Lithospheric density in and near the Midcontinent Rift

Middle Proterozoic passive rifting (Lower) Crustal hydration in the western U.S.

> Levandowski and Lesley Butcher GSA Northcentral 2014

Pigeon River, MN



Average velocity 0-35 km



MCR: High gravity, no topography?!?

D



Questions

- What the heck is the density?
 - Ain't just like the velocity
 - Ain't just like the gravity
- Does lithospheric density inform rift kinematics?
 Active vs. Passive
 Magma source depth
- How does (lower) crustal density compare to the High Plains and Colorado Plateau?
 - Proterozoic regions with similar Paleozoic strata
 - Were all at sea level at ~70 Ma. Not anymore.





3D Density: Initial estimate from velocity



Worked pretty well in the western US...



But no failed rifts in western US... There's a lot of basalt in the MCR, does that matter?

How about juxtaposition of Mesoproterozoic, Paleoproterzoic, and Archean blocks?

AND REAL PROPERTY.

Basalt ~200 kg/m³ denser than predicted
Mantle chemistry may vary from Proterozoic to Archean regions or rift-related modification

Mg-enrichment increases S-velocity, decreases density

Mt. Josephine

Velocity-Density Fail: Reds need to be denser



Improving Density Estimate

Take existing gravity and topography residuals
Add pseudo random perturbations in 3D
Recalculate gravity and topography

 Keep 3D density models that come "close enough"

Repeat for 100 3D density models

Total density adjustments



Final Residual



Total density adjustments





Final Densities



Insights on MCR structure

Gooseberry Falls SP, MN

Increase in basalt NE along strike and with depth Rift pillow from passive rift?



Increase in basalt NE along strike

a) Mean crustal adjustment **Away from Euler Pole** -96° –94° –92° (Chase and Cilmor 1072) 48° 46° CRS Superic 44° sin Block 42° ☆ Euler Po 40°

Merino et al., 2013

no^m

Grenville

Total density adjustments





Total density adjustments

b) Mean mantle adjustment



Lithospheric age?

Iron depletion greater in Archean?

A ~2% variation would do it



Comparison to the western US



Jackass Pass, Wind Rivers, WY



Lake Superior, Isle Royale in the distance

Quick aside Remember these?





Depth Range	Density difference	Relief
0-10 km	-26 kg/ m³,	-82 m
10-20 km	38 kg/ m ³	118 m
20-30 km	53 kg/ m ³	165 m
30-40 km	61 kg/ m ³	191 m
Total		392 m
Lower Crust		474 m

Levandowski, 2014 PhD Thesis CU Boulder

Why? Lower Crustal Hydration?



"Uplift during the Laramide orogeny is attributed to a combination of crustal thickening in the Rocky Mountain area, regional unloading caused by the younging of the Farallon slab AND

LITHOSPHERIC DE-DENSIFICATION OWING TO THE CREATION OF LOW-DENSITY HYDROUS MINERALS"

Humphreys et al., 2003



Role of hydration in elevating topography of and heart rates on the Colorado Plateau

QUESTION #1: Did the lower crust undergo large-scale hydration?



Butcher, 2013 MS CU-Boulder

QUESTION #2: When did this hydration occur?



BEI

U-Pb dating of **secondary monazites** by SIMS will help to constrain the timing of the metasomatic event. Was it Laramide-related, or Paleo-Proterozoic?

Butcher, 2013



Denver is the mile high city. Were the Plains hydrated too?

Wichita Mtns. NWR, OK Homestead Kimberlite, MT

🔁 Rattlesnake Hills, WY

Leucite Hills, WY

Stockdale Kimberlite, KS

United States

Herring Park, CO

Eocene Two Buttes, CO

Navajo Volcanic Field, AZ

Dish Hill, CA



There's no comparison!

Note change in color scale from previous density slides





kg/m³ 2700 2750 2800 2850 2900 2950



2750 2815 2880 2945 3010

Effect on topography

	Midcontinent	Colorado Plateau	Density difference, Topography	High Plains	Density difference, Topography
0-10 km	2681 kg/m ³	2596 kg/m ³	85 kg/m³, 265 m	2570 kg/m ³	111 kg/m³, 347 m
10-20 km	2805 kg/m ³	2752 kg/m ³	53 kg/m³, 175 m	2790 kg/m ³	15 kg/m³, 47 m
20-30 km	2823 kg/m ³	2767 kg/m ³	85 kg/m³, 267 m	2820 kg/m ³	33 kg/m ³ , 103 m
30-40 km	2949 kg/m³	2823 kg/m ³	126 kg/m ³ , 394 m	2884 kg/m ³	65 kg/m ³ , 203 m
Total			1101 m		700 m
Lower Crust			836 m		353 m

Conclusions

- This technique actually works, even in the toughest place imaginable
 - **Rift probably passive**
- Relict depletion preserved (deep magma source depth?)
 - Lower crustal density difference generates hundreds of meters of relief in the Plains and Colorado Plateau

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