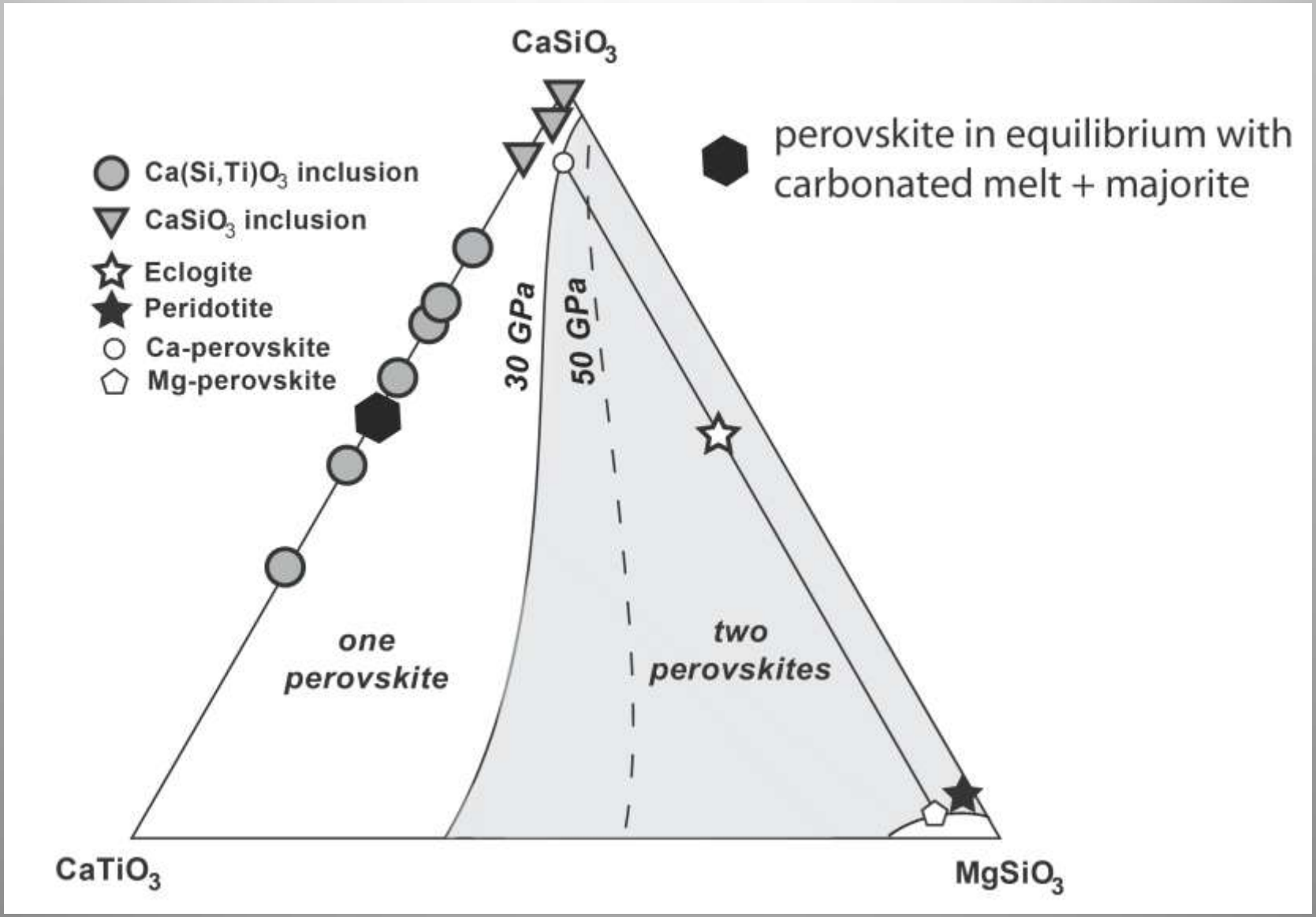
The LA Boundary - MT





Padilha et al, 2013

Perovskite Phase Relations



Walter et al (2008); Armstrong et al (2012)