Solid Earth Discuss., 3, 1–17, 2011
www.solid-earth-discuss.net/3/1/2011/
doi:10.5194/sed-3-1-2011


Solid Earth Discussions



# Relative chronology in high-grade crystalline terrain of the Eastern Ghats, India: new insights

**S. Bhattacharya**[1], **R. Kar**[2], **A. K. Saw**[3], **and P. Das**[4]

[1]Indian Statistical Institute, Kolkata 700108, India
[2]J.K.College, Purulia 723101, India
[3]National Mineral Development Corporation Limited, Hyderabad 500173, India
[4]Uranium Corporation of India Limited, Turamdih 832107, India

Received: 8 December 2010 – Accepted: 16 December 2010 – Published: 17 January 2011

Correspondence to: S. Bhattacharya (samar.bhattacharya@gmail.com)

Published by Copernicus Publications on behalf of the European Geosciences Union.

## Abstract

The two major lithology or gneiss components in the polycyclic granulite terrain of the Eastern Ghats, India, are the supracrustal rocks, commonly described as khondalites, and the charnockite-gneiss. Many of the workers considered the khondalites as the oldest component with unknown basement and the charnockite-protoliths as intrusive into the khondalites. However, geochronological data do not corroborate the aforesaid relations. The field relations of the hornblende- mafic granulite with the two gneiss components together with geocronological data indicate that khondalite sediments were deposited on older mafic crustal rocks. We propose a different scenario: Mafic basement and supracrustal rocks were subsequently deformed and metamorphosed together at high to ultra-high temperatures – partial melting of mafic rocks producing the charnockitic melt; and partial melting of pelitic sediments producing the peraluminous granitoids. This is compatible with all the geochronological data as well as the petrogenetic model of partial melting for the charnockitic rocks in the Eastern Ghats Belt.

## 1 Introduction

High-grade crystalline terrains are characterized by gneissic fabrics resulting from tectonic and metamorphic processes and hence do not reflect the original stratification of the sedimentary or volcanic protoliths (Rey and Galotti, 2008). Moreover, many of the high-grade terrains have suffered polyphase deformation and metamorphism, which further complicate the relative chronological relation between different units or gneiss-components. It is imperative then to distinguish the different generations of the gneissic fabrics in different components. Finally application of geochronological methods is useful to reconstruct the history of the crystalline terrains.





SED

3, 1–17, 2011

Relative chronology in high-grade crystalline terrain

S. Bhattacharya et al.

## 1.1 Eastern Ghats Belt

The Eastern Ghats Granulite Belt along the east coast of India is characterized by polyphase deformation, polycyclic metamorphic record and dehydration melting in different crustal protoliths (Dasgupta et al., 1994; Sen et al., 1995; Sen and Bhattacharya, 1997; Bhattacharya and Kar, 2002; Kar et al., 2003). However, in view of different crustal residence ages from different parts of the regional granulite terrain, as also distinct isotopic records of granulite facies metamorphism across this regional granulite terrain, the tectonic-metamorphic evolution should be discussed separately for the different crustal domains and provinces identified (Rickers et al., 2001; Dobmeier and Raith, 2003). Barring the Archean domains of Rengali and Jaypore, the northern Eastern Ghats Belt, north of the Godavari rift is now described as the Eastern Ghats Province (EGP) and south of the Godavari rift is the Ongole domain (Fig. 1).

Both clockwise and anti-clockwise P-T-t paths have been reported from different parts in the EGP and two contrasting tectonic interpretations have been proposed (Sengupta et al., 1990; Mohan et al., 1997; Bhattacharya and Kar, 2002). Sengupta et al. (1990) related the anti-clockwise P-T-t path with "compressive orogeny that was associated with high heat flux through mafic magmatism". According to these authors granulite metamorphism was caused by magmatic underplating, as in the model of Bohlen (1987). On the other hand, the reported clockwise P-T-t paths were interpreted by Bhattacharya and Kar (2002) as the result of homogeneous shortening in a compressional setting. In this context it may be noted that Thompson (2001) concluded that " a simple orogenic clockwise P-T path of burial, heating, exhumation, then cooling will result in dehydration melting reactions during the heating and decompression phases".

Despite such divergent interpretations, high to ultra-high temperatures (≥950 °C) and dehydration melting in different crustal protoliths are commonly associated with the first or earliest granulite facies metamorphism in the Eastern Ghats Province (Simmat and Raith, 2008; Mukhopadhyay and Basak, 2009). The high to ultra-high temperature records and the P-T-t paths reported from the Eastern Ghats Belt are summarized in Fig. 1. Although, there is still some debate for the timing of this high temperature event, Mukhopadhyay and Basak (2009) argued that the early UHT metamorphic event affected the entire EGP; these authors also noted that the absence of UHT assemblage may be due to the absence of suitable bulk composition. Simmat and Raith (2008) also noted that the earliest and ultra-high temperatures are recorded from both pelitic and charnockitic assemblages.

One significant outstanding issue concerning the tectono-metamorphic evolution in the Eastern Ghats Belt is the relation between the khondalites and charnockites, the two major gneiss components. In this communiqué we focus on this problem, both in terms of field relations and petrological and isotopic relations. In conjunction with our earlier publications, additional field features and some new isotopic data presented here, led us to propose a new tectonic interpretation of the early/first, and high to ultra-high temperature granulite metamorphism, that is separately applicable for the EGP and the Ongole domain.

The Sm-Nd whole-rock isotopic analyses were carried out at the Center of Research in Geochronology of Sao Paulo University, Brasil, using the two-column technique , as described by Richard et al. (1976) with the addition of some improvements. An ion exchange resin was used for primary separation of the REE, followed by a second HDEHP-coated Teflon powder column for separation of Sm and Nd. The Sm and Nd abundances were determined by isotope dilution. The isotope ratios were measured on a VG 354 multi-collector mass spectrometer. The measured ratio of $^{143}$Nd/$^{144}$Nd obtained for La Jolla standard was $0.511857 \pm 0.000046$ ($2\sigma$). The laboratory blanks for the chemical procedure during the period of analysis yielded maximum values of 0.4 ng for Nd and 0.7 ng for Sm.

## 2 Nature of the problem

### 2.1 Field relation and fabric development

Although several reports have been published, correlation of deformational events and attendant gneissic foliation, in different areas or in different lithologies in the same area still remains problematic. In terms of field relation between two major gneiss components, several workers have argued that khondalites or the sedimentary granulites are the oldest components, and multiply intruded by magmatic rocks, including enderbites and charnockites (Rickers et al., 2001; Simmat and Raith, 2008). However, the question of the basement to these sediments remains illusive. On the other hand, correlation between gneissic fabrics in the two components remains debatable. From the Chilka Lake area, Bhattacharya et al., (1994) proposed a generalized deformation history from similar styles of deformation and fabric development in the two major gneiss-components, namely the metasedimentary granulites and charnockitic rocks. Also from the same area Dobmeier and Raith (2000) observed "the enderbitic and metasedimentary rocks have identical structural history..". But from Angul area Mukhopadhyay and Basak (2009) noted that "gneissosity in khondalites formed earlier than that in the charnockitic gneisses, though the two are generally parallel".

### 2.2 Geochronology

During the last decade or so significant isotopic data on different granulite lithologies have been published; but still these could not resolve the problem of the chronological relation between metasedimentary granulites and charnockitic gneiss. The metasedimentary granulites are thought as the oldest component and intruded by magmatic rocks, enderbites and charnockites (Rickers et al., 2001; Simmat and Raith, 2008). It is important to note that coarse-grained pegmatitic charnockites are commonly recognized as distinct from the large-scale charnockitic bodies and an intrusive relation of this pegmatitic variety into khondalites was reported by Subba Rao and Divakara





SED
3, 1–17, 2011

Rao (1988). But an intrusive relation of the large-scale charnockitic bodies into the metasedimentary granulites (supracrustals) is not corroborated by the published isotopic data, as discussed in the following lines.

Based primarily on Nd-mapping, several crustal domains or provinces with unrelated pre-metamorphic histories have been identified in the Eastern Ghats Belt (Rickers et al., 2001; Dobmeier and Raith, 2003). Moreover, considering the metamorphic records in terms of their age two provinces are also recognized. The north and central parts of the Eastern Ghats Belt, north of the Godavari rift, is now described as the Proterozoic Eastern Ghats Province and the earliest granulite event in this province is recorded as 1.2 Ga (Simmat and Raith, 2008). South of the Godavari rift is the Ongole domain of the Krishna Province, and the earliest granulite event in this domain is recorded as around 1.6 Ga (Mezger and Cosca, 1999). This 1.6 Ga metamorphism and partial melting has been recorded from both metapelites and charnockitic gneiss (Simmat and Raith, 2008; Bhattacharya et al., 2010a). It is imperative that the relative chronology between the two gneiss components should be discussed separately for the aforesaid two provinces or domains.

In the Eastern Ghats Province, Simmat and Raith (2008) suggested that "U-Pb detrital zircons preserved in metapelitic granulites and high-Mg-Al granulites provide an upper age limit of ~1.37 Ga for the deposition of sediments". Also these authors indicated the earliest granulite facies metamorphism of 1.2 Ga in the EGP. These authors further suggested that in the Chilka Lake area (EGP) the metasedimentary granulites "form the oldest component" and "it was intruded by concordant bodies of tonalite (now enderbite) of unknown age..." These authors also suggested that in the eastern khondalite domain (Anakapalle area in EGP) "high-grade supracrustal package was intruded by basic magmas (two-pyroxene granulites).." It is evident from these data and interpretations that intrusion of charnockite-gneiss protolith must be younger than 1.37 Ga and granulite metamorphism around 1.2 Ga. But according to the hypothesis of charnockitic magmatism and emplacement (tonalite) followed by granulite metamorphism (Bhui et al., 2007; Simmat and Raith, 2008), the intrusion of charnockite-gneiss protolith must be older than 1.2 Ga. On the other hand, Rickers et al. (2001) indicated that intrusion of the charnockite-gneiss protolith is given by $T_{DM}$ as between 1.9 and 2.9 Ga. It is evident from the aforesaid discussions that neither the khondalites as the oldest component, nor the intrusion of charnockite-gneiss protolith into the metasedimentary granulites (supracrustals) is valid proposition.

Similar problem is encountered for the Ongole domain. Simmat and Raith (2008) indicated that "high to ultra-high grade metamorphism occurred between 1650 and 1540 Ma, after the emplacement of basic and felsic plutonic complexes into the supracrustal granulites at ca. 1.7 Ga". Bhui et al. (2007) also described "intrusion of a suite of voluminous felsic magma (protolith of enderbitic gneiss)" and Kovach et al. (2001) suggested that "U-Pb zircon data from the felsic magma provided the emplacement age of the felsic magma at 1.7–1.72 Ga". Accordingly, the sediment deposition in this domain must be older than 1.7 Ga. Although, no unequivocal evidence for the depositional age of the khondalites in the Ongole domain have so far been published, Upadhyay et al. (2009) indicated that onset of sedimentation in the Eastern Ghats Belt, could be constrained by the rift-valley Alkaline magmatism of the Prakasam Province at the western margin of the Eastern Ghats Belt, as ca. 1.42 Ga. Thus felsic magma emplaced around 1.7 Ga can not be considered as intrusive into the supracrustals of younger depositional age.

## 3 Alternative proposal

It is intriguing that in the Eastern Ghats Belt, hornblende-mafic granulites with abundant prograde hornblende, are not recognized or ignored by most of the workers. Here we demonstrate the significance of the hornblende-mafic granulites, both in terms of their field relations with the charnockitic gneiss and the metasedimentary granulites, and in terms of the petrological and isotopic relations.

In the Eastern Ghats Belt, hornblende-mafic granulites occur as xenoliths within massif-type charnockites in both the Eastern Ghats Province and the Ongole domain





SED
3, 1–17, 2011

(Fig. 2). Our petrogenetic studies indicate charnockitic melt as product of partial melting in mafic rocks under granulite facies conditions (Kar et al., 2003; Bhattacharya, 2003; Bhattacharya et al., 2010a). Hence the protoliths of the charnockite-gneiss are mafic rocks, now represented by the hornblende-mafic granulites. This mafic magmatism may be represented by $T_{DM}$ as between 1.9 and 2.9 Ga (Rickers et al., 2001). Our Sm-Nd isotopic data on hornblende-mafic granulite xenoliths of both the Eastern Ghats Province and Ongole domain (Naraseraopet) indicate the mafic magmatism around 2.5 Ga (Bhattacharya et al., 2010b). Hornblende-mafic granulites also occur interbanded with the khondalites at several locations (Fig. 3). It is interesting to note that these minor bands of hornblende-mafic granulites interbanded with the khondalites have similar mineralogy, namely with abundant prograde hornblende (Fig. 4). Sm-Nd whole rock isotopic data of these mafic granulites interbanded with the khondalites indicate the emplacement of their protoliths, the mafic magmatism, between 1.9 and 2.9 Ga (Table 1).

In the Eastern Ghats Province considering onset of sedimentation around 1.3 Ga, constrained by detrital zircon data reported by Simmat and Raith (2008), the basement is most likely the older crustal rocks (1.9 to 2.9 Ga mafic rocks). And the earliest granulite metamorphism at 1.2 Ga involved both the mafic rocks and the supracrustal rocks. High to ultra-high temperature granulite metamorphism of the mafic rocks produced the charnockitic melt by partial melting (Kar et al., 2003; Bhattacharya, 2003; Kar and Bhattacharya, 2010). And the same high to ultra-high temperature granulite metamorphism of the supracrustal rocks (including khondalites and high-Mg-Al granulites) produced the peraluminous granitoids (Sen and Bhattacharya, 1997; Bhattacharya and Kar, 2002; Bhattacharya et al., 2003).

For the Ongole domain, although no unequivocal evidence for the age of sedimentation is available, it must be older than 1.6 Ga, earliest granulite metamorphism recorded from high Mg-Al metapelites and this way Ongole sediment deposition is distinct from that in the EGP, which is said to be related to rifting and alkaline magmatism of the Prakasam Province. However, in terms of field relations the khondalites as the oldest





SED
3, 1–17, 2011

gneiss component is not corroborated by the published isotopic data. But our alternative petrogenetic model, namely, sedimentation on older crustal rocks (1.9–2.9 Ga mafic rocks) followed by granulite metamorphism in both the sediments and mafic basement around 1.6 Ga, is consistent with all the geochronological data published so far as also the field relations of the hornblende-mafic granulites with the two gneiss components.

## 4 Conclusions

Older mafic rocks, now represented by the hornblende-mafic granulites, were the basement for the khondalite-protolith sediments, in both the Eastern Ghats Province and the Ongole domain of the Eastern Ghats Belt, India.

Earliest granulite metamorphism, 1.2 Ga in the EGP and 1.6 Ga in the Ongole domain involved both the mafic basement and the khondalite sediments.

High to Ultra-high temperature granulite metamorphism of mafic rocks produced the charnockitic melt, and that of pelitic sediments produced the peraluminous granitoids, in the Eastern Ghats Belt.

*Acknowledgements.* Indian Statistical Institute provided the infrastructural facilities, particularly for extensive field work for the last two decades. We also sincerely aknowledge the isotopic analytical facilities provided by the Institute of Geosciences, Sao Paulo University, Brasil.

## References

Bhattacharya, S., Sen, S. K., and Acharyya, A.: The structural setting of the Chilka Lake granulite-migmatite-anorthosite suite with emphasis on the time relation of charnockites, Precambrian Res., 66, 393–409, 1994.

Bhattacharya, S. and Kar, R.: High-temperature dehydration melting and decompressive P-T path in a granulite complex from the Eastern Ghats, India, Contrib. Mineral. Petr., 143, 175–191, 2002.





SED

3, 1–17, 2011

Relative chronology in high-grade crystalline terrain

S. Bhattacharya et al.

Bhattacharya, S.: Dehydration melting in mafic rocks in the Eastern Ghats Belt, India: Implications for variable composition of charnockitic melt and heterogeneity of source rocks, Geol. Soc. India. Memoir, 52, 131–144, 2003.
Bhattacharya, S., Kar, R., Teixeira, W., and Basei, M.: High-temperature crustal anatexis in a clockwise P-T path: isotopic evidence from a granulite-granitoid suite in the Eastern Ghats belt, India, J. Geol. Soc. L., 160, 39–46, 2003.
Bhattacharya, S., Das, P., Chaudhary, A. K., and Saw, A. K.: Mafic granulite xenoliths in the Eastern Ghats Grannulite Belt: Implications for lower crustal processes in the southeastern Peninsular India, Ind. Jour. Geol., 80, 55–69, 2010a.
Bhattacharya, S., Chaudhary, A. K., Saw, A. K., and Das, P.: Mafic granulite xenoliths from the East Indian Shield: evidence for recycled continental crust in the Archean mantle, Lithosphere in press., 2010b.
Bohlen, S. R.: Pressure-temperature-time paths and tectonic model for the evolution of granulites, Jour. Geology, 95, 617–632, 1987.
Dasgupta, S. Sengupta, P., Fukuoka, M., and Chakraborti, S.: Dehydration melting, fluid buffering and decompressional P-T path in a granulite complex from the Eastern Ghats, India. Jour. Met. Geol., 10, 777–788, 1992.
Dasgupta, S., Sanyal, S., Sengupta, P., and Fukuoka, M.: Petrology of granulites from Anakapalle- evidence for Proterozoic decompression in the Eastern Ghats, India. Jour. Petrol., 35, 433–459, 1994.
Dobmeier, C. and Raith, M.: On the origin of “arrested” charnockitization in the Chilka Lake area, Eastern Ghats Belt, India: A reappraisal. Geol. Mag. 137, 27–37, 2000.
Dobmeier, C. J. and Raith, M. M.: Crustal architecture and evolution of the Eastern Ghats Belt and adjacent regions of India, Geolgical Society Special Publication, 206, 145–168, 2003.
Gupta, S., Bhattacharya, A., Raith, M., and Nanda, J. K.: Contrasting pressure-temperature-deformation history across a vestigal craton-mobile belt boundary: the western margin of the Eaastern Ghats belt at Deobhog, India. Jour. Met. Geol., 18, 683–697, 2000.
Jacques Rey and Simone Galotti: Stratigraphy: terminology and practice, Editions TECHNIP, brgm, 2008.
Kar, R., Bhattacharya, S., and Sheraton, J. W.: Hornblende dehydration melting in mafic rocks and the link between massif-type charnockite and associated granulites, Eastern Ghats granulite belt, India, Contrib. Mineral. Petr., 145, 707–729, 2003.
Kar, R. and Bhattacharya, S.: New experimental constraints: implications for the petrogenesis

of charnockite of dioritic composition, Nat. Sci., 2, 1085–1089, 2010.
Kovach, V. P., Simmat, R., Rickers, K., Berezhnaya, N. G., Salnikova, E. B., Dobmeier, C., Raith, M., Yakovleva, S. Z., and Kotov, A. B.: The Western Charnockite Zone of the Eastern Ghats Belt, India- An independent crustal Province of Late Archean (2.8 Ga) and Paleoproterozoic (1.7–1.6 Ga) terrains, Gondwana Res., 4, 666–667, 2001.
Mezger, K. and Cosca, M.: The thermal history of the Eastern Ghats Belt (India), as revealed by U-Pb and 40Ar/39Ar dating of metamorphic and magmatic minerals: implications for the SWEAT correlation, Precambrian Res., 94, 251–271, 1999.
Mohan, A., Tripathi, P., and Motoyoshi, Y.: Reaction history of sapphirine granulites and a decompressional P-T path in a granulite complex from the Eastern Ghats, Proc. Ind. Acad. Sci. (Earth. Planet. Sci.), 106, 115–129, 1997.
Mukhopadhyay, D. and Basak, K. The Eastern Ghats Belt – A polycyclic Granulite Terrain. Jour. Geol. Soc. Ind., 73, 489–518, 2009.
Neogi, S., Dasgupta, S., Sengupta, P., and Das, N.: Ultrahigh temperature decompression in a suite of grannulites from the Eastern Ghats Belt- Bastar craton contact and its significance, Memoir Gondwana Research Group 5, 115–138, 1999.
Richard, P., Shimizu, N., and Allegre, C. J.: 143Nd/144Nd a natural tracer: an application to Oceanic basalts, Earth Planet. Sc. Lett., 31, 269–278, 1976.
Rickers, K., Mezger, K., and Raith, M. M.: Evolution of the continental crust in the Proterozoic Eastern Ghats Belt, India and new constraints for Rodinia reconstruction: implications from Sm-Nd, Rb-Sr and Pb-Pb isotopes, Precambrian Res., 112, 183–210, 2001.
Saw, A. K.: Structural setting and petrogenesis of the granulite-granite-migmatite suite of Sunki, Koraput district, Orissa, in the Eastern Ghats Granulite Belt. Ph. D dissertation, Calcutta University, 2007.
Sen, S. K. and Bhattacharya, S.: Dehydration melting of micas in the Chilka Lake Khondalites: The link between the metapelites and granitoids. Proc. Ind. Acad. Sci. (Earth. Planet. Sci.), 106, 277–297, 1997.
Sengupta, P., Dasgupta, S., Bhattacharya, P. K., Fukuoka, M., Chakraborti, S., and Bhowmmik, S.: Petrotectonic imprints in the sapphirine granulites from Anantagiri, Easttern Ghats Mobile Belt, India. Jour. Petrol., 31, 971–996, 1990.
Sengupta, P., Sen, J., Dasgupta, S., Raith, M., Bhui, U. K., and Ehl, J.: Ultrahigh temperature metamorphism of metapelitic granulites from Kondapalle, Eastern Ghats Belt: implications for the Indo-Antarctic correlation, Jour. Pettrol., 40, 1065–1087, 1999.

Simmat, R. and Raith, M. M.: U-Th-Pb monazite geochronometry of the Eastern Ghats Belt, India: Timing and spatial disposition of poly-metamorphism, Precambrian Res., 162, 16–39, 2008.
Subba Rao, M. V. and Divakara Rao, V.: Chemical constraints on the origin of the charnockites in the Eastern Ghats Mobile belt, India. Chem. Geol. 69, 37–48, 1988.
Thompson, A. B.: Clockwise P-T paths for crustal melting and $H_2O$ recycling in granite source regions and migmatite terrains, Lithos, 56, 33–45, 2001.
Upadhyay, D., Gerdes, A., and Raith, M. M.: Unraveling sedimentary provenance and techtonothermal history of high-temperature metapelites, using zircon and monazite chemistry: A case study from the Eastern Ghats Belt, India, J. Geol., 117, 665–683, 2009.





SED
3, 1–17, 2011

Relative chronology in high-grade crystalline terrain

S. Bhattacharya et al.

**Table 1.** $T_{DM}$ ages for mafic granulites interbanded with the khondalites.

| Location | Sample | Sm (ppm) | Nd (ppm) | $^{147}Sm/^{144}Nd$ | $^{143}Nd/^{144}Nd$ | TDM (Ga) |
|---|---|---|---|---|---|---|
| Paikmal | 4P/05 | 3.77 | 14.274 | 0.1597 ± 9 | 0.512375 ± 9 | 1.9 |
| Paderu | Pa34C | 3.775 | 14.604 | 0.1563 ± 6 | 0.511940 ± 12 | 2.9 |
| Sunki | D2/2 | 6.17 | 24.35 | 0.1532 ± 7 | 0.511999 ± 8 | 2.7 |
| Naraseraopet | A5/1 | 6.02 | 22.36 | 0.1629 ± 5 | 0.512216 ± 11 | 2.8 |



SED

3, 1–17, 2011

Relative chronology in high-grade crystalline terrain

S. Bhattacharya et al.

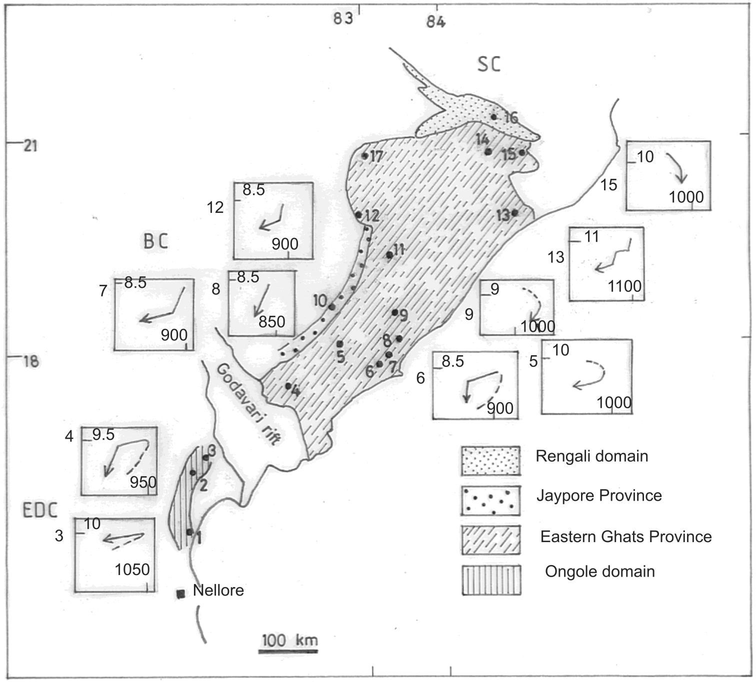


**Fig. 1.** Generalized geological map of the Eastern Ghats Belt; different crustal domains or provinces shown. Important locations also shown. 1. Ongole, 2. Naraseraopet, 3. Kondapalle, 4. Rajamundri, 5. Paderu, 6. Anantagiri, 7. Anakapalle, 8. Garbham, 9. Sunki, 10. Jaypore, 11. Rayagada, 12. Deobhog, 13. Chilka, 14. Angul, 15. Jenapore, 16. Rengali, 17. Paikmal. P-T paths reported from different locations are shown in boxes. References to the above: 3: Sengupta et al., 1999. 4: Neogi et al., 1999. 5: Bhattacharya and Kar, 2002. 6: Sengupta et al., 1990. 7: Dasgupta et al., 1994. 8: Dasgupta et al., 1992. 9: Saw, 2007. 12: Gupta et al., 2000. 13: Sen et al., 1995. 15: Kar et al., 2003.





SED
3, 1–17, 2011

**Fig. 2.** **(A)** Mafic granulite xenoliths in massif-type charnockite at Naraseraopet of the Ongole domain. **(B)** Mafic granulite xenoliths in massif-type charnockite at Sunki of the Eastern Ghats Province.





SED

3, 1–17, 2011

**Fig. 3. (A)** Minor mafic granulite bands interbanded with khondalites and folded together, at Sunki of the Eastern Ghats Province. **(B)** Mafic granulite interbanded with the khondalite at Naraseraopet of the Ongole domain.





SED

3, 1–17, 2011

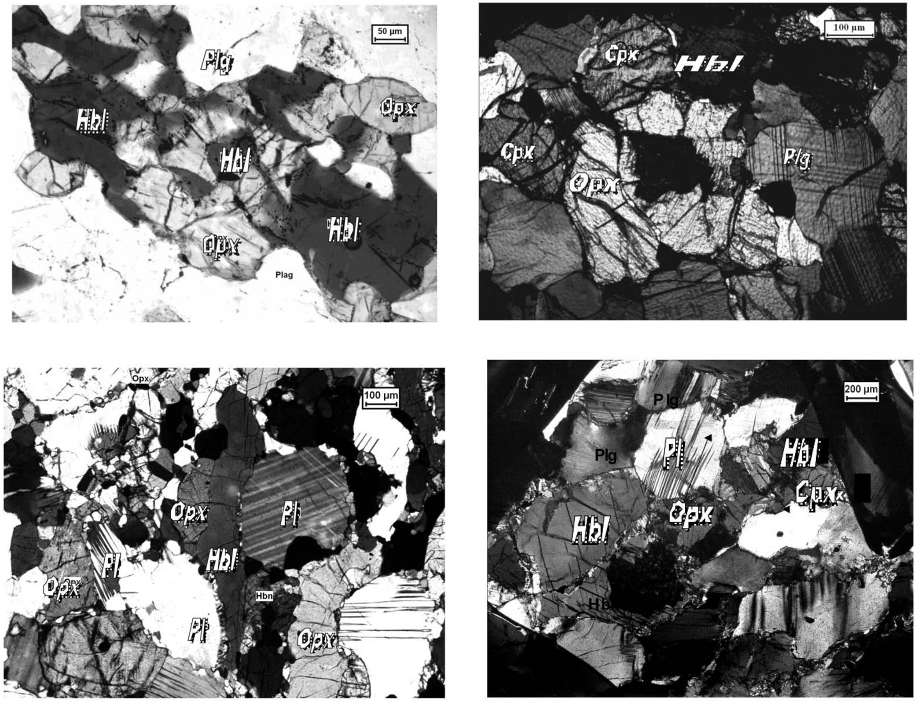


**Fig. 4.** Photomicrographs of hornblende-mafic granulites interbanded with khondalites from different locations.





SED

3, 1–17, 2011

**Relative chronology in high-grade crystalline terrain**

S. Bhattacharya et al.