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Crustal contamination and crystal entrapment during polybaric magma evolution at Mt. Somma–Vesuvius volcano, Italy: Geochemical and Sr isotope evidence

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Abstract

New major and trace element analyses and Sr-isotope determinations of rocks from Mt. Somma–Vesuvius volcano produced from 25 ky BP to 1944 AD are part of an extensive database documenting the geochemical evolution of this classic region. Volcanic rocks include silica undersaturated, potassic and ultrapotassic lavas and tephras characterized by variable mineralogy and different crystal abundance, as well as by wide ranges of trace element contents and a wide span of initial Sr-isotopic compositions. Both the degree of undersaturation in silica and the crystal content increase through time, being higher in rocks produced after the eruption at 472 AD (Pollena eruption). Compositional variations have been generally thought to reflect contributions from diverse types of mantle and crust. Magma mixing is commonly invoked as a fundamental process affecting the magmas, in addition to crystal fractionation. Our assessment of geochemical and Sr-isotopic data indicates that compositional variability also reflects the influence of crustal contamination during magma evolution during upward migration to shallow crustal levels and/or by entrapment of crystal mush generated during previous magma storage in the crust. Using a variant of the assimilation fractional crystallization model (Energy Conservation–Assimilation Fractional Crystallization; [Spera and Bohrson, 2001. Energy-constrained open-system magmatic processes I: General model and energy-constrained assimilation and fractional crystallization (EC–AFC) formulation. J. Petrol. 999–1018]; [Bohrson, W.A. and Spera, F.J., 2001. Energy-constrained open-system magmatic process II: application of energy-constrained assimilation–fractional crystallization (EC–AFC) model to magmatic systems. J. Petrol. 1019–1041]) we estimated the contributions from the crust and suggest that contamination by carbonate rocks that underlie the volcano (2 km down to 9–10 km) is a fundamental process controlling magma compositions at Mt. Somma–Vesuvius in the last 8 ky BP. Contamination in the mid- to upper crust occurred repeatedly, after the magma chamber waxed with influx of new

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mantle- and crustal-derived magmas and fluids, and waned as a result of magma withdrawal and production of large and energetic plinian and subplinian eruptions.

Keywords: Mt. Somma–Vesuvius volcano; Sr isotopes; Geochemistry; Crustal contamination; Mantle source; Phenocryst entrapment

1. Introduction

Mt. Somma–Vesuvius volcano is the predominant morphological feature in an area inhabited by more than 1.2 million people in the Campanian region of southern Italy (Fig. 1). Accurate evaluation of the hazards posed by the volcano is one of the urgent goals of the volcanological community. Great efforts have been made in this classic volcanic region particularly dealing with the volcanological history (Santacroce, 1987; Rolandi et al., 1993, 1998, 2004; Spera et al., 1998; Arrighi et al., 2001; Andronico and Cioni, 2002) and evolutionary processes affecting erupted magmas (Rittman, 1933; Savelli, 1967, 1968; Turi and Taylor, 1976; Cortini and Hermes, 1981; Joron et al., 1987; Civetta et al., 1991; Civetta and Santacroce, 1992; Belkin et al., 1993a,b; De Vivo et al., 1993; Cioni et al., 1995; Marianelli et al., 1995, 1999; Ayuso et al., 1998; Paone et al., 1998; Raia et al., 2000; Del Moro et al., 2001; De Vivo and Rolandi, 2001; Piochi et al., in press). Considerable insights have been gained about the significance of the geochemical and isotopic variability of the magmas associated with large magnitude volcanic events of Mt. Somma–Vesuvius (Rosi and Santacroce, 1983; Joron et al., 1987; Civetta et al., 1991; Cioni et al., 1995; Landi et al., 1999), as well as those represented by its minor eruptions and interplinian activity (Somma et al., 2001; Cortini et al., 2004). However, a comprehensive understanding of source and evolutionary processes contributing to the magmas at Mt. Somma–Vesuvius is still lacking, and much of the required geochemical and isotopic information is incomplete or controversial.

This report provides new geochemical and Sr-isotopic data for volcanic deposits from Mt. Somma–Vesuvius volcano (rocks older than 25 ky BP to 1944 AD) to better constrain the evolution of this magmatic system and its source rocks, and to identify relevant magmatic processes. The complete sets of data for rock, chemical, fluid and melt inclusions (De Vivo et al., 1993; Spera et al., 1998; De Vivo and Rolandi, 2001, and references therein) obtained during the last decade of study are available (De Vivo et al., 2003) from the Dipartimento di Geofisica e Vulcanologia, University Federico II of Napoli, Italy (http://www.dgv.unina.it/ricerca/de_vivo.htm).

Our new interpretation highlights the fundamental role of shallow-level magmatic processes and contributes to the debate concerning the relative role of magma evolutionary processes compared to features inherited from magma sources (Rittman, 1933; Turi and Taylor, 1976; Hawkesworth and Vollmer, 1979; Cortini and Hermes, 1981; Peccerillo and Manetti, 1985; Joron et al., 1987, Civetta and Santacroce, 1992; Santacroce et al., 1993; Ayuso et al., 1998; Peccerillo, 2001; Somma et al., 2001; Pappalardo et al., 2004; Piochi et al., 2004). Specifically, we discuss below how crustal contamination by carbonate rocks, an idea suggested originally by Rittman (1933), and recently by Pappalardo et al. (2004), provided fundamental control on the evolution of the magmas. We propose that reactions involving the magmas and the country rocks, xenocryst inheritance, and entrapment of crystal mush generated during previous magma storage in the crust contributed to the modification of the Sr-isotopic compositions of the magmas, particularly in their last stage of ascent to the surface.

2. Geological setting

Mt. Somma–Vesuvius is a strato-volcano consisting of a recent cone, Vesuvius, which evolved within the older Somma caldera (Santacroce, 1987; Rolandi et al., 2004) (Fig. 1). The volcanic complex rests on a sequence of Mesozoic and Cenozoic carbonates overlain by Miocene sediments of the Campanian Plain (D'Argenio et al., 1973; Ippolito et al., 1975). This thick sedimentary sequence has been found at a depth of about 1.5 km (Brocchini et al., 2001), and in seismic profiles in the Gulf of Naples at more than