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# Cratonic crust illuminated by satellite gravity gradient inversion

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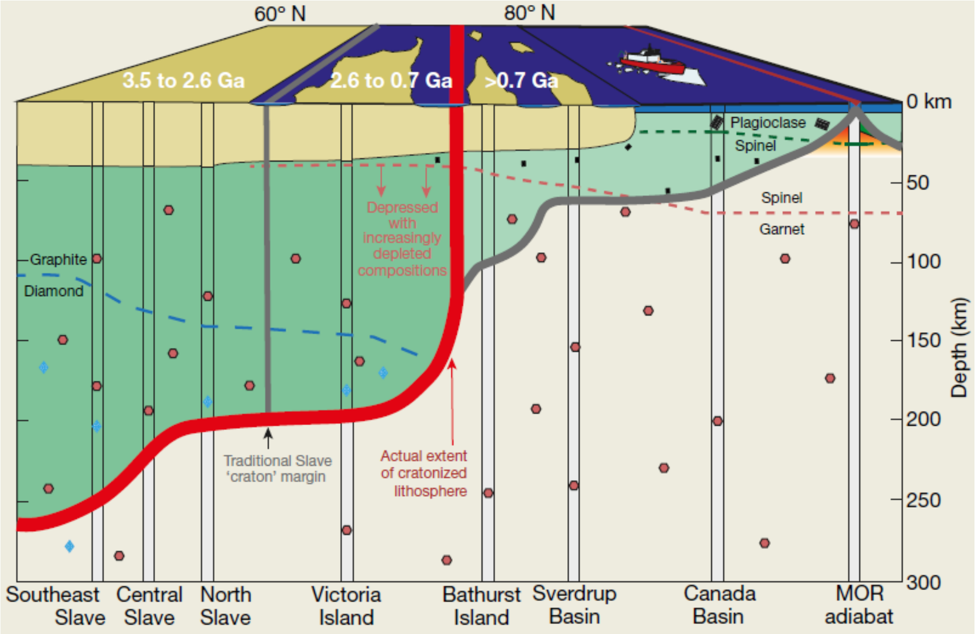
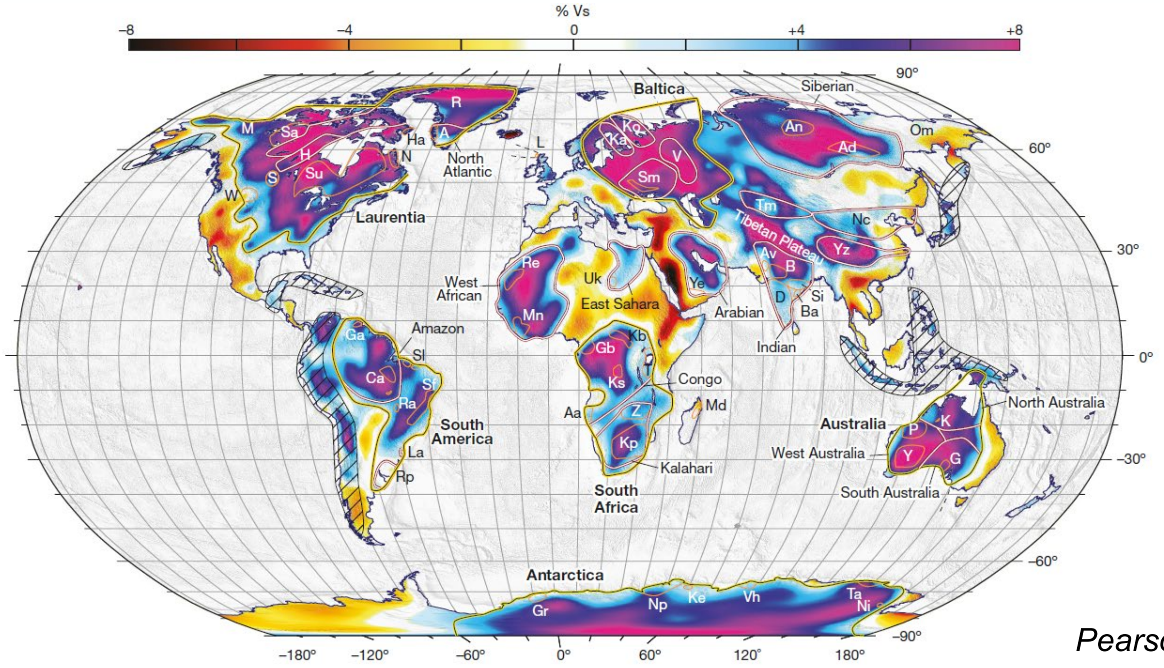
# How can we define a craton?



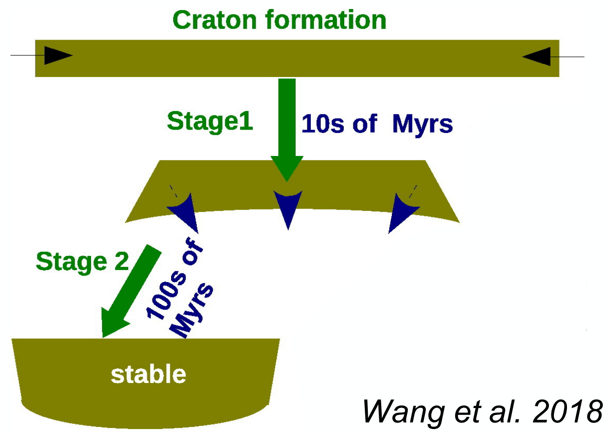




*Pearson et al. 2021*

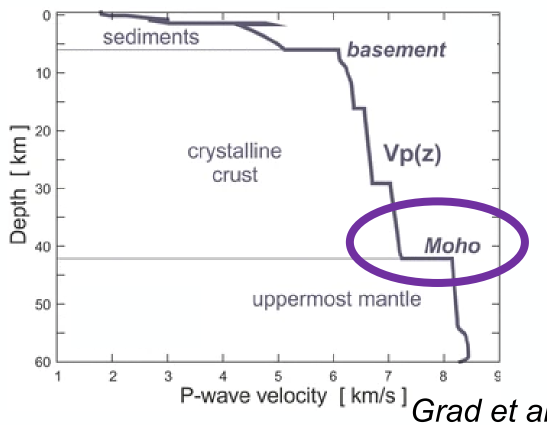
- Cratons can be characterized by deep root, reflecting cold and old lithosphere
- Seismic tomography is well-suited to image the extension of cratonic lithosphere

- How deep is actually cratonic crust?
- What do crustal thickness patterns about the craton stability?

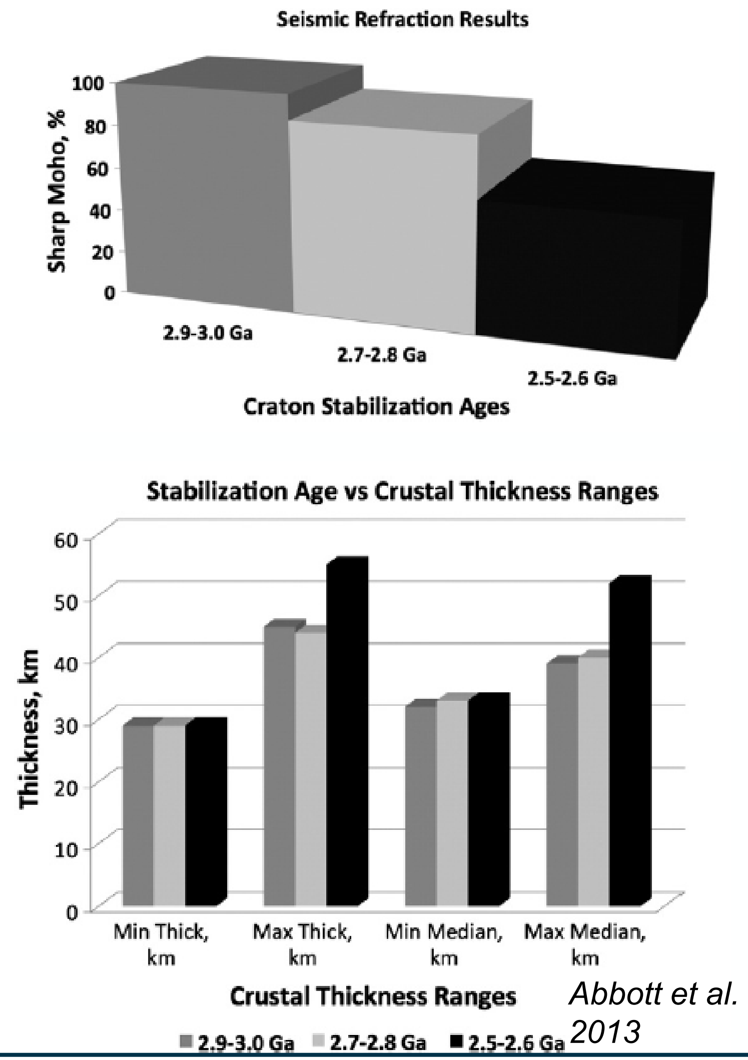
# Craton stabilization




Wang et al. 2018



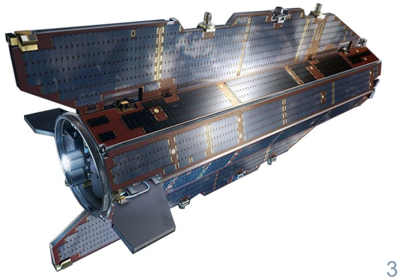

Grad et al. 2018



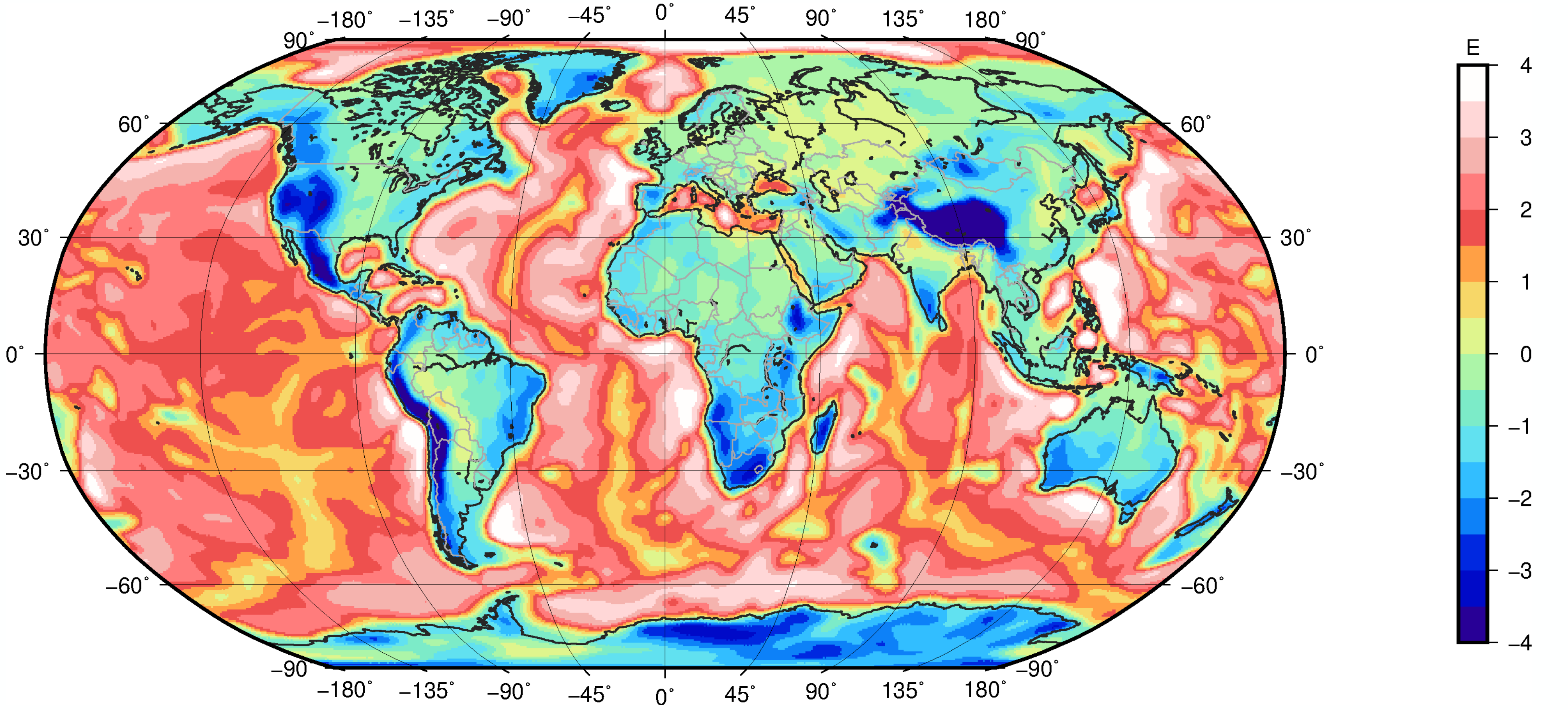

Abbott et al. 2013

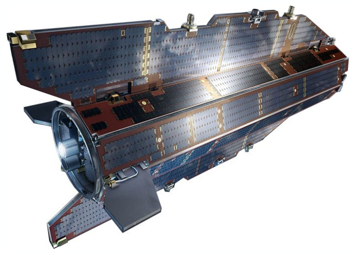
- Stabilization age correlates with Moho sharpness and thickness of the crust (Abbott et al. 2013):
  - The older a craton, the sharper the Moho
  - The older a craton, the shallower the crust

→ Can we add information from gravity inversion?



# Gravity gradient data of GOCE

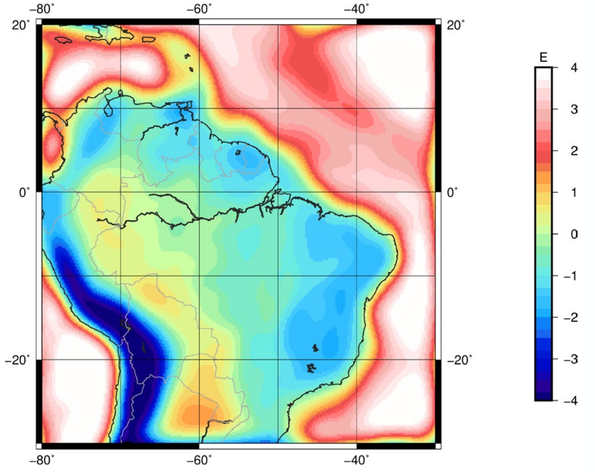


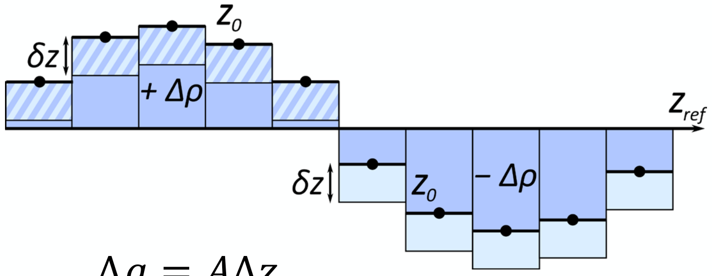
→ Most of the signal reflects the density transition between crust and mantle

Vertical gravity gradient at 225 km height, corrected for the effect of topographic masses

# Gravity gradient inversion for the Moho depth




Initial data



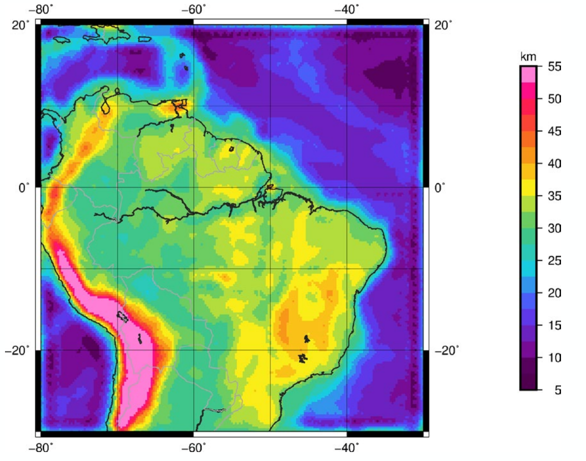

$$\Delta g = A\Delta z$$

$$\Delta z = [A^T A + \beta D^T D]^{-1} A^T \Delta g - \beta D^T D z_i$$

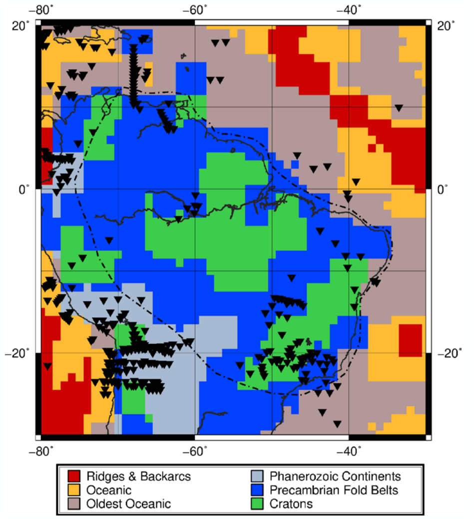
$$\Delta z = z_0 + \Delta z$$

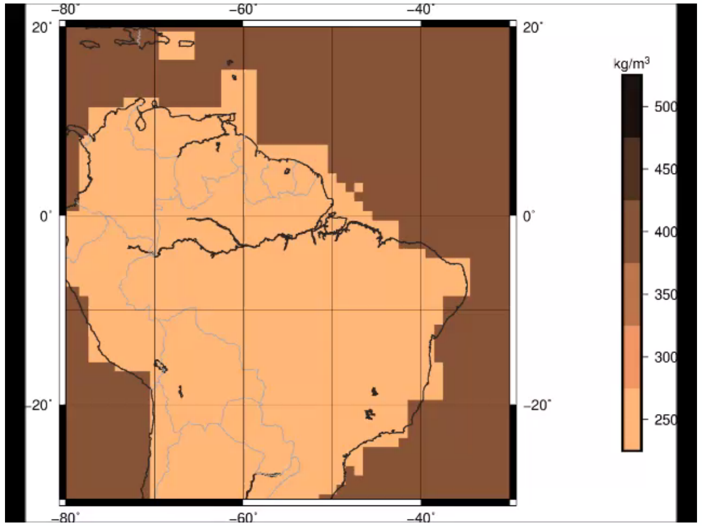
*Haas et al. 2020, GJI*

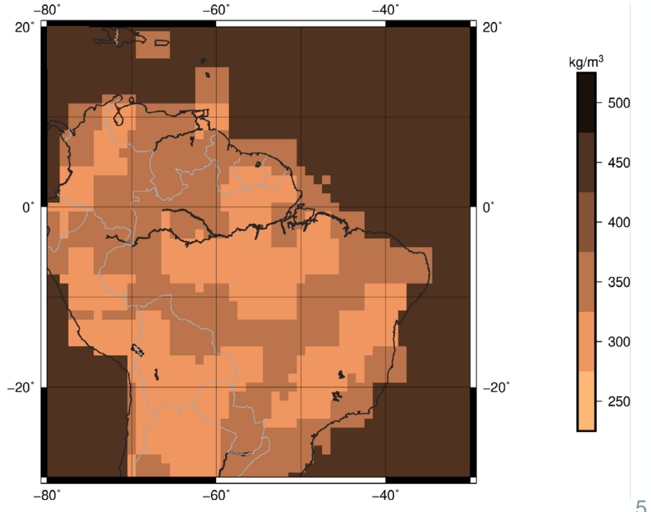
Inversion



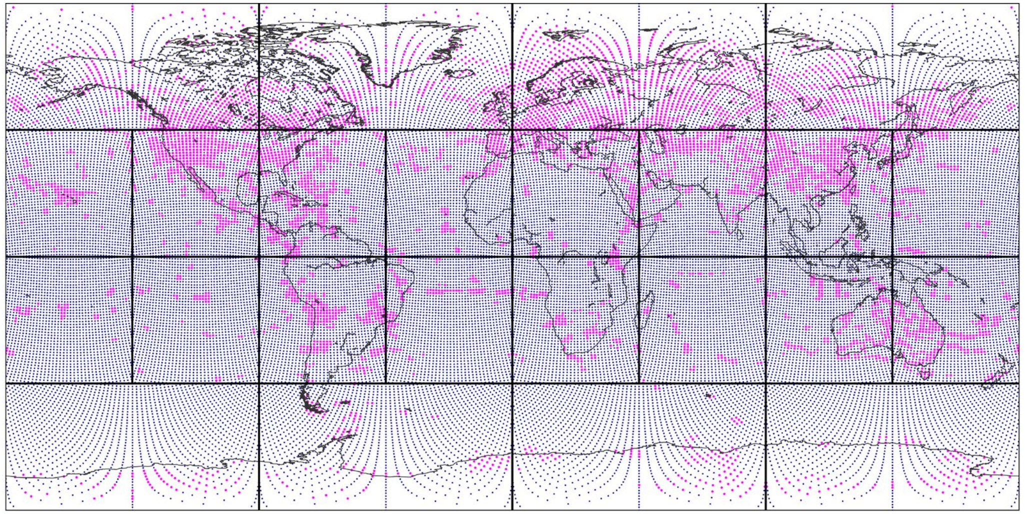

Results



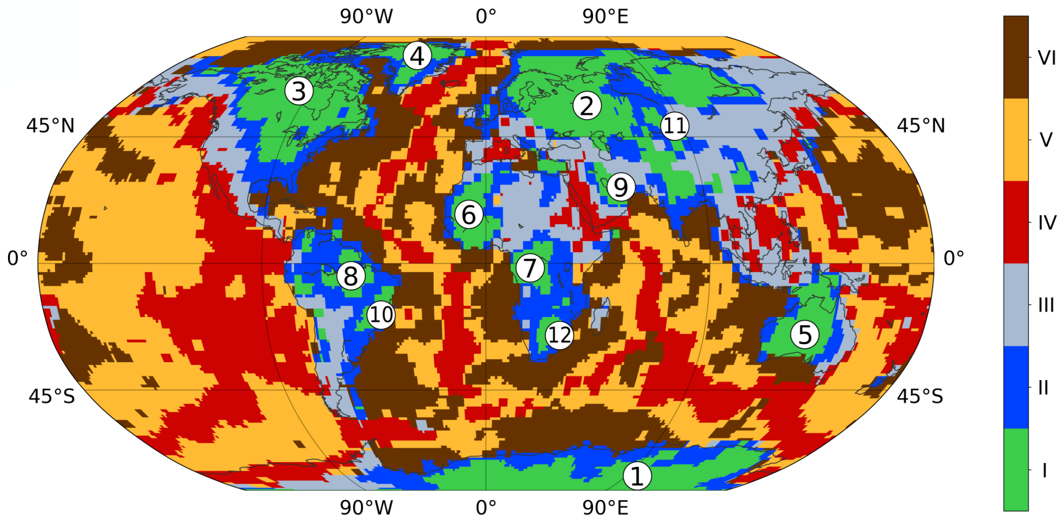



# Global gravity gradient inversion



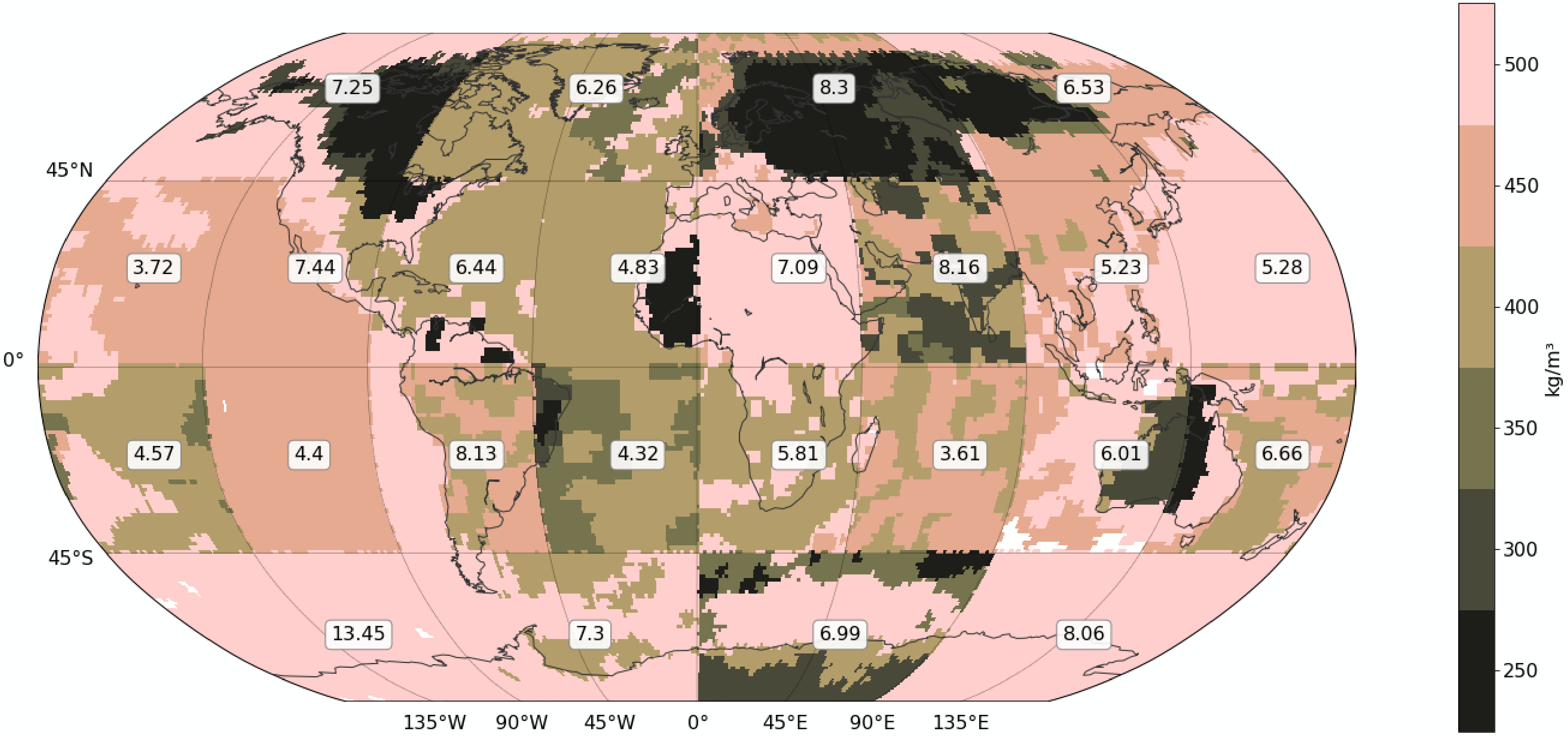
Seismic constraints




Seismological regionalization

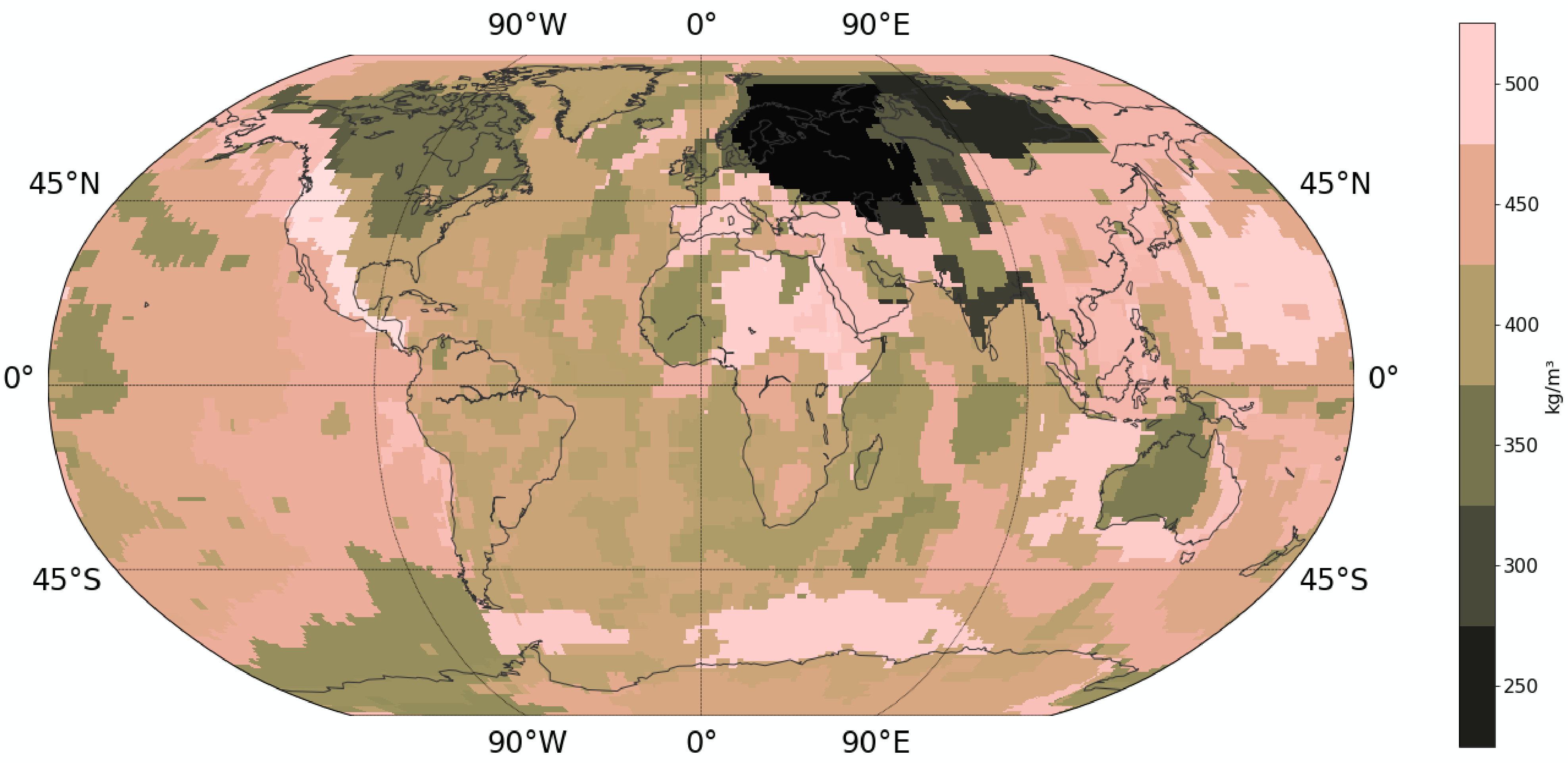
- Split the earth in 24 almost equally sized windows
- Convert coordinates in equidistant projection
- Perform the gravity inversion in each window
- Global tectonic regionalization identifies 12 cratons
- Cratons can be quantitatively investigated

# Estimated density contrasts

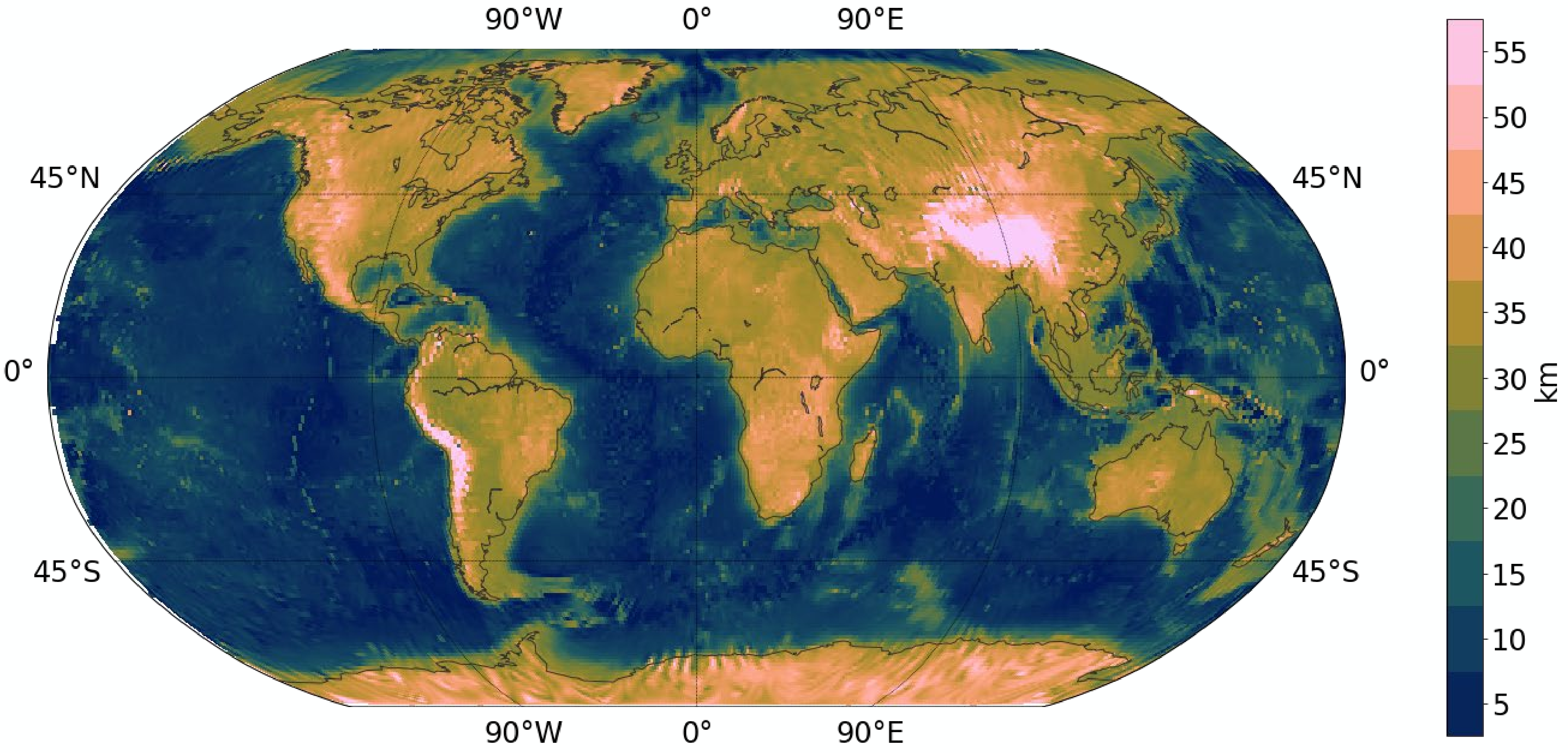



Edge features reflect window boundaries → remove with flood-fill algorithm

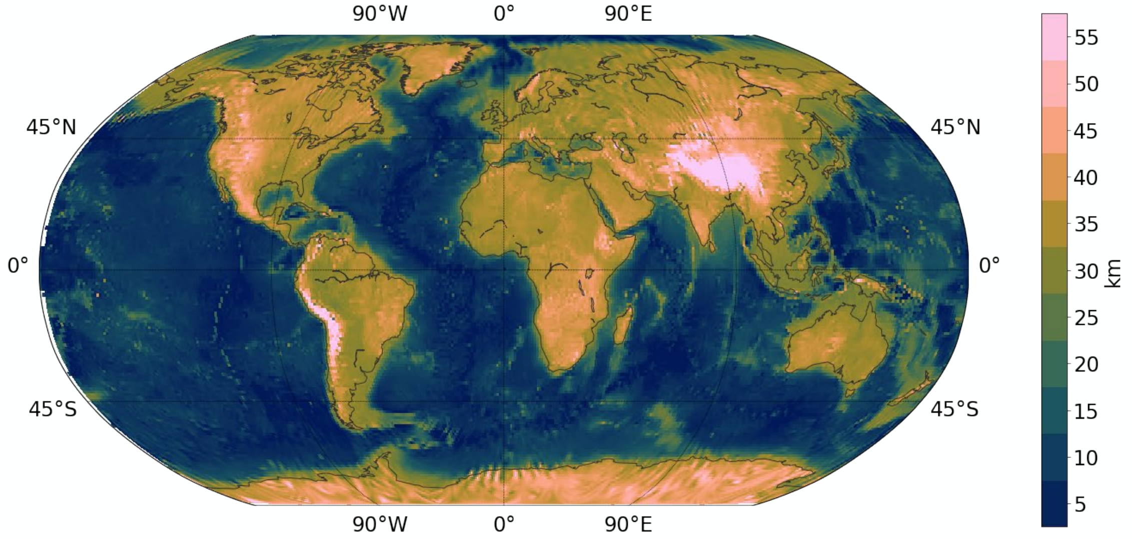
# Smooth density contrasts

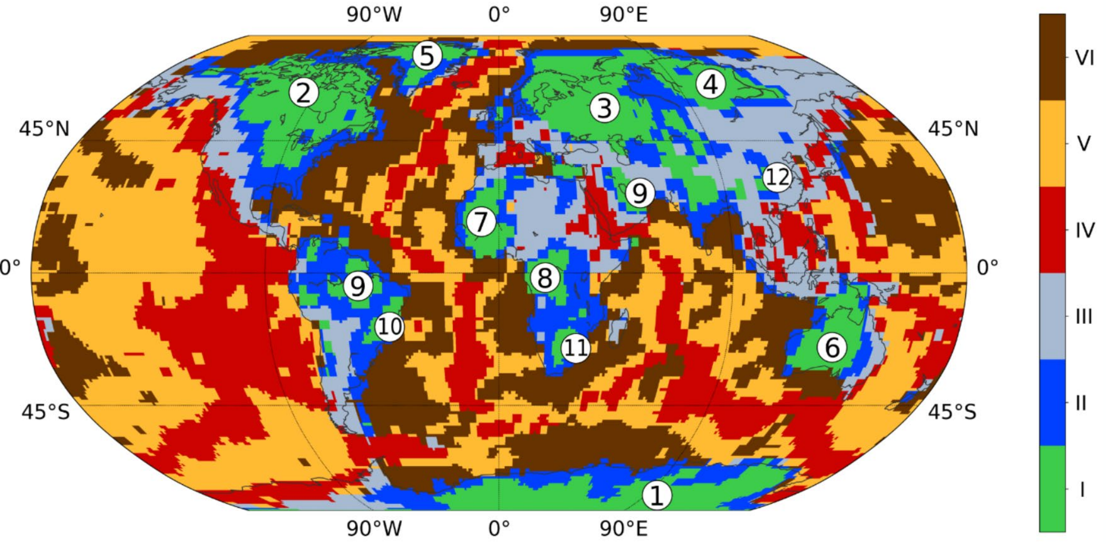


# New Moho depth model



# Yet another Moho model?



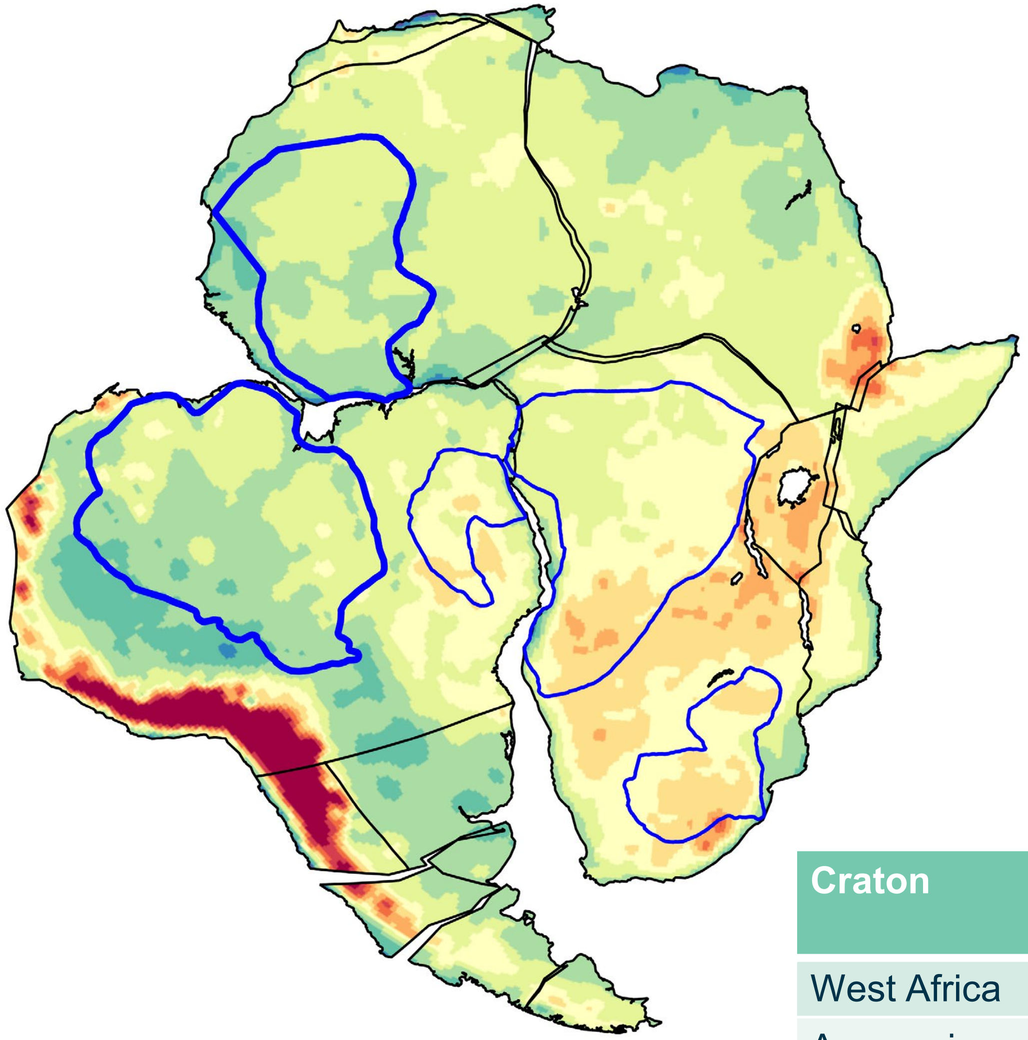

- Large scale tectonic domains are well reflected
- Thickness of continental crust varies between 20-70 km

**What can we infer for cratons?**

→ Use statistical patterns to quantitatively compare Moho depth and density contrast for main cratons of the Earth

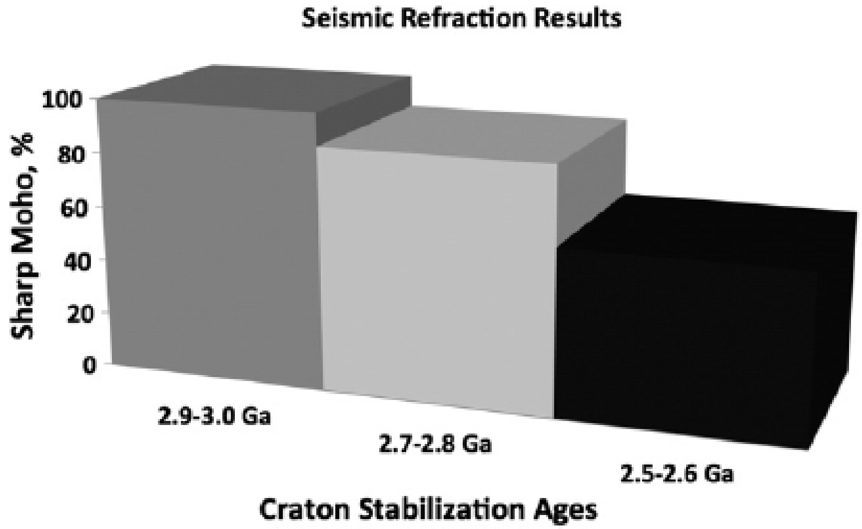
→ Link the patterns to stabilization age

# Moho depth in Western Gondwana framework



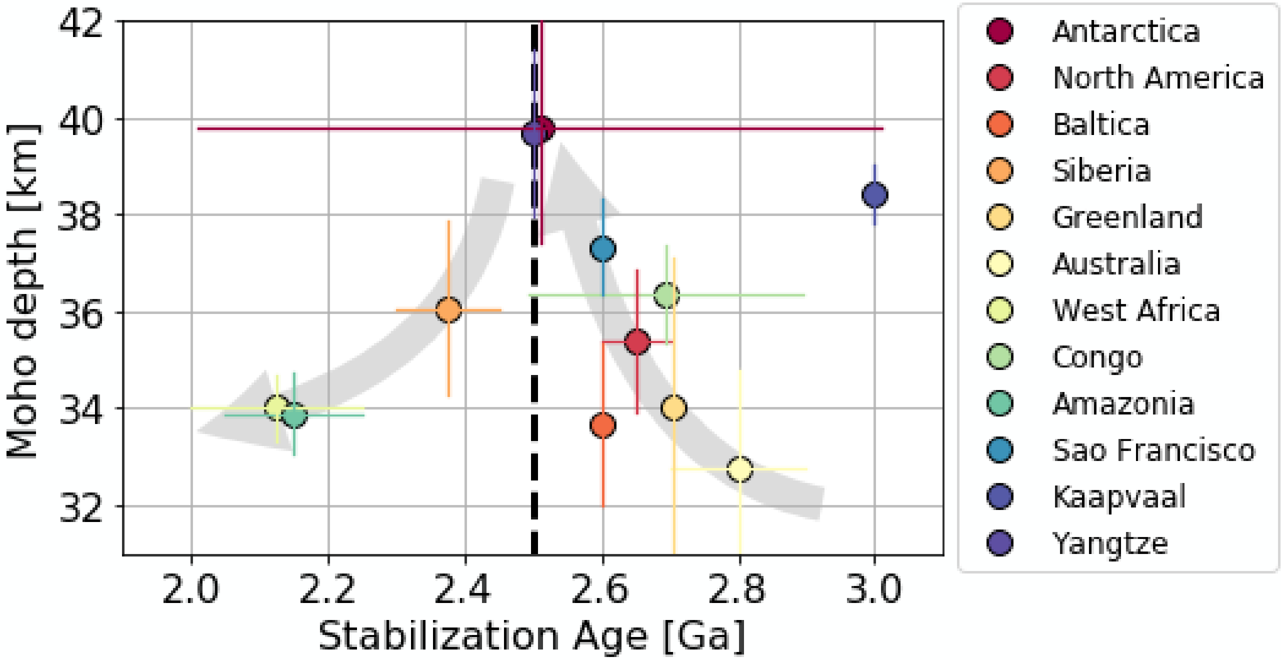
| Craton | Mean [km] | STD [km] |
|---|---|---|
| West Africa | **34.0** | **1.4** |
| Amazonia | **33.9** | **1.7** |

- Amazonia and West Africa both with shallow and flat Moho depth
  - Removal of a dense lower protocrust?
  - Early stabilization in the Archean?




*Abbott et al. 2013, Tectonophysics*

# Moho depth vs. Stabilization age



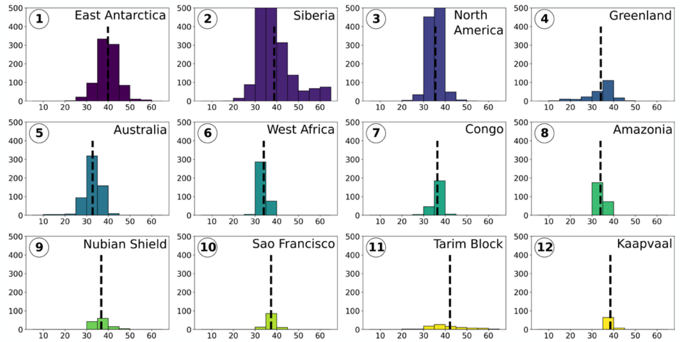

- Definition of stabilization age:

  "basal age of the oldest stable platform sediments" (Abbott et al. 2013)
- Additional data compiled from literature research
  - error bars indicate range of possible ages, depending on available data

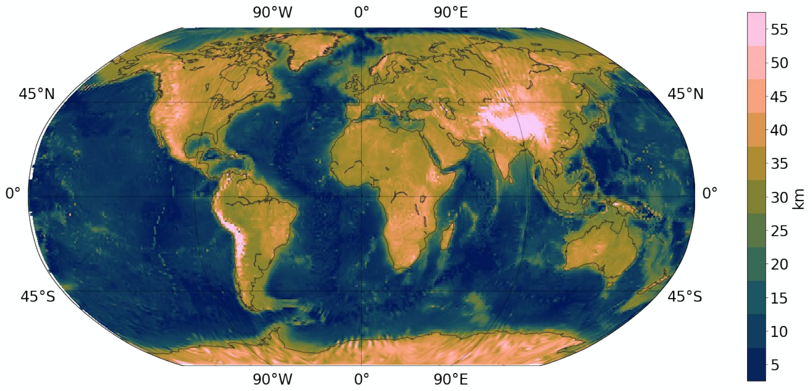
- Secular change in crustal thickness patterns
  - Archean thickening
  - post-Archean thinning
- Kaapvaal Craton with anomalous thick crust
  - Magmatic underplating of Karoo volcanism
  - Isostatic compensation of elevated topography
- Thin old crust reflects removal of a dense lower protocrust (Abbott et al. 2013)
- Post-Archean crustal thinning
  - Exhumation of crust during orogenic processes in the Proterozoic (e.g. Block et al. 2015)?
  - Gravitational collapse of continental crust (e.g. Rey et al. 2001)?

# Conclusions

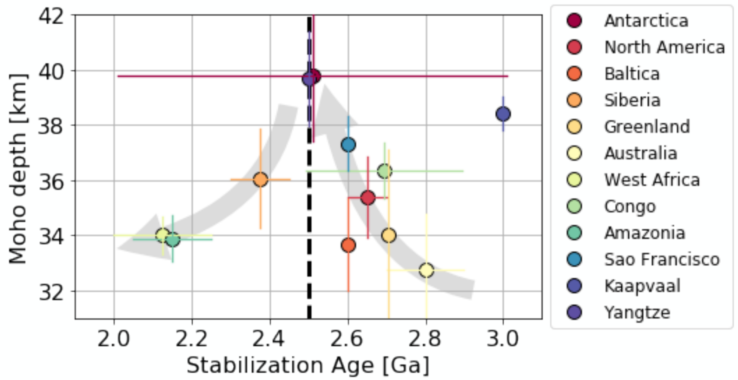
- Global gravity gradient inversion for the Moho depth with laterally variable density contrasts based on seismic tomography has been developed




- Cratons of the Earth reflect a wide range of Moho depth and density contrasts




- Linking Moho depth with stabilization age shows a secular change with turning point at Archean-Proterozoic boundary

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