Volcanic hazard in Italy: a variegated landscape

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Cover photograph. Etna eruption in February 2021.
Source: Photograph by Boris Behncke.

Southern Italy is one of the most active tectonic and volcanic settings in the Mediterranean area, comprising persistently active and dormant volcanoes. As we write, two volcanoes feature a persistent eruptive activity: Stromboli, belonging to the Aeolian Archipelago, in the Tyrrhenian Sea, and Etna, along the Eastern coast of Sicily. Both volcanoes are usually characterized by mild explosivity featuring the launch of pyroclasts near the vent, occasional lava flows and lava fountains up to several hundreds of meters. This kind of activity may culminate in the development of eruptive columns, which may reach up to 10-15 thousand meters, in the case of Etna.

The assessment of volcanic hazard is a formidable challenge, given the wide variety of phenomena potentially involved, which operate on different spatial and temporal scales. Italian volcanoes well represent the wide spectrum of possible states of activities and eruptive styles: from dormant volcanoes to persistent activity, from the largest volcano in Europe to small volcanic islands, Italy faces all sorts of actual and potential threats from volcanic sources. The *Istituto Nazionale di Geofisica e Vulcanologia* (INGV) is the main institution in charge of the monitoring and surveillance of active Italian volcanoes. To fulfil its mission INGV installs and maintains observational networks with technologically advanced instruments concentrated around active volcanoes. Collected signals are conveyed by redundant transmission systems to the 24-h operating rooms in Naples (Figure 1) and Catania, which grant continuous surveillance.

Figure 1. The monitoring room operating 24h/7d in Naples at INGV Osservatorio Vesuviano.
Source: www.ov.ingv.it

Southern Italy is one of the most active tectonic and volcanic settings in the Mediterranean area, comprising persistently active and dormant volcanoes. As we write, two volcanoes feature a **persistent eruptive activity:** Stromboli, belonging to the Aeolian Archipelago, in the Tyrrhenian Sea, and Etna, along the Eastern coast of Sicily. Both volcanoes are usually characterized by mild explosivity featuring the launch of pyroclasts near the vent, occasional lava flows and lava fountains up to several hundreds of meters. This kind of activity may culminate in the development of eruptive columns, which may reach up to 10-15 thousand meters, in the case of Etna. At these altitudes erupted pyroclasts can be dispersed by tropospheric winds for hundreds of kilometres around the volcano. The impacts of these phenomena are broadly different for the two volcanoes, both due to their intrinsic differences and because of their geographic position. Stromboli is a small island and a popular tourist attraction especially during the summer, while Etna is a 3,357 m high volcano surrounded by a productive countryside which overlooks Catania and foothill villages, where about a million people live.

A different kind of threat is posed by **dormant volcanoes.** These volcanoes have been inactive long enough to lose a direct connection with the magmatic system at depth and thus their capacity to erupt frequently. Nevertheless, these volcanoes maintain their full potential to erupt again in the future. With respect to frequently erupting volcanoes that have an open volcanic conduit, a renewal of eruptive activity at dormant volcanoes requires greater energy, and this may lead to explosive eruptions with a larger impact. Prolonged repose time may also contribute to reduce the **risk perception** among the local residents. People may peacefully live on the volcano slopes for decades and acquire a false sense of security that may hinder the implementation of long term mitigation actions.

The re-awakening of a dormant volcano does not pass unnoticed. The development of a new pathway for magma ascent toward the surface is generally accompanied by a number of geophysical and geochemical phenomena, such as shallow seismicity, ground deformation, and by changes in the composition and discharge rate of volcanic gases. These precursory signs may warn against the impending danger, and may directly threaten the local communities even before the eruption begins. Multidisciplinary monitoring networks enable to capture even small changes in observed parameters and the number and magnitude of observed anomalies help to constrain the current state of a volcano. Unfortunately, these precursors do not always provide actual clues on the duration and outcome of the ongoing unrest period. Volcanic unrest may terminate before magma reaches the surface, or may escalate into eruptive activity, and the entire process may take from a few days to several years. This large uncertainty about the final outcome and the time frame involved makes it really difficult to manage volcanic unrest. At this time (late November 2021), two Italian volcanoes are going through volcanic unrest: the Phlegraean Fields caldera, in the densely populated Neapolitan area, and the island of Vulcano, belonging to the Aeolian Archipelago. The volcanic unrest at these two volcanoes poses very different challenges to the community involved and emergency managers.

Other active but dormant Italian volcanoes are completely quiet, but their possible re-awakening must be accounted for in risk assessment. The most famous of these volcanoes is certainly Somma-Vesuvius, also located in the metropolitan area of Naples. Other quiescent volcanoes are the Island of Ischia, in the Gulf of Naples, two Aeolian islands (Panarea and Lipari), and Pantelleria, an island in the Sicilian channel. The list is completed by the submarine volcanoes in the Tyrrhenian Sea and the Sicilian Channel.

In the following, we describe significant features for the main volcanic areas in Italy and highlight the different problems posed by persistently active, unresting and dormant volcanoes. We believe they represent well many of the typical challenges related to volcanic risk assessment and mitigation.

Active volcanoes in Sicily

Stromboli

Stromboli is a volcanic island entirely formed by a stratovolcano that rises from the bottom of the sea (at a depth of 2,000 m) and reaches a maximum height of 930 m above the sea level (Figure 2). At least for the last 1,000 years, Stromboli has been characterized by a persistent, mildly explosive activity, sometimes accompanied by the effusion of lava flows that usually propagate along a horseshoe-shaped escarpment known as Sciara del Fuoco (literally, the Fire slope). This persistent activity features an average of 10 to 15 explosions in an hour, from three active craters situated on a terrace facing the Sciara del Fuoco, at an elevation of 750 m. These explosions have usually a minor impact, with fallout of lapilli and ash that is limited to the summit area. However, bigger events may take place with greater consequences.

Figure 2. Stromboli Island, seen from the west. In the foreground, the erosive depression known as "Sciara del Fuoco". At the top, the summit craters which degases continuously. Bottom left, the town of Stromboli; bottom right, the houses of Ginostra.
Source: Photograph by Marco Neri.

Paroxysmal eruptions usually form eruptive columns that may reach up to a maximum of 7-8 km and may eventually collapse feeding pyroclastic flows, hot mixtures of gas and ashes that rush down the volcano's slope. Given the specific morphology of the island, these flows are commonly directed along the steep and desert western slope of the island. Once they reach the coast, they may threaten shipping as they propagate along the sea surface or cause anomalous waves. These events also launch volcanic bombs and blocks that occasionally reach the two villages located to the NE and SW corners of the island (Figure 2). Even when they are not hit by bombs, the villages are easily engulfed in lapilli and ashes fallout, which may affect roads, crops and air quality, and ignite fires. A recently redacted catalogue of eruptive events at Stromboli shows that 36 paroxysmal eruptions occurred over the last 140 years. The analysis of available data suggests an increased frequency of extreme events during the last 10 years, and shows that paroxysms are more likely to happen shortly after one another. Examples of this behaviour are the two paroxysmal events that took place in 2019, on the 3rd of July and then again on the 28th of August. The first of these two events was marred by one casualty, due to the inhalation of a mixture of smoke, ash and gases. The current alert level for Stromboli is yellow, characterized by a high level of Strombolian activity (Figure 3).

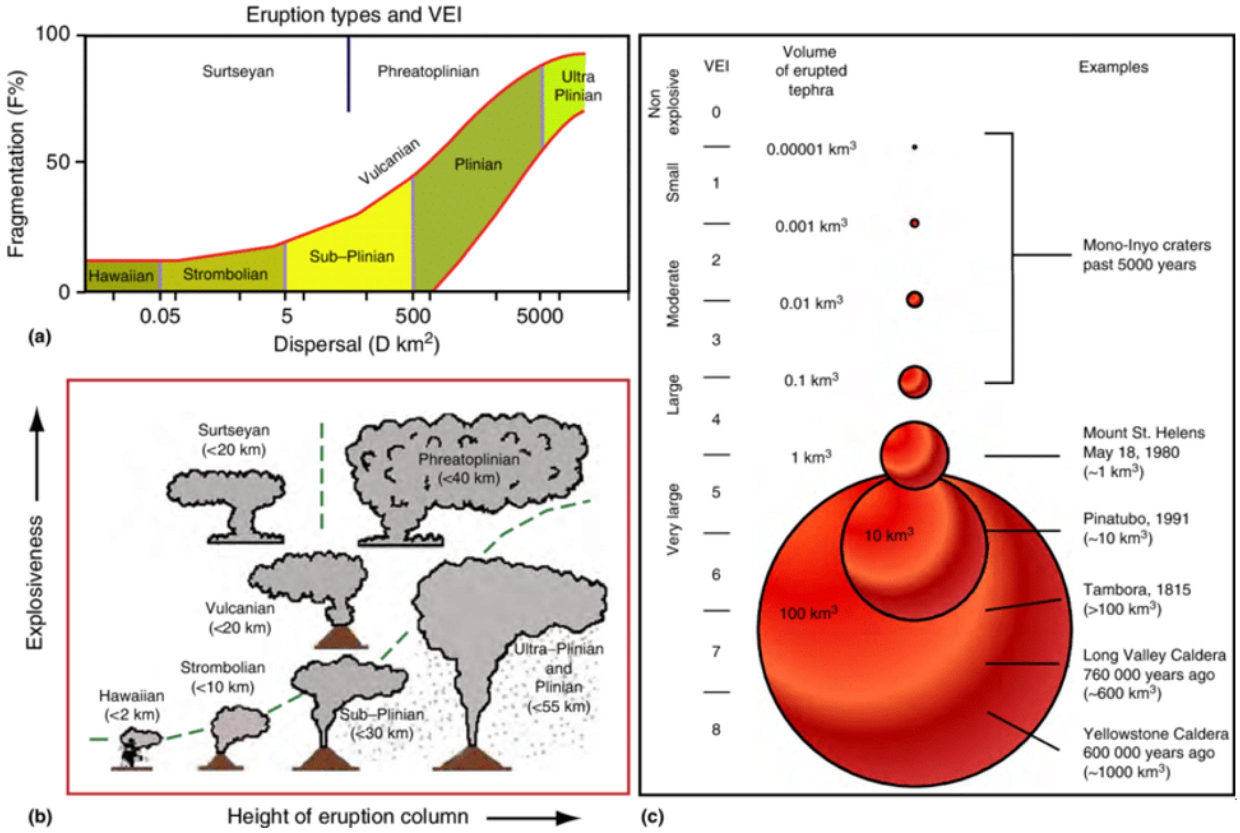

Figure 3. These diagrams show three different ways to classify explosive volcanic eruptions, according to a) the area of ash dispersion and the percentage of fragmentation of pyroclastic fall deposits; b) the height reached by the eruptive column and explosiveness degree; c) Volcanic Explosivity index (VEI).
Source: Hickson, Catherine & Spurgeon, T. & Tilling, Robert. (2013). Eruption Types (Volcanic Eruptions). 10.1007/978-1-4020-4399-4_122.

Etna

Etna is the tallest volcano in Europe and one of the most active volcanoes on Earth. Volcanic activity is mainly focused at the summit, generating gas emissions, strombolian to paroxysmal activity (Hawaiian, violent Strombolian to sub-Plinian, Figure 3) and lava overflows from one of the four summit craters. These nearly continuous summit eruptions do not pose only a seemingly minor threat to human life and property. The development of tall volcanic columns during major eruptive events may inject significant quantities of ashes in the atmosphere (Figure 4) and affect air traffic: sometimes this requires rerouting flights and occasionally it may prevent landing and take-off in local airports. Ash fallout can also affect road conditions and crops. The greater frequency of paroxysmal summit eruptions in recent decades (since 1977 there have been hundreds of paroxysmal explosive episodes!) has undoubtedly increased the hardships for the Etnean populations, who are continually forced to face the problem of ashes and lapilli accumulation on the roofs of houses and on streets and cultivated land.

At times, the Etnean volcanic activity occurs along radial fissures, producing **flank eruptions** (Figure 5) mostly from three main “rift zones”, that is, areas of structural weakness of the volcanic apparatus. In these cases, magma moves vertically towards the topographic surface through the central conduit and, at shallow levels (few hundreds of meters up to 1-3 km), propagates laterally penetrating, in most cases, into the rift zones.

Figure 4. March 4, 2021: Explosive eruption from the Southeast Crater of Etna, seen from the Gulf of Ognina, in Catania. The eruptive column rises vertically for about 8-10 kilometres in height before being pushed by the wind towards the north-east.
Source: Photograph by Marco Neri.

Flank eruptions represent the most dangerous type of eruptive activity, since they occur at lower altitude (between 2000 and 500 meters above the sea level) and thus closer to vulnerable areas such as towns, villages, lifelines, and cultivated land. Potentially hazardous flank eruptions have a frequency ranging from a few months to a few decades, although the time intervals between such eruptions have shrunk to an average of 1.5-3.0 years since 1971.

All known Etnean flank eruptions have produced lava flows, many of which invaded areas of cultivated land, destroyed human property and infrastructures, and sometimes buried entire villages. In 1928, for example, the village of Mascali was almost totally buried and destroyed by the lava and rebuilt elsewhere, further downslope. On the other hand, during the past 70 years the urbanized areas around the volcano have rapidly developed, with an extensive system of lifelines and rapid growth of population centres, often in areas that have been covered by lava flows in the historical period. Tourist facilities have been established high on the volcano (up to 2,600-2,800 m high) and were repeatedly damaged by lava flows, most recently in 2001 and 2002-2003. For these reasons, the Etnean region is more vulnerable now than at any time before.

Figure 5. July 28, 2001: flank eruption of Etna. Lava flows invaded and destroyed part of the Etna-Sud tourist centre.
Source: Photograph by Marco Neri.

In order to mitigate the impact of lava flows by preparing appropriate intervention and civil protection plans, numerous scientific studies, many of which made by INGV researchers, have recently been carried out, focused on mapping the areas of most probable lava invasion and therefore most exposed to destruction. These studies show that the risk from lava invasion is highest around the summit area, due to the frequent activity and the limited range of vent locations. The level of hazard decreases away from the summit, but at the same time, the vulnerability increases exponentially, especially in the areas located downstream of the volcanic rift zones.

The vulnerability of the Etna area is well known by the populations who have lived on its slopes for thousands of years. However, people consider Etna to be a "good volcano", as it hardly ever claims victims, with its lava flows that move slowly enough to allow people to escape. The alert level for Etna is currently yellow.

Vulcano

The island of Vulcano, in the Aeolian archipelago, is made up of several different-sized volcanic centres. The eruptive activity of the island was characterized by a wide range of explosive eruptions, and lava flow effusions, which over time built two important volcanic edifices and several minor centres. These volcanic structures were partially or even largely destroyed by multiple volcano-tectonic collapses, forming two calderas. Inside the most recent caldera, starting from about 5,500 years ago, the tuff cone of La Fossa grew and was mainly characterized by phreatomagmatic (Vulcanian) eruptions (Figure 3). Some effusive eruptions along La Fossa volcanic history are present, too. Afterwards, in the northernmost part of the island the cone of Vulcanello was formed, initially through an underwater lava eruption that began in 126 BC (according to the Roman chronicles) and then from both subaerial explosive and effusive eruptions. It’s noteworthy that in the last 1,500 years, the activities of these two young eruptive centres occurred repeatedly, both alternating and simultaneous. The remnants of another small tuff cone - Il Faraglione -, strongly fumarolized and located just in front of the Vulcano harbour, reveal that a third volcanic centre aroused from the caldera floor in recent but indefinite times. The last La Fossa eruption occurred between 3 August 1888 and 22 March 1890, following several centuries of short-lived, discontinuous but recurring eruptive activities. This eruption, well documented and described by Giuseppe Mercalli, led to the introduction of the term "Vulcanian" activity in the volcanological nomenclature.

Since the last eruption, Vulcano has gone through periods of unrest characterized by an increase of fumarolic activity and gas discharge, both at the fumarolic field on the crater rim and at the base of the cone. Between 1988 and 1993, in particular, a notable increase in the temperatures of fumarolic gases was observed; up to 690° C. Heating was associated with changes in gas composition, suggesting an increased magmatic contribution. With time, all the anomalous signals returned to their background values and the unrest ended without a renewal of eruptive activity. More recently, since September 2021, the INGV monitoring systems have highlighted changes of geophysical and geochemical signals, including shallow seismicity, ground deformation of the crater area, changes in gas composition, temperature and discharge rate (Figure 6). Some inhabited areas have been affected by anomalous gas discharge through the soil, and the evidence of dangerous concentration of volcanic gases in air prompted a temporary ban to overnight in those areas. Based on the changes described above, the Department of Civil Protection has ordered the transition of the alert level from Green to Yellow for the island. Very recently, the framework related to the alert levels that describe the volcanic state of activity by a combination of monitoring parameters and data collected to any ongoing events, has been re-defined through a close collaboration among INGV, Civil Protection and some Universities. In the new scheme, the yellow level corresponds to unrest of the hydrothermal system that feeds the fumaroles.

Different hazard scenarios are possible on Vulcano, which is characterized by a long-standing history of eruptive activities and a geothermal system that has been active since historical times. Some hazardous phenomena from La Fossa cone are also possible due to the slopes instability, strongly influenced by either the volcanic dynamics or hydrothermal activity, as seen in many other tuff cones. The potential renewal of volcanic activity from La Fossa (or caldera rims) carries a high risk especially for the more inhabited northern sectors of the island, which are crowded by thousands of tourists during the summer and located just at the foot of La Fossa cone.

Figure 6. La Fossa crater on the Vulcano island and, in the background, the islands of Lipari, Panarea and Stromboli in November 2021.
Source: Photograph by Gianfilippo De Astis.

The active volcanoes in the Neapolitan area: Somma-Vesuvius, Phlegraean Fields and Ischia island

The densely populated metropolitan area of Naples is located between two highly explosive active volcanoes, the Phlegraean Fields volcanic district (including the Phlegraean Fields caldera and the volcanic islands of Ischia and Procida-Vivara) to the west and the iconic Somma-Vesuvius stratovolcano to the east. The area is inhabited by more than 3 million people and is one of the places at highest risk of volcanic disaster in Europe (Figure 7).

Figure 7. The Somma Vesuvius volcano in the background and the tuff cone of Capo Miseno, in the Phlegraean Fields caldera, in the foreground.
Source: Photograph by Fabio Sansivero.

The two volcanic complexes show remarkable differences in their morphologies as well as eruptive dynamics.

Figure 8. Inside the Vesuvius crater.
Source: Photograph by Giuliana Alessio.

The Somma-Vesuvius volcano is worldwide well known for the catastrophic eruption of 79 AD that destroyed the Roman cities of Pompeii, Herculaneum and Stabiae (Figure 8). Its eruptive history is characterized by the shift from a quiescent (closed-conduit) state, generally interrupted by large-explosive eruptions of either Plinian or Sub-Plinian type, to open-conduit periods producing mixed effusive/low-explosivity events. According to a classification based on the volcanic explosivity index (VEI, Figure 3), these eruptions range from a VEI of 4-5 for large explosive events, to a VEI of 0-3 for open conduit periods. The latest of these periods lasted around 300 years and ended with the last eruption of the volcano, in March 1944 (Figure 9). Since that time, the volcano has entered a new state of closed-conduit repose, with very modest fumarolic activity, low magnitude seismicity, and rare earthquakes swarms. The volcano is at its base level of alert (“green”) due to the absence of significant variations in monitored parameters. Today the area immediately surrounding the volcano hosts about 500,000 residents.

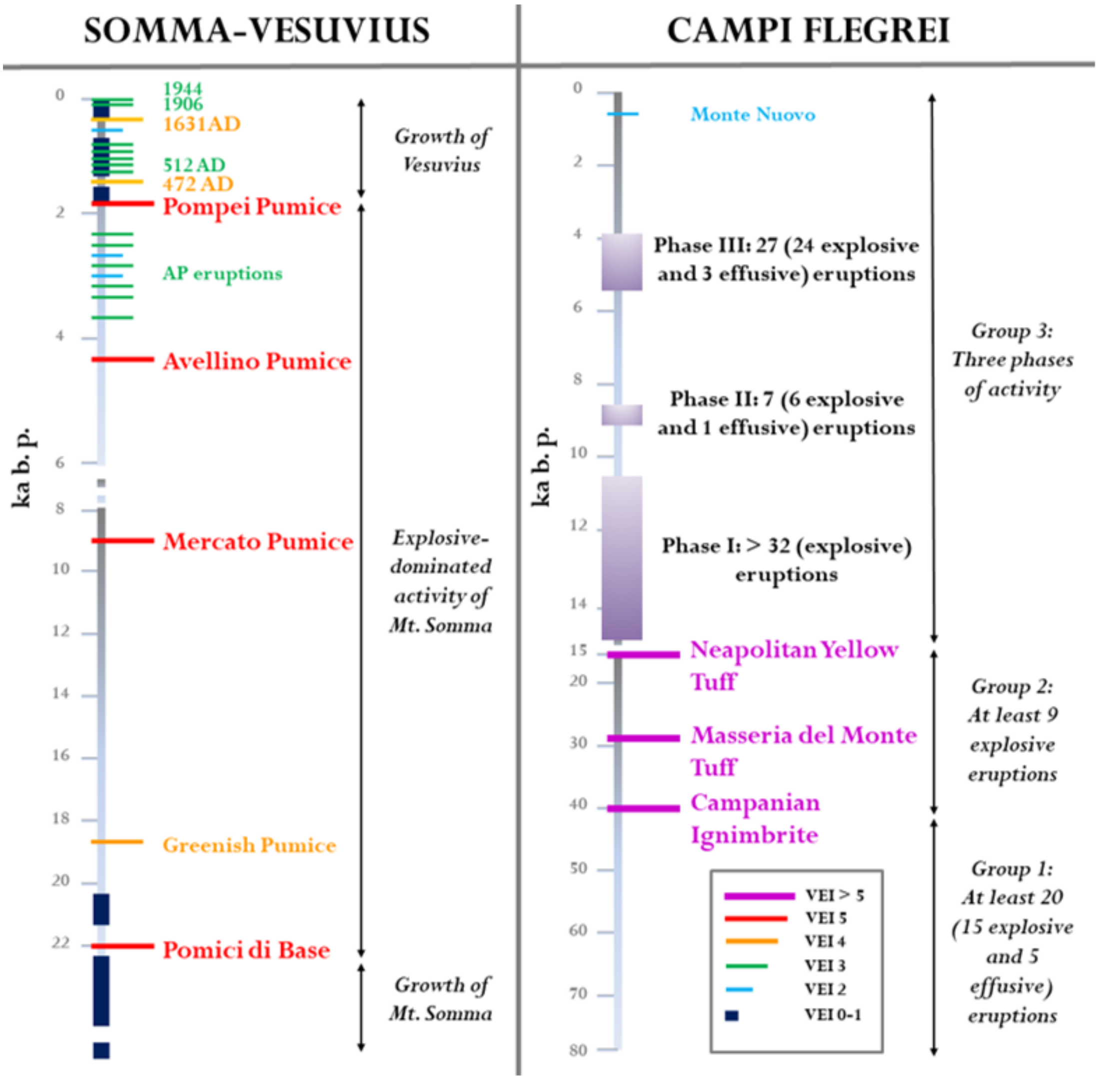

Figure 9. Schematic chronograms of volcanic activity of Somma-Vesuvius and Phlegraean Fields as recorded by stratigraphic successions. At Somma-Vesuvius in the last 22,000 years, four plinian caldera-forming eruptions and at least three major sub-Plinian eruptions occurred. The last cycle of open conduit activity started after 1631 and lasted until 1944. At Phlegraean Fields, volcanic activity started more than 80,000 years ago and includes the large caldera-forming Campanian Ignimbrite eruption and the second major caldera-collapse eruption of the Neapolitan Yellow Tuff. The only eruption in historical times occurred in 1538 AD. For Phlegraean Fields VEIs of the last 14,000 years eruptions are not indicated.

The Phlegraean Fields caldera (Phlegraean Fields, literally 'burning fields'), provides a classic example of how unrest can have a large impact on local communities. Volcanic unrest phenomena (ground uplift and seismicity) occurred during 1982-1984 years caused significant building damage and led to the evacuation of residents from the central part of Pozzuoli town. The Phlegraean Fields caldera (Figure 10) is considered among the most dangerous volcanoes in Europe, as it has been the source of the largest eruption in the whole Mediterranean area: the Campanian Ignimbrite eruption, dated about 40,000 years ago. According to recent studies, this eruption, which emitted a huge amount of ash and volcanic gas into the atmosphere, caused a lowering of the Earth's temperature by several degrees for many years, a real volcanic winter, which contributed to the disappearance of the Neanderthals. A second large eruption dates back 15,000 years ago, with the emplacement of the Neapolitan Yellow Tuff, on which much of the city of Napoli was built (Figure 9).

Figure 10. The figure shows part of the Phlegraean Fields caldera at whose centre is the city of Pozzuoli, in the foreground. Some of the monogenetic volcanoes formed during the last ten thousand years of volcanic activity are visible. The image shows the high urbanization of the caldera. In particular, in its centre, the crater of the Astroni (formed about 3,800 years ago), today a natural park and the Piana di Agnano from which the Plinian eruption of Agnano Montespina occurred (about 4,100 years ago); below on the left the bigger crater of Gauro (formed about 10,000 years ago).
Source: DTM by Laboratory of Geomatics and Cartography, INGV Osservatorio Vesuviano.

Today, the active volcanic area includes a 12-kilometre-wide caldera depression centred in the city of Pozzuoli. In the last 15,000 years, it was the site of a monogenetic (that is, a volcano built up by a single eruption) volcanic activity producing about 70 eruptions (with variable VEI, spanning from 0 to 5), concentrated mainly in discrete epochs separated by long periods of quiescence. The last of these eruptions occurred in 1538 AD, after more than 3,000 years of rest, and in one week led to the birth of a new volcanic cone, the Monte Nuovo, about 130 m high. Since then, many towns have developed inside the caldera, which is currently inhabited by more than 350,000 people.

After a long period of subsidence following the last eruption, in the last decades the caldera showed signs of potential reactivation characterized by episodes of ground uplift, shallow seismicity, significant increase in hydrothermal degassing, and changes in fluid geochemistry (Figure 11). In the Phlegraean Fields caldera the characteristic phenomenon of the slow lifting or lowering of the ground is called bradyseism (Figure 12).

Figure 11. Sampling of fumaroles at Pisciarelli, in the Phlegraean Fields Caldera.
Source: Photograph by Emanuela Bagnato.

The main bradyseismic crises occurred in 1970-72 and 1982-84 and were accompanied by several thousands of earthquakes and 3.5 m of total ground uplift, forcing the inhabitants of Pozzuoli city centre to evacuate. An ongoing unrest phase, resulting until now in a ground uplift of 85 cm in the central sector of the caldera and few thousands of earthquakes, has prompted the Italian Civil Protection Department to shift the Phlegraean Fields volcano alert level from base ("green") to warning ("yellow") at the end of 2012.

Figure 12. The Temple of Serapis, a Roman market located not far from the Pozzuoli coast line. The ruins of this Macellum (which dates back to the end of the 1st century AD) have been fundamental for the reconstruction of the ground movements (bradyseism, from the greek bradius = slow and seismos = movement), due to the presence on the three standing marble columns of lythodome's holes (marine molluscs that live in a coastal environment at the limit between high and low tide) that testify the maximum subsidence of the area.
Source: Photograph by Fabio Sansivero.

The island of Ischia, in the Phlegraean Fields district, is the emerging part of an extensive volcanic system, which rises over 1,000 m from the sea level. At Ischia, volcanism began before 150,000 years ago and has continued intermittently, with quiescent periods lasting centuries to millennia, until the last Arso eruption in AD 1302. The volcano is at base level of alert and is currently characterized by fumarolic and hydrothermal activity, on which a thriving economy is based. A moderate seismicity is also linked to its volcanic nature, which can cause heavy damage since the hypocentres are very shallow. A recent example is the 3.9 magnitude volcano-tectonic earthquake that occurred on August 21th, 2017 at Casamicciola Terme town. The most destructive earthquake of the last centuries occurred in 1883 and completely destroyed the same town, killing 2,313 people. The island is densely populated, with more than 60,000 inhabitants distributed in less than 50 km^2. During tourist seasons this population increases substantially.

Due to the high volcanic hazard and the densely populated urban context, the Neapolitan volcanoes have been the terrain to develop complex risk mitigation strategies aimed at emergency planning. Important information to forecast the future behaviour of the volcanoes derives by an accurate and in-depth analysis of the magmatic and eruptive history, as well as numerical simulations of expected eruptive phenomena. On this basis, the volcano science community has defined the possible pre-eruptive and eruptive scenarios of future eruptions and the areas that will eventually be affected by the effects of volcanic activity. In addition, the monogenic nature of the past Phlegraean Fields eruptive activity implies the uncertainty in the precise location of the future eruptive vent, a new volcano could grow at any place inside the 12 km wide caldera. This knowledge represents the basis for identifying the perimeter of areas potentially subject to dangerous phenomena, adopted in emergency planning by the National Department of Civil Protection in Italy.

The National Plans of Civil Protection for Somma-Vesuvius and Phlegraean Fields include as reference scenario for both the volcanoes, which is an explosive eruption of medium size. This scenario is characterized by three main stages corresponding to different hazard and risk areas: a first phase of "fallout", with the development of a very high (tens of km) and sustained eruptive column associated with the fall of pyroclastic fragments in the downwind sectors (the so-called yellow zone), a second phase of eruptive column collapse with generation of pyroclastic flows (affecting the so-called red zone) and a third phase with abundant precipitation and generation of mud flows.

The impact associated with the first phase consists mainly in the collapse of the roofs in the urbanized area around the volcanoes. At this latitude, stratospheric winds mostly blow eastward. This considerably reduces the hazard of ash fallout for the 1 million inhabitants' city of Naples in case of an explosive eruption of Somma-Vesuvius, located in the eastern sector of the city. However, Naples is highly exposed to ash fallout produced by an eruption from Phlegraean Fields, located in the western sector.

Nevertheless, the maximum risk derives from the passage of pyroclastic flows (second phase). These are clouds of ash and volcanic gas that flow at high speed an d temperature along the volcano flanks and can reach considerable distances in a few minutes, destroying everything along their path. In the areas closest to the vent, due to their high density and speeds (100 km/h), pyroclastic flows are able to knock down even modern reinforced concrete buildings. At greater distances the pyroclastic flows slow down and lose part of their ash load, so the impact force is reduced while the temperature remains always above the survival limits. Recent studies show, in fact, that during the Plinian eruption in 79 AD the unfortunate inhabitants of the towns of Herculaneum and Oplontis (located 5-6 km from Vesuvius), as well as those of Pompeii (10 km from Vesuvius), died of thermal shock due to the high temperature (300-600 °C) of the pyroclastic flows.

In case of medium-high intensity explosive eruptions, the pyroclastic flows coming from Phlegraean Fields and from Somma-Vesuvius can reach the city area of Naples, such as demonstrated both by the volcanic successions present in the metropolitan area, and by the results of numerical calculations that simulate the passage of pyroclastic flows on the current volcanic morphologies. Due to the high impact of pyroclastic flows, the only countermeasure for safeguarding the population remains the complete evacuation of the risk zone at the very onset of the volcanic crisis and before the eruptive phase occurs.

Despite the high volcanic hazard of the Neapolitan area, the resident population does not perceive the volcanic risk as relevant. In the last decades in-depth studies of volcanic risk perceptions have been carried out for inhabitants of the Neapolitan area. The results for the Vesuvius population demonstrates that people are aware of the threat of a future eruption and worried about it, but they feel more concerned by the problems they daily face, such as unemployment and crime. Moreover, 80 % of the sampled population believe that Vesuvius will not erupt within the next 10 years. The study also highlights that knowledge of the Vesuvius Emergency Plan is not widespread. Consequently, trust in public officials and in the success of the plan is low, as well as self-confidence to deal with such an emergency. On the other hand, a positive note is the great confidence in scientists. More recently, another survey has shown that Vesuvius Red Zone inhabitants are more aware about volcanic threat than Vesuvius Yellow Zone ones. This different perception was to be expected, given that they have been most affected by the Vesuvius eruptive activity in recent times.

For Phlegraean Fields caldera inhabitants, as for those of Vesuvius, volcanic hazard is not spontaneously mentioned as a major problem facing the community and is more associated with Vesuvius volcano than with the Phlegraean Fields caldera. However, when asked about the specific issue, citizens expressed serious concern about the volcanic threat and its effects on their community. Only 17 % of the population sample is aware of the existence of the Phlegraean Fields Emergency Plan, and 65 % said that they have not received enough information about the possible effects of an eruption. Nonetheless, citizens feel sufficiently confident in being able to face an eruption but have low confidence in local authorities and civil protection.

Finally, probably because an emergency plan has not yet been implemented, the volcanic hazard perception of a small sample of inhabitants of the island of Ischia is very low, so low that some of them believe they are included in the risk maps for Vesuvius.

All these issues pose a challenge to emergency management in the whole Neapolitan area and highlight the need of an accurate educational and raising awareness campaign about volcanic hazard and emergency plan, which builds knowledge, motivation and coping abilities. Moreover, for both Somma-Vesuvius and Phlegraean Fields areas, citizens ask for their involvement in emergency planning and in particular in preparedness measures. It follows that a participatory process should be established in the construction and update of future emergency plans.