Improving Plate-Reconstruction Models Using Crustal-Thickness Maps from Gravity Inversion

OCTEK

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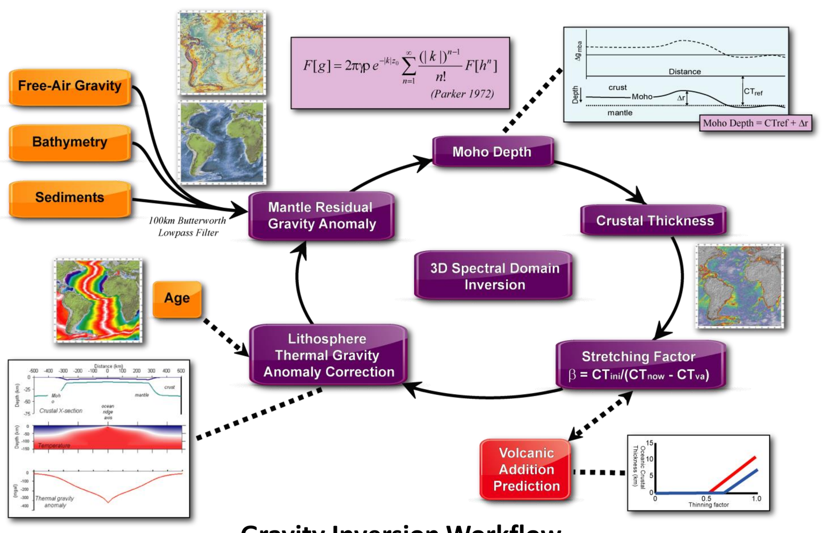
1. Introduction & Methodology

Most plate-restoration models still use features such as present-day coastlines, shelf-breaks and bathymetry to guide their final stages back to the time of breakup. These features are ephemeral and not fixed in the geological past; as a consequence they do not usually provide good tests of the final stages of plate restoration, nor do they constrain reliable predictive models. We show how plate restorations can be improved and made more useful by restoring crustal thickness and lithosphere thinning-factor derived from satellite gravity anomaly inversion.

Using the OCTek gravity inversion methodology (which is described in detail in Greenhalgh & Kusznir (2007, GRL), Chappell & Kusznir (2008, JGI) & Alvey et al. (2008, EPSL)), we can produce a set of digital grids which show 6 parameters:

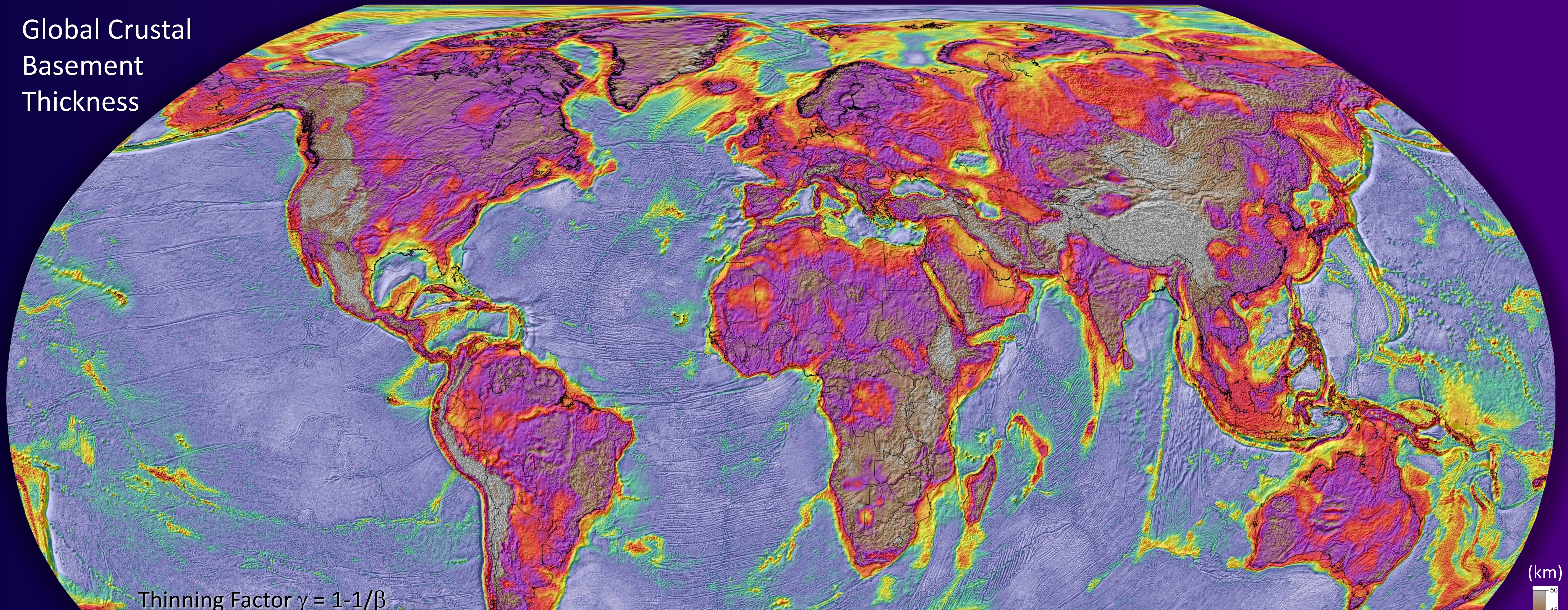
1. Moho depth
2. Crustal basement thickness
3. Residual continental crustal thickness (crustal basement thickness minus magmatic addition produced during rifting/breakup)
4. Continental lithosphere beta factor (β)
5. Continental lithosphere thinning factor ($\gamma = 1-1/\beta$)
6. Lithosphere thermal gravity anomaly

Application of this technique as input to plate-reconstruction models provides new insights into the details of continental breakup and ocean-basin development, together with intriguing new information on ocean-ridge jumps and plate re-organisations. This information can be particularly helpful for planning frontier hydrocarbon exploration.

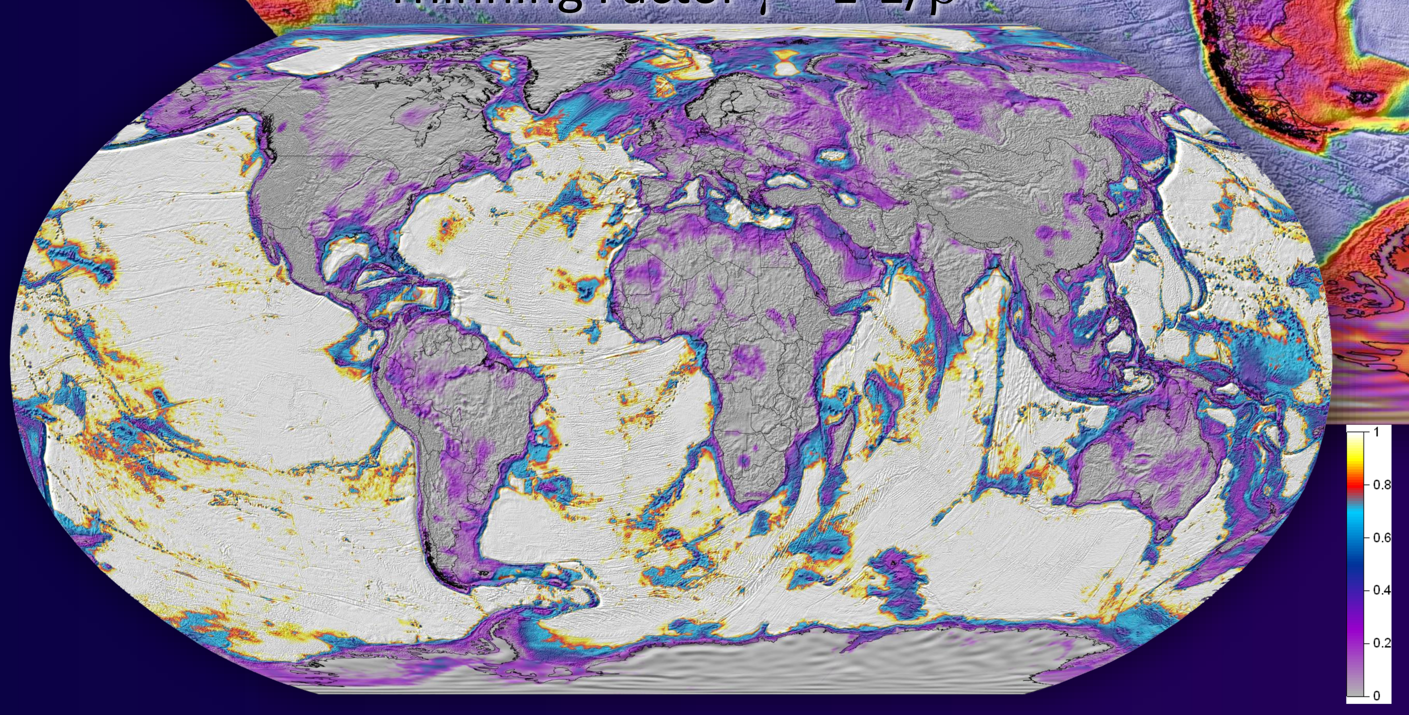


Gravity Inversion Workflow

Global Crustal Basement Thickness



Thinning Factor $\gamma = 1-1/\beta$



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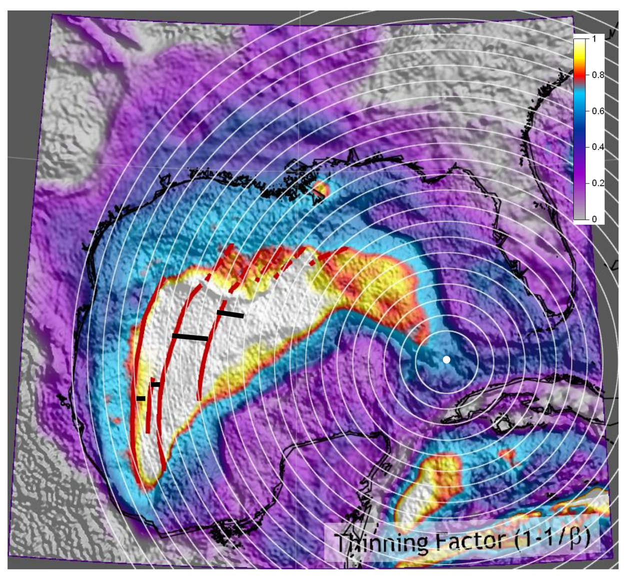
2. Gulf of Mexico

Crustal thickness mapping using satellite gravity inversion for the Gulf of Mexico (GoM) clearly shows the location of an extinct sea-floor-spreading ridge together with the transform faults which segment and offset the ridge. The transform faults reveal the sea-floor-spreading trajectory and rotation poles, providing important constraints on pre-breakup rifted-margin conjugacy.



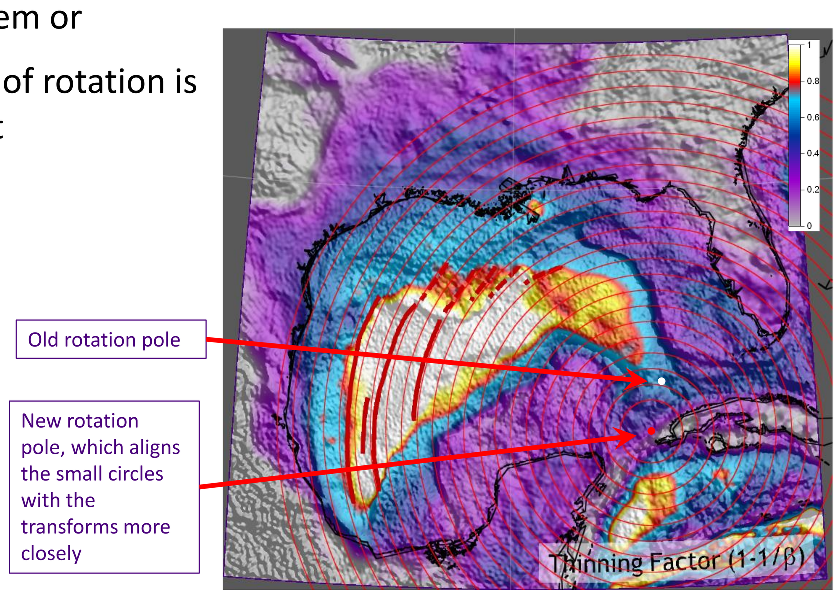
🡐 The small circles associated with the standard pole of rotation (Seton et al, 2012) for the GoM are not consistent with the transform faults observed using satellite gravity.

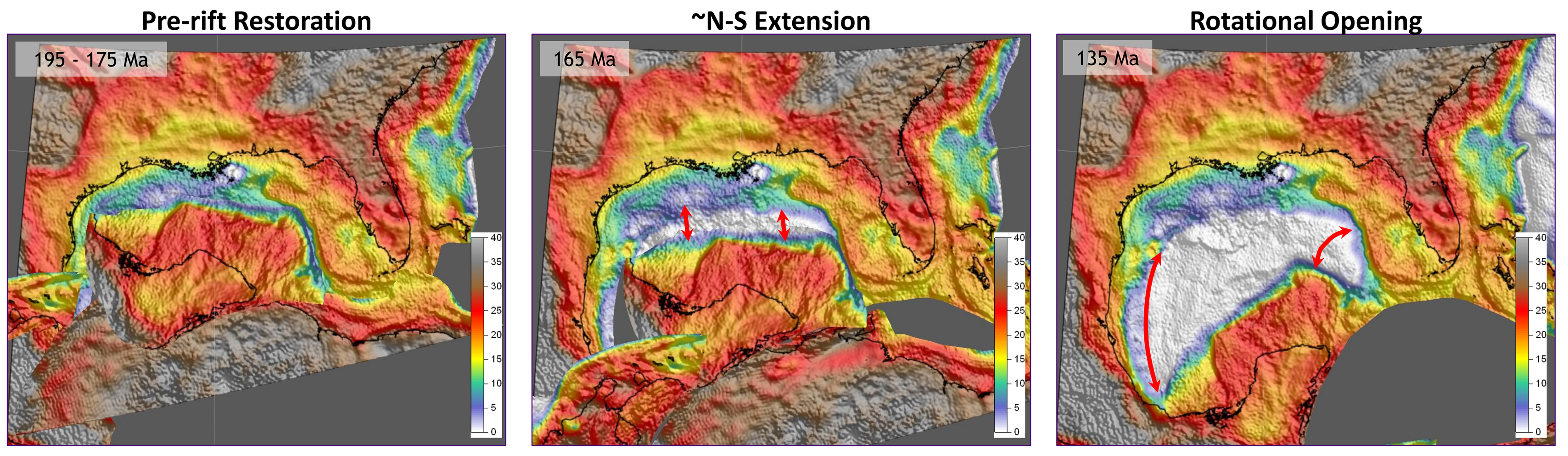
The standard pole of rotation for the GoM implies either:

1) transforms have a significant proportion of transpression along them or
2) the pole of rotation is incorrect

We have used the small circles observed using satellite gravity anomaly to determine a new pole of rotation which is located to the south of the standard pole ➔

The new pole of rotation provides a revised tectonic evolution of the GoM.

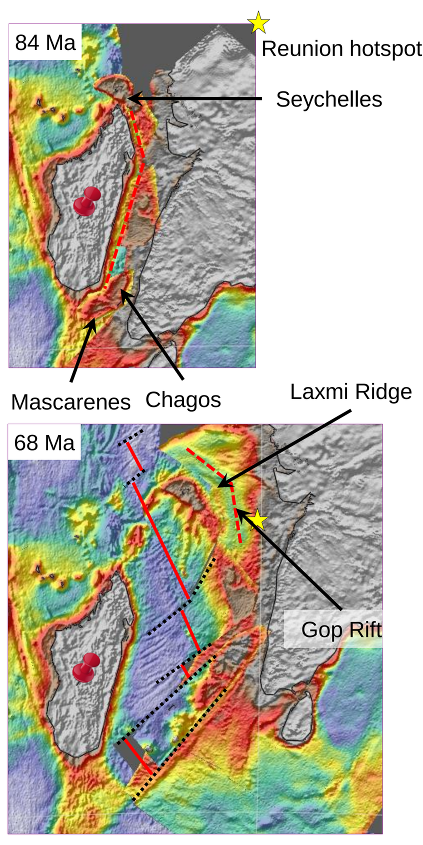




The revised tectonic evolution of the GoM consists of a two-stage process with initial rifting & continental extension occurring in a N-S direction as South America separates from North America, switching to a rotational opening at ~165Ma.

3. Indian Ocean

While the first-order opening history of the Indian Ocean is well understood, we can improve our understanding of its plate-kinematic evolution by using crustal thickness from gravity inversion to test and constrain plate-reconstruction models. In particular additional information can be gained by mapping the many regions of anomalously thick crust within the Indian Ocean which are resolved by gravity inversion. Some of these areas may be rifted micro-continents, while others are associated with intra-plate volcanism, ocean-ridge jumps and plate re-organisations.

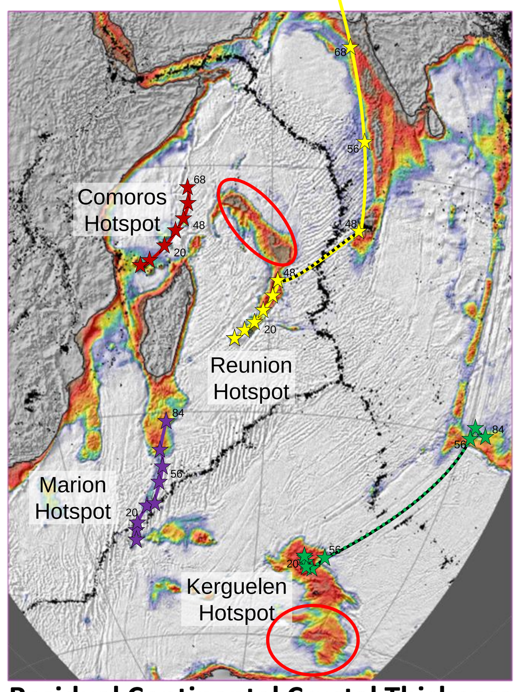


We use crustal thickness derived from satellite gravity inversion to update the existing plate-reconstruction model for the Indian Ocean.

Using the Indio-Atlantic fixed hotspot reference frame we can plot the hotspot tracks onto maps of residual continental crustal thickness to help understand the origins of the anomalously thick crust observed within the Indian Ocean. ➔

We can associate much of the thick crust with the presence of hotspots… BUT not all (i.e. areas circled in red on the right).

Regions such as Laxmi Ridge, Seychelles & Mascarene Bank are of continental origin and should be included in plate-reconstruction models.



Residual Continental Crustal Thickness