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The Mazzola archaeological site of Ischia (Southern Italy), evidence of close interactions between humans and volcanism: at times a hazard but also a resource

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Abstract

The long-term interplay between human settlements and hazardous natural processes is being examined on the island of Ischia, within the Neapolitan volcanic district (Italy), through multidisciplinary collaboration between archaeologists and volcanologists. Despite recurrent volcanic activity and widespread slope instability – especially during the period in which civilization began to gain ground – Ischia has been almost continuously inhabited since the Neolithic, its environment alternately offering resources and posing risks.

This paper presents the preliminary results of recent excavations at the Mazzola site (Lacco Ameno). The area provides a valuable case study for assessing the dynamic relationship between ancient communities and their environment. The data confirm that Ischia's volcanic nature consistently shaped patterns of land use: at times negatively, prompting the abandonment of inhabited areas following eruptive events, but also positively, supplying valuable exploitable resources.

The newly exposed stratigraphy shows that in the late 8th century BC the Greek settlement featured domestic structures alongside open or semi-open spaces dedicated to metallurgical activity, particularly iron and bronze working, likely involving fragmented local volcanic rocks. An abrupt occupational hiatus occurred at the beginning of the 7th century BC, caused by an explosive eruption that deposited a thin pumice-lapilli and ash layer sealing the earlier deposits. Reoccupation began in the early 6th century BC with a new construction phase, including the erection of a rectangular building made of Mt. Epomeo Green Tuff blocks.

The position and sedimentological features of the volcanic layer support its correlation with the Punta Chiarito Tephra, exposed in the island's southwestern sector, which similarly marks the abandonment and later reoccupation of a Greek settlement in the early 7th century BC.

Keywords: Ischia island; Volcanic hazards; Human settlements; Stratigraphy; Iron Age

1. Introduction

Living in active volcanic areas is a challenge that humans have always accepted, despite the hazards posed by volcanoes. This was mainly due to high soil fertility, particularly in favorable climatic conditions, or for the presence of natural raw materials, ore deposits and the abundance of volcanic rocks that are good building materials.

The history of this kind of interaction is under investigations at Ischia, in the Neapolitan volcanic area (Italy), thanks to close collaboration between archaeologists and volcanologists. In fact, integrated volcanological and archaeological studies – conducted by closely comparing sedimentary and cultural stratigraphies – have proven to be highly effective in revealing how volcanic eruptions affected ancient communities and their settlements (Lowe et al., 2000; Newhall et al., 2000; Siebe, 2000; Giaccio et al., 2006; Grattan and Torrence, 2007; Cashman and Giordano, 2008; Di Vito et al., 2009; 2013; 2019; Schminke et al., 2009, 2010; Castaldo et al., 2010; de Vita et al., 2011; 2013; 2021; 2024; Di Lorenzo et al., 2013; Speciale et al., 2021). Current advances in archaeology within volcanic regions go far beyond simply interpreting structures and artifacts. The goal is now to reconstruct the everyday lives of past peoples, understand how they responded to natural catastrophes, and assess their capacity for resilience (de Vita et al., 2013: Di Vito et al., 2019). In this context, the groundbreaking research carried out by Giorgio Buchner on Ischia (Buchner, 1938, 1946, 1969, 1975, 1986) showed that, beginning in the Neolithic period, the island underwent a complex sequence of human occupation phases interrupted by volcanic eruptions that destroyed settlements and forced inhabitants to leave. More recent volcanological studies and archaeological digs have confirmed that volcanic activity was particularly vigorous during the time when early civilizations were developing on the island (Buchner, 1986; Gialanella, 1994; de Vita et al., 2006; 2010; 2013).

Here we present the preliminary results of the resumed excavation activities in the archaeological area of Mazzola (Lacco Ameno, Ischia; Fig. 1). This site, previously investigated between 1969 and 1971 by J. J. Klein (Klein, 1972), is occupied by a series of residential and artisanal structures referable to a Greek settlement, covering a wide chronological span that, with some significant interruptions, goes from the Middle Bronze Age 1B-3 (16th-early 14th century BC) to the Classical period (first half of the 6th century BC). The archaeological site of Mazzola constitutes a case study of particular interest which allows us to reflect, from an ecological perspective, on the close relationship existing between ancient communities and the environment. It highlights, in fact, how the volcanic nature of the island of Ischia has constantly influenced the modes of occupation of the territory, sometimes negatively, causing the abandonment of inhabited areas following eruptive phenomena, but also positively, offering important resources that can be exploited.

2. Materials and methods

The close collaboration between archaeologists and volcanologists in conducting research at the Mazzola site required the use of techniques and methods shared by both disciplines, supplemented by practices specific to each. In particular, the technique of stratigraphic excavation formed the common foundation of the approach, accompanied by archaeological documentation and analysis of the finds, geo-volcanological surveying, and mineralogical-petrographic instrumental analyses.

The techniques used in archaeological excavation and in identifying stratigraphic layers are fundamental for rigorously reconstructing the history of a site, since each deposit preserves information about its formation, human activities (construction, demolition, pit-digging, backfilling), and the natural processes (floods, landslides, sedimentation, volcanic eruptions) that have altered it over time (Barker, 1996; Hester et al., 2016). Stratigraphic excavation is based on the principle of the law of superposition: the oldest layers are found at the bottom and the most recent at the top. To correctly identify and distinguish layers – both volcanic and non-volcanic – it is essential to observe characteristics such as lithology, components, structure, texture, grainsize, color, consistency, the presence of paleosols and soil composition, the presence of materials as inclusions, the physical boundaries between adjacent layers and their lateral variations (geometry and stratimetry). Once a stratigraphic unit has been identified, it is excavated as an independent entity: deposits are removed in a controlled manner using hand tools such as trowels, proceeding slowly to avoid damaging any in-situ remains.

Documentation is an integral part of excavation techniques. Each unit is registered using specific recording sheets, plan and section drawings, photographs, and increasingly via 3D models created by photogrammetry or laser scanning, which enable precise reconstruction of surfaces and stratigraphic relationships. In the end, a Harris Matrix

is used to represent, in a graphic and logical way, the stratigraphic sequence based on the physical relations between the various units; this helps to interpret the series of events that led to the formation of the site.

By analyzing the artifacts found in each layer, especially potsherds, which function as 'guide fossils', it is possible to reconstruct the historical sequences present at a specific archaeological site.

Sampling of volcanic units in an archaeological excavation usually takes place after the documentation phase and is intended to allow for possible chemical, mineralogical, and petrographic analyses to be conducted later, if needed.

In particular, for the lava-flow fragments found in the area of Mazzola, the qualitative mineralogical characterization of the bulk, randomly oriented bulk, as well as the quantitative determination of their phase composition, was carried out by XRPD using a Panalytical X'Pert PRO PW 3040/60 diffractometer equipped with a pyrolytic graphite analyzer crystal. Unfiltered CuKα radiation (40 kV, 40 mA) was used over the range 0°-70° 2θ, with the following operating conditions: step size of 0.02° 2θ, counting time of 30 s per step, 0.5 mm divergence slit, 0.1 mm receiving slit, and anti-scatter slit of 0.5°. Quantitative phase analysis was performed using X'Pert HighScore Plus software (version 4.9). The quality of the refinement was evaluated based on the goodness-of-fit parameter, the profile residual (Rp), and the weighted profile residual (Rwp).

Previous major and minor element characterizations of Zaro lava flow samples were obtained by X-ray fluorescence and both electronic scanning microscope (SEM-EDS) and electron micro probe analysis (EMPA) for whole rocks and minerals, respectively (Pelullo et al., 2020, 2024).

3. Volcanological and archaeological framework

3.1 Volcanological setting

Ischia constitutes an active volcanic field covering approximately 46 km^2, though geophysical evidence suggests that the island constitutes the preserved portion of a formerly more extensive volcanic complex extending westward (Orsi et al., 1999; Bruno et al., 2002; Sbrana and Toccaceli, 2011). The island is composed of volcanic units interbedded with landslide deposits and minor terrigenous sediments, recording a complex evolution shaped by alternating constructive and destructive processes driven by tectonic, volcanic, volcanotectonic, and gravitational dynamics (Vezzoli, 1988; Orsi et al., 1991, 2003; de Vita et al., 2006, 2010; Della Seta et al., 2012). Volcanism on Ischia dates back more than 150 ka and is dominated by the caldera-forming eruption of the Mount Epomeo Green Tuff (60-55 ka; Sbrana and Toccaceli, 2011), which was followed by asymmetric block resurgence of the caldera floor (Selva et al., 2019 and references therein; Marotta et al., 2024). Resurgence occurred intermittently, and its dynamics conditioned subsequent volcanic activity, which was mainly concentrated in the eastern sector of the island and along the margins of the resurgent block (Orsi et al., 1991; Marotta and de Vita, 2014; Trasatti et al., 2019). The most recent phase of volcanic activity began between 13 and 10 ka BP and was characterized by clustered eruptions. The last cluster, which included the largest number of eruptions, occurred during the past 6 ka and culminated in the 1302 CE Arso eruption (de Vita et al., 2010).

The Mazzola archaeological site is located in the north-western corner of Ischia island, at the south-eastern end of the Zaro peninsula (Fig. 1). This comprises a stack of lava flows, domes, and scoria cones emplaced over a relatively short interval along a complex network of NW-SE and NE-SW trending fractures (Fig. 1; Zaro lavas and domes unit in de Vita et al., 2010; Zaro lavas – P. Caruso Member in Sbrana et al., 2018). The lavas are light gray in color and very porphyritic, with large (up to 2 cm) phenocrysts of feldspar, often present as a close-mesh net of crystals with little glassy or microcrystalline groundmass (cfr. section 6). The domes and scoria cones, generally quite well preserved, overlie the oldest lava flows, which have very similar mineralogical and textural characteristics, and have been interpreted as products of the same volcanic activity. Feeding dikes of the Zaro lavas are intruded into an older pyroclastic sequence, exposed along the south-western side of the Zaro peninsula (de Vita et al., 2010). The Zaro Lavas originated from a fissural vent, along which small domes were also aligned, and dated to 6.6 $\pm$ 2.2 ka (Vezzoli, 1988). A sequence of undefined pyroclastic deposits and marine sediments with fossils has been reported by Buchner et al. (1996) in the area of Mezzavia. Although the base of this sequence is not exposed, it is possible that it is intercalated in the Zaro Lava succession, as two fossil shells sampled in the middle part of the sequence have been dated to 5.97 $\pm$ 0.26 and 5.75 $\pm$ 0.22 ka (Buchner et al., 1996), and a scoria fallout deposit associated with the final phase of the Zaro volcanic activity lies above this sequence. The Zaro Lavas overlay older pyroclastic and volcaniclastic deposits of variable age and are overlain by a sequence of pyroclastic and volcaniclastic deposits of prehistoric age (de Vita et al., 2010).

3.2 Archaeological context

Archaeological research conducted by Giorgio Buchner at Ischia profoundly transformed our understanding of Greek colonization in the western Mediterranean. Starting from the recounts of Titus Livius (VIII 22) and Strabo (V 247 C), referring to Timaeus of Tauromenion's writings, and based on 8th century BC geometric pottery finds – with his extensive excavations beginning in 1952, Buchner demonstrated that the Greek colonization of the West originated with the foundation of Pithekoussai on Ischia in the second quarter of the 8th century BC, prior to the establishment of Cumae on the mainland (Buchner and Gialanella, 1994). Founded around 770-750 BC by Euboean settlers from Chalcis and Eretria, Pithekoussai developed in the northwestern part of the island, with its acropolis on Mount Vico, the port area and necropolis in the San Montano Valley, and a metal-production district at Mazzola (Fig. 1). The settlers, however, found that the island was already inhabited; groups had been sporadically present since the Neolithic and more permanently since the 14th century BC. The inhabitants, who had occupied several sites near and around Mt. Vico, had long maintained trading links with the Aegean, as demonstrated by the remains of Mycenaean pottery found at the Castiglione site, on the northern coast of the island (Buchner and Gialanella, 1994).

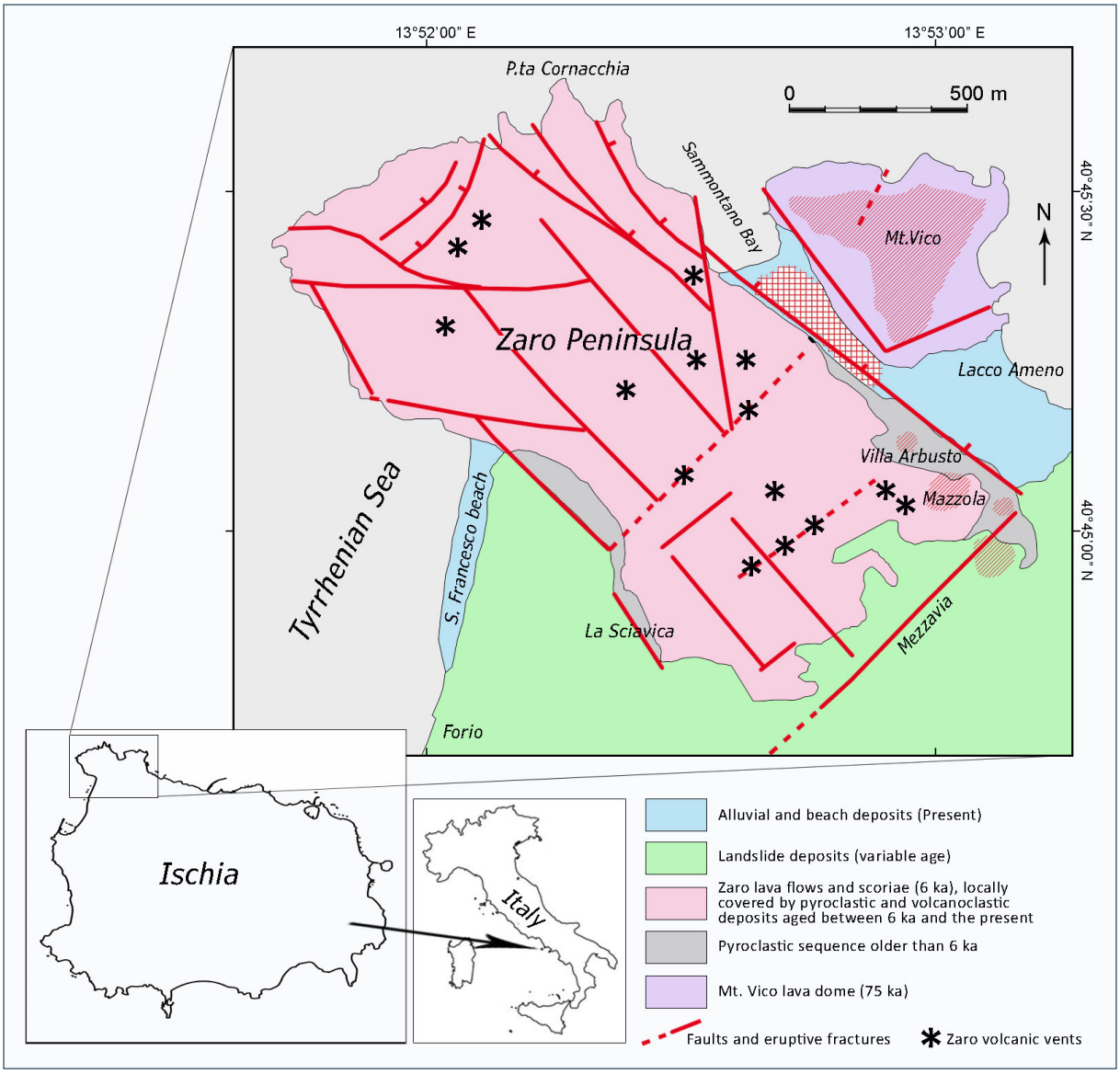

Figure 1. Location and geological sketch map of the investigated area. Areas with red hatching represent the archaeological sites; the cross-hatched area represents the San Montano necropolis. The white arrow indicates the Mazzola site. Redrawn after Buchner and Ridgway, 1996 and Pelullo et al., 2020.

Excavations revealed this long-term occupation of the island, including coexistence between indigenous communities and Greek settlers, almost continuously throughout what is known as the colonial period, but with episodes of local abandonment. Pithekoussai rapidly became a major manufacturing and commercial center, specializing in metallurgy and pottery production, and maintaining extensive trade networks with the eastern Mediterranean, mainland Greece, and central and southern Italy. Magnificent finds attest to the culture of this period; thriving commerce with the Near East and Eastern Mediterranean is demonstrated by the presence of small exotic objects such as seals and scarabs and the varied pottery types found among the grave goods of some burials. Luxury goods were imported from Greece, particularly from Corinth and Euboea itself. These interactions played a fundamental role in the spread of technologies and alphabetic writing to Italic populations, making Pithekoussai a key catalyst in the formation of Magna Graecia (Buchner and Ridgway, 1993; Buchner and Gialanella, 1994; Gialanella, 2013).

The settlement reached its maximum expansion during the second half of the 8th century BC, but began to decline in the early 7th century BC as the focus of Euboean colonization shifted to the mainland with the rise of Cumae. During the 6th century BC, material culture at Pithekoussai reflects strong connections during the 6th century BC with the wider Greek world, particularly through the diffusion of Attic pottery and architectural terracottas. Between 450 and 420 BC Campania was occupied by Sabellian peoples (the Roman name for Oscan-speaking Italic peoples) from the Apennines of Abruzzo and Molise. In about 420 BC Cumae too fell into their hands and became an Oscan city. Only Neapolis resisted the invaders and occupied Pithekoussai, which thus remained a city of Greek culture for a further three centuries (Buchner and Gialanella, 1994).

4. The Mazzola artisan district

4.1 Previous excavations

Between 1969 and 1972, following occasional discoveries, archaeological investigations were conducted on Mezzavia Hill, on the Mazzola locality at Lacco Ameno (Ischia island, South Italy), directed first by Jeremy Rutter and subsequently by Jeffrey J. Klein (Klein, 1972), both researchers at the University of Pennsylvania. These excavations led to the identification of a sector of a predominantly productive quarter, occupied between the late 8th and the 6th century BC (Buchner, 1971; Buchner, 1972; Klein, 1972; Cuozzo, 2021; Gialanella and Guzzo 2021). The quarter extended along the slopes facing Monte di Vico, on the opposite side of the San Montano valley, an area that had previously not been occupied (Fig. 1). The earliest evidence of human presence at the site brought to light during this research consists of a number of potsherds dating to the Middle Bronze Age, in line with evidence from other nearby sites such as the acropolis of Monte di Vico (Buchner, 1971; Buchner, 1972; Ridgway, 1984) and Castiglione Hill at Casamicciola (Pacciarelli, 2016).

The geographic setting is characterized by steep inclines and marked variations in elevation. By the time the buildings were constructed, the area had been artificially leveled by substantial terracing. This is demonstrated by two dry-stone retaining walls intended to stabilize the slopes and mitigate erosion. Similar terraced arrangements, closely tied to the geomorphology of this part of the island, have been documented during recent investigations conducted near the Archaeological Museum of Pithekoussai at Villa Arbusto (Burkhardt and Faust 2021) and at Punta Chiarito (Gialanella, 1994; Gialanella, 1996; De Caro and Gialanella 1998; Gialanella, 2013).

Excavation brought to light an upper terrace and a second terrace located approximately one meter lower, permitting the identification of a sequence of structures, most of which were built in the second half of the 8th century BC (Fig. 2). Already at the time of discovery, the concentration of metal slag and other production indicators of productive activity made it clear that the area constituted an artisan quarter (Buchner, 1971; d'Agostino, 1999; d'Agostino, 2006).

A recent reassessment of the excavation records has increased the number of recognizable structures in the complex to ten (Gialanella and Guzzo 2021), although several are only partially preserved (or have been insufficiently explored).

On the upper terrace, Building I is of particular importance. Its first phase can be dated to the late Geometric I period (750-720 BC). It is an elongated rectangular structure with a rear apsidal room (Buchner, 1971; Buchner, 1972; Klein, 1972; Fusaro, 1982), interpreted variously as either a secluded sleeping space (Barra Bagnasco, 1990) or, more plausibly, as a storage area for the goods of the oikos, given its modest dimensions and the nature of the finds (Gialanella and Guzzo, 2021). The floor yielded a notable concentration of vessels, among which two largely

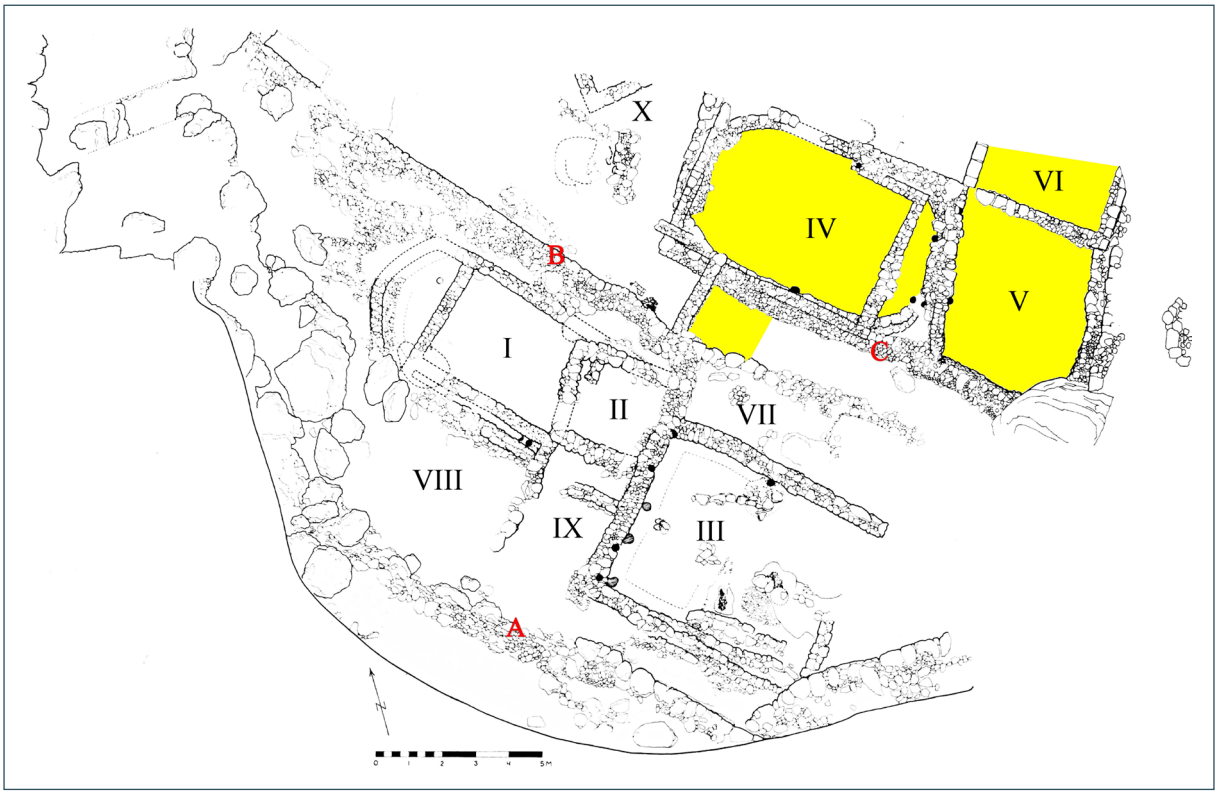

Figure 2. General plan of the Mazzola site. I-X: buildings uncovered by J. Rutter and J. Klein (Klein, 1972). A-C: terracing walls. Areas investigated in 2023 and 2024 are shown in yellow.

reconstructable kraters and a cooking pot set into the beaten-earth surface; no permanent installations were identified (Buchner, 1971; Ridgway, 1984). Crucially, this is the only building that has not yielded any traces of metalworking and has therefore been interpreted as being intended exclusively for residential use (Klein, 1972; Fusaro, 1982; Pesando, 1989; Mazarakis Ainian, 1998; Mele, 2003; Gialanella and Guzzo, 2021). At a later stage of the building's construction, a dry-stone wall was erected to separate the apse from the rest of the structure, while the absence of traces of subsequent refurbishments suggests its early abandonment, attributed by Klein to a landslide occurred at the end of the 8th century BC (Buchner, 1971; Ridgway, 1984).

Building VIII, aligned with Building I, also belongs to the earliest construction phase, although its interpretation remains limited by the lack of excavation data (Gialanella and Guzzo, 2021).

Immediately to the east lies Building III, a rectangular structure with a first phase dating to c. 750 BC. Only its northwestern sector appears to have been roofed, while a series of postholes along the perimeter wall likely supported the roof structure. The floor surfaces produced abundant traces of burning and numerous pieces of iron and bronze slag, permitting the identification of this building as an ergasterion already at the time of excavation (Buchner, 1971; Ridgway, 1984; Barra Bagnasco, 1990).

On the lower terrace, the first phase of Building IV, dated to the third quarter of the 8th century BC, is oval in plan (Mazarakis Ainian, 1997). In a subsequent phase, the building was reconstructed with a rectangular plan, partially reusing the earlier walls, and equipped with a hearth, interpreted by Buchner as a forge on the basis of phonolite stones and metallurgical waste indicative of bronze and iron working (Buchner, 1971). Excavation outside the structure revealed further evidence of metalworking activities (Ridgway, 1984; Gialanella and Guzzo, 2021).

The spatial organisation of the complex appears to have been conditioned both by the irregular topography and by the need to control slope instability. Among the later building phases, the most significant intervention is the reorganization of the upper terrace toward the end of the 8th century BC, involving substantial structural and functional modifications, particularly of Building III. Following the disuse of Buildings VIII and I, an open area created to the northwest of Building III allowed the construction of two service rooms (Buildings II and IX), built using the northwestern perimeter wall of Building III as their rear wall. This restructuring of the upper terrace also appears to include Room VII, located northeast of Building III. Previously interpreted as an open courtyard, it is now

understood to be a small, elongated rectangular room; the presence of materials associated with both metallurgical and domestic activities suggests a multifunctional character (Gialanella and Guzzo, 2021).

The Mazzola district was largely abandoned in the first quarter of the 7th century BC. It was reoccupied at the end of the 7th century BC, before being definitively abandoned around the mid-6th century BC, most likely as a consequence of recurrent natural instabilities affecting the area.

This brief contribution provides an overview of the Mazzola site. Many open questions remain, in view of its evident importance. As described below, 50 years after the first discoveries, a new excavation campaign was conducted by the "Soprintendenza Archeologia, Belle Arti e Paesaggio per l'Area Metropolitana di Napoli", with funds from the Ministry of Culture, which gave new impetus to research in the Mazzola area.

4.2 New data from the Mazzola settlement

The investigations carried out by the "Soprintendenza Archeologia, Belle Arti e Paesaggio per l'Area Metropolitana di Napoli", between November 2023 and March 2024, focused on the lower terrace of the Mazzola archaeological site, concentrating on the north-western portion of this terrace (Fig. 2, in yellow). The chosen excavation area seemed particularly promising, as it had only been partially excavated by J. Klein during the last archaeological campaigns in 1971 and 1972 (Klein, 1972). Klein's excavations had in fact mainly focused on the interior of building IV, reaching the foundation levels of the structure, while the area occupied by buildings VI and V had only been excavated superficially. This offered the opportunity to investigate archaeological stratigraphies that were still intact using modern excavation methods.

This contribution presents the results of research starting from the earliest phase of occupation of the site, dating to the Middle Bronze Age (16th-14th century BC), up to the definitive abandonment of the area around the middle of the 6th century BC. Clear throughout this long period of time is the relationship between humans and the island's geology, which exerted a constant influence on the ways in which the area was occupied and exploited.

The earliest evidence of human presence at the Mazzola site includes several fragments of common ware pottery, from mugs and bowls, that can be generically classified as Middle Bronze Age 1B-3 (16th-15th century BC; Cinquantaquattro et al., 2023; Fig. 3), embedded in a sequence of layers reworked anthropically for the creation of an artificial terrace. Above this terrace was uncovered a sequence of evidence relating to the presence of structures that indicate the permanent settlement of the area. The principal remains were found in the central portion of the lower terrace. Here, only part of a hut was preserved, as it had been partially destroyed by more recent interventions in the late Geometric period (750-720 BC). The hut had a foundation consisting of small stones placed on top of each other, which would have supported a standing structure made of perishable material. A series of postholes along the outer perimeter of the hut show that posts provided additional stability (Cinquantaquattro et al., 2023). Inside the structure, two large circular holes were found, probably used to house storage vessels, dug into an earthen floor characterized by numerous anthropic traces, including fired clay fragments, small pieces of charcoal, and potsherds. The latter proved extremely useful for accurately dating the construction of the hut and its use. In addition to several fragments of common ware pottery dating to the Middle Bronze Age 2-3 (15th-early 14th century BC) (Cinquantaquattro et al., 2023), there are a few fragments of Mycenaean imports (Cinquantaquattro et al., 2023) which, thanks to similar finds at the sites of Castiglione d'Ischia (Marazzi and Tusa 1994; Gialanella, 2001; Giardino and Merkouri 2007) and Vivara (Procida island; Marazzi and Tusa 1994), can be dated to the Late Helladic II-IIIA period.

A long chronological break, lasting about 650 years, followed this first occupation; the Mazzola area was not reoccupied until the mid-8th century BC when a sector of the Greek settlement of Pithekoussai was established in this site. During this break, the protohistoric settlement surface was partially washed away by natural erosion and depositional phenomena; when the Greeks arrived, the site still presented a noticeable slope towards the northeast. For this reason, a series of leveling operations were necessary, as well as the construction of long dry-stone walls to protect two large artificial terraces intended to house residential and craft buildings.

Occupation of the lower terrace was characterized by the presence of a large open space used for pyrotechnological activities related to metalworking, located immediately outside a building (IV). In this open artisanal area, were found numerous earthen floors characterized by fire areas, traces of oxidation, and distinctive irregularly shaped holes filled with sand and similarly-sized fragments of lava stones (Fig. 4). Of particular significance is the fact that these lava stones have notable magnetic properties, casually observed by placing a magnet close to the debris obtained by

Figure 3. Fragments of common ware pottery (bowls) from the Middle Bronze Age 1B-3 (16th-15th century BC).

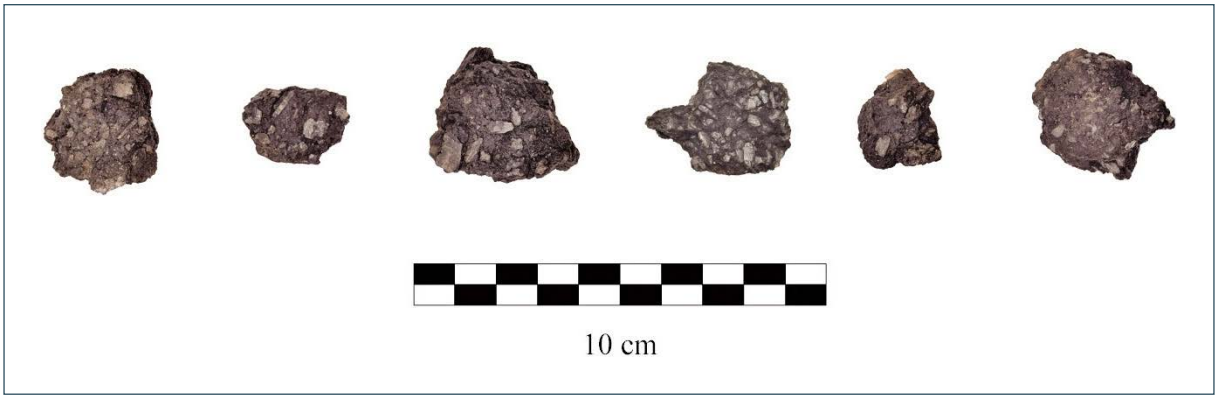

Figure 4. Similarly-sized lava fragments found in the holes dug in the earthen floor of the artisanal area.

crumbling some of these fragments. This seemingly unusual characteristic seems to indicate their direct use in pyrotechnological activities related to in-situ metalworking, as also clearly evidenced by the frequent presence of iron slag (Fig. 5).

Based on the pottery finds associated with these levels, we can date these activities to the second half of the 8th century BC and the early decades of the seventh century BC (Cinquantaquattro et al., 2023). During the first half of the 7th century BC another significant interruption in the occupation of the area occurred, evidenced by the presence of a pyroclastic deposit covering the early 7th century BC archaeological stratigraphy (Fig. 6), above which the subsequent archaeological layers relate directly to the most recent phase of the Mazzola district, dating to the late 7th century and the first half of the 6th century BC (Cinquantaquattro et al., 2023).

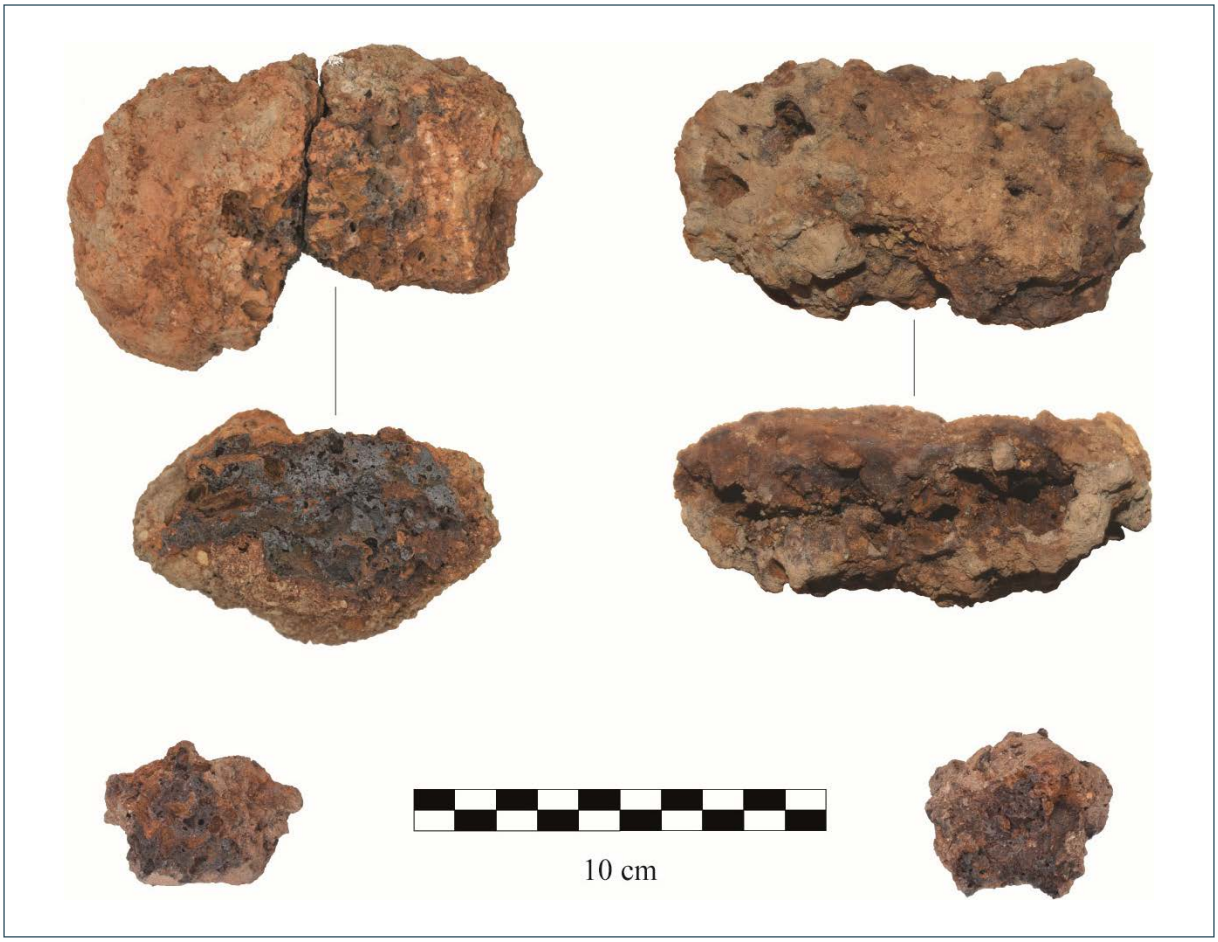

Figure 5. Iron slag: metalworking residues.

It is in this latter phase that we see the reorganization of the lower terrace, with the construction of a new large rectangular building (VI), which involved the use of blocks of "green tuff" quarried from Mount Epomeo. The construction of this structure led to a significant leveling of the upper part of the volcanic deposit. This stratigraphy finds a precise parallel in the archaeological evidence uncovered at the Punta Chiarito site, located in the south-western part of the island of Ischia (Fig. 1).

In this context too, the most recent settlement phase, dating from the late 7th century BC to the early decades of the 6th century BC, was located directly above a volcanic deposit approximately 1-meter-thick, consisting of ash and lapilli (Gialanella, 1994; De Caro and Gialanella 1998; Gialanella, 2013), known in the literature as the "Chiarito Tephra" (de Vita et al., 2010; 2014).

The reoccupation of the site during the first half of the 6th century BC constitutes the last evidence of human presence in the area, which appears then to have been suddenly abandoned once again, this time permanently.

Figure 6. The pyroclastic sequence of Chiarito Tephra (de Vita et al., 2010) lying above the remnants of the 8th century-early 7th century BC structures and buried by the following volcaniclastic sequence (see also Fig. 7 for a detailed description of the pyroclastic deposit).

5. Stratigraphy

Excavation of the Mazzola archaeological site involved a complex stratigraphic sequence composed of pyroclastic and volcaniclastic deposits that in turn overlays lavas and scoriae belonging to the Zaro unit (Zaro lavas and domes; de Vita et al., 2010; Zaro lavas – P. Caruso Member; Sbrana et al., 2018; 6.6 ± 2.2 ka; Vezzoli, 1988; Fig. 7). This latter unit, not exposed in the excavation in question, forms the bedrock of the entire Zaro Peninsula, extending from Punta Caruso-Punta Cornacchia to Mezzavia, between Lacco Ameno and Forio (Fig. 1).

The lowermost bed exposed in the excavation is a hardened layer consisting of reworked, vesiculated volcanic ash, with scattered heterogeneous fragments of pumice of variable nature and size, lithic elements, and hydrothermally altered fragments. The deposit is matrix-supported, and its massive, chaotic, and heterometric structure, combined with its heterogeneous content, allows it to be classified as a lahar (volcaniclastic mudflow). The deposit was emplaced following the natural slope of the site, which dips in a north-easterly direction (m = 28%). It is covered by a series of thin alluvial deposits, consisting of light brown-yellowish silt, overlaid by a layer of coarser reworked pyroclastic material. This layer is mainly composed of millimeter-size, very rounded pumice fragments, resulting from post-depositional runoff. A further alluvial layer, with a variable thickness of 30-50 cm, covers all this sequence.

The 8th-7th century BC remains overlies the above-described sequence and are covered by a pyroclastic sequence, whose slight lateral thickness variation (27-37 cm) is due to post-depositional top erosion. The base of the deposit dips towards the northeast at about 5°. A detailed stratigraphic description of this pyroclastic sequence is given in Fig. 7.

The anthropic structures built directly above this pyroclastic sequence between the late 7th century and the first half of the 6th century BC are covered by a several-meter-thick succession of volcaniclastic deposits (Figs. 6 and 7).

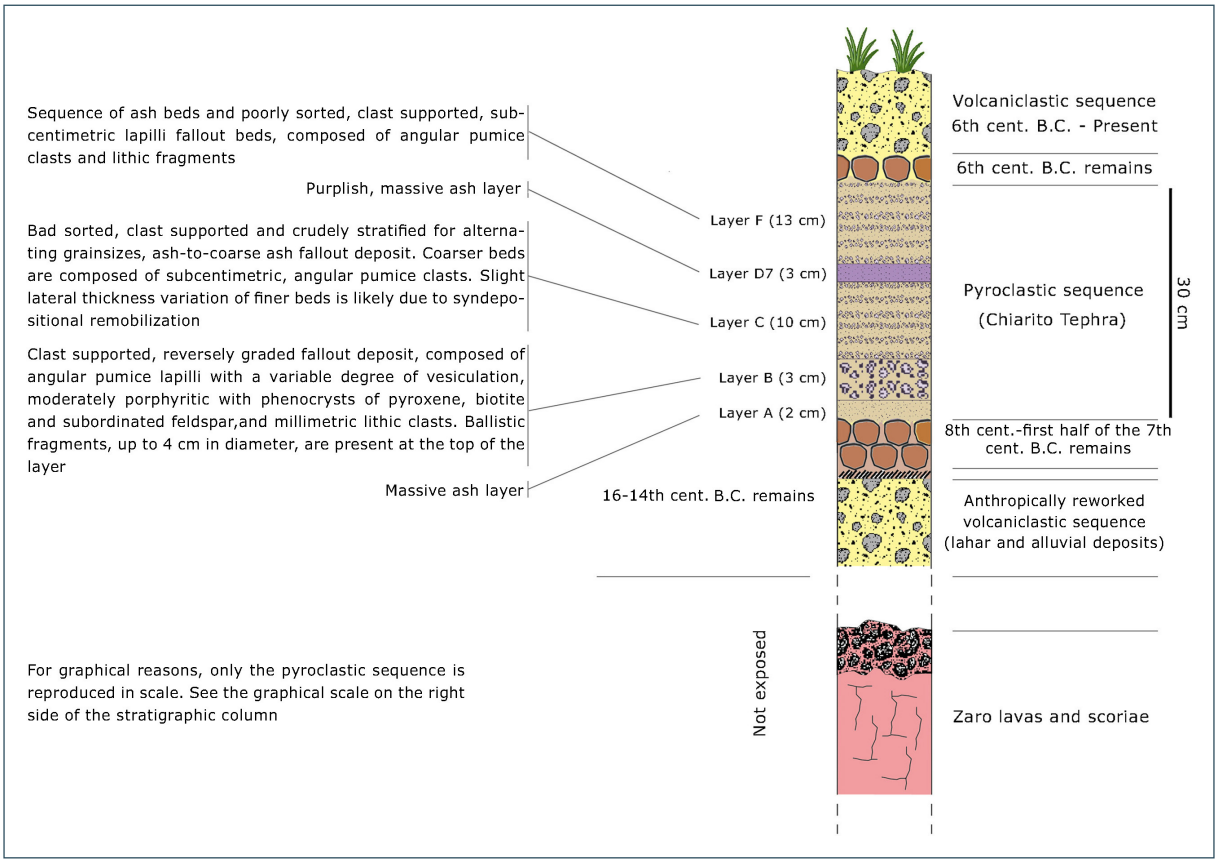

Figure 7. The pyroclastic sequence of Chiarito Tephra (de Vita et al., 2010) lying above the remnants of the 8th century-early 7th century BC structures and buried by the following volcaniclastic sequence (see also Fig. 7 for a detailed description of the pyroclastic deposit).

According to de Vita et al. (2006) a long-lasting phase of an areally diffuse gravitational destabilization of the Mt. Epomeo's slopes followed the Chiarito Tephra eruption, determining the emplacement of debris avalanche, lahar and hyperconcentrated flood flow deposits. In the area of Mazzola this succession includes: a massive, greenish, silt-to-sand, matrix supported, indurated debris avalanche deposit with large green tuffs boulders; massive, silt-to-sand, matrix supported lahar deposits, with a large amount of rounded and angular fragments of various kinds of rocks, altered and coated; massive to parallel or low-angle cross laminated, alternating silt and fine to very coarse sand, matrix to locally clast supported and moderately sorted hyperconcentrated flood flow deposits.

Alluvial and colluvial silt-to-sand deposits, grading upward into the present-day vegetated and anthropically reworked soil, close the sequence exposed in the Mazzola excavation.

6. Mineralogical analyses and petrographic characterization of lava fragments

The unusual discovery of pits filled with fragments of lava stone in the open area in front of building IV, on the lower terrace, prompted further investigation into the nature and provenance of these fragments. A macroscopic field analysis made it clear that the lava fragments were monolithological in composition and could be clearly attributed to the Zaro Lavas, which are widely exposed in the surroundings of the archaeological site (Fig. 1; de Vita et al., 2010; Sbrana et al., 2018). These lavas have been recently petrographically characterized (Pelullo et al., 2020; 2024), and their description can be summarized as follows: they consist of porphyritic trachytes containing ~50 vol% of crystals. Large sanidine phenocrysts (up to 1 cm; An15-4Ab65-34Or62-20) dominate the assemblage, accompanied by subordinate phlogopite, clinopyroxene (Wo52-44En36-30Fs25-13), plagioclase, and Ti-magnetite. These phases are embedded in a microcrystalline groundmass composed of the same minerals, together with apatite. Acicular microlites of alkali feldspar exhibit a typical trachytic/fluidal texture. The Zaro lavas typically contain both felsic and

mafic enclaves, with the mafic varieties being highly porphyritic and enriched in iron-bearing minerals, including olivine, pyroxene, and Ti-magnetite.

To address the question raised by the magnetic response of the powder obtained from grinding the lava fragments, XRPD analyses were performed. The results show that the analyzed sample consists of minerals belonging to the silicate and oxide groups. Quantitative analysis of the bulk sample indicates that magnetite, feldspar, phlogopite, and clinopyroxene are present, listed in decreasing order of abundance. The main minerals identified in the samples are reported in Table 1, and their diffraction patterns are shown in Fig. 8.

Table 1. Percentages by weight of minerals detected in the sample MSI drt.

Mineral name	Wt%
Magnetite	38.6
Feldspar	30.6
Phlogopite	15.7
Clinopyroxene	15.1

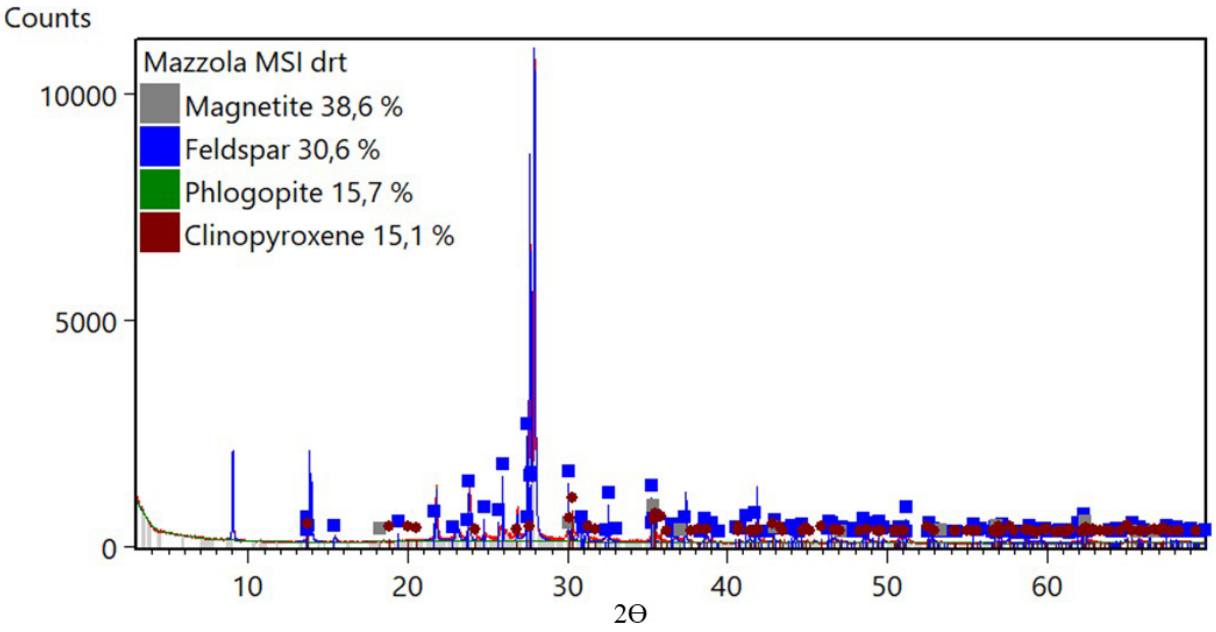

Figure 8. XRD patterns of Mazzola MSI drt sample.

7. Discussion and Conclusions

Excavations carried out in the Mazzola area between 2023 and 2024 brought to light a stratigraphic sequence of great interest, both for aspects related to the evolution of human settlements and for the natural processes that affected them, conditioning their development and at times forcing the population to abandon the area. The finds recovered during the excavations also provide evidence for the possible use of local raw materials in metalworking activities, which are well documented in the Mazzola area (Buchner, 1971).

Based on the previously exposed archaeological and geological evidence, it is possible to reconstruct a precise historical sequence for the repeated occupation and abandonment episodes in the area of Mazzola.

The earliest phases of occupation in the Mazzola area have left only limited traces, buried beneath deposits that testify to intense slope instability: thick sequences of debris avalanches, lahars, and hyperconcentrated flows. Although it is not possible to reconstruct the time span over which this succession of events occurred, it seems reasonable to hypothesize that, given the strong environmental impact of these processes, they led to the abandonment of the settlement for a prolonged period. In fact, after the sudden abandonment of the area in protohistoric times (Middle Bronze Age 3, early 14th century BC), Mazzola Hill was not reoccupied until about the mid-8th century BC, when it became an integral part of the Greek settlement of Pithekoussai, organized on artificial terraces sloping toward the coastline. This settlement, characterized by the coexistence of residential structures and spaces and buildings of an artisanal character, was abandoned due to a major eruptive phenomenon that can be detected archaeologically in various parts of the island. The pyroclastic deposit related to this event is known in the volcanological literature as the Chiarito Tephra and was firstly recognized close to Punta Chiarito, in the south-western part of Ischia, where it marks the abandonment of a Greek settlement in the early 7th century BC (Gialanella, 1994; de Vita et al., 2010). The stratigraphic position of the volcanic deposit uncovered on the lower terrace of Mazzola, and its internal stratigraphy (Fig. 7), demonstrate that the formation of this layer may be attributed to the same volcanic event that affected the site of Punta Chiarito, representing its distal counterpart, mainly emplaced by fallout.

Perhaps this event – along with the growth of nearby Cumae – was one of the contributing factors that led to a significant crisis in the Pithecusan community, as recounted by Strabo in his Geography (5.4.9; Translation by H. L. Jones, 1923): "Pithecusae was once settled by Eretrians and also Chalcidians, who, although they had prospered there on account of the fruitfulness of the soil and on the account of the metal workshops, forsook the island as the result of a quarrell; later on they were also driven out of the island by earthquakes, and by eruptions of fire, sea, and hot waters".

This crisis seems to be reflected also in the archaeological record from the necropolis of San Montano (Buchner and Ridgway 1993), in which burials dating to the second half of the 7th century BC show a sudden decline (Neeft, 1994; Nizzo, 2007). However, the Mazzola site was reoccupied in the first half of the 6th century BC, before being abandoned once again – this time permanently – due to a new phase of widespread instability of the Monte Epomeo's slopes, which resulted in its burial beneath a thick cover of debris-avalanche deposits. In this respect, a clear parallel can be drawn with the site of Punta Chiarito, where a similar attempt to reoccupy the previously abandoned settlement failed because of comparable processes (Gialanella, 1994; de Vita et al., 2006).

The strong interconnections between volcano-tectonism (resurgence), volcanic activity, and slope instability at Ischia were highlighted by de Vita et al. (2006), who proposed a cyclical model for the island's volcanic system. According to this model, the periodical renewal of resurgence induces phases of intense volcanism and determines conditions of gravitational instability. Two of the most recent phases are well documented and resulted in the emplacement of volcanic deposits and large landslide accumulations across wide areas of Ischia between the 8th and 5th centuries BC (de Vita et al., 2006). We can therefore reasonably conclude that among the various events that led to the decline of Pithekoussai starting from the 7th century BC, volcanic eruptions and catastrophic landslides caused the abandonment of several areas of the Pithecusan settlement. These events led to a marked depopulation of the community, which may have found refuge in the facing polis of Cumae, in the shadow of which the island's historical events from this moment onwards seem to have taken place (D'Acunto, 2017; D'Acunto, 2025).

On the other hand, there is no doubt that throughout the entire colonial period, beginning in the 8th century BC, Pithekoussai experienced a phase of great prosperity, supported by trade, metallurgical activities, and pottery production, the latter fueled by the extraction of clay from local sources (Buchner and Gialanella, 1994). The discovery at the Mazzola site of metalworking installations (Klein, 1972) both confirms accounts in historical sources and raises questions regarding the availability of raw materials to support these activities. The finding of deposits of partly-worked lava fragments, characterized by a high magnetic response due to the abundance of iron-rich minerals, allows us to hypothesize an extractive activity based on the exploitation of the extensive outcrops of these lavas in the vicinity of the Mazzola site. This hypothesis is currently being tested through recently initiated experimental archaeology studies. If confirmed, it would provide further evidence that the volcanic nature of Ischia, together with the environmental hazards associated with it, has both constrained and fostered the development of human societies in the area.

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References

Barker, P. (1996). Le tecniche dello scavo archeologico. Longanesi Ed., Milano, 333. ISBN 9788830402546.

Barra Bagnasco, M. (1990). Edilizia privata in Magna Grecia: modelli abitativi dall'età arcaica all'ellenismo. In Pugliese Carratelli, G. (Editor), Magna Grecia, Arte e Artigianato, Milano, 49-51.

Bruno, P. P., G. de Alteriis and G. Florio (2002). The western undersea section of the Ischia volcanic complex (Italy, Tyrrhenian sea) inferred by marine geophysical data, Geophys. Res. Lett., 29, 9, 1029-1034, doi:10.1029/2001GL013904.

Buchner, G. (1938). Vita e dimora umana nelle isole flegree, dall'epoca preistorica ai tempi romani (Ischia, Procida, Vivara). Tesi di Laurea in Paletnologia. Università degli Studi di Roma.

Buchner, G. (1946). Capri, Ischia, Ventotene, Rivista di Scienze Preistoriche 1, 98-101.

Buchner, G. (1969). Mostra degli scavi di Pithecusa, Dialoghi di Archeologia 3, 85-101.

Buchner, G. (1971). Recent work at Pithekoussai (Ischia), 1965-71, AR, 1970-71, 63-67.

Buchner, G. (1972). Pithecusa: scavi e scoperte 1966-1971. In Le genti non greche della Magna Grecia, Atti dell'XI Convegno di Studi sulla Magna Grecia (Taranto 10-15 ottobre 1971), Napoli, 361-373.

Buchner, G. (1975). Nuovi aspetti e problemi posti dagli scavi di Pithecusa con particolari considerazioni sulle oreficerie di stile orientalizzante antico. In Contribution à l'étude de la société et de la colonitation eubéenne, Cahiers du Centre Jean Bérard, 2, Napoli, 54-86.

Buchner, G. (1986). Eruzioni vulcaniche e fenomeni vulcano-tettonici nell'isola d'Ischia. In Albore Livadie, C. (Editor), Tremblement de terre, éruptions volcaniques et vie des hommes dans la Campanie antique, Centre Jean Bérard, Napoli, 145-188.

Buchner, G., A. Italiano and C. Vita-Finzi (1996). Recent uplift of Ischia, southern Italy. Geological Society, London, Special Publications, 110, 1, 249-252.

Buchner, G. and C. Gialanella (1994). Museo Archeologico di Pithecusae Isola d'Ischia, Istituto Poligrafico dello Stato, Libreria dello Stato, Roma 1994.

Buchner, G. and D. Ridgway (1993). Pithekoussai I. La necropoli: tombe 1-723 scavate dal 1952 al 1961, MonAnt Serie Monographica, 4, Roma.

Burkhardt, N. and S. Faust (2021). First Results of the Excavations at Pithekoussai from 2016-2018 (Villa Arbusto, Lacco Ameno, Ischia). In Cinquantaquattro, T. E., M. D'Acunto and F. Iannone (Editors), Euboica II, Pithekoussai and Euboea between East and West, Proceedings of the Conference (Lacco Ameno, Ischia, 14-17 May 2018), AIONArchStAnt, n.s. 28, Napoli, 183-200.

Cashman, K. V. and G. Giordano (2008). Volcanoes and human history, J. Volcanol. Geotherm. Res., 176, 3, 325-329, doi:10.1016/j.jvolgeores.2008.01.036.

Castaldo, N., S. de Vita, M. A. Di Vito and G. Vecchio (2010). Evidenze archeologiche e vulcanologiche di episodi ripetuti di colonizzazione e abbandono nel territorio nolano da parte dell'uomo a causa di eruzioni vulcaniche, dal Bronzo antico all'epoca romana tarda. In Ciarallo, A., M. R. Senatore (Ed.), Scienze naturali e Archeologia, il paesaggio antico: interazione uomo/ambiente ed eventi catastrofici, 67-72. Aracne Editore, Napoli.

Cinquantaquattro, T. E, F. Nitti and M. L. Tardugno (2023). Pithekoussai: nuove indagini di scavo nel quartiere artigianale di Mazzola (2023-2024), AIONArchStAnt, n.s. 30, 19-58.

Cuozzo, M. (2021). Pithekoussai. Pottery from the Mazzola area. In Cinquantaquattro, T. E., M. D'Acunto and F. Iannone (Editors), Euboica II. Pithekoussai and Euboea between East and West, Proceedings of the Conference (Lacco Ameno, Ischia, 14-17 May 2018), AIONArchStAnt, n.s. 28, Napoli, 201-220.

d'Agostino, B. (1999). Euboean colonization in the Gulf of Naples. In Tsetskhladze, G. R. (Editor), Ancient Greeks. West and East, Leiden, Boston, Köln, 206-227.

d'Agostino, B. (2006). The First Greeks in Italy. In Tsetskhladze, G. R. (ed.), Greek colonization. An account of Greek Colonies and Other settlements overseas, Leiden, Boston, 201-237.

D'Acunto, M. (2017). Cumae in Campania during the Seventh Century BC. In Charalambidou, X. and C. Morgan (Editors.), Interpreting the Seventh Century BC: Tradition and Innovation. Proceedings of the International Conference held at the British School at Athens (9th-11th December 2011), Oxford, 293-329.

D'Acunto, M. (2020). The Bay of Naples. In Lemos, I. S. and A. Kotsonas (Editors), A Companion to the Archaeology of Early Greece and the Mediterranean, 2, Hoboken NJ (USA), 1287-1310.

D'Acunto, M. (2025). Cumae and Pithecusae. In Cartledge, P. and P. Christesen (Editors), The Oxford History of the Archaic Greek World, Oxford University Press, Oxford, 222.

De Caro, S. and C. Gialanella (1998). Novità pitecusane. L'insediamento di Punta Chiarito. In Bats, M. and B. d'Agostino (Editors), Euboica. L'Eubea e la presenza euboica in Calcidica e in Occidente. Atti del Convegno Internazionale (Napoli, 13-16 novembre 1996), Coll. CJB, 16 – AIONArchtAnt, Quad. 12, Napoli, 337-353.

Della Seta, M., E. Marotta, G. Orsi, S. de Vita et al. (2012). Slope instability induced by volcano-tectonics as an additional source of hazard in active volcanic areas: the case of Ischia island (Italy), Bull. Volcanol., 74; 79-106, doi:10.1007/s00445-011-0501-0.

de Vita, S., F. Sansivero, G. Orsi and E. Marotta (2006). Cyclical slope instability and volcanism related to volcano--tectonism in resurgent calderas: the Ischia island (Italy) case study, Engin. Geol., 86, 148-165.

de Vita, S., F. Sansivero, G. Orsi, E. Marotta et al. (2010). Volcanological and structural evolution of the Ischia resurgent caldera (Italy) over the past 10 ka. In Groppelli, G. and L. Viereck (eds.), Stratigraphy and geology in volcanic areas, GSA Book series, Special paper, 464, 2010, 193-239.

de Vita, S., F. Sansivero, M. Piochi and G. Minin (2014). The Punta Chiarito Tephra (Ischia, Italy): Eruption Dynamics and Emplacement Mechanism Inferred from Stratigraphic, Sedimentologic and Petrological Data, Rendiconti Online della Società Geologica Italiana, 31, Suppl. 1, 492.

de Vita, S., M. A. Di Vito, E. Marotta and F. Sansivero (2011). Giorgio Buchner precursore del rapporto tra archeologia e vulcanologia: il ruolo delle determinazioni crono-archeologiche nella ricostruzione della storia vulcanica e deformativa recente dell'isola d'Ischia. In Gialanella, C. and P. G. Guzzo (Editors), Dopo Giorgio Buchner: studi e ricerche su Pithekuossai, 75-95. Lacco Ameno, 20 giugno 2009. Naus Editore.

de Vita, S., M. A. Di Vito, C. Gialanella and F. Sansivero (2013). The impact of the Ischia Porto Tephra eruption (Italy) on the Greek colony of Pithekoussai. Quat. Int., 303:142-152, doi:10.1016/j.quaint.2013.01.002.

de Vita, S., M. A. Di Vito, D. Barra, G. Aiello et al. (2021). Disseminating the knowledge on the complex interactions between humans and volcanoes: the geological section of the Villa Arbusto archaeological museum at Lacco Ameno (Ischia, Naples – Italy), Ann. Geophys., 64, 5, VO544, doi:10.4401/ag-8666.

de Vita, S. (2024). L'evoluzione geologica dell'isola d'Ischia e l'interazione tra l'attività vulcanica e gli insediamenti umani dal Neolitico al 1302 d.C. In Benini, A. et al. (Editors), Ischia e la baia di Cartaromana, storia, ricerche, studi, 19-39. Rogiosi Editore, Napoli, 232, ISBN 978-88-6950-583-6.

Di Lorenzo, H., M. A Di Vito, P. Talamo, J. Bishop et al. (2013). The impact of the Pomici di Avellino Plinian eruption of Vesuvius on Early and Middle Bronze Age human settlement in Campania (Southern Italy). In Meller H. H. et al. Eds. 1600 – Cultural change in the shadow of the Thera eruption. Tagungen des Landesmuseum für Vorgeschichte Halle. Band 9, 253-265, ISBN 978-3-944507-01-09. ISSN 1867-4402.

Di Vito, M. A., E. Zanella, L. Gurioli, R. Lanza et al. (2009). The Afragola settlement near Vesuvius, Italy, The destruction and abandonment of a Bronze Age village revealed by archaeology, volcanology and rock-magnetism, Earth Planet. Sci. Lett., 277, 3-4, 408-421, doi:10.1016/j.epsl.2008.11.006.

Di Vito, M., N. Castaldo, S. de Vita, J. Bishop et al. (2013). Human colonization and volcanic activity in the Eastern Campania Plain (Italy) between the Eneolithic and Late Roman Periods, Quat. Int., 303,132-141, doi:10.1016/j.quaint.2013.01.001.

Di Vito, M. A., P. Talamo, S. de Vita, I. Rucco et al. (2019). Dynamics and effects of the Vesuvius Pomici di Avellino Plinian eruption and related phenomena on the Bronze Age landscape of Campania region (Southern Italy). Quat. Int., 499, 231-244, doi:10.1016/j.quaint.2018.03.021.

Fusaro, D. (1982). Note di archeologia domestica greca del periodo tardo-geometrico e arcaico, DialArch, n.s. I, 5-30.

Giaccio, B., I. Hajdas, M. Peresani, F. G. Fedele et al. (2006). The Campanian Ignimbrite tephra and its relevance for the timing of the Middle to Upper Palaeolithic shift. In Conard, N. (Ed.), When Neanderthals and Modern Humans Met, 343-375. Tübingen Publication in Prehistory. Kerns Verlag, Tübingen.

Gialanella, C. (1994). Pithecusa: gli insediamenti di Punta Chiarito. In d'Agostino, B. and D. Ridgway (Editors), Apoikia. I più antichi insediamenti greci in occidente: funzioni e modi dell'organizzazione politica e sociale. Scritti in onore di Giorgio Buchner, AIONArchStAnt, n.s. 1, Napoli, 104-169.

Gialanella, C. (1996). Pithecusae: le nuove evidenze da Punta Chiarito. In I Greci d'Occidente. La Magna Grecia nelle collezioni del Museo Archeologico Nazionale di Napoli, (Catalogo della mostra, Napoli 1996), Napoli, 259-274.

Gialanella, C. (2001). Ischia prima dei Greci. In Marazzi, M. and S. Tusa (Editors), Preistoria. Dalle coste della Sicilia alle Isole Flegree, Napoli, 242-257.

Gialanella, C. (2013). Interazione tra attività vulcanica e vita dell'uomo: evidenze archeologiche nell'isola d'Ischia. In Di Vito, M. A. and S. de Vita (Eds.), L'impatto delle eruzioni vulcaniche sul paesaggio, sull'ambiente e sugli insediamenti umani – approcci multidisciplinari di tipo geologico, archeologico e biologico, Miscellanea INGV, Compendio delle lezioni Scuola estiva Aiqua (Napoli 27-31 maggio 2013), 18, Napoli, 115-123.

Gialanella, C. and P. G. Guzzo (2021). The Manifacturing district in Mazzola and its metal Production. In Cinquantaquattro, T. E., M. D'Acunto and F. Iannone (Eds.), Euboica II. Pithekoussai and Euboea between East and West. Proceedings of the Conference (Lacco Ameno, Ischia, 14-17 May 2018). AIONArchStAnt, n.s. 28, Napoli, pp. 125-146.

Giardino, C. and C. Merkouri (2007). Siti insulari dell'età del bronzo nel Golfo di Napoli: le dinamiche del popolamento. In Strategie di insediamento fra Lazio e Campania in età preistorica e protostorica, Atti della XL Riunione Scientifica IIPP, Firenze, 733-755.

Grattan, J. and R. Torrence (2007). Living under the shadow: cultural impacts of volcanic eruptions. Left Coast Press, Walnut Creek, CA, 307. ISBN 978-1-59874-268-8.

Hester, T. R., H. J. Shafer and K. L. Feder (2016). Field methods in archaeology. Routledge, Taylor and Francis Group, London and New York, ISBN 978-1-59874-428-6.

Klein, J. J. (1972). A Greek metal-working Quarter: eighth-century Excavations on Ischia. In Expedition, 14/2, 34-39.

Lowe, D. J., R. M. Newnham B. G. McFadgen and T. F. G. Higham (2000). Tephras and New Zealand archaeology, J. Archaeol. Sci., 10, 859-870, doi:10.1006/jasc.1999.0614.

Marazzi, M. and S. Tusa (1994). Vivara. Centro commerciale mediterraneo dell'Età del Bronzo, Vol. II. Le tracce dei contatti con il mondo egeo, Roma.

Marotta, E., G. Berrino, S. de Vita, M. A. Di Vito et al. (2024). Structural setting of the Ischia resurgent caldera (Southern Tyrrhenian Sea, Italy) by integrated 3D gravity inversion and geological models. In Marotta, E. et al. (Editors), Volcanic Island: from Hazard Assessment to Risk Mitigation, Geological Society of London Special Publication, doi:10.1144/SP519-2022-129.

Marotta, E. and S. de Vita (2014). The role of pre-existing tectonic structures and magma chamber shape on the geometry of resurgent blocks: Analogue models, J. volcano. and geothermal research, 272, 23-38, doi:10.1016/j.jvolgeores.2013.12.005.

Mazarakis Ainian, A. (1997). From "rulers" Dwelling to Temples. Architecture, Religion and Society in the Early Iron Age Greece (1100-700 BC), Studies in Mediterranean Archaeology, CXXI, Jonsered, 48-63.

Mazarakis Ainian, A. (1998). Oropos in the Early Iron Age. In Bats, M. and B. d'Agostino (eds.), Euboica. L'Eubea e la presenza euboica in Calcidica e in Occidente, Atti del Convegno Internazionale (Napoli, 13-16 novembre 1996), Coll. CJB, 16 – AIONArchtAnt, Quad. 12, Napoli, 179-215.

Mele, A. (2003). Le anomalie di Pithecusa. Documentazioni archeologiche e tradizioni letterarie, IncidAntico, I, 13-19.

Mureddu, P. (1972). *ΧΡΥΣΕΙΑ* e Pithekoussai', PP, 27, Napoli, 407-409.

Neeft, K. (1994). In search of wealth and status in the Valle di San Montano. In d'Agostino, B. and D. Ridgway (Editors), APOIKIA. I più antichi insediamenti greci in Occidente: funzioni e modi dell'organizzazione politica e sociale. Scritti in onore di Giorgio Buchner, AIONArchStAnt, n.s. 1, Napoli, 149-163.

Newhall, C. G., S. Bronto, B. Alloway, N. G. Banks et al. (2000). 10,000 years of explosive eruptions of Merapi volcano, Central Java: archaeological and modern implications, J. Volcanol. Geotherm. Res., 100, 1-4, 9-50, doi:10.1016/S0377-0273(00)00132-3.

Nizzo, V. (2007). Ritorno ad Ischia. Dalla stratigrafia della necropoli di Pithekoussai alla tipologia dei materiali, Napoli.

Orsi, G., G. Gallo and A. Zanchi (1991). Simple-shearing block resurgence in caldera depression. A model from Pantelleria and Ischia, J. Volcanol. Geotherm. Res., 47, 1-11, doi:10.1016/0377-0273(91)90097-J.

Orsi, G., D. Patella M. Piochi and A. Tramacere (1999). Magnetic modelling of the Phlegrean volcanic district with extension to the Ponza Archipelago, Italy, J. Volcanol. Geotherm. Res., 91, 345-360, doi:10.1016/S0377-0273(99)00043-8.

Orsi, G., S. de Vita, M. A. Di Vito, R. Isaia et al. (2003). Facing volcanic and related hazards in the Neapolitan area. In Heiken, G. et al. (Eds.) Earth Sciences in Cities, American Geophysical Union (Special Publication), Washington, 121-170.

Pacciarelli, M. (2016). Castiglione d'Ischia e i Mutamenti del Popolamento Insulare nel Tirreno Meridionale tra il Tardo Bronzo e il Primo Ferro. In Cazzella, A., F. Guidi and F. Nomi (Editors), Ubi minor…Le isole minori del

Mediterraneo centrale dal Neolitico ai primi contatti coloniali. Convegno di Studi in onore di Giorgio Buchner a 100 anni dalla nascita (1914-2014), ScAnt, 22.2, 171-186.

Pelullo, C., G. Cirillo, R.S. Iovine, I. Arienzo et al. (2020). Geochemical and Sr-Nd isotopic features of the Zaro volcanic complex: insights on the magmatic processes triggering a small-scale prehistoric eruption at Ischia island (south Italy), Int. J. Earth Sci., 109, 2829-2849, doi:10.1007/s00531-020-01933-6.

Pelullo, C., S. Chakraborty, C. P. Montagna, I. Arienzo et al. (2024). A multi-methodological approach to record dynamics and timescales of the plumbing system of Zaro (Ischia Island, Italy), Contrib. Mineral. Petrol. 179, 54, doi:10.1007/s00410-024-02138-9.

Pesando, F. (1989). La casa dei Greci, Milano, Loganesi, 274.

Ridgway, D. (1984), L'Alba della Magna Grecia, Milano, Longanesi, 202.

Sbrana, A and R. M. Toccaceli (2011). Carta Geologica della Regione Campania – Foglio 464 – Isola di Ischia, Progetto GARG Regione Campania – Assessorato Difesa del Suolo, Litografia Artistica Cartografica, Firenze. 216 pp. + 1 carta: 10.000.

Scatozza Höricht, L. A. (2021). Pithecusan gold: Anatolian connections. In Cinquantaquattro, T. E., M. D'Acunto and F. Iannone (Eds.), Euboica II. Pithekoussai and Euboea between East and West, Proceedings of the Conference (Lacco Ameno, Ischia, 14-17 May 2018), AIONArchStAnt, n.s. 28, Napoli, 147-155.

Schminke, H. U., S. Kutterolf, W. Perez, J. Rausch et al. (2009). Walking through volcanic mud: the 2,100-year-old Acahualinca footprints (Nicaragua), I: stratigraphy, lithology, volcanology and age of the Acahualinca section, Bull. Volcanol., 71, 479-493, doi:10.1007/s00445-008-0235-9.

Schminke, H. U., J. Rausch, S. Kutterolf and A. Freundt (2010). Walking through volcanic mud: the 2,100-year-old Acahualinca footprints (Nicaragua), II: the Acahualinca people, environmental conditions and motivation, Int. J. Earth Sci., 99, Suppl. 1, S279-S292, doi:10.1007/s00531-009-0438-0.

Selva, J., V. Acocella, M. Bisson, S. Caliro et al. (2019). Multiple natural hazards at volcanic islands: a review for the Ischia volcano (Italy), J. Appl. Volcanol., 8, 1, 5, doi:10.1186/s13617-019-0086-4.

Siebe, C. (2000). Age and archaeological implications of Xitle volcano, southweatern Basin of Mexico-City. J. Volcanol. Geotherm. Res., 104 (1-4), 45-64, doi:10.1016/S0377-0273(00)00199-2.

Sparks, R. S. J., M. I. Bursik, S. N. Carey, J. S. Gilbert et al. (1997). Volcanic plumes. John Wiley and Sons, Chichester, New York, Weinheim, Brisbane, Singapore, Toronto, 574. ISBN:0-471-93901-3.

Speciale, C., G. Montana, R. Mentesana, V. Forgia et al. (2021). Materials and Tools across Volcanoes: Exploitation of Georesources in Piano dei Cardoni (Ustica, Italy) during Prehistory, Ann. Geophys., 64, 5, VO552, doi:10.4401/ag-8684.

Strabo. Geography, Volume II: Books 3-5. Translated by Horace Leonard Jones. Loeb Classical Library 50. Cambridge, MA: Harvard University Press, 1923.

Trasatti, E., V. Acocella, M. A. Di Vito, C. Del Gaudio et al. (2019). Magma degassing as a source of long-term seismicity at volcanoes: the Ischia Island (Italy) case, Geophys. Res. Lett., 46, 24, 14421-14429, doi:10.1029/2019GL085371.

Vezzoli, L. (1988). Island of Ischia,CNR Quaderni de "La ricerca scientifica" 114, 10, 122.

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