Will Volcanoes Erupt in New England?

Mantle upwelling at the edge of the North American Continent

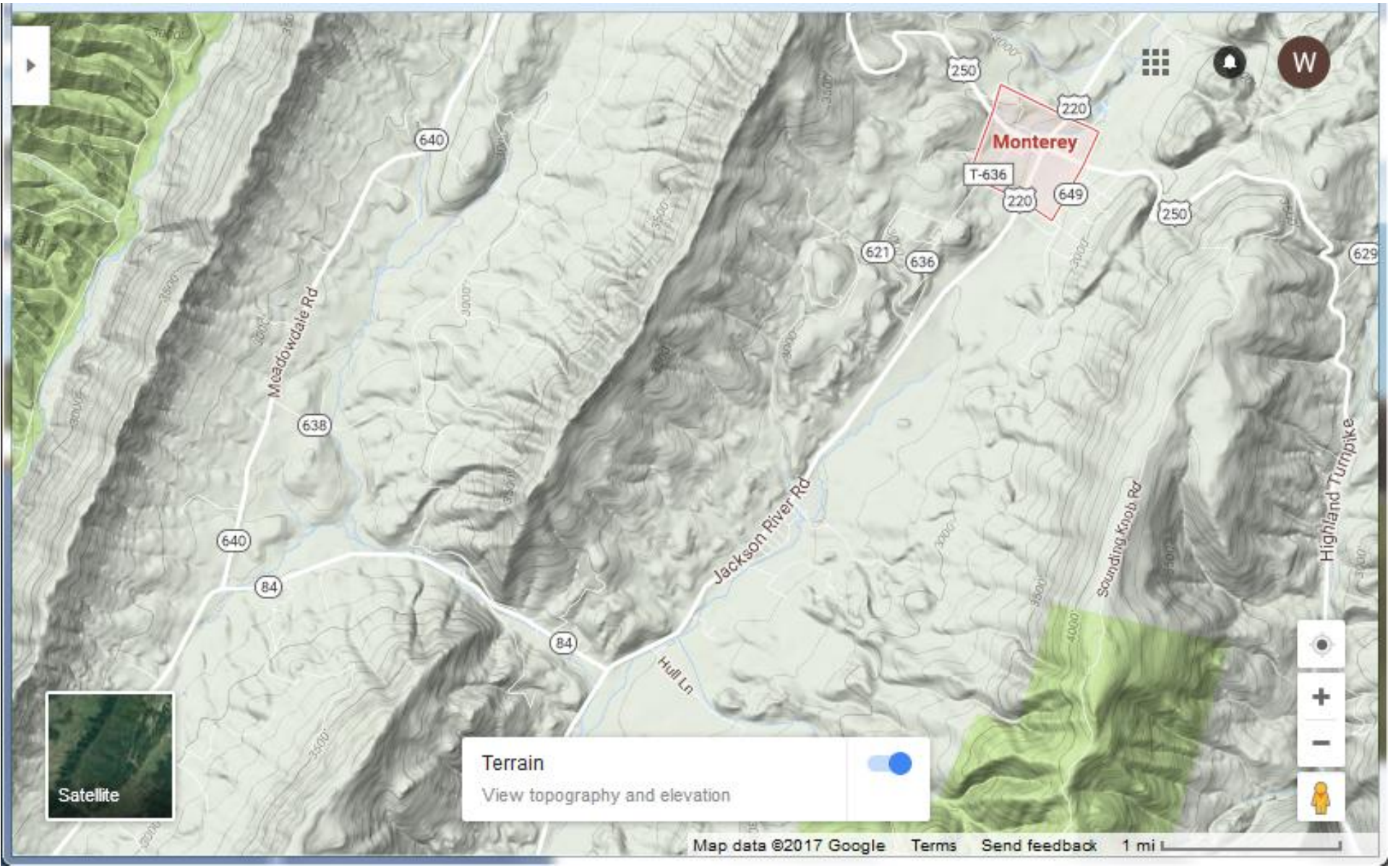
Lecture to the 2017 Summer Interns
by Bill Menke

I was a LDEO Summer Intern in 1975

My interest in volcanism started the year before, when I accompanied MIT Professor Tom MyGetchin to Pacaya Volcano (Guatemala)

Part 1

The youngest volcanoes on the East Coast of North America



Monteray Virgnia area

area of folded sedimenary rock


Monterey
T-636
Trimble Knob
Meadowdale Rd
Jackson River Rd
Sounding Knob Rd
Highland Turnpike
Hull Ln
250
220
649
621
636
629
640
638
84
Satellite
Terrain
View topography and elevation
Map data ©2017 Google
Terms
Send feedback
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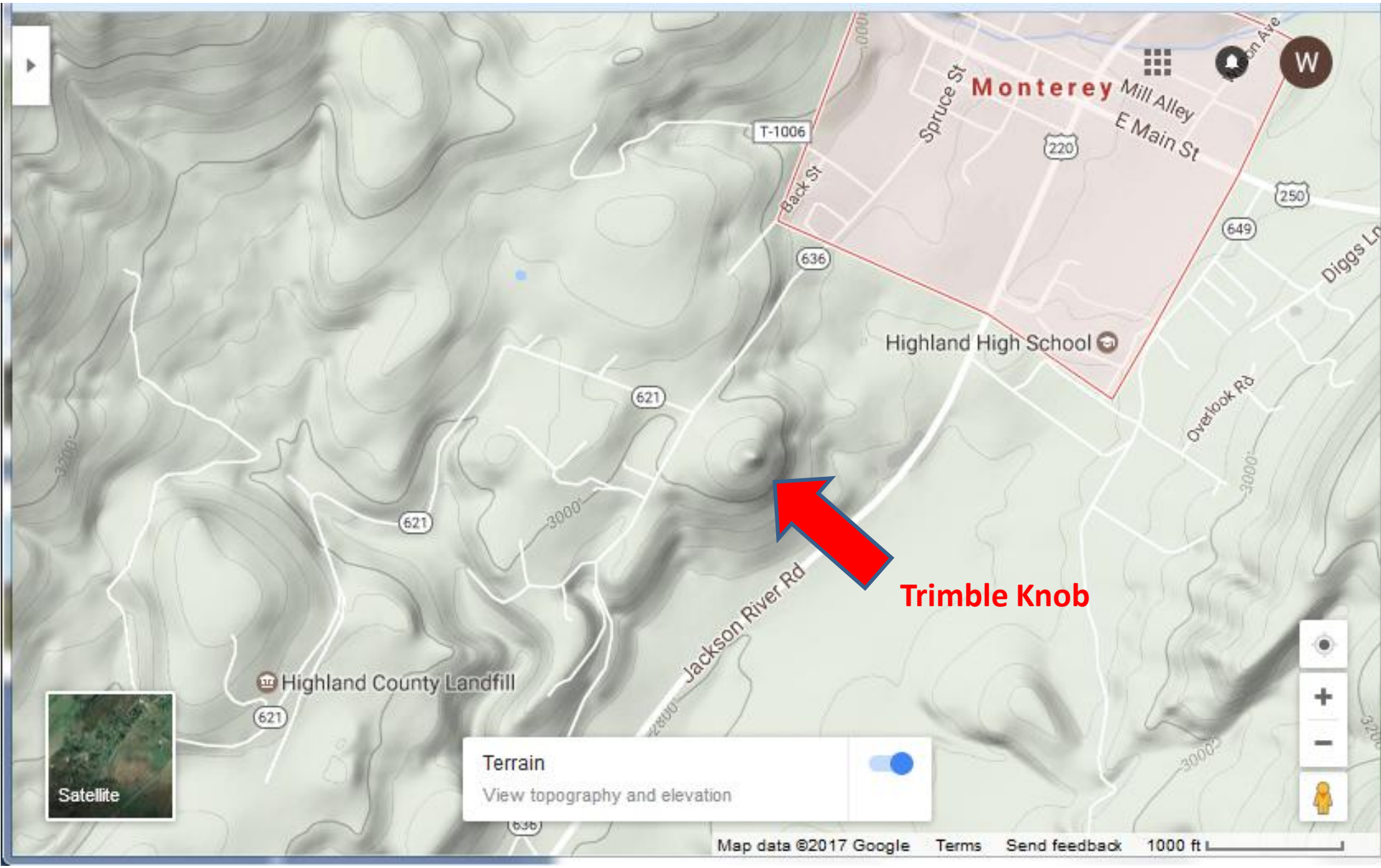
Monterey
Spruce St
Mill Alley
E Main St
T-1006
Back St
220
250
649
636
Diggs Ln
Highland High School
621
Overlook Rd
3000'
Trimble Knob
Jackson River Rd
Highland County Landfill
Satellite
Terrain
View topography and elevation
Map data ©2017 Google
Terms
Send feedback
1000 ft


Monterey
E Main St
W
Highland High School
Trimble Knob
Jackson River Rd
Highland County Landfill
Google
Imagery ©2017 Commonwealth of Virginia, DigitalGlobe, USDA Farm Service Agency, Map data ©2017 Google
1000 ft
3D Earth view is not available
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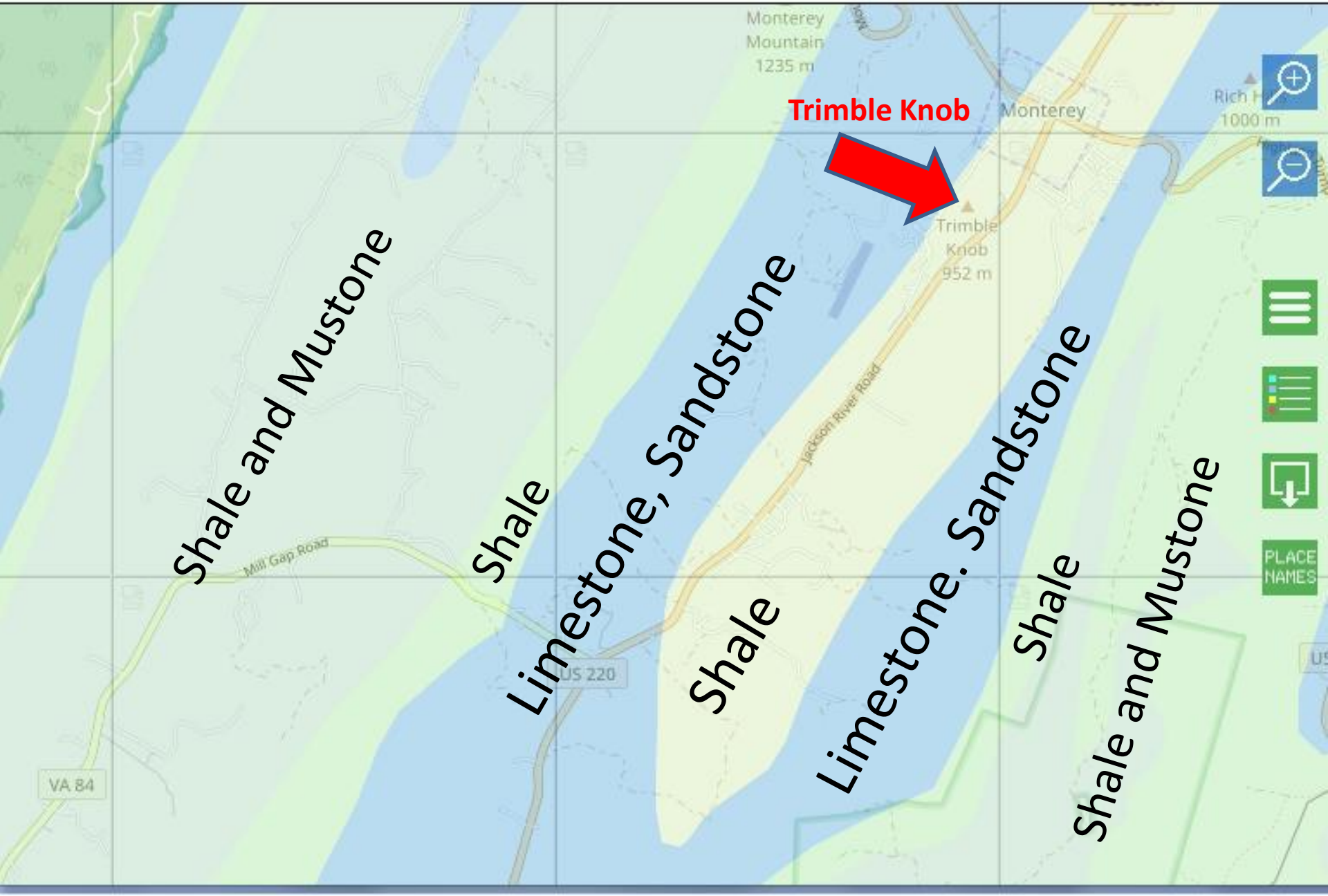
Trimble Knob



area of folded sedimenary rock

48 Ma Basalts

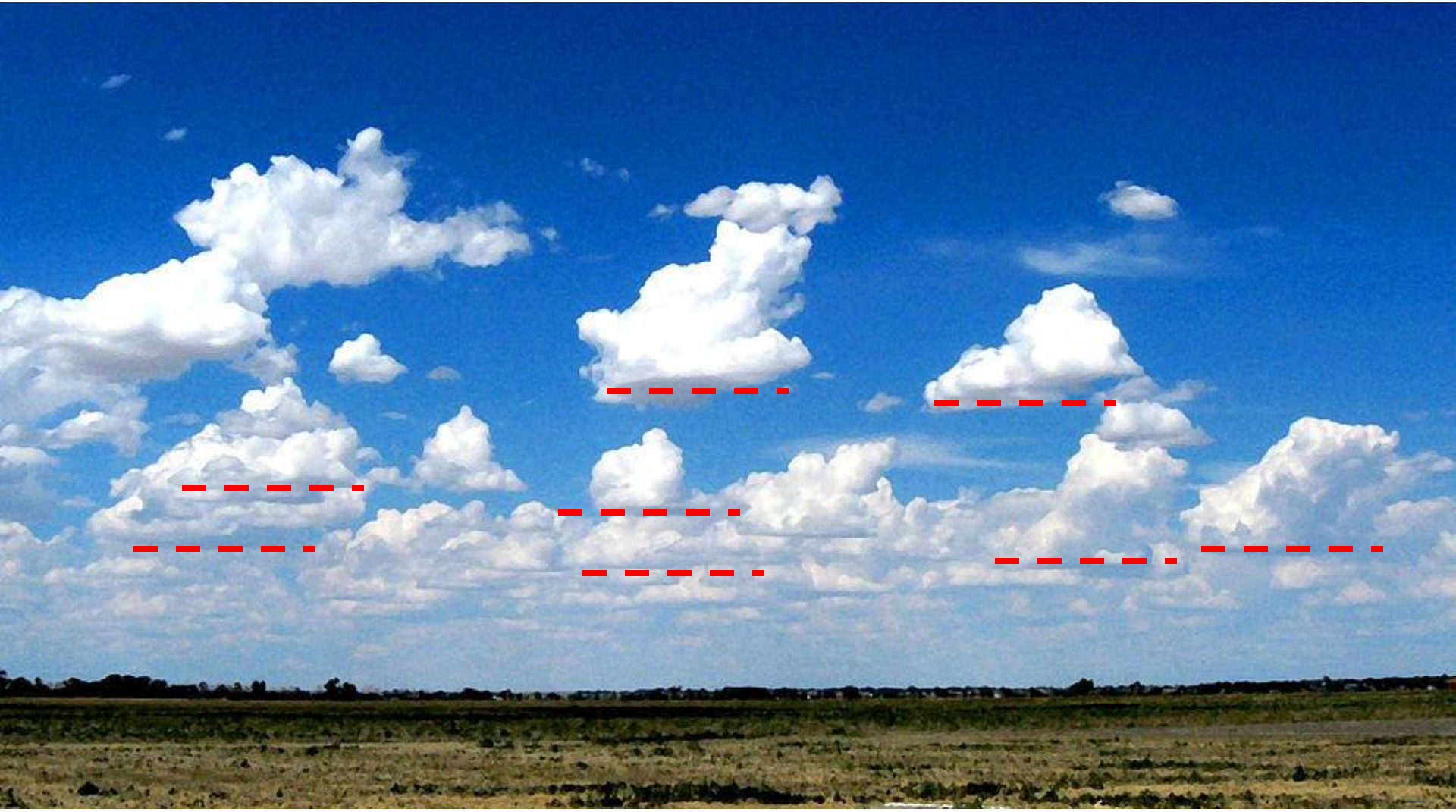
Sunset Crater (Arizona)
erupted ca 1085 CE

Part 2

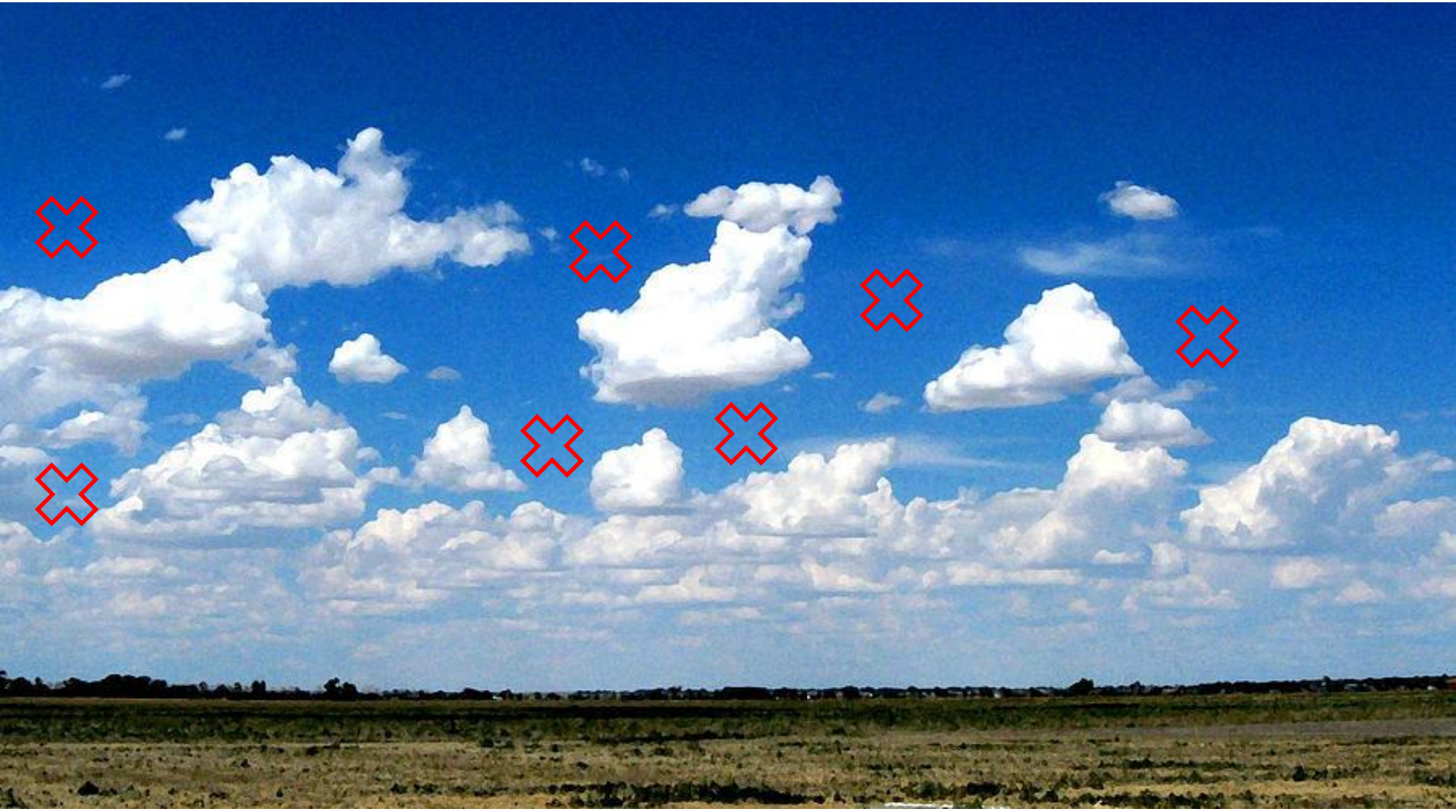
What volcanism can tell us about the earth

digression

clouds

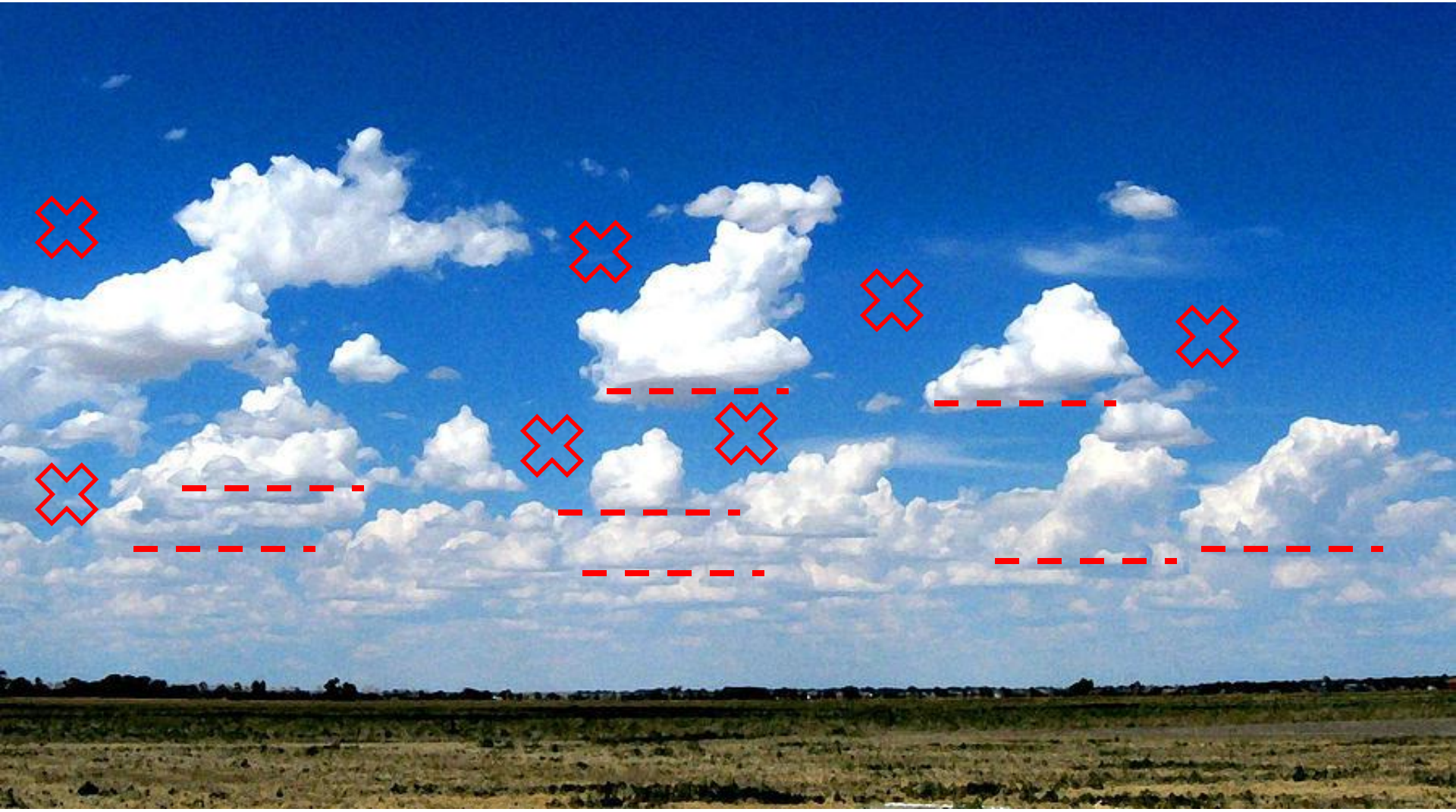


flat bottoms, all at about the same altitude



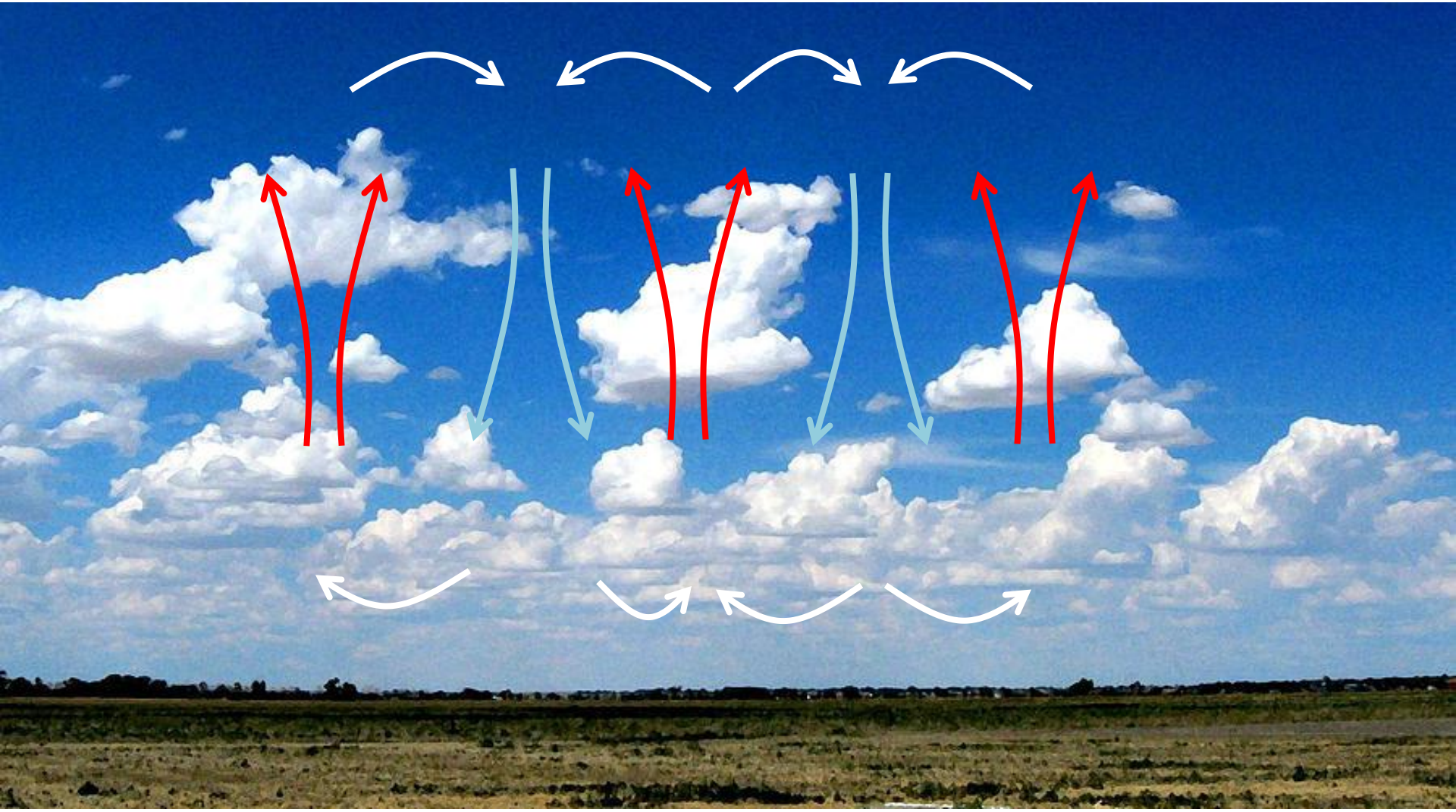
spaces between the clouds

clouds are really not the ‘complete thing’

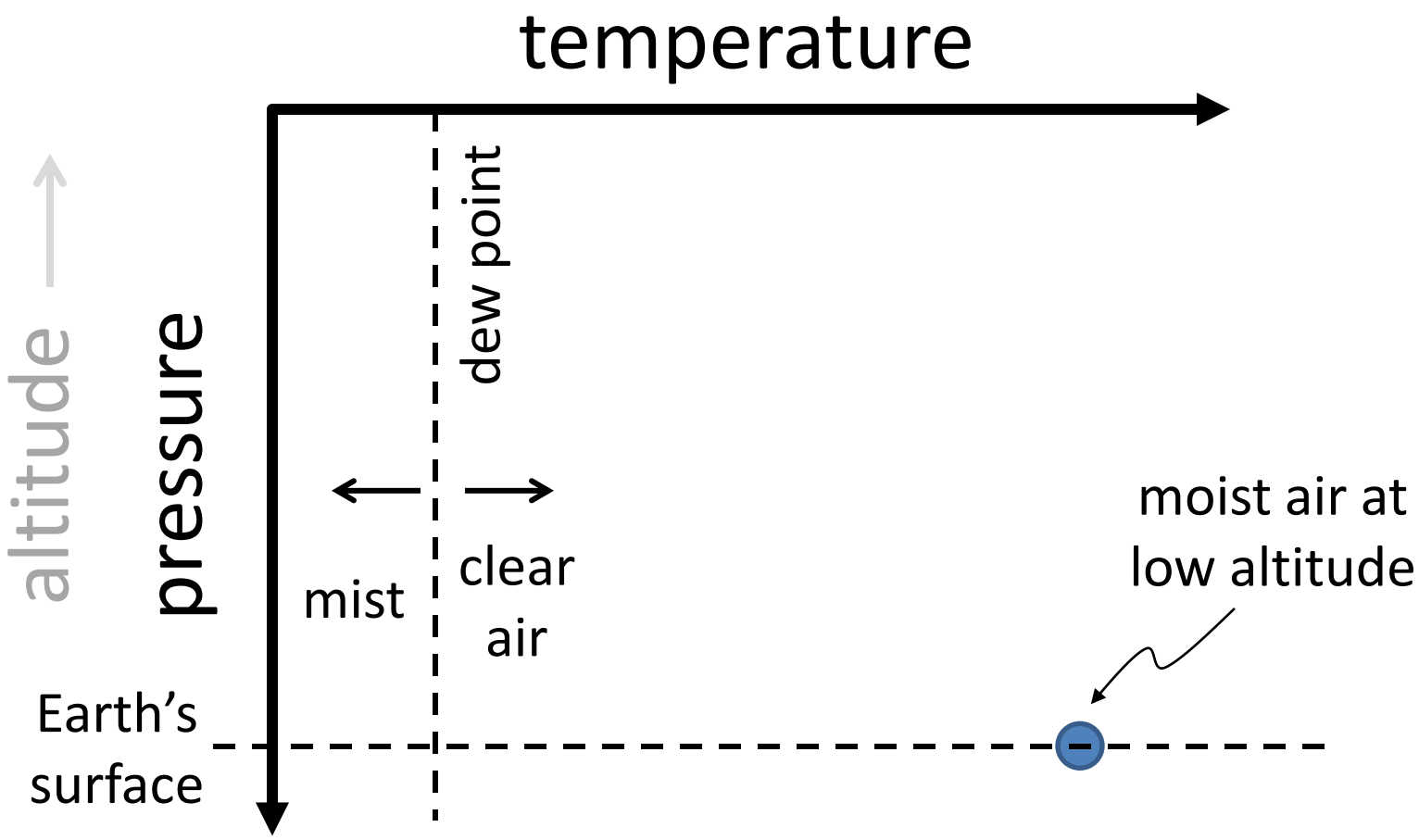


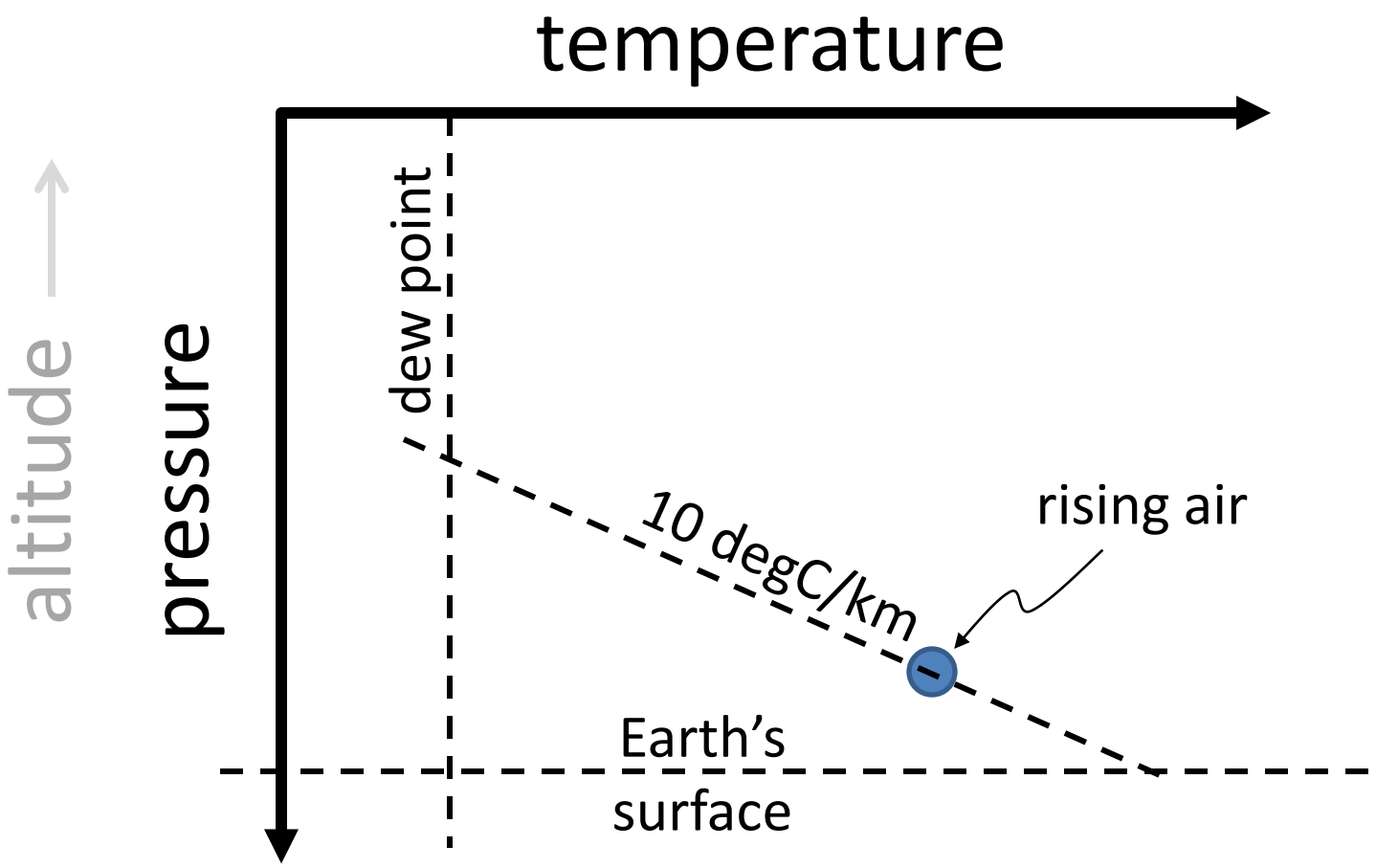
they are the part that you can see

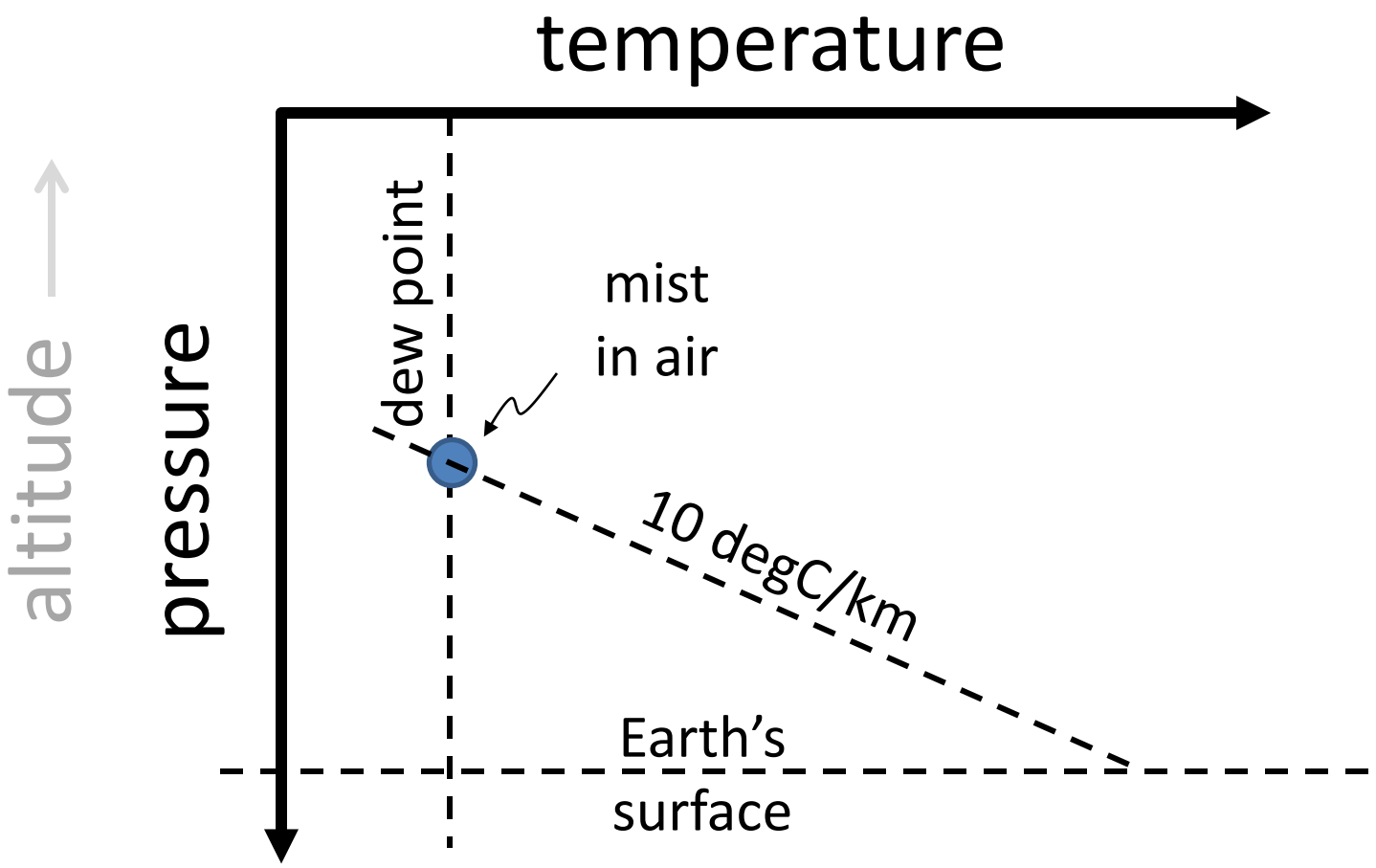
the ‘complete thing’ is a series of

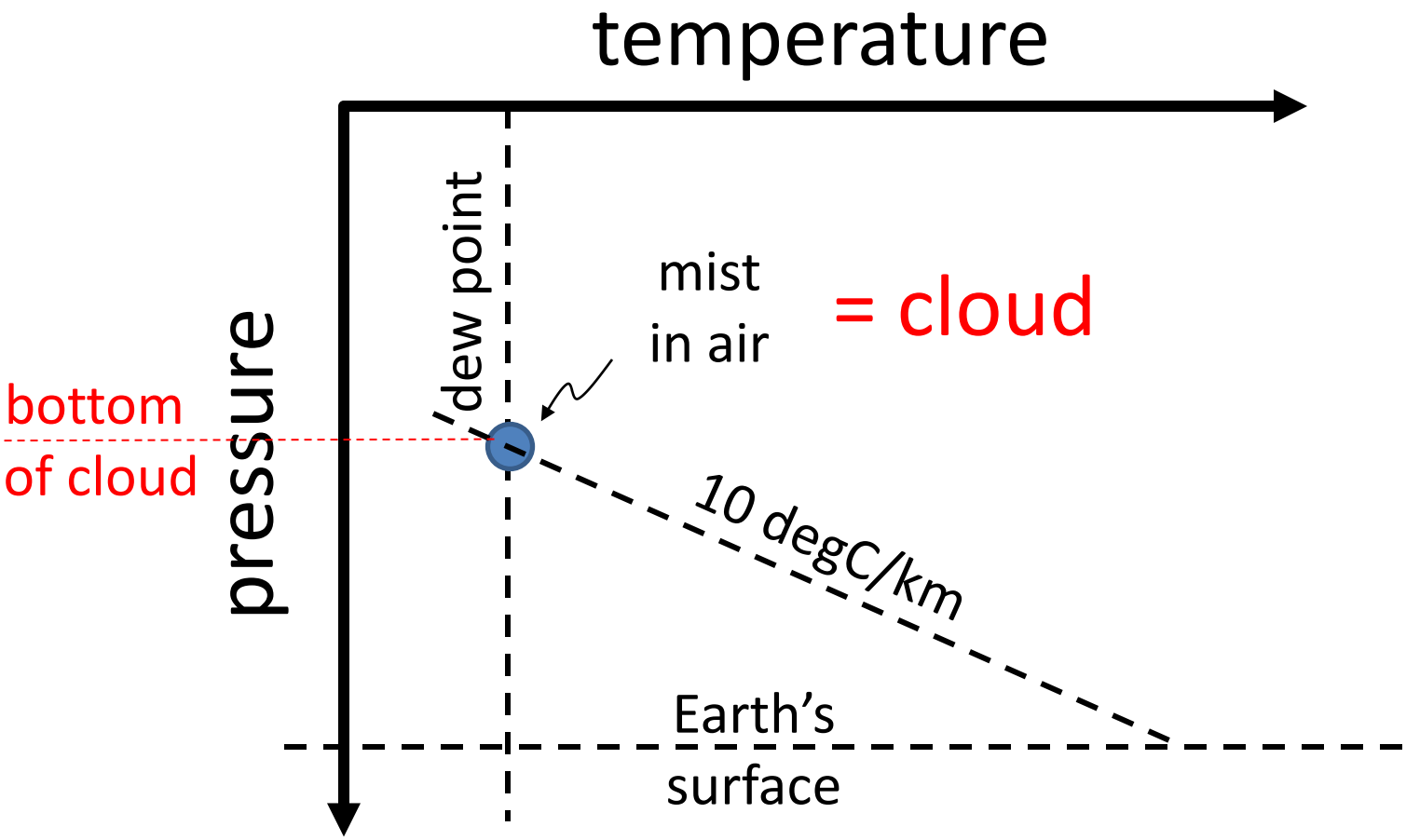


convection cells


temperature
altitude
pressure
dew point
mist
clear
air
moist air at
low altitude
Earth's
surface


temperature
altitude
pressure
dew point
10 degC/km
rising air
Earth's
surface

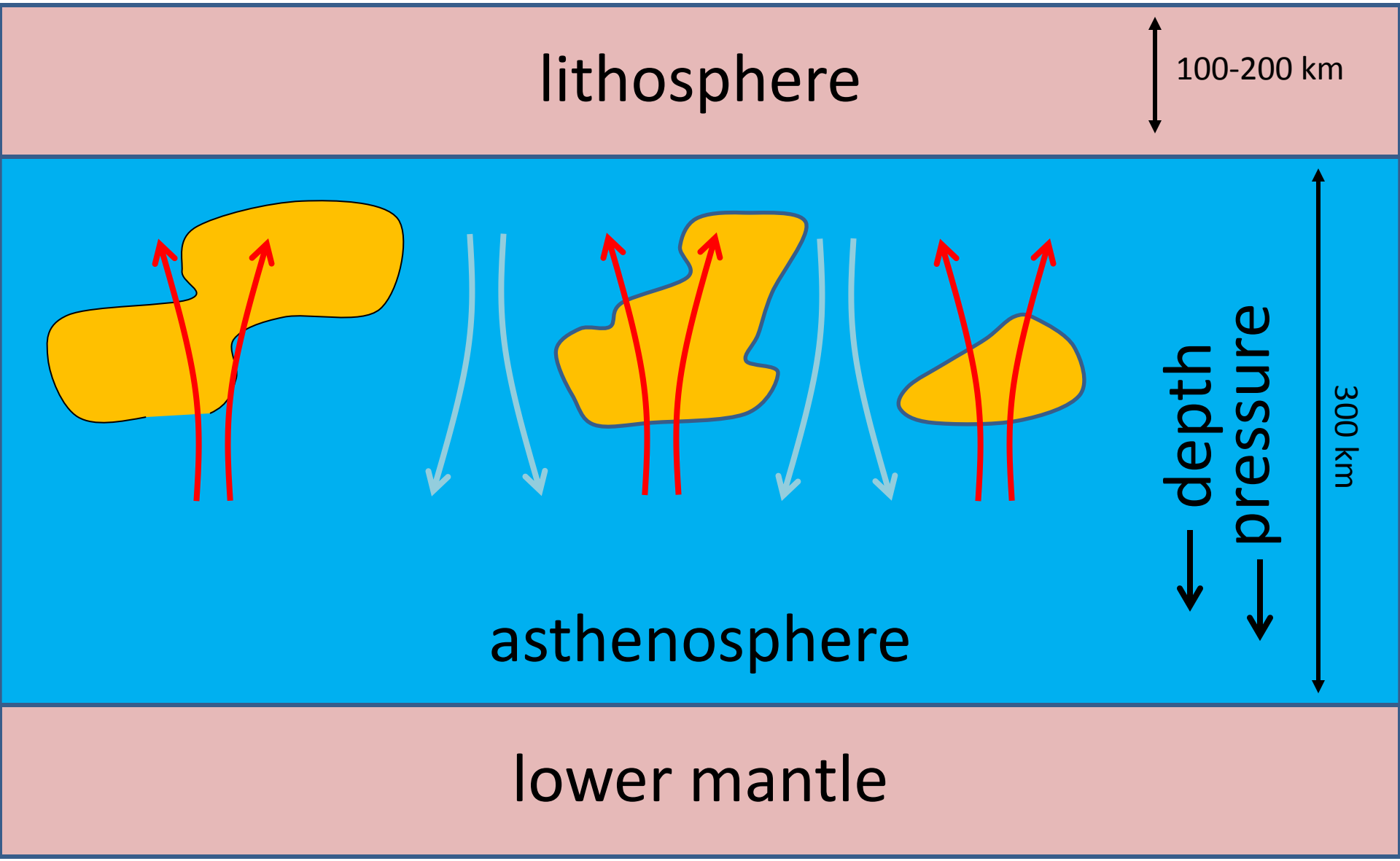

temperature
altitude
pressure
dew point
mist
in air
10 degC/km
Earth's
surface

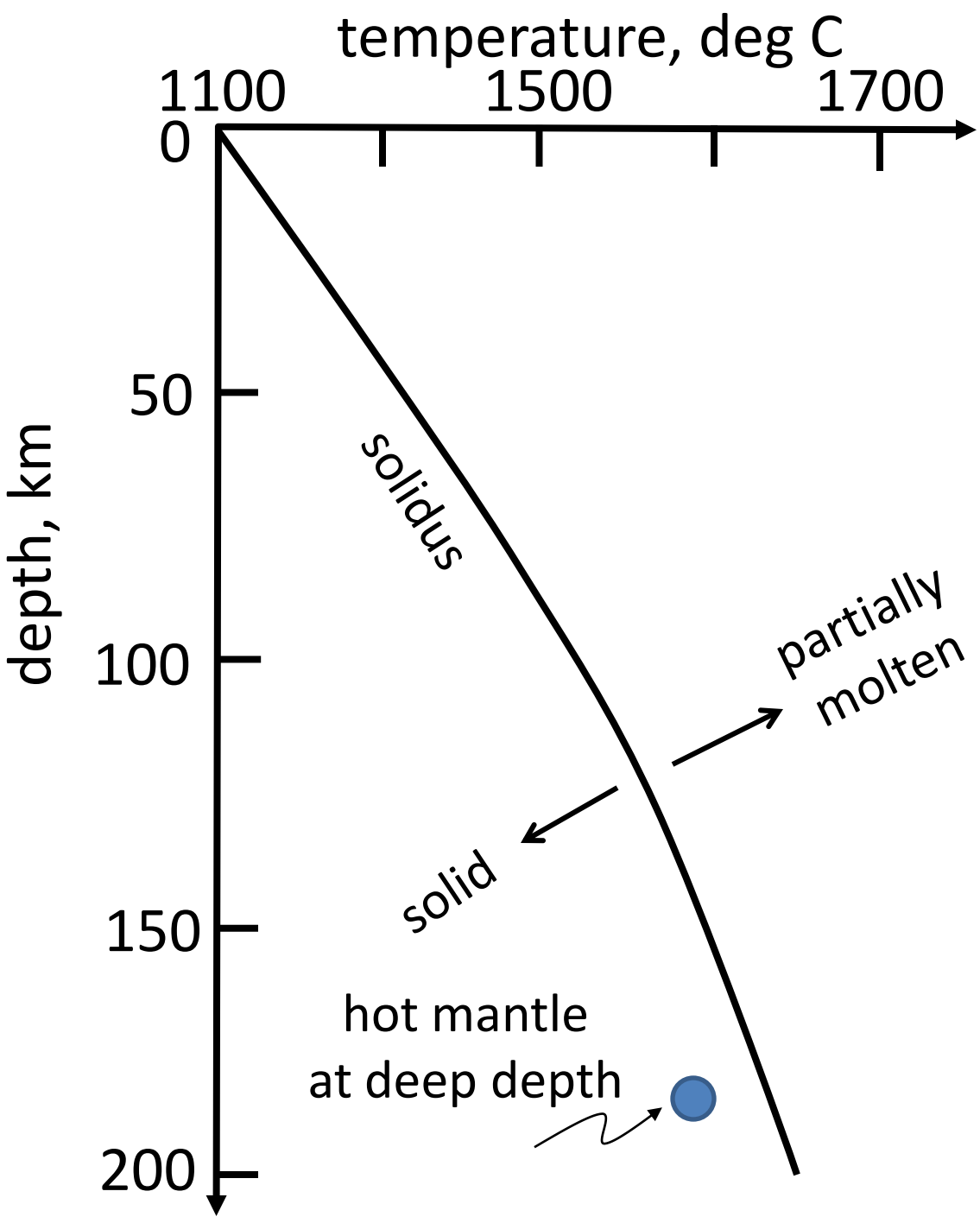

temperature
pressure
dew point
mist
in air
= cloud
bottom
of cloud
10 degC/km
Earth's
surface

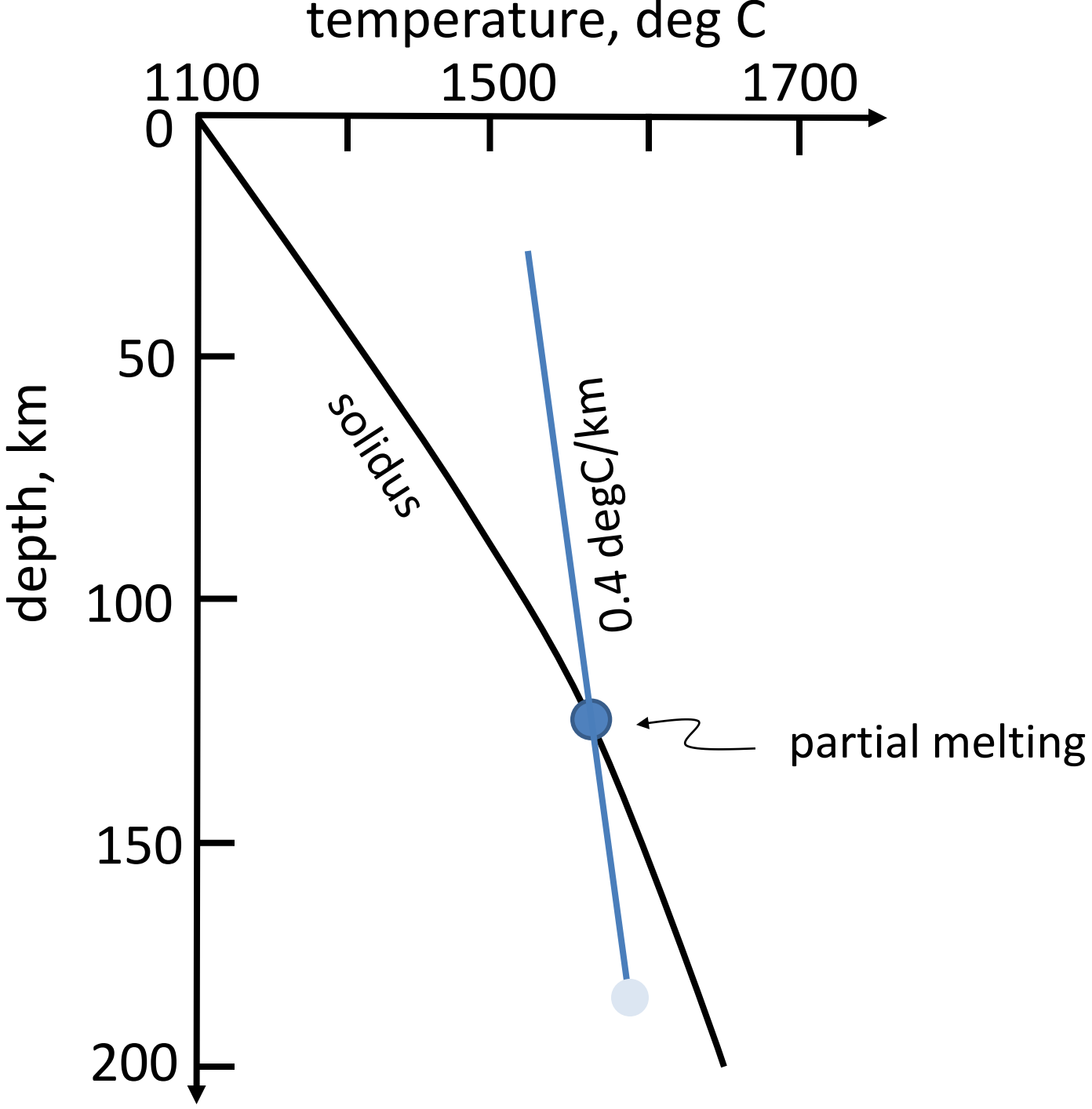
Rain: water droplets more dense than air so they fall down

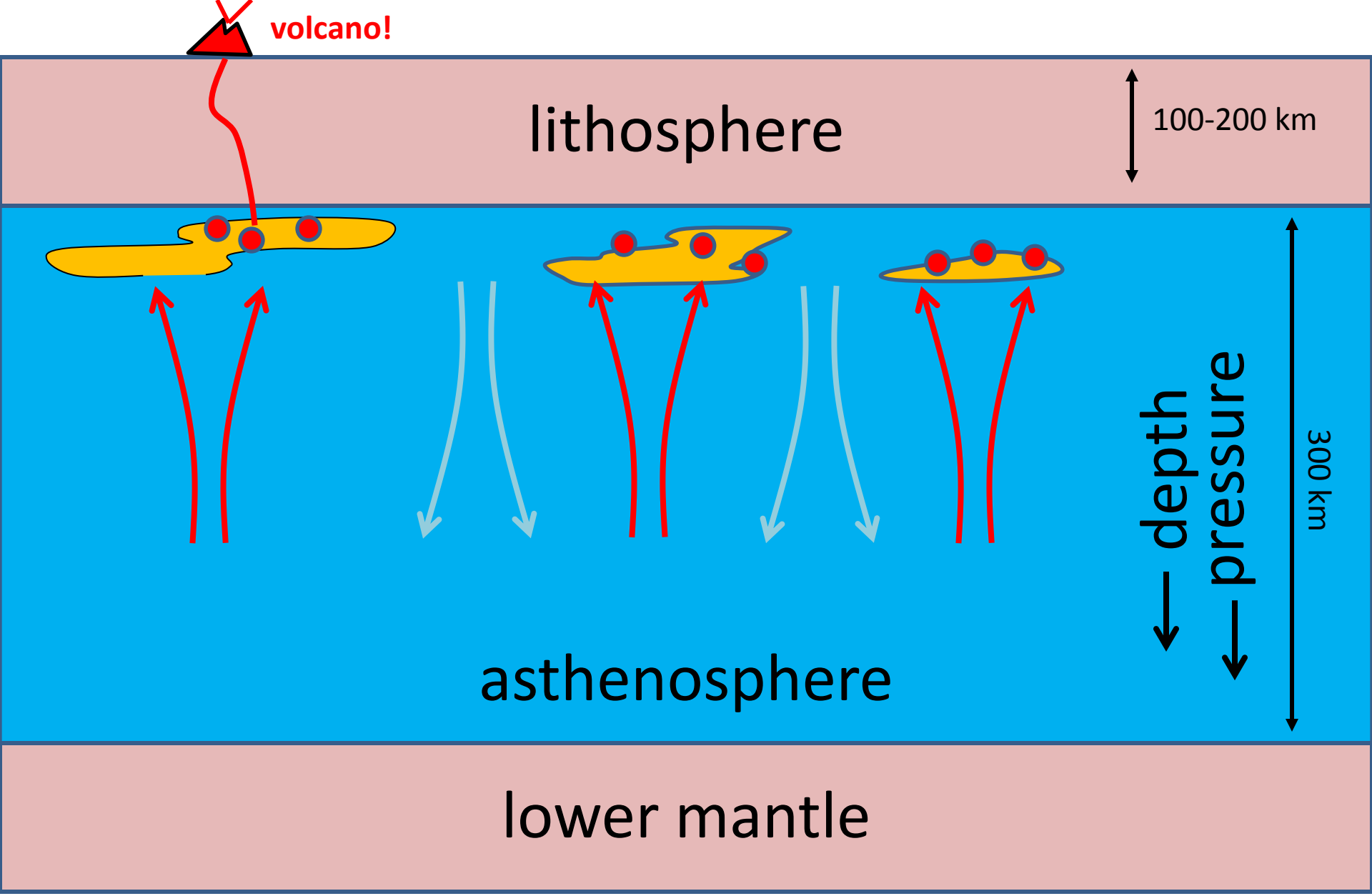
Rain: water droplets more dense than air so they fall down

Rain: water droplets more dense than air so they fall down


lithosphere
100-200 km
depth
pressure
300 km
asthenosphere
lower mantle


temperature, deg C
1100
1500
1700
0
50
100
150
200
depth, km
solidus
partially
molten
solid
hot mantle
at deep depth


temperature, deg C
1100
1500
1700
0
50
100
150
200
depth, km
solidus
0.4 degC/km
partial melting

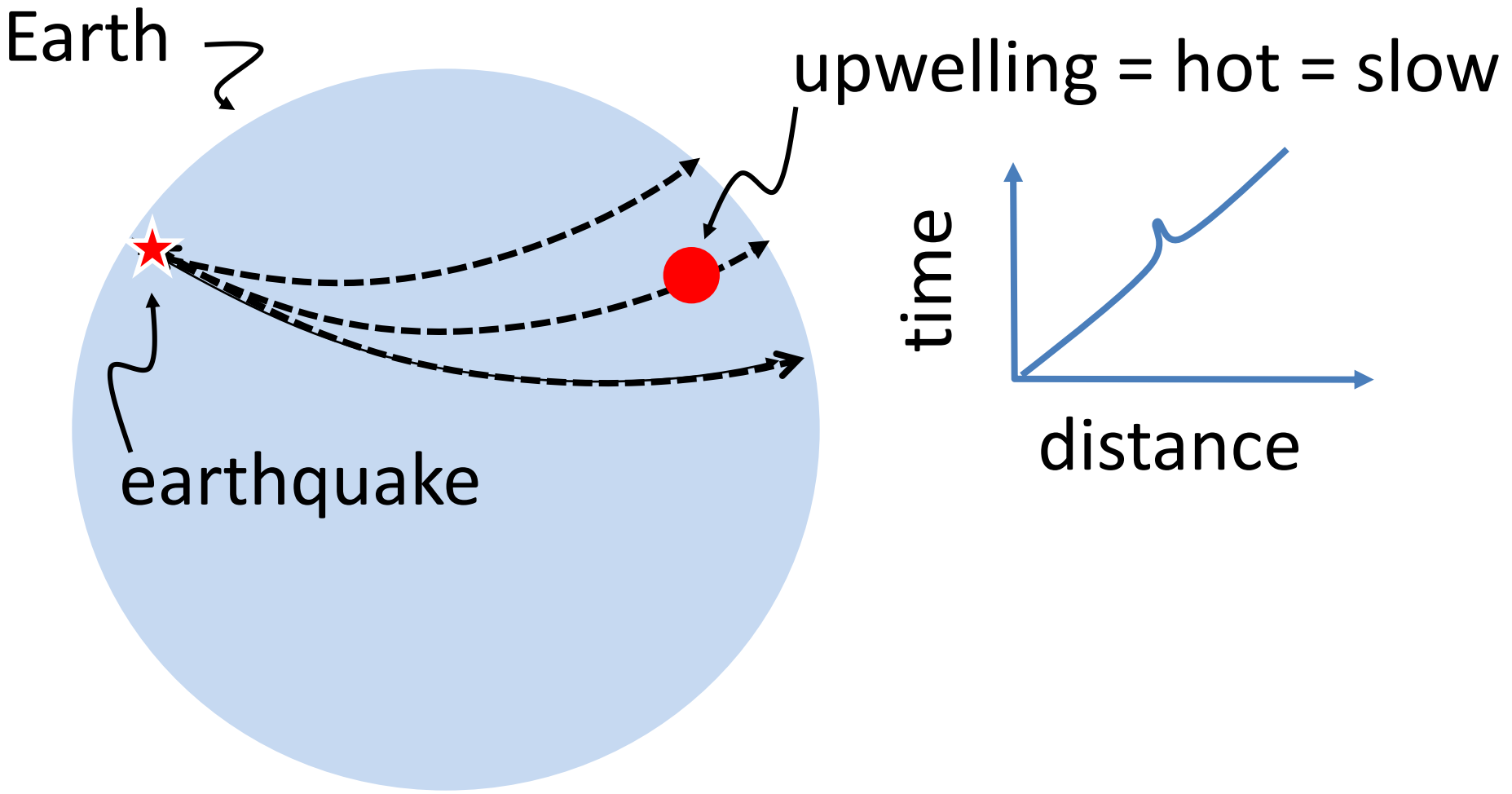


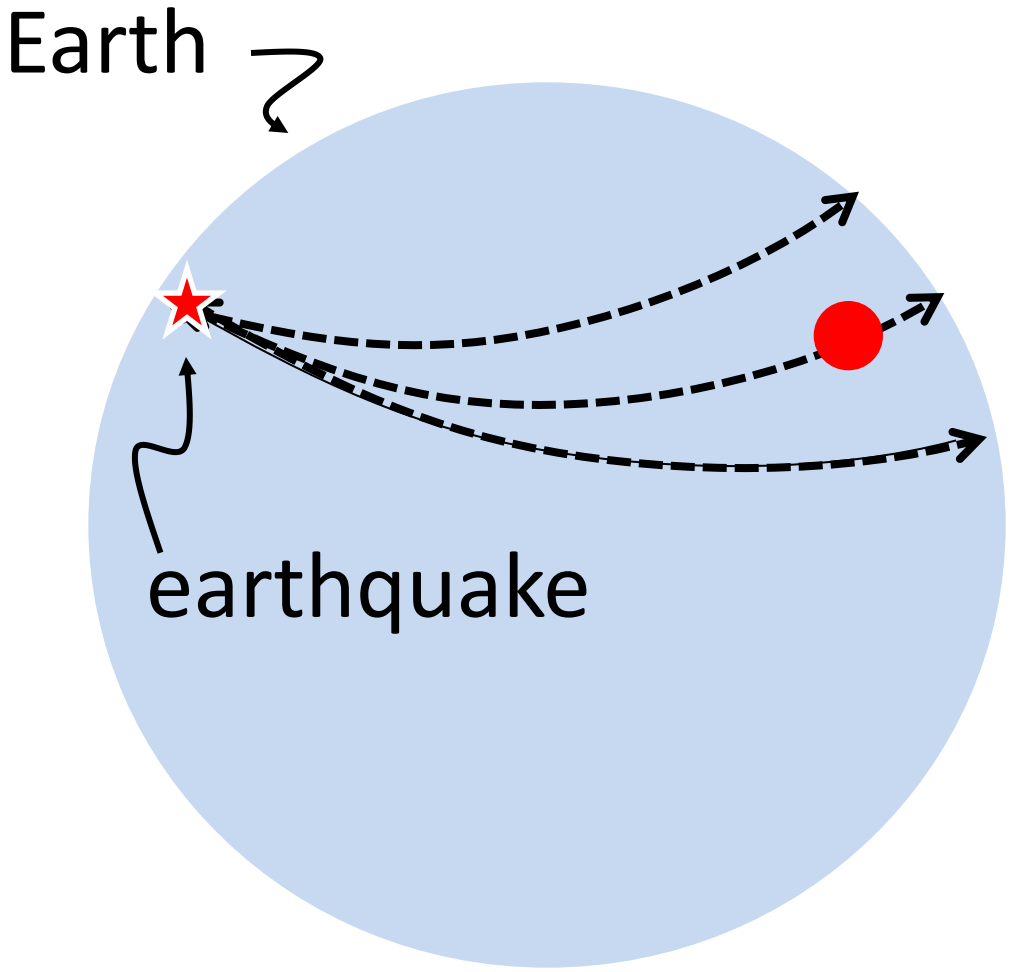
magma ‘rains’ up, since it is less dense than rock

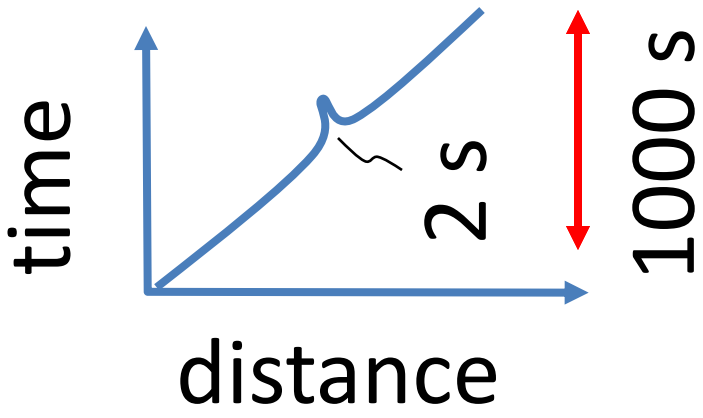
volcanism
tells us where the
asthenosphere is upwelling

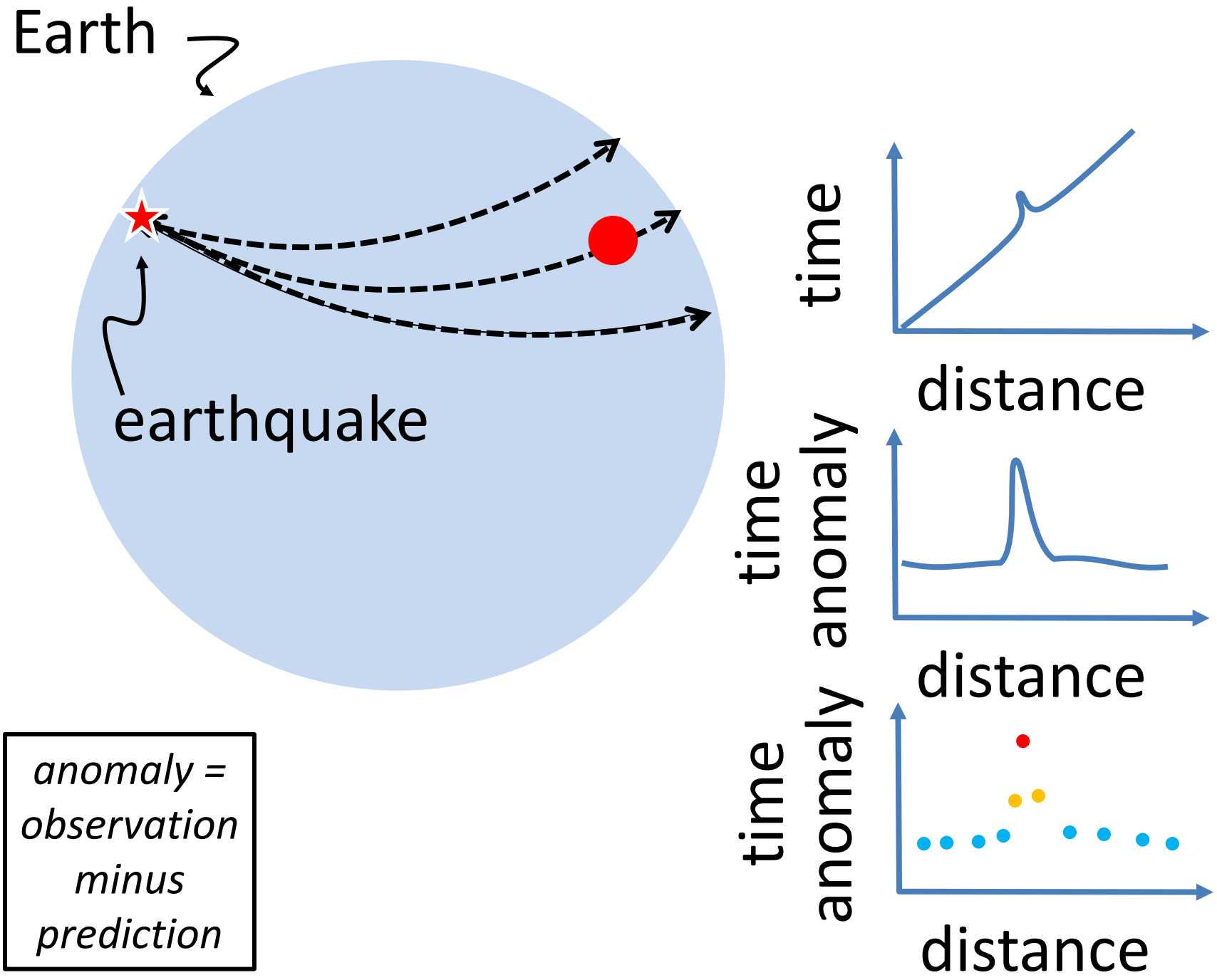
Part 3

The Northern Appalachian Anomaly

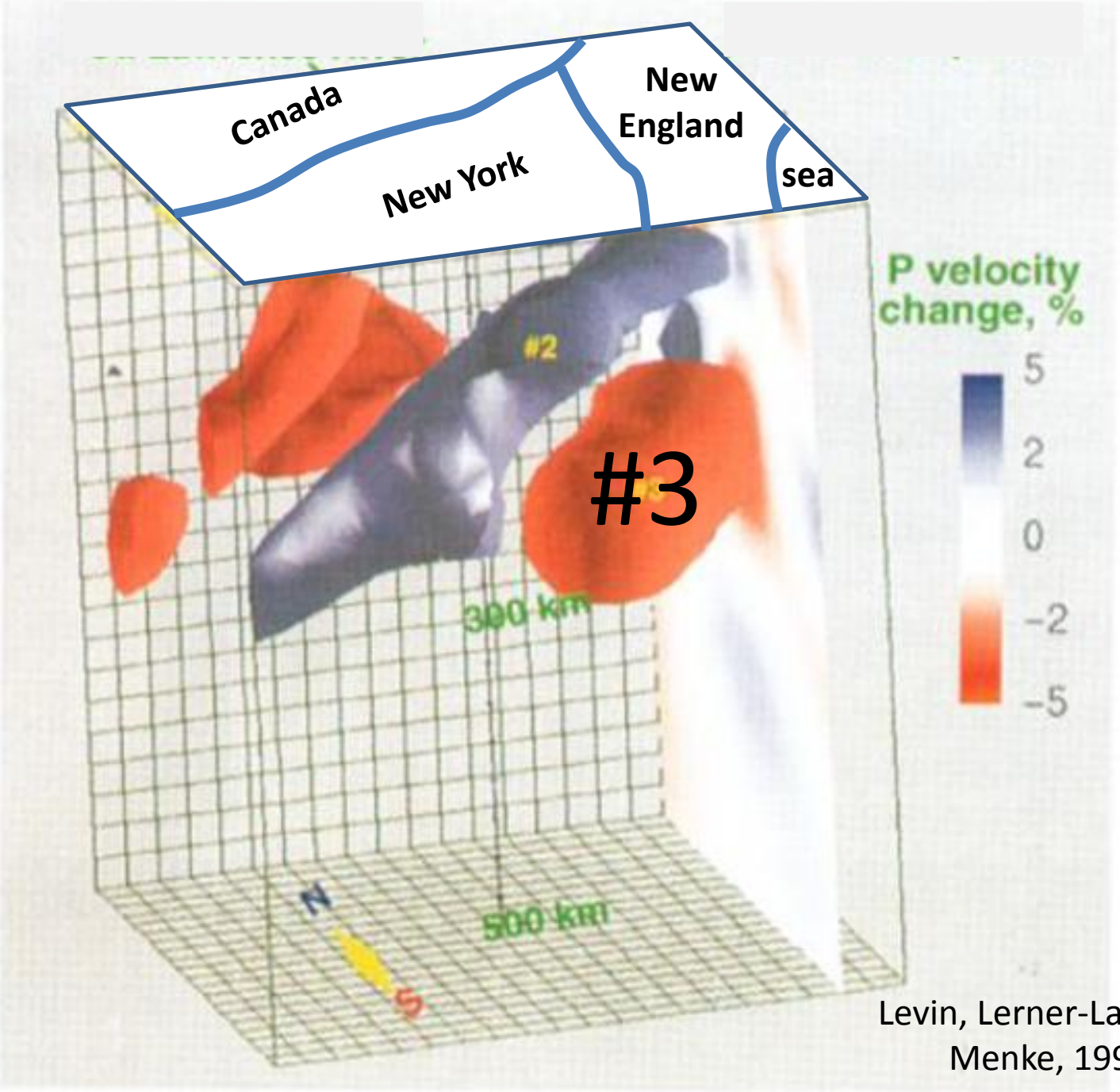

Earth
upwelling = hot = slow
earthquake
time
distance


Earth
earthquake


time
2 s
1000 s
distance


Earth
earthquake
time
distance
time
anomaly
distance
time
anomaly
distance
anomaly = observation minus prediction

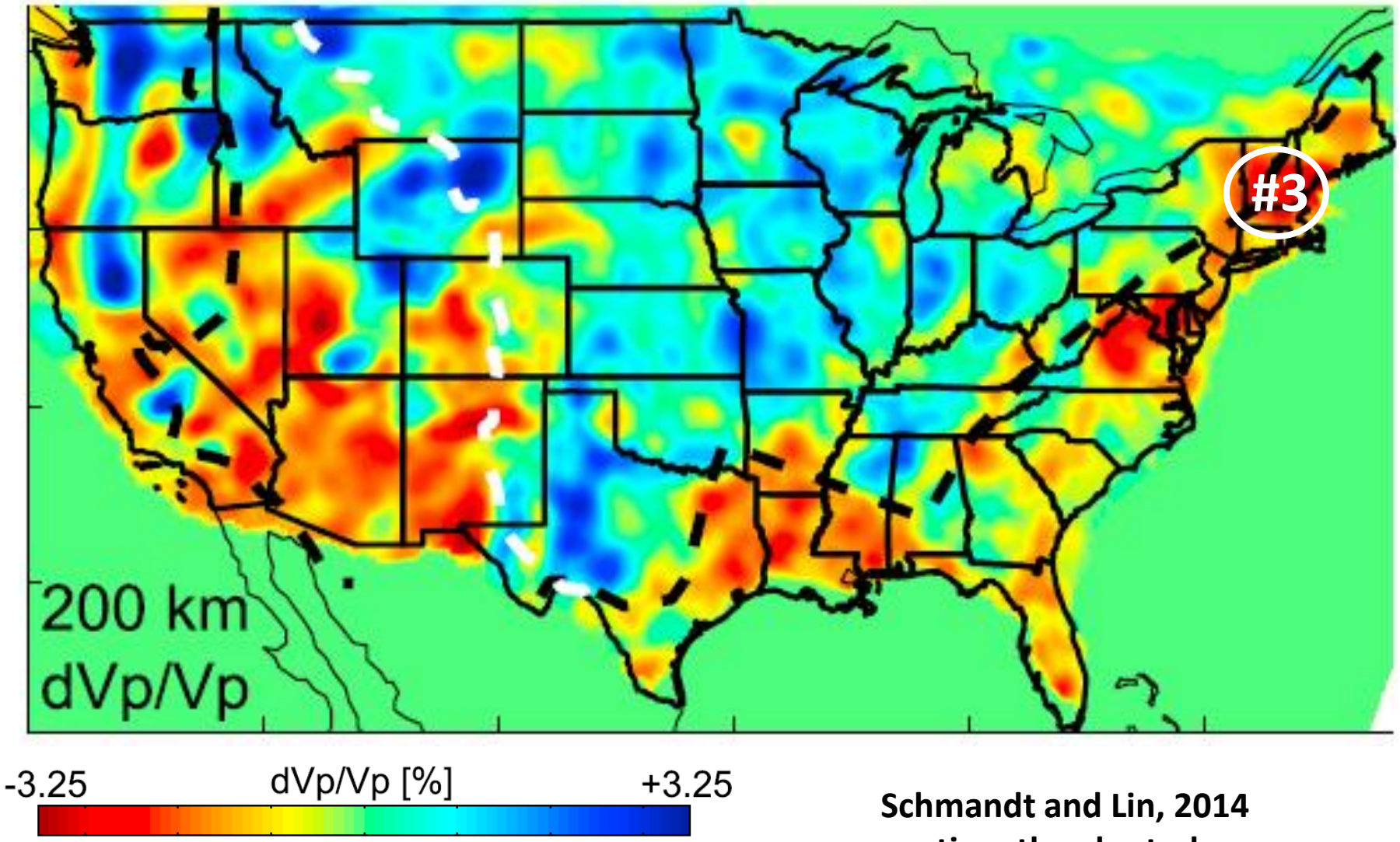
former LDEO Graduate Student Vadim Levin
(now Rutgers Prof)



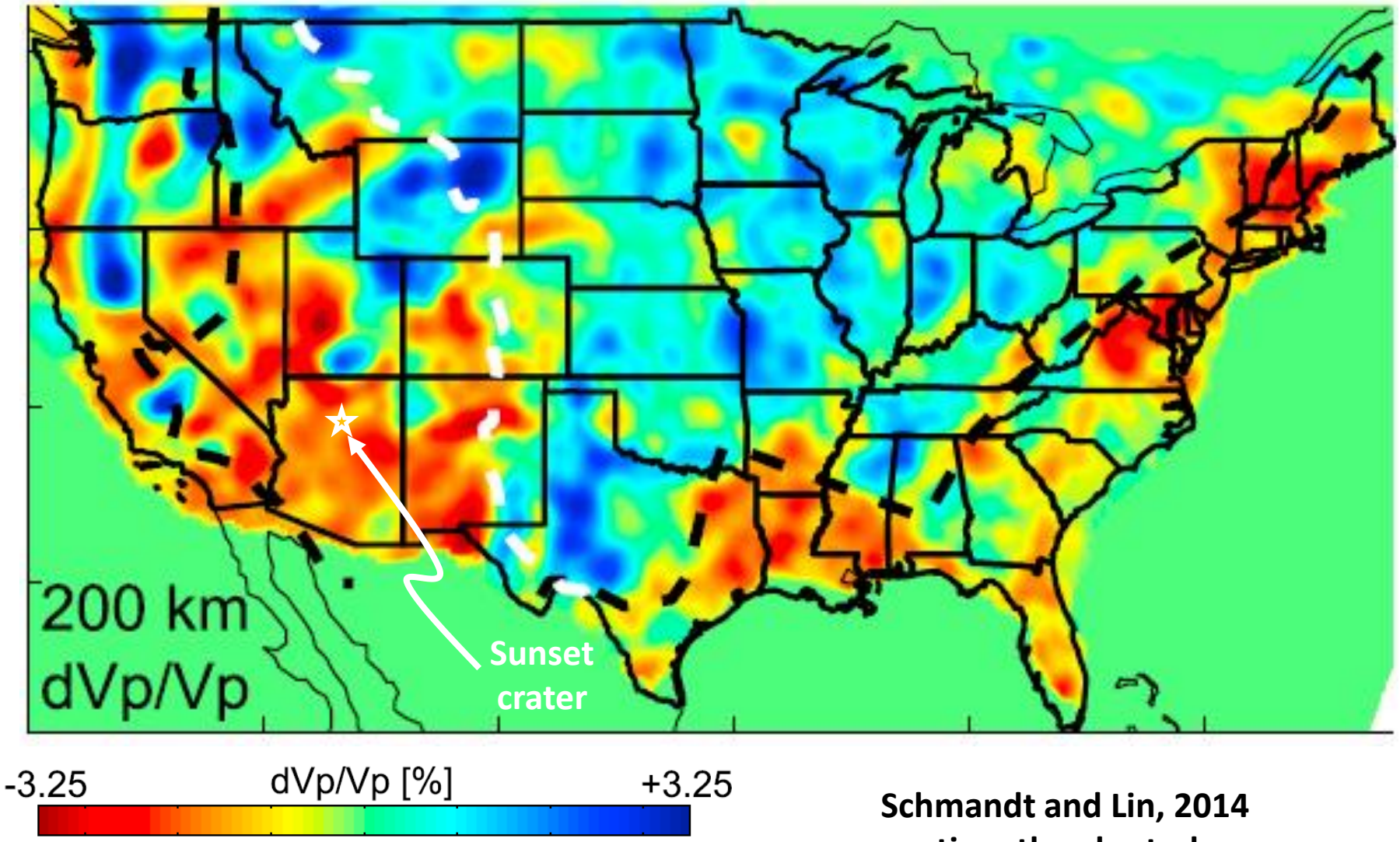
Levin, Lerner-Lam and Menke, 1995

“The interpretation of the velocity low #3 presents a challenge … while elevated temperatures are often associated with low seismic velocity, #3 is unlikely to be of a thermal origin … for at least 100 My this region has been tectonically quiet, and the temperature difference must have equibrated … a temperature anomaly on the order of 800 degC is required for a 5% decrease of compressional velocity” … [which is unrealistic]

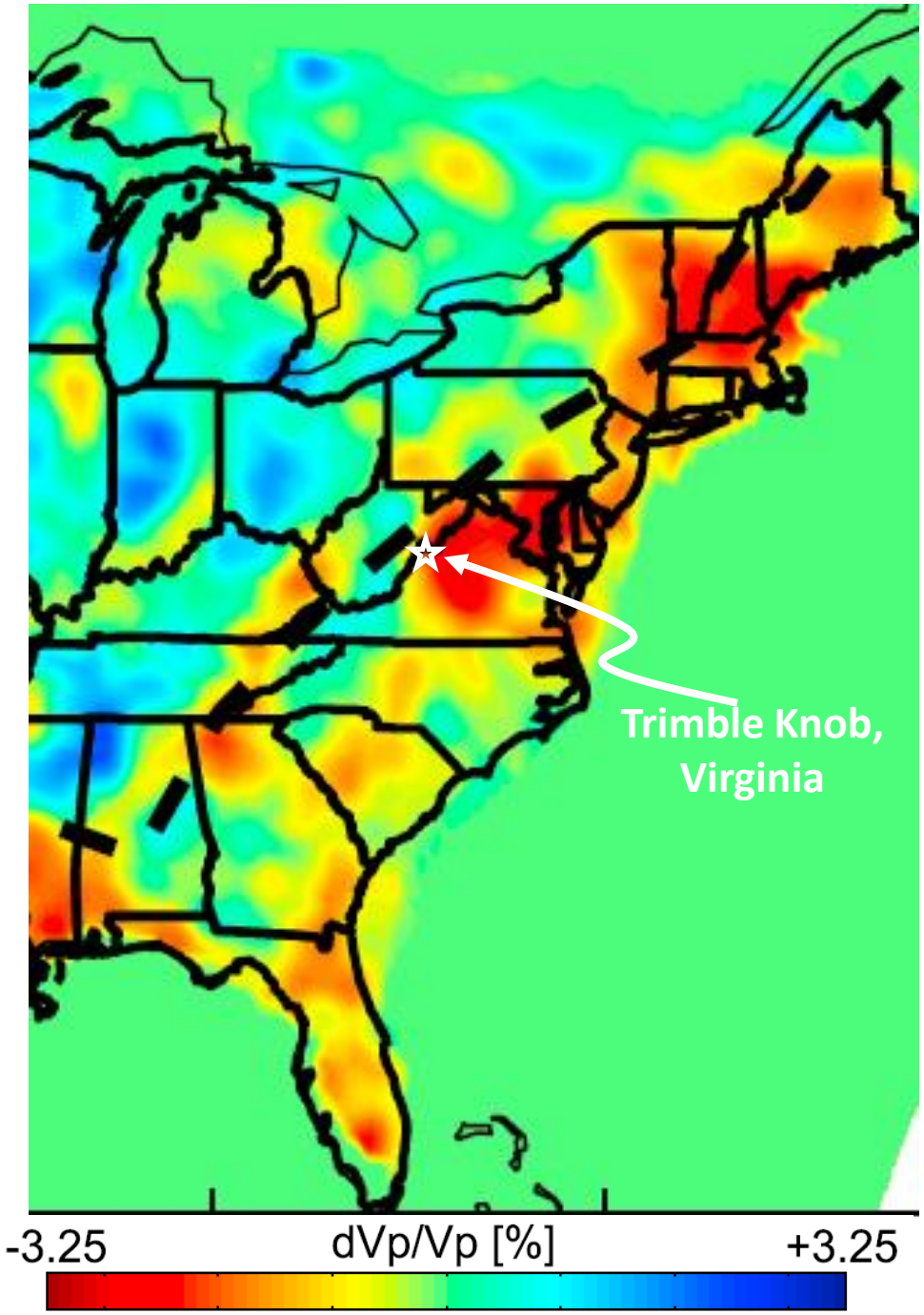
Levin, Lerner-Lam and Menke, 1995



Schmandt and Lin, 2014
continentl scale study
note parts of eastern US as slow (red) as western US



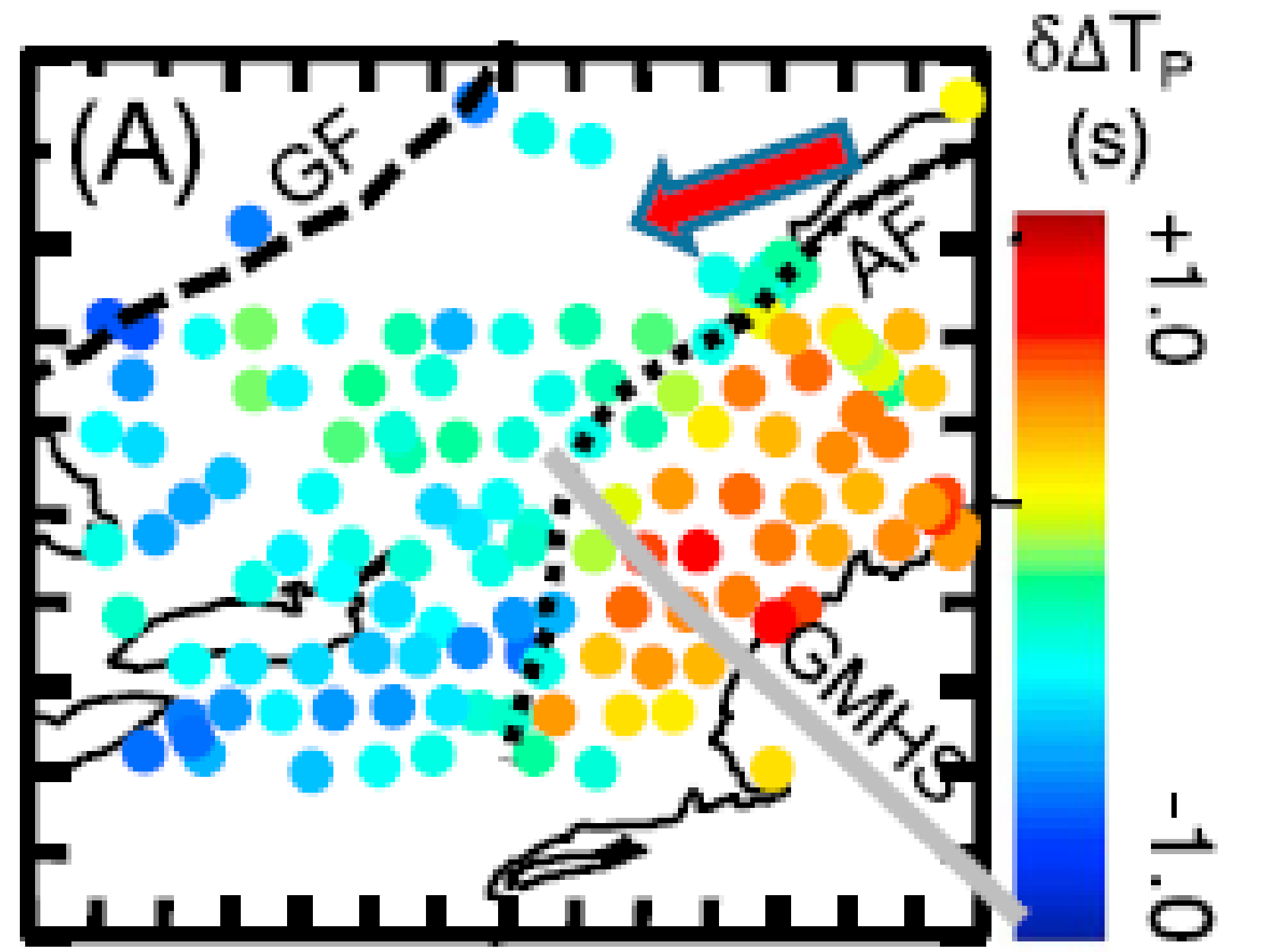
Schmandt and Lin, 2014
continentl scale study
note parts of eastern US as slow (red) as western US

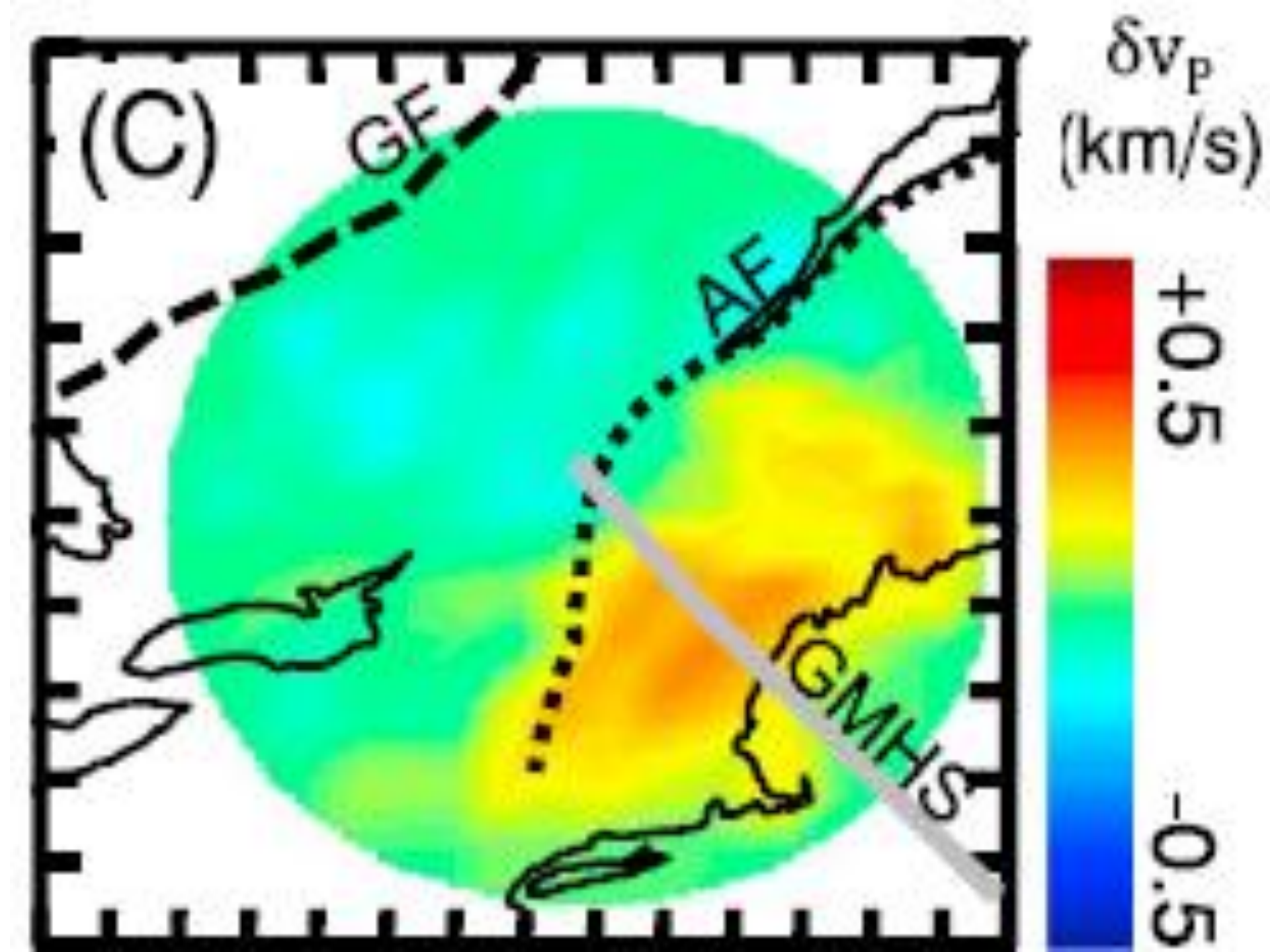


Schmandt and Lin, 2014

Schmandt and Lin, 2014

taking a closer look at the NAA


(A)
GF
AF
GMHS
δΔTP
(s)
+1.0
-1.0

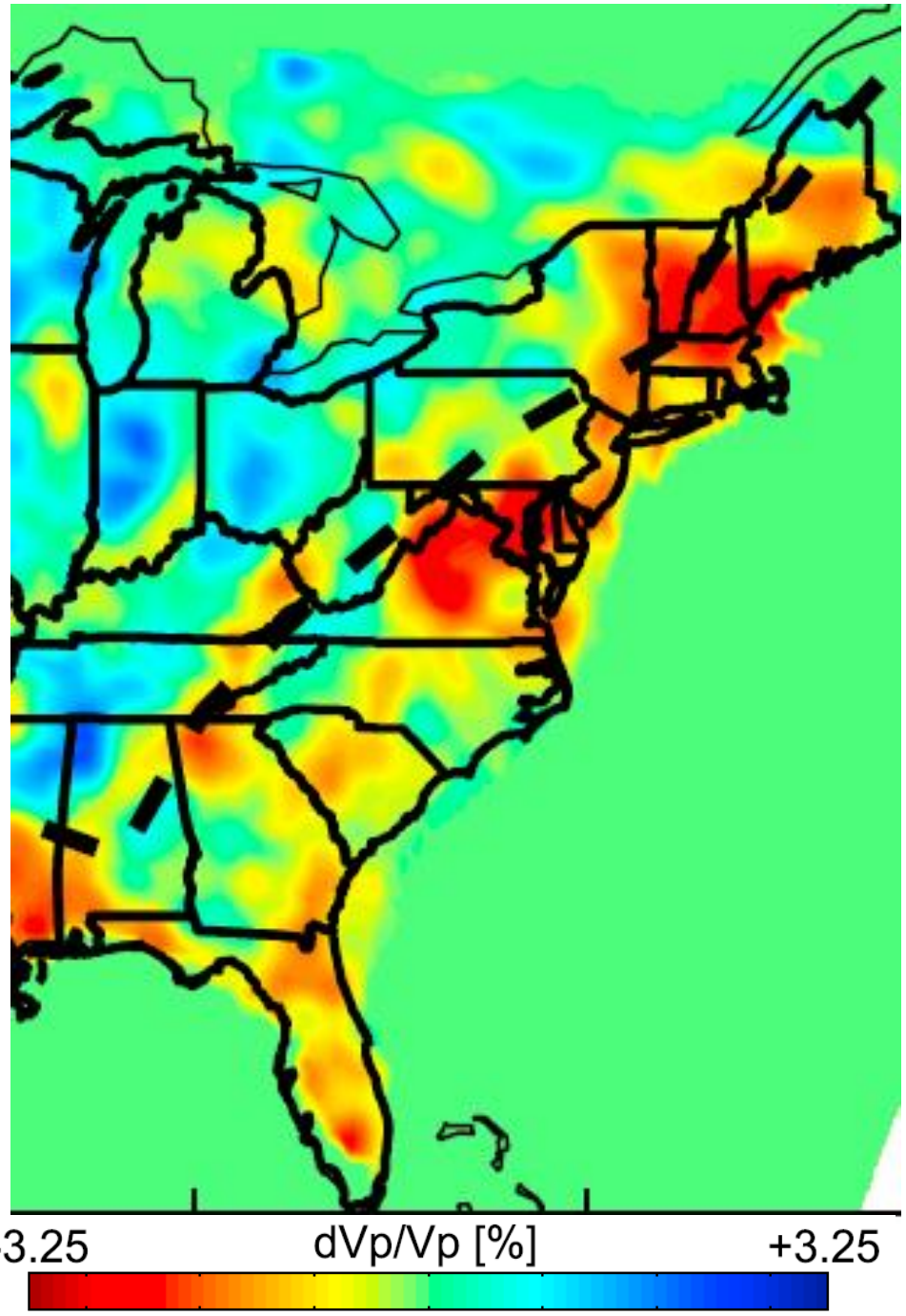

(C)
GF
AF
GMHS
δv_P
(km/s)
+0.5
-0.5

Slow velocities are all west of Appalachian Front (AF)

(proxy for the easternmost edge of ancient North America)

western edge is sub-parallel to the AF

(has AF exerted some influence?)



slow

fast

proxy for 'hot'

proxy for cold

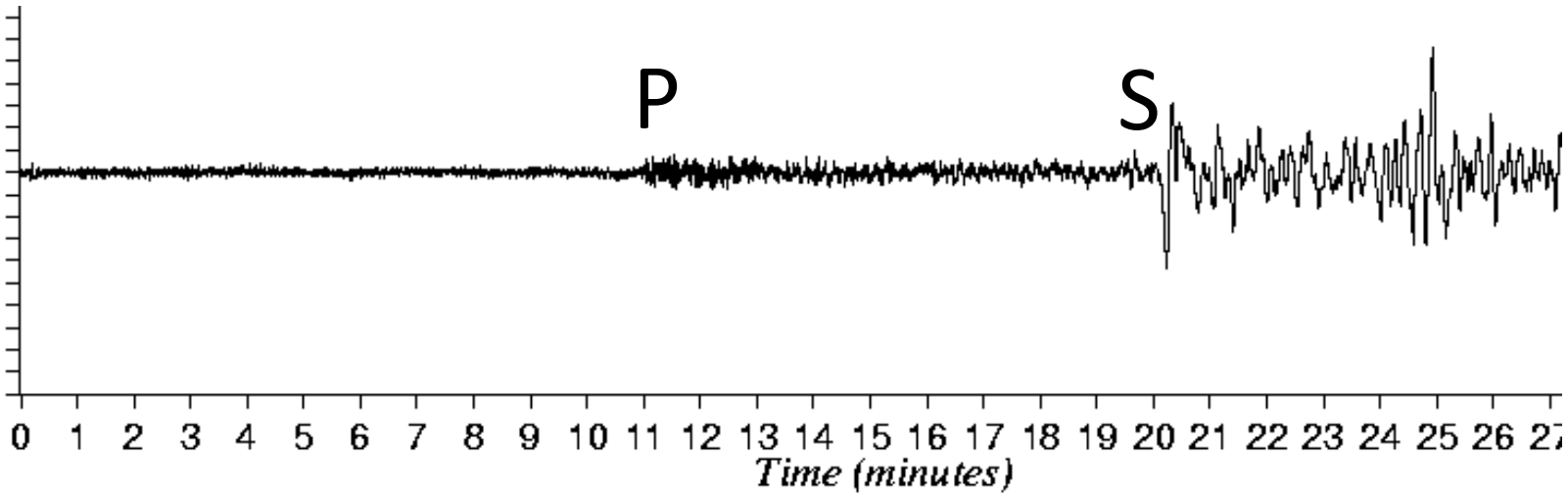
but can also be

proxy for 'dense'

proxy for 'light'

Schmandt and Lin, 2014

Earthquakes generate both P waves and S waves



and the two are affected by temperature and density is (slightly) different ways

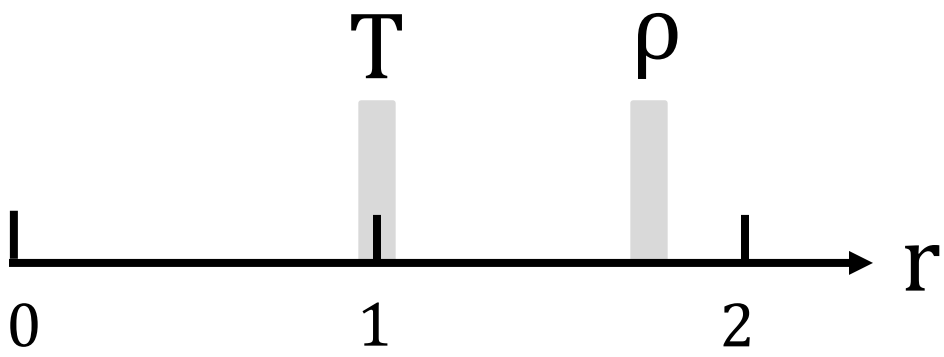
lab experiments and theoretical models

$$r = \frac{\Delta V_P}{\Delta V_S} = 1.0$$

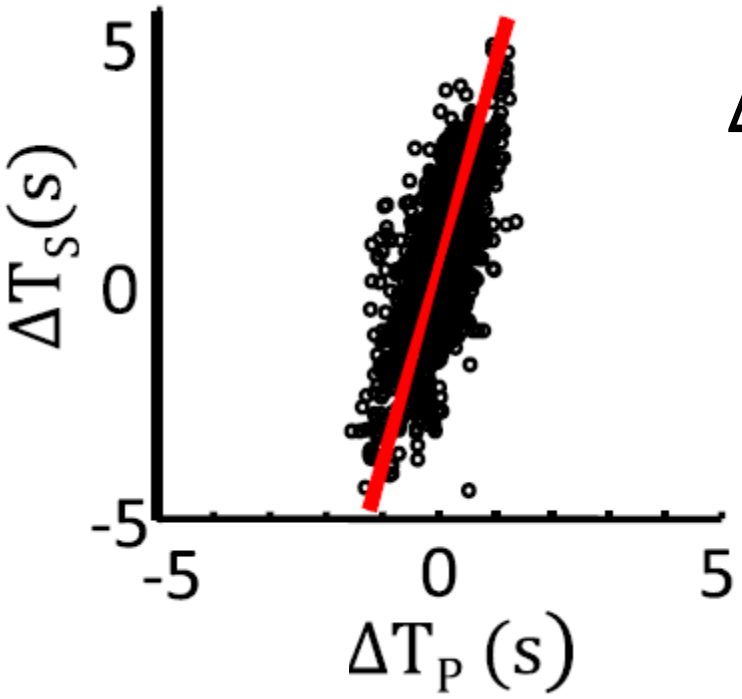
temperature, T

$$r = \frac{\Delta V_P}{\Delta V_S} = 1.8$$

density, ρ

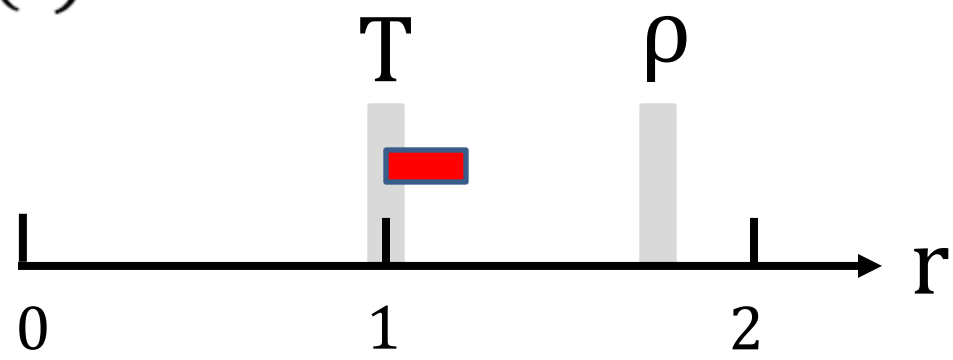


observations

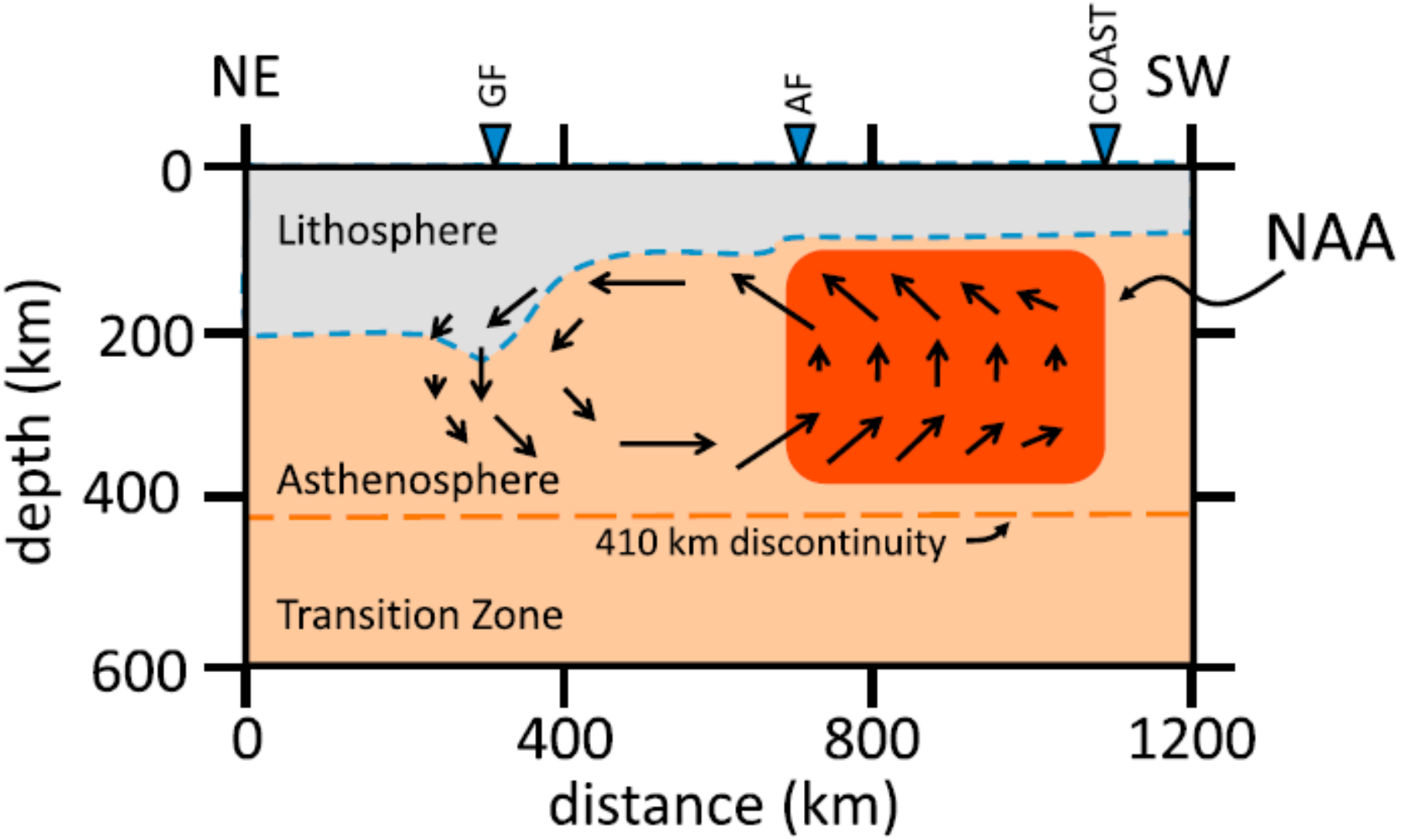


ΔT_P and are ΔT_S are highly correlated

$r=\Delta T_P / \Delta T_S$ favors temperature



Interpretation



Part 4: The Next Steps

infer mantle flow directions

- confirm upwelling at the NAA
- find where down-welling is occurring

better estimates of temperature

- how shallow is the top of the NAA?
- is melt present?
- has it ever erupted?

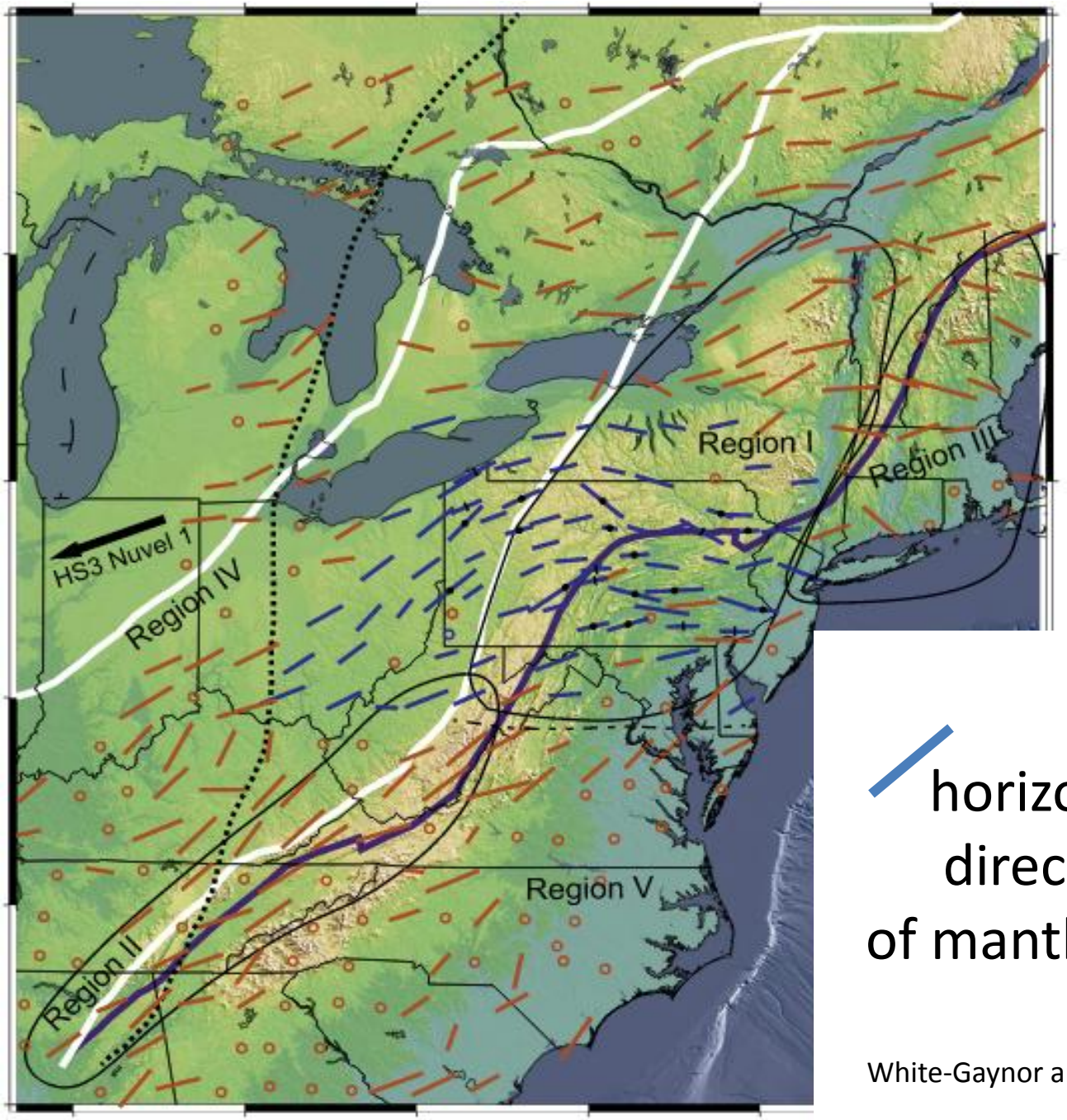
consequences of the convection

- is the asthenosphere deforming/eroding
  - the continent

Shear Wave Splitting

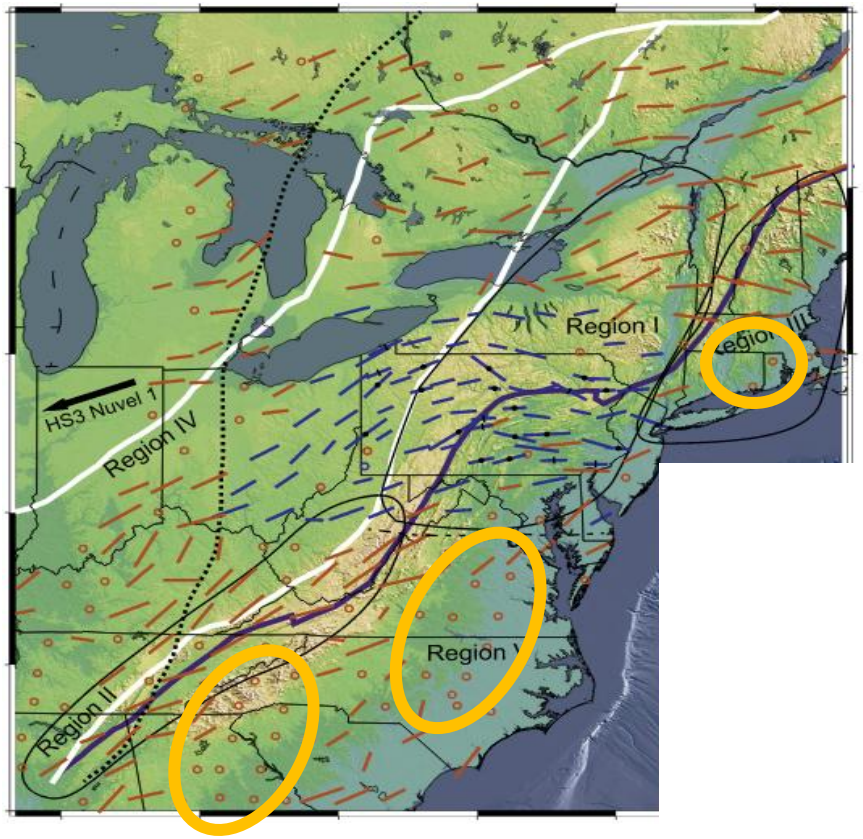
slight variations in S-wave velocity with direction of S-wave vibration direction due to rock "fabric"

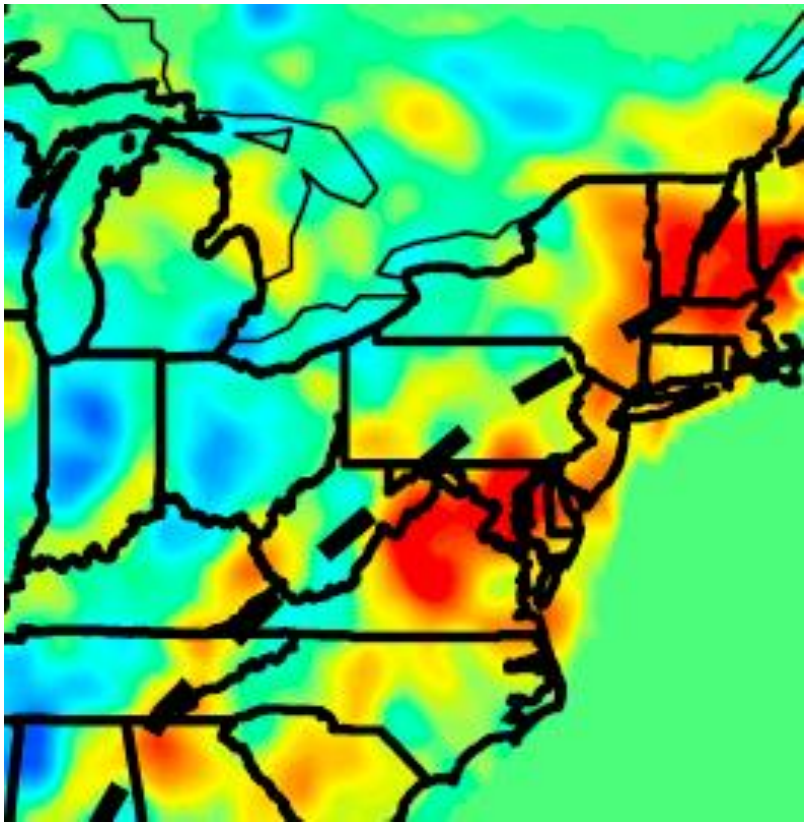
proxy for mantle flow direction since mantle flow creates fabric



horizontal direction of mantle flow

White-Gaynor and Nyblade, 2017





White-Gaynor and Nyblade, 2017

2015 Summer Intern

Peter Skryzalin

doing high resolution study of

NAA Shear Wave Splitting

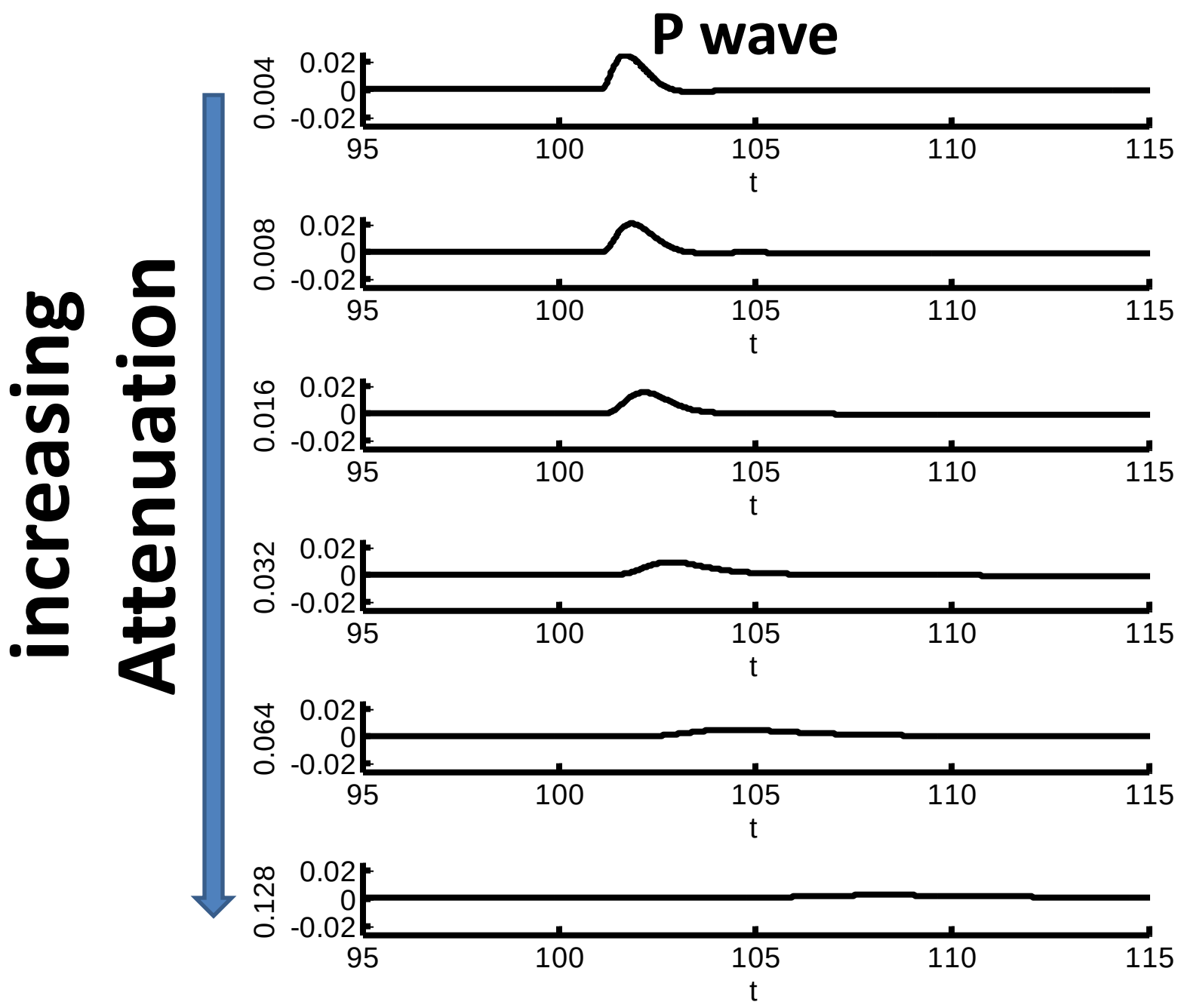
for his Senior Thesis

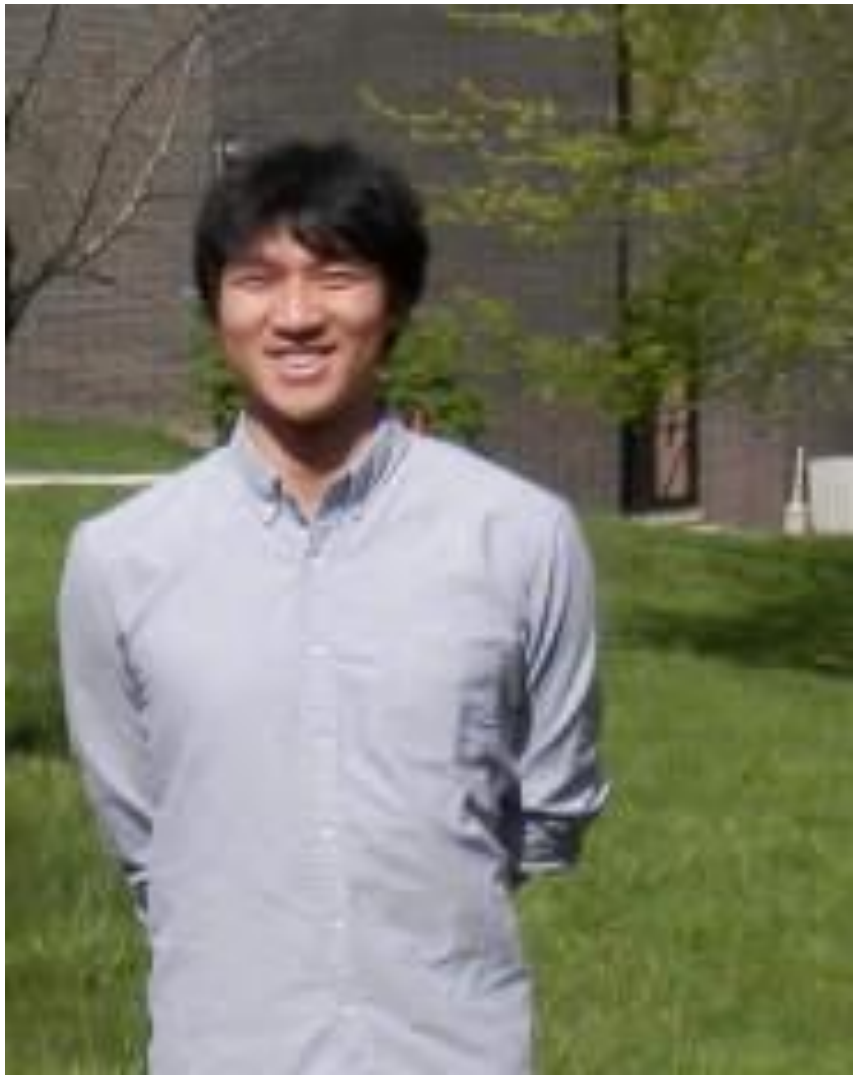
at Rutgers University

Seismic Attenuation

absorption of vibrational energy by “soft” materials

in rocks, softness a proxy for temperature


P wave
increasing
Attenuation
0.004
0.008
0.016
0.032
0.064
0.128
0.02
0
-0.02
95
100
105
110
115
t



Graduate Student

Ted Dong

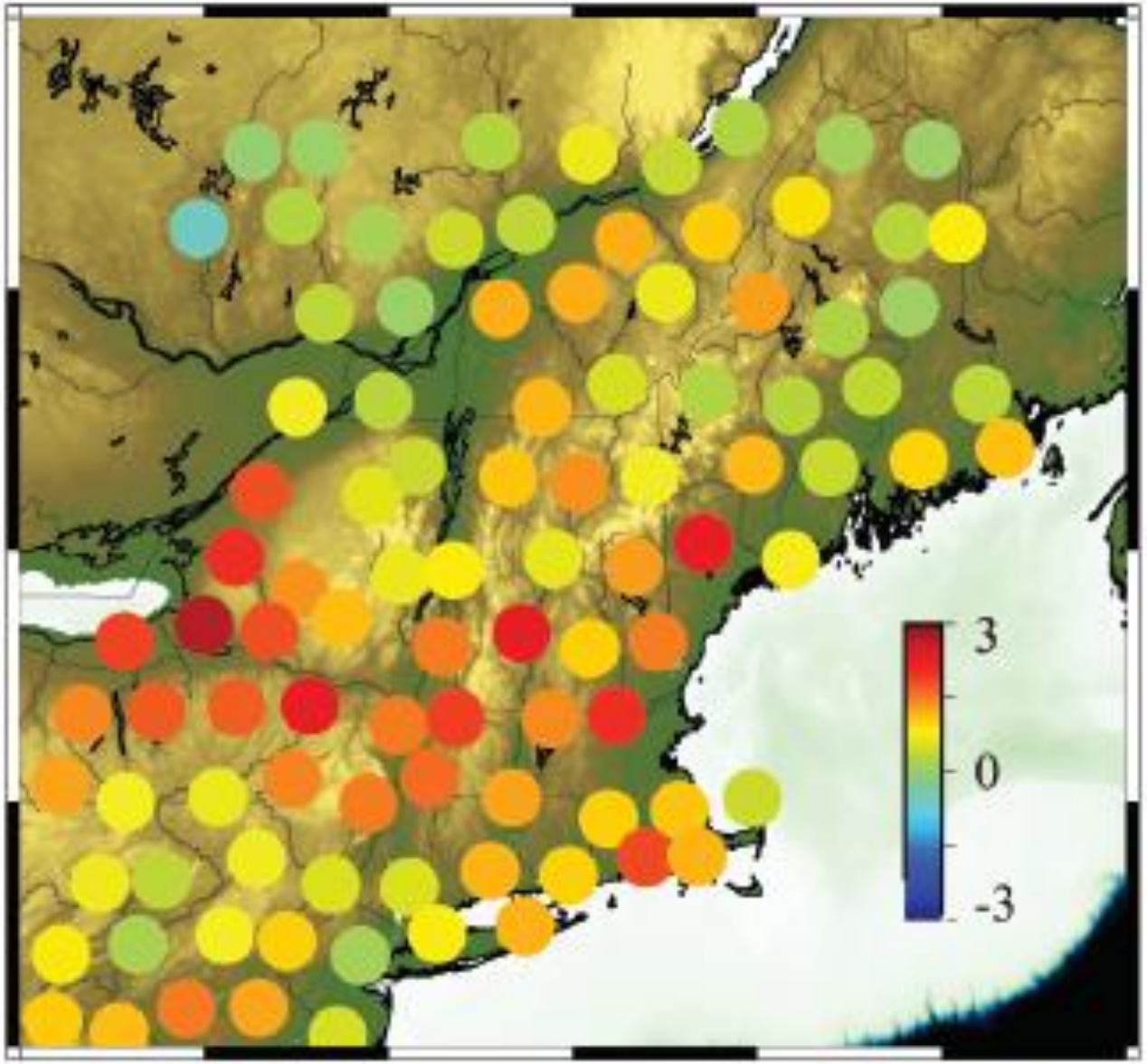
studying

NAA Attenuation

for his Masters Thesis

here at

Columbia



shear wave attenuation

Absence of Evidence is not Evidence of Absence

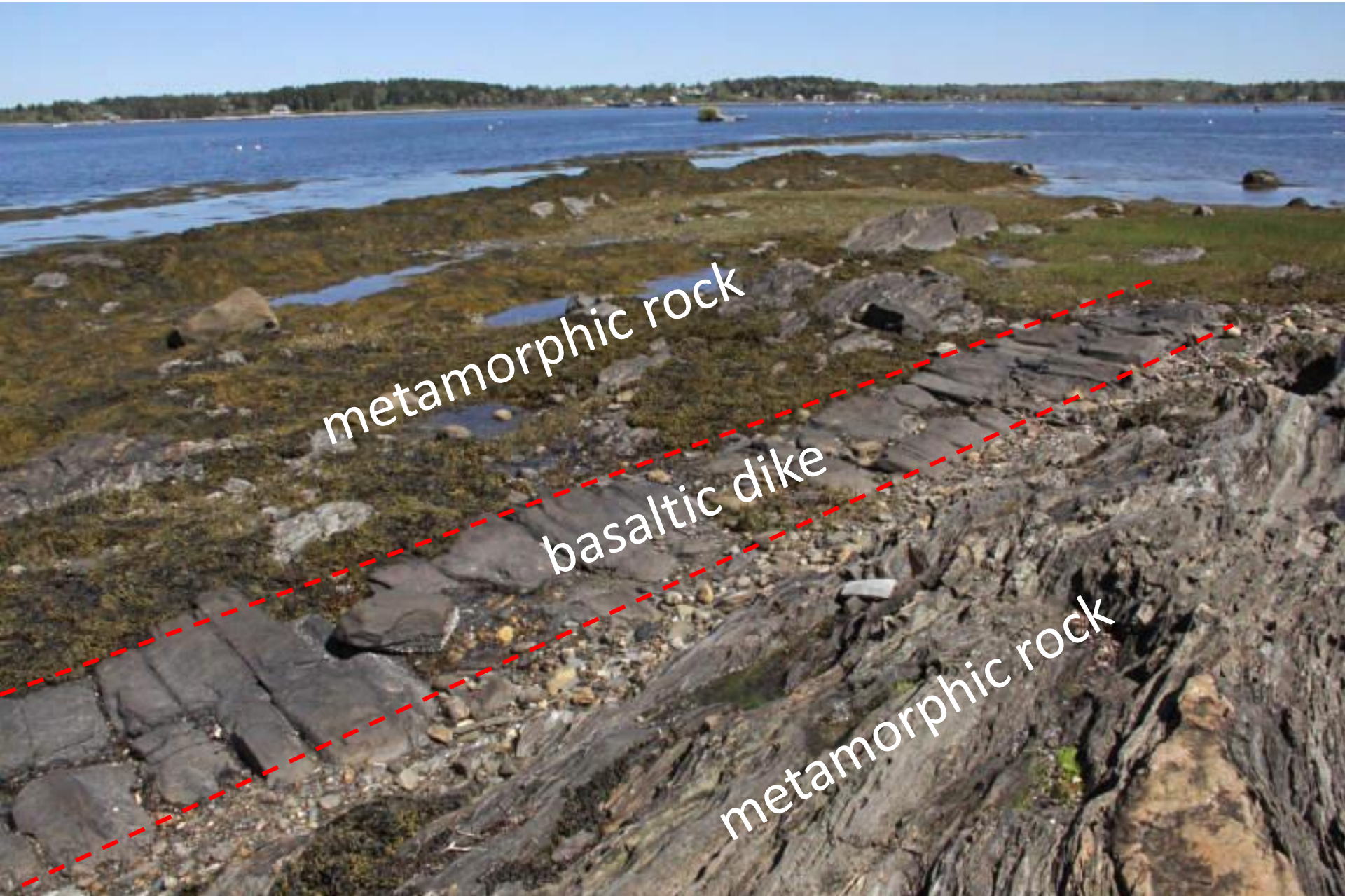
- Carl Sagan, Astronomer

Are we sure that no NAA-related volcanoes have erupted in New England?

unlike Virginia, the region has lots of volcanic features
furthermore, it was heavily eroded by the Pleisocene glaciers
a few, small volcanic features might have been ignored

Harpswell Maine

Every geologist I've asked says this is a 200 My old dike but (as far as I know) no one has actually dated it



The End