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Neoarchean arc magmatism followed by high-temperature, high-pressure metamorphism in the Nilgiri Block, southern India

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ABSTRACT

The Nilgiri Block, southern India is an exhumed lower crust formed through arc magmatic processes in the Neoarchean. The main lithologies in this terrane include charnockites, gneisses, volcanic tuff, metasediments, banded iron formation and mafic–ultramafic bodies. Mafic–ultramafic rocks are present towards the northern and central part of the Nilgiri Block. We examine the evolution of these mafic granulites/metagabbros by phase diagram modeling and U–Pb sensitive high resolution ion microprobe (SHRIMP) dating. They consist of a garnet–clinopyroxene–plagioclase–hornblende–ilmenite ± orthopyroxene ± rutile assemblage. Garnet and clinopyroxene form major constituents with labradorite and orthopyroxene as the main mineral inclusions. Labradorite, identified using Raman analysis, shows typical peaks at 508 cm^{-1}, 479 cm^{-1}, 287 cm^{-1} and 177 cm^{-1}. It is stable along with orthopyroxene towards the low-pressure high-temperature region of the granulite facies (M1 stage). Subsequently, orthopyroxene reacted with plagioclase to form the peak garnet + clinopyroxene + rutile assemblage (M2 stage). The final stage is represented by amphibolite facies–hornblende and plagioclase–rim around the garnet–clinopyroxene assemblage (M3 stage). Phase diagram modeling shows that these mafic granulites followed an anticlockwise *P*–*T*–t path during their evolution. The initial high-temperature metamorphism (M1 stage) was at 850–900 °C and ~9 kbar followed by high-pressure granulite facies metamorphism (M2 stage) at 850–900 °C and 14–15 kbar. U–Pb isotope studies of zircons using SHRIMP revealed late Neoarchean to early paleoproterozoic ages of crystallization and metamorphism respectively. The age data shows that these mafic granulites have undergone arc magmatism at ca. 2539.2 ± 3 Ma and high-temperature, high-pressure metamorphism at ca. 2458.9 ± 8.6 Ma. Thus our results suggests a late Neoarchean arc magmatism followed by early paleoproterozoic high-temperature, high-pressure granulite facies metamorphism due to the crustal thickening and suturing of the Nilgiri Block onto the Dharwar Craton.

1. Introduction

The evolution of a mafic metamorphic rock from its igneous parentage is particularly useful in identifying the extent of metamorphism during convergent tectonics (Bucher and Grapes, 2011). These rocks carry mineral assemblages and reaction textures formed during this intense tectonic process. Compositional variations in these assemblages and calculating its thermodynamic conditions will help to quantify the grade up to which the rock has undergone changes. Prograde and retrograde changes are mainly attributable to continuous net transfer or exchange reactions (e.g., Spear and Peacock, 1989). However, retrograde metamorphic recrystallisation will overprint all the prograde changes during peak metamorphic temperature. During endothermic dehydration reactions in mafic protoliths, like basalt or gabbro, the equilibrium constant would reach its maximum at peak-temperature. This will lead to complete overprinting by the peak mineral assemblage. Thus at peak temperature most of the prograde minerals will be consumed for the production of peak mineral assemblage. Chemical kinetics at this peak equilibrium stage can be understood through textural and compositional variations in different minerals (e.g., Berman, 1988; Bohlen, 1987; Spear et al, 1984). A pressure (*P*)–temperature (*T*) path can be used to represent the evolution of these mafic rocks and the geochronology helps us to understand the timing of the tectonic process. This study focuses on the evolution of mafic granulites/metagabbros from the Neoarchean Nilgiri Block, southern India, through pressure (*P*)–temperature (*T*)–time (t) path and its tectonic significance.

The mafic granulites/metagabbros in the Archean Nilgiri Block mainly consist of a garnet–clinopyroxene assemblage. A recent study by Samuel et al. (2014) has shown, using field relations and geochemical signatures, that these rocks represent mafic underplating with gabbroic composition in an arc magmatic event. Since these rocks represent lower crustal processes in an arc magma chamber, it is worth observing the mineral reactions in them and their petrogenesis to better understand the evolution of

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this terrane. Since garnet–clinopyroxene forms the major minerals, exchange mechanism of Fe–Mg between garnet and clinopyroxene can be used to calculate peak metamorphic conditions (Berman et al., 1995; Ellis and Green, 1979; Pattison and Newton, 1989). Raith et al. (1999) has shown that the charnockites associated with the mafic granulites/metagabbros in the Nilgiri region have undergone granulite facies metamorphism at ~850 °C and 7–9 kbar pressure. Samuel et al. (2014) shows that the charnockites and mafic–ultramafic represents a co-genetic rock suite formed in an arc magma chamber. The evaluation of reaction textures and metamorphic *P–T* path should reveal the nature of the tectonic process that led to the metamorphism of mafic granulites/metagabbro. Depending upon whether the path is clockwise or anticlockwise, tectonic conditions can be evaluated. A clockwise path represents crustal thickening followed by erosional or extensional thinning and an anticlockwise path represents heating followed by crustal thickening (Thompson, 1990). So depending upon the nature of *P–T* path it is possible to evaluate the tectono-thermal history of the terrane.

Tectono-thermal history of the Nilgiri Block, southern India would also reveal crustal growth mechanisms that operated in the Neoarchean. This in turn can be correlated to the nature of formation and accretion of different crustal blocks in the Southern Granulite Terrane and how it is associated with the formation and growth of Neoarchean supercontinent. Comparing the Nilgiri Block with associated crustal blocks in the Southern Granulite Terrane would greatly help in delineating the continental correlation of the Southern Granulite Terrane to nearby terranes. However, in these high-grade rocks, the absence of well-preserved evidence of prograde metamorphism limits our understanding of a variety of tectonic conditions and processes. Following a systematic approach in this study, we use results of field relations, petrography, mineral chemistry, thermodynamic modeling and zircon U–Pb studies to understand the metamorphism and tectonic evolution of mafic rocks in this terrane.

2. Geological settings

The southern Indian peninsula (Fig. 1) is well known internationally for the 3600–2500 Ma old Archean Dharwar Craton (Beckinsale et al., 1980; Buhl, 1987; Jayananda et al., 2000; 2006, 2008, 2013a, b; Nutman et al., 1992; Peucat et al., 1993, 2013; Bhaskar Rao et al., 1996, 2003; Ghosh et al., 2004; Hokada et al., 2013; Ishwar-Kumar et al., 2013; Plavsa et al., 2012; Brandt et al., 2014; Lancaster et al., in press) and a series of late Archean–Proterozoic blocks to the south collectively known as the Southern Granulite Terrane (Bhaskar Rao et al., 2003; Chardon et al., 2008, 2011; Chetty et al., 2003; Clark et al., 2009a; Clark et al., 2009b Collins et al., 2014; Drury and Holt, 1980; Ghosh et al., 2004; Glorie et al., 2014; Harris et al., 1994; Nutman et al., 1992; Peucat et al., 1993,

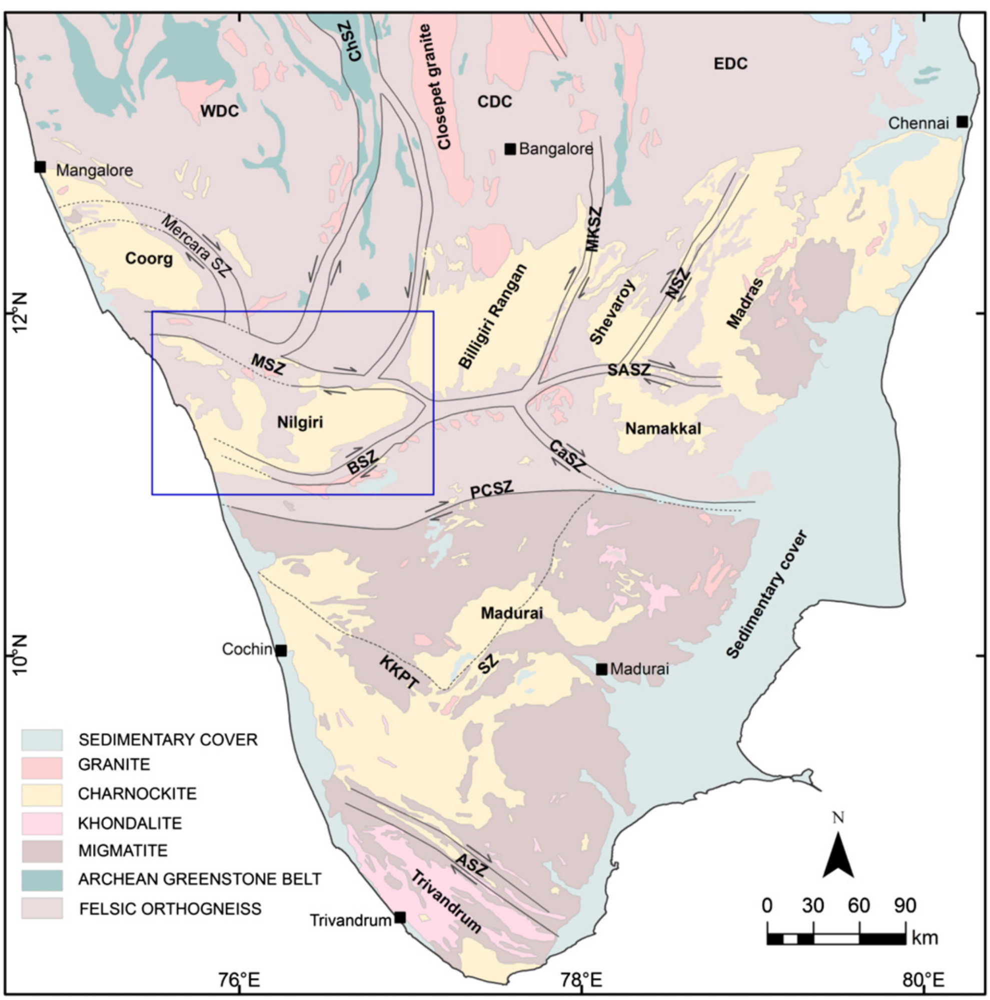

Fig. 1. The regional geology and tectonic framework of southern India after Ishwar-Kumar et al. (2013). The blue box represents the study area (Nilgiri Block, southern India). Acronyms: TTG — Tonalite–Trondhjemite–Granodiorite, KSZ — Kumta Shear Zone. CoSZ — Coorg Shear Zone, ChSZ — Chitradurga Shear Zone, MKSZ — Mettur–Kolar Shear Zone, NSZ — Nallamala Shear Zone, MSZ — Moyar Shear Zone, BSZ — Bhavani Shear Zone, SASZ — Salem–Attur Shear Zone, CaSZ — Cauvery Shear Zone, PCSZ — Palghat–Cauvery Shear Zone, KKPT — Karur–Kambum–Painavu–Trichur Shear Zone; ASZ — Achankovil Shear Zone, WDC — Western Dharwar Craton, CDC — Central Dharwar Craton, EDC — Eastern Dharwar Craton, EGMB — Eastern Ghats Mobile Belt.