C cycling: tectonics to basins

Cin-Ty Lee

Rice University

6.40 m: bentonites B3 and B4

Outline

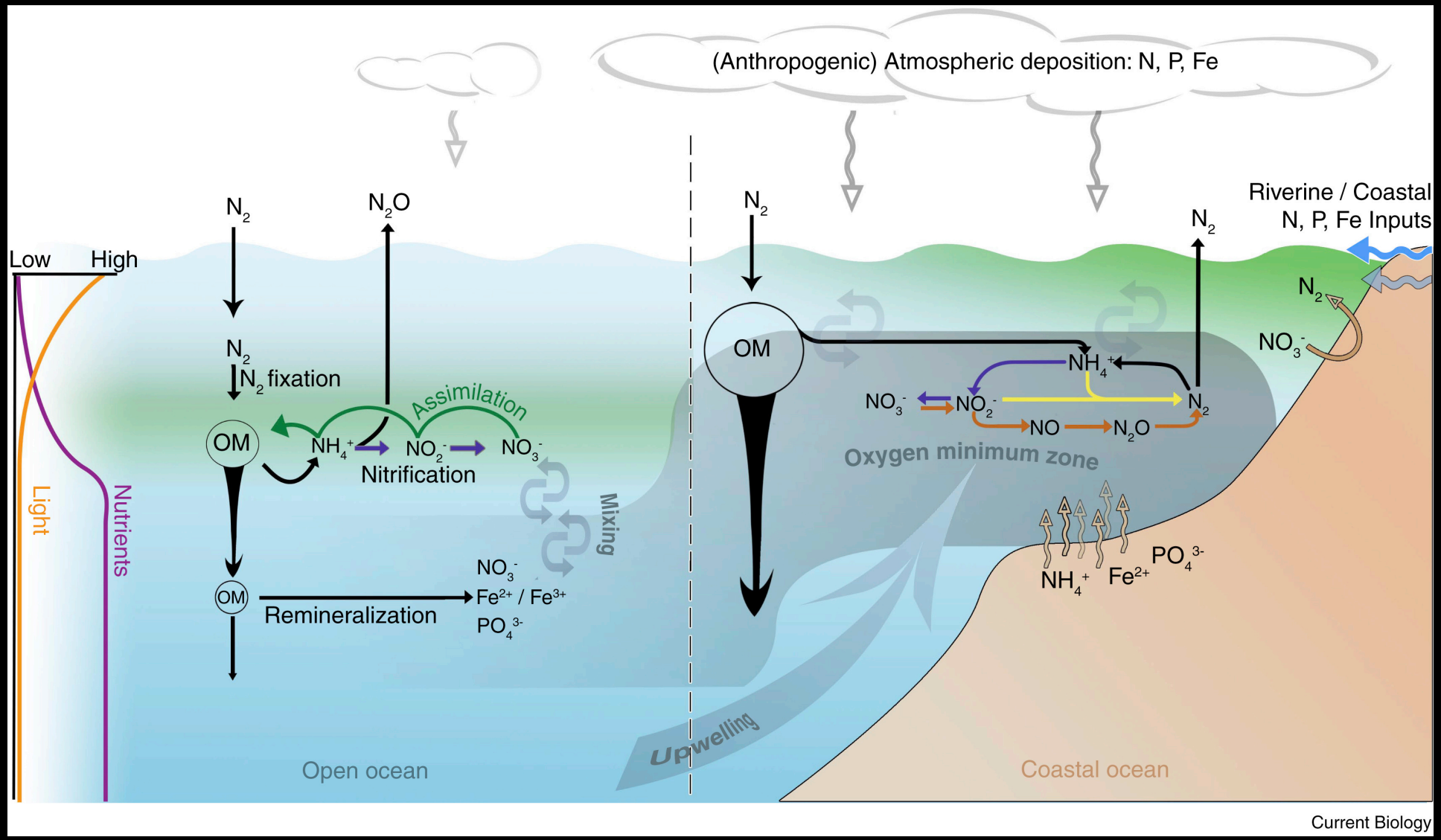
- Whole Earth Carbon Cycling
- Tectonic influence on C fluxing and basin development
- Why are we interested in low perm source rocks
  - Volcanic histories
  - Supervolcano processes
  - Radioactive waste disposal

Photosynthesis

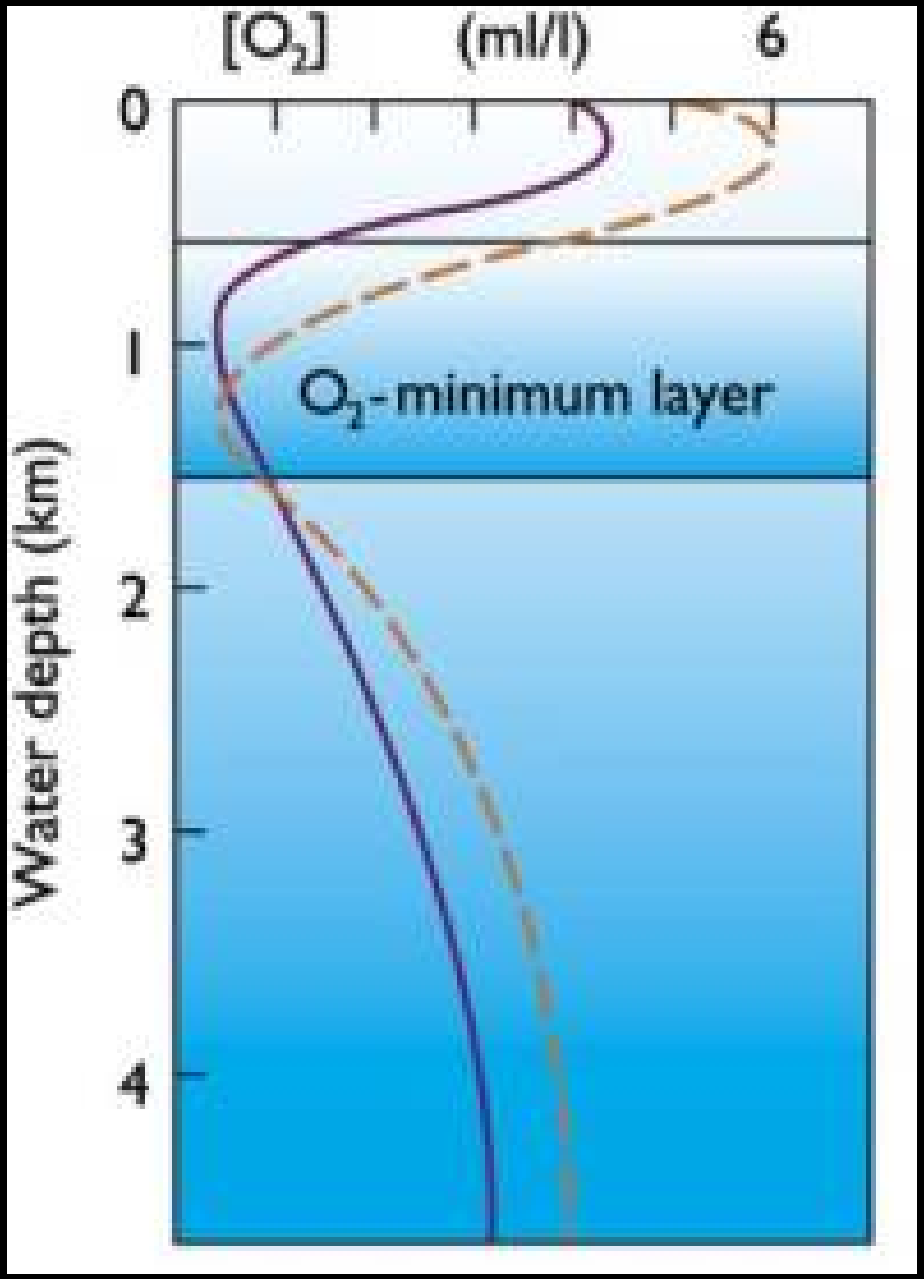
$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

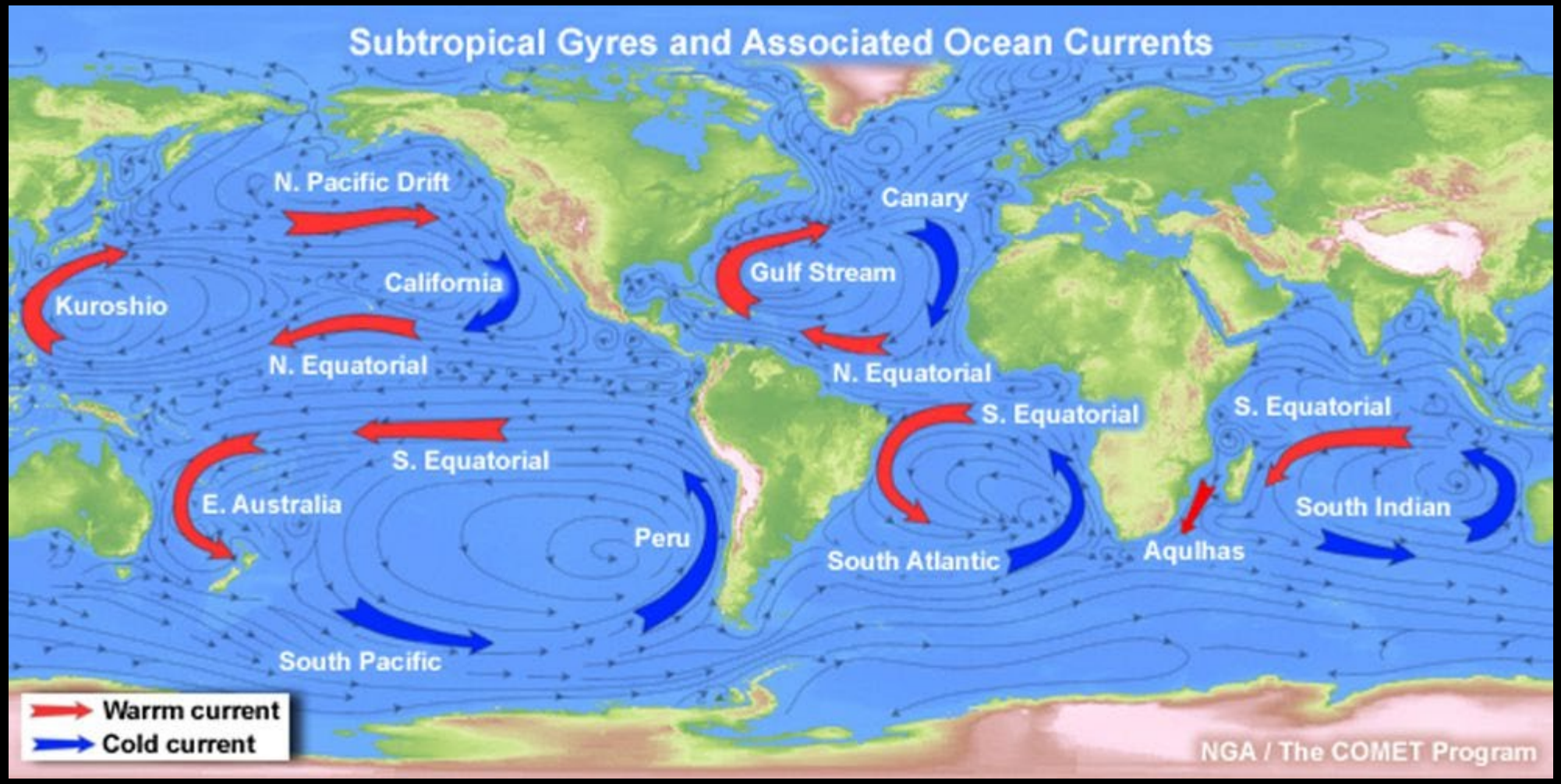
Respiration

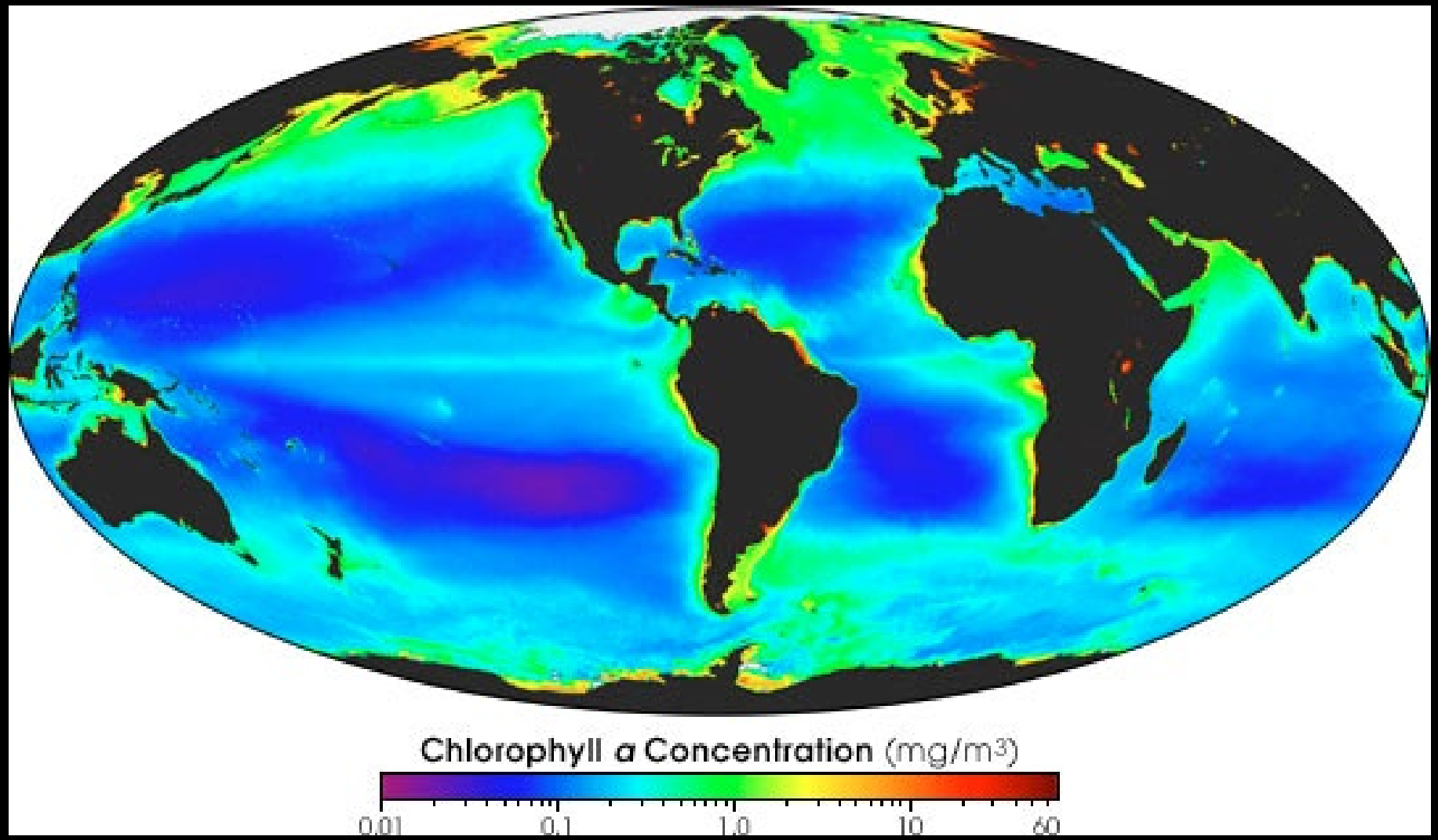
$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

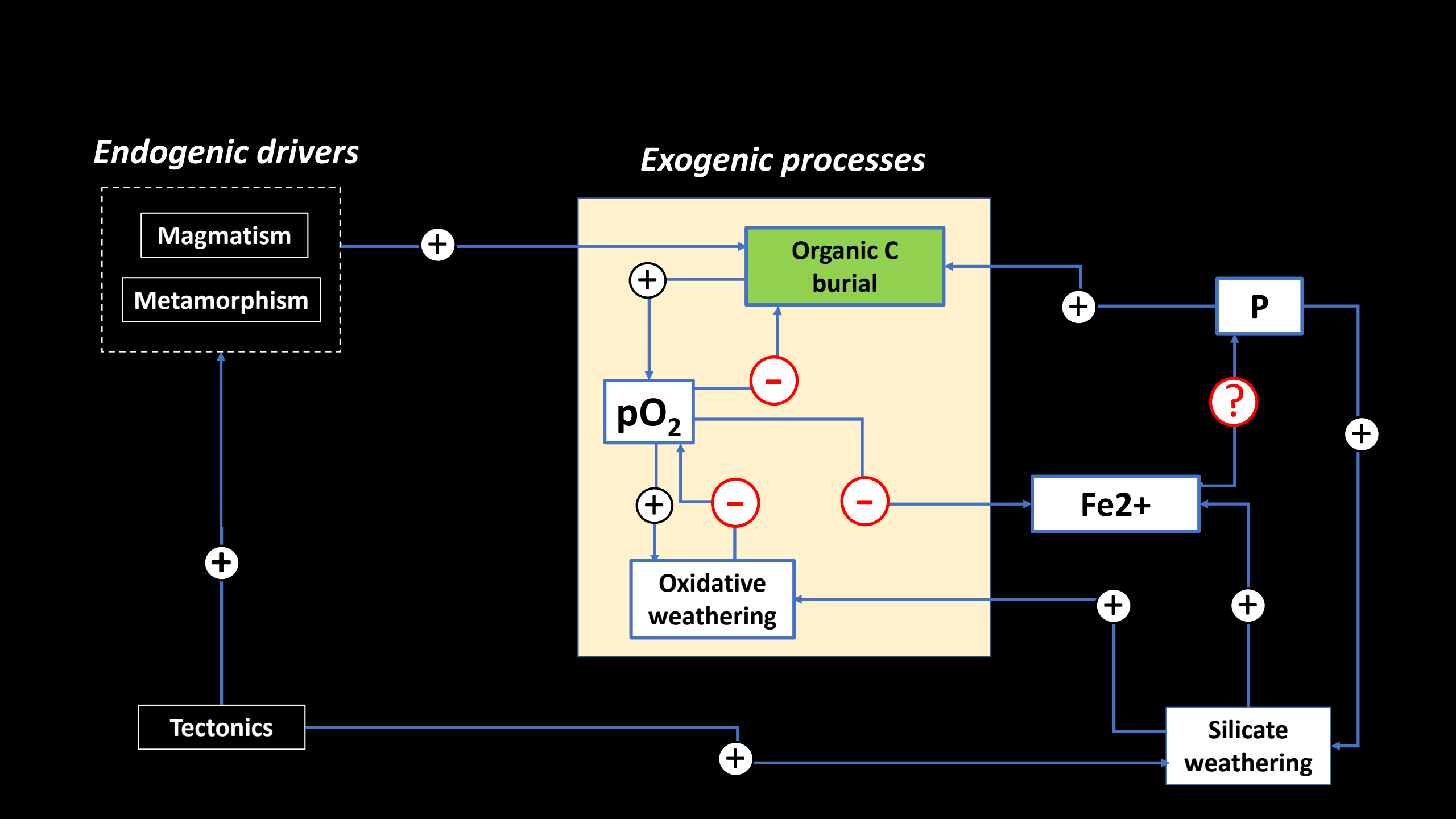


Bristow, Laura A.; Mohr, Wiebke; Ahmerkamp, Soeren; Kuypers, Marvel M.M. "Nutrients that limit growth in the ocean" Volume 27, Issue 11, 5 June 2017, Pages R474-R478.
https://doi.org/10.1016/j.cub.2017.03.030


[O2]
(ml/l)
6
0
1
2
3
4
Water depth (km)
O2-minimum layer

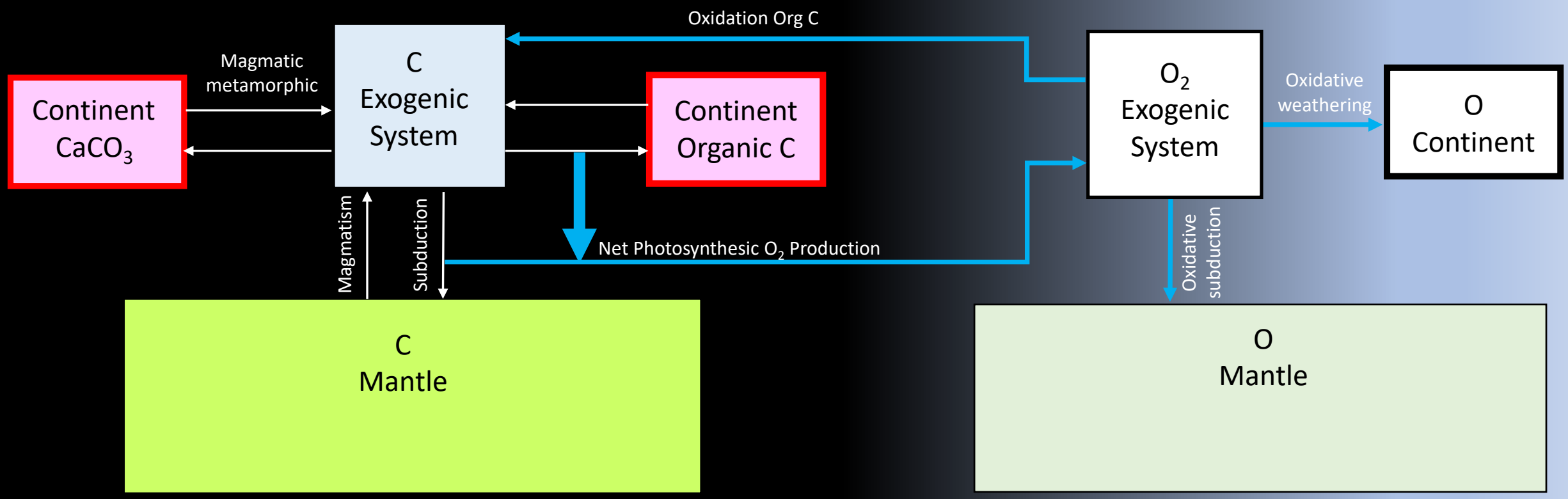

Subtropical Gyres and Associated Ocean Currents
N. Pacific Drift
Kuroshio
California
N. Equatorial
S. Equatorial
E. Australia
Peru
South Pacific
Canary
Gulf Stream
N. Equatorial
S. Equatorial
South Atlantic
Aqulhas
S. Equatorial
South Indian
Warrm current
Cold current
NGA / The COMET Program

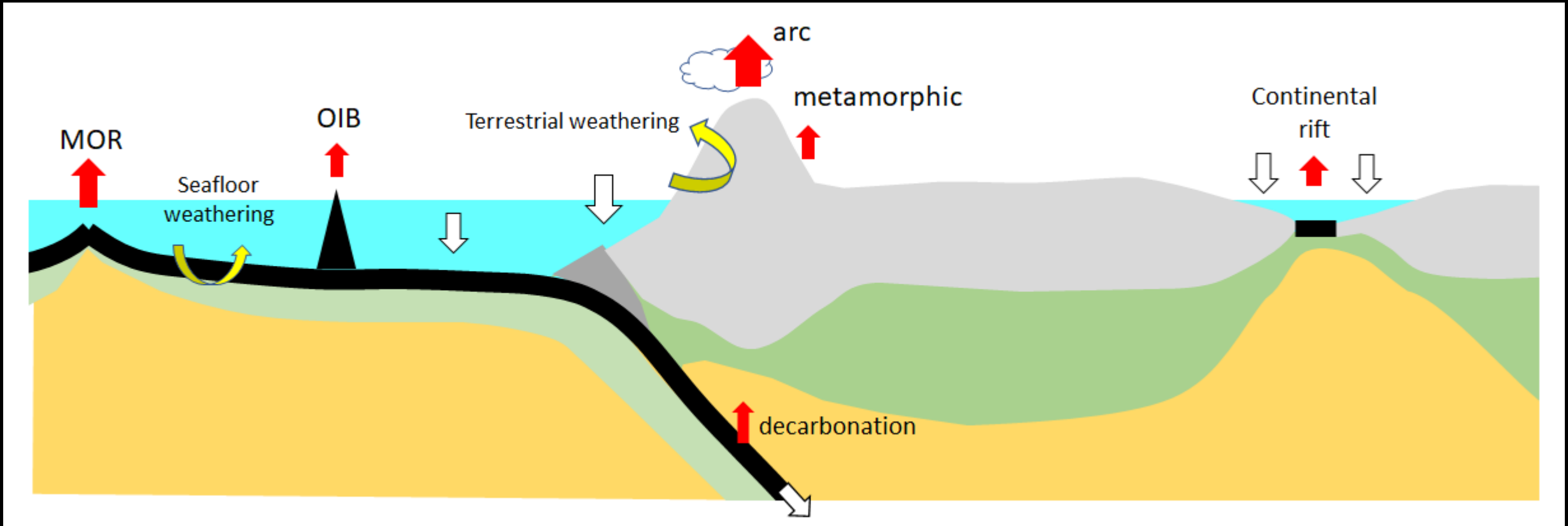

Chlorophyll a Concentration (mg/m3)
0.01
0.1
1.0
10
60


Endogenic drivers
Magmatism
Metamorphism
Exogenic processes
Organic C burial
pO2
Oxidative weathering
P
Fe2+
Silicate weathering
Tectonics
+
-
?

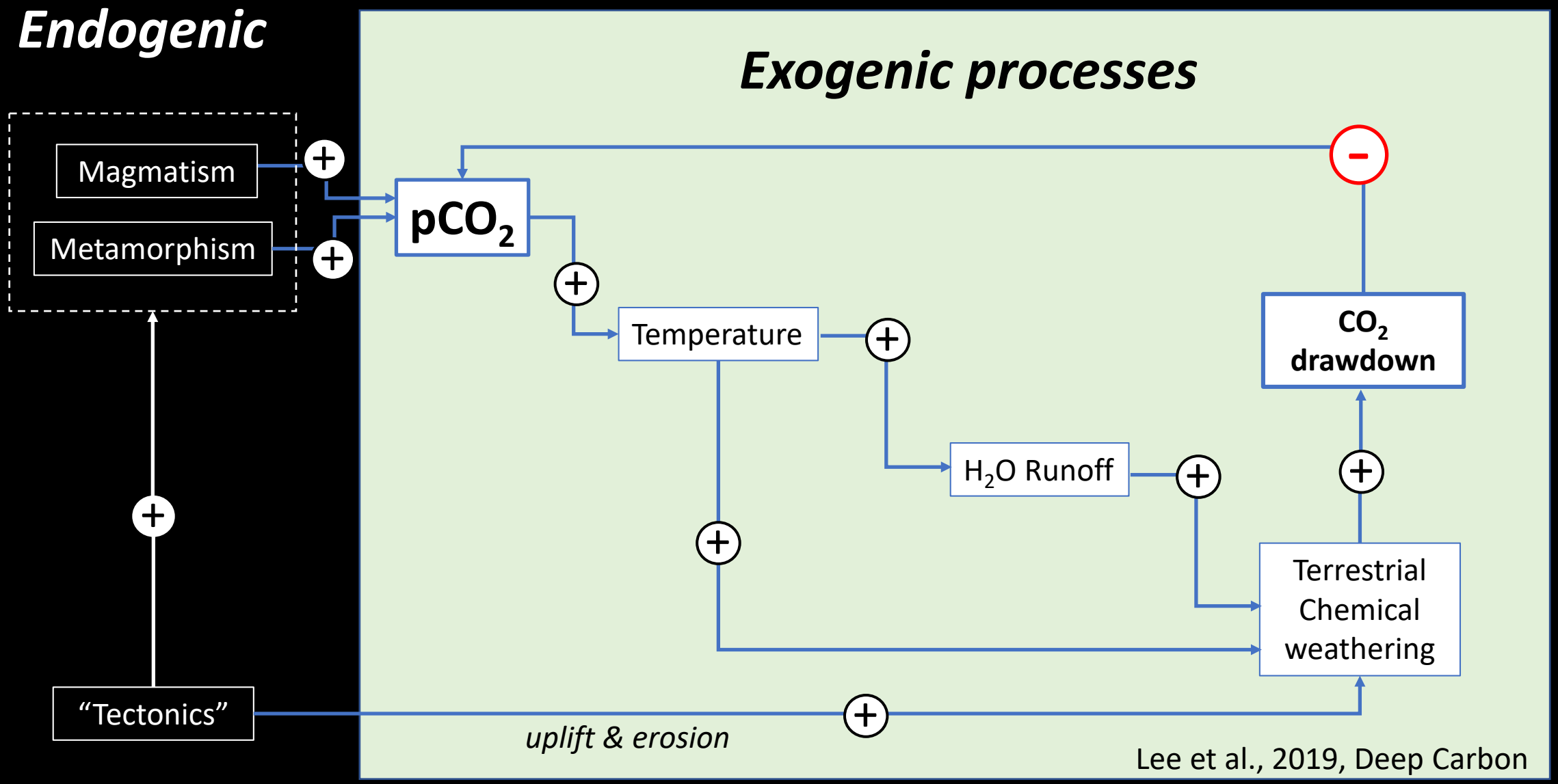
Carbon Cycle

Oxygen Cycle

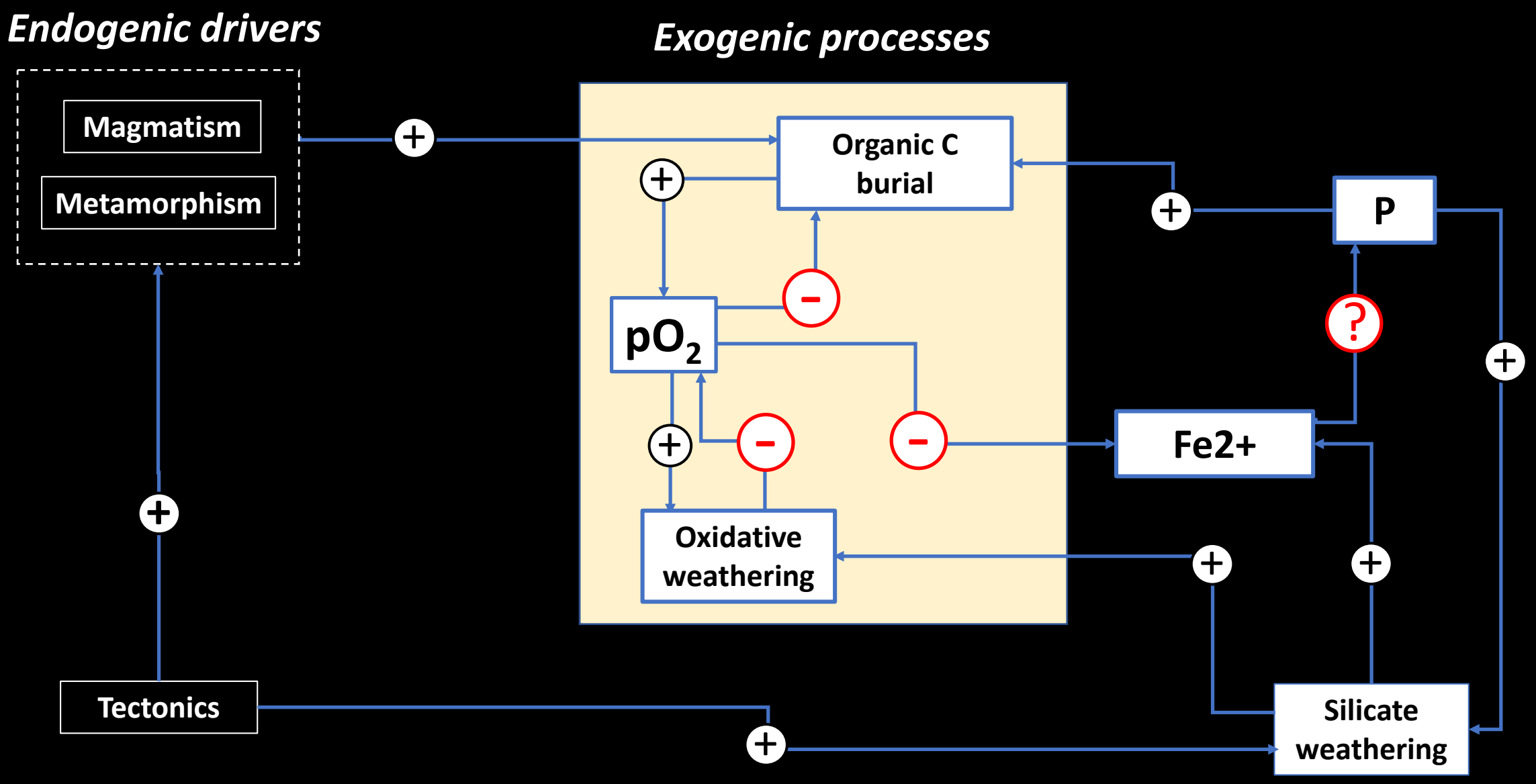



arc
metamorphic
Continental
rift
OIB
Terrestrial weathering
MOR
Seafloor
weathering
decarbonation

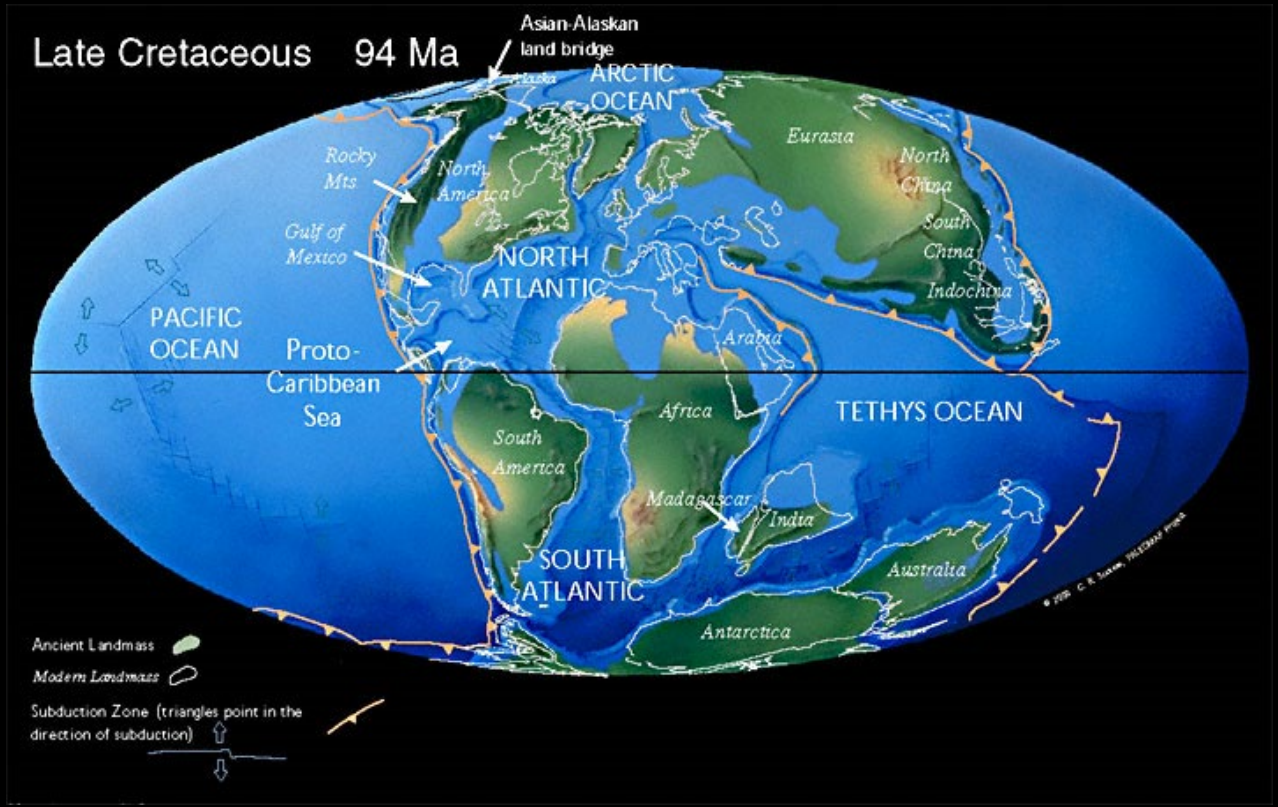
Whole Earth Carbon Cycle



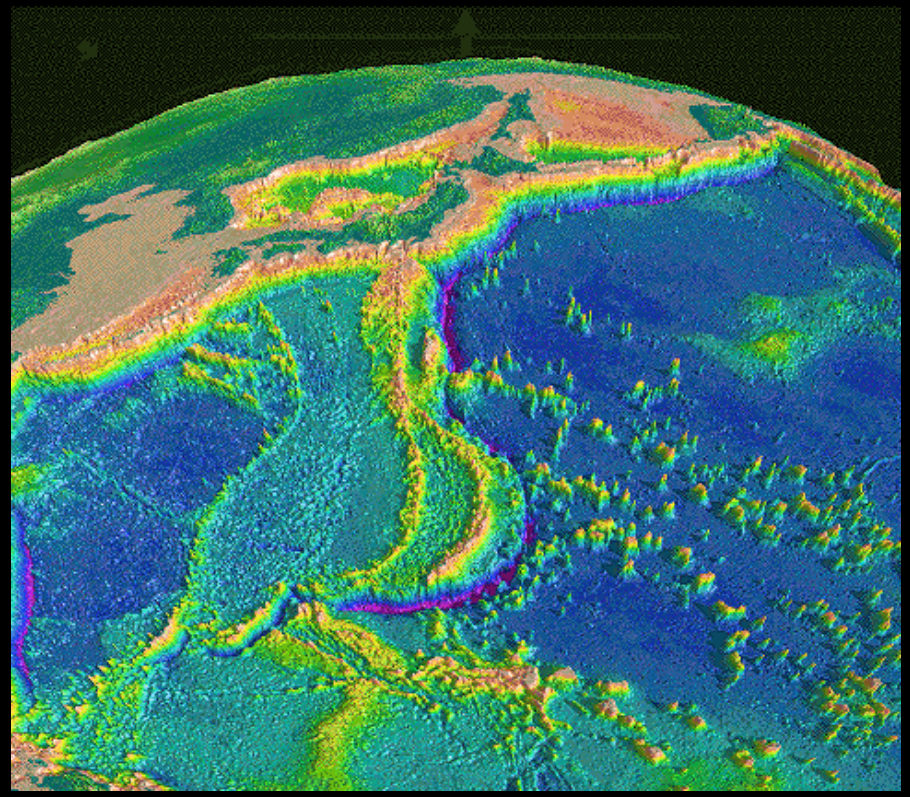
Whole Earth Oxygen Cycle

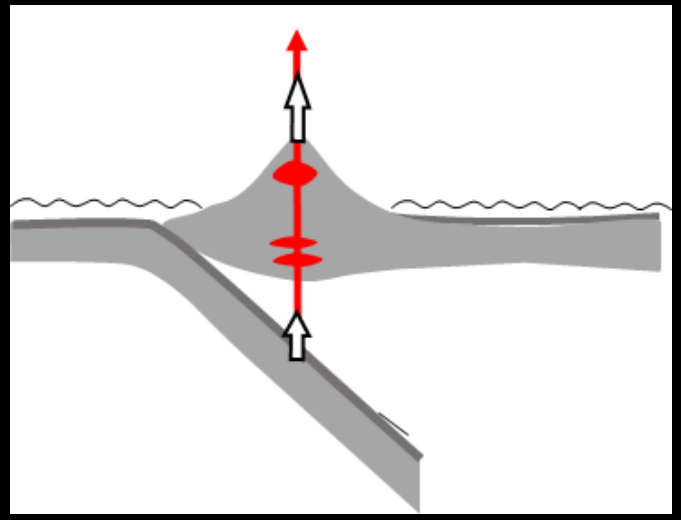


Differences between Cretaceous and modern world

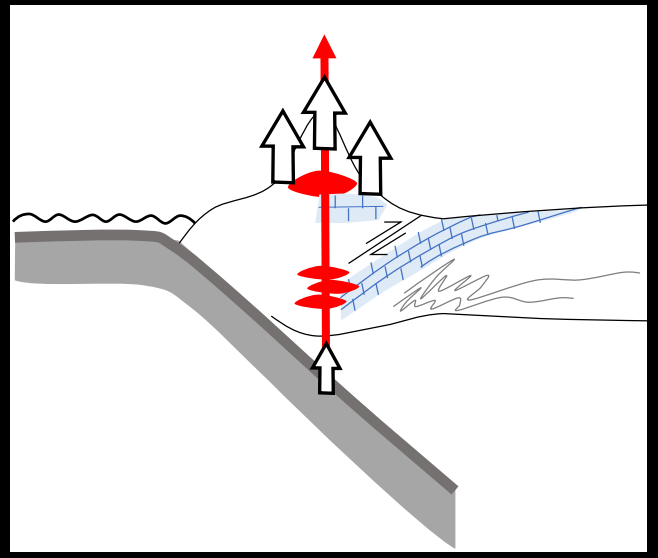


Scotese

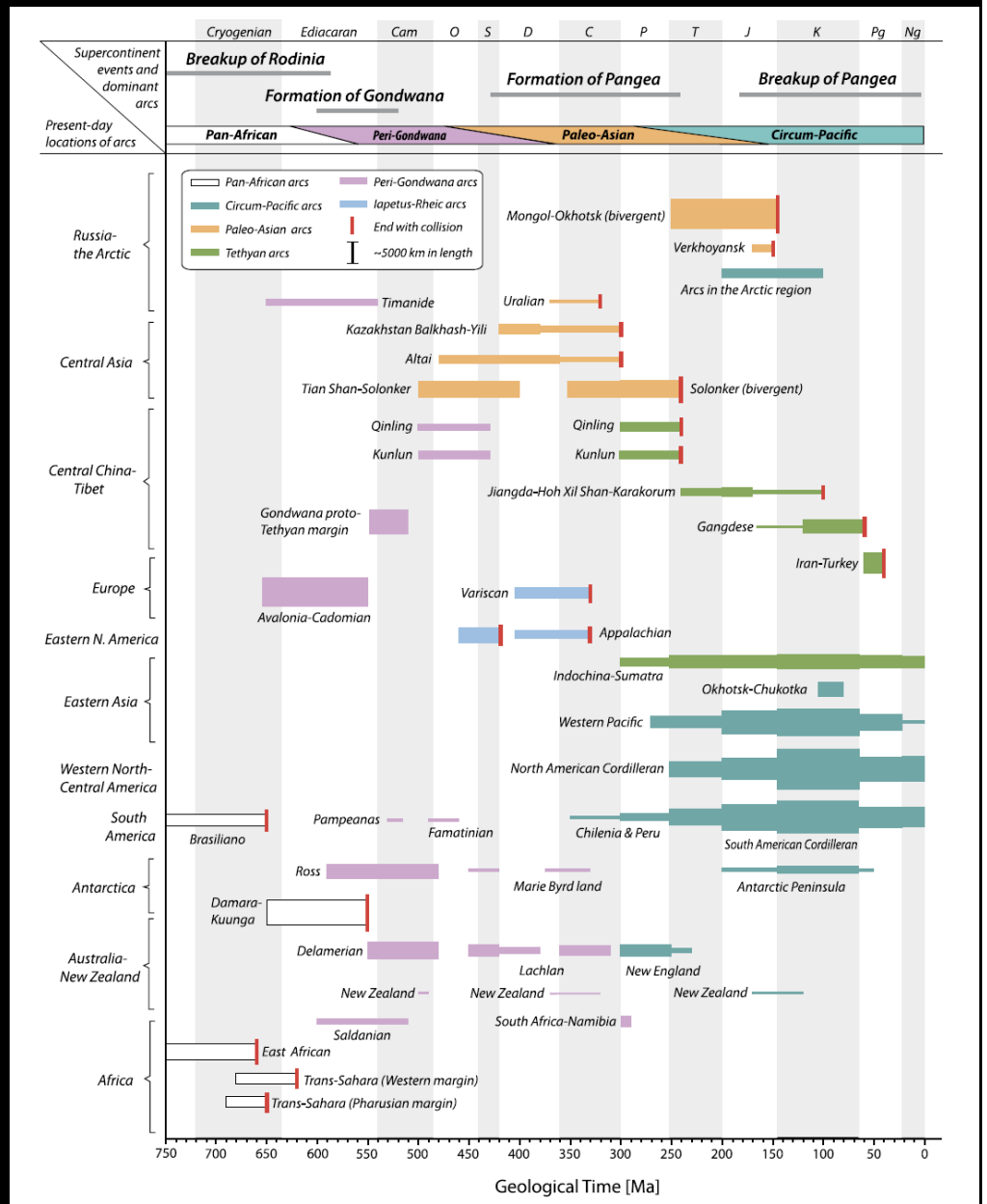


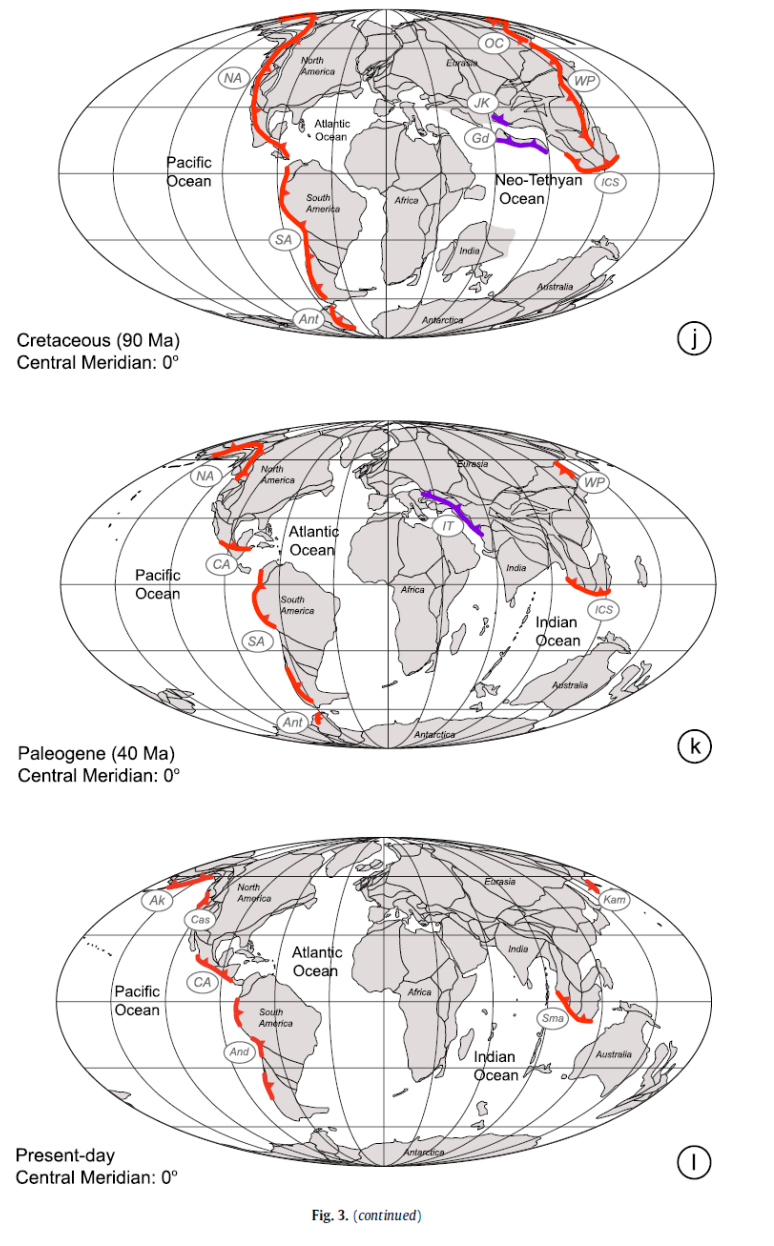


Island vs continental arcs



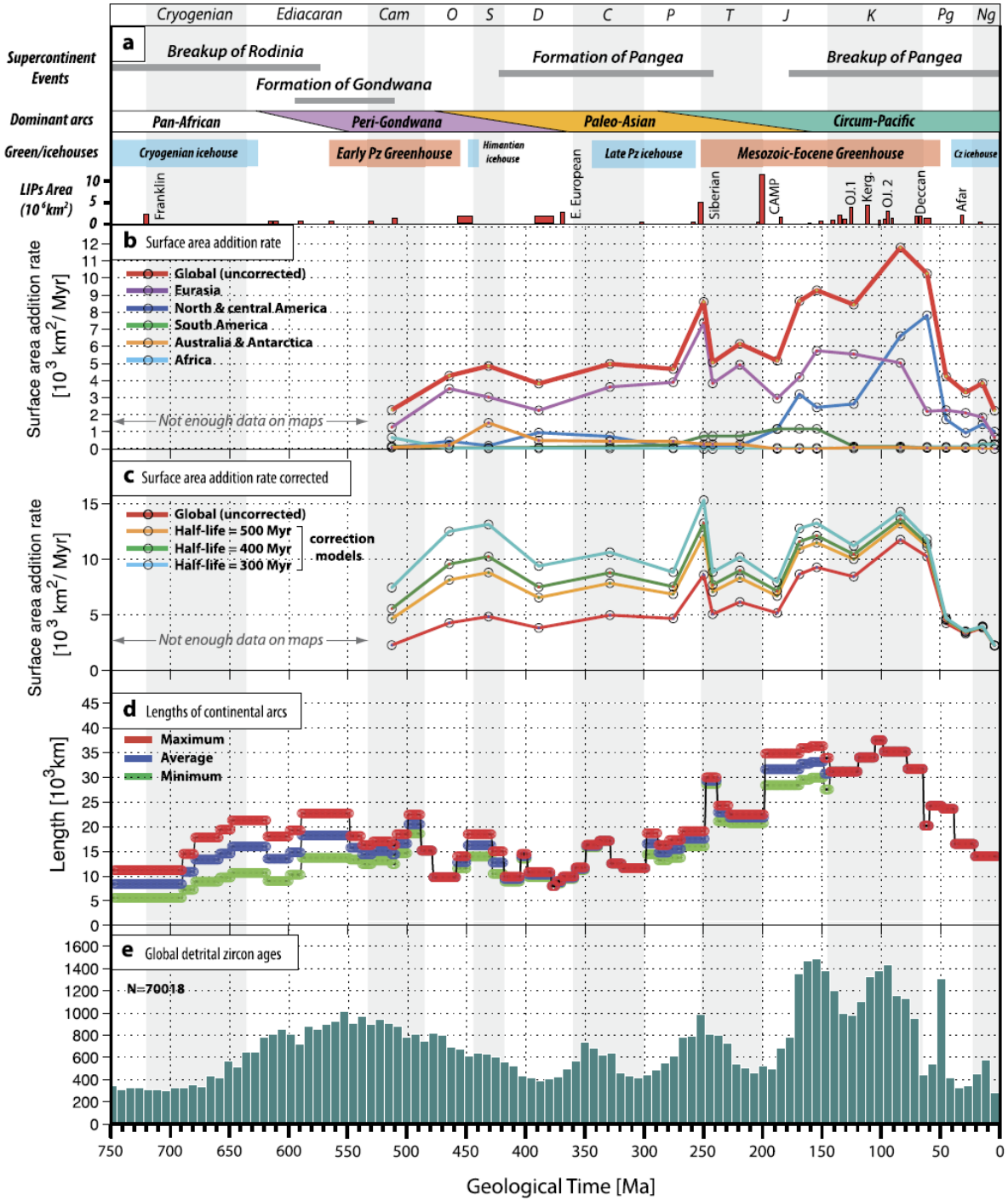
Continental arc length changes with time

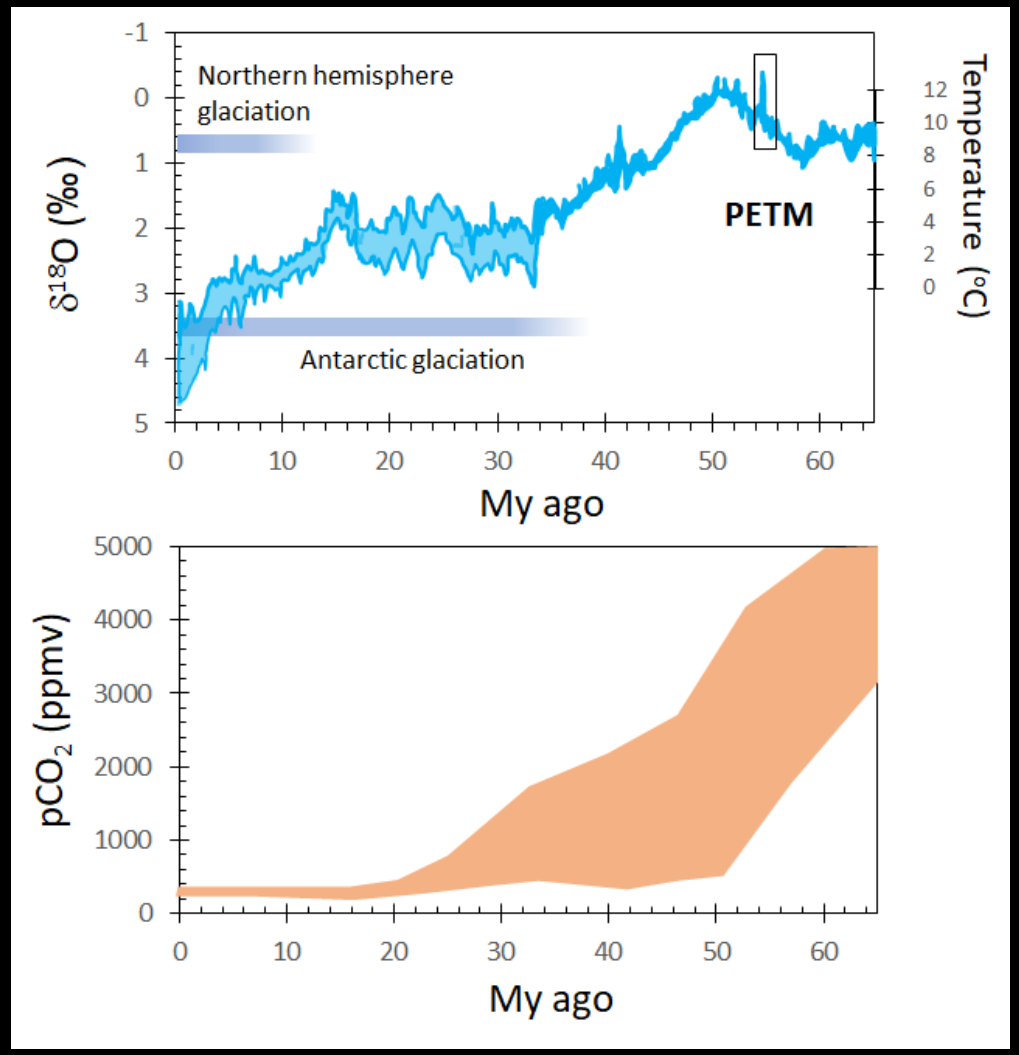




Cao, Lee, Lackey 2018

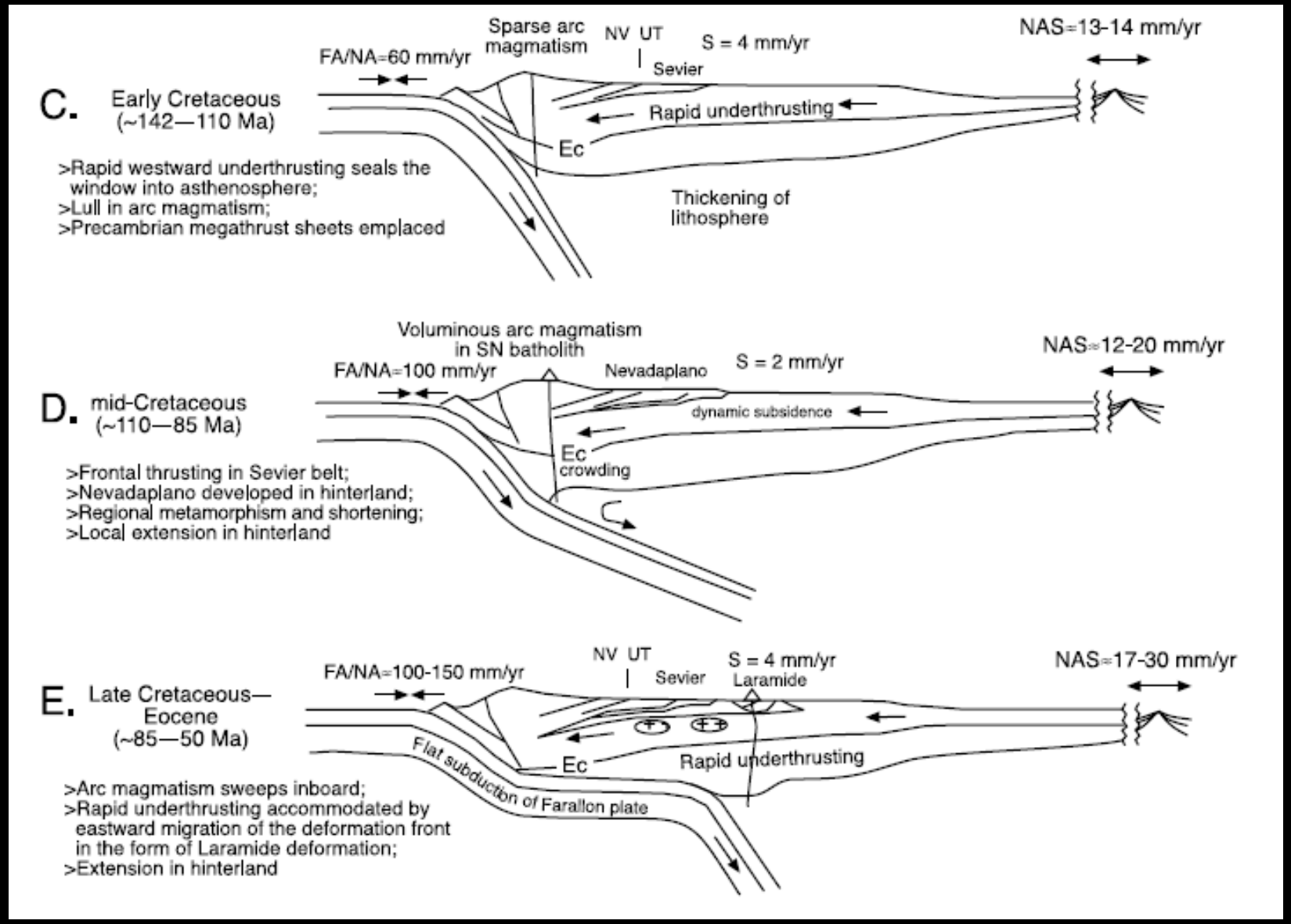
Cretaceous greenhouse



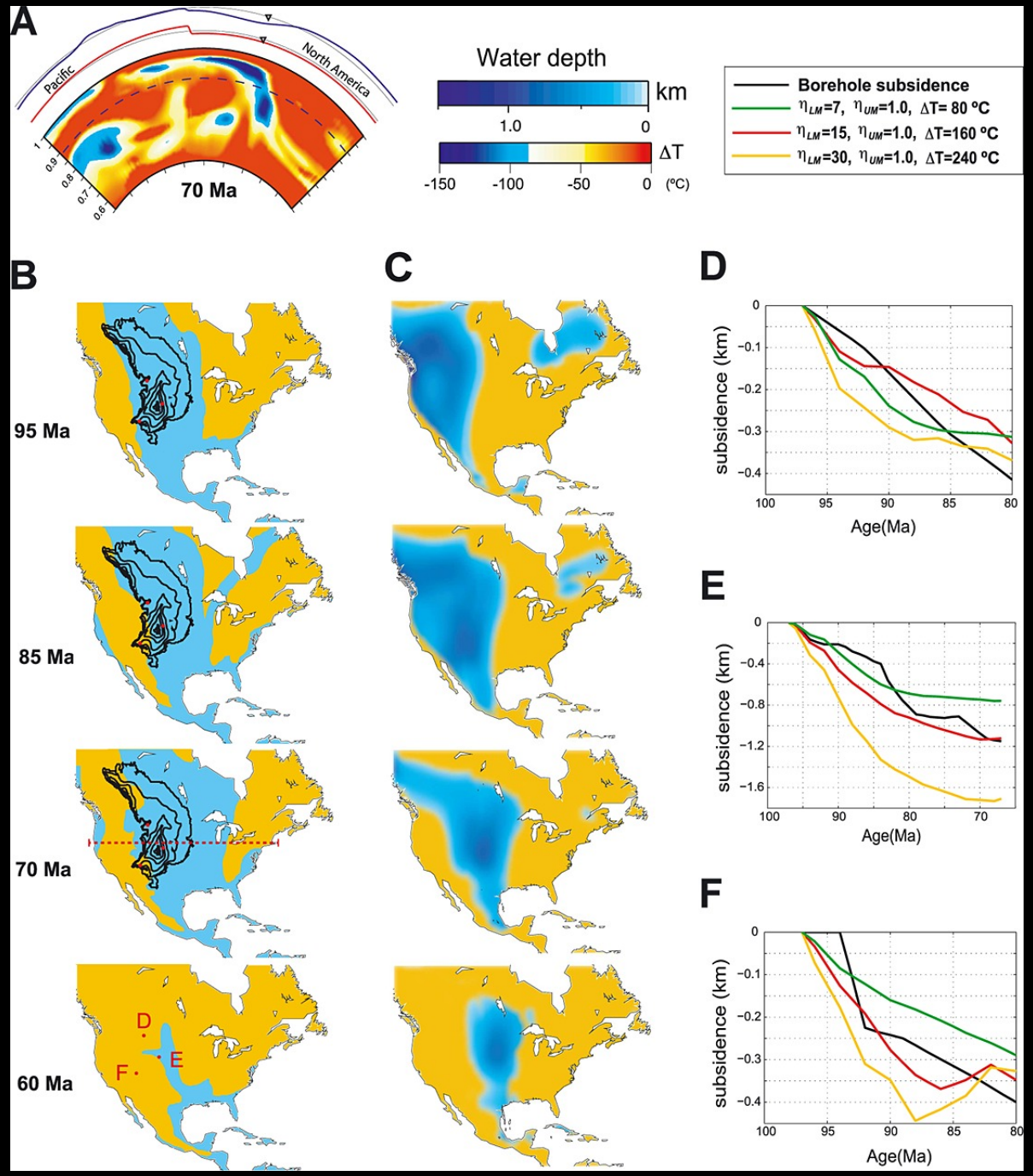


Cao, Lee, Lackey 2018

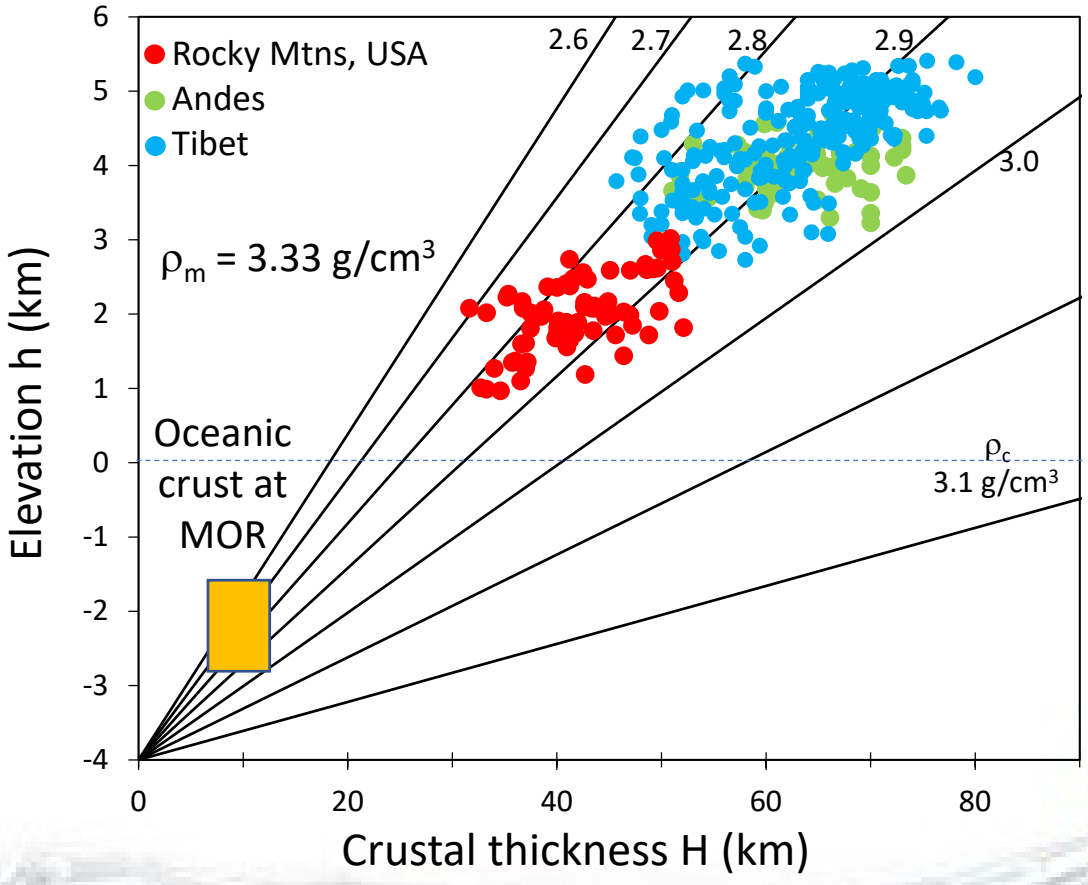
Continental arcs generate retroarc thrusts and foreland basins



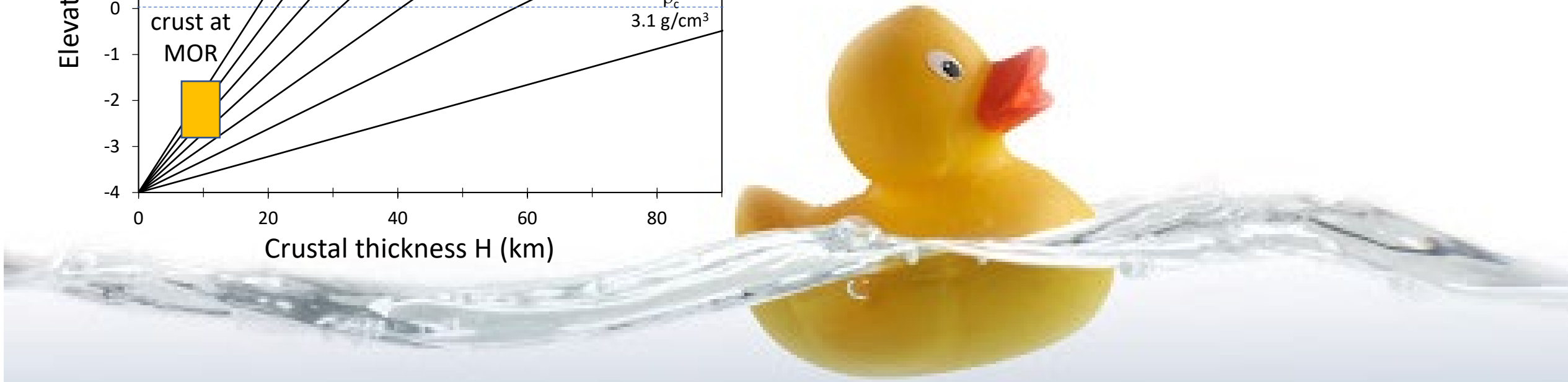
DeCelles, 2004


A
Pacific
North America
70 Ma
Water depth
km
1.0
0
ΔT
-150
-100
-50
0
(°C)
Borehole subsidence
η_{LM}=7, η_{UM}=1.0, ΔT= 80 °C
η_{LM}=15, η_{UM}=1.0, ΔT=160 °C
η_{LM}=30, η_{UM}=1.0, ΔT=240 °C
B
C
D
E
F
95 Ma
85 Ma
70 Ma
60 Ma
subsidence (km)
Age(Ma)

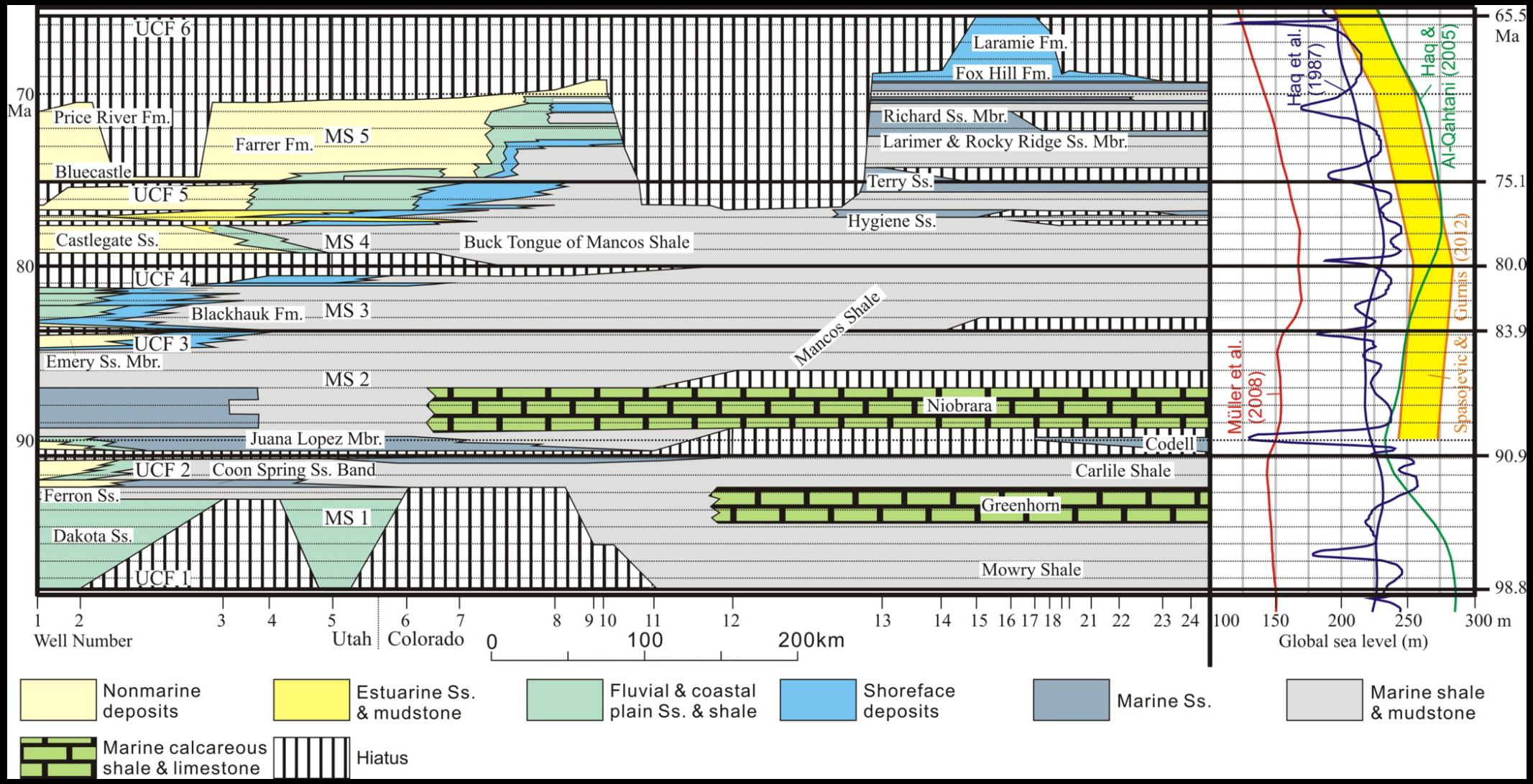
Liu, 2015



Lee et al., 2016

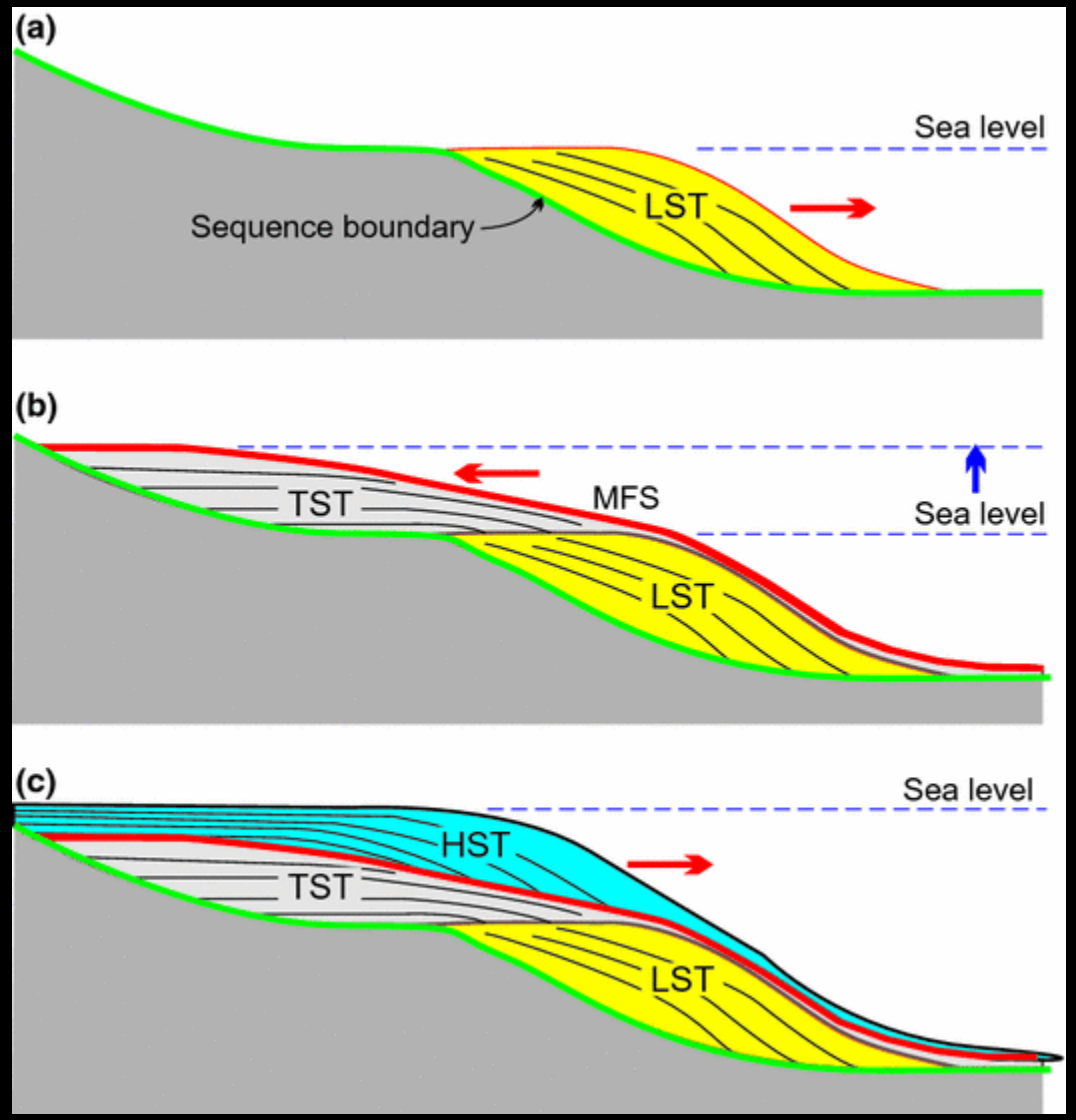


Dynamic versus isostatic topography



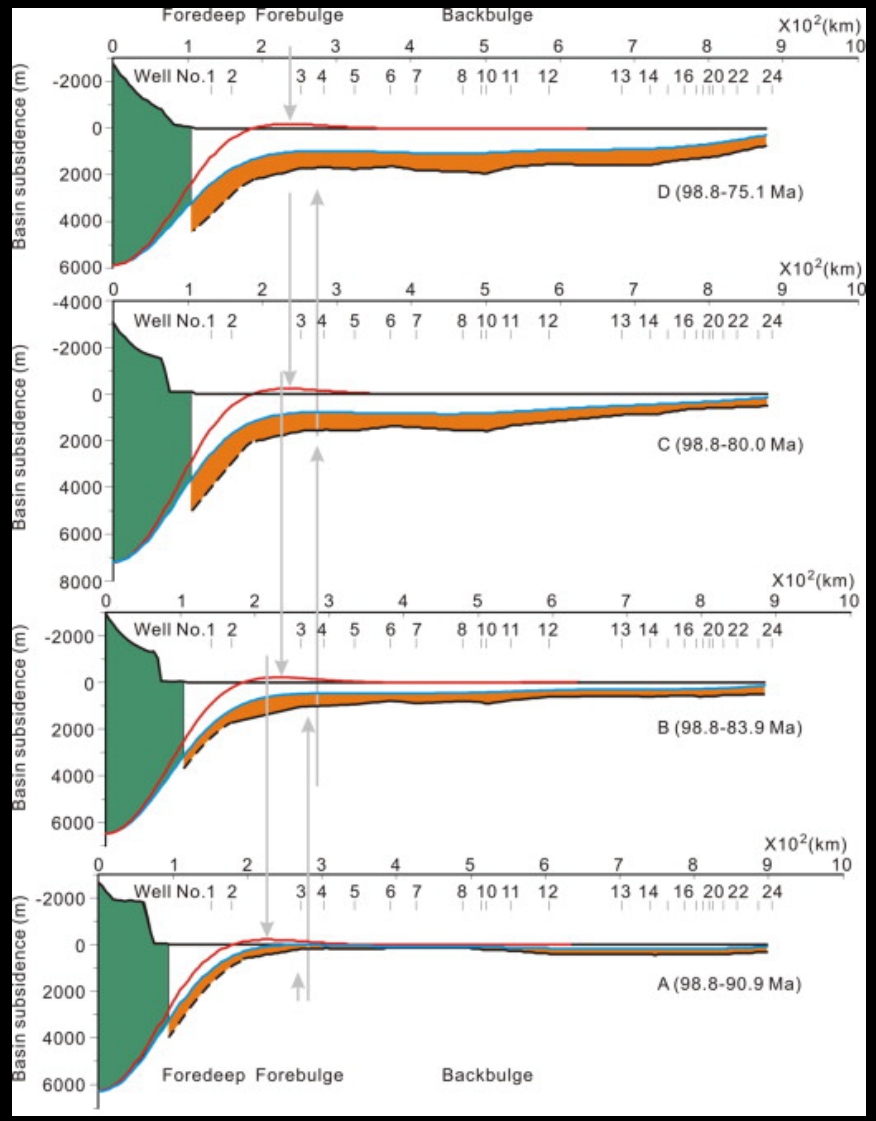
Liu et al., 2014

Eustatic sea level change

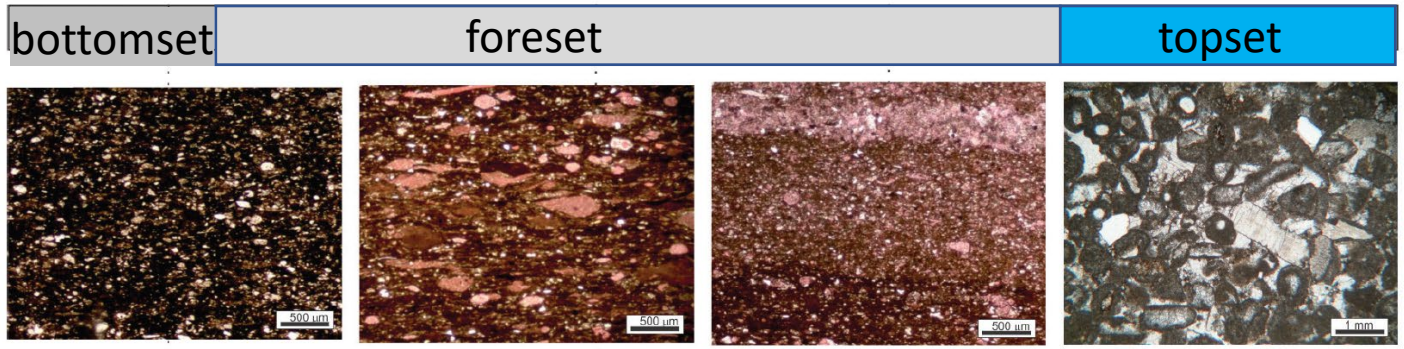


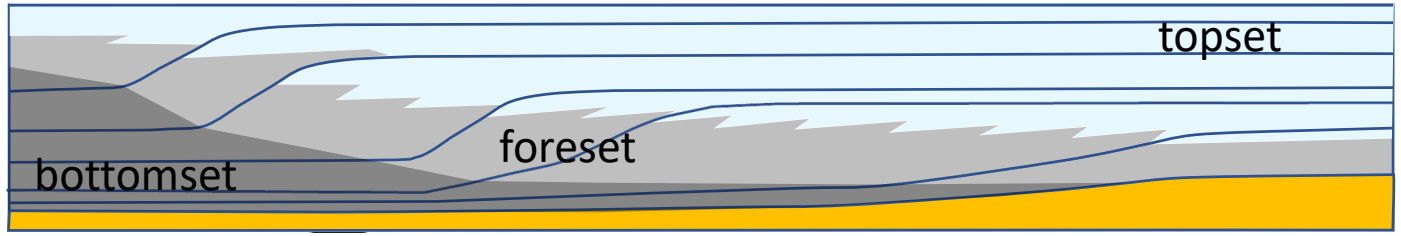
Maliva 2016

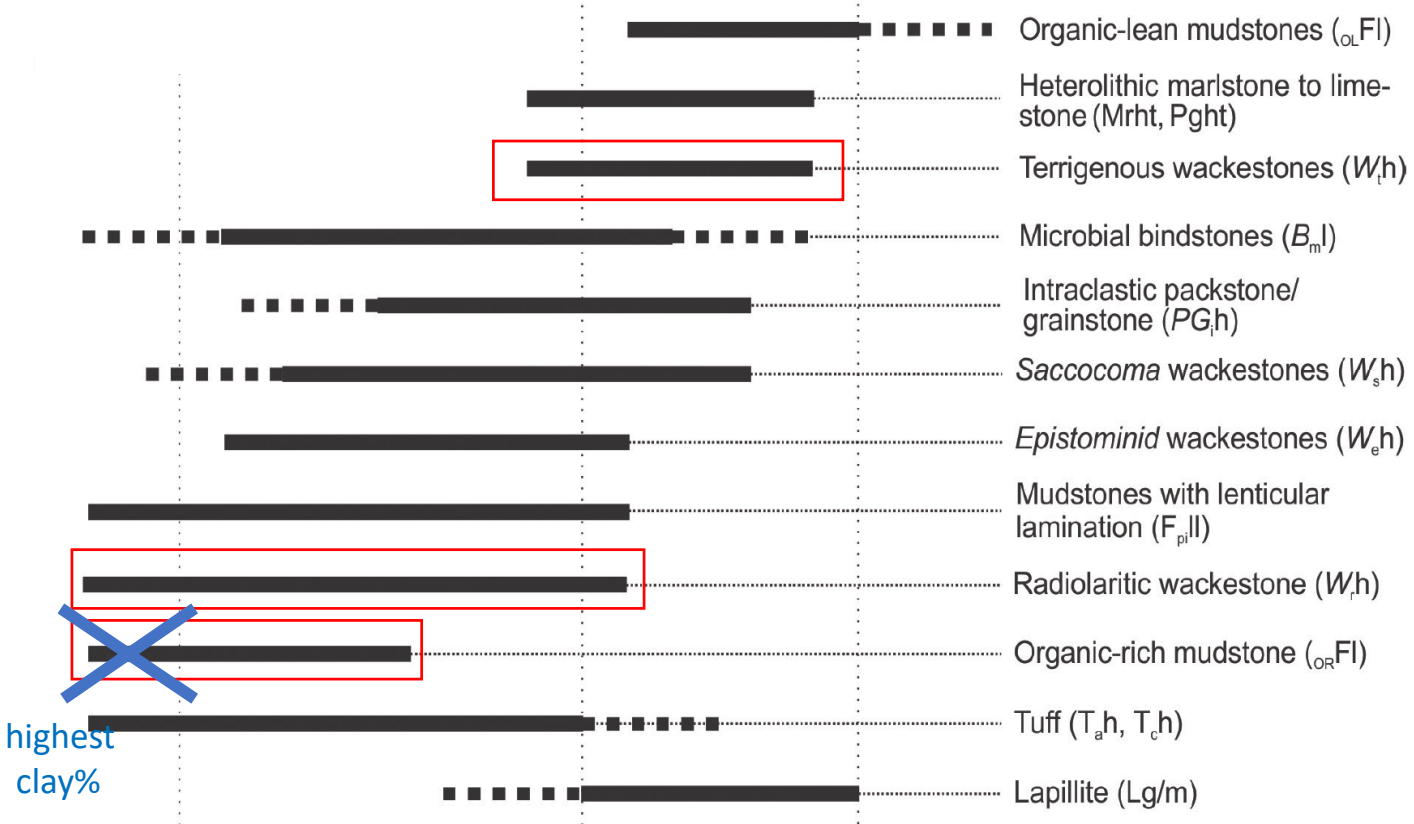
Tectonic change
-base level, sediment supply



Liu et al., 2014

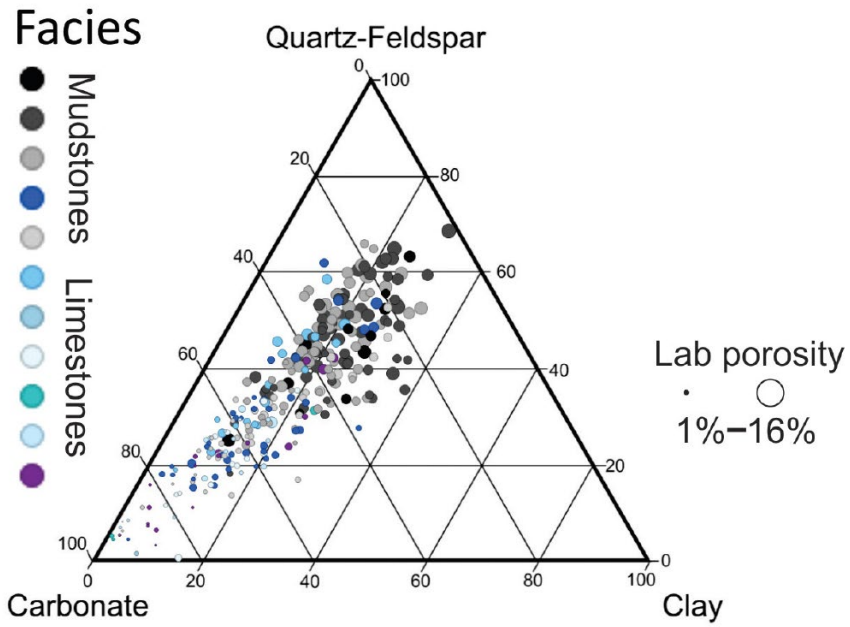






The clinothem presents 3 physiographic sectors: topset, foreset and bottomset. Samples from cores define grain types & microfauna (describing thin sections), porosity (analyzing plugs), and clay content (through XRD) of each sector.

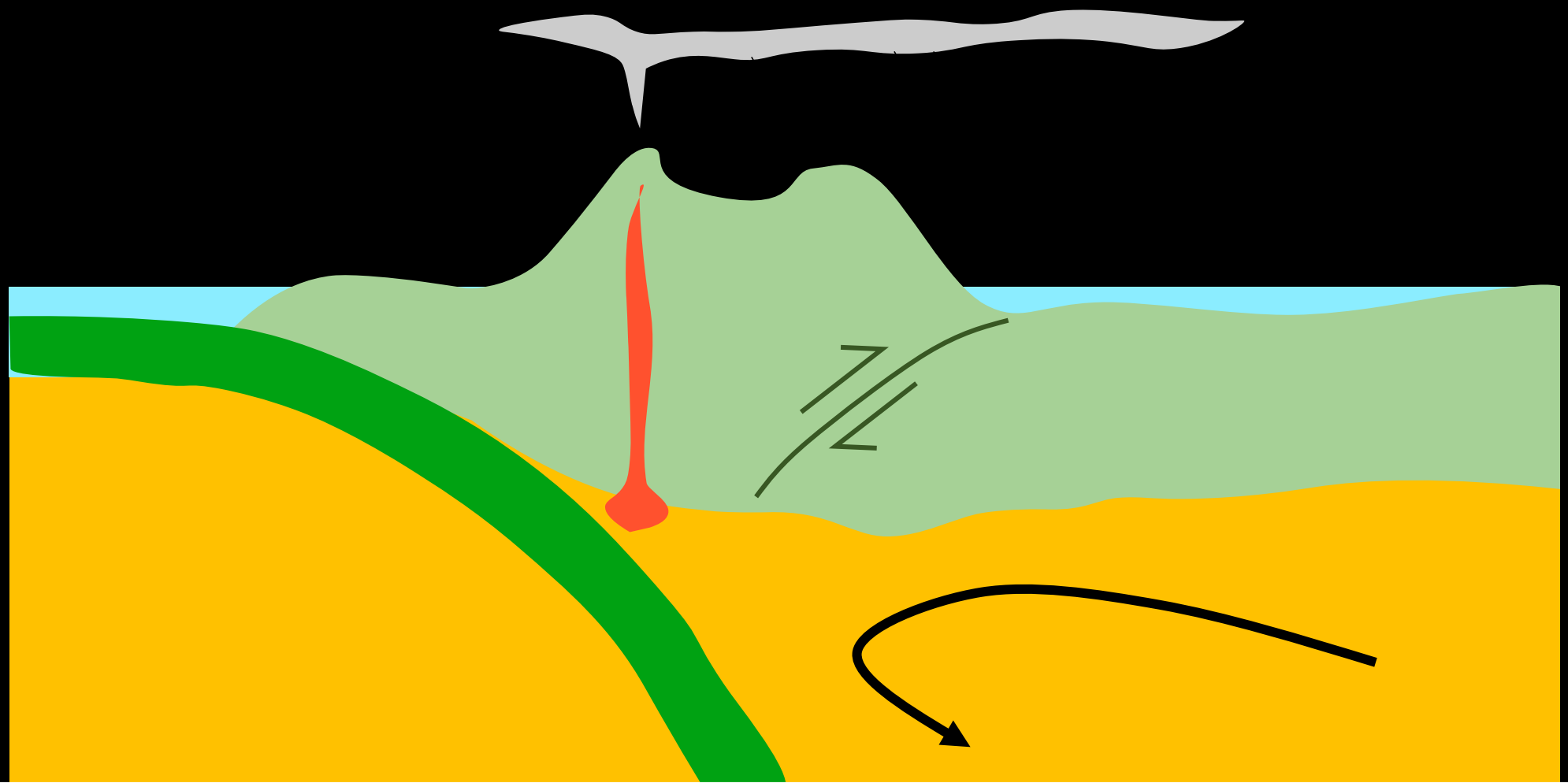
Note highest porosity in samples with elevated Qz content, THEN note that radiolaria made by biogenic Qz coexist with organic-rich mudstone and moderate clay in bottomsets …. →



Kietzmann, et al., 2020

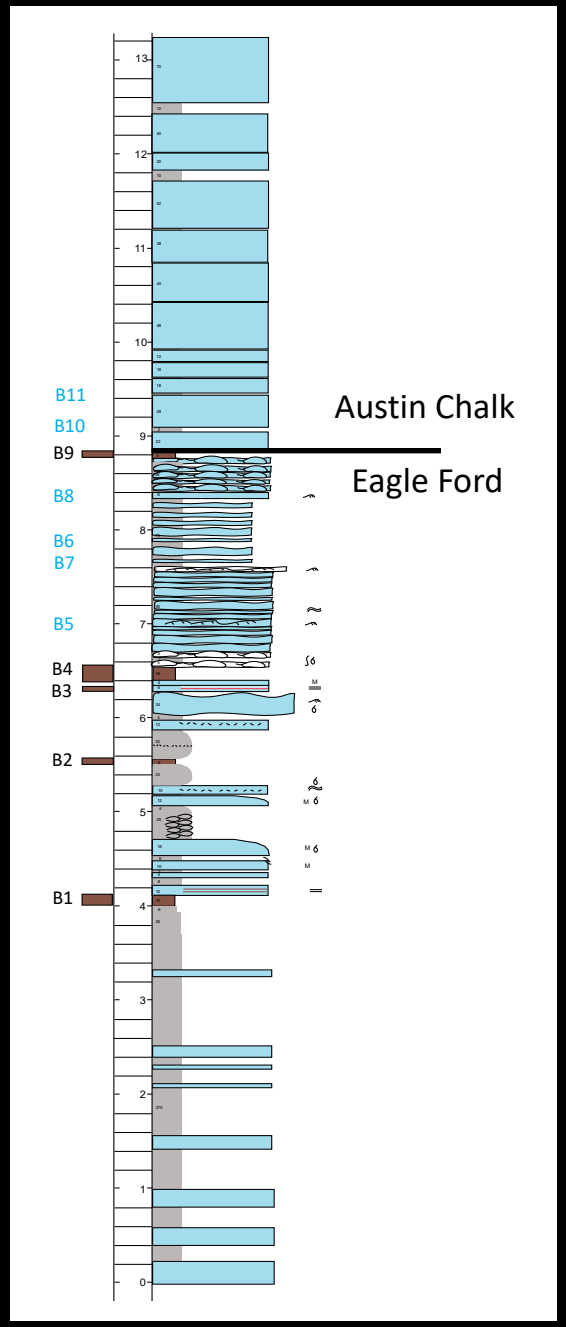
Continental arc features

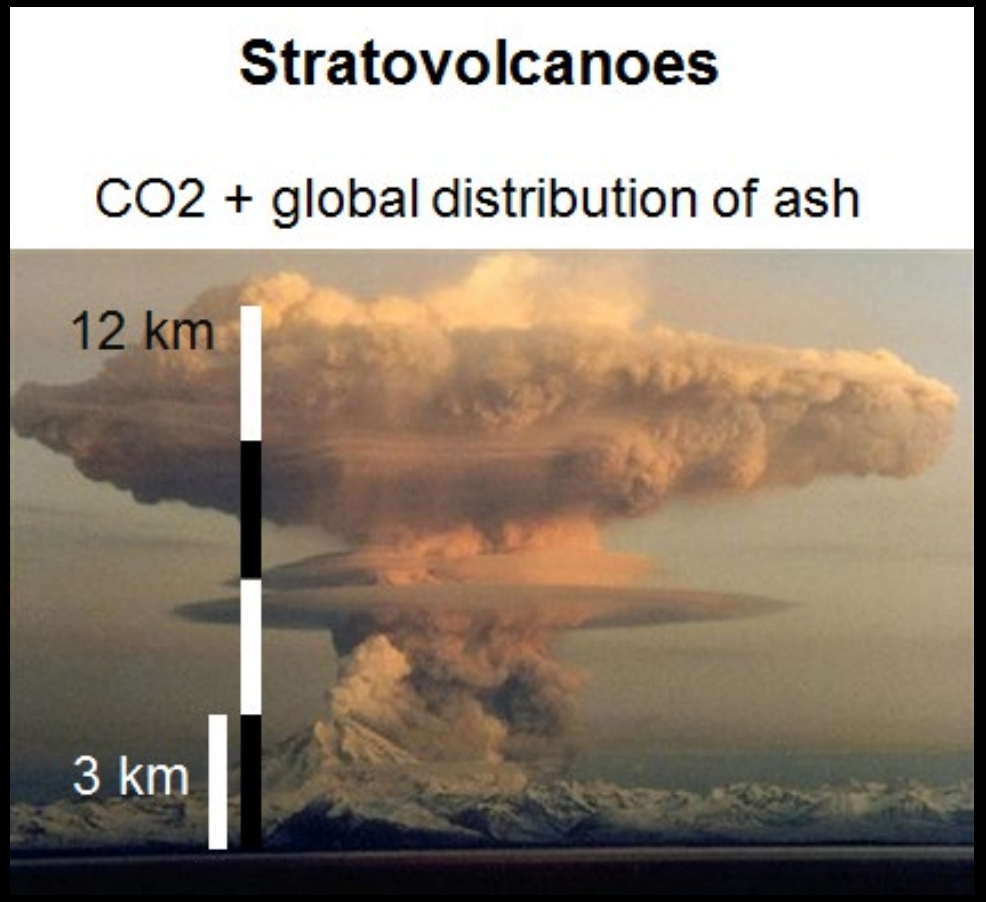
- Magmatic orogen
- Explosive volcanism
- Retro-arc thrust
- Dynamic subsidence in back-arc



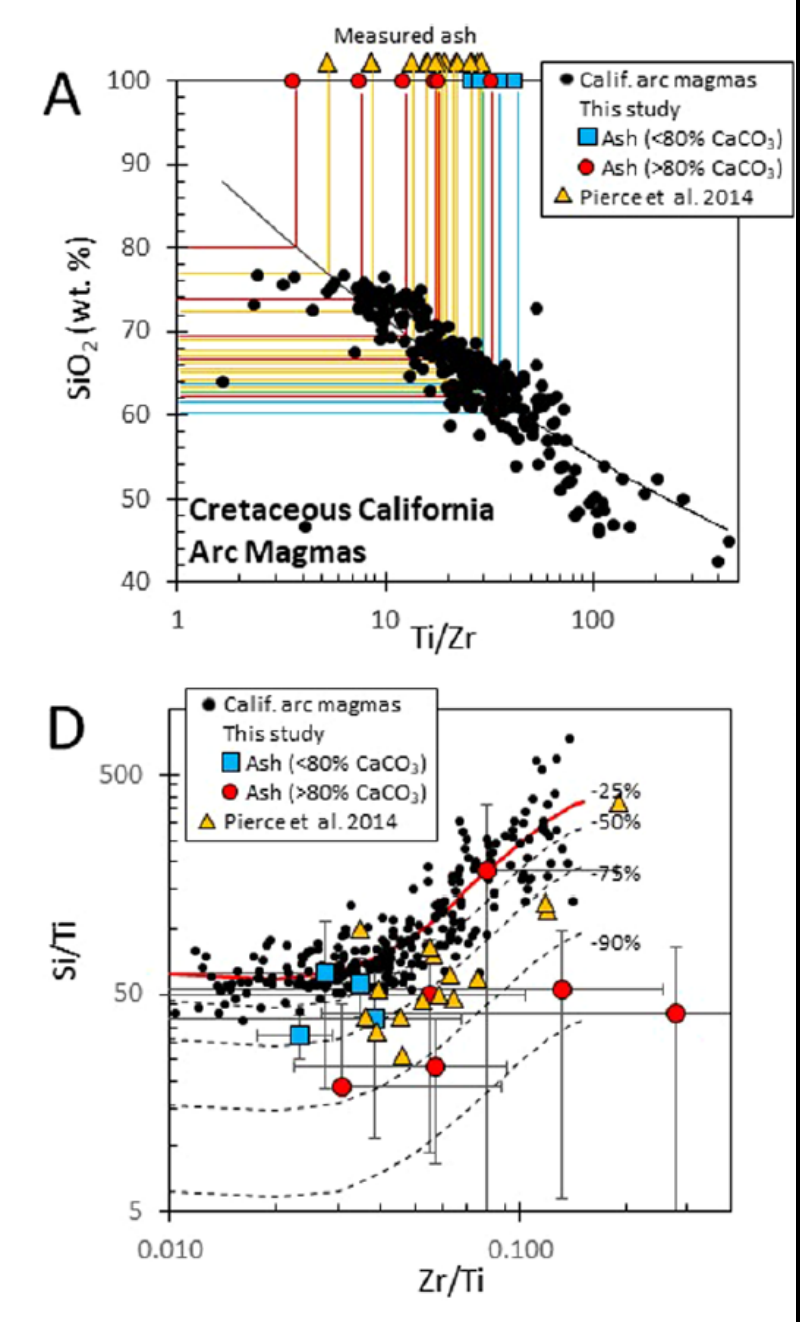
Bentonites

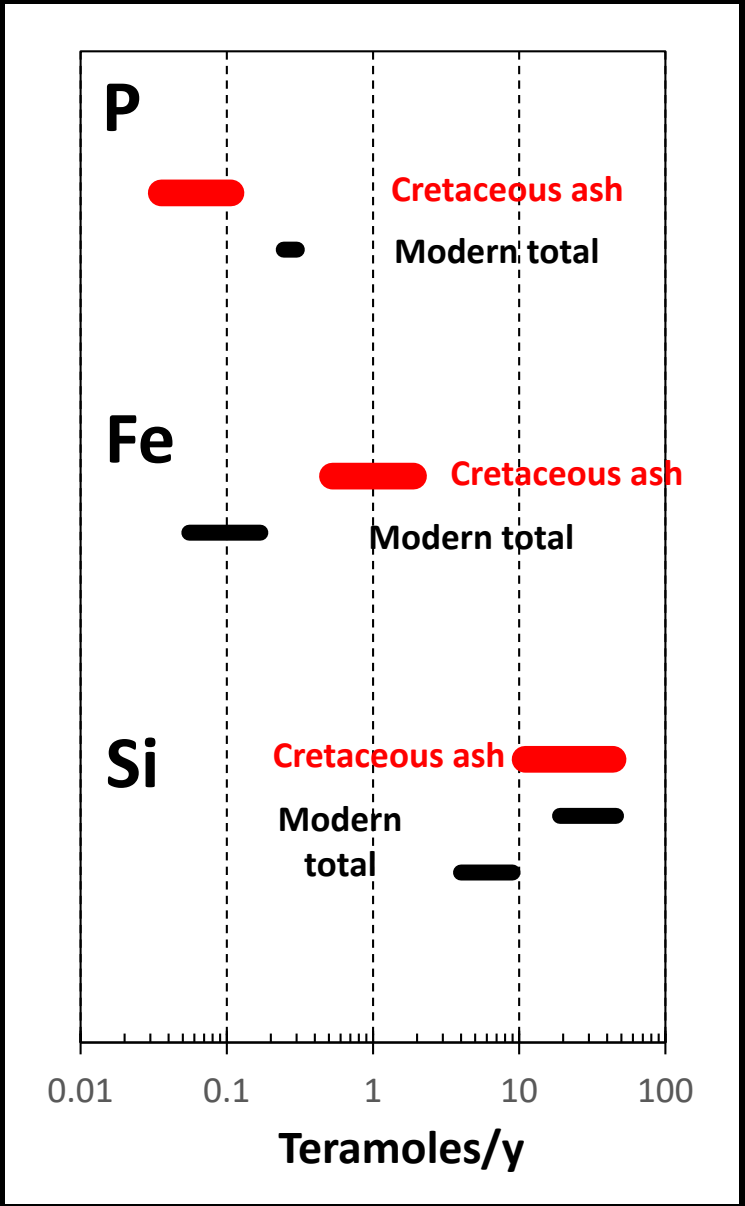

Austin Chalk
Eagleford Shale


B11
B10
B9
B8
B6
B7
B5
B4
B3
B2
B1
Austin Chalk
Eagle Ford


Stratovolcanoes
CO2 + global distribution of ash
12 km
3 km

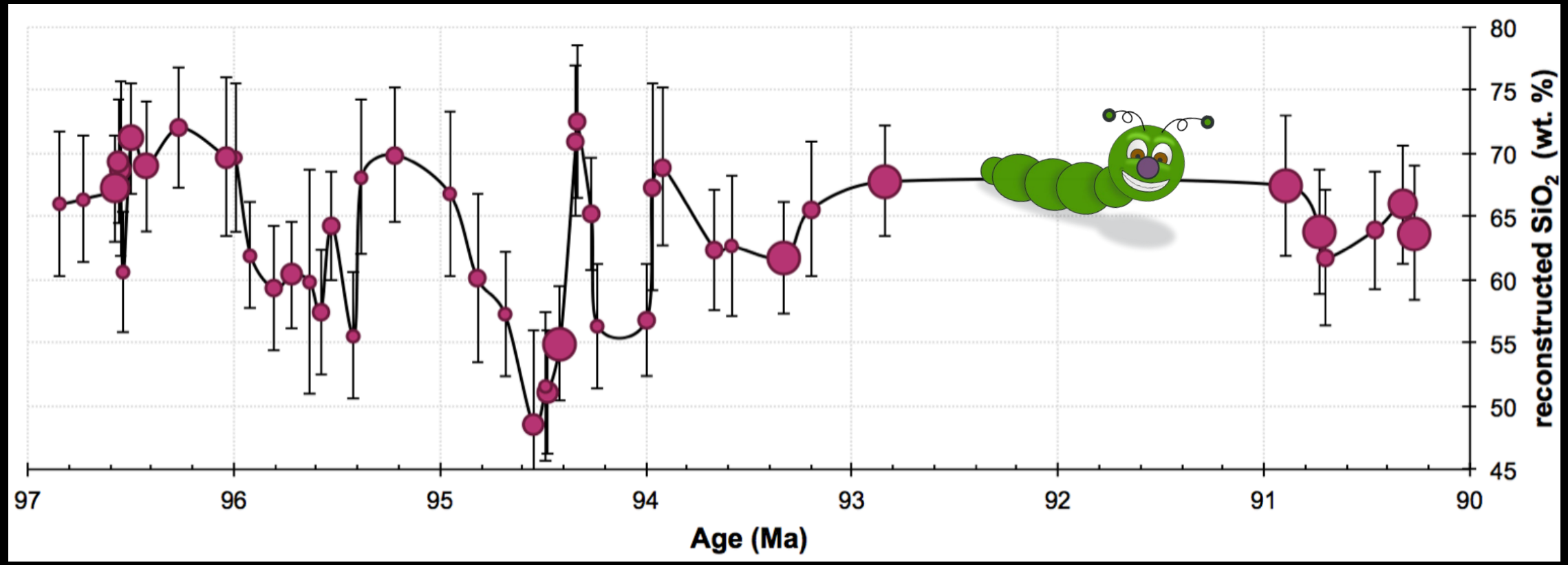
Volcanic ash as nutrient source → org C burial



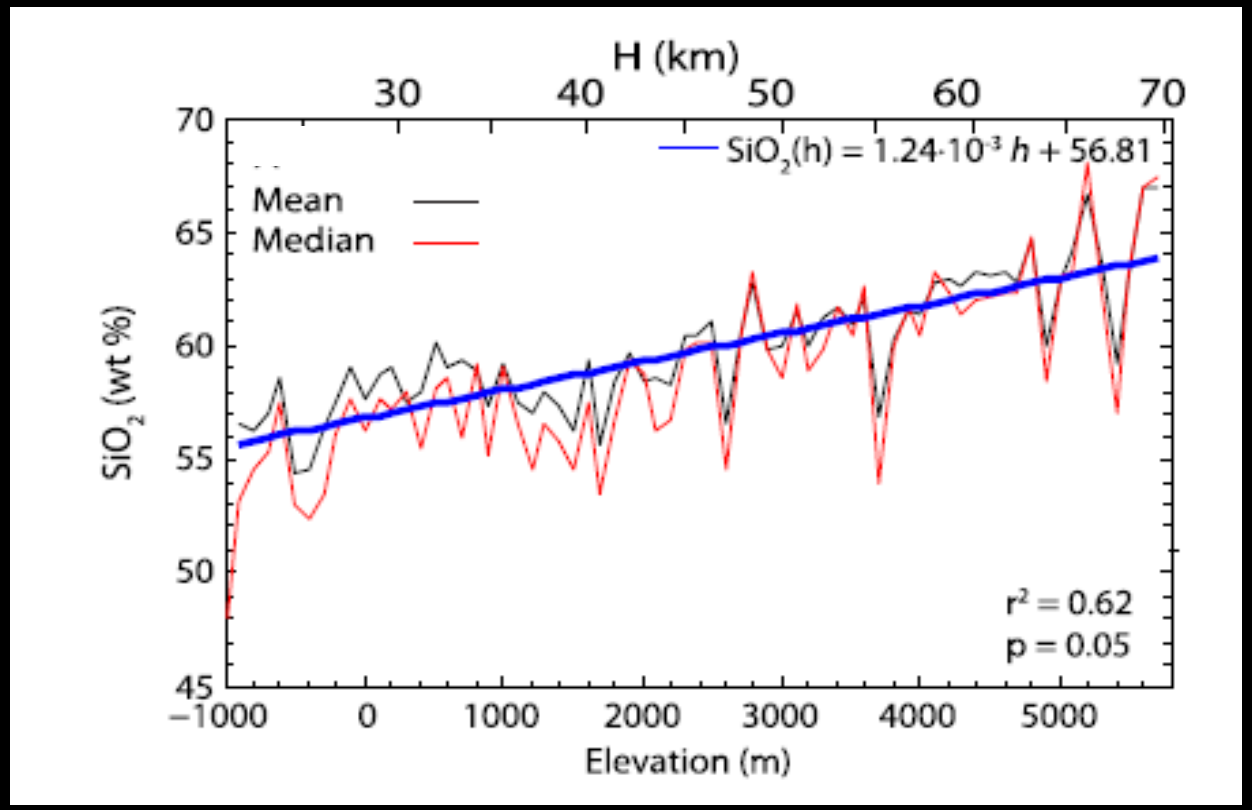


Lee et al., 2018

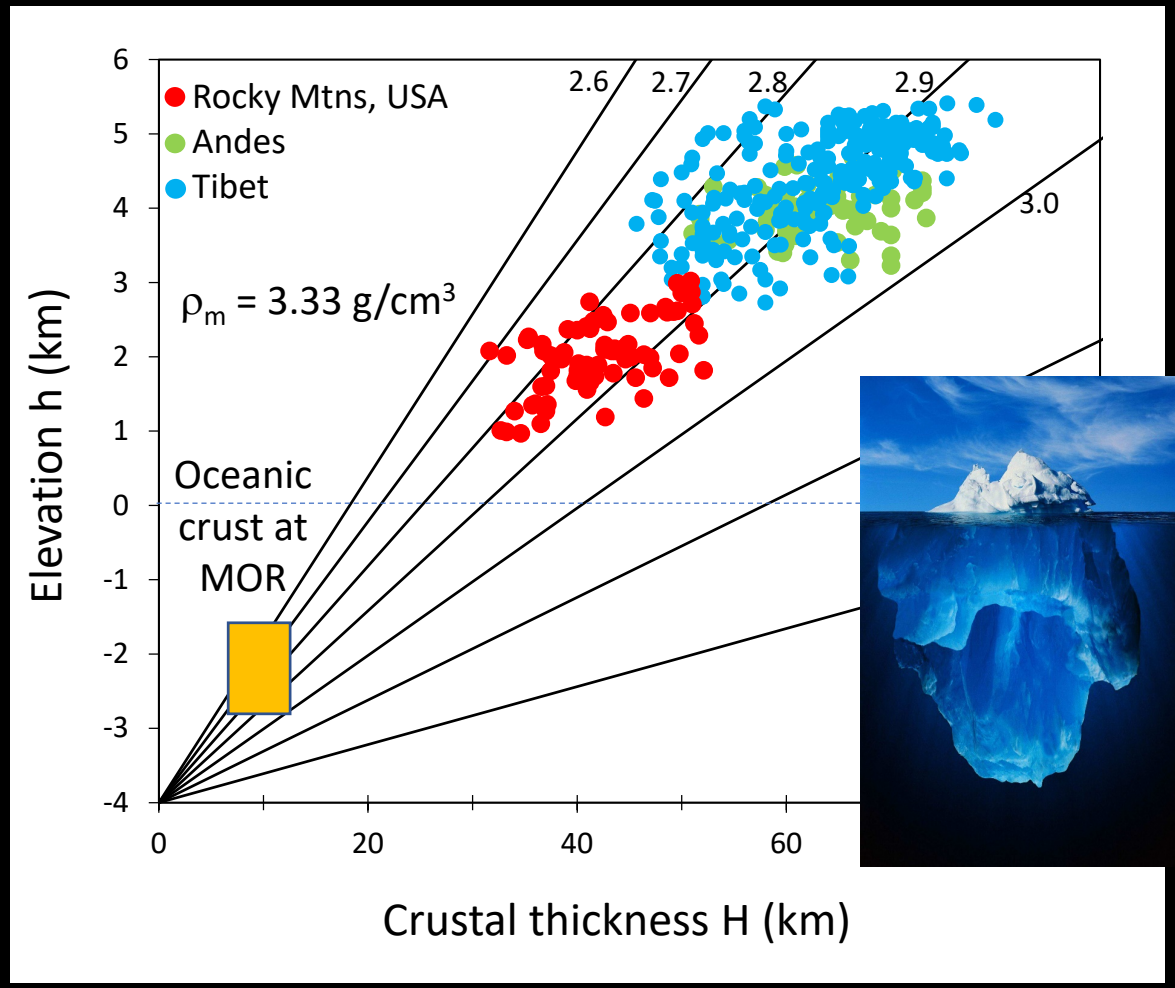
Volcanic arcs are not steady



Sydney Allen



Farner and Lee, 2017 EPSL

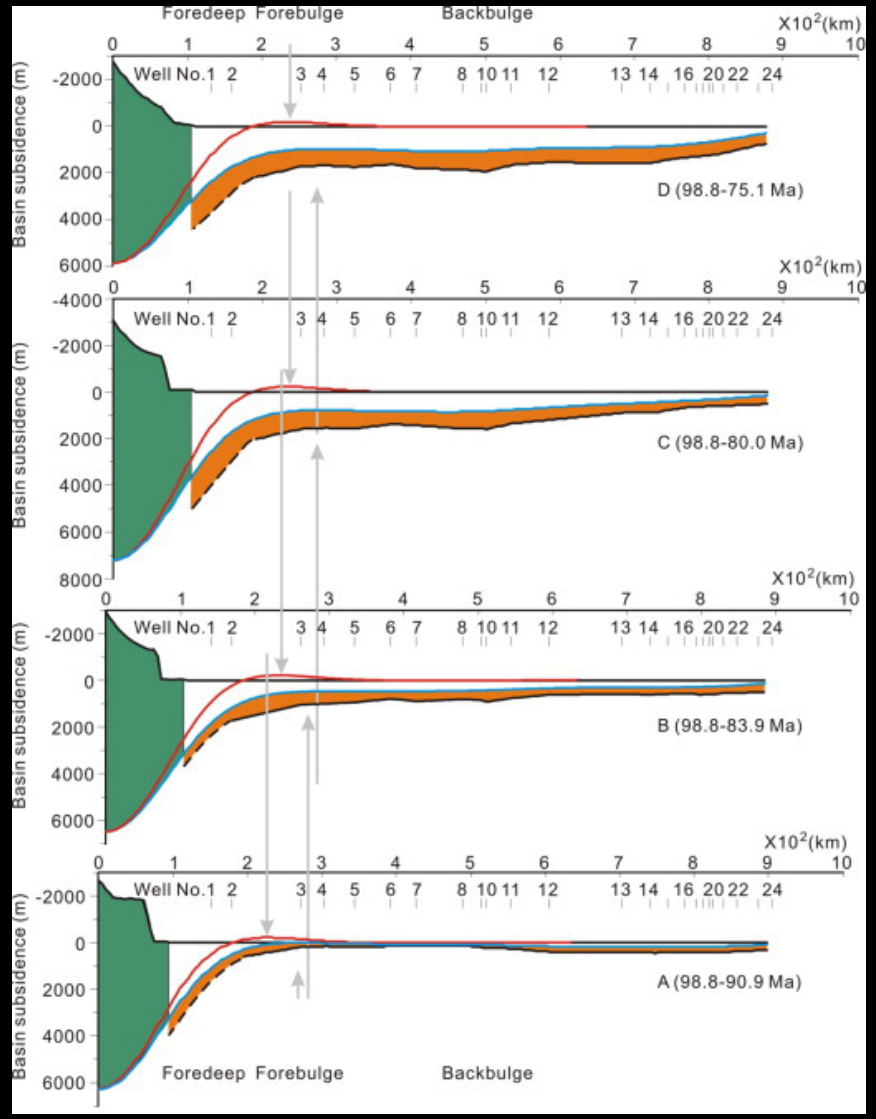


Lee et al., EPSL 2015

Tectonics and magmatism in arc change on 1 My timescales

Rapid external forcings drive 2nd order sequence boundaries?

Tectonic change
-base level, sediment supply

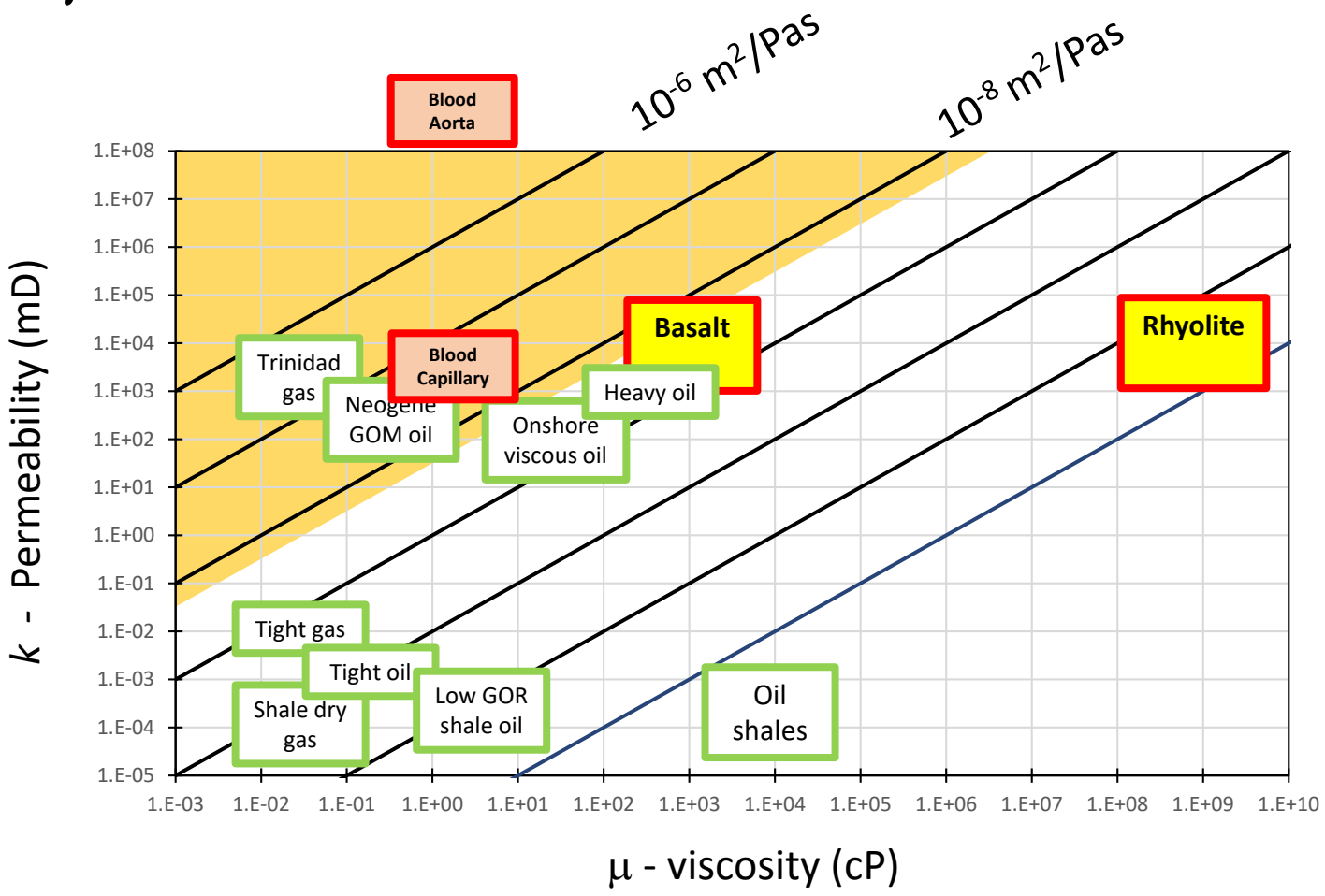


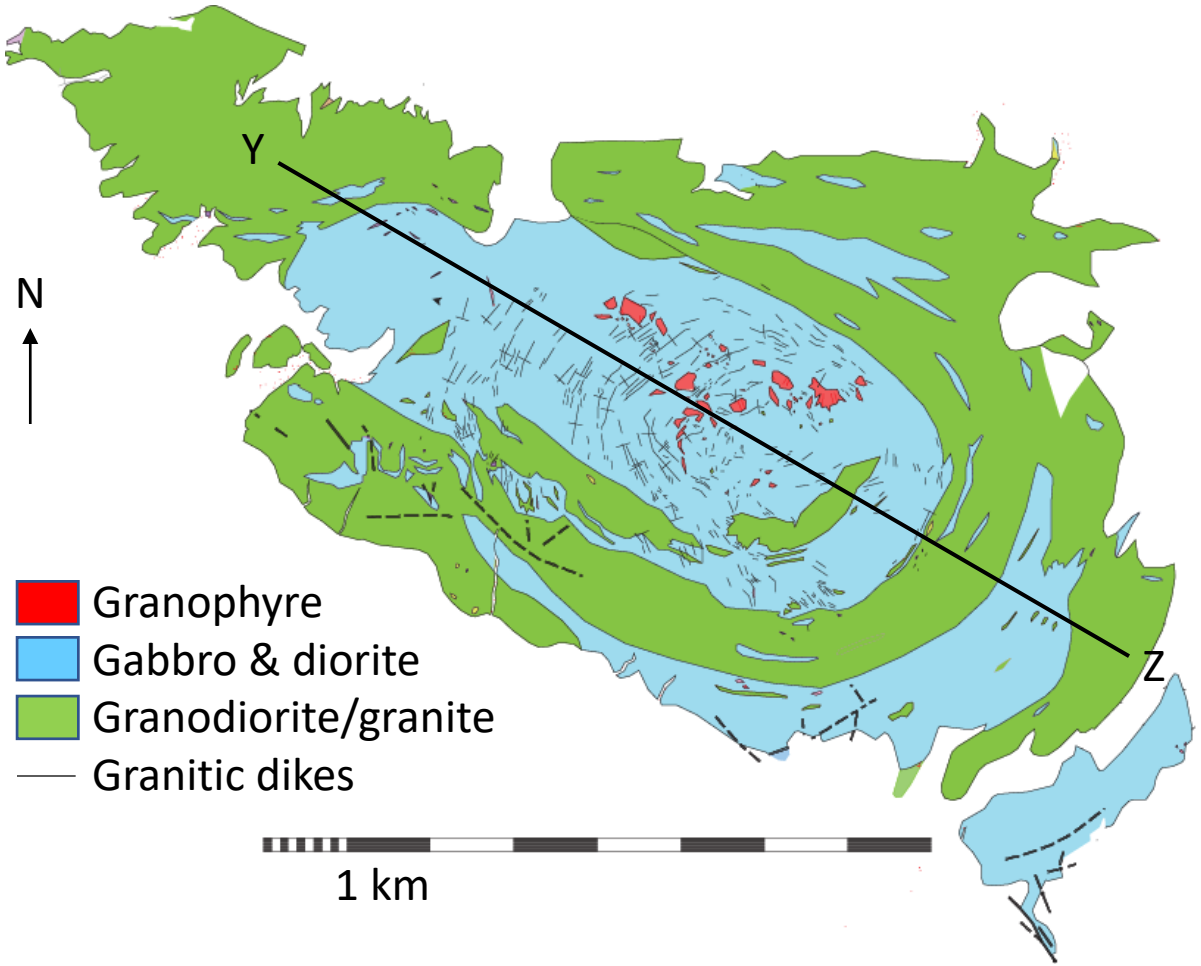
Liu et al., 2014

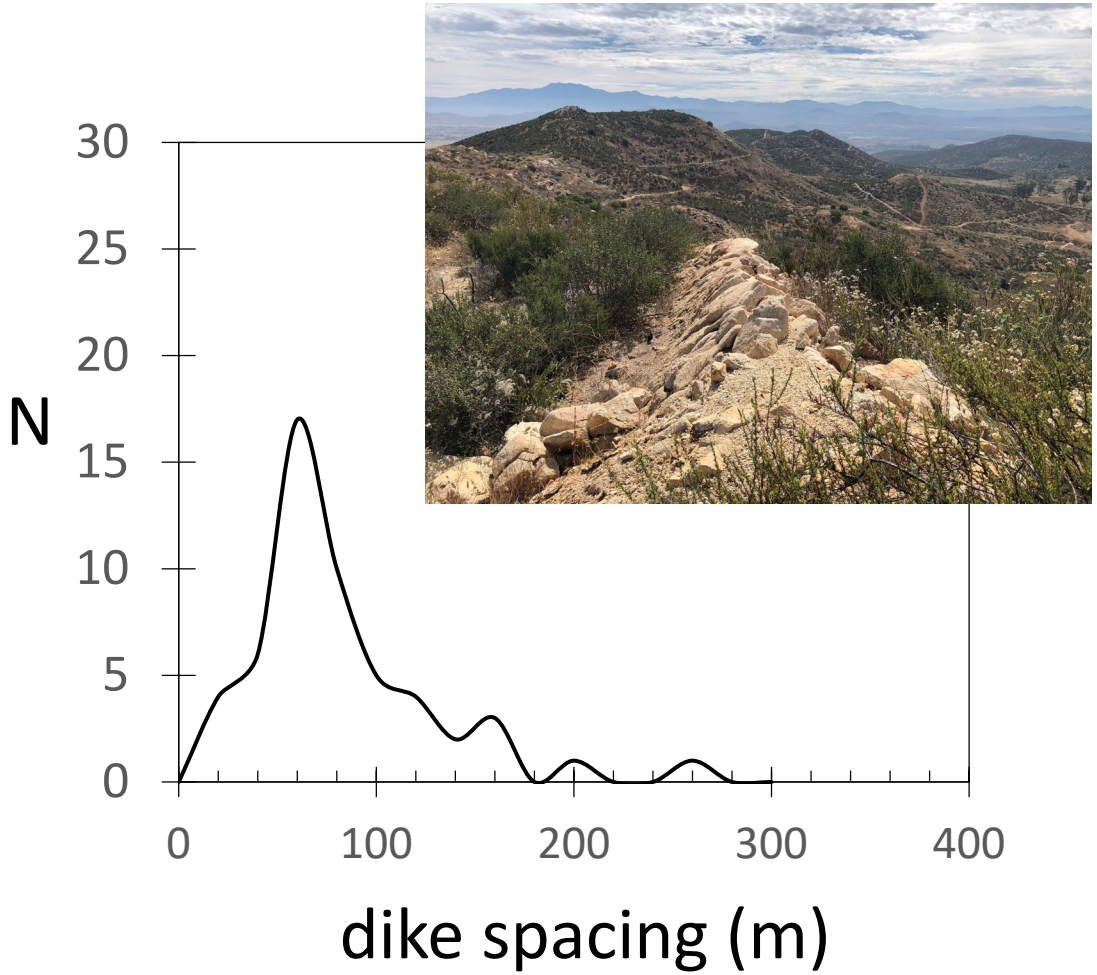
Why are hard rock geologists interested in unconventionals

Volcanoes are unconventional

$$v = \frac{k}{\mu} \nabla P$$




Y
Z
N
Granophyre
Gabbro & diorite
Granodiorite/granite
Granitic dikes
1 km


N
30
25
20
15
10
5
0
0
100
200
300
400
dike spacing (m)


Z
Y

Potential projects/hypotheses to test

1. Sequence boundaries driven by far field magma-tectonic processes, not eustatic sea level change
2. Magma-tectonics can oscillate on 1 My timescales
3. Ash and organic C burial are causally linked
4. Supervolcanoes generated by hydrogranular fracking