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Journal of volcanology and geothermal research
Journal of Volcanology and Geothermal Research 154 (2006) 89–102
www.elsevier.com/locate/jvolgeores

Textural analysis of magmatic enclaves from the Kameni Islands, Santorini, Greece

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Received 30 June 2004; accepted 30 September 2005
Available online 17 February 2006

Abstract

The Kameni Islands have been the focus of historic volcanic activity on Santorini, Greece. The islands comprise a series of dacite lavas, the erupted compositions of which have remained approximately constant for the last ~2200 years. The dacite lava flows of Nea Kameni contain a variety of mafic enclaves, distinguished by differences in texture, composition and mechanical behaviour.

The mafic enclaves represent chilled fragments of mafic magma that crystallised rapidly on contact with the cooler, more silicic host magma. The absence of chilled margins on the enclaves suggests that the replenishing magma initially formed a dense layer at the base of the chamber. Groundmass textures are interpreted as an indication of the degree of undercooling between the enclaves and the host. Groundmass textural information obtained from the enclaves has been used to determine the relative volumes of replenishing magmas injected into the host magma before eruption, which indicates that the volume of erupted magma is directly proportional to the volume of replenishing magma emplaced in the chamber prior to eruption, which thus may act as a potential eruption trigger.

The variety of replenishing magmas implies the existence of a complex conduit and chamber system beneath Santorini volcano. Andesitic enclaves with linear crystal size distributions are thought to have originated as an aphyric andesitic melt expelled from a crystal mush by filter-pressing. Disequilibrium phenocryst assemblages in the lavas and phenocryst-bearing enclaves provide evidence for the entrainment and recycling of older phenocryst populations.

Keywords: mafic enclaves; CSD; textural analysis; magma mixing; Santorini

1. Introduction

In long-lived magmatic systems, batches of hot, more primitive magma may periodically intrude into the cooler and more evolved shallow crustal magma chamber. The intrusion of hot mafic magma into a cooler, silicic magma reservoir has been widely recognised as a potential eruption trigger (e.g. Sparks et al., 1977; Huppert et al., 1982a; Eichelberger et al., 2000). Replenishment of a cool silicic magma reservoir with hot mafic magma may have a number of possible effects. The simple addition of a new volume of magma to the magma chamber has the potential to create an overpressure large

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doi:10.1016/j.jvolgeores.2005.09.021

enough to cause failure of the chamber walls and result in an eruption (Blake, 1981; Tait et al., 1989). Cooling of the mafic magma and heating of the resident magma may result in volatile exsolution which will also contribute to chamber over-pressurisation (Sparks et al., 1977; Huppert et al., 1982a). Heating may also cause convective uprise and remobilisation of the resident magma, possibly resulting in eruption (Murphy et al., 2000; Couch et al., 2001).

Mafic magmatic enclaves are found in many intermediate to silicic volcanic rocks (e.g. Bacon and Metz, 1984; Bacon, 1986; Clynne, 1999; Murphy et al., 2000; Cole et al., 2001; Coombs et al., 2000, 2002) and are often interpreted as the products of magma replenishment and mixing events. In this model, groundmass crystallisation in the replenishing magma occurs as a result of undercooling that develops when replenishing magma comes into contact with cooler host magma in the chamber (Bacon, 1986; Coombs et al., 2002). Groundmass textures and crystal morphologies observed in the enclaves are then interpreted as an indication of the degree of undercooling between the enclaves and the host, which is in turn a function of the thermal and compositional contrast between the inclusions and the host magma (Bacon, 1986).

2. Geological setting and recent eruptive history

Santorini is the largest young volcanic centre in the Aegean arc, which has formed as a result of northward subduction of the African plate beneath the continental Aegean microplate (Jackson, 1994; Druitt et al., 1999). The post-caldera islands of Palaea and Nea Kameni lie in the centre of a flooded caldera, surrounded by the older islands of Thera, Therasia and Aspronisi (Fig. 1a), which preserve the remains of the pre-volcanic island and two cycles of late Quaternary explosive volcanic activity (Druitt et al., 1989, 1999). The caldera is a composite structure resulting from at least four collapse events (Druitt and Francaviglia, 1992), the most recent of which occurred as a result of the Minoan eruption ~3600 years ago (Druitt et al., 1999). The Kameni Islands have been the focus of historic volcanic activity on Santorini. Magmatic activity probably resumed soon after the Minoan eruption, producing a 2.5 km^3 intracaldera volcano, the summit of which rises ~500 m above the caldera floor (Higgins, 1996b; Druitt et al., 1999), and ca. 126 m above sea level. The Kameni edifice broke the surface in 197 BC and subsequently there have been at least nine subaerial episodes of volcanic activity, the last of which was in AD 1950 (Fig. 1b).

The Kameni islands are formed from dacite lavas, the erupted compositions of which have remained approximately constant for the last ~2200 years (Washington, 1926; Huijsmans, 1985; Barton and Huijsmans, 1986); the lavas contain abundant magmatic enclaves, including both cumulates from the chamber floor and quenched fragments of replenishing magma. The petrology and texture of the host lavas has been very well documented (e.g. Fouqué, 1879; Nicholls, 1971; Barton and Huijsmans,

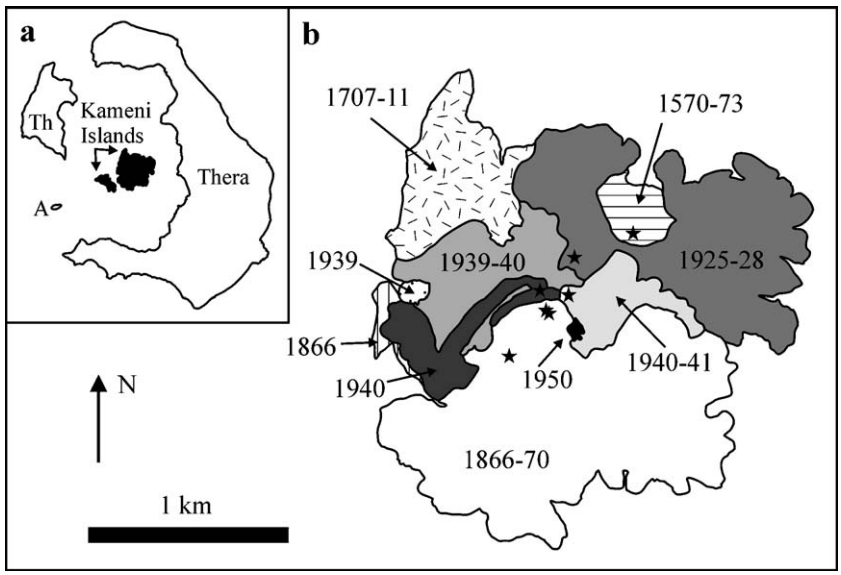

Fig. 1. (a) Map showing the position of the Kameni Islands in the centre of the caldera formed by the outer islands of Thera, Therasia (Th) and Aspronisi (A). (b) Simplified map, after Druitt et al. (1999), showing the extent of the historical lava flows (eruption dates from Georgalas, 1962).