urban science

Article

Urban Geoscience: The Challenge of Street Geology

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Abstract: Beyond the human-related conception, Urban Science is a broad concept that includes and concerns various interconnected issues linked to Natural, Engineering, Human, Social, and Computational Sciences. Natural Science is represented by issues linked to GeoScience and BioScience. GeoScience issues concern (i) the physical-environmental aspects linked to (a) design, planning, and expansion of the urban environment; (b) urban management interventions; (c) prevention and (d) mitigation of natural and human-induced risks; (e) defense against natural and human-induced risks and (ii) cultural aspects linked to (a) educational purposes and (b) promoting, enhancing, and disseminating scientific as well as territorial and environmental knowledge and awareness. Geoscience is represented also by Street Geology, a silent geology mainly present in historical centers of urban areas, but not only, and that can be used as an educational tool, an opportunity for broader discussions on geological-environmental and socio-cultural issues. Look, see, understand, and take awareness are four steps that give voice to street geology. This paper highlights some aspects of GeoScience in two different urban areas, located in Southern Italy, represented by (a) the Longobard Walls of Benevento (BN) and (b) the 1794 Vesuvius' lava flow in Torre del Greco (NA).

Keywords: geoheritage; geotourism; geoeducation; Urban Geoscience; Southern Italy

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1. Introduction

As pointed out by [1], "The urban environment that humans are so busily creating is many things: a biological environment, a social environment, a built environment, a market environment, a business environment, and a political environment. It includes not only the versions of these environments that exist inside a single city, but also those that are emerging from the interaction between cities. Our understanding of the urban environment will draw on existing academic disciplines, but it will also develop its own abstractions and insights". To this list of environments, it is appropriate to add the physical geographic one, due to the fact that the urban environment lies and is comprised in it and is subject to its evolutionary scenarios, and the geological one, in its broad sense, that is represented by Urban Geology and comprising surface geology and underground geology. Urban Geology refers to all issues related to surface and underground geology in an urban environment [2,3], and promotes geoheritage in urban areas [4], represented also by building stones ([5,6] among others). The last may occur in different ways depending on urban realities: through papers, themed trips, school, and extracurricular activities ([4,7–9] among others). Broadly speaking, the definition of Urban Science may reflect the "research/applicative field" to whom this term is referred (e.g., [10,11]), highlighting one aspect more than the other. According to [12], Urban Science is a broad concept that includes and concerns, various interconnected issues linked to Natural, Engineering, Human, Social and Computational Sciences. As regard Natural Science, it is represented by issues linked to GeoScience and BioScience. Human perception of Geoscience and Bioscience in urban environments is limited. The urban environment is perceived as a whole of different aspects (streets, parks, building, people, safety, pollution, goods, business, facilities, etc.), sometimes with a look to bioscience regarding parks and the presence of flora and fauna inside. Geoscience is rarely considered, despite critical events such as earthquakes, alluvial events, landslides, tsunamis, or other "natural disasters" occurring. As pointed out by [13], "This expression (natural disaster, authors' note) disconnects the reality of the most vulnerable by continuously blaming "nature" and putting the responsibility for failures of development on "freak" natural phenomena (. . .)". Often, human perception of vulnerability and risk related to natural events is a flash perception, linked to a single event, directly or indirectly experienced. Gone the event, gone the problem. To avoid this erroneous perception of the natural world and its evolutionary dynamics, and to increase citizens' awareness and participation in environmental issues, as well as to promote the sustainable use and protection and conservation of natural resources, an earth science citizen's education is required, both in school and universities [14,15] and in everyday life [16]. Sciences, as school subjects, are often perceived as boring and uninteresting [17,18]. Many people, including pupils, students, and citizens, often believe that science is only for scientists and has no relevance to their daily lives. However, Urban Science provides a chance to take topics that are typically found only in textbooks and apply them to real-world scenarios, making them more accessible and relatable to everyday life. Not all science topics are suitable for discussion in an urban context, of course. They may also vary depending on the urban area characteristics. Therefore, it is important to carefully analyze the urban context in which you wish to develop Geoscience topics. As Urban Science is a broad concept, Urban Geoscience also includes several issues. They are represented by physical-environmental aspects linked to (a) design, planning, and expansion of urban building; (b) urban management interventions; (c) prevention and (d) mitigation of natural and human-induced risks; and (e) defense against natural and human-induced risks. Moreover, they are represented by cultural aspects linked to (a) educational purposes and (b) promoting, enhancing, and disseminating scientific, as well as territorial and environmental, knowledge and awareness. This paper focuses on the cultural aspects and showcases examples of Urban Geosciences that can be observed along a street, rather than in a museum or archaeological contexts. These are streets that are frequented by students, workers, and ordinary citizens, who may not realize the cultural significance of the objects around them. These streets may also be traveled by tourists who seek multidisciplinary and detailed information to enhance their experience and immerse themselves in the places they visit. Urban Geoscience may represent a form of Informal Science Learning [19,20], associated with situations in everyday life and tourism.

Observers, whether they are looking at geological or non-geological objects that are natural or are human made, perceive things through the filter of their own cultural background and interests. However, before interpreting (i.e., see them), what they are looking at, they must first accurately observe. By "see", we mean correctly identifying objects, shapes, and processes, and by "accurately observe" we mean looking at them with the availability of input and information necessary to identify them. Assuming that everyone is capable of observation, we must consider how to communicate information in a way that allows the observed object or process to be accurately seen and understood for what it truly is, rather than relying on rumors or assumptions. Figure A1 in Appendix A, represents this, focusing on the individual growth of children. Providing the necessary support (input) to promote personal growth and independent thinking is essential for developing critical thinking and the qualities needed for individuals to thrive in harmony with their environment. Without it, there may be an increase in unsubstantiated claims, which hinders the process of growth and requires further interventions to achieve the same results that can be attained with proper initial support and input. The necessary input includes the application of the scientific method [21–26], in a broad sense: observing, collecting data or information, and achieving reliable and verifiable knowledge of reality. This procedure is applicable to other fields, not just purely scientific ones, and it can be applied to everyday life, particularly to prevent the spread of fake news. In particular, students and children can learn this methodology in a way that best suits them, such as through play. Through play, learning can feel natural rather than an obligation, making the learning process more enjoyable and effective [27–30]. Street geology can provide valuable data and information along this cultural path, not only for students and children, but also for adults. The figure of the tourist is evolving; they are no longer just passive observers, but active participants who ask questions and expect answers [31,32].

This paper also offers recommendations and suggestions for city administrations interested in promoting environmental sustainability and scientific and environmental awareness among their citizens. The purpose of this paper is to show how geology, and its topics, is not just an aspect of the natural sciences reserved for "experts". We talk about geology, but this discussion can be related to other cultural contexts (such as biology, ecology, mathematics, physics, chemistry, history, folklore, or other), of course. The term "cultural" is used in its broad sense, linked to knowledge, considering that all the mentioned contexts are part of everyone's personal cultural baggage, or at least they should be with their basic concepts.

2. Materials and Methods

For the purposes of this paper, the applicability of the methodology proposed in [33], appropriately amended, was tested. This methodology, designed for geoconservation actions, involves a series of subsequent steps and can be adapted to other fields of research. In Figure 1, a schematization of the methodology used is presented. Note that in order to obtain a comprehensive understanding of the potential of a particular area, it is important to thoroughly analyze and explore its unique and diverse cultural aspects. After gaining a comprehensive understanding of the area, it becomes possible to analyze its various aspects and decide how to utilize them, determining which ones require further examination or action, also from the perspective of subsequent safeguarding, restoring, or valorizing.

The proposed methodology involves three main activities: (i) data collection; (ii) data processing and action planning; (iii) action implementation.

The data collection activities consist of two steps: (1) Step 00 Why?, which involves (a) choosing the area to analyze, taking into consideration its multicultural and multidisciplinary value, and (b) defining the expected and possible main target, objectives, end users, and stakeholders, based on analytical and/or statistical data; (2) Step 01 Who?, which involves defining the cultural contexts present in the chosen area, as well as distinguishing them between the Geo context and No Geo context, based on available published data and/or new data produced ad hoc. The purpose of Step 00 is to provide brief descriptions that introduce the main aspects to be developed. It also gives an idea of the analyzed area's potential targets, goals, end users, and stakeholders. The possible targets can vary depending on the characteristics of the chosen area and its heritage. These targets can include educational goals for different age groups, as well as management, valorization, protection, and promotion of heritage, and research activities. It is important to specify at least one main target, and in some cases, multiple main targets that may be related or independent. The objectives represent the various activities that need to be carried out to achieve the main target. In Step 01, these aspects are developed individually and, when possible, with cross-references between them. As regards the Geo context, this step defines the area's (i) geological background, according to the area's main geological characteristics; (ii) physical landscape; (iii) geoheritage, referring to the presence of cultural landscape (https://whc.unesco.org/en/culturallandscape/, accessed on 18 December 2023) geosites and/or geodiversity sites (sensu [34]) in the surface or underground, extra situ facilities; (iv) vulnerability of the analyzed area, with respect to natural or human-induced events. Vulnerability is intended as the susceptibility of a system (biosystem/geo-system/infrastructure system) or population to the impact of a hazard (natural or human-induced). In Figure A2a,b (Appendix A), a simplified scheme regarding the main concepts and issues concerning vulnerability, hazards, and risk is presented. Regarding the No Geo context, this step involves defining several background characteristics according to the main No Geo features present in the analyzed area, as well as the correlated heritage and its vulnerability, concerning natural or human-induced events. These activities regard the entire area and are based both on published data and original data, carried out to improve or highlight some of the analyzed aspects. They also enable the identification of elements to be subsequently used as a means of diffusion and around which to build the interconnection network between all possible correlated contexts.

URBAN GEOSCIENCE

Mission	Use of urban cultural issues for: ○ educational purposes; ○ promotion, enhancement, and dissemination of scientific, territorial, and environmental knowledge and awareness; ○ touristic purposes; ○ sustainable territorial development.				
	Step		Action	Object	Criteria/methods
Data collecting	00	Why?	Choose	Area	Multicultural and multidisciplinary value
			Define	Main Target Objective/s[1] End-users and stakeholders[1]	Area's characteristics Analytic Statistic
	01	Who?	Define	Geo context: Background[2]; Physical landscape; Geoheritage; Vulnerability No Geo context: Main features; Background[3]; Heritage[4]; Vulnerability	Available published papers and/or new data
Data processing Action planning	02	What?	Analyze	Geo context No Geo context Multidisciplinary correlations	Main Target End-user's and stakeholder's needs and requirements Time-space evolution
			Choose	Time Target	Area's characteristics End-user's and stakeholder's needs and requirements
			Define	Main Topics Topics Themes Subject Arguments	
			Develop	Argument	End-user's and stakeholder's needs and requirements
Action implementation	03	How?	Prepare	Descriptive Tables Maps Informatic materials	End-user's and stakeholder's needs and requirements
			Make available	Results Open questions Final materials	Printed paper On line accessibility

[1] Expected and possible.
[2] Based on the main geological characteristics of the area, as well as Geological Background (B.) and/or Regional B., Stratigraphic B., Structural B., Geomorphological B., Volcanological B., Mineralogical B., and so on.
[3] Concerning any context present or chosen for the study.
[4] Related to any context present or chosen for the study.

Figure 1. Scheme of the utilized methodology.

The data processing and action planning activities consist of one step, Step 02 What?, dedicated to the element, or elements, chosen to be used as a means of dissemination, and are devoted to (i) analyzing Geoand No Geo contexts, and their possible correlations, as regards the previously defined main target, the identified end user's and stakeholder's needs and requirements; (ii) choosing a time target and defining main topics, themes, subject, and arguments; and (iii) developing arguments. According to [35], the terms Main Topic, Topic, Theme, Subject, and Argument, although synonyms are used to define a hierarchical terminological order starting from global to a more and more specific one. The time target is necessary to provide context for arguments, as geological time has a magnitude that is not comparable with biological and human times.

The action implementation activities consist of one step, Step 03 How?, devoted to preparing and making available results and materials.

Urban environments often feature heritage in various ways. Urban Heritage [36–39] surface and underground tangible heritage elements include (a) archaeological areas or remnants; (b) builds with historical, industrial, or modern value; (c) biological and/or geological features; and (d) cultural facilities; as well as (2) intangible (a) social, cultural, and religious practices and traditions, and (b) traditional art and craftsmanship. Urban Heritage whether tangible or intangible, is vast and offers various possibilities for being connected to other cultural contexts, among which Geosciences are one. In the schematization of Figure 2, although non-exhaustive, Urban Heritage is presented to illustrate the wide range of heritage that can be found in an urban environment. This representation complements the definition of No Geo contexts in Step 01. It begins with a general description of the context (historical, archaeological, cultural, etc.), followed by a description of the elements that constitute its heritage. Urban environment often impacts the surrounding landscape by making significant changes to it, and is itself composed of a physical landscape, sometimes adjusting to it, often modifying it according to its needs. The concept of Urban Landscape has a dual significance, referring to (1) the physical landscape where the urban environment is situated, and (2) the collective human habitation and activities. We include it in Urban Heritage because it can be evidence of human adaptation to an existing landscape or substantial modification of it (1), or it can be a historical urban landscape (2).

Urban Heritage	Tangible/Material	U. Landscape		
		U. Archaeoheritage	In situ	Surface
				Underground
			Extra situ	Museum
		Built Heritage	Archaeological H., remnants of	
			Historical H.	
			Industrial H.	
			Modern H.	
		U. Geoheritage	In situ	Surface
				Underground
			Extra situ	Museum
		U. Bioheritage		
		U. facilities	Museum	
			Permanent or temporary exhibitions	
			Cultural/Religious/Health pathways	
	Intangible/Immaterial	Intangible Cultural Heritage	Social, cultural and religious practices and traditions	
			Traditional art and craftsmanship	

Figure 2. Urban Heritage characterization.

This paper utilized bibliographic material, complemented with original data and analysis by the authors. The chosen sites are presented below with their characteristics and peculiarities. The main historical and cultural aspects will be treated concisely, referring to the cited bibliography for further information. In addition, while preparing this paper, we learned about the Territorial Initiative Groups of Banca Etica (GIT Lazio https://www.labsus.org/2022/05/il-commonspoly-non-e-solo-un-gioco/, accessed on 20 April 2024), who are promoting the use of the Commonspoly free board game (https://commonspoly.cc/, accessed on 22 April 2024) as a means to encourage the management of shared resources. This initiative, which is multicultural and interdisciplinary, aims to utilize a game as a tool to direct people's competitive tendencies toward the understanding of ethical finance, the management of shared resources, and the importance of collaboration in achieving common goals for the benefit of all, in line with Banca Etica's objectives (https://www.bancaetica.it/about-us/, accessed on 20 April 2024). Currently, we are collaborating with several regional GIT on developing specific game squares related to natural and cultural resources, as well as action cards depicting individual and global environmental actions and impacts. The goal is to tailor the game board and action cards to reflect the realities of different cities, in order to raise awareness among citizens about urban heritage and promote ethical management practices. We are currently exploring various scenarios, starting with a general game board and then examining the feasibility of creating game boards specific to the urban contexts and/or topics of analyzed cities. For example, we are considering "River dynamics and management" in Benevento and "Volcanic geotourism" in Torre del Greco, as part of the geo thematic. This multicultural and multidisciplinary approach, utilized in recent works [35,40–43], allows for flexible exploration of a wide range of topics tailored to meet the needs of end users and enhance urban heritage. Although this work is still ongoing, we have decided to include it in this paper because we believe that the Commonspoly free board game is an interesting tool for achieving the objectives of Urban Geoscience, as shown in Figure 1.

3. Results

The two urban areas chosen (Benevento, Torre del Greco) are characterized by evidence of a close correlation between history, natural events, and human adaptation. In these areas, several cultural contexts have been identified, as shown in Figures 3 and 4, also highlighting the possible correlation between some of them. In this paper, we looked at the cultural contexts of physical geography, geology, history, and hazards. We correlated themes, subjects, and topics to converge in the final argument. We focused on the relationship between the river system and human activity for Benevento, and the interaction between humans, the landscape, and the reality of an active volcano for Torre del Greco. The chosen dissemination tools are the Longobards Walls in Benevento, and the church of Santa Maria del Principio in Torre del Greco.

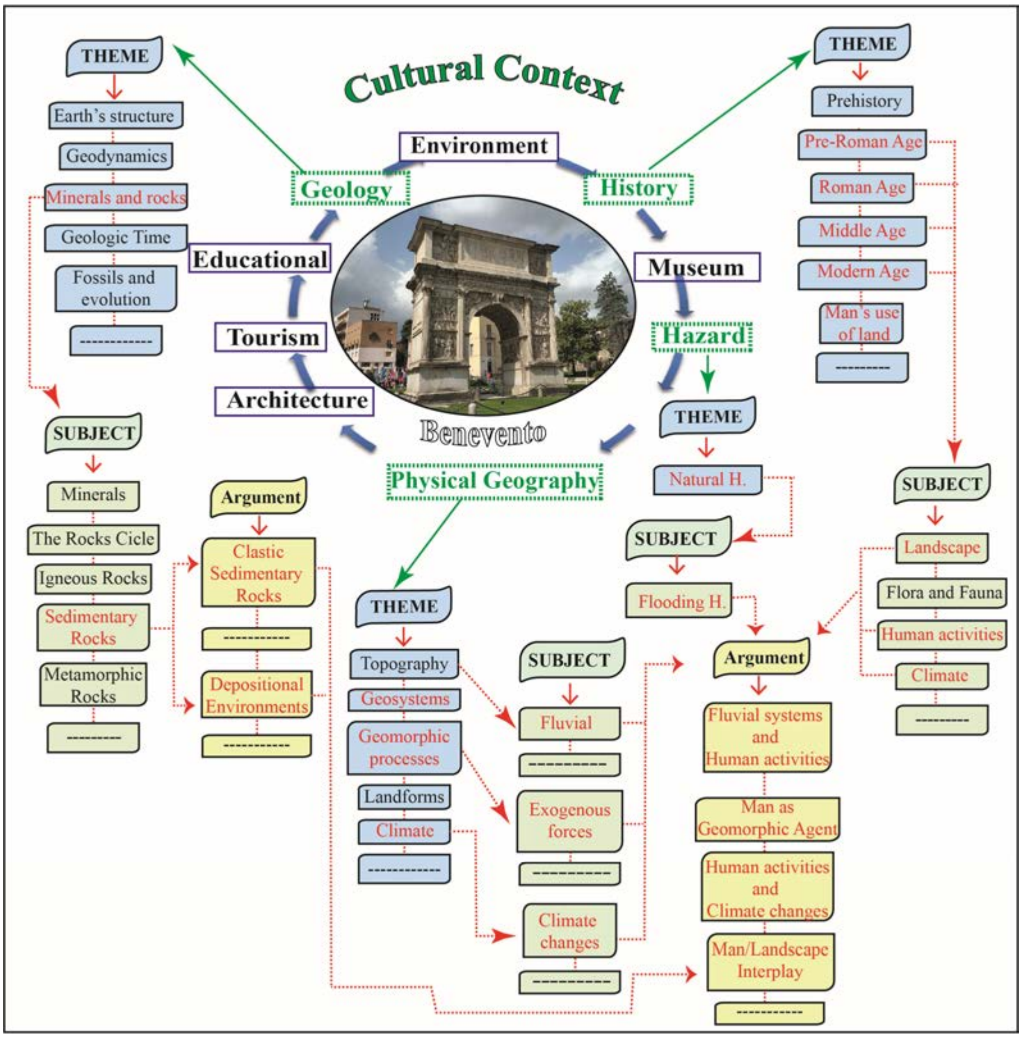

Figure 3. Benevento, Traiano arch. Sketch of the main cultural contexts illustrating some simplified connection between geo and no geo arguments. Photo courtesy of D. Pescatore.

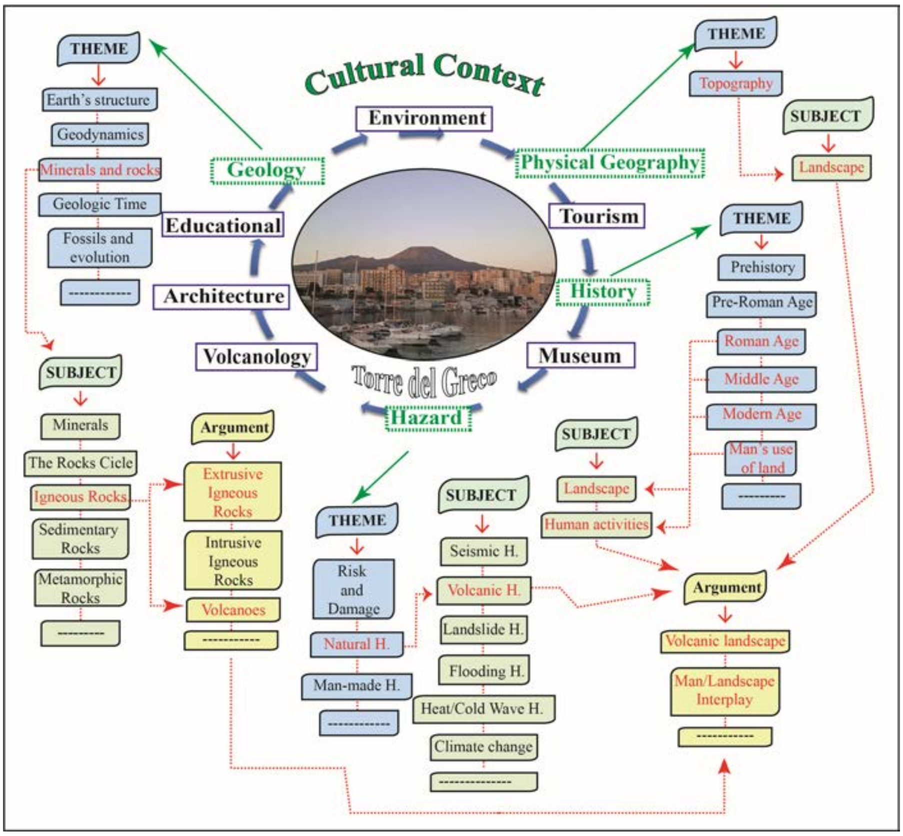

Figure 4. Torre del Greco, panoramic view of Somma-Vesuvius from the port. Sketch of the main cultural contexts illustrating some simplified connection between geo and no geo arguments. Photo courtesy of M. Gallo.

3.1. Data Collecting

Data collecting concerns two steps. Step 00 Why?, concerning (i) the description of chosen areas, and the definition of (ii) the reasons for the choice; (iii) the main target; and (iv) the expected and possible (a) goals, (b) end users, and (c) stakeholders. Step 01 Who?, concerning the cultural contexts considered. In Step 00, descriptions and definitions are intentionally brief, providing a general overview of the selected areas and serving as a starting point for a more detailed description in Step 01.

3.1.1. Step 00—Why?

(a) Benevento (Benevento district, Campania region, Southern Italy)

- Brief description and reasons for the choice

Approximately 55 km northeast of Naples, Benevento is located in the interior sector of the Campanian Apennines in Southern Italy (Figure 5). The current city has managed to preserve significant remnants of its past, represented by its Osco-Samnite origins, the Romanization period, and gradually through the Middle Ages up to the present day, within its urban architecture. Throughout the city's history, various historical moments have overlapped, sometimes leading to the erasure of previous moments, while at other times integrating and preserving them. These remaining artifacts from the past offer an opportunity to enhance the city's multicultural appeal.

- Main target

The main target is to improve local territorial knowledge within a broad scientific context, including geology, archaeology, and socio-cultural context. A secondary, yet equally important, target is to address vulnerability and risk related to natural event issues—hydrogeological vulnerability and risk, in this case.

Figure 5. Location of the analyzed cities.

- Expected and possible goals

Expected goals are the creation of informative material for dissemination and tourism purposes. Possible goals are represented by the involvement of similar urban realities to create thematic itineraries.

- Expected and possible end users and stakeholders

The expected end users and stakeholders include citizens, students, and tourists. Researchers from various disciplines represent potential end users and stakeholders.

(b) Torre del Greco (Napoli district, Campania region, Southern Italy)

- Brief description and reasons for the choice

Torre del Greco is located approximately 11 Km (as the crow flies) southeast of Naples (Figure 5). Its central position in the Gulf of Naples places it in a privileged position to observe—from the port, the entire enchanting gulf towards the southwest, including the enchanting islands of Capri, Ischia, and Procida. Toward the northeast, it offers views of the volcanic edifice of Somma-Vesuvius. The history of the inhabited center is closely connected to that of Somma-Vesuvius, and the urban area retains evidence of the various eruptions that have occurred over time as well as archaeological remains predating the eruption of 79 AD. Although not as famous as the ruins of Pompeii and Herculaneum, these remains provide valuable information about the area during that period. Outcrops related to several eruptions after 79 AD provide a picture of the landscape evolution and the complex relationship between landscape and human activities.

- Main target

The main target is to improve local territorial knowledge within a broad scientific context, including geology, volcanology, and archaeology, as well as in a socio-cultural context. Another objective is to increase the city's tourist appeal. A yet equally important target is to address vulnerability and risk related to natural event issues—volcanic vulnerability and risk, in this case.

- Expected and possible goals

The first goal, already achieved, is the involvement of the local administration, fundamental for the success and achievement of the expected targets. An attentive and active local administration is of primary importance. The subsequent goals are represented by the production of basic information material and their making available to the local administration for dissemination and touristic purposes.

Possible goals are represented by the involvement of researchers from various disciplines to delve deeper into the topics covered, create correlations between similar situations, and compare different approaches to study.

- Expected and possible end users and stakeholders

The expected end users and stakeholders include citizens, students, and tourists.

Researchers from various disciplines represent potential end users and stakeholders, aiming to explore the covered topics, their connections, and potential applications in scientific and practical contexts.

3.1.2. Step 01—Who?

(a) Benevento

- Geo context

Geological background

Benevento's historic center is located on a hill made of quaternary fluvial deposits, near the Calore and Sabato Rivers' confluence. The quaternary deposits lie on a bedrock mainly represented by strongly deformed Pliocene marine deposits [44–48] linked to the evolution of a wedge top basin, located on deformed units Cretaceous to Miocene in age. The tectonostratigraphic evolution of the Benevento wedge top basin is situated within the broad evolutionary framework of this sector of the Southern Apennine chain, a NW-SE-trending fold-and-thrust belt, formed in a time ranging from late Oligocene to Pleistocene involving a complex palaeogeographic context. This context was characterized by the presence and overlap of several depositional environments, including carbonatic platforms and deep basins. During the Pliocene, tectonic deformation of the substrate produced large troughs that were progressively filled with marine to transitional wedge-top basin sediments; the accommodation space in the area of the Benevento basis was controlled by E-W trending normal faults [44]. During the Quaternary, ENE-WSW and NNW-SSE-trending normal faults controlled depositional space for the sedimentary continental successions [44]. In the Benevento area (Figure 6), the outcropping Quaternary deposits [48] are represented by (a) gravel and conglomerate deposits, and gravel and silty-sandy deposits, and silty-sand and silty-clay deposits (lower Pleistocene fluvial deposits), locally a paleosoil is present at the top of the succession; (b) reddish brown silty-clay and sandy beds with lenticular beds of gravel in silty-clay matrix, and yellowish-brown gravel beds with sandy-silty matrix and silty/sandy-clay beds (middle to upper Pleistocene fluvial deposits); (c) reddened sandy-silty gravels (upper Pleistocene fluvial deposits); (d) pyroclastic, eluvial, and colluvial deposits (Holocene altered and reworked pyroclastic deposits, pyroclastic flows or volcanic fall deposits, deposits derived from degradation and erosion of ancient fluvial deposits, Miocene and/or Pliocene deposits); and (e) sandy-silty gravel and clayey sandy silt beds (Holocene to Present day fluvial deposits). The Holocene pyroclastic deposits include reworked and altered material from the Campanian Ignimbrite eruption (39 ka [49]; https://www.ov.ingv.it/index.php/flegrei-storia-eruttiva/le-eruzioni-principali/ignimbrite-campana, accessed on 15 January 2024, related to the activity of the Phlelegrean Field volcanic area, Figure 5), as well as two pumice layers [45]. These layers are attributed to the Avellino eruption (3945 $\pm$ 10 BP [50]) and the Pollena eruption (472 AD [51]), which are related to the activity of Vesuvius. The Pliocene deposits are represented by successions referred to the Ariano Unit ([52] and references therein [53]) and represented by (a) sandy matrix conglomerates and gravel interbedded with pelitic and arenaceous strata; (b) arenaceous and sandy beds with lamellibranch shells; and (c) thin grey silty-clay, rare arenaceous beds interbedded with thin laminate pelitic sandstone, locally, in the clay deposits, shells of bivalves, even in life positions, gastropods, and scaphopods [48]. The pre-Pliocene bedrock is represented by succession referred to as the Flysch Rosso Formation [54–58] and consists of (a) thick strata of calcirudites and calcarenites interbedded with gray marls, as well as yellowish and reddish clayey marls, and (b) claystones, red and grey-green marls interbedded, with limestone and calcilutites with lists and nodules of chert [48].

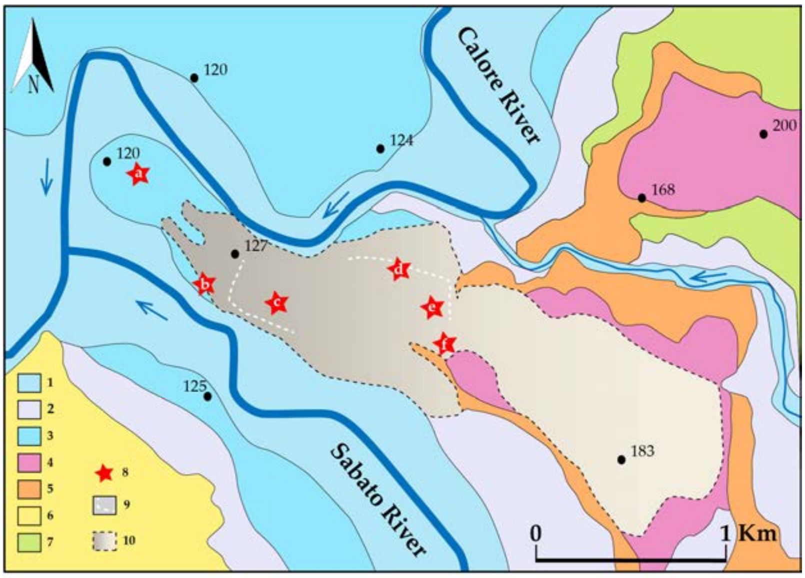

Figure 6. Simplified geological map of the Benevento area. Legend: (1) present-day fluvial deposits; (2) Holocene eluvial-colluvial deposits; (3) Holocene fluvial deposits; (4) pyroclastic and colluvial deposits; (5) Pleistocene fluvial deposits; (6) Pliocene marine deposits; (7) Cretaceous to Miocene calcareous, marly, and pelitic deposits (Flysch Rosso Formation); (8) main archaeological sites and buildings, a—Cellarulo area, b—Roman Amphitheater, c—Roman Theater, d—Traiano Arch, e—Santa Sofia Church, f—Rocca dei Rettori; (9) Longobards Walls; (10) main urbanized area. The blue arrows show the direction of water flow in the rivers. The black dots represent the elevation above sea level.

Physical landscape

The present-day physical landscape corresponds to a vertical-incised fluvial landscape. The Calore and the Sabato rivers are the main responsible forces for the fluvial cut and fill deposits, starting from the Early Pleistocene to the present day. A NW-SE elongated hill, made by Pleistocene fluvial deposits, characterizes the area. The hilltop is a low-angle surface NW dipping with a range of altitude variable from about 130 m asl to about 180 m asl and is higher 20 to 60 m above the Calore and Sabato River. Pleistocene alluvial deposits testify several depositional events, locally marked by paleo soils, and are covered by pyroclastic and colluvial deposits [18]. The Holocene fluvial deposits, present on the hillsides and covered by eluvio-colluvial deposits, are characterized by two orders of fluvial terraces [59]. The Benevento urban area lies on the top of the Pleistocene fluvial terrace and the top of the Holocene ones. The landscape is typically that of an intramountain basin of the central-southern Apennines, characterized by terraced morphology crossed by rivers. The dynamics of the Calore and Sabato rivers have influenced the evolution of the landscape and consequently human frequentation in the past; currently, they represent a risk factor in the event of exceptional rainfall events.

Geoarcheology

The fertile soils on the valley floor and the available water represented both opportunities for settlement improvement and prosperation and also conditions their existence. Several geoarchaeological studies [45,59–64] were conducted to reconstruct the original layout of the places and their human frequentation, starting from the Bronze Age. Studies in the Cellarulo area, in the Roman Theatre and Amphitheatre areas, boreholes, and archaeological trenches analysis, have shown how places have been influenced by river dynamics, as well as by volcanic and seismic events. The archaeological site of Cellarulo, situated in the floodplain area of the Calore River, shows evidence of use from the 4th century BC to the 2nd century AD. It was likely abandoned due to river flooding. Evidence of river flooding is observable in the Roman Amphitheater area. Additionally, there are clear signs of volcanic activity from Somma-Vesuvius, as indicated by pyroclastic deposits interspersed within the stratigraphic layers covering the site [45,62].

Vulnerability

Benevento and its related geological, anthropic, and infrastructure systems are vulnerable to several natural hazards, particularly geological and hydrogeological ones. The main geological hazard is represented by earthquakes, given the area's location in the central zone of the Southern Apennines chain, an area known for frequent earthquakes. Major earthquakes hit the area in 369, 847, 984, 1125, 1456, 1688, 1702, 1732, 1782, 1805, and 1885 [65], with an estimated magnitude ranging from 6.4 to 7.0 [66], and in 1962 [67], causing significant damage. The present-day seismicity is low and characterized by low-magnitude swarms [68,69]. Papers and projects have been dedicated to defining the city's seismic response ([44,69] and references therein, [70] and references therein) to evaluate the corresponding risk. Concerning hydrogeological hazard, multiple historical flood events have impacted the Benevento area, as evidenced by ancient flood events in the Cellarulo and Roman Amphitheatre areas. Notably, the floods on 2 October 1949, 19 October 1961, and 15 October 2015 [71–74] resulted in significant damage to people, property, and territory. Also, landslides may represent a hazard, albeit of minor impact because they are mainly located in suburban areas and their surroundings ([75,76] and references therein). As regards the volcanic risk, the current volcanic risk maps are dedicated to the Phlegraean Fields (https://mappe.protezionecivile.gov.it/en/risks-maps-and-dashboards/national-planning-phlegraean-fields/, accessed on 3 March 2024) and Somma-Vesuvius (https://mappe.protezionecivile.gov.it/en/risks-maps-and-dashboards/national-planning-vesuvius/, accessed on 3 March 2024). The Benevento area is not considered at risk. The presence of ancient and recent volcanic deposits, both in the urban area and in the immediate vicinity, indicates an area potentially at risk for possible volcanic fall deposits in the event of a strong eruption. Land consumption [77] and pollution are the main factors of human-induced hazards influencing vulnerability.

- No Geo context

Historical background

Legend has it that Benevento was founded by the Greek hero Diomedes in 1200 BC after killing a ferocious boar terrorizing the region. As a result, the wild boar became the city's symbol. Two hypotheses exist for the original name: it was, in the Oscan language, Malies or Malocis, then changed to Maloenton or Maloenta [78], or it was of Greek origin, Malòeis, from Malon, a Doric variant of the Attic Mèlon, which means flock of sheep or goats, with reference to pastoral activity, without excluding the possible derivation of Maloenton from mallos (sheep's fleece) [79]. Presumably, the Romans changed the name Maloenton to "malum eventum", recognizing the places as a bad omen (bad event—Maleventum). In 272 BC, after the Pirro victory, it was transformed into Beneventum (good event), indicating a good omen. The location between two watercourses and the presence of elevated areas for territorial control were conducive to human habitation. The Calore River, navigable and surrounded by flat cultivable areas, represented the fulcrum around which various settlements developed and overlapped over time. Archaeological studies indicate human activity in the Benevento area from the ancient Bronze Age [62]. The Samnites, and then the Romans, noticed that the rivers, as well as being a valuable resource, also posed a serious threat when they overflowed, destroying everything within the river flood plains. As a result, they moved towards the higher river terraces. This led to the establishment of a Samnite settlement, followed by a Roman castrum, and then a Longobard civitas nova. As consequence of seismic events affecting the area, these settlements were destroyed and later rebuilt in the same areas, resulting in overlapping levels. Samnium was the site of three wars against the Romans (354–330 BC, 327–304 BC, 298–290 BC). In 268 BC, Benevento became a Roman colony with all the rights of Latin cities. During the Second Punic War, Benevento served as a military base and was the location of two important battles in

214 and 212 BC. Located at the crossroads of the important Roman roads Via Appia and Via Minucia, it was elevated to the rank of municipium in 86 BC. During the Roman period, it reached its peak of development, and the Traiano Arch in 114 AD (Figure 7a); the Roman theater in 126 AD; the Amphitheater in I sec. BC-I sec AD; numerous cult centers, among which was one dedicated to the Egyptian goddess Isis (88 AD); thermae; and commercial and residential areas were built. A series of natural events, such as strong earthquakes (369 AD), volcanic eruptions of Somma-Vesuvius (Pollena 472 AD), and floods (589 AD), caused extensive damage and the abandonment of some areas of the town. Traces of these events have been preserved in the Amphitheatre area [45]. After the fall of the Roman Empire (476 AD), the city suffered several barbarian invasions. In 570 AD, the Longobards founded the Duchy of Benevento. In the Longobard period, the urban fabric was expanded, the city walls were reinforced, and the Roman monuments were used to recover building materials for the construction of the defensive walls (Figure 7b) and the buildings. In 758, the church of Santa Sofia was built [80] with a hexagonal plan and columns on each vertex, probably originating from the Temple of Isis. Around 774, the Duchy became a Principality. From 891 to 895, it was occupied by the Byzantines and then returned to the government of the Longobard princes until 1077, when it became a Papal Enclave. The government of the city was entrusted to two rectors, chosen by the notables within the group of court leaders and subject to papal approval. Benevento was at the center of conflicts between the Empire and the Papacy, with two sieges by Federico II and the holding of the famous Battle of Benevento, between Manfredi of Svevia and Carlo d'Angiò in 1266. In 1798, with the arrival of Napoleon in Italy, it was initially occupied by Ferdinand IV of Bourbon. Subsequently, Napoleon established a new principality there starting from 1806. With the Restoration, the area returned to the Church. In 1860, the city was annexed to the newly formed Regno d'Italia and became a provincial capital.

Figure 7. (**a**) Traiano arch; (**b**) Longobards Walls. Photo D. Pescatore.

Archeological heritage

The city of Benevento, as well as its surroundings, is rich in archaeological and geoarchaeological evidence [45,59,80–84]. The integrated study of archaeological sites in the urban area and nearby allows for the reconstruction of the history of places and people starting from the ancient Bronze Age. The archeological heritage is represented by several sites and builds, among which are the Cellarulo Archeological Park; the Archeological Area of Sacramento Arch; the Ponte Leproso; the Roman Amphitheater and the Roman Theatre; the Traiano Arch; the Rocca dei Rettori; the Longobard Walls; the Santi Quaranta Cryptoporticus; the Church of Santa Sofia, part of the UNESCO World Heritage List as one of the sites of "The Lombards in Italy: The places of power (568–774 AD)"; the Church of Sant'Ilario; and the Port'Arsa. The Sannio Museum is located in the Church of Santa Sofia cloister. It houses archaeological artifacts from the Samnite and Roman periods, including items from the Longobard Age. The collection spans from the 15th to the 19th centuries and also includes works by significant national artists from the 20th century.

Urban fabric

The current urban area is situated on the hill near the meeting point of the Calore and Sabato rivers. It extends, also, (a) to the north in the areas on the right bank of the Calore River, (b) to the east in the areas on the left bank of the Calore River, and (c) to the southwest in the areas on both the right and left banks of the Sabato River. The following text is derived from the papers published by [85–87]. The historical center preserves the original Roman core with its geometries. The Roman settlement was heavily affected by earthquakes in 346 and 375. As a result, buildings and public areas were abandoned and used as burial grounds. The Cryptoporticus of Santi Quaranta, as well as the Amphitheatre, were already being used as burial grounds before the end of the 5th century and, secondarily, throughout the early medieval period. The Longobard settlement occupied a smaller area than in the previous period, and they partially preserved the Roman urban layout by maintaining the main road axes, such as the Via Appia and the Via Traiana, cardos, and decumanus. The city walls were rebuilt and strengthened, and the Sacramento Arch and the Traiano Arch were incorporated in the city walls and used as city gates. The city walls were expanded towards the west in 774, resulting in the growth of the urban area on the previously abandoned Roman settlement. During the Longobard period, numerous churches were constructed within and outside the city walls, such as the Church of Santa Sofia within the walls and the church of Sant'Ilario on the Via Traiana outside the walls. The construction of churches and monasteries continued during the papal period, inside and outside the city walls. Earthquakes (847, 984, 1125, 1456, 1688, 1702, 1732, 1782) affected the area, causing extensive damage to buildings and population reduction, as plagues (1630, 1656) and famines (1316, 1764) also did. In this period, the primary urban infrastructure remained largely unchanged, inside and around the city walls. The city outside the walls developed in four stages. During the latter half of the 19th century, the Rione Ferrovia was established with the construction of the railway station (1867) across the Calore River, becoming the hub for the first industrial, commercial, and artisanal activities. In the first half of the 20th century, the Rione Libertà (1926) was built across the Sabato river with a clearly rationalist layout. Almost all economic and popular construction initiatives are concentrated in this place. In the same years, the Mellusi-Atlantici district developed in the southeast area of the ancient city. During the Second World War, the city was heavily bombed by the Anglo-American forces in 1943 due to its significance in the railway communications between the capital of Italy, Rome, and the Puglia region. The bombings targeted the railway infrastructure, bridges over the rivers, and the city area, resulting in significant damage and casualties. The expansion in the 1950–1970 period was influenced by the post-war Reconstruction Plan of 1945–1947, which spurred significant speculative interests and massive construction. However, it lacked specific connotations and was unrelated to the historical architectural features of the ancient city. Urban expansion from the 1970s onward has encroached on agricultural areas, leading to the establishment of new settlements. After the 1980 earthquake, consolidation works were carried out and new residential areas arose.

Urban Built heritage

Urban Built Heritage is mainly represented by Samnite, Roman, Longobard, Monastic ruins and builds, as well as by Historical Buildings [88], Rationalist Architecture (1926–1948) [89], and Industrial Archaeological buildings. The latter are represented, among others, by Antica Fonderia dell'ITI Lucarelli (https://fondoambiente.it/luoghi/l-antica-fonderia-dell-iti-lucarelli?ldc, accessed on 5 January 2024); Stabilimento Strega [90,91]; and Agenzia del Monopolio dei Tabacchi di Benevento (https://www.kinetes.com/archivio-foto-documentario-tabacco.html, accessed on 5 January 2024).

Vulnerability of Urban Built Heritage

The vulnerability of buildings is influenced by factors such as the types of construction materials used, their natural degradation, exposure to atmospheric agents and pollution, and their response to natural and human-induced events. Earthquakes are the primary cause of potential damage, while heavy rain and floods can also compromise the stability of buildings, especially older ones.

(b) Torre del Greco

- Geo context

Geological background

The city of Torre del Greco is located on the southwestern slope of the Somma-Vesuvius volcanic complex (Figure 8), within the southern part of the Campanian Plain, an area characterized by a significant morpho-structural depression filled with various types of deposits, including marine, continental, transitional, and volcanic materials dating from the Pleistocene to the present ([92,93] and references therein). The volcanic structure is characterized by the presence of a caldera (Somma) that has been modified by various eruptions throughout its history. Inside the caldera is the cone of Vesuvius.

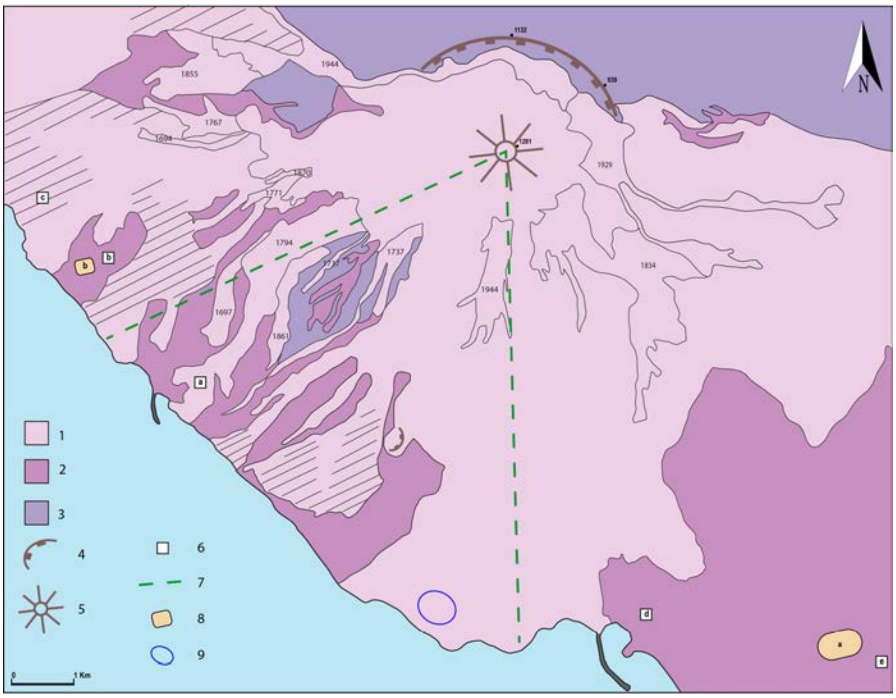

Figure 8. Schematic and simplified geological map of Torre del Greco area. Legend: (1) volcanic deposits related to the activities after the 79 DC eruption; (2) volcanic deposits related to the 79 DC eruption; (3) volcanic deposits related to the activities before the 79 DC eruption; (4) Caldera; (5) Vesuvius' volcanic cone; (6) cities: a—Torre del Greco, b—Ercolano, c—Portici, d—Torre Annunziata, e—Pompei; (7) simplified administrative boundaries of Torre del Greco municipality; (8) archeological areas: a—Pompei, b—Ercolano; (9) Villa Inglese quarry. Data sources [94,95].

The history of Somma-Vesuvius is marked by different periods of activity, starting from the earliest deposits dating between 39.3 Ky BP and 18.3 Ky BP up to the most recent eruption in 1944 (https://www.ov.ingv.it/index.php/monitoraggio-sismico-e-vulcanico/vesuvio/vesuvio-storia-eruttiva, accessed on 3 March 2024). The volcanic activity of Somma-Vesuvius has been quite diverse, featuring mainly effusive eruptions resulting in the formation of cinder cones and lava flows. The products of Somma-Vesuvius are basic, silica-undersaturated, potassic magmas, ranging in composition from tephrites to leucites [93,96,97]. It has also experienced explosive eruptions of moderate magnitude and Plinian explosive eruptions, such as the one in 79 AD. Since its last eruption in 1944, Vesuvius has been in a quiescent state, characterized by mild seismic and fumarolic activity. The area of Torre del Greco, extending from the coast to the crater of Vesuvius, displays various products related to the eruption of 79 AD as well as earlier and subsequent eruptions. This includes the visible lava flows of 1697, 1737, 1794, 1861, and 1944. The quarry area of Villa Inglese (9 in Figure 8, https://www.mindat.org/loc-29836.html, accessed on 3 March 2024) is particularly noteworthy for its mineralogical content. In past years, samples of atacamite, azurite, Sommahausmannite, vesbina, and vonsenitis were discovered [98–100]. Presently, the quarries are no longer active. Numerous scientific works have been dedicated to the study of -Vesuvius, from the descriptions of the 79 AD eruption by Pliny the Younger to the volcanological aspects and associated risks. Additionally, several papers have provided detailed descriptions of the outcrops and their geoarchaeological aspects in this area [101–109].

Physical landscape

The remains of large urban settlements, maritime and agricultural villas from the Roman era, and artifacts from the pre-Roman age found in the Vesuvian area provide insight into the area's appearance before volcanic eruptions transformed its landscape and influenced human settlement. The majority of the present coastline is due to the deposition of volcanic materials from the early medieval and recent periods. These deposits have been responsible for the migration of the coastline by several hundred meters in certain instances. It is believed that the coastline before the eruption of 79 AD must have been quite complex [101,102,105,107,110–113]. The current physical landscape is strongly influenced by the outcropping lithologies and the presence of secondary volcanic reliefs, such as the "Camaldoli di Torre del Greco" caldera, now known as "Colle Sant'Alfonso". The cone of Vesuvius reaches a maximum height of around 1200 m above sea level and is characterized by steep slopes. The pericrateric area has slopes steeper than 40°, while the foothill areas have gentler slopes. The topographic surface is complex due to the presence of lava and pyroclastic deposits, and even the current coastline reflects these lithological differences. The hydrographic network is radial centrifugal, typical of volcanic morphologies. The hydrological regime is torrential, with erosion valleys, named "cupe" (gorge) or "canaloni" (gully) in the local dialect. The volcanic nature of the land makes the area particularly fertile and has favored the development of housing and cultivation settlements over time. Tomatoes, apricots, and Vesuvius vines are particularly well known and appreciated.

Geoarchaeology

The discovery of remains of Roman villas covered by the eruption of 79 AD, as well as the presence of significant portions of volcanic outcrops attributable to pre- and post-79 AD activity, make this part of the territory very interesting from a geoarchaeological point of view. Here, several studies emphasize the need for a multidisciplinary approach when investigating the historical territorial evolution of a site [101–103,105–109].

Vulnerability

The vulnerability of places is influenced by natural (volcanic, seismic, hydrogeological) and anthropic factors (such as pollution and extensive urbanization). The type of eruption and its frequency are crucial in determining the risk of the area, especially when combined with extensive human presence and activity. One of the most destructive eruptions was the Plinian eruption in 79 AD, which significantly altered the morphology of the affected areas, destroying and burying the inhabited centers present at the time (Herculaneum, Pompeii, Stabia, Oplontis). Vesuvius is one of the most controlled volcanoes in the world, and its activity is constantly monitored by the Osservatorio Vesuviano (https://www.ov.ingv.it/index.php/monitoraggio-e-infrastrutture/attivita-di-monitoraggio/monitoraggio-vulcanologico, accessed on 3 March 2024). The seismic factor is related to both the activity of Vesuvius and the Southern Apennine chain seismicity, which has experienced destructive events like the Irpinia earthquake in 1980. The hydrogeological factor is closely related to the type of water system in the area and human activity. During heavy rainfall, water can follow old human-made water paths, which are currently used as roads, posing a risk to people and property. Lastly, the anthropic factor significantly increases the area's vulnerability and risk due to intense human activity and high population density in the entire Vesuvian district.

The eruption of 1794

There are numerous testimonies of the eruption, documented by chroniclers of the time, depicted in paintings, and recounted in letters by ordinary observers [114–116]. Information, testimonials, and descriptions are reported in [114,117,118]. The following brief description is taken from that source. On 15 June 1794, a series of seismic events and the drying up of wells indicated an imminent volcanic eruption. This was followed by a strong earthquake and a loud roar, after which a lava flow began to emerge from a vent on the side of Vesuvius. Subsequently, several other vents opened along a linear fracture. The eruption did not start from the central cone of Vesuvius but from various fractures that opened along its sides. Several written accounts and illustrations describe effusive and explosive phenomena during the eruption. The initial lava flow headed towards Ercolano and then shifted towards Torre del Greco, leading to the evacuation of the town and significant property losses. In a letter reported in [116], the story tells of three victims. The text mentions "at least two memorable deaths" of two sick men, not including the wife of one of them, who remained by her husband's side. Her gesture is recognized as a "rare modern-day example of conjugal love". On the 16th, the central crater began to erupt, while the activity of the lateral vents ended on the 19th. The erupted ashes reached as far as Naples, Caserta, and Avellino. On the 18th, an imposing ash cloud is described and depicted, probably similar to that of 79 AD, even if small in size. Beyond the ashes, small pumice and volcanic sands erupted. In [114], a detailed description of the eruption is reported through writings of the time. The explosive activity lasted until 30 June. The lava flow buried a large part of the town. In [119], a detailed representation of the city of Torre del Greco immediately after the eruption is presented. The map, representing important evidence of the eruption and its effects on the territory, highlights that at least two-thirds of the city was buried by lava. The map is also accompanied by a graphic representation of the situation from the sea; a description of the places affected by the lava flow (Figure 9, https://dspace.oszk.hu/handle/20.500.12346/93948?locale, accessed on 15 April 2024); and much information relating to the places and inhabitants, estimated at around 18,000 souls. The map provides a detailed picture of the urban layout at the time of the eruption. In [118] a detailed description of the map and the places is represented, also providing information relating to the speleological investigations carried out and reporting, in some places, the presence of volcanic deposits that can be correlated to the previous eruption of 1631. The lava flow interrupts the Strada Regia and creates a large bump, still easily identifiable in the city fabric today.

- No Geo context

The original name Torre Ottava has ancient origins, dating back to the construction of a watchtower (Turris octava) during the reign of Federico II. Another hypothesis connects it to the Roman miles, which is supported by citations in documents predating Federico II's reign (1018 Turre de hoctaba, 1129 Turris de Octavo, 1267 Torre de Octava, as reported in [120]) and by the discovery of two road columns also mentioned in the Tabula Peutingeriana (IV Roman mile found in S. Giovanni a Teduccio, VI Roman mile found in Resina, as reported in [121]; note that the distance between the current Resina and Torre del Greco is approximately 2 miles. The word "Greco" appears in a document from 1324 and refers to Greco wine, widely cultivated and highly appreciated [120]. This area has been known for cultivating vines since Roman times, as evidenced by paintings found in Pompeii. Over the centuries, Torre del Greco has developed in terms of urbanization and commerce, especially in fishing and coral collection [122,123]. The shipyards in Torre del Greco were well known and appreciated for building fishing boats and boats for coral collection [124]. Local naval carpentry participated in building the ships for the colossal Cleopatra in 1962 (Cantieri Di Donato) and constructing the S. Giuseppe Due (1967–1968 Cantieri Palomba), which was used for the first Italian expedition to Antarctica. The tradition of coral collection in the Gulf of Naples dates back to ancient times. By the 1600s, coral collection had become the primary economic activity in Torre del Greco. The processing of coral began in the early 19th century, leading to the economic development of the city. Skilled artisans transformed coral (red gold) into highly sought-after jewelry and decorations. This tradition continues to the present day, showcased by the expertise of master engravers. The municipality's motto, "Post fata resurgo", reflects the resilience of the population in overcoming destructive volcanic events and rebuilding the city.

Figure 9. Ciofi D. (1794)—Pianta della Citta della Torre del Greco distrutta dell'Eruzione del 1794. Source: https://dspace.oszk.hu/handle/20.500.12346/93948?locale (accessed on 15 April 2024).

Historical background

There are many aspects that have characterized the evolution over time of the Torre del Greco area and its population. During the Roman period before 79 AD, the territory showed intense human activity, as evident from excavations that revealed ports, maritime and internal villas, rustic villas dedicated to wine production, and flourishing commercial activity. The fertile soil of the Vesuvian territory was cultivated and renowned for its beauty and healthiness. After the eruption of 79 AD, the area likely remained uninhabited for a long time before hosting small settlements. The area's history reflects typical southern center challenges, including wars, disputes for local power, and invasions, often interrupted by short periods of stability. The area also endured the impact of Somma-Vesuvius eruptions, recorded in historical chronicles. Notably, there was a substantial Muslim presence from the end of the Roman Empire until the period of the Duchy of Naples. In the 1400s, the Torre Ottava farmhouse, part of the Kingdom of Naples, was repeatedly offered as collateral for substantial loans, underscoring the wealth and economic significance of the territory. In 1699, the city became Royal State Property. During the Bourbon era, several magnificent villas, such as the Ville del Miglio d'Oro (Villas of the Golden Mile), were constructed, serving as splendid examples of eighteenth-century architecture.

Archaeology

Although little known, several pre-79 AD archaeological sites are present and studied. These are rustic and maritime villas, as well as thermae, in emerged [110,125–145] or submerged [102] areas. Among these, Villa Sora is a Roman villa that dates back to the 1st century AD. This period was characterized by luxury and Greco-Roman architecture along the Gulf of Naples coast, which was filled with luxurious maritime villas. The villa was initially situated on the outskirts of Ercolaneum, at a time when Torre del Greco had not yet emerged as an independent settlement. Geoarchaeological studies [101–103,105–109] contribute to outlining the evolutionary history of places and people, highlighting people's correlation with the changing territory over time.

Urban fabric

The Vesuvian area has a high population density. The existing urban fabric of Torre del Greco reflects the significant impact of ongoing destructive natural events such as eruptions and earthquakes. This is in addition to the historical impact of invasions, wars, famines, and plagues. Throughout the centuries, the urban layout has been destroyed and rebuilt numerous times. Before the eruption of 79 AD, the urban area was likely comprised of both coastal and inland villas, as well as agricultural villas. These were isolated yet connected by main communication routes to the main cities and by secondary roads to more internal areas. The subsequent eruptions of Somma-Vesuvius have periodically, and partially or completely, destroyed the buildings, leading the inhabitants to temporarily abandon them before returning and rebuilding, adapting to the changes in the landscape caused by the volcanic events. Detailed information about the town and its development can be found in [128]. In the current urban layout, the oldest areas exhibit a medieval-style organization. The historical buildings built before 1920 were primarily constructed of sack masonry, tuff, and squared lava stone. School buildings from the period 1920–1960 were made of tuff and lava stone masonry [146,147], while buildings constructed after the 1960s used reinforced concrete.

Urban Built heritage

There have been numerous eruptions of Somma-Vesuvius that have significantly altered the landscape with lava flows, burying homes, churches, and streets. Many remnants of the city from different centuries can still be seen today. This includes the Roman villas buried by the eruption of 79 AD, such as Villa Sora. The following list, although not exhaustive of the built urban heritage, provides an idea of the city's potential from a historical and cultural point of view. The Baronial Palace, believed to have been constructed around 1400 on a hill overlooking the sea and close to a watercourse, was damaged and reconstructed after the earthquake of 1456. It managed to partially withstand the eruption of 1631, which led to the coastline advancing and the river being buried, thanks to its elevated position. The eruption of 1794 further pushed the coastline forward and caused damage to the palace. The Epitaph was built after the devastating eruption of 1631. The Fountain of 100 Fountains (Figure 10a), constructed in 1783 to harness a natural water source, was buried by the eruption of 1794, rebuilt, and drained following the 1861 eruption. The bell tower of the Basilica of Santa Croce is the remnants of a church that was buried during the eruption of 1794; only the upper part of the bell tower remains. The church of the Assumption was also buried during the 1794 eruption and rebuilt in the same location, with some preserved areas beneath the volcanic materials, which have been the subject of speleological expeditions. The church of Santa Maria del Principio was similarly buried during the 1794 eruption and rebuilt in the same place, preserving an underground chapel from the original building (Figure 10b).

Figure 10. (**a**) The Fountain of 100 Fountains. Source: https://fondoambiente.it/luoghi/fontana-delle-cento-fontane?ldc (accessed on 5 April 2024). (**b**) Underground chapel in the church of Santa Maria del Principio. Photo S. Cozzolino.

Vulnerability

The vulnerability of buildings is related to natural factors mentioned earlier, as well as factors associated with their age, natural deterioration of materials, and the requirements for regular and special maintenance and necessary safety precautions

3.2. Data Processing and Action Planning

The selected areas encompass a wide range of topics that can be interconnected using geo elements as a unifying theme. These themes include the relationship between humans and the environment and natural hazards; the impact of human activities and actions on the landscape; as well as human perception of the environment, landscape modification, and risk. Among the various topics, those that best fit into a Street Geology discussion for the selected areas concern (i) the knowledge of the territory/environment/landscape and its natural components, (ii) the valorization of the natural and historical-cultural heritage, and (iii) the implementation of heritage awareness among citizens. The available data were then processed and organized following these topics, appropriately adapted to the two urban realities considered. Although very different in terms of both geo and non-geo contexts, these urban realities represent an example of how it is possible to follow a common procedure to achieve the targets. What? concerns the main object around which the valorization and knowledge path is built. It is about "What" is used to achieve the targets, represented here by the Longobard Walls for the city of Benevento, and by the Church of Santa Maria del Principio for the city of Torre dell Greco. The Longobard Walls have been chosen as a means of dissemination due to their historical significance, easy accessibility, and potential for introducing themes related to flood hazards. They serve as an example of the "reuse of available materials" and can be seen as a puzzle of urban fabrics. In some sites, they are integrated with previous buildings, while in others, they are integrated into subsequent buildings as well. The Church of Santa Maria del Principio has been chosen due to its historical and cultural value and for the possibility of observing outcrops of the lava from 1794. Inside the church, a staircase flanked by bodies of lava leads to an hypogea chapel characterized by a suggestive and unique lava vault. The chosen Time Target is the current time, as we experience these elements today for both sites. These are just examples, non-exhaustive of the cities' potential; they are there for all to see, even if citizens and tourists sometimes look at them without seeing.

Step 02—What?

(a) Benevento: The Longobard Walls

The urban landscape of the Roman settlement was significantly affected by natural disasters like the powerful earthquakes of 346 and 375, as well as invasions by the Visigoths, Vandals, and Ostrogoths in the 5th century. It was likely surrounded by a city wall, which was destroyed in 545 by Totila. In the late 6th century, the Longobards' arrival in Benevento caused significant changes in the city's layout, although the main Roman layout was preserved. The defensive city walls were rebuilt. Initially, the city walls only enclosed the hilly part of the current historical center. In the 8th century, the walls were extended to include the area where the Roman Theater was located. Another expansion took place in 926, encompassing the ancient Porta Somma, which is now part of the Rocca dei Rettori complex. The walls were constructed using locally available materials, mainly the remains of Roman homes and temples (Figure 11(a1,a2,b)).

The construction materials included worked stone blocks and river pebbles (https://web.archive.org/web/20111115222550/http://www.ambientece.arti.beniculturali.it/soprintendenza/didattica/2006-07/Castelli%20e%20borghi/Il%20paramento.htm, accessed on 15 February 2024). The former are represented by squared blocks with dimensions varying from 10 to >100 cm; squared and irregular blocks with inscriptions; worked blocks; and sculptural remains. The latter are represented by river pebbles presumably coming from the river terrace on which the settlement stands or taken from the valley floor of the time (Figure 11c,d). At the base of the wall, there are sometimes large blocks of yellow tuff (Figure 11e), likely remains of pre-existing structures, or coming from the walls of the ancient Cellarulo area. Note the absence of the latter material in subsequent constructions. In the walls, there are also remains of bricks and tiles inserted, sometimes regularly, sometimes irregularly, and sometimes to fill limited areas. The city wall featured an alternation of towers according to the medieval defensive technique. Over the centuries, various reconstruction and restoration interventions have been carried out. The Longobard Walls represent a distinctive sign of the city, well known to the citizens and a tourist destination. Recently, a system of soft projection lights enhanced its particularity and suggestive beauty.

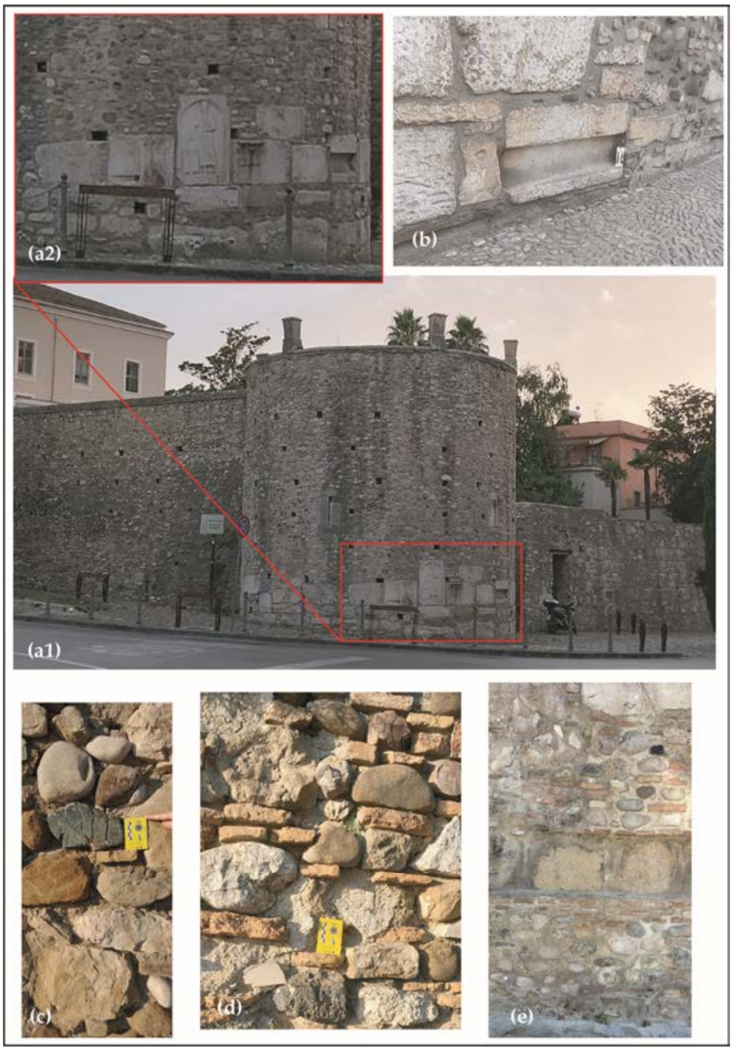

Figure 11. The Longobard Walls. (**a1**) Viale dei Rettori; (**a2**,**b**) details showing the Roman remains; (**c**–**e**) details showing the different types of rocks present in the walls. Photo D. Pescatore.

(b) Torre del Greco

- The Church of Santa Maria del Principio

Around the year 1000, a votive shrine was built near the sea, before the eruptions of Somma-Vesuvius modified the coastline, featuring a painting of the Madonna with her hands open forward the sea; it was subsequently incorporated into a church dedicated to the Madonna del Principio [148]. In 1794, during a volcanic eruption, lava buried the church. After the eruption, the citizens returned and saw blue flames, which they interpreted as an apparition of the Madonna. They took this as a sign to dig underground. Despite the danger of gaseous fumes, they excavated and found the church's remains, along with the intact painting of the Madonna. This was seen as a miracle and a message to rebuild the church and the town. The church was reconstructed on the lava flow (Figure 12a), preserving access to the underground chapel (Figure 12b,c). Visitors to this underground area can see the nearby 1794 lava flow and its unique formation, including the shrine, which was climbed over by the lava (Figure 12d). The church is known as Church of Sant'Anna and is a pilgrimage destination for women asking grace for pregnancy and for protection during pregnancy and for the baby.

Figure 12. The church of Santa Maria del Principio. (**a**) Preset-day church; (**b**,**c**) lava outcrops along the stairs leading to the buried chapel; (**d**) the shrine and its lava vault, Mirko Gallo to the left and Ciro Langella to the right. Photo S. Cozzolino.

3.3. Action Implementation

Action implementation concerns how goals and targets are achieved. It is assumed that there is no single way to reach the target, but rather different ways mainly linked to the training of those who develop and propose action. The suggestions below are based on the authors' personal experience. The two selected cities, which differ in geology, history, culture, and vulnerability, are linked by the potential for a comprehensive discussion. This discussion combines geological and historical-cultural elements to increase territorial understanding for both residents and tourists. In a time when paper has been replaced by digital, it may seem outdated to suggest using panels and brochures. However, information panels still play an important role for those who visit a site of interest and seek more information. Information panels can be made more advanced by incorporating technology such as QR codes to provide additional information. This additional information can include not only text, but also images and videos. For the purposes of this paper, panels containing brief general information, with the option to access more detailed content, have been created. These panels can be placed as information panels in key locations or made available on the municipality's official website. In the first case, further content can be accessed via a QR code, and in the second case, via links. Panels are presented in a graphic format, attesting that a different format allows for the modulation of contents and text.

Step 03—How?

(a) Benevento

Figure A3 in Appendix A, represents an example of an explicative panel. It is organized to provide a wide vision of the Longobards Walls by using a published scheme. Basic information concerning geology and physical geography are presented as schemes and brief text, and additional information will be available and accessible using links. The content is designed to provide basic information first and then delve into more detailed information, organized and developed at various levels in terms of content and language. Considering that this figure is presented in A4 format, the contents may seem too crowded.

The figure depicts what we consider to be fundamental concepts for describing what is observed and introducing geological issues. In the future implementation phase, there will be more space available to avoid the crowding effect. We will also assess whether to keep all the topics in a single panel or divide them into several panels, such as along a tourist route. Figure A4 represents an example of further activities related to the Longobards Walls. There are activities aimed at involving the observer in "Search and Find" (Figure A4a in Appendix A), encouraging the publication of photos and giving the possibility of having more information about the photographed objects. Interactive activities such as "Look and play" associated with individual objects are also possible (Figure A4b in Appendix A). In this scenario, the activities consist of progressing through interconnected levels and then deciding whether to continue playing or reading the detailed information. Figure A4b illustrates a multilevel game concept that requires some imagination. Imagine a QR code placed next to an element X. Scanning the QR code brings up a screen with the question "What is this? Let's play!" along with multiple choice options, presented in green text in Figure A4b. The player selects an answer. Choosing an incorrect answer prompts the player to try again. We have intentionally excluded wrong answers and only provided partially correct ones; probably in the future we will add funny wrong answers such as "It looks like my mama meatball!". A correct answer advances the player to the next level, indicated by text in cyan, orange, purple, or brown, or green if it takes them back to the previous level. Once the element is correctly defined, the player can progress to the next level that involves more detailed topics to Read or Play. Also in this case, the detailed information should be organized and developed at various levels in terms of content and language. As an example, the content for "Why were the Longobards Walls built there?" can be found in Figure A5a for Read and Figure A5b for Play, in Appendix A. In Figure A5b, a multilevel game concept is depicted. The image presents a hypothesis that requires some imagination. The player is represented by the red figure and has to choose a location for their settlement in the Benevento territory. There are several possible sites available, numbered from 1 to 4. The player then chooses a site for their settlement, and something happens, explained by a text related to the chosen site. Finally, the possibility to access more detailed information is available using the "Link to" option. In Figure A6 (Appendix A), a schematic representation concerning the topic of Risk is presented. Figure A6a,b repeat the basic concept presented in Figure A2. Figure A6(c1) provides a schematization for the analyzed cities. A concise overview of Flood Risk is provided in Figure A6(c2), with the main expected Question and Answer (Q&A). Additional information is supposed to be accessed through links associated with significative words in the text.

(b) Torre del Greco

On 15 and 16 June, activities were organized to commemorate the 230th anniversary of the 1794 eruption of Vesuvius. The event included guided tours led by geologist Mirko Gallo, who is a municipal councilor at the municipality of Torre del Greco, as well as local organizations for cultural and tourism promotion such as Wesuvio (https://www.wesuvio.it/, accessed on 15 April 2024) represented by Salvatore Esposito, and Free Spirits on Tour (https://www.facebook.com/FreeSpiritsOnTour/, accessed on 15 April 2024) represented by Sandra Cozzolino, involved in the Vesuvius Cycle Route Project. A cycling tour was organized to provide a sustainable way to explore the city and its unique spots, with participants having the opportunity to explore the lava outcrops that characterize the city (Figure 13a,b). The photos were taken as part of the "Città in Tutti i Sensi—Skilled Workers" project of the Free Spirits On Tour association. Additionally, visits to sites connected to the 1794 eruption, including caves and underground spaces, provided insight into the city's urban landscape before and after the eruption. Notably, the tour also included a visit to the hypogea of the Church of Santa Maria del Principio (Sant'Anna Hypogea, Figure 13c–e).

Figures A7 and A8 in Appendix A, represent examples of explicative panels, devoted to general information about the city and the 1794 eruption; further information will be available using links in the squared box. Also in this case, Figure A6(c1) focuses on the Natural Hazard and related Risk in the analyzed cities. A concise overview is provided in Figure A6(c3), associated with Q&A. As mentioned in the previous case, additional information is supposed to be accessed through the links associated with significant words in the text.

Figure 13. The cycling tour includes a visit to the 1794 lava outcropping and the church of Santa Maria del Principio. (**a**,**b**) Mirko Gallo explaining the outcropping lava; (**c**–**e**) the Sant'Anna Hypogea. Photos S. Cozzolino.

4. Discussion and Conclusions

In this paper, a procedure aimed at analyzing urban environments to highlight elements that could be used as tools for cultural dissemination is presented. The urban environment, often perceived as just a whole of human-related aspects, may represent an unusual occasion for the dissemination of several cultural issues. The proposed procedure consists of successive steps, starting with selecting the area to study, in which a multidisciplinary and multicultural value is recognized. This first step also includes defining the main parameters that will guide the activities. These parameters include the main target, the objectives to achieve it, and the end users and stakeholders. This initial step defines and motivates the reason for the choice (Step 00 Why?). After selecting the area, it is necessary to define its cultural contexts, distinguishing between the Geo context and No Geo context. This Step 01 Who? is dedicated to defining the main characteristics and peculiarities of Geo and No Geo contexts, as well as their potential correlations. In Step 02 What?, the activities focus on using the chosen element as a dissemination tool. They involve analyzing the element's aspects related to the Geo and No Geo contexts, selecting a time target, and defining and developing the possible arguments associated with it and their correlations. Step 03 "How?" is dedicated to preparing and making the results available. The preparation of the material cannot follow a single process, as the final material depends on the characteristics of the chosen area, the topics covered, and the technological know-how available. This procedure applies to every site where a multidisciplinary and multicultural approach is possible. Any site that contains cultural elements, whether studied and documented or not, can have interconnected elements that can be correlated along educational or tourist paths. These paths do not have to follow the geological context necessarily, but can instead follow the biological, historical, architectural, religious, or folkloric one, or what else characterizes the site.

Two urban environments, in the Campania region, Southern Italy, were selected to apply this methodology: Benevento and Torre del Greco.

Benevento is located in the inner part of the Campanian Apennines, at the confluence of two rivers. Geoarchaeological studies testified to the complex interplay between human settlement and environmental dynamics, represented mainly by river dynamics and seismic events; additionally, volcanic events related to the Phlegrean Fields and Somma-Vesuvius are present in the stratigraphic records characterizing the area. After analyzing the available elements, we decided to use the Longobard Walls as the means of dissemination. Initially, we were considering other options due to the presence of several archaeological sites with evidence of floods events, volcanic events, and earthquake damage. However, we chose the Longobard Walls because they are more easily identifiable and accessible compared to these archaeological sites. Figures A3–A6 represent the result of the activities developed. Figure A3 represents an explicative panel concerning the Longobard Walls and the main related geological issue represented by the geomorphological asset of the area, the natural river dynamics, and the definition of a drainage basin. Figures A4 and A5 represent a hypothesis for developing interactive activities. The activities require a dedicated online site, which is currently under development, where participants can upload content and interact. In Figure A4a, the "Seek and find" activity focuses on specific elements, prompting participants to search for them, take a photo, and post it. After posting, a brief description of the element is provided, and more details on related arguments are accessible via links. Also, the "Look and play" activity focuses on specific elements, guiding participants through interconnected levels where they can choose to continue playing or read more detailed information. In Figure A5, there is an example of this activity related to the question "Why were the Longobard Walls built there?" The "Read" box provides a brief answer to the question, with more detailed information accessible through links. The "Play" box presents a progressive play plane, where each choice corresponds to an event explained by related text. Again, more detailed information is accessible via links. The graphics presented in figures are basic and serve as a framework; the detailed development will be left to experts in this sector. These figures represent ideas, contents, and potential correlations. Expert IT developers will handle the implementation to create multifunctional gaming applications. The end user can choose to explore the topics covered in more detail. Typically, shorter and more concise texts are preferred. Finally, Figure A6 addresses potential questions and answers related to flood issues.

Torre del Greco is centrally located in the Gulf of Naples, on the slopes of the quiescent volcanic complex of Somma-Vesuvius. The current coastline has been formed by the deposition of volcanic materials from the early medieval and recent periods, leading to its migration by several hundred meters in certain instances. Geoarchaeological studies provide evidence of landscape changes caused by the activity of Somma-Vesuvius. The presence of maritime and agricultural villas buried by the Vesuvius eruption in 79 AD offers insight into the area's appearance before volcanic activity altered its landscape and affected human settlement. In the municipality's territory, there are several outcrops from various Vesuvius eruptions, as well as relics evidencing the urban fabric between the different eruptions. Initially, sites buried by the significant eruption of 79 AD, similar to Herculaneum and Pompeii, were selected for the activities. Later, a lesser known but equally fascinating element was chosen, the hypogea chapel of the Church of Santa Maria Del Principio. This chapel, buried by the lava flow of 1794, houses an ancient votive shrine that originally overlooked the sea. The chapel can be visited by crossing suggestive lava outcrops, which also constitute the current vault. The decision to utilize the hypogea chapel as a means of dissemination is in line with ongoing initiatives supported by the municipality of Torre del Greco. One of the authors is a municipal councilor actively involved in efforts to promote, protect, and raise awareness of the local known and lesser-known heritage. This aims to increase citizens' appreciation of their municipal heritage and involve them as active participants in sharing knowledge and building resilience. To achieve these goals, activities, along with local associations, have been conducted through a cycling guided tour to engage citizens in learning about the territory and its history. The citizens' participation in the tour, organized to commemorate the 230th anniversary of the 1794 eruption of Vesuvius, was notable, especially since it was the first of its kind. The participants displayed a keen interest and were intrigued by the topics covered during the excursion. They were eager to learn more about both the geological and non-geological aspects of their own territory, indicating a positive response overall. Additionally, the textual contents presented in Figures A7 and A8, which will be used for future activities also, have been created. This aspect of shared participation between the Municipality, local associations, suppliers of ideas and contents, and citizens is of fundamental importance for achieving the common objectives of dissemination; cultural growth; territorial awareness; and, last but not least, tourism promotion. For future plans, considering the Municipality's interest and availability, we intend to create content similar to the one for Benevento regarding the gaming aspect. We are also exploring the possibility of organizing a city treasure hunt.

The two selected urban environments are very different, both in terms of geographical location and geological, geomorphological, historical, and cultural context. They were chosen precisely because of these differences, to test the applicability of the procedure used. What they have in common is the presence of elements that can be used to create geological educational-informative or tourist itineraries. While writing this paper, the most challenging aspect was creating multidisciplinary content and using language that was not overly academic. It was important to avoid using technical terms and content that would not be suitable for the intended audience. The content and terms needed to be calibrated to align with the presumed end user.

In summary, with regards to the urban environment, the procedure aims to define, describe, and link it to its various cultural aspects, approaching it from a geological perspective. The procedure is also designed to guide end users through the process of acquiring data and gaining insights, and it can also assist local administrations in identifying specific or general issues concerning urban heritage valorization actions and any protection measures. It is trivial that for geologists, the geological context is the keystone that supports discussions on the enhancement, protection, and dissemination of both geoscience and territorial and cultural items. The same goes for other contexts, because it may be the historical, biological, architectonical, or cultural context that constitutes the keystone around which to build contents linked to other contexts. The real keystone is the possibility of linking several contexts with the same final aims, which is to improve territorial citizen awareness and promote tourism development. Collaboration and participation of citizens, local administrations, and organizations, along with the involvement of specific professional roles in local administrations, are also essential.

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Appendix A

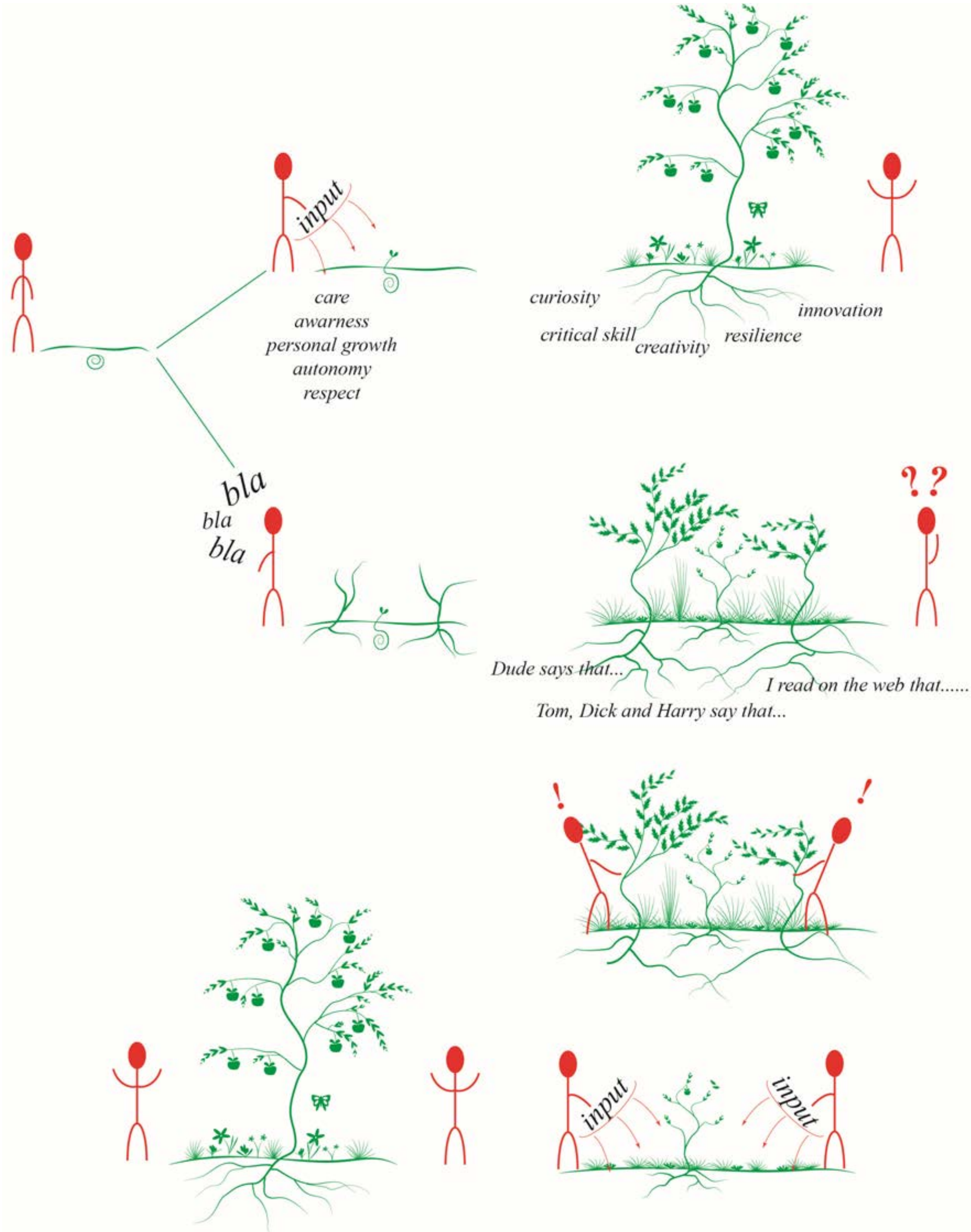
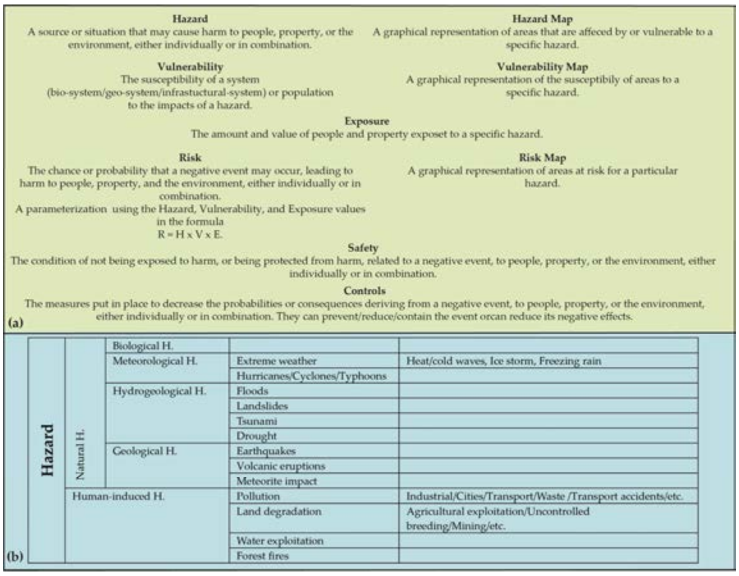


Figure A1. Simplified scheme showing how providing the necessary support (input) is fundamental to promote personal growth and independent thinking. The metaphor in the figure illustrates how, just like a seed that will bear good fruit when properly cared for, individuals can achieve personal growth through adequate support. Proper guidance is essential for developing critical thinking and the qualities needed for individuals to thrive in harmony with their environment. Without this support, there may be an increase in unsubstantiated claims, prejudices, and fake news, hindering the growth process and requiring further interventions to achieve the same results that can be attained with proper initial support and input.



Hazard
A source or situation that may cause harm to people, property, or the environment, either individually or in combination.

Hazard Map
A graphical representation of areas that are affeced by or vulnerable to a specific hazard.

Vulnerability
The susceptibility of a system (bio-system/geo-system/infrastuctural-system) or population to the impacts of a hazard.

Vulnerability Map
A graphical representation of the susceptibily of areas to a specific hazard.

Exposure
The amount and value of people and property exposet to a specific hazard.

Risk
The chance or probability that a negative event may occur, leading to harm to people, property, and the environment, either individually or in combination.
A parameterization using the Hazard, Vulnerability, and Exposure values in the formula
R = H x V x E.

Risk Map
A graphical representation of areas at risk for a particular hazard.

Safety
The condition of not being exposed to harm, or being protected from harm, related to a negative event, to people, property, or the environment, either individually or in combination.

Controls
The measures put in place to decrease the probabilities or consequences deriving from a negative event, to people, property, or the environment, either individually or in combination. They can prevent/reduce/contain the event orcan reduce its negative effects.

(a)

Hazard	Natural H.	Biological H.		
		Meteorological H.	Extreme weather	Heat/cold waves, Ice storm, Freezing rain
			Hurricanes/Cyclones/Typhoons	
		Hydrogeological H.	Floods	
			Landslides	
			Tsunami	
			Drought	
		Geological H.	Earthquakes	
			Volcanic eruptions	
			Meteorite impact	
	Human-induced H.		Pollution	Industrial/Cities/Transport/Waste /Transport accidents/etc.
			Land degradation	Agricultural exploitation/Uncontrolled breeding/Mining/etc.
			Water exploitation	
			Forest fires	

(b)

Figure A2. Simplified scheme regarding the main concepts and issues concerning vulnerability, hazards, and risk. In (**a**) a simplified glossary related to hazards, vulnerability, and risk, along with their corresponding maps, is presented. In (**b**) the main natural and human-induced hazards are outlined.

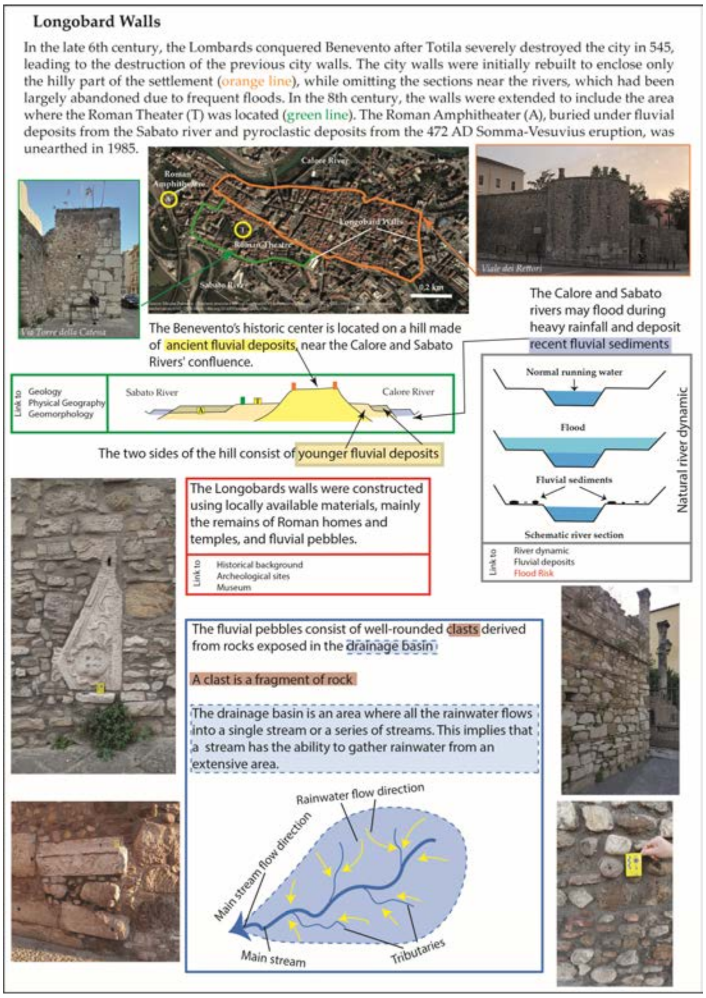


Figure A3. Example of an explicative panel regarding the Longobard Walls and related geological issues. The green box contains information about geological issues, including links for further details.

The red box contains information about the historical-archaeological context, with links for further details. The blue box represents a simplified illustration of a drainage basin and its main characteristics. The figure in the gray box illustrates the natural dynamic evolution of a watercourse, including episodes of flooding. It also has external links for more detailed information, including the risk (red text) shown in Figure A2.

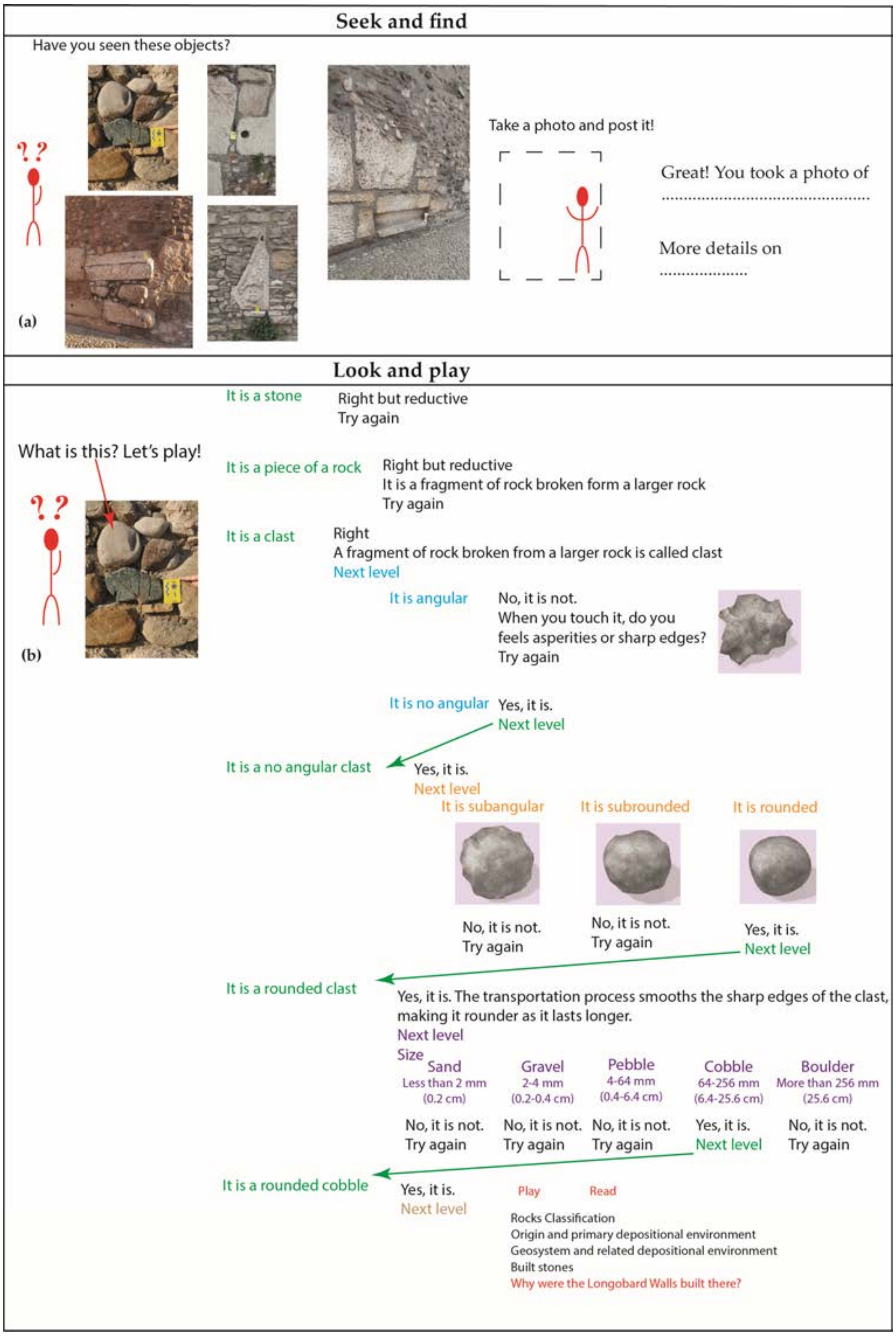


Figure A4. Example of an explicative panel regarding the Longobard Walls and activities of (**a**) Seek and Play and (**b**) Look and Play. Further information is available in the text. The red text (Play, Read, Why were the Longobard Walls built there?) refers to Figure A5.

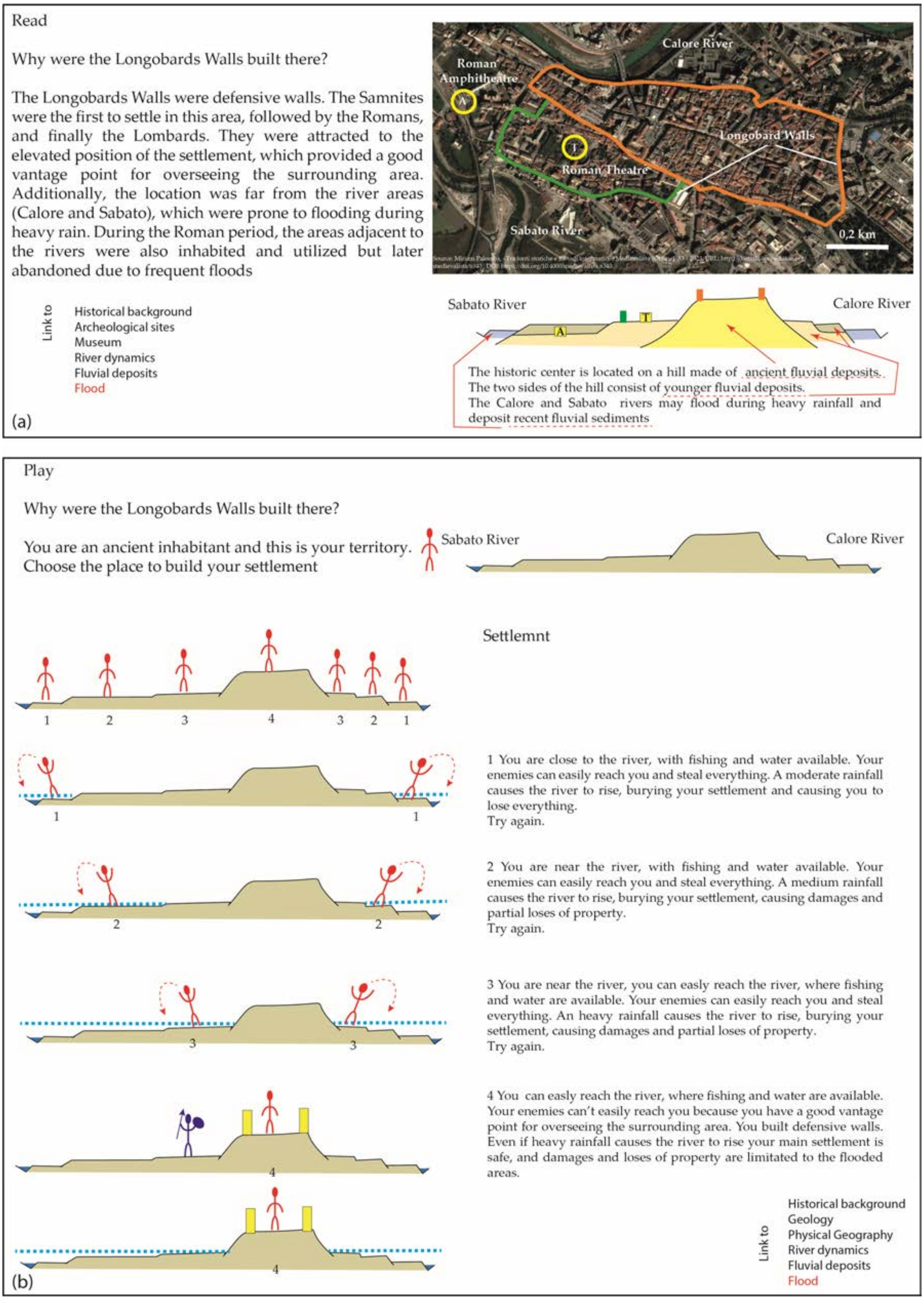


Figure A5. Example of an explicative panel regarding the activities linked to "Why were the Longobard Walls built there?" for (**a**) Read and (**b**) Play. Further information is available in the text. The red text (Flood) refers to Figure A6a,b,c1,c2.

Hazard
A source or situation that may cause harm to people, property, or the environment, either individually or in combination.

Hazard Map
A graphical representation of areas that are affeced by or vulnerable to a specific hazard.

Vulnerability
The susceptibility of a system (bio-system/geo-system/infrastuctural-system) or population to the impacts of a hazard.

Vulnerability Map
A graphical representation of the susceptibily of areas to a specific hazard.

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The chance or probability that a negative event may occur, leading to harm to people, property, and the environment, either individually or in combination.
A parameterization using the Hazard, Vulnerability, and Exposure values in the formula
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(a)

Hazard	Natural H.	Biological H.		
		Meteorological H.	Extreme weather	Heat/cold waves, Ice storm, Freezing rain
			Hurricanes/Cyclones/Typhoons	
		Hydrogeological H.	Floods	
			Landslides	
			Tsunami	
			Drought	
		Geological H.	Earthquakes	
			Volcanic eruptions	
			Meteorite impact	
	Human-induced H.		Pollution	Industrial/Cities/Transport/Waste /Transport accidents/etc.
			Land degradation	Agricultural exploitation/Uncontrolled breeding/Mining/etc.
			Water exploitation	
			Forest fires	

(b)

						Analysed cities	
Natural Hazard	Hydrogeological H.	Floods		Hydrogeological R.	**Risk**	Benevento	Torre del Greco
		Landslides					
	Geological H.	Earthquakes		Seismic R.			
		Volcanic eruptions		Volcanic R.			

c1)

Benevento	Benevento is situated near the confluence of the Sabato and Calore rivers, downstream from the confluence of the Tammaro and Calore rivers. Several historical flood events have impacted the Benevento area, as evidenced by ancient flood events in the Cellarulo archeological area and the Roman Amphitheatre area. Among these events, the floods of October 1949, October 1961, and October 2015 are remembered for their impact on the city and its surrounding areas. The events caused serious damage to infrastructure, buildings, and local agriculture.	
Q&A	What is a flood?	A flood is an event that occurs when an excessive amount of water in a stream or river surpasses its normal limits, causing overflow onto typically dry land, often representing ancient floodplains.
	Which areas can be affected by a flood?	Floods can affect different areas based on the amount of water. Initially, the areas closest to the watercourse are impacted. As the volume of water rises, the affected areas can gradually expand to cover larger areas.
	How can I know if there will be a flood?	If you are wondering how to predict a flood, it's important to note that a flood requires the presence of a river or stream. If you live in an area without a river or stream, the likelihood of a flood is low. However, if there is a river or stream nearby, even if it's not very close to you or underground, it's crucial to pay attention to meteorological alerts and communication and to follow the instructions of local authorities.
	What should I do when there is a weather warning for flood risk?	If you live in an area that has previously experienced floods, it is best to avoid cellars, underground garages, basements, ground floors, underpasses, areas close to embankments and bridges, as well as areas that are lower than the surrounding area. Follow the instructions of local authorities.

c2)

Torre del Greco	Torre del Greco is situated on the southwestern slope of the Somma Vesuvius volcanic complex. The city's layout bears the marks of frequent destructive natural events represented by eruptions. Before the eruption of 79 AD, the urban area likely consisted of coastal and inland villas, as well as agricultural villas. Subsequent eruptions of Somma Vesuvius have intermittently and partially or completely destroyed buildings, causing inhabitants to temporarily abandon them before returning to rebuild and adapt to the changes in the landscape caused by the volcanic events. Since its last eruption in 1944, Vesuvius has been in a quiescent state, characterized by mild seismic and fumarolic activity.	
Q&A	What is a volcano?	A volcano is a landform similar to a mountain, formed as a result of fractures in the earth's crust through which magma, consisting of molten rocks, rises. Upon reaching the surface, the magma cools and solidifies. Volcanoes are primarily composed of solidified magma; their shape and height vary based on the eruption type and the erupting magma's characteristics.
	What is a volcanic complex?	A volcanic complex consists of two or more volcanic structures of different ages
	What does it mean "quiescent state"?	The quiescent state is a period during which no deep magma and fluid transfer occurs, no shallow magma and fluids accumulate, no shallow magma transfers to the surface, and mild seismicity and fumarolic activities are present. A volcano may transition from a state of quiescence to minor or major unrest, ultimately leading to an imminent eruption, or its activity may gradually diminish until becoming extinct.
	Is it possible to predict when the next eruption will happen?	It's not possible to know exactly when the next eruption will occur. However, constant 24/7 surveillance of Vesuvius allows to detect precursor phenomena that typically precede an eruption well in advance. This monitoring enables to initiate evacuation procedures before the eruption happens.

c3)

(c)

Figure A6. Example of an explicative panel regarding the topic of Risk. (**a**) Basic concepts; (**b**) hazard; (**c1**) topics related to the natural hazard and related risk in the analyzed cities; (**c2**) Benevento; (**c3**) Torre del Greco.

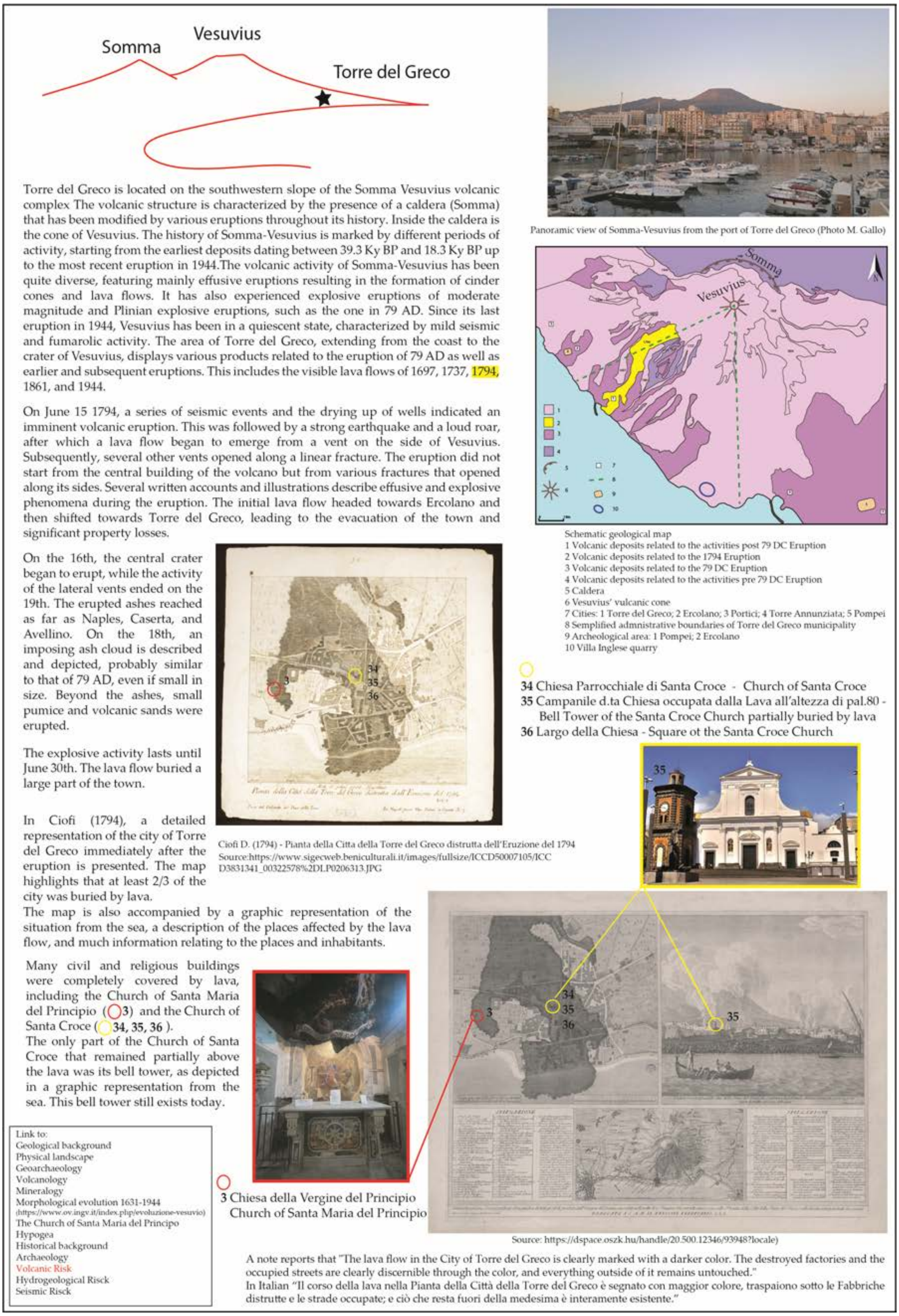
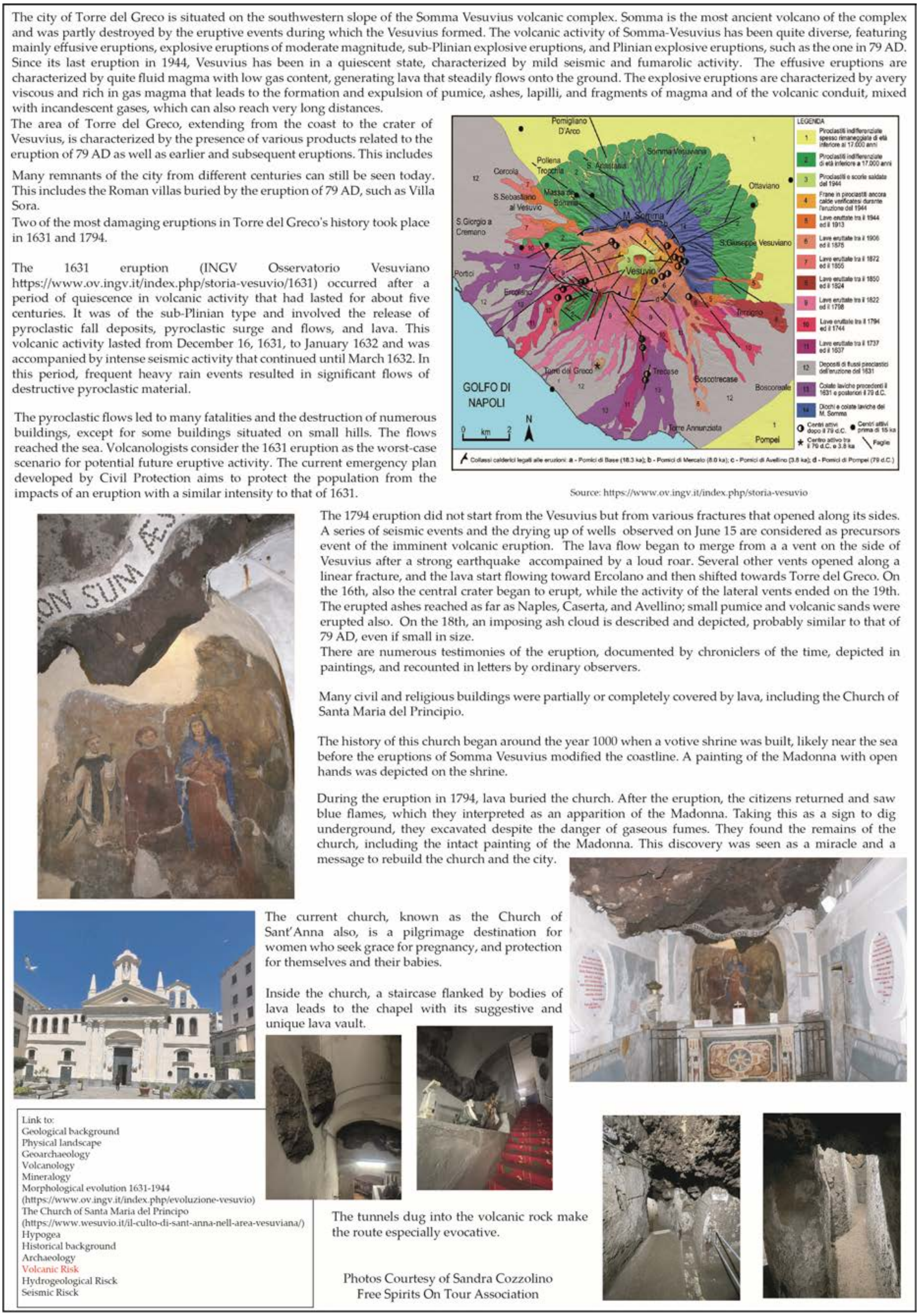


Figure A7. Example of an explicative panel regarding Torre del Greco and the 1794 eruption. The red text (Volcanic Risk) refers to Figure A6(a,b,c1,c3).



The city of Torre del Greco is situated on the southwestern slope of the Somma Vesuvius volcanic complex. Somma is the most ancient volcano of the complex and was partly destroyed by the eruptive events during which the Vesuvius formed. The volcanic activity of Somma-Vesuvius has been quite diverse, featuring mainly effusive eruptions, explosive eruptions of moderate magnitude, sub-Plinian explosive eruptions, and Plinian explosive eruptions, such as the one in 79 AD. Since its last eruption in 1944, Vesuvius has been in a quiescent state, characterized by mild seismic and fumarolic activity. The effusive eruptions are characterized by quite fluid magma with low gas content, generating lava that steadily flows onto the ground. The explosive eruptions are characterized by avery viscous and rich in gas magma that leads to the formation and expulsion of pumice, ashes, lapilli, and fragments of magma and of the volcanic conduit, mixed with incandescent gases, which can also reach very long distances.

The area of Torre del Greco, extending from the coast to the crater of Vesuvius, is characterized by the presence of various products related to the eruption of 79 AD as well as earlier and subsequent eruptions. This includes

Many remnants of the city from different centuries can still be seen today. This includes the Roman villas buried by the eruption of 79 AD, such as Villa Sora.

Two of the most damaging eruptions in Torre del Greco's history took place in 1631 and 1794.

The 1631 eruption (INGV Osservatorio Vesuviano https://www.ov.ingv.it/index.php/storia-vesuvio/1631) occurred after a period of quiescence in volcanic activity that had lasted for about five centuries. It was of the sub-Plinian type and involved the release of pyroclastic fall deposits, pyroclastic surge and flows, and lava. This volcanic activity lasted from December 16, 1631, to January 1632 and was accompanied by intense seismic activity that continued until March 1632. In this period, frequent heavy rain events resulted in significant flows of destructive pyroclastic material.

The pyroclastic flows led to many fatalities and the destruction of numerous buildings, except for some buildings situated on small hills. The flows reached the sea. Volcanologists consider the 1631 eruption as the worst-case scenario for potential future eruptive activity. The current emergency plan developed by Civil Protection aims to protect the population from the impacts of an eruption with a similar intensity to that of 1631.

Source: https://www.ov.ingv.it/index.php/storia-vesuvio

The 1794 eruption did not start from the Vesuvius but from various fractures that opened along its sides. A series of seismic events and the drying up of wells observed on June 15 are considered as precursors event of the imminent volcanic eruption. The lava flow began to merge from a a vent on the side of Vesuvius after a strong earthquake accompanied by a loud roar. Several other vents opened along a linear fracture, and the lava start flowing toward Ercolano and then shifted towards Torre del Greco. On the 16th, also the central crater began to erupt, while the activity of the lateral vents ended on the 19th. The erupted ashes reached as far as Naples, Caserta, and Avellino; small pumice and volcanic sands were erupted also. On the 18th, an imposing ash cloud is described and depicted, probably similar to that of 79 AD, even if small in size.

There are numerous testimonies of the eruption, documented by chroniclers of the time, depicted in paintings, and recounted in letters by ordinary observers.

Many civil and religious buildings were partially or completely covered by lava, including the Church of Santa Maria del Principio.

The history of this church began around the year 1000 when a votive shrine was built, likely near the sea before the eruptions of Somma Vesuvius modified the coastline. A painting of the Madonna with open hands was depicted on the shrine.

During the eruption in 1794, lava buried the church. After the eruption, the citizens returned and saw blue flames, which they interpreted as an apparition of the Madonna. Taking this as a sign to dig underground, they excavated despite the danger of gaseous fumes. They found the remains of the church, including the intact painting of the Madonna. This discovery was seen as a miracle and a message to rebuild the church and the city.

The current church, known as the Church of Sant'Anna also, is a pilgrimage destination for women who seek grace for pregnancy, and protection for themselves and their babies.

Inside the church, a staircase flanked by bodies of lava leads to the chapel with its suggestive and unique lava vault.

The tunnels dug into the volcanic rock make the route especially evocative.

Link to:
Geological background
Physical landscape
Geoarchaeology
Volcanology
Mineralogy
Morphological evolution 1631-1944 (https://www.ov.ingv.it/index.php/evoluzione-vesuvio)
The Church of Santa Maria del Principo (https://www.wesuvio.it/il-culto-di-sant-anna-nell-area-vesuviana/)
Hypogea
Historical background
Archaeology
Volcanic Risk
Hydrogeological Risck
Seismic Risck

Photos Courtesy of Sandra Cozzolino
Free Spirits On Tour Association

Figure A8. Example of an explicative panel concerning Torre del Greco and the 1794 eruption. The red text (Volcanic Risk) refers to Figure A6(a,b,c1,c3).

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