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Magma emplacement at anomalous spreading ridge: Constraints due to plagioclase crystals from basalts of Marsili seamount (Southern Tyrrhenian back-arc)

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ABSTRACT

Plagioclase crystals from four basalt samples dredged from different portions of the Marsili seamount (Southern Tyrrhenian, Italy) provide a detailed record of the changes occurring in the surrounding magma during its ascent in the crust. The textural features and chemical zoning (i.e., An content and Fe, Mg, Sr and Ba concentrations) of the plagioclases from each sample show that aggregation of various generations of crystals occurred in the host melt prior to eruption. Plagioclases resulting from crystallisation in small sill intrusions, where local flotation of plagioclase may have occurred, are ubiquitous. Instead, large (up to 1 mm) homogeneous An-rich plagioclases are rare and have only been found in two of the studied basalts, recovered from the northern and southern portions of the volcano, respectively. These crystals record crystallisation events occurring long before eruption, and probably derive from deep-seated crystalline material. At the highest An values, the Sr and Ba concentrations of the studied plagioclases also indicate the existence of two distinct mafic magmas within the lower crustal plumbing system of the Marsili volcano, one with lower Sr and Ba contents than the other. Three of the four studied basalts came from magma with low Sr and Ba, whereas the fourth, which erupted from the southern portion of the volcano, sampled magma richer in Sr and Ba. The ascent of magma caused resorption of the previously formed plagioclase crystals and regrowth of normally or inversely zoned portions, depending on the water-saturated or water-undersaturated conditions of the surrounding magma, respectively. Small shallow magmatic reservoirs may be located under the southern part of the Marsili volcano, as testified by the resorbed sodic cores ($An_{52–57}$) found in the two basalt samples from this portion.

1. Introduction

Many studies combine compositional data and textural characteristics of plagioclase crystals from basaltic rocks in order to investigate the open- or closed-system processes occurring within volcanic plumbing systems throughout the history of a volcano (e.g., Ginibre and Wörner, 2007; Hellevang and Pedersen, 2008; Viccaro et al., 2010; and references therein). This is because the compositional and textural zoning patterns which develop during primary growth are preserved in plagioclase, due to slow CaAl–NaSi diffusion (Morse, 1984; Smith et al., 2009), and the composition of plagioclase is sensitive to melt composition (Housh and Luhr, 1991; Putirka, 2005) and physical conditions, such as temperature, pressure and H_2O (Blundy and Wood, 1991; Bindeman et al., 1998). More recently, studies carried out on plagioclase crystals from mid-ocean ridge basalts (MORB) have demonstrated that open-system processes are also common in these magmatic systems and reveal that plagioclases hosted in MORB basalts can form in a mixture of environments, including deep-seated or shallow magma reservoirs and even in conduits (Costa et al., 2010; Zellmer et al., 2011).

Here we investigate the textural and compositional characteristics of plagioclase crystals in four basalt samples dredged from the Marsili seamount (Fig. 1) in the Tyrrhenian Sea, which represents the active spreading centre of the Southern Tyrrhenian back-arc basin (Marani and Trua, 2002). The Marsili volcano is an ideal case for this type of study, both because of its distinctive morphology, resembling that found in spreading mid-ocean ridges (Marani and Trua, 2002), and the geochemical and isotope characteristics of the erupted basaltic lavas, which reveal that a compositional variation occurred during the growth of the volcano, from dominant island-arc basalt (IAB) magmas to younger ocean-island basalt (OIB) lavas (Trua et al., 2010, 2011). Here we use the compositional record preserved in plagioclase crystals from selected Marsili basalt samples. The data obtained allowed us to study the plumbing system of the southern and northern sectors of the volcano, revealing, in a single basalt sample, plagioclases of different origins which crystallised over variable time-spans. They also record the input of two distinct mafic magmas under the ridge axis of the volcano, consistent with conclusions based on previous petrological studies of Marsili basic lavas (Trua et al., 2010, 2011).

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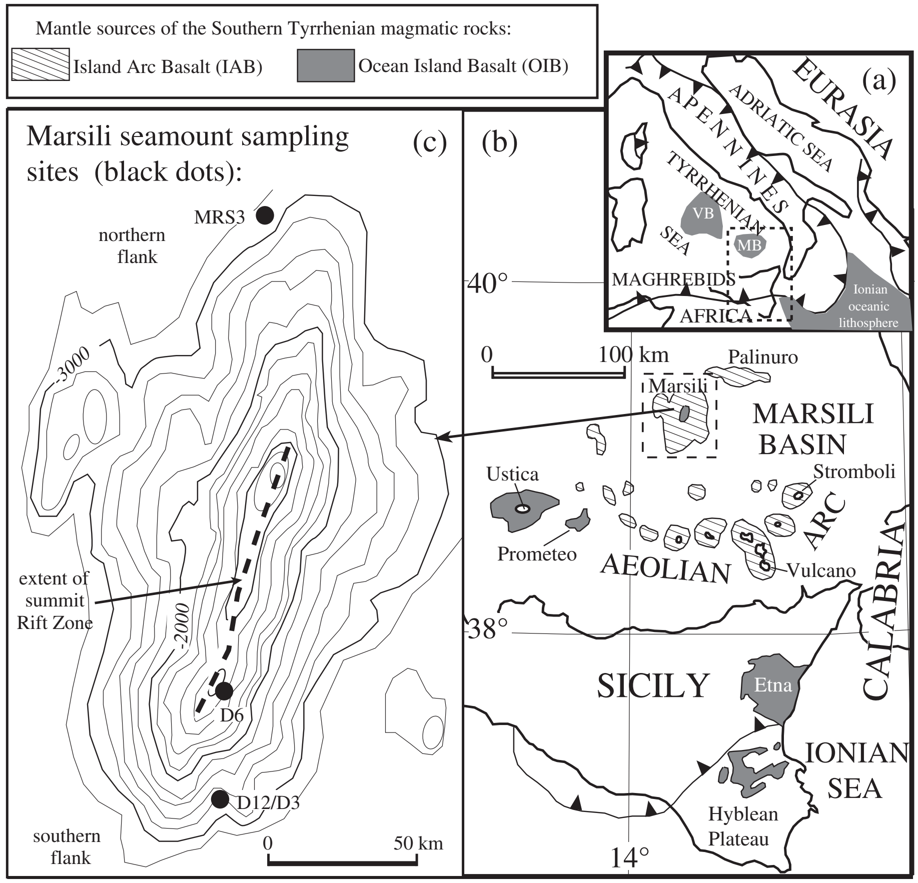

Fig. 1. a) Location of Marsili Basin (Southern Tyrrhenian). b) Sketch-map of Cenozoic magmatic rocks of Southern Tyrrhenian region according to their inferred dominant magma sources. c) Bathymetric map of Marsili volcano, with overlapping volcanic zones identified by Marani and Trua (2002) and location of studied samples (200-m isobaths). Panel b is modified after Trua et al., 2010.

2. Geological setting and petrology of Marsili volcano

The Marsili volcano is the largest seamount in the Tyrrhenian back-arc basin (Fig. 1). The volcanic edifice, which grew during the last 1 My (Cocchi et al., 2009), reveals distinctive morphology and petrogenesis. It is located in the central part of the Marsili Basin, the most recent back-arc basin of the Tyrrhenian, which has spread at an average rate of 3–4 cm/yr since about 1.9 Ma ago, due to the south-eastward retreat and progressive steepening of the subducted Ionian plate (Marani and Trua, 2002, and references therein). The Marsili Basin has features typical of an oceanic back-arc spreading basins, such as a Moho depth of the order of 8 km and a thin (<30 km) lithosphere (Pontevivo and Panza, 2006), but it lacks a classic spreading centre in which MORB crust is produced. Instead, the oceanic accretion centre of the basin is occupied by the Marsili volcano, an edifice 60 km long and 20 km wide, running mainly NNE–SSW and characterised by complex morphology (Fig. 1c). It has steep flanks and magmatically inflated morphology, typical of fast-spreading mid-ocean ridges, and a long (25 km) narrow belt of volcanic cones at depths shallower than 1000 m, like those observed in the neovolcanic zones of slow-spreading mid-ocean ridges, representing the summit Rift Zone of the volcano (Marani and Trua, 2002). A large suite of samples, representative of all the lithologies from the crust of the Marsili volcano, was recovered during the MAR98 and TIR2000 cruises, which complements and up-dates earlier geochemical data (Trua et al., 2002, 2007). Petrological study of these samples reveals that the lavas emitted from Marsili vary from medium-K calc-alkaline basalt to basaltic andesite in composition, whereas more evolved lavas, only dredged from small cones located near the summit, are high-K calc-alkaline andesites in composition (Supplementary material). Overall, all except one basalt so far recovered from Marsili have typical subduction-related trace element features, expressed by high large ion lithophile element/high field strength element (LILE/HFSE) and light rare earth element/high field strength element (LILE/HFSE) ratios. Nevertheless, the subduction signature of these basalts is variable, as illustrated by the samples selected for this study (Supplementary material) and cover most of the range defined by the IAB lavas from the nearby Aeolian arc (Fig. 1; see Trua et al., 2011). Instead, one Marsili basic lava (sample D6), recovered from the summit axis of the volcano, has a pattern similar to the other Marsili basalts but significantly more enriched, revealing a strong trace-element similarity with the nearby OIB lavas of Ustica and Prometeo (Supplementary material). The compositional variation from IAB to OIB magmas recorded by the Marsili basic lavas (Trua et al., 2007, 2011) is consistent with the peculiar Southern Tyrrhenian subduction setting, also revealed by geological (Marani and Trua, 2002) and seismological (Chiarabba et al., 2008) studies of the area. Indeed, the distinctive morphology of the Marsili volcano as well as the petrology of the erupted basic magmas are consistent with a model invoking the "superinflation" of the Southern Tyrrhenian spreading ridge resulting from excess magma production from the underlying mantle wedge (Trua et al., 2002, 2011). Melting was triggered by the lateral ingression of African OIB mantle into the Southern Tyrrhenian mantle wedge, which occurred around the tear at the southern edge of the subducting Ionian slab.