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Review

The structural setting of the Ischia Island (Phlegrean Volcanic District, Southern Italy): Inferences from geophysics and geochemistry

Valeria Paoletti [a,b,*], Massimo D'Antonio [a,c], Antonio Rapolla [a,b,d]

[a] Dipartimento di Scienze della Terra, University Federico II of Naples, Italy
[b] Territorial Town Planning Laboratory, L.U.P.T., Naples, Italy
[c] Istituto Nazionale di Geofisica e Vulcanologia, Sez. di Napoli Osservatorio Vesuviano, Naples, Italy
[d] University Centre for Research on Major Hazards, C.U.G.RI., Salerno, Italy

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A B S T R A C T

In this paper we give an overview of the recent geophysical, geochemical and volcanological studies concerning the island of Ischia within the geological and tectonic framework of Southern Italy. Ischia is an active volcanic field that had a complex volcanic history resulting from dominant explosive and minor effusive activity, several caldera collapses, and renewed volcanism from vents located inside the collapsed area. The island is morphologically dominated by Mt. Epomeo, the result of a prominent resurgence phenomenon taking place since ca. 33 ka BP, and responsible for ca. 900 m of total uplift, one of the largest known compared to the relatively small size of the caldera. The uplift was accompanied by activation of faults, seismic activity and renewal of volcanism, and may be considered a main factor for inducing slope instability. For Ischia, volcanological, petrological and geophysical studies are, at present, limited compared to the other active volcanoes of the Neapolitan Area. Furthermore, the island is characterized by high volcanic, seismic and hydrogeological risks. Thus, this review is aimed at highlighting aspects of the knowledge on Ischia that need more investigations, in order to better assess some characteristics of its structural setting. Features such as the precise location of the caldera boundaries and the depth of the magma chamber representing the *drive* for the resurgence still need to be well defined. A critical analysis of all lines of evidence relevant to the current theories about the island resurgence (*resurgent block* vs. *resurgent dome*) has been carried out. Our analysis reveals that the *resurgent block* model, differently from the *resurgent dome* model, is consistent with the most significant features, such as tilting of the resurgent block, faults type, dip and distribution at the edges of the block, and occurrence of most of the past 10 ka eruption vents on the eastern sector of the island. However, as both model require an input of fresh magma into the shallow plumbing system, it is not clear at present how much magma was necessary to achieve the measured uplift, and whether the drive was provided by magma or magmatic volatiles.

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* Corresponding author at: Dipartimento di Scienze della Terra, University Federico II of Naples, Italy.
E-mail address: paoletti@unina.it (V. Paoletti).

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1. Introduction

The island of Ischia (Fig. 1a) is the westernmost volcanic field of the Phlegrean Volcanic District (PVD), a volcanic area of Southern Italy that includes also the Campi Flegrei caldera and the island of Procida (Orsi et al., 1996). These volcanoes, along with the Mt. Somma–Vesuvius complex, are known as the Neapolitan Volcanic Area, that has been the object of several geological and geophysical studies in the past decades. These investigations have pointed out that, except for Procida, all other Neapolitan volcanoes, including Ischia, are still active, as testified by their historical eruptions and moderate seismicity, as well as hydrothermal and fumarole activity.

The purpose of this review is to gather current knowledge, views and theories on the structural setting of Ischia, and compare and discuss them in the light of the available geological, volcanological and petro-chemical data. For Ischia, volcanological, petrological and geophysical studies are, at present, more limited compared to the very well studied nearby Campi Flegrei and Somma–Vesuvius. Thus, this review is aimed also at highlighting aspects of the knowledge on Ischia that need more investigations, as revealed by a critical analysis of all lines of evidence relevant to the current models about the island resurgence. This effort is mandatory for an active volcanic area, as Ischia is, characterized by a high volcanic hazard due to the explosiveness of its activity occurred in historical times (e.g., Lirer et al., 2010). Furthermore, the island has been hit by strong earthquakes and landslide events occurred in the past centuries (e.g., de Vita et al., 2006; Carlino et al., 2010). All this, and the high exposed value, increasing especially during summertime when the island is reached by thousands of tourists that add to the permanent local population of ca. 50,000 people, make the volcanic, seismic and hydrogeological risks of Ischia quite high.

1.1. Regional tectonic, geological and volcanological framework

Ischia and the other Neapolitan volcanoes are located in the Campanian Plain, a Plio-Quaternary 2000 km^2 wide NW–SE trending graben, bordered by Mesozoic limestone mountains (Fig. 1a; e.g., Scandone, 1979; Fedi and Rapolla, 1987; Sartori, 2003). The plain is delimited by NW–SE trending faults to the north-east, that down-thrust the Apennine mountains, and by NE–SW trending faults to the north-west and south-east, that form the horsts of Mts. Lattari, Island of Capri, and Mt. Massico, respectively. The maximum depth of limestone in the plain is more than 4 km b.s.l. (e.g., Ippolito et al., 1973; Fedi and Rapolla, 1987) buried under alluvial and volcanic materials down to at least 3 km depth (AGIP, 1987).

The origin of the Campanian Plain is related to extensional tectonic events that accompanied the Plio-Pleistocene opening of the Tyrrhenian Sea basin and the counter-clockwise rotation of the Italian Peninsula with consequent thinning of its western edge (Scandone, 1979; Sartori, 2003). These events were accompanied by a regional upraise of the mantle — which reaches its maximum in the center of the Tyrrhenian Sea — through a passive stretching process (Cella et al., 2006) and by an intense phase of Plio-Quaternary calc-alkaline to potassic-alkaline volcanism in correspondence with areas undergoing subsidence along the Tyrrhenian Sea border (e.g., Beccaluva et al., 1991). The volcanic activity in this area, which started in Early Pliocene in relation to the above mentioned extensional processes, is thus controlled by regional stress fields along NW–SE normal faults and, subordinately, NE–SW normal to strike-slip transfer systems (Acocella et al., 1999, Acocella and Funiciello, 2006). The Campanian Plain graben is crossed by a NE–SW trending volcanic ridge, bordering the north-western side of the Gulf of Naples and separating the continental shelf to the NW from a deeper sea-floor topography to the SE: the Phlegrean Volcanic District is located on this ridge (Fig. 1; e.g., Rapolla et al., 1989; de Alteriis and Toscano, 2003).

The intense volcanic activity that affected the Neapolitan Volcanic Area produced significant volumes of volcanic rocks. These rocks are variable from earlier calc-alkaline andesite-basalts and andesites, presently buried underneath the Campanian Plain (Beccaluva et al., 1991, and references therein), to later potassic-alkaline products of Middle Pleistocene–Holocene age (e.g., Di Girolamo et al., 1984; Beccaluva et al., 1991; Pappalardo et al., 1999; D'Antonio et al., 2007; Di Renzo et al., 2007). The Neapolitan volcanoes formed and grew during the past few hundreds of thousands years, assuming their current morphology and size in the past tens of thousands years (e.g., Santacroce et al., 2003). At Campi Flegrei for example, the oldest dated volcanic deposit has an age of 58 ± 3 ka B.P. (Pappalardo et al., 1999), although older deposits, up to 290 ka B.P., occur in the Neapolitan Volcanic Area (Rolandi et al., 2003; Di Renzo et al., 2007); the last eruption occurred in 1538 AD. At Ischia Island, the oldest dated volcanic rock has an age of 150 ka B.P., and the last eruption occurred in 1302 AD (Buchner, 1986).

The three active Neapolitan volcanoes (Ischia, Campi Flegrei and Mt. Somma–Vesuvius) have been characterized through time by moderate to strong explosive activity producing either pyroclastic fallout or pyroclastic density current deposits (e.g., Orsi et al., 1996, 2004; Di Vito et al., 1999; Di Renzo et al., 2007; Brown et al., 2008; Santacroce et al., 2008; de Vita et al., 2010). Effusive activity was intense during Mt. Somma growth (e.g., Di Renzo et al., 2007; Santacroce et al., 2008), whereas it was sparse at Ischia island (e.g., Vezzoli, 1988, and references therein; Vezzoli et al., 2009; de Vita et al., 2010), and rare at the Campi Flegrei caldera (e.g., Di Vito et al., 1999), giving rise to small lava flows and domes only. Ischia and Campi Flegrei were fed by mildly potassic-alkaline magmas throughout their volcanic history. These magmas were mostly trachytes and phonolites, with minor K-trachybasalts, shoshonites and latites (Fig. 2a–b). They were likely related by fractional crystallization processes often accompanied by other, open-system evolution processes such as magma mingling/mixing and crustal contamination, resulting in complex textural, mineralogical, geochemical and isotopic variations in the rocks (e.g., Di Girolamo et al., 1984, 1995; Vezzoli, 1988, and references therein; Crisci et al., 1989; Beccaluva et al., 1991; Civetta et al., 1991; Orsi et al., 1992; Piochi et al., 1999; D'Antonio et al., 2007; Brown et al., 2008; Tonarini et al., 2009; Di Renzo et al., 2011). The abundant trachytes and phonolites, likely resulting from prolonged crystal fractionation processes of more mafic magmas, must have left large volumes of solidified material (i.e., cumulates) in the crust, as hypothesized and modeled on volcanological and petrological grounds for the Campi Flegrei caldera (D'Antonio, 2011, and references therein). The least differentiated products (K-basalts) occur only at Procida island (e.g., Di Girolamo and Stanzione, 1973; D'Antonio et al., 2007; Fig. 2b).