Indo-Australian plate: Fresh reconstruction

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Ever since Arthur Holmes prophetically invoked in 1928 the mechanism of thermal convection in Earth's mantle as the driving force that 'dragged the two halves of the original continent apart, with a consequent mountain building in front where the currents are descending, and the ocean floor development on the site of the gap where the currents are ascending', geologists have steadily modified their ideas of Earth as a rigid planet. The access of sea-floors for exploration through submersibles, and the explosion of data that emerged out of such studies along with improved geophysical investigations have greatly enabled production of accurate sea-floor maps with their maze of mountain ridges, valleys and rifts. These breakthroughs had considerably shaped our conception of ocean floor dynamics and helped later workers in 1960s like H. H. Hess, F. J. Vine, D. H. Mathews, J. T. Wilson and others to resurrect the original idea conceived by Arthur Holmes, and evolve the concept of *plate tectonics*; and soon geoscientists were able to recognize a mosaic of plates on the globe. Through intense geochemical and geophysical studies, ocean floor drilling combined with the data piling from worldwide network of seismic stations, the precise boundaries of these plates, their zones of divergence or spreading which create ocean-ridges, fractures, transfer faults, their zones of convergence marked by trenches and subducting slabs and a host of other deformational and structural features could be defined. The introduction of ocean floor isotopic dating and correlations through palaeomagnetic studies (magnetic stratigraphy) helped to fix the age and movements of the oceanic crust and thus track, more precisely, the plate motions, and their deformational history along the plate boundaries. These inevitably led to revisions in the existing global mosaic of plates.

One of the recent plate reconstructions relates to the Indo-Australian plate. Some years back, investigators from MIT and Lamont-Doherty Earth Observatory in USA and Ecole Normale Supéreure, Paris, discovered faults and signs of deformation in the south Indian Oceanic crust, from data compiled by oceanographic expeditions carried out in 1986 and 1991; based on these observations, they concluded that India and Australia are currently moving in different directions and hence they must be sitting on separate plates[1]. Now, Jean-Yves Royer (Géosciences Azur, Villefranche sur mer Cedex, France) and Richard G. Gordon[2] (Rice University, Houston, Texas) have re-assessed all earlier and their own latest geophysical data in relation to the prevailing seismicity of the area. They noticed several inconsistencies, if the Indo-Australian plate is considered as a single plate having narrow boundaries, or, even as two plates, as earlier proposed by some. The discrepancies in rigid plate motion were noticeable along the three mid-ocean ridge systems: (1) Southwest Indian Ridge (SWIR), (2) Southeast Indian Ridge (SEIR), and (3) Central Indian Ridge (CIR) and its northwestern continuation, the Carlsberg Ridge; these three meet in mid-Indian Ocean at the well-known Rodrigues Triple Junction (RTJ). Apart from these, several earthquakes of magnitude 6–7 have occurred during this century near and around 90°E longitude, better identified by the ocean ridge here, as the Ninety East Ridge (90ER, Figure 1). All these anomalies have

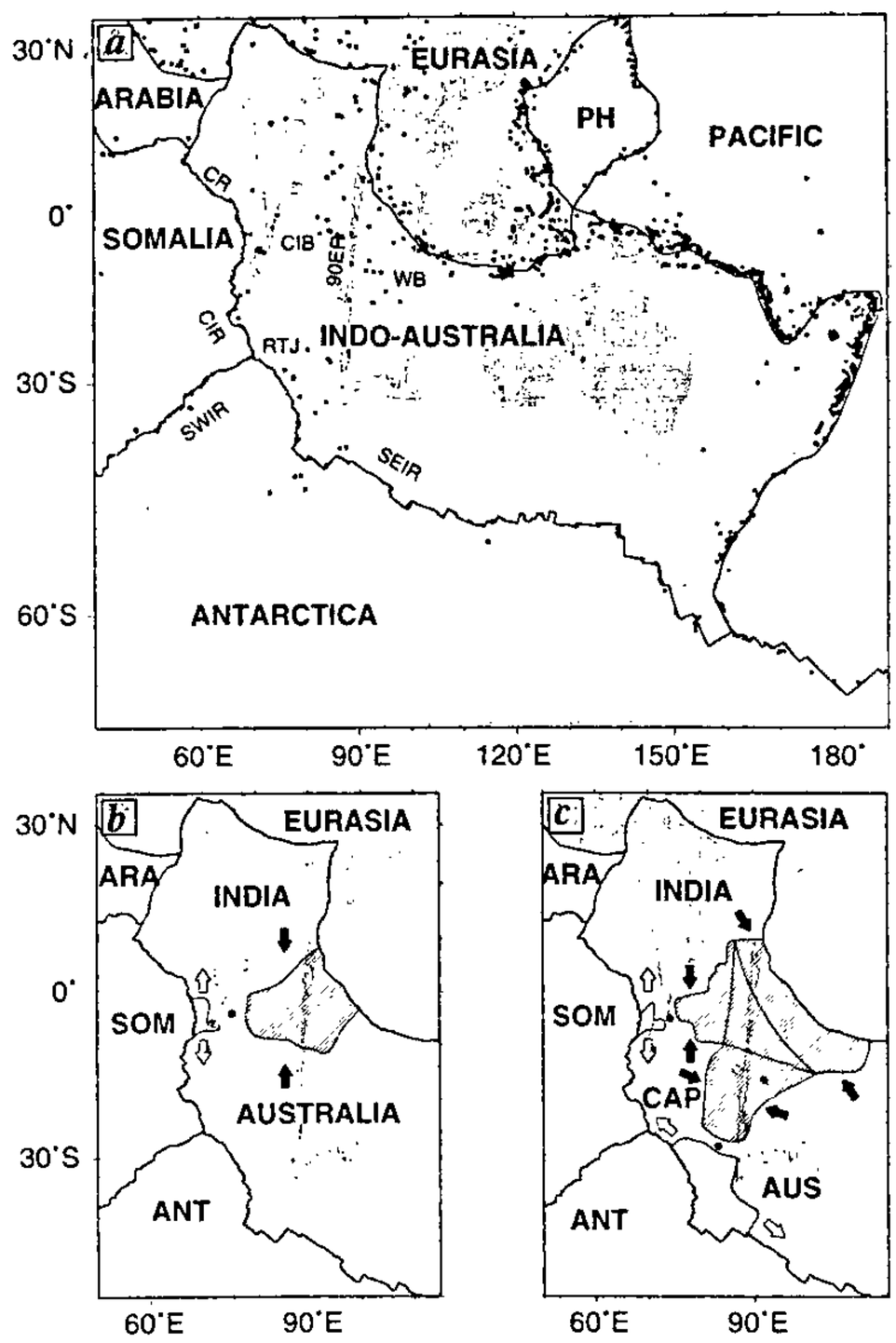

Figure 1. ***a***, Traditional Indo-Australian plate boundaries; solid dots represent sites of earthquakes; RTJ, Rodrigues Triple Junction; CR, Carlsberg Ridge; CIR, Central Indian Ridge; SWIR, Southwest Indian Ridge; SEIR, Southeast Indian Ridge; 90ER, Ninety East Ridge. ***b***, Plate boundaries of the two-plate model. ***c***, New plate geometry proposed by Royer and Gordon; CAP, newly recognized Capricorn plate; Aus, redefined Australian plate; horizontally divergent plate boundaries are stippled and horizontally convergent diffuse boundaries are hatched. (Source: Royer and Gordon[2].)

prompted further revision of existing notion about the Indo-Australian plate as two plates separated along the 90ER with a southwestern continuation at its southern end to intersect SEIR near 80°E (refs 2, 3). Further, reports of repeated anomalous off-ridge earthquakes[4] along this southwestern trend hinted at the need for re-definition of two-plate configuration.

Using magnetic sea-floor anomalies and seismic data, and based on deformational history of adjoining Somalian and Antarctic Plates, Royer and Gordon have proposed a revised plate geometry and a set of angular velocities that are consistent with current seismicity of the area. In the opinion of the authors, the fundamental departures to the rigid plate characteristics can be resolved if the Indo-Australian plate is considered as made up of three plates having diffuse boundaries. Based on record of deformational history they propose:

1. A new Capricorn plate with diffuse boundary on the northeastern side (Capricorn–Australia plate boundary).
2. The pole of relative rotation of the two plates lies between the NW-SE zones of stretching and shortening (Figure 1) and it indicates rotation of $0.78 \pm 30°$ about 29.1°S, 90.3°E.
3. Since 11 Ma, a point now at 17°S, 105°E in Australian plate has moved 27 km approximately along N45°W relative to Capricorn plate.
4. Convergence of 23 ± 26 km since 11 Ma between Capricorn and Australian plate.
5. The convergence rate of 2.1 ± 2.4 mm/year is much slower than global average rate of convergence in trenches (~ 70 mm/year) and happens to be slowest rate of convergence (~ 20 mm/year).
6. The convergence rate, though slow, may yet have triggered large earthquakes and folding of lithosphere, the latter confirmed by gravity undulations.
7. Divergence between Capricorn and Australian plates since 11 Ma at a rate 1.2 ± 2.2 mm/year, is much slower than global average rate of spreading along the mid-ocean ridge (MORs) ~ 40 mm/year and is also less than slowest rate of sea-floor spreading (~ 10 mm/year). The divergence is mainly taken up by normal faulting and consequent thinning of crust during 13 ± 24 km of divergence in this period.
8. Southwestern zone of NW-SE stretching, northeastern zone of NW-SE shortening are all caused by relative rotations of Indian, Capricorn and Australian plates.
9. Indian–Capricorn, Capricorn–Australian zones of shortening merge and are terminated by an overriding plate of subduction zone.

Thus according to Royer and Gordon, the assumption that Somalian, Antarctic and Australian plates are rigid is not valid, and also the traditionally defined Indo-Australian plate consists of three component plates and multiple diffuse boundaries. These plate reconstructions explain all the deformational aspects like stretching and shortening and are also in conformity with one of the main concepts of plate tectonics, namely a rigid plate-interior, as exemplified by little deformation within the new components.

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OPINION

Science in India: 1947–1997

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The year 1997 is a landmark year in our history as we have completed 50 years of our independence. It is a good time to look back and see how we have done as a nation in various spheres of activities in the last half century. Unfortunately, I am disappointed that not many people have come forward and presented a serious analysis. Apart from some semi-popular articles in our magazines and newspapers, I have not come across a single article examining in depth our achievements and failures in S&T or for that matter in any sphere of activity. I was hoping that a serious science journal like *Current Science* would carry articles on our achievements and failures in S&T. In fact it is ironical that apart from the British journal *Nature*, which brings out an in depth study on 'Science in India' once in every ten years, no Indian journal has ventured to do anything similar. I am aware that my knowledge of Indian science (apart from physics) and technology is rather limited but I feel that some one has to take the plunge and initiate a serious debate on our achievements and failures in S&T in the last 50 years. Hence this article.

I am quite aware of the serious dangers involved in undertaking this exercise. This is because, by and large, we Indians have a tendency to take either an extremely negative view or an extremely positive view, both of which are harmful. For example, over the years, I have seen that many of our scientists have developed quite a cynical attitude. These people refuse to see positive things in our science and criticize almost everything in it. I think this attitude is highly dangerous. Apart from painting a distorted and wrong picture, it makes one lose his confidence which is the most important thing in achieving success. Of course, many of these people are using the criticism of the system as an excuse for not working hard and doing their own work with full vigour and enthusiasm. I think only those people who are working extremely hard and doing their own job satisfactorily