

# Tectonic and thermal evolution of South India during the Pan-African orogeny

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In this study we present new isotopic and thermobarometric evidence which constrains the crustal evolution of southern Peninsular India, allowing division into tectonostratigraphic terranes. We relate the Pan-African charnockite forming event to regional extensional tectonics. This study has important implications for the reconstruction of Gondwana.

## Introduction

Southern Peninsular India has been thought to consist of an Archaean craton cut by several large Proterozoic shears. The Dharwar Craton is composed of two greenstone belts metamorphosed from greenschist facies in the north to amphibolite facies and patchy granulite facies in the south. The craton formed at about 3.3Ga, and the last widespread metamorphism occurred at *c.* 2.5Ga. The Palghat Cauvery Shear Zone (PCSZ) incorporates several small terranes, metamorphosed to granulite facies also at 2.5Ga. The Madurai Block lies to the south of the PCSZ

(Fig. 1), but the metamorphic and isotopic history of this large segment of South India is hitherto largely unknown. South of the Achankovil Shear Zone (ASZ) is the Kerala Khondalite Belt (KKB). This area is composed of amphibolite-grade metasediments, noted for the development of incipient charnockite, now known to have formed at 550Ma.

Thus there is an important divide in the structure of South India, separating the stable Archaean craton from a younger terrane or terranes. The metamorphic processes have been reasonably well studied both to the north and south, but very little is known about the relationship between the blocks. A major geological division has been identified, which separates a region of crustal growth due to subduction at an active continental margin at the edge of the Dharwar Craton during the Late Archaean, from one in which growth has resulted from terrane accretion during the Proterozoic. We identify the processes that were important in the formation of incipient charnockites from the new isotopic and trace element data, and suggest a model for the tectonic setting in which they occur, in the context of the regional evolution of the Gondwana supercontinent.

## Results

1) Thermobarometric estimates (using Thermocalc; Powell and Holland, 1985) for metapelitic assemblages from the Madurai Block of *c.* 750°C and 5 kbar indicate remarkably uniform pressures across the Madurai Block and the KKB, suggesting that both have experienced a similar *P/T* event. The southwards regional increase in pressure across the southern margin of the Dharwar Craton led to the view that South India was a continuous section of upturned Archaean crust (Newton and Hansen, 1986). A clear metamorphic break is now indicated across the PCSZ.

2) Rb/Sr mineral isochrons (whole rock-bi-plag ± opx) ranging from 540 to 500 Ma have been obtained for charnockites and metapelites from

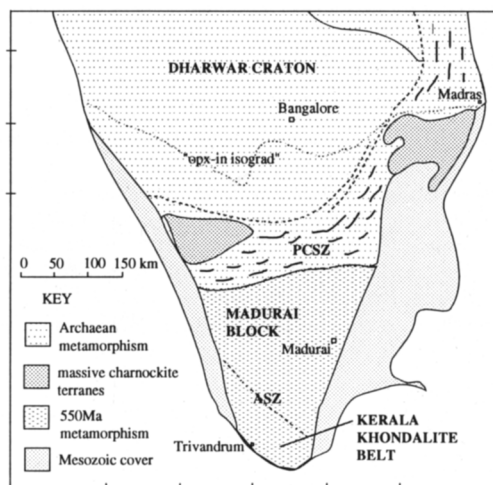


Figure 1. Map of South India, showing the important geological terranes, the shear zones (abbreviations as in text), with the age relations, as identified by this study.

the Madurai Block. Rb/Sr whole rock ages (supported by Pb isotope data) in the Dharwar Craton give unequivocal 2.5Ga ages, whereas the KKB experienced a Pan-African event at about 500Ma. Linking the metamorphic history of the Madurai Block to that of the KKB confirms the importance of the PCSZ as a major geological divide.

3) Model Nd age data for a series of samples throughout the Madurai Block and the KKB show that crustal growth in both terranes occurred between 3.0 and 2.0 Ga. However a small group of metapelite samples from a narrow zone (15 × 3km) along the southern ASZ have model Nd ages of 1.3–1.4 Ga. These samples have chemical compositions distinct from metapelites of the Madurai Block and the KKB, and have been derived from a different source, apparently to the north of the shear zone. Similar rock types of suitable age outcrop north of the Ranotsara Shear in Madagascar. These ages imply that movement on the ASZ must have continued until at least the late Proterozoic.

4) Incipient charnockites (granitoid rocks bearing opx, kfs and quartz) of Pan-African age occur throughout the Madurai Block and KKB. These were formed in an anhydrous regime, probably rich in CO<sub>2</sub>. Although often associated with consumption of garnet, solid solution thermobarometric studies do not support a decompression-related origin for the charnockites. The association of a leucocratic rim to incipient charnockite patches in one locality is superficially suggestive of melt-assisted charnockitisation, but LIL and RE element modelling is not consistent with the charnockite assemblages being restitic after melt extraction.

5) An extensional tectonic setting for charnockite formation at c. 550 Ma is suggested by (i) rapid cooling rates (10°C Ma<sup>-1</sup>) determined by mineral chronometry; (ii) steep transient geotherms (70°C km<sup>-1</sup>) associated with some charnockite localities indicative of convective heat transfer; and (iii) recognition of coeval carbonatites and syenites in south India.

## Discussion

The Dharwar Craton was formed around 3.0Ga. The charnockites here are thought to have been formed as a result of subducting oceanic crust, in a terrane-accreting event, compatible with the observed range of carbon isotope values ( $\delta^{13}\text{C}$  -4 to -12‰) determined from fluid inclusion studies. Preservation of late Archaean biotite Rb/Sr ages suggests that the craton has remained stable since about 2.5Ga.

Much of the Madurai Block and the KKB were formed around 3.0–2.5Ga and have experienced a polymetamorphic history that includes Proterozoic amphibolite facies metamorphism and local granulite facies metamorphism (750°C, 5–6kbar) at c. 550Ma. Similar geological histories have been delineated from the high-grade terranes of Sri Lanka. However, there is evidence from the presence of cordierite-bearing metapelites with young Nd model ages that the South Indian terranes were juxtaposed at some point after 1.3 Ga, by movement along the ASZ.

We can now propose a model for the tectonic setting in which Pan-African charnockites were formed. An increase in the transient geotherm under conditions of low aH<sub>2</sub>O locally produced granulites at relatively low pressures. An influx of mantle CO<sub>2</sub> ( $\delta^{13}\text{C}$  -5 to -7‰) during granulite formation is suggested by fluid inclusion studies in graphite-free charnockites. Magmatic intrusions during the Pan-African event may have both increased the geotherm, and acted as a carrier of dissolved CO<sub>2</sub> (Farquhar and Chacko, 1991). These observations are strongly suggestive of an extensional regime associated with incipient rifting of the Gondwanan supercontinent.

## References

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