JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.81, April 2013, pp.459-471

Neotectonic Response of the Godavari and Kaddam Rivers in Andhra Pradesh, India: Implications to Quaternary Reactivation of Old Fracture System

S. J. SANGODE[1], D. C. MESHRAM[1], Y. R. KULKARNI[1], S. S. GUDADHE[1],
D. B. MALPE[2] and M. A. HERLEKAR[1]
[1]Department of Geology, University of Pune, Pune - 411 007
[2]Department of Geology, R.T.M. Nagpur University, Nagpur - 441 001
Email: sangode@unipune.ac.in; sangode@rediffmail.com

Abstract: A field and imagery based study at the eastern margin of the Deccan Volcanic Province (DVP), and in the Precambrian terrain of Adilabad and Karimnagar districts of Andhra Pradesh, India display a striking response of the Godavari and Kaddam rivers to Kaddam lineament-fault fracture (KLF) system. Brittle to ductile deformations within the Precambrian formations indicate its antiquity, while the continuity of Kaddam lineament over DVP suggests its Tertiary reactivation. The morpho-tectonic response of the Godavari and Kaddam rivers in this area depict southward tilt of the fault block west of Kaddam fault during Quaternary. In the given set-up we postulate a greater role of crustal loading of the Deccan traps, and its rapid erosional unloading during Late Cenozoic intensified monsoon conditions as one of the causative factors for the above neotectonic response demanding further detailed work on the KLF and elsewhere in the peripheral regions of DVP encountered by active faults and old fractures.

Keywords: Kaddam fault, Neotectonics, Godavari and Kaddam rivers, Deccan Volcanic Province.

INTRODUCTION

Trending N126°-306°, the ~300 km long Kaddam mega lineament extending Kaddam fault in the Central Indian region at the junction of the crustal scale structures of Godavari Graben, Dharwar Craton and the Deccan trap's easternmost margin appears to have greatly controlled the course of Godavari and Kaddam rivers (Figs. 1 and 2). The Kaddam lineament along with its conjugate fracture system appears to have deflected the Godavari river into four sharp unidirectionaly rectilinear bends finally joining the linear and fault controlled trend of the Kaddam river along Kaddam fault (Fig. 2). The Kaddam mega-lineament is traceable (over imageries) into Deccan province up to the intersection of Tapi and Purna faults (Fig. 2). Our geomorphic observations of channel migration, sharp knee bends of the river course, tilted terraces and bedrock exposed channel beds indicate its Quaternary reactivation. An account of the geological observations further suggested its multi-phase tectonic reactivations since Precambrian. The NW extension of the Kaddam lineament abutting with the seismically active zone of Purna fault and the Bhadrachalam seismic zone in the SW further suggests its possible active tectonic role needing more detailed investigation on seismotectonic aspects. This paper reports the neotectonic response of the Godavari and Kaddam rivers and the tilt of the west block of Kaddam fault proposing a role of erosional unloading of Deccan traps as one of the reasons for the resulting morpho-tectonic configuration of the two rivers in this area.

METHODS

The present study is based on field observations along with profile mapping aided by SOI topo sheets and the study of Google Earth images. Areas around Nirmal, Adilabad, Sattanpalli, Khanapur, Bellala, Kaddam, Jannaram, Luxetipet, Jagtiyal, Jaina, Dharmapuri, Mancherial, Godavarikhani, Ramagundam, Peddapalli, Manthani, Sironcha and Kaleswaram in Andhra Pradesh and Maharashtra are elaborately traversed with these aspects during three field seasons from 2008 to 2010. Basement lithology and broad structural trends were noted with more detailed observations on river profile geometry, terrace thicknesses, clast composition and imbrications over the

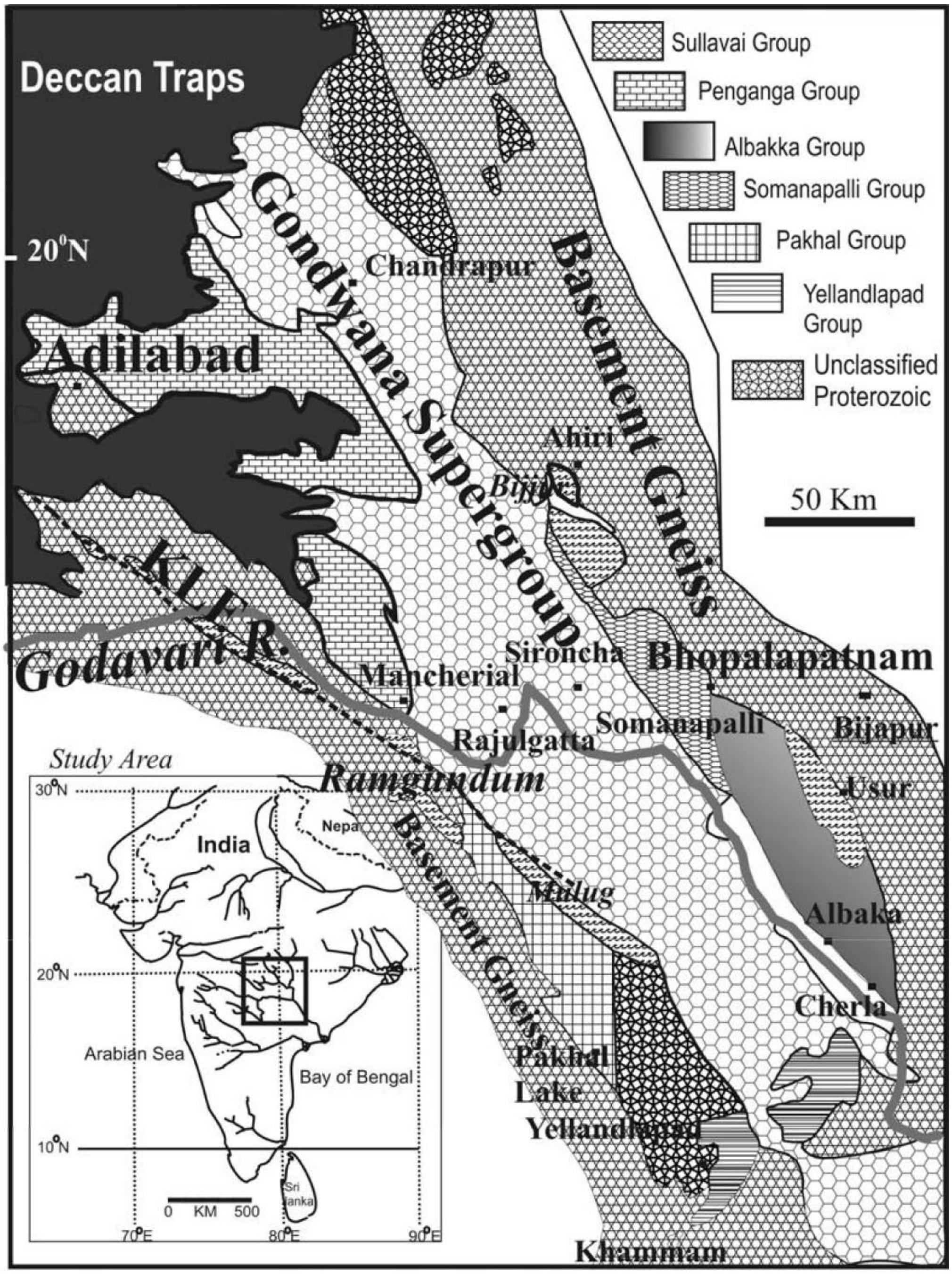

Fig.1. Geological map of the study area (after Saha and Chaudhari 2003) showing the regional attributes of the Godavari Graben in a prominent NW-SE trend and the location of the Kaddam lineament/fault fracture system as explained in text.

entire region. Based on the field studies we divided the entire area into five blocks (A-E) as shown in Fig.2, and the Kaddam fault/lineament divides the entire area into western and eastern blocks.

GEOLOGICAL SET-UP

The Peninsular India represents a multi-cratonic assembly of the Precambrian crustal blocks of varied lithology, style of tectonics and evolutionary trends (Naqvi and Rogers, 1987; Santosh et al. 2003; Naqvi, 2005; Collins and Pisarevski, 2005; Rogers and Santosh, 2005; Valdiya, 2010). The Central Indian region comprises of important geotectonic units of cratonic margins, shear zones, rift basins, mobile belts besides the modern (eroded) margins of the Deccan trap (*op. cit*). The Godavari graben represents a

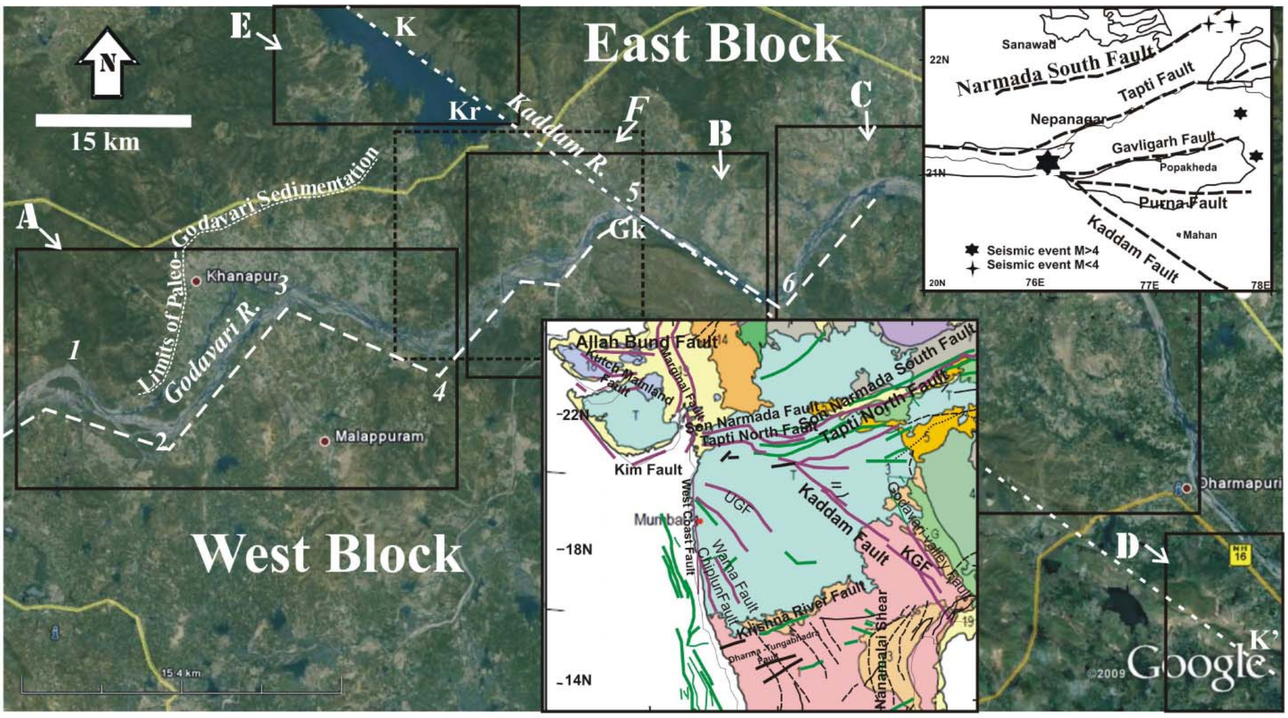

Fig.2. The Google image of the study area showing the KLF system. The blocks (A-F) mark the study domains described in text. The inset of right top corner shows the tectonic configuration of the northern extent of the KLF while the inset in the central part is the seismotectonic map overlained on the general geological map (both from the GSI Atlas).

major structural trend in the study area, and the Kaddam fault being sub-parallel to it.

The Godavari Graben

The rift like block faulting trending NW-SE, in the central and southeastern Peninsular region, attested by several geological and geophysical observations has been unanimously termed as 'Godavari Graben'. A four to five stage rift-basin development has been suggested by many workers proposing its antiquity to the pre-Rhodinian assembly (Chakraborty and Choudhari, 1993; Saha and Choudhary, 2003; Choudhari and Deb, 2004). This rift basin is the site of deposition of the Upper Carboniferous to Jurassic Gondwana sediments over Middle to Late Proterozoic Pakhal, Albaka and Sullavai formations (Chaudhari and Howard, 1985; Chaudhari and Chanda, 1991; Patranabis Deb and Chaudhari 2001; Patranabis Deb, 2001; Chaudhari et al. 1989, 1999, 2003). The Gondwana sediments of the Godavari valley are thus linearly disposed in a general NW-SE direction, with northeasterly dips, over a length of 450 km and average width of 50 km (Saha and Ghosh, 1997; Deb, 2000; Deb, 2003; Chaudhari, 2003). Archean granites and gneisses form the basement to western and eastern Proterozoic belts in the area, respectively (Naqvi and Rogers, 1987; Rajesham et al. 1993; Ramam and Murthy, 1997). Towards the extreme northwestern part in the study area, all the older rocks are covered by Deccan traps.

The Godavari graben forms the most conspicuous tectonic margin (TB3 in Veeraswamy and Rawal, 2005) of the Greater Dharwar terrain and consists of Karimnagar granulite belt and pronounced by its traverse from the Bhadrachalam earthquake region. Various deep crustal attributes including the asymmetric nature of the Godavari graben has been described by geophysical anomalies of gravity, magnetic, magnetotelluric and DSS profiles (Mishra et al. 1999; Gokarn et al. 2001; Sarma and Krishna Rao, 2005; Chakravarti et al. 2007; Naganjaneyulu et al. 2010). Sarma and Krishna Rao (2005) and Mishra et al. (1999) inferred that the contact between Gondwana sediments and the northeastern Proterozoic sediments is a steep fault, described as master fault. The heat flow characteristics in the Godavari valley area show higher values than the adjacent cratons (Rao et al. 1976; Rao and Rao, 1983; Rogers and Elaine, 1987; Ravi Shanker et al. 1991; Ramana et al. 2003). Seismicity in the Godavari graben and its peripheral region is conformable with the Precambrian basement geometry (Mohan, 1981; Kaila et al. 1990; Rao, 2000; Murty, 2002; Roy, 2006; http://www.asc-india.org). In the western side of the Godavari main basin, some epicenters are clustered along a short NW-SE trending zone in Karimnagar area situated close to the western boundary of Godavari main basin (Mohan et al. 1981; Kaila et al. 1990; Rao, 2000; Murthy, 2002; Parvez et al. 2003). In the eastern side of Godavari valley, several epicenters occur along a broad NW-SE alignment in the Bhopalpatanam area extending towards SSE in the Eastern Ghat belt. This zone also partially coincides with the Bhopalpatanam granulite belt. A third cluster of epicenters occur in Manuguru-Kothagudem-Khammam belt, which coincides with the Mailaram-Yellandu-Khammam tectonised junction zones of the Dharwar craton. The Bouguer gravity data and Deep Seismic Soundings studies reveal an active compressional regime prevailed during Precambrian period (Sarma and Krishna Rao, 2005; Roy, 2006). There are evidences of the graben structure further extending towards northwest below the Deccan Traps and towards southeast under the coastal sediments and possibly beyond the coast (Kaila et al. 1990; Biswas, 1999; Mishra et al. 1999; Gokarn et al. 2001; Murthy, 2002; Rajaram and Anand, 2003; Chakravarti et al. 2007). However, the relation of Kaddam fault with Godavari graben is not ascertained in the literature and, therefore, needs a detailed investigation.

MORPHOTECTONIC OBSERVATIONS RELATED TO KADDAM LINEAMENT FAULT-FRACTURE SYSTEM (KLF)

The Kaddam lineament (with conjugate fracture system) can be traced over general imagery like Google earth due to prominent tectonically controlled trends of the Godavari and Kaddam rivers in this area (Fig. 2). The Kaddam lineament (KL) is oriented N126^{o}-306^{o} and makes an angle of 14^{o} anticlockwise to the Pranhita-Godavari (PG) mega-lineament related to the Godavari graben. The relationship between the KL and PG mega-lineaments cannot be ascertained due to absence of sub-surface data across these faults. In northern extension the KL abuts with seismically active zone of E-W trending Tapi, Purna and Gavilgarh faults (Naganjaneyulu, 2010 and Fig. 2). The recent seismic activity in the area is indicated by the Satpura earthquake (Mw 6.2), which occurred on 14th March 1938 (Rao, 2000). In the south the KL can be intermittently extended (combined with the Kinnerasani-Godavari fault/KGF in Fig.2) up to Bhadrachalam representing another important seismic zone (1969 Bhadrachalam earthquake, Rao, 2000). Geological Survey of India in their seismo-tectonic atlas (2000) has further indicated the Kaddam as neotectonic fault (Fig. 2, inset seismotectonic map of GSI). We, therefore, consider the observable surface limits of the Kaddam lineament/fault to these two end points (i.e., Tapi in the north and Bhadrachalam in the south).

The study area can be divided into western and eastern blocks obliquely by the NW-SE trending Kaddam fault/ lineament (KK' in Fig. 2). Overall the eastern block is elevated and shows generally west-sloping positive surfaces and the west block is mostly erosional with few hillocks sharply aligned in the trend of Kaddam fault. The basement granite complex comprises of granite-gneisses, migmatites, basic dykes, and few banded magnetite quartzites. The extensive granite-gneisses of the country rock shows a variation from pink to grey color, generally coarse grained, foliated to unfoliated, and contains meta-sedimentary xenoliths at places. Kumar et al. (2008) characterized the granites in the study area as 'two-mica granite' comprising of both muscovite and biotite; and predominantly composed of potash feldspar, quartz and albite-oligoclase. The Kaddam fault zone as exposed in the Kaddam river, also displays intense ductile deformation (described later).

The Kaddam fault in the field, near the Kaddam dam predominantly shows sharp, deep and narrow furrow like, single long open fracture along the left bank of the Kaddam and Godavari rivers (after joining Kaddam, see Fig. 3a and block B in Fig. 2). In the rest of the area, the Kaddam fault continues as lineament with its NW and SE extensions (as described above) but without any major sub-surface expressions in the field (as in Kaddam fault near the dam). The displacement of outcrops along Kaddam fault depict strike slip motion with clear sense of shear visible by disruption of dykes and folding of the Precambrian and Palaeozoic rocks (Fig.3). The deformed dykes (by strike slip motion) within the basement granites in the west block (Fig. 3b), folding in the Chanda limestone north of the Kaddam dam in the east block (Fig. 3c) as well as the axis of the superposed folding in the east block (Fig. 3d-f) indicates multistage dextral- dominating over sinistral movements. Exactly near the dam wall, the east block margin shows intense doubly plunging complex folding with superposed folding perpendicular to it within granite and dykes (See Fig. 3d-3f). The axial planes for majority of these folds at this location fall within N310° to N320° (i.e., parallel/sub parallel to the trend of Kaddam fault) with the superimposed folds showing N40° to N50^{o} axial trends. This suggests that the E-W early compression regime is followed by NE-SW compression resulting from the strike-slip movement along the Kaddam fault. The ductile nature of deformation in granites and dykes indicates elevated thermal conditions during the movement. This paper is short of any further detailed work on structural analysis and is more focused on the geomorphological aspects. These structures

Fig.3. **(A)** Panoramic view of the Kaddam fault through which the Kaddam River flows. The narrow (~4-5m) deep furrow is filled with water, **(B)** The dykes in Precambrian granites showing disruption as strike slip motion with their sense of orientation in the direction of the Kaddam fault, **(C)** Northern part of the east block showing the open folds with their axes perpendicular to the Kaddam lineament, **(D)-(E)-(F)** Complex superposed folding at the exposures near the dam (described in text).

are, however, evident of multiphase tectonic regime in the Kaddam fault zone. More detailed investigation is essential to elaborate such deformation in detail. Immediate to this site of deformation in the east block, a dug well pit within Quaternary terraces shows complex cross-cut and high angle faults trending N 300° dipping NE (Fig. 4a). The terrace of this left bank of the Kaddam river is of tilted nature (Fig. 4b) depicting the Quaternary reactivation along the Kaddam fault, although, a detailed geometry of such neotectonic signatures needs to be worked out with extensive trenching in this area.

There is an average elevation difference of >50 m between the west and east blocks in this area (see Fig. 5) depicting either uplift of the east block or downthrow of west block. Further, from the DEM, the step-like deflections of the Godavari river, southward shift of the Godavari-

Fig.4. (A) A pit opened adjacent to the Kaddam fault in the east block showing the traces of fault plane in the Quaternary deposits, **(B)** Tilted terraces on the left bank of the Kaddam River.

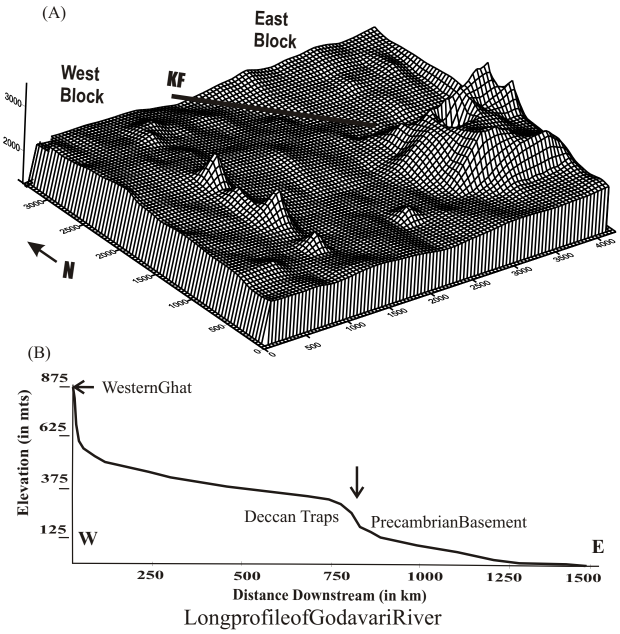

Fig.5. Digital elevation model demarcated by the block 'F' of Fig.2.

Kaddam confluence and other morphometric observations along Kaddam river indicates a general southward tilting of the west block. Morphometric observations along Kaddam river basin infer that the 2^{nd} order channels over Deccan traps are unaffected compared to that of the Pre- Deccan (Paleozoic and Precambrian) outcrops. The major 1^{st} order streams are greatly controlled by the trend of the Kaddam lineament (Fig. 6). Few other lineaments in the northern part of the Kaddam river basin makes acute angles with the Kaddam lineament and they truncate with the Kaddam lineament (Fig. 6). This suggests that the reactivation of the Kaddam lineament being the youngest in the Kaddam river basin.

The Godavari river in the west block shows sharp rectilinear deflections (Figs. 2 and 7). Further, the southern part (near Ramagundum) is expressed by composite (conjugate?) lineament system (Fig. 8) with their surface expressions by steep joint planes in the granitic terrain (Figs. 9a-b) as well as in the Precambrian sedimentary exposures (Figs. 9c-d). In the east block the basement granites show major jointing patterns as; (1) E-W trending, dipping 70° due S, (2) N-S trending, dipping W, and (3) NW-SE trending, dipping 60°-70° due NE. The prominent joint pattern in the pink granites after Luxetipet (west of Godavari in the east block) is NW-SE, dipping 65° due SW with other sympathetic trends of NW and westward dipping. Fresh rock surfaces are exposed along these NW-SE joint planes that are parallel - sub-parallel to the Kaddam Fault. It needs a detailed structural mapping in order to understand the relation of this conjugate joint-fracture system to the Kaddam main lineament. The above observations along with the topographic expressions, however, suggest the southern limit

Fig.6. The Google image showing the fracture pattern along which the drainage of Kaddam and its tributaries are aligned.

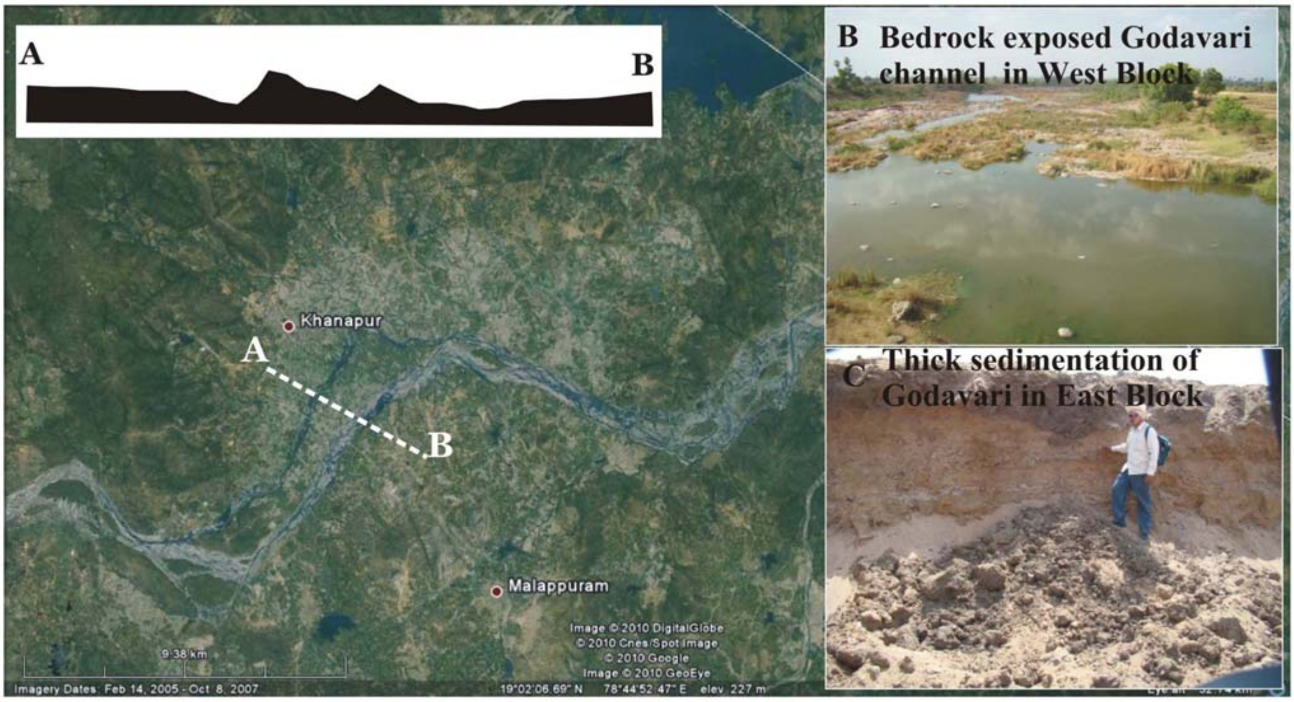

Fig.7. (A) A closer look at the drainage pattern of Godavari river where several cross profiles are studied. The inset 'B' shows the rocky channel bed which is common in the west block, while 'C' shows the thick channel sedimentation and the proportionately thick terraces in the east block of the Godavari river at Mancherial.

of the west block tilt marked by the rectilinear bends of the Godavari river ending with the complex jointing pattern near Ramagundum.

Fluvial Response of the Godavari and Kaddam Rivers

The sharp knee-bend like deflections of the Godavari river and the linear fault controlled trend of the Kaddam river are the key features representing the fluvial response in this region. Assuming a pre-deflection course, the Godavari river in this region can be directly subtended to the location of Kaddam reservoir lake (Kr in Figs. 2 and 8). The field observations from this probable pre-deflected course of the Godavari river show Quaternary alluvium with clast imbrication paleoflow suggesting the paleo-river course and, hence, the paleo-confluence of the Godavari with Kaddam river at the point Kr. Although the actual paleo-confluence area is submerged in the lake reservoir and the dam wall; the terraces from the point Kr (paleo-confluence) towards the modern confluence (Gk in Fig. 8) can be studied well. In the block B (Fig. 2) along the Kaddam river (before its confluence with Godavari river at Gk), we find the un-matched terraces (Figs. 9e-f). In this course the right bank of Kaddam river shows conglomeratic terraces with granitic clasts imbricating at high angle to the modern river coarse (Fig. 9f). Whereas, the left bank shows coarse sand with phreatic calcareous cemented beds (5-10 cm) tilting at 25° towards NE. The compaction, tilting, vegetation growth and soil formation for the left bank terrace of Kaddam river (e.g., Fig 4b) indicates its older age relative to the unconsolidated thick gravelly and conglomeratic terrace of the right bank. The immediate source terrain for the Kaddam river is entirely sedimentary (the Penganga Group) and is well represented by the clasts in the left bank. In contrast the right bank terrace of the Kaddam river comprises entirely of granitic clasts similar to the Godavari river alluvium. This suggests that the right bank is representing paleo-channels of Godavari river before its deflection southwards (or the modern confluence). The Godavari river appears to have systematically migrated southwards to its present position (Fig. 8). This entire area swept by Godavari river is represented by extensive alluvial terraces supporting the above observations.

The modern course of Godavari river in this sector (marked 1 to 5 in Fig. 8b) shows rocky (bedrock exposed) channels with few rare dissected mid-channel bar deposits suggesting the youthful occupation. On the other hand, it shows thick left bank terrace with extensive floodplains, which is misfit for this bedrock exposed channel. The rocky right bank aligns with the prominent fracture system (Figs. 2 and 8). The left bank terraces show dissected Quaternary

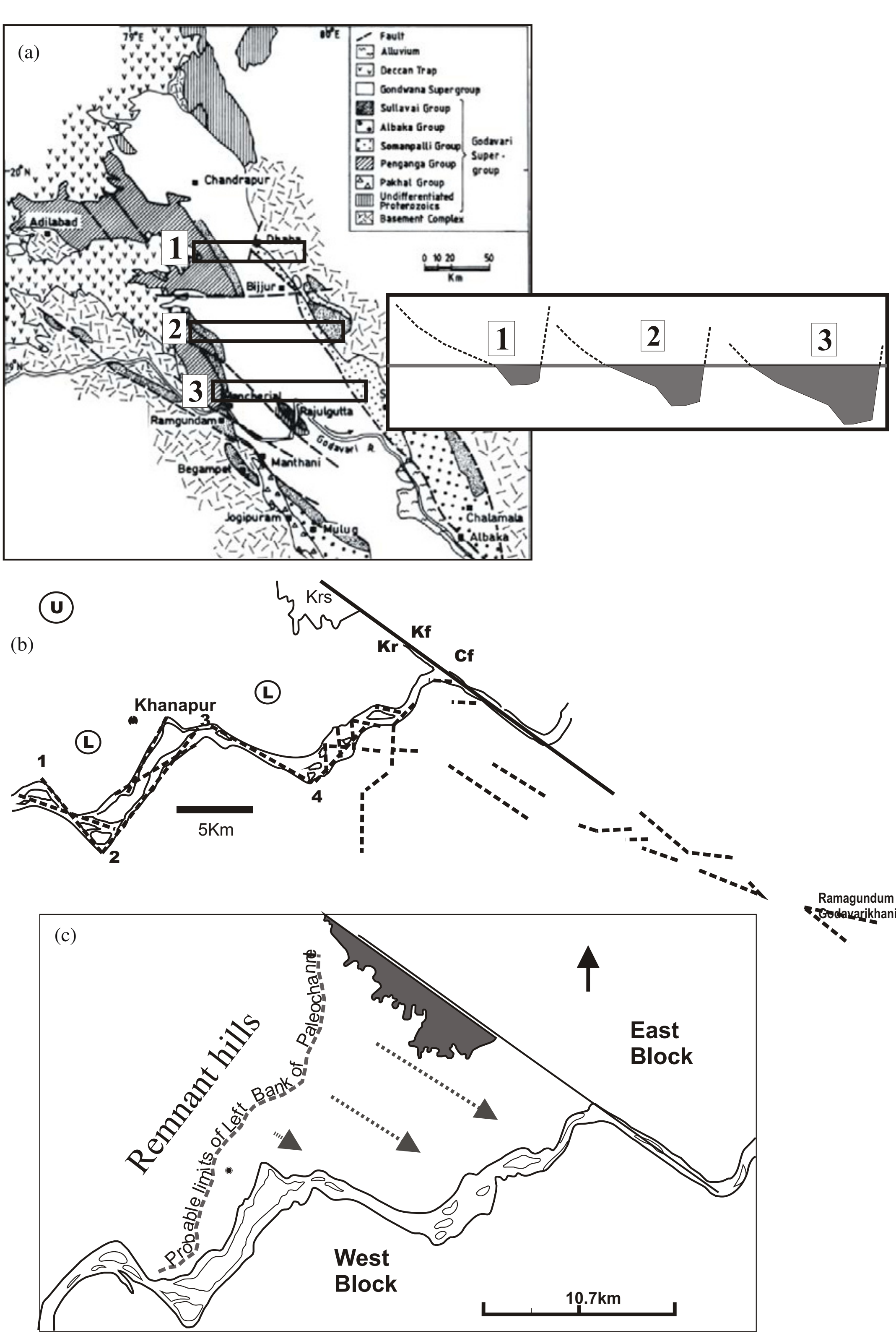

Fig.8. A tectono-morphic model proposed from the distribution of the major lineaments and field studies. The map (a) shows the geological map with disposition of the outcrops within the Godavari graben and our postulation with the sketched 1-3 showing the prevalence of the relative upliftments in the northern blocks. This helps to explain the southern tilt as common process and happened during Quaternary too inferred from the paleochannel migration as shown in the diagrams (b and c). The letters 'U' and 'L' in the diagram (b) show the uplifting and subsiding sides of the west block.

deposits represented by remnants of channel bars mainly comprising of conglomerates (of granitic clasts) with its gradation to pebbly and sandy deposits. The thick alluvium over the left bank, therefore, depicts paleo-channel deposits of Godavari river that can be attributed to the paleochannel migration shown in Fig.8.

Further, we took several cross profiles along the Godavari river in this region (marked 1 to 5 in Figs. 2 and 8). The representative profile P-P' (in Fig. 7) where, the river splits (and again joins downstream) appears to have been tectonically controlled or by bedrock. The bedrock is directly exposed in the channel with little or no sedimentation, the absence of bars and terraces suggest more recent phenomenon of channel shifting for such an old river. In summary, in the entire western block, the modern Godavari river shows bedrock exposed channel and mismatched left and right bank terraces in contrast to the thick sedimentation seen immediately as the river crosses the Kaddam fault in east block (e.g., Fig. 7c). The Godavari river after the confluence with Kaddam follows a remarkably straight course in the Kaddam fault and then cross-over the eastern block. In the east block, the Godavari river typically shows notable increase in channel (and thalwege) widths, thick coarse channel bar sedimentation as well as matching terrace and well sorted medium grained sands of granitic source. The nature of cross profiles, the migration of paleochannels and the sharp rectilinear bends of the Godavari river in the west block, therefore, indicates its response to latest neotectonic during the Quaternary period. The sharp alignment of these rivers to the basement structures and their younger morphology as described above indicate their response to some of the youngest tectonic reactivation phases of the Kaddam fault and associated tectonic configurations.

REGIONAL TECTONO-GEOMORPHIC RESPONSE

Based on the unique tectonic configurations, the fluvial response and other neotectonic signatures elaborated above we further examine the reasons for the neotectonic activity. The southward shift of the Godavari river (and hence its confluence) clearly suggested the southward tilt of the west block probably guided by the Kaddam fault and an existing fracture system producing the sharp rectilinear drainage patterns (Fig. 8). We also demarcated the southern boundary of this west block ending near Ramagundum area based on the topographic attributes (uplands), the convergence of conjugate lineament system and the jointing pattern described. The western and northern boundary of this block, however, could not be ascertained due to the Deccan trap cover. The eastern boundary is well defined due to the sharply visible Kaddam fault. In this instance, if we assume the area near Kaddam reservoir as the axis of fulcrum to such a tilt, then the northern end of the west block will be uplifted. At this stage we cannot relate any magnitudes of tilting, but the fluvial systems obviously respond even to a small amount of basin tilt of few degrees. In this context we propose the erosional unloading of the Deccan traps in the northern part of the west block as possible reason for such minor (?) tilt and guided by the Kaddam fault as explained below.The sedimentation records in the Bengal fan have indicated intensive erosion of the Deccan traps during Holocene (Kolla and Biscaye, 1973; Sager and Hall, 1990; Curray, 1994; Sangode et al. 2001) that can be attributed to the higher susceptibility of the basalts to chemical weathering during intensified monsoon. The Deccan trap source is significantly well represented till upto the distal fan region of the Bay of Bengal contributing a large mass of the sediments derived from the DVP. Additionally in our recent mineral magnetic work we find that all the flood plain sedimentation of the river Godavari from head up to its distal end is dominated by the Deccan source in contrast to local sources in the channel sedimentation (Kulkarni et al. communicated). It is beyond the scope of the present manuscript to estimate the mass of sediment eroded from the DVP. However, the overall predominance of the Deccan source in floodplains as well as in the Bengal fan off the Godavari delta indicates that the SW monsoon recharge the major sediment flux into the Bengal fan off the Godavari coast. The abrupt intensification of SW monsoon during Late Cenozoic (e.g., Overpeck et al. 1996) therefore, must have resulted in significant weathering of the Deccan traps.

The Deccan traps representing an average (eroded) thickness of over 2000 m of flood basalts of densities >2.8 gm/cc must have produced significant crustal load over the basement. Previously, Veeraswamy and Rawal (2005) suggested that the tectonic boundaries of the Precambrian basement of the Deccan traps get reactivated subjected to intense thermo-tectonic event (e.g. flood basaltic eruption) resulting in intra-plate seismicity like Koyna and Latur. Here we additionally propose that the rapid erosional unloading (due to intensified monsoon) can be one of the factors for the reactivation of the basement fault fracture systems such as the KLF in the peripheral regions of DVP. The neotectonic response of the flood basalt loading and erosional unloading over the Precambrian basement in the margins of the Deccan syneclise needs a special attention. Recent examples of fault reactivation in Precambrian crust (Rajendran et al. 1996; Valdiya, 1998; Pati et al. 2006; Chetty, 2006) encourage such attempts for detailed investigation in the study area

Fig.9. (**A**) Prominent erosion of the uplifted basement blocks along the major joint plane seen in east block near Luxetipet, (**B**) Three prominent joint planes in the west as well as east blocks, (**C**) Prominent jointing at Kaddam lineament near Mancherial-Godavari Khani-Ramgundum giving a sharp topography of the Kaddam lineament in the block 'C' of figure 2, (**D**) The ridge like appearance of the lineament in the block 'D' of figure 2, (**E**) The misfit right bank terraces of the Kaddam river near its inferred paleo-confluence in the block 'B' of figure 2. The clast imbrications is clearly at high angles to the river coarse of Kaddam, (**F**) The thick right bank terraces of the Kaddam river with younger sedimentation (typical of Godavari river clast composition), before its modern confluence with the Godavari river.

and elsewhere in the margins of Deccan traps, which encounters the structurally controlled Precambrian basement.

The importance of basement reactivation was previously emphasized by Hills (1946) to explain many present-day geomorphologic features associated with faults traversing the Australian landmass. He empirically showed that most of the present tectonic trends are observed in the basement lying parallel to the older trends with long tectonic history. Although the older features like Godavari graben are accreted during Precambrian, the crustal inhomogeneity resulting in the rheological heterogeneity can yield complex stress patterns. Release of these stresses during Late Cenozoic erosional regimes may generate the superimposed lineament pattern in the central Indian region. The most recent of these activities are expressed within Quaternary fluvial system and the present study attests such postulations.

Further there are evidences of fluid flow triggered seismic activity along fault zones (Hickman et al. 1995; Noir et al. 1997; Floyd et al. 2001; Janssen et al. 2005) demanding similar investigations over the Kaddam fault being trapped by the Kaddam reservoir besides Kaddam and Godavari rivers. Johnston (1992) have suggested that these factors could be important in case of intra-plate earthquakes of low strain cratonic terrain, as the crust under the inter-cratonic tectonic boundaries would be relatively weaker than that of the intra-cratonic region.

Acknowledgements: We acknowledge Heads, Department of Geology, Pune University and R.T.M. Nagpur University. The present work was partly funded by DST, New Delhi (grant SR/S4/ES-409/2009) and we are thankful to Dr. M. Mohanty (DST) for the generous and prompt funding.

References

AMATEUR SEISMIC CENTRE, Web Site: http://www.asc-india.org/, Pune, India.

BISWAS, S. K. (1999) A review on the evolution of the rift basins in India during Gondwana with special reference to western Indian basin and their hydrocarbon prospects. Proc. Indian National Sci. Acad., v.65(A/3), pp.261-283.

CHAKRABORTY, T. and CHAUDHURI, A.K. (1993) Fluvial–aeolian interactions in a Proterozoic alluvial plain: example from Mancherial Quartzite, Pranhita-Godavari Valley, India. Geol. Soc. London Spec. Publ., v.72, pp.127-141.

CHAKRAVARTHI, V., SHANKAR, G.B.K., MURALIDHARAN, D., HARINARAYANA, T. and SUNDARARAJAN, N. (2007) An integrated geophysical approach for imaging sub-basalt sedimentary basins: Case study of Jam River basin, India. Geophysics, v.72(6), pp. B141–B147.

CHAUDHURI, A.K. and DEB, G.K. (2004) Proterozoic Rifting in the Pranhita-Godavari Valley: Implication on India-Antarctica Linkage. Gondwana Res., v.7(2), pp.301-312.

CHAUDHURI, A.K. (2003) Stratigraphy and palaeogeography of the Godavari Supergroup in the south-central Pranhita-Godavari Valley, south India. Jour. Asian Earth Sci., v.21, pp.595–611.

CHAUDHURI, A.K. and CHANDA, S.K. (1991) The Proterozoic basin of Pranhita-Godavari valley: an overview. In: S.K. Tandon, C.C. Pant and S.B. Casshyap (Eds.), Sedimentary Basins of India: Tectonic Context. Gnanodaya Prakashan, Nainital, pp.13–30.

CHAUDHURI, A.K., DASGUPTA, S., BANDOPADHYAY, G., SARKAR, S., BANDOPADHYAY, P.C. and GOPALAN, K. (1989) Stratigraphy of the Penganga Group around Adilabad, Andhra Pradesh. Jour. Geol. Soc. India, v.34, pp.291-302.

CHAUDHURI, A.K. and HOWARD, J.D. (1985) Ramgundam Sandstone - a middle Proterozoic shoal-bar sequence. Jour. Sediment. Petrol., v.55, pp.392–397.

CHAUDHURI, A.K., MUKHOPADHYAY, J., PATRANABIS DEB, S. and CHANDA, S.K. (1999) The Neoproterozoic successions of Peninsular India. Gondwana Res., v.2, pp.213-225.

CHAUDHURI, A. K., SAHA, D., DEB, G. K., PATRANABIS DEB, S., MUKHERJEE, M.K. and GHOSH, G. (2002) The Purana basins of southern cratonic province of India - a case for Mesoproterozoic fossil rifts. Gondwana Res., v.5, pp.23-33.

COLLINS, A.S. and PISAREVSKY, S.A. (2005) Amalgamating eastern Gondwana: The evolution of the Circum-Indian Orogens. Earth Sci. Rev., v.71, pp.229–270.

CURRAY, J.R. (1994) Sediment volume and mass beneath the Bay of Bengal. Earth Planet. Sci. Lett., v.125, pp.371-383.

DEB, G.K. (2003) Deformation pattern and evolution of the structures in the Penganga Group, the Pranhita–Godavari Valley, India: probable effects of Grenvillian movement on a Mesoproterozoic basin. Jour. Asian Earth Sci., v.21, pp.567–577.

DEB, G.K. (2000) Fold-geometry in the Chanda Limestone of the Proterozoic Penganga Group of the Pranhita–Godavari Valley, and its origin. Jour. Earth Sci., v.27, pp.11–14.

FLOYD, J.S., MUTTER, J.C., GOODLIFFE, A.M. and TAYLOR, B. (2001) Evidence for fault weakness and fluid flow within an active low-angle normal fault. Nature, v.411, pp.779–783.

GOKARN, S.G., RAO, C.K., GUPTA, G., SINGH, B.P. and YAMASHITA, M. (2001) Deep Crustal structure in the Central India from Magnetotelluric studies. Geophys. Jour. Internat., v.144, pp.685–694.

GSI (2000) Seismotectonic Atlas of India and its Environs. Geological Survey of India.

GUPTA, M.L. (1982) Heat flow in the Indian peninsula—its geological and geophysical implications. Tectonophysics, v.83, pp.1721-1732.

HICKMAN, S., SIBSON, R. and BRUHN, R. (1995) Introduction to special section: Mechanical involvement of fluids in faulting. Jour. Geophys. Res., v.100, pp.12,831–12,840.

HILLS, E.S. (1946) Some aspects of the tectonics of Australia. Proc. Royal Soc. N.S. I'E., v.79, pp. 67-91 (cross referred).

IYENGAR AND OTHERS (2007) Final report on the development of probabilistic seismic hazard map of india technical report of the working committee of experts constituted by the national disaster management authority Govt. of India, New Delhi, pp.80.

JANSSEN, C., ROMER, R. L., HOFFMANN-ROTHE, A., MINGRAM, B., DULSKI P., MOLLER, P., AL-ZUBI, H. (2005) The role of fluids in faulting deformation: a case study from the Dead Sea Transform (Jordan). Internat. Jour. Earth Sci. (Geol Rundsch), v.94, pp.243–255.

JOHNSTON, A.C. (1992) Intraplate not always stable. Nature, v.355, pp.213–214.

KAILA, K.L., MURTHY, 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.

KOLLA, V. and BISCAYE, P.E. (1973) Clay mineralogy and sedimentation in the eastern Indian Ocean. Deep Sea Res., v.20, pp.727-738.

KULKARNI, Y.R., SANGODE, S.J., MESHRAM, D.C., DUTT, Y. and PATIL, S.K. (2012) Mineral magnetic characterization of the Godavari River 'Source' in the context of Bay of Bengal 'Sink' (communicated).

KUMAR, S.N., BABU, G.N., JEYAGOPAL, A.V. and MAITHANI, P.B. (2008) Discovery of Uranium mineralization in sheared quartzite and associated crystallines in the environs of Pranhita-Godavari basin, Mysemgutta, Kaddam area, Adilabad district, Andhra Pradesh. Jour. Geol. Soc. India, v.71, pp.331-336.

MISHRA, D. C., CHANDRA SEKHAR, D. V., VENKATA RAJU, D. CH. and VIJAYA KUMAR, V. (1999) Crustal structure based on gravity–magnetic modelling constrained from seismic studies under Lambert Rift, Antarctica and Godavari and Mahanadi rifts, India and their interrelationship. Earth Planet. Sci. Lett., v.172, pp.287–300.

MOHAN, I., SITARAM, M.V.D. and GUPTA, H.K. (1981) Some recent earthquakes in peninsular India. Jour. Geol. Soc. India, v.22, pp.292-298.

MUKHOPADHYAY, J. and CHAUDHURI, A.K. (2003) Shallow to deep-water deposition in a Cratonic basin: an example from the Proterozoic Penganga Group, Pranhita–Godavari Valley, India. Jour. Asian Earth Sci., v.21, pp.613–622.

MURTHY, Y.S. (2002) On the correlation of seismicity with geophysical lineaments over the Indian Subcontinent. Curr. Sci., v.83(6), pp.760-766.

NAGANJANEYULU, K., DHANUNJAYA NAIDU, G., SOMESWARA RAO, M., RAVI SHANKAR, K., KISHORE, S. R.K., MURTHY, D.N., VEERASWAMY, K. and HARINARAYANA, T. (2010) Deep crustal electromagnetic structure of central India tectonic zone and its implications. Physics Earth Planet. Inter., v.181, pp.60–68.

NAQVI, S.M. (2005) Geological evolution of Indian plate (from Hadean to Holocene). Capital Publishing Company, New Delhi, 450p.

NAQVI, S.M. and ROGERS, J. J. W. (1987) Precambrian Geology of India. Oxford Monograph Geology and Geophysics, Oxford University Press, Oxford, 223p.

NOIR, J., JACQUES, E., BE'KRI, S., ADLER, P.M. and KING, G.C.P. (1997) Fluid flow triggered migration of events in the 1989 Dobi earthquake sequence of Central Afar. Geophys. Res. Lett., v.24, pp.2335–2338.

OVERPECK, J., ANDERSON, D., TRUMBORE, S. and PRELL, W. (1996) The southwest Indian Monsoon over the last 18000 years. Climate Dynamics, v.12, pp.213–225.

PARVEZ, I. A., VACCARI, F. and PANZA, G.F. (2003) A deterministic seismic hazard map of India and adjacent areas. Geophys. Jour. Internat., v.155, pp.489–508.

PATI, J.K., MALVIYA, V.P. and PRAKASH, K. (2006) Basement reactivation and its relation to neotectonic activity in and around Allahabad, Ganga plain. Photonirvachak, Jour. Indian Soc. Remote Sensing, v.34(I), pp. 47-56.

PATRANABIS DEB, S. (2001) Origin of Mesoproterozoic basins of India: implications on India Rodinia assembly. Gondwana Res., v.4, pp.604–605.

PATRANABIS DEB, S. and CHAUDHURI, A.K. (2001) Stratigraphic architecture of the Proterozoic succession in the eastern Chattisgarh basin: its tectonic implication. Sedimentary Geol., v.147, pp.105–125.

RAJARAM, M. and ANAND, S.P. (2003) Central Indian tectonics revisited using aeromagnetic data. Earth Planets Space, v.55, pp.e1–e4.

RAJENDRAN, C.P., RAJENDRAN, K. and JOHN, B. (1996) The 1993 Killari (Latur), Central India, earthquake: An example of fault reactivation in the Precambrian crust. Geology, v.24, pp.651-654.

RAJESHAM, T., BHASKAR 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.

RAMAM, P. K. and MURTY, V. N. (1997) Geology of Andhra Pradesh. Geological Society of India, Bangalore, 245p.

RAMANA, D. V., THIAGARAJAN, S. and RAI, S.N. (2003) Crustal thermal structure of the Godavari graben and coastal basin. Curr. Sci., v.84(25), pp.1116-1122.

RAO, B.R. (2000) Historical seismicity and deformation rates in the Indian Peninsular Shield. Jour. Seismology, v.4, pp.247–258.

RAO, G.V. and RAO, R.U.M. (1983) Heat flow in Indian Gondwana basins and heat production of their basement rocks. Tectonophysics, v.91, pp.105-117.

RAO, R.U.M., RAO, G.V. and NARAIN, H. (1976) Radioactive heat generation and heat flow in the Indian shield. Earth Planet. Sci. Lett., v.30, pp.57-64.

RAVI SHANKER, GUHA, S.K., SETH, N.N., GHOSH, A., SIBDAS GOSH, NANDY, R., JANGI, B.L. and MUTHURAMAN, K. (1991) Geothermal Atlas of India. Geol. Surv. India, Spec. Publ. v.19, 144p.

ROGERS, J.J.W. and SANTOSH, M. (2005) Continents and Supercontinents. Oxford University Press, 287p.

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

ROY, A.B. (2006) Seismicity in the Peninsular Indian Shield: Some geological considerations. Curr. Sci., v.91(4), pp.456-463.

SAGER, W.W. and HALL, S.A. (1990) Magnetic properties of black mud turbidites form ODP leg 116, distal Bengal fan, Indian Ocean, *In:* J.R. Cochran (Eds.), Proc. ODP Scientific Results, v.116, pp.317-336.

SAHA, D. and CHAUDHARY, A.K. (2003) Deformation of the Proterozoic succession in Pranhita-Godavari basin, south India: A regional perspective. Jour. Asian Earth Sci., v.21, pp.557-565.

SAHA, D. and GHOSH, G. (1997) Tectonic setting of Proterozoic sediments around Somanpalli, Godavari Valley. Jour. Indian Assoc. Sedimentologists, v.7, pp.29–45.

SANGODE, S.J., SURESH, N. and BAGATI, T.N. (2001) Godavari source in the Bengal fan sediments: results from magnetic susceptibility dispersal pattern. Curr. Sci., v.85(5), pp.660–664.

SANTOSH, M., YOKOYAMA, S., BIJU-SEKHAR, S. and ROGERS, J.J.W. (2003) Multiple Tectonothermal events in the granulite blocks of Southern India revealed from EPMA dating: implications on the history of supercontinents. Gondwana Res., v.6, pp.29–63.

SARMA, B.S.P. and KRISHNA RAO, M.V.R. (2005) Basement structure of Godavari basin, India – Geophysical modelling. Curr. Sci., v.88(7), pp.1172-1175.

VALDIYA, K.S. (2010) The making of India: Geodynamic evolution; Macmillan Publishers India Ltd. 816p.

VALDIYA, K.S. (1998). Late Quaternary movements and landscape rejuvenation in Southeastern Karnataka and adjoining Tamil Nadu in southern Indian shield. Jour. Geol. Soc. India, v.51, pp.139–166.

VEERASWAMY, K. and RAVAL, U. (2005) Remobilization of the palaeoconvergent corridors hidden under the Deccan trap cover and some major stable continental region earthquakes. Curr. Sci., v.89/3, pp.522-530.

(Received: 10 February 2012; Revised form accepted: 26 April 2012)