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Comparative petrogenesis and tectonics of Paleoproterozoic Malanjkhand and Dongargarh granitoids, Central India

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ABSTRACT

The Malanjkhand granitoid (MG) and two units of Dongargarh granitoids (DGs) represent contemporaneous episodes of Paleoproterozoic felsic magmatism in the Bastar Craton, Central India. A comparative geochemical study is carried out between the mineralized Malanjkhand granitoid (MG) and barren Dongargarh granitoids (DGs) that occur adjacent to each other separated by the Dongargarh Group of rocks. Major element oxides geochemistry reveals that MG is granite–granodiorite whereas DG is strictly granite in composition and both plutons show calc-alkaline affinity. Geochemical discrimination indicates that MG is an I-type, whereas an A-type affinity can only be suspected in case of DG and both can be labeled as 'peraluminous'.

Trace element data from these Paleoproterozoic granitoids indicate that they evolved in a tectonic environment similar to continental rift setting. HFSE ratios suggest variable degree of fractionation of highly differentiated granitic magma was a very complex crystallization process results in the formation of these two granitoids by common mechanism, possibly fluid separation might be involved. Highly fractionated REE and depleted MREE patterns with Eu-anomaly absent in MG and negative in DG, inferred that the parental magma derived by low-degree partial melting of heterogeneous mafic source probably amphibolitic in nature, followed by progressive differentiation.

Zircon saturation temperature and Zr content reveals that MG crystallized from wet melt whereas DG crystallized from relatively dry melt but both are classify as hot-granites. Thermobarometric calculations indicates that MG has emplaced at upper level whereas DG at relatively deeper or middle-upper level in the continental crust. The origin of Palaeoproterozoic granitoids in Central India has attributed to the magma mixing process between crustal derived felsic and mafic magma contributed by basaltic underplating in a continental rift environment.

1. Introduction

Granitoids are the ultimate products of magmatic evolution and crustal differentiation (Kemp et al., 2007; Vigneresse, 2007). Continental granite magmatism involves four stages: melting, segregation, ascent, and emplacement (Petford et al., 2000; Vigneresse, 2004). Experimental studies indicate that most granitic magma formed by dehydration melting processes (Naney, 1983; Rushmer, 1991; Rapp and Watson, 1995). Generation of granitic magma in the crust often results in the formation of precious-, chalcophile- and lithophile-metal deposits due to precipitation of metal-bearing fluids that separate during crystallization (Sillitoe, 1996). However, most of the granitoids are economically unproductive due to insufficient supply of metals from the source magma during partial melting. Magma generated during partial melting of the crust or mantle have variable proportions of compatible as well as incompatible elements. The compatible are elements easily incorporated into the cations sites of mineral phases whereas incompatible elements are concentrated in the melt phase of the magma. The distribution of relatively immobile incompatible elements in crustal rocks are used to characterize the sources of igneous protoliths (Rudnick and Taylor, 1987; Condie, 1997) assuming that the distribution of incompatible element inherited directly from the source via crystal/melt equilibria (Condie et al., 2004). These elements are an important group of chemical tracers that used to investigate magmatic differentiation processes (Fulmer et al., 2010).

The world class copper deposit is hosted by the Paleoproterozoic Malanjkhand granitic pluton. The Dongargarh granitoid pluton, located further south of Malanjkhand, have no signature of mineralization, and supposed to be barren in nature. Panigrahi et al. (2004) provided precise SHRIMP RG data on zircons from the

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Malanjkhand granitoid and suggested the age of granitic activity at ca 2.48 Ga. However, whole rock Rb–Sr ages range between 2.24 and 2.46 Ga (Ghosh et al., 1986; Panigrahi et al., 1993) which can be attributed to hydrothermal overprint (Panigrahi et al., 2004). Whole rock isochron studies using Rb–Sr, Sm–Nd, and Pb–Pb isotope ratios on the Dongargarh granitoids gave variable ages that range between 2.27 and 2.46 Ga (Sarkar et al., 1981; Krishnamurthy et al., 1988; Pandey et al., 1993). Various workers (Panigrahi et al., 1993, 2004, 2009; Kumar and Rino, 2006; Narayana et al., 2000) have suggested that Malanjkhand and Dongargarh granitoids were derived from crustal sources and contemporaneous in age because their whole rock isochron ages overlap. In this paper, we present data on major, trace element (including REE) and mineral–chemical data from these two Paleoproterozoic granitoids from Central India located in the south of Central Indian Tectonic Zone (CITZ). Primarily, we attempt an evaluation of the petrogenesis of these granitoids in terms of geochemical variations and estimate the P–T conditions of granite emplacement. The main objective is to compare the geochemical characteristics of mineralized (Malanjkhand) vs. barren (Dongargarh) granitoids and their tectonic environments.

2. Regional geology

The Precambrian shield of Central India is dominantly occupied by the continental block known as Bastar/Bhandara craton (Naqvi and Rogers, 1987). The ENE–WSW trending Central Indian Tectonic Zone (CITZ; Fig. 1a) comprises of two parallel structural domains (Fig. 1a): Son-Narmada (SONA) lineament in the north and Sausar Mobile Belt (SMB) in the south. It bisects the Peninsular Indian subcontinent into two halves (Yedekar et al., 1990; Acharyya, 2003). The CITZ lies in the north-northwestern contact formed because of accretion of the Bundelkhand Craton and Bastar Craton (Yedekar et al., 1990; Roy et al., 2001, 2006). The southern boundary of the CITZ is associated with granulite belt with high strain ductile shear zone called Central Indian Suture (CIS) is ~500 km in length trending ENE–WSW from southeast of Nagpur to south of Korba (Jain and Yedekar, 1989; Jain et al., 1991; Mall et al., 2008). The major granitic activities in the Central India comprises of Malanjkhand, Dongargarh, Dhanora–Manpur, Kanker–Mainpur, Malkangiri and Bastar plutons.

The Malanjkhand granitoid (MG) exposed over an area of 1400 km^2, located adjacent to south-southeast of CIS and hosting one of the largest copper deposit of India (Fig. 1b). It is dominantly constituted of coarse-grained granodiorite, well exposed in the copper mines, where it is dominantly pink and sporadically gray in the rest part. The pink and gray granitoids together furnish identical age ~2.48 Ga (U/Pb SHRIMP RG dating of zircons; Panigrahi et al., 2004) and labeled as phase-I of the Malanjkhand granitoid complex. There are occurrences of a minor but prominent phase of leucogranite (granodioritic to granitic) within the main phase, considered as the phase-II of the Malanjkhand grabitoid complex by the same authors. This unit yielded an imprecise younger Rb–Sr whole rock age ~2.1 Ga (Panigrahi et al., 1993). Gneissic rocks of Amgaon group occur adjacent to the western and southern margins and younger volcanic rocks of Nandgaon Group occur to the eastern contact of the Malanjkhand pluton. Some petrogenetic aspect of MG including the minor leucogranite phase was discussed by earlier workers (Panigrahi et al., 1993; Sarkar et al., 1996). Kumar and Rino (2006) proposed that MG has originated due to mixing of mafic and felsic magma in various proportions within a dynamic magma chamber and emplaced at shallow crustal level. However, Stein et al. (2004) suggest that MG may be part of a separate micro-continent in the Neoarchean–Paleoproterozoic times that experienced growth through subduction-related calc-alkaline magmatism and subsequently dismembered between the Bastar and Bundelkhand Cratons. Stein et al. (2004, 2006) also provided Re–Os models and isochron ages of molybdenite (2.49–2.44 Ga) from the Malanjkhand deposit and interpreted them as discrete deformation episodes and molybdenite deposition, which overlaps with the zircons ages (~2.48 Ga) possibly due to protracted or episodic hydrothermal activity (Panigrahi et al., 2008). Further, microstructural and anisotropy of magnetic susceptibility studies reveals that emplacement of MG and tectonic evolution of CITZ was synchronous during the Neoarchean/Paleoproterozoic time (Majumder and Mamtani, 2009). Bhandari et al. (2010) presented Mesoproterozoic timing (~1.6 Ga) of high pressure–ultra high temperature metamorphic event in CITZ. In a recent study, Naganjaneyulu and Santosh (2010) considered the Mesoproterozoic event to mark the timing of subduction-collision tectonics along the CITZ after examining various geochronological data. However, Mohanty (2010) suggested Mesoproterozoic–Neoproterozoic event (~2.1–0.8 Ga) for the development of CITZ subjected to multiple deformation and metamorphic episodes (~2.1–1.9 Ga, ~1.8–1.7 Ga, ~1.6–1.5 Ga, ~1.1–1.0 Ga, and ~0.9–0.8 Ga events). Therefore, we consider the development of CITZ was younger event compared to the granite magmatism in Central India, possibly a Mesoproterozoic event or later.

Dongargarh granitoids exposed over an area of about 10,000 km^2, located about 50 km south of the Malanjkhand and comprises of three units such as Amgaon, Chichola, and Manpur pluton, supposedly devoid of economic mineral deposits or barren in nature. In the present study (Fig. 1b), Amgaon and Chichola units are considered as Dongargarh granitoids (DGs). The Dongargarh granitoids yielded whole rock isochron age based on Rb–Sr systematics ~2.27 Ga (Sarkar et al., 1981), ~2.46 Ga (Krishnamurthy et al., 1988), Sm–Nd systematics ~2.36 Ga (Krishnamurthy et al., 1990), and Pb–Pb systematics ~2.41 Ga (Pandey et al., 1993). The Dongargarh Supergroup (Fig. 1b) divided into two groups of bimodal volcano-sedimentary sequences (Nandgaon and Khairagarh Group; Sarkar, 1994). Some petrogenetic aspect of the DG was discussed by earlier workers (Deshpande et al., 1990; Narayana et al., 1995; Rao et al., 1997; Ramachandra and Roy, 1998; Divakara Rao et al., 2000). Earlier, Narayana et al. (2000) suggested that DG comprises three distinct textural and compositional varieties such as porphyritic granodiorite, coarse equigranular granite, and microgranite/aplite containing rounded microgranular enclaves. The texture and mineralogy of these microgranular enclaves are similar to the enclaves found in MG (Kumar et al., 2004, Kumar and Rino, 2006). Prophyritic dolerite dykes with feldspar phenocrysts and small-scale fluorite mineralization found at Chandi Dongri occurs in DG (Deshpande, 1984; Changkakoti et al., 2006). Geochemical investigation on DG and basic volcanics indicates that there was a continental rift setting in this area during Neoarchean–Paleoproterozoic time (Narayana et al., 1995; Rao et al., 1997). In a similar approach, origin of rhyolites from a source of intermediate composition and large scale bimodal volcano-sedimentary sequences of Nandgaon group also attributed to rift-type tectonic settings (Deshpande et al., 1990; Ramachandra and Roy, 1998; Divakara Rao et al., 2000). Dongargarh bimodal volcanics show a close affinity with island-arc magmas whereas associated sedimentary sequences indicates a stable continental margin setting. Therefore, a continental rift setting rather than an island arc conditions was more favorable for Dongargarh volcanics (Neogi et al., 1996). Anatexis of the Archean lower continental crust in the continental margin tectonics setting favor the generation of I-type granodiorite followed by A-type granite because of episodic mafic magma underplating (Narayana et al., 2000). The field relations, compositions of both granitoids and their associated mineralization suggest that the MG phase intruded prior to the intrusion of DG (Narayana et al., 2000). A comparative approach suggests that