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Dacite–andesites of Narcondam volcano in the Andaman Sea — An imprint of magma mixing in the inner arc of the Andaman–Java subduction system

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Abstract

Narcondam Island represents a dormant inner arc volcano of the active Andaman–Java Subduction Complex in the Andaman Sea. The Narcondam volcano along with the active Barren volcano lies in the chain of inner arc volcanoes extending from Burma to Indonesia. The Narcondam volcanics are represented by a) porphyritic dacite, b) amphibole–andesite and c) andesite. Dacite contains plagioclase, hornblende, biotite and quartz with minor apatite as phenocrysts set in a groundmass comprising plagioclase, hornblende, opaque (magnetite, ilmenite) and glass. In amphibole–andesite, plagioclase and cummingtonite occur as phenocrysts as well as groundmass phases along with minor quartz and apatite. In contrast, in andesite, calcic plagioclase, olivine, orthopyroxene (hypersthene, bronzite) and clinopyroxene (augite, diopside) represent both phenocrysts and groundmass phases. The plagioclase grains occur mainly in two major populations as: A) unreacted crystals-coarsely crystalline twinned plagioclase with or without resorption and without mantling of dusty zone, B) reacted crystals-coarse plagioclase usually with a clear, resorbed core of sodic plagioclase is surrounded by a dusty zone which is again fringed by a clear rim. In dacite, the unreacted crystals are andesine (An 46–49) whereas the reacted phenocrysts show an overgrowth of sodic plagioclase (An 44–66) over the dusty cores of calcic plagioclase (An 75–85). In andesite, the unreacted phenocrysts are represented by both andesine (An 44–49) and labradorite/bytownite whereas in the reacted phenocrysts the andesine core (An 46–49) is surrounded by a dark zone containing labradorite (An 60–65) and then fringed by a clear rim of bytownite (An71–77).

The reacted grains of amphibole have dark rims of glass and microlites of plagioclase and Fe–Ti oxide, and the phenocrystic grains are engulfed by a mixture of glass and pyroxene crystals. Around the border of biotite, amphibole is developed at the expense of biotite. The phenocrysts of olivine show more or less homogeneous composition with no appreciable change from core (Fo 87–89) to rim (Fo 87). The resorbed grains of orthopyroxene show a small increase in MgO from core (22.38–24.0%) to rim (23.61–24.23%) with an overall hypersthene composition (En 63–65) but the phenocrysts without rims are represented by hypersthene (En 66) and bronzite (En 72). The augites occurring as unresorbed phenocrysts show En 44, Wo 41 whereas unresorbed diopside grains show En 42, Wo 47. The strongly resorbed grains show a significant change in composition between core (En 45,Wo 37) and rim (En 40, Wo 45) but the resorbed diopsidic phenocrysts show a minor change in composition from core (En 46, Wo46) to rim (En 47, Wo 45).

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The trace element abundances do not show differences between amphibole–andesite and andesite. The distribution pattern of trace elements for dacite to amphibole–andesite to andesite is also similar except for low Cr and Ni for dacite. Dacites contains slightly higher Rb, Sr and, Zr than those in amphibole–andesite and andesite. The variation diagram of trace elements indicates that LIL elements are enriched relative to HFSE e.g., Zr, Ti, Y as well as a strong positive anomaly in respect of N-MORB.

The textures as well as compositions of the phenocrysts of the volcanics exhibit disequilibrium caused by magma mixing. The sodic plagioclases, occurring as unreacted grains in dacite and as cores of the reacted grains in andesite, as well as the presence of rhyolitic glass as inclusions, record rhyolite as one magma source. On the other hand, preponderances of phenocrysts of basaltic origin (high Fo olivine and Mg rich pyroxene) as well as basaltic glass as matrix and inclusions in the phenocrysts in andesite suggest basalt as another source magma. In reacting grains showing fresh andesine, the core was derived from acid magma and the reacting zones showing labradorite composition were developed by the reaction of andesine crystals with hot basic magma. In andesite, unreacted grains of andesine and labradorite/bytownite were trapped from the evolved dacitic magma and basaltic magma respectively. During super-heating of dacite magma by basic magma biotite was replaced by amphibole as a result of dehydration. Olivine grains were replaced by pyroxene during gradual cooling of basaltic magma and magma mixing. The presence of mixtures of phenocrysts of both the magmas and glasses of the source and intermediate magmas indicate that dacite, amphibole–andesite, and andesite are the products of magma mixing.

Keywords: Narcondam volcano; Andaman Sea; rhyolite magma; basaltic magma; magma mixing

1. Introduction

Petrographic studies indicate that magma mixing has an important role in the petrogenesis of intermediate magmas in volcanic arcs (Eichelberger, 1975; Anderson, 1976; Eichelberger, 1978; Sakuyama, 1979; Luhr and Carmichael, 1980; Sakuyama, 1981; Turner and Campbell, 1986; Philpotts, 1990; Clynne, 1999) and mid-ocean ridge basalt (Donaldson and Brown, 1977; Dungan and Rhodes, 1978; Walker et al., 1979). Experimentally it is well documented that basaltic and dacitic magmas can easily be mixed to form banded dacite and homogeneous andesite (Kouchi and Sunagawa, 1985). The phenocrysts larger than a critical size accelerate the efficiency of mixing and much smaller crystals around 10 μm have a negligible effect in mixing (Kouchi and Sunagawa, 1985). If magmas mix incompletely compositional banding or under-cooled inclusions are apparent, but in the case of complete mixing, mineralogical disequilibrium may be the only direct evidence for a mixing origin (cf. Clynne, 1999). Magma mixing is minimized when the two magmas have widely differing thermal and compositional characteristics and have large volume differences (e.g., Bacon, 1986). The result is under-cooled inclusions formed from hybrid magmas (Bacon, 1986) which, themselves retards magma mixing (Sparks et al., 1977; Sakuyama, 1984; Sparks and Marshall, 1986; Koyaguchi and Blake, 1991). The hybrid magmas usually contain reacted phenocrysts derived from a host silicic magma (Heiken and Eichelberger, 1980). The fragmentation and or disaggregation of under-cooled inclusions often effects hybridization in some magma systems (Thompson and Dungan, 1985; Clynne and Christiansen, 1987; Clynne, 1989; Linneman and Myers, 1990; Feely and Dungan, 1996). The magma mixing process records: a) disequilibrium textures and b) presence of both sodic and calcic plagioclase together, and c) presence of quartz and forsteritic olivine in the same rock (cf. Eichelberger et al., 2000). The chemical disequilibrium of the phenocrysts is preserved due to the presumably short time gap between mixing and eruptive quenching (Nakamura, 1995). Experimental study also indicates that the strong variations of phenocryst compositions, especially plagioclase, could be linked to variations of temperatures and/or water activity during the magma mixing process (Holtz et al., 2005).

Narcondam Island (13°25′N, 94°16′E) is located 135 km NE of the main Andaman and Nicobar group of islands with an exposed area of 7 km^2 and a maximum height of 710 m. This island has hardly been studied geologically because: 1) it is far away from the main Andaman group of islands, 2) it is densely covered with jungle, and 3) it can only be approached by the Eastern coast. Very limited geological information is available in the literature. From the Geological Survey of India, a limited study was conducted by Mallet (1885) and Ball (1893). They reported the presence of hornblende andesite lava without any crater activity. Subsequently Halder (1985–88, Geological Survey of India unpublished progress report) reported a uniform lava pile of andesite to dacite and described this calc alkaline magma as the product of assimilation of basaltic melt with sialic crust. The Narcondam volcano representing a calc alkaline magma suite along with Barren volcano is considered to lie in the inner arc belt of the Andaman–