Journal of Geodynamics 50 (2010) 256–267

Contents lists available at ScienceDirect

Journal of Geodynamics

journal homepage: http://www.elsevier.com/locate/jog

The Cambrian collisional suture of Gondwana in southern India: A geophysical appraisal

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ARTICLE INFO

Article history:
Received 1 September 2009
Received in revised form 8 December 2009
Accepted 9 December 2009

Keywords:
Palghat–Cauvery suture zone
Gravity anomalies
Deep seismic studies
Magnetotellurics
Electrical resistivity
Tectonics
Gondwana
Southern India

ABSTRACT

The southern Indian crustal fragment occupied a central position within the Late-Neoproterozoic-Cambrian Gondwana supercontinent assembly. Here we synthesize the available geophysical data that includes gravity, seismic tomography, deep seismic sounding (DSS) and magnetotellurics (MT) from the Palghat–Cauvery Suture Zone (PCSZ), which is considered as a trace of the Gondwana-forming suture in southern India, as well as the surrounding regions to delineate the crustal architecture and tectonic history of the region. An increased crustal thickness immediately north of the PCSZ is correlated to crustal thickening associated with the subduction–collision processes during continental amalgamation. A prominent gravity low of about −45 m gal beneath Kodaikanal in the central Madurai Block, south of the PCSZ might suggest the deep root of a thick magmatic arc. Deep seismic studies in and around Chennimalai at the central domain of the PCSZ indicate the presence of ca. 10 km thick low velocity (6.0 km/s) layer at mid-crustal depths. The gravity model indicates a high density (2.80 gm/cm^3) layer corresponding to these depths. Two-dimensional MT model shows highly resistive (>20,000 Ω-m) felsic upper crust down to 15–16 km all along the profile. The resistivity of the mid-crust is more than 10,000 Ω-m and the resistivity of the lower crustal domains is in the range of 500–3000 Ω-m. The MT model and revised gravity model, constrained by MT, show a southward dipping low resistive zone (<100 Ω-m) and a high density region at a depth range of 15–45 km beneath the Chennimalai dome within the PCSZ. The interpretation of magnetotelluric and revised gravity model confirm the PCSZ to be the trace of a major suture zone, and correlate with a plate tectonic model of subduction–collision–accretion tectonics along this zone related to the final amalgamation of the Gondwana supercontinent.

1. Introduction

The southern Indian continental fragment occupied a central position in the Gondwana supercontinent assembly during the Late-Neoproterozoic-Cambrian (Collins and Pisarevsky, 2005; Meert and Lieberman, 2008; Santosh et al., 2009a,b) (Fig. 1). With the Archaean Dharwar Craton in the north and a collage of Proterozoic granulite-facies blocks to the south (Fig. 2), southern India comprises two contrasting tectonic provinces dissected by two major suture zones, the Palghat–Cauvery Suture Zone (PCSZ) in the north and the Achankovil Shear/Suture Zone (ACSZ) in the south (Fig. 2). The boundary between the Archaean Dharwar Craton and the accreted Neoproterozoic Southern Granulite Terrane is marked by the PCSZ (Chetty et al., 2006, and articles therein). This E–W zone is considered as a trace of the suture developed during the amalgamation of the Gondwana supercontinent in Late-Neoproterozoic-Cambrian (Santosh et al., 2003, 2006, 2009a,b; Collins et al., 2007a,b; Clark et al., 2009a,b). The PCSZ extends westwards into Madagascar as the Betsimisaraka suture that separates the Archaean Antongil Craton to the east from the Antananarivo granulite-facies Neoproterozoic orogenic belt to the west (Collins and Windley, 2002; Janardhan, 1999), and continues eastwards into Antarctica where it marks the junction between Napier and Rayner complexes in Enderby Land (Harris et al., 1994). The PCSZ defines an isotopic boundary (Harris et al., 1994), contains several discontinuous ultramafic–mafic bodies (Bhaskar Rao et al., 1996) and is marked by several crust-penetrating shear zones that offset the Moho (Reddy et al., 2003). Available geochronological data including U–Pb zircon and EPMA monazite ages indicate that the rocks along the PCSZ underwent an episode of high-grade metamorphism at ca. 530 Ma (Collins et al., 2007a,b; Santosh et al., 2006, 2009b; Clark et al., 2009b) that broadly coincides with the time of final assembly of the Gondwana supercontinent.

To the north of the PCSZ is the Salem Block, which was previously referred as the Northern Granulite Terrane (e.g. Chetty and Bhaskar Rao, 2006a,b). Charnockites (hypersthene-bearing granulites) from

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doi:10.1016/j.jog.2009.12.001

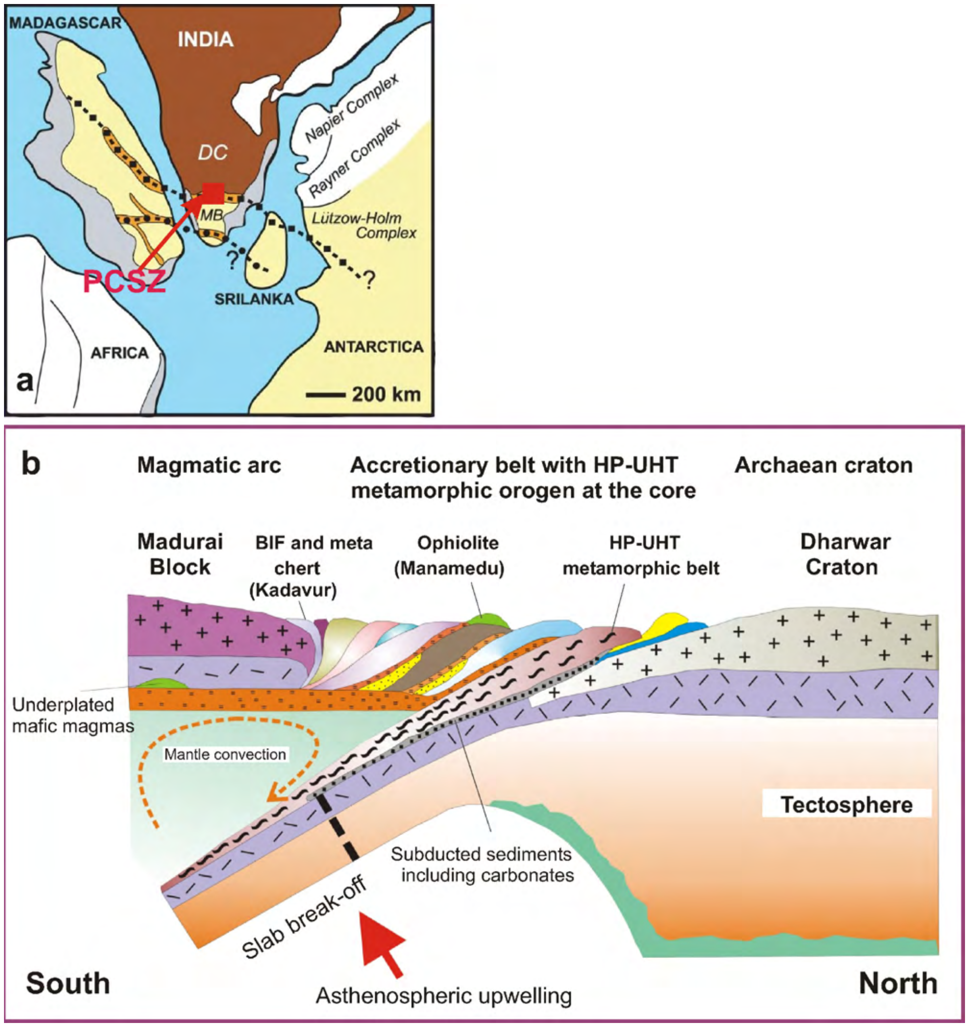

Fig. 1. (a) Part of East Gondwana assembly showing the Cambrian Gondwana sutures within southern India and the location of the study area within Palghat–Cauvery Suture Zone (PCSZ). DC, Dharwar Craton; MB, Madurai Block. (b) Cartoon illustration showing plate tectonic model for the subduction–collision tectonics in southern India (modified after Santosh et al., 2009b).

this block were recently dated by Clark et al. (2009a) which yielded U–Pb zircon ages of ca. 2530 Ma for the magmatic protolith and ca. 2480 Ma for the high-grade metamorphism. On the other hand, the crustal fragments to the south of PCSZ including the Madurai, Trivandrum and Nagercoil Blocks which comprise a mixture of Neoproterozoic arc magmas and accretionary belts (cf. Santosh et al., 2009b) preserve the common imprint of a major thermal event of latest Neoproterozoic-Cambrian (e.g. Miller et al., 1996; Bartlett et al., 1998; Bhaskar Rao et al., 2003; Santosh et al., 2003, 2009a,b,c; Collins et al., 2007a,b) when all the rock units were subjected to high- and ultrahigh-temperature metamorphism (Tateishi et al., 2004; Tsunogae et al., 2008; Sato et al., 2009; Tsunogae and Santosh, in press; Santosh et al., 2009b).

The suggestion that the Southern Granulite Terrane was accreted onto to the northern Dharwar craton, and the preliminary estimate of crustal thickness and thermal gradient based on metamorphic grade (e.g. Rogers, 1986; Nutman et al., 1989; Gopalkrishnan et al., 1990; Newton, 1990) derived support from earlier geophysical studies (Table 1). Some of the earlier studies also speculated a subduction model, such as the northward subduction proposed by Drury et al. (1984), and the southward subduction speculated from tomographic studies by Rai et al. (1993). Some works also proposed rift tectonics (Mahadevan, 2003; Vijaya Rao and Rajendra Prasad, 2006; Vijaya Rao et al., 2006). However, lack of adequate field, petrological, structural and geochronological data hampered a coherent understanding of the tectonics of this region in these earlier studies.

In a recent synthesis, Santosh et al. (2009b) proposed a plate tectonic model for the evolution of the PCSZ and the Neoproterozoic granulite blocks to the south based on updated information. They defined a Himalayan-style Cambrian collisional suture along the PCSZ, marking the final phase of an earlier Pacific-type orogeny dominated by subduction-accretion process (Fig. 1). The model also identified a southward polarity of subduction along the PCSZ, with the charnockite massifs and associated tonalite–trondhjemite–granodiorite (TTG) suite of rocks in the Madurai Block to the south representing a long-lived magmatic arc. The wide belt of gneisses and migmatites thrust onto the Archaean basement with northward vergence probably represent the eroded counterparts of a foreland-fold-and-thrust belt developed to the north of the suture zone. In another recent study, Sato et al. (submitted for publication) reported LA-ICP-MS age of 817 ± 16 Ma from zircons in a plagiogranite associated with the Manamedu ophiolite suite at the southern margin of the PCSZ, constraining the birth of the Mozambique Ocean floor as prior to ca. 800 Ma. In their study, euhedral zircons with magmatic cores from the Banded Iron Formations from PCSZ yield $^{206}Pb/^{238}U$ age of 760 ± 16 Ma probably marking the turning point from passive margin to active margin in the Wilson Cycle and the construction of an arc-trench system with a southward subduction polarity. Detrital