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Petrogenesis of a basanite–tephrite–phonolite volcanic suite in the Bobaomby (Cap d'Ambre) peninsula, northern Madagascar

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Abstract

The Late Cenozoic Bobaomby volcanic field is located in the northernmost Madagascar, in the area north of the Massif d'Ambre. It comprises widely scattered outcrops of lava flows, dykes, scoria cones, tuff rings and plugs, emplaced in the Meso-Cenozoic sedimentary rocks of the Diego Basin. The Bobaomby rocks range in composition from Mg-rich, sodic basanite to phonolite (MgO from 13 to 0.15 wt.%), with a marked compositional gap between mafic and relatively evolved compositions (phonotephrites and tephritic phonolites). The volcanic rocks form a clear differentiation trend, that can be modelled by fractional crystallization of olivine, clinopyroxene, opaque oxides and kaersutitic amphibole (i.e. the observed phenocryst phases). The phonolites have alkali feldspar and nepheline phenocrysts (±sodalite and mafic phases), plot very close to or at the phonolite minimum in the Petrogeny's Residua system and are the result of about 90% fractional crystallization, starting from basanite.

The most mafic basanites, often carrying xenoliths of mantle-derived spinel lherzolites, show typical enrichment in the most strongly incompatible elements, have a peak at Nb in the mantle-normalized diagrams, and have a trough at K, a feature of within-plate basalts with HIMU-like geochemical affinity. Their composition can be modelled after ca. 4% partial melting of an enriched mantle source, possibly located in the lowermost lithospheric mantle. This source (that may be amphibole-bearing) is very similar in composition with the source of the Nosy Be basanites, located some 170 km southwest of the study area.

Keywords: Basanite; Tephrite; Phonolite; Bobaomby Cenozoic volcanic field; Northern Madagascar

1. Introduction

Late Cenozoic igneous rocks with alkaline and strongly alkaline affinity are widespread in northern Madagascar. The most important areas covered or intruded by igneous rocks belonging to this cycle are: the Ampasindava peninsula, the Nosy Be archipelago, the Ankaizina district, and the Massif d'Ambre (Fig. 1). A few of these volcanic fields have received some attention in the recent literature (e.g. Melluso and Morra, 2000; Buchwaldt et al., 2005; Woolley, 2001) but most primary information available about the petrogenetic features of the igneous rocks is more than 30 years old (e.g. Lacroix, 1923; Besairie et al., 1957; Besairie, 1964; Besairie and Collignon, 1972; Karche, 1973). A set of reliable age determinations for the Cenozoic Madagascan volcanics is still lacking (cf. Emerick and Duncan, 1982; Nougier et al., 1986).

The ultimate causes of this voluminous igneous activity, the age span of this large province, as well the mantle sources and the evolution processes which generated the very extended spectrum of compositions, are still matters

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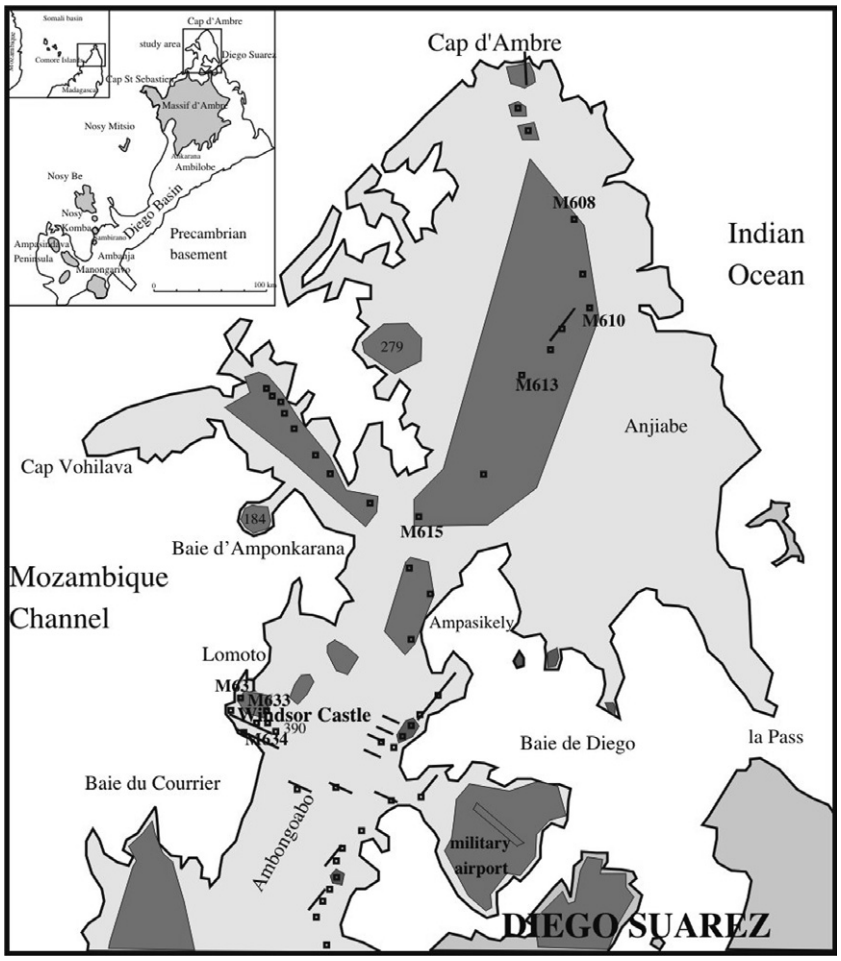

Fig. 1. Simplified sketch map of Bobaomby. The areas covered by volcanic rocks are shown in deep grey. The sample locations are plotted as squares, and the samples analyzed for ICP–MS are given in full. The GPS coordinates of the samples are given in Table 1. The Ankaizina volcanic field is located southeast of the Ampasindava peninsula (inset).

of speculation. Melluso and Morra (2000) noted general geochemical and isotopic similarities between the basanites of the Nosy Be archipelago and the volcanic rocks with similar degree of differentiation erupted in the Comorean archipelago (Späth et al., 1996; Class and Goldstein, 1997; Class et al., 1998), but pointed out that excluded that the complexes do not follow the track of a Comore mantle plume which started in Cretaceous times from the Seychelles archipelago (Emerick and Duncan, 1982, 1983). For further information, other roughly coeval (and much larger) volcanic complexes in Madagascar are located thousands of km away from the Comorean archipelago (e.g. the Ankaratra, Takarindioha and Itasy massifs in central Madagascar), and these complexes cannot be related to the Comore mantle plume either from a genetic or structural points of view. It is evident that the main causes of this igneous activity must be linked to the regional extensional events which occurred throughout Madagascar (and Eastern Africa) in the Late Cenozoic times (e.g. Ashwal and Burke, 1989). In any case, the existence of a plume track ending at the Comore archipelago is only a matter of speculation.

Northernmost Madagascar is dominated by the Massif d'Ambre stratovolcano, whose products cover an area of roughly 60 km × 50 km, and show an apparently prolonged interval of activity (being active from late Miocene to Pleistocene; Emerick and Duncan, 1983). In this paper we focus our attention on the igneous rocks of the area north of Massif d'Ambre towards Cap d'Ambre. These rocks are among the oldest Cenozoic volcanic rocks of this sector, and certainly pre-date the formation of the large Massif d'Ambre. The rocks of the Massif d'Ambre will be the subject of a forthcoming paper.

1.1. Geological setting and sampling strategy

The Bobaomby volcanic field is located in the northernmost part of Madagascar, widely scattered over an area of 40 km × 25 km (Fig. 1). The highest peak of the area is the calcareous outcrop of Windsor Castle (ca. 400 m. a.s.l.). The volcanic field is formed by scoria cones with small lava flows, some of which are still well preserved and form at least two prominent hills on the western side of the peninsula, a dyke swarm with orientation mostly ENE–SSW and