



Enhancing Social Resilience Through Fruition of Geological Heritage in the Vesuvio National Park

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Abstract

The Vesuvio National Park, established in June 1995, is the green area closest to Napoli megacity, which suffers the absence of urban green spaces and could hence offer to citizens the opportunity to enjoy healthy places in a peculiar environment as the landscape of an active volcano. We here propose two trails with several stops, named the Ancient Railway Track and the Valle dell'Inferno. They start from San Sebastiano al Vesuvio and Ottaviano towns, located on two opposite sides of northern Somma-Vesuvio area, and are both directed towards the Vesuvio crater. Along the trails, the visitors can enjoy several volcanic forms and products (the Somma caldera rim, dykes, lava domes, ropy lava flows, pyroclastic fall deposits) together with historical remains, such as the Cook Railway track, and the typical botanic association, the Mediterranean bush. The stops were illustrated with panels describing in detail both geological and landscape features with pictures and simple text boxes, clear and engaging for a wide set of excursionists of different ages and cultural backgrounds. The quality of the two trails was assessed through a quantitative evaluation of the single stops considering the different typologies of expected visitors. The project of promotion and fruition of green spaces in an active volcanic area here proposed contributes to encourage healthy living and raise well-being and could represent one of the means to achieve a better level of resilience for a society exposed to high volcanic risk.

Keywords Natural heritage · Volcanic risk · Social resilience · Vesuvio National Park

Introduction

The peculiar geotectonic setting of the Italian territory makes most of the country prone to the effects of natural hazards. This is even truer in the active volcanic areas of Southern Italy (Campi Flegrei, Vesuvio, Eolian Islands, Etna), where scientific community and public institutions are currently cooperating to find effective measures for natural risk reduction. Building disaster resilience is critical for achieving this

goal and makes the communities able to cope and recover from the impacts of disaster (UNISDR 2015).

Resilience, rooted in ecology to describe the capacity of a natural system to adsorb shocks from disturbances and to turn in equilibrium state (Holling 1973), in the last decades emerged as an important quality of natural and artificial systems (Folke 2006) to cope with the effects of stressor events. The resilience concept expresses the capacity of a system to withstand, respond to, adapt and prepare more readily to shocks and stresses in order to emerge stronger after hard times and live better in good times (Chapin et al. 2009). The effectiveness of identifying and exploiting material and immaterial resources and of adopting dynamical behaviours able to get with the times and changes has been proved a significant mean to enhance resilience (Fiksel et al. 2014; Martin and Sunley 2015). Mostly peripheral areas can pursue this goal also using green spaces and specific cultural resources, encouraging local communities to take part to the social life and town management and, finally, favouring the adoption of technological resources to stimulate economic growth. In this frame, cultural heritage has an important role to play because it contributes to strengthen the relationship between

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people and territory, providing communities with the sense of belonging that is necessary to enhance well-being for present and future generations (UNISDR 2015). Aiming at emphasizing significant interactions between people and the natural environment, the term “cultural landscape” has been recently coined (Migoñ 2018). As stated by Reynard and Giusti (2018), “the landscape relates to the total surface form of any area, rural or urban, and includes both natural and man-made features, i.e., both the natural and the cultural landscape”. This definition well emphasizes the inclusion of the perception by humans in the European Landscape Convention (2000), according to which “landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors”.

Geoheritage, as other types of natural heritage, can be regarded as a part of cultural heritage (Panizza and Piacente 2003), considering that landforms and geological features as heritage elements are clearly the result of a perceptual process (Reynard and Giusti 2018). The geologic valuables are fundamental to understand the landscape evolution and, when opportunely promoted, they can represent an attraction for their singularity (Dingwall 2000; Gray 2004). Some peculiar sites can hence be chosen as possible “geosites”, defined as “geological and geomorphological ‘objects’ having scientifically value for a better understanding of the history of the Earth, being it historical-cultural, aesthetic or socio-economic” (Wimbledon 1996). The scientific value is emphasized by Brillha (2016) who proposes that geodiversity, i.e. the abiotic part of natural diversity, can be a resource for education, tourism or cultural identity and, within it, an added high scientific value makes geosites different from “geodiversity sites”. In this frame, only geosites and geoheritage elements, represented by ex situ elements collected and exposed in museums (minerals, fossils), thanks to their scientific importance, make up the geoheritage.

In any case, a geosite represents a reliable tool for environmental education, because it provides people with basic means for the knowledge of geological and geomorphological aspects of an area. This knowledge, on the counterpart, is fundamental for preservation and promotion of natural resources through a correct policy of territorial management and decision planning, in as much in the active volcanic areas of Campania that are among the highest volcanic risk areas in the world.

During the last decades, the sensibilization and interest of public opinion toward improving access to green spaces and preservation of naturalistic resources greatly increased, as the promulgation of specific directives dealing with this crucial matter and the establishment of new natural reserves testify (Gordon et al. 2018).

Protected areas, also in the light of Italian national laws and of the directives of 5th Environmental Action Programme of the European Community, represent the best places where the

Campania Region implements its policies of environment preservation and territorial planning, aiming at joining the needs of development with the priority needs of conservation. Natural Parks were instituted mostly to protect the precious and sensitive environments where the progressive increase of man action was causing severe damages, with the need to assure their pristine integrity. Currently, this goal can be also achieved through specific actions devoted to restore compromised equilibrium, to favour the resuming of natural processes and to educate and train residents and enjoyers for a sustainable relationship with natural environment (<http://www.regione.campania.it/regione/it/tematiche/natura/i-parchi-in-campania?page=1>).

The presence of a natural reserve has many positive consequences: the environment is preserved in all its aspects and floral and faunal singularities are protected from the extinction. In the towns pertaining to a reserve, unauthorized building is strictly forbidden and even restoration of pre-existing edifices is severely regulated. Nowadays, the Vesuvio National Park, established in June 1995, is the only national park in Italy that comprises an active volcanic area. Since its establishment, the landscape of the thirteen encompassed municipalities is preserved and protected: this represents a major breakthrough with respect to the previous decades, when the area had been the theatre of dense and unruled urbanization even along the slopes of the volcano (Petrosino et al. 2004).

Most of the geological heritage is still poorly known to the general public, although over the last few years, a new type of tourism, known as Geotourism, has been rapidly developing (Dowling 2011; Suzuki and Takagi 2018). Geotourism encourages people to look to geodiversity as to the key factor influencing the biodiversity and, consequently, the whole of natural landscapes.

As far as the fruition of geological heritage is concerned, Vesuvio comprises a substantial number of sites remarkable in terms of their scientific quality, rarity, aesthetic appeal and educational value, most of which are valuable for their geodiversity, but they may also raise archaeological, ecological, historical or cultural interest. In this frame, we chose to set two different trails that start from the footslopes of Somma and reach the crater of Vesuvio, known as *Gran Cono* (*Great Cone*), enabling excursionists to appreciate the various elements of natural landscape. As a matter of fact, our idea is that the trails can be visited not only by geologists and naturalists but also by students from primary school to college and mostly by common people fond of trekking and outdoor activities in general. The Vesuvio National Park is the green area closest to Napoli megacity, which suffers the absence of urban green spaces, and could offer to citizens the opportunity to spend their spare time in touch with nature. Enjoying green spaces is essential in promoting healthy living and well-being and could represent one of the means to achieve a better level of resilience for society. A further goal of diffusing the cultural

use of geological heritage could be the geoconservation, conceived as preservation of the elements of geodiversity in the territory to allow its fruition to future generations, in an area where the respect of natural environment is still too little accounted for.

Geological and Morphological Settings

Somma-Vesuvio is a composite volcano, where the remnants of an ancient strato-cone, the Somma, whose products range in age between 40 ka and 79 A.D., surround a younger cone, the Vesuvio, that last erupted in 1944 (Fig. 1). The building phases of the Somma strato-cone consisted in intervening effusive and mildly explosive eruptions: starting from ca. 30 ka the activity turned to a different type, with high-size explosive eruptions, sub-Plinian to Plinian, that interrupted variably lasting quiescence periods; at least four main Plinian events occurred during this period of activity (De Vivo et al. 2010 and reference therein). These eruptions progressively disrupted the Somma strato-cone, building a horseshoe-shaped caldera, within which grew the Vesuvio cone, source of effusive and low-size, mainly strombolian, explosive eruptions (Cioni et al. 1999; Rolandi et al. 2004). The resulting morphological setting underpins different zones. The first zone is the northern

Somma flank, which, from W to E, encompasses the towns comprised between San Sebastiano al Vesuvio and S. Giuseppe Vesuviano, where the lava flows making up the ancient strato-volcano are covered by the products of the post-30 ka explosive eruptions. The slopes are deeply incised by stream river channels, the so-called Lagni, along the steep walls of which successions of pyroclastic deposits embedded to paleosols, overlying ancient lava flows, are somewhere observable. The better exposures of these lava flows in the same area are along the rim of the caldera (*Cognoli*—a local word meaning *Hilltops*). To find good outcrops of pyroclastic deposits is nowadays much more difficult, because the better ones were exposed along the quarry walls, but since two decades, quarrying activity has been strictly forbidden in the Vesuvio National Park area, and most of the meaningful outcrops have been obliterated. In the western zone, on the counterpart, the Vesuvio products prevail over the Somma ones. Vesuvio recent lava flows mainly poured toward the W, and many of them reached the sea along the Ercolano and Torre del Greco coastline. In this area mostly prevail the pyroclastic products of 79 A.D. eruption, the famous explosive eruption used as an archetype for Plinian eruptions, that inherited their name from Pliny the Elder, the Roman admiral and naturalist writer who died at Stabiae during the last phases of the eruption. The chronicle of the eruption was told in full detail by his

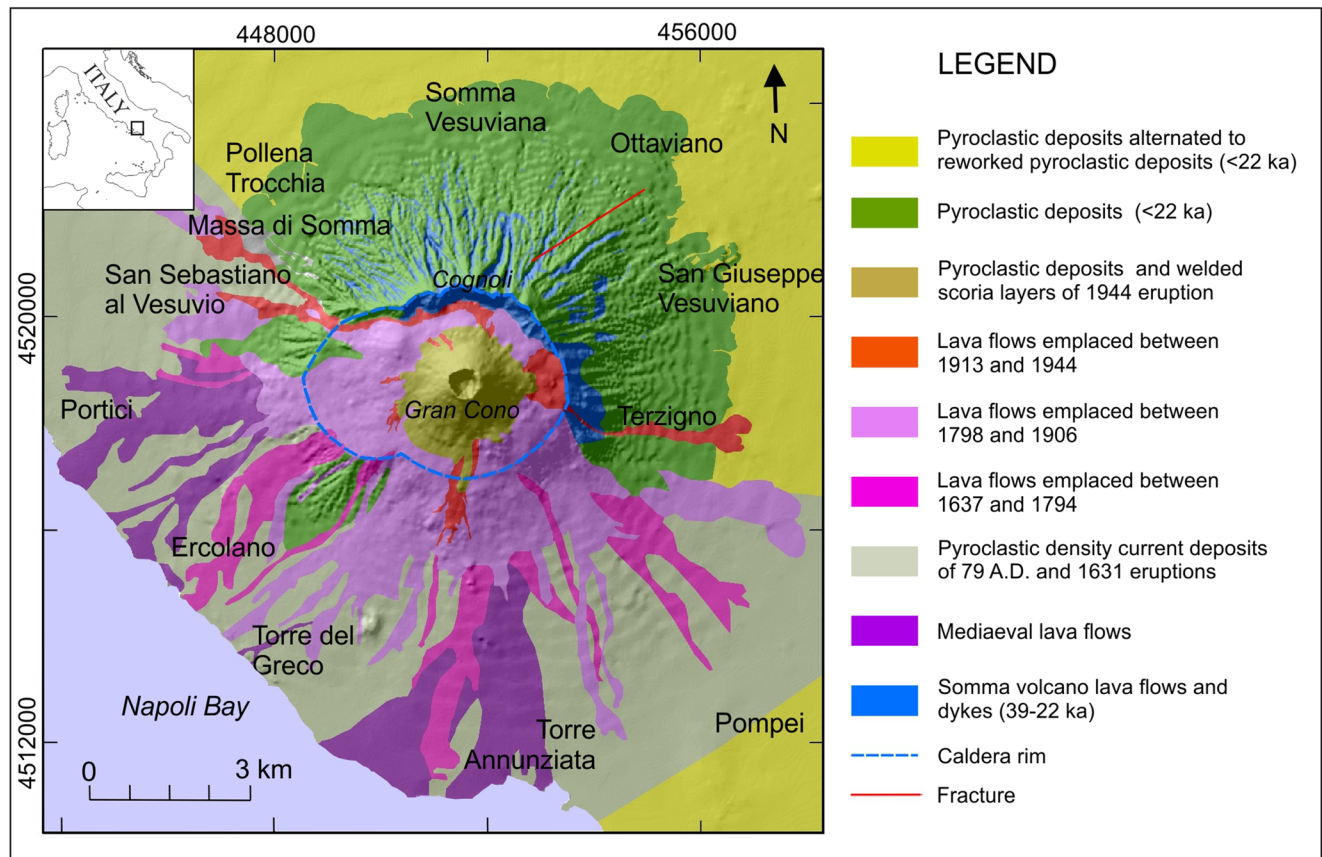


Fig. 1 Geological sketch map of Somma-Vesuvio volcano, modified from Santacroce and Sbrana (2003)

nephew Pliny the Younger, who eyewitnessed it from Miseno Cape, in two letters to the historian Tacitus, who had asked him to write the circumstances of his uncle's death (Pliny's *Epistulae*, 6, 16 and 20—Logan Lobley 1868). These letters are worldwide considered the first document of modern volcanology. Following a general scheme, which holds for all the highly explosive Somma eruptions, volatile overpressure in a magma residing deep inside the volcano basement triggered an explosive eruption: in the first phase, an eruptive column some tenths of kilometres high, emplaced pyroclastic fall deposits up to hundred kilometres SE from the volcano. The eruption was also featured by column collapse phases that produced pyroclastic density currents (PDCs), mixtures of hot gas and clasts that, speeding along the slopes of the volcano, overrun the perivolcanic and coastal area with the hosted Roman towns. Their ruins, brought to light, are now among the most famous testimonies of life and habits during the Roman Imperial period (first century B.C.–third century A.D.). In the final phases of the eruption, water gained the access to the magma reservoir and its explosive interaction with the left residing magma caused the formation of further PDCs. As a rule, after the high-size explosive events, heavy rain episodes were able to remobilize loose debris along the volcano slopes, and debris flow phenomena occurred, emplacing thick volcanoclastic deposits in the flat areas surrounding the volcano.

The Two Proposed Geosites

The two geosites here proposed consist in two trails with several stops, named the Ancient Railway Track and the Valle dell'Inferno (*Hell's Valley*). They start from two opposite sectors of Somma-Vesuvio, respectively, from the north-western (San Sebastiano al Vesuvio town) and the north-eastern (Ottaviano town) sides, and both are directed towards the Gran Cono. We suggested an itinerary with fixed stops, numbered progressively from the entry to the exit, but the trails can be walked in both directions because the first and the last stop are located close to main roads, where a car or a minivan can easily be parked. Nonetheless, currently, the visitors are expected to do a round-trip, doubling the length of the trail, because the public transportation does not routinely serve the entry/exit areas. On the whole, the paths are easy to be walked along, with only some very short steeper parts. Furtherly, in a whole spring or summer day, the excursionists can join the Gran Cono as an additional tour to both the itineraries, travelling a little more road (Fig. 2).

Choice of the Sites and Phases of the Work

First of all, we carried out a preliminary investigation of geological features along the nine naturalistic visiting tracks

managed by the Vesuvio National Park, with the purpose of selecting those that better fulfill a variety of different expectations, combining the needs of specialists and mere tourists. Starting from the fact that a restoration of the touristic resource is impending, we tried and verified if the area was worthy of exploitation of the geovolcanological resources alongside with the naturalistic aspects, which at present, the Vesuvio National Park mainly takes care of (Alberico et al. 2012; Sabbatino 2015).

Some trails currently result difficult to access or to be walked across, whilst several of them mainly offer the possibility of observing good biodiversity or panoramic spots, with very few well-preserved rock outcrops. Conversely, the sites we chose could provide visitors with a complete observation of the geovolcanological features of the volcano.

In the area encompassed by the Ancient Railway Track, the products of the whole sequence of the Somma-Vesuvio activity crop out, starting from the ancient lava flows that make up most of the structure of the ancient strato-volcano (the Somma), ranging in age between 39 and ca. 22 ka. The explosive products of the Somma Plinian eruptions are well represented, both as pyroclastic fall and as pyroclastic density current deposits. The 1944 Vesuvio lava flow closes the stratigraphic sequence.

Along the Valle dell'Inferno itinerary, the effusive products of both volcanoes prevail over the pyroclastic deposits. The tour offers good spots to observe the products of the last Vesuvio eruption, which occurred in March 1944, both as lava flows and pyroclastic fall deposits. Apart from the geovolcanological valuables, the sites also arise a lively historical interest, as testified by the numerous documents collected and investigated during the research (Lirer et al. 2009 and references therein).

The main purpose of our work was to highlight the scientific peculiarity of the site, so the itineraries are planned to accompany the visitor through the geological history of the site itself and to aid him in touching by his own hand the “products” of this history.

After the revision of the scientific literature dealing with the area, we carried out a field survey 1:5000 in scale, drawing as a support to the promotion of the geological resource both a detailed geological (Fig. 3a, b) and a geolithological map (Fig. 4a, b), where the geological formations have been grouped according to the source volcano (Somma or Vesuvio) and to the eruptive mechanism emplacing the single deposit (lava flow, pyroclastic fall or pyroclastic flow). This simplified map was thought to represent a geological tool also for secondary school students and non-expert visitors. At the same purpose, for self-guided tours, at the entry of each itinerary was prompted a colour poster that contains the photos of all the stops and describes their main features. More detailed panels were realised for the single stops, where also simplified sketches of the eruptive and depositional mechanisms of main

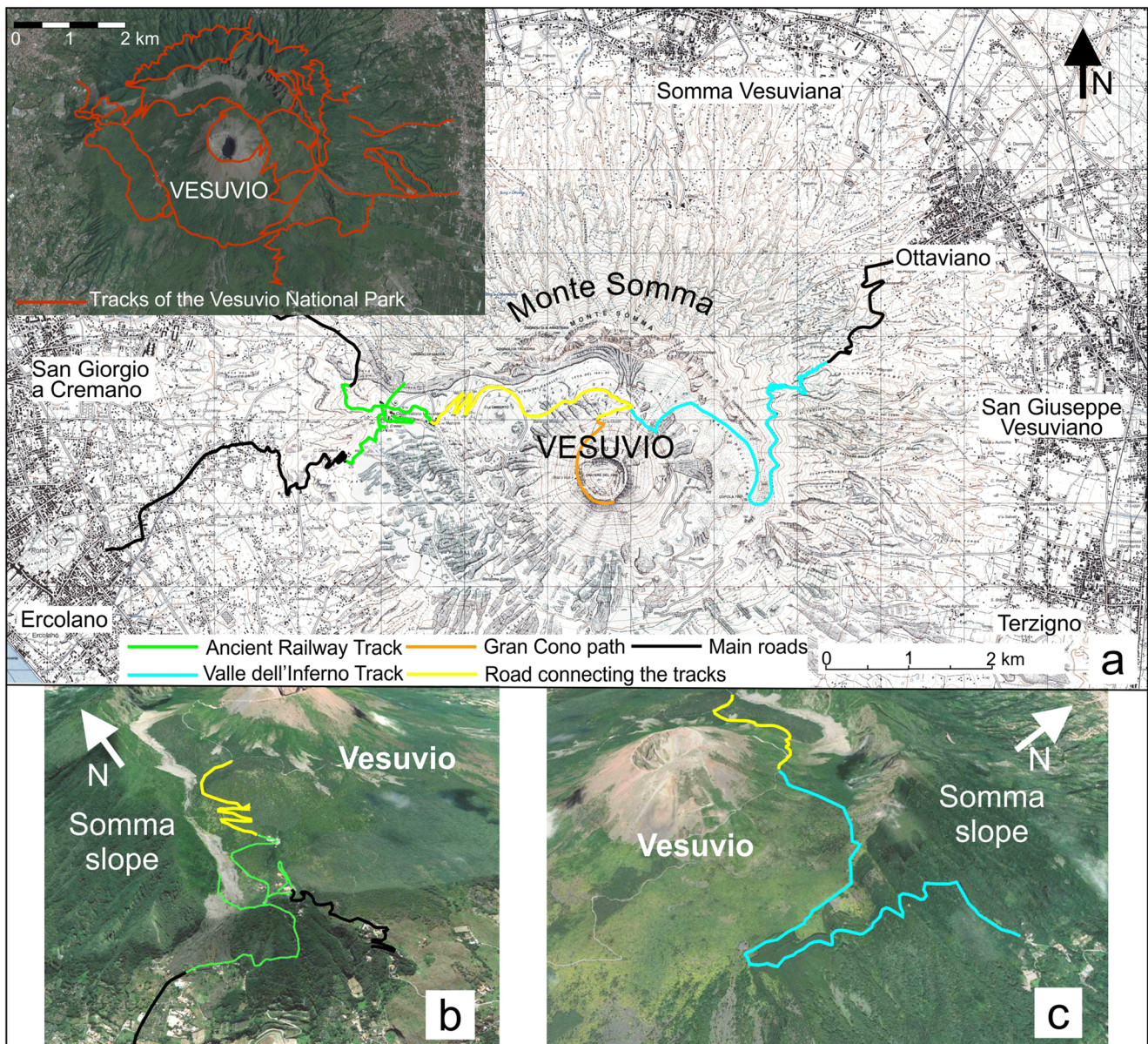


Fig. 2 Topographic map of Somma-Vesuvio northern area with the Ancient Railway Track and Valle dell’Inferno trails and the connection to the Gran Cono. In the upper inset, the nine naturalistic visiting tracks managed by the Vesuvio National Park, hiring map from www.parconazionaledelvesuvio.it/wp-content/uploads/2018/07/CARTA-SENTIERI-VESUVIO_Fronte.pdf (a); 3D global view of the Ancient Railway Track (b) and of the Valle dell’Inferno (c) trail

street signs to Panoramica Fellapane road, you reach the site that represents one of the visiting tracks of Vesuvio National Park (*Sentiero del Trenino a Cremagliera—Racktrain Track*). Walking along the main paved road, closed to car traffic, the path crosses the toe of a lava flow, very thin and deeply fractured (Fig. 5). On your right-hand side, only a few metres from the main road, you can enjoy a very interesting spot from which a panoramic scenery of the Napoli Bay can be viewed (stop 1). Back to the road, just on your left, the superimposition of two lava flows, erupted in 1870 and 1872, gives rise to a lava tube. Both the lava flows show a massive basal part

exposed lithotypes are reported. As previously anticipated, we hypothesize that the geosite could be visited not only by geologists and naturalists but also by students from primary school to college, tourists and unaware common citizens. This is the reason why the description of the stops was planned at various difficulty levels, complying with the different features and background of possible visitors.

The Ancient Railway Track Geosite

From Pollena Trocchia, crossing Massa di Somma and San Sebastiano al Vesuvio town and finally following

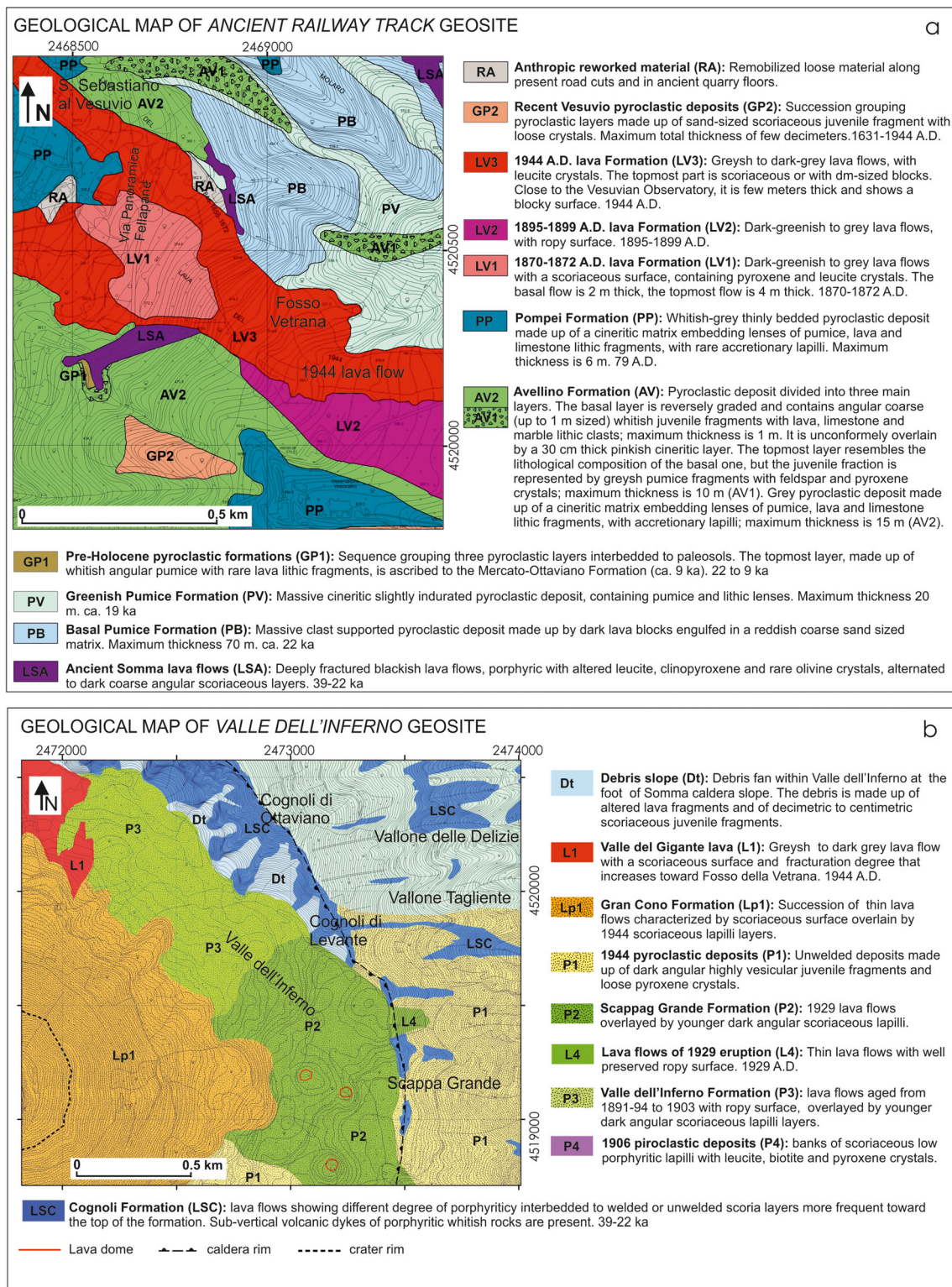


Fig. 3 Geological map of the Ancient Railway Track (a) and Valle dell'Inferno (b) geosites

overlain by a scoriaceous and deeply fractured top (stop 2). Moving along the road, the 1944 lava tongue covers the steep slope on the left and, just at the end of the paved road, at the basis of the succession, dark scoriaceous

fragments and lava blocks from the ancient Somma volcano (39–22 ka) crop out (stop 3); they are overlain by thin layers of pyroclastic fall products from several eruptions of the Somma volcano embedded to paleosols,

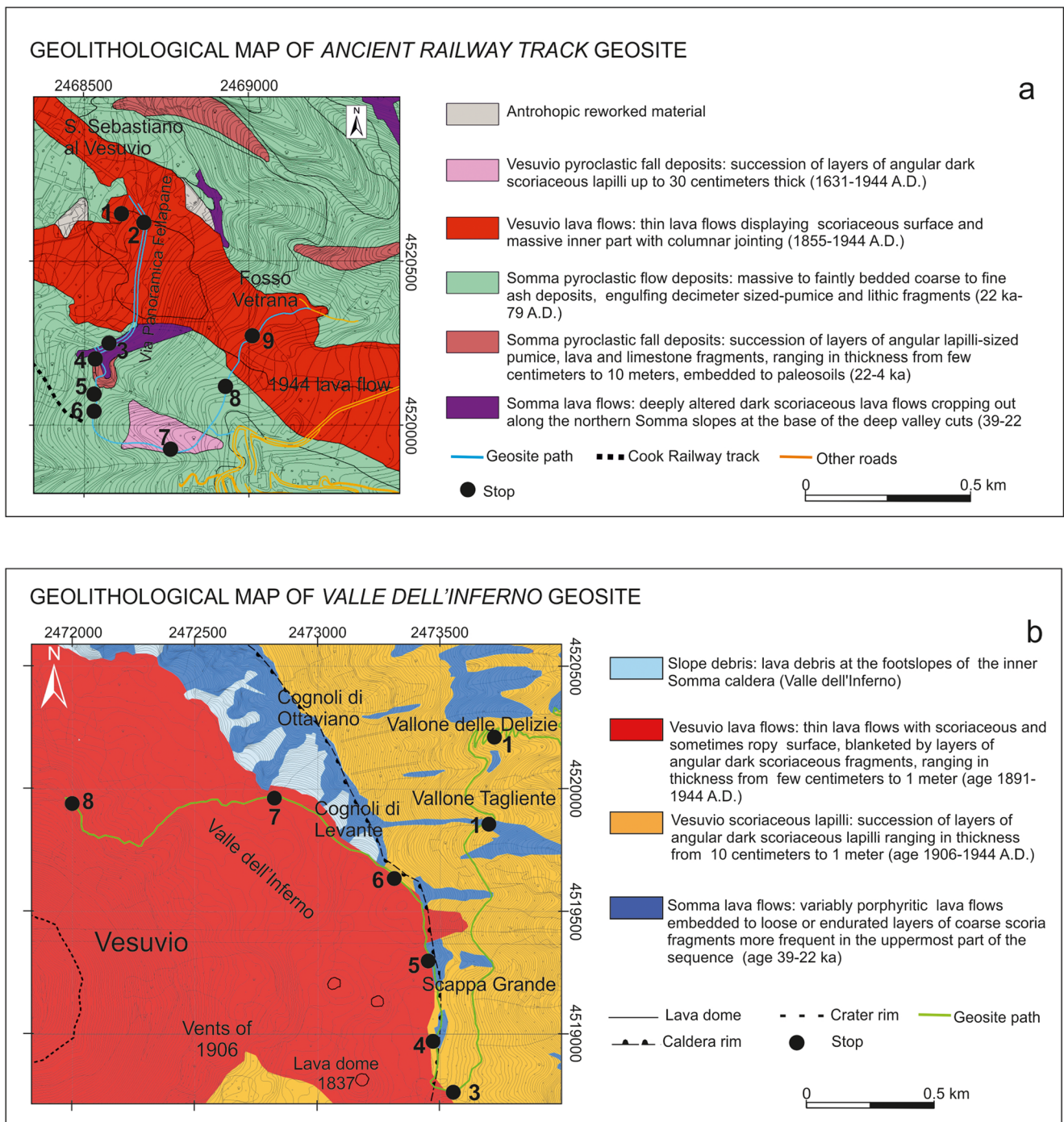


Fig. 4 Geolithological map of the Ancient Railway Track (a) and Valle dell'Inferno (b) geosites

observable along the narrow path that enters in the wood (stop 4). After ca. 100 m, along a steep wall on the left, the deposits of the opening phases of the Avellino eruption (ca. 4.0 ka—Passariello et al. 2009) crop out. The deposit is mainly made up of coarse angular pumiceous fragments, with lava and limestone lithic clasts. Some extra-size (> 50 cm) ballistic blocks, both juvenile and lithic, can be found within it, testifying to the proximity of the outcrop. The pumice fragments, whitish in the basal

part, become greyish in the topmost, because of the passage from the drainage of phonolitic to tephriphonolitic magma during the eruption (stop 5). Along the opposite wall faintly waved pyroclastic density current deposits from the same eruption crop out, made up of centimetre-sized pumice and lithic fragments, together with accretionary lapilli, engulfed in an ash matrix (stop 6). Walking upwards less than 100 m, the itinerary crosses a narrow path coming from NW, which represents the trail



Fig. 5 Panel designed for the entries of the Ancient Railway Track trail illustrating all the stops with photos and a brief description of their geovolcanological, landscape and botanical features

of the Cook Railway, and goes up towards the historical site of the Vesuvian Observatory.

At the end of eighteenth century Italy was the hearth of the *Grand Tour*, when the wealthy, young men typically haired

from England spent several months—at least—traveling in Europe after finishing their formal schooling, and Napoli, with the excursion to Pompeii and Herculaneum excavations, was one of the must-see favourite stops. The most adventurous travelers climbed Vesuvio to see fire, smell smoke and hear roars close but, being members of the rich aristocracy, were mostly carried by porters in sedan chairs. The popularization of travelling, together with the scientific importance of the Vesuvian Observatory and the spectacular volcanic activity at the end of 1800, brought to try and find new facilities to climb the volcano. In 1878 (as the famous Neapolitan jingle *Funiculi Funiculà* reminds), the *Funicolare* (*Funicular Railway*) started to operate from Lower Station, close to the Observatory, to the Gran Cono. Anyway, the station could be reached only riding a horse or a donkey or by a carriage, so the journey from Napoli to the volcano needed at least 4 hours. To overcome this problem, in 1903 was inaugurated the Cook Railway from the Pugliano to the Eremo station, nearby the Lower Station of the Funicolare. For the steepest part of the path, the train moved through a rope system (stop 7).

The itinerary follows the rope train trajectory up to a path cross, where the visitor can turn to his left to follow the National Park trail “Fiume di Lava (Lava River)”, the only one managed by the Park where self-guided tours are allowed at present. Along the path, when the topography becomes flat, discontinuous outcrops of the 1885–1899 lava flows can be observed. Here the path runs in the Mediterranean bush, the vegetal association endemic in areas with summer drought and winter rainfall. The natural beauty of the Vesuvio slopes is due both to the richness of species and, mostly in spring, to the picturesque overlapping and brilliant splashing of colours. The Somma slope, visible from stop 8, is characterized by mixed bush of humid climate and the vegetation is very flourishing thanks to the fertility of its soils. On the top of the recent lava flows, you have scanty vegetation, where pioneering plants prevail. Together with the lichen *Stereocaulon vesuvianum*, red valerian (*Centranthus ruber*), helichrysum (*Helichrysum litoreum*), artemisia (*Artemisia campestris*) and French sorrel (*Rumex scutatus*) can be found. These plants contribute to form a thin soil layer, where different species of brooms (*Cytisus scoparius*, *Spartium junceum*) grow, which mostly in late spring blanket in yellow the slopes of the volcano.

The path reaches the 1944 lava flow where it fills a channel known as *Fosso della Vetrana*, the Italian for *Glassy Valley*, a place-name probably linked to the broken glass sound that the lava flows, already cold and viscous at this distance from the vent, emitted overcoming the Somma rim. The 1944 lava at this site is a grey to dark-grey vesicular and blocky lava flow, with a whitish grey surface, due to the dense blanket of lichen *Stereocaulon vesuvianum* (stop 9—Fig. 6). This is also a good spot to have a panoramic look on Napoli city, sandwiched between two active volcanic areas, Campi Flegrei and

Vesuvio. The highest peak on the background of the city is the Camaldoli Hill, part of the rim of Campi Flegrei caldera, and very evident is the intense urbanization of the plains located at its footslopes. A continuous urban area stretches from Napoli to the Somma-Vesuvio, easily allowing the evaluation of the high exposure that characterizes both the volcanic areas (Alberico et al. 2011). From stop 9, you go back to the path cross and then up along a steep trail to the paved road that takes to the Vesuvian Observatory. It is located at 608 m height a.s.l. on the Salvatore Hill, which represents the westernmost peak of the Somma caldera, where pyroclastic products of the 79 A.D. eruption can be observed (stop 10). Ferdinand II the Bourbon king promoted the foundation of the first volcano observatory in the world in 1845. Since then, it has been visited by the most important volcanologists in the world and by many local and foreign visitors as well. From 1970, it became the site devoted to the preservation of many collections of minerals, historical instruments and valuable books regarding the activity of the volcano. Nowadays, the operation site of Vesuvian Observatory is in Napoli, and the so-called *Sede storica* (*Historical building*—stop 11) hosts a permanent museum for geophysics and volcanology. One of the most important instruments kept inside is the Palmieri seismograph, the first electromagnetic device that indicated precise time of occurrence, relative intensity and duration of the ground motion when an earthquake took place.

The Valle Dell’Inferno Geosite

The itinerary starts from the paved road Valle delle Delizie (*Valley of Delights*) in the Ottaviano town, namely at Palazzo Mediceo (seventeenth century), a former palace of the nobiliar Ottajano family that currently hosts the offices of Vesuvio National Park, and climbs the volcano from the NE. At the end of the road, it enters in the bush and goes up toward the top of the volcano (Fig. 7). Several road cuts put in light pyroclastic fall deposits from the 472 A.D. eruption along the main path, that for the first 2 km is quite large but rather steep in several places and is generally run also by cyclocrossers. At ca. 600 m height a.s.l., a panoramic spot (stop 1) allows the observation of the dense urbanization that characterizes even the Somma footslopes and the plain north-east of the volcano. The Somma lava flows are observable along the trail in the cuts where the water flow has removed the pyroclastic cover. They are well-preserved dark massive lava flows with a thin scoriaeous surface (stop 2). Going on for ca. 500 m along the path, the visitor reaches the flat surface known as “*Slargo della Legalità*” (*Legality plain*) so-called after the demolition of a building that had been erected in 1970, irrespective of the building laws and was used as a mountain shelter (stop 3); in the middle of the plain, a statue of St. Michel with the shoulders to the volcano vent seems to

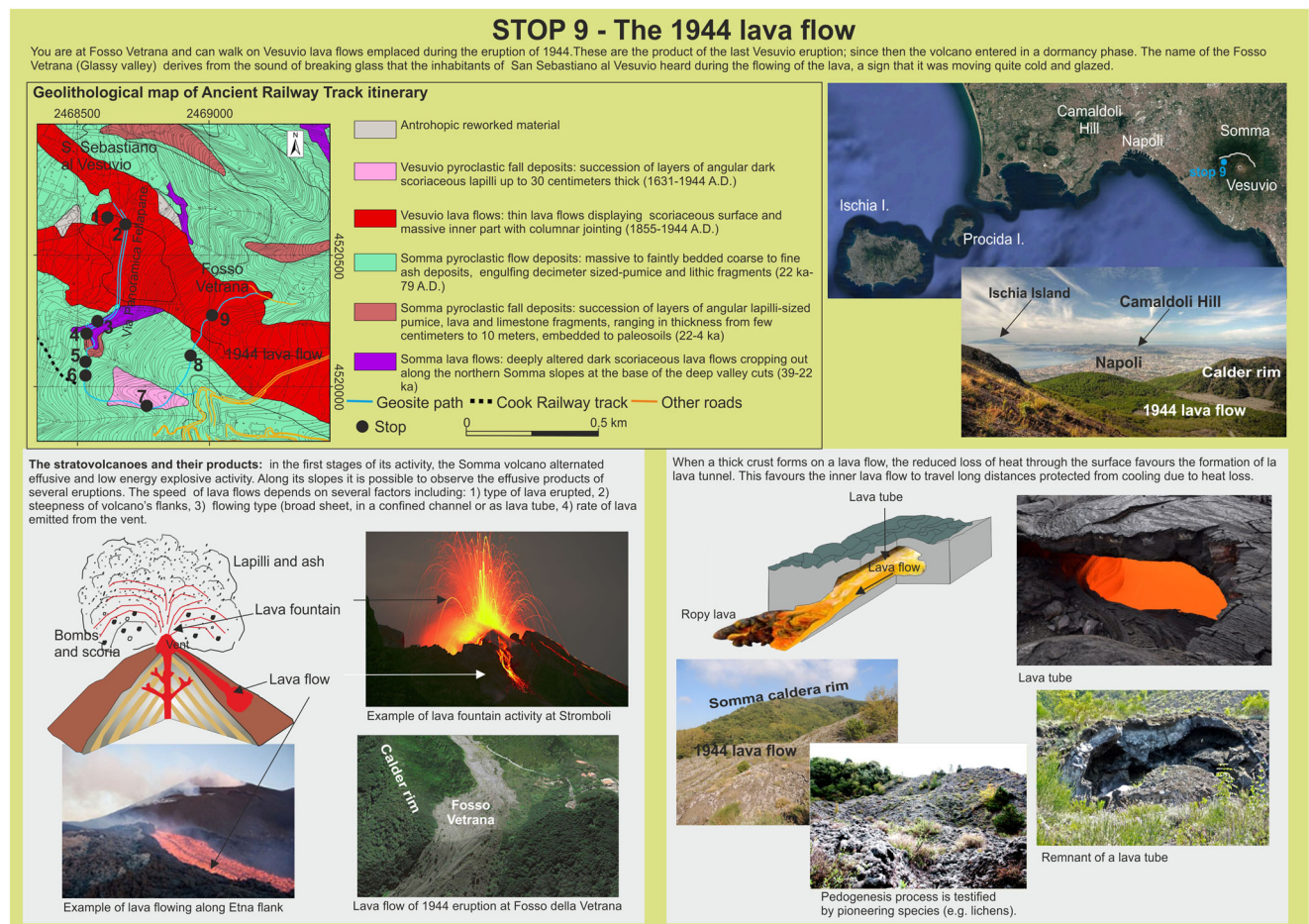


Fig. 6 Panel illustrating in detail the 1944 lava flow at stop 9 of the Ancient Railway Track trail with simplified sketches of the eruptive and depositional mechanisms

protect the towns at the footslopes from the damaging action of the mountain. The next stop is represented by a dome that was constructed in 1937 by lateral effusive activity and lava fountaining, whose shape is well evident from the trail (stop 4). Going on along the path, you find an impressive outcrop of the 1929 lava flow with a well-preserved ropy surface. Where the maximum slope is reached, on the topmost part of one of the main stream valleys of the western Somma border, Scappa Grande (a local toponym that can be translated as *Large Way out*), the lava flow forms a narrow and indented fracture, which allows the view of the whole lava flow thickness. The wall cuts of the deposits above the fracture show very good outcrops of the 1944 fall products (Cole and Scarpati 2010), made up of centimetre-sized dark scoriaceous lapilli with loose clinopyroxene crystals (stop 5—Fig. 8). Moving forward along the path, just before turning on the left to enter the Valle dell'Inferno, another stop (stop 6) is suggested to enjoy a panoramic view of the Sarno River plain and the Sarno Mounts, where still evident are the traces of the landslides occurred in May 1998 that, as a consequence of heavy rain episodes, remobilized pyroclastic fall

deposits from the limestone slopes and caused more than 160 casualties (Calcaterra et al. 1999, 2003).

Next stop (stop 7) is located within the Somma caldera. The Somma wall, here well observable, exposes thin lava flows, deeply fractured by physical weathering due to the large temperature excursion, alternating to reddish to dark brown scoria layers. Both lava blocks and scoria fragments pile up at the foot of the steep walls, where they form well-preserved debris fans. The most noticeable volcanic morphology are the dykes, pinkish-grey tabular bodies that cut the Somma caldera wall in a complex network (Tramparulo et al. 2018). Those dykes are the remnants of feeding conduits of lateral activity, a typical feature of strato-volcanoes. As subvolcanic bodies, with respect to lava flows, which are low to middle porphyritic for clinopyroxene and leucite phenocrystals, the rocks from dykes are highly porphyritic mainly for clinopyroxene phenocrysts and are densely fractured as well. The last stop (stop 8) is located at the entry of the path in the backwards of the Gran Cono ticket office, from where the visitor can realise that the Somma rim is made up by a series of indented lava peaks, known as Cognoli with reference to the municipality they pertain to (e.g. Cognoli of

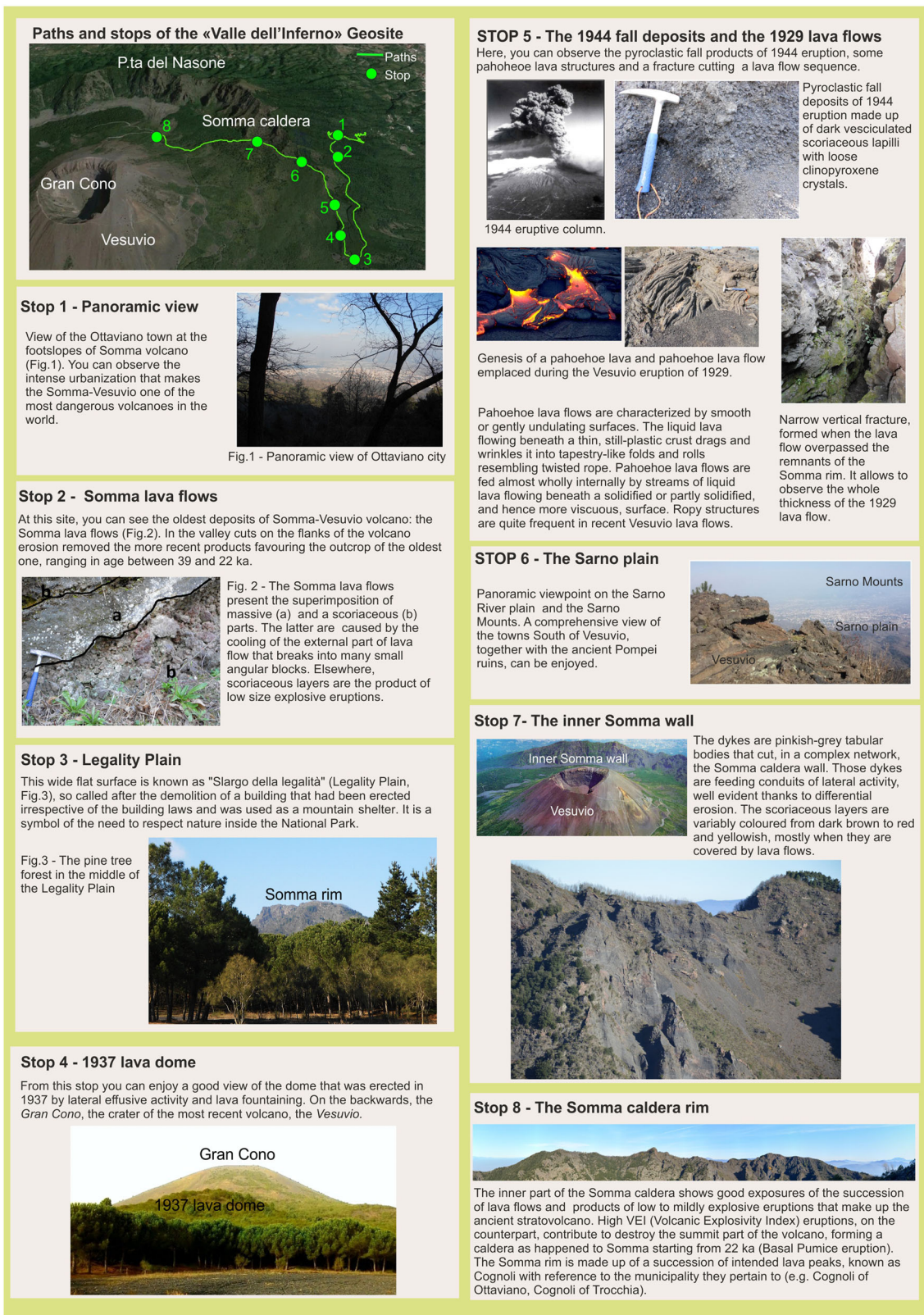


Fig. 7 Panel designed for the entries of the Valle dell'Inferno trail illustrating all the stops with photos and a brief description of their geovolcanological, landscape and botanical features

Ottaviano). The highest peak, at 1132 m a.s.l. elevation, is the *Punta del Nasone* (*Big Nose peak*), so-called from its typical

shape; furthermore, a panoramic view of the network of dykes cutting the Somma lava flows can be enjoyed.

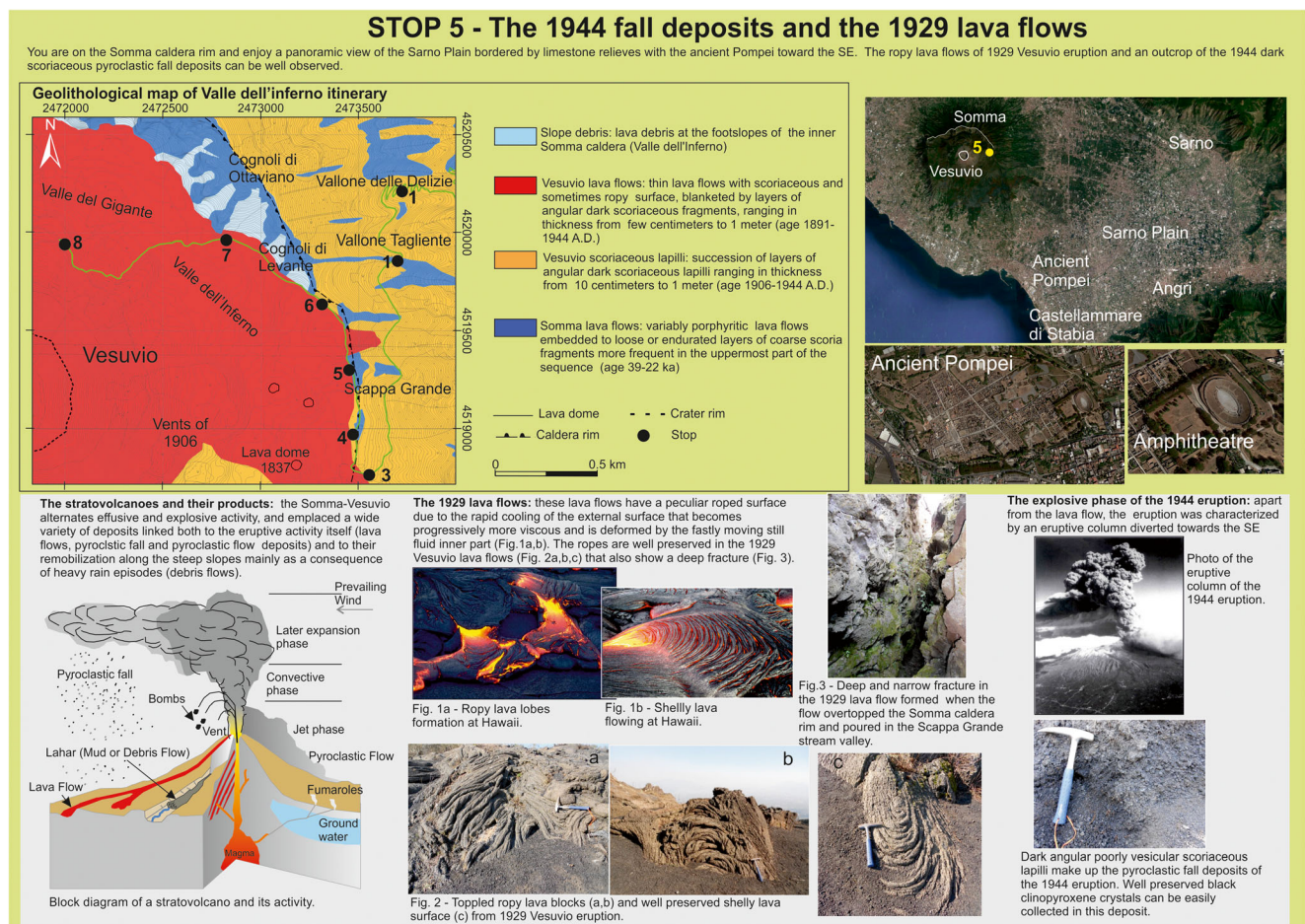


Fig. 8 Panel illustrating in detail the 1944 lava flow at stop 9 of the Valle dell'Inferno trail with simplified sketches of the eruptive and depositional mechanisms

The Gran Cono

Both the itineraries, as previously anticipated, can be supplemented by the visit to the Gran Cono (Alessio and De Lucia 2017). For the excursionists coming from the Ancient Railway Geosite, which has the historical building of the Vesuvian Observatory as the last stop, ca. 5 km of paved road have to be walked, but they can also use the scheduled buses of public transportation that from Ercolano leave to the Vesuvio every 40 min. Only 400 m of paved road separates the last stop of the Valle dell'Inferno geosite from the entry to the Gran Cono path, which requires the payment of a ticket including a fee for a guide. The path, quite steep, runs on the northern flank of the Gran Cono, blanketed by the scoriaceous lapilli with abundant loose clinopyroxene crystals from the 1944 eruption (Fig. 9a). The crater is made up by the superimposed lava flows outpoured from the crater between 1631 and 1944. The alternation of explosive and effusive activity that characterized this three centuries time span made the shape of the vent continuously vary, since it was truncated by the explosive episodes, and rebuilt by the effusive phases. The maximum current altitude, after 1944 eruption, is 1281 m

a.s.l. The topmost lava flow, thicker on the eastern side, pale grey in colour was erupted during the effusive phases of the 1944 eruption and is blanketed by dark brown scoriaceous lapilli from the sustained column phase of the same eruption (Fig. 9b). This effusive-explosive event occurred in the second half of March 1944, during the Second World War, when the soldiers of the Allied Forces that occupied Napoli gave the very first example of Civil Protection intervention in Italy, helping the population to evacuate the towns of San Sebastiano al Vesuvio and Massa di Somma, where the lava flow directed toward the NW finally stopped (Fig. 10). Along the trail the 1906 lava flows and Colle Umberto (*Umberto Hill*), an eccentric lava dome grown between July 1895 and December 1896, so-called after the Italian king of the age, Umberto I, can be observed. At the highest altitude of the trail, you can see the whole of the Napoli Bay and, in the background, Ischia, with its highest peak Monte Epomeo, 700 m high, and Procida islands. The Campi Flegrei caldera looks precisely outlined as well, with its eastern border, the Posillipo Hill and the western one, represented on the background by the Miseno Cape. In the clearest days, even the Camaldoli Hill, another important remnant of the caldera rim, can be well

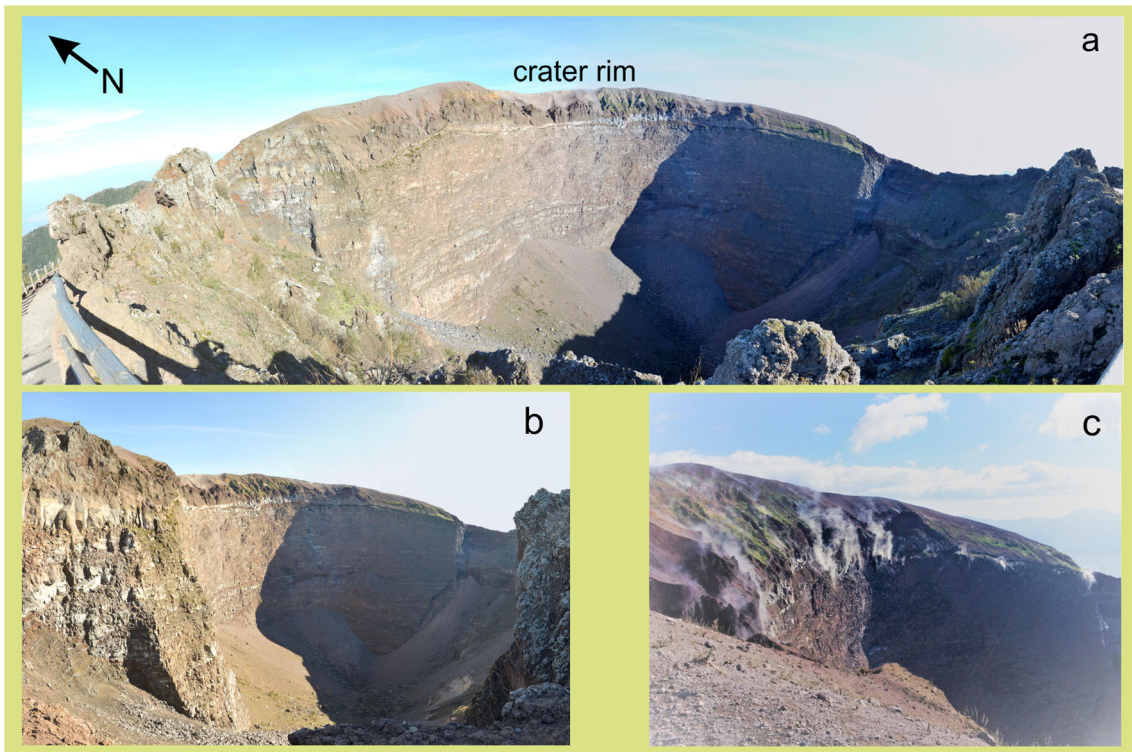


Fig. 9 Panoramic view of the Gran Cono from north-east (a) with a detail of the 1944 scoria fall along the rim (b) and of fumaroles (c). Photos courtesy of Jacopo Natale

spotted. Towards the south, the look goes to the Vesuvian coast, with the Lattari Mts. and the Sorrento Paeninsula, separated from Capri by a narrow sea loch. Looking at the plain at the footslopes of the volcano, the ruins of the ancient Pompeii and the Sarno River, which outflows in the sea at Castellammare di Stabia, are well evident. Once again, the intense urbanization characterizing all the plains surrounding the volcano can be pointed out, meaning a high exposure and, consequently, a very high volcanic risk. Along the crater rim, the smokes of the fumaroles coming from inside the vent testify to the persisting activity of the volcano (Fig. 9c).

Going through the path, some instruments for the geodetic and geophysical monitoring of the volcano can be observed.

Evaluation of the Quality and Potential of Geosites

The evaluation of the quality of the sites is generally carried out through the quantitative assessment of several indicators. Brillha (2016) fixes four criteria for classifying potential geosites (representativeness, integrity, rarity and

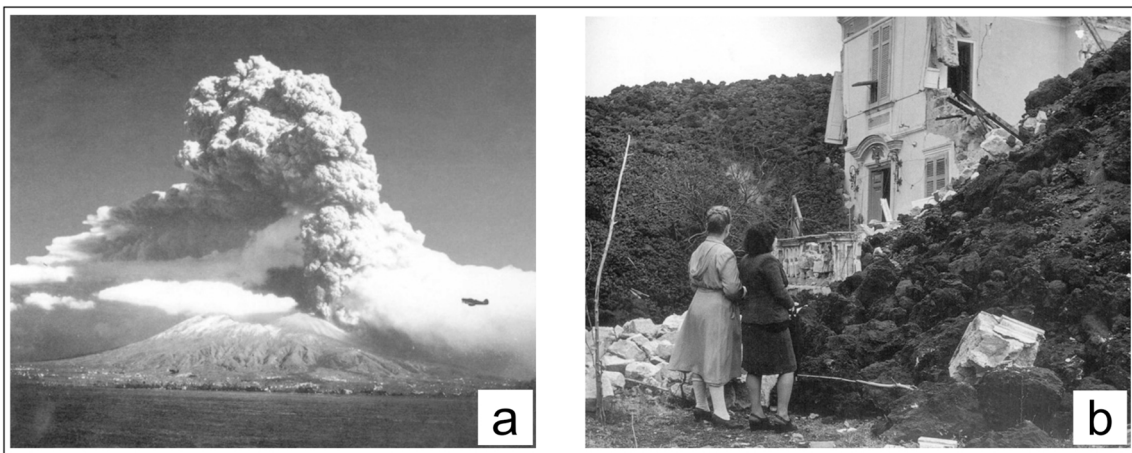


Fig. 10 The sustained column phase of the 1944 eruption (a) and the 1944 lava flow at San Sebastiano al Vesuvio on 22nd March 1944 (b) (from Pesce and Rolandi 1994)

scientific knowledge) and specifically for the geodiversity sites proposes a set of different criteria, mainly regarding the educational potential. In the same time, he states that “for small areas with just a few sites, these procedures have no practical results and may be discarded”. Being the extent of the Vesuvio National Park only ca. 70 km², we decided to try and apply the quantitative assessment to the evaluation of the quality of the single stops along the two selected tracks and opportunely merged the results in order to state which itinerary better fits the different types of visitors and how their current status could be improved to favour and enhance the fruition. At this aim, we used the six criteria (scientific value, educational value, additional value, aesthetic value, accessibility and state of preservation) proposed by Różycka and Migoń (2018) and adapted the indicators to the quality evaluation of

the single stops along the two trails (Table 1). A numerical value ranging from 0 (absence or low quality of the feature) to 3 (best expression of the feature) was attributed to the single indicators and the main geological and/or landscape singularities were enlightened (Table 2a, b; Fig. 11a, b).

Thanks to the decadal experience acquired as field trip leaders accompanying on the Vesuvius tracks geologists and scientists from Italy and abroad, college students (one of the authors teaches Volcanology at Napoli University), secondary school teachers and their pupils and, finally, many groups of friends fond of nature and volcanoes, we deduced that all of them postulate a different approach to the field trip and have different expectations. In the light of this, we grouped the possible visitors into three categories: scientists, which are more interested in

Table 1 Criteria for the evaluation of the quality of the single stops along the Ancient Railway Track and Valle dell’Inferno trails

Criterion	Code	Features of the stop (indicators)	Score
Scientific value	S1	Archetypal feature with high scientific relevance	3
	S2	Singular feature of the volcanic morphologies and kind of products, investigated in literature	2
	S3	Representative in the area and quoted in literature	1
	S4	Common in the region, no scientific relevance	0
Educational value	E1	Very representative to explain an utmost geovolcanological process	3
	E2	Useful for explaining a characteristic geovolcanological subject	2
	E3	Well illustrative of a geovolcanological topic	1
	E4	Low geoeducational use	0
Additional value	A1	Meaningful part of cultural heritage of biological communities	3
	A2	Representative item of cultural heritage or presence of noticeable biological entities	2
	A3	Historical element of local importance and/or view-point	1
	A4	No significant cultural heritage elements	0
Aesthetic value	AE1	Exceptional panoramic view of the geomorphological features of a large part of the Napoli Gulf and Campanian Plain	3
	AE2	Good panoramic view of landscape on a reduced scale	2
	AE3	View of a single element of local morphological features	1
	AE4	No specific panoramic value	0
Accessibility	AC1	Site can be reached in more/less than 15 min from a parking lot	0/1
	AC2	Access to the site poorly/clearly marked	0/1
	AC3	Access to the object itself restricted/object fully accessible	0/1
State of preservation	SP1	Well preserved and very good exposure	3
	SP2	Slightly vandalized outcrop, partially overgrown by brambles in summer	2
	SP3	Poorly preserved and markedly overgrown	1
	SP4	Very badly preserved and completely overgrown, outcrops fully hidden	0

Table 2 Quantitative assessment of the quality of the single stops along the Ancient Railway Track (a) and Valle dell’Inferno (b) trails

Criterion	Scientific				Educational				Additional				Aesthetic				Accessibility			State of preservation				Remarks			
	S1	S2	S3	S4	E1	E2	E3	E4	A1	A2	A3	A4	AE1	AE2	AE3	AE4	AC1	AC2	AC3	SP1	SP2	SP3	SP4				
Score	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0	0	1	0	1	0	1	3	2	1	0	
Stop 1				1			1				1		1				1	1					1				Good viewpoint on Napoli Bay
Stop 2			1			1						1					1	1							1		Example of lava tunnel formation
Stop 3			1			1						1					1	1						1			Example of altered ancient lava flows
Stop 4			1				1					1					1	1									
Stop 5		1			1			1				1					1	1							1		Good example of chemically zoned pyroclastic fall
Stop 6		1				1						1					1	1								1	Good example of diluted pyroclastic density current
Stop 7				1				1			1						1	1						1			Remnants of the Cook Railway track
Stop 8				1			1		1					1			1	1									Excellent exposure of the Mediterranean bush
Stop 9		1			1					1			1				1	1					1				Best outcrop of the last Vesuvio lava flow
Stop 10			1					1				1					1	1								1	
Stop 11				1	1						1			1			1	1					1				Guided tour of the first volcano observatory

a

Criterion	Scientific				Educational				Additional				Aesthetic				Accessibility			State of preservation				Remarks			
	S1	S2	S3	S4	E1	E2	E3	E4	A1	A2	A3	A4	AE1	AE2	AE3	AE4	AC1	AC2	AC3	SP1	SP2	SP3	SP4				
Score	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0	0	1	0	1	0	1	3	2	1	0	
Stop 1				1			1				1		1				1	1					1				Best spot on the high exposure at the footslopes of the volcano
Stop 2			1			1						1					1	1							1		
Stop 3				1				1		1							1	1						1			Good panoramic view of the caldera rim
Stop 4		1					1					1					1	1									Good view of the 1937 lava dome
Stop 5		1				1						1					1	1							1		Excellent exposure of pahoehoe lava flow
Stop 6				1			1					1					1	1					1				Good viewpoint on the Sarno Plain and Lattari Mounts
Stop 7		1				1						1		1			1	1								1	Excellent exposure of dykes
Stop 8		1					1					1					1	1					1				Best view of the composite volcano morphology

b

eruptive and depositional mechanisms of volcanic deposits; students, for which the botanical and historical aspects are more appealing; and tourists or common

people, who mainly want to enjoy an exciting day outdoor (see “The Two Proposed Geosites”). To take into account their different needs, we made a parallel between our

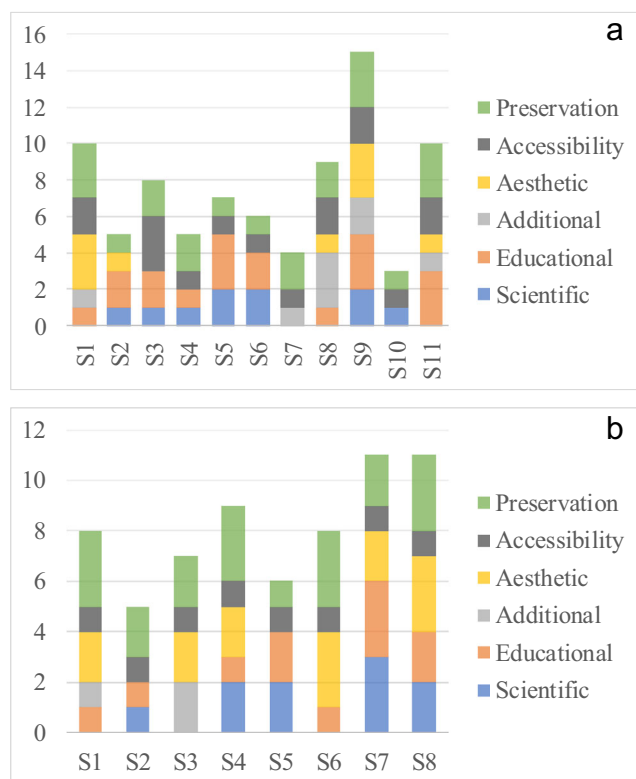


Fig. 11 Bar plots summarizing the results of quantitative evaluation of the quality of the single stops of the Ancient Railway Track (a) and Valle dell'Inferno (b) trails

categories of possible visitors (scientists, students, tourists and common people) and those selected by Różycka and Migoń (2018) (geoexpert, interested visitors and unaware visitors). The quality of the single stops was recalculated by multiplying the scores reported in Table 2a, b by the weights, inherited from those authors, quantifying the relative importance of the quality assessment criteria from the perspective of different groups of visitors (1.5 for maximum, 1.0 for intermediate and 0.5 for minimum importance). The average scores obtained for all the stops of the two geosites, both unweighted and weighted according to the diverse classes of customers, are plotted in the diagrams of Fig. 11.

The Ancient Railway Track geosite joins the peculiar geological heritage, testified by the high scientific value (Fig. 11a—main stops 5, 6, 9) to several different aspects of landscape, as the outstanding Mediterranean bush (stop 8) or the view on the Somma caldera rim (stop 9). It is supplemented by historic remains, as the ancient track of the Cook Railway, which in the first half of the twentieth century made it possible to reach the intermediate station of the Funicolare Railway, and from there to climb the Gran Cono (stop 7), and the historic building of the Vesuvian Observatory (stop 11), where a guided tour is feasible.

Along the Valle dell'Inferno geosite path, the scientific value is very high, since the most representative outcrops both of

recent Vesuvio lava flows (Fig. 11b—stops 4, 5) and of the Somma lava flows and feeding dykes are found (stop 7). The highest scores are gained for the aesthetic value, because along this track, many viewpoints that allow the illustration of the geomorphic features of the composite volcano and the surrounding plains have been selected (stops 6, 8). The highest additional value has been attributed to stop 3, thanks to its outmost symbolic value, represented by the defense of the concept of legality, in a territory where it is too often neglected.

The comparison of the averaged scores of all the stops for both geosites yields to some considerations.

The parallel view of the pie charts in Fig. 12a, a1 shows that of the two proposed geosites the Ancient Railway Track displays a better accessibility (ca 20% vs. 13% of the total value), a singular feature for the Somma-Vesuvio volcano where most of the good outcrops pertained to quarry sites and are now hardly accessible, being quarrying activity forbidden in the whole of the National Park area. This is a not trivial feature, because a site has greater potential to be visited if it can be reached by any means of transport (at least to a nearby point) by roads in good state (Gray 2004). Accessibility to the Ancient Railway Track from two different entries located on main roads is very easy, and walking along it is not very difficult and feasible all over the year, which again makes it more enjoyable for tourists. The uppermost entry faces the historic site of the Vesuvian Observatory, and the visit to the Museum therein can be favourably coupled to the visit of the geosite (additional value ca. 10%). As far as the educational criterion is concerned, the Ancient Railway Track marks a better score, thanks to the presence of representative examples of both effusive and explosive products (Table 1a). The same is for the aesthetic value, due to the abundance of panoramic stops.

A higher aesthetic value (ca 11% vs. 19% of the total value) characterizes, on the counterpart, the Valle dell'Inferno geosite, where the best panoramic views of many landscape features, typical of a coastal volcanic area facing the Mediterranean Sea, can be enjoyed.

The differences slightly change in the plots of Fig. 12b–d, b1–d1 in response to the class of potential customers. A clear example is represented by the comparison of the importance of accessibility for geologists and tourists or common people, which for the latter is three times higher, reflecting the fact that common people are not used to hard trekking. The weighted evaluation of the quality of the site, and of the single stops, promptly points out the importance of the different demands of expected visitors and can be fruitfully taken into account by local stakeholders for future development of the geotouristic facilities and resource allocation. The results of this preliminary analysis should be reconsidered once the proposed trails will be officially

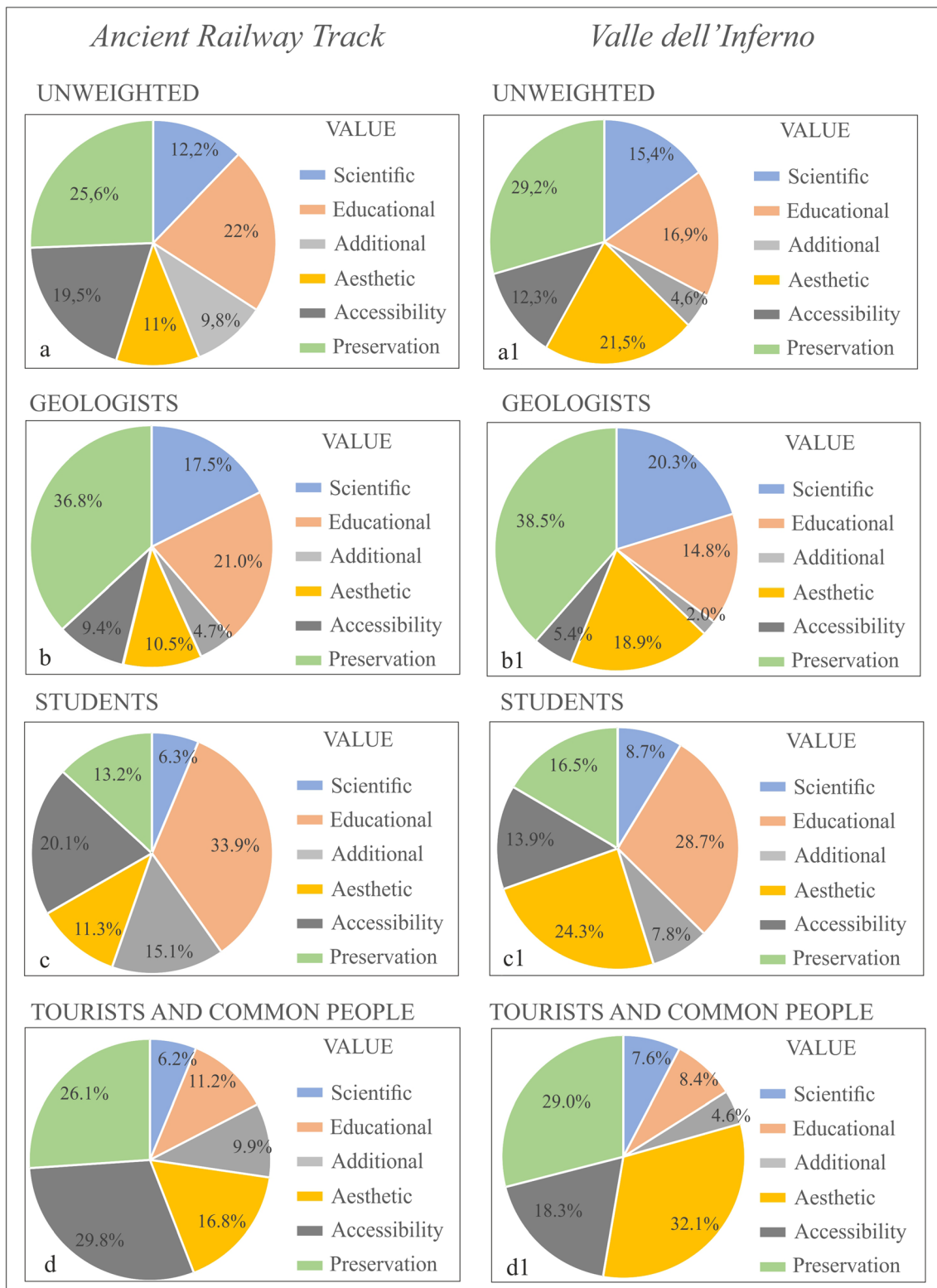


Fig. 12 Pie diagrams comparing the quality of the Ancient Railway Track and Valle dell’Inferno trails unweighted (a, a1) and based on the different categories of potential visitors (b–d; b1–d1)

involved in a fruition plan, through the direct survey of the opinions of the visitors on-site rightly after the field trip. The required information should come from attractive,

easily understood and simply answered self-completed questionnaires that could be collected and suitably processed for the management of the park.

Vesuvian Geoheritage and Social Resilience

Natural heritage, and geoheritage as a part of it, plays a positive role for improving resilience thanks to its historic, aesthetic, social, scientific and spiritual values for past, present and future generations. It often represents the only memory of landscape evolution in a territorial setting, able to influence the settlements and the consequent interaction between men and the environment. All these testimonies enrich people’s lives, providing a deep and inspirational sense of connection between community and landscape (ICOMOS 1999).

Promotion and preservation of geoheritage could result in the positive effect of contributing to preserve natural diversity in all its aspects. Geodiversity still lacks the status and standing of biodiversity in governmental, political and public forums, and natural reserves are generally more devoted to the promotion and preservation of faunal and floral biological communities. Geodiversity, on the other hand, provides the substrates, landform varieties and geophysical processes for habitat development and conservation and hence deserves at least the same importance of biodiversity. Their integrated fruition in a natural reserve as the Vesuvio National Park could contribute to enhance well-being (Fig. 13), which is much more important in an area as the Napoli neighbourhood where usable green zones are few and poorly maintained and improved. This could strengthen the relationship between people

and territory, reducing social isolation and increasing in local communities a sense of belonging to the place and cohesion that, in turn, can favour general development of a territory. The expansion of the touristic resource linked to programmes of geoheritage fruition represents a benefit for the economy of the territory, upgrading where necessary the related infrastructures of the area, resulting in increasing number of job opportunities and, on the long time, in a general growth of the area. This is a sort of self-feeding process, where the final product, represented by new investments, induces again well-being and reactivates the process.

Moreover, population in this area has always to face the possibility that the volcano can resume eruptive activity, so people must be prepared to cope with a dangerous event. All the tools that can contribute to build such an awareness in the population of the Vesuvian neighbourhood are hence welcomed and, among these, the fruition of a geosite can certainly help, during a quiescence period as the present, to remind people that they live in an active volcanic area, promoting the knowledge of the fragility of their territory (Armiero et al. 2011). Currently, this weakness is not fully acknowledged by the inhabitants of the towns belonging to the territory and the insertion of the geosites here proposed in an educational programme could represent a step forward to increase locals and visitors’ awareness concerning the impending volcanic risks. This consciousness is the starting

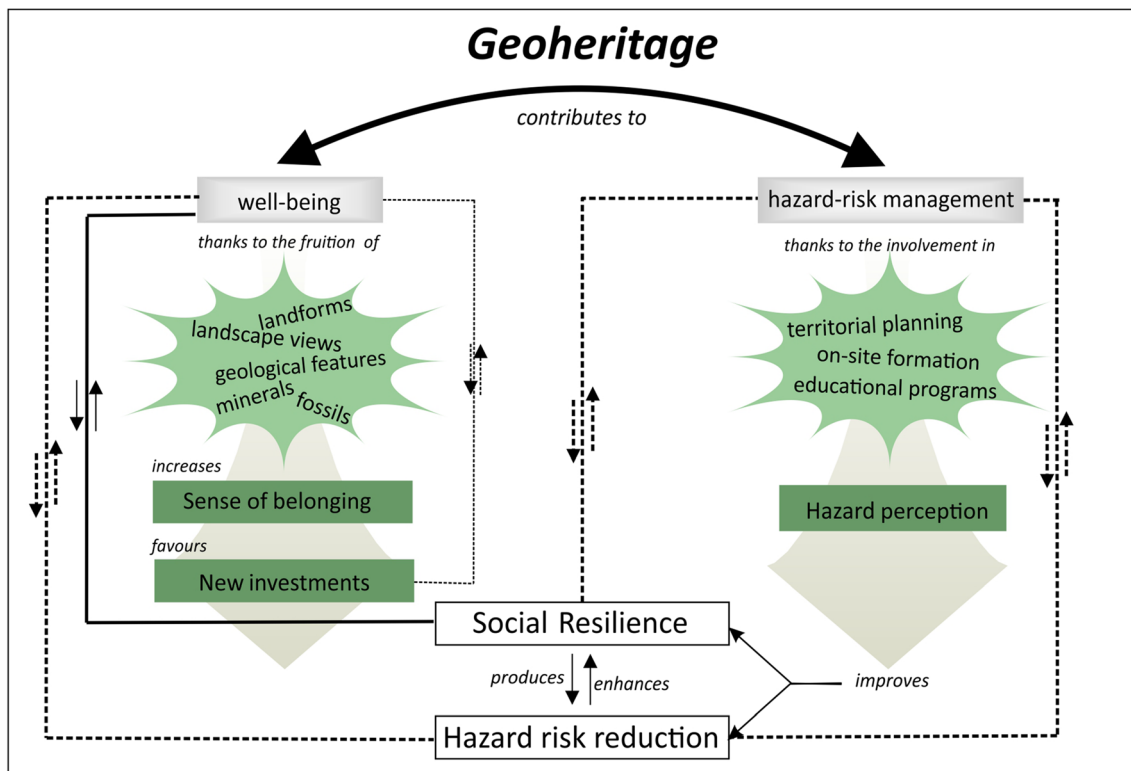


Fig. 13 Conceptual map depicting the role of geoheritage in enhancing social resilience and reducing the hazard risk through the promotion of the culture of sense of belonging to place and the improvement of hazard perception

point for the concrete involvement of inhabitants in a bottom-up process devoted to territorial management, with the final aim to improve the volcanic hazard perception and gain risk reduction.

All these aspects highly contribute to achieve a better level of social resilience, fundamental in a high risk area as the Vesuvian zone where an active role of citizens in coping with adverse natural events is needed. In this frame, Campania Region is allocating a good deal of the funds provided by European Union within the financial programme POR CAMPANIA FESR 2014–2020 devoted to increase the competitiveness of urban areas by encouraging touristic destinations with a high development potential for the meaningful concentration of natural, environmental and cultural resources not adequately promoted at national and international level. A huge added value is represented by the possible restoration of monumental and historical heritage as elements functional to the urban regeneration and to the growth of a shared sense of the territorial identity.

Conclusive Remarks

Active volcanic areas in Campania combine fascinating geology with unique landscape features that represent an attraction for both experts and unaware tourists thanks to their singularity. Along two different itineraries of the Somma Vesuvio volcano (Ancient Railway Track and Valle dell’Inferno), we selected some attractive spots that overall can be easily visited and offer a comprehensive view of deposits and eruptive mechanisms characterizing the volcano. Most of them can be used for educational purposes thanks to the archetypal features of the outcrops. Both tracks are also valuable for their aesthetic value, since they provide the visitor with the possibility of admiring all the features of such a morphologically complex area, overlooking limestone mountains, river plains, tuff cliffs, the islands of Neapolitan archipelago and Campi Flegrei monogenetic volcanoes on the background.

The quantitative evaluation of the quality of the tracks in response to the backgrounds and needs of the different categories of potential visitors brought to the conclusion that both the itineraries are very suitable for scientists, whereas students, tourists and common people could either choose the Valle dell’Inferno, thanks to the several viewpoints, or the Ancient Railway Track, where historic remains and museums can be enjoyed.

Geoheritage promotion and fruition highly contributes to social resilience, providing the local communities with a sense of belonging to the place that can encourage new investments mainly in the outdoor recreation sector, indirectly enhancing the economy. In this frame, the outcomes of our research can be shared by local institutions that could decide to promote the fruition of Ancient Railway Track and Valle dell’Inferno trails,

for which we supplied the guidelines and produced the illustrating material. Moreover, the results of the quantitative evaluation here carried out could drive stakeholders in allocating the economic resources and be usefully taken into account for future development based on the different demands of expected visitors.

Furthermore, in an area exposed to hazard the promotion and fruition of geological resources can gain a specific role in establishing the correct relationship between people and territory, improving the response of citizens to adverse natural events. Most of all, the inclusion of the proposed itineraries in educational programmes might help to make young generations more aware about the risk impending on the area. On the long time, this could produce future territorial planners and local administrators aware of the necessity to cope with dangerous events and to make the necessary steps for risk reduction.

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References

- Alberico I, Petrosino P, Lirer L (2011) Volcanic hazard and risk assessment in a multi-source volcanic area: the example of Napoli city (Southern Italy). *Nat Hazard Earth Syst* 11:1057–1070
- Alberico I, Minolfi G, Petrosino P (2012) The “Ancient Railway Track”: proposal of a geosite in the Vesuvio National Park. 7th EUREGEO, Bologna, pp 1–4
- Alessio G, De Lucia M (2017) Promotion and development of protected volcanic areas through field-based environmental communication activities: the ‘Gran Cono’ Tour in the Vesuvius National Park (Italy). *Geoheritage* 9(4):435–442
- Armiero V, Petrosino P, Lirer L, Alberico I (2011) The GeoCaF project: proposal of a geosites network at Campi Flegrei (southern Italy). *Geoheritage* 3:195–219
- Brillha J (2016) Inventory and quantitative assessment of geosites and geodiversity sites: a review. *Geoheritage* 8(2):119–134
- Calcaterra D, Parise M, Palma B, Pelella L (1999) The May 5th, 1998, landsliding event in Campania (Southern Italy): inventory of slope movements in the Quindici area. *Proc International Symposium on Slope Stability Engineering*, Shikoku, Japan, 2:1361–1366
- Calcaterra D, Palma B, Parise M (2003) Combining historical and geological data for the assessment of the landslide hazard: a case study from Campania, Italy. *Nat Hazard Earth Syst* 3:3–16
- Chapin FS, Kofinas GP, Folke C (2009) Principles of ecosystem stewardship: resilience based natural resource management in a changing world. Springer, New York, pp 1–409
- Cioni R, Santacroce R, Sbrana A (1999) Pyroclastic deposits as a guide for reconstructing the multi-stage evolution of the Somma-Vesuvius caldera. *Bull Volcanol* 60:207–222
- Cole PD, Scarpati C (2010) The 1944 eruption of Vesuvius, Italy: combining contemporary accounts and field studies for a new volcanological reconstruction. *Geol Mag* 147(3):391–415
- De Vivo B, Petrosino P, Lima A, Rolandi G, Belkin HE (2010) Research progress in volcanology in Neapolitan area, Southern Italy: a review and alternative views. *Mineral Petrol* 99:1–28

- Dingwall PR (2000) Legislation and international agreements: the integration of the geological heritage in nature conservation policies. In: Baretino D, Wimbledon WAP, Gallego E (eds) *Geological heritage: its conservation and management*. Instituto Tecnológico Geominero de España, Madrid
- Dowling RK (2011) Geotourism global growth. *Geoheritage* 3:1–13
- European Landscape Convention (2000) *European Treaty Series - no. 176*, Florence, 20-X-2000, pp 1–7
- Fiksel J, Goodman I, Hecht A (2014) Resilience: navigating toward a sustainable future. *Solutions*:1–13
- Folke C (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. *Glob Environ Chang* 16(3):253–267
- Gordon JE, Crofts R, Díaz-Martínez E (2018) In: Reynard E, Brilha J (eds) *Geoheritage: assessment, protection, and management*. Geoheritage conservation and environmental policies: retrospect and prospect. Elsevier, Amsterdam, pp 231–229
- Gray M (2004) *Geodiversity: valuing and conserving abiotic nature*. Wiley, Chichester
- Holling CS (1973) Resilience and stability of ecological systems. *Annu Rev Ecol Syst* 4:1–23
- ICOMOS (1999) *The Burra Charter. The Australia ICOMOS charter for places of cultural significance*. Australia
- Lirer L, Petrosino P, Munno R, Grimaldi M (2009) *Vesuvius through history and science*. Electa Mondadori, Napoli, pp 1–160
- Logan Lobley J (1868) *Mount Vesuvius: a descriptive, historical, and geological account of the volcano: with a notice of the recent eruption, and an appendix, containing letters by Pliny the younger, a table of dates of eruptions, and a list of Vesuvian minerals*. Stanford, London, pp 1–55
- Martin R, Sunley P (2015) On the notion of regional economic resilience: conceptualization and explanation. *J Econ Geogr* 15(1):1–42
- Migoń P (2018) *Geoheritage and world heritage sites*. In: Reynard E, Brilha J (eds) *Geoheritage: assessment, protection and management*. Elsevier, Amsterdam, pp 237–249
- Panizza M, Piacente S (2003) *Geomorfologia culturale*. Pitagora Ed, Bologna, pp 1–360
- Passariello I, Albore-Livadie C, Talamo P, Lubritto C, D’Onofrio A, Terrasi F (2009) ^{14}C chronology of Avellino pumices eruption and timing of human reoccupation of devastated region. *Radiocarbon* 51(2):803–816
- Pesce A, Rolandi G (1994) *Vesuvio 1994. l’ultima eruzione*. Magma Edizioni, Napoli, pp 1–216
- Petrosino P, Alberico I, Caiazza S, Dal Piaz A, Lirer L, Scandone R (2004) Volcanic risk and evolution of the territorial system in the active volcanic area of Campania. *Acta Vulcanol* 16(1–2):163–178
- POR CAMPANIA (2014–2020) <http://porfesr.regione.campania.it/assets/documents/por-campania-fesr-2014-2020.pdf>. Accessed 1 Feb 2019
- Reynard E, Giusti C (2018) The landscape and the cultural value of geoheritage. In: Reynard E, Brilha J (eds) *Geoheritage: assessment, protection and management*. Elsevier, Amsterdam, pp 147–166
- Rolandi G, Bellucci F, Cortini M (2004) A new model for the formation of the Somma Caldera. *Mineral Petrol* 80(1):27–44
- Różycka M, Migoń P (2018) Customer-oriented evaluation of geoheritage—on the example of volcanic geosites in the West Sudetes, SW Poland. *Geoheritage* 10:23–37
- Sabbatino M (2015) *Proposal of a geosite in the Vesuvius National Park, the itinerary of “la Valle dell’Inferno”*. Master Thesis University of Napoli Federico II, pp 1–107
- Santacroce R, Sbrana A (2003) *Carta geologica del Vesuvio, Scala 1:15,000*. Progetto CARG. Servizio Geologico Nazionale – CNR, S.E.L.C.A., Firenze
- Suzuki DA, Takagi H (2018) Evaluation of geosite for sustainable planning and management in geotourism. *Geoheritage* 10:123–135
- Tramparulo FDA, Vitale S, Isaia R, Tadini A, Bisson M, Prinzi EP (2018) Relation between alternating open/closed-conduit conditions and deformation patterns: an example from the Somma-Vesuvius volcano (southern Italy). *J Struct Geol* 112:138–153
- UNISDR (2015) *Sendai framework for disaster risk reduction 2015–2030*. Sendai
- Wimbledon WAP (1996) *Geosites—a new conservation initiative*. *Episodes* 19:87–88