[PS]Modelling Continental Margin Extension Using Combined Rigid/Deformable Plate Tectonic Reconstructions*

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Abstract

Plate tectonic reconstructions are essential for placing geological information in its correct spatial context, understanding depositional environments, defining basin dimensions and evolution, and serve as a basis for palaeogeographic mapping e.g. for palaeo-climate modelling. A well-known problem with traditional 'rigid' plate reconstructions is overlap and underfit of plates when restored in their pre-drift assemblages. To address these challenges, a new high-resolution palaeogeographic plate reconstruction model has been developed for the Mesozoic and Cenozoic that restores the extensional deformation produced at continental margins.

Continent-ocean boundaries (COB) have been redefined by utilising gradient changes in gravity anomalies, crustal thickness depth to Moho, differences in gravity signature over continental, transitional and oceanic crust, and observing fracture zones in oceanic crust. The relative motions between major plates are determined by matching fractures and magnetic anomalies of similar age in oceanic basins. The relative plate motions of minor plates are calculated by Euler Pole addition in a global circuit, with central Africa at the uppermost position of the plate motion chain. For modelling extension on a global tectonic scale, beta factors have been calculated from the overlap of stretched conjugate passive margins over the relevant geological time span. To remove the deformation effects produced by overlap in the reconstructions, an ArcMap™ extension has been developed (PLATE WIZARD™). This program creates displacement vector maps that allow restoration of the plate margins by 'warping' the mapped extended regions. The program also allows the restoration of the geometries of geo-referenced datasets that intersect with the plate margins defined by the model.

To date, a consistent global plate tectonic model has been achieved, that incorporates stretching factors and scales deformation for the Cenozoic and Mesozoic. It is noted, however, that by resolving deformation geometries to pre-drift positions, the imprint of earlier rifting, strike slip and collisional histories are more clearly defined. This allows areas with a multi-phase tectonic history to be accurately modelled within a dynamic global framework.

FUGRO ROBERTSON

Modelling continental margin extension using combined rigid/deformable plate tectonic reconstructions

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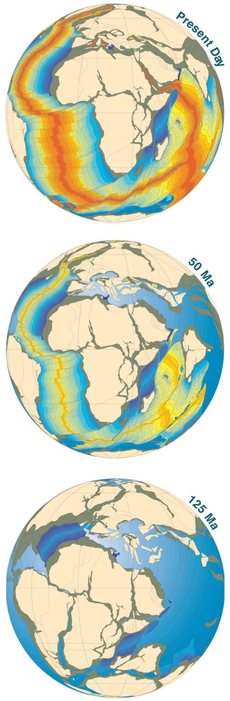
- New, global high-resolution dynamic plate tectonic model for the Cenozoic and Mesozoic
- Consistent global set of new continent-ocean boundary definitions
- Accurately reconstructs position and interaction of Earth's tectonic plates and geo-referenced datasets for the past 250 Ma
- Deformable plates method - ability to warp deformable plates to reduce overlap and underfit problems



INTRODUCTION

PLATE WIZARD™ is a plate tectonic model and GIS software extension that accurately reconstructs and predicts past positions and geometries of 'rigid' and 'deformable' plates of the Earth.

WHY?

PLATE WIZARD™ is used for:

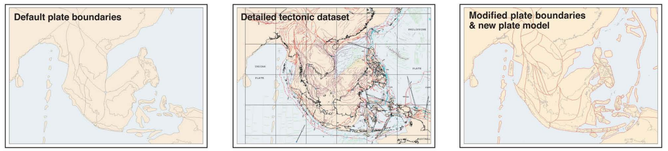
- Understanding depositional environments
- Defining basin shape, form and evolution

Forms the basis of palaeogeographic mapping for:

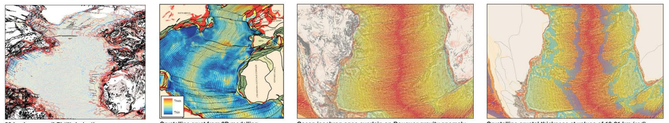
- Modelling climate palaeo-Earth systems
- Predicting source facies, sediment transport/reservoir facies, assessing timing of deformation and trap development

DEFINING THE CONTINENT-OCEAN BOUNDARY

New plates have been identified, mapped and defined as either 'rigid' cratonic interiors or deformable margins that accommodate extension and contraction at plate boundaries.



A consistent global set of new continent-ocean boundary (COB) definitions is constrained by the mapping of structural, geophysical and satellite-altimetry derived Bouguer gravity anomaly and crustal thickness datasets.



20 km low pass (LP) tilt derivative of Bouguer gravity anomaly | Crystalline crust from 3D modelling | Ocean isochron ages overlain on Bouguer gravity anomaly | Crystalline crustal thickness at values of 19-21 km (red), 9-11 km (blue).

General characteristics of Continent-Ocean Transition Zone

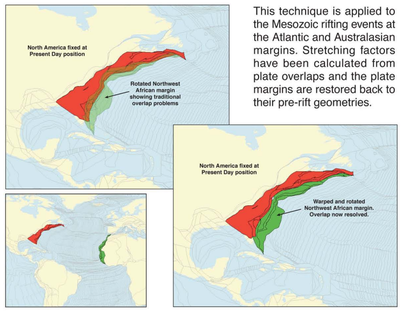
- Crystalline crust thins seaward (from ~30 km to ~ 6 km)
- Crustal density increases seaward
- Moho depth shallows seaward
- High gradient change in crustal thickness/Moho depth within transition zone
- High gradient change of gravity anomaly
- Difference in signature across continental and oceanic crust

DEFORMATION OF EXTENSIONAL MARGINS

An issue with traditional plate reconstructions has been the problem of plate margins that when reconstructed into their pre-break up positions result in overlap or underfit.

The definition of new deformable plates within the model allows extension and contraction to be modelled at these plate margins.

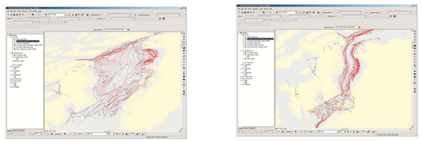
The two margins are restored together and the overlap is measured and then used to calculate the beta factors involved in the stretching.



This technique is applied to the Mesozoic rifting events at the Atlantic and Australasian margins. Stretching factors have been calculated from plate overlaps and the plate margins are restored back to their pre-rift geometries.

FRL's internal PLATE WIZARD™ administrator tool uses these beta factors and trajectories to create a deformation model.

The user version of the PLATE WIZARD™ tool then analyses the deformation model and applies the appropriate warp to the user's shape files. The two margins are then reconstructed and a new tighter fit is achieved with the overlap problem eliminated.

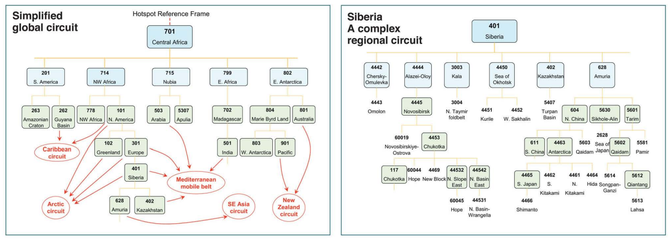


TELLUS™ isopach data shown in Present Day positions and warped back to 84 Ma using new ArcMap deformable plate model extension

PLATE HIERARCHY

The relative motions between major tectonic plates are determined by matching fracture zones and magnetic anomalies of similar age. These are then integrated into a global plate circuit that utilises Euler pole addition to calculate relative motions of less well-constrained plates.

Central Africa has been kept at the uppermost level of the plate hierarchy in PLATE WIZARD™ with the rotation of Africa relative to a hypothetical fixed hotspot reference frame.



CONCLUSIONS

- PLATE WIZARD™ is a new plate tectonic model and ArcGIS software extension capable of reconstructing the positions of newly-defined plates and geo-referenced datasets for the last 250 Ma.
- The model is based on detailed mapping of the Earth's crust incorporating geophysical, seismic and structural datasets that redefine the COB to allow accurate positioning of plate boundaries.
- Deformable plate margins have been modelled and the PLATE WIZARD™ software uses this modelling to warp extensional plate boundaries to their pre-rift geometries and minimise overlap problems inherent in many previous plate reconstructions.

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