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Gondwana Research 10 (2006) 6 – 17

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Analysis of airborne magnetic and gravity anomalies of peninsular shield, India integrated with seismic and magnetotelluric results and gravity anomalies of Madagascar, Sri Lanka and East Antarctica

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Received 18 January 2005; accepted 24 November 2005
Available online 3 May 2006

Abstract

Modelling of gravity and airborne magnetic data integrated with seismic studies suggest that the linear gravity and magnetic anomalies associated with Moyar Bhavani Shear Zone (MBSZ) and Palghat Cauvery Shear Zone (PCSZ) are caused by high density and high susceptibility rocks in upper crust which may represent mafic lower crustal rocks. This along with thick crust (44–45 km) under the Southern Granulite Terrain (SGT) indicates collision of Dharwar craton towards north and SGT towards south with N–S directed compression during 2.6–2.5 Ga. This collision may be related to contemporary collision northwards between Eastern Madagascar–Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC). Arcuate shaped N and S-verging thrusts, MBSZ-Mettur Shear and PCSZ-Gangavalli Shear, respectively across Cauvery Shear zone system (CSZ) in SGT also suggest that the WDC, EDC and SGT might have collided almost simultaneously during 2.6–2.5 Ga due to NW–SE directed compressional forces with CSZ as central core complex in plate tectonics paradigm preserving rocks of oceanic affinity. Gravity anomalies of schist belts of WDC suggest marginal and intra arc basin setting.

The gravity highs of EGFB along east coast of India and regional gravity low over East Antarctica are attributed to thrusted high-density lower crustal/upper mantle rocks at a depth of 5–6 km along W-verging thrust, which is supported by high seismic velocity and crustal thickening, respectively. It may represent a collision zone at about 1.0 Ga between India and East Antarctica. Paired gravity anomalies in the central part of Sri Lanka related to high density intrusives under western margin of Highland Complex and crustal thickening (40 km) along eastern margin of Highland Complex with several arc type magmatic rocks of about 1.0 Ga in Vijayan Complex towards the east may represent collision between them with W-verging thrust as in case of EGFB. The gravity high of Sri Lanka in the central part falls in line with that of EGFB, in case it is fitted in Gulf of Mannar and may represent the extension of this orogeny in Sri Lanka.

Keywords: Proterozoic collision; Southern Granulite Terrain; Highland complex; Napier complex; Airborne magnetic and gravity anomalies

1. Introduction

The Southern Granulite Terrain (SGT) of India offers a unique natural laboratory for study of collision tectonics and other plate tectonic processes during the Archaean–Proterozoic period. It is located in southern most part of the country mainly south of 12° N (Fig. 1; GSI, 1998) and is characterized primarily by high-grade lower crustal charnockite rocks and gneisses and several deep-seated mafic/ultramafic and acid intrusives. There are several known shear zones such as Moyar Bhavani Shear Zone (MBSZ), Palghat Cauvery Shear Zone (PCSZ) and Achankovil Shear Zone (AKSZ). The structural trends and shear zones are primarily E–W in the central part of continent changing to NW–SE and NE–SW along the west and east coasts of India, respectively. The SGT as a whole is divided into three parts, namely a Northern block, north of Moyar Bhavani Shear Zone, which predominantly shows metamorphic ages of 2.6–2.5 Ga. A southern block, south of the PCSZ preserves primarily Ediacaran–Cambrian and Neoproterozoic ages (Santosh et al., 2003; Bhaskar Rao et al., 2003; Ghosh et al., 2004; Cenki and Kriegsman, 2005). Between these blocks lies the Palghat–Cauvery Shear Zone System (PCSZ), a low lying linear strip of about 100 km width

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doi:10.1016/j.gr.2005.11.014

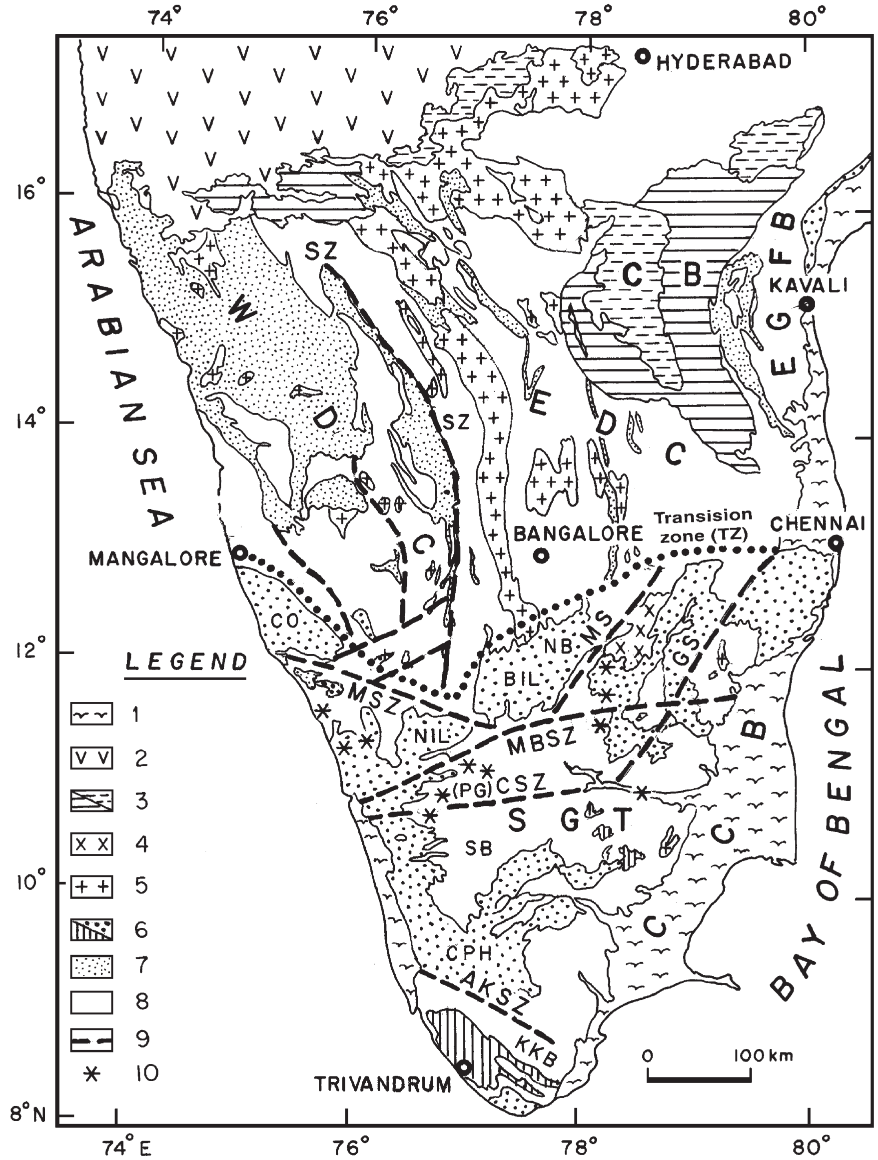

Fig. 1. Simplified geological map of a part of southern India (Ray et al., 2003; Modified after GSI, 1998) showing the Dharwar craton and the Southern Granulite Terrain (SGT), which is to the south of the Transition zone (TZ). Various abbreviations are as follows AKSZ = Achankovil Shear Zone, BIL = Biligirirangan Hills, CB = Cuddapah basin, CCB = Cauvery coastal basin, CO = Coorg Hills, CPH = Cardoman–Palani Hills, CSZ = Cauvery Shear Zones, EDC = Eastern Dharwar Craton, EGFB = Eastern Ghat Fold Belt, GS = Gangavalli Shear Zone, KKB = Kerala Khondalite Block, MS = Mettur Shear Zone, MBSZ = Moyar Bhavani Shear Zone, NB = Northern Block, NIL = Nilgiri Hills, PCSZ = Palghat Cauvery Shear Zone, PG = Palghat gap, SB = Southern Block, SZ = shear zone between EDC and WDC, WDC = Western Dharwar Craton. Various geological formations and symbols are as follows: 1 = Cretaceous — recent sediments, 2 = Cretaceous Eocene Deccan basalts, 3 = Proterozoic sediments, 4 = Alkaline complexes and Carbonatites, 5 = Granites (Un differentiated), 6 = Charnockites/ Khondalites, 7 = Archaean greenstone belts, 8 = Gneisses, 9 = Major lineaments and 9 = Earthquakes.

also known as the Palghat gap, which is occupied by several mafic/ultramafic and felsic intrusives of Neoarchaean–Neoproterozoic ages (Bhaskar Rao et al., 2003). Gopalakrishnan (1996) had identified three distinct units in the Palghat Cauvery Shear Zone System viz (i) marginal sequences of the adjoining terrains (ii) rocks of oceanic affinity and (iii) rocks formed during latter extensional stage. To the north, the Dharwar Craton is divided into western and eastern parts, both characterized by low-intermediate grade gneisses and schist belts with bimodal volcanics separated by the shear zone (SZ, Fig. 1). The Western Dharwar Craton (WDC) consists primarily of two groups of schist belts with bimodal volcanics of 3.4–3.0 and 2.9–2.7 Ga (Anil Kumar et al., 1996). The Eastern Dharwar Craton (EDC) is characterized by 3.4–3.0 Ga gneisses, with several N–S oriented linear granite plutons and schist belts of 2.6–2.5 Ga (Jayananda et al., 2000). The eastern Dharwar craton is bound to the east by the Eastern Ghat Fold belt (EGFB), which extends all along east coast of India from Bhubaneshwar in the north to Chennai in the south. It is characterized by high-grade charnockite and khondalite rocks and several deep-seated intrusives, anorthosites and carbonatites of Mesoproterozoic period (1.6–1.0 Ga, Mezger and

Cosca, 1999). However the most prominent metamorphic event in EGFB is reported at 1.0–0.9 Ga (Paul et al., 1990).

2. Airborne magnetic and bouguer anomaly maps of SGT

The airborne magnetic map of SGT (Reddi et al., 1988) recorded at three different levels (Inset; Fig. 2) of 5000′, 7000′ and 9500′ at 5 km spaced flight lines are reduced to a common datum of 7000′ (~2.1 km; Fig. 2). A data gap in the NE part of the map, indicated by dashed black lines in Fig. 2, is filled from ground magnetic data continued upwards to a height of 7000′ (~2.1 km) to match with the airborne magnetic data. However a small gap still exists and continuation of anomalies through it can be easily visualized through extrapolation. Reddi et al. (1988) and Rajaram et al. (2003) attributed most of the observed anomalies to exposed charnockite rocks and the latter suggested the thickness of magnetic crust as 22 km. The total intensity magnetic map of SGT (Fig. 2) presents linear bands of magnetic highs and lows, which follow the structural trends of this region and the known shear zones viz. MBSZ, PCSZ, and AKSZ etc. Broadly one can identify seven sets of magnetic highs and lows marked as H1...H7 and L1...L7. A magnetic body located in a low geomagnetic latitude as in case of the SGT produces a pair of magnetic low and high with magnetic low towards north of magnetic high for induced magnetization and the magnetic body is located under the anomaly gradient between the two extending towards the magnetic low. The pairs of magnetic lows and highs L1, H1;

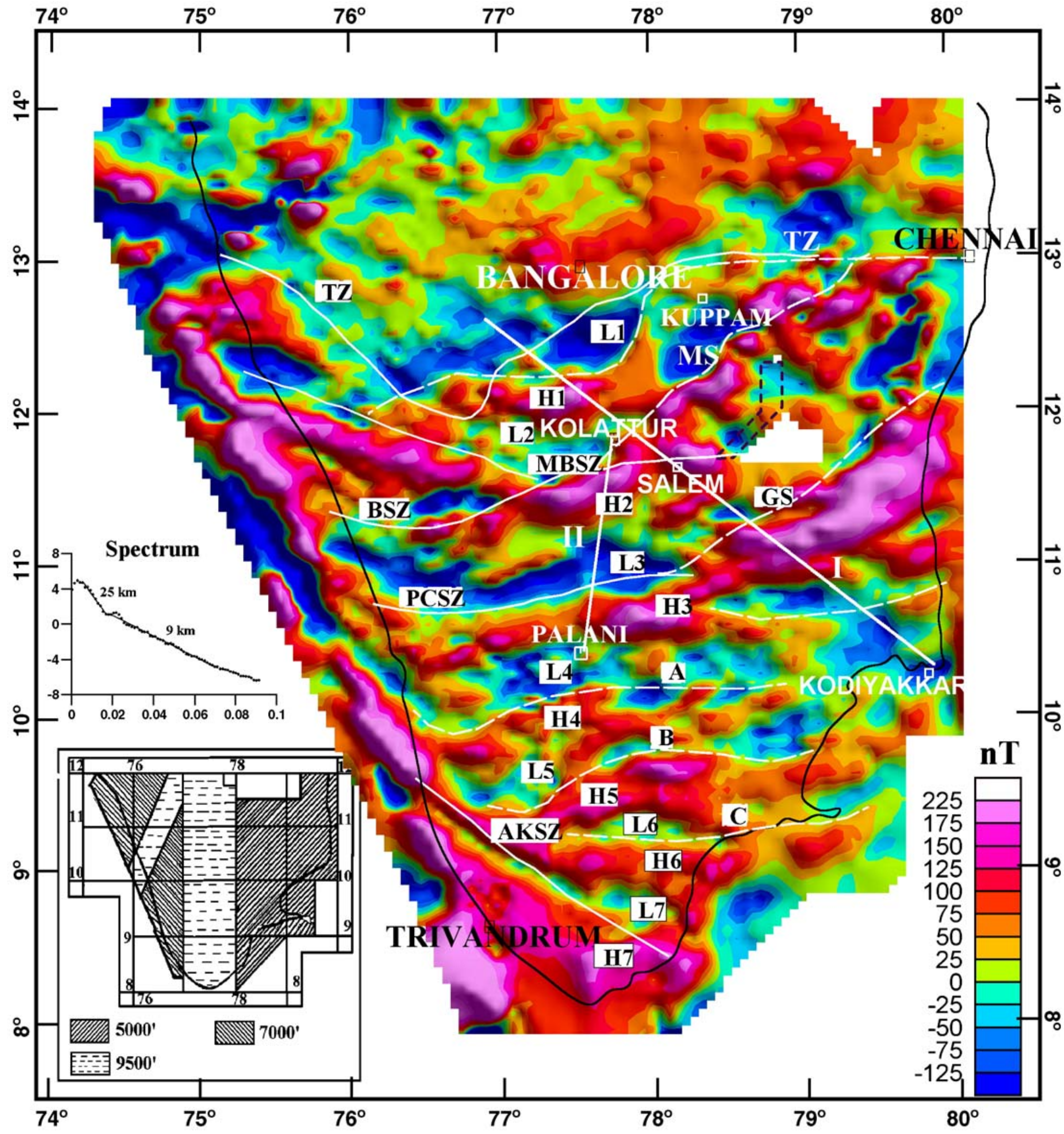

Fig. 2. Airborne total magnetic intensity map of Southern Granulite Terrain, India, recorded at flight elevations of 5000′, 7000′ and 9500′ above mean sea level (Inset), and have been reduced to a common datum of 7000′ (~2.1 km) for a composite map. Some data gap in the NE part marked by dash black line is filled from ground magnetic data continued to same height. H1...H7 and L1...L7 indicate magnetic highs and lows forming pairs of magnetic anomalies. The inset of spectrum presents its plot versus wavelength, which shows two linear segments with their slopes equivalent of 7 and 23 km depths below surface representing top and bottom of magnetic mafic layer, respectively.

L2, H2; L3, H3 and L7, H7 appear to be related to Transition Zone, MBSZ, PCSZ and AKSZ, respectively, while L4, H4; L5, H5 and L6, H6 may represent some unknown/subsurface shear zones/thrusts. L5 and H5 coincide partially with Karur-Kambam-Painavu-Trichur (KKPT) shear zone as given by Ghosh et al. (2004), but this shear zone, as a whole is not reflected in this data set. The Transition Zone marked based on geology in the eastern part coincides with the junction of magnetic lows and highs, L1 and H1 marked in Fig. 2. However, in the central and western parts the two differ considerably, the latter based on magnetic anomalies passes through Billigirirangan hills and south of Coorg hills. The magnetic anomalies due to the MBSZ (L2, H2) and the PCSZ (L3, H3) join with those associated with parts of Mettur Shear and Gangavalli Shear Zones towards east, extending up to the east coast of India. In geological map (Fig. 1), these shears extend northwards but in airborne magnetic map (Fig. 2), their magnetic anomalies extend eastwards and join with those along east coast of India. It thereby suggests that under sedimentary cover of Cauvery basin (Fig. 1) along eastern India, these shear zones affect the basement and extend up to east coast of India. It is to be noted that magnetic anomalies north of PCSZ are of higher amplitude (400–500 nT) compared to those south of it (100–150 nT) indicating that the PCSZ is a major magnetic boundary and the presence of more magnetic rocks north of it. Airborne magnetic anomalies north of the Transition Zone related to the southern part of the Dharwar Craton also show NW–SE trend in the western part and an ENE–WSW trend in the eastern part, which are almost similar to Transition Zone and structural trends in the northern block of SGT.

The Geoid corrected Bouguer Anomaly Map of this region (Fig. 3; Mishra et al., 2004) shows major gravity lows over the WDC, the EDC and the SGT (GL1–GL5) and relative gravity highs (GH1–GH5) in adjoining locations. This map shows two sets of paired gravity anomalies (GH1, GL1 and GH2, GL2) over the SGT with gravity highs north of the Transition Zone—Moyar Shear Zone and over the CSZ and gravity lows south of them. The gravity signatures of the Eastern Ghat Fold Belt (EGFB), along the east coast of India, primarily shows linear gravity highs related to EGFB (GH4) which extend southwards (GH3) under sedimentary cover of Cauvery basin east of the SGT. It may be noted here that the SGT is primarily characterized by gravity lows while its eastern part covered by sediments shows prominent linear NE–SW oriented gravity highs (GH3)

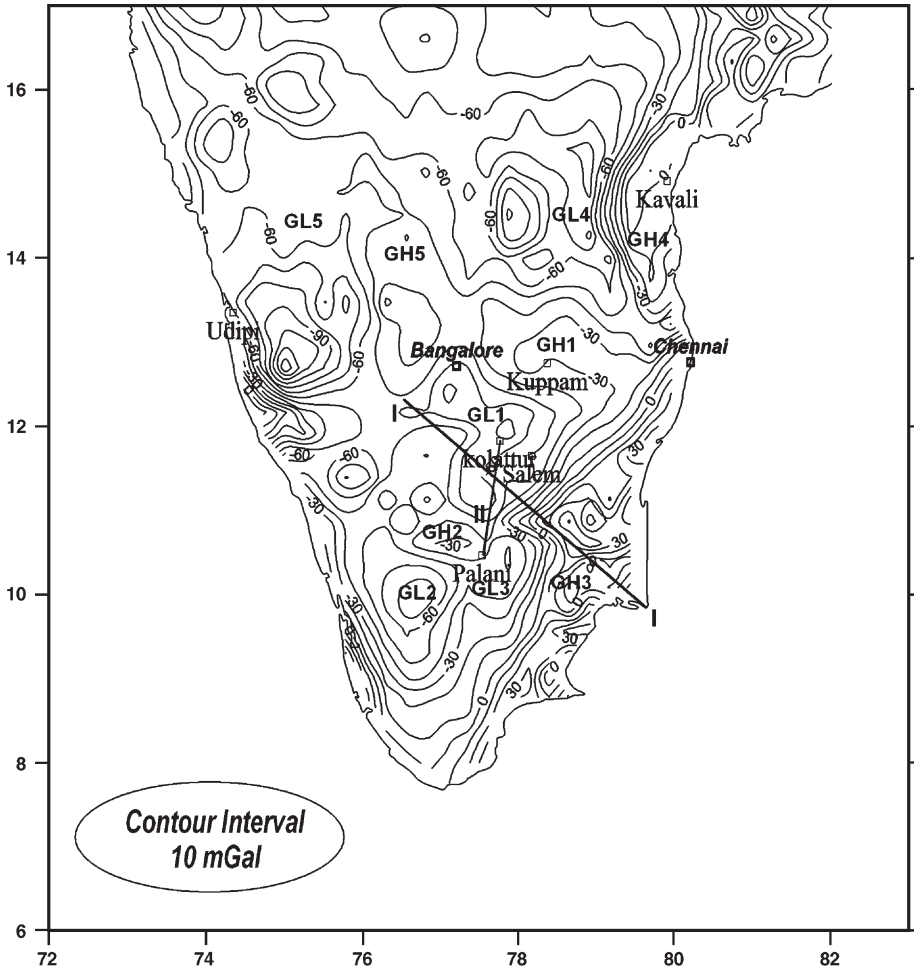

Fig. 3. Geoid corrected Bouguer anomaly map of southern granulite terrain showing GH1–GH5 and GL1–GL5 gravity highs and lows. Profile I and II are used to model crustal section.

similar to that observed over the exposed EGFB north of Chennai (GH4; Fig. 3). The gravity lows and highs, GL5 and GH5 are observed over WDC, which coincide with schist belts and adjoining gneisses.

3. Modelling of gravity and magnetic anomalies of SGT along profiles I and II

3.1. Profile I

In the present study, we modelled gravity and magnetic data along a NW–SE (Profile-I; Figs. 2 and 3), which starts at the east coast of India and extends up to the Transition Zone and crosses gravity anomalies GH3, GL1 and GH1. It is modelled using a three layered standard crustal model viz. upper, middle and lower crusts of bulk densities 2700, 2800 and 2900 kg/m^3 constrained from nearby seismic section (Reddy et al., 2003). The average densities of three layers coincided well with the densities derived from reported seismic velocities for these layers based on empirical relationship given by Barton (1986). However, these values and their configuration are modified wherever essential to match the observed and the computed fields specially in sections where specific gravity highs and lows are observed.

It is important to note that the observed gravity highs and lows GH3, GL1 and GH1 almost coincide with magnetic anomalies H3, L3, H2, L2, H1, L1 respectively. As the magnetic bodies in low geomagnetic latitudes will primarily produce a magnetic low and an accompanying high towards south for induced magnetization, it therefore, appears that the sources for these gravity anomalies and magnetic lows and highs are related to each other. Due to high upper mantle heat flow in this region (Ray et al., 2003) the Curie point geotherm for magnetite (550 °C) is relatively shallow at a depth of 20–25 km, which will control the depth extent of magnetization in these rocks. The exposed charnockite rocks and gneisses do not show high magnetic susceptibility through out the section and only the reported susceptibility of mafic granulite and basic rocks (Ramchandran, 1990) reported from certain sections, this area can produce the observed magnetic anomalies of this amplitude (300–400 nT) at a flight altitude of ~2.1 km. Therefore, the magnetic sources are primarily subsurface concentrated in the mafic layer of high density (2800 kg/m^3). An average bulk density of 2800 kg/m^3 for mafic layer is justified as reported density of mafic granulites in SGT varies from 2700–3000 kg/m^3 (Radhakrishna et al., 2003). In order to obtain on average estimate of depth to magnetic sources, spectrum of airborne magnetic data using Fast Fourier Transform (FFT) is computed (Hahn et al., 1976) which is shown in the inset of Fig. 2. Spectrum usually shows linear segments representing magnetic sources at particular depths, approximately equal to their slopes. The spectrum in present case shows two linear segments related to sources at average depths of 7 and 23 km, which may broadly represent the top and bottom of

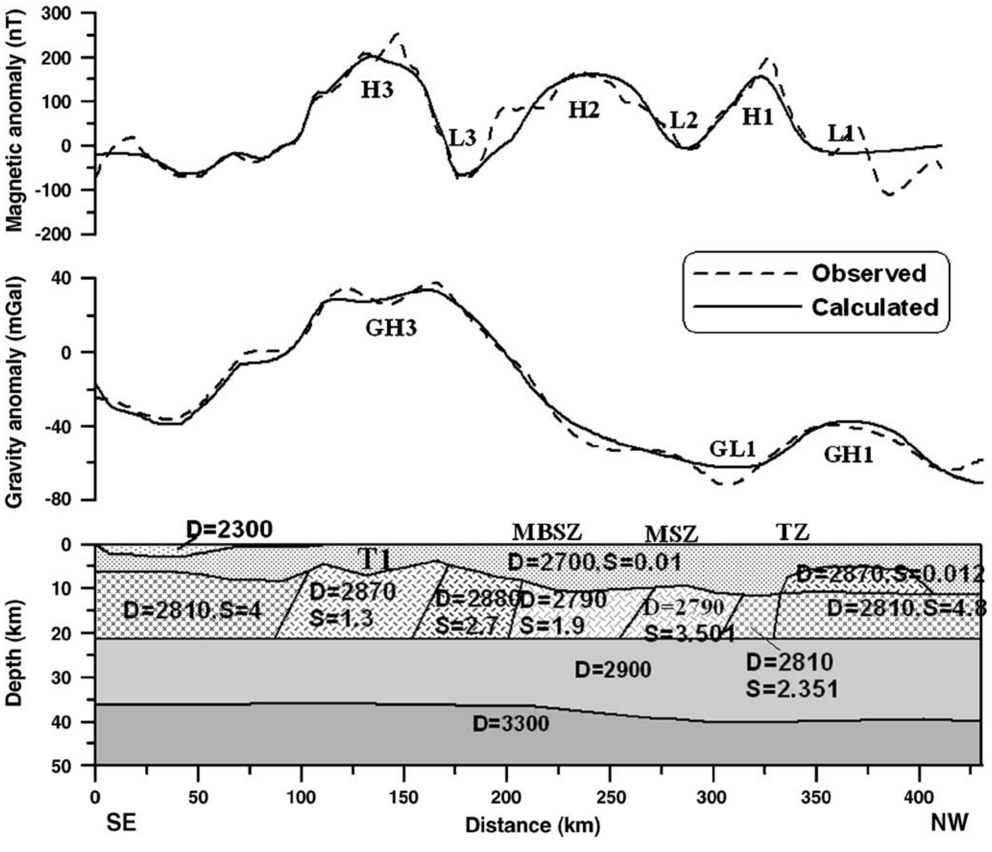

Fig. 4. Gravity and magnetic fields along Profile I (Figs. 2 and 3) and computed crustal model and their physical properties based on comparison between observed and computed fields. *D* denotes density in kg/m^3 and *S* denotes susceptibility in 10^{-3} CGS units.

magnetic sources in this region. With these constraints a crustal model along profile I is prepared in Fig. 4, which explains both the observed magnetic and gravity fields. The gravity high GH3 is primarily related to a eastward dipping thrust T1, which is similar to the model used to explain the gravity highs related to the EGFB to the north (Mishra and Tiwari, 1995) and magnetic anomalies are related primarily to the magnetization distribution in the second layer. This layer shows lateral variations in density and susceptibility, which may be related to large-scale thrusting in this region. It also provides a thick crust of 42–43 km north of Moyar Shear Zone (MSZ; Fig. 4), which decreases to 36–37 km along east coast of India.

3.2. Profile II: Kolattur–Palani

Gravity and magnetic data along a profile from Kollatur to Palani (Figs. 2 and 3) across the Cauvery Shear Zone System (CSZ, Fig. 1) including the MBSZ and the PCSZ is modelled in Fig. 5. This profile shows gravity high in the centre of the profile (GH2, Fig. 3) and magnetic anomalies H2, L3 and H3 apparently related to the MBSZ and the PCSZ, respectively (Fig. 3). The geometries are constrained from a seismic section along this profile (Reddy et al., 2003). The gravity high is interpreted due to thickening of high-density second layer of crustal model and crustal thinning. Previous gravity models have also suggested thin crust under CSZ and thick crust towards south and north of it (Mishra and Rao, 1993; Singh et al., 2003). The magnetic anomalies are related to variation in susceptibility across MBSZ and PCSZ in the second layer, which is the source of magnetic anomalies as inferred from spectral analysis of magnetic data described above (along Profile- I). This model shows N and S verging thrusts related to MBSZ and PCSZ respectively.

4. Bouguer anomaly of Madagascar and Enderby Land, East Antarctica

The Bouguer anomaly map of Madagascar (Pili et al., 1997) shows a regional gravity low over the central part that rises towards the coast forming a high over the east coast of Madagascar. The gravity high over eastern Madagascar matches quite well with the gravity high along west coast of India. The large wavelength gravity high and low observed over east coast of Madagascar and central Madagascar were modelled due to west verging thrust of high density rocks along east coast of Madagascar and crustal thickening in the central part. These observations in conjunction were interpreted to

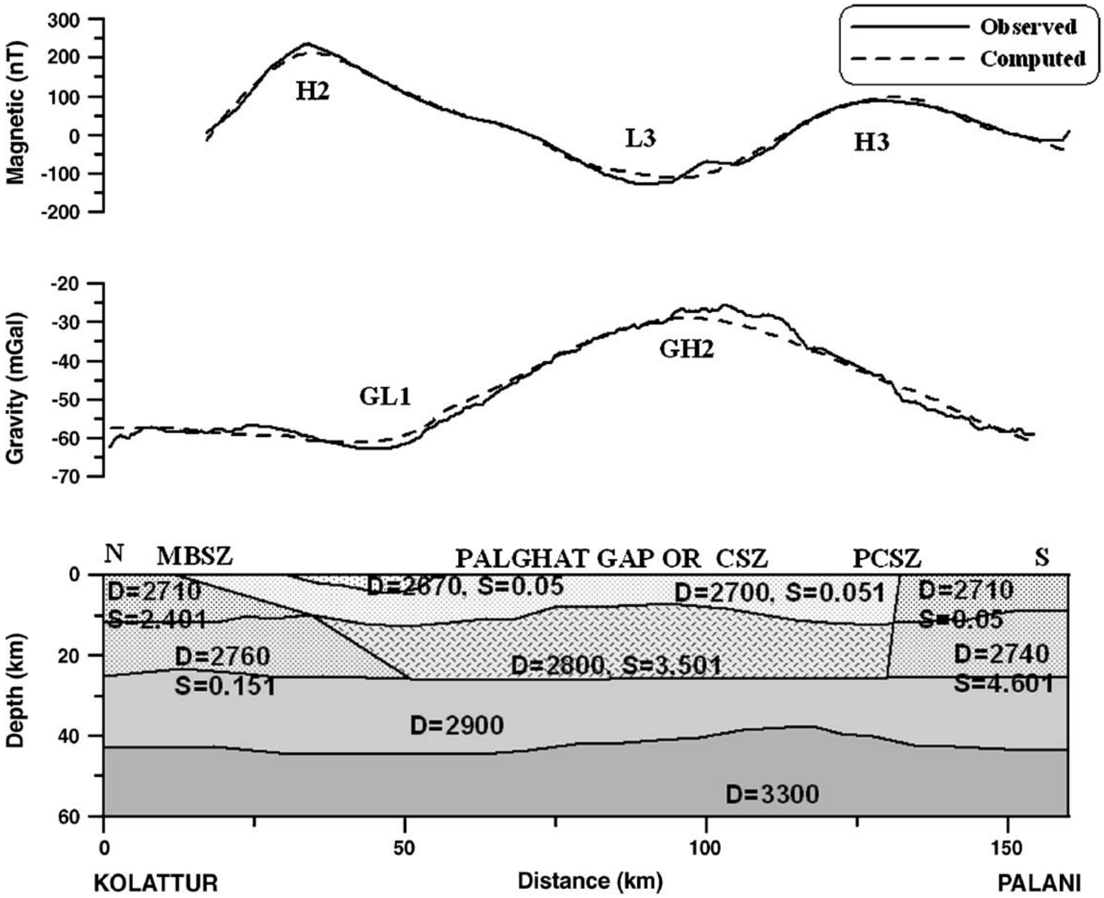

Fig. 5. Gravity and magnetic fields along Profile-II (Kolattur–Palani, Figs. 2 and 3) and computed crustal model with physical properties, *D* denotes density in kg/m^3 and *S* denotes susceptibility in 10^{-3} CGS units. Susceptibility is primarily limited to first and second layers with high susceptibility rocks in the second layer showing variations across shear zones. It shows an up warping of Moho under Cauvery Shear Zone system/Palghat gap and crustal thickening on either sides towards north and south.

indicate collision between Eastern Madagascar and WDC during Mesoarchean period (Mishra and Prajapati, 2003).

The free air gravity anomaly of Enderby Land and deglaciated topography (Wellman, 1982) show a good correlation, which indicate a compensated crust. With average elevation in the region being 1000 to 1500 m, the gravity data suggest a crustal thickening of 8–10 km for Airy's model of isostatic compensation. Free air anomaly and deglaciated topography along a N–S profile following the 54°E longitude from the northern tip of the Napier Complex to the central part of Enderby Land (Fig. 9) are used to compute Bouguer anomaly profile, which is given in Fig. 6. This profile shows gravity high (H1) in the centre followed by gravity lows (L1 and L2) similar to that observed across the CSZ in SGT, India described above. The northern gravity low (L1) coincides with intrusive granites of the Napier Complex while the central gravity high coincides with high grade rocks of the Napier Complex and the southern gravity low with rocks of the Rayner Complex. The modelled crustal section based on this Bouguer anomaly profile is given in Fig. 6, which shows a three layered standard crustal model modified based on comparison between computed and observed fields. It shows a crustal thickening from 37 km along the north coast up to 45–46 km inside the continent as tentatively suggested by the regional field (Fig. 6) and isostatic compensation discussed above. Besides changes in crustal thickness indicated by the regional southward dipping field, the local gravity lows (L1 and L2) and high (H1) are interpreted as felsic and mafic intrusives of low (2630 km/m^3) and high (2900 km/m^3) densities in the upper crust. A gravity profile in the neighbouring region across the Lutzow Holm Complex on land also shows a consistently decreasing gravity field from the coast to the interior of the continent related to crustal thickening up to 45–46 km which is supported from seismological studies (Kanao et al., 1994).

5. Bouguer anomaly map of Sri Lanka and modelling along a profile

The Bouguer anomaly map of Sri Lanka (Hatharton et al., 1975) is corrected for geoid anomaly (Marsh, 1979), which represents deep-seated features in the mantle. This map is reproduced in Fig. 7. It basically shows N–S oriented gravity lows (L1 and L2) coinciding with the central Wanni Complex and the junction of the Highland Complex and the Vijayan Complex separated by a small gravity high (H1) over the Kadugannawa Complex and the junction between the Wanni and the Highland Complexes. These anomaly especially the central gravity high (H1) are delineated only after correcting for geoid anomaly, which has a large amplitude over Sri Lanka. The Kadugannawa Complex is characterized by mafic intrusives of about 1.0 Ga (Braun and Kriegsman, 2003), and may cause the gravity high H1. Similar intrusives under the junction between the Wanni and the Highland Complexes may be responsible for this anomaly. Both the west and the east coasts of Sri Lanka and the offshore are characterized by gravity highs. This is especially marked along the east coast. In the absence of any information regarding sources of these gravity anomalies, the spectrum of the digital data of Bouguer anomaly (Mishra and Pederson, 1982) is computed and presented in Fig. 7 (Inset), which provides three

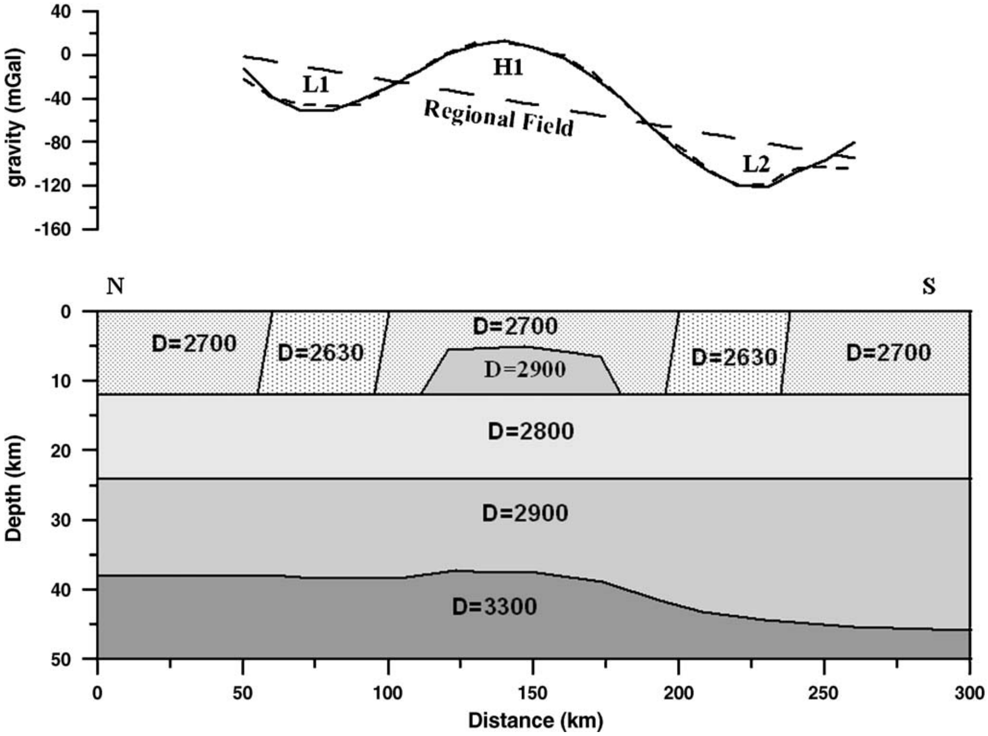

Fig. 6. A gravity profile across Enderby Land, East Antarctica. Location of profile is approximately shown in Fig. 9. The Regional field shows thickening of crust towards south with a central gravity high (H1) and flanking lows (L1 and L2). The individual gravity lows and highs are modelled due to low and high density intrusives, respectively representing felsic and mafic intrusives.

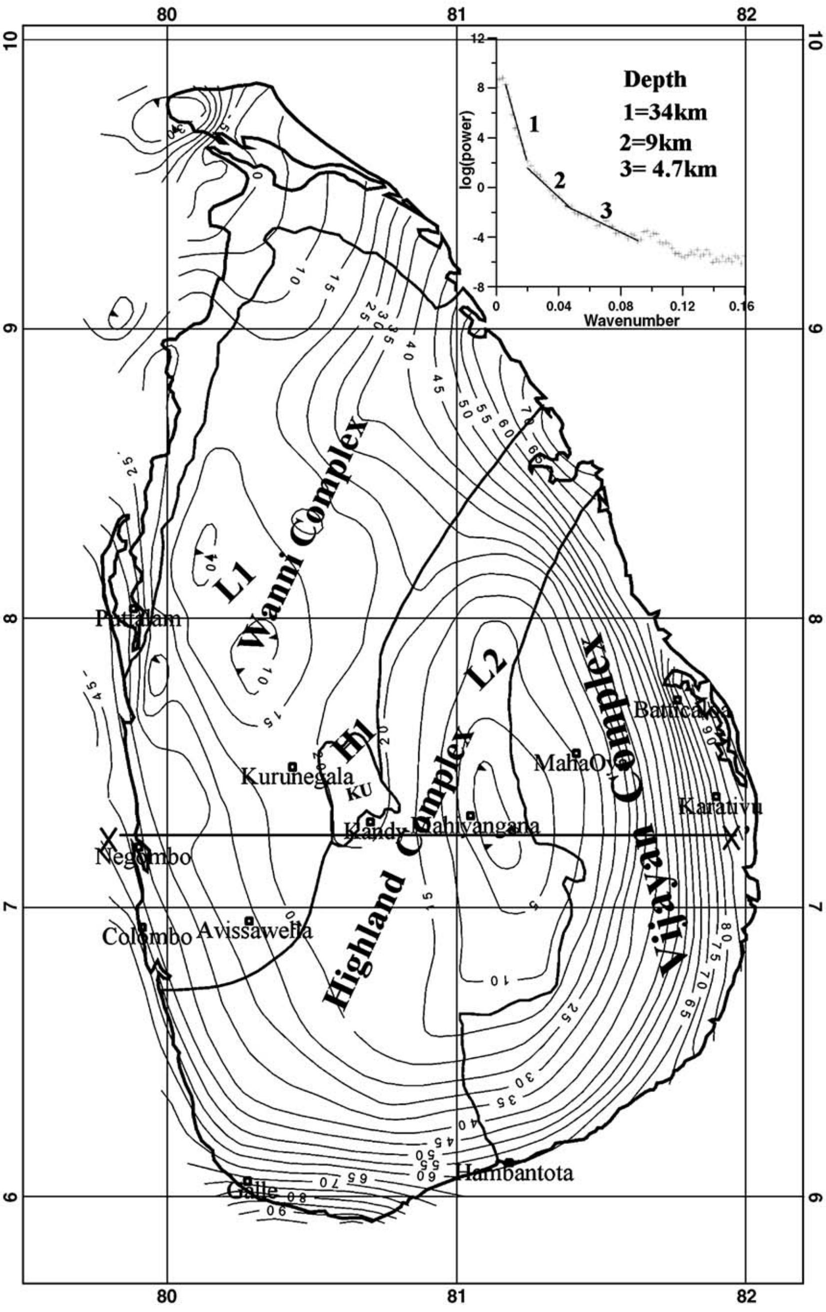

Fig. 7. Geoid corrected Bouguer anomaly map of Sri Lanka with geological boundaries superimposed on it. XX′ is Profile along which gravity anomaly is modelled as given in Fig. 8. Spectrum vs wave number of Geoid corrected Bouguer anomaly is given in the inset, which shows three linear segments of slopes corresponding to 34, 9 and 4.7 km which may represent depth to Moho and sources in the upper crust.

linear segments with sources at approximate average depths of 34, 9 and 4.7 km, respectively as discussed above. These sources may represent in general Moho and sources in the upper crust. Being average depths of short and large wavelength sources it may not provide the exact depths to different sources but provides an average estimate, which can be used as initial input for detailed modelling of gravity anomalies. Gravity high (H1) being of smaller wavelength, can be related to shallow sources while gravity lows (L1 and L2) being of larger wavelength can be related to deeper sources. An east–west profile XX′ (Fig. 8) along 7.25° N is taken from Fig. 7 and modelled for the possible causative sources using three layered standard crustal model of about bulk densities 2700, 2800 and 2900 kg/m^3 and initial depth to the sources for gravity anomalies L1, L2 and H1 is constrained from spectral depths as given above. The modelled crustal section shows the intermediate high density (2800 kg/m^3) layer protruding in the upper crust, which indicate thrusting of lower crustal rocks in the central part of the island under the Highland Complex related to the gravity high H1 while crust thickens up to 40–41 km under the eastern part of the Highland Complex and its junction with the Vijayan Complex related to the gravity low L2.

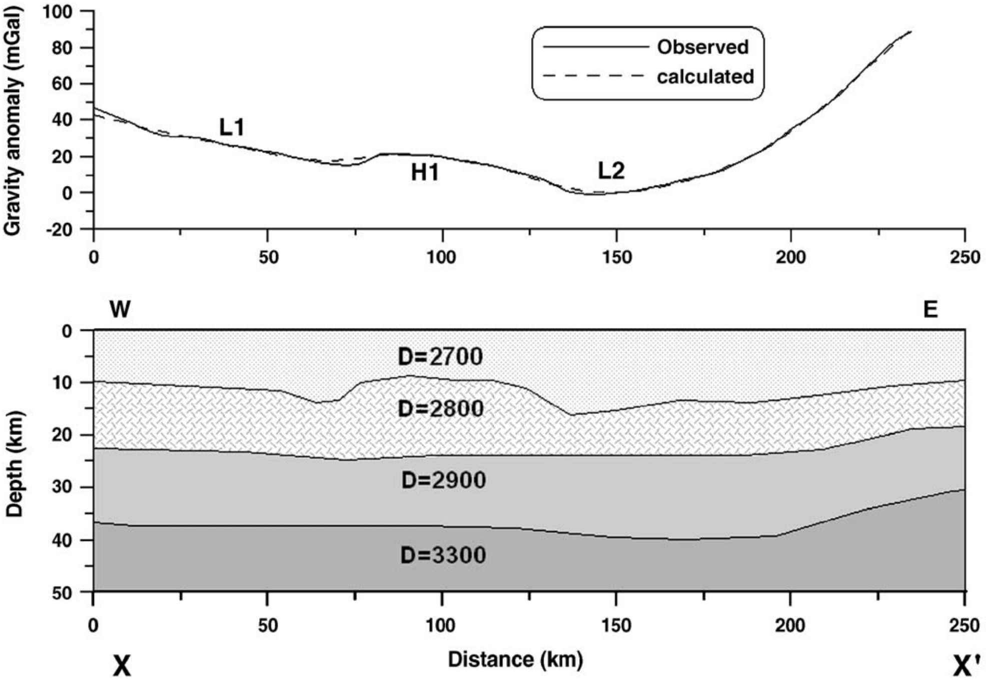

Fig. 8. Crustal model along Profile XX′ (Fig. 7) computed using three layered standard crustal model with densities given in kg/m^3. L1 and L2 are flanking lows with a central gravity high (H1). It shows crustal thickening (40–41 km) towards east with high density intrusive related to second layer in the upper crust.

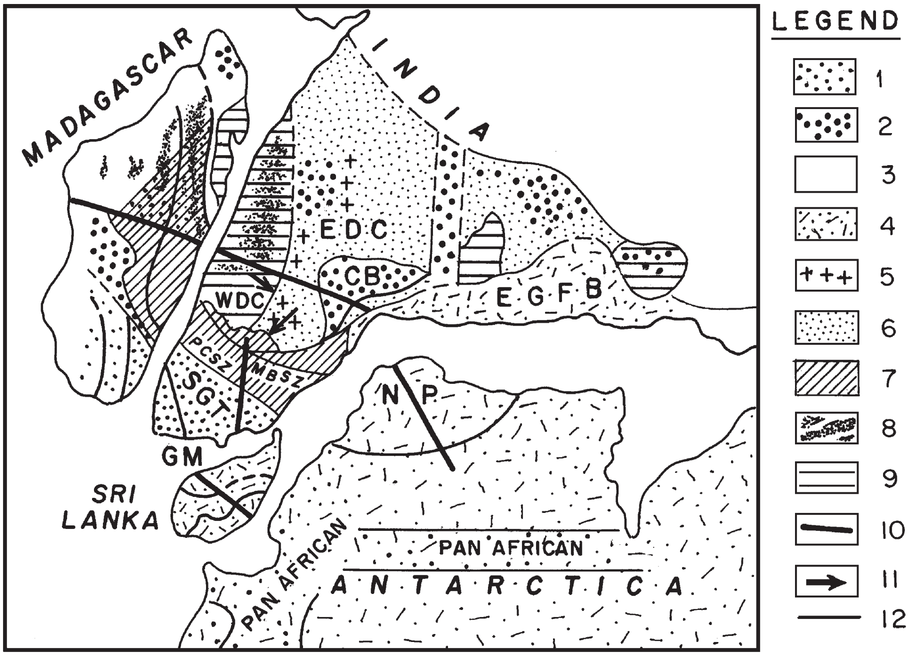

Fig. 9. Reconstruction of Madagascar, India and Antarctica before their break up and some common rock types and shear zones (modified after Yoshida et al., 1999). MBSZ and PCSZ represents Moyar–Bhavani and Palghat Cauvery shear zones of Southern Granulite Terrain of India, which appear to extend in Madagascar. The EGFB of India appears to fit with the Napier Complex (NP) of East Antarctica and Sri Lanka, in case Sri Lanka is fitted in Gulf of Mannar (GM). It also shows the lay out of gravity profiles across different continents, which have been used in the present study. Various geological formations and symbols are as follows: 1 = Metamorphic High grade rocks (Ca.550 Ma), 2 = Proterozoic platform cover sediments, 3 = Metamorphic Plutonic rocks (Ca. 1.0 Ga–1.2 Ga), 4 = Metamorphic High grade rocks (Ca. 1.0 Ga– 1.6 Ga), 5 = K-Granite plutons of EDC (Ca. 2.6 Ga– 2.5 Ga), 6 = Archaean Proterozoic Metamorphic and Plutonic rocks (Middle Grades), 7 = Neo archaean Caharnockites (High grades) (Metamorphism 2.6–2.5 Ga), 8 = Archaean green stone belt (Ca.3.4–2.7 Ga), 9 = Archaean Cratonic Nuclei (Mostly older than 3.0 Ga), 10 = Gravity profiles in the present study, 11–Direction of convergence and 12 = Shear zone.

6. Discussion and conclusions

The Bouguer anomaly map of peninsular shield of India shows a number of paired gravity anomalies, which are significant for Proterozoic collision tectonics (Thomas, 1985) and are examined in the present study based on their causative sources and regional geology/ tectonics of the region. The gravity anomalies observed over the SGT are modelled constrained by seismic results along a near by profile, which suggests that the gravity highs are primarily related to high density mafic rocks in the upper crust, whilst the gravity lows are due to crustal thickening. The association of magnetic anomalies with shear zones and thrusts suggests that the mafic rocks are associated with them. High density and high susceptibility rocks in the upper crust at a depth of 6–8 km under the CSZ suggests concentration of subsurface mafic rocks at shallow depths. Their high velocity (Reddy et al., 2003) along with their high conductivity (Harinarayana et al., 2003) suggest that they may represent upper mantle rocks with carbon content such as graphite to provide high conductivity rocks thrusted in upper crust, related to collision of two blocks. Peak metamorphism at ultra high temperature conditions in CSZ (Santosh et al., 2004) also suggest that it represents a collision zone between two blocks.

The magnetic anomalies indicate a connection between firstly the MBSZ and the Mettur shear zone and secondly the PCSZ and the Gangavalli shear zone. Also the crustal structure north of the MBSZ—Mettur shear zone and south of the PCSZ—Gangavalli Shear zone is different from that between them, suggesting that they formed arcuate shaped collision zone. The period of this collision may be related to the metamorphic ages of rocks thrusted along N-verging thrust north of the CSZ (2.6–2.5 Ga). This also conforms with the ages of basic/ultra basic rocks exposed in the CSZ as part of oceanic crust between the two blocks, which are slightly older than these metamorphic ages (Bhaskar Rao et al., 2003). Large scale thickening of the crust under SGT suggest N–S directed compression. In plate tectonics paradigms, CSZ bounded by N and S verging thrusts with rocks of oceanic affinity represents central core complex. This presents an ideal cross section as observed across several orogenic belts such as Appalachians, Caledonian etc. (Hatcher and Williams, 1986). Further due to high topography of the central core complex, it got eroded faster resulting into thin crust under it (Fig. 5) compared to surrounding on either side of it due to isostatic uplift.

The collision between the Dharwar Craton and the SGT during 2.6–2.5 Ga may be related to contemporary collision northward between Eastern Madagascar—WDC and EDC along a Shear Zone between them (SZ; Fig. 1) and related eastward subduction may have given rise to K-granite plutons and the schist belts of the EDC of almost the same period (Mishra and Prajapati, 2003). Eastern Madagascar was a part of the WDC during the Mesoarchaean (Collins and Windley, 2002) and major shears of SGT find reflection in eastern Madagascar (Yoshida et al., 1999). It may be visualized that the three continental blocks viz Eastern Madagascar—WDC, EDC and SGT collided almost simultaneously during 2.6–2.5 Ga with forces directed in NW–SE direction providing an W–E component between the WDC and the EDC and N–S component between the Dharwar Craton and the SGT (Fig. 9). This is supported by arcuate shaped shear zones as MBSZ—Mettur shear and PCSZ and Gangavalli shear as discussed above. Alternatively WDC and EDC collided first during 2.6–2.5 Ga due to W–E directed compressional forces followed by a N–S directed compression between the WDC–EDC and the SGT. Oblique convergence in Dharwar craton have been suggested by Chadwick et al. (2000). This is similar to the Proterozoic collision between the Bundelkhand Craton and Bhandara Craton in central India along the Satpura Fold belt (SFB) with N–S directed subduction (Mishra et al., 2000), which is also characterized by similar geophysical signatures of high density, high susceptibility, high velocity and high conductivity rocks in upper crust under the SFB.

The small wavelength mixed gravity highs and lows superimposed over relatively large wavelength lows (GH5, GL5; Fig. 3) observed over schist belts of the WDC suggests bimodal volcanics, which represent mafic and felsic rocks indicating an extensional environment (Mishra, 1990). However, the associated large wavelength gravity lows of schist belts (GL5, Fig. 3) indicate reduced crustal density under them (Arora et al., in press), which is confirmed from exposed tonalite–trondhjemite–granodiorite (TTG) rocks. These schist belts may therefore, represent marginal and intra arc basins where rocks similar to oceanic crust are found with an over all continental crustal structures with reduced density as is presently found in case of Japan and Philippine seas. This is similar to crustal structure under some other schist belts in other parts of the world (Burke et al., 1976). The linear nature of Chitradurga schist belt along shear zone (SZ; Fig. 1) between WDC and EDC suggest that it may represent intra arc basin while those west of it may represent marginal basin.

The CSZ also known as Palghat gap is a linear geomorphological feature of about 80–100 km width bounded by MBSZ and PCSZ and resembles like a continental rift valley. The reported high upper mantle heat flow (Ray et al., 2003) and high seismicity in this section suggest that there have been some recent tectonic activity in this section, which has been prone to such activity due to its highly deformed nature and can be attributed to present day plate tectonic forces (Mishra and Vijaya Kumar, 2005).

The eastern part of SGT covered by Cretaceous–Tertiary sediments along east coast of India show NE–SW oriented gravity highs (GH3), which are extension of the gravity highs related to EGFB north of it (GH4; Fig. 3) indicating that the Eastern Ghat orogeny may be extending southwards along east coast of India. The gravity highs (GH4) due to EGFB were attributed to high density rocks thrusted from lower crust/upper mantle along west verging thrusts and gravity lows (GL4) along its western margin is attributed to crustal thickening (Mishra and Tiwari, 1995; Singh and Mishra, 2002). Thrusting of lower crustal/upper mantle rocks for gravity high related to EGFB (GH4) is supported from high seismic velocity (Kaila et al., 1979) and high conductive rocks in this section (Naganjaneyulu and Harinarayana, 2004). Similarly gravity high, GH3 representing southward extension of GH4 due to EGFB also appears to be caused by high density rocks in middle crust (T1; Fig. 4) which may represent thrusted lower crustal rocks as in case of GH3. These gravity highs can also be attributed to under plating at the time of the break up of India from Antarctica during early Cretaceous. However, seismic studies (Kaila et al., 1979) do not show any signatures of under plating along east coast of India especially in southern part. The high density thrusted lower crustal rocks along with crustal thickening west of it (GL4) and deformed sediments of Cuddapah basin towards east along EGFB (Fig. 1) suggest collision tectonics presumably between Dharwar craton and SGT, India and the Napier Complex of East Antarctica (Fig. 9) and Cuddapah basin was formed as peripheral foreland basin. The Nellore schist belt of Neoarchaean period at the eastern margin of EGFB may represent an exotic/suspect terrane caught in between EGFB and East Antarctica as it does not fit with surrounding rock types. The Bouguer anomaly of Napier and Rayner Complexes of Enderby Land and Lutzow Holm Bay of East Antarctica, which were supposed to be juxtaposed with EGFB primarily show large wavelength gravity lows caused by crustal thickening up to 45–46 km and gravity lows and highs related to felsic and mafic intrusives in the upper crust indicating a compressive regime.

The crustal model under Sri Lanka is almost similar to those described above for EGFB and East Antarctica with high density intrusives occupying the Kadugannawa complex and western part of Highland complex and crustal thickening east of it. If Sri Lanka is fitted in Gulf of Mannar, the central gravity high of Sri Lanka will form the extension of gravity highs along east coast of India, which along with the Wanni and Highland complexes of almost same age (~1.0 Ga) appears to represent similar orogeny. Crustal thickening under the eastern part of Sri Lanka suggest W–E directed compression as envisaged above in case of EGFB with thrust between Wanni and Highland complex acting as a suture between these two blocks. It is also supported by arc type intrusives in Vijayan complex towards the east (Kröner et al., 2003).

The rock types and predominant metamorphic ages of rocks in the Rayner complex is almost same (1.0 Ga) as that of EGFB, India and Vijayan Complex of Sri Lanka which were juxtaposed with each other (Rao et al., 1995; Fitzsimons, 2000). The gravity anomalies and their sources indicating compressional phases suggest that these continents appear to have collided during 1.0 Ga and formed the orogenic fold belts (Fig. 9). In this regard Antarctic continental Margin Magnetic Anomaly (ACMMA) (Golynsky et al., 2002) showing linear magnetic highs offshore Enderby Land to Lutzow–Holm Bay and extending further west up to Dronning Maud Land where Africa was attached to Antarctica assumes special significance. Satellite magnetic data (MAGSAT) has shown a magnetic high over EGFB along east coast of India and offshore and Sri Lanka (Mishra and Venkatrayudu, 1985). These linear magnetic highs can represent mafic rocks related to collision tectonics such as thrusted lower crustal rocks or intrusives related to break up of continents during Mesozoic period. However, in absence of other geophysical data specially offshore Antarctica, it is difficult to resolve among the two settings specially in the present case as both these tectonics have known to have taken place along this section during different periods. However, the former namely ACMMA representing collision tectonics is preferred as it extends over the entire section of East Antarctica affected by this event while break up of continents took place in stages during Mesozoic period, which cannot produce such linear magnetic anomaly all through this section.

Acknowledgement

The authors are thankful to Director, NGRI for his permission to publish this work. D.C. Mishra and R.P. Rajasekhar are thankful to CSIR for Emeritus Scientist scheme 21(0563)/03/EMR-II. Authors are thankful to Dr. Alan Collins and Dr. L.K. Das whose suggestions have been extremely useful in improving a previous draft of this manuscript. We are also thankful to Drs. B. Singh, A. P. Singh, D. V. Chandrasekhar, Y. J. Bhaskar Rao and Dr. T. R. K. Chetty for discussions. Thanks are also due to Ch. Ramaswamy for his help towards preparation of this manuscript.

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