Earth's unique Continents

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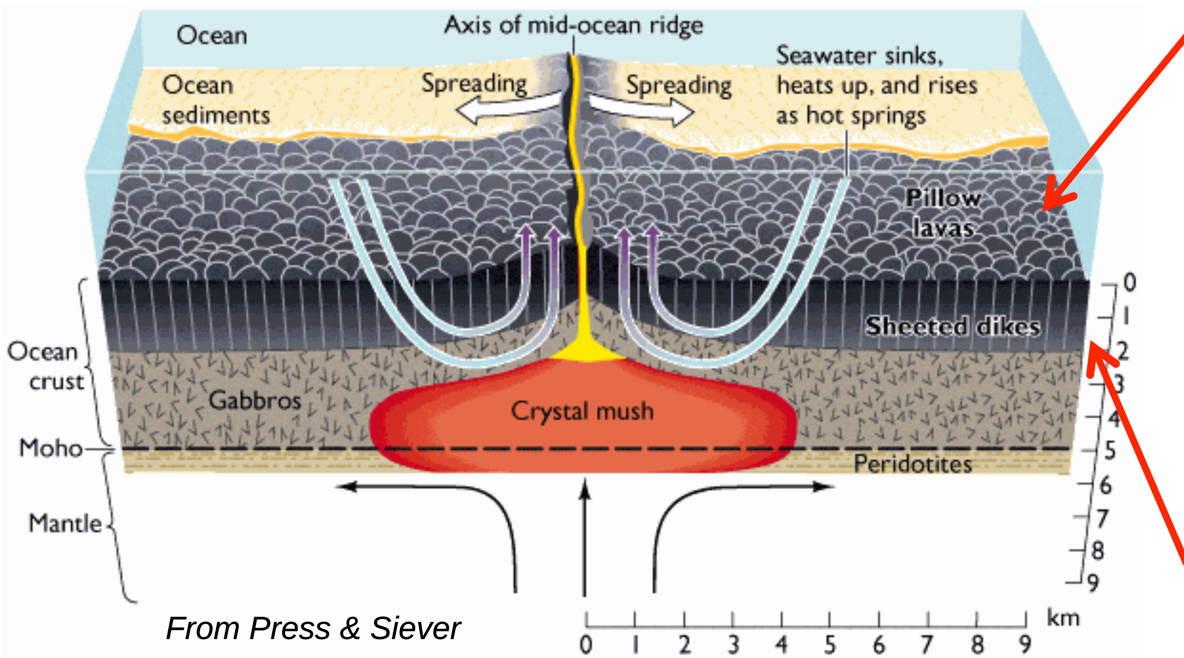
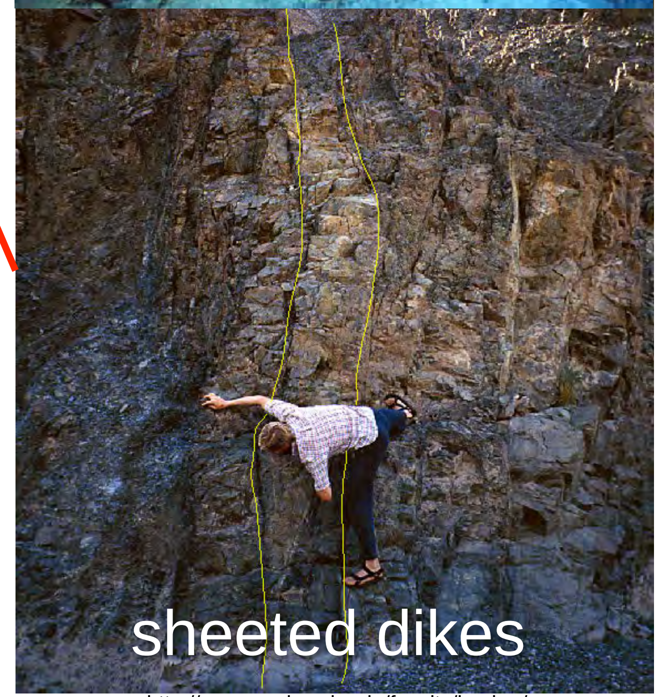
Apollo 17 view of Earth

Plate tectonics gives rise to two types of crust: oceanic and continental

Generation of the Oceanic Crust

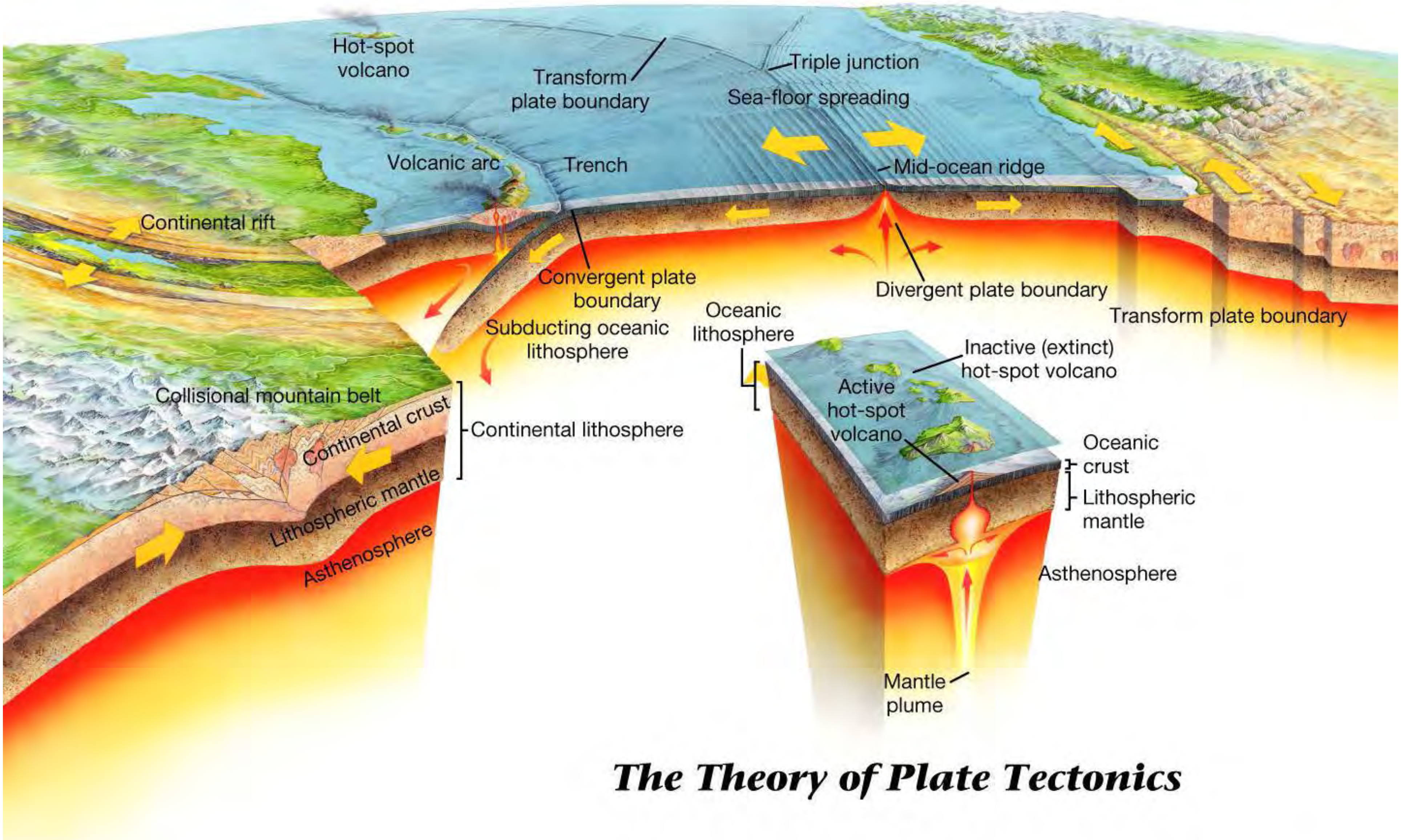


From Press & Siever



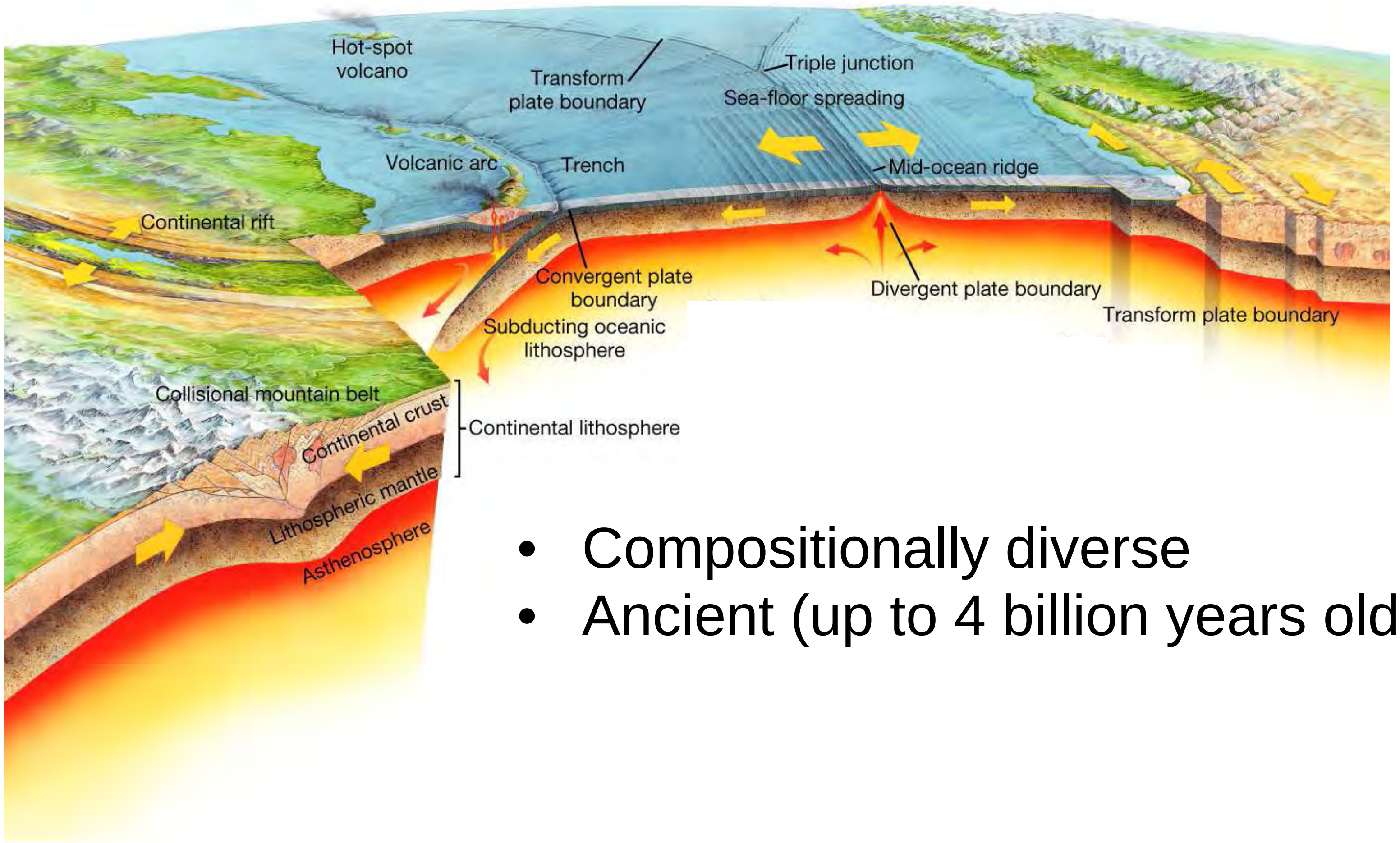
http://www.geol.ucsb.edu/faculty/hacker/geo102C/lectures/sheetedDikes.jpg

- Melt ascends from mantle and freezes as basaltic crust
- Young (<200 million years old)



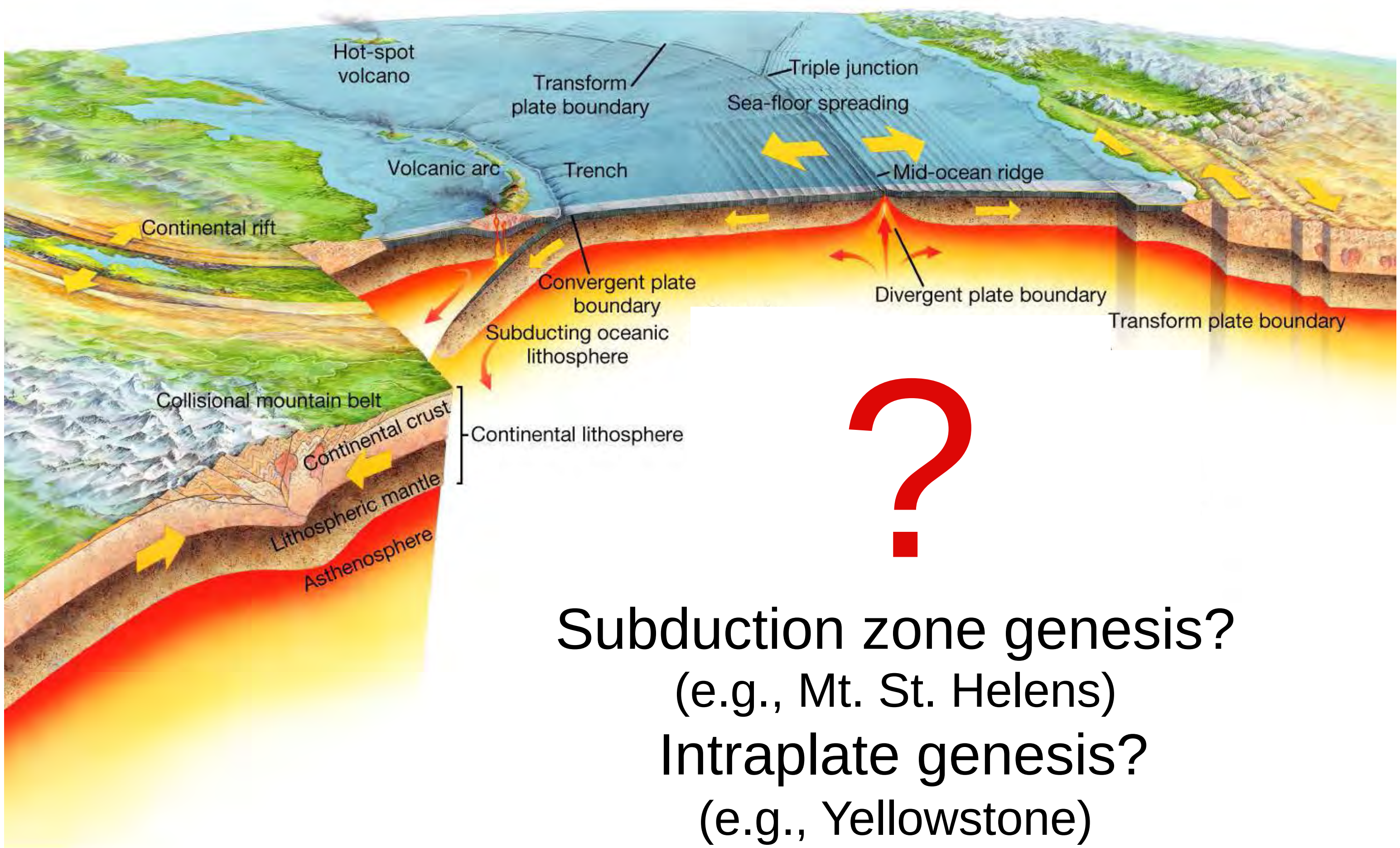
The Theory of Plate Tectonics

Generation of the Continental Crust



- Compositionally diverse
- Ancient (up to 4 billion years old)

Growth of Continental Crust via magmatic addition



?

Subduction zone genesis?

(e.g., Mt. St. Helens)

Intraplate genesis?

(e.g., Yellowstone)

Questions:

- How does continental crust form?

- Earth is the only planet with continents. Why?

What is continental crust?

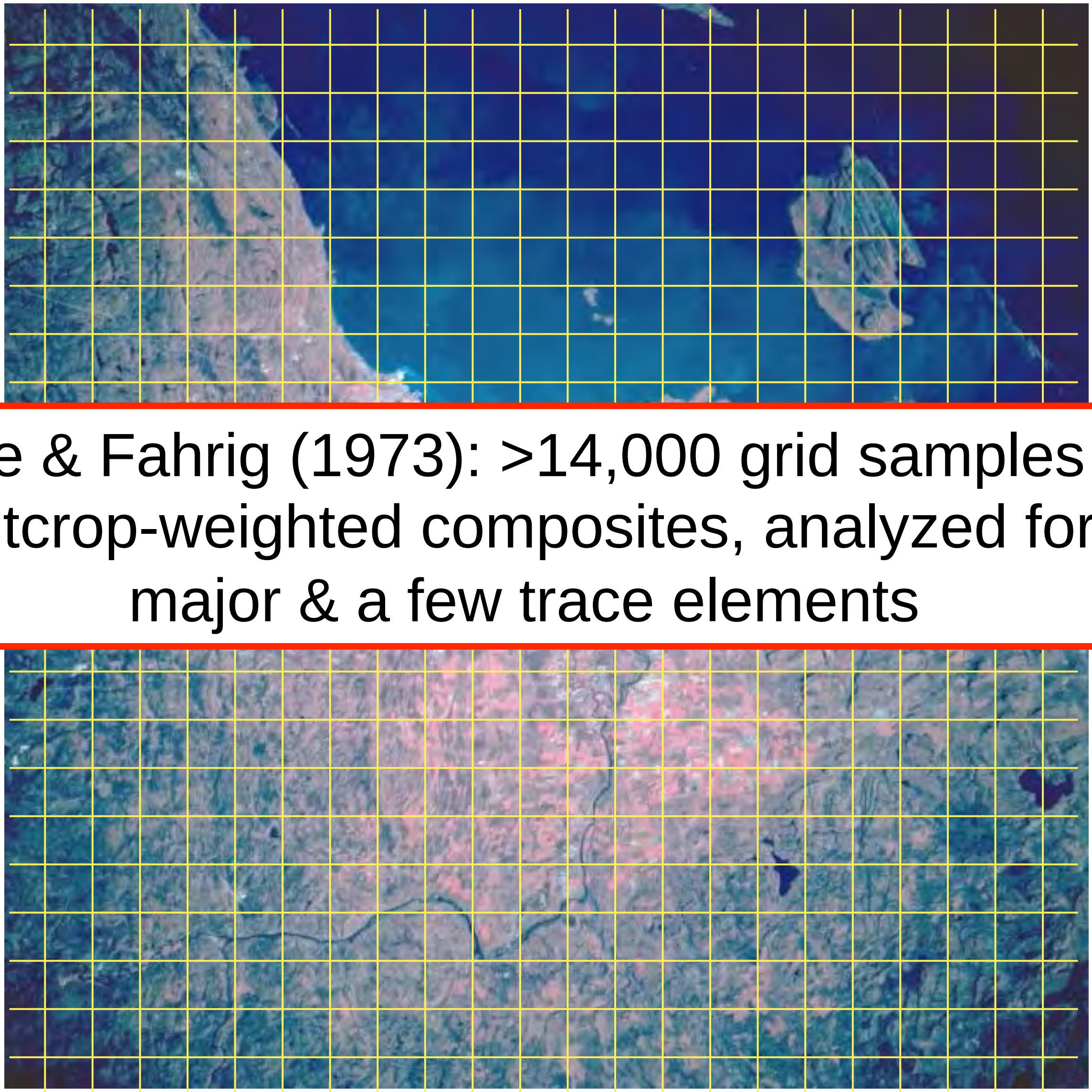
Vertical: surface to Moho
Horizontal: slope break on continental shelves

~34± 4 km thick* (15 to 80 km)
Low density: ~2.8 g/cm^3
High standing (average elevation 800 m)

**Huang et al., 2013*

How do we determine the composition of continental crust?

Upper crust ~10 to 15 km thick
major (abundant) elements: grid sampling



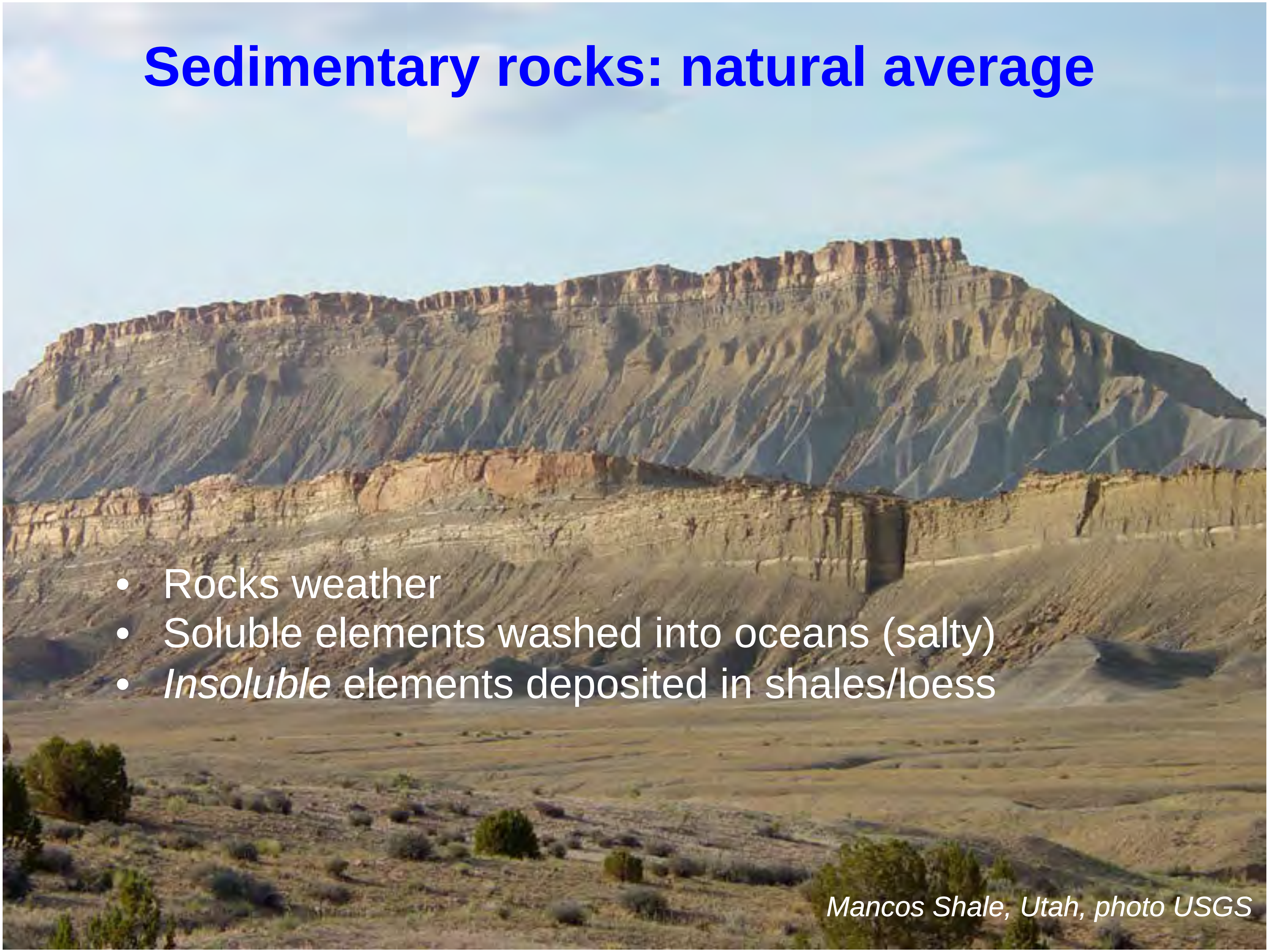
Eade & Fahrig (1973): >14,000 grid samples in outcrop-weighted composites, analyzed for major & a few trace elements

Space shuttle view of Thunder Bay, Ontario

Upper continental crust is “granitic” (67 wt.% SiO_2)

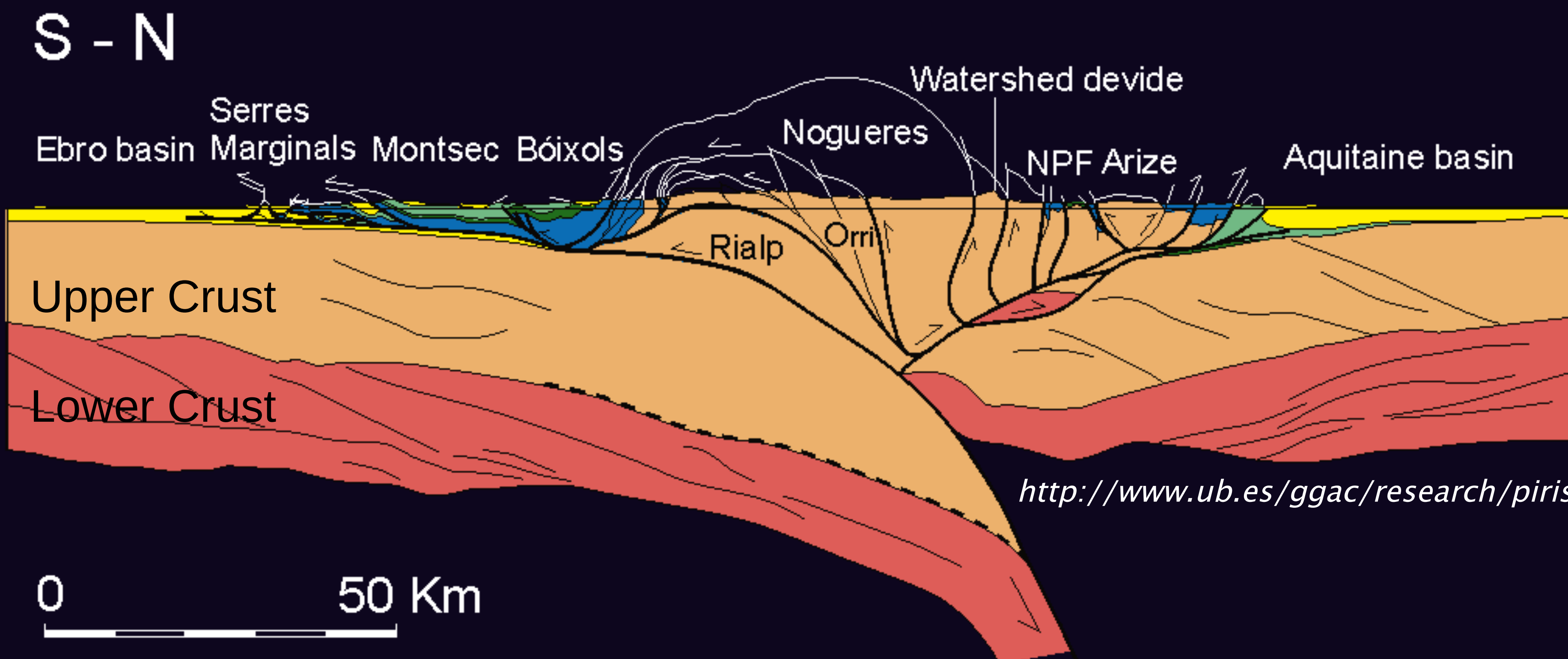
Sedimentary rocks: natural average

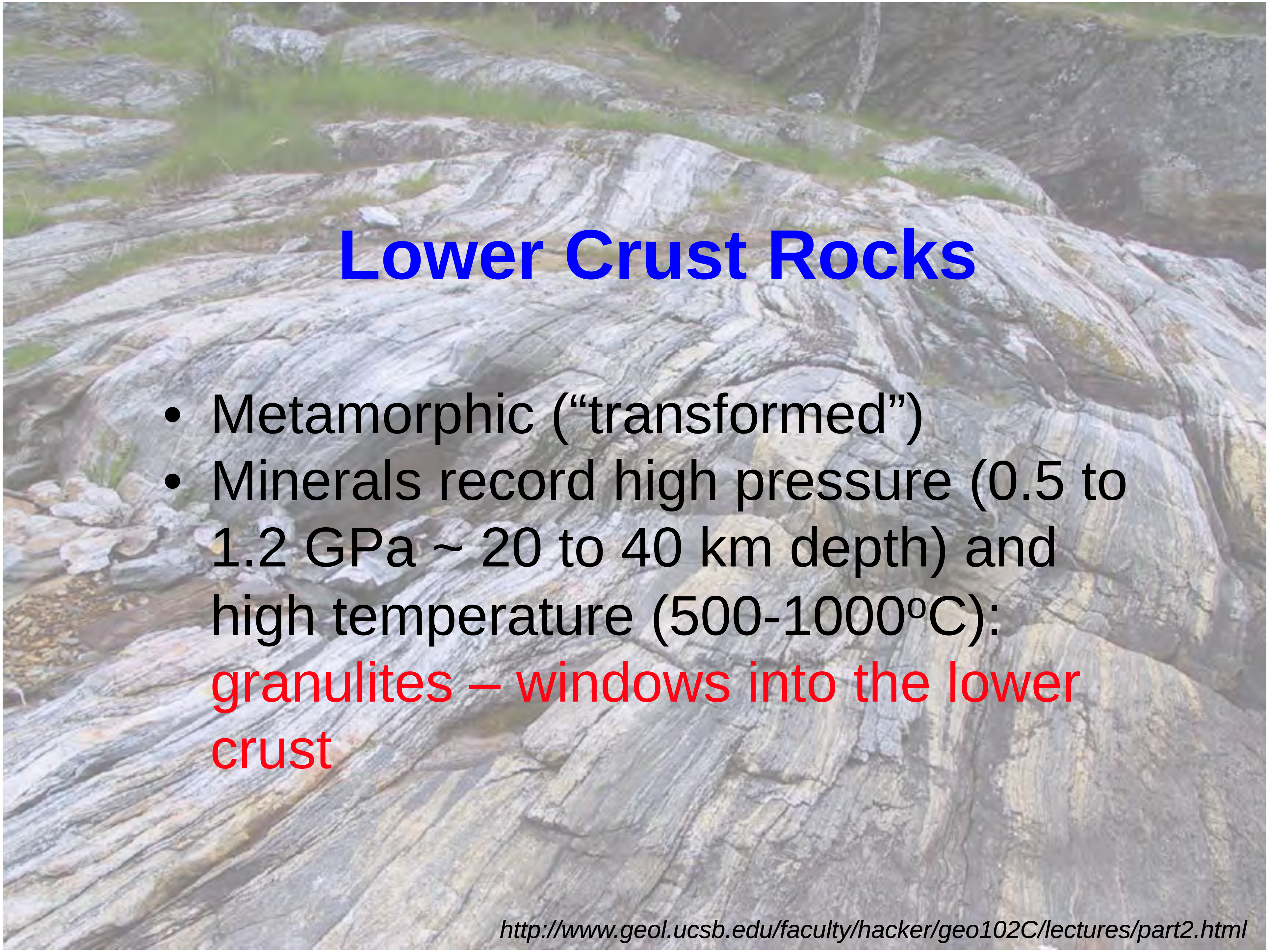
- Rocks weather
- Soluble elements washed into oceans (salty)
- *Insoluble* elements deposited in shales/loess



Mancos Shale, Utah, photo USGS

Seismic cross section through Central Pyrenees





Lower Crust Rocks

- Metamorphic (“transformed”)
- Minerals record high pressure (0.5 to 1.2 GPa ~ 20 to 40 km depth) and high temperature (500-1000^{o}C): granulites – windows into the lower crust

http://www.geol.ucsb.edu/faculty/hacker/geo102C/lectures/part2.html

Two sources of granulites

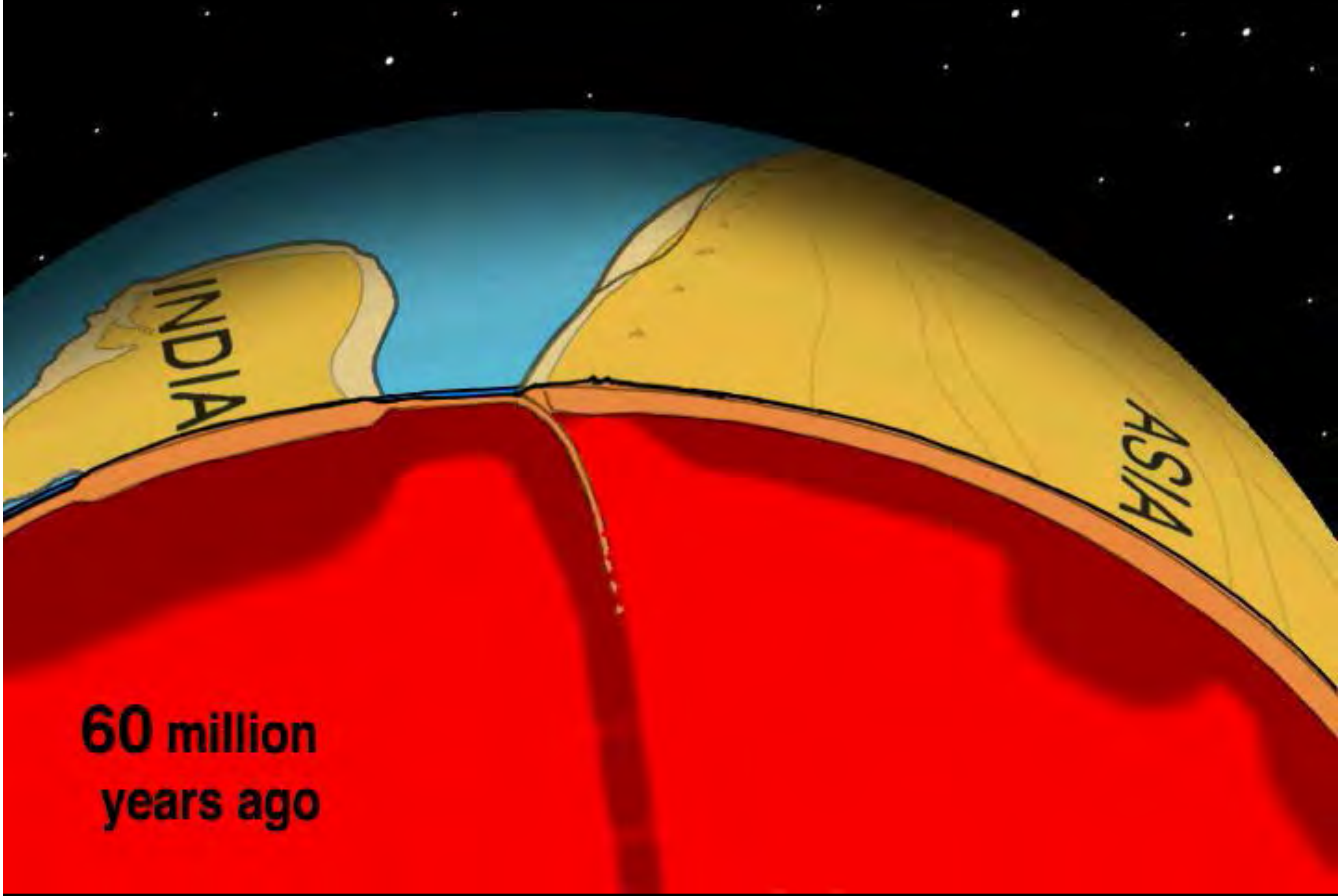
Granulite Terrains

Rocks formed at 20-40 km depth, tectonically uplifted during continent-continent collision

Granulite Xenoliths

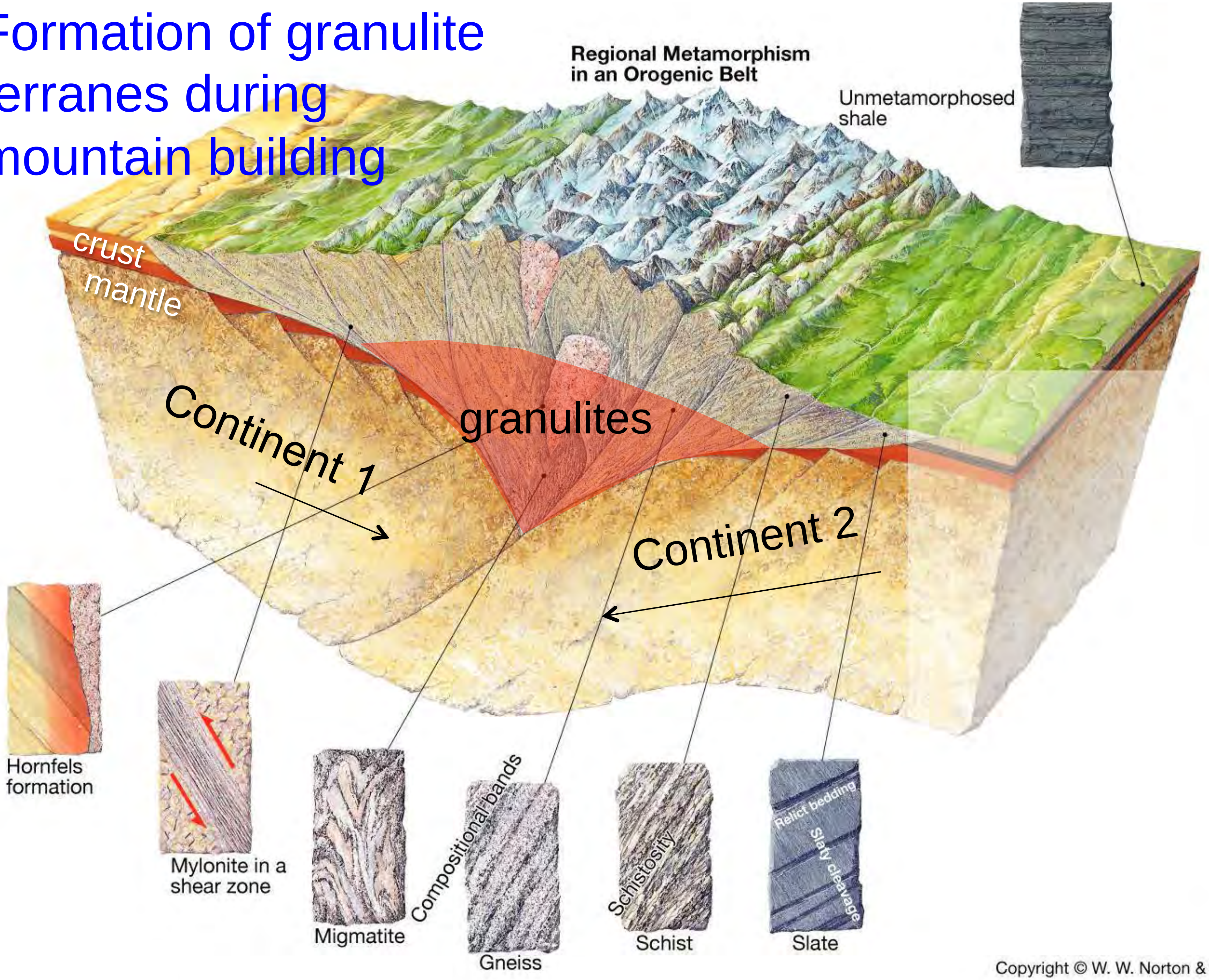
"foreign" rock fragments carried by magmas "poor man's drill core"

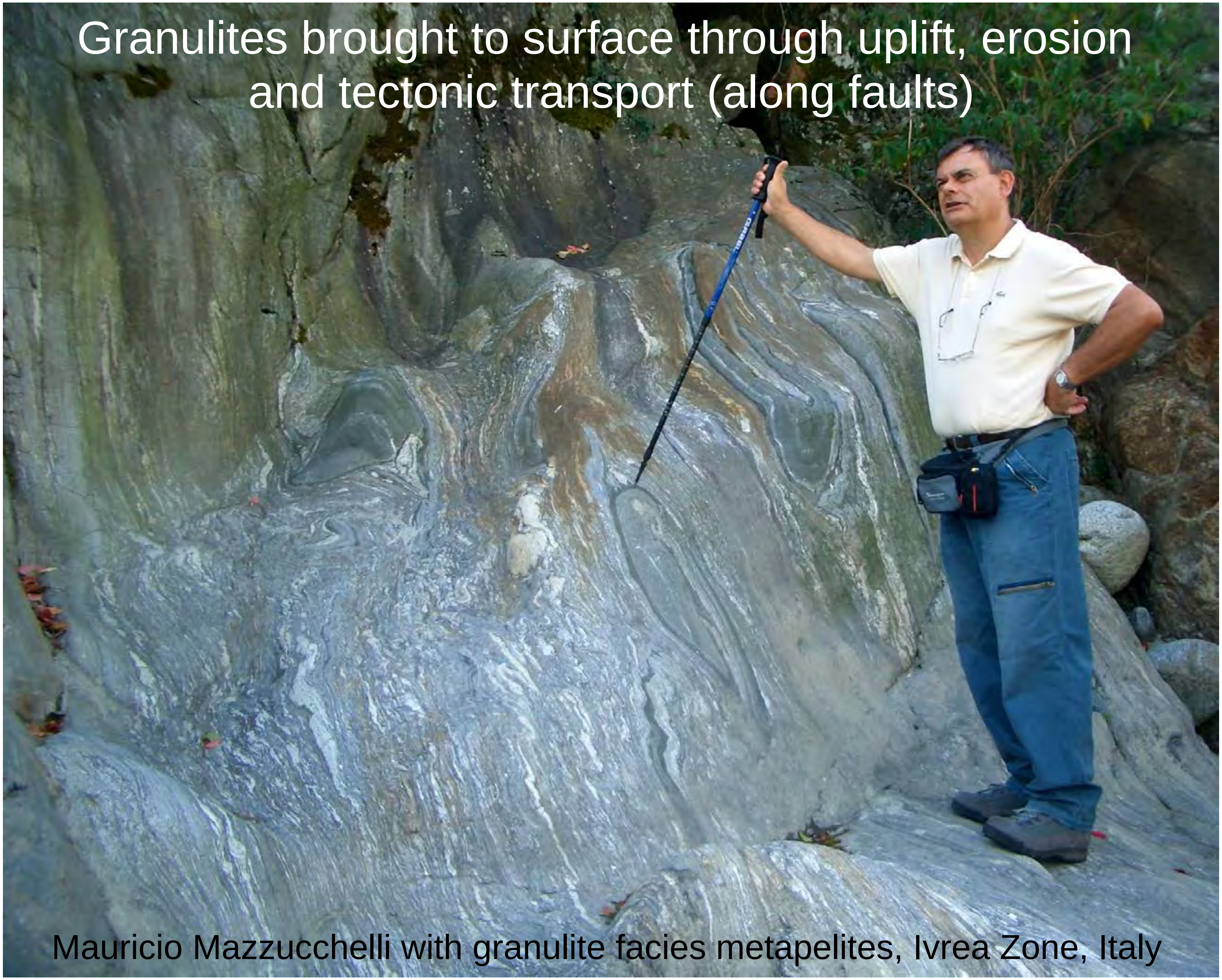
Continents Colliding



Animations courtesy T. Atwater, UCSB *http://emvc.geol.ucsb.edu/*

Formation of granulite terranes during mountain building



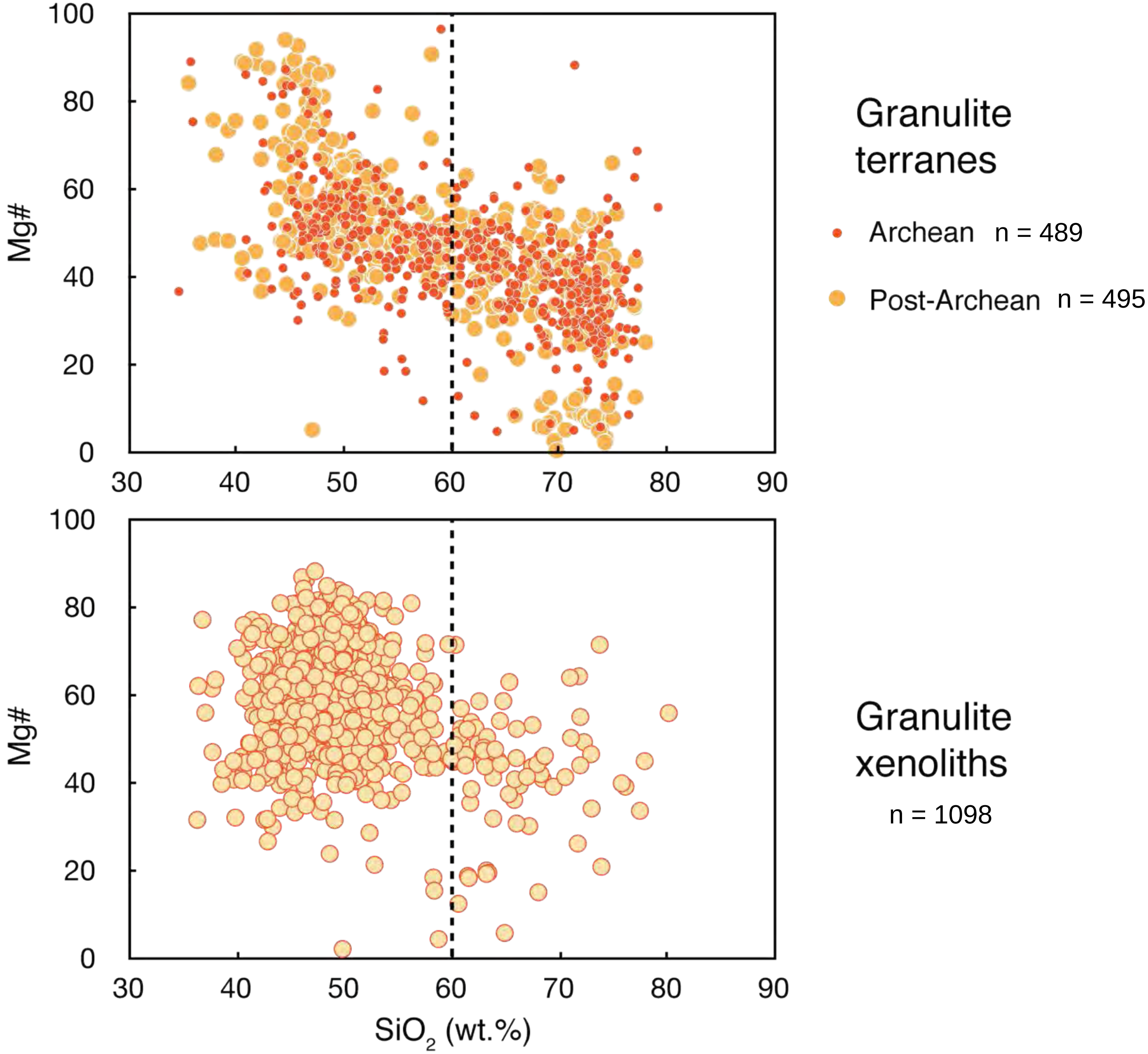

Granulites brought to surface through uplift, erosion and tectonic transport (along faults)
Mauricio Mazzucchelli with granulite facies metapelites, Ivrea Zone, Italy

The great xenolith hunt

Prof. Shukrani Manya, Univ. Dar es

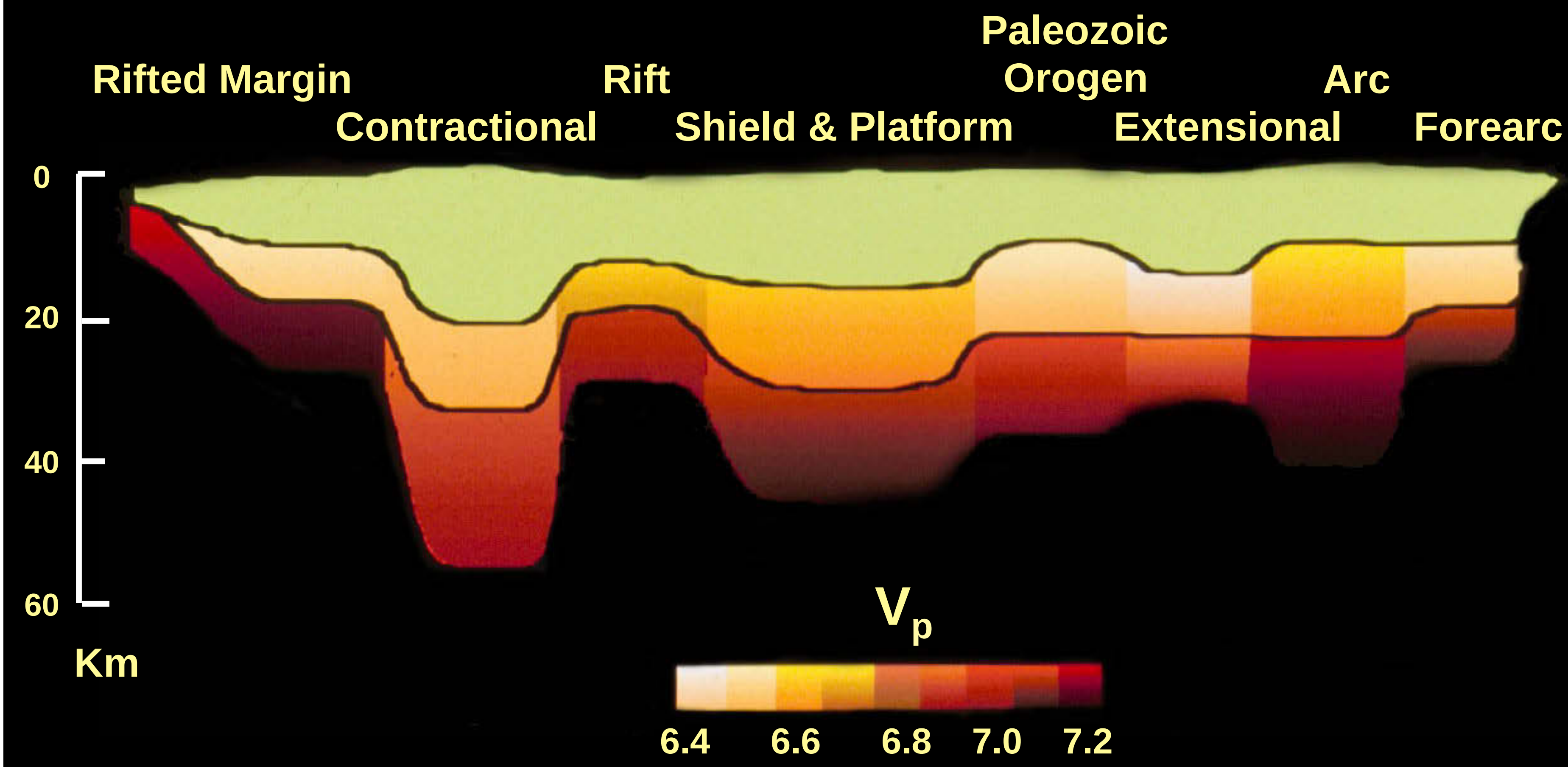
Bill McDonough, Queensland, Australia

rofs. Gao and Wu, Shanxi, China



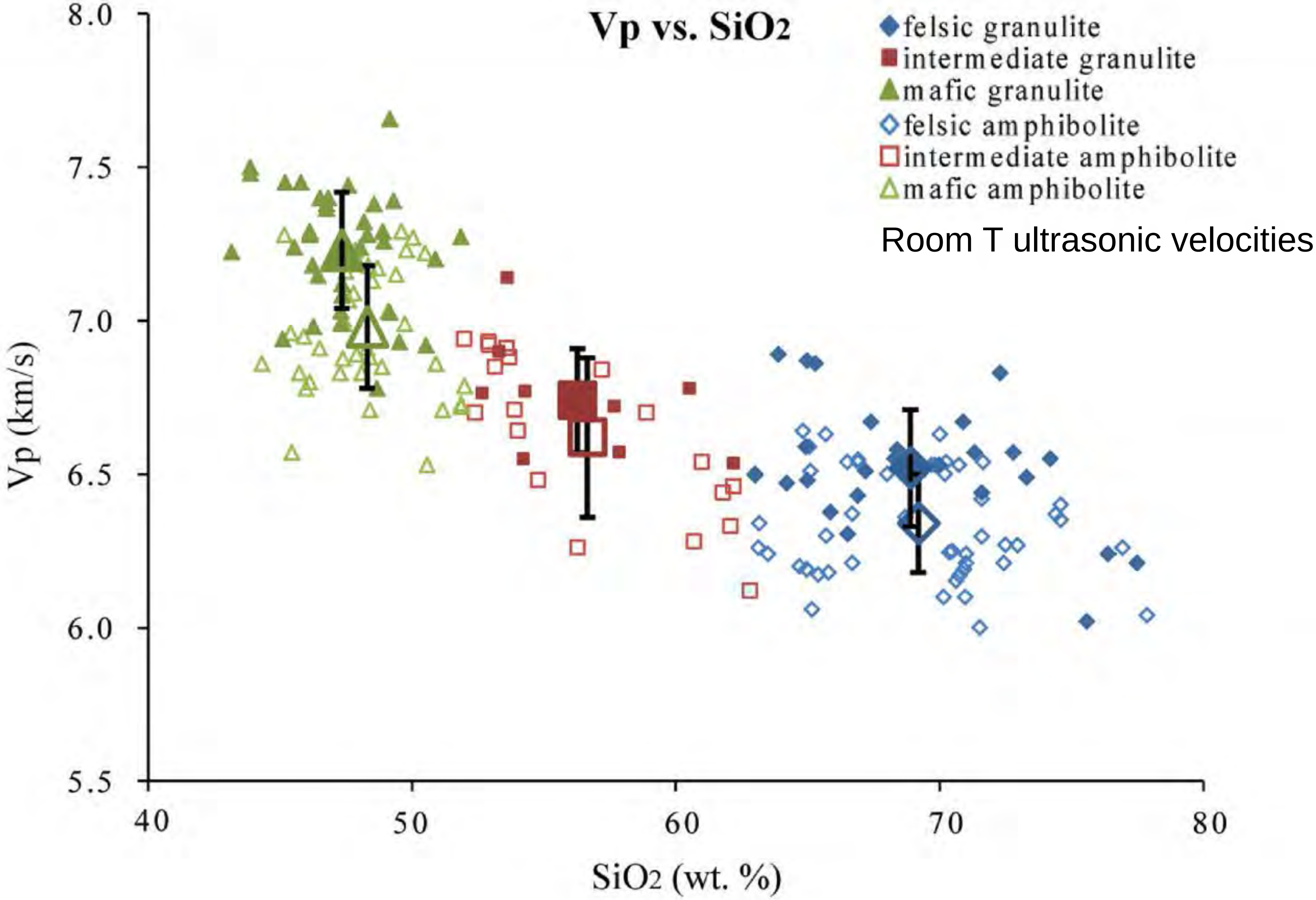
Mg#
SiO2 (wt.%)
Granulite terranes
Archean n = 489
Post-Archean n = 495
Granulite xenoliths
n = 1098

Middle and Lower Crust -- Seismic evidence



From Rudnick & Fountain, 1995

Remote sensing of lower crust from seismic waves



Huang et al., 2013

Composition of the Continental Crust

	Christensen & Mooney 1995	Rudnick & Fountain 1995	Wedepohl 1995	Taylor & McLennan 1985, 1995	Rudnick & Gao, 2003	Hacker et al., 2011
SiO_2	62.4	60.1	62.8	57.1	60.6	65.2
TiO_2	0.9	0.7	0.7	0.9	0.7	0.7
Al_2O_3	14.9	16.1	15.4	15.9	15.9	15.0
FeO_T	6.9	6.7	5.7	9.1	6.7	5.8
MnO	0.1	0.1	0.1	0.2	0.1	0.1
MgO	3.1	4.5	3.8	5.3	4.7	2.5
CaO	5.8	6.5	5.6	7.4	6.4	3.4
Na_2O	3.6	3.3	3.3	3.1	3.1	3.0
K_2O	2.1	1.9	2.7	1.3*	1.8	1.9
P_2O_5	0.20	0.20			0.13	0.10
Mg#	44.8	54.3	54.3	50.9	55.3	44.0

**Updated by McLennan and Taylor, 1996*

Composition of the Continental Crust

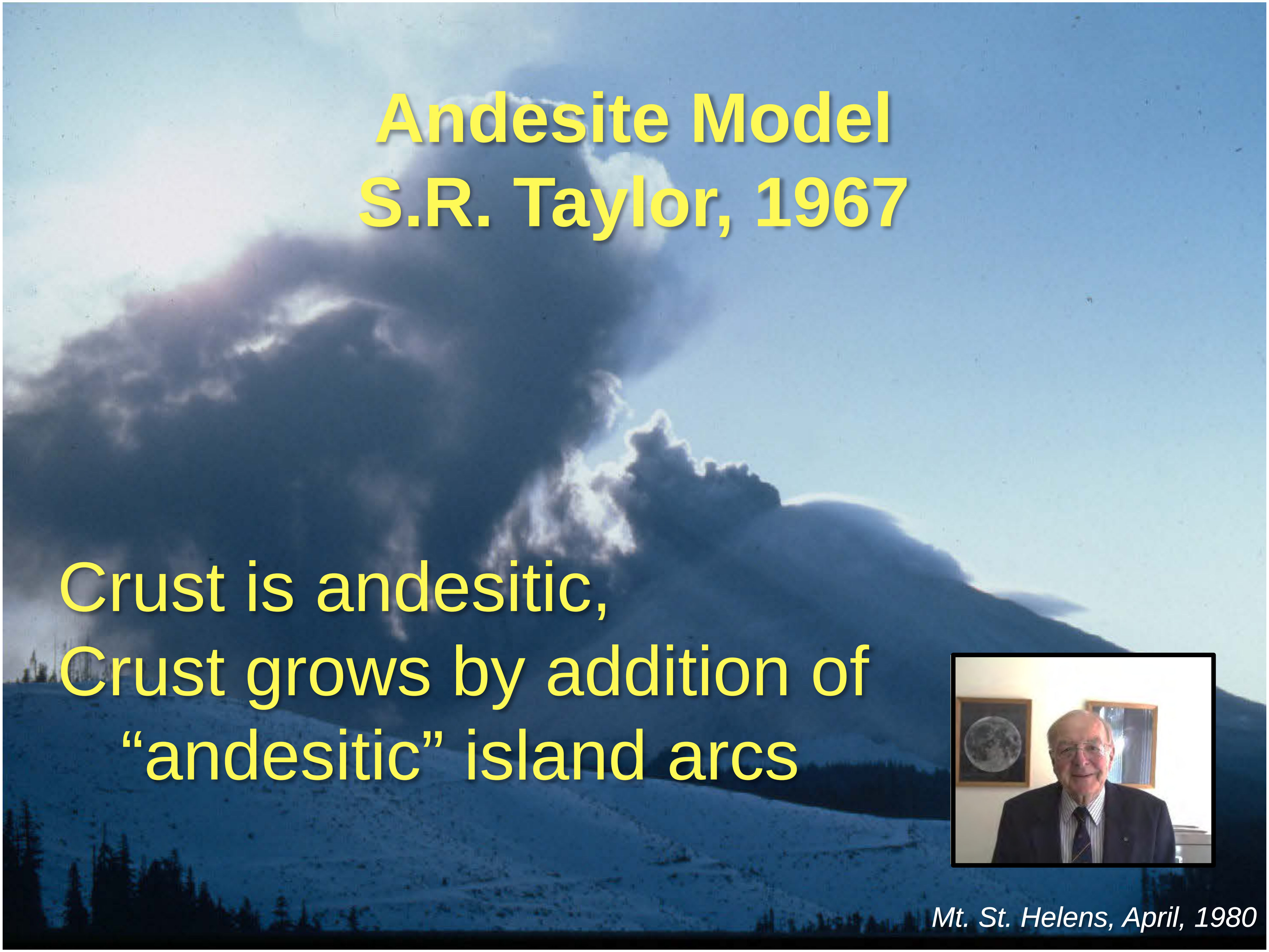
	Rudnick & Gao, 2003	Clarke 1889*
SiO_2	60.6	60.2
TiO_2	0.7	0.57
Al_2O_3	15.9	15.27
FeO_T	6.7	7.26
MnO	0.10	0.10
MgO	4.7	4.59
CaO	6.4	5.45
Na_2O	3.1	3.29
K_2O	1.8	2.99
P_2O_5	0.13	0.23
Mg#	55.3	53.0

F.W. Clarke, 1847-1931

**Frank Wigglesworth Clarke, Phil. Soc. Washington Bull. Vol. XI pp. 131-142*

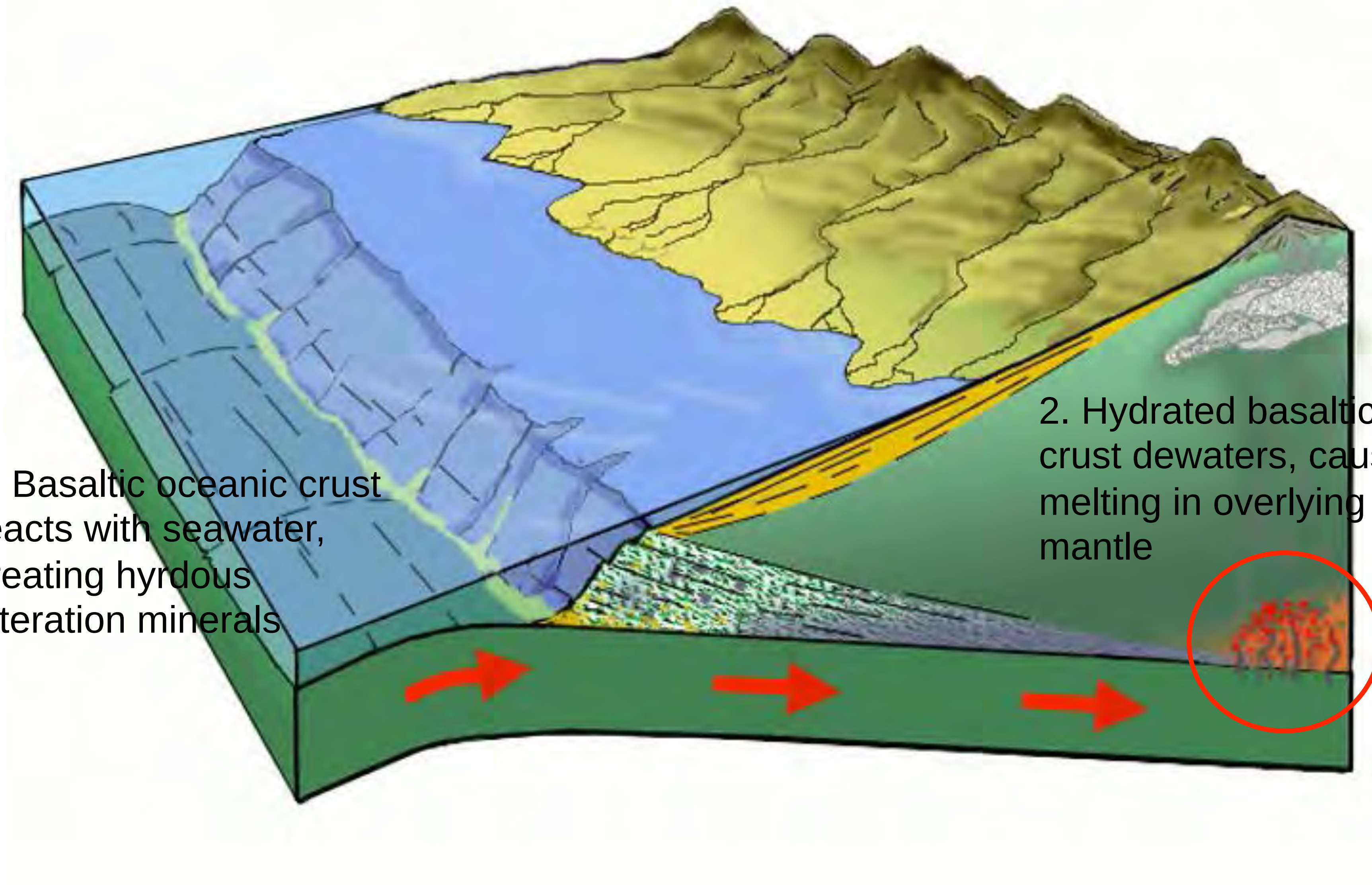
Andesite Model
S.R. Taylor, 1967

Crust is andesitic,
Crust grows by addition of "andesitic" island arcs



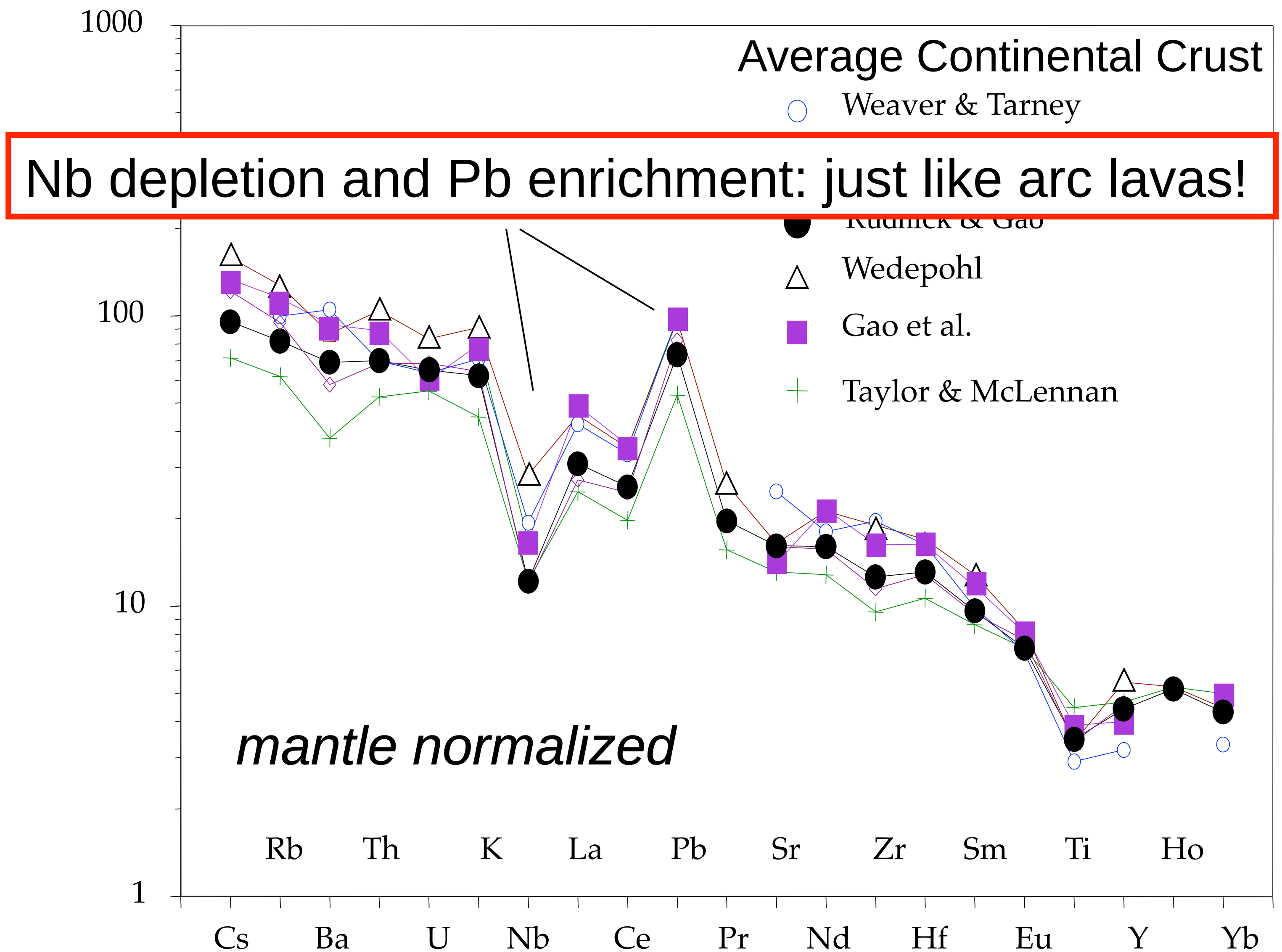
Mt. St. Helens, April, 1980

Island Arc



Animations courtesy T. Atwater, UCSB http://emvc.geol.ucsb.edu/

‘DNA’ elements reveal where crust forms



The problem with andesite

- Can't melt mantle and make andesite
- Basalt forms by mantle melting

How did basalt become andesite?