THE CRUSTAL MAGMA PLUMBING SYSTEM BENEATH THE AEOLIAN VOLCANIC ARC (ITALY): INFERENCES FROM FLUID INCLUSIONS IN CRUSTAL XENOLITHS

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Introduction

A determination of the location and geometry of magma conduits beneath volcanoes is a key issue in the assessment of volcanic hazards. Attempts to locate magma conduits and magma storage areas have been made based mainly on seismic and geophysical studies. An alternative useful approach for this purpose is to combine fluid-inclusion barometric studies with petrological and geochemical investigations on erupted magmas. The Aeolian archipelago comprises seven volcanic islands (Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea and Stromboli) and nine seamounts located on the south-eastern continental slope of the Tyrrhenian abyssal plain. Volcanism initiated recently (~1 Ma; basalts from the western seamounts) and is active at present (e.g. Stromboli and Vulcano). Volcanic products consist of lavas and pyroclasts of variable composition (basalts to rhyolites) belonging to the calcalkaline, high-potassic calcalkaline, shoshonitic and alkaline (potassic) associations. Calcalkaline and high-potassic calcalkaline rocks are present on all the islands, whereas shoshonitic and potassic rocks characterise the islands of Lipari, Vulcano and Stromboli (De Astis et al., 2000).

Results

Quartz-rich xenoliths are commonly present in basic lavas forming the main volcanic cycles of all the Aeolian Islands. They have angular shapes, sizes ranging from a few cm to a few dm, and a typical white colour. Xenoliths consist almost exclusively of quartz crystal (> 98 % modal), with subordinate zircon, apatite and sphene. Isolated K-feldspar and/or pyroxene and plagioclase grains are also observed. Abundant clear glass is present both as intergranular films between quartz grains and as silicate-melt inclusions within single quartz grains. Quartz-rich xenoliths are interpreted to represent fragments of restitic rocks originated by different degrees of partial melting of SiO_2-rich metamorphic rocks such as a quartz-feldspatic gneisses and/or mica-schists (Peccerillo, Wu, 1992; Zanon et al., 2003).

In quartz grains, two main generations of CO_2-rich fluid inclusions are distinguished: a) Type I early inclusions occur isolated or in small clusters within most quartz grains, often associated to silicate melt inclusions. At room temperature, Type I inclusions (3-10 μm) are single-phase (L) or may contain a vapour bubble (L+V). Many inclusions often show cracks radiating from the inclusion walls; b) Type II late inclusions are distributed along inter- and intragranular trails, with variable shape and size (3-30 μm). At room temperatures, Type II inclusions are single-phase (V) or more commonly, two-phase vapour-dominated (V+L). They are never found associated to silicate-melt inclusions.

Pure CO_2 is the most common component in both Type I and Type II fluid inclusions melting instantaneously within a narrow temperature interval between -56.8 and -56.4 °C, with most data at -56.6°C. Two exceptions are observed: (1) a few early Type I inclusions in quartz-rich xenoliths from Filicudi contain some water (20 to 30 % in vol.); (2) some early Type I inclusions in quartz-rich xenoliths from Alicudi show a Tm's depression for CO_2 (down to –59.5°C). Raman microspectrometric measurements indicate the presence of 1-10 mole % of N_2 ± 1-14 mole % of CO. Type I inclusions homogenise always to liquid (Th_L) between –2.5 and 31.1°C (d=0.93-0.47 g/cm^3) at Alicudi, 21.4- 31.1°C (d=0.76-0.47 g/cm^3) at Filicudi and 6.3-31°C (d=0.85-052 g/cm^3) at Vulcano; Type II inclusions homogenise to vapour (Thv) in the –6 to 31°C range (d=0.47-0.08 g/cm^3) at Alicudi, 18-30°C (d=0.41-0.18 g/cm^3) at Filicudi and 9-31°C (d=0.42-0.13 g/cm^3) at Vulcano (Fig. 1).

Discussion and conclusions

The trapping pressure of the fluid inclusions are calculated combining the isochoric fluid P-T conditions with the host magma temperature (1090°C; Zanon, et al., 2003). Two pressure intervals of fluid trapping are observed and interpreted to reflect two distinct episodes of magma rest in the crust, as also suggested by petrological studies : a) Type I fluid inclusions indicate that an important magma accumulation level is present at pressures comprised between 0.6 and 0.3 GPa. Pressures are variable in the different islands and correspond to depths which increase going westward from Stromboli (≅16 km; Vaggelli et al., 2001) to Alicudi (≅25 km); b) Type II fluid inclusions are trapped at considerably lower pressures (0.17-0.05 GPa; ≅ 5 km depth), during the final magma upwelling, indicating that magmas and xenoliths rested for a time span sufficient to allow new fluid trapping and decrepitation of many Type I inclusions.

Petrological, geochemical and fluid inclusion studies allow us to suggest a model for the plumbing system of the Aeolian Islands. Mafic magmas which characterise the early stages of the activity of most islands reflect tapping of deep level reservoirs located at the base of the crust, where continuous feeding by mantle-derived mafic magmas does not allow differentiation toward acid composition. On the other hand, the evolution in the shallow magma chambers produce differentiated magmas, which are particularly abundant in the central island of Vulcano and Lipari. The short residence time of deep magmas and xenoliths in the shallow reservoirs, as indicated by preservation of both quartz-rich xenoliths and high density Type I fluid inclusions, has important volcanological implications. The arrival of deep magma into the shallow reservoir shortly before the eruption, in fact, suggest that such an event might be responsible for triggering volcanic eruptions.

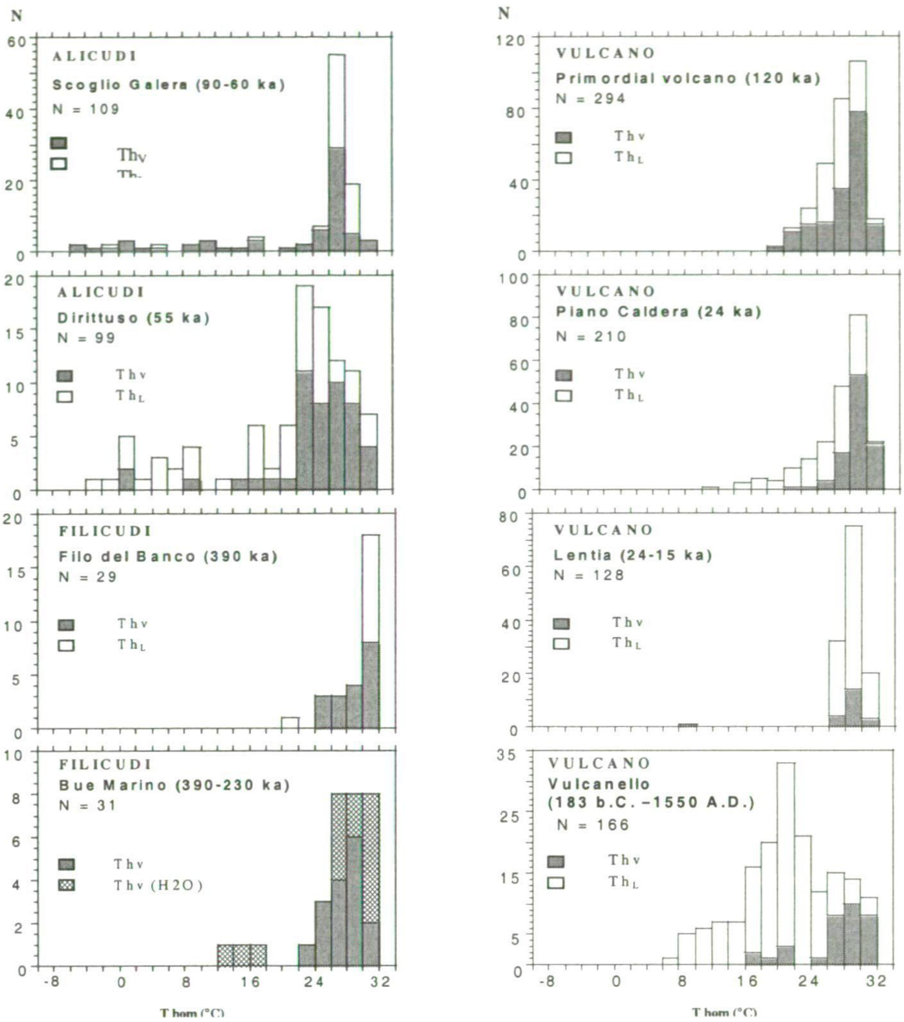

Fig.1. Histograms of homogenisation temperatures for fluid inclusions present in xenoliths of the studied volcanic islands. Histograms report homogenisation temperatures to the liquid phase (Th_L) for early Type I fluid inclusions and homogenisation temperatures to the vapour phase (Th_V) for late Type II fluid inclusions (Frezzotti et al. 2002).

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