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Petrology and mineral chemistry of Mesoproterozoic granitoids from the southwestern Chhotanagpur Granite Gneiss Complex (CGGC), Central India: Physico-chemical conditions of crystallization

Mohammad Qasim[1,2], Satya Narayana Mahapatro[3], Aparajita Tripathi[4] and M. Ram Mohan[1,2*]
[1]CSIR-National Geophysical Research Institute, Hyderabad - 500007, India
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad - 201002, India
[3]Geological Survey of India, Southern Region, Hyderabad - 500068, India
[4]Department of Geology, Centre for Advanced Study, Institute of Science, Banaras Hindu University, Varanasi - 221005, India
*Corresponding Author (Email): rammohan.ngri@csir.res.in

ABSTRACT

We present field relationships, petrographic features, and mineral chemistry of feldspar, biotite, and amphibole for the Mesoproterozoic granitoids from the southwestern part of the Chhotanagpur Granite Gneiss Complex (CGGC) in central India. Based on field and petrographic observations, the granitoids in the study area are characterized as porphyritic granite and equigranular granite. The P-T-fO_2 conditions and physico-chemical environment during the emplacement of these granitoids have been established based on mineral compositions of amphibole and biotite. The estimated temperatures from amphibole and biotite thermometry are similar with ranges of 738-769 °C for porphyritic granite and 723-798 °C for equigranular granite, respectively. The calculated barometry based on amphibole and biotite shows pressures ranging from 3.2 to 4 kbar for porphyritic granite, from 2 to 2.8 kbar for equigranular granite, and attaining up to 5.7 kbar for the equigranular granite. The estimated barometric conditions suggest the crystallization of porphyritic granite at a depth of ~13 km, and the equigranular granite, at ~14 km, corresponding to the upper-crustal crystallization conditions. The amphibole composition indicates that the granite crystallized from a volatile-rich magma under high oxygen fugacity conditions. Biotite and amphibole thermobarometric conditions of equigranular granite, indicate that these rocks crystallized under a high-oxidizing environment buffered in NNO (nickel-nickel-oxygen) to HM (hematite-magnetite) conditions. Biotite compositions indicate these granitoids to have been derived from a crustal source due to alkaline A-type parental magma in an anorogenic tectonic environment.

Keywords: Mineral chemistry; Thermobarometry; Mesoproterozoic; A-type granitoids; Chhotanagpur Granite Gneiss Complex (CGGC); oxygen fugacity.

INTRODUCTION

Granitoids constitute a significant part of the continental crust and exhibit diverse chemical compositions. Petrogenetic studies of granitoids, play a vital role in unravelling the crustal evolution and crust-mantle interaction across different tectonic settings, providing a broader picture of crustal growth (Campbell and Taylor, 1983; Annen et al., 2006; Cawood et al., 2022). Understanding the geochemical diversity in granitoids of calc-alkaline and alkaline affinity under different temperature (T), pressure (P), and oxygen fugacity (fO_2) conditions, helps to decipher the physico-chemical conditions of magma crystallization and the tectono-magmatic evolution (Wones and Eugster, 1965; Speer, 1987; Vyhnal et al., 1991; Abdel-Rahman, 1994; Ague, 1997; Bhattacharya et al., 2014).

Amphibole and biotite are two common ferromagnesian mineral phases present in granitic rocks, which are sensitive to changes in pressure, temperature, and oxygen fugacity (fO_2) (Putirka, 2016; Joshi et al., 2021; Gion et al., 2022; Bartoli et al., 2024). Thus, compositions of these mineral phases are utilized to determine the thermobarometric conditions during the emplacement of granitic rocks. The compositions of these minerals are substantially influenced by the magma chamber processes, their source characteristics, and tectonic setting (Abdel-Rahman, 1994; Elliott, 2001; Bachmann and Dungan, 2002; Kumar and Pathak, 2010; Ridolfi et al., 2010; Elangovan et al., 2020). Studies have shown that aluminium and titanium contents in amphibole are sensitive to crystallization depth, temperature, pressure, and oxygen fugacity (fO_2) (Schmidt, 1992; Ridolfi et al., 2010). Several parameters, such as the Al-in-hornblende (Hammarstrom and Zen, 1986; Schmidt, 1992; Ridolfi et al., 2010), Ti-in-hornblende (Otten, 1984), coexisting hornblende-plagioclase compositions (Holland and Blundy, 1994), and water contents in amphibole (Naney, 1983; Dall'Agnol et al., 1999; Parat et al., 2008; de Oliveira et al., 2010), are widely used to measure the geothermobarometric conditions and stability depth for amphibole crystallization. Similarly, biotite is also sensitive to the crystallization conditions of magma, such as pressure, temperature, fO_2, and water contents (Wones and Eugster, 1965; Czamanske and Wones, 1973). It has been demonstrated that the chemistry of biotite provides reliable constraints on parameters such as oxybarometer, melt composition, and the tectonic setting (Czamanske and Wones, 1973; Abdel-Rahman, 1994; Shabani et al., 2003). Redox conditions of granitic magma (Kumar and Pathak, 2010; Raju et al., 2022) correspond to the biotite end-members, such as annite (Fe^{2+}) and oxynite (Fe^{3+}). These end-members of biotite are also associated with the magnetite- and ilmenite-series of Ishihara (1977), respectively.

The Chhotanagpur Granite Gneiss Complex (CGGC) (Figure 1a) lies in central India and represents an extended crustal segment of the Proterozoic Central Indian Tectonic Zone (CITZ) (Acharyya, 2003; Sanyal and Sengupta, 2012). The basement complex of the CGGC is intruded by several episodes of calc-alkaline and alkaline granitic magmatism during the Proterozoic. Nonetheless, the granitoids are the major components of the CGGC and exhibit a wide range of