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*Corresponding author

Meraj Alam, Department of Geology, Indira Gandhi National Tribal University, Amarkantak, MP-484887, India

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Mini Review

Geochemical Constraints on Granulites of the Central Indian Shield: Key Insights into Crustal Evolution

Meraj Alam[1*], Shahnoor Alam[2], Shahina[3] and Rakesh Kumar P[1]

[1]*Department of Geology, Indira Gandhi National Tribal University, Amarkantak, MP-484887, India*

[2]*Department of Geology, Aligarh Muslim University Aligarh, UP-202002*

[3]*Geological Survey of India, Northern Region, Lucknow, UP-226024, India*

Abstract

Granulites are significant rocks that are eminent by distinct factors. One of the vital factors is that these rocks are counterparts of middle and lower crustal rocks because they are ready for fairly rational pressure-temperature estimation, existing on the borderline between melting and metamorphism. In the central Indian shield, the granulite belts commonly occur along the shear zones within the Central Indian Tectonic Zone (CITZ). The CITZ is a collage of different granulite belts, including Bhandara-Balaghat Granulite (BBG), Ramakona Katangi Granulite (RKG), and Makrohar Granulite (MKG) belts from south to north, which correspond to a multiphase orogenic evolution during Late Paleoproterozoic to Early Neoproterozoic time. Previously, numerous investigations were carried out in the central Indian shield, which are majorly refrained based on phase equilibria, thermobarometry, and metamorphic reactions. Geochemical and geochronological data sets may indicate that the granulite and granitic magmatism connected with the acidic magmatism during the Columbian crustal assembly.

Introduction

The last three decades have been notable for granulites because this is prominent by several factors. These rocks are considered suitable analogs of lower and middle crustal rocks because they are adaptable to estimate a pressure temperature and exist on the border between metamorphism and melting. For the successful understanding of lower crustal geodynamic processes in orogenic belts, P-T trajectories in granulite facies rocks need to be reconstructed [1]. The Indian Shield was formed during the Late Mesoproterozoic-Early Neoproterozoic by collisions between the Northern Indian Block (NIB) and the Southern Indian Block (SIB). The Indian Shield is the collage of different cratonic blocks bounded by the mobile belts and exposed by the distinct tectonic magmatism (Figure 1). In the central Indian Shield, the granulite facies terrains commonly occur along the shear zones within the Central Indian Tectonic Zone (CITZ). The tectonic zone is a union of different granulite belts like Bhandara-Balaghat Granulite (BBG), Ramakona Katangi Granulite (RKG), and Makrohar Granulite (MKG), which correspond to a multiphase orogenic evolution at the period between Late Paleoproterozoic to Early Neoproterozoic. These rocks have received little attention until about a decade ago. However, they may provide significant evidence to constrain the manifestation of the lower crust and the overall crustal evolution. Numerous petrological investigations have been carried out for two decades. Indeed, in recent decades, several studies have also been conducted on the petrology of these granulites. These studies are majorly refrained by the phase equilibria, thermobarometry, and metamorphic reactions. Complementary studies such as geochronological determinations have been enabled based on these petrological studies.

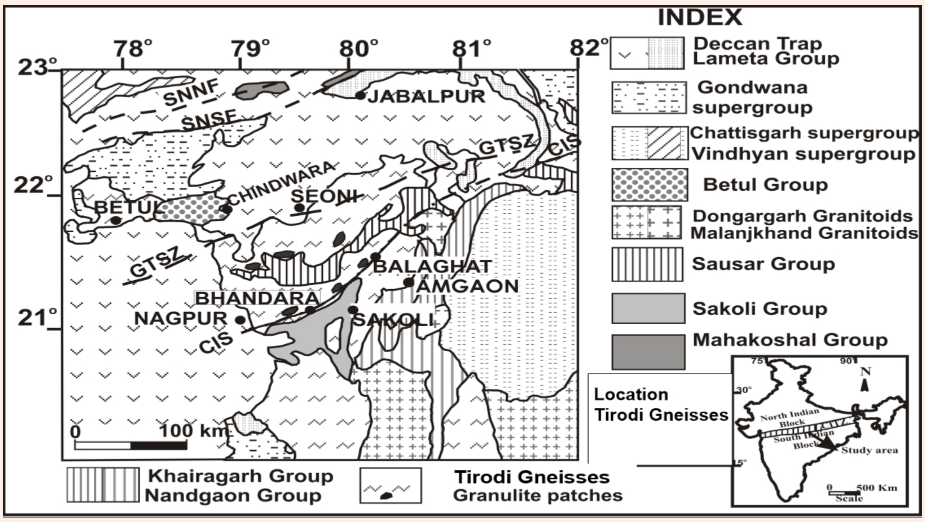

Figure 1: Geological map shows the major share zones, granulites belts, and other lithological units within the CITZ, central India (modified after [2]. Abbreviations: SNSF-Son-Narmada South Fault; SNNF-Son-Narmada North Fault; CIS-Central India shear; GTSZ-Gavilgarh-Tan shear zone.

Background of Granulites in the CITZ: Geochemical Constraints

Bhandara-Balaghat Granulite Belt (BBGB)

The multiphase tectonic-thermal and tectonic-magmatic events developed this allochthonous block [3]. This belt is characterized by the two-pyroxene granulite, a variety of garnet-bearing and garnet-free rocks developing in gabbroic magmatic emplacement in the Bhandara region [4]. Geochemically, the average REE pattern shows moderate Light Rare Earth Element (LREE) enrichment and having a nearly similar abundance of Heavy Rare Earth Element (HREE) without any anomaly with respect to chondrite (data used after [5, Figure 2a]. The Primitive Mantle (PM)-normalized multi-element patterns display a nearly flat pattern, and the depletion occur in Th, Nb, P, Zr and Ti elements. However, the elements, including U and Pb depict positive anomalies (data used after [5, Figure 2b]. The geochemical characteristics suggest a moderate abundance of REE with higher degrees of partial melting of the upper mantle with some crustal influence for source derivation of granulite protolith. These signatures correspond to an Archaean island-arc tholeiitic source, which has been derived from a variably enriched lithospheric mantle source [4]. Furthermore, the protolith of mafic granulites can be linked to melts that evolve from metasomatized SCLM through fractional crystallization processes [5].

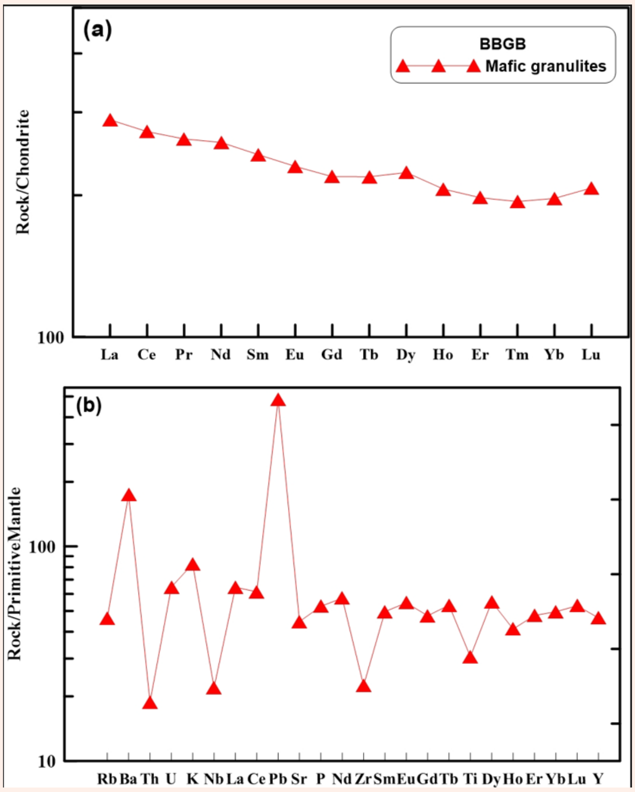

Figure 2: (a) Rock/chondrite normalized rare earth element diagrams for mafic granulites from BBGB, CITZ (average data used after Alam et al. [5]) (b) Rock/primitive mantle normalized spider diagram for studied rocks (data used after Alam et al. [5]). Normalization values of chondrite and primitive mantle use after

Ramakona Katangi Granulite Belt (RKGB)

The RKGB is a high-pressure upper amphibolite–granulite-facies domain that is locally referred to as the Ramakona-Katangi Granulite (RKG) belt in the northern margin of the Sausar Mobile Belt (SMB) intruded with numerous pods and lenses of mafic granulite, garnetiferous amphibolite, pelitic granulite, and porphyritic charnockite occur within high-grade gneisses [6]. Grenville-aged collisional events have inferred this belt during the final collision of the SIB and the NIB [7,8]. In this metamorphic region, the peak metamorphism occurs between 9-10 kbar and 750°-850 °C [9]. The geochemical and geochronological data on the RKGB is not sufficiently robust, and a synthesis can be attempted.

Makrohar Granulite Belt (MKGB)

The MKGB is parallel to the Son-Narmada lineaments and NE-SW trending belt in the CITZ. The granulite pods and lenses have varying dimensions, trending NW-SE and EW [10], comprising corundum-bearing, two-pyroxene granulites and meta-pelite [11]. These are typically linked to mantle-derived mafic, alkaline rocks, and granitic units. According to [11,12], the granites that host these granulite lenses provide an age of 1.73 Ga, which implies the granulite metamorphic age, which is older. The MKGB in the Mahakoshal basin has followed a clockwise trajectory [10], indicating a collisional environment. No geochronological data is available on the granulites from Makrohar, but granites dated as 1.73 Ga [11,12], contain lenses of granulites, which implies that they formed earlier. Based on these observations, the eastern part of CITZ has a similar Columbian history. It is possible to synthesize the geochemical and geochronological data for the MKGB since the data still need to be sufficiently robust.

Evolution of Granulites and Crust in the Central Indian Shield

The granitoids from Tirodi Gneissic Complex (TGC), SMB, and BBGB show the Nd (TDM) model ages, which are bracketed (2.36-2.78 Ga), (1.49-3.00 Ga), and (1.51-3.29 Ga), respectively [13]. Lower model ages imply that this suite of rocks developed from the source extracted from the crustal/lithosphere during or before 1600 Ma (Figure 3a-3e), in agreement with U-Pb zircon ages (1534-1618 Ma [14,15]. The geochemical and isotopic evidence suggests that the BBGB has been derived from variably enriched lithospheric mantle source inferred to the Archaean island-arc tectonic setting [4]. The RKGB is marked by Grenville-aged collisional events that have inferred the final collision of the SIB and the NIB [7]. The petrological evidence suggests that the MKGB has followed a clockwise trajectory [10], which corresponds to the collisional environment. Moreover, geochemical and isotopic evidence may suggest that the granulite and granitic magmatism connected with the felsic magmatism inferred to the Columbian crustal assembly. Moreover, the Columbia supercontinent disintegrated, and the evolution of the Indian landmass (Indian Peninsula) also played a role.

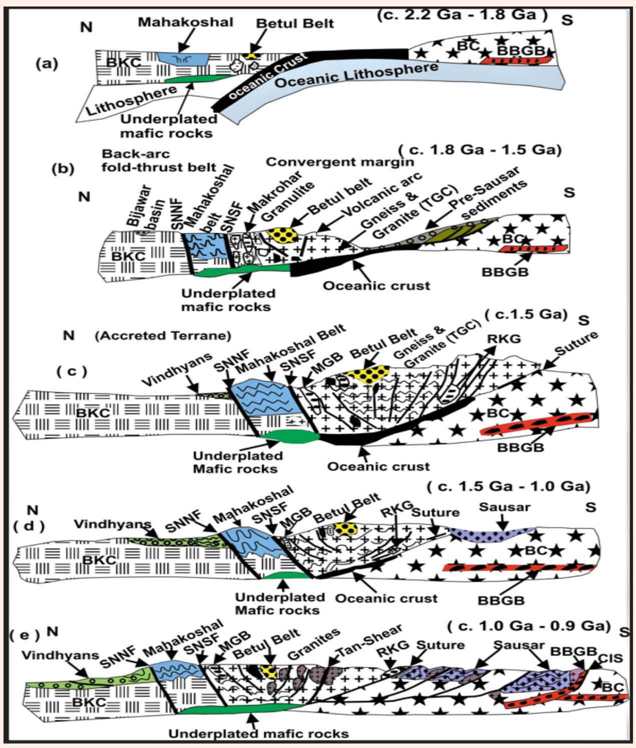

Figure 3: (a-e) A tectonic cartoon model for the CITZ evolution emphasizes the continent-continent collision-related granulite and granitic magmatism (modified after [13,16] Abbreviations: Bundelkhand Craton- BKC; Bastar Craton-BC; Bhandara-Balaghat Granulite Belt-BBGB; Makrohar Granulite Belt-MGB; Ramakona-Katangi Granulite-RKG.

Conclusion

The granulite belts, including Bhandara-Balaghat Granulite (BBG), Ramakona Katangi Granulite (RKG), and Makrohar Granulite (MKG) belts from south to north commonly occurs along the shear zones within the Central Indian Tectonic Zone (CITZ), which correspond to a multiphase orogenic evolution during Late Paleoproterozoic to Early Neoproterozoic time. These belts comprise two-pyroxene (mafic granulites), garnetiferous amphibolite, and meta-pelitic granulites within felsic rocks. Geochemical evidence suggests that the mafic granulites have been derived from variably enriched lithospheric mantle sources. Although, the geochemical and geochronological data on the RKG, MKG BBG belts are not sufficiently robust hitherto, a synthesis can be attempted to unravel the clear picture of overall crustal evolution in the Indian shield. Nevertheless, available geochemical and geochronological data sets may indicate that the granulite and granitic magmatism connected with the felsic magmatism during the Columbian crustal assembly [16,17].

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