Global gravity gradient inversion reveals variability of cratonic crust

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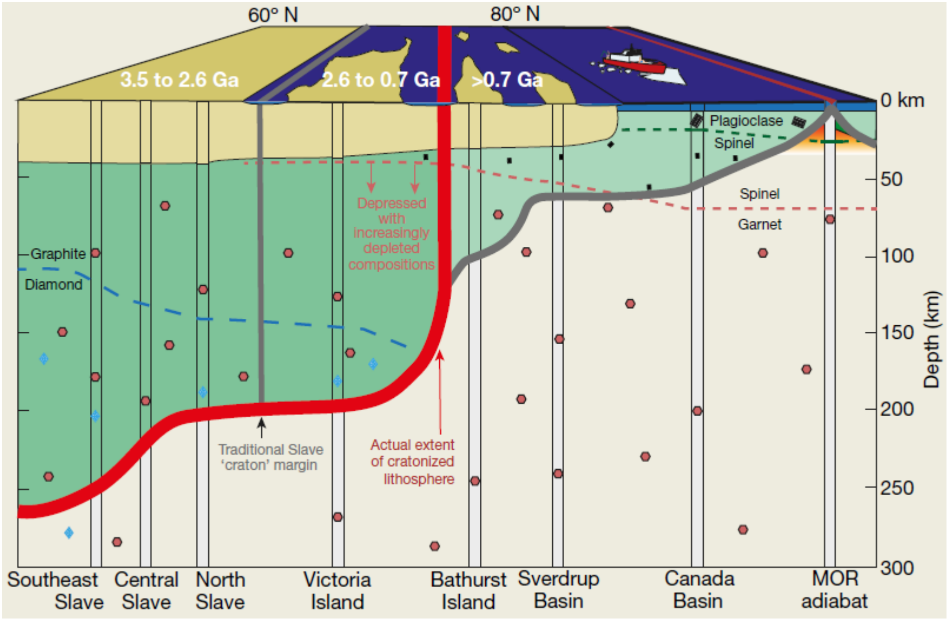
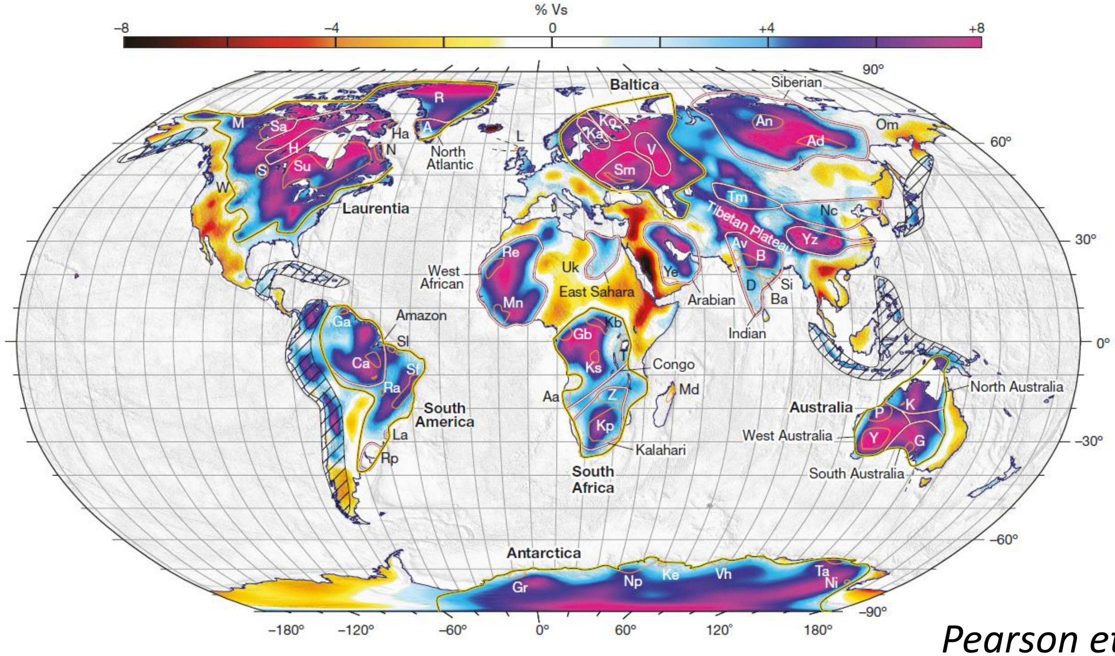
How can we define a craton?





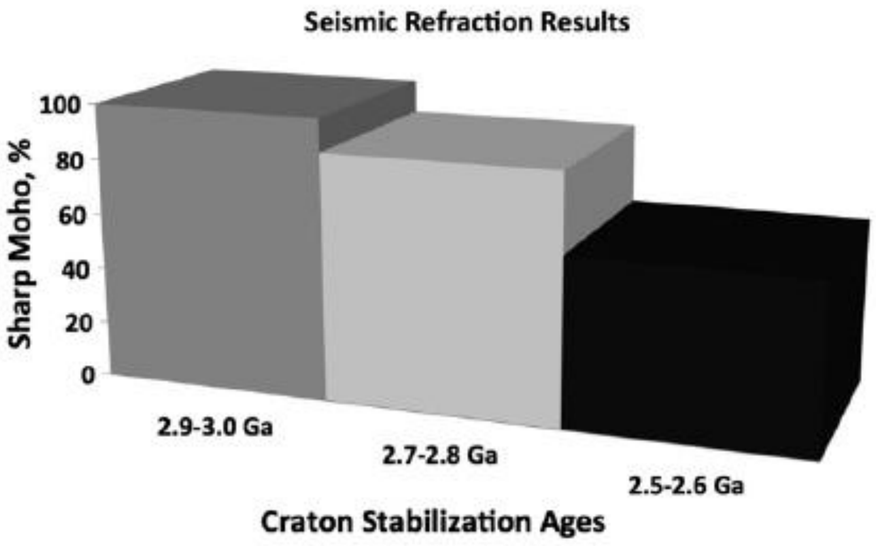
Pearson et al. 2021

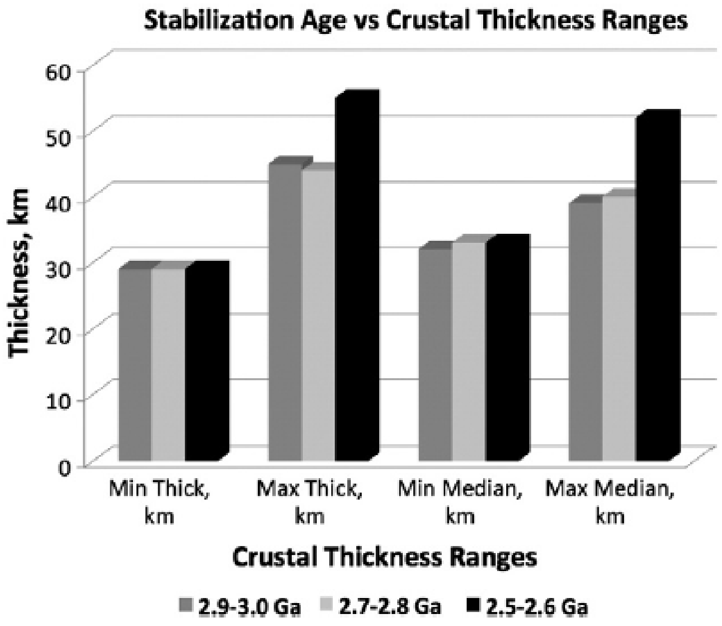
- Cratons can be characterized by deep root, reflecting cold and old lithosphere
- Seismic tomography is well-suited to image the extension of cratonic lithosphere

➢ **How deep is actually cratonic crust?**

➢ **What do crustal thickness patterns tell us about the craton stability?**

Craton stabilization

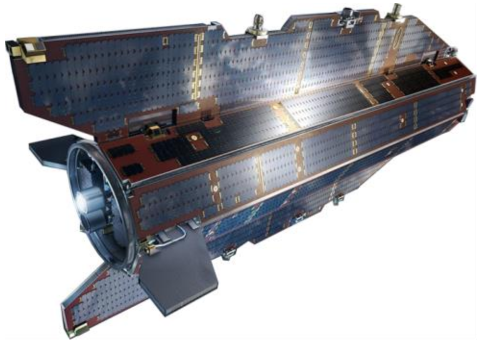




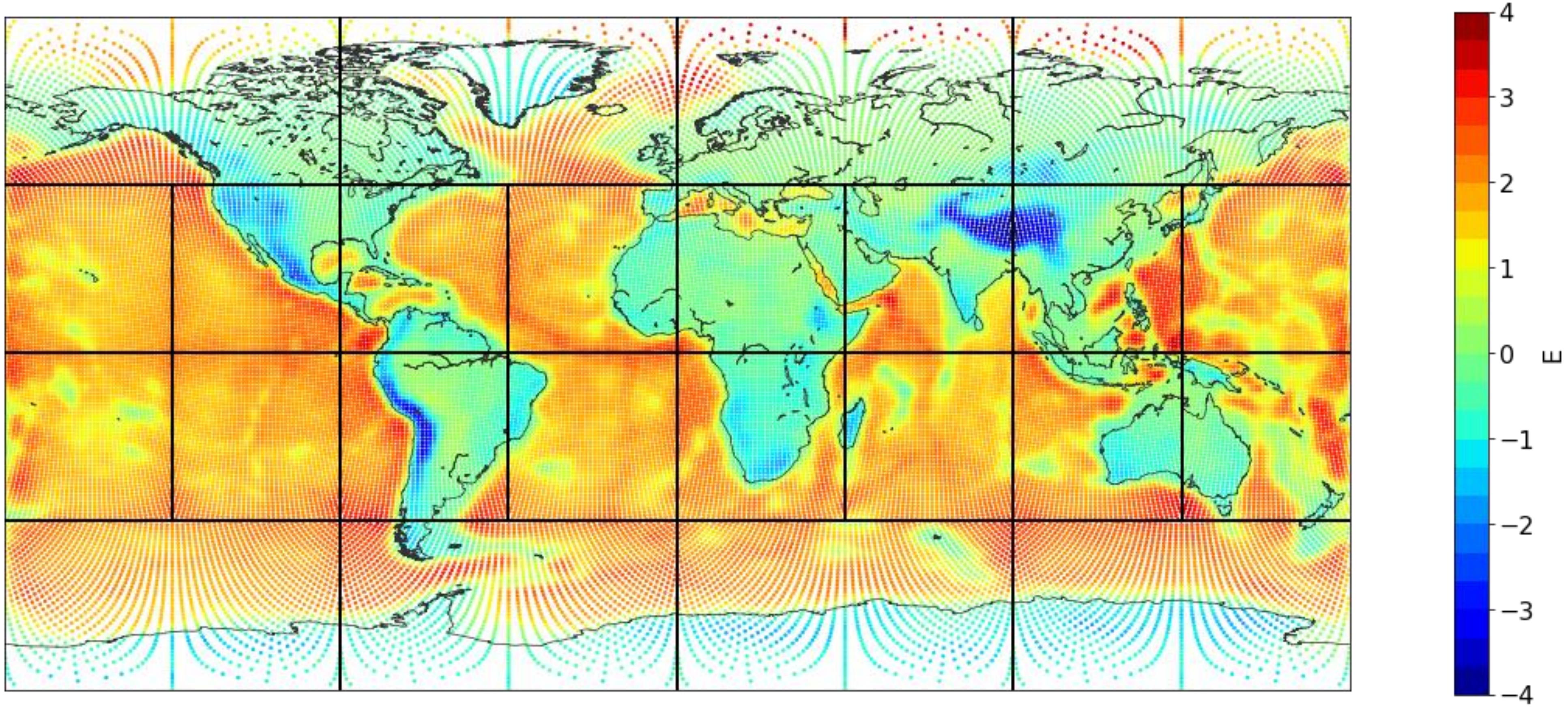
Abbott et al. 2013

- 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

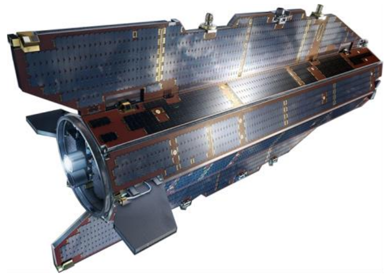
→ **Can we add information from gravity inversion?**



Gravity gradient data of GOCE

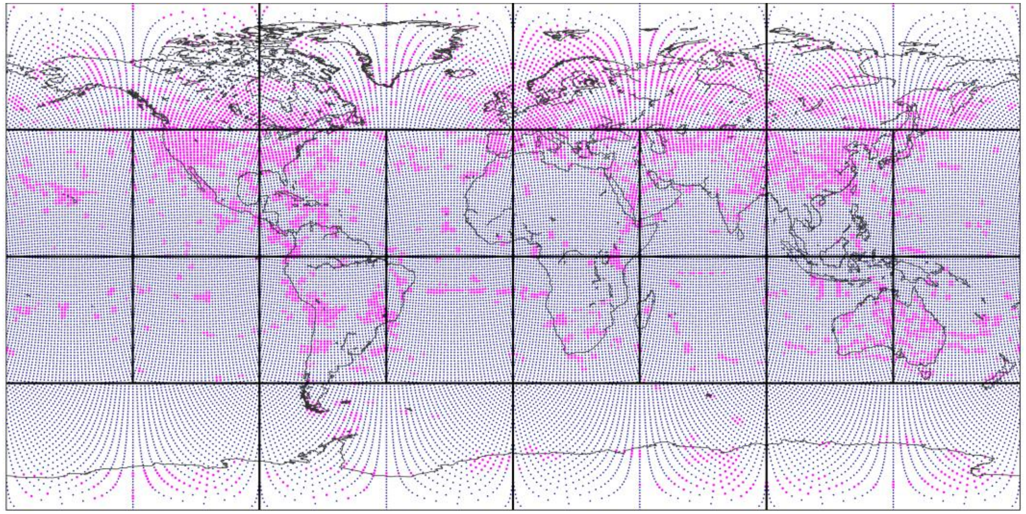


Vertical gravity gradient at 225 km height, corrected for the effect of topographic masses

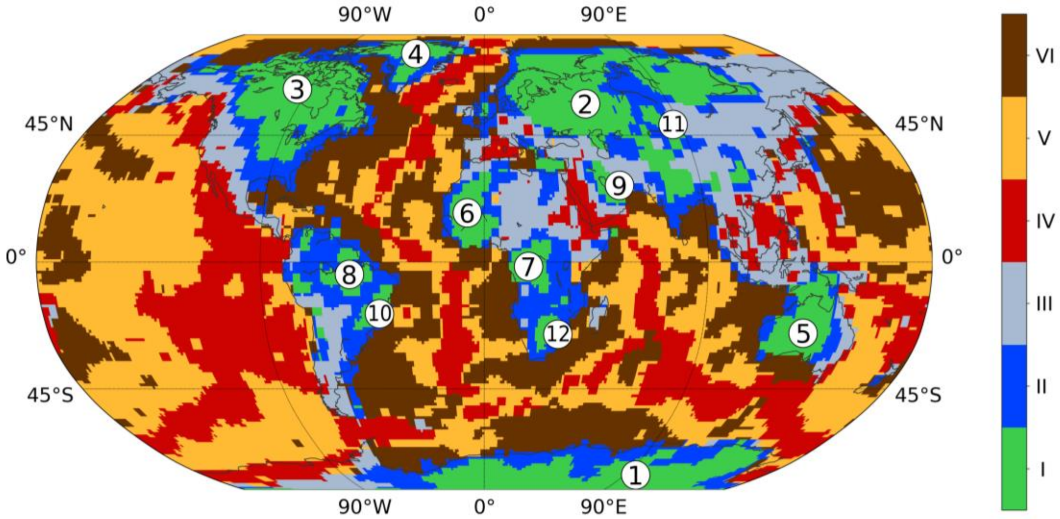


→ Most of the signal reflects the density transition between crust and mantle

Global gravity gradient inversion



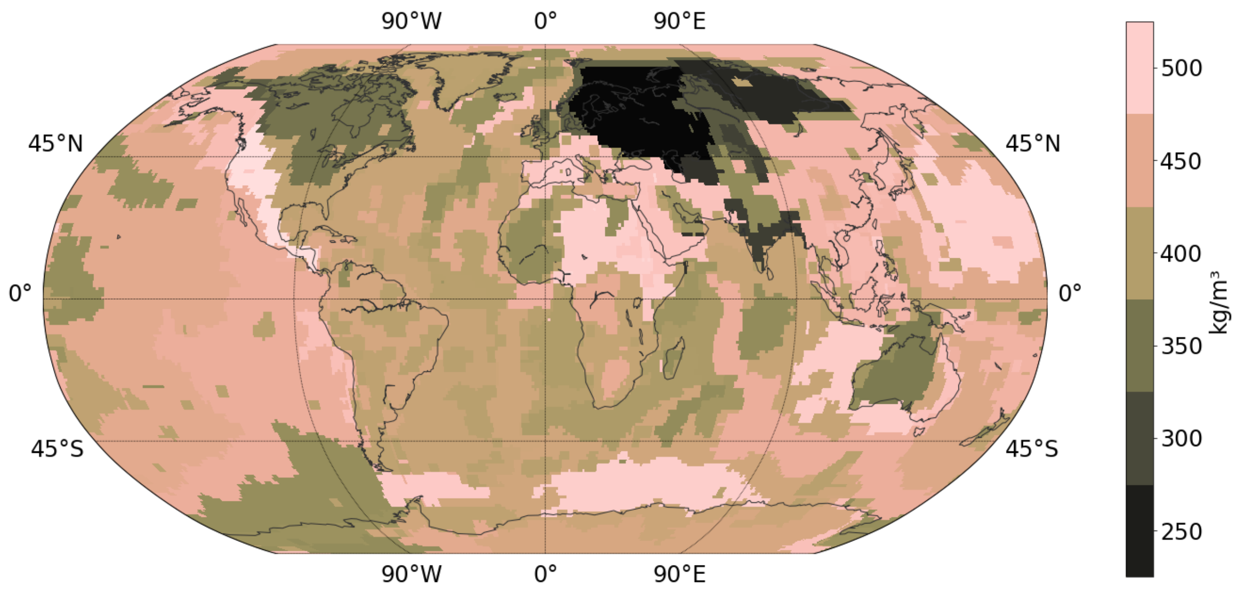
Seismic constraints



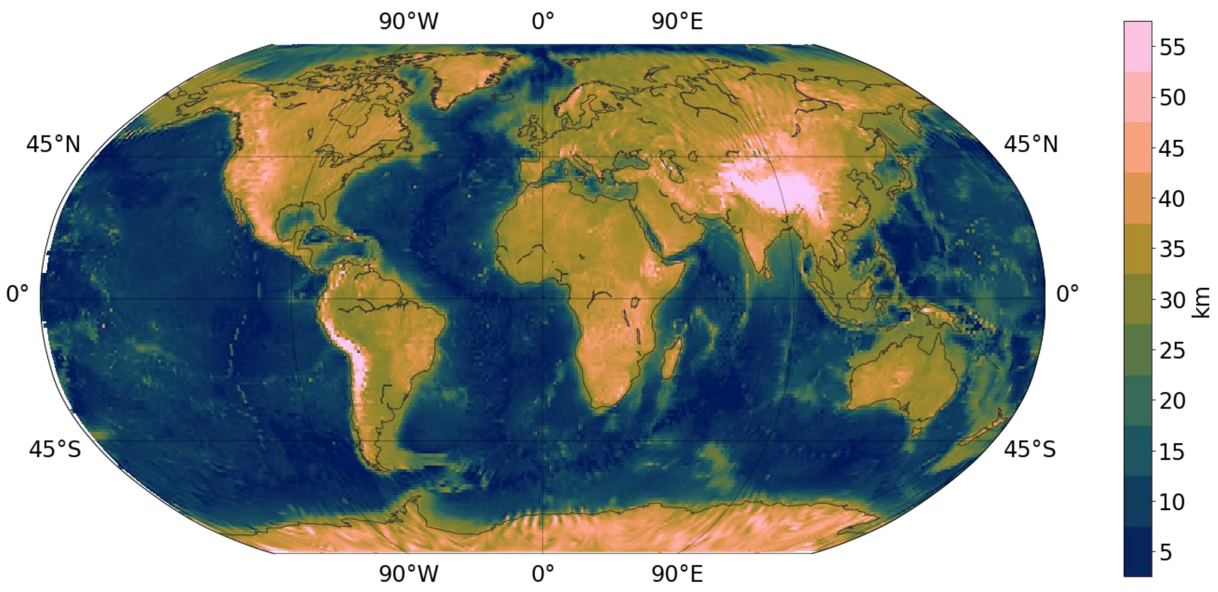
Seismological regionalization

- 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

Results

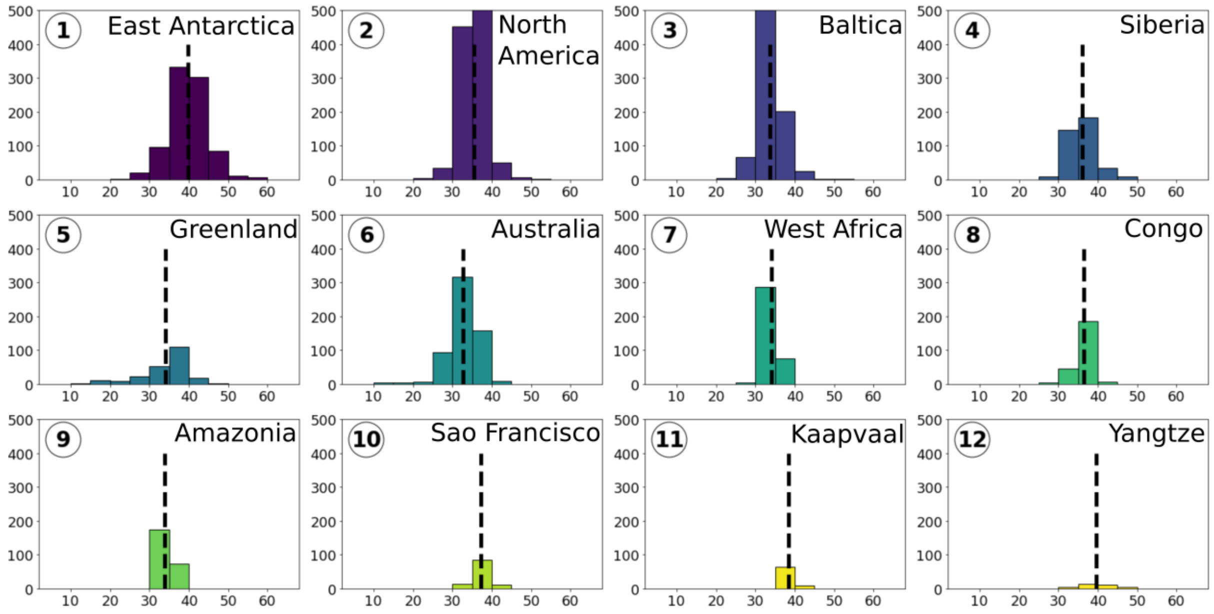


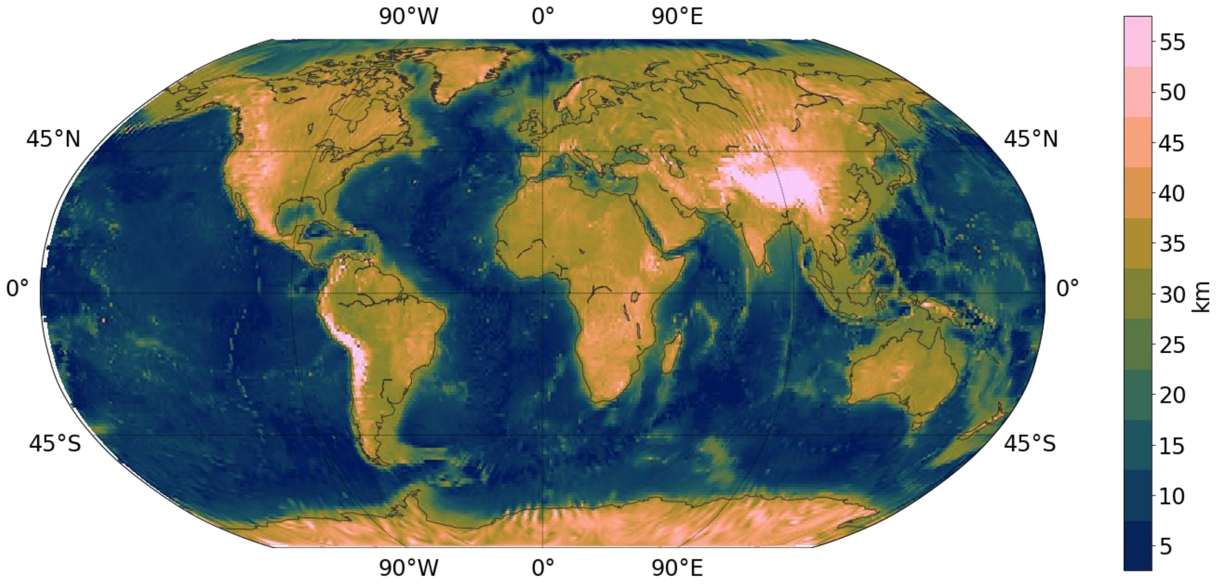
Density contrast



Moho depth

Results



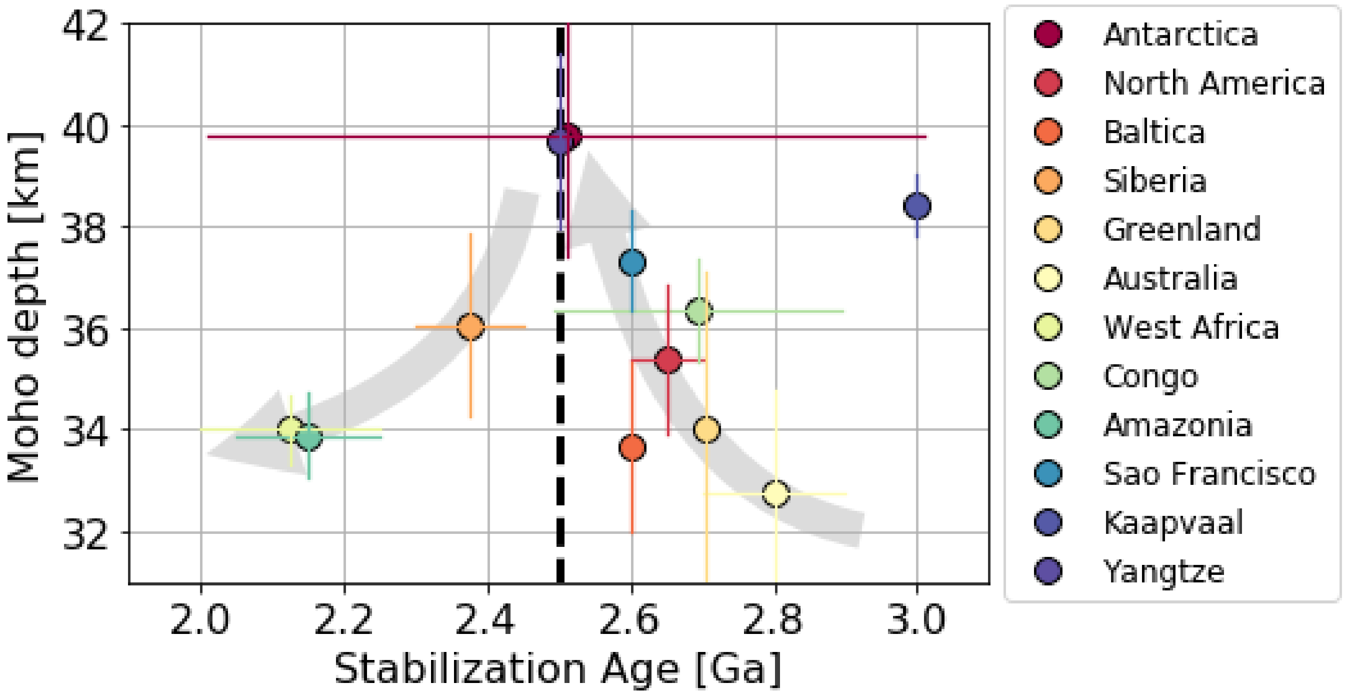


Moho depth

What can we infer for cratons?

- Use statistical patterns to quantitatively compare Moho depth and density contrast for main cratons of the Earth
- Link patterns to stabilization age

Moho depth vs. Stabilization age



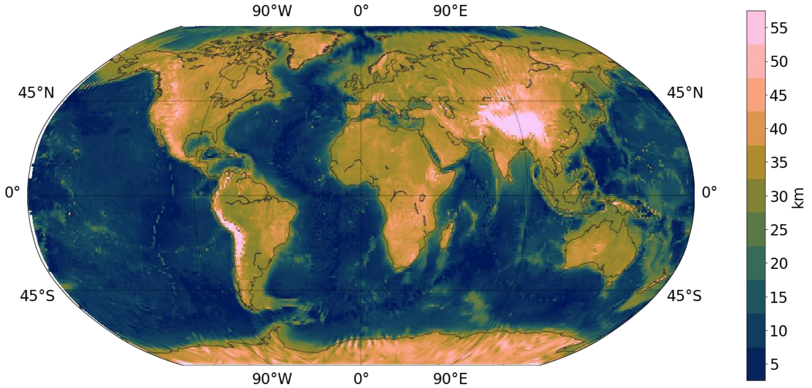
Definition of stabilization age: "basal age of the oldest stable platform sediments" (Abbott et al. 2013)

- Additional data compiled from literature research
- error bars indicate range of possible ages, depending on available data

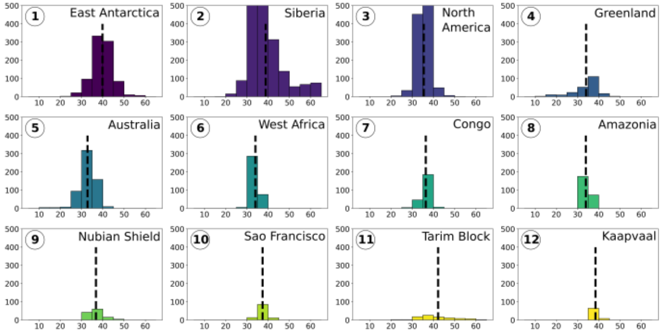
- Secular change in crustal thickness patterns
  - Archean thickening
  - post-Archean thinning
- Thin old crust reflects removal of a dense lower protocrust (Abbott et al. 2013)
- Post-Archean crustal thinning
  - Exhumation of crust during orogenic processes in the Proterozoic (e.g. Block et al. 2015)?
  - Gravitational collapse of continental crust (e.g. Rey et al. 2001)?

Conclusions

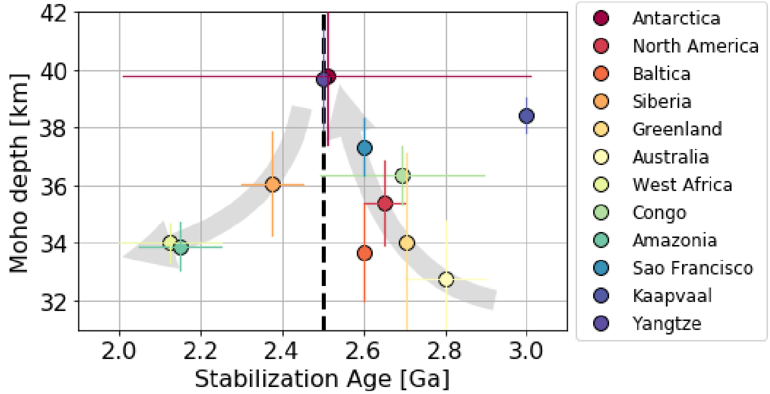
➢ Global gravity gradient inversion for the Moho depth with laterally variable density contrasts based on seismic tomography has been developed



➢ 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



This study has been funded by the German Research Council (DFG) and additional funding by the ESA STSE 3D Earth (www.uni-kiel.de)

Thank you for your attention!

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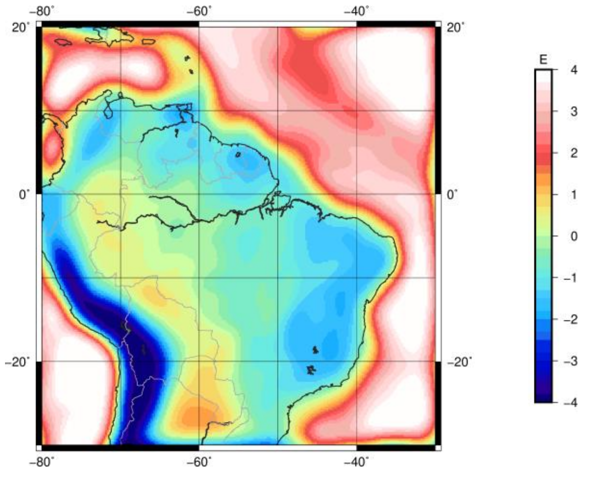
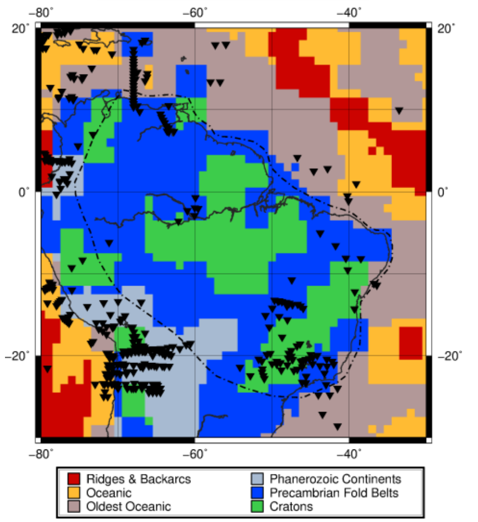
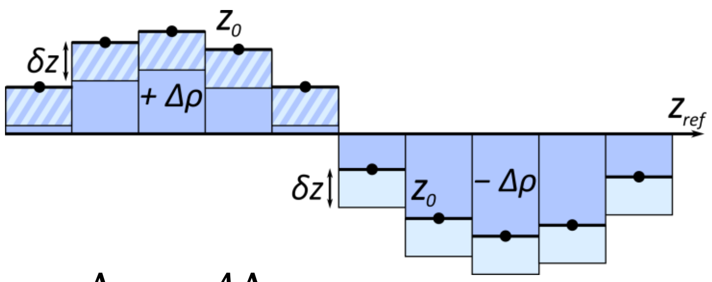
Back-up Material

Gravity gradient inversion for the Moho depth



Initial data





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

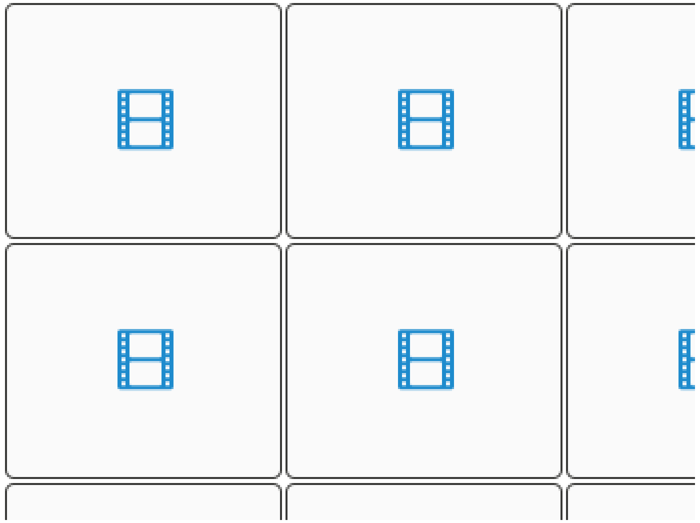
$$\Delta z = [A^T A + ßD^T D]^{-1} A^T \Delta g$$

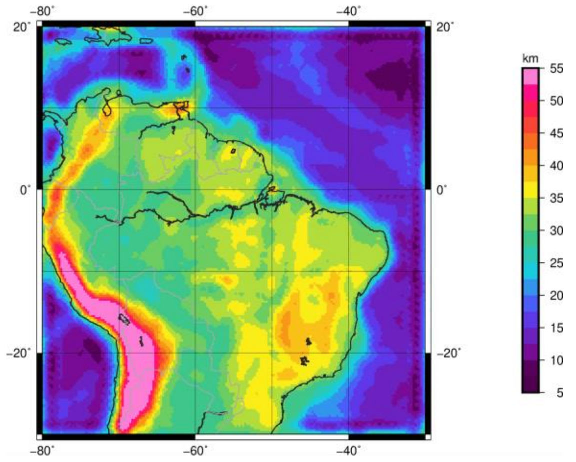
$$\Delta z \; \beta D^T D z_i$$

$$= z_0 + \Delta z$$

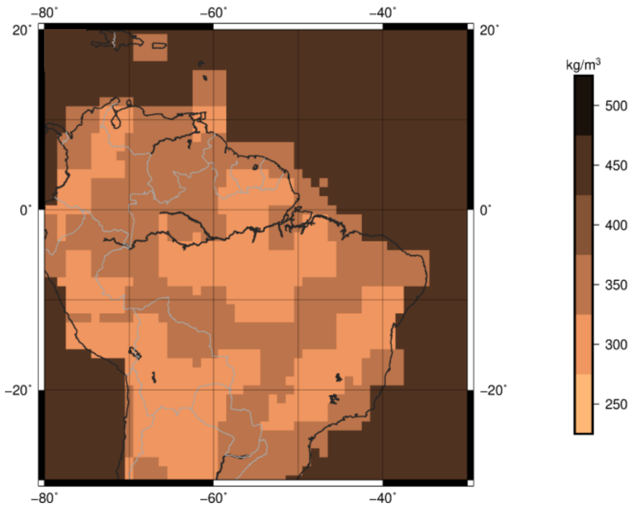
Haas et al. 2020, GJI

Inversion

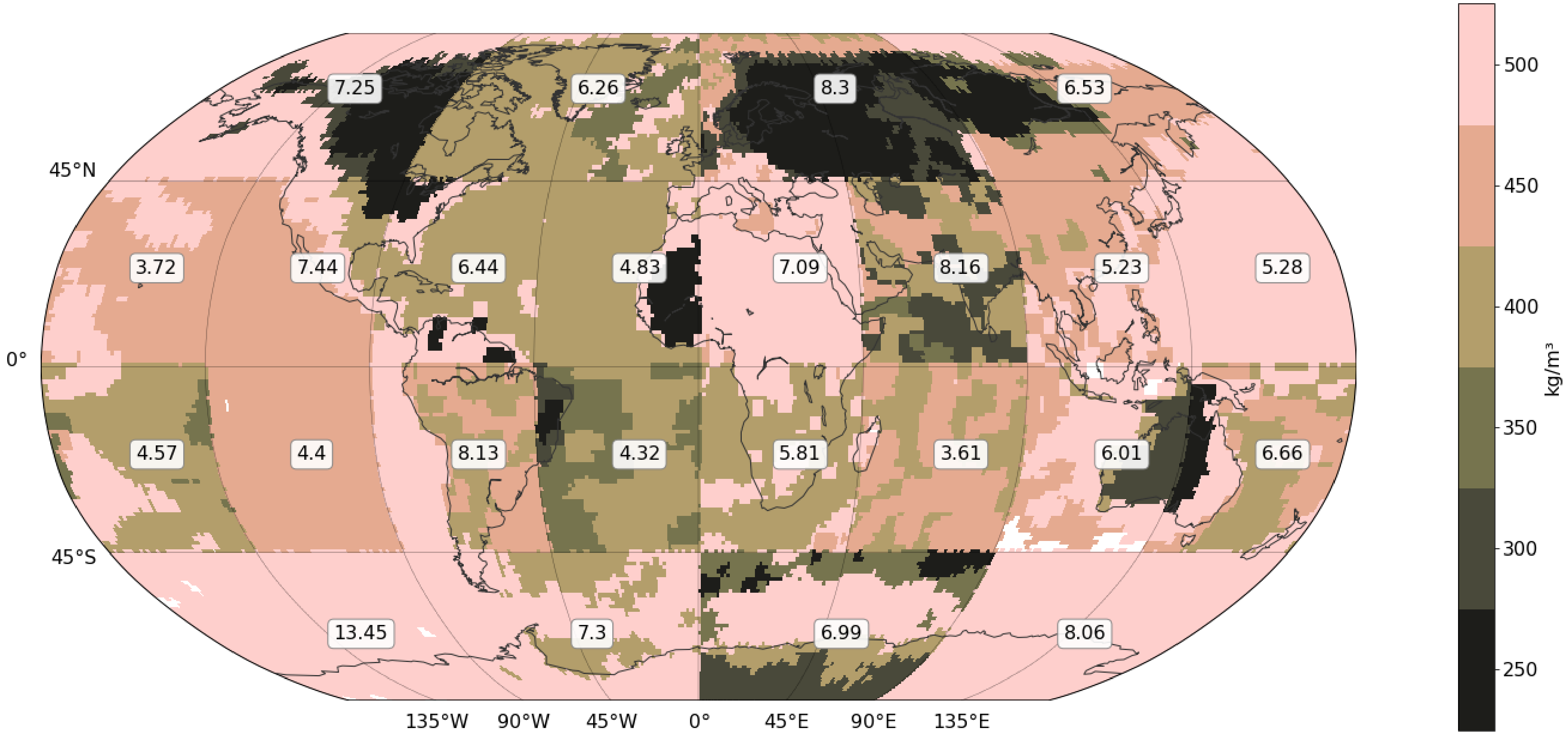




Results

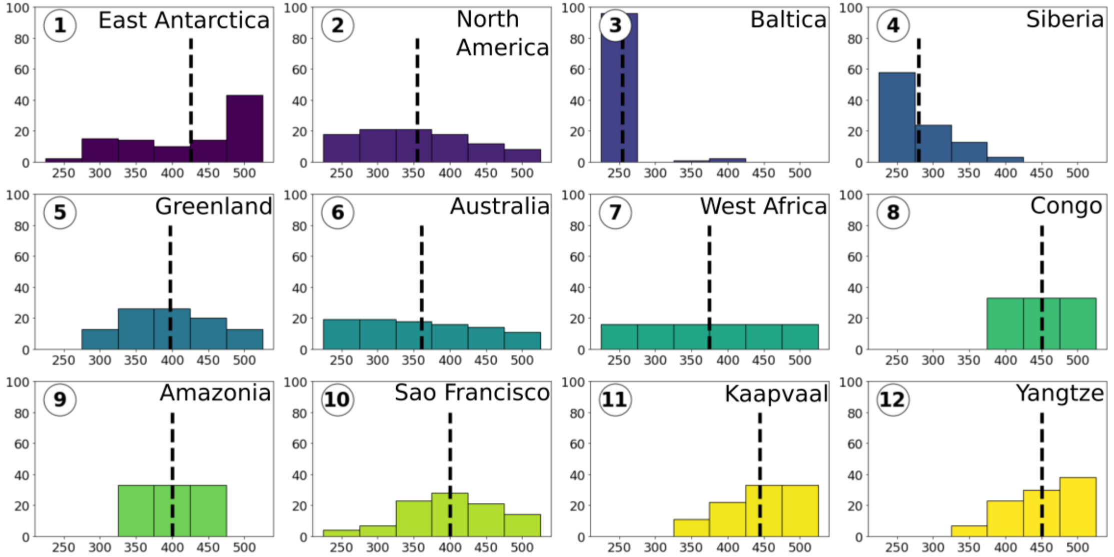


Estimated density contrasts

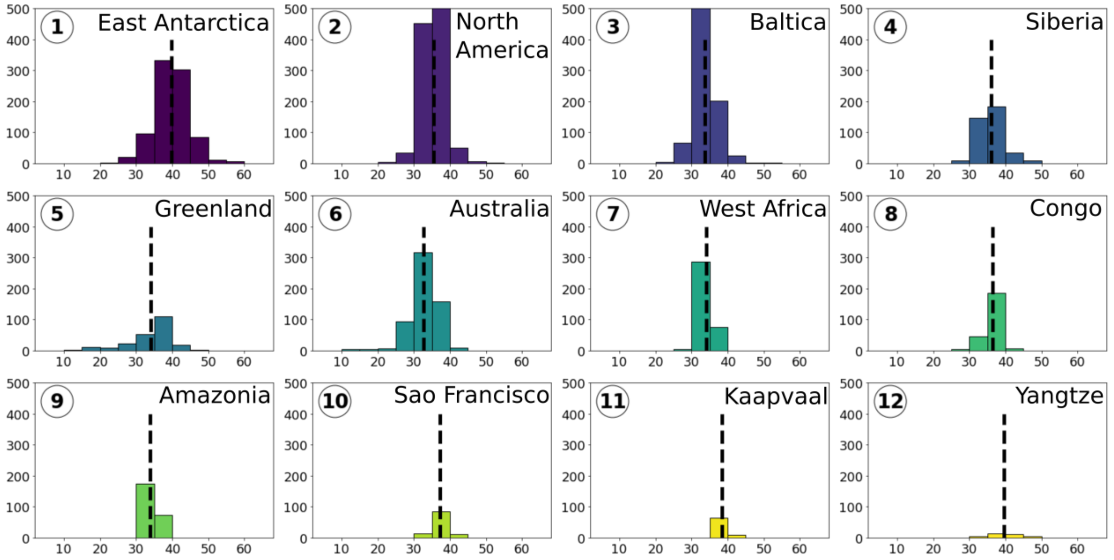


Edge features reflect window boundaries → remove with flood-fill algorithm

Some statistics



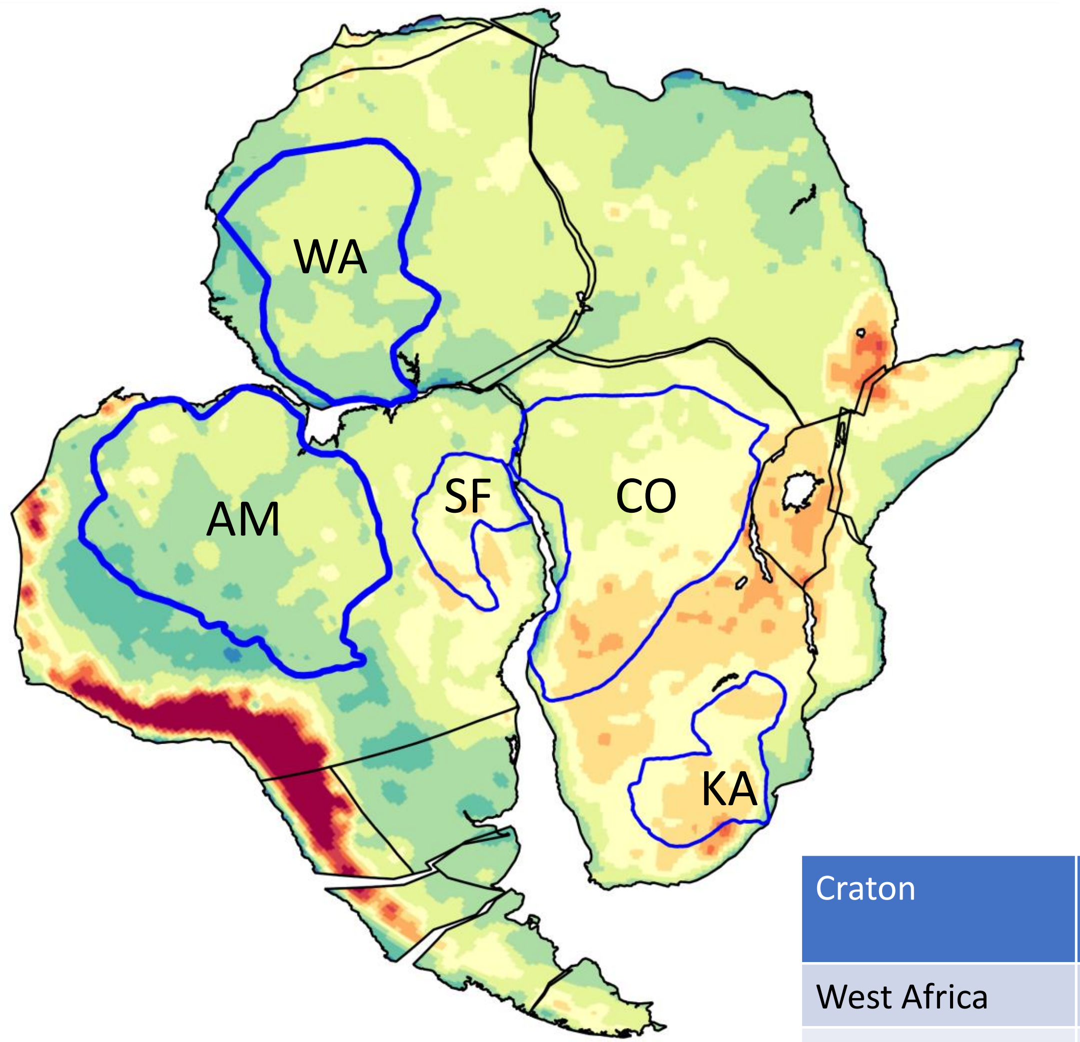
Density contrast



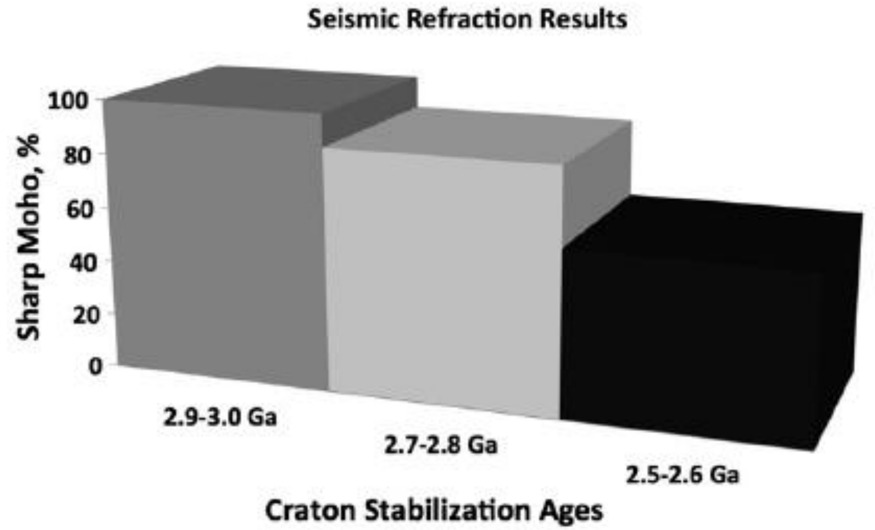
Moho depth

Craton	Mean [km]	STD [km]	Mean [kg/m³]	STD [kg/m³]
Antarctica	39.8	4.8	425	80
North America	35.4	2.9	355	76
Baltica	33.7	3.4	254	23
Siberia	36.0	3.6	280	42
Greenland	34.0	6.2	396	62
Australia	32.7	4.1	360	82
West Africa	**34.0**	**1.4**	**375**	**85**
Congo	36.4	2.0	450	41
Amazonia	**33.9**	**1.7**	**400**	**41**
Sao Francisco	37.3	2.0	400	65
Kaapvaal	38.4	1.2	444	49
Yangtze	39.7	3.4	450	48

Moho depth in Western Gondwana framework



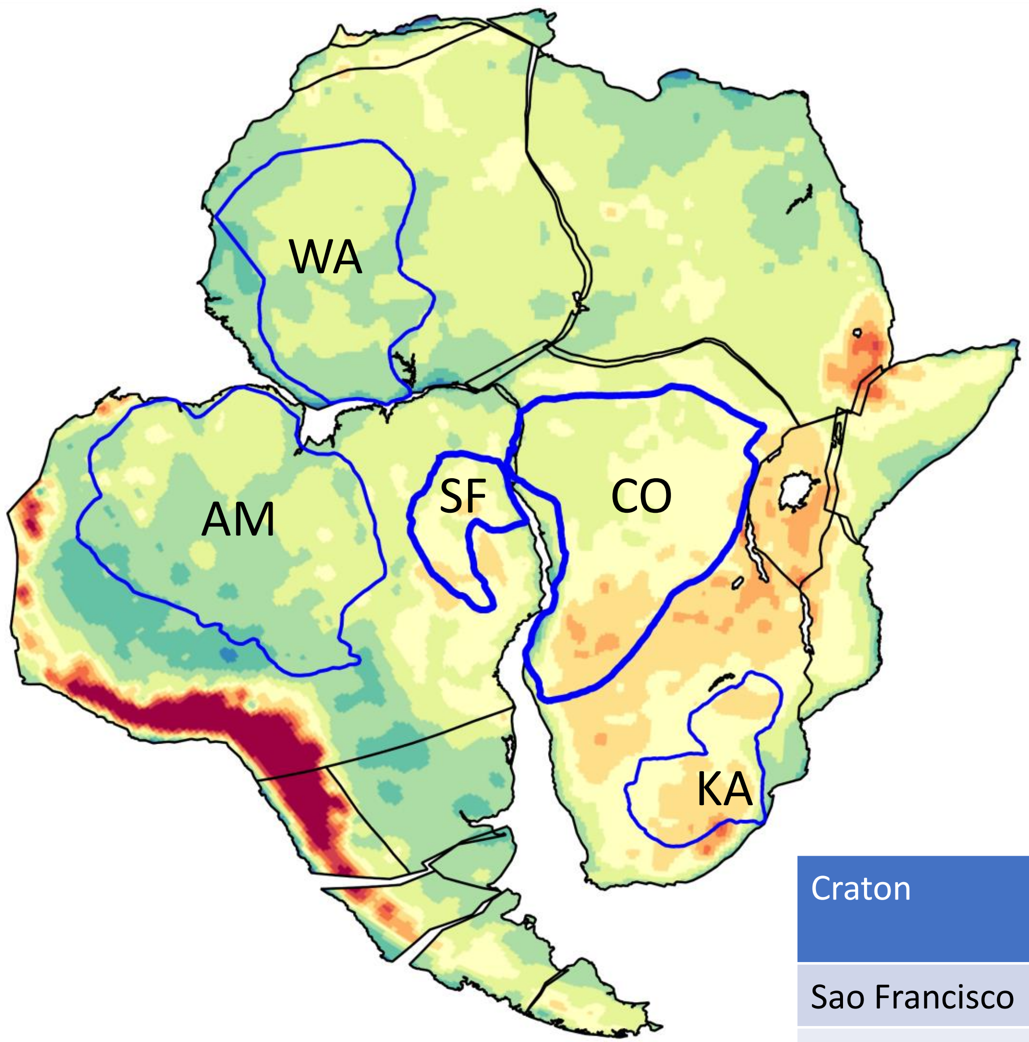
- Amazonia and West Africa both with shallow and flat Moho depth
  - Removal of a dense lower protocrust?
  - Early stabilization in the Archean?



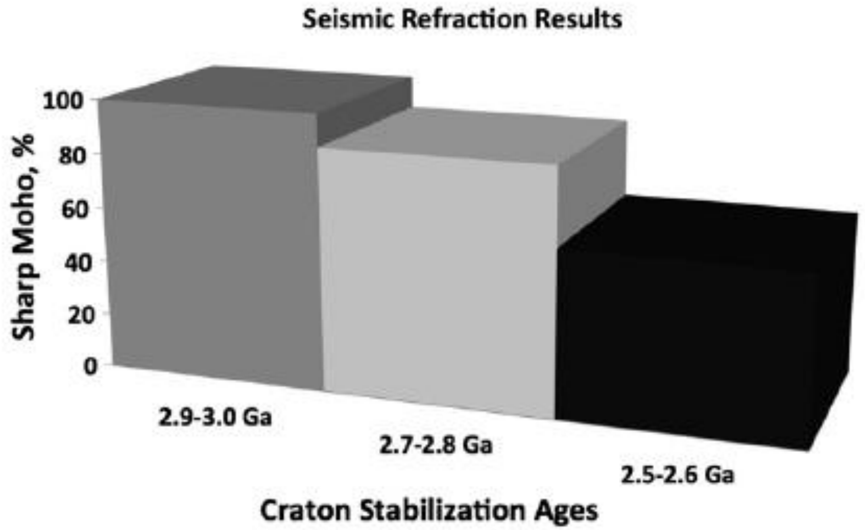
Abbott et al. 2013, Tectonophysics

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

Moho depth in Western Gondwana framework



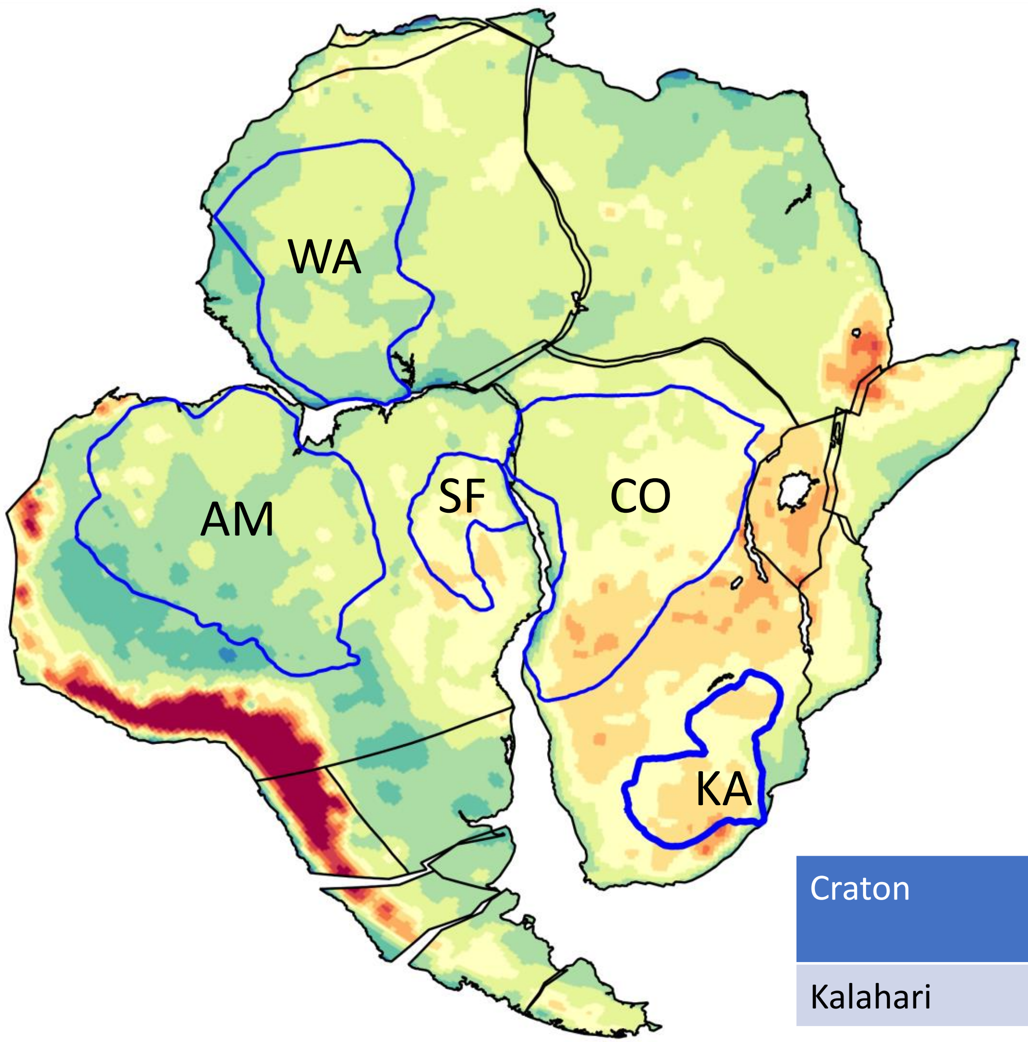
- Sao Franscisco and Congo Craton with a deeper and less sharp Moho
  - Post-Archean crustal thickening



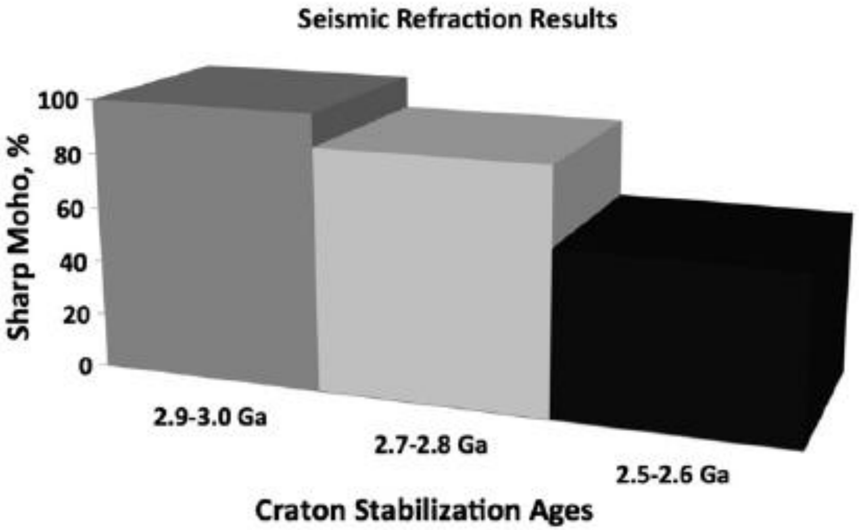
Abbott et al. 2013, Tectonophysics

Craton	Mean [km]	STD [km]
Sao Francisco	**37.3**	**2.0**
Congo	**36.3**	**2.0**

Moho depth in Western Gondwana framework



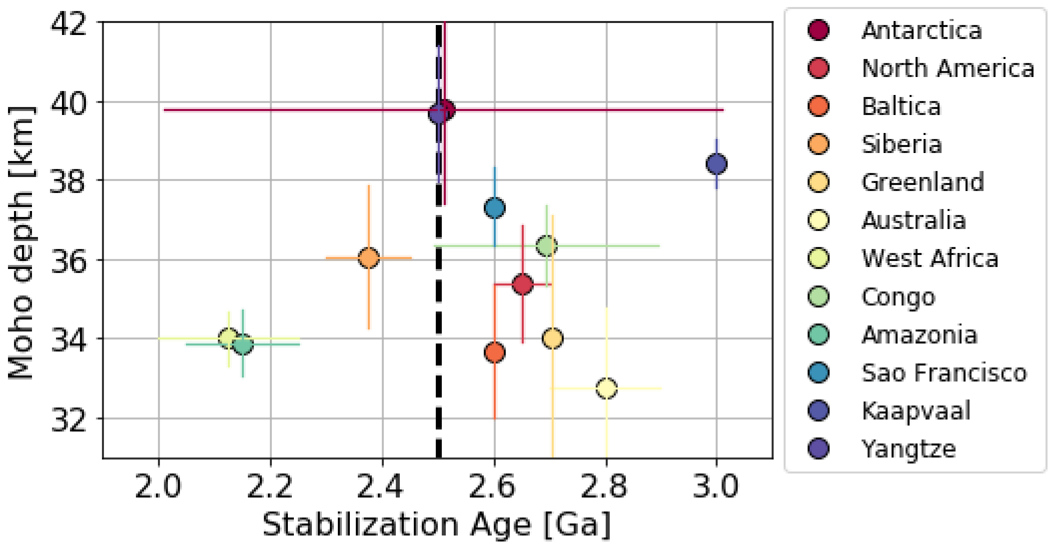
- Kalahari Craton with deep Moho and sharp Moho depth
  - Very early stabilization age



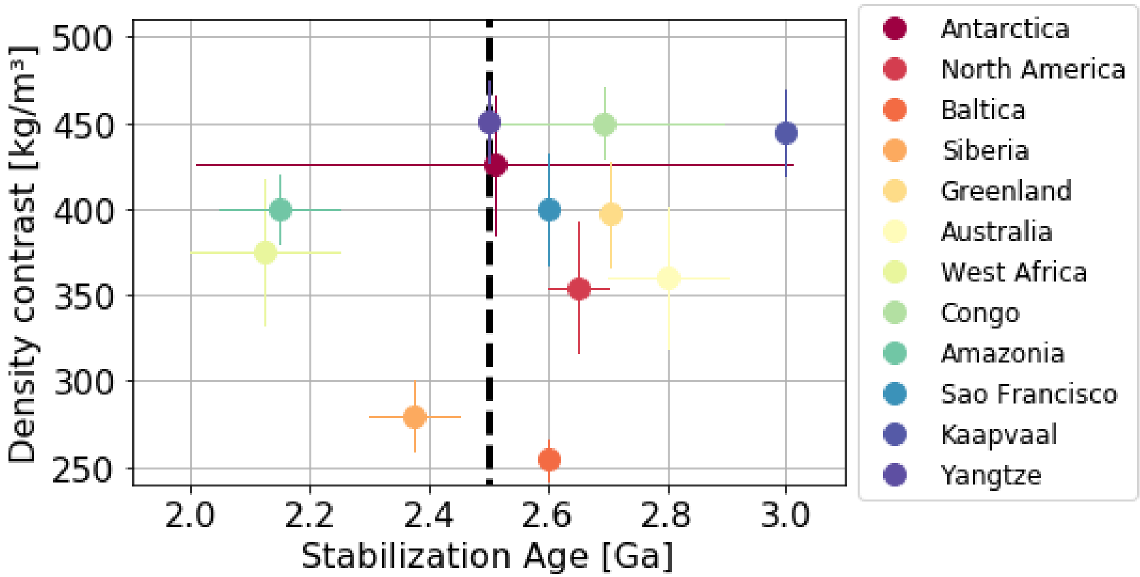
Craton	Mean [km]	STD [km]
Kalahari	**38.4**	**1.2**

Abbott et al. 2013, Tectonophysics

Some statistics

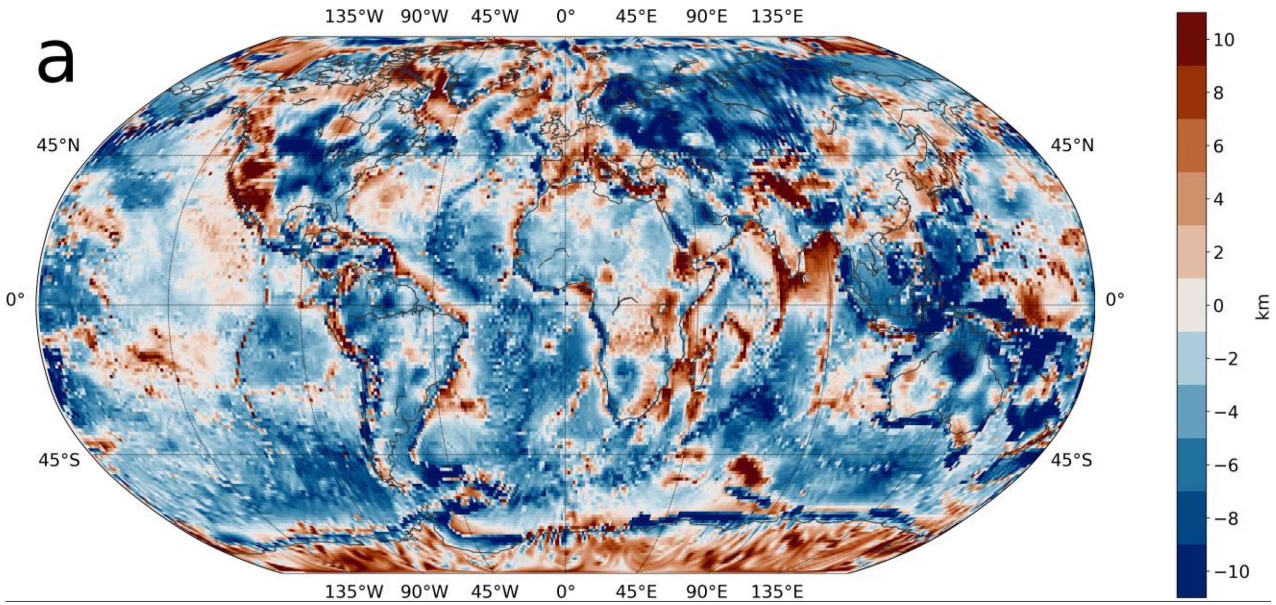


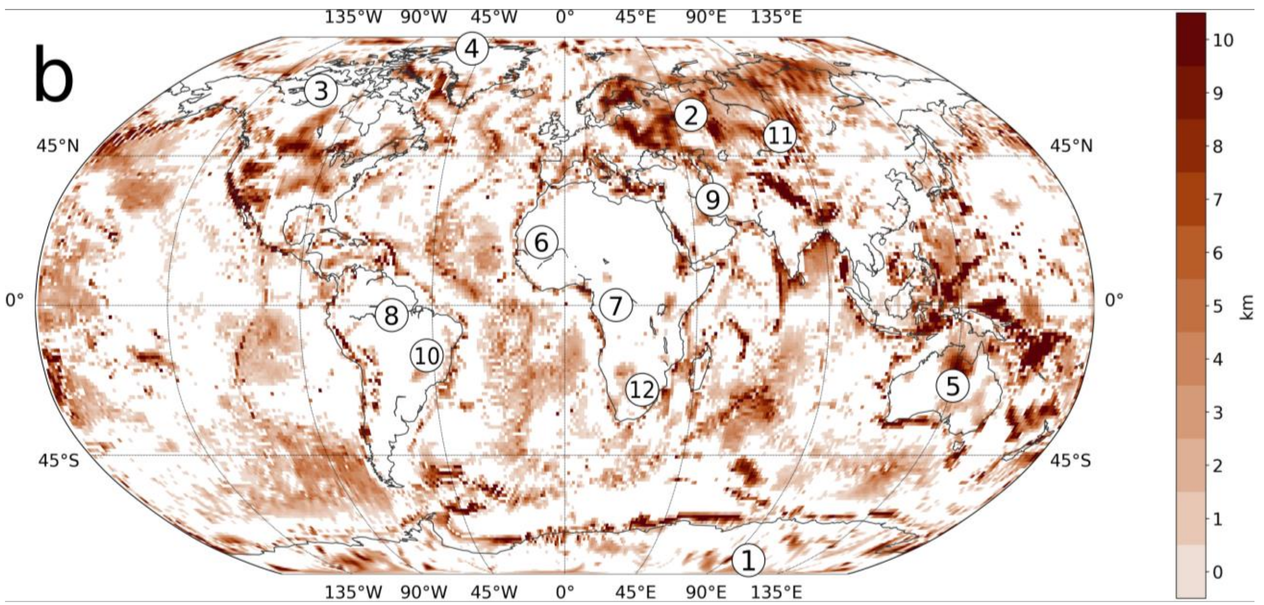
Moho depth



Density contrast

Difference to seismic Moho depth





a: Difference between Moho of this study and seismic Moho of Szwillus et al. 2019
b: Difference between a) and uncertainties of Szwillus-Moho

→ For many areas, the difference is lower than the uncertainty of seismic Moho!