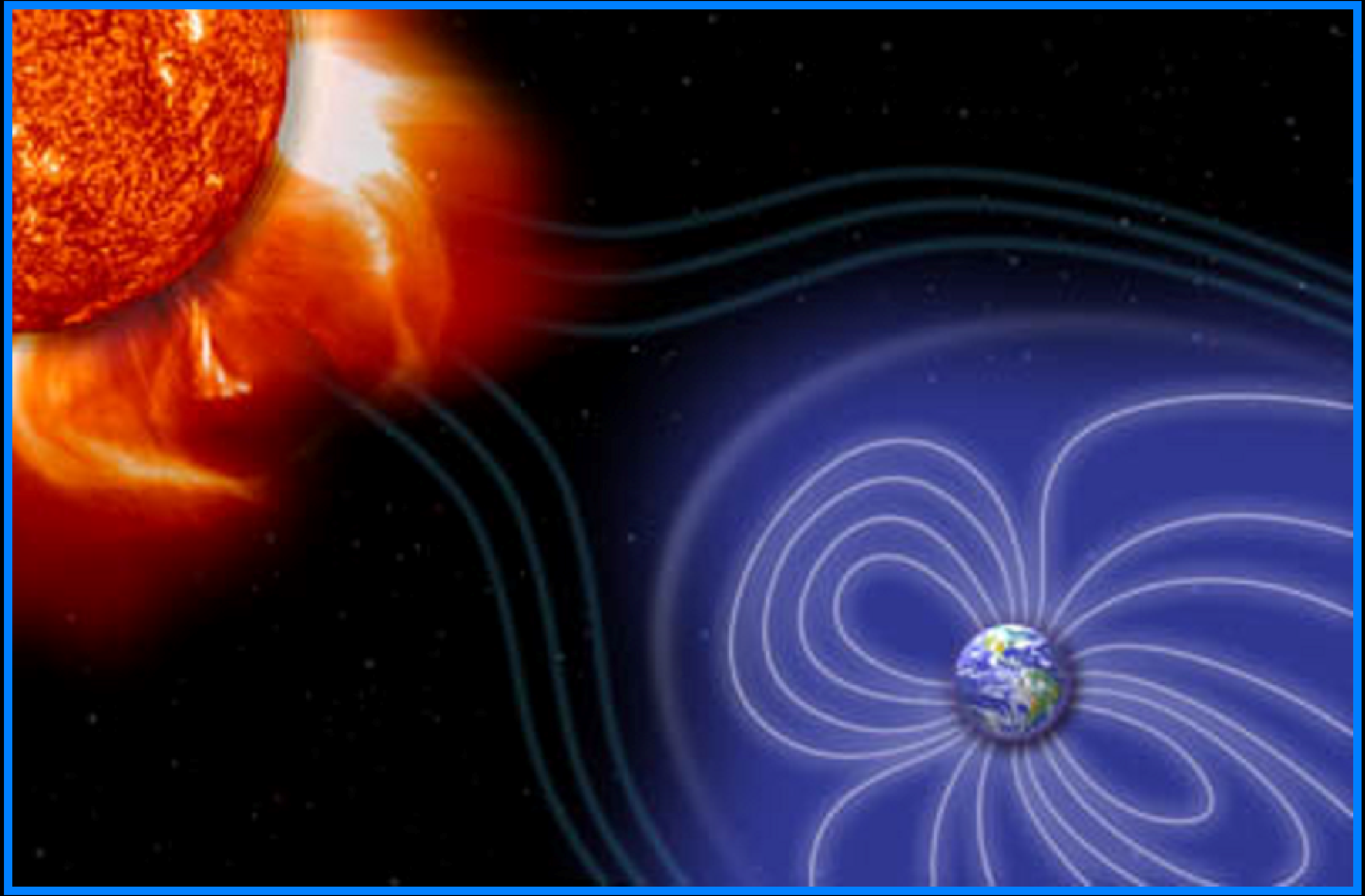
U.S. National Science Foundation, U.S. Department of Energy, GNS Science, Royal Society of New Zealand

Petrological Systematics of the Electrical Resistivity Structure of Continental Subduction Arc-Extensional Backarc Regimes Including Closure and Stabilization

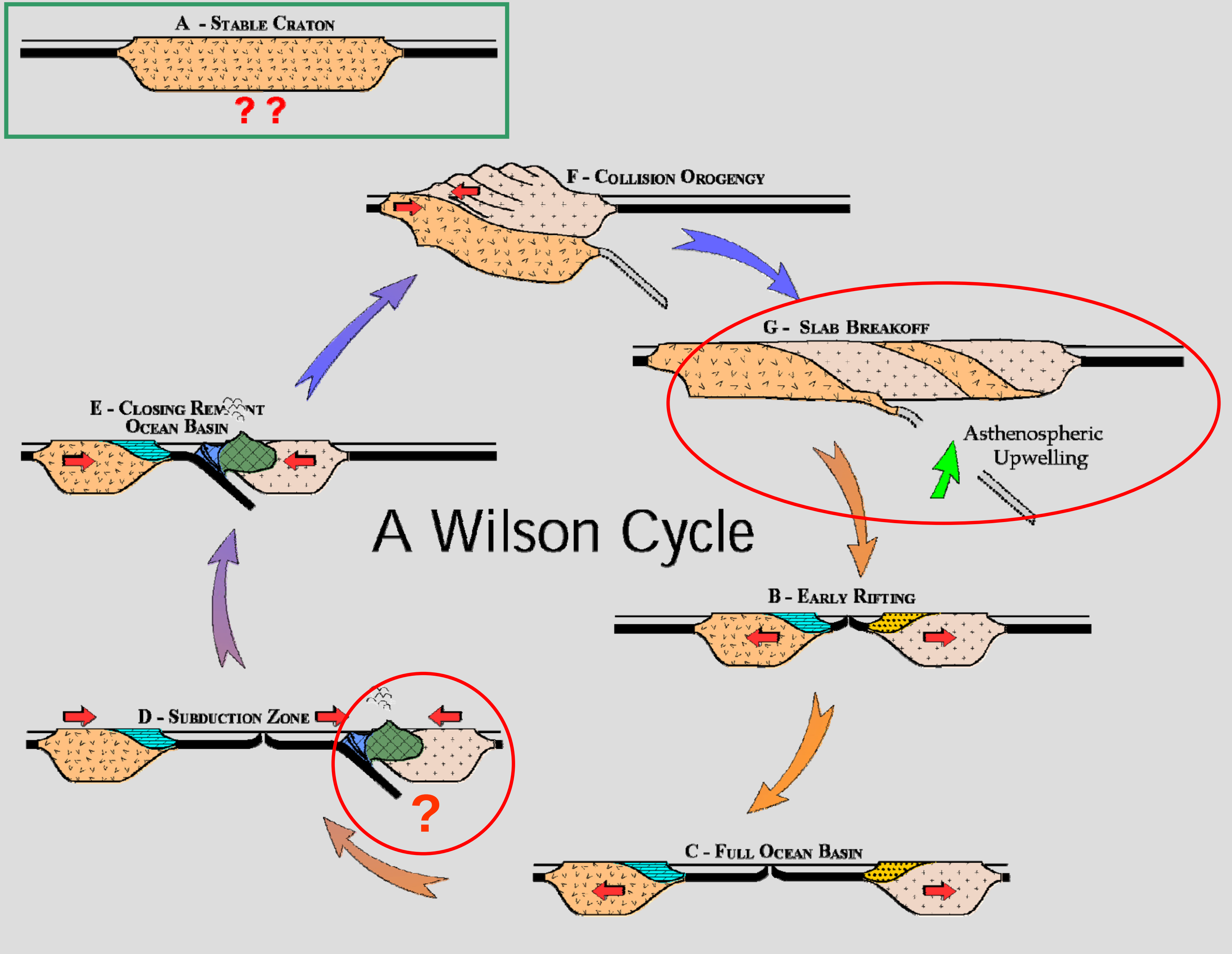
Phil Wannamaker, University of Utah/EGI

- Explore example resistivity expressions in Wilson Cycle phases.
- Role of P-T-X and stress conditions on resistivity properties.
- Source-sink process views from upper mantle to upper crust.
- Mix of ancient to modern contributions to structure.

Source Fields for the Magnetotelluric Method



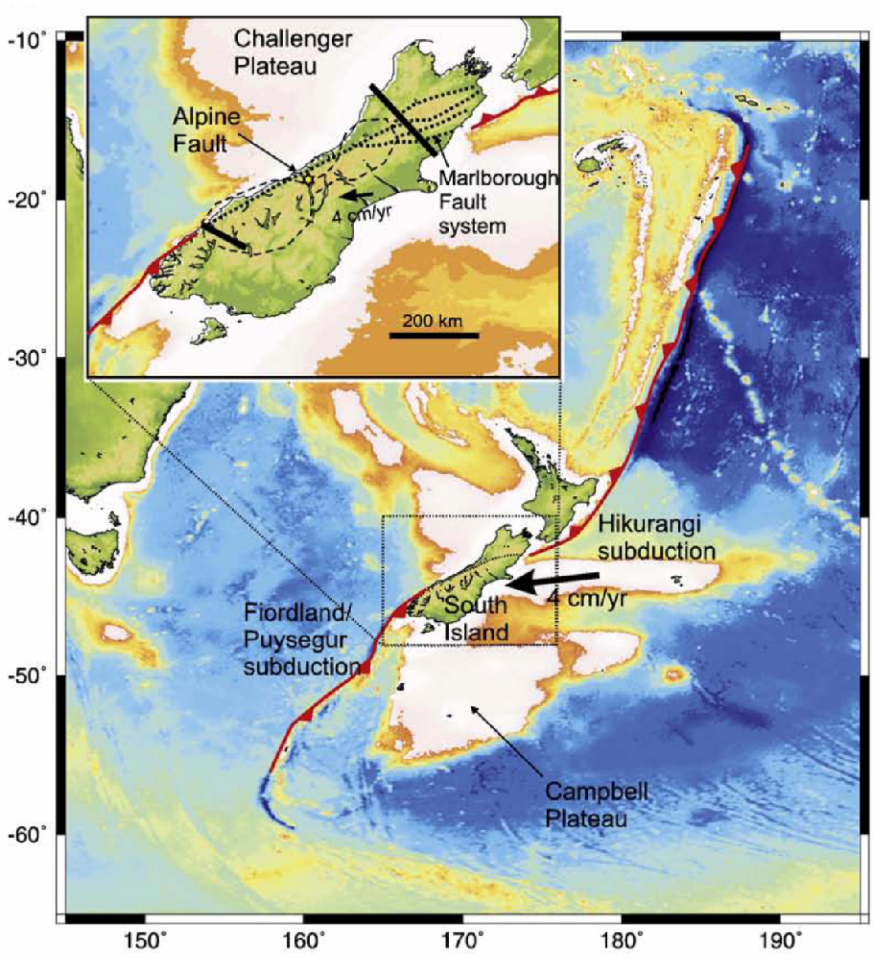
Regional and Global Lightning Activity for f > 1 Hz
Solar Wind-Magnetospheric Interactions for f < 1 Hz

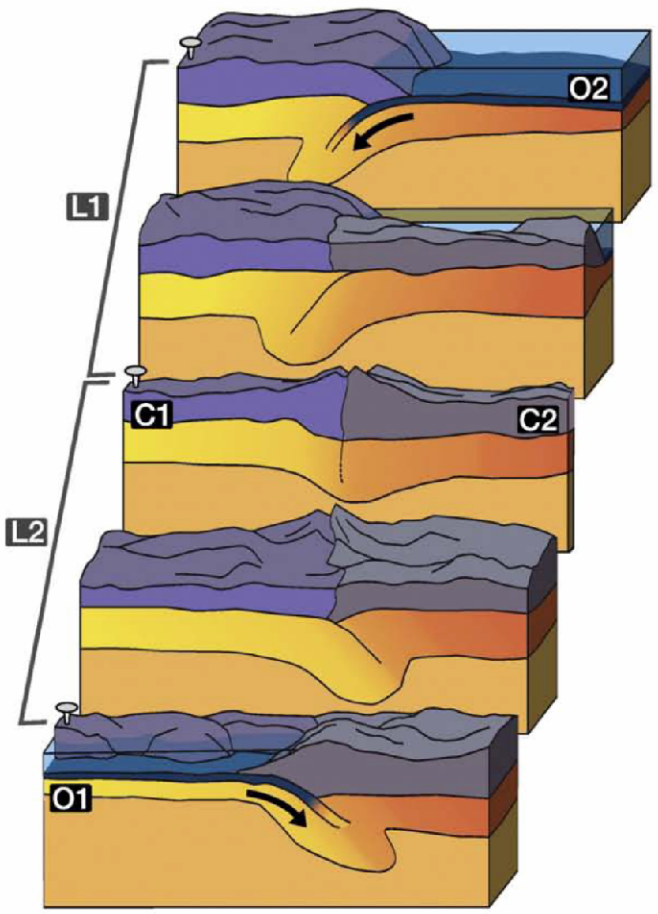


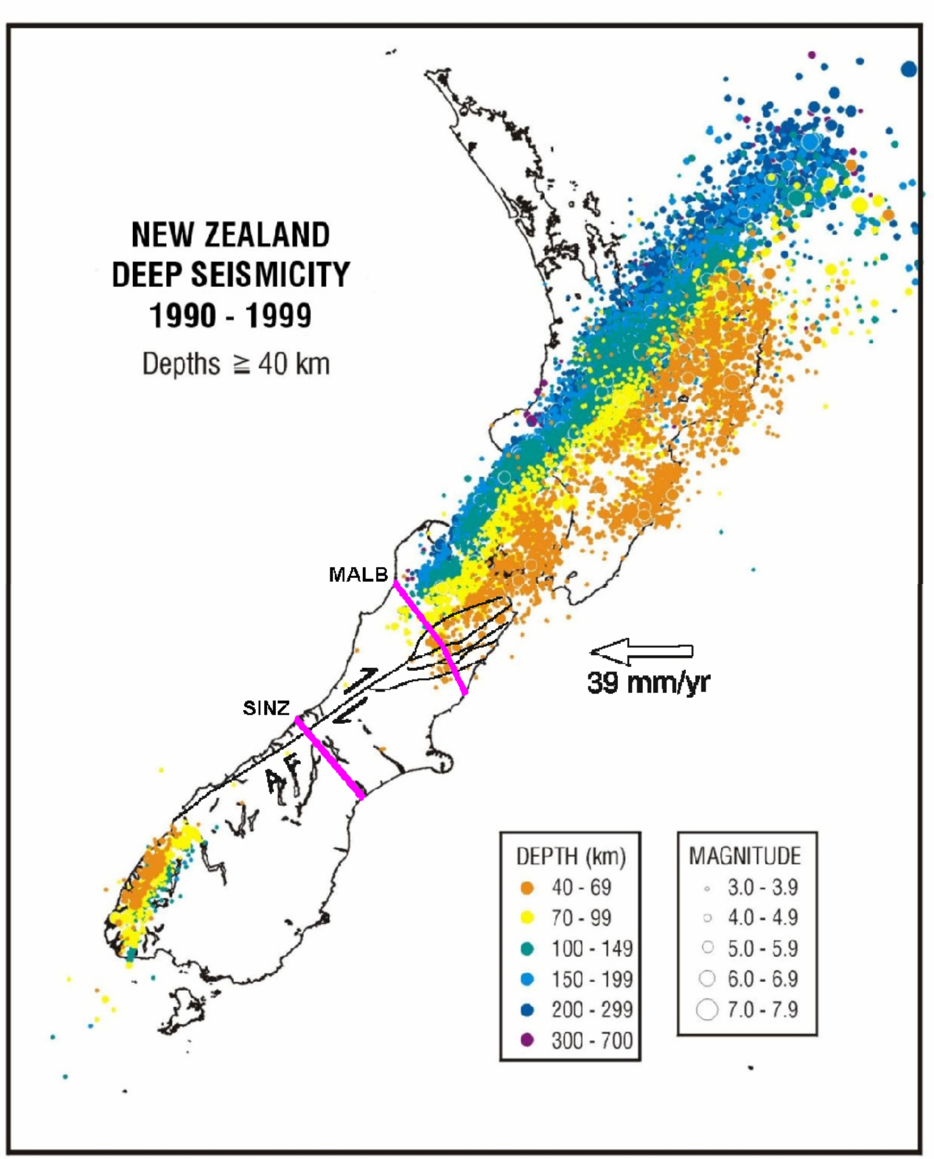
Mod from http://geollab.jmu.edu/Fichter/Wilson/wilsoncircl.html

J. Tuzo Wilson (1966)

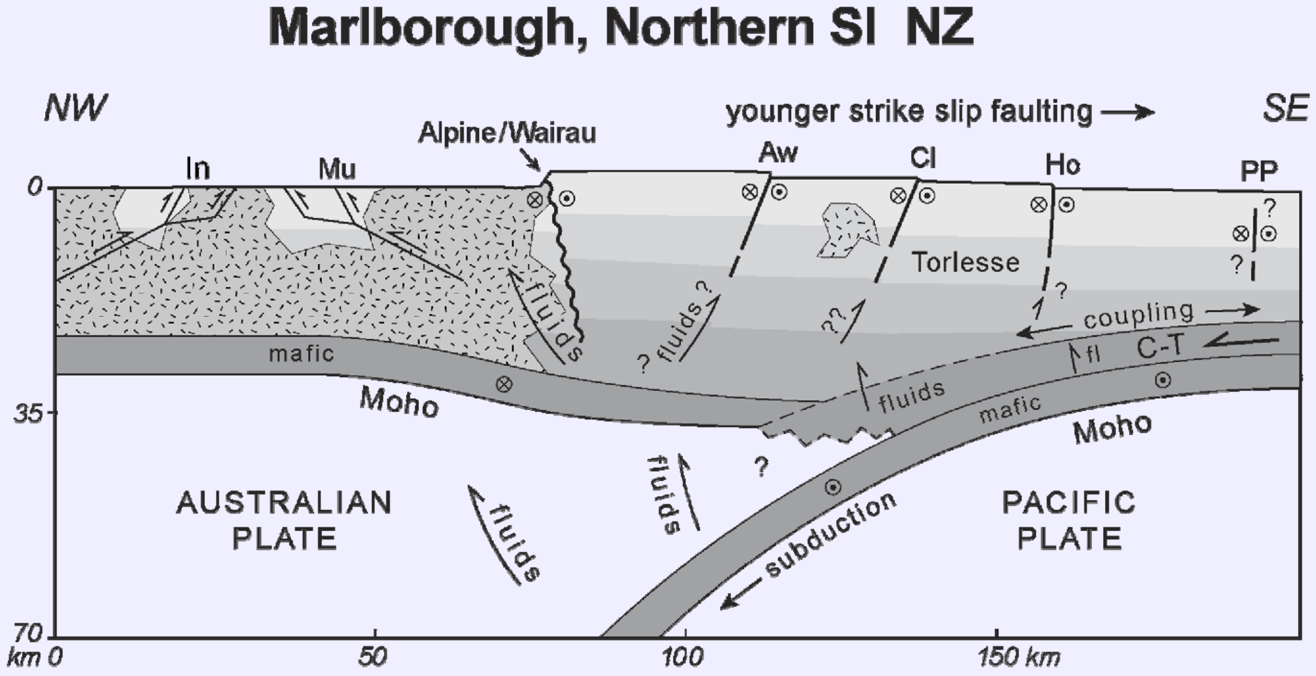
- "Did the Atlantic close and then re-open?"
- 2D: Little recognition of strike-slip processes (apart from oceanic transforms).
- Processes driving initial rifting (slab breakoff?, plume?).
- What are heat and element transfer processes in the cycle?
- Fossil resistivity traces of cycle processes.
- Biological contributions to resistivity structure.

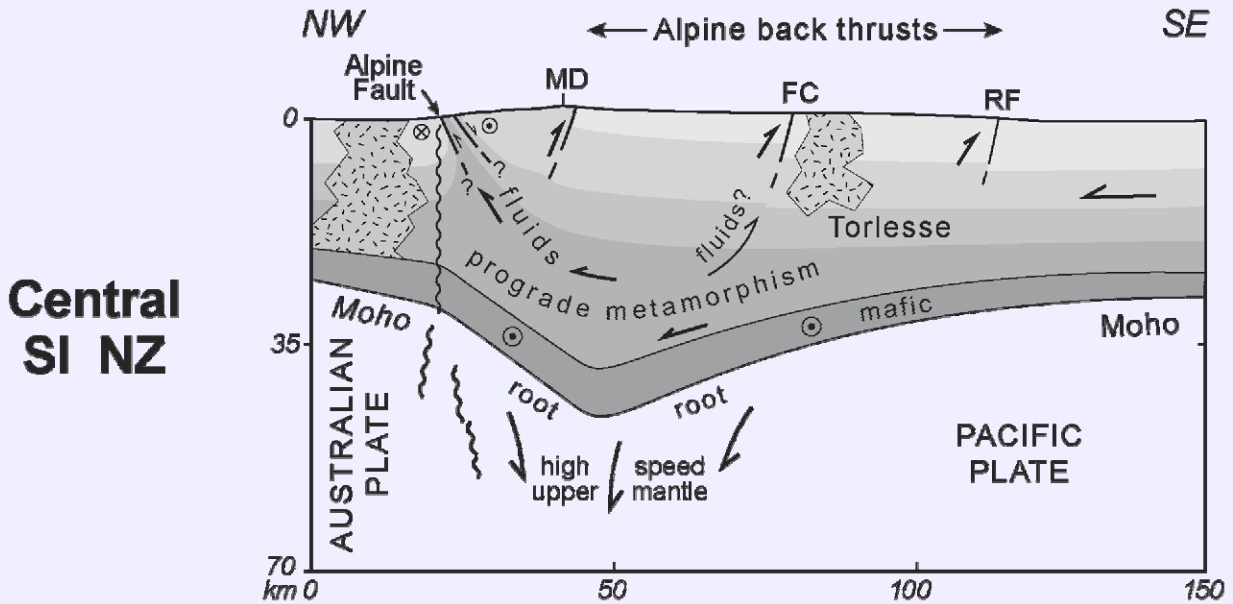




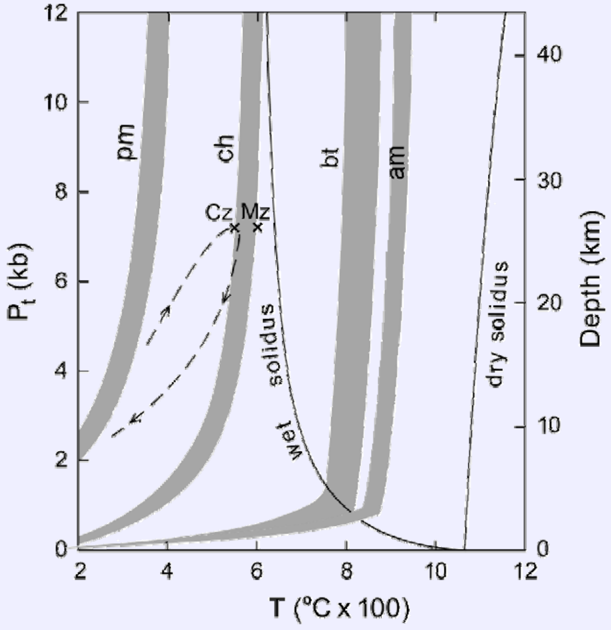


A Subduction Scissor (Pysklywec et al., 2010)



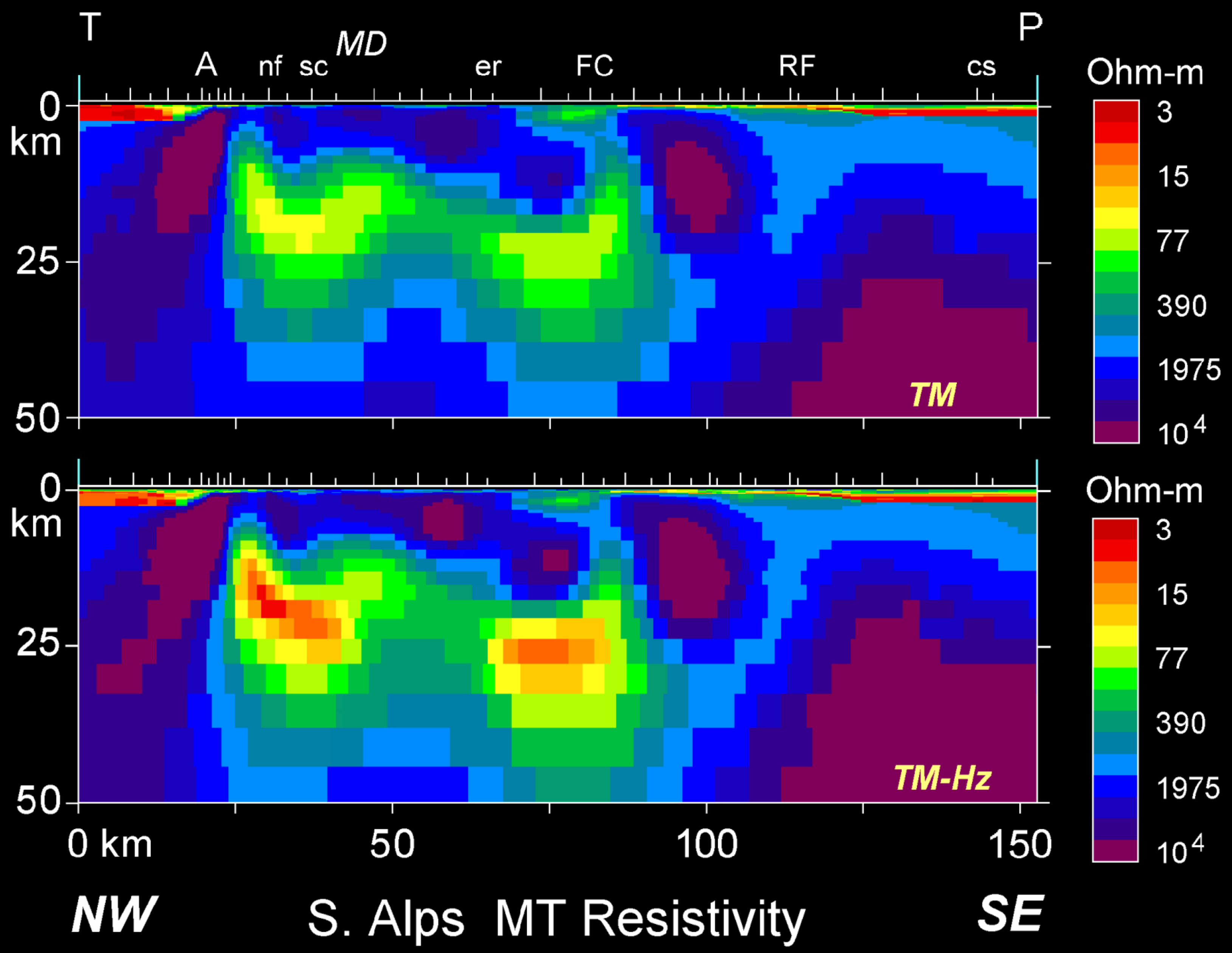


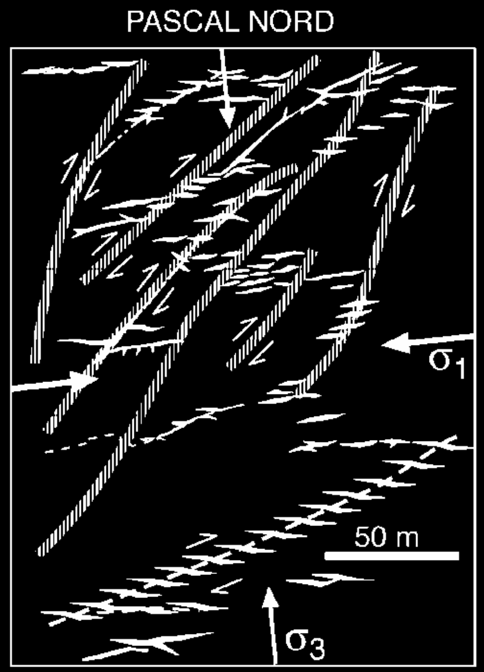
Diorite-H2O petrogenetic grid



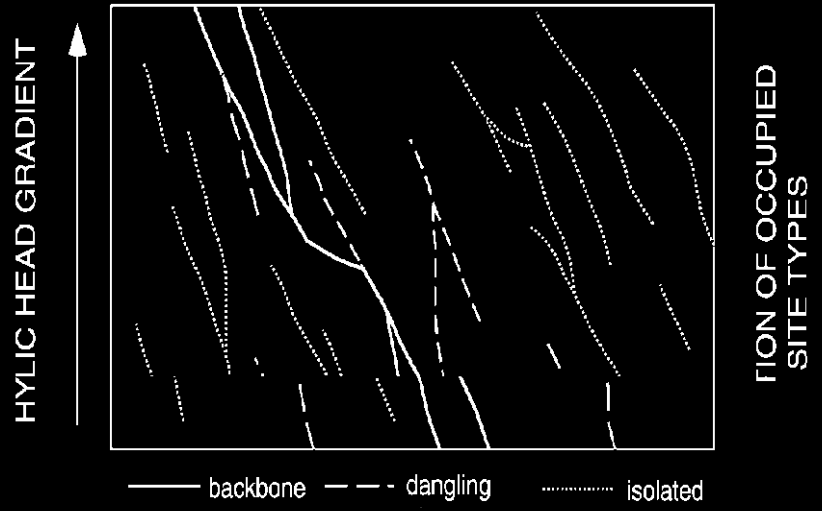
Aranovich and Newton (1997)

Complex salts reduce T of last fluid

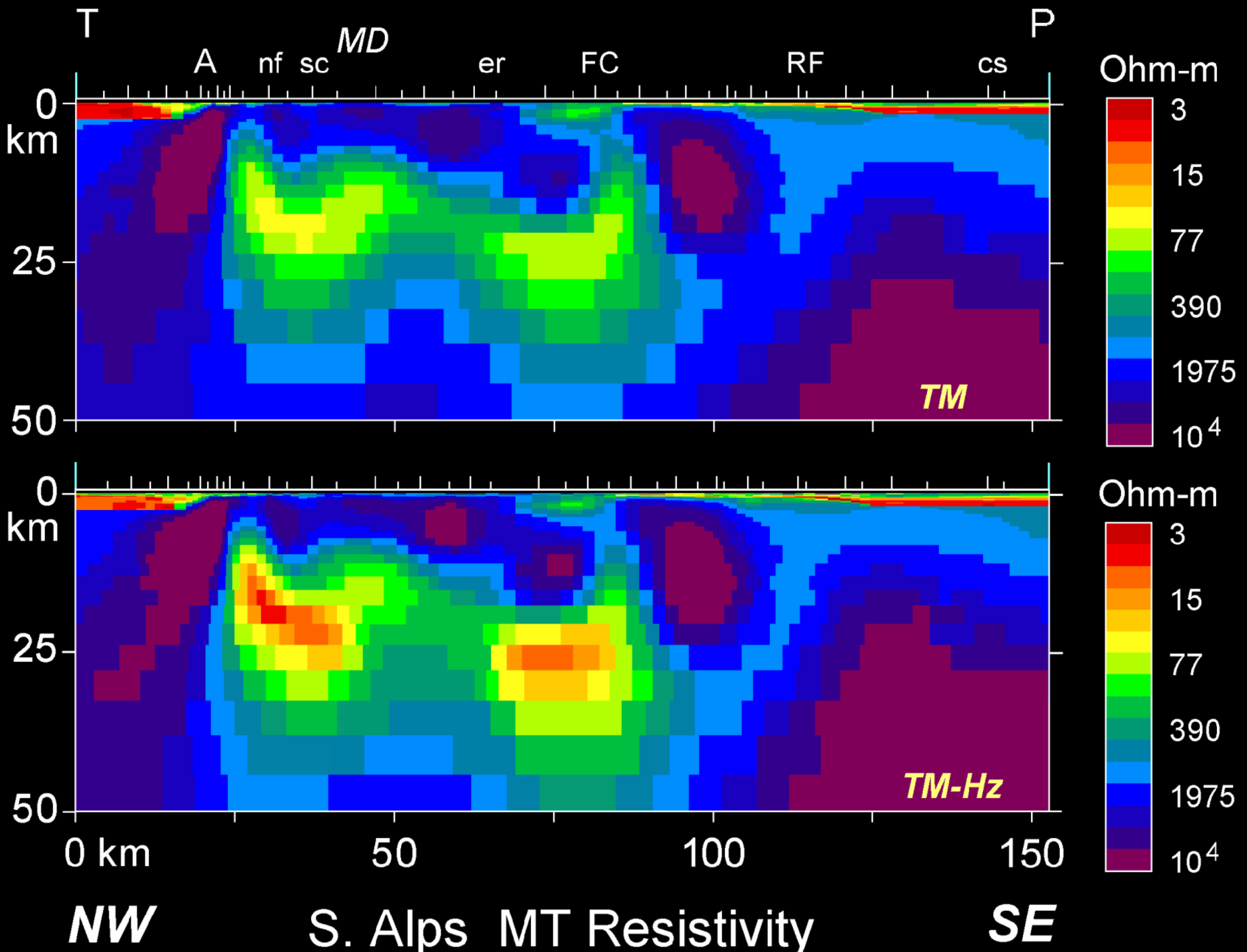




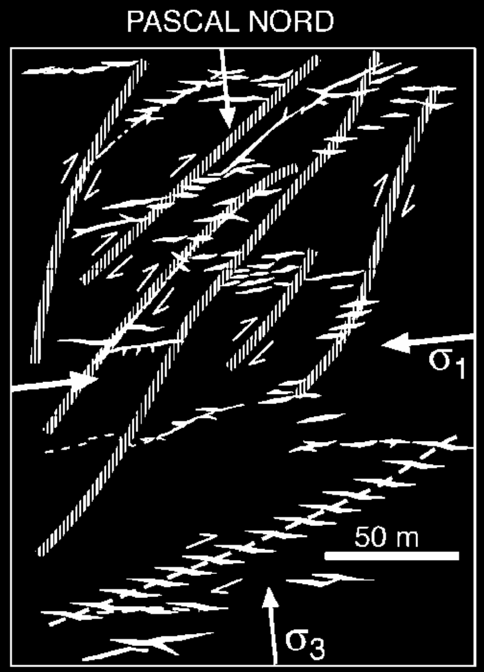
Sibson (2004)



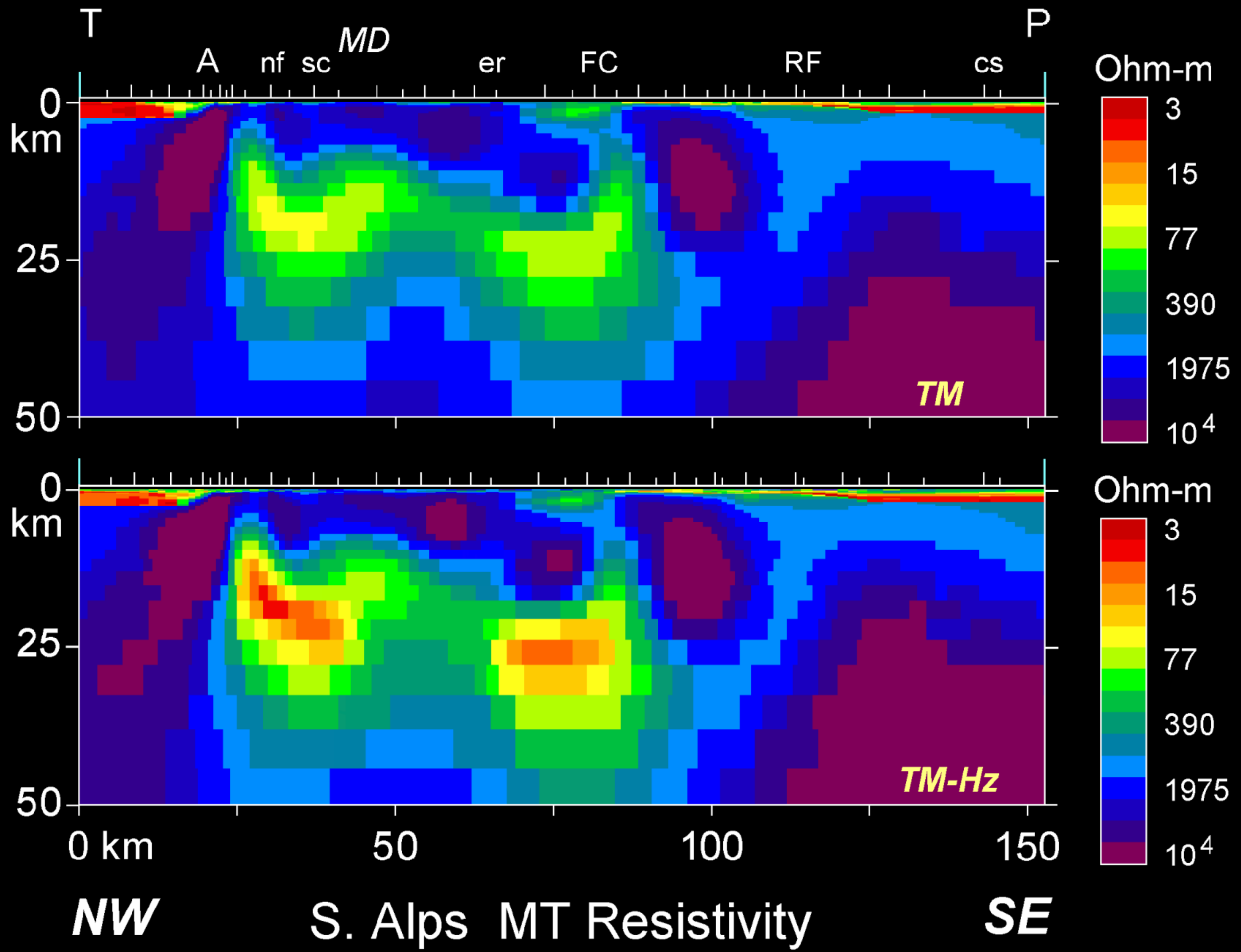
Cox (1999)

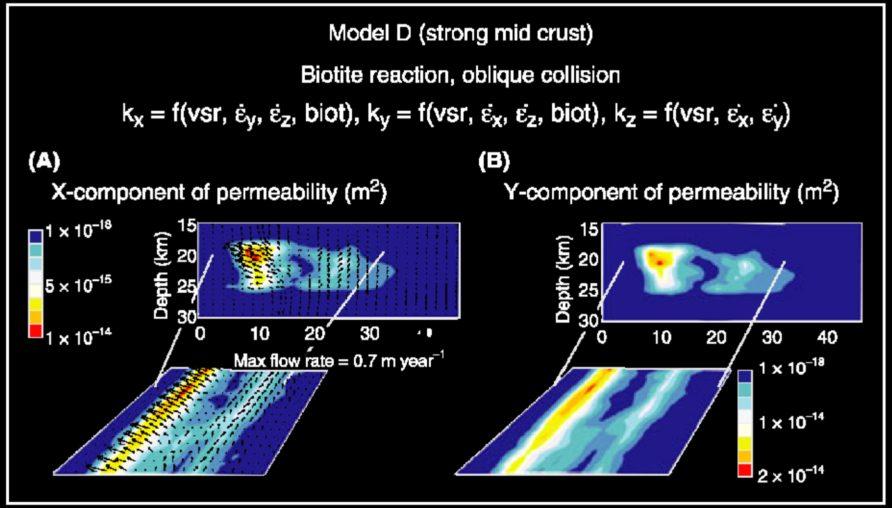


S. Alps MT Resistivity



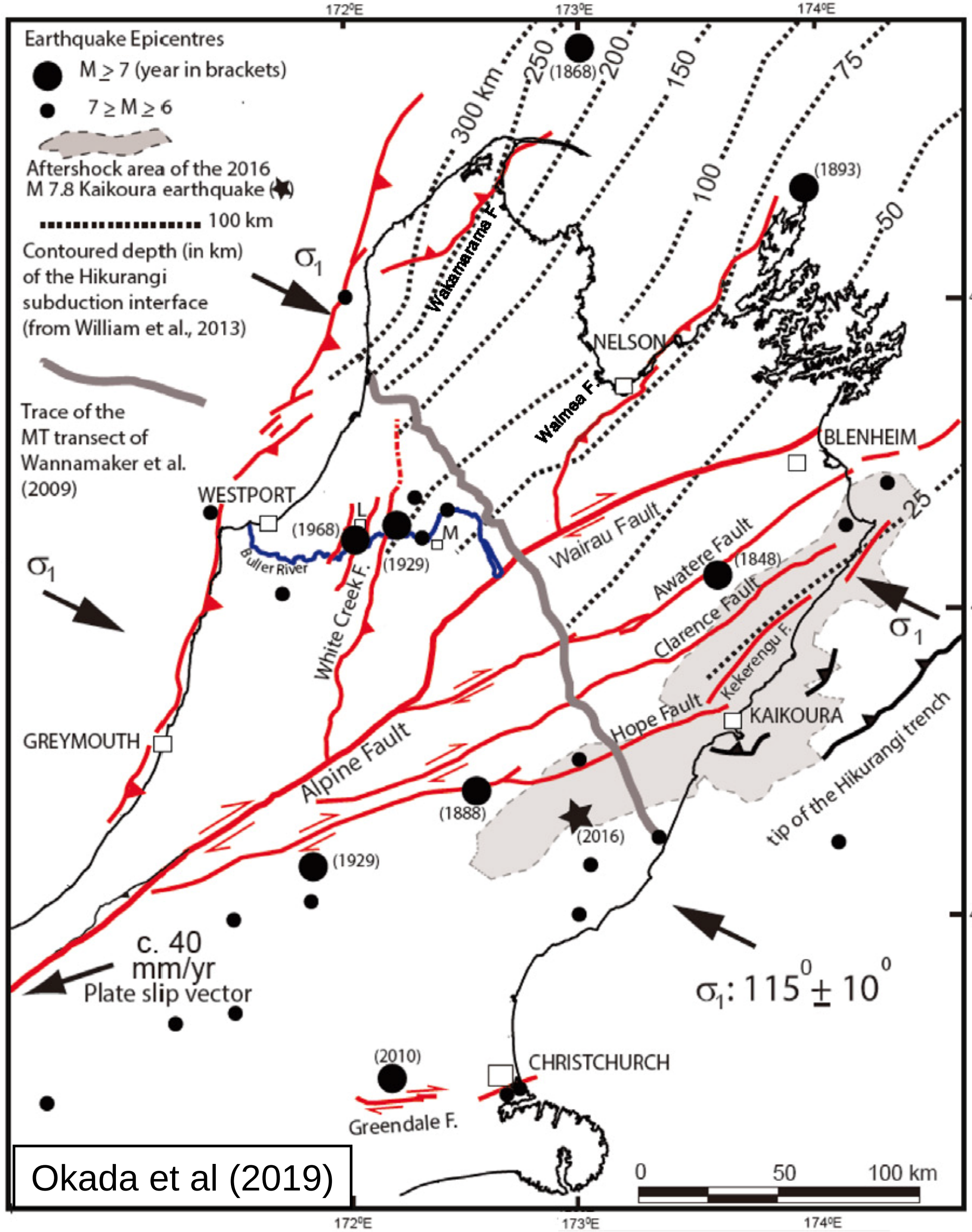
R. Sibson (2009)





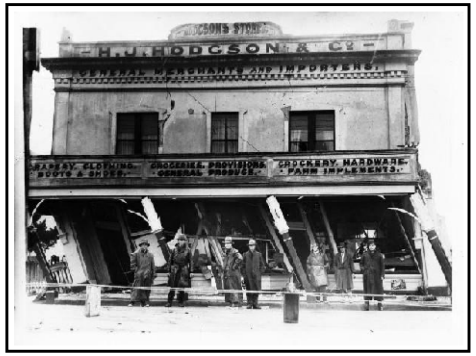
FLAC3D; Upton and Craw (2009)

Wannamaker et al (2002)

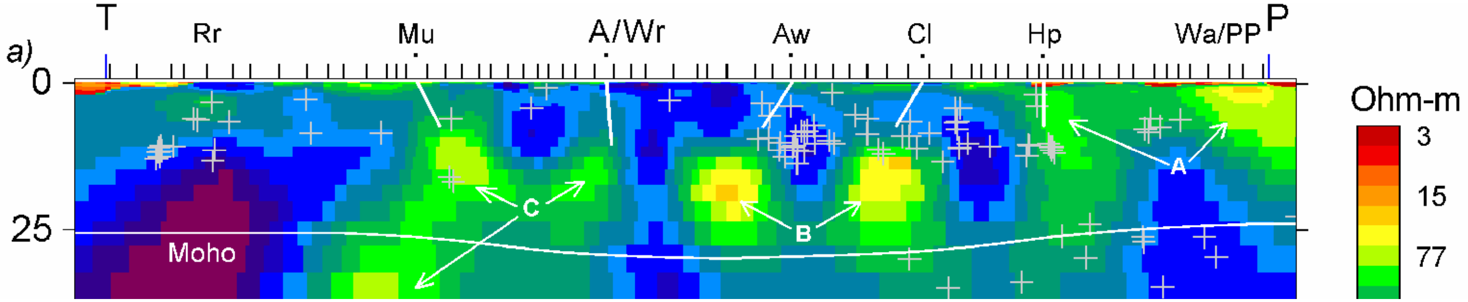


Okada et al (2019)

Murchison, Westland (Ghisetti and Sibson, 2006)



Slip and Slip Rate, Marlborough FS

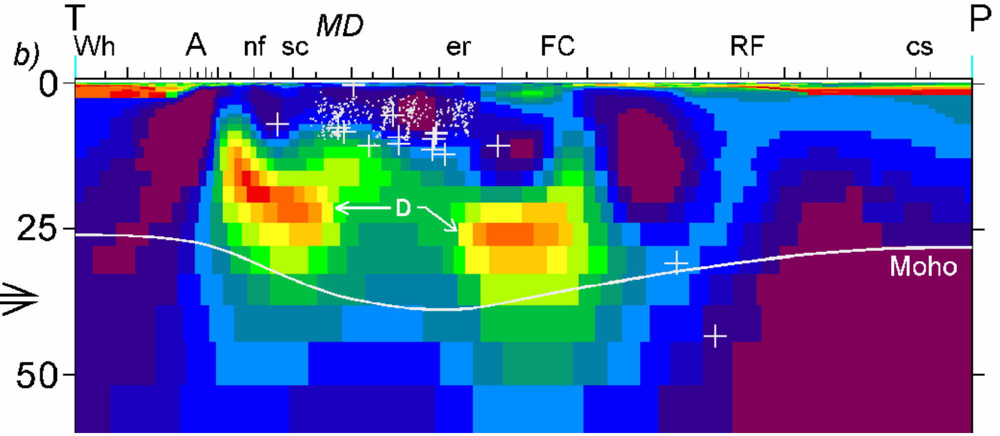


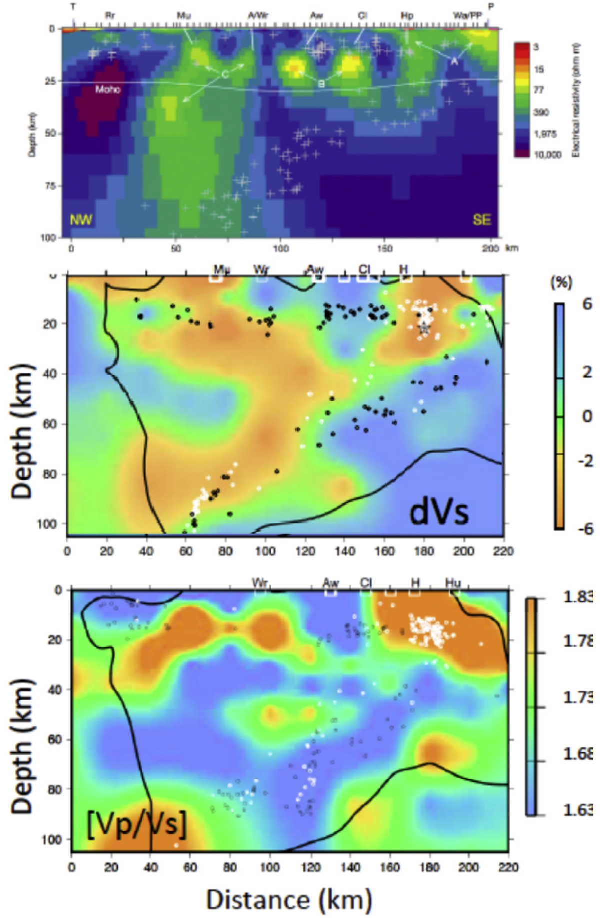
||

Marlborough

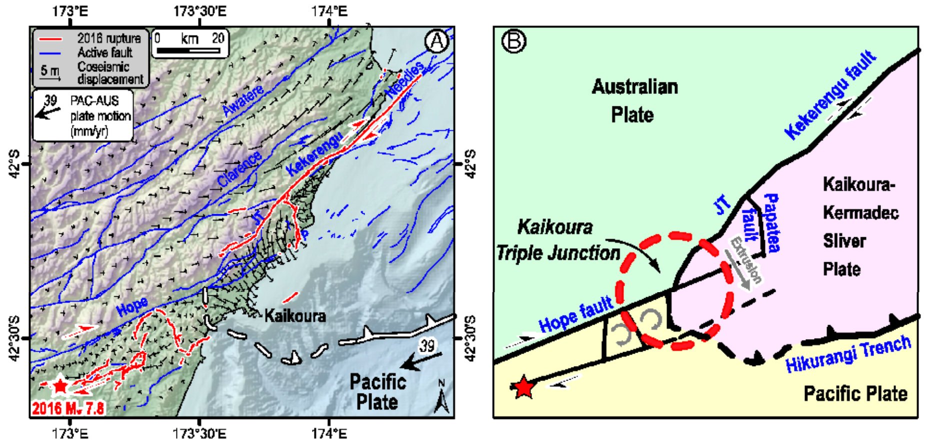
S. Alps ⟹

(Wannamaker et al. 2009)

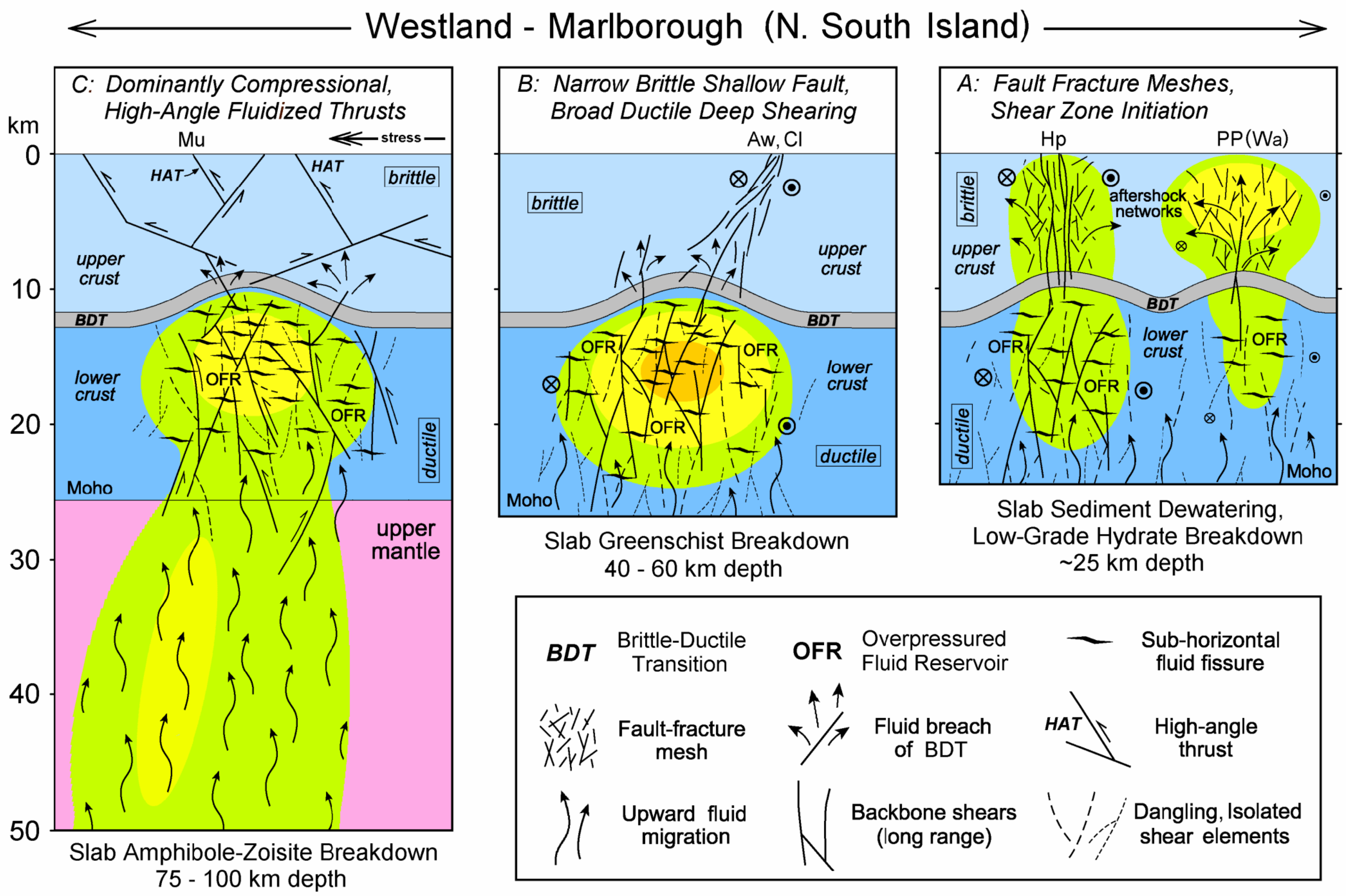




Okada et al (2019)

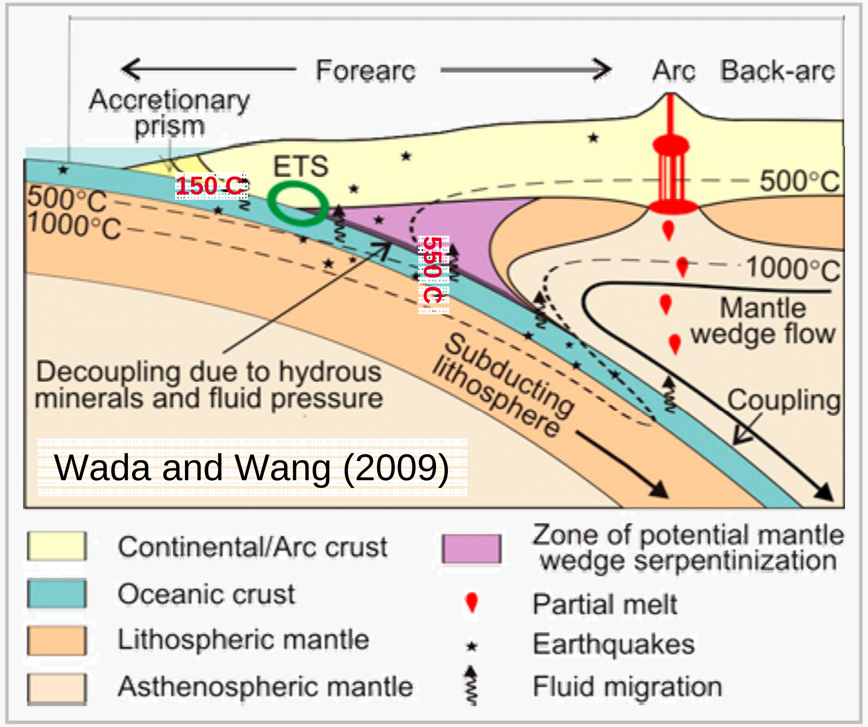


Shi et al (2019)

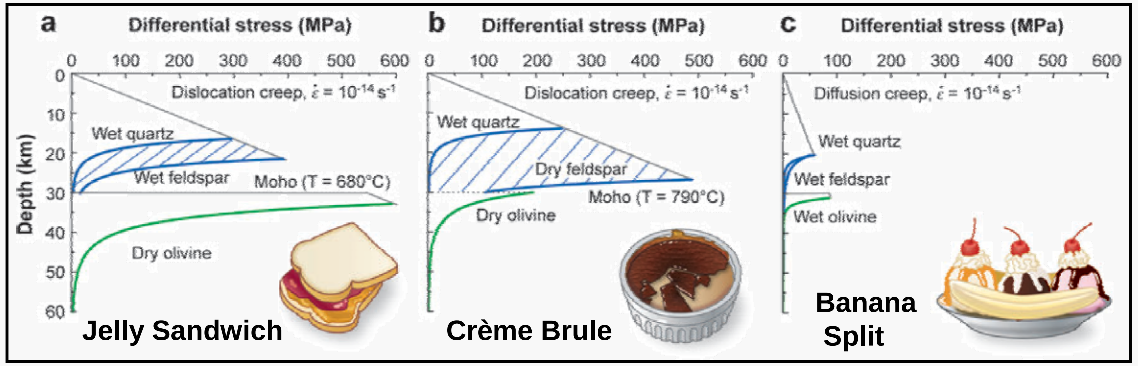


Westland - Marlborough (N. South Island)
C: Dominantly Compressional, High-Angle Fluidized Thrusts
Mu
stress
km
0
10
20
30
40
50
HAT
HAT
brittle
upper crust
BDT
lower crust
OFR
OFR
ductile
Moho
upper mantle
Slab Amphibole-Zoisite Breakdown
75 - 100 km depth
B: Narrow Brittle Shallow Fault, Broad Ductile Deep Shearing
Aw, Cl
brittle
upper crust
BDT
OFR
OFR
OFR
lower crust
ductile
Moho
Slab Greenschist Breakdown
40 - 60 km depth
A: Fault Fracture Meshes, Shear Zone Initiation
Hp
PP(Wa)
brittle
aftershock networks
upper crust
BDT
OFR
lower crust
OFR
OFR
ductile
Moho
Slab Sediment Dewatering, Low-Grade Hydrate Breakdown
~25 km depth
BDT
Brittle-Ductile Transition
OFR
Overpressured Fluid Reservoir
Sub-horizontal fluid fissure
Fault-fracture mesh
Fluid breach of BDT
HAT
High-angle thrust
Upward fluid migration
Backbone shears (long range)
Dangling, Isolated shear elements

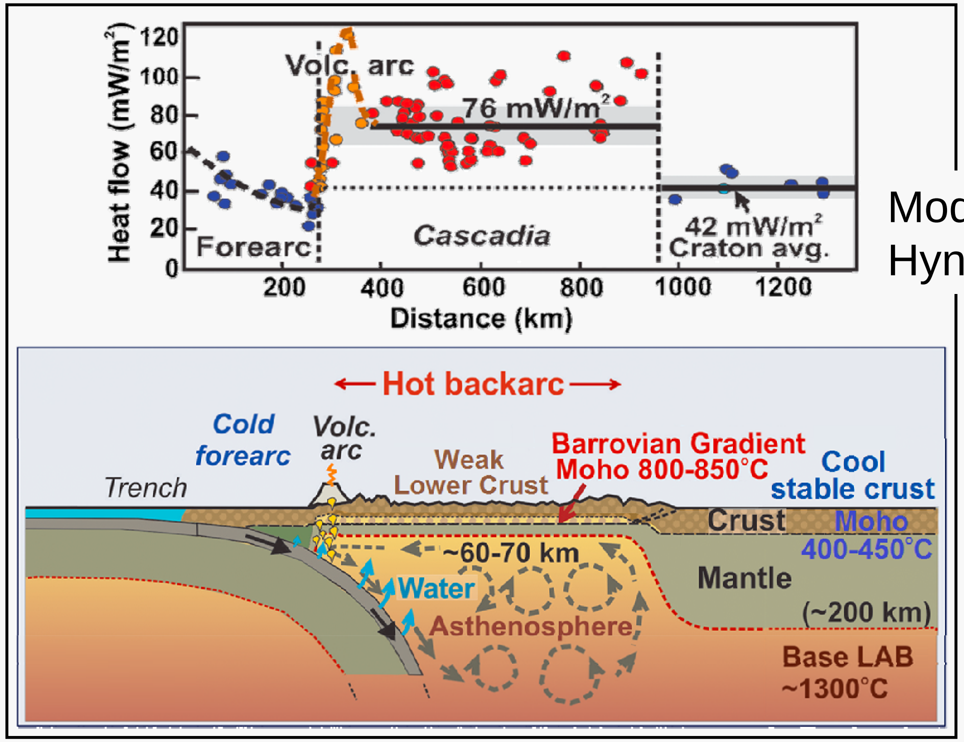
Ocean-Continent Subduction, Backarc Extension and Upper Mantle Hydration in the Central Western U.S.



Hacker (2008)

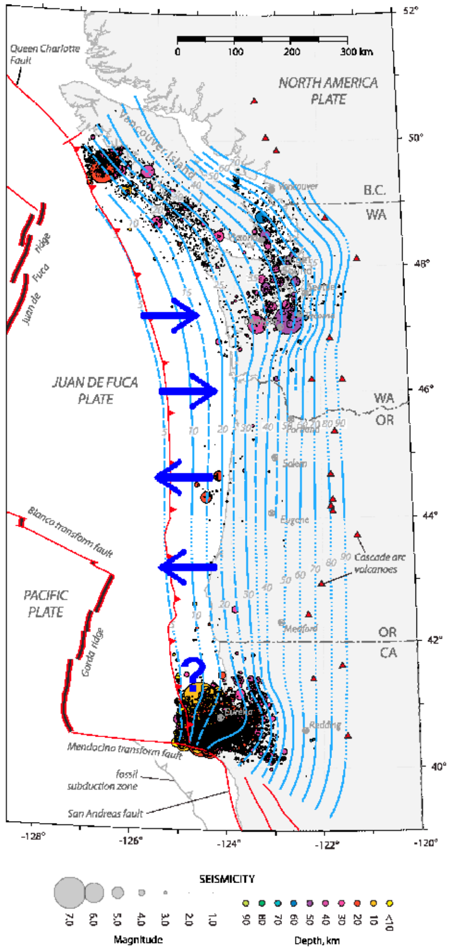


Burgmann and Dresen (2008)

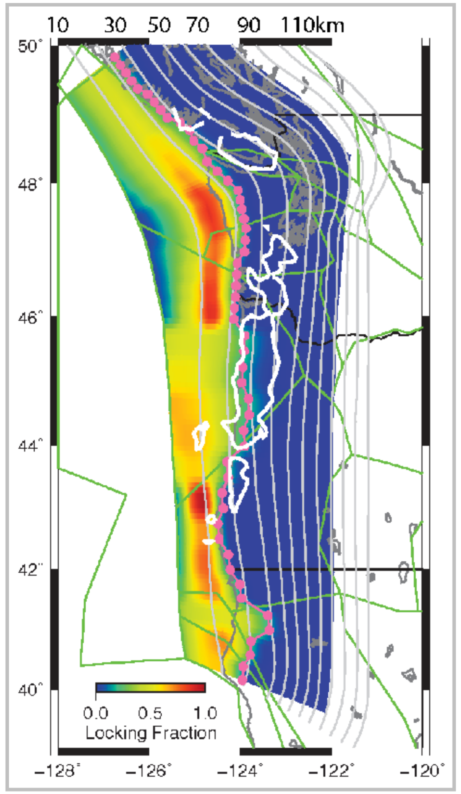


Modified from Hyndman (2018)

2

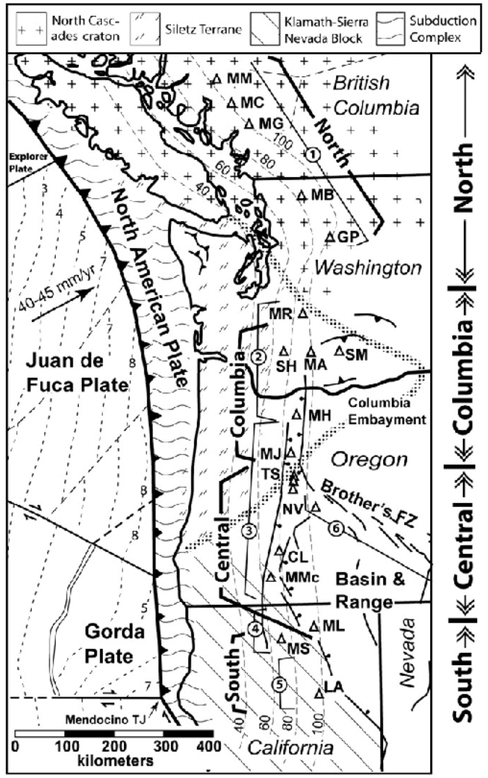


Slab Depth Contours & Prism Thrust Verg. (McCrory et al, 2012; Gulich et al, 1998)



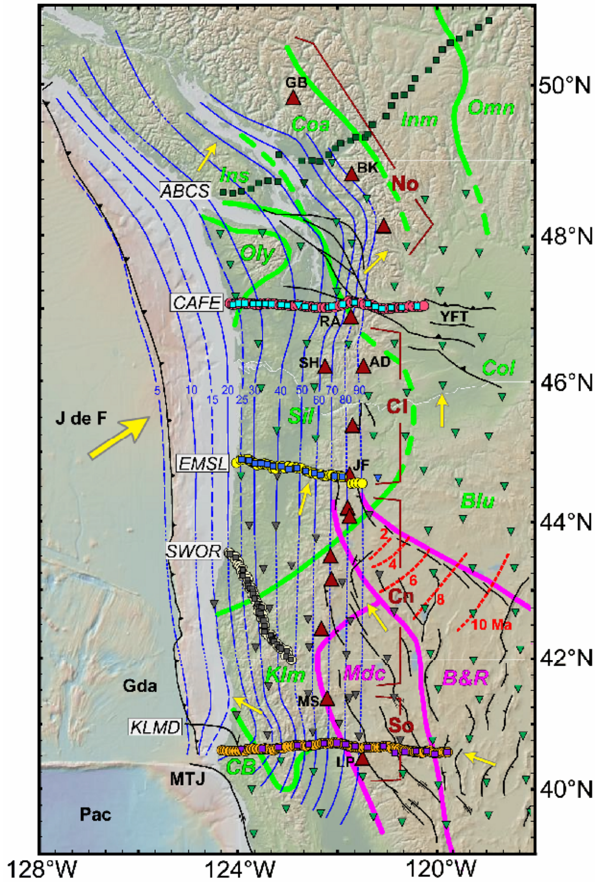
Geodetically-Inferred Plate Coupling (Schmalzle et al., 2014)

ETS Segments (Brudzinski and James, 2007)



Arc Magma Segments (Schmidt et al, 2008)

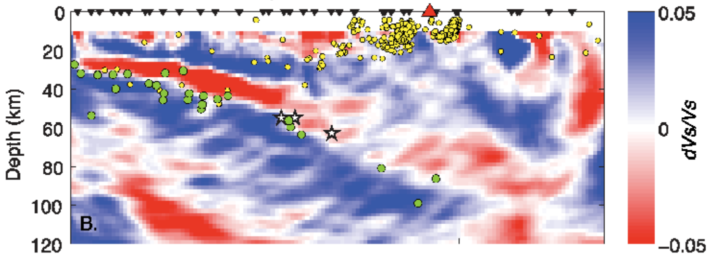
Transect MT (Wannamaker et al, 2014)

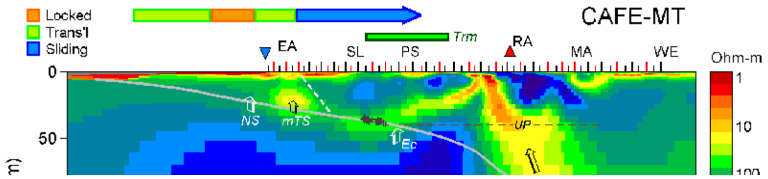


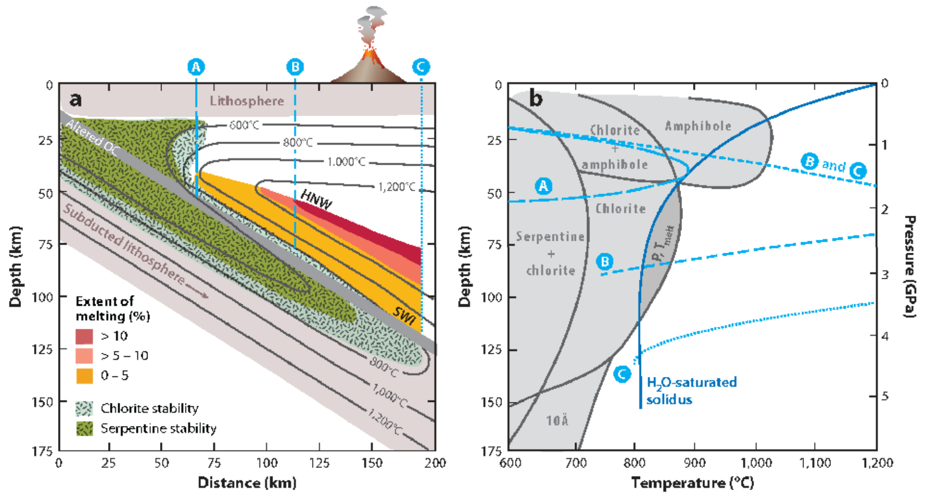
Segmentation of Seismicity, Plate Locking, ETS, and Arc Magmatism in Cascadia Investigated with MT

U.S. Cascadia Segments MT Resistivity

CAFE V_s Profile; Abers 09

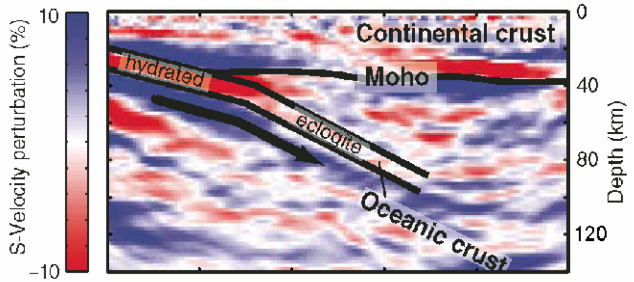


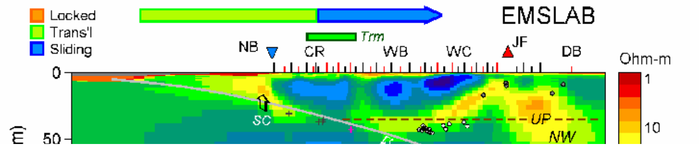




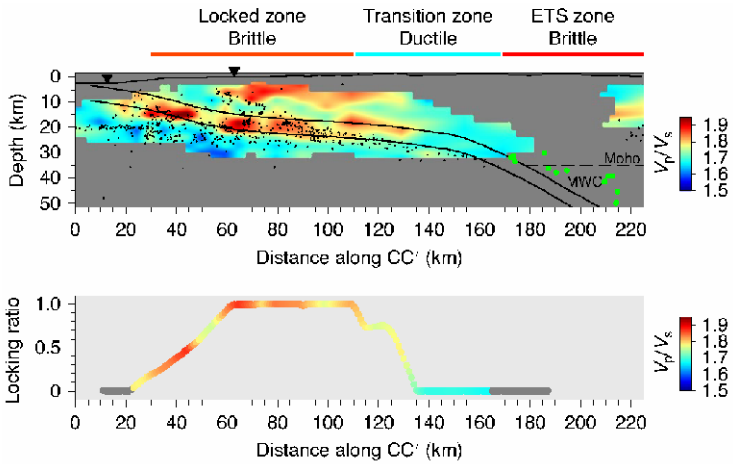
Grove (2012)

NW Oregon V_s Profile; Rondenay 08

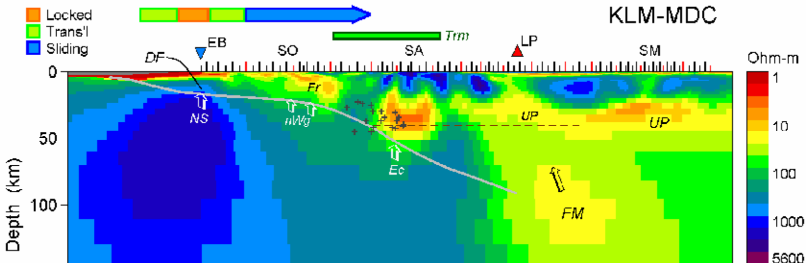




Klamath; Guo 19

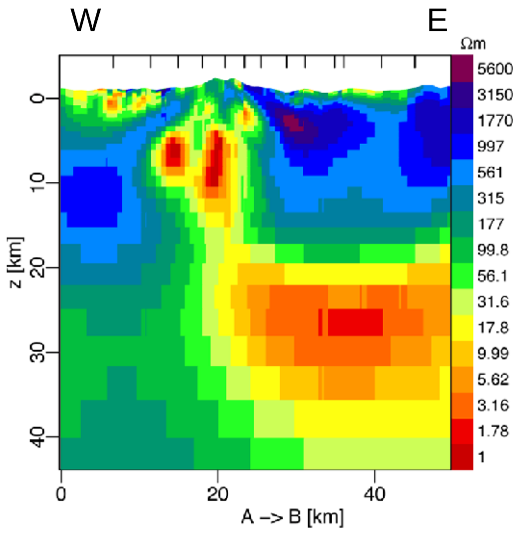


40.5N

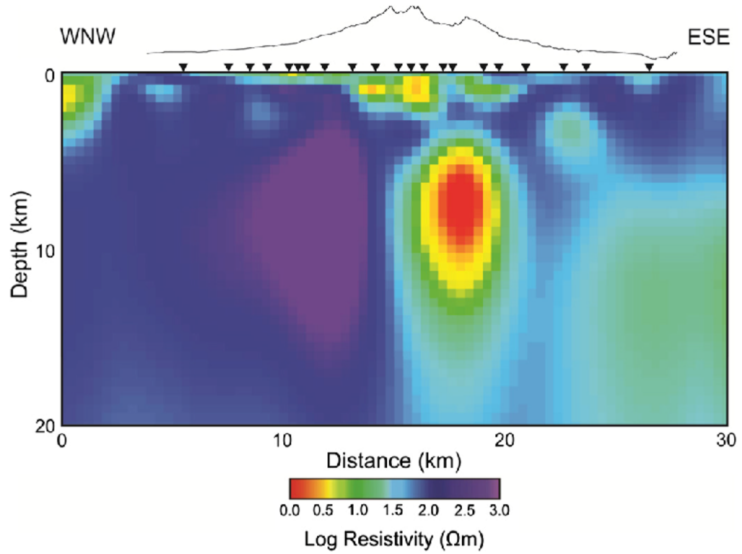


Wannamaker et al (2014)

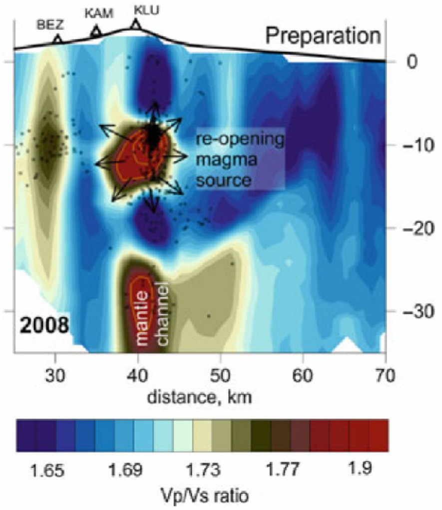
Plank 13



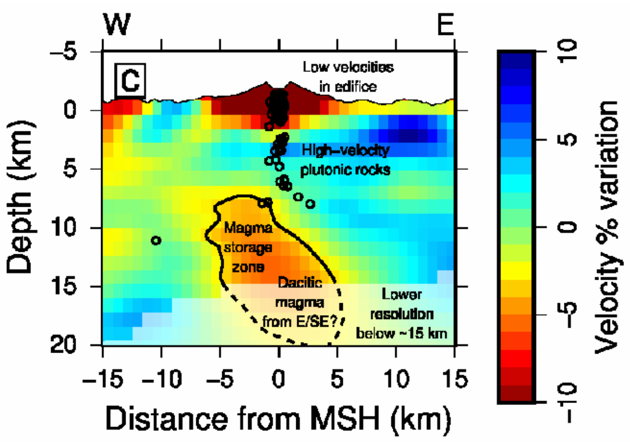
MSH (Kordy 16)



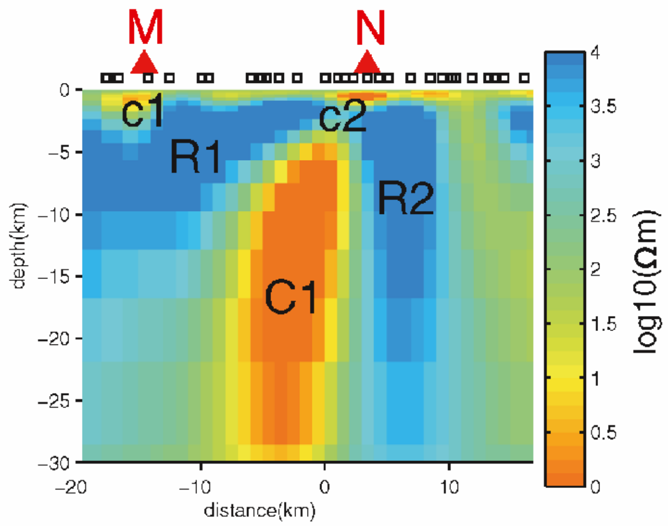
Tongariro (Hill 15)



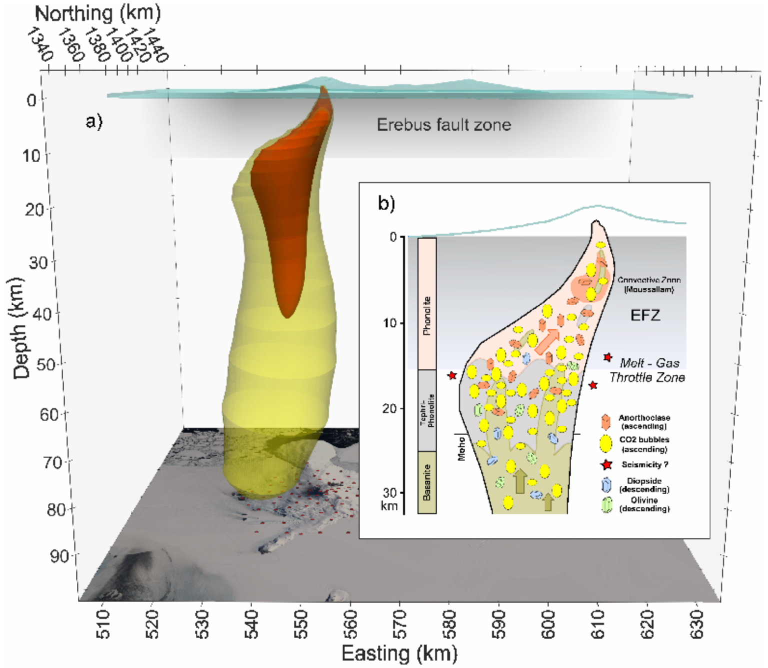
Klyuchevskoy
(Koulikov 15)



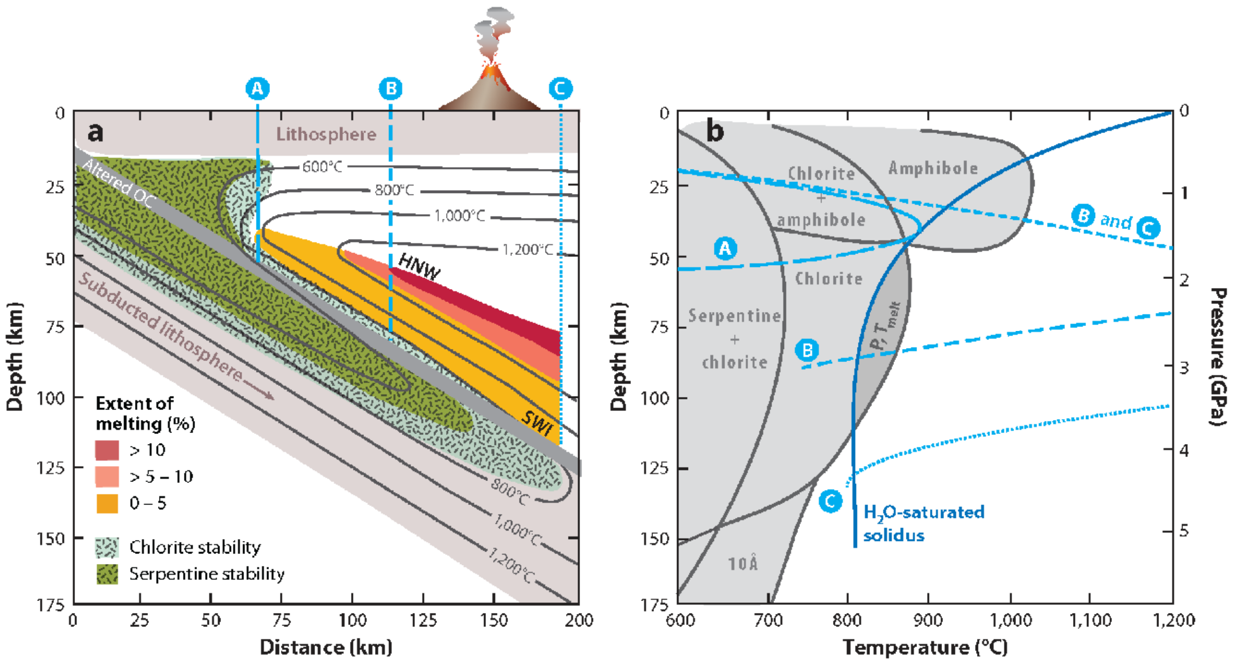
Mt St Helens
(Ulberg 20)



Naruko
(Ogawa 14)

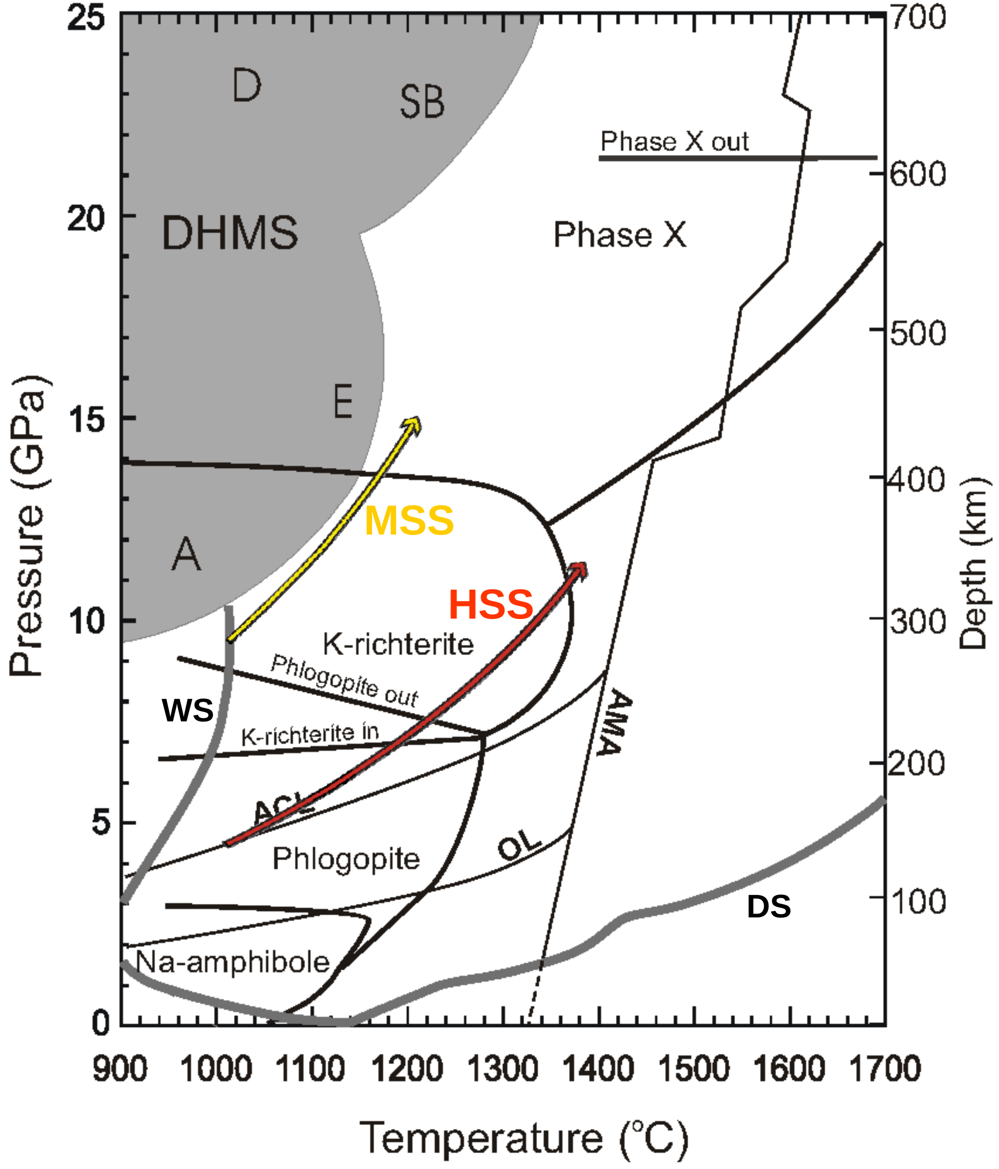


Erebus – CO_2
Hill 21



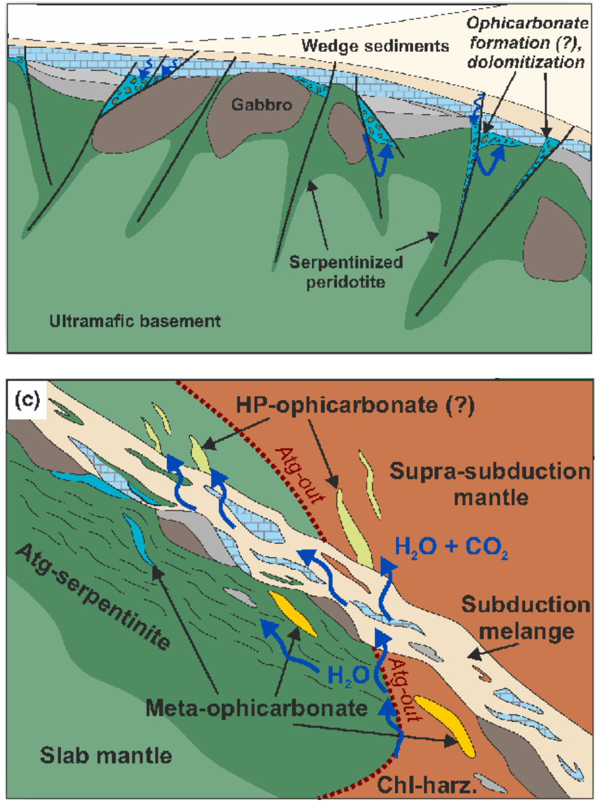
Grove (2012)

Hacker (2008)

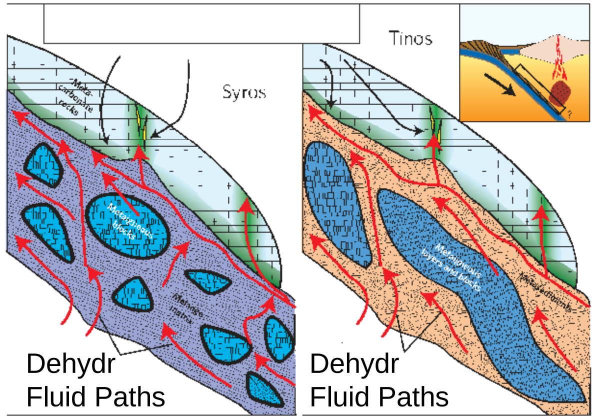


Frost (2006)

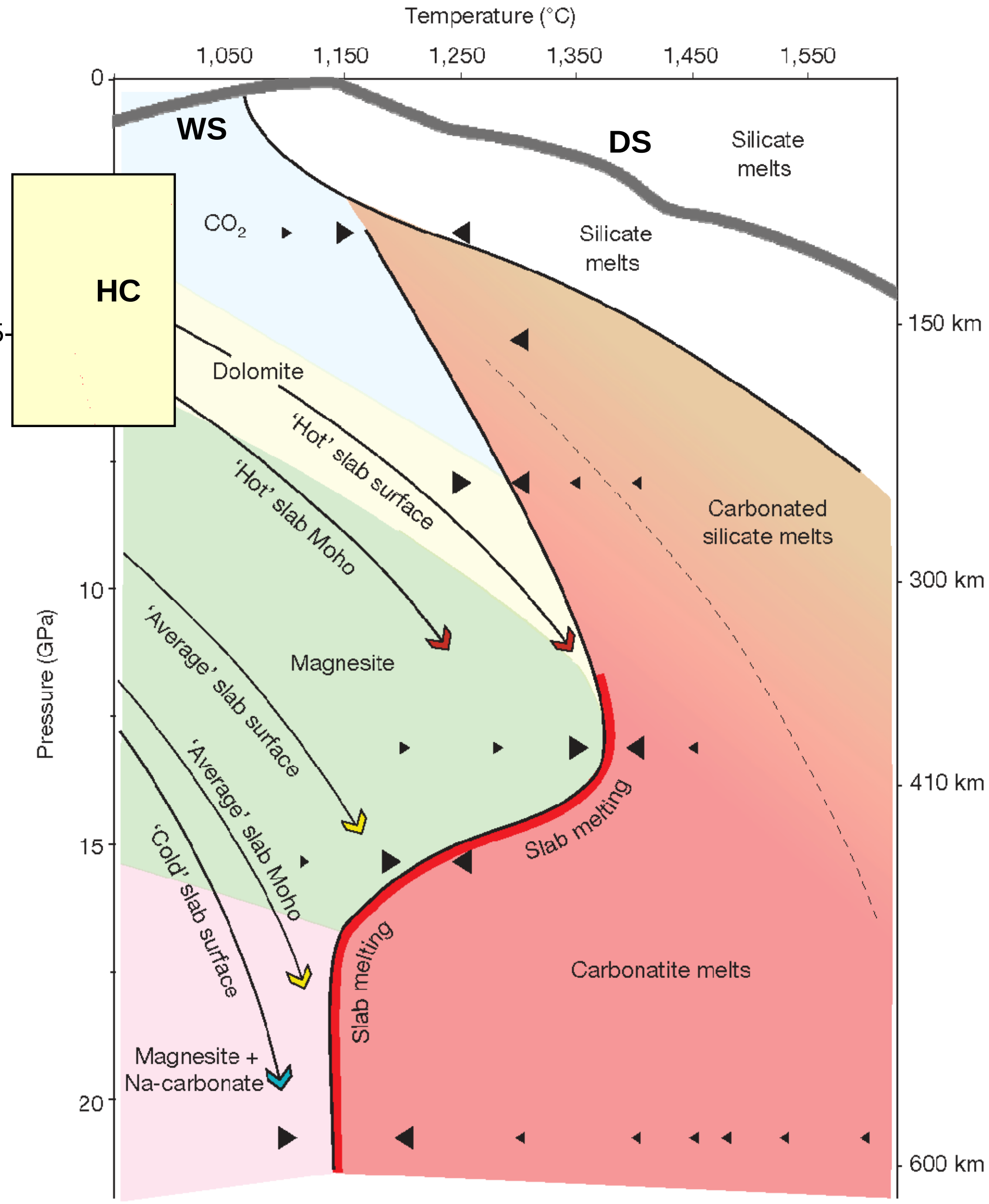
Slab Surface Geotherms after Thomson et al (2016)



Menzel (2021)



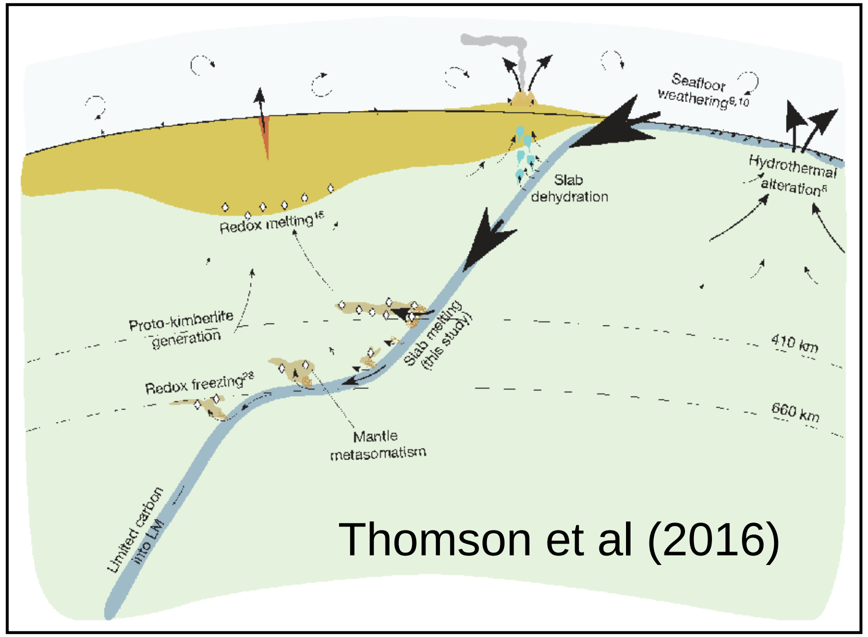
Ague (2014)



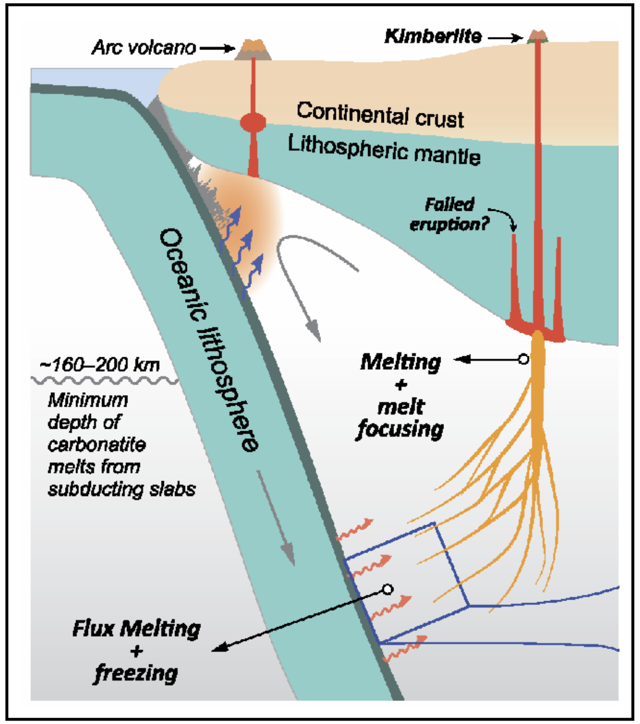
Thomson et al (2016)

Dry and Wet Solidii (DS, WS) after Frost (2006)

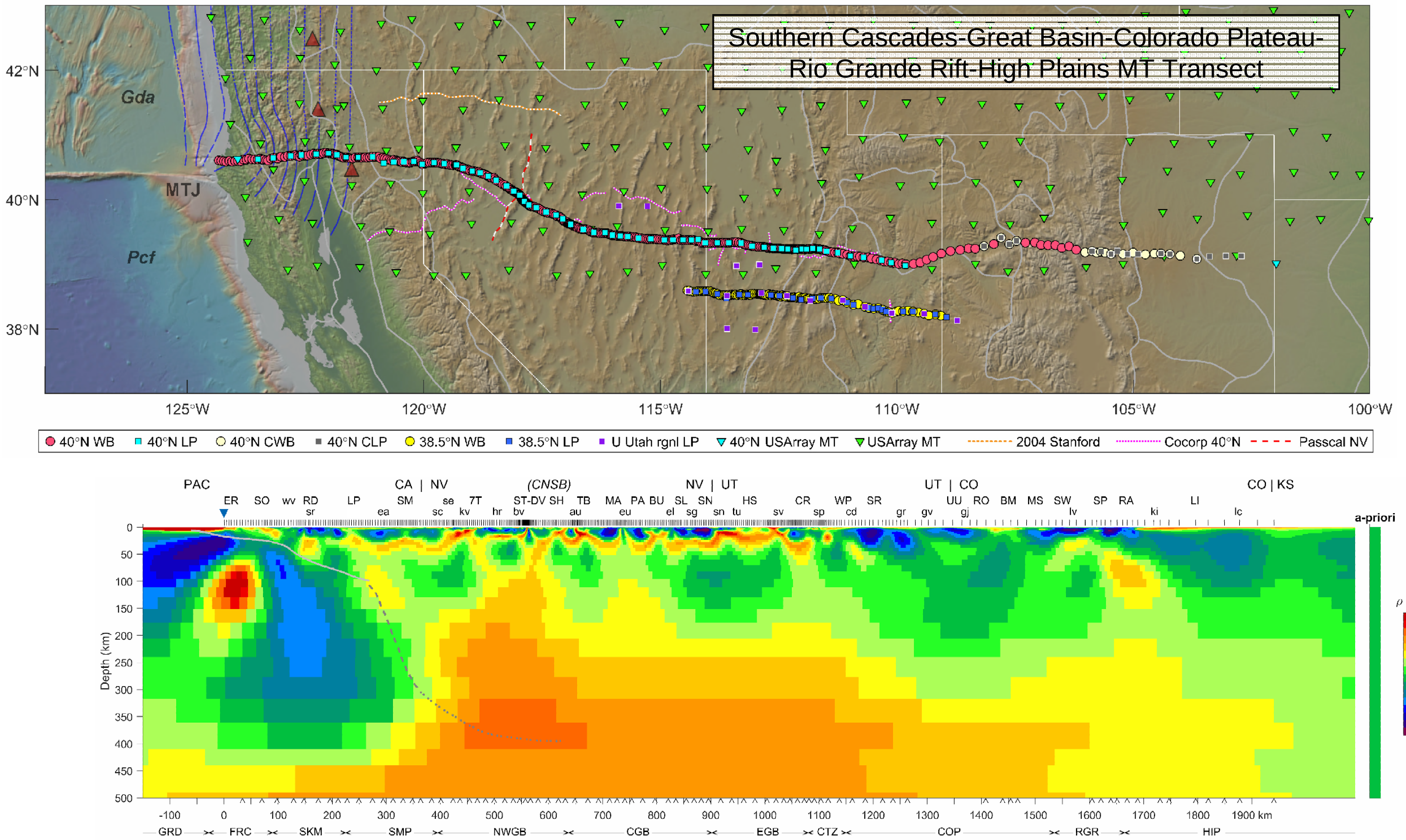
Hydrous Carbonatite (HC) after Poli (2015)



Thomson et al (2016)

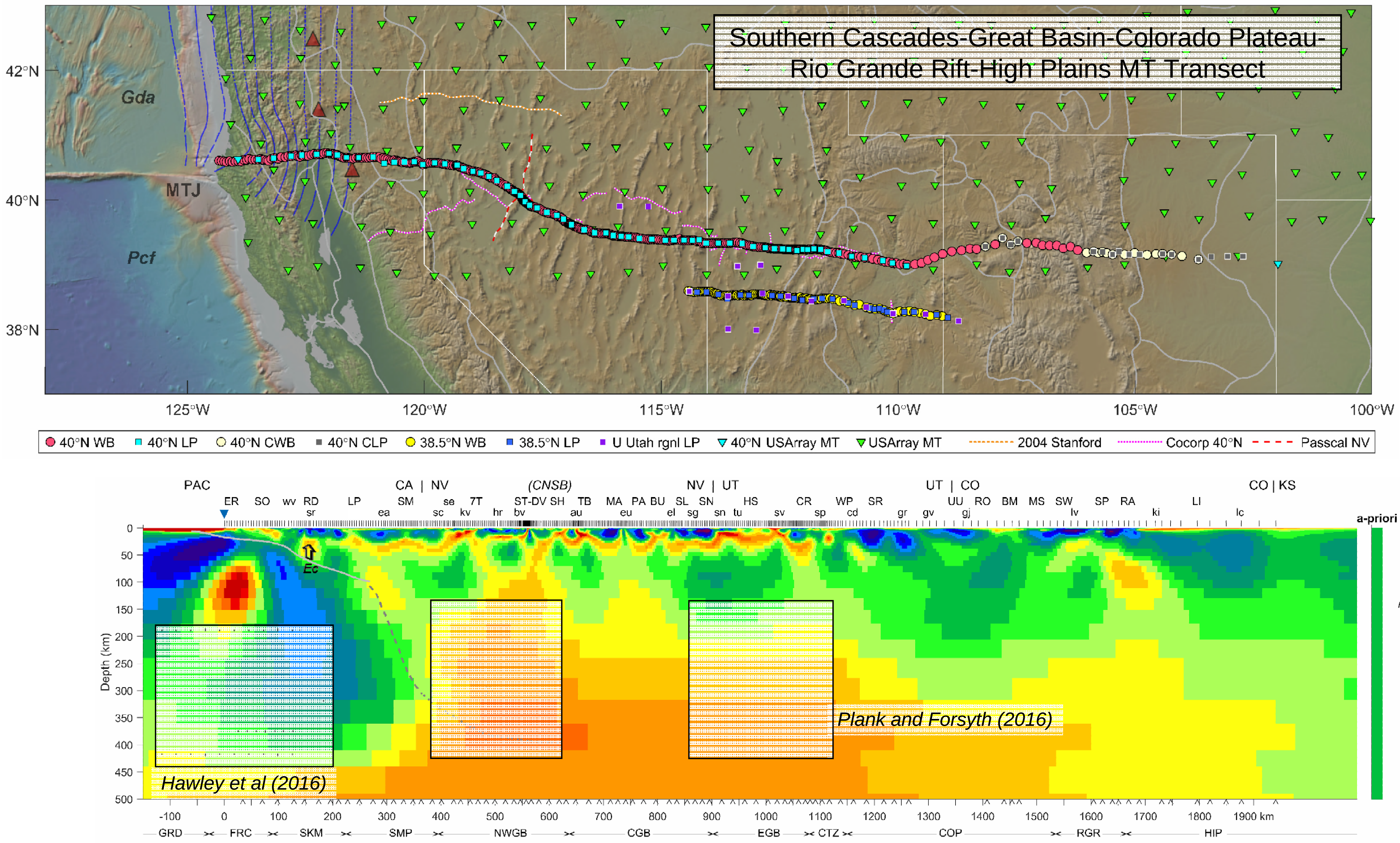


Sun et al (2019)



Southern Cascades-Great Basin-Colorado Plateau-
Rio Grande Rift-High Plains MT Transect
Gda
MTJ
Pcf
42°N
40°N
38°N
125°W
120°W
115°W
110°W
105°W
100°W
40°N WB
40°N LP
40°N CWB
40°N CLP
38.5°N WB
38.5°N LP
U Utah rgnl LP
40°N USArray MT
USArray MT
2004 Stanford
Cocorp 40°N
Passcal NV
PAC
CA | NV
(CNSB)
NV | UT
UT | CO
CO | KS
ER SO wv RD LP SM se 7T ST-DV SH TB MA PA BU SL SN HS CR WP SR UU RO BM MS SW SP RA LI
sr ea sc kv hr bv au eu el sg sn tu sv sp cd gr gv gj lv ki lc
a-priori
Depth (km)
ρ (Ω-m)
1
10
100
1000
5600
-100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 km
GRD FRC SKM SMP NWGB CGB EGB CTZ COP RGR HIP

2b



Southern Cascades-Great Basin-Colorado Plateau-Rio Grande Rift-High Plains MT Transect
42°N
40°N
38°N
Gda
MTJ
Pcf
125°W
120°W
115°W
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105°W
100°W
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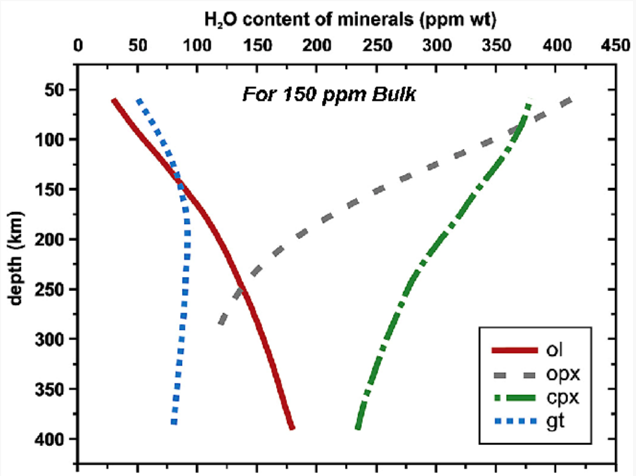
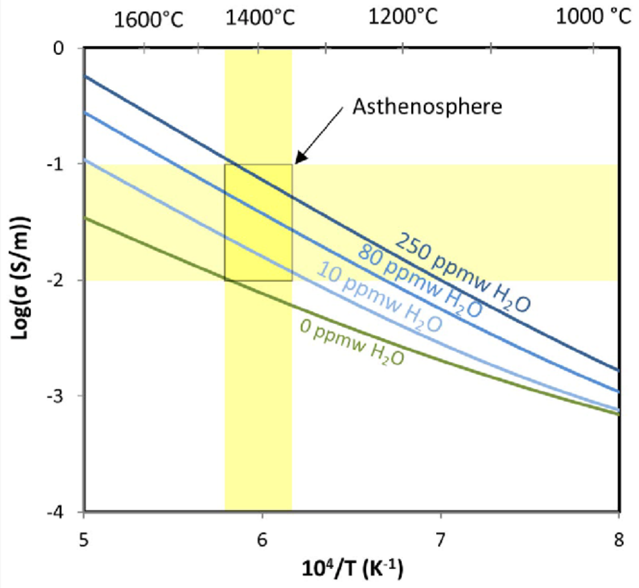
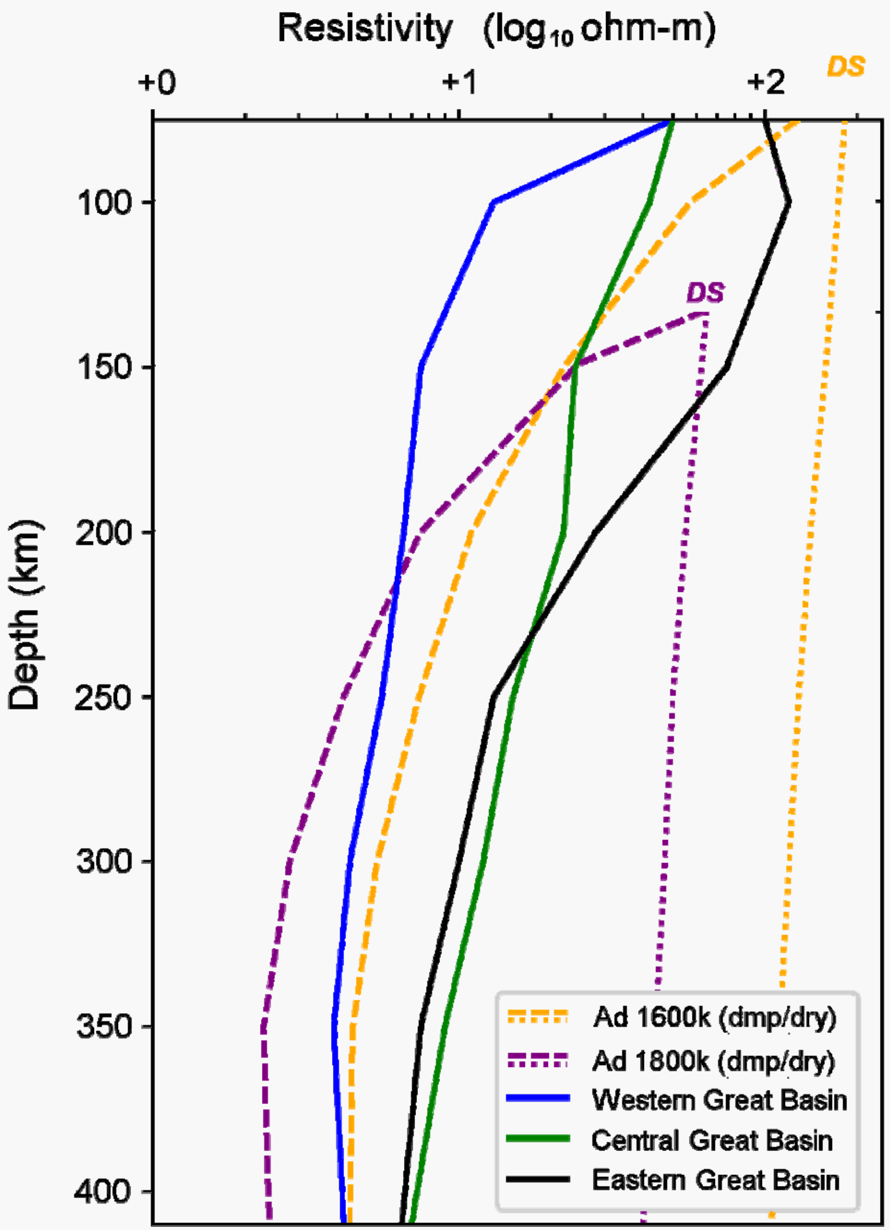
ER SO wv RD LP SM se 7T ST-DV SH TB MA PA BU SL SN HS CR WP SR UU RO BM MS SW SP RA LI
sr ea sc kv hr bv au eu el sg sn tu sv sp cd gr gv gj lv ki lc
a-priori
Ec
Depth (km)
0
50
100
150
200
250
300
350
400
450
500
Plank and Forsyth (2016)
Hawley et al (2016)
ρ (Ω-m)
1
10
100
1000
5600
-100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 km
GRD FRC SKM SMP NWGB CGB EGB CTZ COP RGR HIP

Novella et al (2014, EPSL)

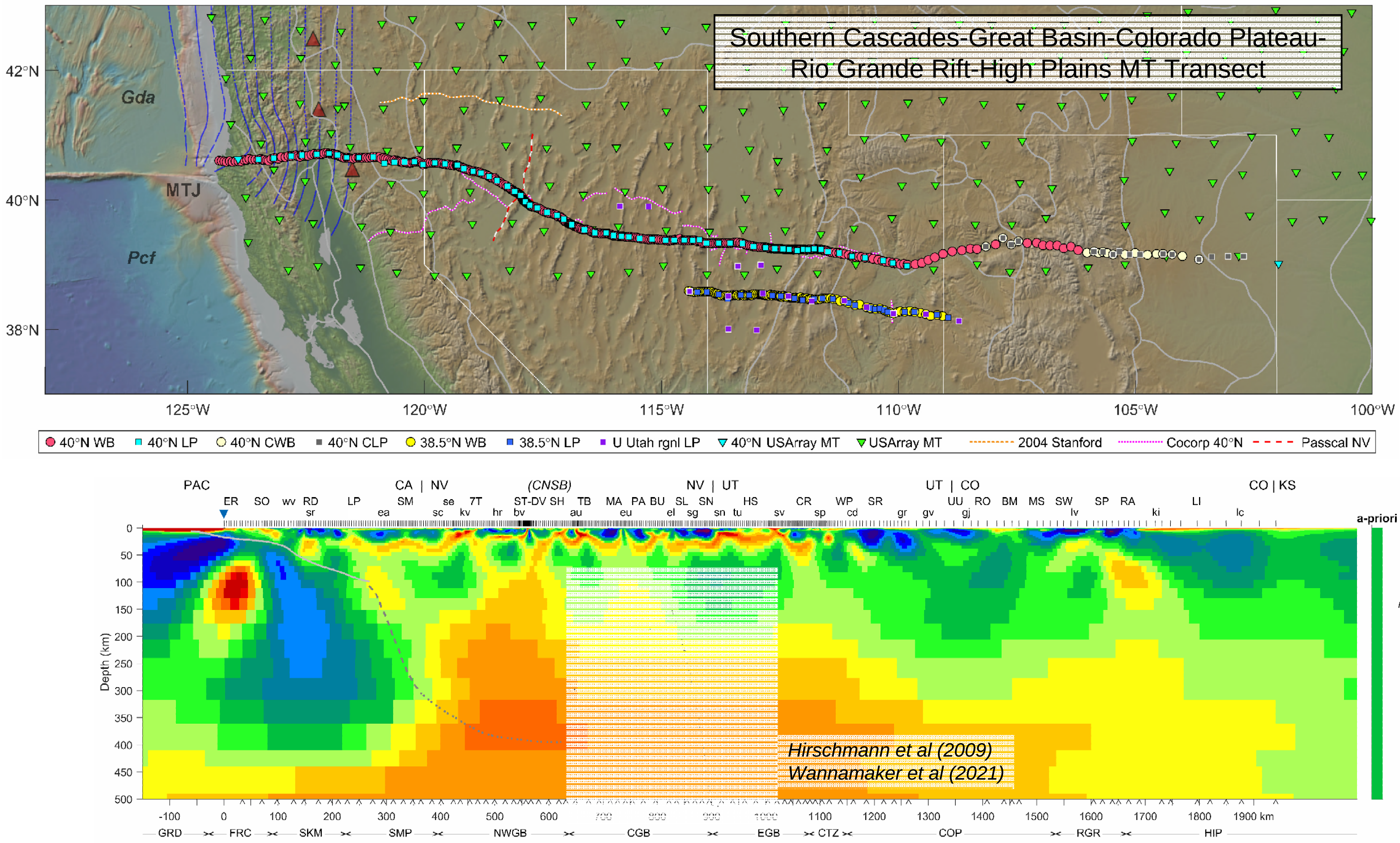




Novella et al (2017, Sci Rpt)



Hirschmann et al (2009, PEPI)
Stixrude and Lithgow-Bertelloni (2011, GJI)


Southern Cascades-Great Basin-Colorado Plateau-Rio Grande Rift-High Plains MT Transect
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a-priori
Depth (km)
0
50
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ρ (Ω-m)
1
10
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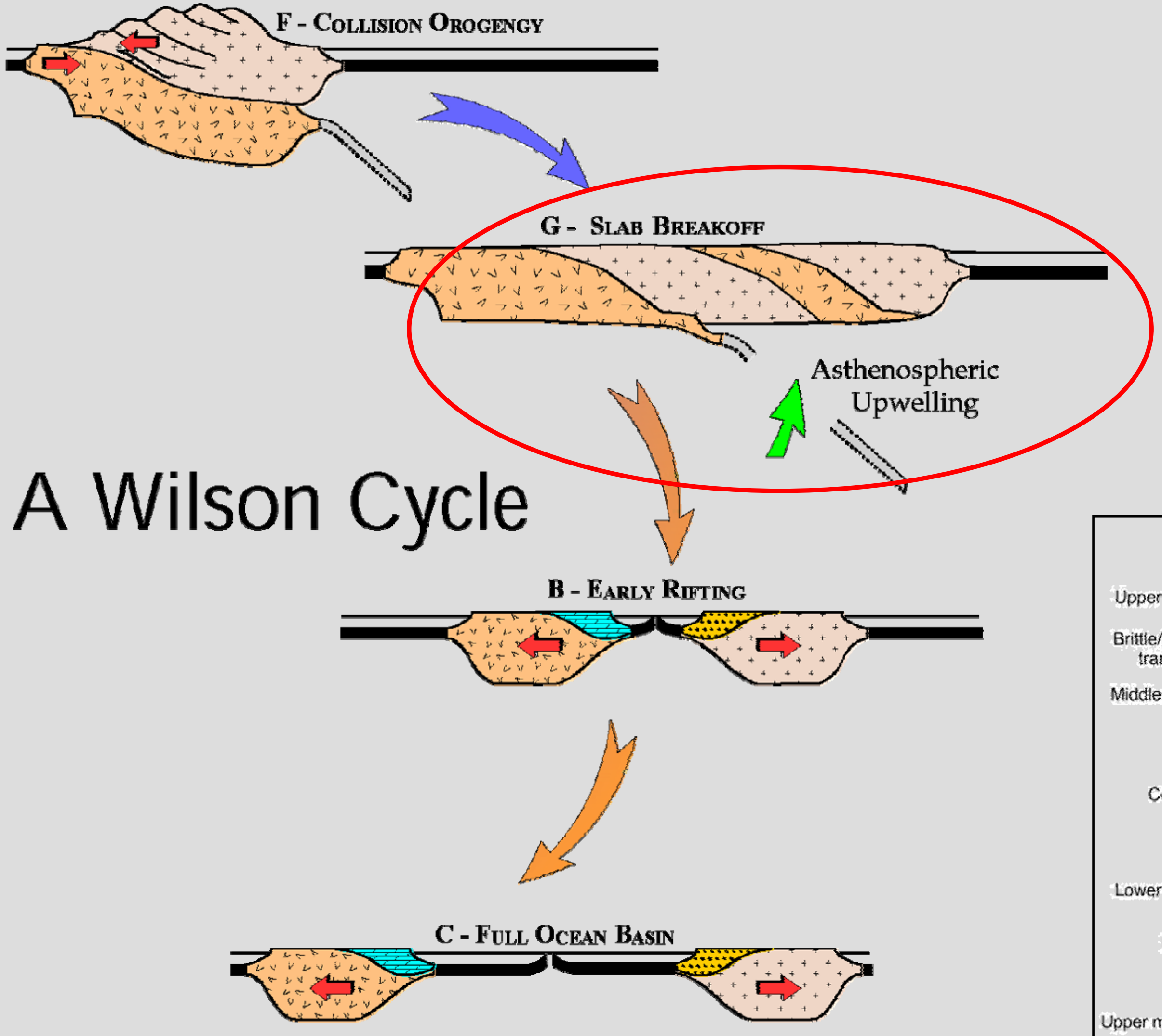
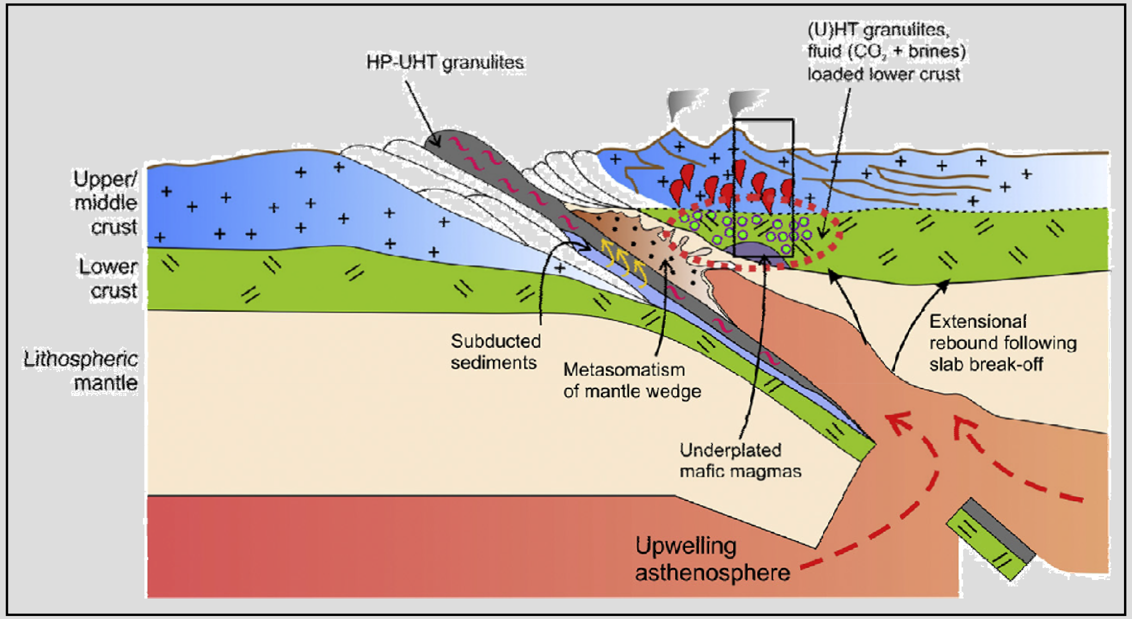
1000
5600
Hirschmann et al (2009)
Wannamaker et al (2021)
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900 km
GRD
FRC
SKM
SMP
NWGB
CGB
EGB
CTZ
COP
RGR
HIP

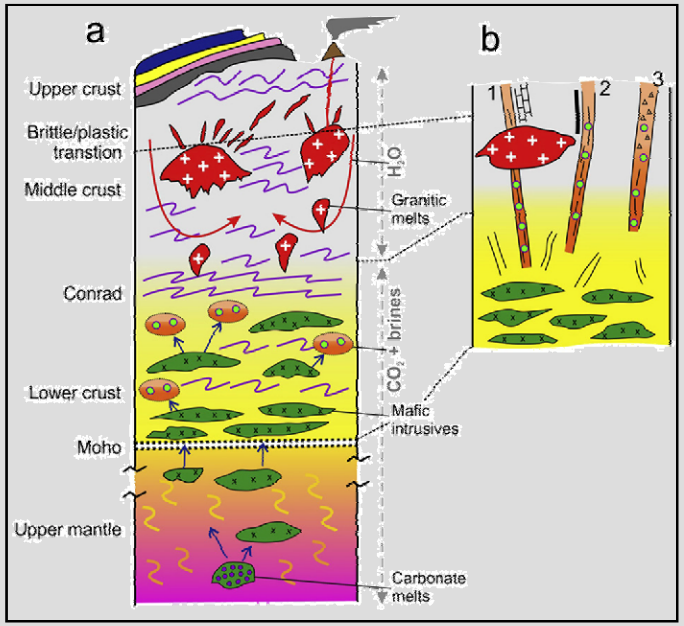
2c

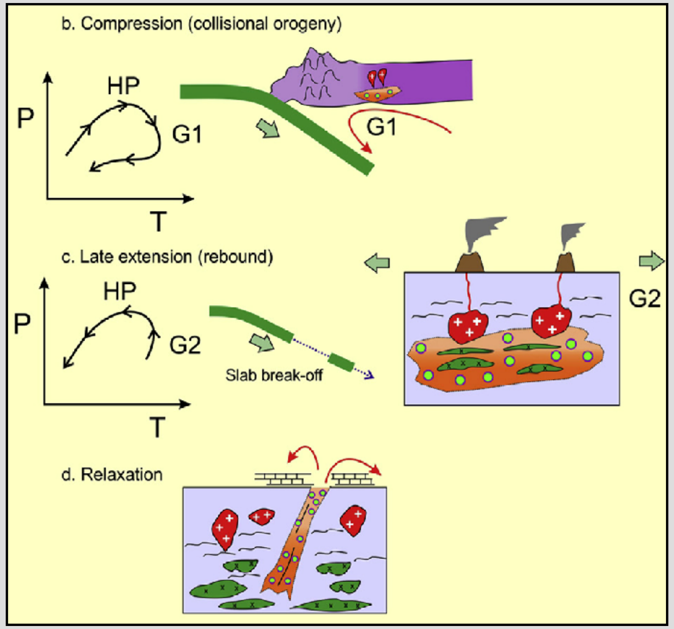
A Wilson Cycle



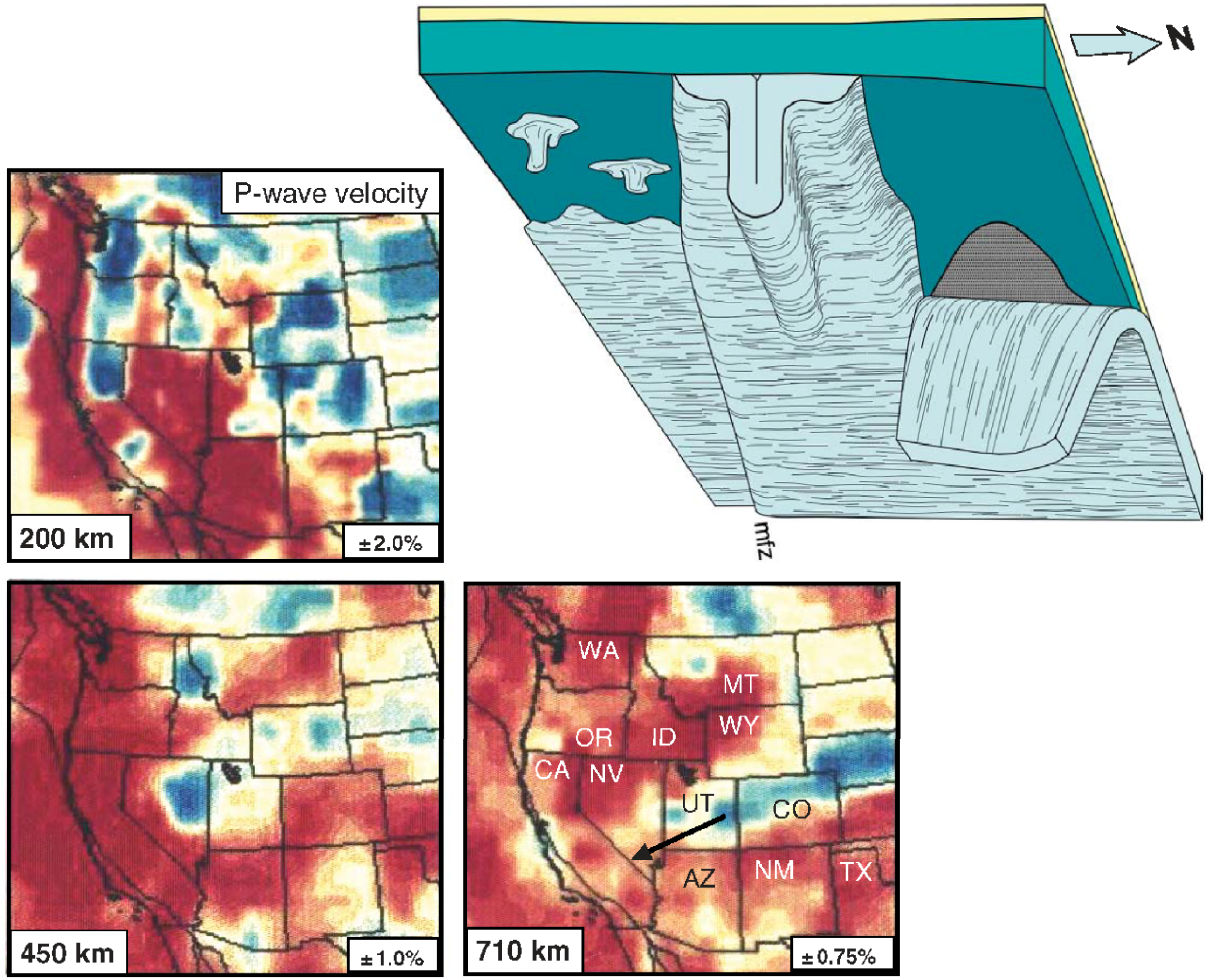
Mod from http://geollab.jmu.edu/Fichter/Wilson/wilsoncircl.html



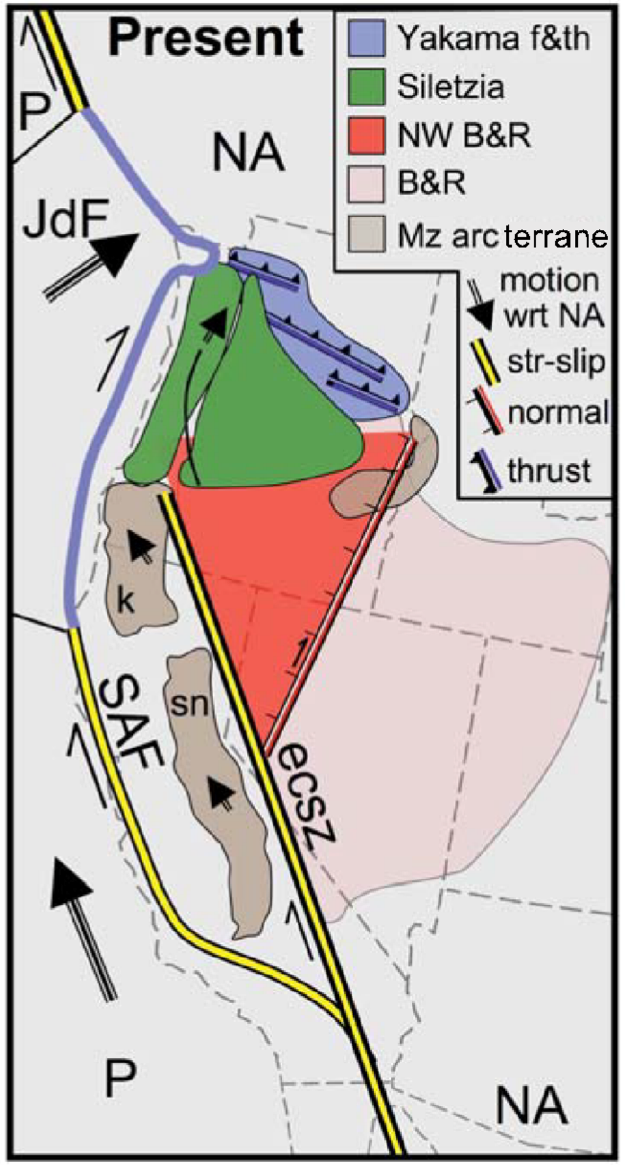




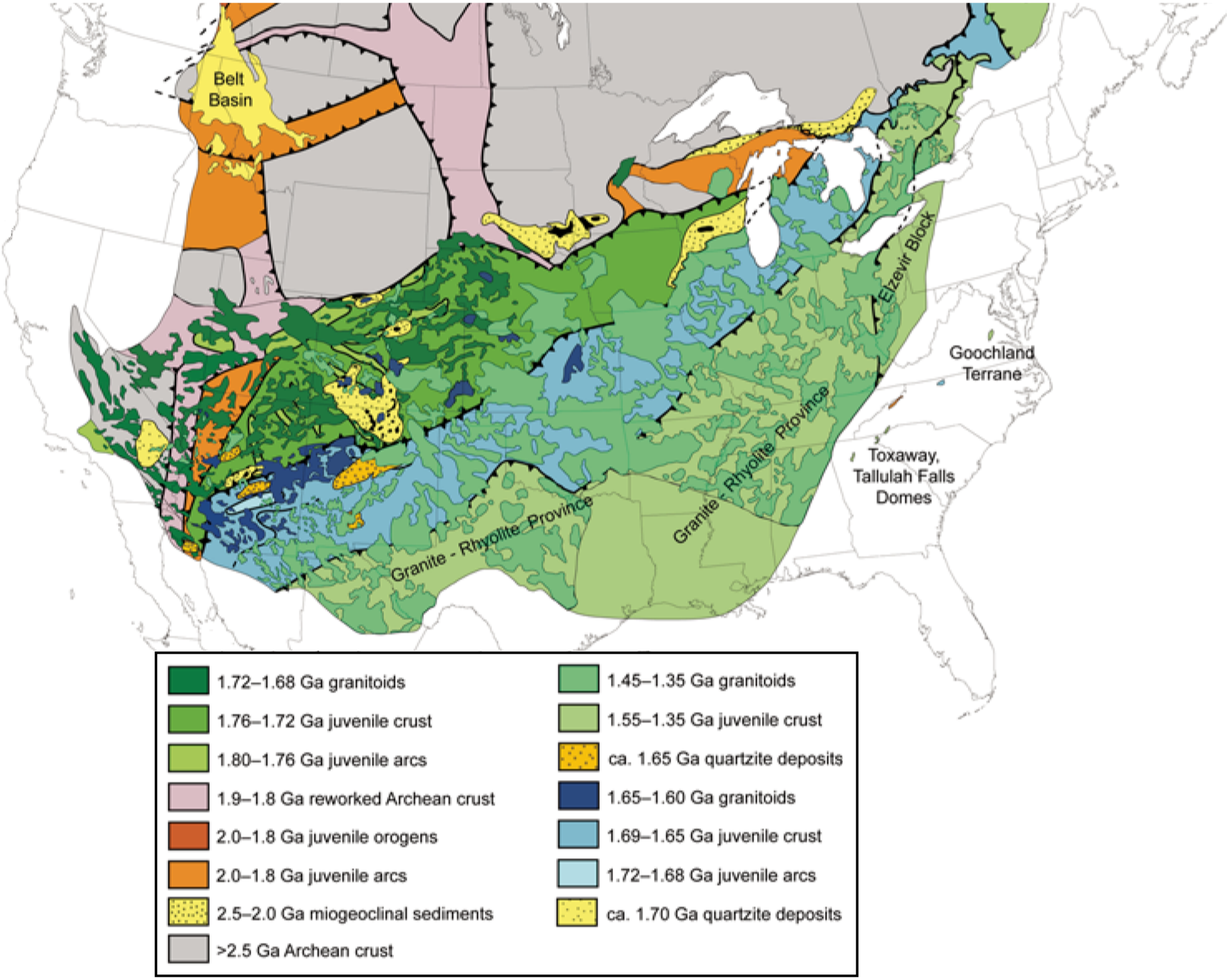
Touret et al (2016)



Early to Middle Tertiary Slab Rollback/Breakoff, W US; Humphreys (2009)

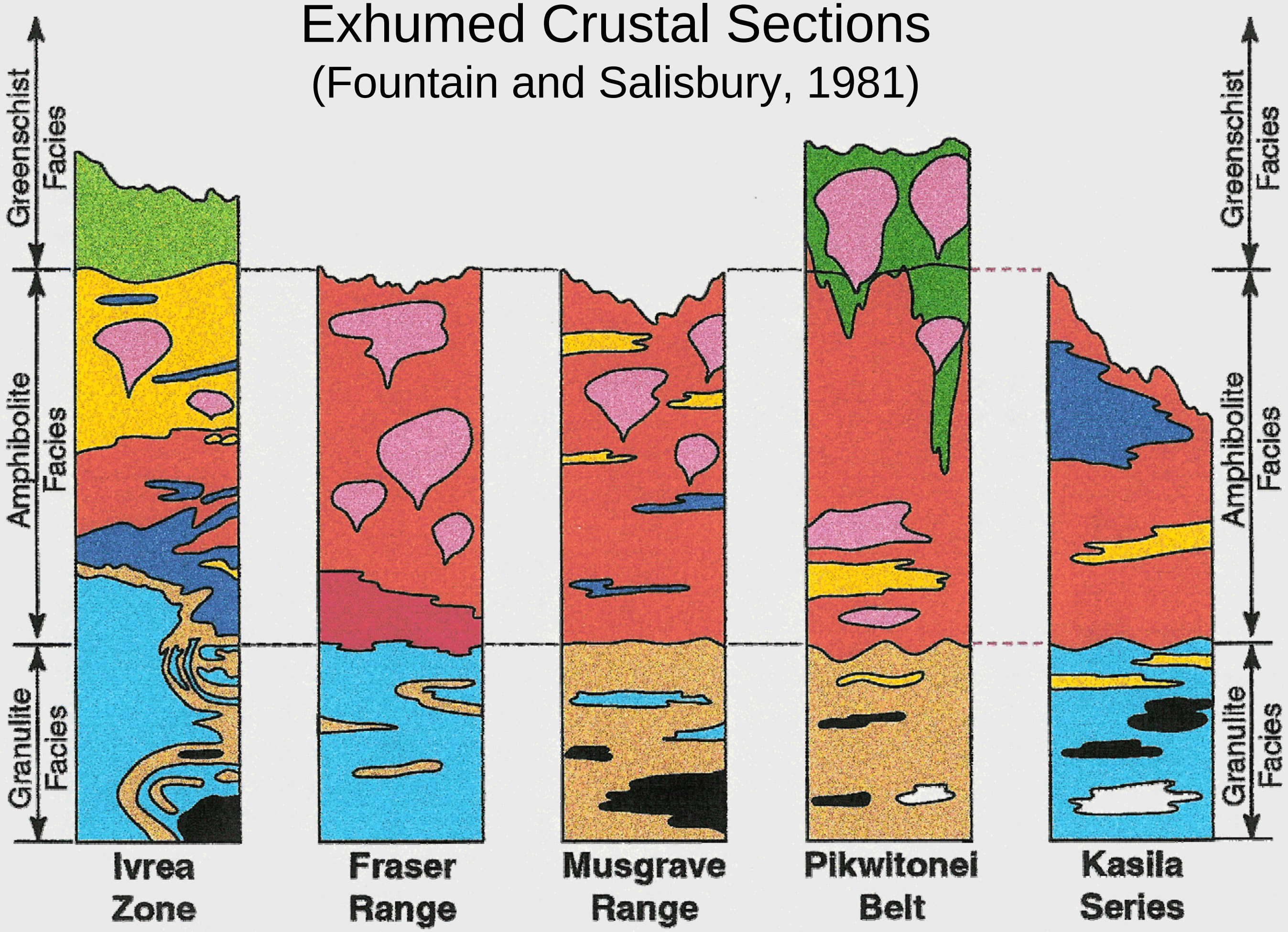


Late Tertiary Extension, W US;
Humphreys (2009)

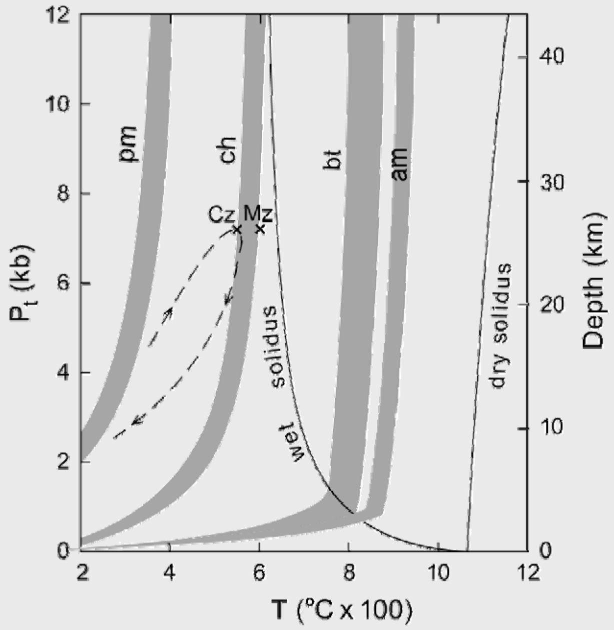


Early-Middle Prot. Assembly, Plutonism
Whitmeyer and Karlstrom (2007)

Exhumed Crustal Sections
(Fountain and Salisbury, 1981)



- Free water not compatible with granulite-upper amphibolite facies- resorbed to more amph/biotite
- Any present fluid must be of low a(H2O)
- Complex salts may provide a mechanism
- Comment/Reply Yardley (1997, 2000), Wannamaker (2000)



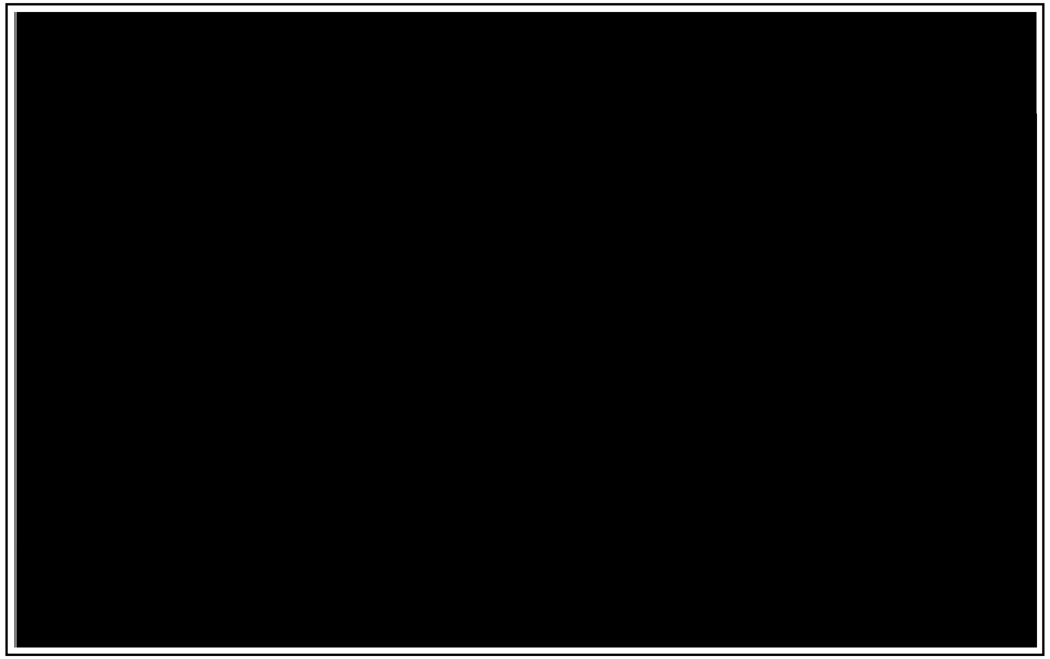
Diorite-H2O petrogenetic grid

Aranovich and Newton (1997)

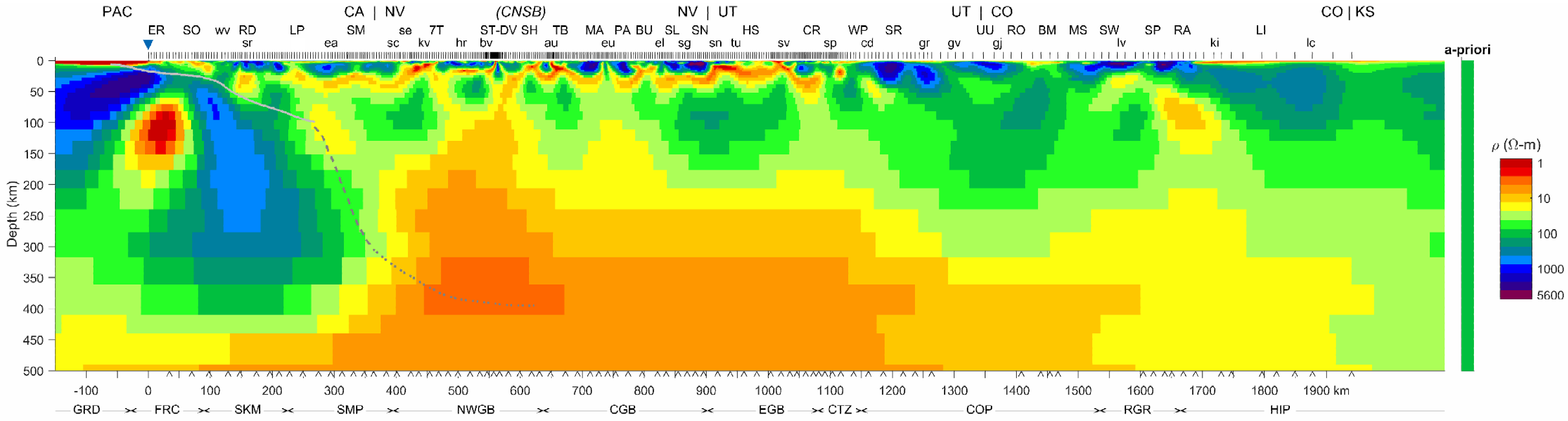
Complex salts reduce T of last fluid

Southern Cascades-Great Basin-Colorado Plateau-Rio Grande Rift-High Plains MT Transect

Wannamaker
et al (2005-20)
Siler et al (2014)

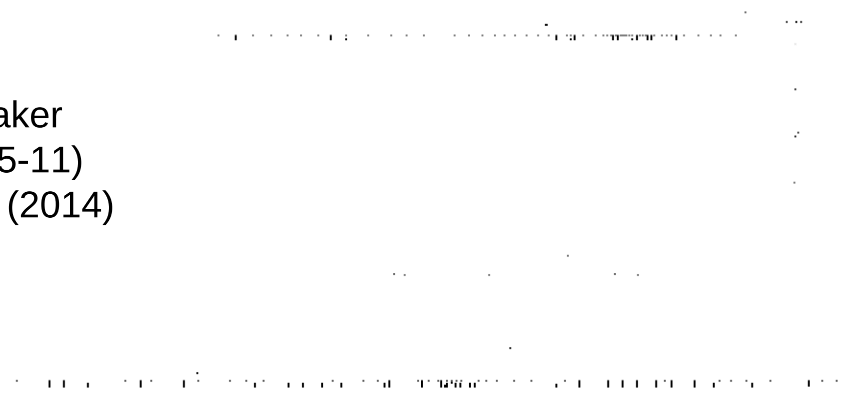


WB only inv.

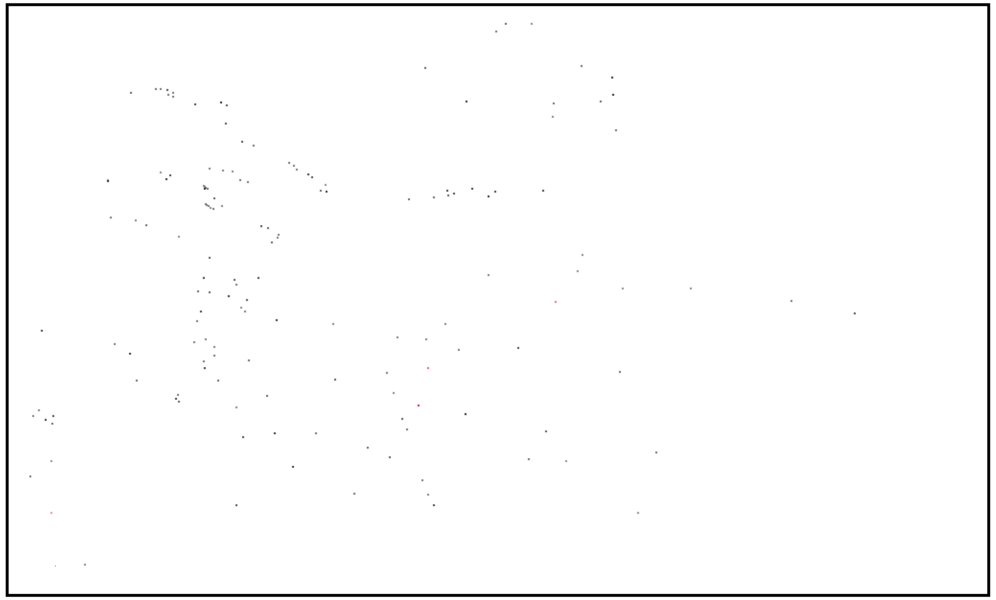


Southern Cascades-Great Basin-Colorado Plateau-Rio Grande Rift-High Plains MT Transect

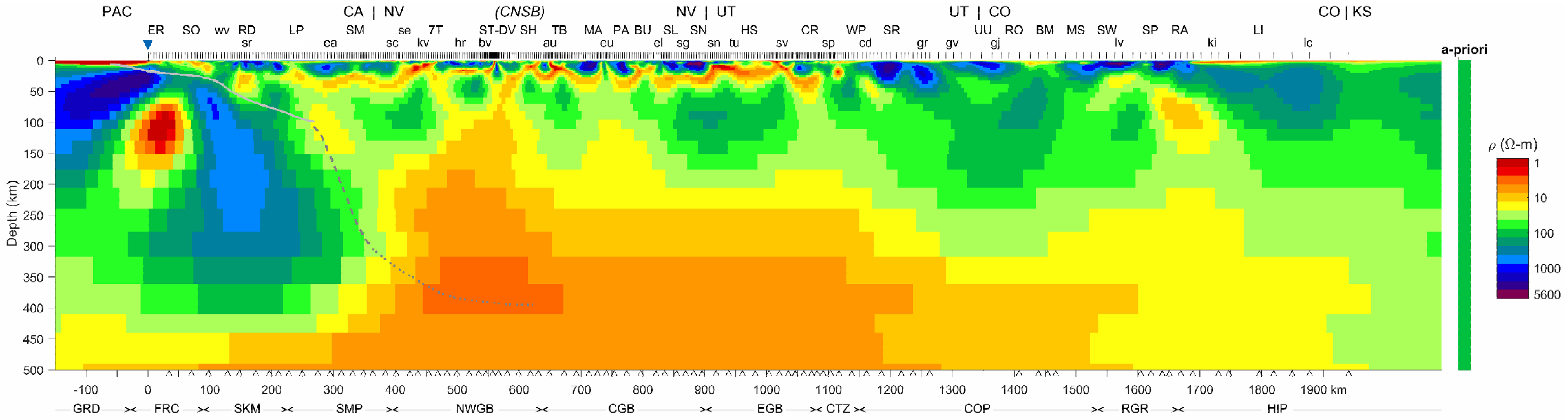
Wannamaker et al (2005-11)
Siler et al (2014)

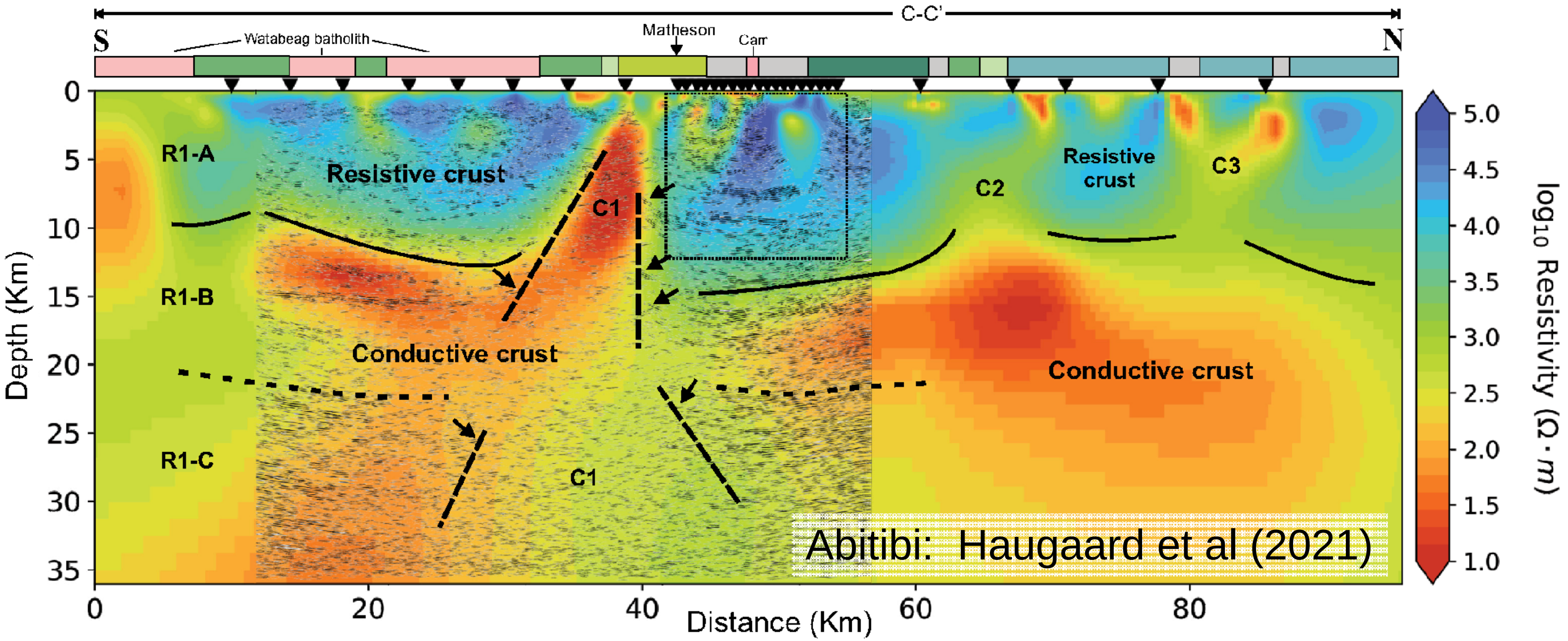


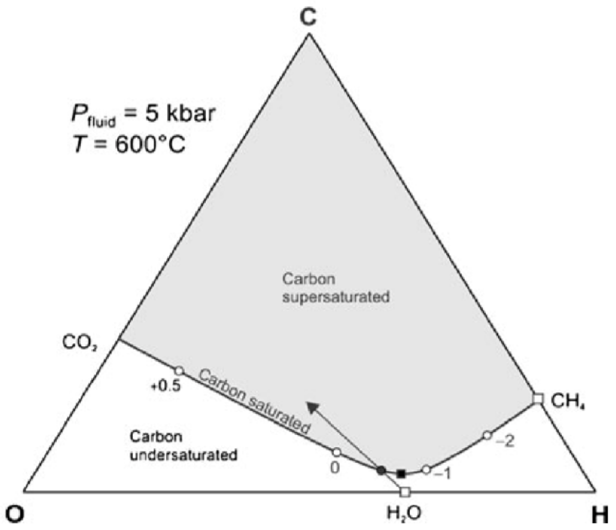
WB only inv.



Crossey and Karlstrom (2012)

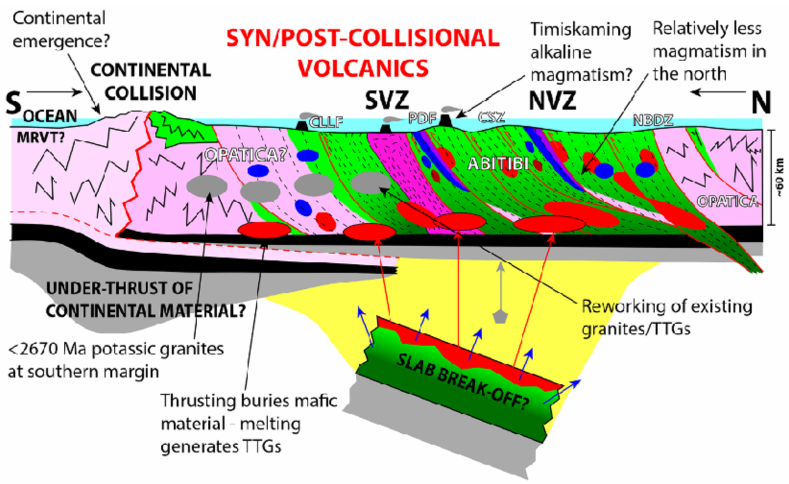






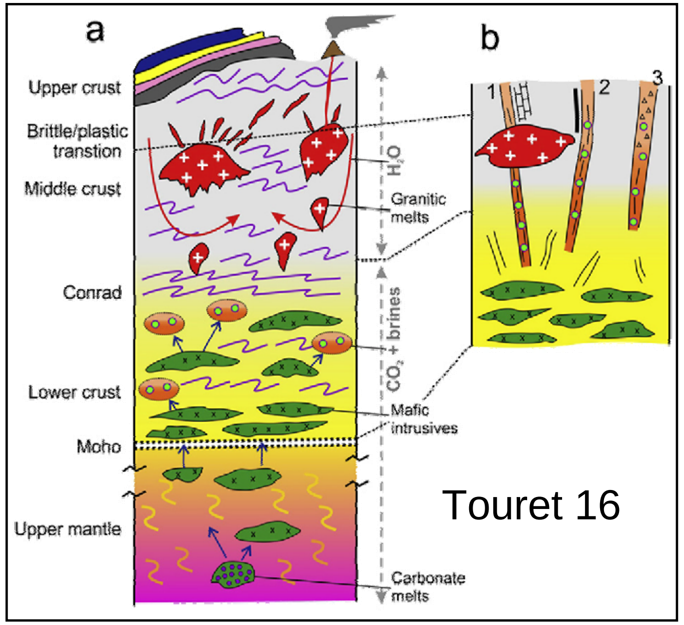
Luque et al 2014

Vein graphite precipitation from:
Absorption of fluid H2O by host rock
Cooling



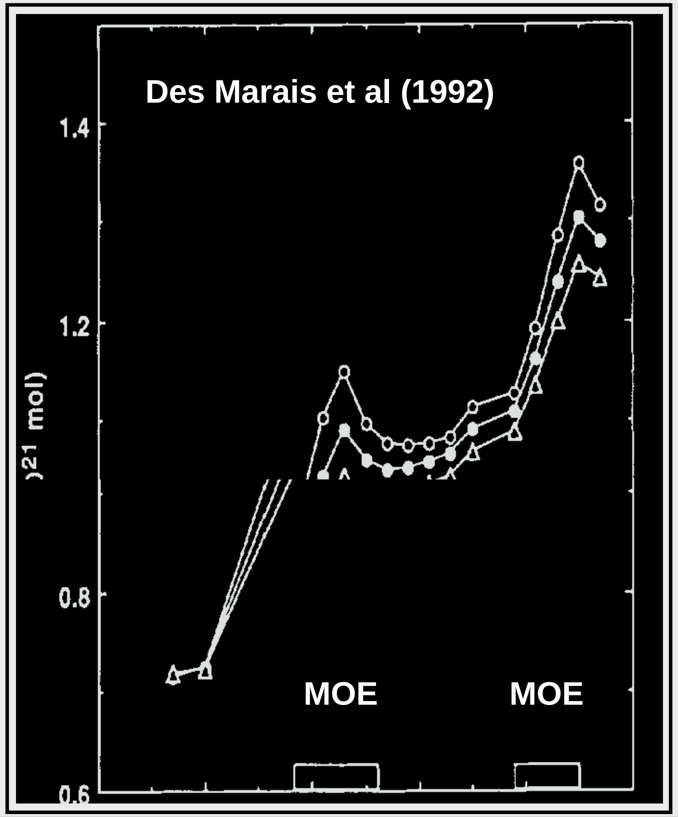
2685-2670 Ma: MINNESOTAN OROGENY

Mole et al (2021)

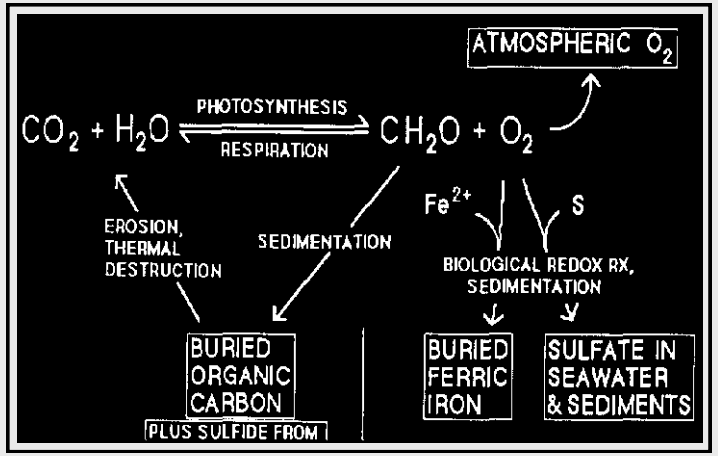


Touret 16

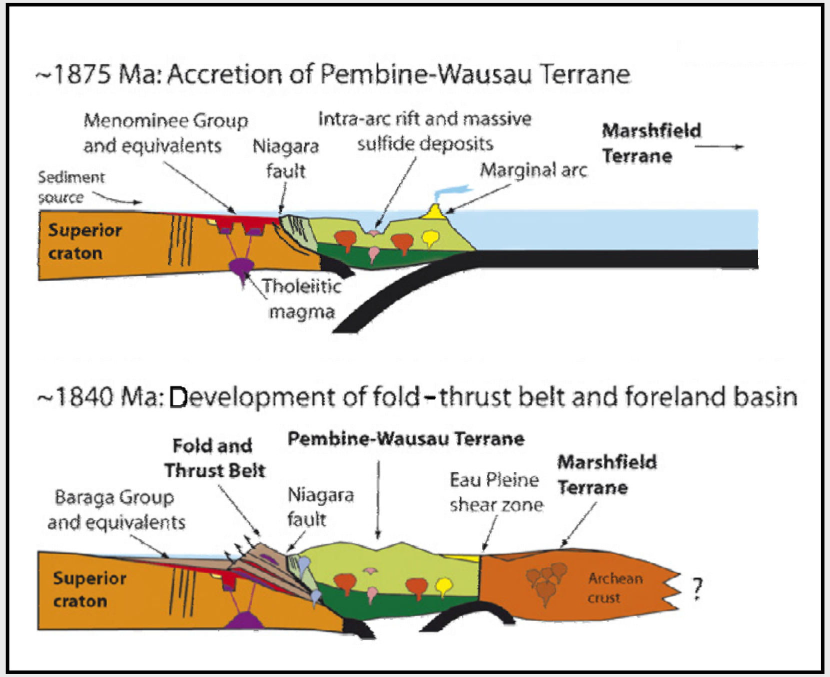
Luque et al. (AJS, 1998)
Fluid remobilized graphite



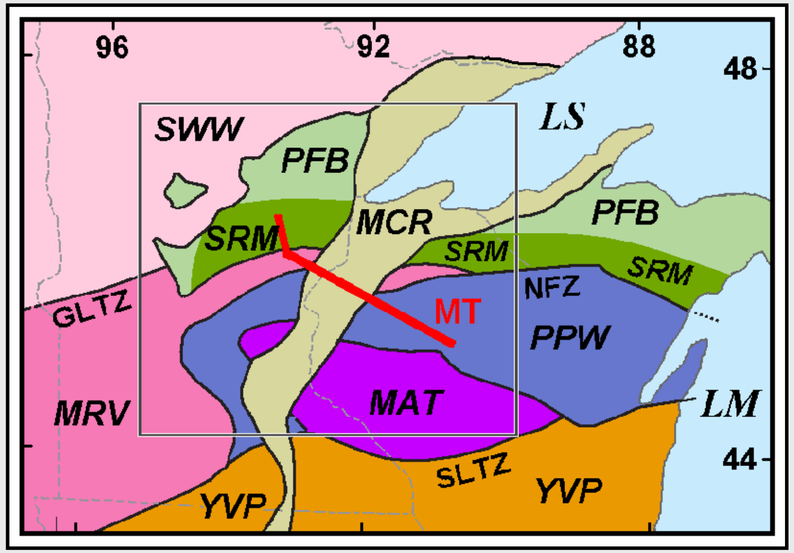
oC-Sd global primary production



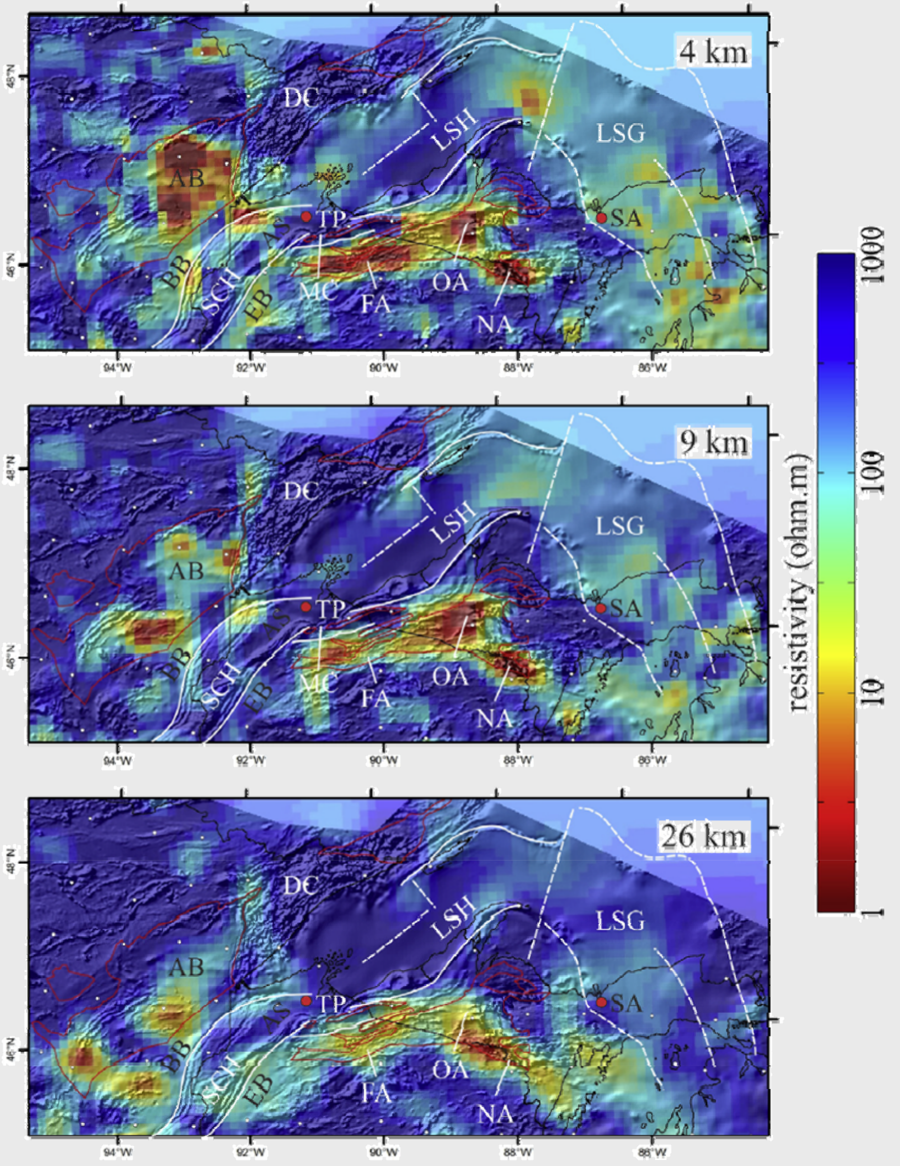
oC-Sd sequestration



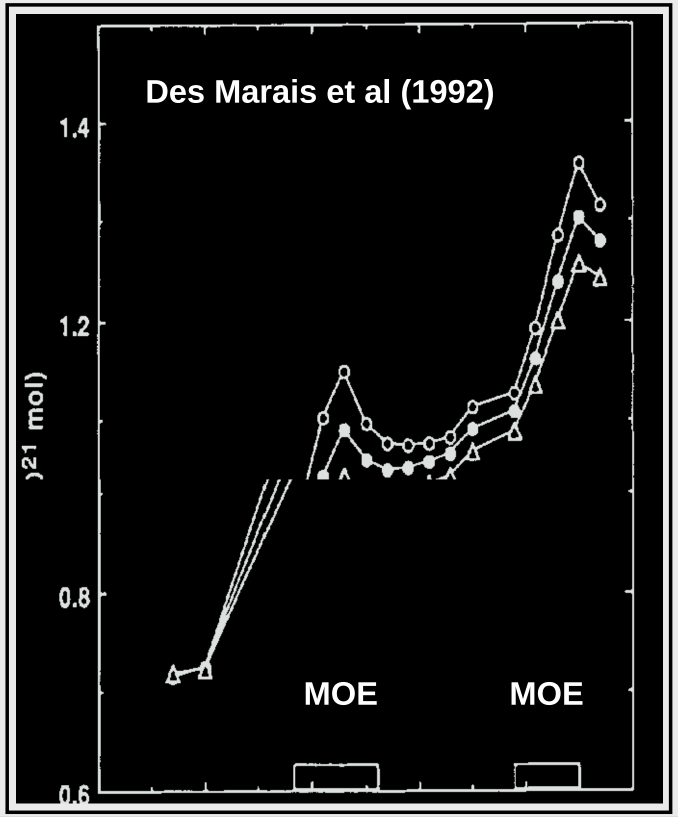
Mod from Schulz and Cannon (2007)



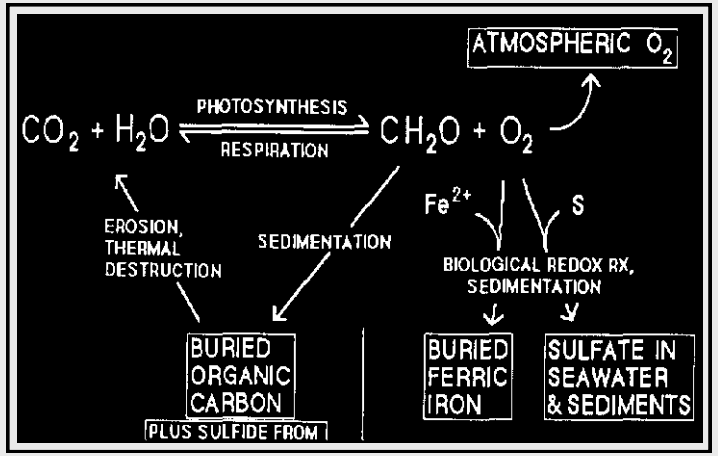
Mod from Southwick (2014)



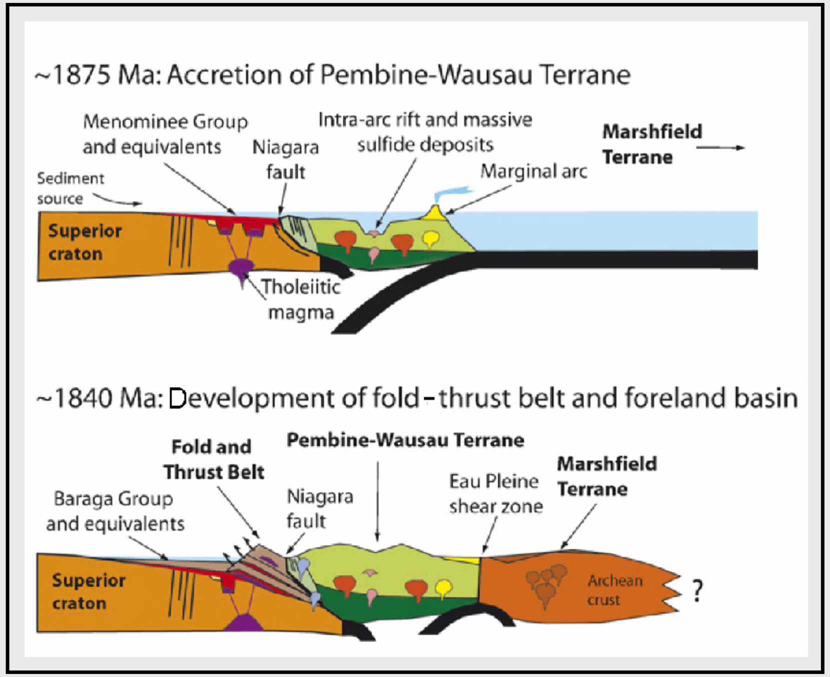
Bedrosian (2016)



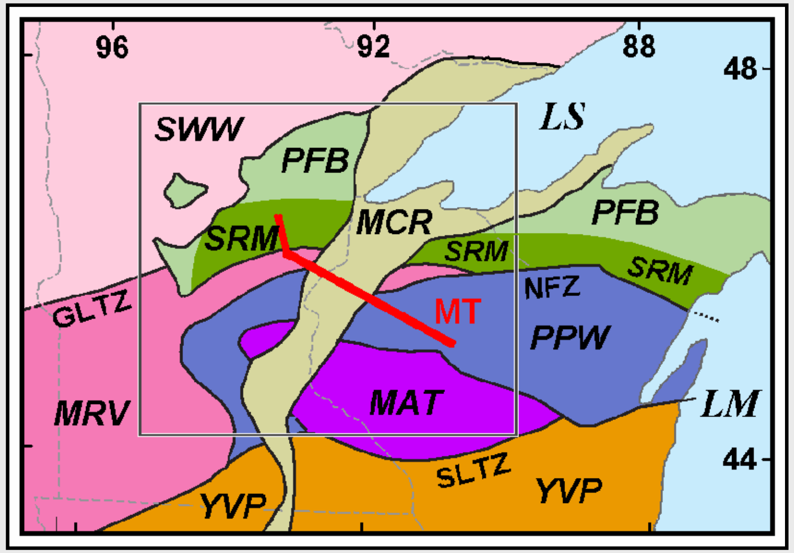
oC-Sd global primary production



oC-Sd sequestration

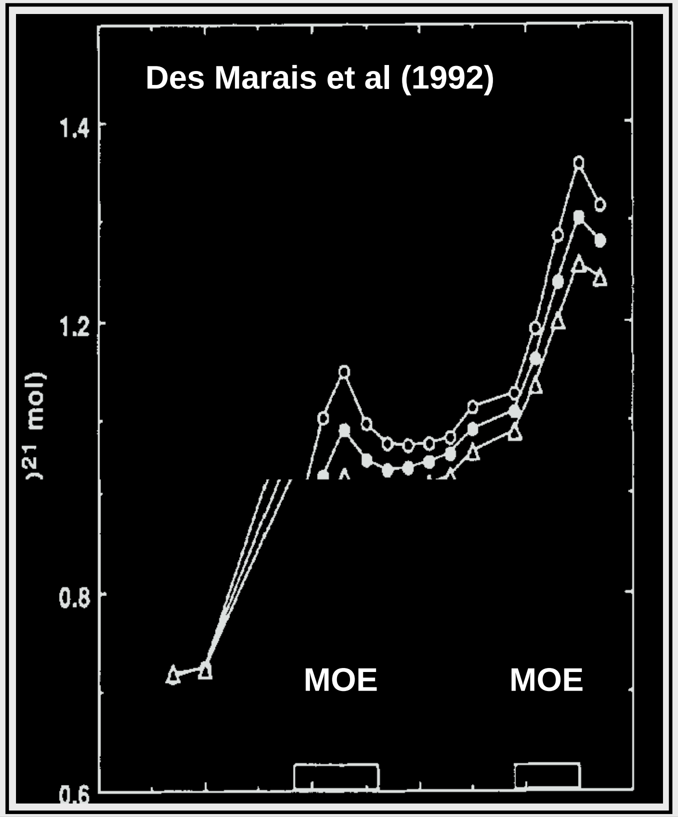


Mod from Schulz and Cannon (2007)

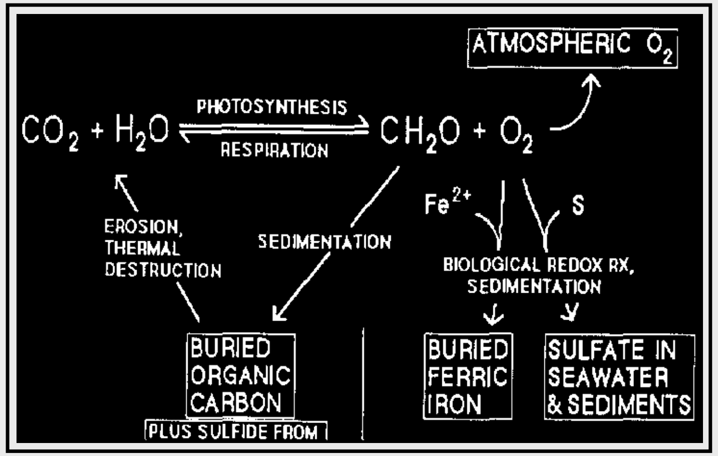


Mod from Southwick (2014)

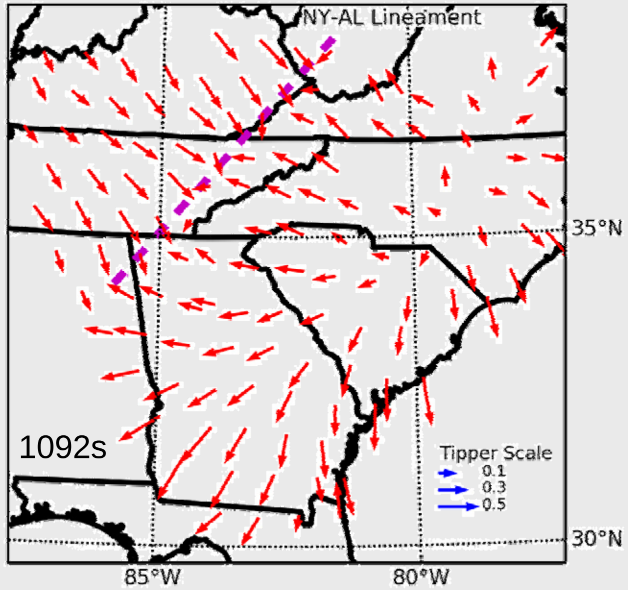
Wunderman et al. (2018)



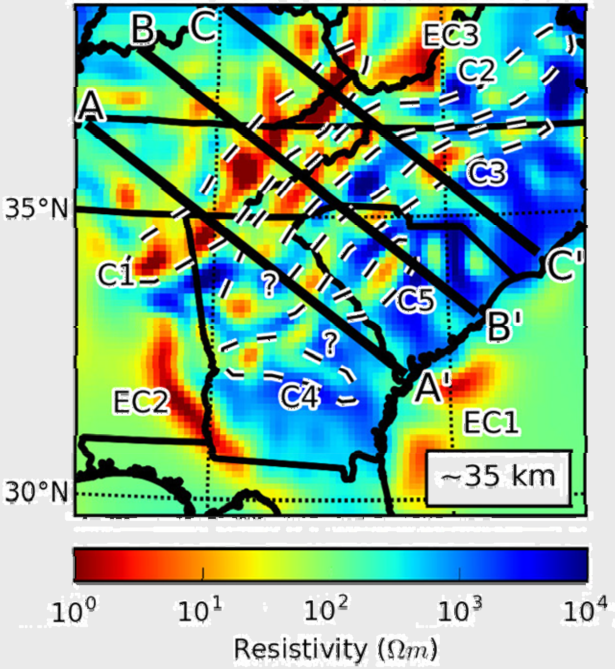
oC-Sd global primary production

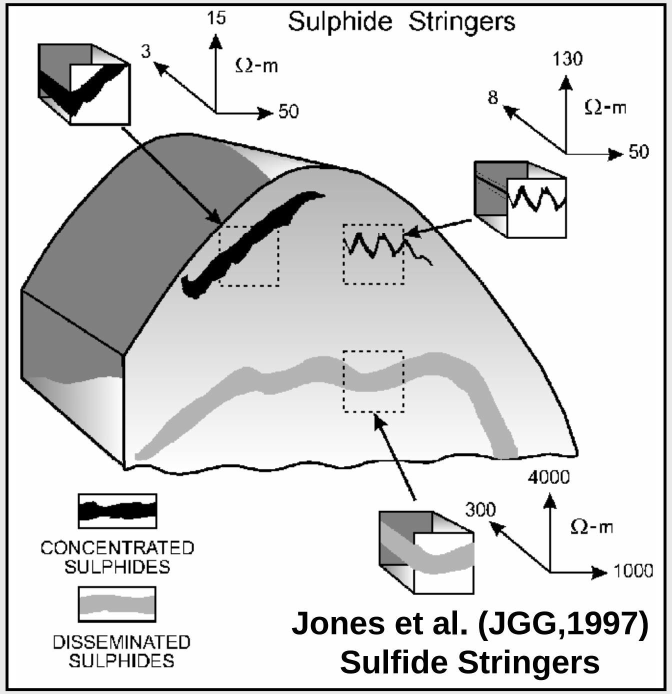


oC-Sd sequestration



Murphy and Egbert (2017)

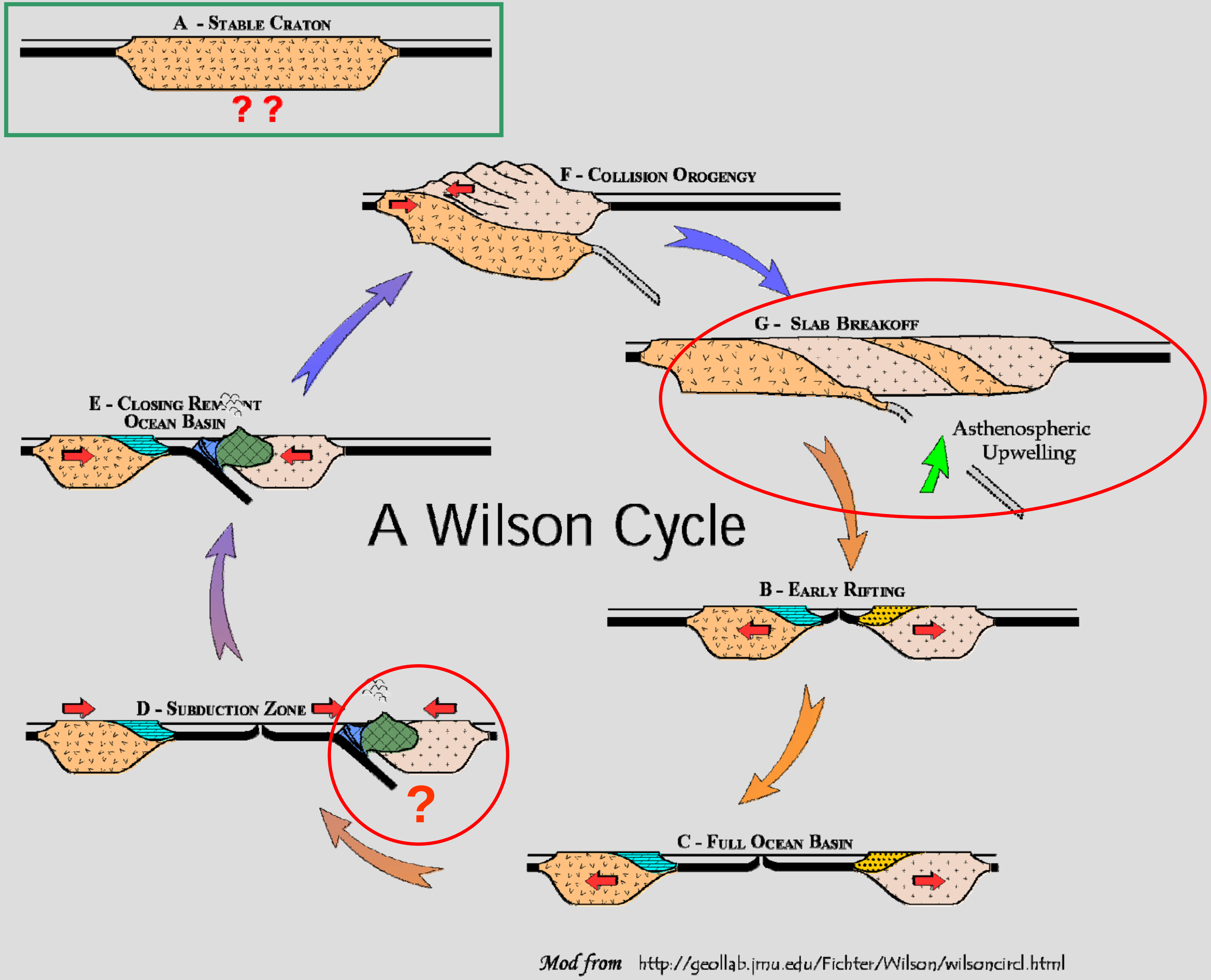




Jones et al. (JGG,1997)
Sulfide Stringers

Luque et al. (AJS, 1998)
Fluid remobilized graphite

Graphite-sulfide textures in crustal-scale conductors



Takeaways:

Brief trip around Wilson cycle highlights volatile transport processes.

- Temperature constraints valuable re non-uniqueness.
- Whole crustal and upper mantle circuits of element movement illuminated via resistivity.
- Ancient, even primordial volatile components are remobilized in visible events.
- Fossil resistivity traces of cycle processes common.
- Biological contributions to resistivity structure.
- High MT b/w allows source to sink views.