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Coexistence of MORB and OIB-type mafic volcanics in the Manipur Ophiolite Complex, Indo-Myanmar Orogenic Belt, northeast India: Implication for heterogeneous mantle source at the spreading zone

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ABSTRACT

This paper presents the first report of the coexistence of tholeiitic mid-ocean ridge basalt (MORB) – type and alkaline ocean island basalt (OIB) – type mafic volcanics from the Manipur Ophiolite Complex (MOC), Indo-Myanmar Orogenic Belt, northeast India. The MORB-types have comparatively lower TiO_2 concentrations (0.6–1.6 wt.%), show almost flat REE patterns with depleted LREEs $[(La/Sm)_N = 0.62–1.03]$. However, few samples in the MORB group show enrichment in LREE $[(La/Sm)_N = 2.83–2.95]$ which is the typical composition of P-MORB. Alkaline OIB-types are characterized by high concentration of TiO_2 (1.7–3.5 wt.%) with highly enriched LREE pattern as compared to their HREE $[(La/Sm)_N = 2.27–3.44$, $(Sm/Yb)_N = 2.56–3.29]$. Such geochemical variation implies more than two sources. Possibly, one for OIBs (enriched mantle) and several ones for MORBs; from depleted MORB mantle (DMM) source to significantly enriched DMM source by OIB-type components. Petrogenetic modeling suggests that 20% partial melting of depleted mantle within spinel stability facies zone (shallow depth) is responsible for generation of MORB tholeiites and 5–10% partial melting of enriched mantle or plume material at garnet facies stability zone (deeper depth) is responsible for production of alkaline OIB-type. Geochemical signatures of variably enriched MORB and P-MORB samples further suggest possible scenario of mixing of depleted N-MORB and enriched OIB melt. It is therefore likely that mafic volcanics of the MOC were derived from chemically heterogeneous mantle sources erupted at the sea floor spreading zone as MORB generated by partial melting of depleted upper mantle and as OIB generated by partial melting of enriched mantle or a plume source, which was proximal to the spreading axis. Later, due to prolonged subduction of the Indian plate beneath the Myanmar plate and afterward collisional activity, they might have accreted along the Indo-Myanmar Orogenic Belt as upthrust ocean crust.

1. Introduction

The Manipur Ophiolite Complex (MOC) which is part of the Nagaland-Manipur Ophiolites (NMO) is a remnant of Tethyan ophiolites preserved at the eastern margin of the NNE–SSW trending Indo-Myanmar Orogenic Belt (IMOB), northeast India. It is believed that NMO was accreted on land prior to the mid-Eocene as a result of the collision of the Indian plate with the Burma plate (Gansser, 1980a; Mitchell, 1981; Acharyya, 2007). Such ancient oceanic lithosphere preserved as ophiolite could be generated at diverse tectonic settings (Coish and Church, 1979; Coleman, 1981; Gass, 1982). Oceanic crust can be produced in a mid-oceanic ridge (MOR), supra-subduction zone (SSZ) or within plate environment (Pearce, 2008; Dilek and Furnes, 2011; Saccani, 2015). However, which among these tectonic processes was/were actually responsible to generate the NMO prior to obduction on land is still a debatable question. Some workers proposed that it was generated by multiple subduction processes of the Indian plate beneath Myanmar plate (Agrawal and Kacker, 1979; Bhattacharjee, 1991; Mitchell, 1993; Nandy, 2001). Parallel to this idea, the Andaman ophiolite which is an extension of the NMO belt to the south and easternmost continuation of Tethyan ophiolite belt was also evaluated as subduction origin (Pal et al., 2003; Ghosh et al., 2009, 2014a). Another school of thought believed that NMO is a melange

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of rootless sub-horizontal nappes, which are westward-propagated from the Eastern Ophiolite Belt of Myanmar (Acharyya et al., 1990; Bhattacharjee, 1991). Recently, from the geochemical behaviors of ultramafic rocks, Singh (2009, 2013) and Ningthoujam et al. (2012) did claim that the initial origin of the NMO is supposed to be at mid oceanic ridge (MOR) setting.

In this paper, we focus on petrological and geochemical behaviors of mafic volcanics from the MOC because their chemistry is regarded as an important indicator of petrogenesis and geodynamic evolution of the ancient oceanic lithosphere (Pearce, 2008; Dilek and Furnes, 2011; Saccani, 2015; Yang et al., 2015). Immobile elements present in such rocks preserve the very distinctive identity of their magma source. Despite of having such strong significance, very less work has been done so far on mafic volcanic rocks in MOC except Singh et al. (2008) reported a preliminary geochemical data of limited pillow basalts. In fact, most of the geochemical studies on mafic volcanics of the NMO were documented from its northern part i.e. Nagaland Ophiolite Complex (Ghose et al., 1986; Sengupta et al., 1989; Srikanth et al., 2004) but MOC (southern part of NMO) has remained a virgin area in terms of geochemical studies of mafic volcanic rocks. For this reason, new geochemical and petrological dataset of mafic volcanics from the MOC are presented in this paper with an attempt to constrain the petrogenetic processes behind the generation of basaltic oceanic crust of this ophiolite complex. The data presented in this paper are also used to discuss about the source material of lavas, as well as to propose a model on the possible tectonic setting(s) in which the MOC was generated prior to its emplacement on continent.

2. Geological setting

The IMOB of northeast India is interpreted as representing the eastern suture of the Indian plate, which was formed due to the collision of the Indian plate with the Myanmar plate (Fig. 1) (Gansser, 1980a; Mitchell and Mckerrow, 1975; Acharyya et al., 1989; Bhattacharjee, 1991). Seismic studies indicated subduction of the Indian plate under the Myanmar plate along a Benioff zone that incline at 30–40° toward Myanmar (Dutta and Saikia, 1976; Saikia et al., 1987). Ophiolitic suit of rocks in the IMOB are highly tectonised and dismembered, showing three phases of deformational events broadly comparable to the Himalayan orogeny and sea floor spreading of the Indian Ocean (Ghose et al., 1986). The dismembered basic and ultrabasic rocks of this belt are closely associated with oceanic pelagic sediments and occur as folded thrust slices riding over distal shelf sedimentary rocks of Eocene to Oligocene age (Acharyya et al., 1990). The ophiolites along the IMOB have been assigned to wide range of age from Cretaceous to Middle Jurassic. Fossil assemblages recovered from the pelagic sediments suggest Maastrichtian age (Acharyya et al., 1986) for the NMO. Using K–Ar dating method, Sarkar et al. (1996) dated basaltic rock from the NMO juxtaposed with red and green chert at 148 ± 4 Ma. These geochronological data from NMO are consistent with Chin Hills and Andaman ophiolites which lie at the same flank. Hornblende–plagioclase bearing pegmatite vein intruding serpentinites from southern Chin Hills ophiolites has yielded 158 ± 20 Ma K–Ar hornblende age (in Mitchell (1981) and in Mitchell et al. (2010)). Plagiogranite from eastern margin of South Andaman ophiolite has yielded 93.6 ± 1.3 Ma U–Pb age on zircon (Sarma et al., 2010).

Structurally, the MOC overthrusts the Disang-Barail turbidites on the western side as shown in the map (Fig. 1(c)), and is over thrust by a klippen of metamorphic rocks in the eastern side which is not shown in the map. These Pre-Mesozoic metamorphic rocks composed of low to medium grade phyllitic schist, quartzite, marble and granite-gneiss are considered to be the oldest group in this section (Brunnschweiler, 1966; Roy and Kacker, 1980; Chattopadhyay et al., 1983). Disang are a group of monotonous sequence of dark gray to black splintery shales, occasionally intercalated with siltstone and fine-medium-grained sandstones with gray to brown, fine to medium grained sandstones with minor to considerably thick interbeds of shale. The lower Disang turbidites are intermixed with pelagic cherts and limestone (Bhattacharjee, 1991). The age of the Disang turbidites is assigned to be Eocene to Upper Cretaceous while Barail groups have a younger age of Oligocene to Upper Eocene (Mallet, 1876; Evans, 1932). Olistolith bodies trending NE–SW and NNE–SSW in the area have been assigned middle Eocene to Paleocene age (Mitra et al., 1986; Vidyadharan et al., 1989). Close association of carbonates with the pelagic sedimentary rocks suggests deposition above carbonate-compensation-depth (Acharyya et al., 1989). The Barail turbidites are unconformably overlain by the molasse-type sedimentary rocks characterized as the Surma group (Evans, 1932) and Tipam group (Mallet, 1876) of Miocene to Oligocene age.

This MOC predominantly consists of well-preserved mantle sequence of serpentinised peridotite (around 90%) associated with podiform chromitites which occur mainly as concordant bodies of variable dimensions up to 20 m length, mafic crustal units (gabbroic rocks in particular) are poorly developed (Singh et al., 2008; Ningthoujam et al., 2012; Singh, 2013; Singh et al., 2013; Ghosh et al., 2014b). Close association of harzburgite, lherzolite, pyroxenite, gabbro, plagiogranite and oceanic pelagic sediments was also documented by Vidyadharan et al. (1989), Singh (2013). In contrast to previous works, our detailed field work highlighted the occurrence of appreciable amount of in-situ mafic volcanic rocks cropping out in different localities.

The area under investigation is characterized by highly rugged topography and thick vegetation cover, and so it remained uneasy for geologist to penetrate and explore the region for detailed geological investigations. Mafic volcanics are exposed as massive lava, spilitic pillow lava, agglomerate and vesicular lava (Fig. 2). The pillow lavas are rounded or elliptical in shape with bulbous flow top. They are closely associated with serpentinised ultramafic rocks, gabbro, pelagic sediments (red clay and phyllite) and mafic dikes. Small volumes of chert and limestone are occasionally interbedded with these extrusive mafic rocks.

3. Petrography

Petrographically, the rocks can be categorized as phyric to moderately aphyric-type. Plagioclase is the dominant primary mineral, present in the form of phenocrysts, lath-like crystals and elongated microlites in groundmass. Mafic minerals like clinopyroxene, orthopyroxene (minor amount) and opaque minerals (especially magnetite) are also present. Rocks show different textures in thin section indicating different mode of crystallization. Massive lavas exhibit two types of texture: (1) intergranular texture where interstices between anhedral crystals of plagioclase are occupied by small grains of clinopyroxene (Sample – 8P2B, Fig. 3(a)). (2). Glomeroporphyritic texture, where phenocrysts of plagioclase laths and anhedral clinopyroxene crystals are clustered together within fine grained groundmass which is a characteristic of earlier stage of crystal consolidation before the magma reaches on the surface (Sample – 2VO2, Fig. 3(b)). Some samples show subvariolitic texture with elongated plagioclase crystals streaking out in different directions from a nucleus and smaller pyroxene crystals occupy interstitial position (Sample – 8P5R, Fig. 3(c)). Vesicular basalts have variable sizes of vesicles within a range of 1–9 mm and are filled up by secondary minerals (Calcite, Zeolite, epidote and quartz), giving an amygdaloidal texture to the samples (Sample – 8N5, Fig. 3(d)). Many of the samples have undergone varying