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Anatomy of a Cambrian suture in Gondwana: Pacific-type orogeny in southern India?

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ABSTRACT

Southern India occupies a central position in the Late Neoproterozoic–Cambrian Gondwana supercontinent assembly. The Proterozoic mosaic of southern India comprises a collage of crustal blocks dissected by Late Neoproterozoic–Cambrian crust-scale shear/suture zones. Among these, the Palghat–Cauvery Suture Zone (PCSZ) has been identified as the trace of the Cambrian suture representing Mozambique Ocean closure during the final phase of amalgamation of the Gondwana supercontinent. Here we propose a model involving Pacific-type orogeny to explain the Neoproterozoic evolution of southern India and its final amalgamation within the Gondwana assembly. Our model envisages an early rifting stage which gave birth to the Mozambique Ocean, followed by the initiation of southward subduction of the oceanic plate beneath a thick tectosphere-bearing Archean Dharwar Craton. Slices of the ocean floor carrying dunite–pyroxenite–gabbro sequence intruded by mafic dykes representing a probable ophiolite suite and invaded by plagiogranite are exposed at Manamedu along the southern part the PCSZ. Evidence for the southward subduction and subsequent northward extrusion are preserved in the PCSZ where the orogenic core carries high-pressure and ultrahigh-temperature metamorphic assemblages with ages corresponding to the Cambrian collisional orogeny. Typical eclogites facies rocks with garnet + omphacite + quartz and diagnostic ultrahigh-temperature assemblages with sapphirine + quartz, spinel + quartz and high alumina orthopyroxene + sillimanite + quartz indicate extreme metamorphism during the subduction–collision process. Eclogites and UHT granulites in the orogenic core define *P*–*T* maxima of 1000 °C and up to 20 kbar. The close association of eclogites with ultramafic rocks having abyssal signatures together with linear belts of iron formation and metachert in several localities within the PCSZ probably represents subduction–accretion setting. Fragments of the mantle wedge were brought up through extrusion tectonics within the orogenic core, which now occur as suprasubduction zone/arc assemblages including chromitites, highly depleted dunites, and pyroxene bearing ultramafic assemblages around Salem. Extensive CO_2 metasomatism of the ultramafic units generated magnesite deposits such as those around Salem. High temperature ocean floor hydrothermal alteration is also indicated by the occurrence of diopsidite dykes with calcite veining. Thermal metamorphism from the top resulted in the dehydration of the passive margin sediments trapped beneath the orogenic core, releasing copious hydrous fluids which moved upward and caused widespread hydration, as commonly preserved in the Barrovian amphibolite facies units in the PCSZ. The crustal flower structure mapped from PCSZ supports the extrusion model, and the large scale north verging thrusts towards the north of the orogenic core may represent a fold-thrust belt. Towards the south of the PCSZ is the Madurai Block where evidence for extensive magmatism occurs, represented by a number of granitic plutons and igneous charnockite massifs of possible tonalite–trondhjemite–granodiorite (TTG) setting, with ages ranging from ca. 750–560 Ma suggesting a long-lived Neoproterozoic magmatic arc within a >200 km wide belt. All these magmatic units were subsequently metamorphosed, when the Pacific-type orogeny switched over to collision-type in the Cambrian during the final phase of assembly of the Gondwana supercontinent. One of the most notable aspects is the occurrence of arc magmatic rocks together with high *P*/*T* rocks, representing the deeply eroded zone of subduction. The juxtaposition of these contrasting rock units may suggest the root of an evolved Andean-type margin, as in many arc environments the roots of the arc comprise ultramafic/mafic cumulates and the felsic rocks represent the core of the arc. The final phase of the orogeny witnessed the closure of an extensive ocean — the Mozambique Ocean — and the collisional assembly of continental fragments within the Gondwana supercontinent amalgam. The tectonic history of southern India represents a progressive sequence from Pacific-type to collision-type orogeny which finally gave rise to a Himalayan-type Cambrian orogen with characteristic magmatic, metasomatic and metamorphic factories operating in subduction–collision setting.

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1. Introduction

Orogeny incorporates a collage of processes such as magmatism which generates continental crust, rejuvenation and recrystallization by metamorphism where metamorphic belts occupy the orogenic core, deformation to produce major structures of orogenic belts and sedimentation where mountain building occurs through the transportation of large volumes of sedimentary material (Miyashiro, 1961; Miyashiro et al., 1982; Maruyama, 1997; Santosh et al., submitted for publication, and references therein). According to the classic work of Dewey and Bird (1970), the Cordilleran-type orogens are considered to originate from the steady-state subduction of an oceanic plate beneath a continental plate, in contrast to the continent–continent collision in the Alpine–Himalayan style orogen. Dewey and Bird (1970) also defined the concept of orogenic welt and crustal “flower structure” within tonalite–trondhjemite–granodiorite (TTG) belts, and also identified symmetric development of thrusts from opposite directions simultaneously. Recent concepts of orogens in the plate tectonic paradigm recognize various collisional orogens such as continent–continent (Alpine), continent–arc (Andean), and arc–arc (Alaskan) types (Sengor et al., 1993).

The classic concepts on the role of mountain building through the Cordilleran-type orogeny have been revised in the recent years. Maruyama et al. (1996) classified orogens into collision-type and Pacific type. In the Pacific type, oceanic lithosphere subducts under the continental margin, and in the collision type, large continents collide with each other. Among the different types of subduction and collision processes, arc–arc collision orogeny is thought to have been widespread throughout the early geologic history of the Earth, although most of the intraoceanic arc crust must have been subducted and dragged down to the Archean–Proterozoic Core–Mantle Boundary (CMB), which is now present in the D” layer (Maruyama et al., 2007; Santosh et al., 2009a; Senshu et al., 2009). Continental growth is regarded to be episodic, reflecting the episodic nature of mantle dynamics as well as surface dynamics of the Earth (cf. Maruyama et al., 2007; Rino et al., 2008). During the early half of the Earth history, the felsic continental crust on the surface which formed in an intra-oceanic environment has mostly been subducted into the deep mantle, except in the rare case of parallel arc collision of arcs (Yamamoto et al., in press; Santosh et al., 2009a).

Among the sub-divisions of orogeny, the Andean type orogens represent continental arc, and the Japan type denotes matured intra-oceanic environment, which earlier originated as the Andean type and was later separated by the formation of a back-arc basin. Thus, it is evident that even in collisional orogenic belts, the Pacific-type orogeny must have prevailed before the final closure of the intervening ocean between two continents culminating in collision-type orogeny. A recent study revealed the occurrence of a narrow blueschist belt, the Anglesey blueschist belt, paired with a 200–300 km wide TTG belt unconformably covered by Phanerozoic sediments from the British Isles, to the south of Hercynides, indicating a Pacific-type orogen (Kawai et al., 2007). In another study, the presence of accretionary complex, defined by ocean plate stratigraphy, and its strong horizontal shortening indicated by duplex structures have been identified from the Archean Isua complex in Greenland (Komiya, 2004) indicating 3.8 Ga old subduction. Komiya (2004) proposed that the common presence of TTG complexes in Archean granite–greenstone terrains as well in high-grade gneiss–granulite terrains suggest the possible

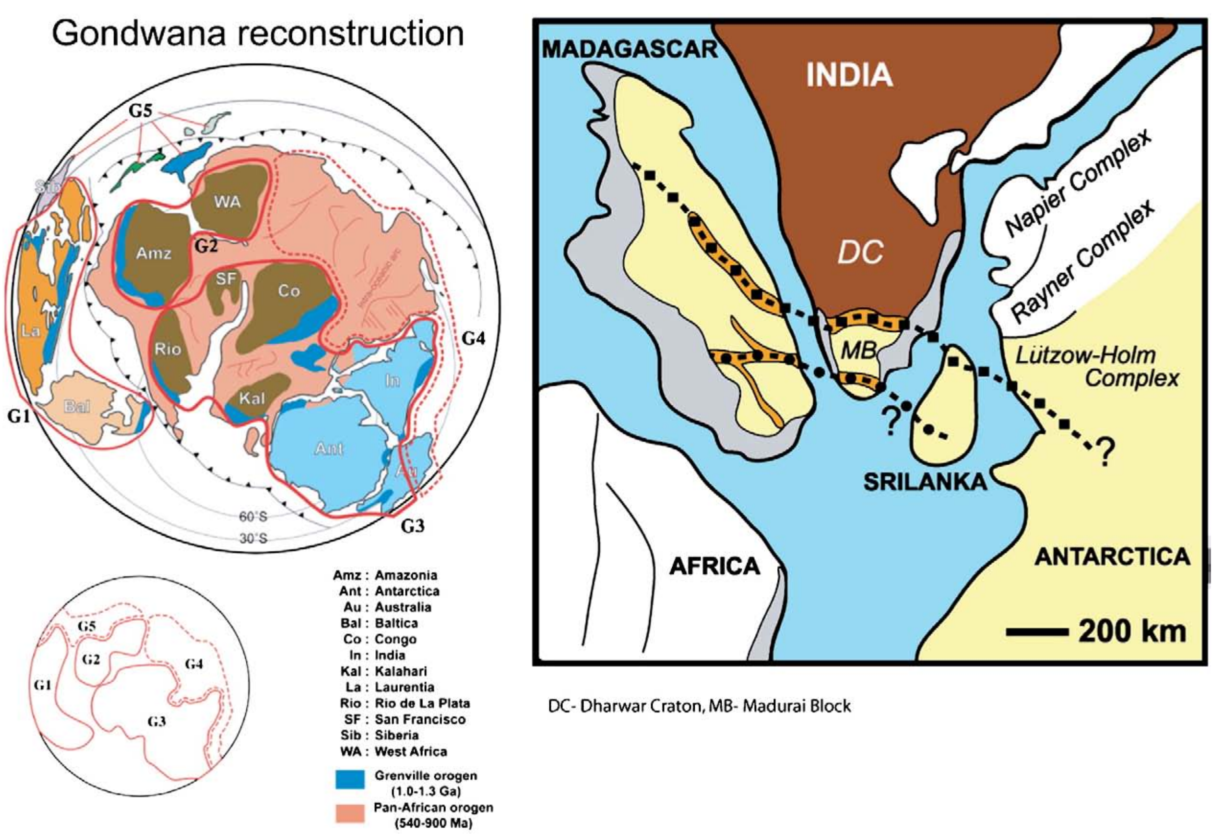

Fig. 1. Left figure shows the distribution of Pan-African and Grenville orogenic belts on the paleogeographic map of the Gondwana supercontinent at ca. 540 Ma (after Rino et al., 2008). The distribution of the intra-oceanic juvenile arcs is schematically shown as red line. The inset diagram on the lower left shows the distribution pattern of five groups of cratonic assemblages discussed by Rino et al. (2008). The right figure shows the central part of Gondwana supercontinent assembly with the trace of the Mozambique Ocean suture extending from Madagascar, into India, Sri Lanka and East Antarctica. The Gondwana-forming orogens developed by consumption of intervening Neoproterozoic oceans (Collins et al., 2007a). See text for discussion.