

Absolute migration and the evolution of the Rodriguez Triple Junction since 75 Ma

D.C.P. Masalu

Institute of Marine Sciences, University of Dar es Salaam, P.O. Box 668, Zanzibar, Tanzania

ABSTRACT

The Rodriguez Triple Junction (RTJ) is a junction connecting three mid-ocean ridges in the Indian Ocean: the Southwest Indian Ridge (SWIR), the Central Indian Ridge (CIR) and the Southeast Indian Ridge (SEIR). The evolution of the RTJ has been studied extensively for the past 10 Ma and the triple junction is believed to be largely a ridge-ridge-ridge (RRR) triple junction. However, due to the scarcity of data its configuration prior to that period is poorly understood. The migration of the RTJ in the hotspot reference frame, for the past 75 million years has been mapped, by reconstructing its traces on the three plates (African, Antarctic and Indian) to their former positions. The results show that the RTJ has migrated northeasterly at velocities varying from 10cm/yr at 70 Ma to 2.6cm/yr at 43 Ma and thereafter 3.6–3.8cm/yr, in a fairly straight-line trajectory, suggesting a stable configuration of the RTJ since its formation. Because the RRR triple junction is the most stable configuration that is possible, it is suggested that the configuration of the RTJ has been largely RRR triple junction since its formation.

INTRODUCTION

The Rodriguez Triple Junction (RTJ) is one of the outstanding features on the Indian Ocean seafloor. This triple junction is defined by three ridges: the Central Indian Ridge (CIR) which separates the African and Indo-Australia plates, the Southwest Indian Ridge (SWIR) which separates the African and Antarctic plates, and the Southeast Indian Ridge (SEIR) which separates the Indo-Australia and Antarctic plates. The RTJ came into existence at Chron 28 (64 Ma) when the Seychelles microplate drifted from India, giving birth to Carlsberg Ridge (McKenzie and Sclater, 1971). The evolution of the RTJ since Chron 5 (~10 Ma) has been studied extensively (McKenzie and Sclater, 1971; Tapscott et al., 1980; Patriat and Courtillot, 1984; Munsch and Schlich, 1989) and is relatively well constrained. For this period the most widely accepted model of evolution of the RTJ is alternating RRF and RRR configurations. However, the evolution of the RTJ before 10 Ma is only poorly understood due to the scarcity of geophysical data. Based on the apparently consistent configuration of the three ridges between 10 and 39 Ma (Chron 18), it has been

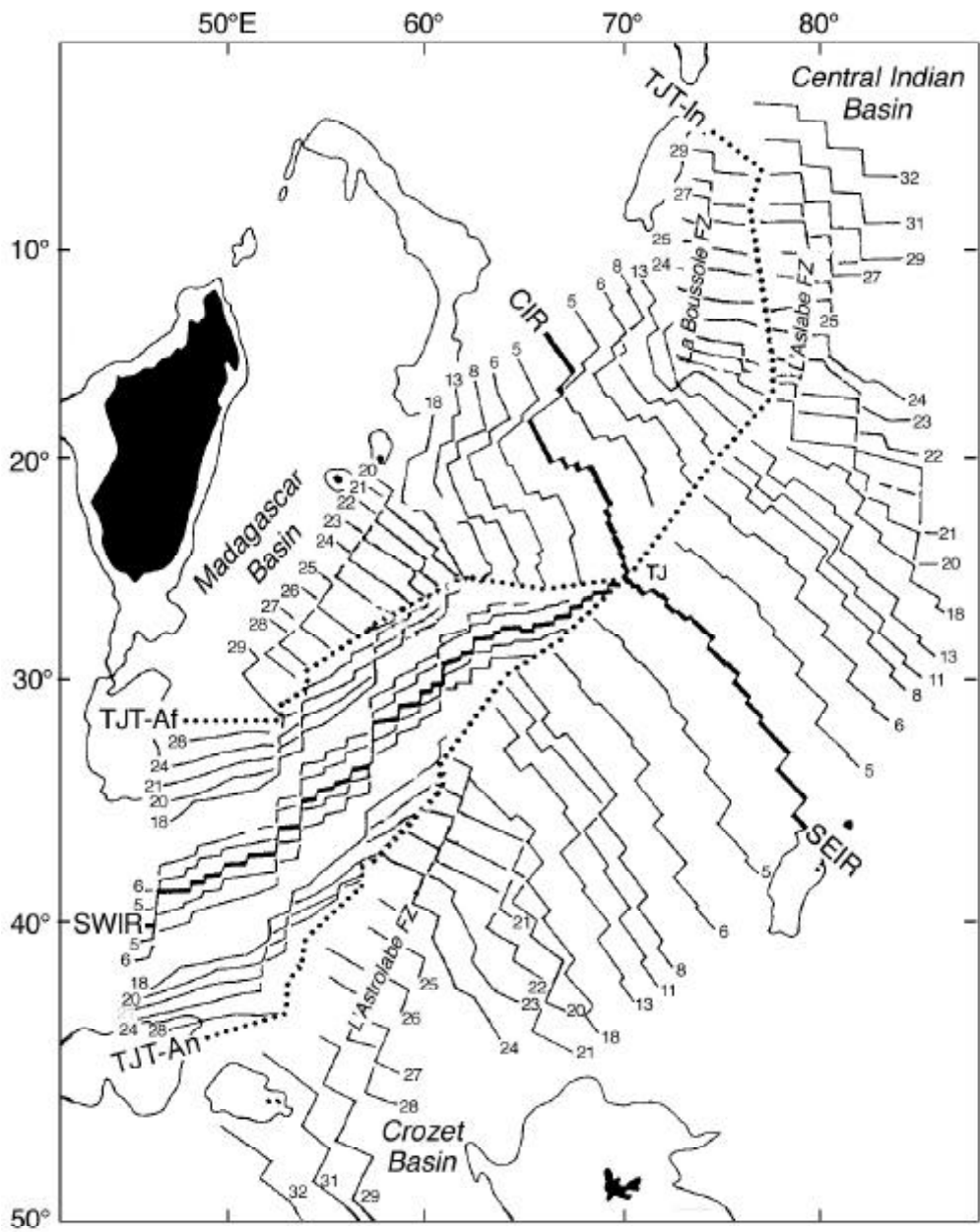


Figure 1. Tectonic map of the Central Indian Ocean (after Patriat and Segoufin, 1988). Thin lines are either isobath 2500 m or magnetic lineations with their anomaly number; thick lines are spreading centres as indicated; dotted lines are traces of the RTJ (TJT-Af = trace on the African plate; TJT-In = trace on the Indo-Australia plate; TJT-An = trace on the Antarctic plate)

suggested that the configuration of the RTJ did not change during this period (Dyment, 1993). Similarly, available data for the period before Chron 18 are too sparse to accurately define the RTJ, but they are sufficient to approximately define the trace of the RTJ location (Patriat and Segoufin, 1988). Based on paleogeographic reconstruction results of the central Indian Ocean to derive past positions of the spreading axes at Chron 28 and 24, alternating RRF and RRR configurations (Patriat and Courtillot, 1984) similar to the present configuration were proposed. Recently, Dyment (1993) using updated data in the central Indian basin re-examined the evolution of the RTJ between 65 and 49 Ma (Chron 28 to 21). He suggested that between Chron 29 and 24 the RTJ followed either an unstable RRR or more likely, a pseudo RRF mode: and that between Chron 24 and 21 the evolution was characterised by a predominantly RFF configuration that episodically turned to a transient RRR configuration. This paper investigates the evolution of the RTJ since 75 Ma to Present by mapping its migration in the hotspot reference frame, for the first time ever.

METHODS OF ANALYSIS AND DATA

Magnetic anomaly lineations form concurrently with new seafloor on mid-ocean ridges. On the other hand, a trace of a triple junction is a trajectory that records past locations of the triple junction (TJ). Therefore, if there exist points of intersection between a trace of a TJ and identified magnetic lineations, and a relevant model of absolute motion of the plate on which the trace of the TJ resides, absolute paleopositions of the TJ can be reconstructed by rotating the points to their former positions (Masalu and Tamaki, 1994). However, this method should be used cautiously in cases where the intersections of magnetic lineations with same age on the two sides of the trace of the TJ are significantly dislocated. In such situations, intersections that are relatively younger should be used. For each of the derived successful paleolocations (migration trajectory) from the TJ traces, the absolute migration velocity of the RTJ are computed.

In this study, Figure 1 was used as the base map from which the intersection points of magnetic lineations and the TJ traces, for all three traces of the RTJ were digitised. The reconstruction rotations were performed using Muller et al. (1993) models of absolute plate motions for the Indo-Australia, African and Antarctic plates, and assigned Chron ages based on the recent geomagnetic polarity time scale for Late Cretaceous and Cenozoic time (Cande and Kent, 1992).

Trace of the RTJ on the Indo-Australia plate

The trace of the RTJ on the Indo-Australian plate marks the intersection of the CIR and SEIR. The two ridges have quite similar spreading rates (Dyment, 1993) and as a result intersections of magnetic lineations of the same age with the TJ trace are very consistent (Figure 1). Thus there was no problem deciding which set of intersection points to digitise, for use in reconstructing the paleolocations of the RTJ.

Trace of the RTJ on the African and Antarctic plates

The trace of the RTJ on the African and Antarctic plates is not straightforward. There is one major difficulty, which is the scarcity and complexity of identified magnetic lineations formed by the CIR on the African plate (Tapscott et al., 1980; Sclater et al., 1981), and those formed by the SWIR on both the African and Antarctic plates. This prohibits the intersection points between the TJ traces and magnetic lineations that were formed by the SWIR from being accurately determined. Furthermore, based on tectonic setting of the Indian Ocean basin (Figure 1) the SWIR appears to be propagating into crust that was formed by the CIR and the SEIR. Other investigators have suggested that processes involved on the SWIR close to the TJ are more likely related to extension of the SEIR and the CIR crusts than normal spreading at the SWIR axis (Patriat and Parson, 1989; Mitchell, 1991). However, because the SWIR appears to be propagating into the crust that was formed by the CIR and SEIR, the migration trajectory of the RTJ based on magnetic lineations formed by the SWIR, may be constrained by the reconstructions based on the CIR and the SEIR magnetic lineations.

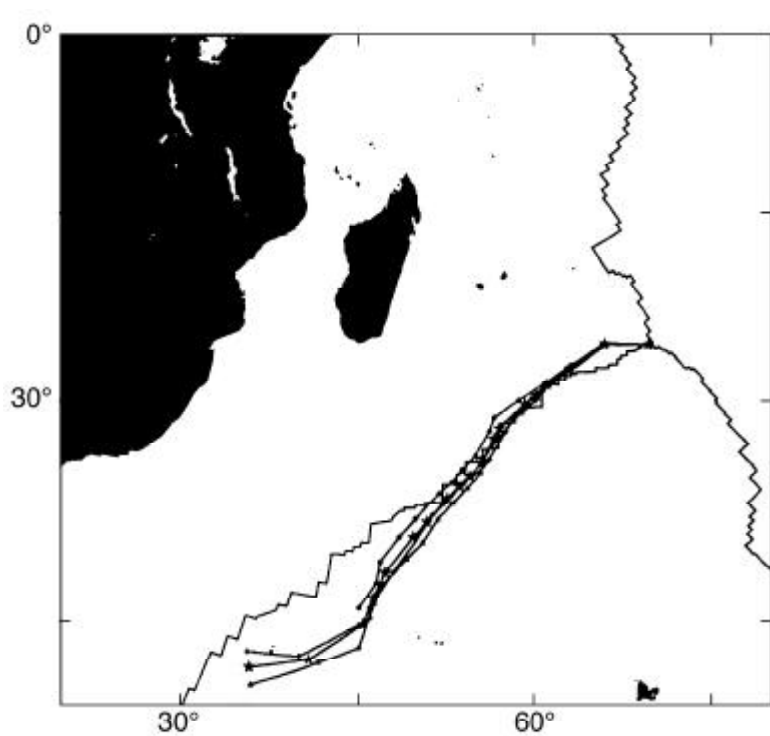


Figure 2. Reconstructed absolute paleolocations of the RTJ traces. Line with solid circles is reconstruction based on TJT-Af; line with crosses is reconstruction based on TJT-In; line with triangles is reconstruction based on TJT-An; Line with asterisks is the average reconstruction based on the three traces. Crosses, triangles, solid circles and asterisks represent Chron ages 0, 5, 6, 8, 11, 13, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, and 31 sequentially from the TJ. Note that TJT-Af does not have Chron 11, 31, and 32

RESULTS AND DISCUSSION

Figure 2 shows the results of the reconstructions. Reconstructions based on the three TJ traces: the Indo-Australian, African and Antarctic plates, yield coincident migration trajectories for the RTJ. The RTJ appears to have been migrating northeasterly since 64 Ma (Chron 28). The migration trajectories do not indicate any major changes that could be related to instability of the RTJ. The fairly straight-line trajectory suggests that the configuration of the RTJ has been stable throughout since 64 Ma, in favour of the RRR (Ridge-Ridge-Ridge) configuration.

The northern section of the SWIR presently lies on the RTJ trajectory for the period from 52 Ma (Chron 24) to Present. This may have important geochemical and petrological implications because both mid-ocean ridges and triple junctions are locations of passive mantle upwelling and recycling.

Figure 3 shows absolute migration velocities of the RTJ. The average velocity decreased since about 65 Ma from 10cm/yr to about 2.6cm/yr at 43 Ma. Since 41 Ma to Present the migration velocity remained almost constant between 3.6–3.8cm/yr. The timing at 41 Ma coincides with the time when the Wharton ridge in the central Indian Basin became inactive (Liu et al., 1983), and the Emperor-Hawaii bend in the Pacific Ocean (Engebretson et al., 1985), suggesting a major global plate reorganisation.

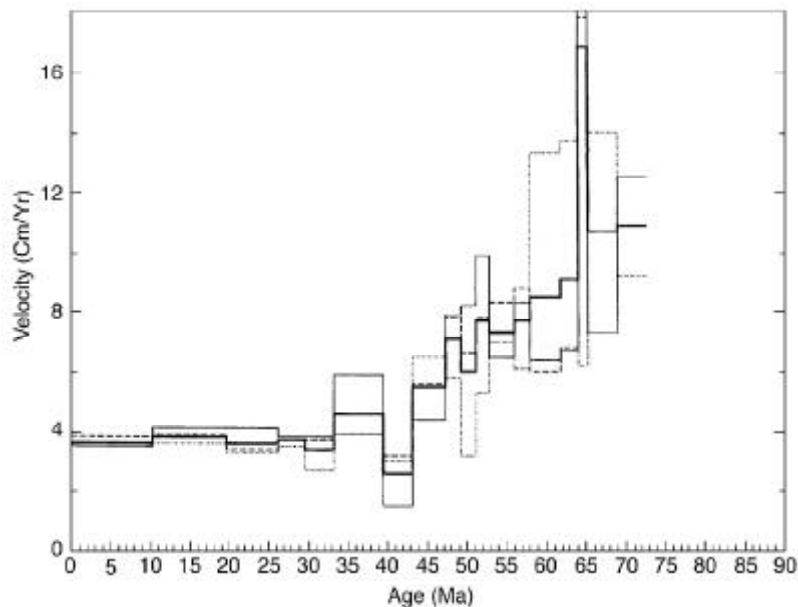


Figure 3. Absolute migration velocity of the RTJ since 90 Ma to present. Thin solid line based on the TJT-An, dashed line based on the TJT-Af, dotted line based on TJT-In, and the thick solid line is the average of the three traces

CONCLUSIONS

The absolute migration of the RTJ in the Indian Ocean for the past 75 Ma is reconstructed. This kind of study is the first ever performed for a triple junction. Reconstruction of the RTJ traces on the African, Indo-Australia and Antarctic plates gives coincident trajectories implying reliable results. Furthermore, the migration trajectories do not indicate any major changes in direction suggesting that the RTJ has had a stable configuration since 65 Ma. On this basis the RRR configuration for the RTJ is favoured. The results indicate that since 65 Ma the RTJ has been migrating due northeast. The migration velocity of the RTJ decreased from 10cm/yr at 70 Ma to about 2.6cm/yr at 43 Ma, and thereafter (at about 41 Ma) has remained almost constant at 3.6–3.8cm/yr to Present. The coincidence of the timing at 41 Ma with other major event such as the Emperor-Hawaii bend and the 'death' of the Wharton ridge may suggest a major global plate reorganisation. The northeastern section of the SWIR lies on the RTJ migration trajectory for 52 Ma to Present. This has important geochemical and petrological implications as far as mantle recycling is concerned.

ACKNOWLEDGEMENTS

I would like to express my sincere acknowledgment to JSPS of Japan for giving me a postdoctoral fellowship during which I was able to make this paper. I would also like to acknowledge the friendly cooperation I got from Prof. Dr Tamaki of the Ocean Research Institute, University of Tokyo, who was my host researcher. Members of the Ocean-floor Geotectonics Division at ORI provided the conducive research environment.

REFERENCES

- Cande, S.C. & Kent, D.V. 1992. A new geomagnetic polarity time scale for the Late Cretaceous and Cenozoic. *J. Geophys. Res.* 97: 13917–13951.
- Dyment, J. 1993. Evolution of the Indian Triple Junction between 65 and 49 Ma (Anomalies 28 to 21). *Journal of Geophysical Research* 98: 13863–13877.
- Engelbreton, D.C., Cox, A. & Gordon, R.G. 1985. Relative motions between oceanic and continental plates in the Pacific basin. Geological Society of America - Special paper.
- Liu, C.S., Curray, J.R. & McDonald, J.M. 1983. New constraints on the tectonic evolution of the eastern Indian Ocean. *Earth and Planetary Science Letters* 65: 331–342.
- Masalu, D.C.P. & Tamaki, K. 1994. Highlights on global absolute motion and tectonics of the mid-ocean ridge system from 85 Ma to present: Abstract in 1994 Japan Earth and Planetary Science Joint Meeting, p. 159.
- McKenzie, D.P. & Sclater, J.G. 1971. The evolution of the Indian Ocean since the Late Cretaceous. *Geophysical Journal of the Royal Astronomical Society* 25: 437–528.
- Mitchell, N.C. 1991. Distributed extension at the Indian Ocean triple junction. *Journal of Geophysical Research* 96: 8019–8043.
- Muller, R.D., Royer J.Y. & Lawver, L.A. 1993. Revised plate motions relative to the hotspot from combined Atlantic and Indian Ocean hotspot tracks. *Geology* 21: 275–278.
- Munsch, M. & Schlich, R. 1989. The Rodriguez Triple Junction (Indian Ocean). Structure and evolution for the past one million years. *Marine Geophysical Research* 11: 1–14.

- Patriat, P. & Courtillot, V. 1984. On the stability of triple junctions and its relation to episodicity in spreading. *Tectonics* 3: 317–332.
- Patriat, P. & Parson, L. 1989. A survey of the Indian Ocean triple junction trace within the Antarctic plate: Implications for the junction evolution since 15 Ma. *Marine Geophysical Research* 11: 89–100.
- Patriat, P. & Segoufin, J. 1988. Reconstruction of the Central Indian Ocean. *Tectonophysics* 155: 211–234.
- Sclater, J.G., Fisher, R.L., Patriat, P., Tapscott, C.R. & Parsons, B. 1981. Eocene to recent development of the Southwest Indian Ridge, a consequence of the evolution of the Indian Ocean Triple Junction. *Geophysical Journal of the Royal Astronomical Society* 64: 587–604.
- Tapscott, C.R., Patriat, P., Fisher, R.L., Sclater, J.G., Hoskins, H. & Parsons, B. 1980. The Indian Ocean Triple Junction. *Journal of Geophysical Research* 85: 4723–4739.

