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Geochemistry and Origin of Neoproterozoic Granitoids of Meghalaya, Northeast India: Implications for Linkage with Amalgamation of Gondwana Supercontinent

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Abstract

Many granitic bodies intrude the basement gneisses in Meghalaya Plateau, Northeast India. Rb–Sr whole-rock isotopic ages of the granitoids range from 881 to 479 Ma while the ages of the basement orthogneisses vary from 1714 to 1150 Ma. All the plutons are dominantly metaluminous and show geochemical variation. Oxygen isotopic compositions in the granitoids and gneisses are concordant ($\delta^{18}O$: + 5.78‰ to + 8.70‰). However, the gneisses from high-grade terrain have low $\delta^{18}O$ value of +2.52‰ to +5.31‰. Initial $^{87}Sr/^{86}Sr$ (I_{Sr}) ratios of the plutons vary from 0.70459 to 0.71487 and tend to increase with progressive younging in age. The geochemical characters suggest derivation of the granites from lower crustal source. The fractionated rare earth patterns observed in the granitoids can be obtained by partial melting of gneisses or diorites. Some gneiss samples have experienced interaction with hydrothermal fluids resulting in lowering $\delta^{18}O$. The isotopic ages of granite plutonism in Meghalaya are similar to the plutonic and tectonothermal events in other parts of India, southwestern Australia and document final amalgamation events of the Gondwana Supercontinent.

Key words: Neoproterozoic granite, oxygen isotope, petrogenesis, Meghalaya, Northeast India.

Introduction

A suite of granite plutons intrudes the Proterozoic orthogneiss and metasediments of the Meghalaya Plateau, NE, India. Rb-Sr whole-rock isotopic ages of the granite plutons range from 881 to 479 Ma and contrast with the 1714–1150 Ma ages of the basement gneisses (Ghosh et al., 1991; 1994a; Chimote et al., 1988; Selvan et al., 1995). These isotopic ages are similar to those of the granite plutons of Kerala (740–550 Ma, Santosh and Drury, 1988); Tamil Nadu (637 to 395 Ma, Nathan et al., 2001; Santosh et al., 2005) and acid volcanic activity in Rajasthan (780 to 680 Ma, Rathore et al., 1999) and tectonothermal events in Eastern Ghats, Orissa (553 to 550 Ma, Aftalion et al., 2000). The magmatic history of Meghalaya is important as the plateau forms the northeastern margin of Neoproterozoic India and records evidence of the evolving plate boundary at this time. On the ongoing debate on the evolution of the supercontinent Rodinia, current views favour its formation during the Grenvillian event (1300–1000 Ma ago), subsequent disintegration and final amalgamation around 550 Ma ago (see Kröner and Cordani, 2003 for a review). On a regional scale, the East African Orogen (Stern, 1994) consisting of deformed and metamorphosed Precambrian rocks has been widely regarded as the principal collision zone during late Neoproterozoic amalgamation of Gondwana (Collins and Windley, 2002; Collins et al., 2003 and references therein). Fitzsimons (2000) recognised continent-scale sutures of similar age in other parts of Gondwana. Long et al. (2005) discussed the age and origin of a granite pluton from Brazil in the light of amalgamation of western Gondwana supercontinent. Reconstruction of the continental assembly in the Neoproterozoic period juxtaposes southwestern Australia against northeastern India (Collins, 2003; Harris and Beeson, 1993; Fitzsimons, 2000; Rogers and Santosh, 2002). The evolutionary history of Meghalaya in northeastern India thus assumes special significance in inter-continental correlation.

Models of growth of continental crust invoke episodic addition of juvenile material onto cratonic areas. The chronology, petrology and geochemistry of magmatic bodies document origin and growth of continental crust. This paper presents oxygen and strontium isotopic data, rare earth element contents and major element composition of the granite plutons and basement gneisses of Meghalaya and discusses their petrogenetic evolution. The relevance of the granite to understand crustal evolution during Neoproterozoic in the context of dispersal and reassembly of Gondwana crustal fragments is also discussed.

Geological Set-up

The Meghalaya Plateau forms the northeastern extension of the Indian Peninsular Shield. It is an E-W trending oblong horst block elevated about 600 to 1800 m above the Bangladesh plains in the south and separated from Peninsular India by the Rajmahal-Garo gap (inset map in Fig. 1). The Proterozoic metasedimentary Shillong Group and the basement Gneissic Complex make up most of the plateau. The southern part of the plateau is covered by Cretaceous Sylhet basalt and Tertiary shelf sediments (Fig. 1).

The Shillong Group of rocks, occurring in a 240 km long NE-SW trending intracratonic basin, was metamorphosed to greenschist facies and rests unconformably as indicated by a basal conglomerate (Nandy, 2001) on an assortment of rock types including sillimanite-bearing gneisses, amphibolite, banded iron formation, granulites and granite gneisses collectively known as the Gneissic Complex. Basic eruptives occur as concordant and discordant bodies within the Shillong Group metasediments and are referred to as Khasi greenstones (Mazumder, 1986). Syn- to late tectonic granites occur as discordant plutons cross-cutting the Shillong metasediments (Kyrdem, Mylliem plutons) and basement gneiss (Rongjeng, Sindhuli plutons) (Fig.1). In Nongpoh and South Khasi areas the granite plutons cut across both the Shillong metasediments and the gneissic complex (Fig.1). For convenience, the granites and gneisses are described by the locality names. The mineralogical data for the basement gneisses suggest medium- to upper- amphibolite - grade metamorphism. Around Sonapahar, in the central part of the plateau (Fig. 1), the peak metamorphism reaches granulite grade (Lal et al., 1978). The common rock types include medium- to coarse grained granitic gneisses, cordierite-garnet-biotite-sillimanite bearing granulitic gneisses and pyroxene-hornblende granulites intruded at places by quartzo-feldspathic veins (Lal et al., 1978). Noritic/dioritic enclaves are present in the granite plutons. Such enclaves are particularly common in the South Khasi and Mylliem plutons and attain sizes up to 10 to 12 km^2. The contact between the enclaves and the younger porphyritic granite is both sharp and intermingled at different localities. A number of prominent lineaments trending NE-SW and E-W are present in the plateau; the most prominent structural feature is the E-W- trending Dauki fault, which marks the southern border of the plateau (Fig. 1). The granite plutons occur in greater number in the eastern part of the plateau compared to the western part. Some salient petrological and mineralogical descriptions of the intrusive plutons are given in table 1.

Analytical Methods

Major element analyses of representative samples were carried out using an automated sequential X-ray fluorescence spectrometer (PW 1400 of M/s. Philips, Holland) with side window Rhodium tube on fused discs, while Rb, Sr concentrations of the whole-rock samples were determined on pressed powder pellets using a 3 KW Mo side window anode tube, LIF220 crystal and scintillation detector at 75KV, 40mA settings. The conversion of measured X-ray intensities into element concentration is based on calibration of the spectrometer by measuring the peak intensities for a series of international whole-rock standards. Sr was extracted by conventional ion exchange chromatography and Sr isotopic analyses were carried out using a single collector VG 54R thermal ionisation mass spectrometer. Measured $^{87}Sr/^{86}Sr$ ratios were normalised to $^{86}Sr/^{88}Sr$ value of 0.1194. The experimental uncertainty in $^{87}Rb/^{86}Sr$ ratio is 2% and about 0.02% in $^{87}Sr/^{86}Sr$ ratio. The isochron parameters were calculated by the linear regression method of York (1969) and using ^{87}Rb decay constant of 1.42×10^{-11} a^{-1}. All errors are quoted at 2σ level.

The rare earth elements as well as Hf, Th, U, Sc, Cs, Cr were determined by instrumental neutron activation (INAA) at the Open University, U.K. following techniques described by Potts et al. (1985). Analyses were performed on 300 mg sample aliquots; activity data were corrected for sample mass, radioactive decay, and neutron flux variations. INAA detection limits generally lie in the range 0.03–1 ppm depending on elemental sensitivity.

Oxygen isotope analyses of silicates were performed at SUERC, East Kilbride by the fluorination method of Clayton and Mayeda (1963) as modified for ClF_3 rather than BrF_5 by Borthwick and Harmon (1982). Prior to oxygen extraction, ~10mg samples were heated under vacuum at 200°C for a minimum of one hour and briefly prefluorinated. Oxygen was released by reaction at 650°