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The Geosites of the Sacred Rock of Acropolis (UNESCO World Heritage, Athens, Greece): Cultural and Geological Heritage Integrated

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Abstract: Athens, the capital of Greece, is notable for its distinctive environment. Numerous archaeological and historical monuments contribute to the city's cultural wealth. These cultural monuments should include geological monuments, which are part of Athens' natural heritage. The Acropolis of Athens is one of the world's most recognizable and admired monuments, renowned for its archaeological, historical, and touristic significance. The Acropolis Rock is also a spectacular geological heritage monument. This article is about the Acropolis monuments, which are of great geological interest in addition to their cultural value. In recognizing each monument's unique geological features and quantitatively evaluating them, in terms of educational, touristic, cultural, and accessibility value, we document their special value in geoeducation and geotourism, not only for the public, but also for the scientific community. The potential for exploiting these geosites, in terms of geotourism, is very high and important not only for strengthening the local economy, but also for raising visitor awareness of environmental, geological, and geoconservation issues. However, the lack of understanding of geological heritage in relation to cultural heritage is underlined. The need for strategic educational planning and integration of geo-environmental education into school practice is evident.

Keywords: Athens; Acropolis; geosites; quantitative assessment; geotourism; geoeducation

1. Introduction

Greece is one of the few regions on earth where geology has been the most important factor in shaping its unique and beautiful natural environment, as well as its social, economic and historical development from ancient times to the present day.

Indeed, complex geological processes are responsible for the genesis and evolution of the unique island complexes, the many kilometres of coastline and the landscapes of unusual beauty, for the unique climate conditions, for the soil which supports a wide variety of flora and fauna, for the mineral raw materials and, of course, for its culture. As a result, there has been a strong scientific movement in Greece in recent years to evidence its geological heritage and to manage its geosites (e.g., [1–5]), with studies aimed at recording geotopes in specific areas that represent important moments in the history of the country and our planet.

Furthermore, the emergence of another, alternative form of tourism, geotourism, has gained its own momentum and is seeking its own share in the country's economy. Geotopes, Geoparks and Natural History Museums are the best fields for geotourism activities and, therefore, geotourism could be an important opportunity for local community development and sustainability [6–9].

Geotourism is a “new” challenge, not only because it can redistribute the country's tourism products in areas that have not been tourist destinations to date, but also because it can create a new quality of tourist stream in the country.

Although, the term “urban geotourism” is relatively new, the use of geology, geomorphology and other associated man-made activities and features (building stones or anthropogenic landforms) within urban areas for tourism and education is much older.

Del Lama [10] defines urban geotourism as tourism in places anywhere within the boundaries of a city (whether in the form of built heritage or geological formations) related to geological concepts and characteristics. As evidenced by numerous publications and books from various parts of the world with diverse cultural and social environments, the number of studies highlighting the use of geodiversity and geological heritage in urban areas is growing, yet mainly focuses on European cities. The rest of the world remains rather “unexplored” in this respect [11,12].

Urban geodiversity is defined by Palacio-Prieto [13] as “buildings and other man-made features of the city that developed under specific geological conditions or that have undergone specific geological processes over time”. Such anthropogenic geodiversity elements can be beneficial to community cultural development, leading to the conclusion that cultural heritage associated with the abiotic, natural environment can be treated as a component of geocultural diversity and included in the urban geodiversity typology.

There are several classifications of urban geodiversity, but we focus on the one developed by Habibi et al. [11], who distinguished between *in situ* and *ex situ* geodiversity, which is consistent with other classifications [14] that include both *in situ* and displaced geodiversity features, such as those held in museum collections or used as building/decorative stones.

An “urban geotope” is defined as a place of geological or geomorphological interest within a city [15]. This location can be natural, originating from geological processes, or it can be the result of artificial constructions where characteristic rock types were used for their construction [13,16]. Urban geotopes highlight the relationship between geology-geomorphology and society. They are preserved not only because of their geological value, but also for aesthetic, cultural and economic reasons.

Urban geotopes usually occupy small territorial areas and their location depends on the size of the city, and its population, as well as its spatial structure. Therefore, only a few urban geoparks exist in the center of cities, while many of them are located on the outskirts of cities where there are more open spaces. As a result of their locations, they are more affected by anthropogenic activity, especially by urbanization. Some scholars refer to anthropogenic pressure to describe the urgency and necessity of their conservation [17].

In recent years, examples of geotourism with urban characteristics (urban geotourism) have appeared in many countries around the world, such as Brazil [18], which combines geological heritage with cultural heritage [19].

Athens, the capital of Greece, combines history and the past with modern reality. There are numerous archaeological and historical monuments which constitute the cultural wealth of the city. To these cultural monuments should also be added the geological monuments, which constitute the natural heritage of the country.

The city, although it gathers several important inherent advantages (such as archaeological sites, cultural heritage, and climatic conditions), fails to show itself as an attractive city break destination, mainly due to its functional disadvantages (it is not a tourist-friendly city, there is traffic congestion, high costs, an unattractive urban landscape, an absence of large conference spaces, etc.) and its lack of promotion. Whilst points of interest located in the area do exist, there is a decline in Attica’s position in the tourism sector [20].

However, especially for Athens, the potential of dynamic tourism development remains extremely favorable. The promotion of the geo-cultural heritage of the city, which is directly related to the preservation and protection of the environment, can strengthen and diversify the development of tourism, identity, culture, and interests of the local population.

The well-known Acropolis is an ancient temple complex standing atop a rocky outcropping in the heart of Athens. The Acropolis of Athens is one of the most impressive and recognizable monuments in the world, world-renowned and of exceptional archaeological, historical, and touristic value. At the same time, however, the Acropolis Rock is also an

admirable monument of geological heritage. Unfortunately, only a few people know that there are numerous and varied urban geosites within the sacred rock of Acropolis, reflecting its natural and cultural heritage, showing the connection between geology, geomorphology, and urban development, and which are interesting geotourist objects.

In this paper, we will deal with the monuments of the Acropolis, which, apart from their cultural value, are of high geological interest. The geotouristic potential of the city of Athens is highlighted through the identification and quantitative assessment of these geosites. The main goal of this assessment is to select the geosites that combine the best conditions for use in environmental education and that also have a high value for urban geotourism, due to their intrinsic value as representative geological sites, their connection with environmental issues (pollution, climate change, natural hazards, waste, and recycling, among others), and their accessibility conditions. The result of our study not only helps in scaling the regional tourism industry, adding value to tourism, but also reveals the geodiversity of the area, aiming at its geoconservation.

2. Material and Methods

The identification and assessment of geosites for geotourism was based on fieldwork and a detailed review of published literature and maps (both contemporary and historic). It not only focused on the traditionally accepted characteristics of geodiversity, but also covered aspects reflecting the interactions between geodiversity and culture.

According to today's holistic concept of geotourism, the inventory of geotourism resources should consider the following: (1) the natural features, geological, geomorphological, hydrological or paleontological, and ecological elements related to geodiversity and (2) the cultural aspects related to geodiversity and geographical heritage, e.g., churches and cemeteries, pavements and stone buildings or toponyms associated with geodiversity (e.g., [21]).

Particular attention was paid to anthropogenic landforms, which are of high interest, are very common in urban areas and have high potential for geotourism and education [22].

2.1. The City of Athens

Attica is one of the 13 regions of Greece and includes the Prefecture of Athens, which is the capital of the Attica region and of Greece (Figure 1).

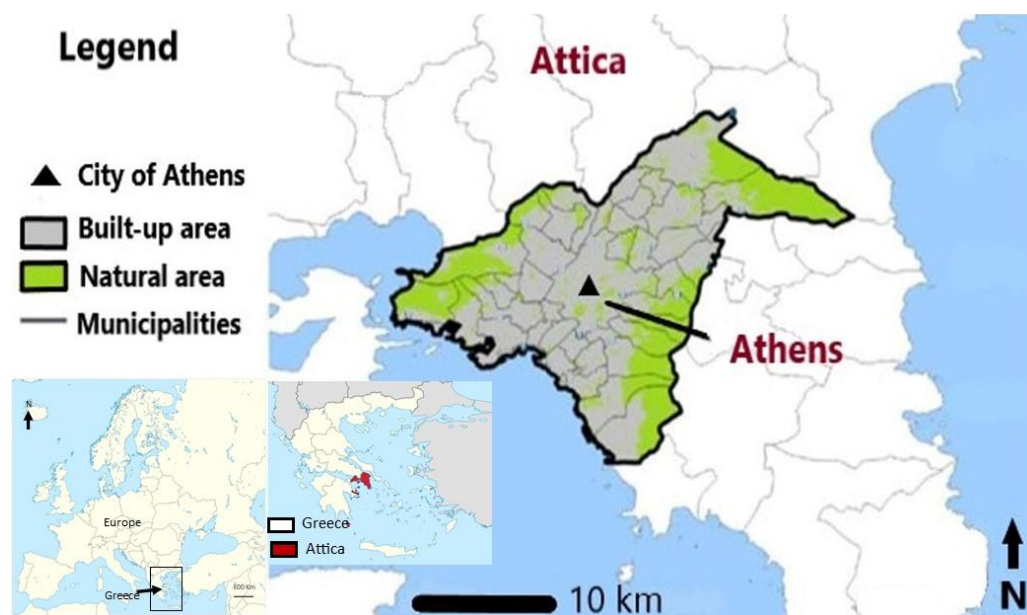


Figure 1. Map depicting the prefecture of Athens in Attica region. In insets, the location of Greece in Europe and the location of Attica region in Greece.

Athens is a heavily urbanized area with severe traffic problems, both in the city center and in its harbour, Piraeus. The settlement of Athens covers a total area of 414.6 km², including the entire city of Athens and the harbour of Piraeus, as well as its suburbs. It has a subtropical Mediterranean climate with mild winters and hot, dry summers.

In the first post-war decades, a rapid concentration of the population took place in the central and western parts of the city. Since the mid-1970s, urbanization has shifted to the suburbs in the northeast and southeast. Unlike most European capitals, the urbanization of modern Athens is not related to the industrial revolution.

The city's population grew rapidly from 400,000 people in 1925 to about 1,000,000 by 1950. The population growth of modern Athens was due to the return of Greek refugees from Asia Minor in the 1920s after World War I and extensive internal migration after World War II.

Today, the urban areas of Athens and Piraeus have a population of approximately 3.2 million inhabitants in an area of 412 km². This number corresponds to approximately 1/3 of the Greek population. The Attica region is home to nearly half of Greece's population, more than 60% of the country's industrial production, as well as high-value real estate and infrastructure. The population density (people per km²) is about 7500 and over 20,000 in some municipalities with a high frequency of residential, commercial, and business activities. There is no large-scale industry in Athens. Several industrial support services, including warehouses, commercial transport companies, and building materials yards, are located between Athens Center and Piraeus. Earlier industries in recent decades produced ceramics, textiles, footwear, and engaged in tanning and metallurgy.

Athens is mainly known for its ancient history and especially for the Golden Age of Pericles in 500 BC. Under his rule, Athens became the most powerful city-state in Greece. His main contribution was, of course, the establishment of democracy. Athens became the intellectual and artistic center of the ancient world. Among all other things, Pericles was also responsible for the construction of the Parthenon.

2.2. Geology–Geomorphology

The basin of Attica, also known as the basin of Athens, or the Athenian plain, is about 22 km long from NE to SW and 11 km wide across, and includes Athens, Piraeus and the municipalities of their surrounding suburbs. It is the most densely populated region of Greece. It is a large tectonic depression running NNE-SSW, bounded by Parnitha to the northwest, Pendeli to the northeast, Aegaleo and Poikilo to the west and Hymettus to the east, while the Saronikos Gulf opens up to the southwest (Figure 2).

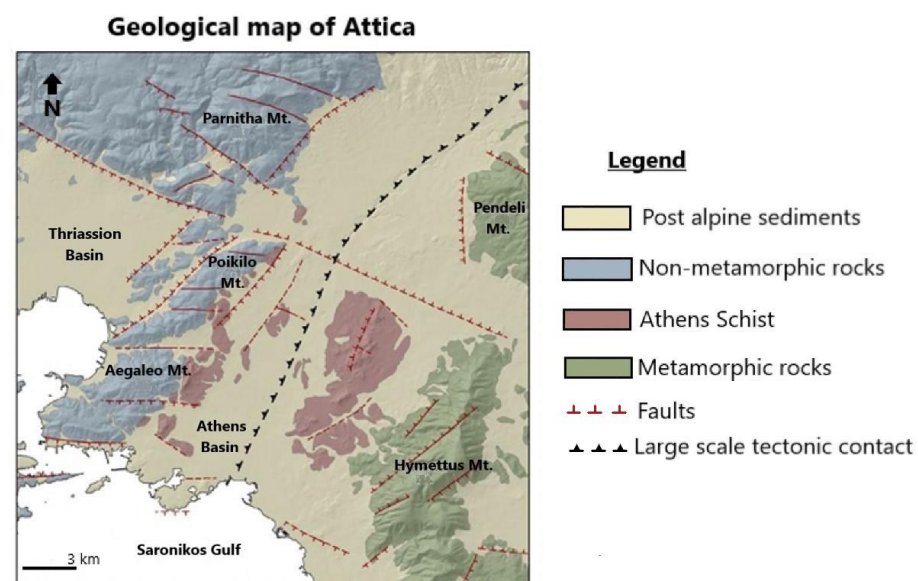


Figure 2. Simplified geological map of the basin of Attica [23], modified by us.

Inside the basin, a series of hills, the altitudes of which decreases towards the SW, has developed along the central axis in a NE-SW direction (Figure 3). The main ones, from north to south, are the Tourkovounia (339 m), Lykabettus (278 m), the Acropolis (156 m) and the Museum Hill or Filopappou (147 m), all made of a lowermost Upper Cretaceous (100 My) limestone, called locally the “Tourkovounia Formation” [24]. These hills have the same geological age and the same geological structure as the Acropolis hill.

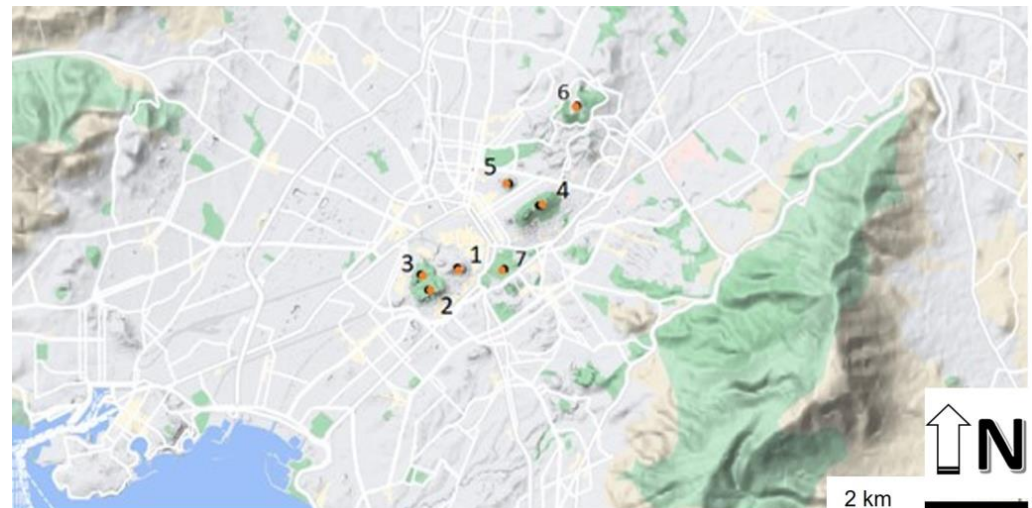


Figure 3. Satellite photo of Athens city indicating the location of the hills of the city. 1. Akropolis, 2. Filopappou 3. Hill of the Nymphs 4. Lycabettus 5. Hill of Strefi 6. Tourkovounia 7. Ardittos Hill.

The four hills located on the surface of the basin are rocky remnants of a previous relief and are characterised as “inselberg hills,” i.e., isolated hills [25]. There are also smaller ones, such as Ardittos (131 m), Strefi Hill, the Hill of the Nymphs, and Areios Pagos.

Pliocene marine deposits have been detected west of Lycabettus at a height of 120 m [26,27] and in the western part of Hymettus. In the area of Tourkovounia, clay deposits were found in the cracks and fractures of limestones, which chronologically belong to the Pleistocene [28].

The Attica basin is drained by two main hydrographic networks, the Kifissos and the Ilissos (Figure 4). Both hydrographic networks are characterised by the existence of mainly small and seasonal streams. Kifissos is the largest river in the region, 27 km long, originating from western Pendeli and southern Parnitha, flowing through the basin in a N-S direction into the bay of Faliro. Most of the river’s route was formed by the mid-20th century into an open channel, which was later covered by the national highway A1, meaning that the Kifissos River has been largely modified and covered by the continuous development of the urban fabric [29]. Ilissos originates from Hymettus and also flows into Faliro bay (Figure 4).



Figure 4. Map showing the hydrographic networks of Attica [30], modified by us.

Since the mid-18th century, several researchers have studied the geological setting of the Athens area [31–38]. Despite this, the understanding of Athens' lithostratigraphic structure remains incomplete.

The Attica Basin was formed during the Alpine orogeny. It is located in the back-arc area of the Hellenic Arc and comprises Alpine basement rocks, both metamorphic and non-metamorphic, and post-Alpine sediments (Figure 2). The alpine formations today form the mountains that surround the basin, as well as the hilly area in its centre (Filopappou, Acropolis, Lycabettus, Tourkovounia, etc.), while the post-alpine sediments, i.e., the sediments that have been deposited in the Athens basin after the uplift of the mountains, come mainly from the erosion of the latter.

The main rocks that make up the uplifted alpine formations are as follows:

1. The limestones of the western mountains (Aegaleo, Poikilo Oros, Parnitha). These are rocks formed about 200 million years ago, from deposits in a marine environment, indicating that the area was once a large ocean.
2. The metamorphic rocks of the eastern mountains (Hymettus, Pendeli). These are rocks that were metamorphosed under conditions of high pressure and temperature. The main ones are marbles (an example is the well-known Pendelic marble) and schists.
3. The "Athens schists", as they have come to be called, albeit somewhat misleadingly, because, in reality, they are a complex system of different rocks (pelites, argillaceous shales, marls, sandstones), formed on the sea bed during the uplift of the mountain

ranges mentioned above. The Athens schists are overlain, in some places, by relatively young limestone, forming hilltops (e.g., Acropolis, Lycabettus, Tourkovounia).

2.3. The Geology and Geomorphology of the Acropolis Hill

The Acropolis hill rises 156 m above sea level, while the perimeter ground rises between 60 and 70 m. When viewed from above, the ridge of the hill resembles the shape of an ellipse. The largest axis of this ellipse, which runs east-west, is estimated to be about 250 m long, while the smallest axis, which runs across the width of the rock, is about 150 m long (Figure 5).

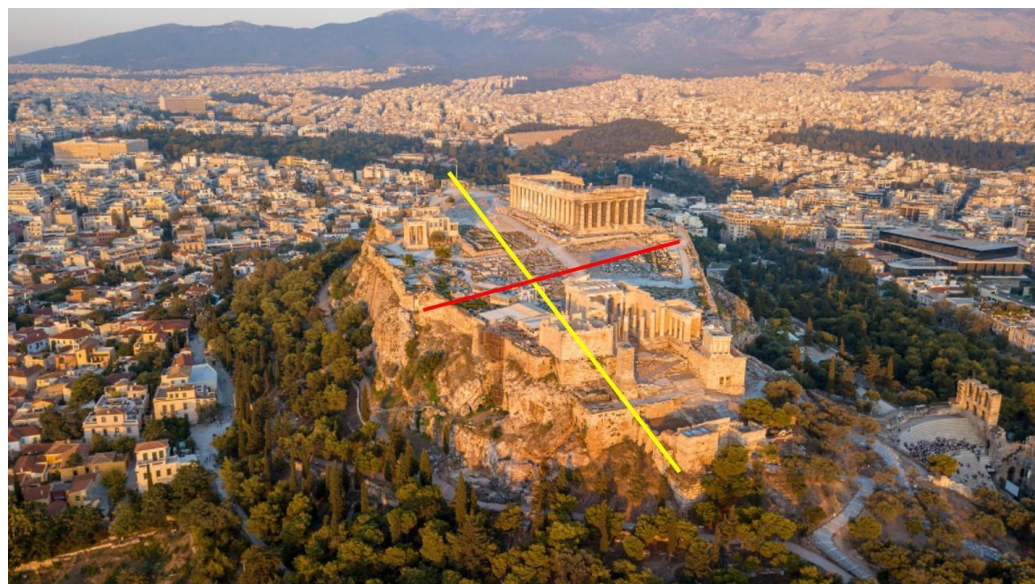


Figure 5. The hill of Acropolis which resembles the shape of an ellipse with its largest axis running east-west, of 250 m length (yellow line), and its smallest axis of about 150 m length (red line).

The lithostratigraphy of the Acropolis area is relatively simple. It is primarily made up of two lithostratigraphic units: the Athens schist and the Acropolis limestone [39].

The Athens schists are found in the basal zone of the area and at the base of the hillsides (Figure 6) and date back to the Cretaceous period (Maastrichtian to Eocene (?) in age) with the original sediments being deposited 72 million years ago, in a river delta. According to Marinou et al. [40] the Athens schist is a flyschoid phase of a delta-type deposit, which means that what we see today was once the talus of a huge river's delta. This formation has a distinct reddish color and is composed primarily of soft rock. The Athens schist is made up of a variety of low-grade metamorphic and relatively soft rocks. The stratigraphic formation was given its name because it covers a large portion of the city of Athens. The Athens Schist bedrock exhibits exceptional weathering, as well as intense folding, shearing, and extensional faulting, completing the structural “downgrading” of the rock mass.

The upper parts of the Acropolis hill (Figure 6) are made of limestone of the Cenomanian-Turonian age, about 30 million years older than the underlying Athens schist, that is no more than 40 m thick [39]. Compressional tectonic forces thrust the Acropolis limestone over the Athens schist, forming a nappe or overthrust sheet. Erosion of the limestone nappe caused the Acropolis to detach, resulting in the current feature. There are springs and karstic caves where the Athens schist and the limestone meet. The erosion of the same nappe that formed the Acropolis formed many of the hills in the Athens region. These include the Lycabettus, Areopagus, and Museum hills. The marble used to build the Acropolis came from the quarries of Mount Penteli, a mountain to the northeast of Athens [39,41].

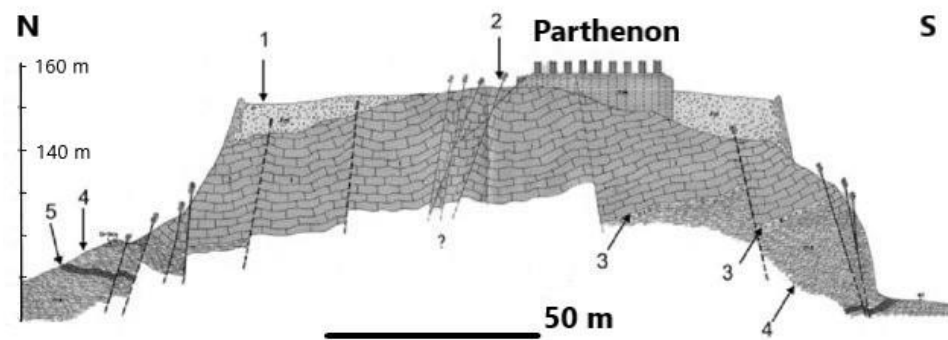


Figure 6. Geological section of the Acropolis hill, passing near the Klepsydra spring in the North, after Andronopoulos and Koukis [41], simplified; 1: artificial earth fill, 2: Upper Cretaceous limestones, 3: conglomerate, 4: the upper marly unit of the formation of the Athenian Schists composed of sandstones, limestones and marls, 5: limestones interbedded in the marly unit, ?: no data.

The geological composition and structure of the Acropolis Hill were crucial in its preservation. Perhaps it influenced human history as well, as we know that despite the major earthquakes that struck Attica during the historical years, this monument remained unaffected. Aside from the Parthenon, earlier and later buildings and constructions dating back over 2500 years have been preserved on the hill.

2.4. The Geosites of the Sacred Rock of Acropolis

The Sacred Rock of the Acropolis is an important urban geosite of archaeological, historical, ecological and geological interest [42], which has been designated a UNESCO World Heritage Site, since 1987. Acropolis and its monuments are global symbols of classical spirit and culture and constitute the largest architectural and artistic complex bequeathed by Greek antiquity to the world. Its monuments were developed by an extraordinary group of architects (such as Ictinus, Callicrates, and Mnisiklis) and sculptors (such as Phidias, Alcamenes, and Agoracritus), who transformed the rocky hill into a unique complex that heralded the emergence of classical Greek thought and art. The Acropolis hill, apart from its great archaeological and cultural value, also has very important geological value due to the numerous geosites it hosts.

In this study we will focus on the following geotopes (Figure 7):

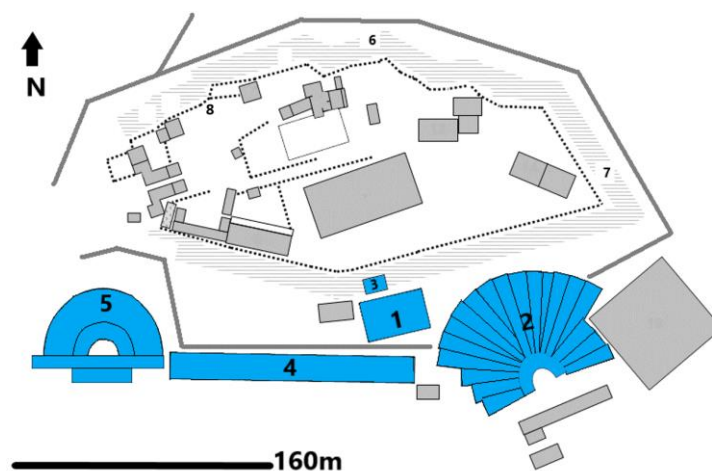


Figure 7. Plan of the Acropolis hill, showing the locations of the studied geotopes: 1. GS1 Asclepieion, 2. GS2 Theater of Dionysus, 3. GS3 The Choragic Monument of Thrasyllus, 4. GS4 Stoa of Eumenes, 5. GS5 Odeon of Herodes Atticus—Herodeion, 6. GS6 Caves, 7. GS7 Klepsydra, 8. GS8 Mycenaean Fountain.

2.4.1. GS1: Asclepieion

The Asclepieion of Athens (Figure 7) was a sanctuary dedicated to the god Asclepius, one of the most important healing deities of Ancient Greece, and his daughter Hygieia. It is located on the south side of the Acropolis, west of the theater of Dionysus, and occupies the space between the ancient Promenade and the Acropolis rock. A spring inside a cave in this location still gushes water today. The action of rainwater causes chemical corrosion on limestone rocks. Water penetrates the soil and forms karst forms, such as hollows and caves, where there is no surface drainage. The limestone rocks on the Acropolis hill's slopes are intensely karstified, with caves and an aquifer at the contact of the permeable limestone with the underlying Athens schist, which is impenetrable, due to its clay composition. The ancient Greeks considered "clean water" to be essential for the purification and the healing of the sick. People worshiped the god while receiving medical treatments, surgical operations and advice in their sleep. The ritual of ascension was the most distinctive aspect of Asclepius' therapeutic practice. After being cleansed with spring water and sacrificing on the altar, the patients slept in order to have healing dreams or visions [43].

2.4.2. GS2: Theater of Dionysus

The Theater of Dionysus (Figures 7 and 8a,b) was a monumental stone theater, built in the decade of 330 or 320 BC. Its cavity had a capacity of between 17,000 and 19,000 seats. Due to its location and construction materials, it is an important geosite. By the end of the 6th century, a theater with wooden seats had already been built. Aktitis Lithos (Stone) eventually took their place. The coast of Piraeus, now known as Themistocles Coast, was famous for its quarries until a few decades ago and for the extraction of a white rock known as Aktitis Lithos (Figure 8c), which means stone from the coast. This is a marly limestone, a rock which was used to build many monuments in Attica [44]. The first row of seats, 67 in total, were made of Pendeli marble and were intended for prominent city people [45]. To emphasize the connection between the events and worship of Dionysus, an elevated and richly decorated marble throne of the priest Dionysus was placed in the center [46]. The beautiful orchestra floor, which was intended for the "Chorus," was made of Hymettus marble. The parapet around the stage was also built during the Roman era to safely fill the orchestra with water when boat races were held in the space [47]. The theater's location on the south side of the Acropolis meets the requirements of bioclimatic construction. As the theater was open, and the performances took place in early spring, the viewing conditions were heavily influenced by environmental factors, such as temperature, winds, sunshine, the orientation of the theater, the slope of the ground, and so on. Temperatures were higher on the south side of the hill than on the north during this period, as the Rock of Acropolis blocked the north winds. During the day, much of the orchestra was in the shade, but it gradually illuminated until noon. The clarity of the Athenian atmosphere, on the other hand, did not allow the shadow to significantly obscure the action space [48]. To remove rainwater, a sewer was carved into the rock or built around the orchestra. Its architectural design and implementation on sloping ground were archetypal in architectural history.

2.4.3. GS3: The Choragic Monument of Thrasyllus

The Choragic Monument of Thrasyllus (Figures 7 and 8d) is situated on the southeast side of the Acropolis, above the Theater of Dionysus. According to the epistle, Thrasyllus, an eminent Athenian, built the monument in the year 320/319 BC, during the reign of archon Neaichmos, to house the bronze tripod, his victory trophy, in the dramatic games held in the theater of Dionysus [49,50]. The monument is located at the entrance of a karst cave. The hidden parts are made of Piraeus Aktitis Lithos and Acropolis limestone. The exposed ones are made of Pendeli and Hymettus marble, while the architraves and the frieze are made of coarse-grained white marble from the Greek islands. The construction of the monument required the adaptation of the curved surface of the cave mouth to a large rectangular opening which presented many technical challenges [51]. The way the

construction problems were solved demonstrates ancient Greek technology, and knowledge of cutting rocks, particularly marble, but also knowledge of geometry [52,53].



Figure 8. (a,b) GS2: Theater of Dionysus; (c) Aktitis Lithos; (d) GS3: The Choragic Monument of Thrasyllos and (e) GS4: Stoa of Eumenes; (f) Sanctuary of Aglauros; (g) GS7: Klepsydra; (h) GS8: Mycenaean Fountain; (photos by Fani Tripolitsiotou and Panos Karoutsos).

2.4.4. GS4: Stoa of Eumenes

The Stoa of Eumenes (Figures 7 and 8e) is located on the southern slope of the Acropolis, between the Theater of Dionysus and the Herodeion. It was granted to the city of Athens by the king of Pergamon, Eumenes II (197–159 BC), around 160 BC. Vitruvius (Roman writer, architect, and engineer), referring to the galleries built near theaters in general, mentioned that the Stoa served as a shelter for the spectators in inclement weather or as a storage area for the theater scenery. Its structural elements, such as triglyphs, metopes, cornices, columns, and architraves, were made of Pergamon marble which was shipped

to Athens. Pergamon marble is not found in any building of Athens. The Stoa was built along the North Wall, which had been built earlier, during the reign of Lycurgus (330 BC), to hold back the embankments of the Promenade level to the north [54]. The North Wall was reinforced with buttresses joined by arches and was made of hard limestone with gray Hymettos marble uprights. It is regarded as one of the finest examples of extensive pre-construction in the ancient world. Indeed, its architectural members were numbered and marked with masonic letters, to make assembly easier [54]. The Stoa was also supported in an unusual way, on the Northern Wall of limestone with marble uprights. The Stoa is considered a great technical project of antiquity, the value of which was not fully appreciated until today [55].

2.4.5. GS5: Odeon of Herodes Atticus–Herodeion

The Odeon of Herodes Atticus (Figures 7 and 9a,b) is located at the western end of the Acropolis' southern slope. Tiberius Claudius Herodes of Atticus donated the land for its construction in the second century AD. The richness of the construction was impressive. White and black marbles were laid on the floor of the orchestra, while colorful marbles adorned the walls. More than 3000 trees, primarily cedars and cypresses, were required to house the hollow. It had the largest roof of any other ancient theater, and it appears to have burned down during the Heroulian raid in 267 AD. The roof covered an area of 3 acres and weighed between 750 and 800 tons. Adding the estimated weight of 180 tons of tiles, the total weight must have been 1000 tons. It was conical and built in one piece, with no intermediate posts, and had a span of 50 m. It was an admirable achievement at the time, and methods used for the construction of bridges were most likely used [56]. Furthermore, it was initially constructed in the Stoa of Eumenes, which had been converted into a construction site, where the construction's strength tests were carried out. Later on, with special scaffolding a height of 30 m was built, where the final installation took place. Until the "Hilton" hotel was built, the Odeon was the tallest building in the country. According to Korres [56], it is a construction marvel comparable to Trajan's bridge (105 AD), the work of the famous Trajan of Damascus. Its acoustics were suitable for musical performances when there was a ceiling, as opposed to its current outdoor form, where its acoustics are primarily suitable for speech reproduction, such as in the large outdoor ancient theaters used for ancient drama performances [57].

2.4.6. GS6: Caves

The landscape on the north slope of the Acropolis is steep, wild, and imposing, with karst caves and springs (Figure 7). It is the site of ancient myths and the worship of the earthy powers of vegetation and fertility [58]. There are temples of Zeus, Panas, and Apollo Hypoakraios. The Sanctuary of Aglauros (Figure 8f) is located on the eastern side of the Acropolis and is the city's largest cave (22 m east-west, mouth 14 m). According to Herodotus, the Persians invaded the Acropolis from here in 480 B.C. Aglauros, the daughter of the mythical king Kekrops, jumped from the Acropolis to save Athens from an extended siege. It was to her shrine that Athenian ephebes, once they had reached the age of 18, brought their military gear, swearing to protect the "sacred and holy" to the death, following the example of the Nymph.

2.4.7. GS7: Klepsydra

Klepsydra (Figures 7 and 8g) is the oldest water source on the Acropolis, dating back to before the city of Athens. It is situated on the northwest side of the rock, at the crossroads of the ancient Panathenaia and Promenade streets. The hidden spring was discovered by Neolithic people, who dug 22 wells 3–5 m deep to draw its water. The Athenians discovered water at the bottom of a deep fissure in the Late Bronze Age and built a stone and a wooden staircase to reach it [59]. It is thought to have formed as a result of an earthquake that caused a 35 m fault to cut through the rock formations on the north-east side of the Acropolis and reach the underlying red shale. This fault contributed to the formation of a cave and a

karst spring within it. The spring was dedicated to the worship of Empedus, the water nymph. The Athenians named it “Klepsydra,” which means “water thief,” because its water rose and overflowed when the annual winds, the meltemia, blew, but vanished when they stopped [60]. This water supply alternation is typical of karst springs, where rainwater infiltrates through cracks in the limestone rocks. Today, the spring’s ruins can be found deep underground, where a 69-step staircase leads to a 10 m deep marble-mouthed well. The ancient spring’s water can be found at the bottom. During rainy seasons, there is so much water that it reaches the Ancient Agora.

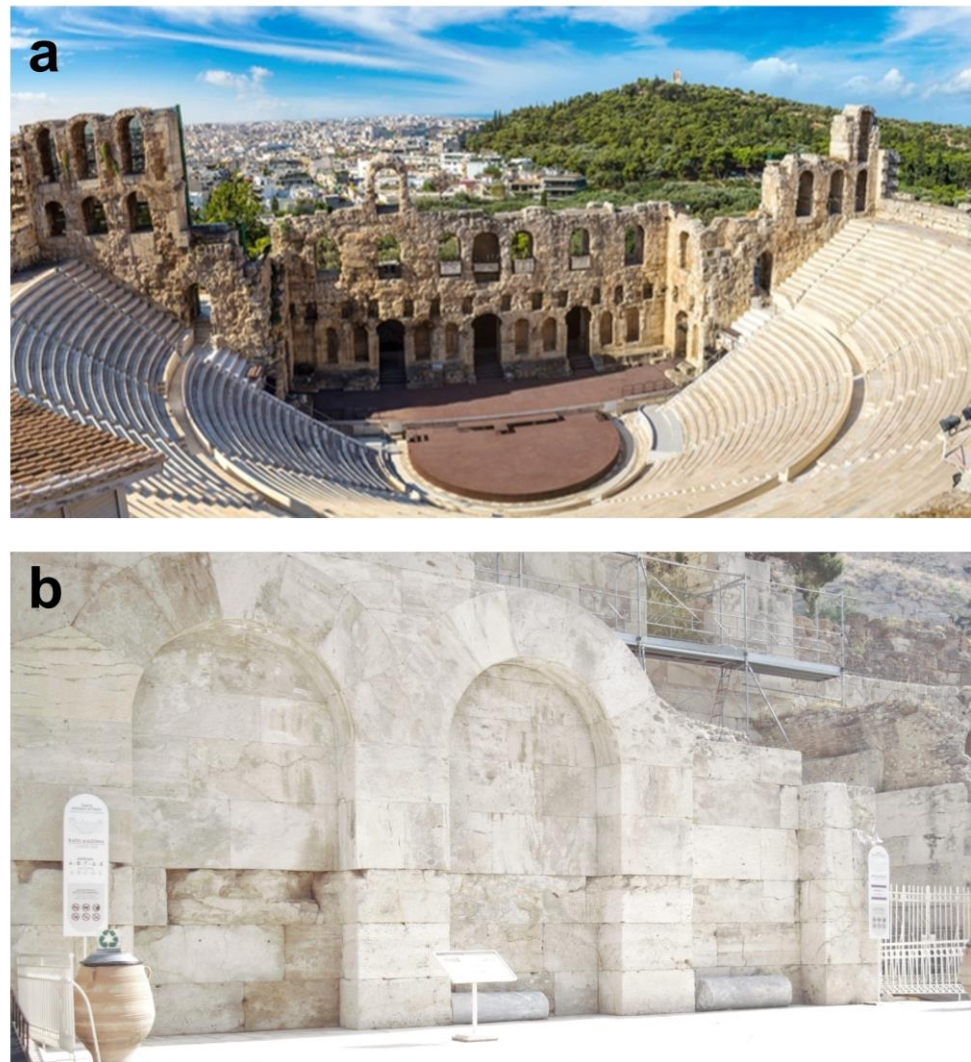


Figure 9. (a) Panoramic view of GS5: Odeon of Herodes Atticus–Herodeion (b) Details of the building stones in GS5: Odeon of Herodes Atticus–Herodeion (Photo by Fani Tripolitsiotou).

2.4.8. GS8: Mycenaean Fountain

The Mycenaean fountain (Figures 7 and 8h) was built in the second half of the 13th century AD. It was discovered alongside the Mycenaean wall during the 1937 excavations [61]. It only lasted 30 years before being destroyed by an earthquake rendering its deepest part useless. Then a large part of the rock detached resulting in the formation of a fault. Its depth is 40 m while its width is 1 to 1.5 m. It was accessible via an invisible ladder, constructed with timber ties and built-in sections. Despite its destruction, it remained a secret passage throughout ancient times. The scale was divided into eight sections. The two upper ones had wooden steps attached to both sides of the rock that led to the northern slope’s cavernous exit. The remaining sections were made of stone slabs, with a well

carved in the background, 8 m deep and 2 m in diameter on the upper surface and 4 m on the bottom. The water was pumped with containers, while there was a cavity to collect sediments [58]. According to Pausanias' description, the scale is related to the festival of the "Arrifores", and it is believed that the Arrifores, who were four aristocratic girls aged seven to eleven, descended from here one night in early summer, bringing the "Arrita", the unspoken things, to the Sanctuary of Aphrodite [58].

2.5. Quantitative Assessment

Although there are numerous methods for quantitatively assessing geodiversity sites and elements, few of them were designed for urban areas [62], and urban geodiversity inventories are still uncommon [63].

In this study, the Suzuki and Takagi [64] method is used to evaluate geosites in urban environments, modified by Vegas [65], who evaluated the geosites of the Spanish city of Segovia.

This method consists of six main axes (fields): educational value (Ved), scientific value (Vsc), tourism value (Vtr), safety and accessibility assessment (Vsa), conservation-sustainability status (Vcs) and tourist information material (Vti).

Suzuki and Takagi [64] set three sub-criteria for each axis, while Vegas [65] set one extra sub-criterion for each axis, so that the method now has a total of 24 sub-criteria, four for each main axis. Each sub-criterion is scored from 1 to 4, with 1 indicating no score, 2 indicating low, 3 indicating medium, and 4 indicating high.

The six criteria and sub-criteria designed for this assessment are described in Tables 1–6.

Table 1. Value for environmental education and sub-criteria [64,65].

Ved: Value for Environmental Education					
Score					
ID	Sub-Criteria	1	2	3	4
Ved1	Ease of understanding of the geological history	Difficult to understand, even with the explanation from a geoguide	Understandable with an explanation from a geoguide	Can be understood with an explanation board or other information sources	Easy to understand without any additional explanations
Ved2	Representativeness	None, only for scientific use	Low, content is complicated or not very representative of what the geosite is intended to illustrate	Moderate, it is representative of the geosite, but it is not the best example in the city	High, it is very representative of the geological framework and is the best example in the city
Ved3	Ease of understanding information at the geosite (panels, brochures, website ...)	There is no interpretational information	Content is complicated or is not adequate for environmental education	The interpretational material is simple and easy to understand, but without any content for environmental interpretation	The interpretational material is simple and easy to understand and contains aspects for environmental education
Ved4	Flexibility for educational use	Low, only by adults with secondary or higher education levels	Moderate, can only be understood by adults with basic studies	Can be understood by adults with basic studies and students of secondary education	High, can be understood by adults and students of all educational levels

In the present study, it was considered necessary to redefine certain criteria due to the specificity of some geotopes of the Acropolis rock, which is located at a central point of the city of Athens. Specifically, in the third axis Vtr, in the last sub-criterion concerning the proximity to tourist information points, there was the following change in the scoring steps: score 1 corresponded to a time interval of more than half an hour; score 2 corresponded to a time interval of less than 30 min and more than 15 min; score 3 corresponded to a time interval of less than 15 min and more than 5 min; and finally, score 4 corresponded to a time interval of less than 5 min.

Table 2. Scientific value and sub-criteria [64,65].

Vsc: Scientific Value					
Score					
ID	Sub-criteria	1	2	3	4
Vsc1	Research significance	Low, there are no exclusive scientific publications on the geosite, nor is it the object of research	Moderate, there are scientific publications or it has been the object of study or visits by research teams with a national scope	High, there are over five scientific publications and it has been the object of study by international teams	Very high, it has been highlighted as a site of reference in multiple international publications or has aroused interest from the international scientific community
Vsc2	Clarity and non-obsolescence of the scientific story in the interpretational material (panels, guide books and web sites)	Low: there is no scientific material or it is obsolete	Partially explained: there is scientific information but not specific to the geosite	Explained: there is scientific information but it is incomplete or not as up-to-date as it could be	Clearly explained: the scientific information is clear, up-to-date and specific to the geosite
Vsc3	Rarity in the city of Athens and its municipal district	Not rare: there are many examples in the city	Moderate: there are at least five examples in the city	Rare: there are fewer than five examples in the whole municipal district	Very rare: there is only one example at the provincial or national level
Vsc4	Representativeness of the geosite within the city's geological frameworks	It is not representative of any of the geological frameworks	The geosite is only representative of a single geological framework	The geosite allows the representation of more than one geological framework	The geosite is the most representative example of its geological framework

Table 3. Tourism value and sub-criteria [64,65] (modified by us).

Vtr: Tourism Value					
Score					
ID	Sub-Criteria	1	2	3	4
Vtr1	Aesthetic/Emotional value, such as beauty or iconic site	Low: it has no scenic or aesthetic significance (small-scale reliefs, no chromatic variety, no watercourses ...)	Moderate: it has morphological expression or some chromatic variety	High: it forms part of the relief in a sector in the city, with chromatic variety and the presence of water courses	Very high: it defines the structural landscape of the city or has emotional links to many sectors of the population
Vtr2	Other natural and cultural values	None, it has no more value than geological	Unimportant, there is some natural or cultural element, but it is not relevant	Important, there are natural or cultural elements	Very important, there are natural or cultural heritage elements and they are catalogued and recognised (property of cultural interest, singular trees, nesting sites ...)
Vtr3	Other tourist attractions in the vicinity	None	Exist, but they are not in themselves important enough to attract tourism	Exist, and they are of interest to tourists, but are outside the Athens Tourist Board's main routes and guided visits	Famous attractions. They are among the most popular guided visits in the city
Vtr4	Proximity to the city's tourist offices and information centres (measured by walking time)	More than half an hour	Between half an hour and fifteen minutes	Between fifteen and five minutes	Less than five minutes

Table 4. Safety and accessibility and sub-criteria [64,65] (modified by us).

Vsa: Safety and Accessibility					
Score					
ID	Sub-Criteria	1	2	3	4
Vsa1	Safety conditions of the geosite and the route leading to it	Relatively dangerous: it is on the verge of a street or road without a pavement or it is necessary to cross very busy roads, or near dangerous places (escarpments or sites with natural hazards)	Moderate risk of danger: there is a pavement or a small space for accommodating large groups, or the need to cross roads on zebra crossings	Not very dangerous: located in parks or on broad pavements, without nearby traffic, or on roads closed to traffic	Safe geosite: located in broad spaces without vehicle traffic, very little pedestrian transit, flat and with no natural hazards
Vsa2	Transit time walking between environmental interpretation centres in the city of Athens	More than one hour	More than 30 min	More than 15 min	Less than 15 min
Vsa3	Walking time from the closest bus stop to the geosite	More than 30 min	More than 15 min	More than 5 min	Right beside the bus stop
Vsa4	Accessibility for people with mobility problems	Not accessible for people with mobility problems	It is accessible for people with mobility problems, but assisted by carers	It is accessible to people with mobility problems, but not throughout the geotope	It is accessible to people with mobility problems and even throughout the geotope

Table 5. Conservation and site sustainability and sub-criteria [64,65].

Vcs: Conservation and Site Sustainability					
Score					
ID	Sub-Criteria	1	2	3	4
Vcs1	Current state of conservation	Low: the geological values of the geosite are not conserved	Partially conserved: there are some elements of the geosite that are not conserved	Moderately conserved: all the geological elements can be recognised	Well conserved: the geosite is entirely conserved
Vcs2	Legal protection	Not protected: it is not covered by any law or regulations	Existing plans for protection, but with a general scope for the geosite, not specifically referring to its geological values	Partially protected: it is recognised in the GUOP, but for its natural or cultural values rather than its geological value	Protected due to its geological value
Vcs3	Natural site sustainability	Difficult to preserve, subjected to natural processes (geomorphological processes or vegetation that conceals it) with high activity or frequency, or possible extreme catastrophic events	It may be damaged by medium- term natural processes (return periods of ten or more years)	It could be affected by some natural disaster or exceptional vegetation growth with return periods of over 100 years	With no incidence of natural processes that could affect its conservation
Vcs4	Anthropic sustainability	Difficult to preserve, subjected to constant, direct and damaging anthropic impacts on the geosite	It may be damaged by medium-term anthropic activities (over ten years)	It may suffer some anthropic impact but exceptionally, and with a frequency of over one century.	No incidence of anthropic activities that affect its conservation

Table 6. Value for environmental information for geotourism and sub-criteria [64,65].

Vti: Value of Environmental Information for Geotourism					
Score					
ID	Sub-Criteria	1	2	3	4
Vti1	Information panels of the approach to geosite	No information or panels that do not contain any environmental information	Limited information, but they are at high risk of vandalism or deterioration	There are panels but they only moderately facilitate environmental education	There are panels and they provide useful information for environmental education
Vti2	Geosite information on the Internet and in brochures and guide books	No information	There is information on websites or in printed matter	There is information both on the Internet and in printed matter	There is a wide range of information resources and also guides specialising in environmental interpretation
Vti3	International character of the environmental information (in different languages)	No information	One language only (Greek)	Two languages (Greek and English) or in Braille	More than two languages or the people who perform the environmental interpretation speak more than two languages (including sign language)
Vti4	Transmission of values and attitudes for the geoconservation	No value or attitude	Some vague reference to geoconservation	It contains references to recommendations and prohibitions related to geoconservation	The information includes clear and explicit references encouraging values and attitudes for geoconservation

Regarding the fourth axis, Vsa, the last sub-criterion which concerns the accessibility of geosites by people with physical or mental disabilities, was limited only to accessibility by people with mobility problems, including people who have limitations (temporary or permanent) who require accessibility to the environment: the elderly, children, pregnant women, families with pushchairs, people in plaster casts, etc. For this reason, there were the following changes in the scoring steps: score 1 indicated the non-accessibility of the geosite to people with mobility problems, score 2 indicated the accessibility of people with mobility problems but with the help of caregivers, score 3 indicated the accessibility of people with mobility problems but not throughout the entire geosite, and finally, score 4 indicated the accessibility of people with mobility problems throughout the entire geosite.

To make reading and interpreting the results easier, the six axes were grouped into pairs to represent a broader concept. The first axis of educational value, for example, in conjunction with the fourth axis of assessment for safety and accessibility, could indicate educational utility. This value encompassed all age groups, as well as all the characteristics that govern each visitor group. Similarly, the second axis of scientific value, in conjunction with the fifth axis, the assessment of conservation-sustainability status, could encompass all the elements that promote the enhancement of geological heritage. Finally, the third axis, which refers to tourism value, in conjunction with the sixth axis, which refers to the availability of information material on the area's environment and geology, could indicate the possibility of promoting geotourism.

3. Results

Table 7 shows the six axes with the four sub-criteria and their respective scores.

Table 7. Score of the sub-criteria for each assessment axis, for each geotope.

	Asklepeion (GS1)	Theater of Dionysus (GS2)	Thrasyllus Monument (GS3)	Stoa Eumenos (GS4)	Herodeion (GS5)	Caves (GS6)	Klepsydra (GS7)	Mycenaean Fountain (GS8)
Ved ₁	3	2	3	3	3	3	3	2
Ved ₂	3	4	4	4	4	3	4	2
Ved ₃	3	3	3	3	3	3	3	3
Ved ₄	4	4	4	4	4	4	4	4
Vsc ₁	4	4	3	4	4	4	4	4
Vsc ₂	4	2	2	3	2	3	2	2
Vsc ₃	3	3	3	4	4	2	4	2
Vsc ₄	3	3	3	3	4	3	4	3
Vtr ₁	2	4	4	4	4	4	3	2
Vtr ₂	4	4	4	4	4	4	4	3
Vtr ₃	4	4	4	4	4	4	3	3
Vtr ₄	3	3	3	3	3	2	2	2
Vsa ₁	2	2	1	3	4	1	1	1
Vsa ₂	4	4	3	4	4	2	3	2
Vsa ₃	3	3	2	3	3	2	2	2
Vsa ₄	2	3	1	2	4	1	1	1
Vcs ₁	3	2	3	3	3	3	2	3
Vcs ₂	3	3	3	3	3	3	3	2
Vcs ₃	2	2	2	3	3	3	2	3
Vcs ₄	2	2	3	3	3	3	3	2
Vti ₁	1	3	1	1	1	1	1	1
Vti ₂	2	2	2	2	2	2	2	2
Vti ₃	3	3	3	3	4	3	3	2
Vti ₄	2	1	1	1	1	1	1	1

Table 8 shows the mean values for each axis, obtained by summing the corresponding sub-criteria for each axis, dividing by 4.

Table 8. Mean value for each axis, for each geotope.

Average	Asklepeion (GS1)	Theater of Dionysus (GS2)	Thrasyllus Monument (GS3)	Stoa Eumenos (GS4)	Herodeion (GS5)	Caves (GS6)	Klepsydra (GS7)	Mycenaean Fountain (GS8)
Ved	3.25	3.25	3.5	3.5	3.5	3.25	3.5	2.75
Vsc	3.5	3	2.75	3.5	3.5	3	3.5	2.75
Vtr	3.25	3.75	3.75	3.75	3.75	3.5	3	2.5
Vsa	2.75	3	1.75	3	3.75	1.5	1.75	1.5
Vcs	2.5	2.25	2.75	3	3	3	2.5	2.5
Vti	2	2.25	1.75	1.75	2	1.75	1.75	1.5

At first glance, according to the results presented in the tables above, the Odeon of Herodes Atticus (Herodeion) exhibited the highest scores in each axis, except the last one, which concerns environmental information for geotouristic purposes. It was the

most widely recognised geotope, with significant scientific and tourist value. Indeed, it presents interdisciplinarity as it combines architecture with physics (acoustic) and geology (building stones). It is relatively well-preserved, and it is also valuable for environmental education. However, it has limited geological information, which is required for geotourism exploitation.

On the other hand, the Mycenaean Fountain had the lowest scores on each axis, with safety and accessibility being extremely low, and environmental information for geotourism almost non-existent. However, the average score on the first and second axes for environmental education and scientific value was 2.75, indicating that it is interesting in terms of geological heritage.

Regarding the first axis (Value for environmental education—Ved) scores, all geotopes had high scores, ranging from 2.75 to 3.5, with the Mycenaean fountain having the lowest, indicating high value for Environmental Education. The Asclepeion, the caves and the Klepsydra are ideal geotopes for informing and educating the public about the phenomenon of karstification. The Theatre of Dionysus, the Monument of Thrassylus and the Stoa of Eumenes provide information about marly limestone (Aktitis Lithos), the marble of Pendeli and the marble of Hymettus, as well as their use as building materials. Moreover, the bioclimatic construction of the Dionysu Theatre can provide additional information on the climatic conditions prevailing at the time of its operation. The Klepsydra, apart from the phenomena of karstification, is directly linked to natural hazards, since its origin is due to seismic activity and the creation of a fault line. Consequently, because these geotopes are part of the world-famous Acropolis rock, their educational use is especially beneficial to students around the world. However, geo-environmental education has not taken advantage of this very important urban geotops. Students are more concerned with the cultural and historical significance of the Acropolis rock and its monuments than with its geological and scientific significance. They are perplexed by the close relationship between geological and cultural heritage [66].

As far as the second axis is concerned, which is about the scientific value, the studied geotopes scored highly, ranging from 2.75 to 3.5. Indeed, these geotopes are studied from an interdisciplinary perspective, since they serve as reference points in different areas of study and research (petrology, paleoclimatology, architecture, mechanics, physics, hydrology, natural hazards).

The scores on the third axis, which reflects the geotopes' tourist value, remained high, ranging from 2.5 to 3.75, indicating that the studied geotopes have great potential for tourist development and appeal to a diverse range of tourists.

In the fourth axis, which concerns safety and accessibility, four of the eight geotopes had very low accessibility, less than 2 (caves, Mycenaean fountain, Klepsydra, Thrasyllus monument), while the others appeared to be more accessible and safer for a tour. The Herodeion demonstrated the highest level of safety and accessibility.

In the fifth axis, which concerns conservation and sustainability, scores ranging from 2.25 to 3 were observed. In its long history, the geological and cultural heritage of the Acropolis rock have been severely damaged. As an example, in June 1641, many buildings in Athens were severely damaged by stones falling from the Acropolis. In November 1805, a strong earthquake caused significant damage to the Parthenon. However, if there is one thing that has been of great concern to scientists and engineers, it is the secret of the Acropolis rock's flawless seismic behaviour in a 25-century history of earthquake tremors. In general, the Acropolis and its monuments are genius structures in terms of their seismic risk behaviour. However, these unique monuments have suffered man-made and natural disasters over the course of history from various causes (wars, earthquakes, etc.), requiring a special study by experts to restore them, which is a particularly demanding and difficult task. Since the foundation of the new Greek state in 1830, restoration efforts have been made and projects have been launched to repair any damage caused by natural disasters. However, it is always imperative that man-made interventions protect and enhance these

geological sites so that they are preserved as unchanged as possible over time, as they are monuments of historical and geological value of global interest.

Finally, the sixth axis had rather low scores, ranging from 1.5 to 2.25. While the historical and cultural information material is very rich, the same is not true for the geoenvironmental information. Therefore, the visitor's knowledge of the geological characteristics of the area is minimal, which means that geological information to promote geotourism is almost non-existent. Furthermore, there is no information leaflet on the geoheritage of the Acropolis Rock as one of the most intensively developed and visited areas, nor are there any signs or QR codes. There is, therefore, a lack of awareness of the fact that the Acropolis Rock has high geological value, and its promotion is expected to increase geotourism and public awareness of geoenvironmental and geoconservation issues.

The scores for each axis for each geotope were plotted with radar type diagrams, as shown in Figure 10.

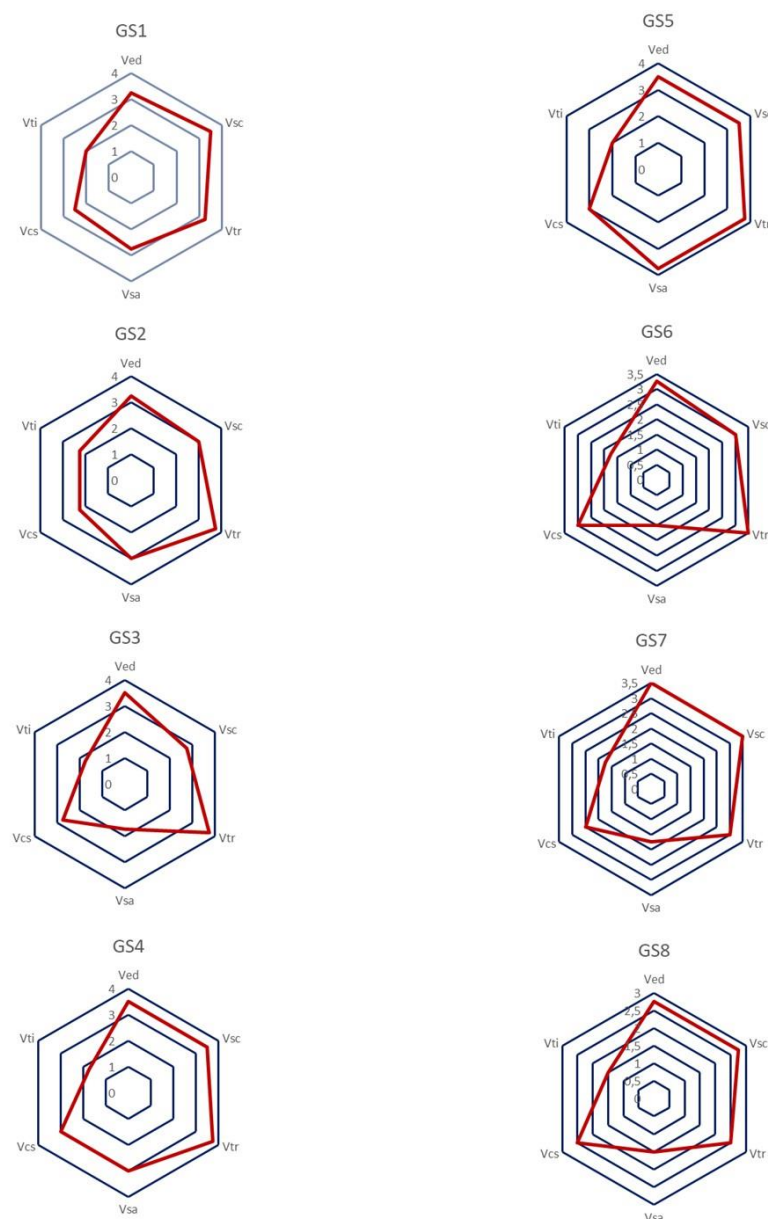


Figure 10. Radar diagrams which depict the axes scores for each geotope where Ved: educational value; Vsc: scientific value; Vtr: tourism value; Vsa: safety and accessibility assessment; Vcs: conservation-sustainability status and Vti: tourist information material.

According to the radar charts, all the geotopes studied had a high educational value (Ved) (score > 3), except for the Mycenaean Fountain (GS6), which was close to score 3. However, in addition to educational value, the majority of the geotopes had relatively high accessibility scores (Vsa). This is critical, because educational activities for all age groups could be developed without difficulty.

All the geotopes had a high scientific value (Vsc) (values/scores > 3) (except the Thrasyllus Monument-GS3 and the Mycenaean Fountain-GS6, which were close to score 3), while also having satisfactory conservation status values (Vcs).

As a result of the above combinations, there is the possibility of promoting and highlighting the geological heritage reflected in the study areas.

Finally, all the study sites had quite high scores in terms of the tourism value (Vtr) they project (six of the eight study sites had values greater than 3). However, they did not quite have satisfactory scores in relation to the information material (Vti) provided (all study sites had scores < 3). This highlights an issue that must be addressed immediately in terms of informing and promoting the values held by these sites. This will only highlight their geotourism value.

4. Discussion

Athens is a city with high geotourism potential due to the large concentration of unique, easily accessible geotourist sites in the area, well-developed tourist infrastructure and good information support. The geotourist sites of Athens are carriers of historical and cultural information, elements of the urban ecosystem.

The Acropolis of Athens, a monument with worldwide fame and recognition, is a combination of natural and cultural heritage. Its natural heritage cannot be separated from the building heritage, according to the UNESCO Convention for the Protection of the World Cultural and Natural Heritage, adopted by the General Conference of UNESCO on 16 November 1972. The study of building and decorative stones used throughout the history of Acropolis hill is, therefore, one of the most important approaches to combining geology and cultural heritage in an urban environment. It is worth noting that natural stones were used as building and/or decorative materials in historical cities. Many experts have focused on building materials that reflect geology at the local/regional level. Morra et al. [67], for example, investigated volcanic materials used in various construction projects in Naples (Italy) and discovered links between geological and architectural heritage. D'Atri et al. [68] and Borghi et al. [69] attempted something similar for Milan and Turin, respectively, in Italy. No doubt, this reflects an aspect of urban geoheritage that cannot be ignored. Del Lama et al. [18], in their publication on urban geotourism opportunities in the old centre of Sao Paulo (Brazil), highlighted the value of building stones in addition to the importance of local geomorphological features for the development of the city.

The importance of the cultural history of the Acropolis, which is linked to its archaeological and mythological history, is considered indisputable. Its geological history is evident in the field and one can easily perceive how the geological features have contributed to the preservation of the monument over the centuries. However, geo-environmental education has not utilized this very important urban site. Cheila [66], in her study, revealed that students perceive, to a high degree, the cultural and historical value of the Acropolis rock and its monuments, in contrast to its geological and scientific value. They struggle to understand the close interaction between geological and cultural heritage. The case of the Acropolis of Athens is an excellent opportunity for the implementation of geo-environmental education programmes that will help students to understand the close relationship between the two types of heritage [66]. Unfortunately, students lack the fundamental understanding of geosciences, which is important for the daily life of citizens [70]. Therefore, it is vital to include geoeducation in school curricula, which will take place in the field under the supervision of qualified personnel, using a multidisciplinary, holistic approach, with the goal of producing environmentally responsible citizens with well-developed geoethical values [66]. Geoeducation is called on to help students recognize the need for management

of the natural environment, with a sense of responsibility and participation. Furthermore, geoeducation makes it clear that the preservation of geodiversity is a basic condition for the preservation of biodiversity [71].

Unfortunately, in the Greek educational system, this knowledge is provided in primary school through a series of course-thematic units of a few teaching hours, in the context of Geography course, taught by unskilled geology teaching staff [72], while in Lower High School Education, through the subject of Geology-Geography, where there is a lack of topics on geoheritage [73]. Moreover, the number of environmental groups in Greek schools that choose to develop an environmental program with a geoenvironmental theme is very limited [74], according to annual data. As a result, student education is characterised as very limited or non-existent, and it is regarded as incomplete to negligible in the fields of geosciences and geoenvironmental sciences [66].

In contrast to geological heritage, the orientation of curricula in cultural heritage understanding is evident through various disciplines (History, Religion, Literature, Visual Arts) and several cultural programs that are annually and voluntarily prepared in Greek schools. However, no research has been conducted on pupils' and students' geological understanding, geoethical awareness, or cultural heritage understanding. The work of Georgousis et al. [75], who investigated the younger generation's geocultural consciousness, focused on the geological dimension of the world-famous cultural heritage object, Meteora Geomorphes, in Greece, to establish the younger generation's understanding of the geological heritage concerning cultural heritage, and is the only exception. According to their results, pupils and students in Greece perceived, to a high degree, the aesthetic value and cultural value of geodiversity, with its historical, archaeological and religious aspects, compared to geological value, which was perceived only to a moderate degree. At a moderate grade, they also perceived the scientific value of geoheritage, but recognised the need for geoeducation.

Geotourism has several considerations as well. The high historical and cultural values of the studied geotopes have enormous geotourism potential, which could be developed by establishing a visitor center and organizing more frequent tours. The geoheritage of the Acropolis rock could be promoted through geotours that offer a special tourist (and educational) package and provide an overview of the Acropolis' geodiversity, and could be included in Athens' tourism strategy and promotion. Similar cases of geotours exist in London [76], São Paulo [18] and Rome [77].

Except for the caves, the geosites studied in this work are open to the public. This is critical because visitors can see the rocks and unique geological features of each monument. They can tell the difference between the various rocks from which they are formed, such as Pendeli marble, Aktitis Lithos, and so on. However, for the description, understanding, and importance of the geological value, a specialised person who knows geology is required to transmit this knowledge.

Some key considerations and future projects that should be adopted by local governments and incorporated into city planning processes, are proposed. This initiative could be developed into a geodiversity action plan for the city of Athens, which would be the first of its kind for a city in Greece. Such a plan is urgently required to avoid the degradation and destruction of the Acropolis rock's geological heritage.

The assessment of these geosites should serve as a catalyst for further research into the following: the recording of fauna and flora, in order to highlight biodiversity (biodiversity is listed as an additional value in several inventories, and its detailed assessment should be done separately by appropriate experts); cultural heritage relevance, inviting experts to record the possible associations of each site in this regard; safety and conservation by landscape engineers and architects, who can survey sites to find creative ways to ensure safety while preserving heritage and integrating it into the urban fabric sustainably.

Furthermore, our findings demonstrated the utility of applying the quantitative assessment method developed by Suzuki and Takagi [64] to urban geosites. This is not the first time this method has been used to assess the potential for geotourism and geoeducation

in an urban setting. However, it should be emphasised that in order for the assessment results to be representative of the studied geosites and the target audience group (audience specificities), the peculiarities that may be concealed in each geotope must be taken into account. Modification of the sub-criteria (addition or removal of sub-cases) is required in this case.

5. Conclusions

The Acropolis Rock is one of the most admirable and recognisable monuments in the world, known worldwide for its archaeological, historical, and tourist value. At the same time, it is a remarkable monument of geological heritage, which is, however, unknown to the public. The study of building and decorative stones used throughout the history of the Acropolis hill is one of the most important approaches to combining geology and cultural heritage in an urban environment.

This study described and evaluated eight geosites on the Acropolis rock.

From the assessment data, it was concluded that the studied geosites presented high scientific and touristic value, as well as high value for environmental education. Through the discussion, the immediate need for the integration of geoeducation into the curricula of schools became apparent, so that, apart from the archaeological and cultural value of this world-famous monument, its connection with geological heritage can be made known. At the same time, however, in most geosites there is difficulty in accessibility for different reasons in each one, as they are located in different parts of the rock of the Acropolis, which presents special geological and topographical interest.

The possibility of exploiting these geosites in terms of geotourism is very high and important for strengthening the economy of the place, but mainly for raising the awareness of visitors on matters of the environment, geological heritage, and geoconservation. The sustainability and utilisation of geosites, based on the principles of sustainable development, provide multiple benefits for society and future generations.

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References

1. Drinia, H.; Tsipra, T.; Panagiaris, G.; Patsoules, M.; Papantoniou, C.; Magganis, A. Geological Heritage of Syros Island, Cyclades Complex, Greece: An Assessment and Geotourism Perspectives. *Geosciences* **2021**, *11*, 138. [CrossRef]
2. Zafeiropoulos, G.; Drinia, H. Kalymnos Island, SE Aegean Sea: From Fishing Sponges and Rock Climbing to Geotourism Perspective. *Heritage* **2021**, *4*, 3126–3146. [CrossRef]
3. Evelpidou, N.; Karkani, A.; Tzouxanioti, M.; Spyrou, E.; Petropoulos, A.; Lakidi, L. Inventory and Assessment of the Geomorphosites in Central Cyclades, Greece: The Case of Paros and Naxos Islands. *Geosciences* **2021**, *11*, 512. Available online: <https://www.mdpi.com/2076-3263/11/12/512> (accessed on 25 June 2022). [CrossRef]

4. Spyrou, E.; Triantaphyllou, M.V.; Tsourou, T.; Vassilakis, E.; Asimakopoulos, C.; Konsolaki, A.; Markakis, D.; Marketou-Galari, D.; Skentos, A. Assessment of Geological Heritage Sites and Their Significance for Geotouristic Exploitation: The Case of Lefkas, Meganisi, Kefalonia and Ithaki Islands, Ionian Sea, Greece. *Geosciences* **2022**, *12*, 55. Available online: <https://www.mdpi.com/2076-3263/12/2/55> (accessed on 25 June 2022). [\[CrossRef\]](#)
5. Golfopoulos, V.; Papadopoulou, P.; Koumoutsou, E.; Zouros, N.; Fassoulas, C.; Zelilidis, A.; Iliopoulos, G. Quantitative Assessment of the Geosites of Chelmos-Vouraikos UNESCO Global Geopark (Greece). *Geosciences* **2022**, *12*, 63. Available online: <https://www.mdpi.com/2076-3263/12/2/63> (accessed on 25 June 2022). [\[CrossRef\]](#)
6. Zouros, N.; Valiakos, I. Geoparks Management and Assessment. *Bull. Geol. Soc. Greece* **2017**, *43*, 965–977. [\[CrossRef\]](#)
7. Karamani, P.; Drinia, H.; Panagiaris, G. Geotourism as a tool for the protection and promotion of the Cave of Galaxidi. In Proceedings of the 15th International Congress of the Geological Society of Greece Athens, Athens, Greece, 22–24 May 2019.
8. Zafeiropoulos, G.; Drinia, H.; Antonarakou, A.; Zouros, N. From Geoheritage to Geoeducation, Geoethics and Geotourism: A Critical Evaluation of the Greek Region. *Geosciences* **2021**, *11*, 381. [\[CrossRef\]](#)
9. Vlachopoulos, N.; Voudouris, P. Preservation of the Geoheritage and Mining Heritage of Serifos Island, Greece: Geotourism Perspectives in a Potential New Global Unesco Geopark. *Geosciences* **2022**, *12*, 127. [\[CrossRef\]](#)
10. Del Lama, E.A. Urban geotourism with an emphasis on the city of São Paulo, Brazil. In *Handbook of Geotourism*; Dowling, R.K., Newsome, D., Eds.; Edward Elgar Publishing: Cheltenham, UK, 2018; pp. 210–223.
11. Habibi, T.; Ponedelnik, A.A.; Yashalova, N.N.; Ruban, D.A. Urban geoheritage complexity: Evidence of a unique natural resource from Shiraz city in Iran. *Resour. Policy* **2018**, *59*, 85–94. [\[CrossRef\]](#)
12. Habibi, T.; Ruban, D.A. Geoheritage of the Neyriz ophiolite-related radiolarite sequence (Cretaceous; southwest Iran): First report and evaluation in regional and global contexts. *J. Afr. Earth Sci.* **2018**, *145*, 227–233. [\[CrossRef\]](#)
13. Palacio, J. Geoheritage Within Cities: Urban Geosites in Mexico City. *Geoheritage* **2014**, *7*, 365–373. [\[CrossRef\]](#)
14. Brilha, J. Inventory and quantitative assessment of geosites and geodiversity sites: A review. *Geoheritage* **2016**, *8*, 119–134. [\[CrossRef\]](#)
15. Reynard, E.; Pica, A.; Coratza, P. Urban geomorphological heritage. An overview. *Quaest. Geogr.* **2017**, *36*, 7–20. [\[CrossRef\]](#)
16. Petrović, M.D.; Lukić, D.M.; Radovanović, M.; Vujko, A.; Gajić, T.; Vuković, D. “Urban geosites” as an alternative geotourism destination - evidence from Belgrade. *Open Geosci.* **2017**, *9*, 442–456. [\[CrossRef\]](#)
17. Ng, C.Y.; McManus, P.; Dragovich, D. Using geoparks to conserve geological features in urban areas: A critical assessment of the potential and challenges of developing geotourism in Hong Kong. Abstract. In Proceedings of the UNESCO Global Geopark Conference, Geological Society of Northern Ireland, Belfast, Northern Ireland, 21 September 2006; p. 157.
18. Del Lama, E.A.; Bacci, D.D.L.C.; Martins, L.; Garcia, M.D.G.M.; Dehira, L.K. Urban Geotourism and the Old Centre of São Paulo City, Brazil. *Geoheritage* **2015**, *7*, 147–164. [\[CrossRef\]](#)
19. Riganti, A.; Johnston, J.F. Geotourism—A focus on the urban environment. In *Handbook of Geotourism*; Dowling, R.K., Newsome, D., Eds.; Edward Elgar Publishing: Cheltenham, UK, 2018; pp. 192–201.
20. Asprogerakas, E. City Competition and Urban Marketing: The Case of Tourism Industry in Athens. *Tour. Int. Multidiscip. Refereed J. Tour.* **2007**, *2*, 89–114.
21. Ólafsdóttir, R.; Tverijonaite, E. Geotourism: A Systematic Literature Review. *Geosciences* **2018**, *8*, 234. [\[CrossRef\]](#)
22. Brandolini, P.; Mandarino, A.; Paliaga, G.; Faccini, F. Anthropogenic landforms in an urbanized alluvial-coastal plain (Rapallo city, Italy). *J. Maps* **2021**, *17*, 86–97. [\[CrossRef\]](#)
23. Fountelis, M.; Fountoulis, I.; Papanikolaou, I.D.; Papanikolaou, D. Geodetic evidence for passive control of a major Miocene tectonic boundary on the contemporary deformation field of Athens (Greece). *Ann. Geophys.* **2013**, *56*, S0674. [\[CrossRef\]](#)
24. Karfakis, J.; Loupasakis, C. Geotechnical characteristics of the formation of “Tourkovounia” Limestones and their influence on urban construction-City of Athens, Greece. In *IAEG 2006, Paper number 794*; The Geological Society of London: London, UK, 2006.
25. Pavlopoulos, K.; Kotambasi, C.; Skentos, A. Geomorphological evolution of the Athens basin. *Bull. Geol. Soc. Greece Thessalon.* **2005**, *38*, 1–13.
26. Gournelos, T.; Maroukian, H. Geomorphological observations concerning the evolution of the Basin of the Athens. *Geol. Balc. Sofia* **1990**, *20*, 15–24.
27. Papanikolaou, D.; Lozios, S.G.; Soukis, K.I.; Skourtos, E.N. The geological structure of the allochthonous “Athens schists”. *Bull. Geol. Soc. Greece Thessalon.* **2004**, *36*, 1550–1559. [\[CrossRef\]](#)
28. Sindowski, F.K.H. Results and problems of heavy mineral analysis in Germany; a review of sedimentary-petrological papers, 1936–1948. *J. Sediment. Res.* **1949**, *19*, 3–25. [\[CrossRef\]](#)
29. Diakakis, M. An inventory of flood events in Athens, Greece, during the last 130 years. Seasonality and spatial distribution. *J. Flood Risk Manag.* **2013**, *7*, 332–343. [\[CrossRef\]](#)
30. Bathrellos, G.D.; Karymbalis, E.; Skilodimou, H.D.; Gaki-Papanastassiou, K.; Baltas, E.A. Urban flood hazard assessment in the basin of Athens Metropolitan city, Greece. *Environ. Earth Sci.* **2016**, *75*, 319. [\[CrossRef\]](#)
31. Lepsius, R. *Geologie von Attika. Ein Beitrag zur Lehre vom Metamorphismus der Gesteine*; D. Reimer: Berlin, Germany, 1893; p. 81.
32. Kober, L. *Der Hallstätter Salzberg*; Holder-Pichler-Tempsky: Wien, Austria, 1929.
33. Marinos, G.; Petrascheck, W.E. Laurium. Geological and Geophysical Research. *Inst. Geol. Subsurf. Res.* **1956**, *5*, 266.
34. Tataris, A. Recent researches on the structure of Salamis Island and the opposite area of Perama. *Bull. Geol. Soc. Greece* **1967**, *7*, 36–51.

35. Niedermayer, J. Geological map and underground map of Athens, scale 1:10000. *Tech. Chamb. Greece Greek Geol. Soc.* **1971**.
36. Marinos, G.; Katsikatsos, G.; Georgiadou-Dikaoulia, E.; Mirkou, R. The Athens Shale system. Stratigraphy and tectonics. *Ann. Geol. Pays Hell* **1971**, *23*, 183–260.
37. Trikkalinos, J. The age of the metamorphic rock of Attica. *Ann. Géologiques Des Pays Helléniques* **1955**, *VI*, 193–198.
38. Paraskevaïdis, H.; Chorianopoulos, P. An intersection through Mount Aegaleo. The schist of Athens. The hills of Athens. *Bull. Geol. Soc. Greece* **1979**, *13*, 116–141.
39. Regueiro, M.; Stamatakis, M.; Laskaridis, K. The geology of the Acropolis (Athens, Greece). *Eur. Geol.* **2014**, *38*, 45–52.
40. Marinos, G.; Katsikatsos, G.; Georgiadou-Dikeoulia, E.; Mirkou, R. The Athens schist formation, I. Stratigraphy and structure (in Greek). *Ann. Géologiques Des Pays Hell.* **1971**, *22*, 183–216.
41. Andronopoulos, B.; Koukis, G. *Engineering Geology Study in the Acropolis Area, Athens*; Engineering Geology Investigations 1976, Internal Reports, No. 1; IGME: Athens, Greece, 1976.
42. Aravantinos, A.; Kosmaki, P. *Outdoor Spaces in the City, Athens 1988, Greece*; Symeon Publications: Athens, Greece, 1988; pp. 150–152.
43. Panagiotidou, O. Illness and Healing in the Sanctuaries of Asclepius: A Cognitive Approach. Thessaloniki: Aristotle University of Thessaloniki. Acropolis Museum 2014. Available online: <https://www.theacropolismuseum.gr/idrytiki-stili-toy-ieroy-toy-asklipiomyamfiglyfo-toy-tilemahoy> (accessed on 7 July 2022).
44. Milesis, S. Aktitis Piraeus Stone—The Quarries of Piraeus 2012. Available online: http://pireorama.blogspot.com/2012/10/blog-post_20.html (accessed on 8 July 2022).
45. Albini, U. *Nel Nome di Dioniso: Il Grande Teatro Classico Rivisitato Con Occhio Contemporaneo*; Prezzo Garzanti Libri: Milano, Italy, 1999.
46. Moretti, J.C. *Theater and Society in Ancient Greece*; Translated by Dimitrakopoulos, E.; Patakis Publications: Athens, Greece, 2004.
47. Boletis, K.; Samara, A.; Aslanidis, K.; Papastamati Von Mook, H.; Parianou, E. *Restoration Work in the Theater of Dionysos*; Scientific Committee of the theater and sanctuary of the Asklepiion South Slope of the Acropolis; Ministry of Foreign Affairs-T.D.P.E.A.E.: Athens, Greece, 2009.
48. Blume, H.D. *Introduction to the Ancient Theater*; National Bank Educational Foundation: Athens, Greece, 1986.
49. Welter, G. Das choregische Denkmal des Thrasyllus. In *Archäologischer Anzeiger*; Walter de Gruyter: Berlin, Germany, 1938; pp. 36–68.
50. Greco, E. *Topografia di Atene, Sviluppo Urbano e Monumenti Dalle Origini al III Secolo D.C.*; Scuola archeologica italiana: Athens, Greece, 2011; Volume 2.
51. Boletis, K. Sponsored Thrasyllus Monument, Athens 2012, Ministry of Culture and Sports. Available online: http://odysseus.culture.gr/h/2/gh251.jsp?obj_id=19820 (accessed on 7 July 2022).
52. Townsend, R. *Aspects of Athenian Architectural Activity in the Second Half of the Fourth Century B.C.*; University of North Carolina: Chapel Hill, NC, USA, 1982.
53. Coulton, J.J. *The Architectural Development of the Greek Stoa*; Oxford University Press: Oxford, UK, 1977.
54. Lefantzis, M.; Mpriana, M. *New Research During the Restoration of the Stoa of Eumenes the II; Journal Anthemion*; Centre of the Acropolis studies: Athens, Greece, 2005; Volume 13.
55. Giannikapani, E. In Efmenou. Ulysses Junction Athens 2012. Ministry of Culture and Sports. Available online: http://odysseus.culture.gr/h/2/gh251.jsp?obj_id=6623 (accessed on 9 July 2022).
56. Korres, M. *Herod's Roof and Other Giant Bridges*; Melissa Publications: Athens, Greece, 2014; pp. 150–160.
57. Vassilantonopoulos, S.L.; Mourjopoulos, J.N. The Acoustics of Roofed Ancient Odeia: The Case of Herodes Atticus Odeion. *Acta Acust. United Acust.* **2009**, *95*, 291–299. [CrossRef]
58. Tsakos, K. *Adorations and Loves on the Northern Slopes of the Acropolis*; Society of Friends of the National Archaeological Museum: Athens, Greece, 2016.
59. Hurwit, J.M.; Newton, A.D. *The Acropolis in the Age of Pericles*; Cambridge University Press: Cambridge, UK, 2004.
60. Parsons, A.W. Klepsydra and the Paved Court of the Pythion. *Hesperia: J. Am. Sch. Class. Stud. Athens* **1943**, *12*, 191–267. [CrossRef]
61. Broneer, O. A Mycenaean Fountain on the Athenian Acropolis. *Hesperia: J. Am. Sch. Class. Stud. Athens* **1939**, *8*, 317–433. [CrossRef]
62. Kubalíková, L.; Kirchner, K.; Kuda, F.; Bajer, A. Assessment of urban geotourism resources: An example of two geocultural sites in Brno, Czech Republic. *Geoheritage* **2020**, *12*, 7. [CrossRef]
63. Vegas, J.; Díez-Herrero, A. An assessment method for urban geoheritage as a model for environmental awareness and geotourism (Segovia, Spain). *Geoheritage* **2021**, *13*, 27. [CrossRef]
64. Suzuki, D.A.; Takagi, H. Evaluation of geosite for sustainable planning and management in geotourism. *Geoheritage* **2018**, *10*, 123–135. [CrossRef]
65. Vegas, J. El patrimonio geológico de la provincia de Segovia: Geodiversidad y geoconservación. *Colección Nat. Y Medio Ambiente Segovia* **2000**, *26*, 1–69.
66. Cheila, T. The importance of geoenvironmental education in redefining the relationship of students with the environment and society. The case of the sacred rock of the Acropolis. MsS Thesis, Post-graduate Program Environmental, Disaster & Crisis Management Strategies. Master's Thesis, National and Kapodistrian University of Athens, Zografou, Greece, 2022.

67. Morra, V.; Calcaterra, D.; Cappelletti, P.; Colella, A.; Fedele, L.; de' Gennaro, R.; Langella, A.; Mercurio, M.; de' Gennaro, M. Urban Geology: Relationships between Geological Setting and Architectural Heritage of the Neapolitan Area. *J. Virtual Explor.* **2010**, *36*, 27. [\[CrossRef\]](#)
68. D'Atri, A.; Borghi, A.; Martire, L.; Castelli, D.; Costa, E.; Dino, G.; Favero Longo, S.; Ferrando, S.; Gallo, L.M.; Giardino, M.; et al. Sedimentary rocks in the urban geological heritage of the Torino city. *J. Mediterr. Earth Sci.* **2013**, *5*, 51.
69. Borghi, A.; D'Atri, A.R.; Martire, L.; Castelli, D.; Costa, E.; Dino, G.A.; Longo, S.E.F.; Ferrando, S.; Gallo, L.M.; Giardino, M.; et al. Fragments of the Western Alpine Chain as Historic Ornamental Stones in Turin (Italy): Enhancement of Urban Geological Heritage through Geotourism. *Geoheritage* **2014**, *6*, 41–55. [\[CrossRef\]](#)
70. Trikolos, K.; Ladas, I. The necessity of teaching earth sciences in secondary education. In Proceedings of the 3rd International GEOschools Conference, Teaching Geosciences in Europe from Primary to Secondary School, Athens, Greece, 28–29 September 2013; pp. 28–29.
71. Fermeli, G.; Markopoulou-Diakantoni, A. Selecting Pedagogical Geotopes in Urban Environment. *Bull. Geol. Soc. Greece Thessalon.* **2004**, *36*, 649–658. Available online: <https://ejournals.epublishing.ekt.gr/index.php/geosociety/article/view/1677> (accessed on 8 July 2022).
72. Rokka, A.C. Geology in Primary Education: Potential and Perspectives. *Bull. Geol. Soc. Greece* **2018**, *34*, 819–823. (In Greek) [\[CrossRef\]](#)
73. Meléndez, G.; Fermeli, G.; Koutsouveli, A. Analyzing Geology textbooks for secondary school curricula in Greece and Spain: Educational use of geological heritage. *Bull. Geol. Soc. Greece* **2007**, *40*, 1819–1832. [\[CrossRef\]](#)
74. Spartinou, M.; Zerlantis, I. The geological heritage of Cyclades and the Environmental Education. In Proceedings of the 6th Pan-Hellenic Geographical Conference of the Hellenic Geographical Society, Thessaloniki, Greece, 3–6 October 2002; Volume III. (In Greek)
75. Georgousis, E.; Savelides, S.; Mosios, S.; Holokolos, M.-V.; Drinia, H. The Need for Geoethical Awareness: The Importance of Geoenvironmental Education in Geoheritage Understanding in the Case of Meteora Geomorphes, Greece. *Sustainability* **2021**, *13*, 6626. [\[CrossRef\]](#)
76. Robinson, E. Geological walks around the city of London—Royal Exchange to Aldgate. *Proc. Geol. Assoc.* **1982**, *93*, 225–246. [\[CrossRef\]](#)
77. Pica, A.; Reynard, E.; Grangier, L.; Kaiser, C.; Ghiraldi, L.; Perotti, L.; Del Monte, M. GeoGuides, urban geotourism offer powered by GeoGuides, Urban Geotourism Offer Powered by Mobile Application Technology. *Geoheritage* **2018**, *10*, 311–326. [\[CrossRef\]](#)