ABSOLUTE MIGRATION AND THE EVOLUTION OF THE RODRIGUEZ TRIPLE JUNCTION SINCE 75 Ma

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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 (Africa, Antarctica and Indian) to their former positions. It is shown that the RTJ have migrated northeasterly at velocities varying from 10 cm/yr at 70 Ma to 2.6 cm/yr at 43 Ma and thereafter 3.6-3.8 cm/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 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 & Sclater 1971). The evolution of the RTJ since Chron 5 (~10 Ma) has been studied extensively (McKenzie & Sclater 1971, Tapscott *et al.* 1980, Patriat & Courtillot 1984, Munschy & 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 that would allow such detailed studies to be done. Based on the apparently consistent configuration of the three ridges between 10 and 39 Ma (Chron 18), it has been suggested that the configuration of the RTJ did not change during this period (Dyment 1993). Similarly, available data for the period before Chron 18 is too sparse to accurately define the RTJ, but is sufficient to approximately define the trace of the RTJ location (Patriat & 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 & Courtillot 1984) similar to the present configuration were proposed. Recently, Dyment (1993) using updated data in the central Indian basin, reexamined 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 characterized by a predominant RFF configuration that episodically turned to a transient RRR configuration. The present study investigated 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

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 & 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 is computed.

In the present 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 digitized using a Calcomp digitizer. 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 times (Cande & Kent 1992).

RESULTS AND DISCUSSION

The trace of RTJ on the Indo-Australian plate marks the intersection of 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 (Fig. 1). Thus there was no problem in deciding which set of intersection points to digitize, for use in reconstructing the paleolocations of RTJ.

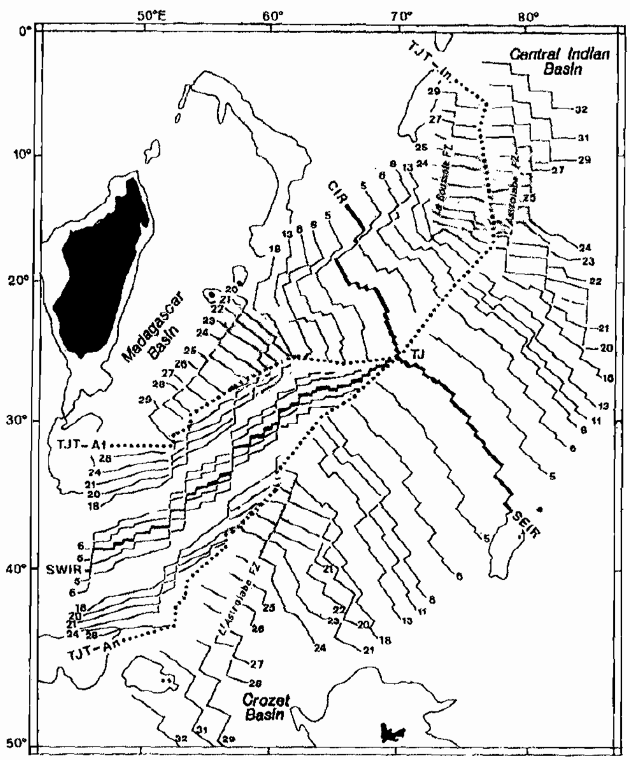

Fig. 1: Tectonic map of the Central Indian Ocean (after Patriat & Segoufin 1988). Thin lines are either isobath 2500 m or magnetic lineations with their anomaly number; thick lines are spreading centers as indicated; dotted lines are traces of the RTJ (TJT-Af = trace on the African plate; TJT-In = trace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

For the trace of RTJ on the African and Antarctic plates, things are 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 (Fig. 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 & Parson 1989, Mitchell 1991). However, because the SWIR appears to be propagating into the crust that was formed by the CIR and the SEIR, results obtained by reconstructing intersection points between the TJ traces and magnetic lineations that were formed by the CIR and the SEIR on the African and the Antarctic plates will constrain the migration trajectory of the RTJ based on magnetic lineations formed by the SWIR, as this should lie between the two reconstructed trajectories.

Reconstructions based on the three TJ traces: on the Indo-Australian, African and Antarctic plates, yield coincident migration trajectories for the RTJ (Fig. 2). 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 favor of the RRR (Ridge-Ridge-Ridge) configuration.

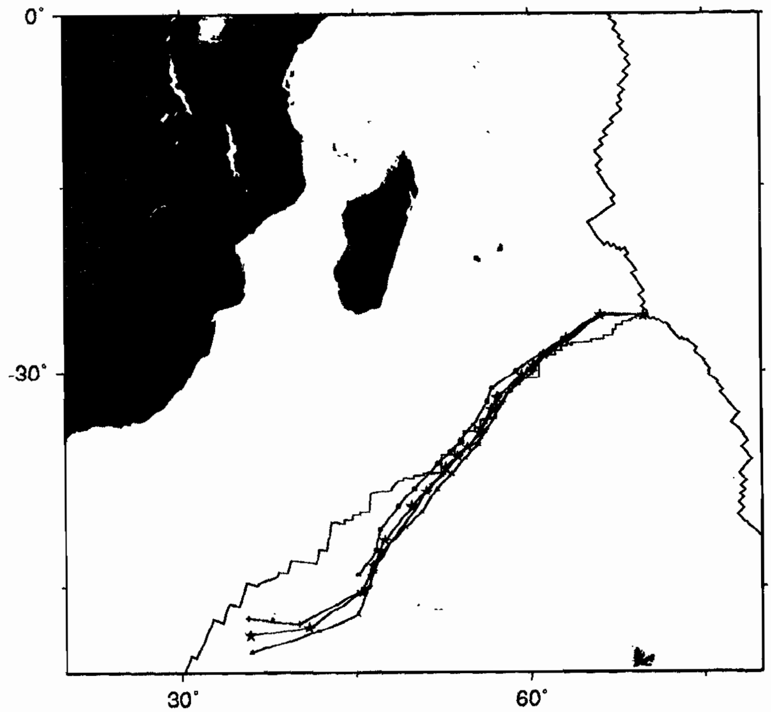

Fig. 2: Reconstructed absolute paleolocations of the RTJ traces. Line with solid circles is reconstruction based on TJT-Af; Line with crosses is reconstruction based on TJT-In; Line with triangles is reconstruction based on TJT-An; Line with asterisks is the average reconstruction based on the three 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, 31, and 31 sequentially from the TJ. Note that TJT-Af does not have Chron 11, 31, and 32

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.

The average absolute migration velocity for RTJ decreased since about 65 Ma from 10 cm/yr to about 2.6 cm/yr at 43 Ma (Fig. 3). Since 41 Ma to Present the migration velocity remained almost constant between 3.6 —3.8 cm/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 reorganization.

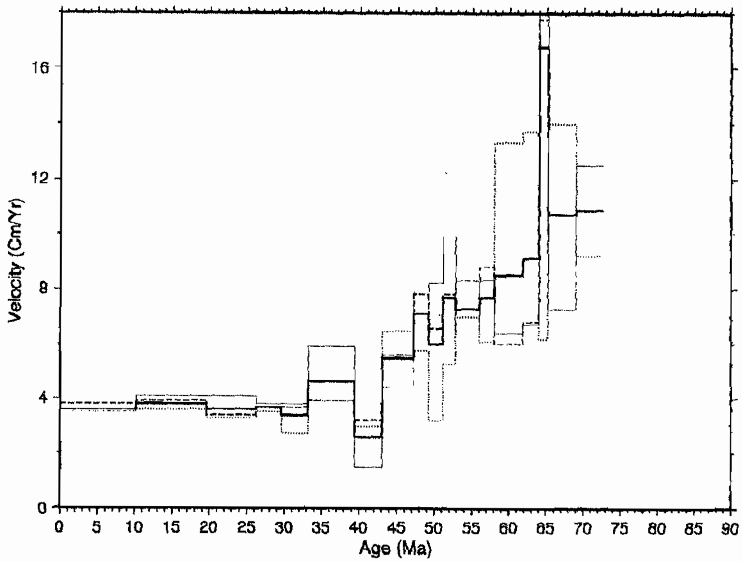

Fig. 3: Absolute migration velocity of the RTJ since 90 Ma to present. Thin solid line based on the TJT-An, dashed line based on the TJT-Af, dotted line based on TJT-In, and the thick solid line is the average of the three traces

CONCLUSION

This kind of study is apparently the first to be done 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 a stable configuration since 65 Ma. On this basis the RRR configuration for the RTJ is favored. The present study suggests that, since 65 Ma the RTJ has been migrating northeasterly. The migration velocity of the RTJ decreased from 10 cm/yr at 70 Ma to about 2.6 cm/yr at 43 Ma and thereafter (at about 41 Ma) has remained almost constant at 3.6-3.8 cm/yr to present. The coincidence of the timing at 41 Ma with other major events such as the Emperor-Hawaii bend and the death of the Wharton ridge, may suggest major global plate reorganization. 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.

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REFERENCES

Cande SC and Kent DV 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). *J. Geophys. Res.* **98**: 13863-13877

Engebretson DC, Cox A and Gordon RG 1985 Relative motions between oceanic and continental plates in the Pacific basin. *Geol. Soc. Am.* Special paper

Liu CS, Curray JR and McDonald JM 1983 New Constraints on the tectonic evolution of the eastern Indian Ocean. *Earth Planet Sci. Lett.* **65**: 331-342

Masalu DCP and Tamaki K 1994 *Highlights on global absolute motion and tectonics of the mid-ocean ridge system from 85 Ma to present.* Abstr. in 1994 Japan Earth and Planetary Science Joint Meeting

McKenzie DP and Sclater JG 1971 The evolution of the Indian ocean since the Late Cretaceous. *Geophys. J. Royal Astro. Soc.* **25**: 437-528

Mitchell NC 1991 Distributed extension at the Indian ocean triple junction. *J. Geophys. Res.* **96**: 8019-8043

Muller RD, Royer JY and Lawver LA 1993 Revised plate motions relative to the hotspot from combined Atlantic and Indian Ocean hotspot tracks. *Geology* **21**: 275-278

Munschy M and Schlich R 1989 The Rodriguez Triple Junction (Indian Ocean): Structure and evolution for the past one million years. *Mar. Geophys. Res.* **11**: 1-14

Patriat P and Courtillot V 1984 On the stability of triple junctions and its relation to episodicity in spreading. *Tectonics* **3**: 317-332

Patriat P and Parson L 1989 A survey of the Indian ocean triple junction trace within the Antarctic plate: Implications for the junction evolution since 15 Ma. *Mar. Geophys. Res.* **11**: 89-100

Patriat P and Segoufin J 1988 Reconstruction of the Central Indian Ocean. *Tectonophys* **155**: 211-234

Sclater JG, Fisher RL, Patriat P, Tapscott CR and Parsons B 1981 Eocene to recent development of the South-west Indian Ridge, a consequence of the evolution of the Indian Ocean Triple Junction. *Geophys. J. Royal Astro. Soc.* **64**: 587-604

Tapscott CR, Patriat P, Fisher RL, Sclater JG, Hoskins H and Parsons B 1980 The Indian Ocean Triple Junction. *J. Geophys. Res.* **85**: 4723-4739