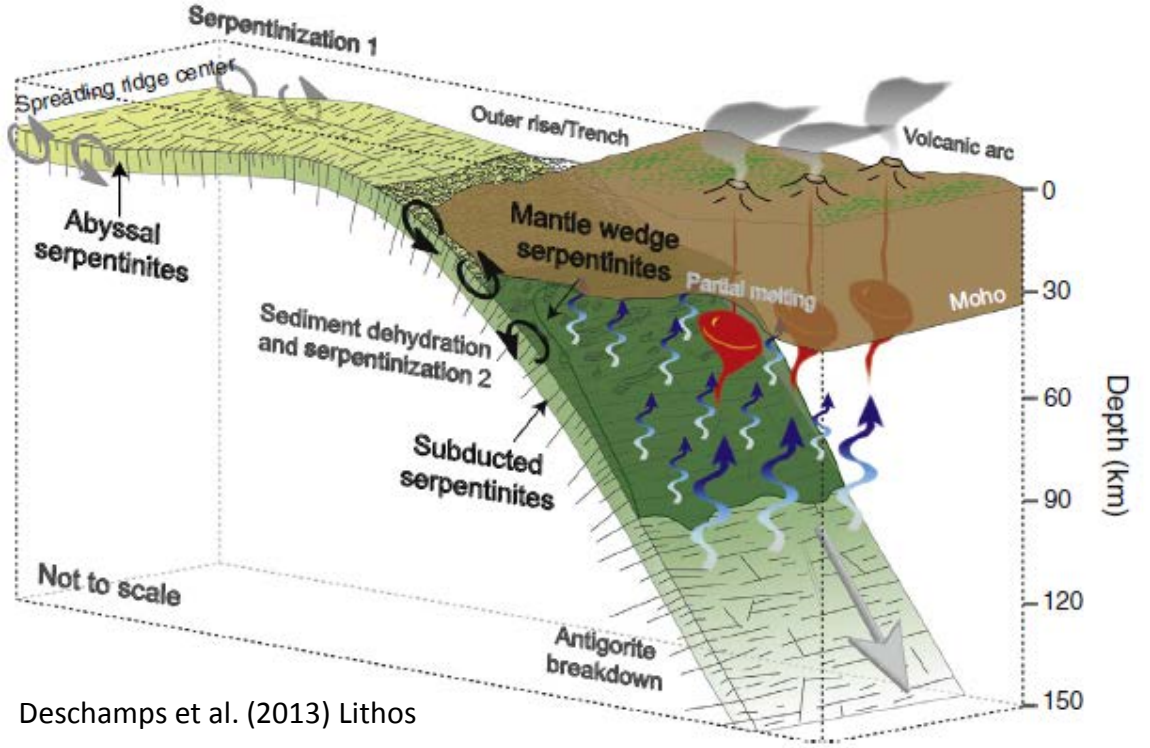
Geochemical signature of a serpentinized mantle wedge



Deschamps et al. (2013) Lithos

Jaime D. Barnes
University of Texas at Austin

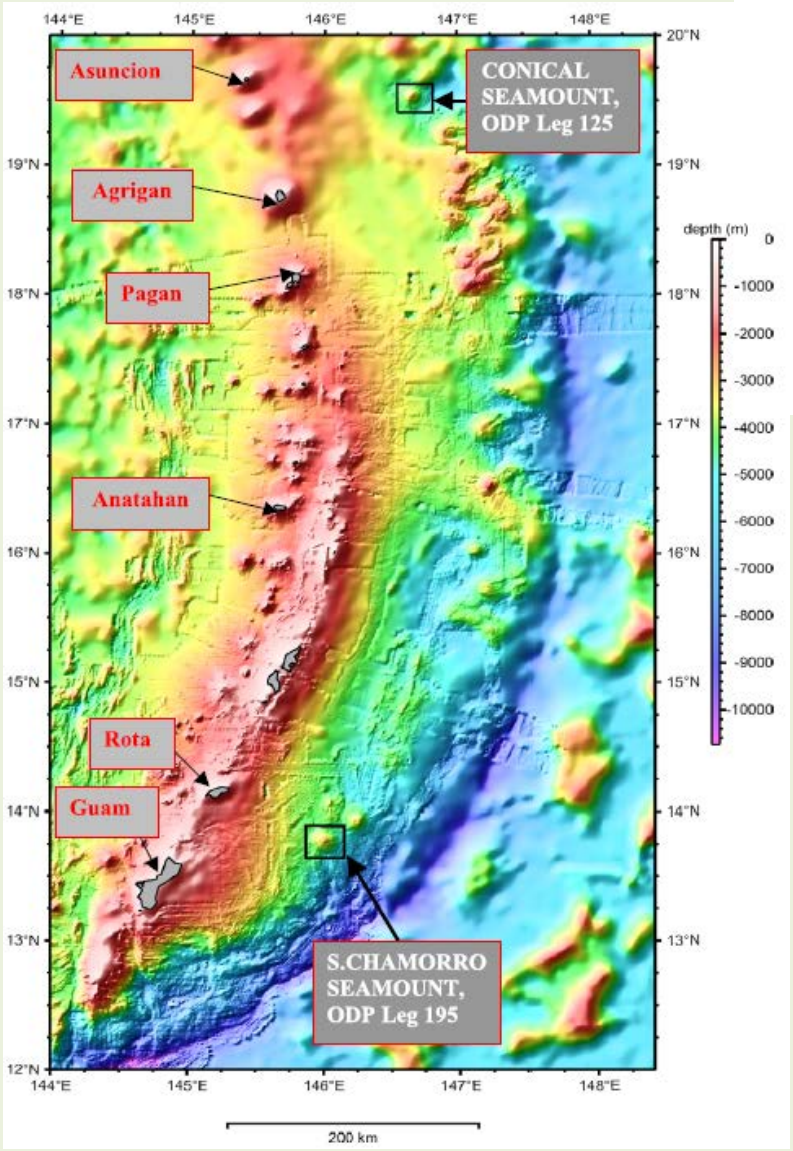
Implications and consequences of a serpentinized mantle wedge

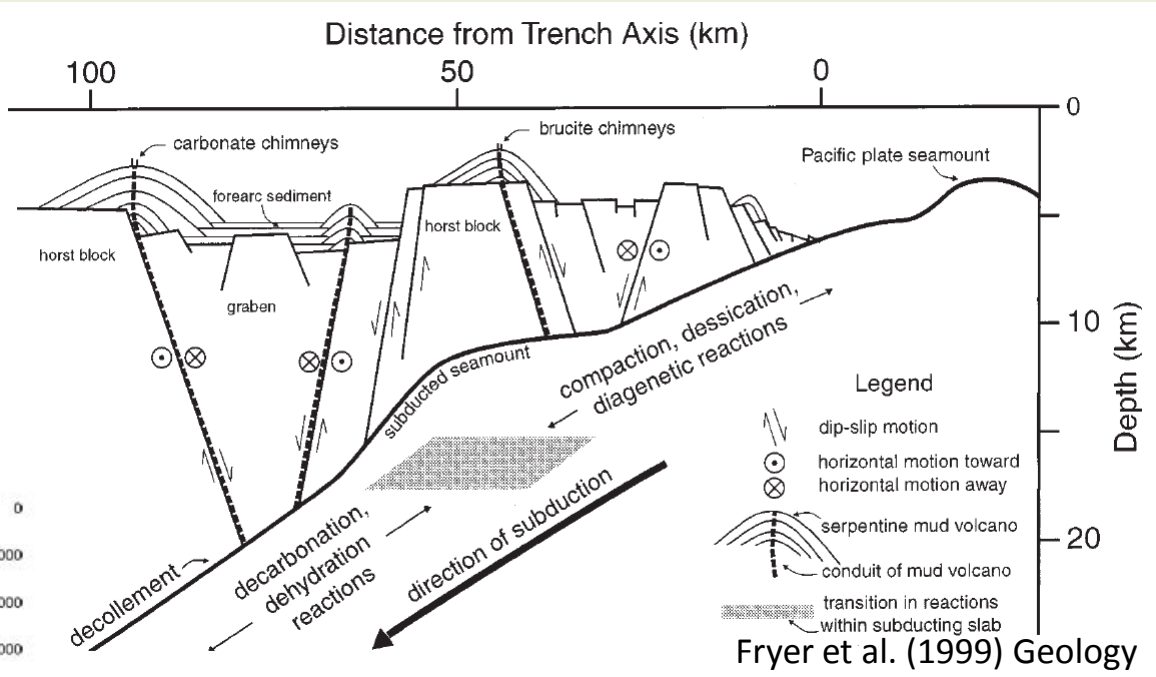
1) Rheologically *weak*
   - -Aseismic forearc (stable sliding impedes rupture)
   - -May control the down-dip rupture limit of subduction thrust earthquakes
   - -Influence the nature of mantle flow (coupling depth)
   - -Influence thermal models
2) "Sponge" for FME (e.g., As, Sb, B, Li, Cs, Pb, U, Ba, Sr) → dragged down & contribute to arc magmatism
3) Buoyant → mechanism of exhumation

Evidence of Serpentinization

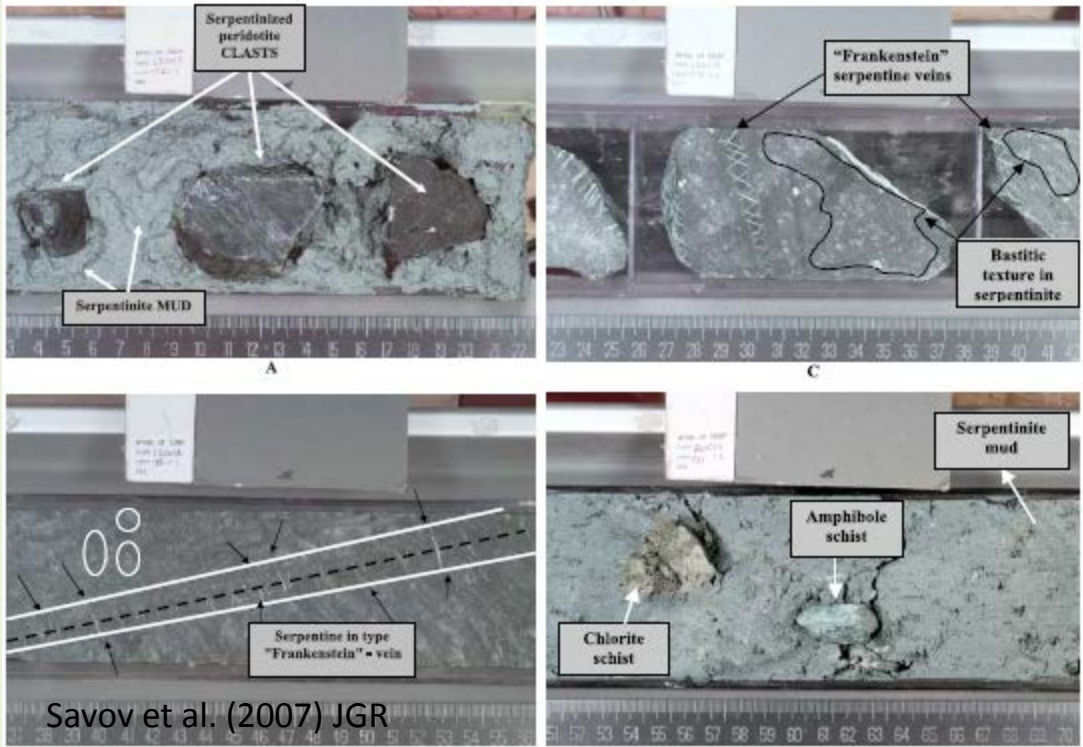
- Direct observations- serpentine seamounts
- Geophysical evidence- seismic velocity
- Magnetic anomalies
- Others (reduce amplitude of seismic reflections from the Moho; gravity anomalies; heat flow; increase in electrical conductivity; anisotropy)

Direct Observations



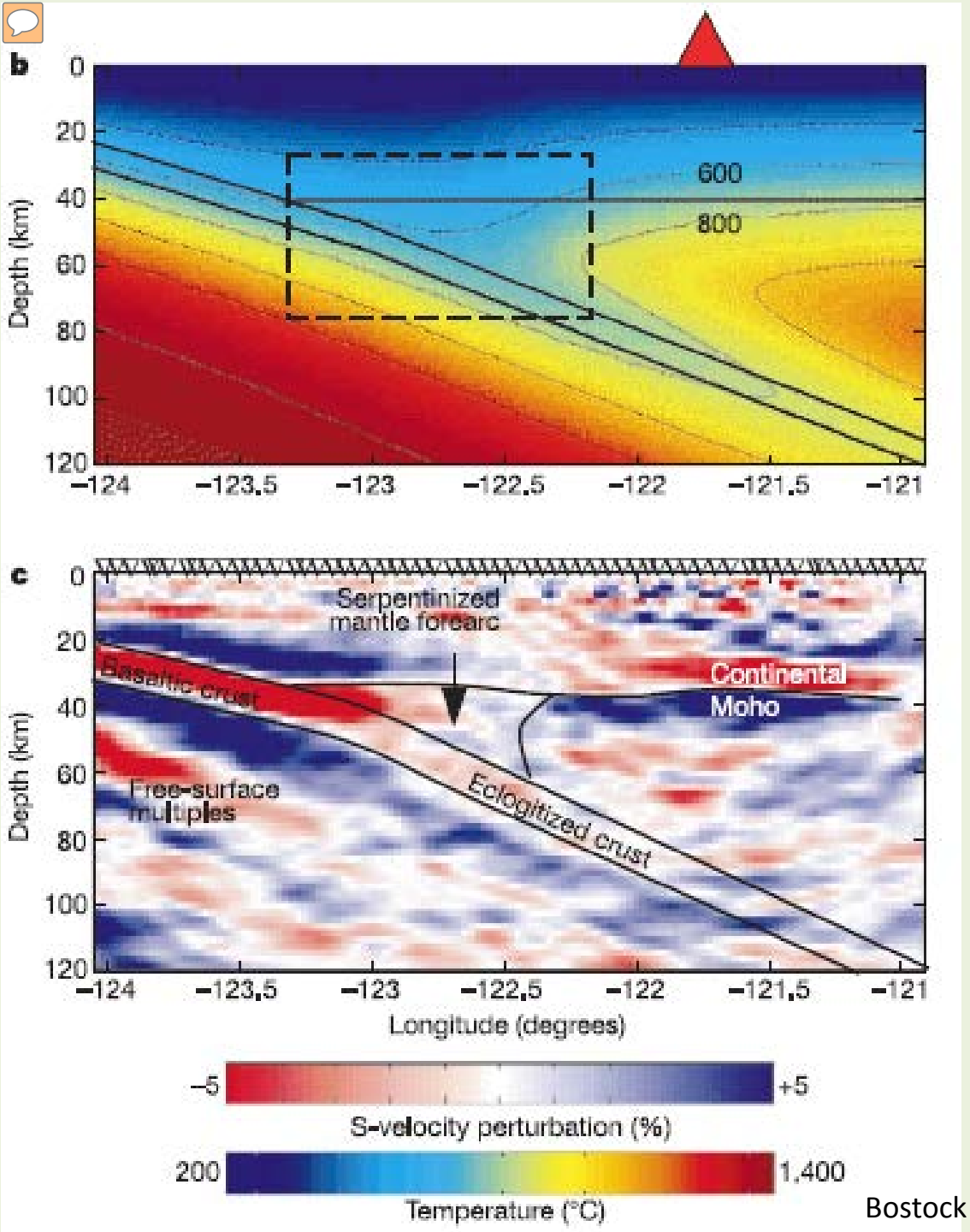


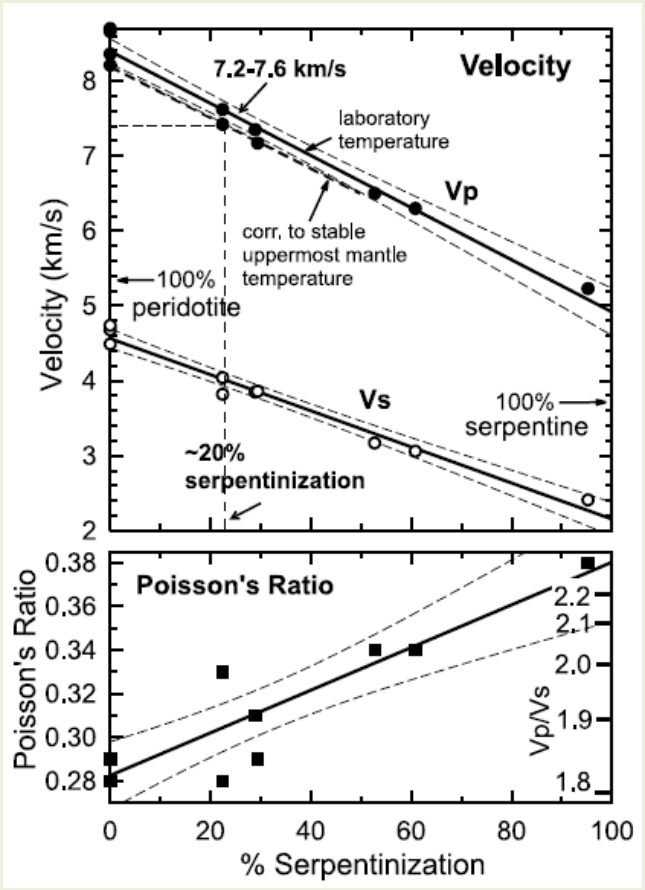
Fryer et al. (1999) Geology



Savov et al. (2007) JGR

Seismic velocity





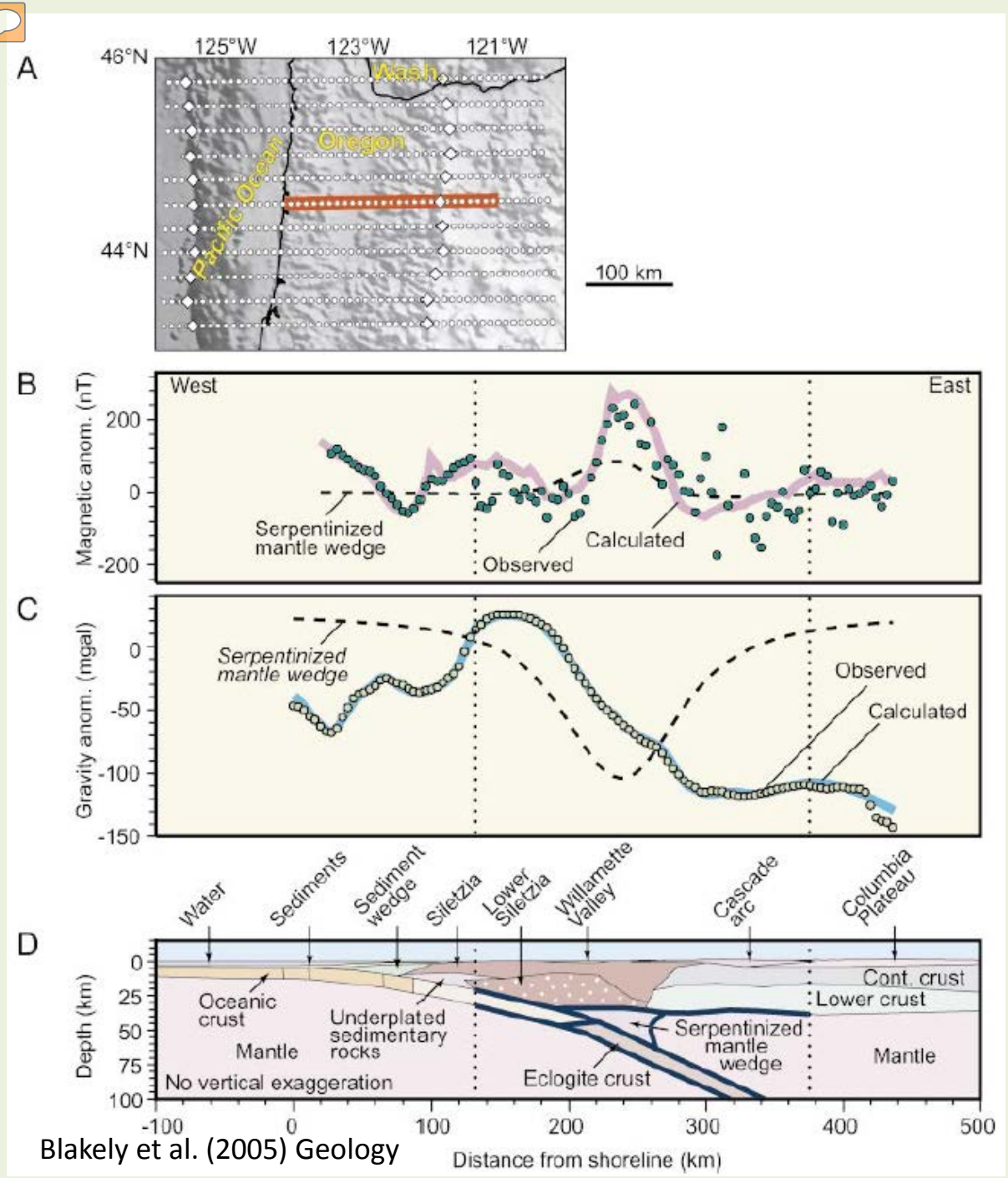
Hyndman & Peacock (2003) EPSL

Very low S-wave velocities in the cold "nose" of the mantle wedge.

50-60% serpentinization of the wedge in Cascadia.

Bostock et al. (2002) Nature

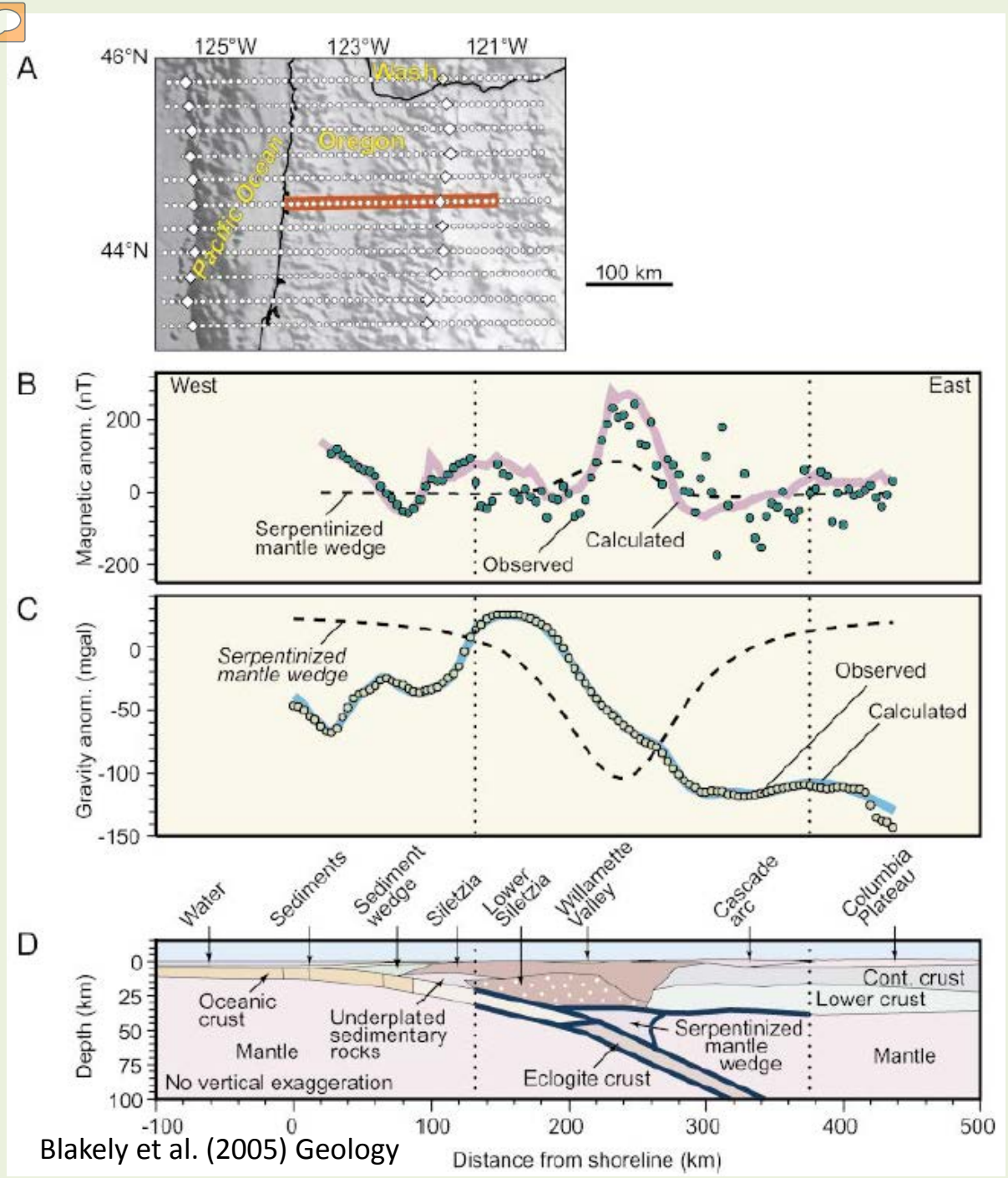
Magnetic Anomalies



Blakely et al. (2005) Geology

Serpentine → low density and high magnetization

Magnetic Anomalies



Blakely et al. (2005) Geology

Evans (2010) Geology

- Low-T serpentinization:

olv + H_2O → serp + brc + mgt +H_2

- High-T serpentinization:

Fo + H_2O → atg + brc

Fo + tlc + H_2O → atg

Fo + en + H_2O → atg

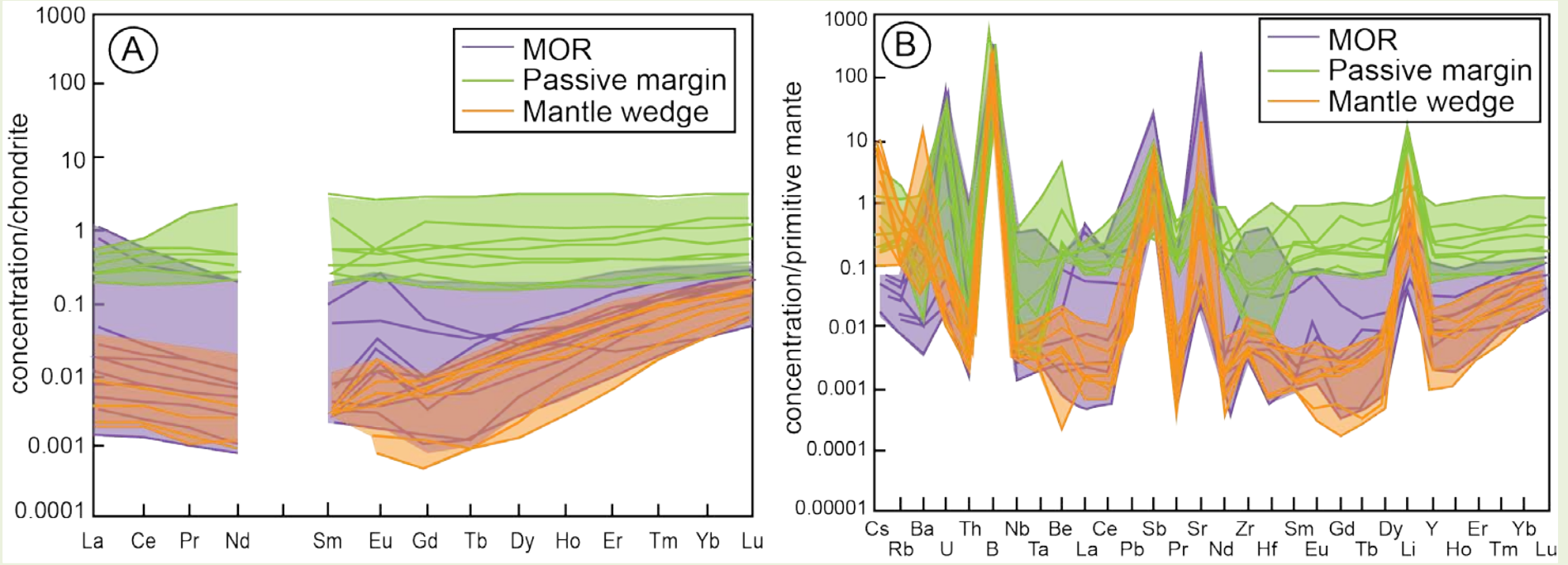
Fo + SiO_2 (aq) + H_2O → atg

Fo + tr + H_2O → atg + di

Look at the rocks! → ExTerra

ExTerra!

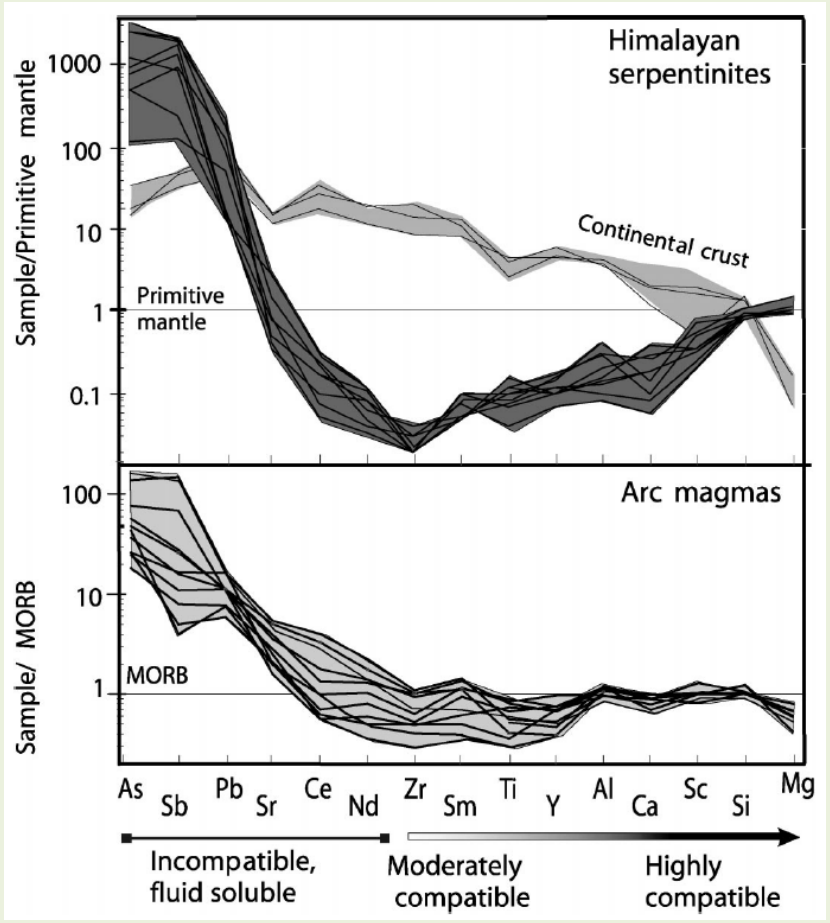
Establishing the baseline

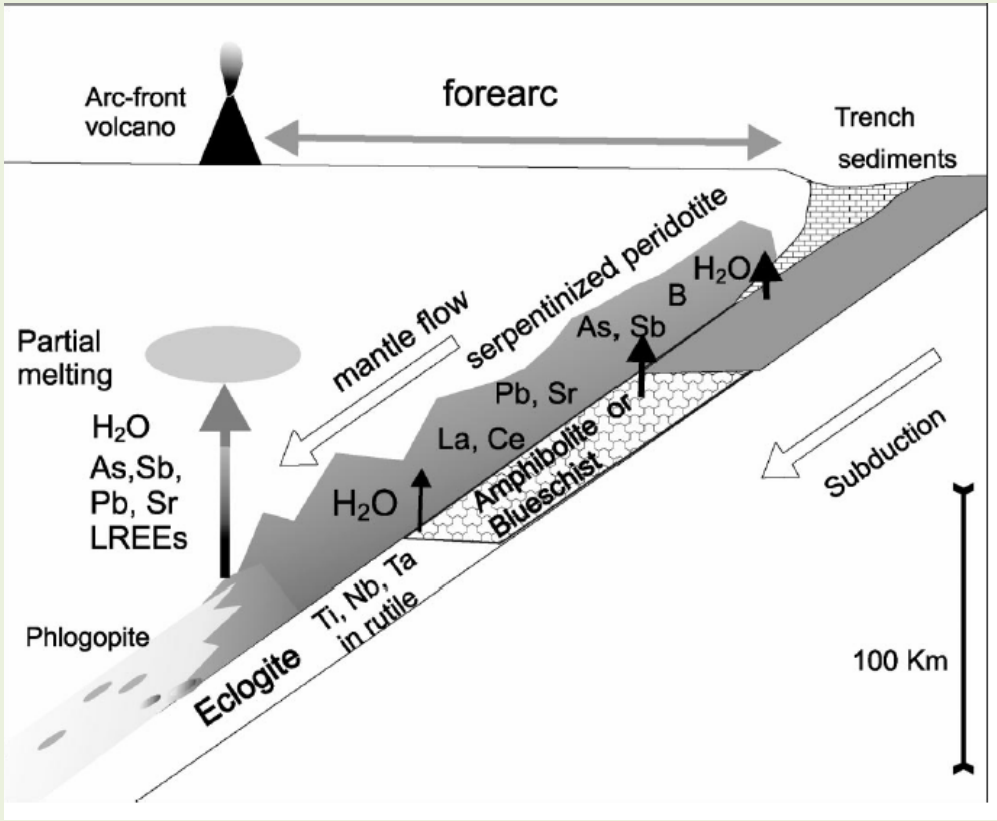


modified from Kodolánya et al. (2012) J. Petrology

Mantle wedge serpentinites are characterized by low Al/Si weight ratios (<0.03), enrichments in FME compared to abyssal peridotites, U-shaped REE patterns, and slight enrichments in LREE relative to HFSE.

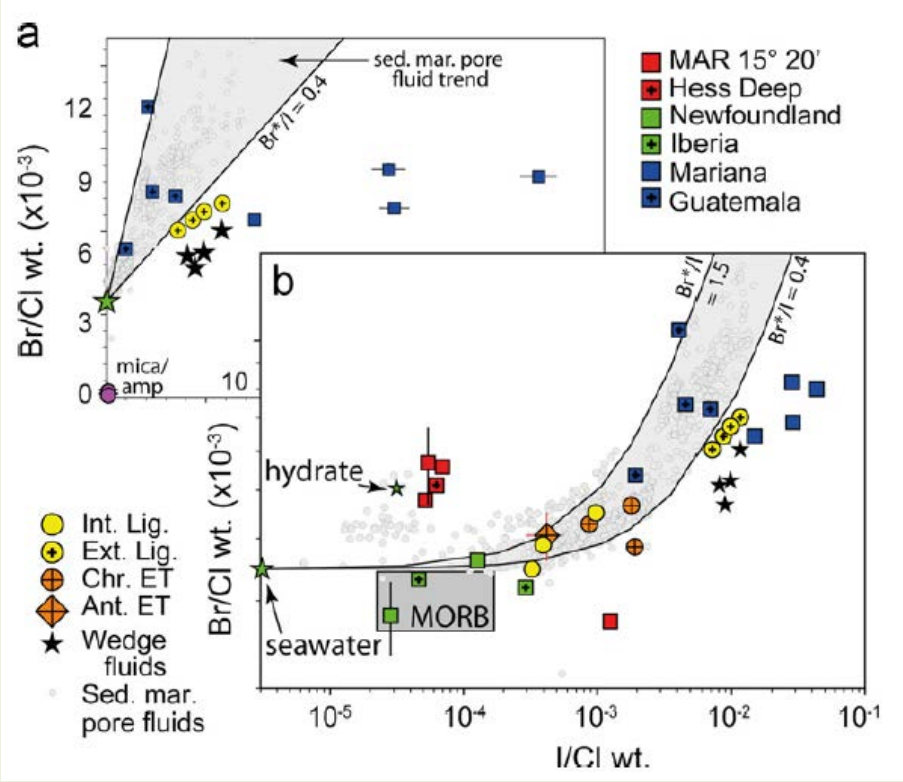
Fluid-mobile Elements



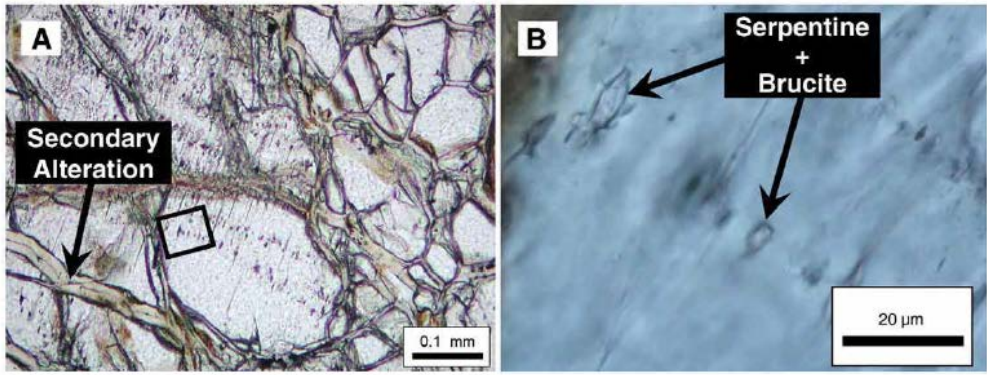


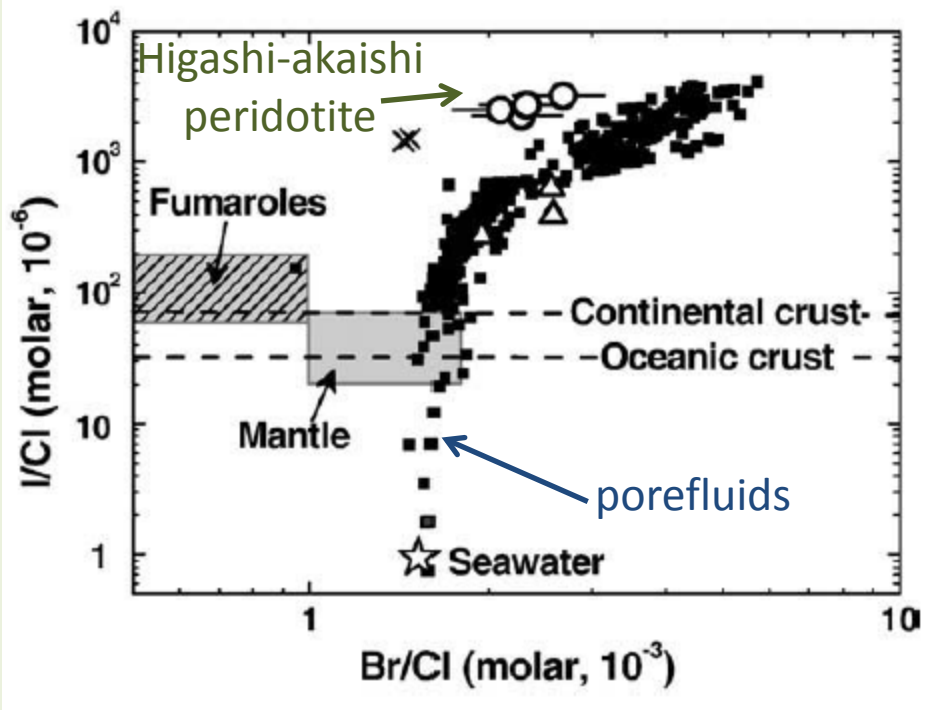
Hattori & Guillot (2003) Geology

Halogens



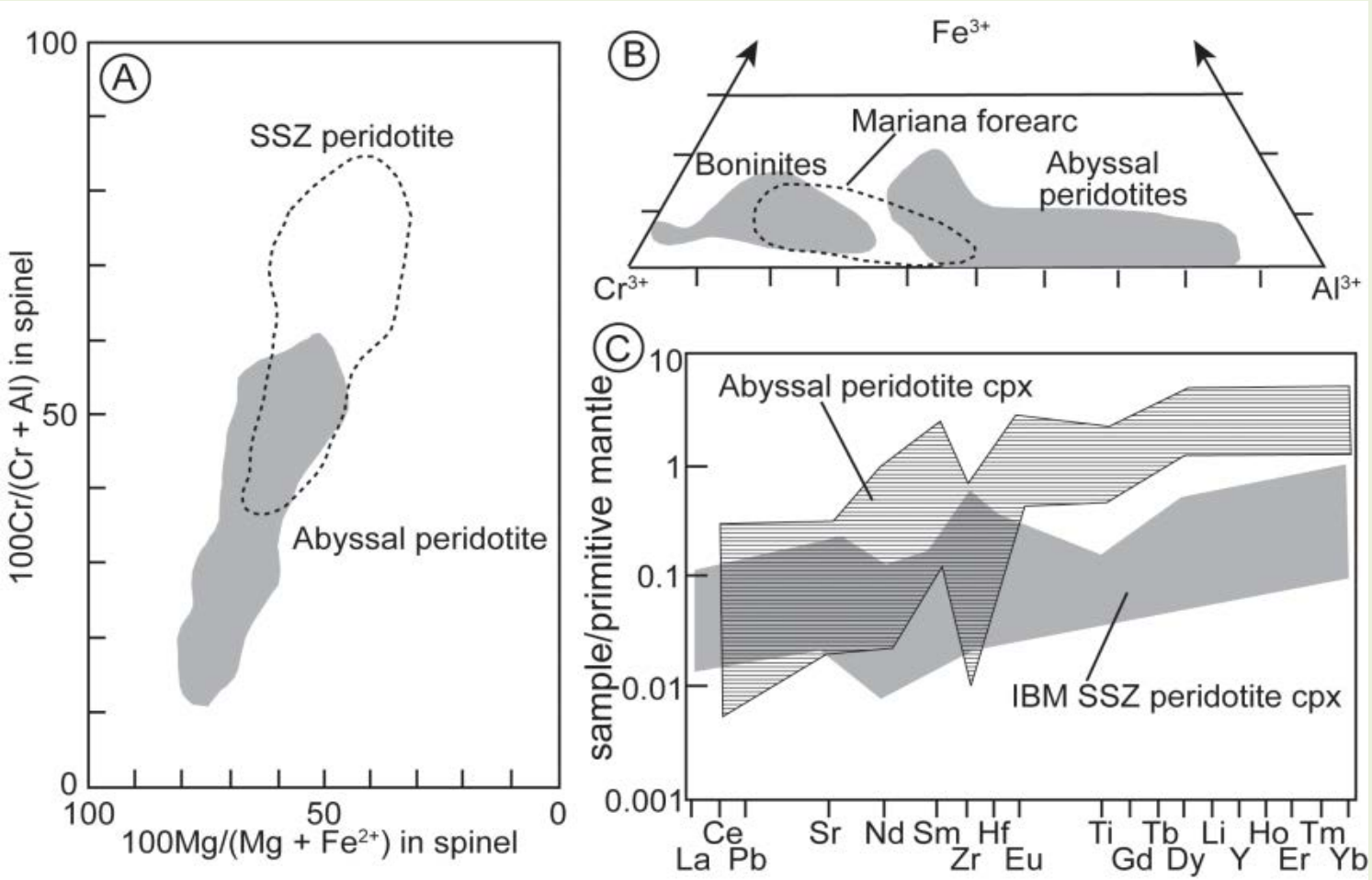
Kendrick et al. (2013) EPSL



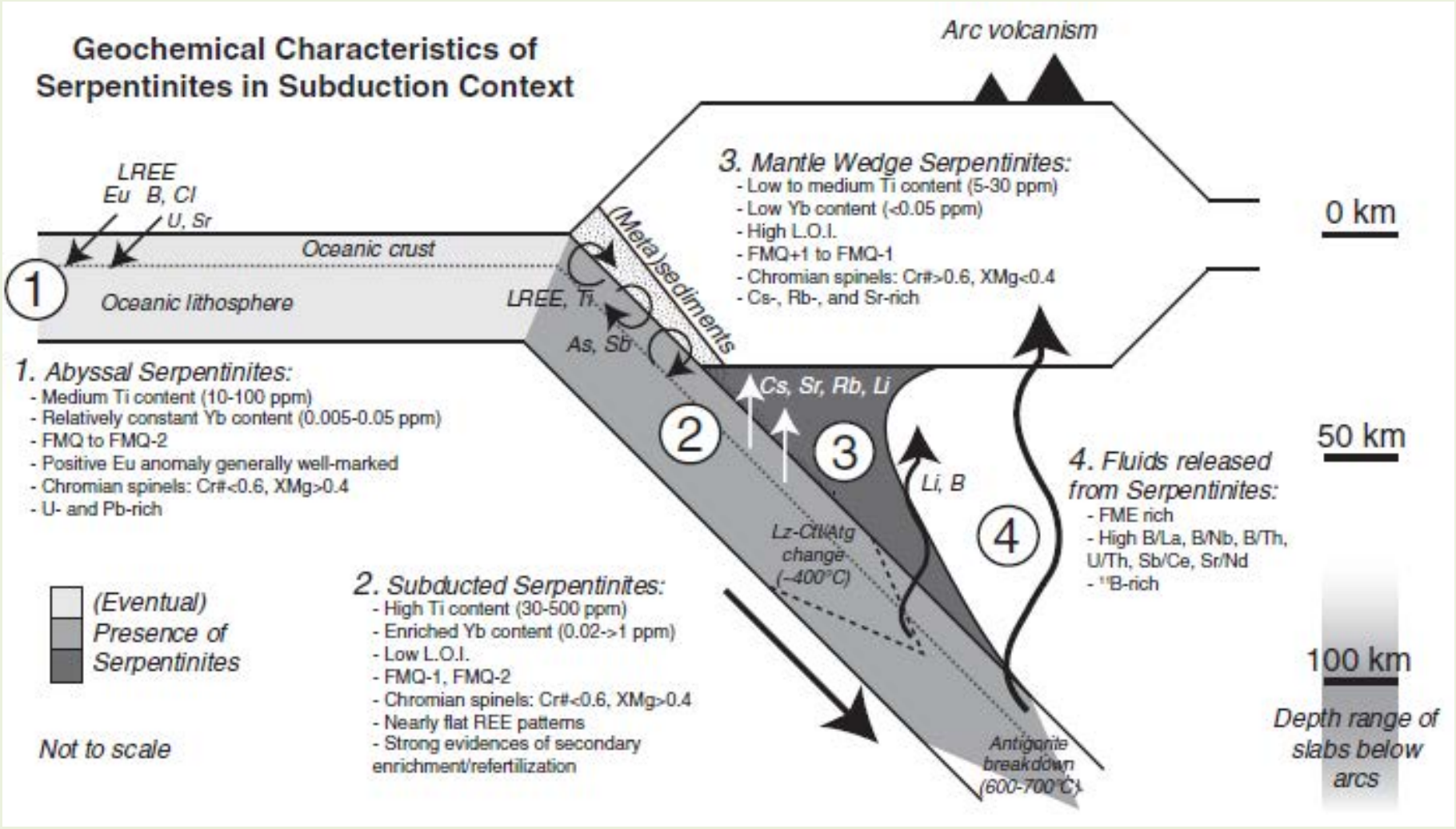


Sumino et al. (2010) EPSL

Relict minerals



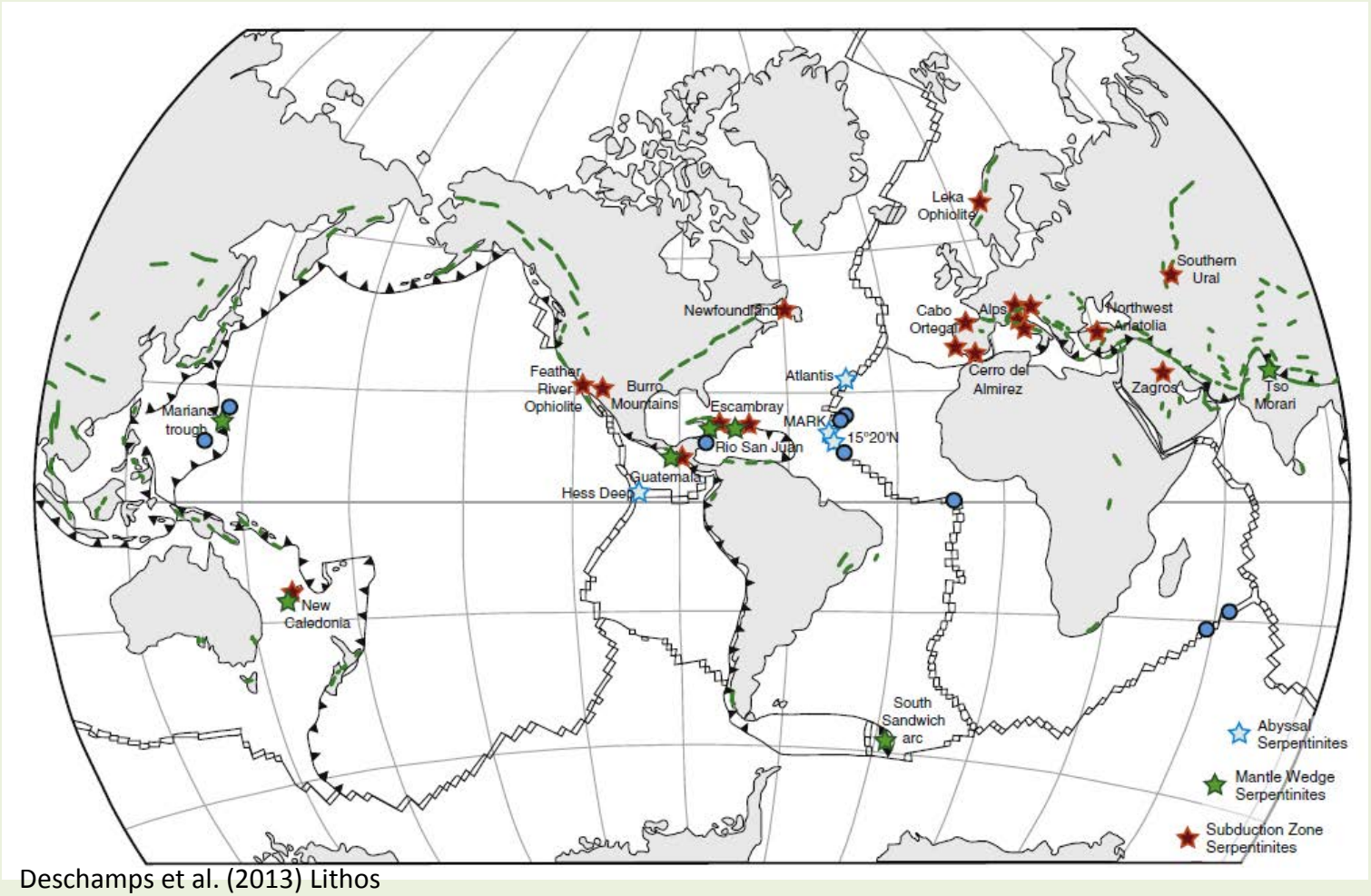
Data from Johnson et al. (1990), Parkinson et al. (1992), Dick & Bullen (1984), Parkinson & Pearce (1998), Pearce (2000)



Deschamps et al. (2013) Lithos

Exhumed mantle wedge (forearc; SSZ) serpentinites

- Examples: Himalaya, Cuba, Guatemala, Trinity



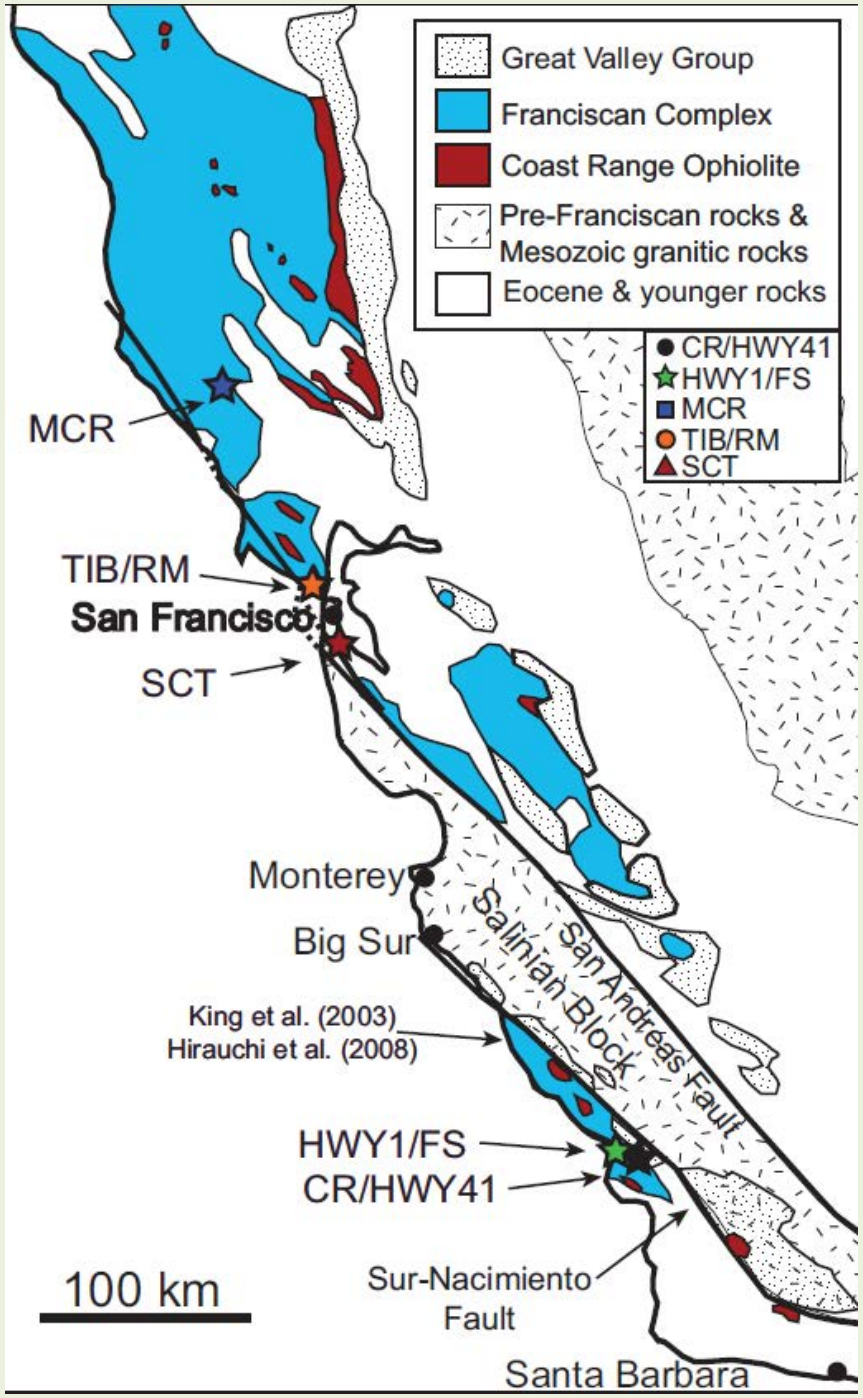
Deschamps et al. (2013) Lithos

Case study: Franciscan Complex, western California

- Accretionary Wedge
- Shale melange containing low-T, high-P blocks of blueschist, eclogite, amphibolites, and serpentinites

Rania Eldam

Jess Errico



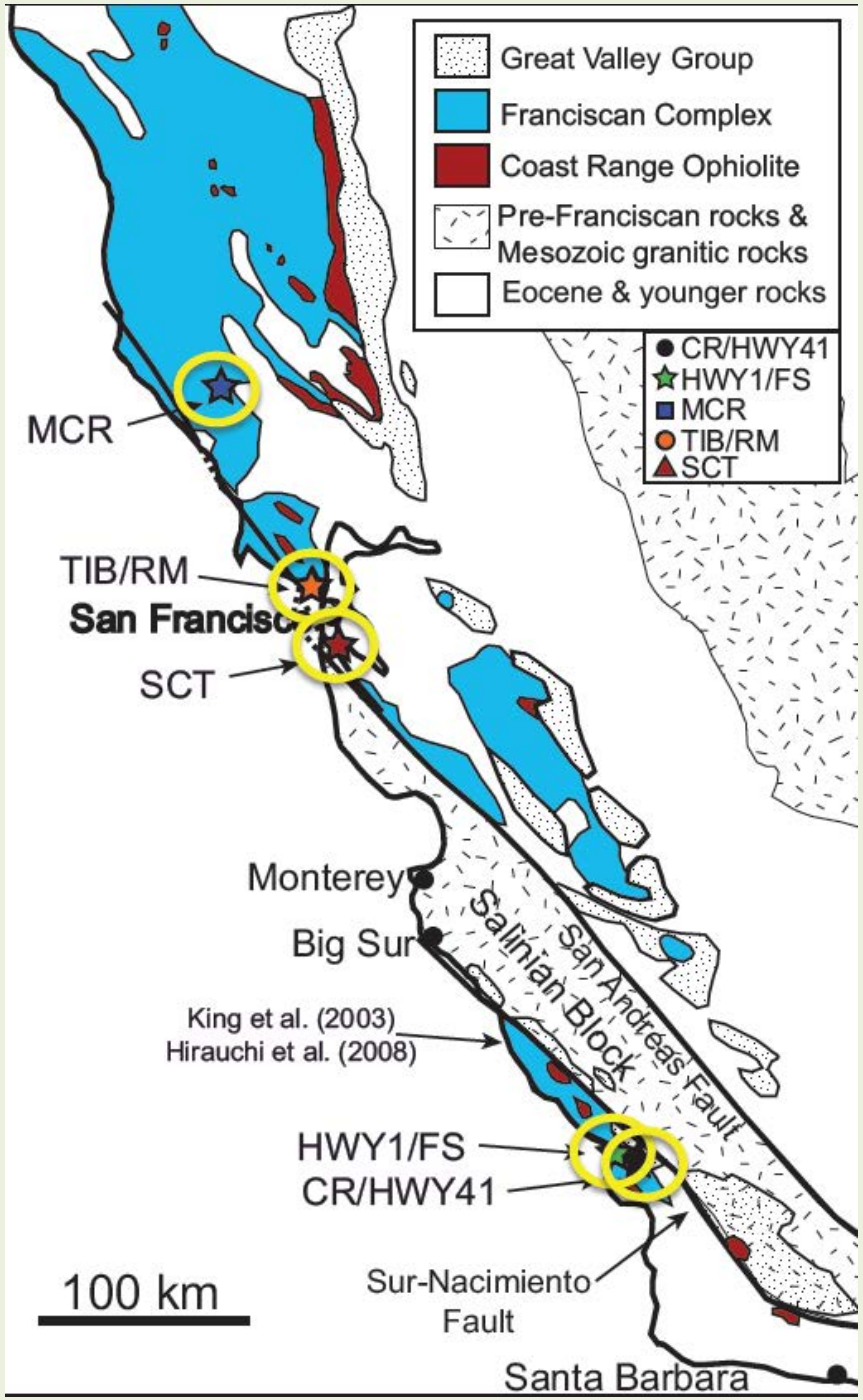
Case study: Franciscan Complex, western California

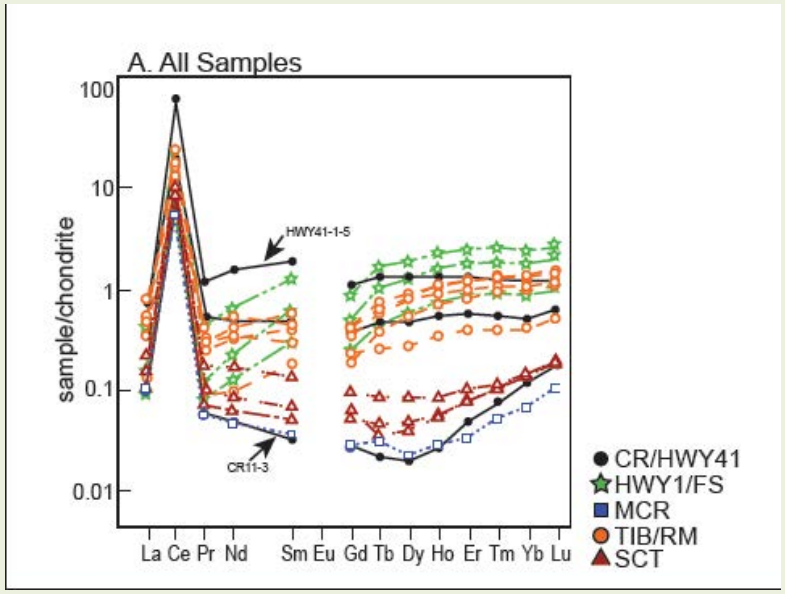
Franciscan Serpentinites:

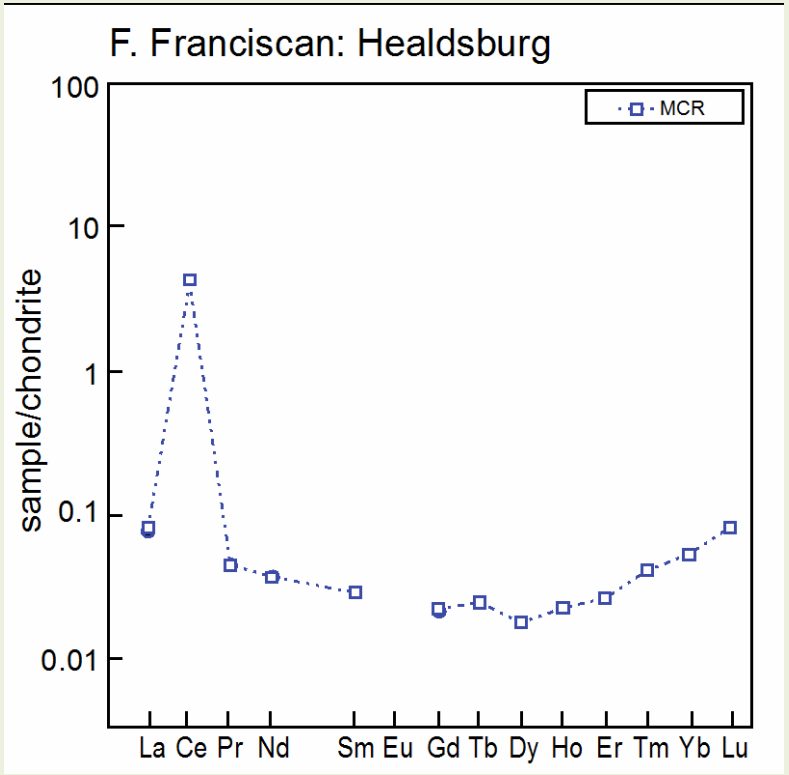
- Abyssal → low Cr# of spinel and LREE depletion in cpx from one body near Monterey (Hirauchi et al., 2008; King et al., 2003)
- Altered and scattered remnants of the CRO (King et al., 2003; Wakabayashi, 2004)

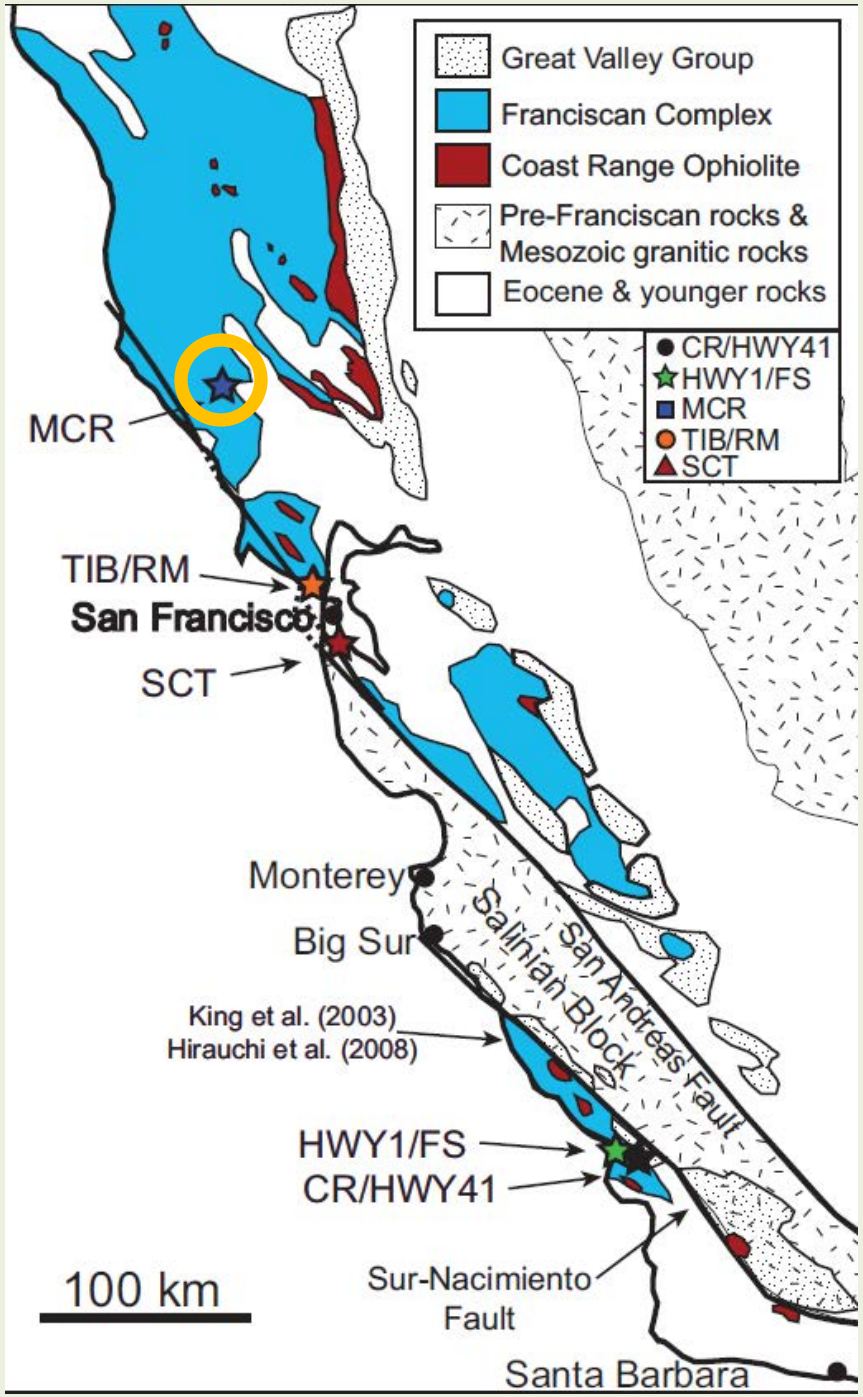
Coast Range Ophiolite:

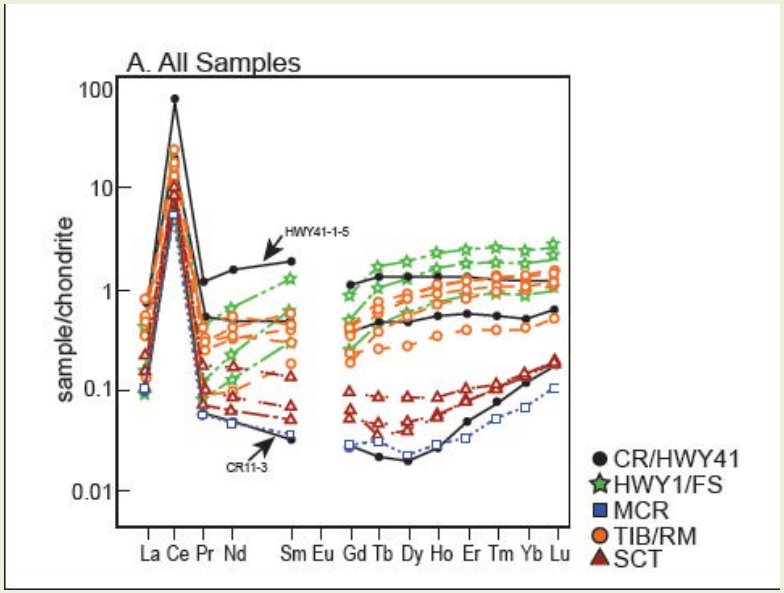
- Mantle wedge (e.g., Saleeby, 1982; Shervais, 2001; Shervais and Kimbrough, 1985; Stern and Bloomer, 1992

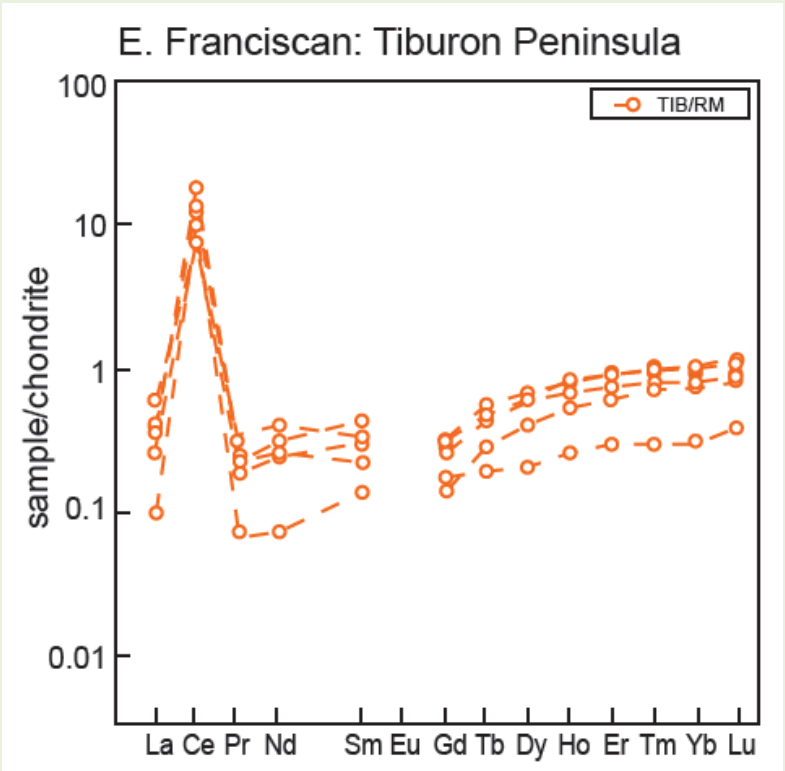


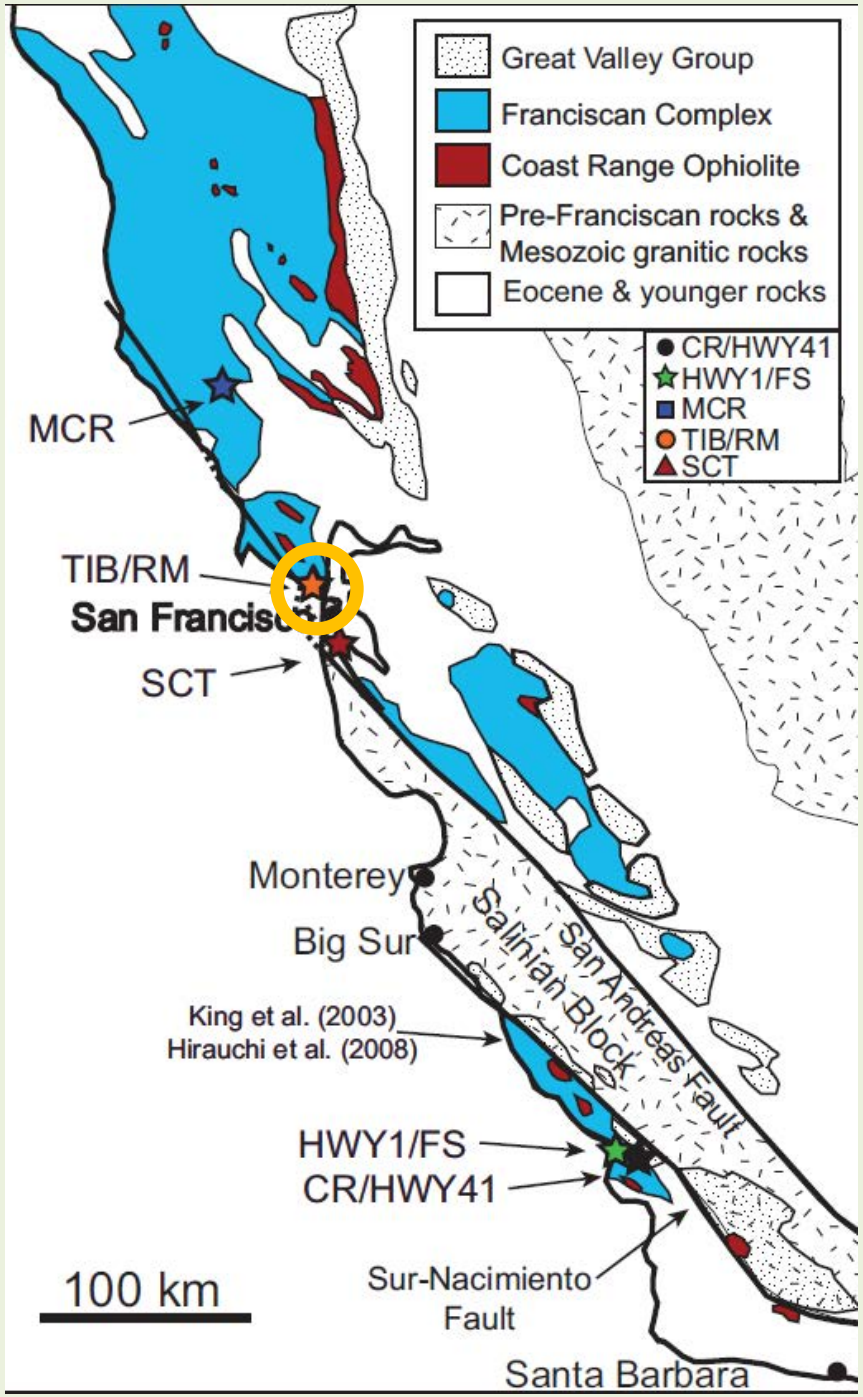

A. All Samples
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT

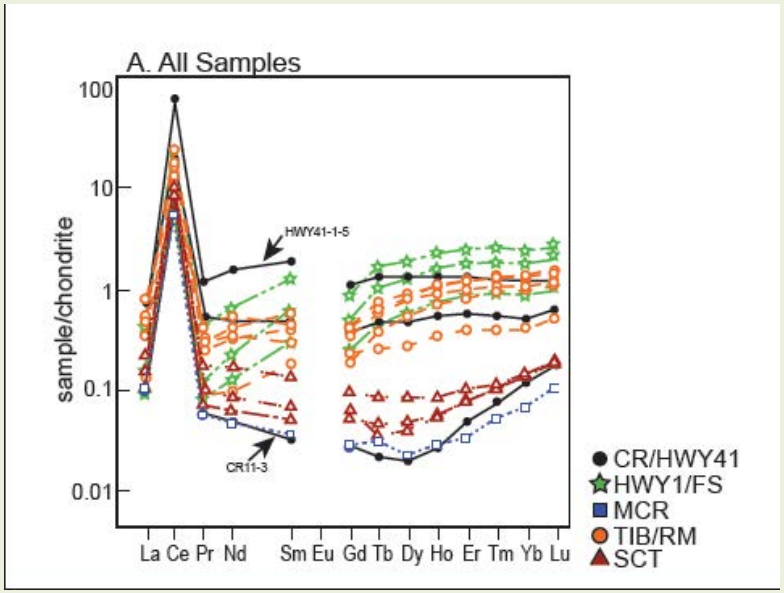

F. Franciscan: Healdsburg
sample/chondrite
100
10
1
0.1
0.01
MCR
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

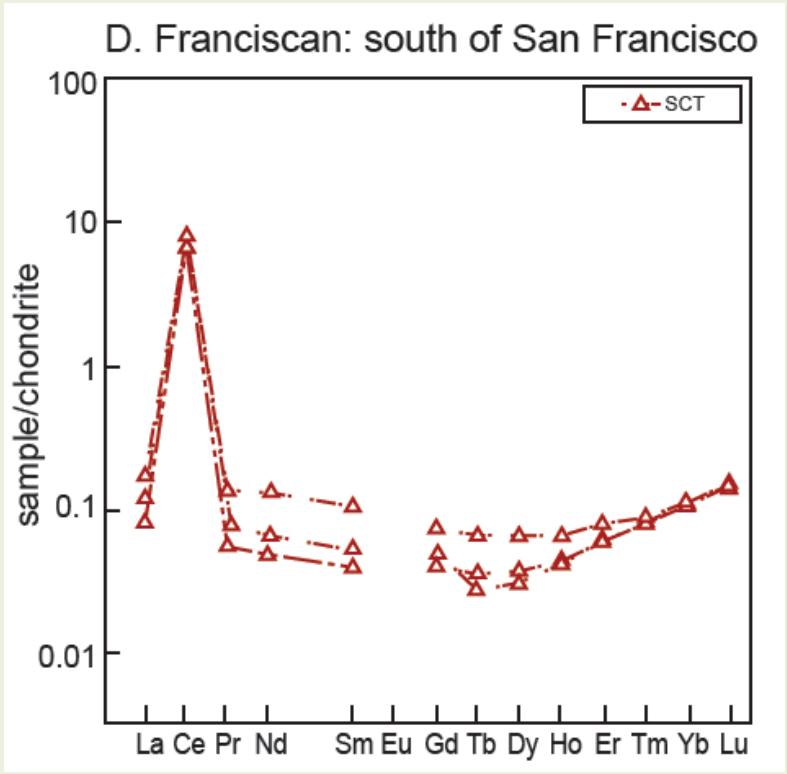

Great Valley Group
Franciscan Complex
Coast Range Ophiolite
Pre-Franciscan rocks & Mesozoic granitic rocks
Eocene & younger rocks
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT
MCR
TIB/RM
San Francisco
SCT
Monterey
Big Sur
Salinian Block
San Andreas Fault
King et al. (2003)
Hirauchi et al. (2008)
HWY1/FS
CR/HWY41
100 km
Sur-Nacimiento Fault
Santa Barbara

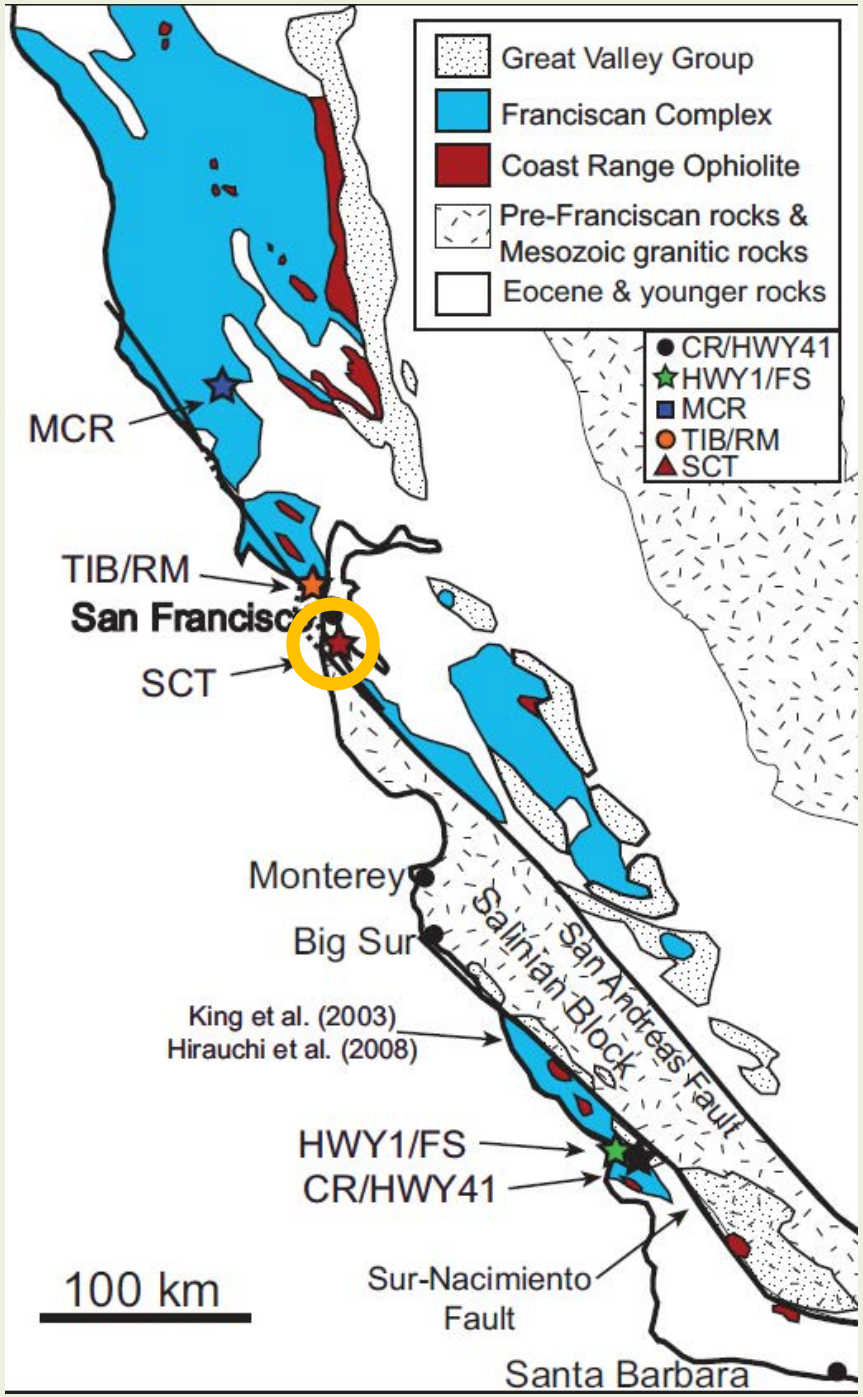

A. All Samples
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT

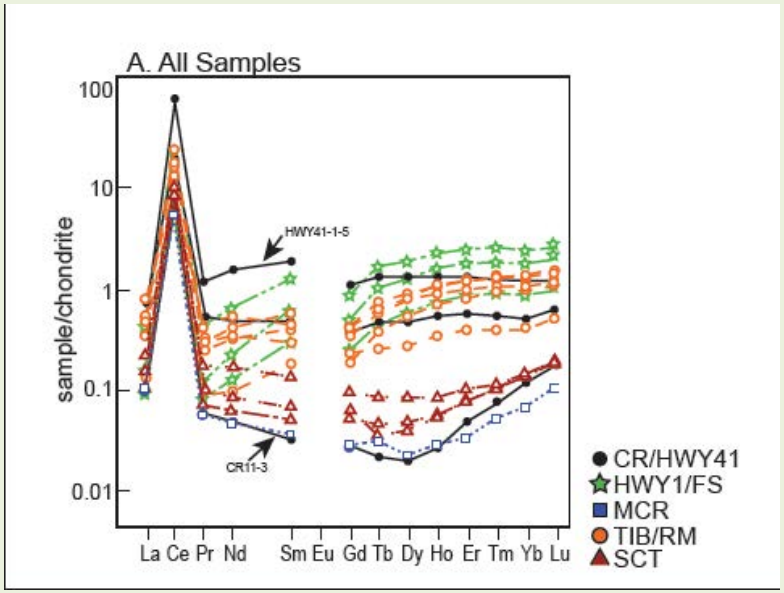

E. Franciscan: Tiburon Peninsula
TIB/RM
sample/chondrite
100
10
1
0.1
0.01
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

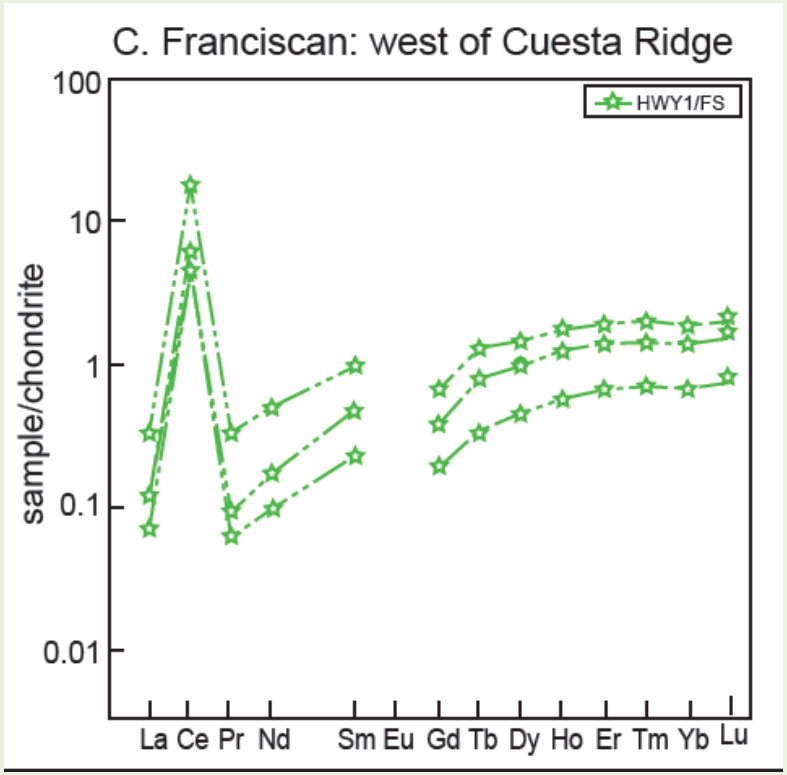

Great Valley Group
Franciscan Complex
Coast Range Ophiolite
Pre-Franciscan rocks & Mesozoic granitic rocks
Eocene & younger rocks
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT
MCR
TIB/RM
San Francisco
SCT
Monterey
Big Sur
King et al. (2003)
Hirauchi et al. (2008)
Salinian Block
San Andreas Fault
HWY1/FS
CR/HWY41
100 km
Sur-Nacimiento Fault
Santa Barbara

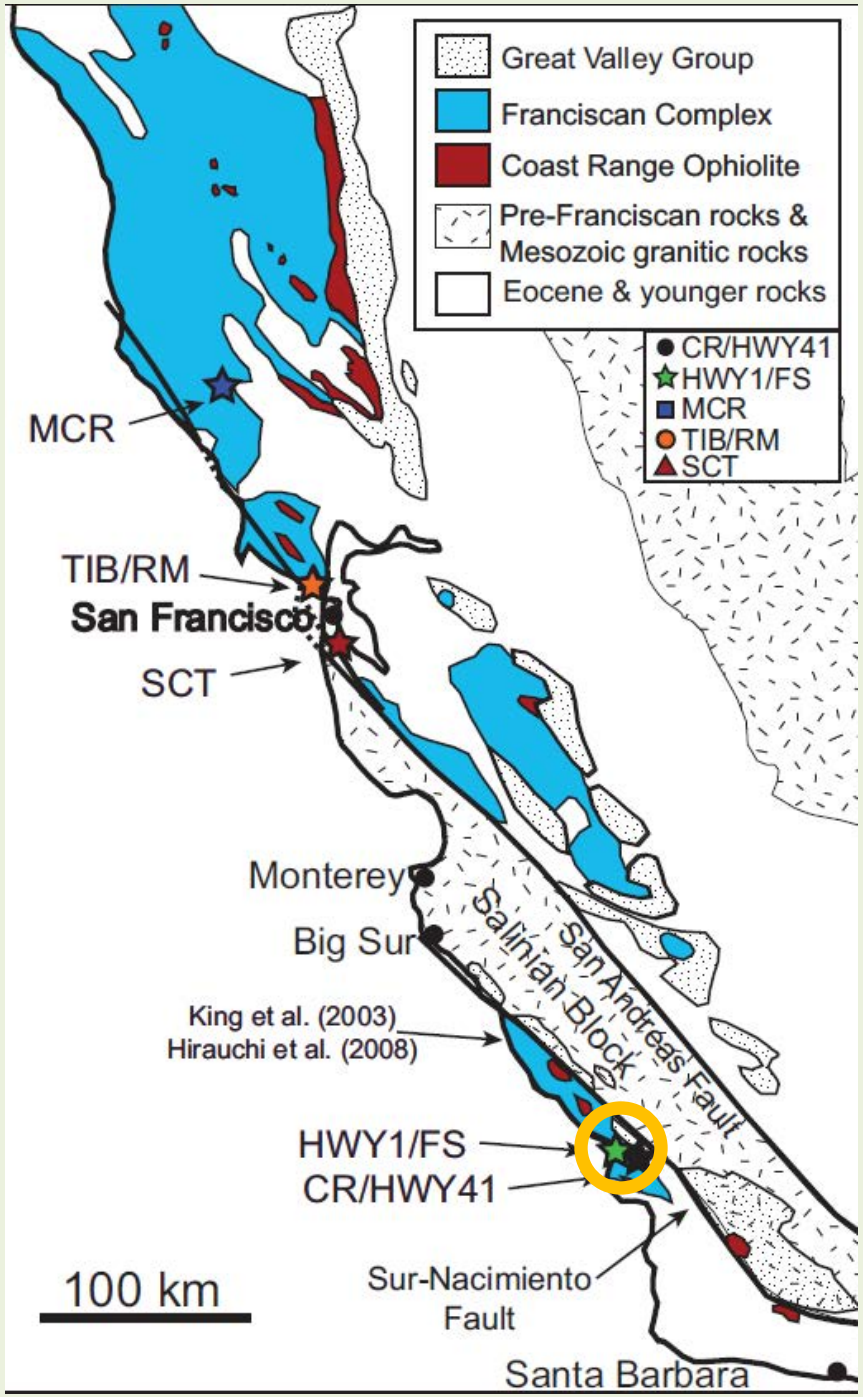

A. All Samples
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT

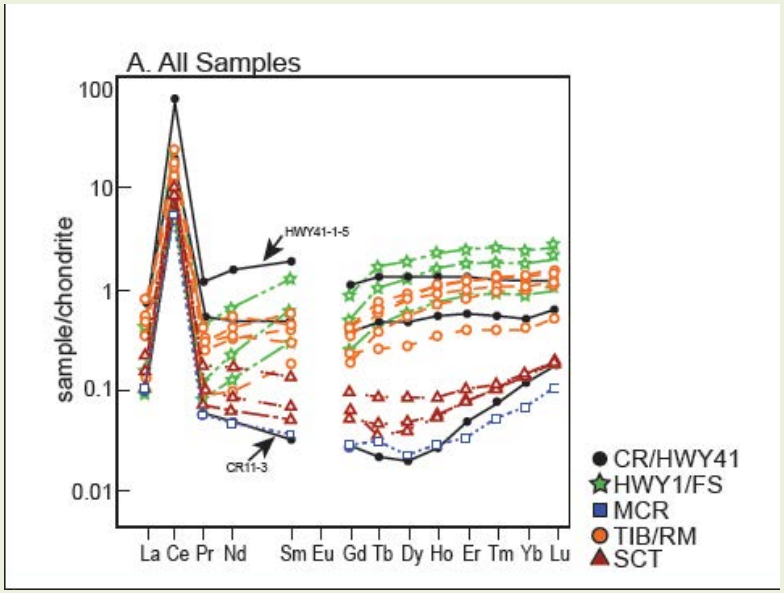

D. Franciscan: south of San Francisco
SCT
sample/chondrite
100
10
1
0.1
0.01
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

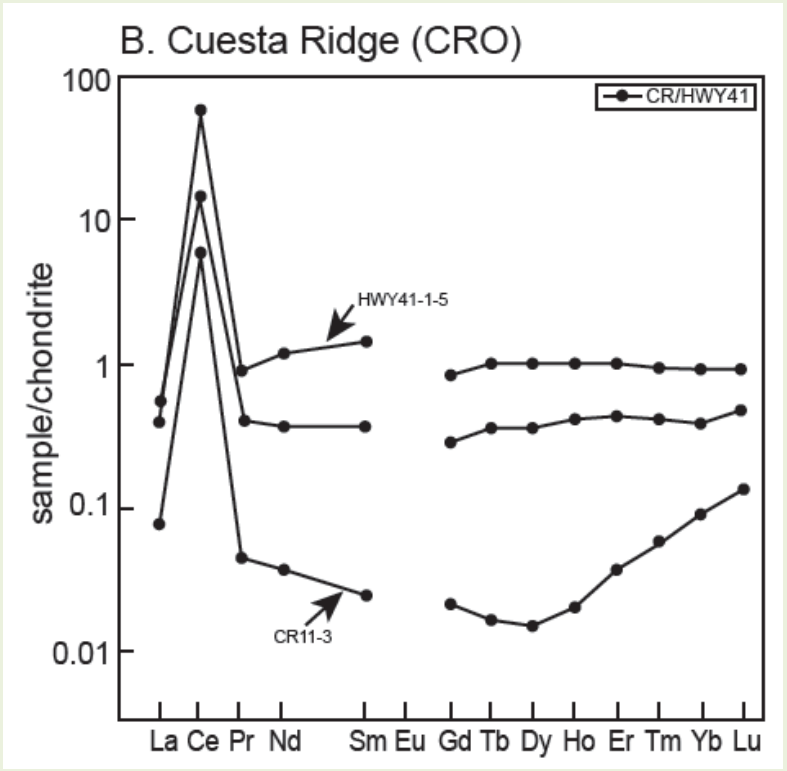

Great Valley Group
Franciscan Complex
Coast Range Ophiolite
Pre-Franciscan rocks & Mesozoic granitic rocks
Eocene & younger rocks
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT
MCR
TIB/RM
San Francisco
SCT
Monterey
Big Sur
King et al. (2003)
Hirauchi et al. (2008)
Salinian Block
San Andreas Fault
HWY1/FS
CR/HWY41
100 km
Sur-Nacimiento Fault
Santa Barbara

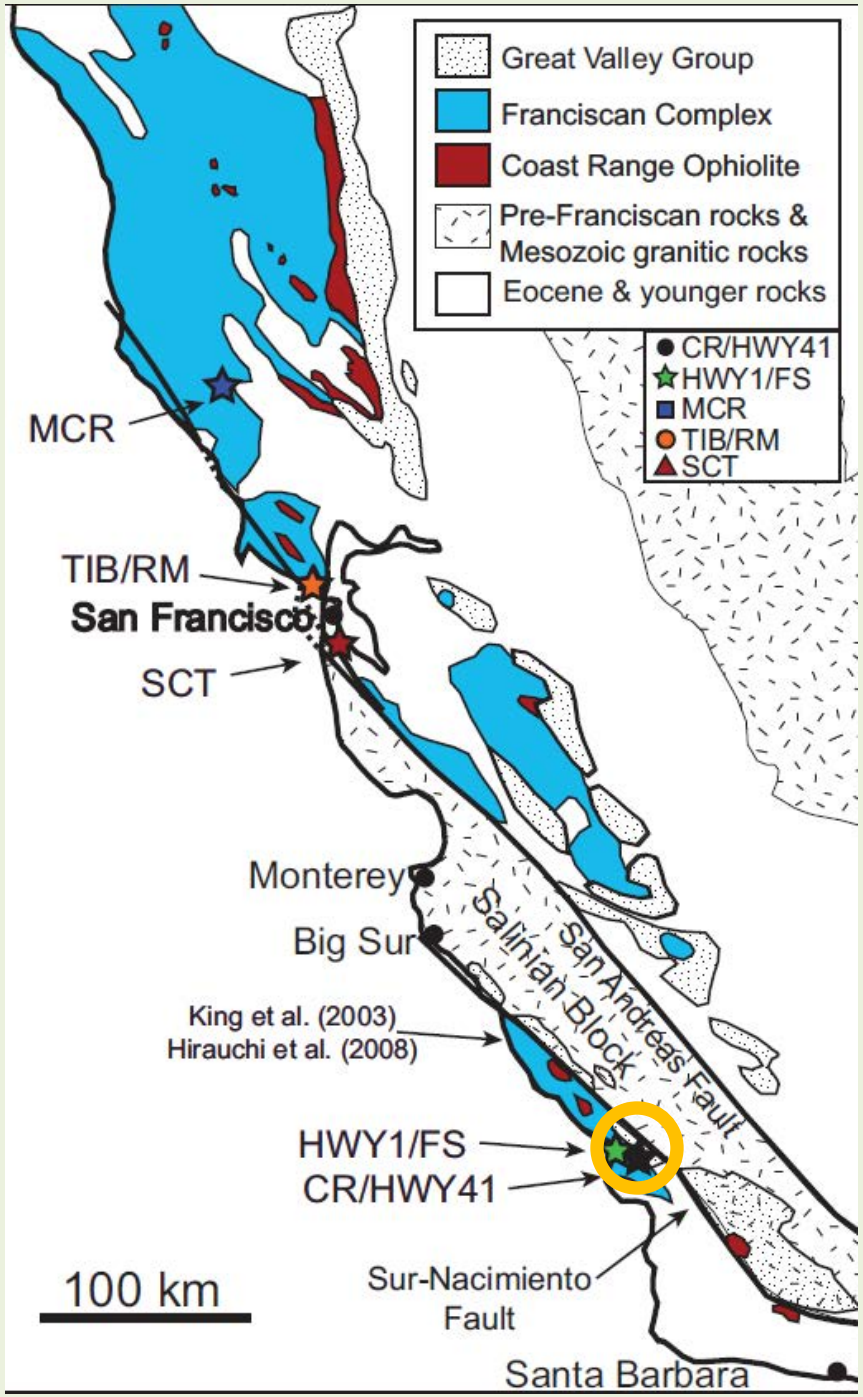

A. All Samples
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT


C. Franciscan: west of Cuesta Ridge
HWY1/FS
sample/chondrite
100
10
1
0.1
0.01
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu


Great Valley Group
Franciscan Complex
Coast Range Ophiolite
Pre-Franciscan rocks & Mesozoic granitic rocks
Eocene & younger rocks
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT
MCR
TIB/RM
San Francisco
SCT
Monterey
Big Sur
King et al. (2003)
Hirauchi et al. (2008)
Salinian Block
San Andreas Fault
HWY1/FS
CR/HWY41
100 km
Sur-Nacimiento Fault
Santa Barbara


A. All Samples
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT


B. Cuesta Ridge (CRO)
CR/HWY41
sample/chondrite
100
10
1
0.1
0.01
HWY41-1-5
CR11-3
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu


Great Valley Group
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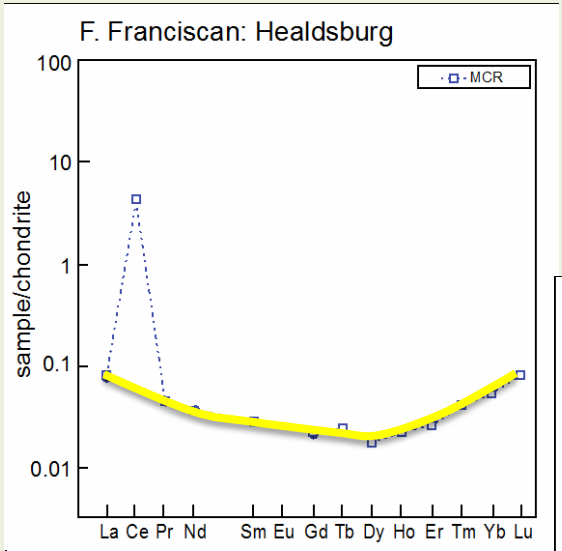
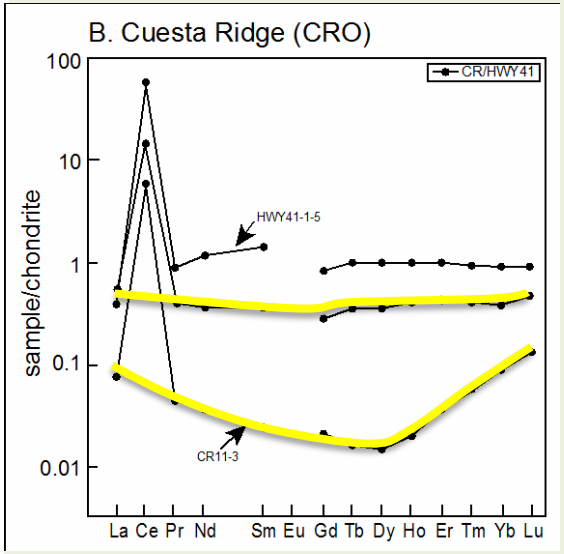
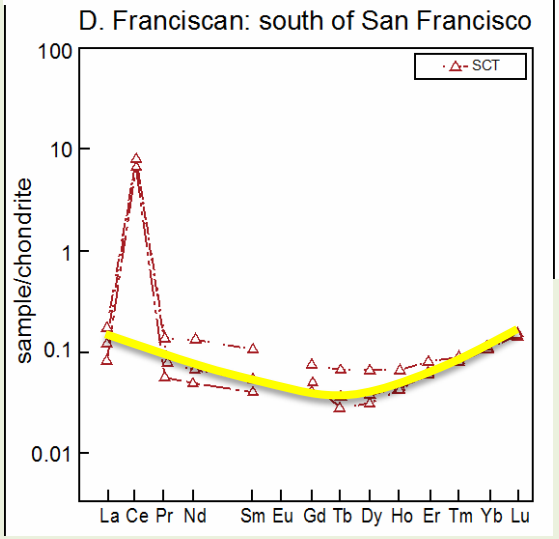
CR/HWY41
HWY1/FS
MCR
TIB/RM
SCT
MCR
TIB/RM
San Francisco
SCT
Monterey
Big Sur
Salinian Block
San Andreas Fault
King et al. (2003)
Hirauchi et al. (2008)
HWY1/FS
CR/HWY41
100 km
Sur-Nacimiento Fault
Santa Barbara

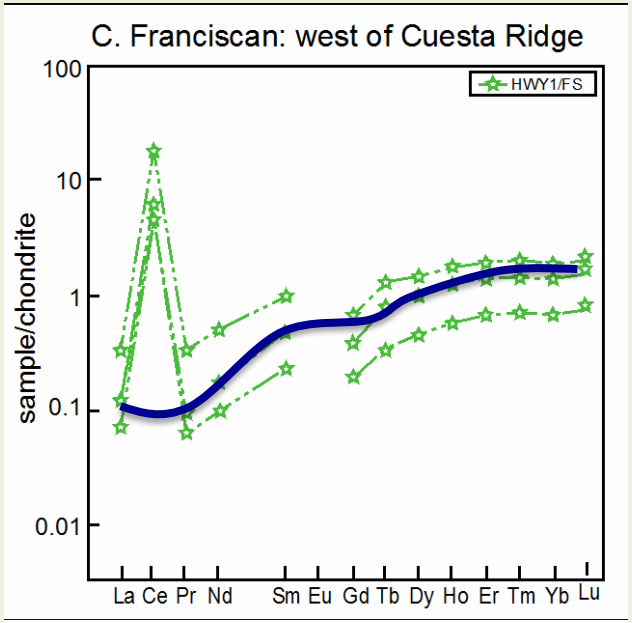
U – Shaped:
MCR, SCT, CRO

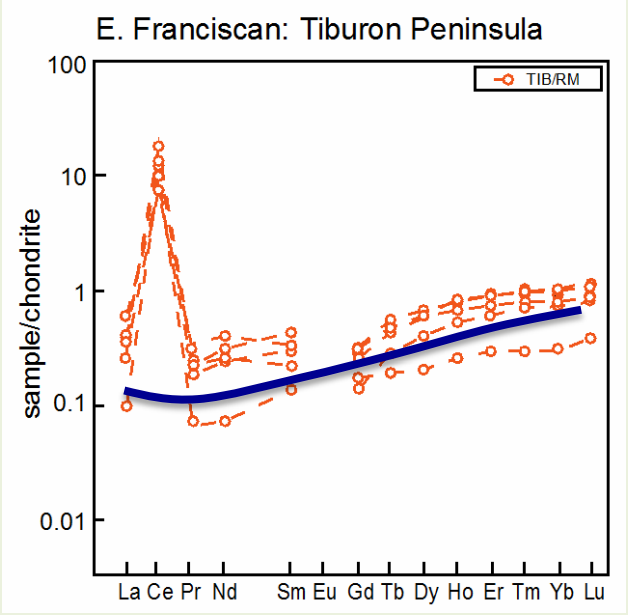


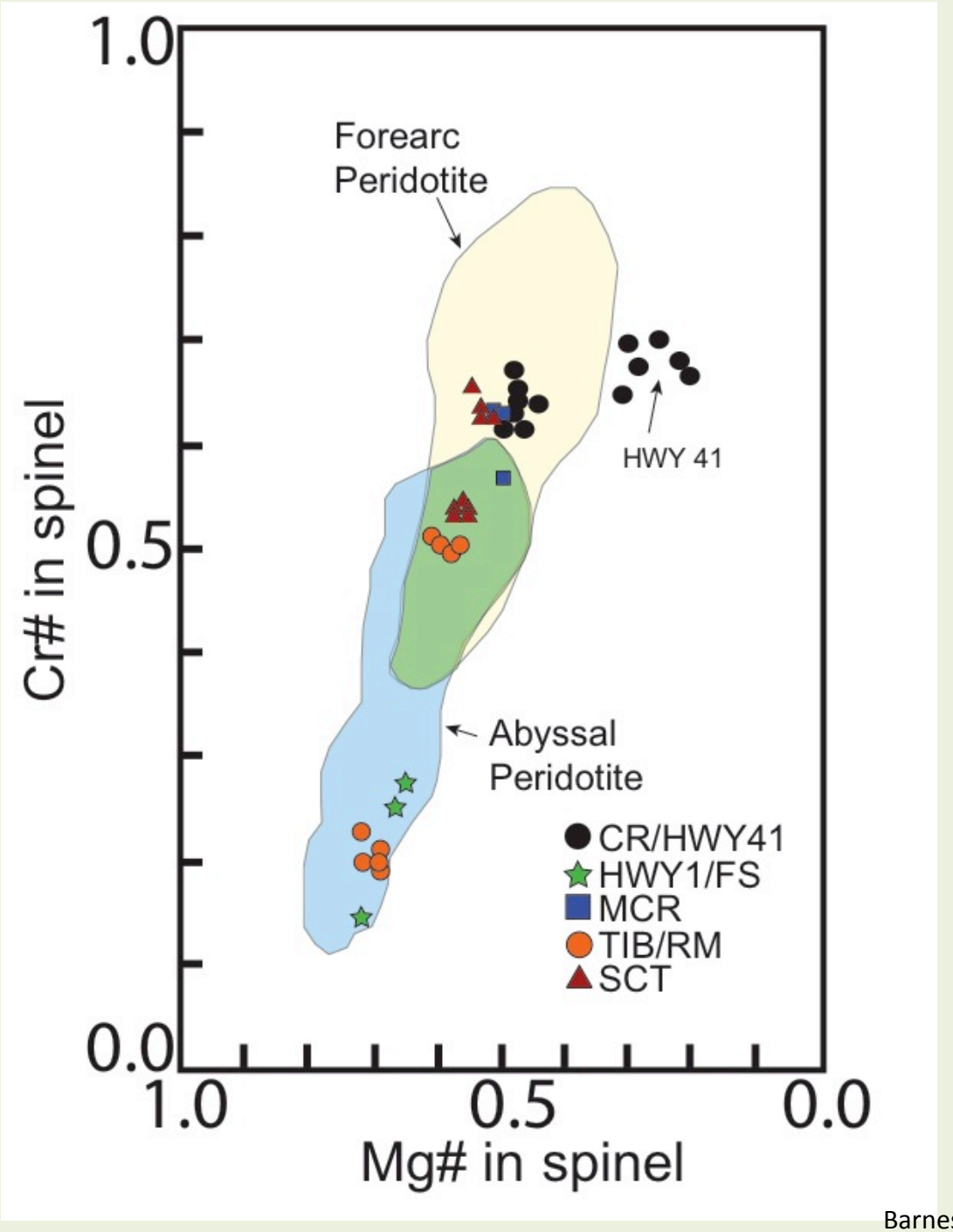




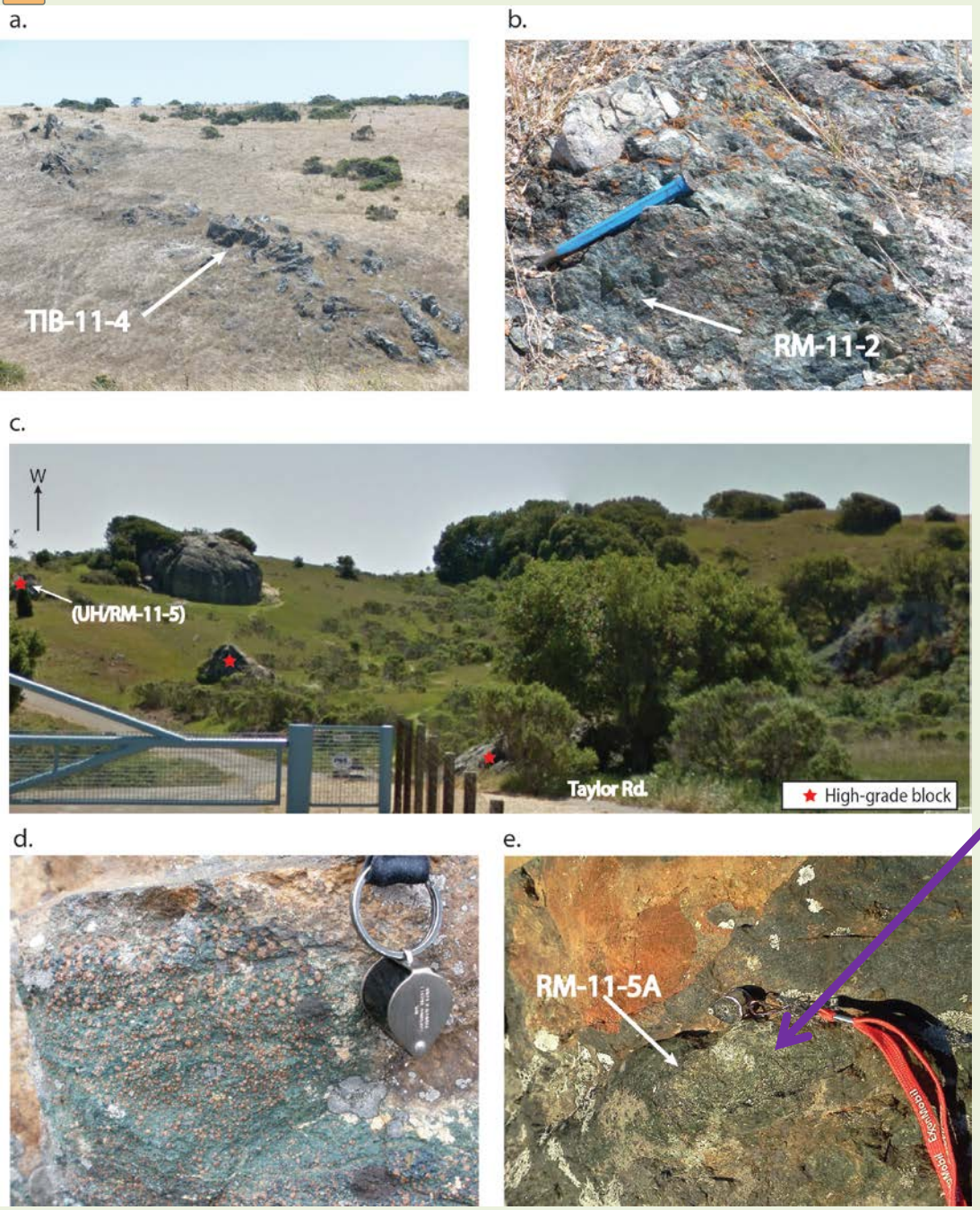
Positive Trend:
TIB/RM & HWY1/FS





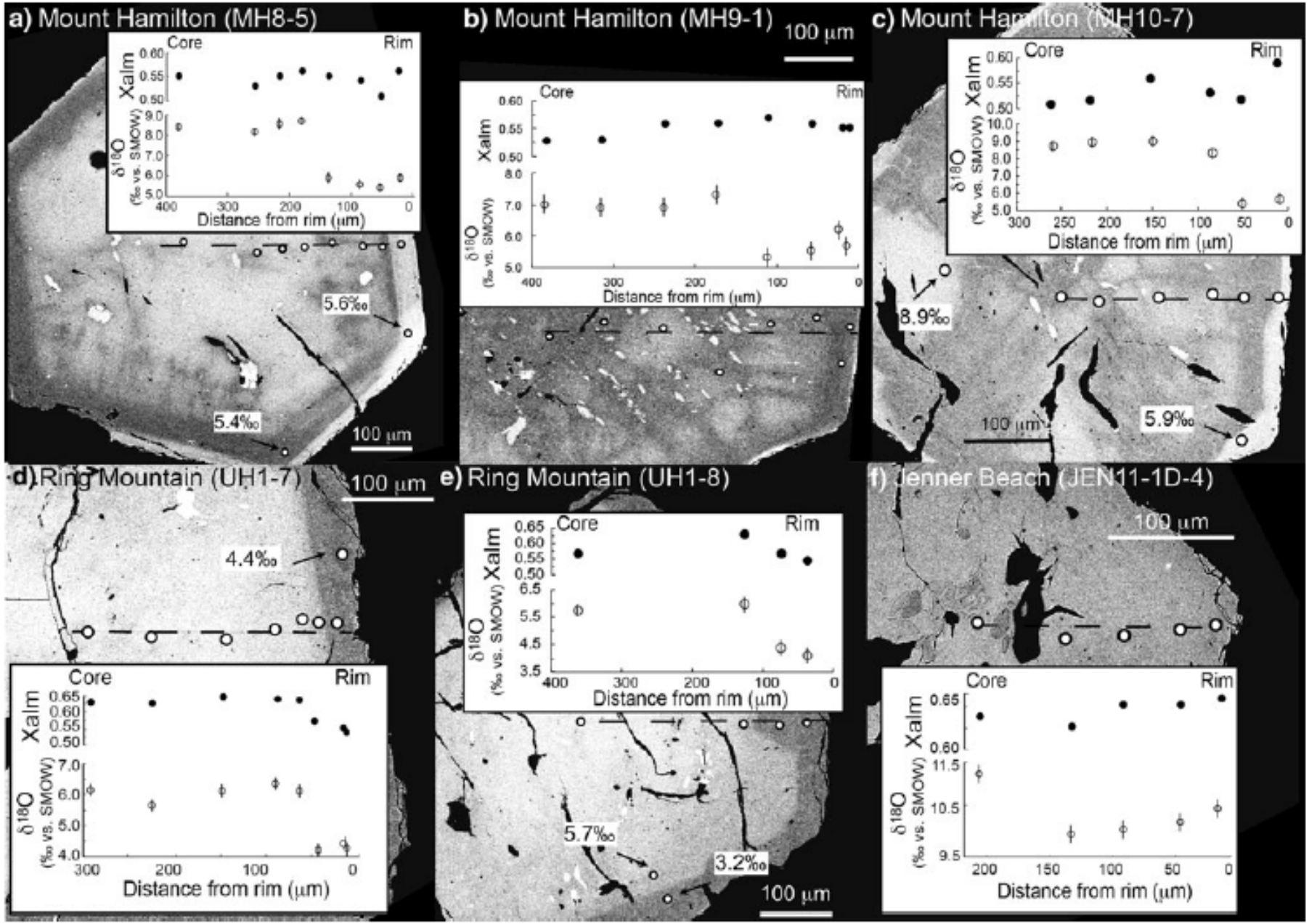


Barnes, Eldam, et al. (2013) Lithos

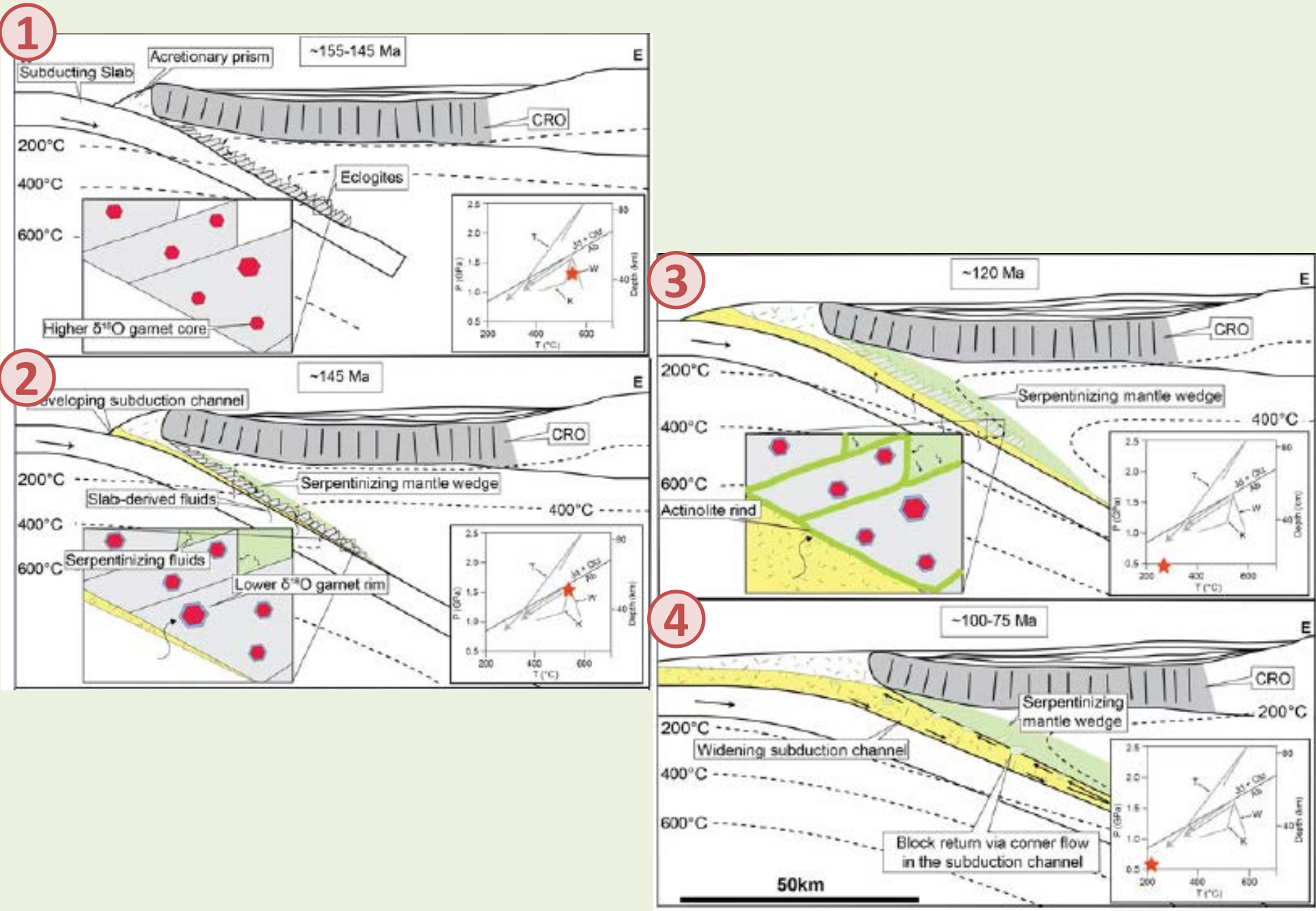


High-Grade Blocks: Interaction with serpentinites

Reaction rinds on high-grade blocks



Errico et al. (2013) CMP



Errico et al. (2013) CMP

Outstanding Questions

How prevalent is serpentinization of the mantle wedge?

How extensive is serpentinization of the mantle wedge?