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Heterogeneity in crustal structure across the Southern Granulite Terrain (SGT): Inferences from an analysis of gravity and magnetic fields in the Periyar plateau and adjoining areas

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Abstract

The study region forms the western part of the Madurai block (southern block) and shares several lithological characteristics of the Proterozoic exhumed South Indian Granulite Terrain (SGT). The crustal structure of the area has been derived from gravity data, constrained partly by aeromagnetic data. The Bouguer anomaly map of the region prepared based on detailed gravity observations shows a number of features (i) the Periyar lineament separates two distinctly different gravity fields, one, a high gravity gradient tending to be positive towards the coast in south west and significant gravity lows ranging from -85 to as low as -150 mGal in the NE covering a large part of the Periyar plateau (ii) within the broad gravity low, three localised circular anomalies of considerable amplitude occur in the region of Munnar granite. A magnetic low region in the central part coincides with the area of retrogressed charnockites and the major lineaments suggestive of a genetic link and considerable downward extent. The crustal models indicate that the upper layer containing exhumed lower crustal rocks (2.76 gm/cc) is almost homogeneous. most part of the gravity field resulting from variations in intracrustal layers of decharnockitised hornblendic gneisses and granite bodies. Below it, a denser layer (2.85 gm/cc) of unknown composition exists with Moho depth ranging from 36 to 41 km. The structure below the region is compared with that of two other segments of the SGT from which it differs markedly. The Wynad plateau forming the western part of the Northern Block of the SGT is characterised by a heterogeneity due to the presence of contrasting crustal blocks on either side of the Bavali shear zone, possibly a westward extension of the Moyar shear zone and presence of high density material in the mid-to-lower crustal portions. The crust below the Kuppam-Palani transect has a distinctive four-layer structure with a mid-crustal low density layer. The differences in crustal structure are consistent with the different tectonic settings of the three regions discussed in the paper. It is suggested that the crustal structure below the Kuppam-Palani transect corridor is not representative of the SGT as a whole, an aspect of great relevance to intra-continental comparisons and trans-continental reconstructions of continent configurations of the Gondwanaland.

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1. Introduction

The southern Indian Shield comprises the Archaean granite– greenstone terrains of Dharwar Craton in the north and the high-grade Southern Granulite Terrain (SGT) in the south. The

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SGT is separated from the Dharwar Craton by the orthopyroxene isograd identified by Fermor (1936), which essentially separates the charnockitic and non-charnockitic terrains in the shield. Fermor initially suspected a fault along what has come to be known as the Fermor line. There, however, exists a narrow transition zone (rather than a linear boundary) along which the low-grade greenstone–granite domain transforms to high-grade granulite facies rocks (Swaminath et al., 1976). The southern Indian Shield, therefore, provides an oblique crosssection across the continental crust (Fountain and Salisbury,

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1981). The SGT south of the transition zone is traversed by a set of major faults or shear zones, the most prominent among them are the shear systems of Moyar–Bhavani, Palghat–Cauvery and the Achankovil–Thenmalai (Fig. 1). Notably, the Moyar shear zone takes a NW–SE trend further west into the Wynad plateau and is named as the Bavali shear zone (Nair et al., 1976).

Landsat imagery study in this region by Drury and Holt (1980) revealed the regional nature of the major shear zones. The high-grade domain north of the Palghat–Cauvery shear zone (PCSZ) is referred to as the "northern block" and the domain to the south of the PCSZ, the "southern block". The Achankovil–Thenmalai shear zone divides the "southern block" into the northern Madurai block and the southern Kerala

block (also called the Trivandrum block). Both the high-grade domains in the north and south have witnessed several phases of ultrabasic, basic, granitic and alkaline magmatism through mainly the Proterozoic (2500–550 Ma).

It is generally held that the southern Indian Shield is a composite continental segment, formed by the accretion of various crustal blocks during the mid-Archaean to Neoproterozoic (Radhakrishna, 1989; Harris et al., 1994; Jayananda and Peucat, 1996). However a unitary model of one continent dissected by steep faults has also been recently proposed (Mahadevan, 1998), consistent with earlier concepts of Fermor (1936). Based on geochronology and isotope data different age provinces with distinct precrustal histories are proposed within the composite unit of southern Indian Shield (Harris et al., 1994;



Fig. 1. Simplified geological map of South India (modified after Raith et al., 1983, incorporating recent data). Also shown is the Kuppam–Palani (K–P) geotransect. PRL: Periyar lineament; IML: Idamalayar lineament; KRL: Kerala lineament; JHE: Javadi Hills East fault; MPL: Mettur–Palakkodu shear lineament; KBL: Kambam lineament; DRZ: Dharmapuri rift zone. Marked as rectangles represent 1. Central Kerala (present study area), 2. Wynadu plateau and 3. Kuppam–Palani geotransect area. Also shown are the profiles selected for modelling as AA' and BB'.

Bartlett et al., 1995; Jayananda et al., 1995; Bhaskar Rao et al., 2003; Santosh et al., 2003; Cenki et al., 2004). Thus, for the Dharwar Craton the crust formation is considered to be Archaean (3.58–2.50 Ga), while the exhumed high-grade region to the south continued to evolve during late Archaean to Neoproterozoic. The Madurai and Trivandrum blocks witnessed a dominant impact of the Pan-African tectono-thermal events, manifested in the emplacement of many alkaline and calc-alkaline granitic intrusives (Santosh, 1989; Santosh et al., 2003).

An important question that needs to be addressed is whether the deep continental structure across several segments of the South Indian Shield reflects the diverse geological settings brought out by the earlier studies. Such an attempt is made in this paper based on interpretation of geophysical data. In the present study, we undertake a detailed gravity investigation constrained with aeromagnetic anomalies in the Periyar plateau and the surrounding regions of the SGT covering parts of Kerala and Tamilnadu so as to delineate the crustal structure in the region. The area falls within the Madurai block of the SGT and is bounded by the Palghat–Cauvery shear zone in the north and the Achankovil–Thenmalai shear zone in the south. The results will be compared with the deep continental structure below adjacent regions of the SGT. The regions selected are (i) the Wynad plateau forming the western part of the Northern Block and (ii) the Kuppam–Palani geotransect corridor that runs along the central part of the Northern Block, along the a Proterozoic Dharmapuri intra-continental rift zone and the Palghat–Cauvery shear zone.

2. Regional geology

The geological map of the Periyar plateau and the surrounding areas is presented in Fig. 2. It is based on the revised maps of Kerala and Tamilnadu prepared by the Geological Survey of India (GSI, 1995). The main geological formations in the area comprise members of charnockite suite with bands of leptynites, garnet-free mafic granulites, migmatitic



Fig. 2. Geological map of the study area (after GSI, 1995). Lines AA' and BB' show the location of the regional gravity profiles considered for modelling.



Fig. 3. Bouguer anomaly map of the Periyar plateau and the adjoining regions. Contour interval 5 mGal (PPGL: Periyar plateau gravity low). The location of profiles selected for modelling are shown as lines AA' and BB'. The gravity data distribution is shown in the inset.

gneisses, garnet cordierite gneisses, garnet cordierite sillimanite gneisses and granitoids. The charnockitic rocks are possibly of Archaean and Proterozoic age. The charnockitic basement rocks have been transformed along major lineaments into hornblende-biotite gneisses (Mahadevan, 1964) possibly during the Pan-African tectono-thermal event, culminating in the emplacement of granite rocks, dated 740 ± 30 and 550 Ma (Santosh et al., 1989, 2003). Major dykes running for a few tens of kilometres closely related to the Kerala lineament and in a NW–SE to NNW–SSE direction, somewhat parallel to the coast are prevalent in the area (Fig. 2). They are mostly late Mesozoic in age and include fresh dolerites and subalkalic Fe-rich quartz tholeiites (Radhakrishna et al., 1986, 1994).

The lineaments of the study region could be classified based on their orientation as 1) NW-SE to WNW-ESE, 2) NNW-SSE to N-S and 3) ENE-WSW trending lineaments. One of the most prominent lineaments in study area is the NW-SE trending Periyar lineament, extending over a distance of about 90 km from NE of Angamali to SE of Udumbanshola (Fig. 2). The lineament is joined by the Idamalayar lineament, striking NNW-SSE, east of Kothamangalam. The Periyar lineament is often been considered as an active tectonic feature and the seismicity in the area is suspected to be due to strike-slip movements along this lineament. However, their association with major dykes led to the inference that the lineaments may be due to tensional fractures related to the major distensional faulting of the West Coast (Karunakaran and Mahadevan, 1971). The third major lineament, the Kerala lineament too has such associated dyke emplacement.

Perhaps the most significant feature of the Precambrian evolution is the exhumation of the high-grade rocks (charnockites and khondalites) from depths of 20–30 kb (30–45 km) culminating in the emplacement of the granitic rocks of Pan-African age (\sim 550 Ma). The exhumation may have been differential resulting in major shear zones (Mahadevan, 2003a).

3. Gravity data and anomaly map

3.1. Data

In order to understand the nature of crust and the attendant tectonics, we carried out detailed gravity surveys in the Periyar plateau and the adjoining areas. A Lacoste-Romberg (Model G) gravimeter with an accuracy of 0.01 mGal was used for the data acquisition and nearly 1200 gravity measurements were made covering all possible motorable roads at an average station spacing of 1-2 km in the region. The measurements were made utilising already available base stations and by establishing additional secondary base stations. The elevation data has been considered from spot heights, benchmarks and toposheets. The 1930 international gravity formula and the surface rock density of 2.67 gm/cc were used for the purpose of gravity data reduction. The error in the elevation could be of the order of 3-5 m and considering other factors such as instrumental limitations, the maximum error in the gravity data may be about 1.5 mGal. Apart from the gravity map prepared from this data, the available aeromagnetic and analytic signal maps pertaining to the study region have also been considered as an additional constraint. The density and magnetic susceptibility of various

rock types of the region were determined by collecting a good number of rock samples.

3.2. Gravity anomaly map

The Bouguer anomaly map prepared for the study region at a contour interval of 5 mGal is shown in Fig. 3. The Bouguer contour map shows good correlation with the surface geology and the minor geological structures of the area. The anomaly map suggests that the gravity field in the NE of Periyar lineament is distinctly different from that of SW part. It separates a strong gravity gradient tending to be positive towards the coast from the significant gravity lows ranging from -85 to as low as -150 mGal covering a larger part in the Periyar plateau. The presence of granitic plutons is brought out by domical low in the Bouguer anomaly map over Periyar plateau, the Munnar granite mass being characterised by three gravity lows (PPGL-1, PPGL-2 and PPGL-3). However, two strong gradient zones have been observed on the Bouguer anomaly map (LM1and LM2). While the LM1 coincides with the earlier identified Kerala lineament, LM2 is not so far been recognised and is named here as Kottayam-Kodungallur lineament. The Bouguer gravity field does not appear to be sensitive to lineaments due to lack of distinctive density contrast on either side of the lineaments. The isostatic anomalies in the region under study vary from -20 to -80 mGal (NGRI, 1978). Such variations in the isostatic anomalies suggest lateral inhomogeneities in the crustal masses or changes in crust-mantle interface.

4. Geological inferences from gravity and magnetic anomalies

Recently Harikumar et al., (2000) and Rajaram and Anand (2003) generated an aeromagnetic anomaly and the analytic signal maps of the peninsular shield region. The colour-coded images of the aeromagnetic and analytic signal maps prepared by them were provided to us for the purpose of correlation. These maps along with the gravity map have been used for qualitative analysis. The significant trends and patterns observed from these maps have been depicted in Fig. 4 so as to understand the surface and subsurface geological characteristics.

In this region, two distinct sub-provinces of magnetic highs may be distinguished (i) Trichur–Udumbanshola province in the NE and (ii) the Trichur–Ernakulam–Kottayam province in the SW (Fig. 4). A prominent NW–SE trending belt of magnetic low separates the two provinces of magnetic high. Interestingly these low magnetic belts encompass a large area of hornblende gneisses (retrograded charnockites), mapped in the geological map of the region. The boundary of these magnetic high and low provinces on either side correlate with the Periyar and the Kottayam–Angamali lineaments. The analytic signal map reveals that the block of outcropping hornblende gneisses in the NE is underlain by strong magnetic sources, which suggests the presence of pristine charnockites at depth. The Periyar and the Kottayam–Angamali lineaments find expression in the analytic signal map also. It may therefore



Fig. 4. A generalized map depicting gravity and magnetic (both total field and analytic signal) anomaly trends and patterns in the study area. Details are discussed in the text. PPGL-1, -2 and -3 are small gravity low closures in the Periyar plateau.

be inferred that these lineaments are boundaries (edges) of crustal segments with distinct magnetic characteristics. Further, the gravity anomaly map reveals that the Kottayam–Angamali lineament coincides with a gravity gradient and the Periyar lineament separates two distinctly different gravity fields on either side. The presence of large retrograded charnockites in the area between these two lineaments indicates the possibility of genetic linkage between the retrogression and the lineament. This further indicates that both Periyar and Kottayam–Angamali lineaments could be deep seated features, where the latter may have special status as it separates a distinctive magnetic field along the coastal tract from that of the interior.

5. Gravity modelling and deep structure

In order to obtain the crustal structure in the region, twodimensional gravity modelling was carried out along a number of profiles using the SAKI program of USGS (Webring, 1985). Two representative selected profiles AA' and BB' are presented here. Considering the average densities for the surface rocks and the mid-to-lower crustal exhumation in the SGT, a two-layer crustal



Fig. 5. Interpreted crustal models along profiles AA' and BB' in the Periyar plateau region.



Fig. 6. Interpreted crustal models along profiles AA' across the Bavali shear and the Wynad plateau (after Radhakrishna et al., 2003).

model consisting of high density lower crustal rocks (charnockites 2.76 g/cc) as the upper crustal layer and a 2.85 g/cc density lower crustal layer below it. The upper mantle below these two layers is assigned a density of 3.3 g/cc. This two-layer density model for the crust is consistent with the simplified two-layer crustal model proposed for the SGT based on velocity–density relation of the major rock types (Ramachandran, 1992). In addition to these two layers, the other surface rock exposures become a part of the crust as localised bodies or as thin layers.

Gravity modelling along these two profiles (Fig. 5a and b) in the region reveal crustal thickness (depth to Moho) of the order of 40–41 km below the Periyar plateau and a tendency to thin up to 34–37 km along the fringes of the plateau bounded by rift zones of different ages. The models show that the thickness of the lower crustal layer (dominated by charnockites) is different on either side of the Periyar lineament.

Profile AA' covers the central and northern part of the study area. An interesting feature is the presence of localised highly weathered surface rock extending down to a depth of 500 m in the area between Idamalayar and Periyar lineaments bringing out a steep gravity low. A granitic body with a small outcrop length extending down to a depth of 8 km has been inferred below it. Towards northeast of the profile, hornblende gneisses extend down to depths of 4-8 km as a top layer. The upper crustal layer consisting of charnockites extends down to a depth of 27 km in SW part of the profile and 21 km in NE part of the profile and shows an irregular wavy layered shape. The Moho depth extends to 34 km in the SW part of the profile and deepens down to 41-42 km in the central part of the profile and again thins to 39 km in the NE part of the profile.

Profile BB' covers the southern part of the study area. A thin layer of highly weathered surface rock is seen to extend down to depth 700 m in the Udumbanshola region over the Periyar plateau. A blind granite body extends down to 16 km in the

central part of the profile. Hornblende gneisses and biotite gneisses appear to be floating on the charnockites up to depth of 1-2 km. The upper crustal layer consisting of charnockites extends down to a depth of 22 km in SW and NE part of the profile and thins down to 6-9 km in the either side of the blind granite body. The Moho depth extends to a depth of 37 km in the SW part of the profile and deepens down to 41-42 km in the central part of the profile and again thins to 39 km in the NE part of the profile.

5.1. Model implications

The models in general show that the hornblendic gneisses are relatively thin bodies and do not extend to greater depth. Granitic bodies also extend to relatively shallow depths. Both of them occur as outcrops and blind bodies and also in shallow depths. The charnockitic rocks with density 2.76 gm/cc seem to be extending 10-22 km as seen in all the profiles and are underlain by a denser crustal layer having a density of 2.85 gm/cc. The composition of this layer is not known, but it is speculated that it may possibly be a denser residual layer left behind after the extraction of granite magmas, which may have migrated to upper portion of the crust above.

Most of the granite bodies with a density of 2.67 gm/cc have shallow roots and it has been necessary to introduce concealed granite bodies at depth less than 16 km so that the observed and calculated anomalies are matched. In general, granite bodies emplaced into the charnockitic rocks do not extend deeper down in to the crust. Such large scale granite emplacement has the potential to retrograde and transform the charnockitic rocks in the region into hornblende and biotite gneisses (Mahadevan, 1964). There is a tendency for the charnockitic rock (2.76 gm/cc) to extend deeper down to depth of 21–25 km towards the SW part of the area.

6. Comparison with other areas of SGT

Detailed gravity derived crustal models are available for other areas of SGT that include the Bavali shear and the Wynad Schist belt of the Wynad plateau region (Radhakrishna et al., 2003) and the Kuppam–Palani geotransect region (Singh et al., 2003). It is, therefore, relevant to compare the crustal configuration in the present study region with these areas in order to understand the nature of crust in different parts of the SGT.

6.1. Wynad Schist belt and adjoining areas

Gravity modelling was carried out along several profiles across the Bavali shear zone (Radhakrishna et al., 2003), which has thrown light on the nature of crust below the Wynad Schist belt and the adjoining area. A representative gravity model has been selected for comparison. The crustal model (Fig. 6) points the presence of a crust around 38 km with a high density mass of 2.98 g/cc at its base.

The schist–gneiss complex of the Kannur/Manathavady extends for about 150 km in an WNW–ESE direction with an approximate width of 10–20 km. The NW–SE trending Bavali shear with a length of 100 km passes through the centre of the area (Nair et al., 1976). The Bavali shear possibly may be a westward extension of the Moyar shear zone. The adjoining regions constitute charnockites and their retrograded products as the predominant rock type. The area is also characterised by the occurrence of several igneous plutons of felsic and mafic composition emplaced within or close to the gneisses and schists.

The models presented in Radhakrishna et al., (2003) exhibit a plane separating two contrasting crustal densities close to the Bavali shear zone. However, crustal model from the Wynad plateau region (Fig. 6), the shear zone appears to be less prominent.

6.2. Kuppam–Palani geotransect profile

The Kuppam-Palani geotransect encompasses a large section of continental crust that displays a transition from granite-greestone terrain in the north through high-grade gneiss and granulites in the south. The Kuppam-Jalakandapuram segment of the Kuppam-Palani transect runs along the NE trending Proterozoic Dharmapuri intra-continental rift zone (DRZ) and the Jalakandapuram (Kolattur)-Palani segment transects across the E-W running Palghat-Cauvery shear zone (PCSZ) (Gopalakrishnan, 1996; Mahadevan, 2003b). Four east west trending shear zones dissect the corridor, from north to south and these are Moyar-Bhavani shear zone, the Chennimalai-Moyar shear zone, Dharmapuri shear zone and Devathur-Kallimandyam shear zone (Chetty et al., 2003). The transect is also characterised by the occurrence of several alkaline complexes like Savattur, Yelagiri, Samalpatti, Pakkanadu and Sivamalai and granite plutons such as Trihankode, Karamadai, etc. One of the significant aspects of this transect is that it cut across the major structure in the SGT, namely the Palghat–Cauvery shear zone, which is considered as a major ductile shear (Drury and Holt, 1980), collision zone (Gopa-lakrishnan, 1996), crustal suture (Radhakrishna, 1989), and reactivated rift (Mahadevan, 2003b).

Detailed gravity modelling along the transect, where, well controlled seismic refraction–reflection profile from Kuppam to Palani is available (Reddy et al., 2003) has been undertaken by Singh et al.(2003). Their models along Kuppam–Kumarapalayam and Kolattur–Palani segments are presented here for comparison (Fig. 7). The crustal models reveal a four-layered crustal configuration with Moho varying from 41 km beneath Kuppam to 43–44 km further south. The maximum thickness of the crust is 46 km below Kambainallur. The models also indicate the presence of a low density mid-crustal layer all along the transect. According to them the intense crust–mantle interaction and flushing out of fluids has led to the presence of mid-crustal low density layer.

7. Tectonic setting and deep crustal structure

The three regions referred to above, namely the Periyar plateau, the Wynad plateau and the Kuppam–Palani transect corridors, are an integral part of the southern Indian exhumed high-grade domain (the SGT) but are characterised by distinctive tectonic settings. The Kuppam–Palani geotransect is located along the central part of the SGT cutting across the major E–W structural trends and shears like the Dharmapuri rift zone and the Palghat–Cauvery shear zone and the rocks exposed are essentially unclassified gneisses. On the other hand, the Periyar plateau is dominated by massive charnockites and is devoid of major shear zones within it, though major shears mark its the northern and southern boundaries. The Wynad plateau lies close to the gneiss–granulite transition zone and is cut across by the Bavali shear passing through the middle of the area.

A comparison of the crustal structure in these three different parts of the SGT is worth attempting, as these regions are distinctly different from each other in terms of their tectonic setting and nature of the crust. The crustal structure is characterised by an almost homogeneous thickened crust below the Periyar plateau with most part of the gravity field resulting from variations in the intracrustal layers/bodies of hornblendic gneisses and granites. On the other hand, in the Wynad region, the crust is rendered highly heterogeneous by the presence of contrasting crustal blocks on either side of the Bavali shear in shallow part and the presence of high density material in the mid-to-lower crustal portions (Radhakrishna et al., 2003). The crust below the central part of the SGT, along Kuppam-Palani transect corridor running along the Dharmapuri palaeo-rift has the distinction of the presence of a 7-15 km thick mid-crustal low density layer evolved during the emplacement of large volumes of granitic rocks and alkaline plutons and a very highly thickened crust (41-45 km) (Singh et al., 2003). The inherent ambiguity in the gravity models obtained for the Periyar and Wynad plateau areas may partly be due to the absence of seismic data control. However, the presence of a high density material in the lower part of the crust in the Wynad region and



Fig. 7. Interpreted gravity 2-D crustal structure along Kuppam–Bhavani and Kolattur–Palani geotransects across the Southern Granulite Terrain (after Singh et al., 2003). Inset shows the velocity layering along Kuppam–Bommidi and Kolathur–Palani DSS seismic section (after Reddy et al., 2003).

highly variable mid-crustal interface and the granite emplacements in the Periyar plateau region have been necessitated considering the amplitude and wavelength of anomalies.

8. Conclusions

The results presented in this paper underline the fact that the SGT, though comprising largely of exhumed lower crust of the Indian Shield in the Proterozoic, comprises segments, which have been affected differentially by tectonic and magmatic events of both the Proterozoic and Phanerozoic that have brought about distinctive continental structure below them. The continental crustal structure below the centrally placed Kuppam-Palani transect, though well constrained by seismic profiling, may not still be extended to the whole of the SGT. The gravity models presented in this paper need to be further refined by incorporating seismic data, but may not, even then, portray the same picture as is obtained in the Kuppan-Palani transect. Thus it is suggested that the crustal structure below Kuppam-Palani transect corridor is not representative of the SGT as a whole. This aspect is particularly relevant when comparisons are made of the deep continental structure in the inter-cratonic blocks and across the continental boundaries, as for example, when modelling the continental reconstructions across the constituents of the Gondwanaland.

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References

- Bartlett, J.M., Harris, N.B.W., Hawkesworth, C.J., Santosh, M., 1995. New isotope constraints on the crustal evolution of South India and Pan-African granulite metamorphism. Mem. Geol. Soc. India 34, 391–397.
- Bhaskar Rao, Y.J., Janardhan, A.S., Kumar, T., Narayana, B.L., Dayal, A.M., Taylor, P.N., Chetty, T.R.K., 2003. Sm–Nd model ages and Rb–Sr isotropic systematics of charnockites and gneisses across the Cauvery shear zone of southern India: implications for the Archean–Neoproterozoic terrain boundary in the Southern Granulite Terrain. In: Ramakrishnan, M. (Ed.), In Tectonics of Southern Granulite Terrain: Kuppam–Palani Geotransect Geol. Soc. of India, Mem., vol. 50.
- Cenki, B., Braun, I., Broker, M., 2004. Evolution of the continental crust in the Pan-African mobile belt of southern most India: evidence from Nd isotope mapping combined with U–Pb and Rb–Sr geochronology. Precambrian Res. 134, 1–20.
- Chetty, T.R.K., Bhaskar Rao, Y.J., Narayana, B.L., 2003. A structural crosssection along Krishnagiri–Palani corridor, Southern Granulite Terrain of India. Mem. Geol. Soc. India 50, 255–277.
- Drury, S.A., Holt, R.W., 1980. The tectonic framework of the South Indian craton: a reconnaissance involving LANDSAT imagery. Tectonophysics 65, T1–T15.

- Fermor, L.L., 1936. An attempt at the correlation of the ancient schistose formations of Peninsular India. Mem. Geol. Surv. India 70, 1–52.
- Fountain, D.M., Salisbury, M.H., 1981. Exposed cross-sections through the continental crust; implications for crustal structure, petrology and evolution. Earth Planet. Sci. Lett. 56, 263–277.
- Gopalakrishnan, K., 1996. An overview of Southern Granulite Terrain, India constraints in reconstruction of Precambrian assembly of Gondwanaland. Gondwana Nine, vol. 2. Oxford and IBH, New Delhi, pp. 1003–1026.
- GSI (Geological Survey of India), 1995. Geological and Mineral Map of Kerala and Tamilnadu.
- Harikumar, P., Rajaram, M., Balakrishnan, T.S., 2000. Aeromagnetic study of Peninsular India. Proc. Indian Acad. Sci., A Earth Planet. Sci. 109 (3), 381–391.
- Harris, N.B.W., Santosh, M., Taylor, P.N., 1994. Crustal evolution in South India: constraints from Nd isotopes. J. Geol. 102, 139–150.
- Jayananda, M., Peucat, J.J., 1996. Geochronological framework of southern India. Gondwana Res., Mem. 3, 53–75.
- Jayananda, M., Janardhan, A.S., Sivasubramanian, P., Peucat, J.J., 1995. Geochronologic and isotopic constraints on granulite formation in the Kodaikanal area, southern India. Mem. Geol. Soc. India 34, 373–390.
- Karunakaran, C., Mahadevan, T.M., 1971. Some aspects of the seismicity of peninsular shield. Indian J. Power River Val. Dev. 15–24 (Sp.number Proc Symp. Koyna earthquake and related).
- Mahadevan, T.M., 1964. The charnockites and related gneiss in parts of the western ghats in Trichur district, Kerala. XXII International Geological Congress India, Proceedings of section X, Archaean and Pre-Cambrain Geology, 482–491.
- Mahadevan, T.M., 1998. A unitary model of evolution of the Precambrian Indian shield. Inter. Sympo. on charnockite and granulite facies rocks. Geol. Asson. Tamil Nadu, 153–174.
- Mahadevan, T.M., 2003a. Geological Evolution of South Indian shield constraints on modelling. Mem. Geol. Soc. India 50, 25–46.
- Mahadevan, T.M., 2003b. Kuppam–Palani transect programme and new insights into continental evolution. Mem. Geol. Soc. India 53, 99–114.
- Nair, M.M., Vidhyadharan, K.T., Pawar, S.D., Sukumaran, P.V., Murthy Y.G.K., 1976. The structural and stratigraphic relationship of the schistose rocks and associated igneous rocks of the Tellicherry–Manantoddy area, Cannanore district, Kerala India Mineral, 16, 89–100.
- NGRI, 1978. Isostatic Gravity Anomaly Map of India. National Geophysical Research Institute, Hyderabad.
- Radhakrishna, B.P., 1989. Suspect tectono-stratigraphic terrane elements in the Indian subcontinent. J. Geol. Soc. India 34, 1–24.
- Radhakrishna, T., Dallmeyer, R.D., Mathew, J., 1994. Paleomagnetism and ³⁸Ar/⁴⁰Ar vs. ³⁹Ar⁴⁰Ar isotope correlation ages of dyke swarms in central Kerala, India: tectonic implications. Earth Planet. Sci. Lett. 121, 213–226.
- Radhakrishna, T., Poomachandra Rao, G.V.S., Mitchell, J.G., Venkatesh, A.V., 1986. Proterozoic basic dyke activity in Kerala along the western continental margin of India. J. Geol. Soc. India 27, 245–253.
- Radhakrishna, M., Kurian, P.J., Nambiar, C.G., Murty, B.V.S., 2003. Nature of the crust below the Southern Granulite Terrain (SGT) of Peninsular India across the Bavali shear zone based on analysis of gravity data. Precambrian Res. 124, 21–40.
- Raith, M., Rasse, P., Ackermand, D., Lal, R.K., 1983. Regional geothermobarometry in the granulite facies terrain of South India. Trans. R. Soc. Edinb. Earth Sci. 73, 221–224.
- Rajaram, M., Anand, S.P., 2003. Crustal structure of South India from aeromagnetic data. Journal of the Virtual Explorer 12, 72–82.
- Ramachandran, C., 1992. P-wave velocity in granulites from South India: implications for the continental crust. Geophysics 201, 187–198.
- Reddy, P.R., Rajendra Prasad, B., Vijaya Rao, V., Sain, Kalachand, Prasada Rao, P., Khare, Prakash, Reddy, M.S., 2003. Deep seismic reflection and refraction/wide-angle reflection studies along Kuppam–Palani transect in the Southern Granulite Terrain of India. Mem. Geol. Soc. India 50, 79–106.
- Santosh, M., 1989. Alkaline plutons, decompression granulites and late Proterozoic CO2 influx in Kerala, South India. Mem. Geol. Soc. India 15, 177–188.
- Santosh, M., Iyer, Vasconcellos, M.B.A., Enzweiler, J., 1989. Late Precambrian alkaline plutons in southwest India: geochronologic and rare earth element constraints on Pan-African magmatism. Lithos 24, 6S–79S.

- Santosh, M., Yokoyama, K., Biju Sekhar, S., Rogers, J.J.W., 2003. Multiple tectonothermal events in the granulite blocks of southern India revealed from EPMA dating: implications on the history of super continents. Gondwana Res. 6 (1), 29–63.
- Singh, A.P., Mishra, D.C., Vijaya Kumar, V., Vyaghreswara Rao, M.B.S., 2003. Gravity-magnetic signatures and crustal architecture along Kuppam–Palani geotransect, South India. In: Ramakrishnan, M. (Ed.), Tectonics of Southern Granulite Terrain: Kuppam–Palani Geotransect. Geol. Soc. of India, Mem., vol. 50.
- Swaminath, J., Ramakrishnan, M., Viswanatha, M.N., 1976. Dharwar stratigraphic model and Karnataka craton evolution. Rec. Geol. Surv. India 107, 149–175.
- Webring, M., 1985. Semi-automatic Marquardt inversion of gravity and magnetic profiles. U.S. Geological Survey Open-file Report OF-122.