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Aeromagnetic signatures of Precambrian shield and suture zones of Peninsular India

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A R T I C L E I N F O

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A B S T R A C T

In many Precambrian provinces the understanding of the tectonic history is constrained by limited exposure and aeromagnetic data provide information below the surface cover of sediments, water, etc. and help build a tectonic model of the region. The advantage of using the aeromagnetic data is that the data set has uniform coverage and is independent of the accessibility of the region. In the present study, available reconnaissance scale aeromagnetic data over Peninsular India are analyzed to understand the magnetic signatures of the Precambrian shield and suture zones thereby throwing light on the tectonics of the region. Utilizing a combination of differential reduction to pole map, analytic signal, vertical and tilt derivative and upward continuation maps we are able to identify magnetic source distribution, tectonic elements, terrane boundaries, suture zones and metamorphic history of the region. The magnetic sources in the region are mainly related to charnockites, iron ore and alkaline intrusives. Our analysis suggests that the Chitradurga boundary shear and Sileru shear are terrane boundaries while we interpret the signatures of Palghat Cauvery and Achankovil shears to represent suture zones. Processes like metamorphism leave their signatures on the magnetic data: prograde granulites (charnockites) and retrograde eclogites are known to have high susceptibility. We find that charnockites intruded by alkali plutons have higher magnetization compared to the retrogressed charnockites. We interpret that the Dharwar craton to the north of isograd representing greenschist to amphibolite facies transition, has been subjected to metamorphism under low geothermal conditions. Some recent studies suggest a plate tectonic model of subduction–collision–accretion tectonics around the Palghat Cauvery shear zone (PCSZ). Our analysis is able to identify several west to east trending high amplitude magnetic anomalies with deep sources in the region from Palghat Cauvery shear to Achankovil shear. The magnetic high associated with PCSZ may represent the extruded high pressure–ultra high temperature metamorphic belt (granulites at shallow levels and retrogressed eclogites at deeper levels) formed as a result of subduction process. The EW highs within the Madurai block can be related to the metamorphosed clastic sediments, BIF and mafic/ultramafic bodies resulting from the process of accretion.

1. Introduction

Understanding the tectonic evolution of Precambrian cratons and shear/suture zones is very complex. The Precambrian geologic history of Peninsular India covers around 3.0 billion years. The area comprises of several cratons and surrounding mobile belts that have challenged the Earth scientists. The Department of Science and Technology, Government of India, under its Deep Continental Studies Program, identified the South Indian shield as a challenging and critical area of research and selected a transect corridor from Kuppam to Palani (and later extended to Kanyakumari) for integrated multidisciplinary research to be carried out on a national scale. The outcome of this multidisciplinary venture including studies like Deep Seismic Studies (Reddy et al., 2003), magnetotelluric (Harinarayana et al., 2003), geochronological (Bhaskar Rao et al., 2003), geo-chemical (Ravindra Kumar and Sukumaran, 2003), gravity (Singh et al., 2003), etc. has been published as a book (Ramakrishnan, 2003) and later a volume on crustal structure

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and tectonic evolution of Southern Granulite Terrain (SGT) was published (Chetty et al., 2006). Further, as summarized by Sharma (2009) three geodynamic models have been proposed for the evolution of the SGT: the subduction–collision model, the accretion model and the reworked granulite terrane sans mobile belt model. Santosh et al. (2009) believed the tectonic history of southern India represents a progressive sequence from Pacific-type to collision-type orogeny operating in subduction–collision setting. Also, Naganjaneyulu and Santosh (2010) from reanalysis of magnetotelluric and gravity data along a profile across Palghat Cauvery shear zone (PCSZ) suggested a plate tectonic model of subduction–collision–accretion tectonics along this zone. To have a three-dimensional understanding of the region, uniform data coverage over the entire area is required. It is in this regard that the aeromagnetic and gravity data can prove useful.

In many Precambrian provinces the understanding of the tectonic history is constrained by limited exposure which leads to difficulty in developing links between local and regional architecture. High resolution aeromagnetic data can provide information, below the surface cover (Li and Morozov, 2008) allows interpretation and modeling at a scale comparable to structural mapping (Aitken et al., 2008; Aitken and Betts, 2009; Metelka et al., 2011). In the absence of high resolution aeromagnetic data in the present paper we look at the aeromagnetic data collected at the reconnaissance scale to understand the tectonic evolution of the South Indian shield. We analyze data from the southern tip of India up to latitude 19°N to lay emphasis on the Dharwar craton, Southern Granulite Terrain and the surrounding Eastern Ghat mobile belt (EGMB) to help build a tectonic model of the region.

2. Generalized geology and tectonics

Peninsular India is a mosaic of Precambrian crustal blocks that exhibit low- to high-grade crystalline rocks, surrounded by mobile belts, with varied lithologies, tectonic style and evolutionary history that have been brought into juxtaposition and sutured together during different epochs. The study area up to 19°N latitude is composed mainly of the Dharwar craton and a part of the Bastar craton separated by the Godavari Gondwana graben. Toward the east of the Dharwar and Bastar cratons is the Eastern Ghat mobile belt, the junction between them being the Sileru shear zone. South of the Dharwar craton is the Southern Granulite Terrain (SGT). Fig. 1 gives the generalized geology and tectonic map of the study region redrawn from Ramakrishnan and Vaidyanadhan (2008) and GSI (2001, 2010).

The entire Dharwar craton can be viewed as a matrix of Peninsular gneisses interspersed with high- and low-grade schist belts (greenschist to amphibolites facies) and the intrusive granites. Within the Dharwar craton, the grade of metamorphism changes from greenschist facies in the north through amphibolite facies in the middle to high-grade granulite facies in the south (Radhakrishna and Vaidyanadhan, 1997). The Dharwar craton is divided into western Dharwar craton and eastern Dharwar craton based on the differences in the metamorphic facies of the schist belts, their relationship with the surrounding gneisses and limited geochronological data. It is debated whether the Chitradurga boundary shear (Swami Nath and Ramakrishnan, 1981; Anand and Rajaram, 2002; Gokarn et al., 2004) or the Closepet granite is the divide between the western and eastern Dharwar cratons (Ramakrishnan and Vaidyanadhan, 2008). Western Dharwar craton, associated with intermediate pressure kyanite–sillimanite type metamorphic facies, is prominently occupied by tonalite–trondhjemite–granodiorite (3.0–3.4 Ga) with minor schist belts of Sargur age (3.0–3.3 Ga), major large schist belts of Dharwar age (2.9–2.6 Ga) and few late Archean granitoid plutons (2.6–2.65 Ga) (GSI, 2010). Eastern Dharwar craton, registered with low pressure–high temperature andalusite–sillimanite type metamorphism, is characterized by voluminous late Archean Granitoids (2.51–2.75 Ga) with minor tonalite–trondhjemite–granodiorite gneiss and thin volcanic dominated schist belts of Dharwar age (GSI, 2010). The Dharwar craton is affected by NNW–SSE to NW–SE trending transcrustal faults/shears which are intersected by major ENE–WSW to EW and NE–SW trending faults/lineaments. Deep Seismic Sounding studies (Kaila et al., 1979) have shown that the western Dharwar craton is thicker than the eastern Dharwar craton, the depth to Moho being 40–45 km and 35–37 km respectively under the two cratons. The crescent shaped Proterozoic Cuddapah basin consists of highly metamorphosed sediments while the Godavari graben forming the northern limit of the Dharwar craton comprises Gondwana sediments. High-grade granulite rocks of Karimnagar (Rajesham et al., 1993) and Bhopalpatnam are reported along the shoulders of the Godavari graben (Anand and Rajaram, 2003). The Eastern Ghat mobile belt toward the east of the Dharwar craton, is a granulite terrane composed mainly of charnockites, khondalite, quartzite, calc-granulite, pyroxene granulite and leptynites (Ramakrishnan et al., 1998) having a predominant NE–SW trend. EGMB is separated from the Dharwar–Bastar craton by the Sileru shear zone (Chetty and Murthy, 1994). Age determination from recent isotopic data has provided information on the chronostratigraphy of this Precambrian terrane which range from Archean to pan-African (GSI, 2010).

In this paper we refer to the region south of the Fermor line/orthopyroxene isograd as the Southern Granulite Terrain (SGT). The NW–SE trending Moyar shear joins the NE–SW trending Bhavani shear and continues east as Moyar Bhavani shear zone (MBSZ). The region between the orthopyroxene isograd and the Moyar Bhavani–Salem Attur shear system is called northern block and comprises the Coorg (c), Biligirirangan (b) and Shevaroy granulite hills massifs. The low lying area, Palghat gap, bounded by MBSZ and the Palghat Cauvery shear zone (PCSZ) is the central block (Meert et al., 2010). Within the central block, the Moyar shear zone to the north and the NE–SW trending Bhavani shear to the south delineate the Nilgiri block or the Nilgiri (n) granulite massif. The Madras block lies to the east of Salem Attur shear and is bounded by the PCSZ to the south. Lithologies present in the northern block include charnockites, migmatitic gneiss, mafic granulites, and ultra mafic intrusives. Dating of charnockitic rocks (Clark et al., 2009) within the northern block indicated ages of 2530 Ma and subsequent high-grade metamorphism and partial melting at 2480 Ma (Santosh et al., 2009). The lithologies within the central block consist of deformed and variably retrograded charnockitic gneiss associated with biotite and hornblend bearing migmatites and metavolcanics intercalated with metaphilites, calc-silicate rocks, series of quartzite bands and banded iron formation (Santosh et al., 2009). The E–W trending crustal-scale shear zones, namely Moyar, Bhavani, and Palghat Cauvery have been taken to represent major lineaments that are associated with significant regional strike-slip movements and delineated by major river valleys. The region bounded to the north by PCSZ and south by the NW–SE trending Achankovil shear zone (AKSZ) is the Madurai block and further south of AKSZ is the Kerala khondalite block, a seat of meta-sedimentary granulites. Within the Madurai block, the rocks are predominantly charnockites with the Anamalai–Kodaikanal ranges comprising of massive to gneissic charnockites with minor bands of metasediments (mainly khondalites). Kerala khondalite block consists of assemblage of migmatized meta-sedimentary and meta-igneous rocks (khondalite–charnockite assemblages). Several intrusive igneous bodies occur amidst the granulites, greenstone belts, gneiss and the Proterozoic sediments. The alkaline related plutonism, recorded in the form of several NNE–SSW trending