Missing Granitic Crust (?) in the Godavari Graben of Southeastern India

O. P PANDEY and V K RAO*
National Geophysical Research Institute Uppal Road Hyderabad – 500 007
*Email: vijay_k_rao@ngri res in

Abstract: Detailed analysis of seismic signatures of the Godavari graben together with available geological and geophysical informations suggests that the granitic crust, especially in the axial part of the graben, may be altogether missing There is a possibility that Gondwana sediments rest directly over the granulitic basement

Keywords: Seismic signatures, Basement relationships, Godavari graben, Southeastern India

In a global tectonic context, the Indian shield is unique and differs considerably from other stable areas of the earth (Rogers and Callahan, 1987, Naqvi and Rogers, 1987, Pandey and Agrawal, 1999) It contains a number of Archaean – early Proterozoic cratons composed of diversified geological units These cratonic blocks are separated by sutures, shears, mega lineaments and rift valleys Godavari graben, situated in southeastern part of the Indian shield is one such prominent feature sandwiched between Bastar craton in the north and Dharwar craton in the south (Fig 1) It is basically a narrow and long intracratonic basin, situated between lat 17-20° N and long 79-82° E It is roughly about 400 km in length and about 50 km in width, containing 3 to 4 km thick Gondwana sediments of Permian–Cretaceous age This graben is bifurcated by Bhadrachalam ridge into two major parts, i e Pranhita-Godavari basin in the north and Chintalpudi sub-basin in the south (Fig 1)

To delineate the deep structure of this graben, two Deep Seismic Sounding (DSS) profiles (Kallur-Polavaram and Polancha-Narsapur) were shot during 1985-86, across the Chintalpudi sub-basin situated in the southern part of the graben (Kaila et al 1990) In this study, wide angle seismic method was used which provided very precise velocity-depth information, as it utilised refraction velocities for constraining reflected bands in the seismogram, however it did not attempt to establish compositional aspects of the basement in the graben One of the two profiles, Kallur – Polavaram, which is about 100 km in length (shown as K-P in Fig 1) runs across the Chintalpudi sub-basin Two dimensional velocity modelling of the upper crust in this basin indicates presence of a major interface at shallow depth of about 3 5 km, where velocity increases from 5 4- 5 5 km/s to 6 2-6 4 km/s (Kaila et al 1990) This interface coincides with an up warped domal structure which runs across Godavari graben

To delineate more precisely the detailed shallow velocity structure in Godavari graben, in view of the granulitic occurrences on both sides (Rajesham et al 1993, Ramakrishnan, 2003), an inversion approach was also attempted to model velocity-depth function as velocities obtained by forward modelling are often not unique For this, we used Tau-P inversion method (Bessonova et al 1974, Kennet, 1976) to reanalyze seismic refraction data recorded along this profile (Kaila et al 1990) This method uses the concept of delay times In this technique, the first arrival refraction data is inverted into a velocity depth function, which provide maximum allowable depth bounds for a particular velocity in z-direction Detailed method of inversion procedure can be found in Rao (2002) The computed one-dimensional estimates of velocity-depth function to a depth of 10 km are shown in Fig 2 for shot points a,b,c,d and e which are in good agreement with the 2-D velocity model of the same region (Kaila et al 1990) Composite seismic crustal section up to the Moho depth is also shown in Fig 3

As can be seen from Fig 1, shot points a and e lie outside the Godavari graben, sitting respectively over Archean terrain and Khondalites of Eastern Ghat Mobile belt (EGMB), while the other shot points are within the graben From Fig 2, it would appear that beneath all the shot points, seismic velocities reach as high as 6 0 km/s at

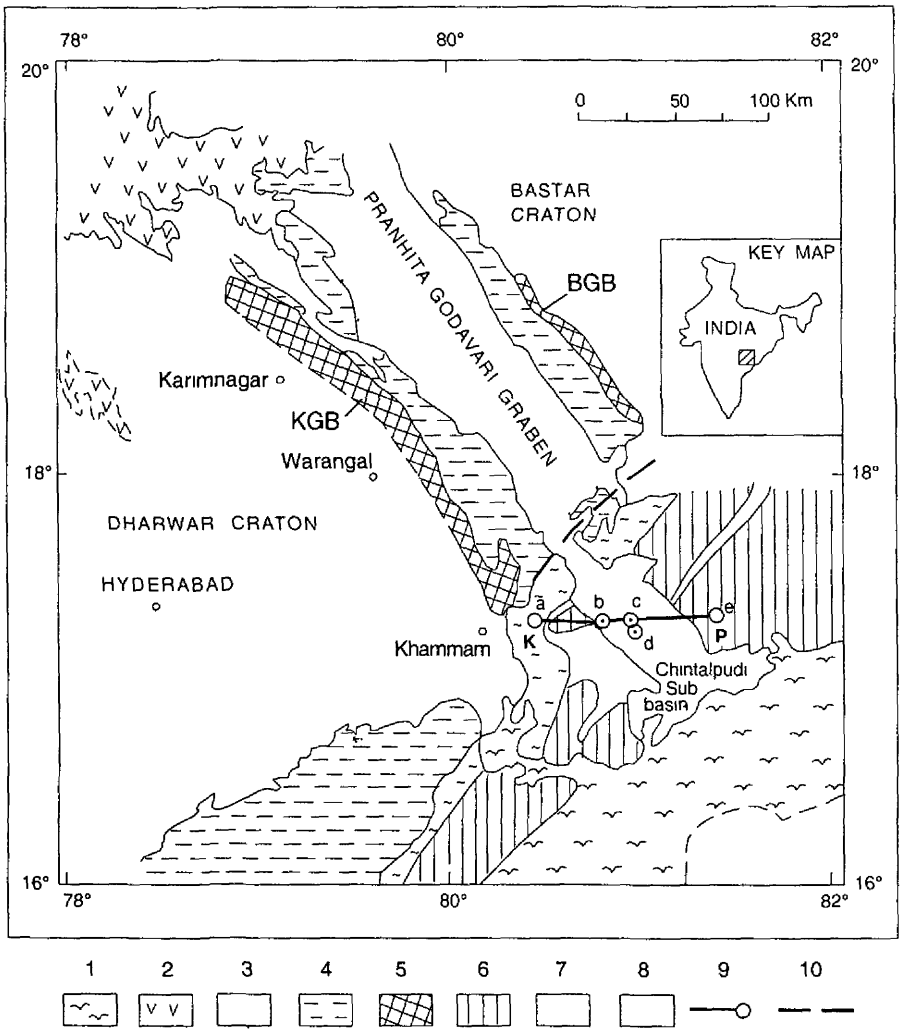

Fig.1. Geology around Pranhita- Godavari and Chintalpudi sub-basin (adopted from Rajesham et al 1993) **1**- Recent cover, **2** - Deccan Traps, **3** - Gondwana Formations, **4** - Proterozoic supracrustal belts, **5** - Karimnagar Granulite Belt (KGB) and Bhopalpattanam Granulite Belt (BGB), **6** - Eastern Ghat Mobile Belt, **7** - Nellore supracrustal belt, **8** Unclassified Peninsular gneisses, **9** - Kallur-Polavaram (K-P) DSS profile where a-e are the shot points, **10** - Bhadrachalam Ridge

shallow depths Inferred velocities are much higher inside the graben (shot points b,c and d) compared to outside region (a and e) In fact a broad domal upwarped region as revealed by Fig 3 conspicuously coincides with a broad gravity low (Mishra et al 1987) along the axis of the graben In this upwarped region, P-wave velocities are as high as 6 3 km/s at the intrabasement level of about 3 km only, which rises consistently to 6 9 km/s at the base of the crust lying at 41-43 km In comparison to this, the estimated upper crystalline (granitic–gneissic) crustal velocity is only of the order of 5 3-5 6 km/s in the adjacent region (Kaila et al 1990)

This would mean that in all likelihood, granitic crust in the Chintalpudi sub-basin is altogether missing in the central part of the graben coinciding with the domal upwarp where the Gondwana sediments appear to lie directly over the granulite facies of rocks, as measured intrabasement velocity of 6 3 km/s cannot correspond to either sedimentary section or a granitic-gneissic crust A detailed DSS work in the Southern Granulite Terrain (SGT) of southernmost India (Reddy et al 2003) has revealed that P-wave velocity in the upper crustal granulites are of the order of 6 1 to 6 3 km/s only Our conjecture would be well supported when we plot P-wave crustal velocity, as observed in Godavari graben, against to that obtained in SGT (Fig 4) A close look at this figure would reveal unambiguously that starting from the intrabasement depth to about 30 km depth, measured velocities in the Chintalpudi sub-basin of the Godavari graben are higher than observed in the Southern Granulitic Terrain (SGT) It can thus be inferred that the upper and middle crustal rocks

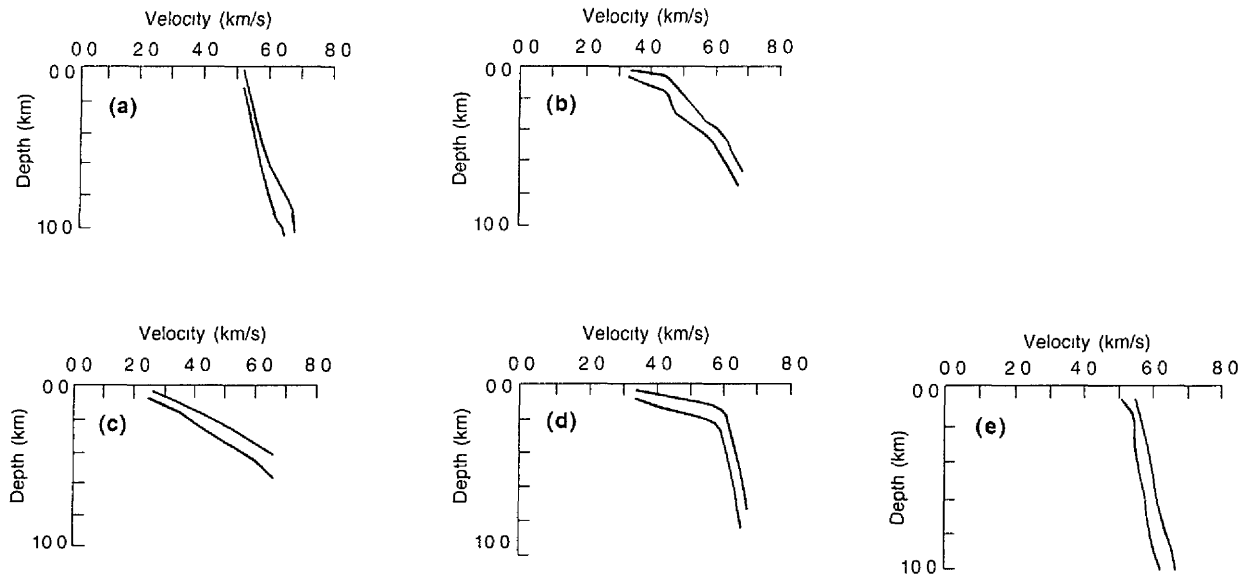

Fig.2. Velocity -depth models with upper and lower bounds of depth for any particular velocity for the shot points a, b,c,d, and e of Kallur-Polavaram profile High velocities at shallower depths are seen in the graben part (b,c and d) as compared to outside region of the graben (a and e)

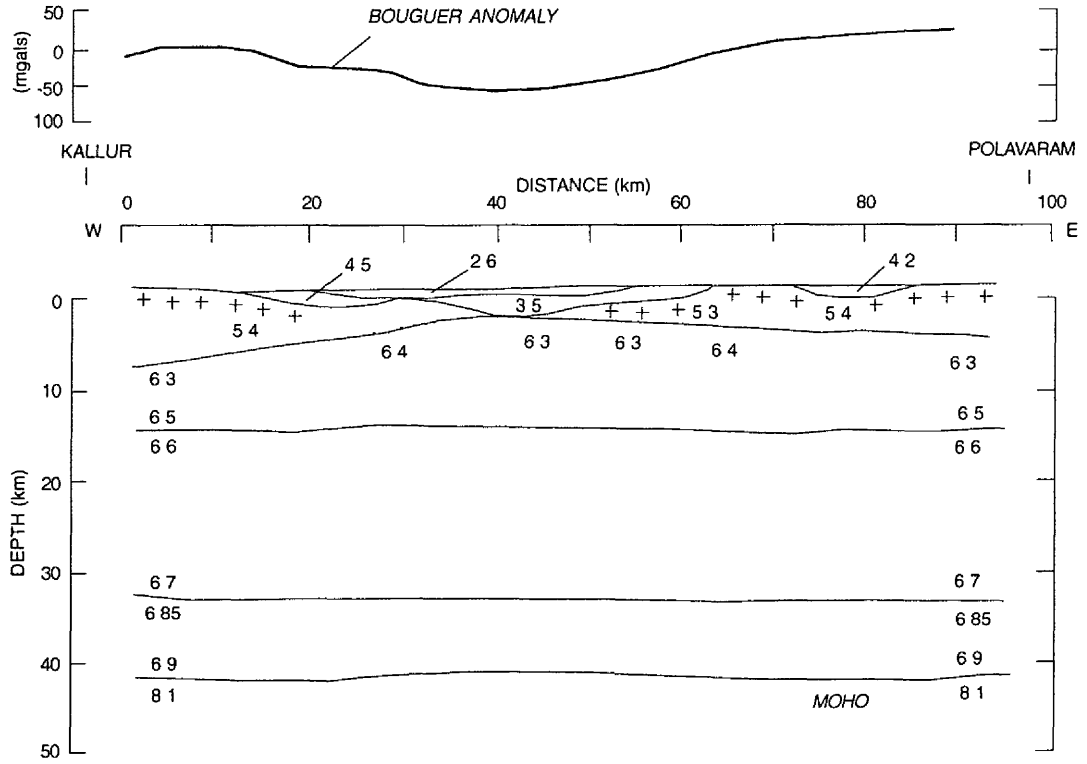

Fig.3. Crustal structure along Kallur-Polavaram (K-P) DSS profile P- wave velocities are in km/s The seismic boundaries are drawn from 2-D modelling of reflection data in which shallow section is largely derived from refraction data The large dots on intracrustal boundary are derived from 2-d modelling of reflection data + + + denotes crystalline basement (*after* Kaila et al 1990)

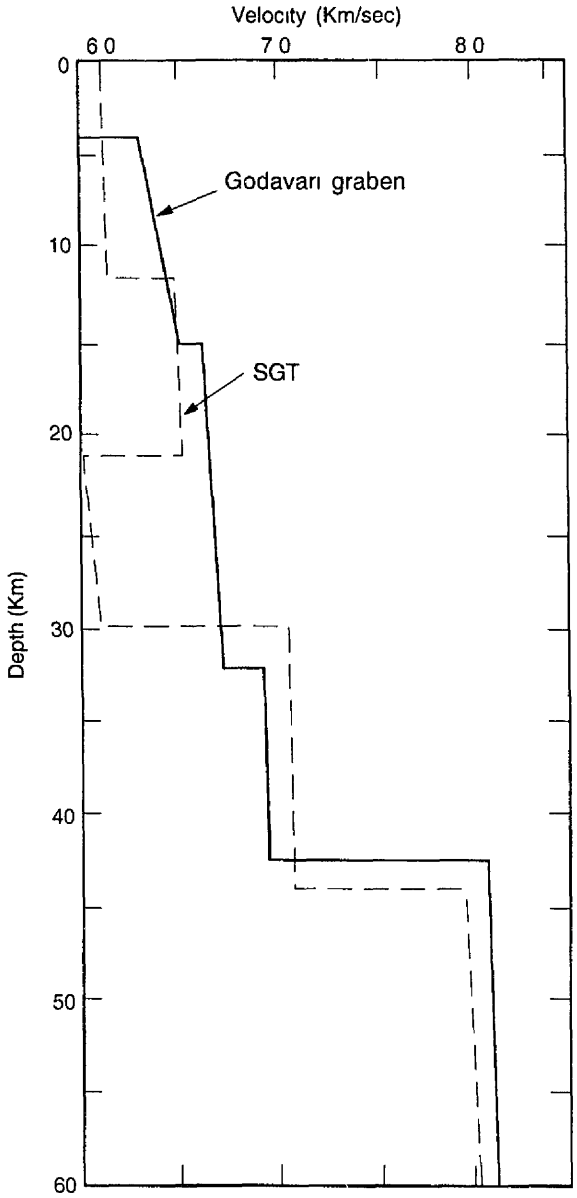

Fig.4. Comparison of Velocity-Depth relationship between Godavari graben (Kaila et al 1990) and Southern Granulite Terrain (Reddy et al 2003)

in this part of the graben are more mafic than the granulitic rocks exposed in SGT, but there could still be a thin crystalline basement left at some places in the graben However, they are certainly missing as a basement rock in the Chintalpudi sub-basin For example, an inlier of granite–gneiss is reported (Lakshminarayana and Murti, 1990) at the contact between the lower and upper Gondwana formation in the area northeast of Sattupally (close to Shot point b, Fig 1) which is situated over the fringe of graben

Quite likely, the granitic crust may possibly be almost missing from the entire Godavari graben, specially in the axial part, as regional gravity pattern would suggest It is a well-known fact that all along the basinal part of the Godavari graben (including Chintalpudi sub-basin), gravity is prominently low which is bounded on either side by gravity highs (Mishra et al 1987) Such gravity highs could very well correspond mid-Proterozoic Purana sediments and recently discovered mid to early Proterozoic Karimnagar (KGB) and Bhopalpatnam (BGB) granulitic belt (Rajesham et al 1993, Ramakrishnan, 2003), which bound the Pranhita-Godavari basin on both the sides (Fig 1) Both the granulitic belts are about 20-40 km in width and 150-300 km in length (Santosh et al 2004) It is then, but natural, to expect that such granulitic belt would also form the basement in the Pranhita-Godavari basin Since the Godavari graben is a known extensional feature, exhumation of granulitic crust to shallow depths is understandable (Gibson and Ireland, 1995 and references therein)

Above inference is not surprising as granitic crust has become quite thin (less than a km to ~8 km thick) in many segments of Eastern Dharwar craton due to several tectonothermal episodes and consequent uplift and erosion (Pandey et al 2002, Agrawal and Pandey, 2004, Catherine and Pandey, 2005, Reddy et al 2004, Singh et al 2004 etc) Similar situation prevails elsewhere in the Indian crust also as indicated by the current geological and geophysical knowledge Does this means that a major part of the Indian crust is granulitic at shallow depth? The answer may possibly be yes, however, more detailed geological and geophysical studies are still needed to confirm this

Acknowledgements The authors are extremely thankful to the anonymous reviewer for his constructive suggestions and to the Director, NGRI for permitting to publish this work

References

Agrawal, P K and Pandey, O P (2004) Unusual lithsopheric structure and evolutionary pattern of the cratonic segments of the South Indian Shield, Earth Planets Space, v 56, pp 139-150

Bessonova, E N , Fishman, V M , Ryabov, V Z and Sitmokova, G A (1974) The tau method for the inversion of travel time-1 Deep seismic sounding data Geophy Jour Astron Soc v 36, pp 377-398

Catherine, J K and Pandey, O P (2005) Differential uplift between Hyderabad and Banglore geotectonic block of

Eastern Dharwar craton (south India) Jour Geol Soc India, v 65, pp 493-496

GIBSON, G M and IRELAND, T R (1995) Granulite formation during continental extension in Fiordland, New Zealand Nature, v 375, pp 479-482

KAILA, K L, MURTY, P R K, RAO, V K and VENKATESWARLU, N (1990) Deep seismic sounding in the Godavari graben and Godavari (coastal) Basin, India Tectonophysics, v 173, pp 307-317

KENNET, B L N (1976) A comparison of travel time inversions Geophys Jour Astron Soc, v 44, pp 517-536

LAKSHMINARAYANA, G and MURTI, K S (1990) Stratigraphy of the Gondwana formations in the Chintalapudi sub-basin, Godavari valley, Andhra Pradesh Jour Geol Soc India, v 36, pp 13-25

MISHRA, D C, GUPTA, S B, RAO, M B S V, VENKATRAYUDU, M and LAXMAN, G (1987) Godavari basin - A geophysical study Jour Geol Soc India, v 30(6), pp 469-476

NAQVI, S M and ROGERS, J J W (1987) The Precambrian Geology of India Oxford University Press, New York, 223p

PANDEY, O P and AGRAWAL, P K (1999) Lithospheric mantle deformation beneath the Indian cratons Jour Geol, v 107, pp 683-692

PANDEY, O P, AGRAWAL, P K and CHETTY, T R K (2002) Unusual lithospheric structure beneath the Hyderabad granitic region, eastern Dharwar craton, south India Phys Earth Planet Inter, v 130, pp 59-69

RAJESHAM, T, BHASKARA RAO, Y J and MURTI, K S (1993) The Karimnagar granulite terrane - a new sapphirine-bearing granulite province, south India Jour Geol Soc India, v 41, pp 51-59

RAMAKRISHNAN, M. (2003) Craton-Mobile belt relations in southern granulite terrain Mem Geol Soc India, v 50, pp 1-24

RAO, V K (2002) Crustal studies and evolution of Godavari graben (Chintalpudi sub-basin) and Krishna-Godavari basin – An integrated approach Ph D Thesis (unpublished), Osmania University, Hyderabad

REDDY, P R, RAJENDRA PRASAD, B, VIJAYA RAO, V, SAIN, K, PRASADA RAO, P, KHARE, P and 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, v 50, pp 79-106

REDDY, P R, CHANDRAKALA, K, PRASAD, A S S S R S and RAMA RAO, CH (2004) Lateral and vertical crustal velocity and density variations in the southwestern Cuddapah basin and adjoining Eastern Dharwar Craton Curr Sci, v 87, pp 1607-1614

ROGERS, J J W and CALLAHAN, E J (1987) Radioactivity, heat flow and rifting of the Indian continental crust Jour Geol, v 95, pp 829-836

SANTOSH, M, YOKOYAMA, K and ACHARYYA, S K (2004) Geochronology and tectonic evolution of Karimnagar and Bhopalpatnam granulite belts, Central India Gondwana Res, v 7, pp 501-518

SINGH, A P, VIJAYA KUMAR, V and MISHRA, D C (2004) Subsurface geometry of Hyderabad granite pluton from gravity and magnetic anomaly and its role in the seismicity around Hyderabad Curr Sci, v 86, pp 550-556

(Received 23 August 2004, Revised form accepted 5 September 2005)