Correlating tectono-stratigraphic events along the East African Margin: Combining high-resolution plate kinematic models, plate-scale stress simulations and regional sedimentary basin fill histories

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1. INTRODUCTION

The Northwest Indian Ocean and the passive continental margins of East Africa and West Madagascar formed during the breakup of Gondwana in the Mid-Jurassic. It was during this time that the marginal sedimentary basins, currently attracting attention for hydrocarbon exploration, were formed.

Since initial rifting, the development of the Indian Ocean has been punctuated by a number of boundary relocations. As a result of this complicated history, it has proven difficult to reconcile the area into a coherent tectonic model. A new high-resolution plate kinematic model of the opening of the NW Indian Ocean has been developed using finite rotation poles generated by a mixture of visual fitting and iterative joint inversion of magnetic isochron and fracture zone data [2,3]. The model is correlated with the tectono-stratigraphy and subsidence history of the sedimentary basins. It will also be used to predict and then quantify the regional stress field of the African plate at important tectonic stages.

2. PLATE KINEMATIC MODEL AND BASIN HISTORY

The new plate model identifies four phases of sea floor spreading during the opening of the NW Indian Ocean, from the Jurassic to the present day. This was preceded by intracontinental 'Karoo' rifting episodes from the late Carboniferous to late Triassic which culminated with the eruption of the Karoo-Ferrier LIP. The Karoo rifting failed to reach continental breakup but initiated the formation of the sedimentary basins along the East African and West Madagascan margins (Fig. 1) with infill of thick continental sediments of the Karoo Supergroup.

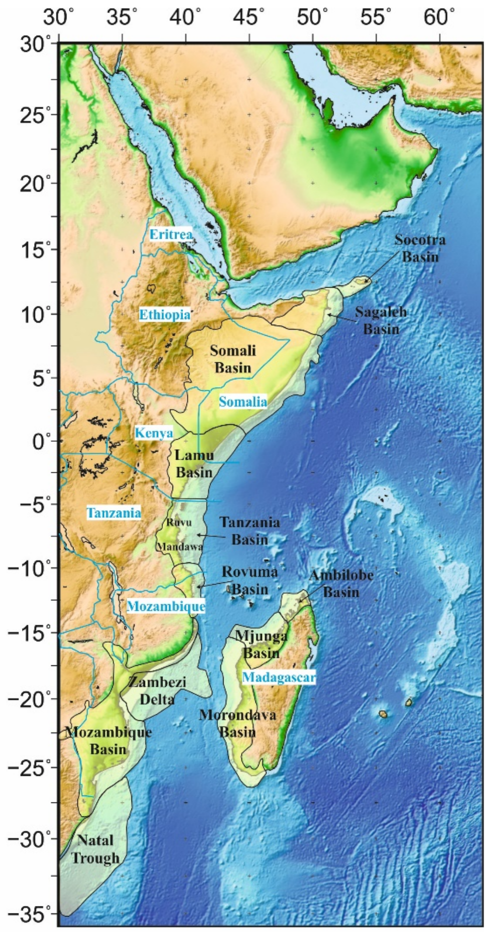

Figure 1: Sedimentary basins of East Africa and West Madagascar (modified from [6])

2.1. Phase One: Initial Rifting and Seafloor Spreading between Africa and Madagascar/India/Antarctica (183–133Ma)

Following the eruption of the Karoo volcanics, a new phase of continental rifting began at approximately 183Ma, with predominantly NW–SE extension that eventually separated Madagascar/India/Antarctica from Africa. Syn-rift sediments have been recognised in most marginal sedimentary basins ranging from Early Jurassic (~180–190Ma) to Aalenian age (170Ma, Mid-Jurassic). A relatively contemporaneous, Early Bajocian (171Ma) breakup unconformity can be traced throughout the basins. By 169Ma, syn-rift sedimentation had ceased in all basins and full marine conditions had been established.

Subsidence data is limited for these times, however the Somali Basin showed very high rates of subsidence at ~175–170Ma which corresponds well to the syn-rift stage recognised in our model and the basin stratigraphy. During the latter part of phase one, the Somali, Lamu, Morondava, Mozambique and Rovuma basins all experienced moderately high subsidence rates, likely due to changes in the Indian Ocean, such as the cessation of spreading in the West Somali basin and the relocation of the boundary south between Madagascar/India and Antarctica.

2.2. Phase Two: Boundary Relocation and Separation of Madagascar/India and Antarctica (133 Ma–Present)

At ~133Ma, spreading in the West Somali basin ceased and the divergent plate boundary shifted to the south between Madagascar/India and Antarctica, incorporating Madagascar and India to the African plate. The orientation of the plate divergence vector however did not change markedly, remaining in a North–South direction.

2.3. Phase Three: Rifting between India and Madagascar and the Opening of the Mascarene Basin (89–61Ma)

During phase three, the initiation of the Mascarene Ridge separated India from Madagascar which led to renewed tectonic activity in the sedimentary basins of western Madagascar in the form of wrench faulting and compressional folding [1]. Coincident with this was a period of rapid subsidence along the Indian Margin, including the Morondava Basin, Madagascar [1,4], the Mozambique and Rovuma Basins and to a lesser extent the Lamu Basin, Kenya [4].

The anti-clockwise rotation of the independent Seychelles microplate between chrons 28n (64.13 Ma) and 26n (58.38Ma) and the opening of the short-lived Laxmi Basin (67 Ma to abandonment within chron 28n (64.13–63.10Ma)) have been further constrained by the new plate kinematic model. Coeval with the ridge jumps accelerated subsidence was observed in the basins of Somalia and Kenya, together with unconformities in the Somali, Lamu, Rovuma and Mozambique basins [4].

2.4. Phase Four: Separation of India and the Mascarene Plateau (61Ma–Present)

In the fourth phase asymmetric spreading of the Carlsberg Ridge separated India from the Seychelles and the Mascarene Plateau. As a consequence of the southward propagation of the Carlsberg Ridge, the Central Indian Ridge formed. The regional tectonic stress field in the passive margin basins became overprinted by local gravity-driven stresses trending parallel to the margin due to loading and extensional collapses of thick sediment wedges. These affects are amplified by the development of the East African Rift System in the Oligocene, e.g. the Rovuma deep water fold-and-thrust belt, caused by uplift and doming of East Africa prior to rifting, and increased sedimentation [5]. Coeval with the development of the EARS was increased subsidence in the Lamu, Rovuma and Mozambique basins.

3. SUMMARY

Our new model illustrates four stages in the tectonic evolution of the NW Indian Ocean, from the Mid-Jurassic to present day, supported by evidence in basin histories. The model will form the basis for the qualitative and quantitative analysis of plate boundary forces and regional stress field across the African plate, to highlight the important interplay between plate boundary forces and basin formation.

4. REFERENCES

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