Neapolitan Habitats and Volcanoes

Organizer
Flavio Dobran

GVES
Naples, Italy

Field Leader
Claudio Scarpati

University of Naples Federico II
Naples, Italy

Abstract. The aim of the excursion to Neapolitan habitats and volcanoes is to examine deposits of Campi Flegrei and Vesuvius eruptions and provide a general outlook of the danger of these volcanoes to the densely populated areas of Naples and surrounding towns. In particular, the field trips will examine the exposures of the Neapolitan Yellow Tuff on which Naples is built and the deposits of the A.D. 79 Vesuvius eruption that buried Pompeii. This brief guide summarizes recent research on the topics illustrated during the field trips.

Keywords: Naples, Pompeii, Vesuvius, Campi Flegrei

1. Introduction

The Neapolitan area was first populated in the pre-historic time, and it is only with the colonization of Greeks in the eight century B.C. that it began thriving commercially and in the twentieth century that it developed into one of the most populated and abused areas in the world. Under Greeks and then Romans this area enjoyed a relative autonomy, and when in 79 A.D. Vesuvius erupted with one of its powerful plinian eruptions and buried the nearby cities of Pompeii, Herculaneum, and others still protected by the modern urbanization, it took several centuries before the area began thriving again. With the fall of the Roman Empire in the fifth century the Neapolitan area passed under the domination of feudal landlords where there were no incentives to produce, and where the Byzantine, Norman, Angevin, Aragonese, and Spanish feudal barons maintained the territory at subsidence levels. With the spread of renaissance beginning in the thirteenth century the Greeko-Roman contributions began to be appreciated again and the volcanic character of the area taken in serious considerations [1].

The rediscovery of the buried cities of Pompeii and Herculaneum in the seventeen century and the eruption of Vesuvius in 1631 brought the Neapolitan area to the attention of Europe and the area thrived under the new-established Bourbon monarchy until the Neapolitan Jacobians declared the city of Naples a republic in 1799. The seventeenth and eighteenth century ideals of Enlightenment and the Age of Revolutions in Western Europe brought to an end the monarchic traditions and Naples passed from being the largest city of Europe to a subservient city serving the new-found Italian State that was established in 1865 [2].

When during the second half of the twentieth century Naples could not absorb anymore the demographic pressure, many Neapolitans settled on the slopes of Vesuvius and surrounding towns built on the deposits of Campi Flegrei eruptions, and today there are more than one million people living within 10 km of the craters of these volcanoes and one million people in Naples who for most part believe that the city will not be affected by future eruptions. The ignorance of the consequences of Campi Flegrei and Vesuvius eruptions is widespread in the Neapolitan area, because the current population has no experience with eruptions and the information and education campaigns are not directed at building a security culture that would make the area more resilient to these eruptions [1].

2. Campi Flegrei Volcano

2.1 Campi Flegrei Geological Setting

The Campi Flegrei volcanic field is a vast area that includes a large part of the city of Naples and the Island of Procida (Fig. 1). This area is characterized by the presence of diffuse monogenetic volcanic cones and two nested calderas associated with the Campanian Ignimbrite (39 ka BP) [3-5] and the Neapolitan Yellow Tuff (15 ka BP) [6,7] eruptions, respectively. These areas consist of pyroclastic deposits and subordinate lavas separated by paleosols. Numerous small volcanic centres have also been identified, including a lava dome and five scattered monogenetic vents located in the city of Naples [5], three lava domes along the morphological border of Campi Flegrei [3,8,9] and five local vents on Procida Island [10-12]. The products of this early activity are covered by tephra from different sources: (a) coarse fallout and flow deposits from Ischia Island (one of which has an age of 55 ka [13]) mantle the ancient volcanoes of Procida and Monte di Procida [9]; (b) stratified fall deposits from the eastern part of Campi Flegrei (Torre di Franco Tuffs dated at >42ka [14]) lie on the Neapolitan volcanoes [5]. An ubiquitous succession formed by coarse welded beds (Piperno) and lithic breccia (Breccia Museo) associated with the Campanian Ignimbrite eruption [3] covers the ancient sequence. These proximal deposits dated at 39 ka [15,16] or 37 ka [17] mark the oldest caldera rim that occupies the Campi Flegrei region and part of the city of Naples [3-5]. A few small volcanoes (Solchiaro and Trentaremi) located inside and outside the caldera and some local tephra layers (e.g. Withish Tuffs) crop out below the Neapolitan Yellow Tuff (15 ka) [7]. This huge pyroclastic deposit (50 km^3 dense rock equivalent) [6] crops out extensively in the Neapolitan area and produced a second caldera collapse inside the pre-existing Campanian Ignimbrite caldera. Tens of small volcanic edifices (most made up by lithified yellow tuff) emplaced almost exclusively within the Neapolitan Yellow Tuff caldera both during the prehistorical and historical times (Monte Nuovo volcano, 1538 AD) (Table 1).

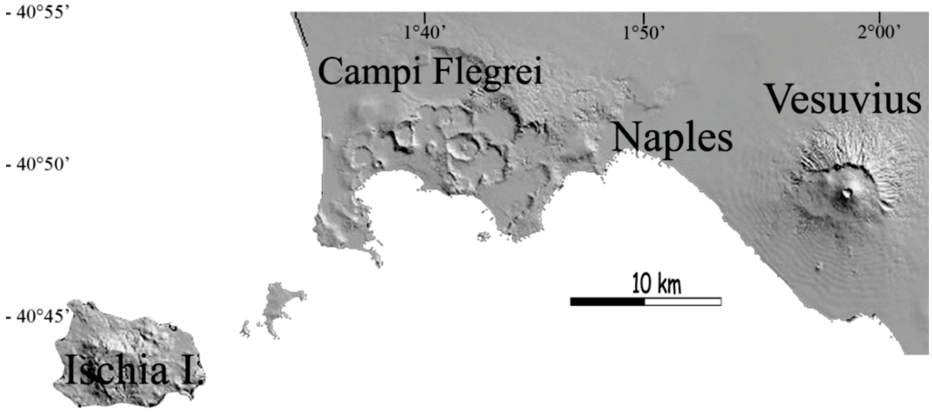

Figure 1. Map of the Campi Flegrei area.

Table 1. Stratigraphic scheme of Campi Flegrei

<table>
<tr><th colspan="2" rowspan="2">Previous Campi Flegrei Stratigraphy</th><th colspan="2">Synthemic Unit</th></tr>
<tr><th>Synthem</th><th>Supersynthem</th></tr>
<tr><td rowspan="3">III period</td><td>III Epoch
20 explosive eruptions and 3 lava flows</td><td rowspan="3">Monte di Procida
9 explosive eruptions
6 volcanic edifices</td><td rowspan="4">Flegrean</td></tr>
<tr><td>II Epoch
6 explosive eruptions</td></tr>
<tr><td>I Epoch
37 explosive eruptions</td></tr>
<tr><td colspan="2">Neapolitan Yellow Tuff</td><td>Neapolitan Yellow Tuff</td></tr>
<tr><td>II period</td><td>More than 9 explosive eruptions.
7 volcanic edifices</td><td>Solchiaro
12 explosive eruptions
2 volcanic edifices</td><td rowspan="2">Campanian</td></tr>
<tr><td colspan="2">Campanian Ignimbrite</td><td>Campanian Ignim-brite</td></tr>
<tr><td rowspan="2">I period</td><td rowspan="2">More than 11 explosive eruptions and 5 lava flows.
2 volcanic edifices</td><td>Serra
19 explosive eruptions
1 volcanic edifice</td><td rowspan="2"></td></tr>
<tr><td>Paleoflegrei
6 volcanic edifices</td></tr>
</table>

The Campi Flegrei is in a persistent state of activity, as testified by the last eruption of Monte Nuovo in 1538 [18,19], the 1970-72 and 1982-84 unrest episodes and bradyseismic crises [20], and intense fumarolic activity [21].

On the basis of the presently available age data, a new chronostratigraphic model of the Campi Flegrei recent volcanism can thus be drawn [22]. The proposed scheme is characterized by three epochs of approximately continuous activity (Table 1): (1) Epoch I from 15 to 10.9 ka; (2) Epoch II from 9.6 (Fondi di Baia eruption) to 8.6 ka (Bacoli eruption); (3) Epoch III from 6.5 (Porto Miseno) to 3.9 ka (Nisida). Such epochs are separated by time spans of non-documented volcanic activity which are here no more referred to as "quiescent intervals" given that future dating of presently undated eruptions (which still make the great part of the ~60 post-NYT events) can result in a much more complex scenario, possibly totally lacking a clear distinction between periods of activity and periods of volcanic quiescence.

2.2 Volcanism of Naples and the Campanian Ignimbrite Caldera Collapse

The autochthonous volcanism in the central part of the city of Naples lies on sedimentary rocks. This ancient activity is recorded in few boreholes which cut 200 m of loose pyroclastic deposits with minor lava horizons. The main lava body was a lava dome identified during the excavation of various tunnels beneath S. Martino [23]. The subsequent activity was exclusively explosive producing the monogenetic vents of Parco Margherita, Parco Grifeo, Funicolare di Chiaia, S. Sepolcro and Capodimonte. Where exposed, the contacts between the remnants of the cones show a west to east trend of this pre-caldera activity. These volcanic edifices were successively covered by three lapilli pumice fall deposits associated with ash and pumice beds possibly related to the Torre di Franco Tuffs of Campi Flegrei. Rolandi and co-workers [24] do not recognize the paleosols between the different lapilli pumice fall deposits and attribute all this thick sequence to a single plinian event, vented in this area, that predate the Campanian Ignimbrite eruption of almost 1 ka. Our interpretation, based on the presence of paleosols and the good sorting of the lapilli pumice fall deposits, is that these deposits are the products of different eruptions and that their source is possibly within the Campi Flegrei. We suggest that only the uppermost and coarser fall deposit is related to the onset of the Campanian Ignimbrite eruption. The grading features and the thickness of this deposit are not easily comparable with that defined for distal locations (>30km from the presumed source, see details in [25,26]) but this is possibly due to the combined effect of deep erosion and the emplacement in a proximal environment. During the Campanian Ignimbrite eruption a thick sequence of welded tuff, spatter deposit and lithic breccia was emplaced in this area. The large average size of the clasts, their lithic nature and the welding feature suggest the proximal character of these deposits.

A caldera collapse cut through the Campanian Ignimbrite and Ancient Tuffs forming the steep scarps that border the south and east sides of Vomero-S. Martino hill and south side of Capodimonte hill. This collapse possibly produced a scarp also west of the Vomero-S. Martino hill, linking this structural high with the well known Piperno-Breccia Museo outcrop of Camaldoli, that is supposed to be completely buried by recent volcanic products (Neapolitan yellow Tuff). It is noteworthy that few tens of meters from the previously described proximal deposits of the Campanian Ignimbrite we have found a grey welded tuff, 5 metres thick, with reverse graded, black scoriae, embedded in an ashy matrix. We speculate that this deposit could represent the lateral transition between the proximal coarse and welded products and the typical facies of the Campanian Ignimbrite.

The volcanic activity post-Campanian Ignimbrite is represented by the Chiatamone volcano which, with the Trentaremi tuff ring located on the west side of the bay of Naples [27], testify of an explosive activity inside the city of Naples after the Campanian Ignimbrite caldera collapse. The thicker pyroclastic sequence present, at the same stratigraphic height, in the intra-caldera boreholes should be related to remobilized deposits during the prolonged (24ka) erosion of these scarps. Around 15 ka ago, the Neapolitan Yellow Tuff was erupted, producing about 50 km^3 DRE [6] of material and forming a second major caldera collapse in the Campi Flegrei. The eruption produced up to 150 m thick deposit in proximal areas, which draped the erosive remnants of the Campanian Ignimbrite rim, in the Campi Flegrei and Naples. The seaward side of the structural heights was deeply eroded again to the local exhumation of the Campanian Ignimbrite caldera wall. The primary (i.e. volcanic) post-Neapolitan Yellow Tuff activity produced several thin ash and pumice lapilli layers that do not contribute significantly to the structural and morphological features of the study area with the exception of Mt. Echia volcano [27]. On the contrary, volcanoclastic hydrologic remobilization and resedimentation processes were capable of transporting a voluminous sediment load to the level part of the city.

3. Somma-Vesuvius

3.1 Somma-Vesuvius Volcanism

The volcano of Somma-Vesuvius, located near Naples (southern Italy), buried Pompeii and Herculaneum during the 79 A.D. eruption. This volcano consists of an old stratovolcano, Monte Somma, that collapsed several times because of huge explosive eruptions, and a recent cone, Vesuvius, produced from the inside of the summit depression (caldera) after the 79 eruption (Figs. 2,3).

The Vesuvius crater is about 450 m in diameter and the highest elevation of its rim is 1283 m asl. Several large explosive eruptions (plinian) occurred a few thousand years apart (Fig. 4), with more frequent weakly explosive and effusive episodes that produced stratified ash and lapilli beds (pyroclastic deposits) and lava flows. The plinian events have an age of 21,670 yr B.P. (Pomici di Base eruption), 18,456 yr BP (Pomici Verdoline eruption), 9,348 yr B.P. (Mercato eruption), 3,670 yr BP (Avellino eruption) and 79 (Pompei eruption). During these eruptions the eruptive columns rose several kilometers above the vents forming umbrella-shaped tops that dispersed by the prevailing winds. Solid material (pumice lapilli) fell back from the ascending columns and the clouds draped the topography. Due to the prevailing direction of the wind in the Neapolitan area, the dispersions of fall deposits of the Somma-Vesuvius are usually towards the east, and the frequent collapses of sustained columns produce pyroclastic density currents that may be radially distributed around the volcano.

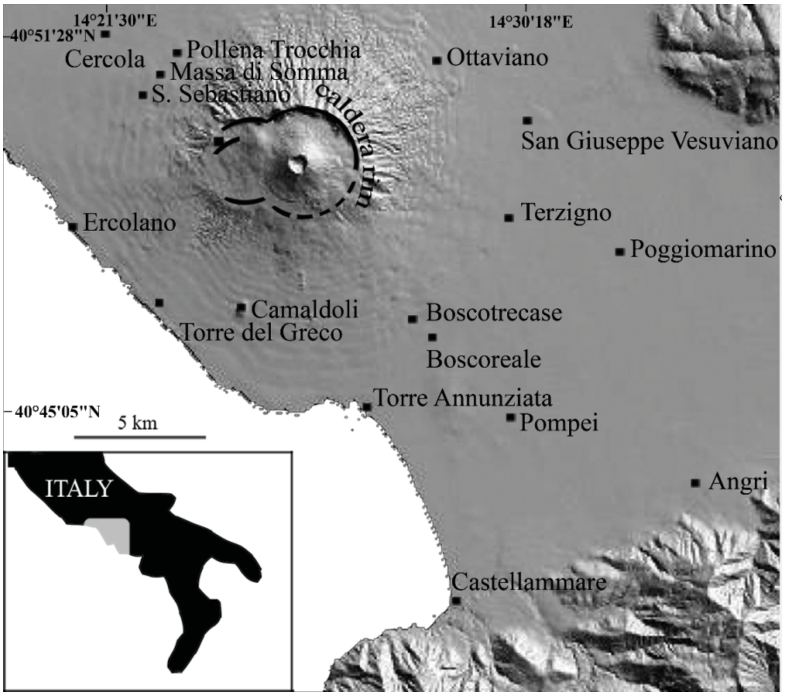

Figure 2. Campanian Plain with Somma-Vesuvius.

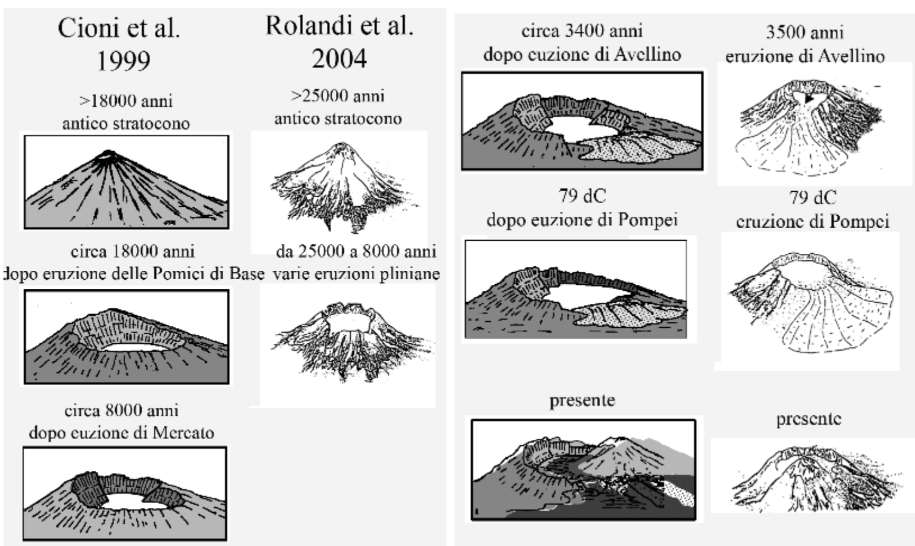

Figure 3. Schematic models of Somma-Vesuvius caldera genesis.

The destructive impact of the major Vesuvian eruptions on the surrounding volcanic territory is documented both by the numerous archaeological sites that suffered extensive damage and by historical accounts of the more recent eruptive events. In fact, many villages, towns and rural farms in a large area around the volcano were destroyed and buried under a blanket of tephra and mass flows in prehistoric and historic times. Some examples are the burying of Bronze Age villages by the products of the Avellino plinian eruption and the most famous destruction of Pompeii and Herculaneum during the 79 eruption as described by Pliny the Younger [28]. Pliny the Elder and thousands of other people were killed in the few days of this eruption. The next major subplinian eruptions occurred in 472 and 1631. During the 472 eruption the plain at the foot of the northern slope of the volcano was inundated and large Roman buildings and villae rusticae (country estates) were buried under several metres of volcanic debris. Historical records report over 4000 people killed and some 40,000 displaced in consequence of the 1631 eruption [29]. A few other smaller explosive episodes were reported in 512, during the Medieval period, and during the most recent activity cycle (1631–1944).

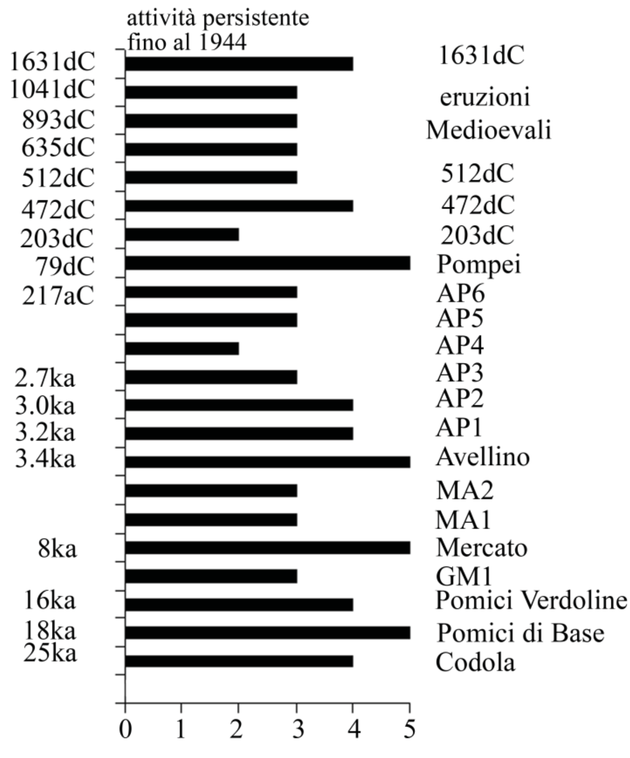

Figure 4. Chronostratigraphy of Somma-Vesuvius eruptions.

GVES, Napoli – New York, ISBN 978-88-903183-1-3

3.2 The A.D. 79 Vesuvius Eruption and its Effects on Pompeii

The A.D. 79 eruption started at about 1 p.m. on 24 August with the formation of a plinian column that was preceded by a phreatomagmatic opening phase. A thick layer of pumice lapilli resulting from this phase covered a vast area to the south of Vesuvius [30]. The pumice deposit reached its maximum depth of 2.8 m at Pompeii [31]. Numerous pyroclastic currents occurred during and after the emplacement of the upper part of the basal lapilli pumice deposit (Fig. 5). Some cities around Vesuvius received successive waves of pyroclastic currents in which material achieved temperatures of up to 400°C [32]. The phreatomagmatic final stage of the eruption is displayed by the presence of accretionary lapilli into the deposit.

The process of Pompeii's burial is here briefly reported [33,34]. It began in the early afternoon on 24 August with the initial stage of the eruption. The rate of deposition in the open areas of the city was 15 cm per hour; areas accumulating additional material, such as that falling from the sloped roofs of buildings, received 25 to 30 cm per hour. Within the first six hours of the eruption, roofs began to collapse under the weight of the pumice lapilli, causing some supporting walls to crumble as well. By the early morning on 25 August, most structures were seriously compromised. Portions of many houses had collapsed, and it appears that only those roofs whose angle were considerably sloped survived. A notable quantity of pumice lapilli had infiltrated the internal spaces of houses through the compluvia (roof openings) or collapsed roofs, forming the deposit ranging between 1-5 m thick. Approximately 3 m of material accumulated into peristyles and alleys between the houses, before the sustained pyroclastic currents overcame the town. This phase was punctuated by at least three episodes of lithic sand to lapilli fall, suggesting pauses between the passage of pyroclastic currents that allowed the deposition from the sustained column. We suggest that only the lower portions of the pyroclastic currents had contacts with the structures of the town, destroying preferentially the upper floors and the walls of the ground floors that happened to run perpendicular to the direction of the pyroclastic currents. The impact with the solid masonry of the houses caused deceleration of the currents, which consequently lost their solid matter and, hence, their kinetic energies. The ash and pumice lapilli transported by the pyroclastic currents formed compact and very hard layers upon the basal pumice lapilli deposit.

4. Conclusions

This brief overview of the eruptions of Campi Flegrei and Vesuvius volcanoes attest to the recurring and destructive nature of the hazards from these volcanoes, and to the resilience of the cohabiting populations that resettled after the destructive volcanic events. Naples and the surrounding towns are today continuously expanding and facing not only the hazards from the volcanoes but also from the human activities (household and industrial landfills). While the past Neapolitan populations managed to rebuild after the devastating volcanic events, it remains to be seen whether the future generations will also succeed in cohabiting with their volcanoes.

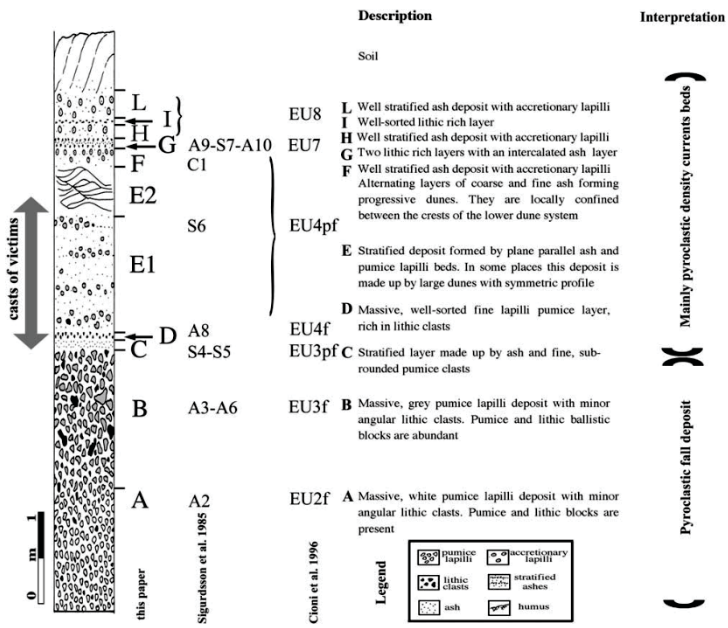

Figure 4. Stratigraphic section of A.D. 79 deposit at Pompeii.

References

1. Dobran, F. (2006). VESUVIUS 2000 Toward security and prosperity under the shadow of Vesuvius. In F. Dobran (ed.) VESUVIUS Education, Security and Prosperity. Elsevier, Amsterdam, pp. 3-69.
2. Dobran, F. (2006). Education: Cognitive tools and teaching Vesuvius. In F. Dobran (ed.) VESUVIUS Education, Security and Prosperity. Elsevier, Amsterdam, pp. 73-218.
3. Rosi M., Sbrana, A. (1987). Phlegraean Fields. C.N.R. Quaderni della Ricerca Scientifica 114-9, 1-175.
4. Orsi, G., De Vitta, S., Di Vito, M. (1996). The restless, resurgent Campi Flegrei nested caldera (Italy): Constraints on its evolution and configuration. Journal of Volcanology and Geothermal Research 74, 179-214.
5. Perrotta A., Scarpati C., Luongo G. & Morra V. (2006) - The Campi Flegrei caldera boundary in the city of Naples. In: De Vivo B. (ed), Volcanism in the Campania Plain: Vesuvius, Campi Flegrei and Ignimbrites. Elsevier, Amsterdam, pp. 85-96.
6. Scarpati C., Cole P., Perrotta A. (1993) - The Neapolitan Yellow Tuff – A large volume multiphase eruption from Campi Flegrei, Southern Italy. Bulletin of Volcanolology 55, 343-356.
7. Insigna, D., Calvert, A., D'Argento, B., Fedele, L., Lanphere, M., Morra, V., Perrotta, A., Sacchi, M., Scarpati, C. (2004). $^{40}Ar/^{39}Ar$ dating of the Neapolitan Yellow Tuff eruption (Campi Flegrei, southern Italy): volcanological and chronostratigraphic implications. In European Geophysical Union (EGU) 1st General Assembly, Nice.

8. Rittmann, A. (1950). Sintesi geologica dei Campi Flegrei. Bollettino Società Geologica Italiana 69, 117-128.
9. Di Gerolamo, P., Ghiara, M.R., Lirer, L., Munno, R., Rolandi, G., Stanzione, A. (1984). Vulcanologia e petrologia dei Campi Flegrei. Bollettino della Società Geologica Italiana 103, 349-413.
10. Di Girolamo, P., Rolandi, G., Stanzione, D. (1973). L'eruzione di pomici a letto dell'Ignimbrite Campana ("Tufo grigio campano" Auct.). Periodico di Mineralogia 42(3), 439–468.
11. Rosi, M., Sbrana, A., Vezzoli, L. (1988). Stratigrafi a delle isole di Procida e Vivara: Bollettino Gruppo Nazionale di Vulcanologia 4, 500–525.
12. De Astis, G., Pappalardo, L., Piochi, M. (2004). Procida volcanic history: New insights into the evolution of the Phlegraean volcanic district (Campanian region, Italy). Bulletin of Volcanology 66, 622–641. DOI 10.1007/s00445-004-0345-y
13. Vezzoli, L. (ed.) (1988). Island of Ischia. CNR Quaderni della Ricerca Scientifica 114-10, 1-133.
14. Alessio, M., Bella, F., Improta, S., Belluomini, G., Cortesi, C., Turi, B. (1973). University of Rome Carbon-14 dates X. Radiocarbon 15, 165-178.
15. Ricci, G., Lanphere, M.A., Morra, V., Perrotta, A., Scarpati, C., and Melluso, L. (2000). Volcanological, geochemical and geochronological data from ancient pyroclastic successions of Campi Flegrei (Italy). Eos (Transactions, American Geophysical Union) 81(48), Fall meeting supplement, p. 28.
16. De Vivo, B., Rolandi, G., Gans, P.B., Calvert, A.. Bohrson, W.A., Spera, F.J., Belkin, H.E. (2001). New constraints on the pyroclastic eruptive history of the Campanian Volcanic Plain (Italy). Mineralogy and Petrology 73, 47-65.
17. Deino, A.L., Orsi, G., De Vita, S., Piochi, M. (2004). The age of the Neapolitan Yellow Tuff caldera-forming eruption (Campi Flegrei caldera – Italy) assessed by $^{40}Ar/^{39}$ dating method. Journal of Volcanology and Geothermal Research 133, 157.170. et al 192
18. Lirer, L., Luongo, G., Scandone, R. (1987). On the volcanological evolution of Campi Flegrei. EOS Transactions of the American Geophysical Union 68, 226-234.
19. D'Oriano, C., Poggianti, E., Bertagnini, A., Cioni, R., Landi, P., Polacci, M., Rosi, M. (2005). Changes in eruptive style during the A.D. 1538 Monte Nuovo eruption (Phlegrean Fields, Italy): The role of syn-eruptive crystallization. Bulletin of Volcanology 67, 601-662.
20. Barberi, F., Cassano, E., La Torre, P., Sbrana, A. (1991). Structural evolution of Campi Flegrei caldera in light of volcanological and geophysical data. Journal of Volcanology and Geothermal Research 48(1-2), 33-49.
21. Orsi G., Di Vito M.A. & Isaia R. (2004) - Volcanic hazard assessment at the restless Campi Flegrei caldera. Bulletin of Volcanolology 66, 514-530.
22. Fedele L., Insinga D., Calvert A., Morra, V., Perrotta A., Scarpati C. (2011). $^{40}Ar/^{39}Ar$ dating of tuff vents in the Campi Flegrei caldera (southern Italy): Toward a new chronostratigraphic reconstruction of the Holocene volcanic activity. Bulletin of Volcanology 73, 1323-1336.
23. Cole, P.D., Perrotta, A., Scarpati, C. (1994). The volcanic history of the southern part of the city of Naples. Geological Magazine 131, 785-799.

24. Rolandi, G., Munno, R., Postiglione, I. (2004). The A.D. 472 eruption of the Somma volcano. Journal of Volcanology and Geothermal Research 129(4), 291-319. DOI: 10.1016/S0377-0273(03)00279-8
25. Rosi, M., Vezzoli, L., Castelmenzano, A., Grieco, G. (1999). Plinian pumice fall deposits of the Campanian Ignimbrite eruption (Phlegraean Fields, Italy). Journal of Volcanology and Geothermal Resserach 91, 179-198.
26. Perrotta A. and Scarpati C. 1994. The dynamics of the Breccia Museo eruption (Campi Flegrei, Italy) and the significance of spatter clasts associated with lithic breccias. Journal of Volcanology and Geothermal Research, 59(4): 335-355
27. Cole P.D. and Scarpati C. 1993. A facies interpretation of the eruption and emplacement mechanisms of the upper part of the Neapolitan Yellow Tuff, Campi Flegrei, southern Italy. Bulletin of Volcanology, 55: 311-326
28. Radice, B. (1963). The Letters of the Younger Pliny. Penguin Books, New York.
29. Rosi, M., Principe, C., Vecci, R. (1993). The 1631 Vesuvian eruption: A reconstruction based on historical and stratigraphic data. Journal of Volcanology and Geothermal Research 58, 151-182.
30. Lirer, L., Pescatore, T.S., Booth, B., Walker, G.P.L. (1973). Two Plinian pumice-fall deposits from Somma-Vesuvius, Italy. Geological Society of America Bulletin 84, 759-772.
31. Sigurdson, H., Carey, S., Cornell, W., Pescatore, T. (1985). The eruption of Vesuvius in A.D. 79. National Geographic Research 1, 332-387.
32. Kent, D.V., Ninkovich, D., Pescatore, T., Sparks, R.J. (1981). Paleomagnetic determination of emplacement temperature of Vesuvius AD 79 pyroclastic deposits. Nature 290, 393-396.
33. Luongo, G., Perrotta, A., Scarpati, C. (2003(. Impact of 79 AD explosive eruption on Pompeii I: Relations amongst the depositional mechanisms of the pyroclastic products, the framework of the buildings and the associated destructive events. Journal of Volcanology and Geothermal Research 126, 201-223.
34. Luongo, G., Perrotta, A., Scarpati, C., De Carolis, E., Patricelli, G., Ciarallo, A. (2003). Impact of 79 AD explosive eruption on Pompeii II: Causes of death of the inhabitants inferred by stratigraphical and areal distribution of the human corpses. Journal of Volcanology and Geothermal Research 126, 169-200.