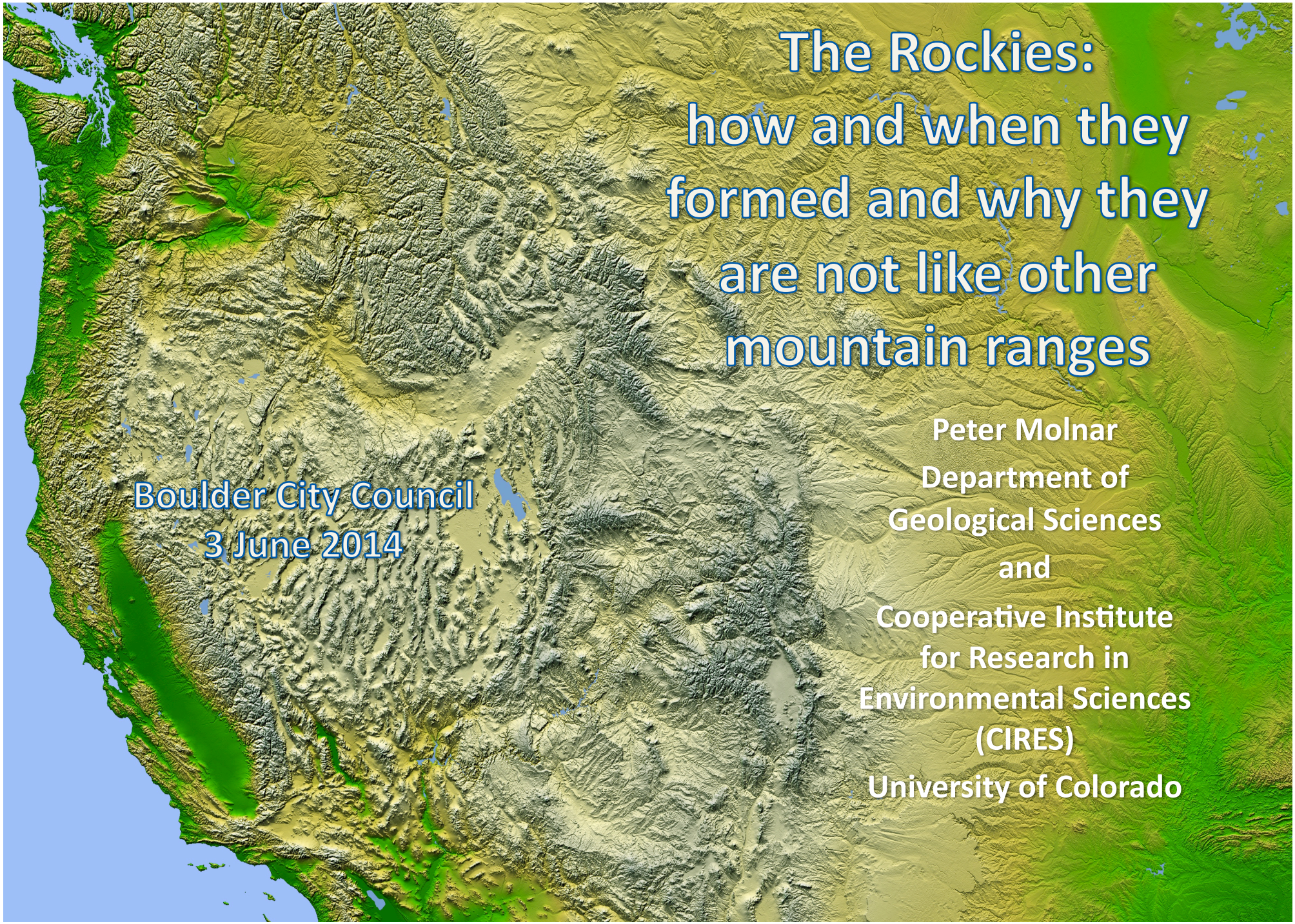

The Rockies: how and when they formed and why they are not like other mountain ranges

Boulder City Council
3 June 2014

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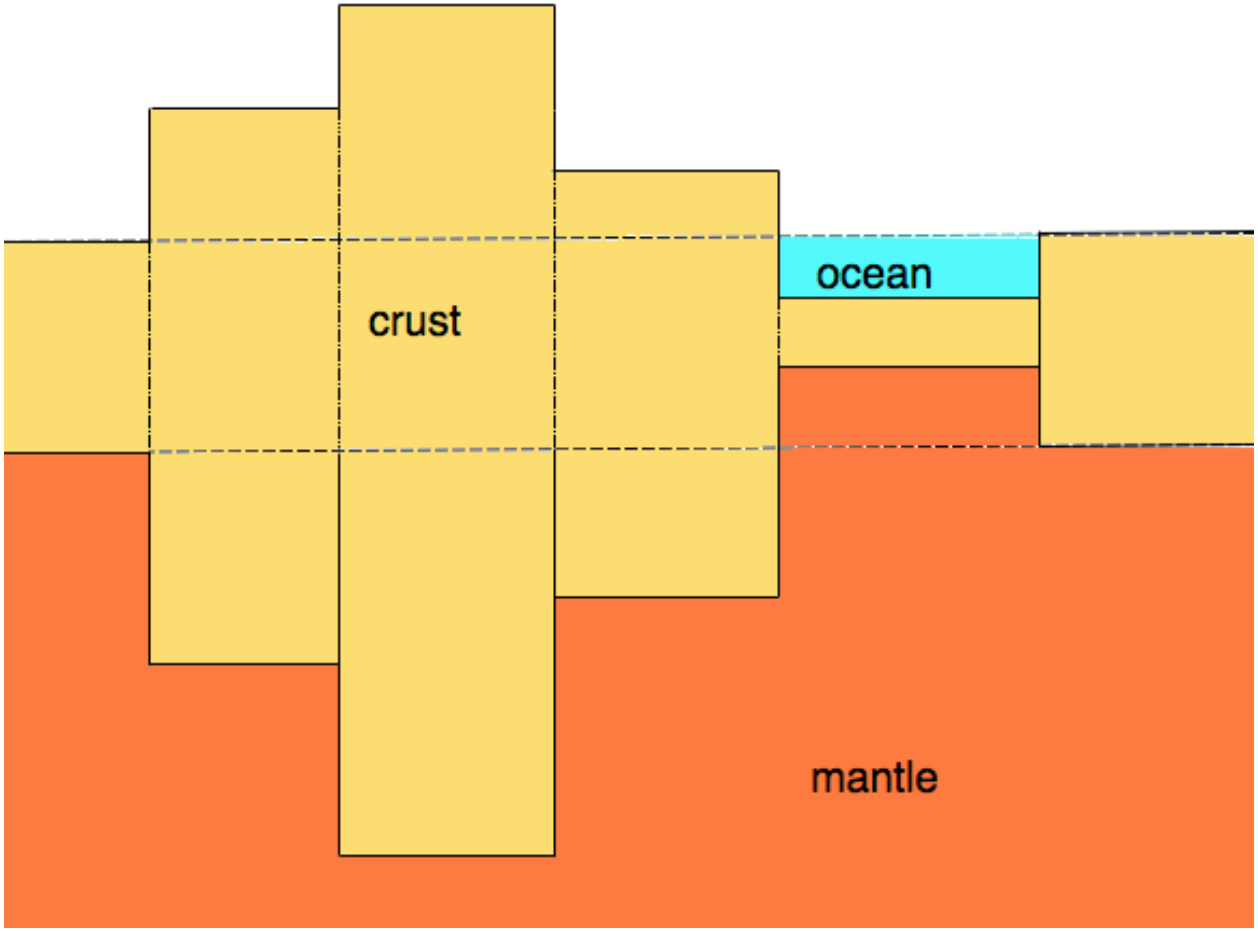
Department of Geological Sciences
and
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado

Archimedes' Principle: applied to icebergs

http://www.accuweather.com/en/weather-news/icebergs-still-a-threat-100-ye/63626

Isostasy: Archimedes' Principle applied to the Earth's lighter crust over its heavier mantle

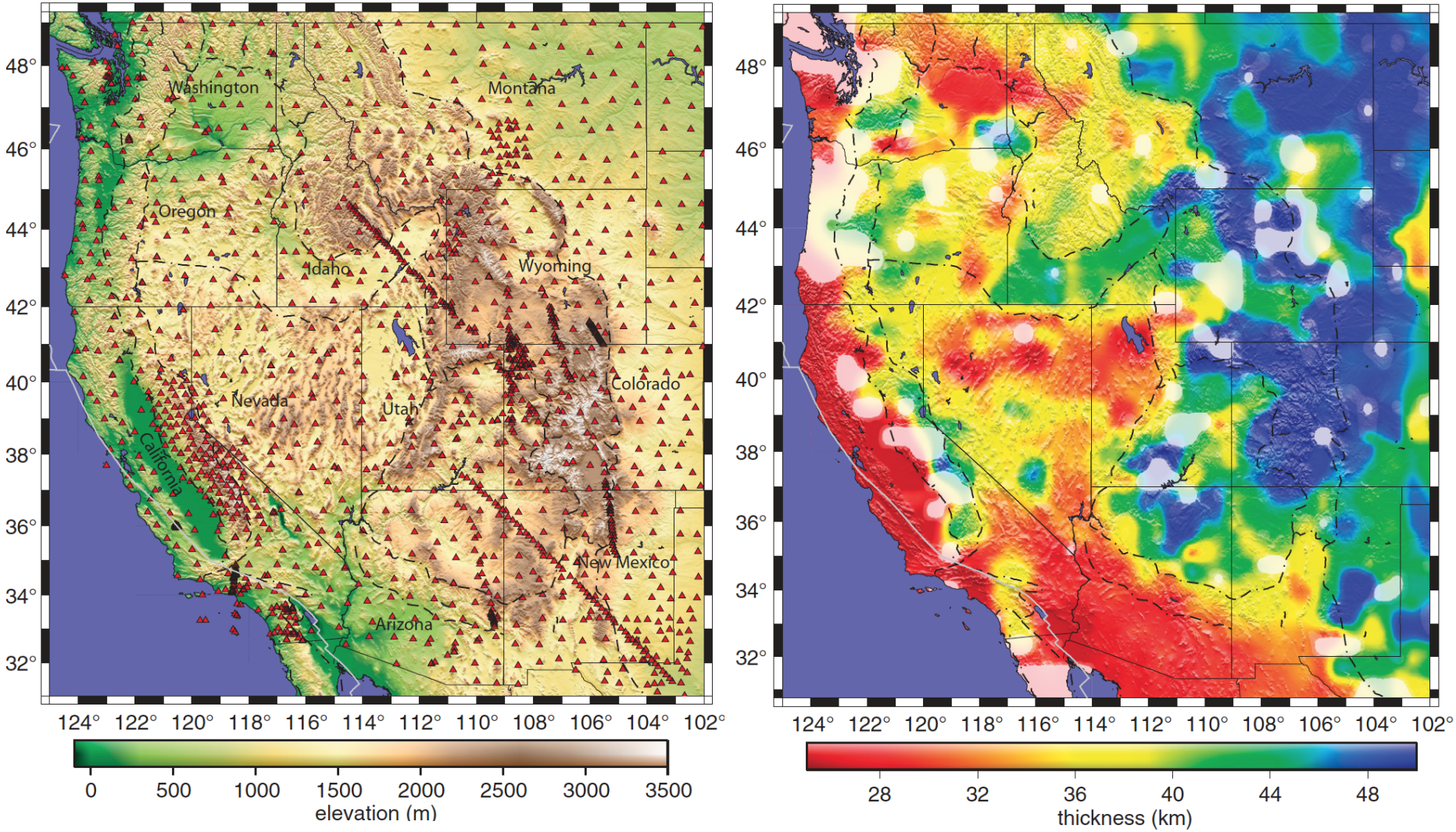


Densities:
Water: 1.0 g/cc
Crust 2.8 g/cc
Mantle 3.3 g/cc

http://deepearthscience.blogspot.com/2013/09/regional-isostasy-supporting-volcano.html

Western United States: Crustal Thickness

Crustal thickness does not mirror topography



From Gilbert [2012], built on work of **Gilbert and Sheehan** [2004] and **Sheehan** et al. [1995]

Western United States: Crustal Thickness

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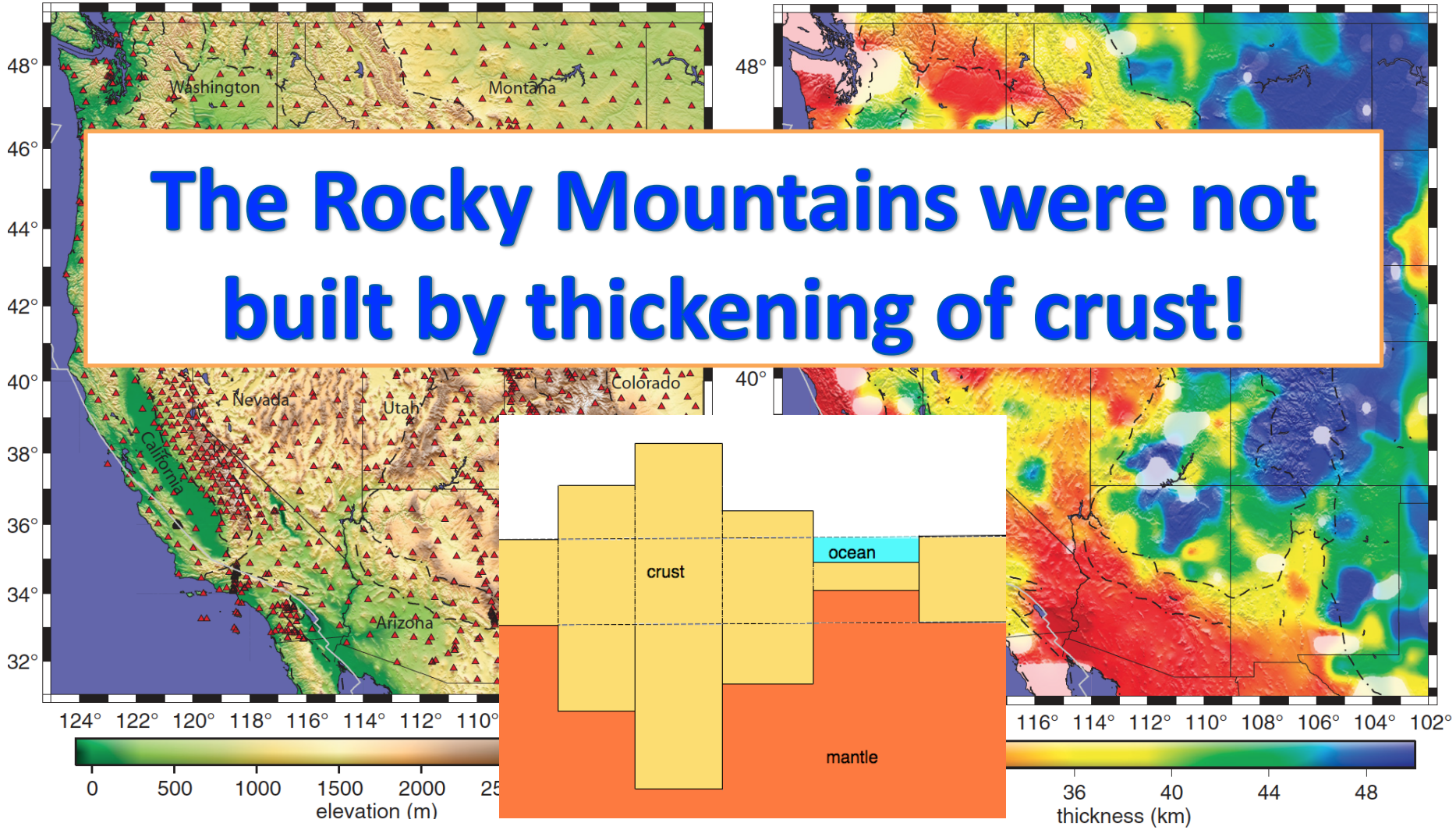
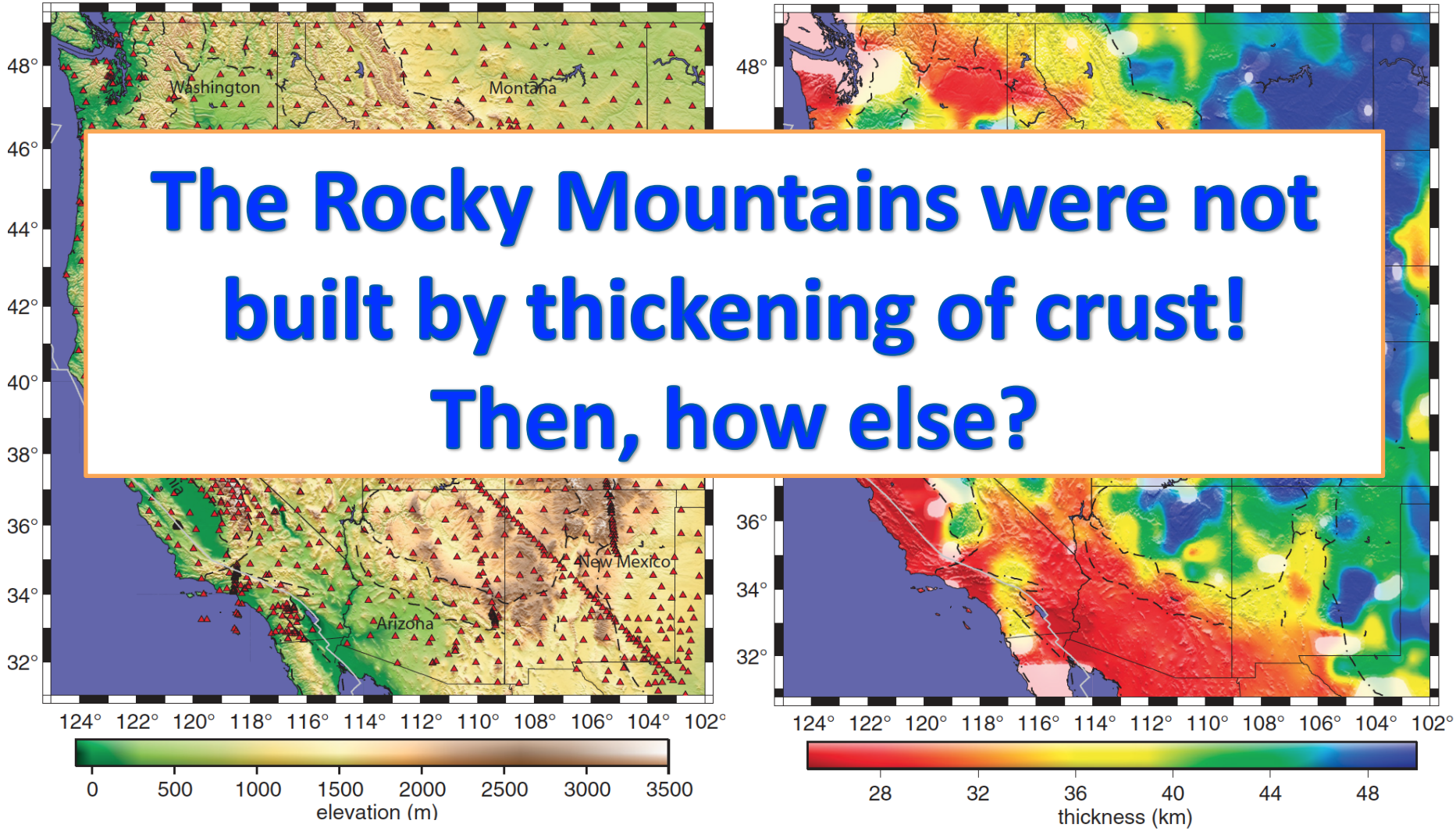


The Rocky Mountains were not built by thickening of crust!

From Gilbert [2012], built on work of **Gilbert and Sheehan** [2004] and **Sheehan** et al. [1995]

Western United States: Crustal Thickness

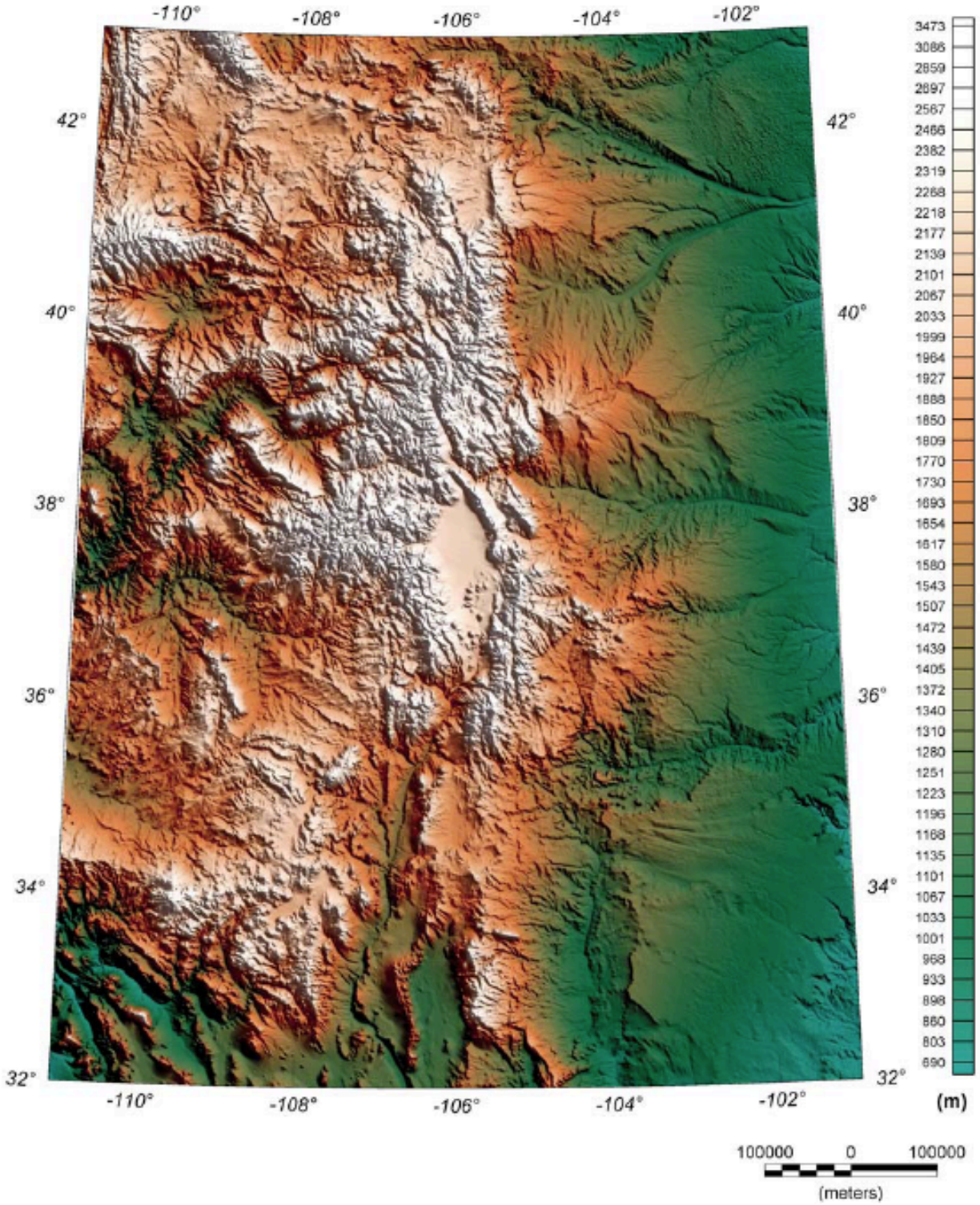
Crustal thickness does not mirror topography



The Rocky Mountains were not built by thickening of crust!

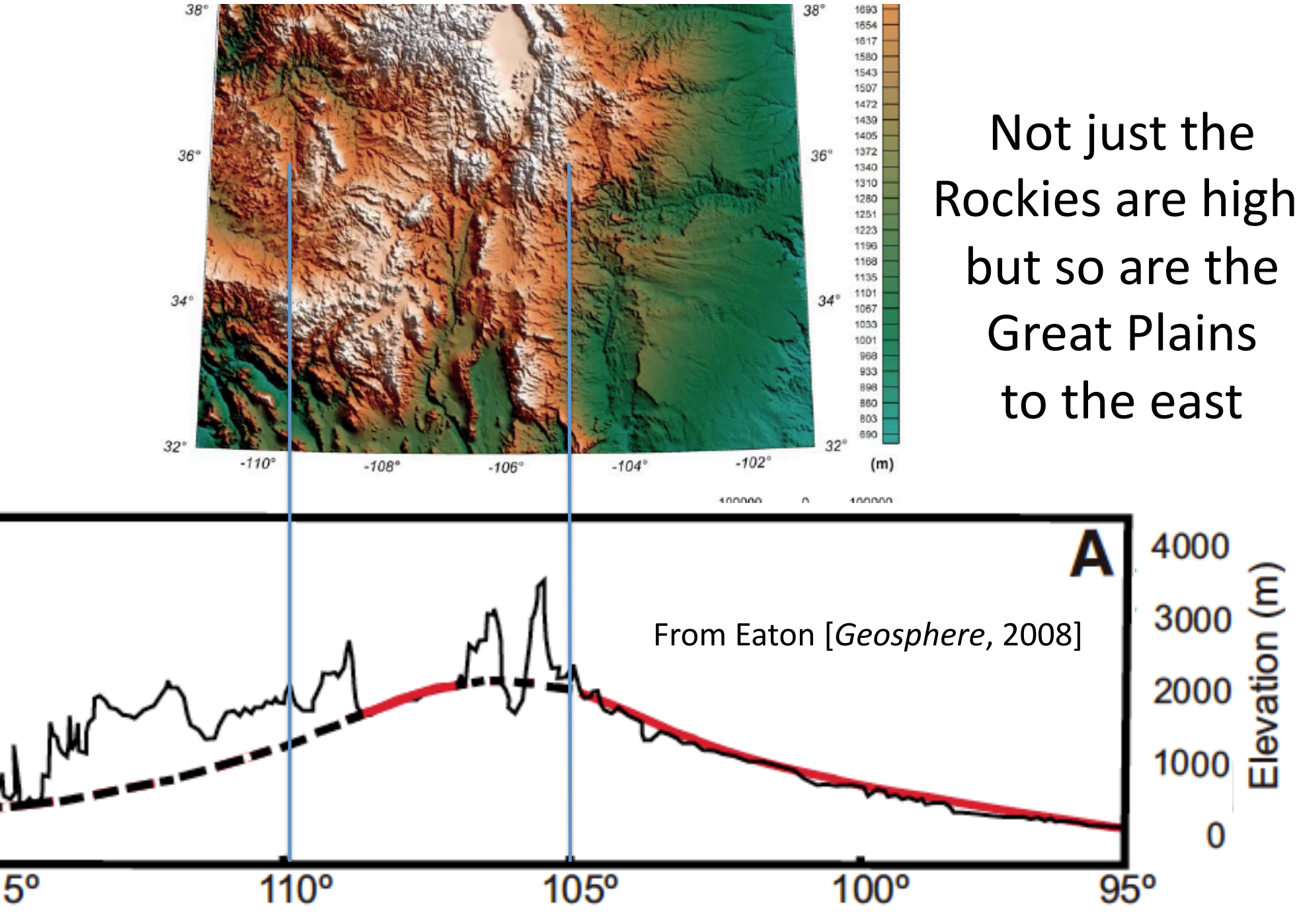
Then, how else?

From Gilbert [2012], built on work of **Gilbert and Sheehan** [2004] and **Sheehan** et al. [1995]



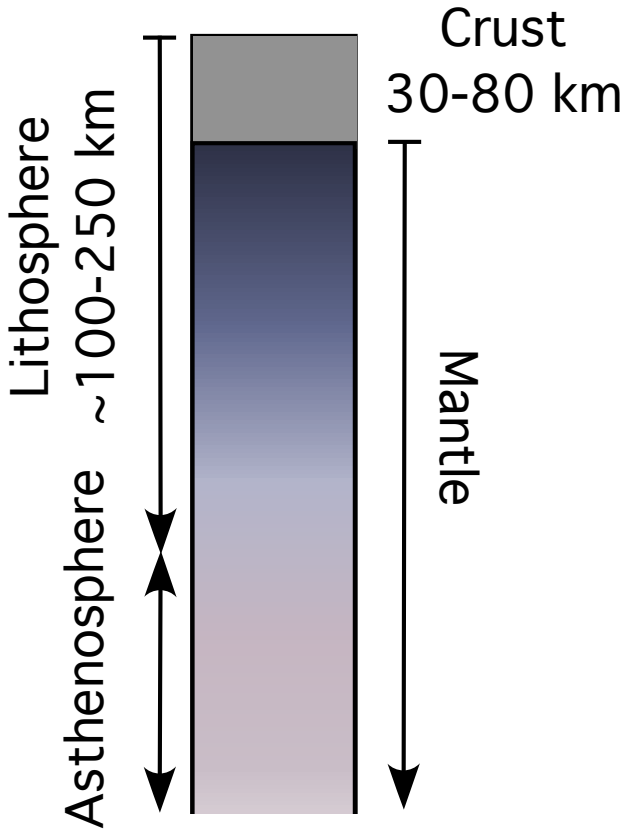
A closer look at the Rockies in and near Colorado

From Eaton [*Geosphere*, 2008]



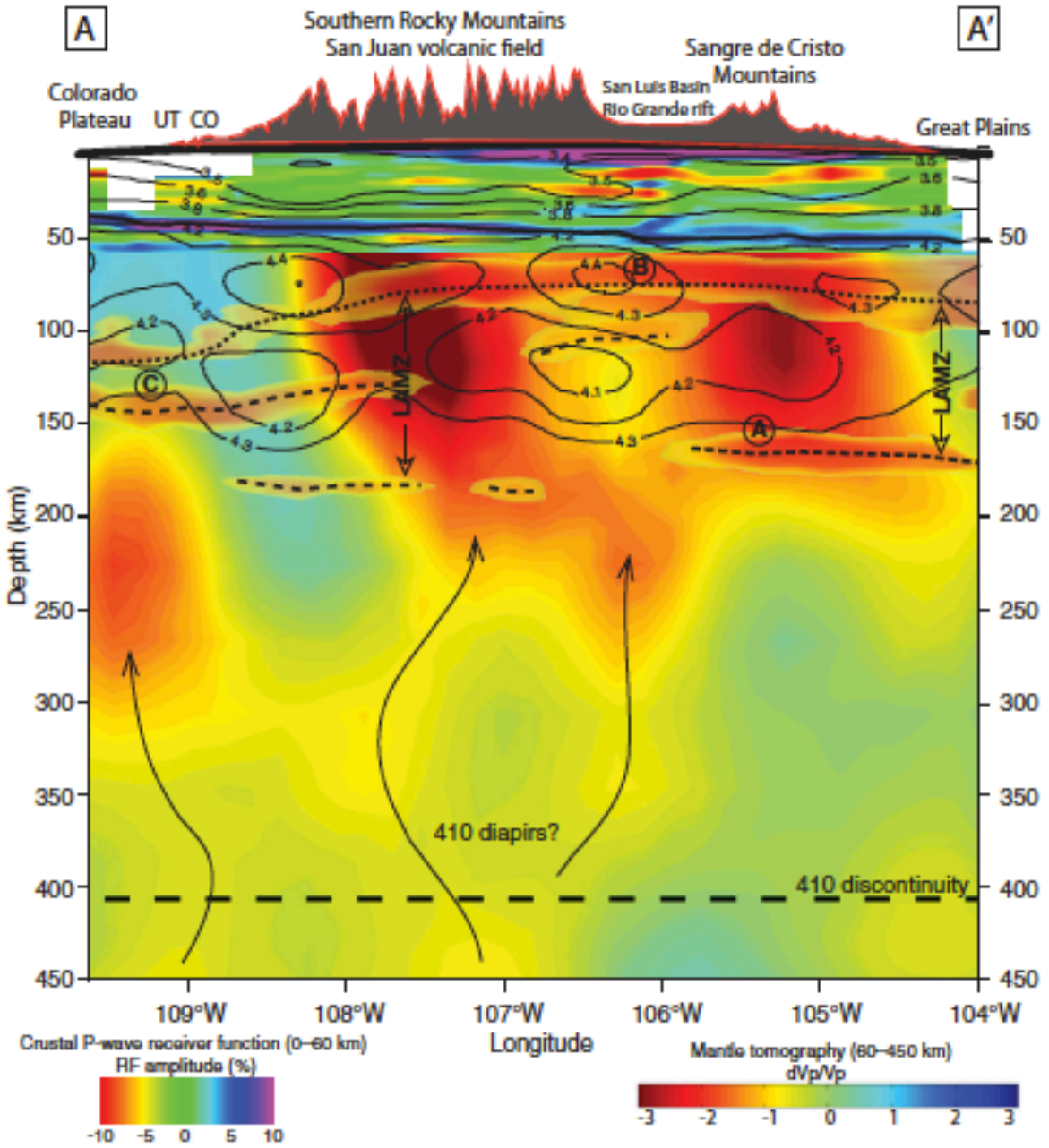
Not just the Rockies are high, but so are the Great Plains to the east

Simple structure of the upper few hundred kilometers of the Earth



Crust is less dense than **Mantle.**

Lithosphere is colder, and therefore stronger and slightly denser, than **Asthenosphere**



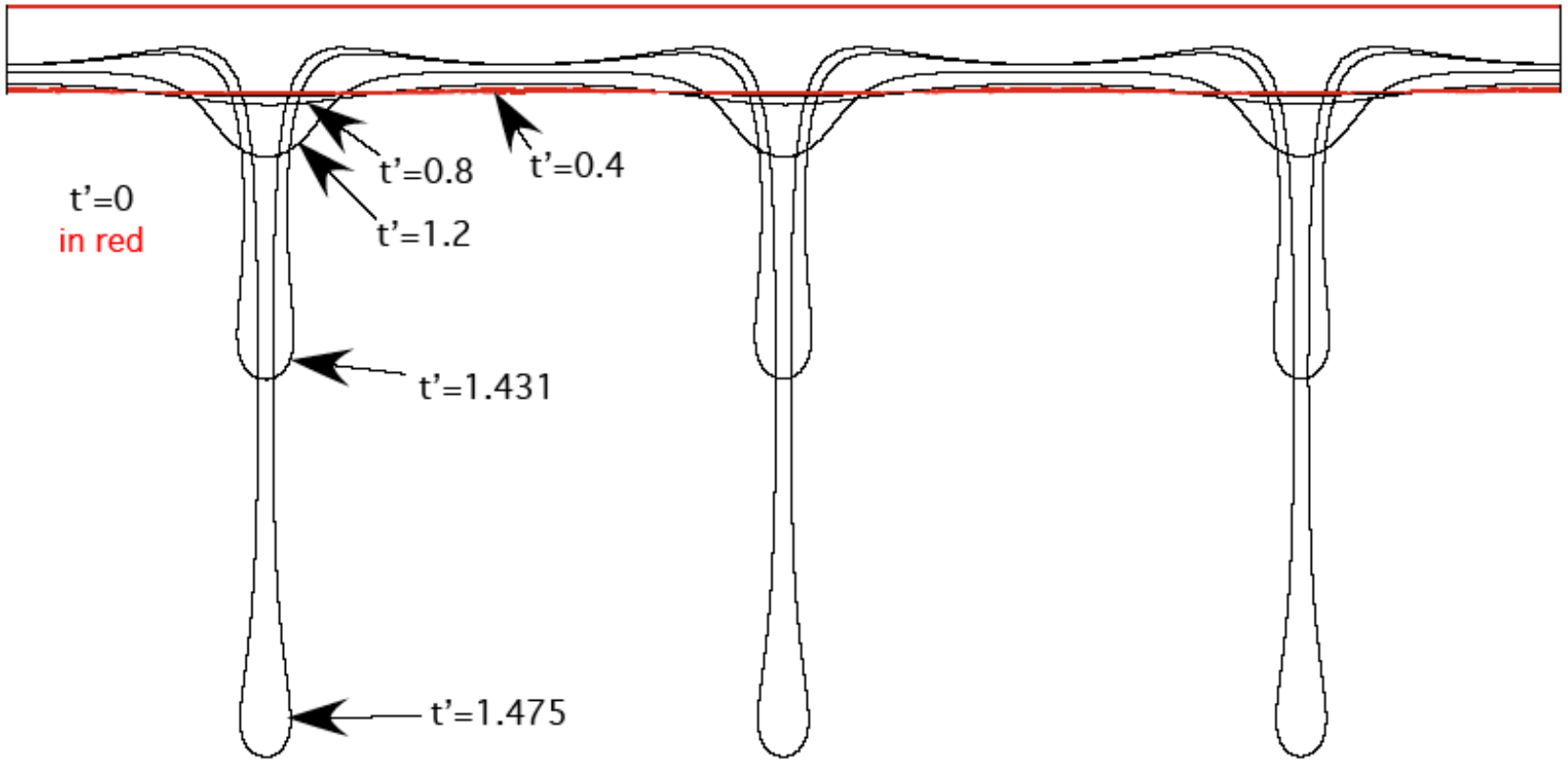
[Karlstrom et al., 2012]

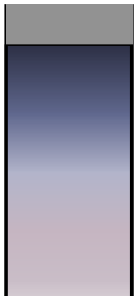
A **hot**, *thermally expanded* uppermost mantle underlies, and *buoys up*, the Rockies

Rayleigh-Taylor Instability

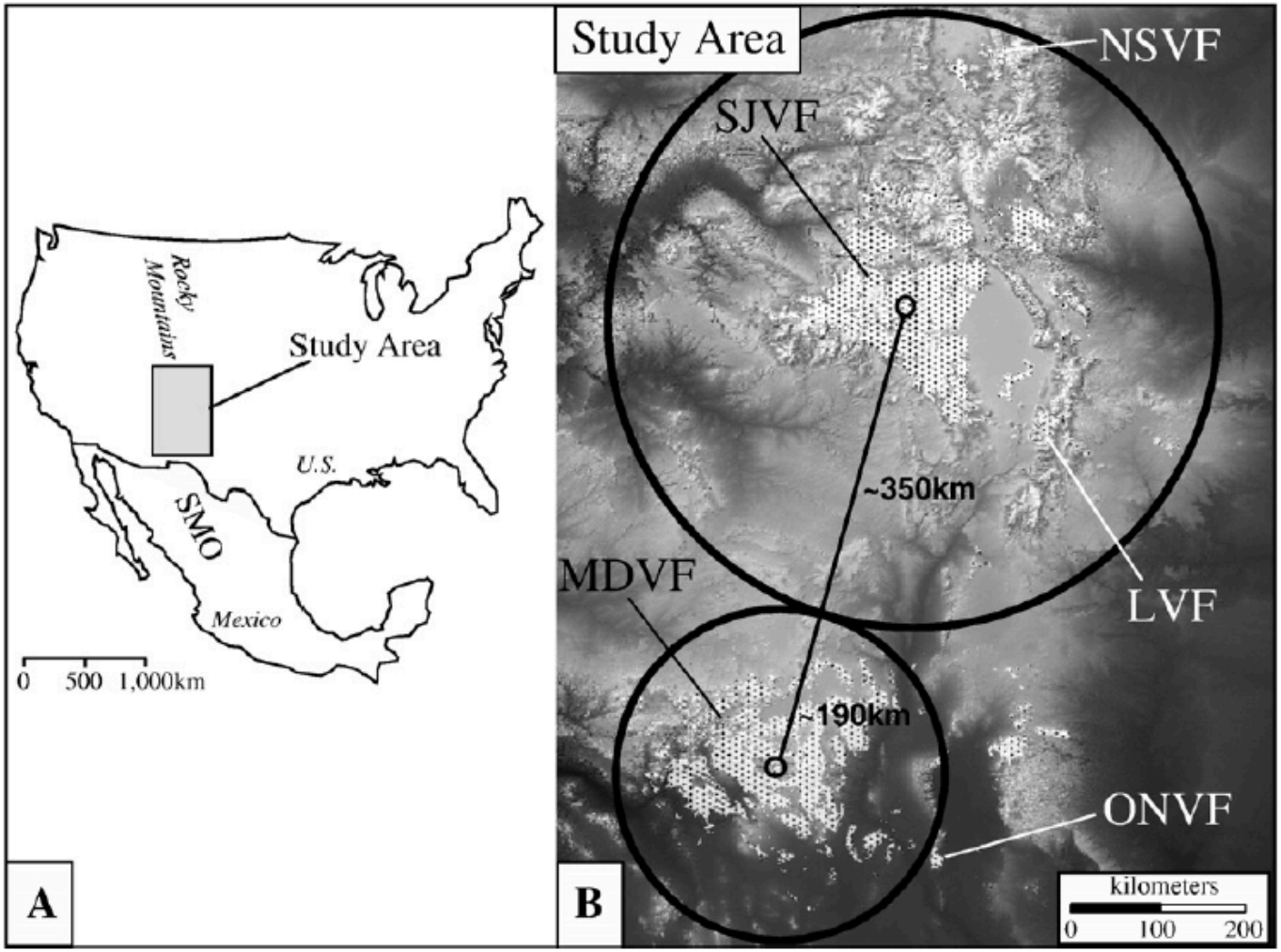
(Heavy fluid-like layer over lighter one)

(*like paint dripping from a ceiling through less dense air*)





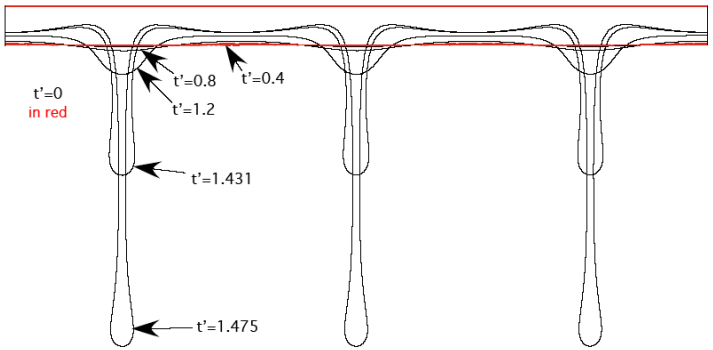
Melting of the mantle to produce the volcanic rock in the San Juan Mountains, 35 million years ago, required melting over a huge area, beneath the whole of the Southern Rocky Mountains.



From **Farmer, Bailey**, and Elkins-Tanton [2008]

Interim conclusion #1

The high terrain comprising the Rocky Mountains of Colorado and the western part of the Great Basin developed largely because (somehow) the mantle portion of the cold lithosphere was removed and replaced by hotter asthenosphere.



Interim conclusion #2

The Rocky Mountains of Colorado became high 35 million year ago, or maybe earlier.

Interim conclusion

The Rocky Mountains of Colorado became high 35 million year ago, or maybe earlier.

Can we test this idea?

Interim conclusion

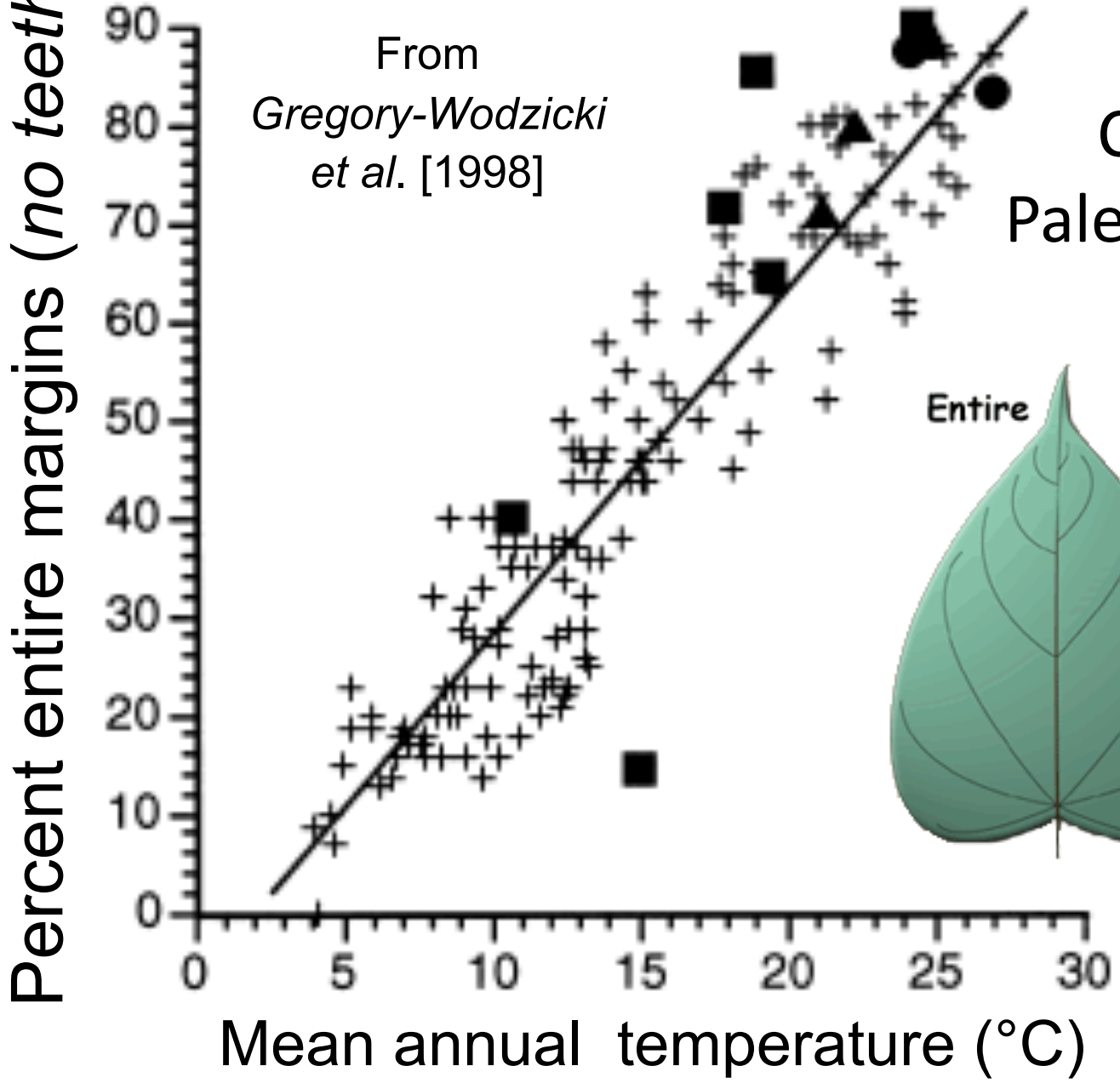
The Rocky Mountains of Colorado became high 35 million year ago, or maybe earlier.

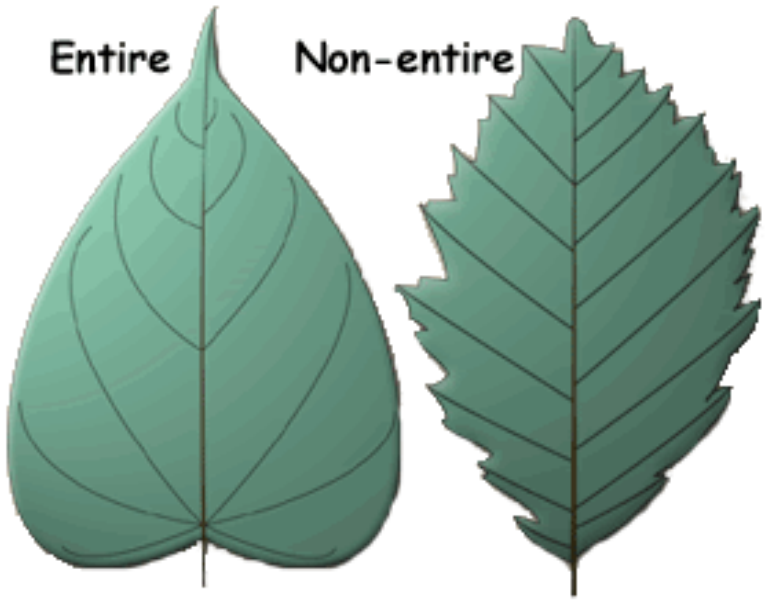
Can we test this idea?

Yes, using fossil leaves, like those from Florissant National Monument.

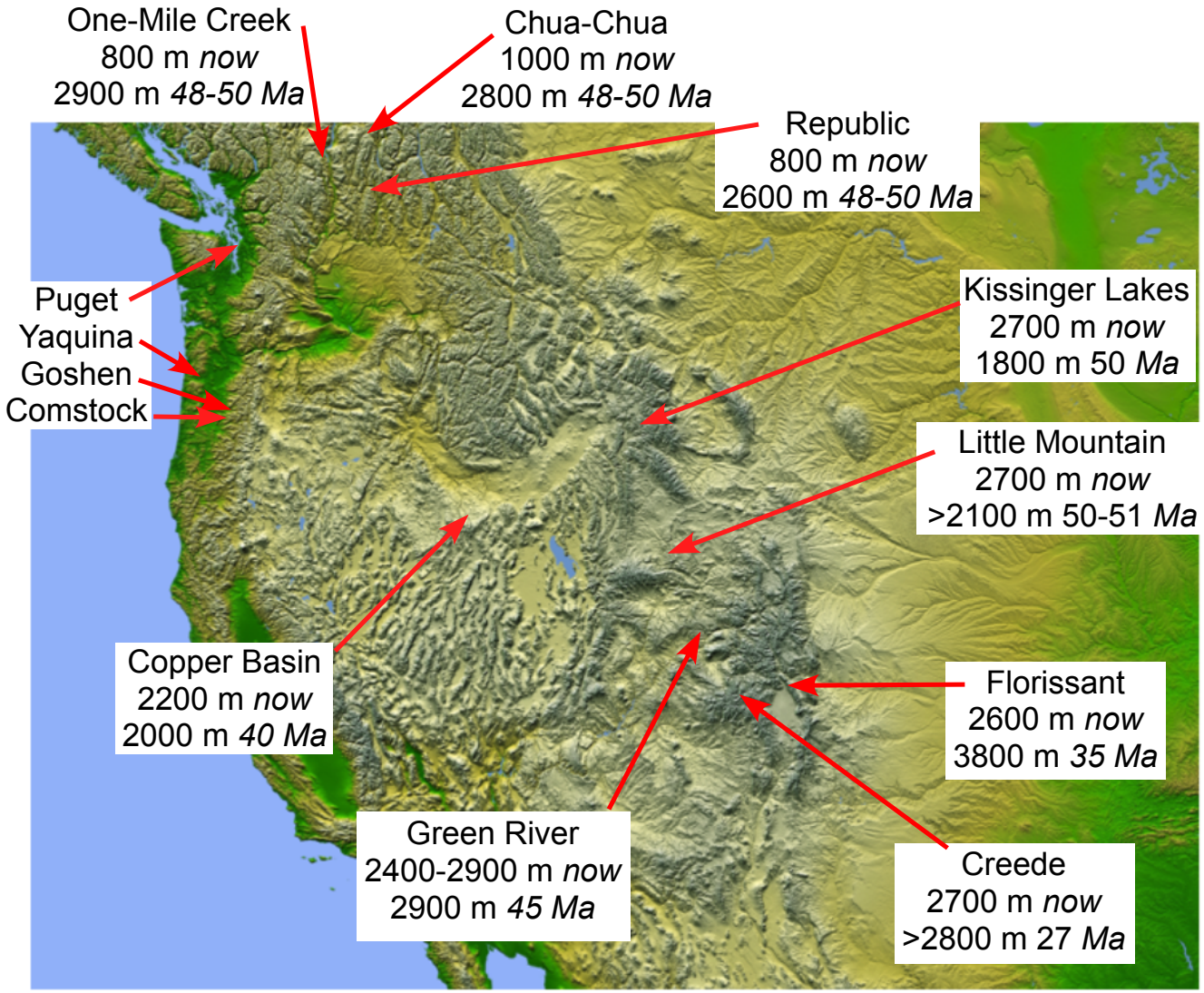
Leaf Physiognomy and Climate: Paleoaltimetry

From *Gregory-Wodzicki et al*. [1998]





http://www.nps.gov/flfo/forteachers/leaves-as-climate-indicators.htm



Nearly all fossil leaf localities in the Rockies were as high 25-50 million years ago as they are today.

The Controversy: many think that the Rockies rose recently, since 5, or even 2.5, million years ago.

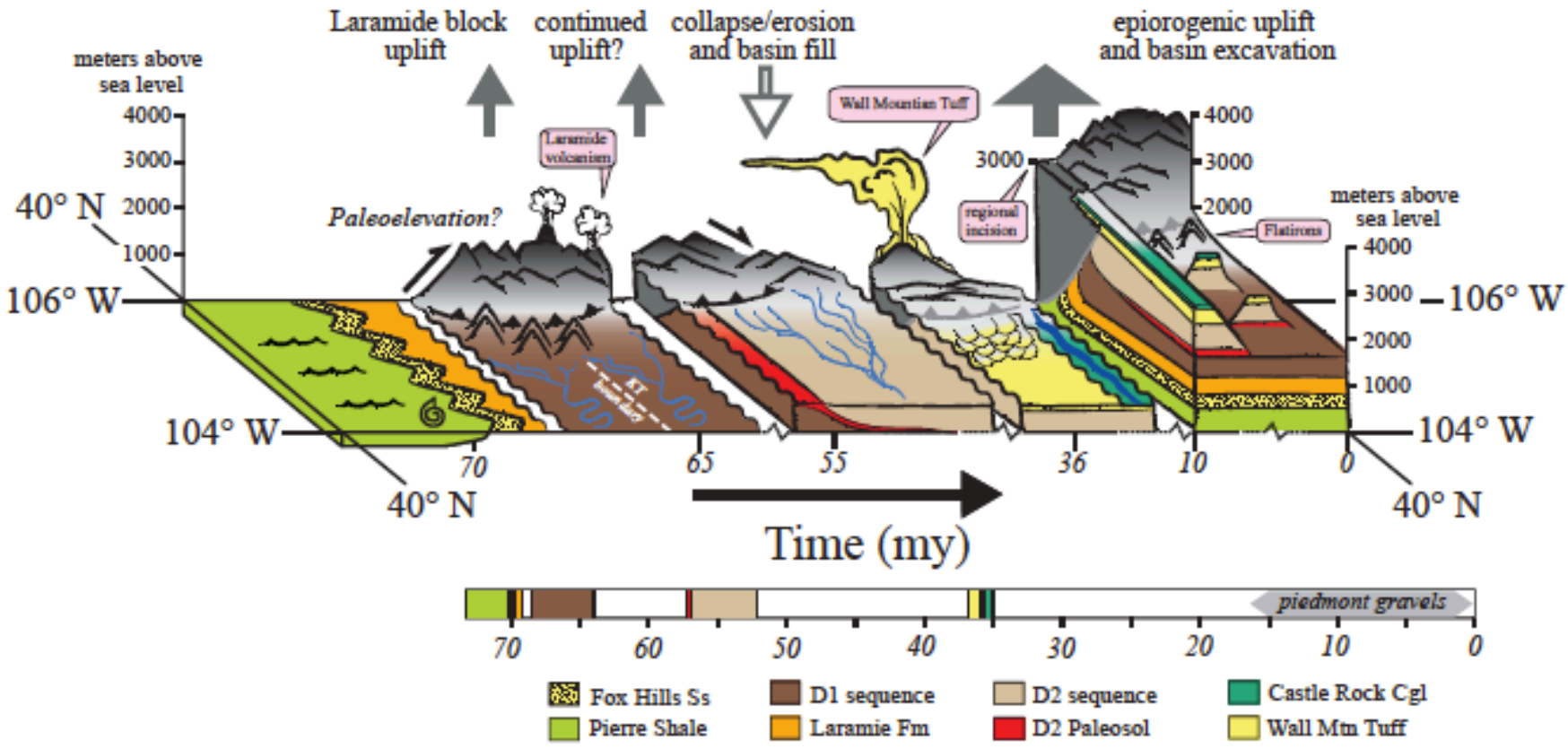
Northern Colorado (Izett, 1975, p. 184): "**Pliocene time [5-2.5 Ma]** ... was seemingly a time of **uplift** and **erosion**."

Front Range (Wahlstrom, 1947, p. 551): "Uplifts initiated in **late Pliocene of early Pleistocene** accelerated erosional processes which resulted in **deep dissection** of the **uplifted** surface during **later Pleistocene** to produce the **modern canyons** and valleys."

Southern Rocky Mountains (Tweto, 1975, p. 4): "Most of the altitude and relief ... resulted from … **uplift** and differential **erosion** in **late Tertiary time**."

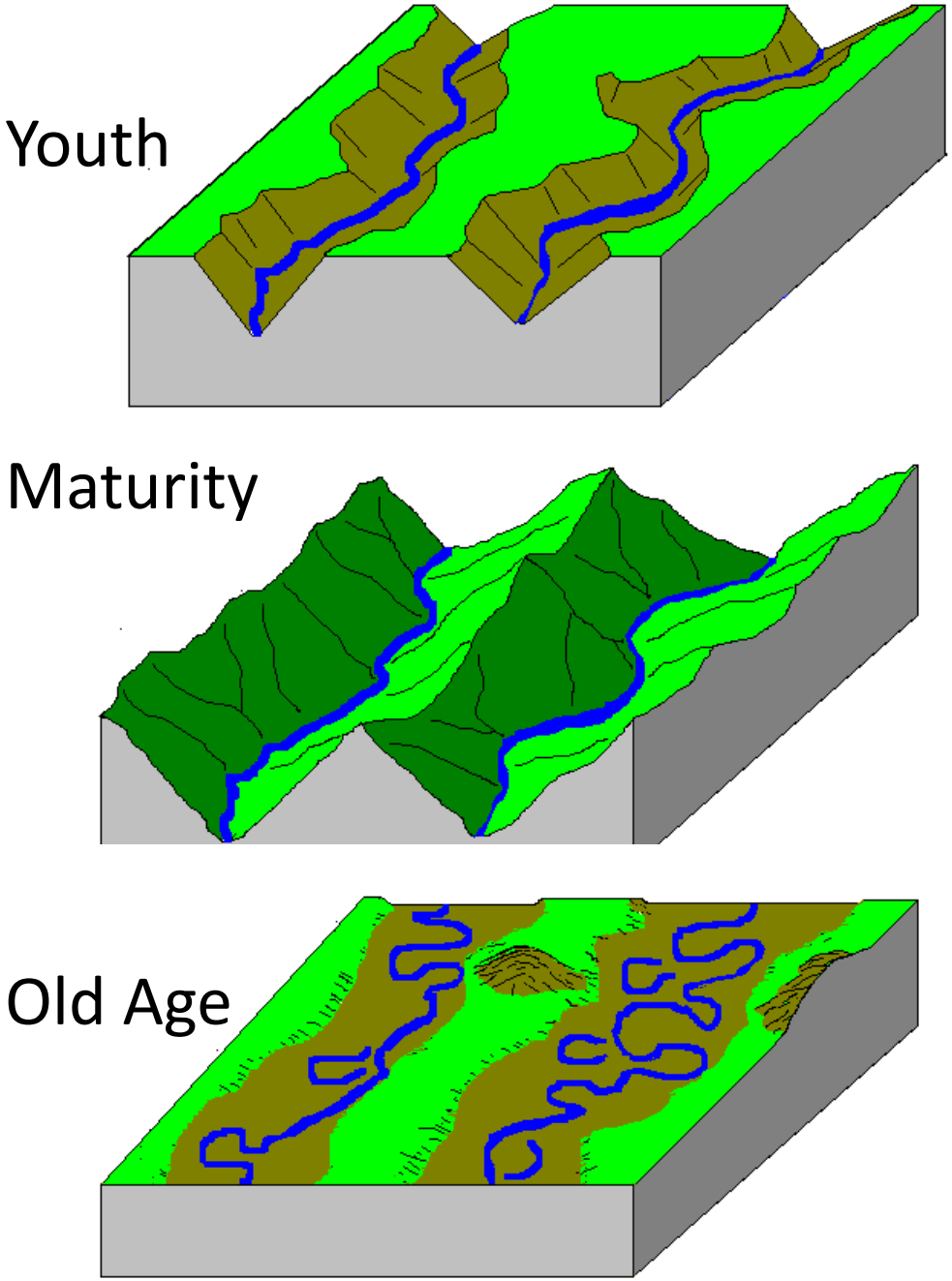
Southern Rocky Mountains (Scott, 1975, p. 240): "**Uplift** apparently was greatly accelerated in **Pliocene … time**, and the resulting **accelerated erosion** cut the **deep canyons** that characterize the mountain flanks…"

Some younger scientists allow for a slightly older rise of the Rockies and Plains: since 10 million years ago



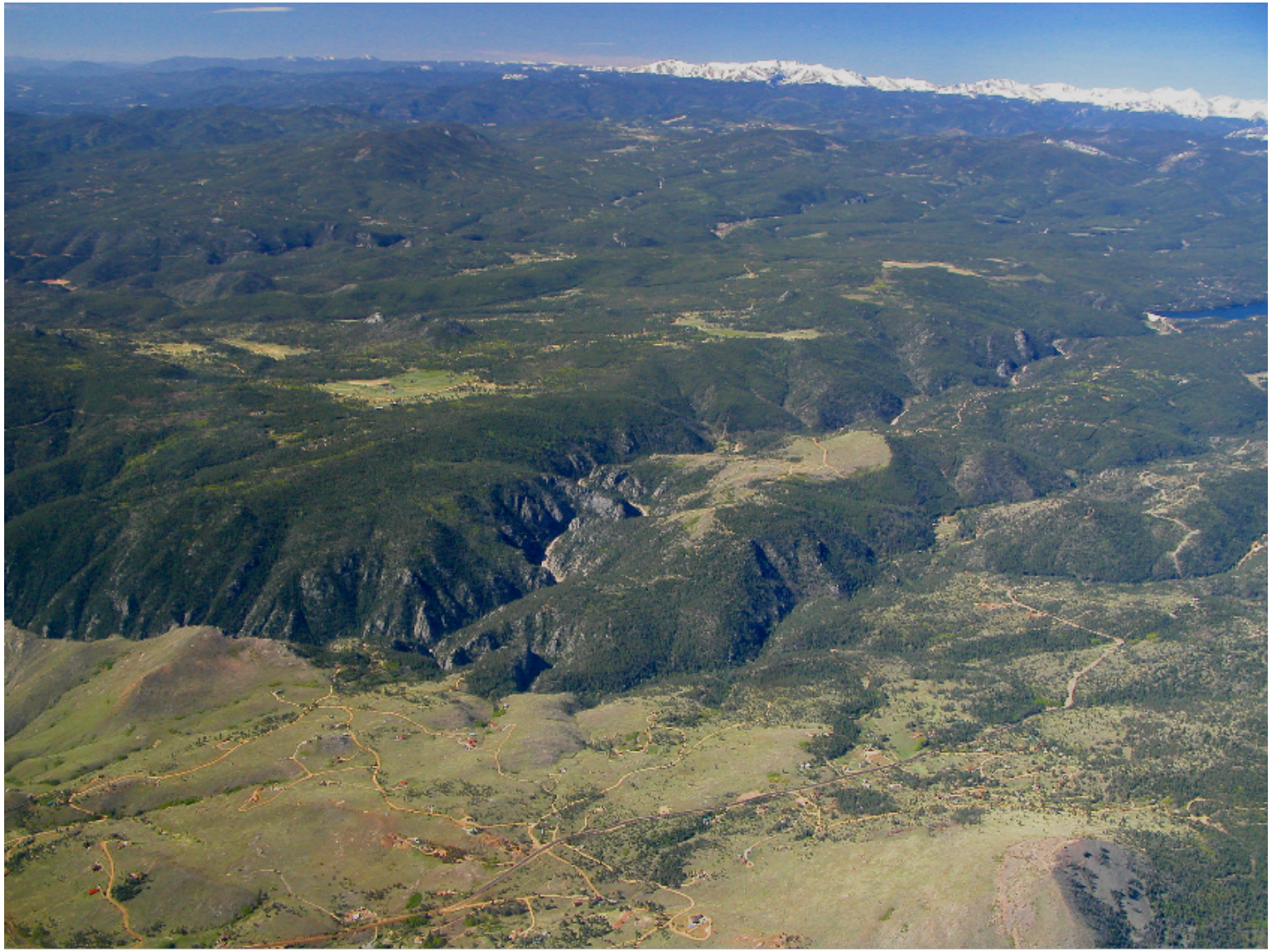
[Raynolds, Johnson, Ellis, Dechesne, and Miller, *GSA Today*, 2007]

Why do they think the Rocky Mountains are so young?



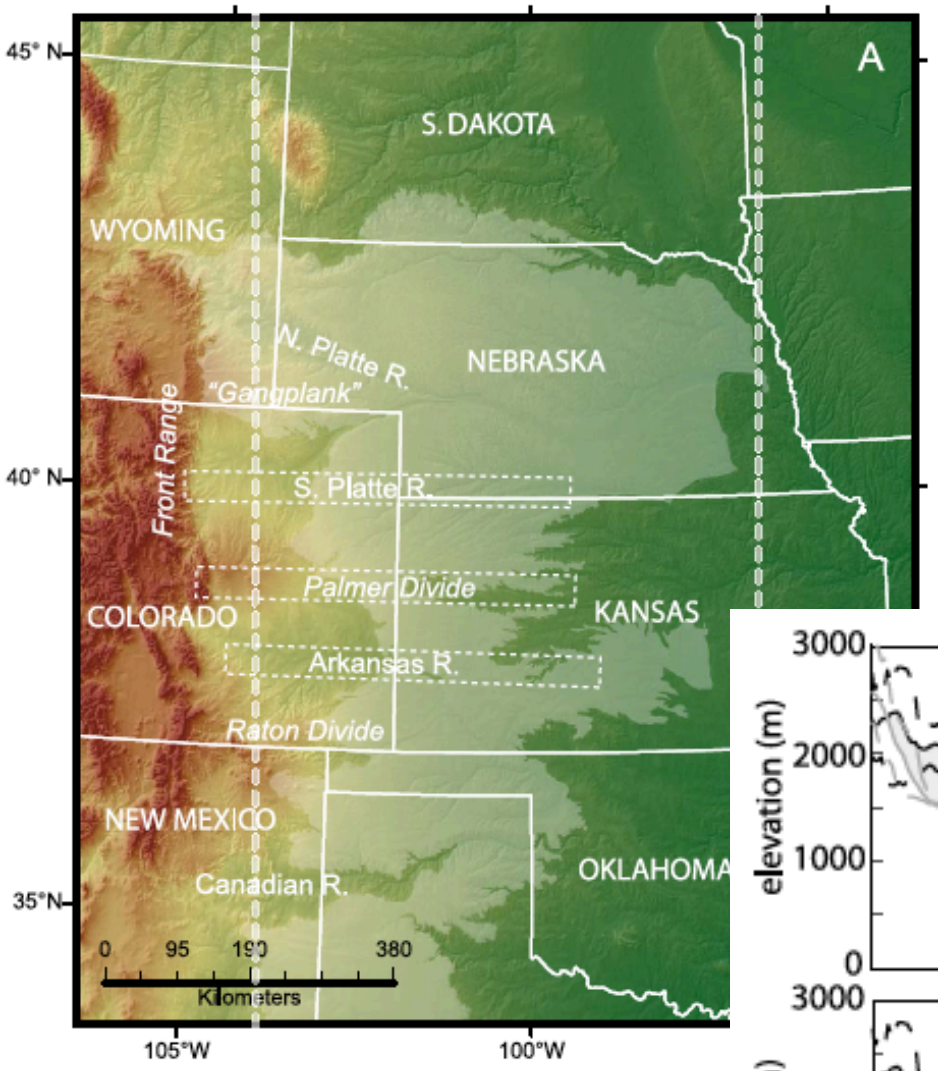
http://www.uwgb.edu/dutchs/earthsc202notes/erosion.htm

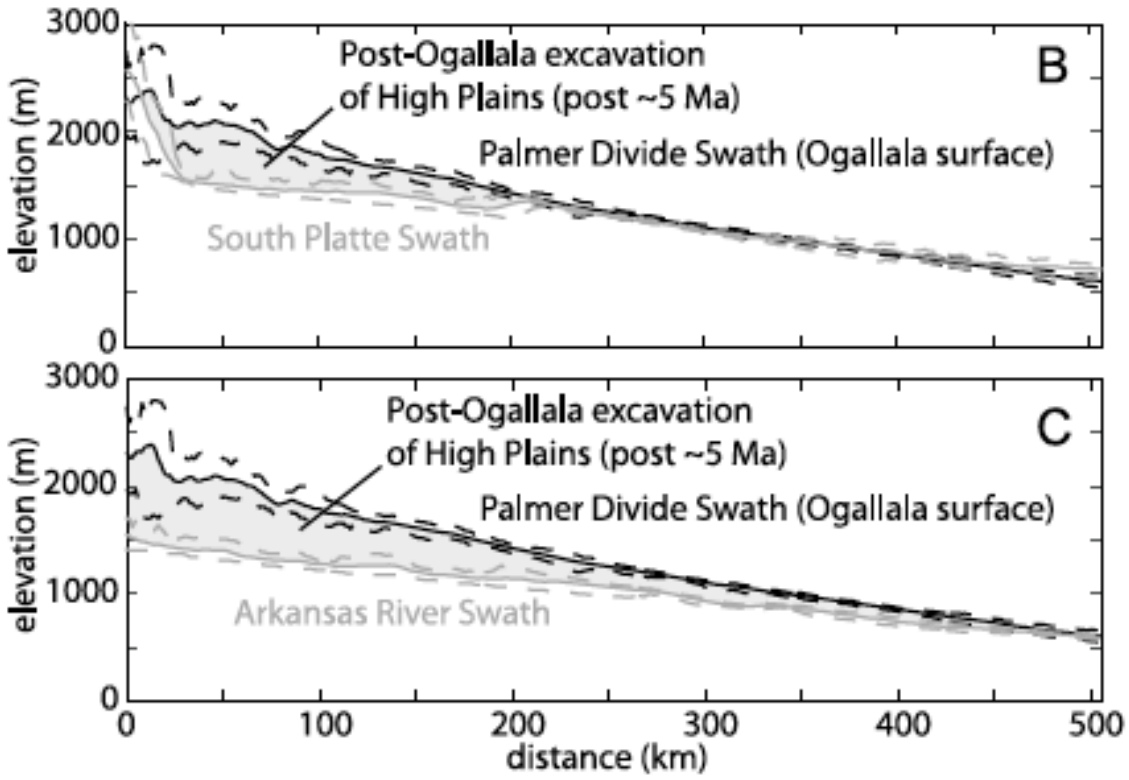
Boulder Creek, Front Range



Rocky Mountain National Park

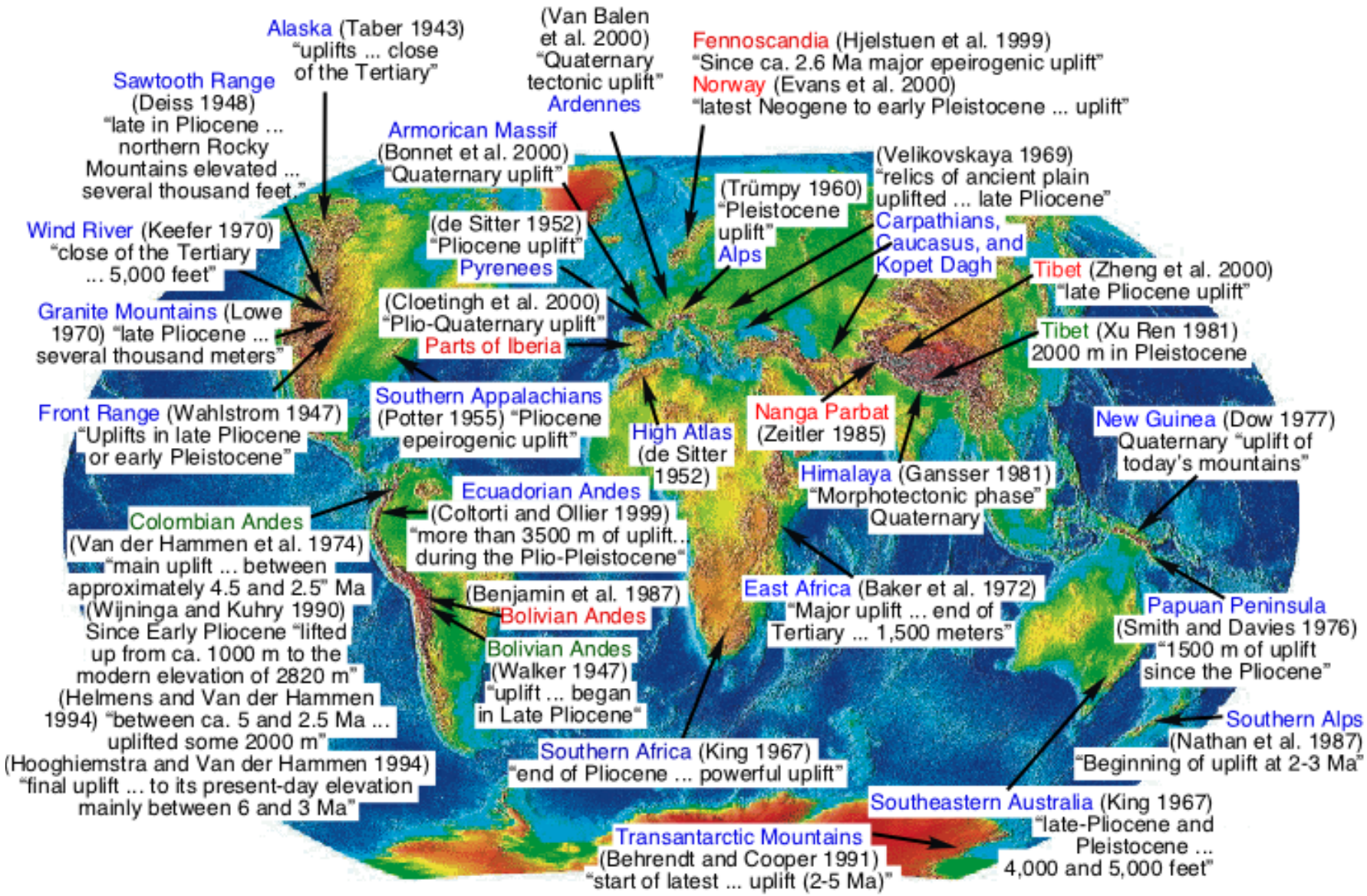
Enhanced erosion since 5-2.5 million years ago



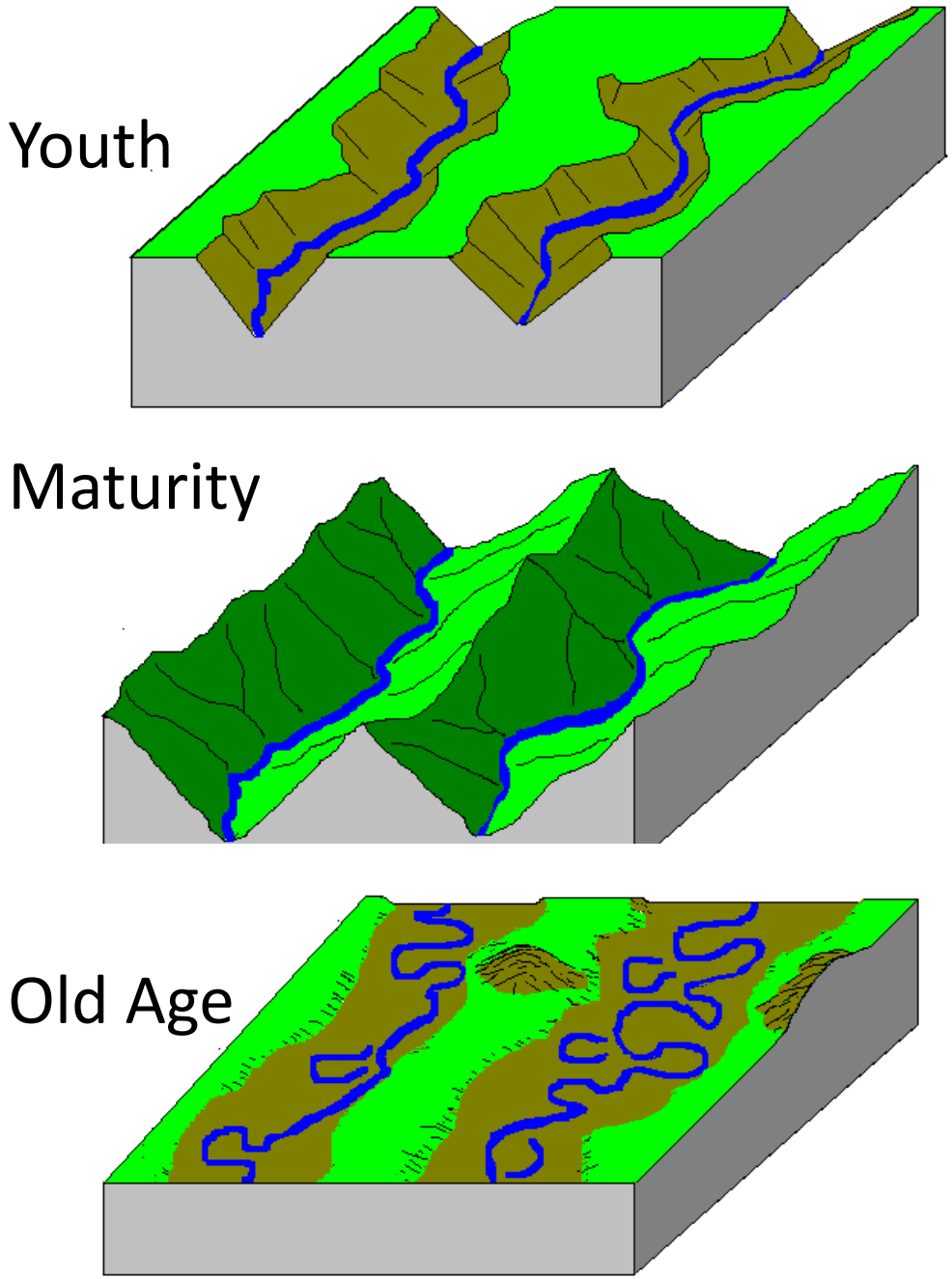


[**Wobus, Tucker, and Anderson**, *J. Geophys. Res.*, 2010]

Find me a mountain range, and I will find a good geologist who said it rose recently in geologic time, since 5-2.5 Ma



Climate change, ~4 million years ago, accelerated erosion globally



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What happened since 5 Million years ago?

1. Climate changed toward a colder world.

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What happened since 5 Million years ago?

1. Climate changed toward a colder world.

2. Alpine glaciers formed.

3. Glaciers, which commonly erode faster than rivers, carved and sculpted the landscape to give us steep slopes.

4. Skiing and mountaineering became possible.

If we lived in Colorado 5 million years ago, would we have seen mountains, or just high rolling terrain?

1. High terrain had been here since **35 million years ago** or earlier.
2. The high terrain results from an unusually hot, *thermally expanded* uppermost mantle, that also has been present since 35 million years ago or earlier.
3. **Mountains**, as we see them, and enjoy them, would **not have been obvious**, because erosion was slow in the warmer, less erosive climate.