Silicic magma entering a basaltic magma chamber: eruptive dynamics and magma mixing – an example from Salina (Aeolian islands, Southern Tyrrhenian Sea)

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Abstract. The Pollara tuff-ring resulted from two explosive eruptions whose deposits are separated by a paleosol 13 Ka old. The oldest deposits (LPP, about 0.2 km³) consist of three main fall units (A, B, C) deposited from a subplinian column whose height (7–14 km) increased with time from A to C, as a consequence of the increased magma discharge rate during the eruption (1–8 × 10⁶ kg/s). A highly variable juvenile population characterizes the eruption. Black, dense, highly porphyritic, mafic ejecta (SiO₂ = 50–55%) almost exclusively form A deposits, whereas grey, mildly vesiculated, mildly porphyritic pumice (SiO₂ = 56–67%) and white, highly vesiculated, nearly aphyric pumice (SiO₂ = 66–71%) predominate in B and C respectively. Mafic cumulates are abundant in A, while crystalline lithic ejecta first appear in B and increase upward. The LPP result from the emptying of an unusual and unstable, compositionally zoned, shallow magma chamber in which high density mafic melts capped low density silicic ones. Evidence of the existence of a short crystal fractionation series is found in the mafic rocks; the andesitic pumice results from complete blending between rhyolitic and variously fractionated mafic melts (salic component up to 60 wt%), whereas bulk dacitic compositions mainly result from the presence of mafic xenocrysts within rhyolitic glasses. Viscosity and composition-mixing diagrams show that blended liquids formed when the viscosities of the two end members had close values. The following model is suggested: 1. A rhyolitic magma rising through the metamorphic basement entered a mafic magma chamber whose outer portions were occupied by a highly viscous, mafic crystal mush. 2. Under the pressure of the rhyolitic body the nearly rigid mush was pushed upwards and mafic melts were squeezed against the walls of the chamber, beginning roof fracturing and mingling with silicic melts. 3. When the equilibrium temperature was reached between mafic and silicic melts, blended liquids rapidly formed. 4. When fractures reached the surface, the eruption began by the ejection of the mafic melts and crystal mush (A), followed by the emission of variously mingled and blended magmas (B) and ended by the ejection of nearly unmixed rhyolitic magma (C).

Key words: Volcanology – Explosive eruptions – Magma chamber – Magma mixing – Eruption dynamics – Calc-alkaline rocks – Pyroclastic deposits

Introduction

Recent studies have shown that magma mixing in shallow reservoirs frequently plays an important role in triggering explosive eruptions and influencing eruptive dynamics. An explosive eruption may be initiated under different circumstances which lead to the fluid pressure in the chamber exceeding the tensile strength of the country rocks (Sparks et al. 1977; Huppert et al. 1982; Turner et al. 1983; Blake 1984). All studied cases involving magmas with strongly contrasting compositions are interpreted as the injection of hot mafic magmas from below into relatively cold silicic melts stagnating within the chamber (Sparks et al. 1977; Thompson 1980; Ferriz and Mahood 1987). This recurrent situation actually appears to be a general rule for most long-lived polygenetic stratovolcanoes whose magma chambers are replenished through small mafic inputs (Huppert et al. 1986; Santacroce 1983; Civetta et al. 1991).

The explosive emptying of a silicic magma chamber originated by injections of mafic melts commonly produces compositionally zoned pyroclastic deposits. This zonation may be the result of either differentiation processes in the chamber and/or (1) the dynamics of the magma withdrawal and the geometry of the chamber, (2) the emplacement of new mafic magma at the base of the chamber. Variations of the magma discharge rate during an explosive eruption can actually provoke the withdrawal of dense underlying layers.
through overlying low density layers, thereby reversing the expected stratification of the deposits (Spera 1984; Blake and Ivey 1986; Sigurdsson et al. 1990).

The compositional zonation from early erupted, crystal-rich, basaltic andesite to last erupted aphyric rhyolite of the fallout deposits erupted about 24 Ka ago from the Pollara centre (Salina, Aeolian islands, Southern Tyrrhenian Sea) cannot be explained in these terms. Detailed field and geochemical data instead suggest a model in which silicic magma from below enters a poorly evolved, possibly residual, basaltic magma chamber, mixes with resident magma and triggers the eruption.

Evidence is provided for the ejection of juvenile fragments forming a nearly complete basalt-rhyolite mixing series in which true, perfectly blended, hybrid magmas are abundant. Following the approach of Sparks and Marshall (1986), the physical constraints on the proposed process are established.

**Geological and volcanological setting**

Salina is the second largest island of the volcanic Aeolian archipelago (Southern Tyrrhenian Sea) and includes five main subaerial eruptive centres ranging in age from 430 to less than 13 Ka (Gillot and Villari 1980; Keller 1980; Gillot 1987; De Rosa et al. 1990). The geology and the evolution of the island has been studied by Keller (1980), who distinguishes two main cycles of volcanic activity (Fig. 1). The older cycle is characterized by the eruption of high-alumina basalts from four stratovolcanoes (Capo, Rivi, Corvo, Fossa delle Felci) with dacites and andesites as the final products. The younger cycle (100–13 Ka) built up the andesitic cone of Monte dei Porri and ended with the formation of the explosion crater of Pollara on the northwestern edge of the island (Calanchi et al. 1988; De Rosa et al. 1990). In the last 30 Ka the volcanic activity resumed at least three times within the Pollara depression. It began with the effusion of the andesitic to dacitic lava flows of Punta di Perciato (30 Ka) and was followed by two explosive eruptions (Lower and Upper Pollara pyroclasts, Keller 1980) whose deposits built up a complex tuff-ring structure which represents one of the most impressive morpho-tectonic features of Salina. The coastal profile from Pizzo Corvo to Punta di Perciato shows that the depression has an asymmetric shape (Fig. 2): the demantled core of the Pizzo Corvo stratocone (480 m high) forms the western pillar of the depression; primary pyroclastic products outcrop only on the northeastern side of the depression above the Punta di Perciato lavas and form the eastern rim of the Pollara tuff-ring (300 m high at Semaforo). The