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PLUME MAGMATISM AND GROWTH OF ARCHAEAN LOWER CONTINENTAL CRUST : EVIDENCE FROM THE EASTERN GHATS BELT, INDIA

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ABSTRACT

Massif-type charnockites of the Eastern Ghats belt, India. are products of partial melting of mafic rocks at lower crustal depths; mafic crustal xenoliths represent the precursor plume-derived basaltic magma. A short time interval between formation of basaltic lower continental crust and partial melting under granulite condition can explain the Fe-poor and intermediate composition of the Archaean (3.0 Ga) lower continental crust, now represented by the massif-type charnockites.

Key words : Lower crustal xenoliths, Plume magmatism, Charnockite-massifs, Archaean lower crust.

INTRODUCTION

Mantle plume tectonics should normally generate basaltic and Fe-rich lower continental crust. But Archaean lower crust is generally Fe-poor, hence if plume tectonics operated well in the Archean, the question of Fe-depletion in the Archaean lower continental crust becomes a major issue of the early evolution of continental crust. One method could be partial melting shortly following the formation of the lower crust (Abbott et al., 2001).

From the high-grade Eastern Ghats belt, India we present evidence which corroborates the hypothesis of partial melting shortly following the formation of the lower crust.

DISCUSSION

TTG's of Archaean cratons are distinctive in their trace element compositions : they are enriched in incompatible trace elements and some recent melting experiments suggest partial melting of a mafic crust as their mode of origin (Patino Douce and Beard, 1995; Rapp and Watson, 1995; Springer and Seck, 1997). However, Rudnick (1995) pointed out that it is difficult to constrain the depth of melting. If the melting occurred within the lower crust, the problem remains that voluminous mafic residues are not present in either the lower crust or in the uppermost mantle below Archaean cratons (Ireland et al., 1994).

Several massif-type charnockite bodies, a few kilometers in length and upto a kilometer in width, are exposed in the high-grade Eastern Ghats belt, along the east coast of India (Fig. 1). The presence of hornblende-bearing mafic granulite xenoliths with primary hornblende; common oscillatory zoning in plagioclase in the charnockite; and distinctive plagioclase (less anorthitic) and orthopyroxene (less magnesian) compositions in the charnockite in comparison to those in the mafic granulite residues (Kar et al., 2003; Bhattacharya, 2003), are consistent with hornblende-dehydration melting experimens (Patino

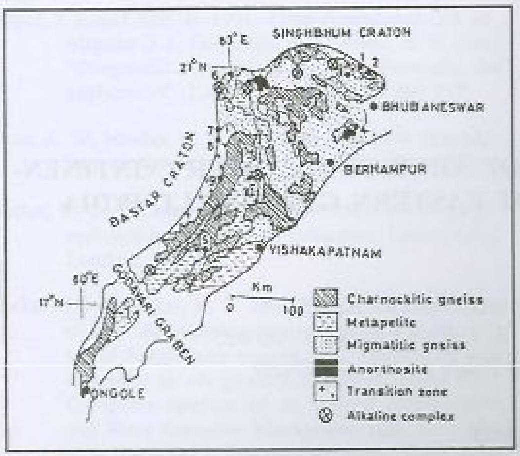

Fig. 1. Generalised geological map of the Eastern Ghats Granulite Belt, India.

Douce and Beard, 1995; Rapp and Watson, 1995; Springer and Seck, 1997). Charnockite-massifs (geochemically equivalent to TTG magma) are thus demonstrably product of hornblende-dehydration melting in a mafic crust and the presence of crystalline orthopyroxene indicates crystallisation at lower crustal depths (Kramers and Ridley, 1989). Moreover, garnet-granulite residues are actually present as cognate xenoliths (Bhattacharya et al., 2001; Kar et. al., 2003), unlike the TTG's of Archaean cratons.

Two examples of massif-type charnockite are described here. These are of tonalitic to trondjhemitic chemistry and are Fe-poor (1 to 5% Fe_2O_3) relative to the Archean mantle estimates of 9.0% to 9.3% (Bickle et al., 1977; Sun and Nesbitt, 1977) and much depleted relative to the mafic granulite residues (8 to 15% Fe_2O_3). The comparative trace element contents of the massif-type charnockites and mafic granulite residues further corroborate the hypothesis of partial melting origin of the massif-type charnockites, which represent the lower continental crust (pressure estimates - 9.0 kilobar) in this high-grade belt. These spidergrams (Figs. 2 & 3), show depletion of Ti, Ni, Zn and Y and enrich-

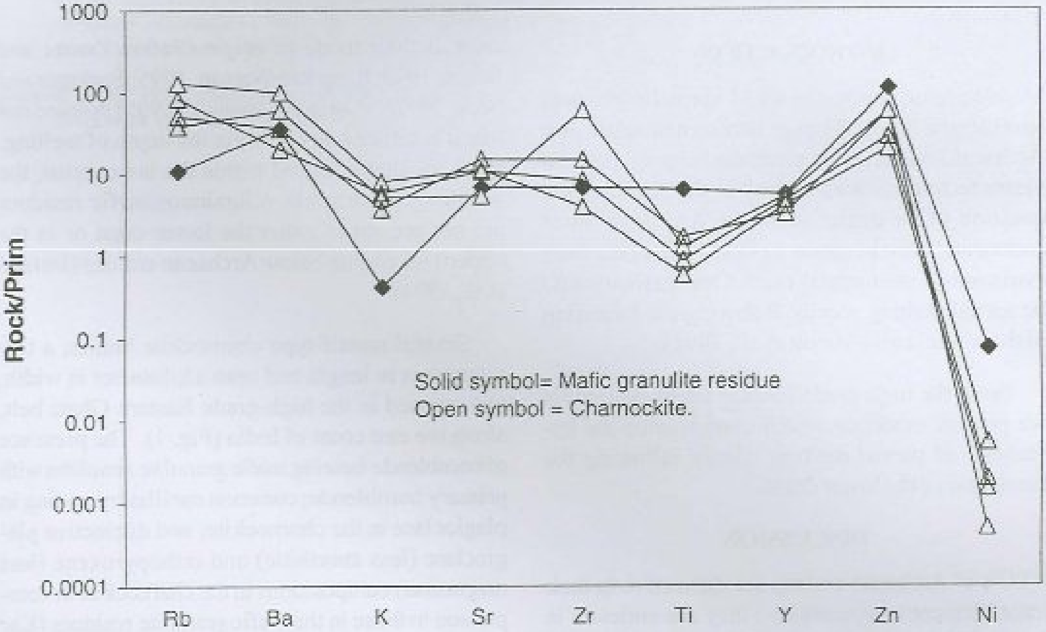

Fig. 2. Multi-element spider plots of the charnockites and hornblende-bearing mafic granulites of the Jenapore suite, Orissa, India. (Location 2 in figure 1).

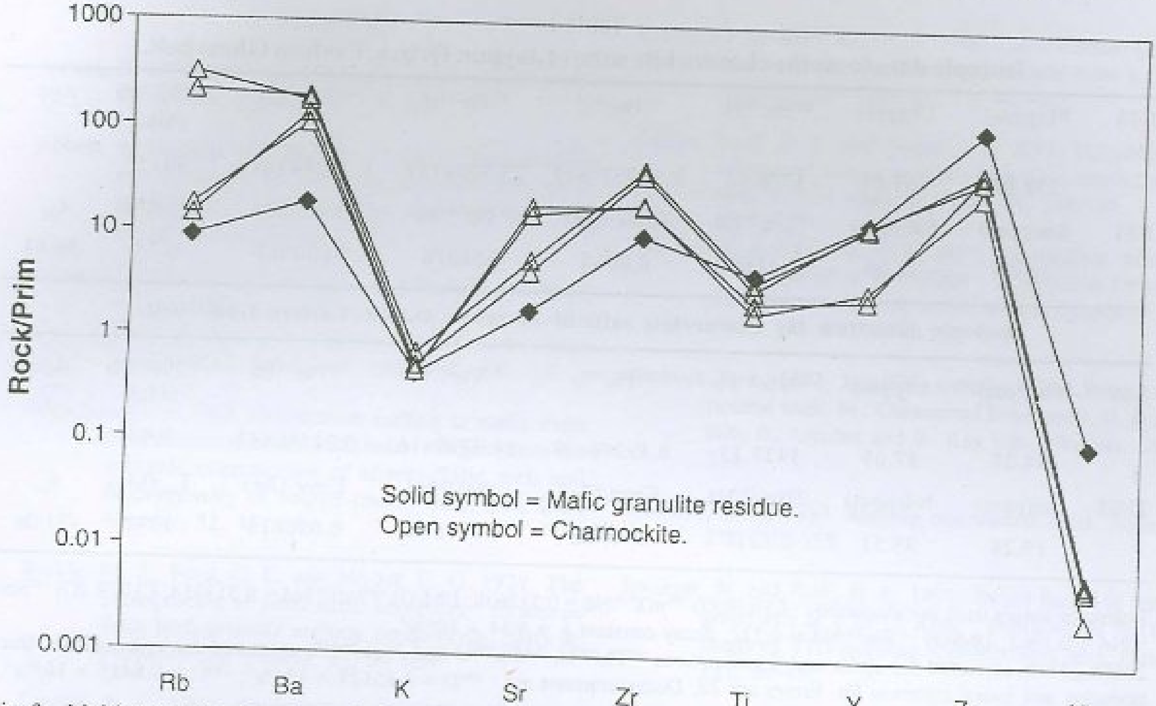

Fig. 3. Multi-element spider plots of the charnockites and hornblende-bearing mafic granulites of the Jaypur suite, Orissa, India. (Location 9 in figure 1).

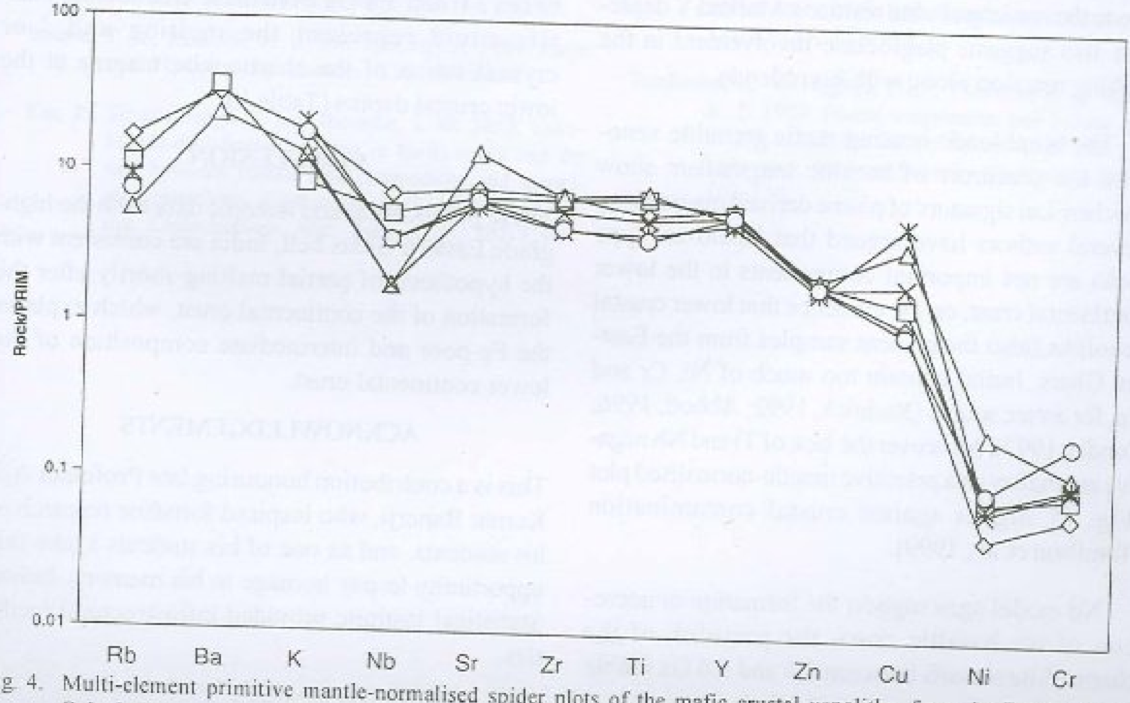

Fig. 4. Multi-element primitive mantle-normalised spider plots of the mafic crustal xenoliths, from the Eastern Ghats Belt, India.

Table 1

Isotopic data from the charnockite suite of Jaypur, Orissa, Eastern Ghats belt.

J-53	Pb(ppm)	U(ppm)	^{206}Pb/^{204}Pb	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb	^{207}Pb/^{206}Pb (Ma)	Age
	258.25	367.65	3778.63	0.584574±27	23.3054±17	0.289145±77	3413	
J-51	Sm(ppm)	Nd(ppm)	^{147}Sm/^{144}Nd	Error (2σ)	^{143}Nd/^{144}Nd	Error (2σ)	T_{DM}(Ma)	$\varepsilon_{(0)}$
	10.04	52.00	0.1168	0.0004	0.51076	0.000017	3675	-36.61

Isotopic data from the charnockite suite of Janepore, Orissa, Eastern Ghats belt.

J-69	Pb(ppm)	U(ppm)	^{206}Pb/^{204}Pb	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb	^{207}Pb/^{206}Pb (Ma)	Age
	34.28	57.69	1423.13	0.49396±18	14.9398±16	0.21456±62	2976	
2J/68	Sm(ppm)	Nd(ppm)	^{147}Sm/^{144}Nd	Error (2σ)	^{143}Nd/^{144}Nd	Error (2σ)	T_{DM}(Ma)	$\varepsilon_{(0)}$
	19.28	95.51	0.1217	0.0006	0.511046	0.000015	3370	-31.06

Reference values used in calculations : CHUR(O) ^{143}nD/^{144}Nd = 0.512638; DM(O) ^{143}Nd/^{144}Nd = 0.513114; CHUR (O) ^{137}Sm/^{144}Nd = 0.1967; DM(O) ^{147}Sm/^{144}Nd = 0.222; decay constant $\lambda = 6.54 \times 10^{-12}a^{-1}$.
206Pb/204Pb corrected for spike and fractionation; ^{207}Pb/^{235}U, ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb corrected for spike, blank, fractionation and initial common Pb. Errors are 2d. Decay constant are : $^{238}U = 1.55125 \times 10^{-10}a^{-1}$; $^{235}U = 9.8485 \times 10^{-10}a^{-1}$.

ment of incompatible elements Rb, Ba and Sr relative to the mafic granulite residues. Marked Y depletion also suggests plagioclase involvement in the melting reaction along with hornblende.

The hornblende-bearing mafic granulite xenoliths, the precursor of basaltic magmatism show geochemical signature of plume derived magmatism. Several authors have argued that island arc type rocks are not important components in the lower continental crust, on the evidence that lower crustal xenoliths (also the present samples from the Eastern Ghats, India) contain too much of Ni, Cr and Co, for an arc source (Rudnick, 1992; Abbott, 1996; Condie, 1997). Moreover the lack of Ti and Nb negative anomalies on a primitive mantle-normalised plot (Fig. 4), argues against crustal contamination (Tomilson et. al., 1999).

Nd model ages suggest the formation or accretion of the basaltic crust, the protolith of the charnockite massifs between 3.4 and 3.6 Ga (Table 1). On the other hand, ^{207}Pb / ^{206}Pb zircon ages between 3.0 and 3.4 Ga from these charnockite massifs could represent the melting and / or crystallisation of the charnockite magma at the lower crustal depths (Table 1).

CONCLUSION

These geochemical and isotopic data from the high-grade Eastern Ghats belt, India are consistent with the hypothesis of partial melting shortly after the formation of the continental crust, which explains the Fe-poor and intermediate composition of the lower continental crust.

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