 doi:10.20944/preprints202101.0305.v1

Article

Geological heritage of Syros Island, Cyclades Complex, Greece: a new assessment and geotourism perspectives

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Abstract: Syros Island, Cyclades complex, central Aegean Sea, Greece, is a prime locality for the study of processes active in deep levels of orogens and is world famous for its exceptionally well preserved glaucophane schist-to eclogite-facies lithologies. Glaucophane schists and eclogites are witnesses of one of the fundamental tectonic processes operating on planet Earth. Results of geological research on Syros have contributed a lot to our present understanding of why and how these processes work that make oceans disappear, how mountain ranges can start to form, how magma chambers form to feed volcanoes, how subduction mechanisms can trigger earthquakes and lead to tsunamis, and a series of other spectacular or very impressive phenomena which have been observed and studied throughout the earth s window offered in that particular place of the world. The description, interpretation and evaluation of the important geological heritage of Syros, in combination with a preliminary SWOT analysis, showed the geotourism potential of the region. The results of this paper are intended to constitute a valuable tool for enhancing and raising awareness of the geological heritage of the island of Syros, with regard to the added value activities to be developed on a sustainable basis.

Keywords: Geosite; geotourism; Syros island; metamorphic rocks; subduction zone; sustainable development;

1. Introduction

Greece, due to its position along the convergence zone between two tectonic plates (African and Aegean microplate), presents a variety of geoforms and formations worthy of conservation for world science and research. For this reason, Greece is well known to the world geological community as a "natural geological laboratory", which provides valuable information concerning global geodynamic processes as it is characterized by intense earthquake activity, volcanoes, variable sediment processes, coastal dynamics and other. At the same time, Greece represents a great geo-museum hosting "moments" of the complicated evolution of our planet, from Proterozoic until today. These "moments" are represented by the Geosites which, according to Reynard [1], are 'portions of the geosphere that present a particular importance for the comprehension of Earth history'. These geosites or geotopes are of unparalleled scientific, aesthetic, cultural and ecological value. Yet, very often, these geosites are irreparably destroyed by ignorance.

In recent years, the involvement of the Greek scientific community with geotopes has intensified, with the result that the research is expanded and new aspects are analyzed that highlight the educational value of geotopes [2- 5] as well as their connection with Greek mythology [6, 7].

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Moreover, nowadays, Greece faces the "new" challenge of Geotourism, not only because it can redistribute the tourism product of the country in areas that until now are not tourism destinations, but mainly because it can provoke a new quality tourism flow. Geotourism constitutes a very good tool for highlighting and developing an area and should be used properly and especially prudently.

The present paper focuses on the promotion of the geological wealth of the island of Syros, central Aegean Sea, with the aim of integrating the island in the international environment of Geoparks, in the near future. The promotion and connection of the geological heritage of Syros in the already provided tourism product will attract people from all over the world with different kind of interests and will make it known to alternative tourists.

Syros Island belongs to the Cycladic Islands Complex, which forms the so-called Cycladic plateau in the central Aegean Sea (Greece) (Figure 1). The archipelago of the Cyclades, according to historical sources, is named after the circle formed by the islands around the sacred center of Dilos. In reality, however, it is a group of islands that stretch away from mainland Greece southeastwards and are nothing but the tops of sunken mountains which are bordered to the west by Evvoia and the peninsula of Attica. The Cycladic archipelago is located between the parallels 38°.05 'and 36°.20' (north latitude) and meridians 24th and 26th (east longitude) and is bounded to the west by the Myrtoan Sea, to the east by Ikarian and Southern Aegean Seas, to the south by the Cretan Sea and to the north by the sea of the central Aegean.

Figure 1. Location map of Syros island and bathymetry of the Cyclades Plateau [8] (modified)

The Cycladic plateau is composed of 20 large islands, the largest being Naxos (430 km²), followed by Andros (380 km²) and Tinos (196.5 km²), all situated in the eastern part of the Cycladic plateau. Four islands are much smaller and are located along the western edge of the plateau (Kea, Kythnos, Serifos, Sifnos). Syros, Paros, Ios and Mykonos are between these two island groups. Milos, Santorini and Amorgos are considered peripheral extensions of the plateau and are clustered along the southern edge of it (Figure 1).

Syros belongs to the administrative Region of the South Aegean which is a region with high potential in geotopes and geodiversity. The volcanic complex of Santorini is ranked as a global geological monument. The Kleftiko and the Sarakiniko of Milos, the

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volcanic complex of Nisyros, and the Antiparos cave are geological monuments of international interest. In addition, there are many geological sites which are of tourism interest only at regional - local level. According to Skentos [9], the geotopes are placed as a whole, in areas with intense relief, mostly connected to the coastal environment. They have a high concentration density in areas associated with volcanic activity both during the Upper Miocene and during the Pliocene - present (Milos, Santorini, Nisyros).

Syros Island, located in the central part of the Cyclades, is primarily made up of the Cycladic Blueschist Unit (CBU) (Figure 2), one of the world's best case studies of a fossilized subduction system, and is known for its outstanding preservation of metamorphic HP-LT rocks such as eclogites and blueschists. Hence, many studies focusing in petrology, structure and geochronology, are being carried out in this island, in order to unravel the tectonometamorphic evolution of the CBU subduction complex (e.g. [10 – 22]).

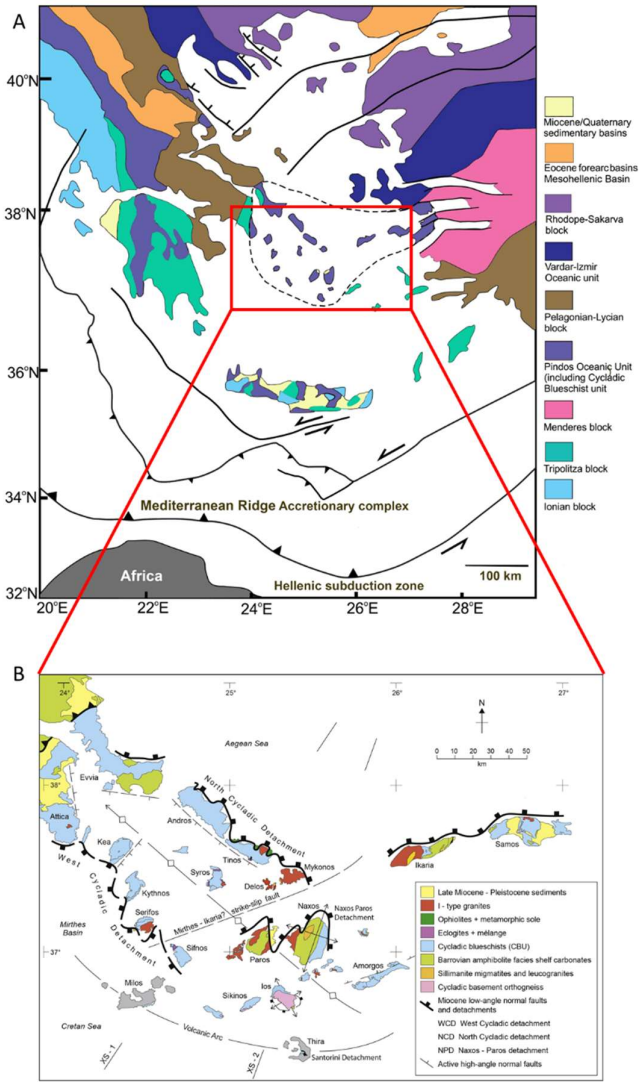

Figure 2. A. A simplified tectonic map showing the major tectonic zones above the Hellenic subduction zone of the Aegean region (modified after [23, 24]), **B.** Simplified geological map of the Attic-Cycladic Crystalline Belt, showing the major tectonic units [23] (modified).

For the scientific community, Syros is considered a geological museum that combines research, geological, archaeological and cultural interest, and needs to be preserved and highlighted, as it constitutes a significant and highly representative location to analyze the structure of a subduction zone, that is a major component of the earth lithosphere. While the geological evidence is spectacularly visible –and easily accessible- on Syros, and

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numerous geology students and earth scientists keep visiting, and hundreds of research articles have been written on Syros geology, the island's significance is essentially unknown to the general public.

2. Materials and Methods

Many of the results of previous research and studies concerning the geological setting of Syros Island were selected and incorporated in this paper. Most of the studies are focusing on geological-geomorphological field descriptions and mapping, as well as morphometric and morphotectonic studies concentrating on the geological characteristics and geomorphological landforms of this area (e.g. [17]; [19]; [14]; [15]). The main and most exciting findings were chosen from these studies and additional field observations were carried out in order to be presented to a wide public.

Concerning the geological heritage of the island, its scientific value was appreciated by highlighting its importance in the contribution to knowledge advance. At the same time its academic value, translated as the ease with which this knowledge is communicated to society, was valorized. Under this respect, in a systematic literature review of project papers, theses, articles and scientific publications on the study area, all available information was collected. It is worth mentioning that a huge number of students and scientists, following the initiatives of international Universities exceeding a number of one hundred, have visited the island so far.

The first phase in the decision-making framework for the implementation of geotourism is the assessment of geosites. Evaluation is used to assess appropriate locations and to determine the current status of the geosite. Although evaluation is adequate for the recognition of important geosites, there is a need for additional data to make available access decisions. For this purpose, a SWOT analysis should be generated based on evaluation data, which clearly determines the strengths and weaknesses, opportunities and threats. The SWOT analysis was applied, with the participation of a small number of representatives of the public and private sectors, as well as of the general public, with the objective of gathering some preliminary opinions in order to consider and further evaluate the geotourism potential of the area.

3. Geological Setting

The island of Syros is in the Aegean Sea and specifically in the center of the Cycladic archipelago. The Aegean region (eastern Mediterranean Sea) has experienced a tectonic and metamorphic transformation established by two distinct stages. Initially, the collision of Africa-Eurasia plates from the late Cretaceous to the Eocene contributed to the formation of the Hellenides-Taurides chain, which consists of a pile of oceanic and continental nappes attributed to Apulia [25]. Then, the kinematics in the upper plates of the Mediterranean subduction zone have been mainly affected by the southward retreat of the African slab since 35 Ma [26 - 28], [23], accounted for the expansion of the back-arc zone (Figure 3). The archipelago of the Cyclades is the result of the collapse of the Hellenides-Taurides belt generated by this retreating subduction that altered the kinematic boundary conditions in the back-arc area from compressional to extensional [29], [30].

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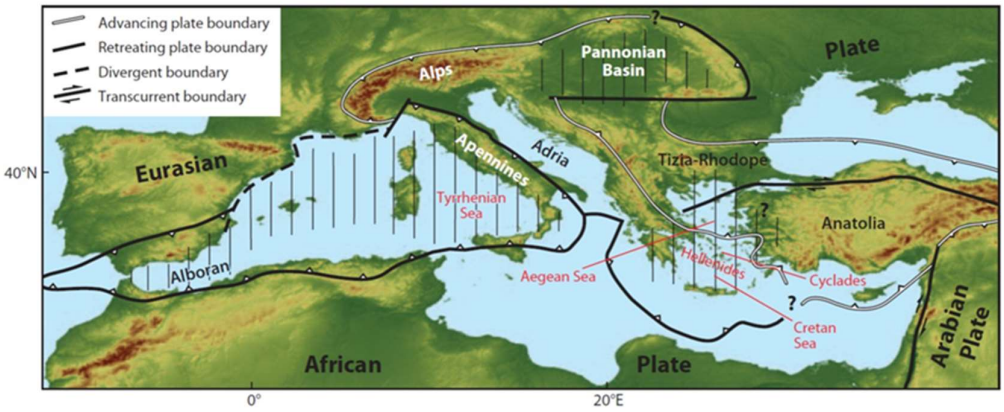

Figure 3. Simplified tectonic map of the Mediterranean plate-boundary zone showing the three major plates (Eurasian, African, and Arabian) shown, and the microplates between them. Vertical lines indicate highly extended regions above retreating plate boundaries. The Hellenides, the Aegean and Cretan Seas, and the Cyclades are shown (after [24]).

From a geological view point, Syros island is part of the Attic-Cycladic Crystalline Belt (ACCB), (Figure 2). This Belt is characterized by the occurrence of four major tectonic units, which are from top to bottom: the Upper Unit (UU), the Cycladic Blueschist Unit (CBU), the Cycladic Basement Unit and the Basal Unit.

The island of Syros incorporates the two uppermost structural units of the ACCB, separated between them by low-angle faults [31 - 33] (Figure 4). The Upper Unit (known also as Vari Unit) is mostly exposed in the SE part of the island. It is primarily composed of a diverse sequence of Late Cretaceous epidote-amphibolite-facies orthogneisses originated from Triassic granitoids, as well as schists and phyllites of greenschist facies, which enclose few serpentinite blocks [11]; [19]. The underlying Cycladic Blueschist Unit, consists of a pre-Alpidic basement of micaschists and gneisses superimposed by metamorphosed volcano-sedimentary thrust sheets, which comprise alternating sequences of marble, micaschist and metabasites. Recent field observations together with structural and petrological findings on the island of Syros allows the subdivision of the CBU into three subunits, from top to base, the Kampos, Chroussa and Posidonia Subunits, separated by major ductile shear zones, all structurally resting below the Vari Unit, showing no signs of HP [14]. In northern and central Syros dominant are the two tectonic subunits at kilometer scale: the Chroussa Subunit composed mostly of light marble and dark glaucophane schists and the Kampos "mélange" zone comprising mainly eclogites and serpentinites. In opposite Posidonia Subunit, which is mostly located at the southwestern part of the island, comprises the felsic gneiss of Komito, albitic micaschists, some marbles and few metabasites.

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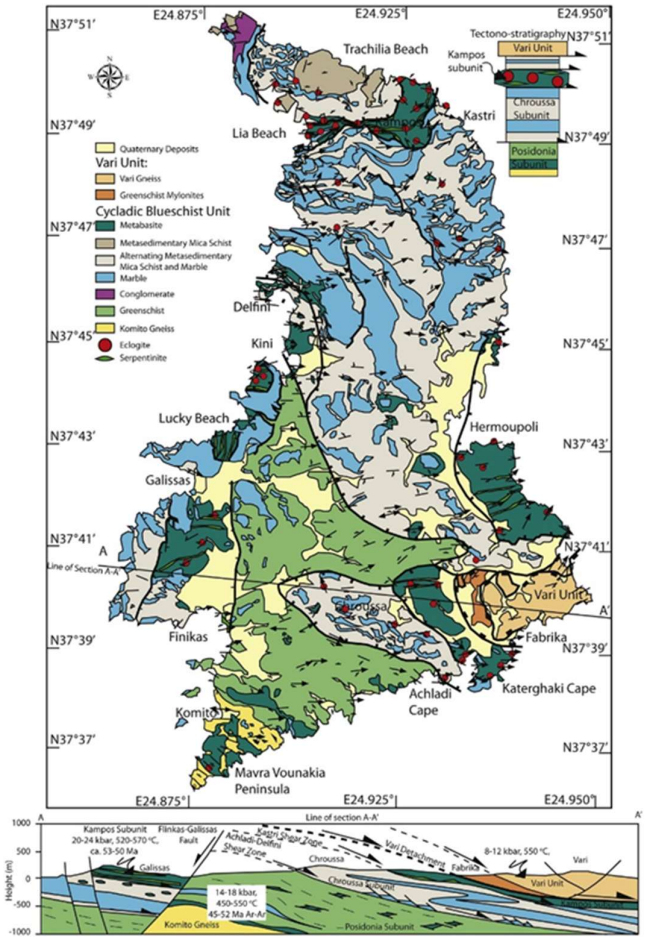

Figure 4. Geological map and cross-section of Syros island, simplified after [11], [12], [17], [15] and our own observations

Syros Island is mostly known all over the geological world, among many others, for the occurrence of HP-LT parageneses in the CBU, offering one of the best examples to study in situ and unravel the tectonometamorphic evolution of a subduction system. Two phases of Tertiary metamorphism were registered in the CBU. The subduction of the Apulian microplate under the Eurasian continent [34], fueled the first metamorphic event at eclogite-to-blueschist-facies conditions (T = 500-550 °C, P = 15-20 kbar; e.g. [35]; [36]; [37]; [21]; [18]), which probably culminated at Lower Eocene (ca. 53–49 Ma) ([20]; [13]). The retrograde second metamorphic event, which was of greenschist-to amphibolite-facies, was dated at 25-21 Ma [38]. Finally, the CBU exhumed between 12 and 8 Ma ago [39]; [19].

4. Results and Discussion

4.1. What actually is the geological heritage of Syros island?

The special petrological and tectonic history of Syros is highlighted through the extraordinary, perhaps unique, preservation and easily accessible mineral parageneses and tectonic structures on a very soft relief of the island. These mineral parageneses are related to a geotectonic environment, that of subduction, which is critical and essential to understanding how the planet works and evolved.

On our planet, the conditions suitable for these mineral parageneses to grow, are limited to special tectonic environments, notably subduction zones. In fact, research geologists from all over the world keep coming to Syros for their studies because the rocks exposed on the island were formed in such a subduction zone. Therefore, the area is suitable for geoconservation and geo-education.

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Indeed, in Northern Syros, the Chroussa and Kampos subunits offer insight into how a deep subduction complex was assembled and then carried up to the Earth's surface (Figures 4 and 5). In both subunits, strong deformation is clearly visible, at all scales (cm to km), including folds and fractures within rocks and between different layers or bodies of rock. Strong deformation reflects several important stages in the evolution of Syros, essentially starting 55 million years ago, when oceanic crust (parts of the Pindos ocean) began to be subducted beneath a continental block (Adria). Over a period of at least 5 million years, a tectonic channel was assembled by thrusting and strong folding. This is when, at depths of up to 50 km, the Kampos "mélange" started to form at very high pressures (ca. 16,000 times normal pressure). As the northward movement of Africa slowed down, this allowed the mélange to be exhumed between 50 and 35 Ma ago. As a result of these giant movements, the Kampos shear zone ended up being squeezed in between two tectonic slices of the Chroussa unit. The contact surfaces, along which the tectonic units moved into their present position, are precisely known on Syros because of the detailed geological maps produced over half a century of study. Deformation features, such as folded rocks and faults in between kilometer-size masses of rocks are well visible. Based on numerous geological investigations, the assembly of the tectonic units has been reconstructed, and the evolution of the rocks present on Syros can now be understood in some detail. However, results of the studies are continually being debated, and many questions remain open, which is why international geological research continues in order to resolve these.

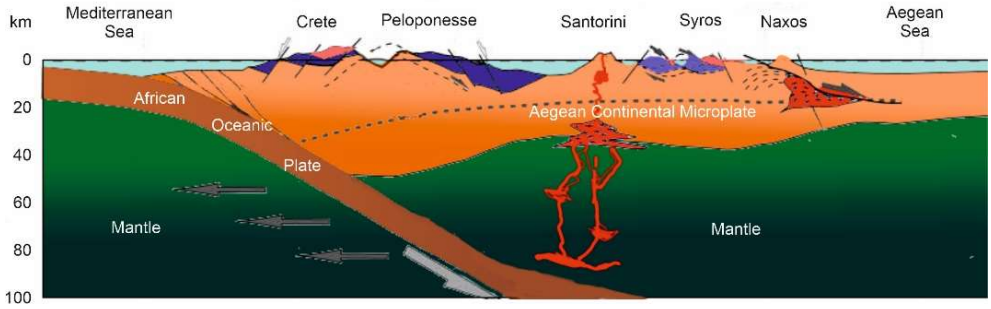

Figure 5. Schematic reconstruction of the Hellenic Subduction system (after [21], modified)

Consequently, Syros, possibly is a unique "geological laboratory" around the world, in which are being studied processes with the orogenesis at the Earth's crust, attributable to the collision between two lithospheric plates, with the one subducting under the other. More precisely, the uniqueness lies in the fact that the submergence of outcropping lithological units to the mantle depth of around (40-70 km or down to 100 km) and their uplifting again on the surface, at geological period of relatively recent time. This round-trip of the rock formations, reflected exceptionally in Syros with the creation and favorably display well-preserved rare rock types. For this reason, a great number of petrological, geochronological and structural studies have focused on the rocks of this island, resulting in various interpretations mainly concerning 1) the overall CBU geometry, 2) metamorphic peak conditions, 3) the position of significant tectonic contacts and 4) the geochemical processes taken place.

In view of their exceptional petrological characteristics, there are many interesting outcrops, scattered throughout the island, though mostly occur in its northern part. For example, in the coastal outcrop in the SW of Grizzas Bay igneous-textured metagabbro, meta-plagiogranite and megalithic ophiolitic breccia are observed, at the northern side of Ermoupolis sphene and tourmaline-bearing reaction zones (blackwalls) occur, in San Michalis (Kampos) and on the way to Lia Beach jadeitite is found, which by the way is considered the largest known source of jadeite ancient artifacts in the Aegean, and one of the largest in the Mediterranean area [40](Voudouris et al. 2019) (Figure 4). Outcrops which exhibit the exceptional petrological diversity of the HP-LT metamorphic rocks, can be considered also those occur in between San Michalis and Lia Beach. These outcrops

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include firstly two impressive dark colored monolithic rock structures. The biggest monolith, which has been named by the locals "aerolithos" – that means rock coming from the air(!) – is an eclogitic large block partially enveloped by relatively thin blueschist layers (Figure 6a, c) - a rock which, as written before, was originated from the great depth of about 80 km within the earth. Other very interesting outcrops in Kampos – Lia beach area also include phengite glaucophane schists bearing emerald like and highly aesthetic pseudomorphs of lawsonite crystals, schists bearing large garnet porphyroblasts (Figure 6e) and light green serpentinitic rocks. Moreover, in northern Syros outcrops of rare impure marbles bearing pseudomorphic aragonite needles and glaucophane exist, as well as dark gray graphite schists. In the Kini bay the outcrops comprising mainly blueschists, eclogites, coarse grained green Mg-rich and blackish Fe-rich metagabbros (Figure 6f, g), as well as the dark green epidote-rich sandy beach, are quite remarkable. It is notable that Mg-gabbros of Kini contain large crystals of green omphacite – a mineral named from the ancient Greek word όμφαξ (omphax = unripe grape) in allusion to its typical green color – and plagioclase [41](Katerinopoulou et al….), while Kini is also known as type locality of another important and characteristic blue mineral of HP-LT metamorphism, the glaucophane [named also from the Greek γλαυκός (glaukos) for "sky-blue" and φαίνεσθαι (phainestai) "to appear", in reference to its color], which firstly discovered therein by Hausman at 1845 [42]. Other places with outcrops deserved to be visited are found in the broader area of Airport, where one can observe striking vivid blue colored schists and the rarely preserved phenomenon of felsic and mafic magma mixing (Figure 6c, d), the Vari area exhibiting interesting tectonic structures as evidence for exhumation of the southern Syros, and the Komito area where an orthogneiss, dated as the oldest rock of Syros, occur.

By these above-mentioned reasons, we consider the outcrops/areas of Syros described are places having an undoubted petrological and generally great earth science interest. They can be easily characterized as places of substantial geological heritage that is worth protecting from imminent threat for destruction for various economic or other uses.

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Figure 6. a. Eclogitic monolith locally known as "aerolithos", from near to Lia Beach, b. Close up of the monolith depicting the blueschist envelope, c. Vivid colored blueschist folded intensely, Airport area, d. Felsic and mafic magma mixing engulfing a rectangular eclogitic fragment, Airport area, e. Fine grained pelite with large garnet porphyroclasts, Kampos, f. Retrograded eclogite from Kini, g. Mg-rich omphacitic metagabbro from Kini.

4.2. Quantitative Evaluation

Successful and efficient management of geological heritage, whether geotope or geopark, should be focused on its contribution to local, national or global geodiversity conservation. The value of geological heritage to science and contemporary culture through a comparable and quantitative assessment method must be demonstrated in order to expose this contribution [43]. Therefore, the importance of geological heritage must be

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quantified and recorded and geodiversity assessed using a standardized approach appropriate to geoscientists and the broader environmental community. The application of this standardized approach, which will be a powerful and reliable assessment process, can increase the effectiveness of geodiversity protection and geotourism, which is the tool for highlighting the geological heritage.

According to Archontikis [44], the purpose of a quantitative assessment is to minimize the subjectivity associated with any evaluation process.

In the last decade, research on the numerical evaluation of geotopes has been growing, but a widely accepted approach has not yet been established in the geoscientific community. Quantitative approaches are usually focused on various standards and relevant metrics to which different scores or parameters can be assigned [43]; [45 - 56].

In this study, the adopted evaluation method is based on 13 criteria: Geological History, Representativeness, Geodiversity, Rarity, Conservation, Education, History-Archeology, Religion, Visibility, Landscape Differentiation, Accessibility, Tourist infrastructure, Ecological value, and the rating is from 1 (lowest value) to 5 (highest value) for each criterion. For the quantitative evaluation, Skentos [9] grouped the above criteria into: Geology, Culture, Aesthetics, Tourism, Ecology. The quantification of data from all the criteria set for the assessment of geotopes led to the comparison and correlation of geotopes. For each registered geotope, there is a specific value (Total Score = Sum of rating criteria/Number of used criteria), indicative of the value of the geotope, which is related to its final classification position. If Total Score >3.5, then the Geotope is of Global interest. In case where 3.5>Total Score >3.0, then it is a Geotope of National interest and finally, if Total Score <3, then it is a Geotope that is of Local interest only.

In this research, the assessment process focused on the most impressive, to the general public, geosite which is the "Aerolithos" Eclogites, The results of the evaluation are shown in Table 1. The assessment process of the proposed geosite is attempted after having gathered all the necessary data from the literature and fieldwork. The average of all these values outlines the geotope's final classification and it is concluded that the "Aerolithos" Eclogites in Northern Syros belongs to the category "Geotopes of Global Interest".

Table 1. Geosite evaluation. The numerical expression of the group indicators is given, followed by the values for each indicator

Geology	4,5	Geological History	5
		Representativeness	5
		Geodiversity	3
		Rarity	4
		Conservation	5
		Education	5
Culture	2,5	History-Archeology	4
		Religion	1
Aesthetics	5	Visibility	5
		Landscape Differentiation	5
Tourism	3,5	Accessibility	3
		Tourist infrastructure	4
Ecology	3	Ecological value	3
Total	**3.7**		

The results of the assessment indicate that the geosite of Northern Syros' Eclogites has great potential to become a popular geotourism destination. The first two group indicators describe the classic ABC [Abiotic (geology and climate) – Biotic (flora and fauna) – Culture (lifestyle of people)] approach of Dowling [57] which must be accompanied by another set of objective parameters, named "aesthetics". Indeed, there are geological sites

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of great scientific value which are short of interest to the general public due to low aesthetic value. It is the beauty of geosites that makes people want to understand how these places were made.

4.3. The archaeological and cultural framework of Syros island

The promotion and utilization of a geotope as a geotourism product is directly dependent on other tourism possibilities that a place may present.

Syros Island is well known for it is also an island of great archaeological wealth worth discovering. The most important and famous archaeological sites of Syros are concentrated in the northern part of the island: Chalandriani with the Early Cycladic cemetery and the more than 600 excavated tombs, Kastri which is acropolis and settlement of the same period, the bay of Grammata with the inscriptions engraved on the rocks of the Hellenistic and Byzantine period, the cave of Ferekidis with traces of human presence during the Archaic period.

"The Sun-cave of Ferekidis" is a perfect ancient solar observatory. This is a kind of well, a perfectly made ancient solar observatory with which the ancient Greeks were able to calculate the movement of the Sun during a whole year, the seasons, equinoxes and such phenomena. Its name origins from the ancient philosopher-physicist Ferekidis, who was born in Syros (6th century B.C.) and designed, perfected and completed the monument. He is believed to be the inventor of the heliotrope, the first solar clock ever made.

Of the same importance are "The Rock-engravings" on Syros island, which are located on mount Gerousi. "The Rock-engravings" illustrate ancient conquests of the Cycladic civilization and astronomical events, just like "The Sun-cave of Ferekidis".

A more practical and efficient way to determine the seasons and other important astronomical events throughout the year was "The Heliotrope of Cycladic Idols" , with which ancient Greeks were able to calculate five (5) seasons instead of four (4) that we have today. Ancient Greeks used the idols in order to calculate the year for their farming activities.

The cultural attractions of Syros keep the visitor's interest undiminished at every step on the island. The cities and villages are themselves the most important cultural attractions. Ermoupolis, the capital of Syros and the Cyclades, a city built in the 19th century has a variety of buildings of the time, with neoclassical style and influences from romantic architecture. Among the cultural attractions of Syros that can be seen in the city are the City Hall, the Cultural Center, Miaouli Square, the church of Agios Nikolaos, the port and the Municipal Theater "Apollo", a work of the great German architect Ernst Ziller. Ano Syros, the old town of the island stands on the spot since the Middle Ages and is one of the most important cultural attractions of Syros. The medieval gates lead to the narrow streets of the settlement, with the countless churches, most of them catholic. The other villages of the island, such as Poseidonia, Finikas, but also the small villages of Apano Meria, host many of the sights and cultural events of Syros, which are worth seeing. Events such as the International Film Festival, or exhibitions held at the Ermoupolis Industrial Museum and the Maritime Museum in Kini, the Accordion Festival and the AnimaSyros International Animation Festival take place every year on the island. Concerts, theatrical performances, art exhibitions and festivals give the visitor a multicultural experience in the field of art and culture.

4.4. SWOT Analysis

A preliminary study was conducted to assess the real geotourism potential of geological heritage growth on Syros Island, summarizing and comparing strengths, weaknesses, opportunities and threats (SWOT analysis), (e.g. [58-59]).

Strengths

In a single context, the proposed product of geotourism encompasses geological and archaeological history together with cultural activities. In collaboration with local authorities, universities and research centers, numerous archaeological and geological studies and projects have been carried out in the region, providing a high-level knowledge and scientific dissemination. At national and international scientific congresses, the findings

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of scientific studies and dissemination activities have already been presented. This geotourism product could combine "on-site" tools (totems and panels) and "digital" tools (smartphone and tablet-readable explanatory material) and could attract people of various age and digital alphabetization range. This will result in at least several thousand visitors to this unique location each year. In addition, local schools will begin to organize field trips and visits.

Weaknesses

An inhibitory parameter is the fact that the community residents of Syros Island are mainly engaged in tourism activities, yet they are not educated in and on earth sciences. They have limited understanding of their own geoheritage. As a consequence, the valorization of the geological heritage of the island and its exploitation is hindered by many adverse factors. The geological heritage promotion project on the island of Syros is barely funded by the local authorities and the universities involved. It is based mainly on regional financial support. So far, there has not been an actual marketing campaign triggered. Generally, there is still a lack of a management framework for identifying, determining and reporting whatever has to do with the geotourism product and its principles in conjunction with the surrounding areas. The high importance and future opportunities of geological and archeological heritage have not yet been understood by the locals which they still have low cognition and knowledge about its protection.

Opportunities

Geotourism will provide good opportunities for public access. The number of tourists already arriving in Syros island could definitely be increased by developing a network linking North Syros to the rest of the island and Syros island to the rest of Cycladic and Aegean islands. This new tourism perspective could encourage the expansion of tourism offerings and the increase of economic challenges and competitive investments in the fields of hospitality (hotels, bed and breakfast, agritourism, restaurants, etc.), current and new cultural events, etc. This can also develop new employment opportunities as local tourist guides for geological-archaeological tourism. An integrated archaeological and geological wealth management strategy in relation to other natural reserves with local landscape features and local value for food and wine would directly promote and enhance economic tourism opportunities.

Moreover, the prospect of geotourism development will trigger the creation of a geomuseum in which the regional mineralogical heritage should be presented. Until today, no permanent museum dedicated to mineralogy exists in the area, but temporary exhibitions are organized, particularly in connection with annual cultural events. The geo-museum will provide all the necessary facilities for rock exhibition and popularization of related scientific knowledge. In this way, all the information will be delivered to the public.

Threats

The identification and evaluation of the geological heritage of the island of Syros and the construction of adequate infrastructure for the development of geotourism depend on the local municipality and is mostly funded by regional funding. This may result in management problems (many bodies involved) and inconsistent funding, depending on the variable funding opportunities and variable local-regional political circumstances.

4.5. Geotourism potential

Geotourism activities are rapidly increasing worldwide [60], and geological heritage of significant value should therefore be considered as the primary natural resource for these initiatives. The geological heritage of Syros Island, as a world-class geological heritage, will draw numerous geotourists interested in visiting unique phenomena and gaining knowledge of the Earth history and evolution. The island as a whole provides several additional possibilities that would make geotourism flows easier. Information sharing of geological knowledge can be of great benefit in order to achieve 1) the improvement of the attractiveness of the destination for geotourism, 2) attention to the need to preserve geological sites and the associated natural environment, and 3) the popularization of geology in general.

The geotourism potential of Syros is reinforced by the importance of tourism in general. The study area hosts the infrastructure facilities and also features significant biodiversity. These conditions make the island of Syros an attractive, nature-focused popular destination. Its current popularity among tourists would add value to the interest of geotourism, and vice versa, geotourism would strengthen tourism industry offerings.

The promotion on a global scale of the geo-cultural heritage of Syros presupposes the development of geotourism Management in terms of sustainability with the parallel protection and promotion of the natural environment, i.e. the geotopes, with the establishment of an integrated management system for the future application of these areas as Geoparks. to the UNESCO World Geoparks Network. In this light, some specific actions should be developed:

- Development of a Management Plan and a Four-Year Action Plan" and "Detailed presentation of the Geotopes of Syros and their Evaluation",
- Creation of Interpretation and Centers of geotopes, which function as information centers
- Creation of outdoor geological routes and museums with placement of signs in the geotopes of interest and markings on the geotrails

A geotope is of greater interest if combined with its anthropogenic environment. A geological monument must be related to the surrounding area and the cultural heritage of the surrounding area. This direction may be assisted by the "Geotourist Guides" that describe various actions that can be carried out in a place depending on the interest, time and opportunity of each visitor. In these guides, it is advisable to provide information about the cultural monuments and to make a direct connection of the geological with the cultural element, but also with the daily life of the inhabitants.

The touristic infrastructure of Syros is well developed. It includes, besides the famous beaches, a lot of hotels, hostels and private accommodations, restaurants, golf courses, riding and water sport possibilities, boat and sailing tours, discotheques, as well as other leisure and sportive activities.

4.6. Institutional framework

Syros, and particularly Northern Syros, is an important habitat of great archaeological interest and today is protected by Greek law, as an area of special natural beauty. It is also included in the European network of protected areas NATURA 2000, which is the main national means for the purpose of Directive 92/43/EEC of the European Council "for the conservation of natural habitats and wild fauna and flora" which are significant at European level (the aforementioned Directive was incorporated into a Joint Ministerial Decision 33318/3028 / 1998 1289/V/28-12-98-Government Gazette).

Nowadays, there is a government initiative aiming to protect sites that are considered very important in terms of their geodiversity, particularly if they are listed as geological heritage [61-63]. The development of a geosite inventory should be the first step in any strategy for the conservation of geological heritage. The implementation of preservation and evaluation without a complete inventory of geotopes is an unacceptable starting point for any geoconservation project [64]. Establishing a protected area is a long and complicated bureaucratic process in several countries. This initiative must therefore be applied only to those geotopes which stand out because of their scientific, academic and tourism values. To assess this importance, a consistent national inventory is crucial. Following the creation of an inventory of geosites, the basic steps in the geo-conservation strategy must be to characterize them by assessing their relevance, protecting them in accordance with the national legal framework, preserving, interpreting and monitoring them.

Although well-known and identified, the eclogites and the other important and rare HP-LT rocks and geological structures on Syros Island are not officially protected. All related international conventions have been signed by Greece, and the institutional structure established guarantees the possibility of preserving and enhancing even individual geotopes surrounded by incompatible uses of the mild and sustainable development model (i.e urban environment, industrial park, etc.). In particular, the protection structure given by Law 1650/86 for the category 'natural formations-landscapes-landscapes'

 doi:10.20944/preprints202101.0305.v1

components' has been substantially improved by the new Biodiversity Law 3937/2011. This legislation specifically provides for the preservation of functional parts of nature or of human creations which are of particular scientific, ecological, geological, geomorphological or aesthetic significance and thus contribute to the conservation of natural processes and to the protection of natural resources.

4.6. Future perspectives

Syros has a strategic advantage in the field of geotourism, as the island is considered one of the most representative location of blueschists, jadeitites and eclogites in the world. The whole island is a geological museum that is hard to find. For these reasons, Syros island is characterized by geological heritage of global interest. Given the importance of the local natural and geological environment to the active development of tourism, it is proposed that this locality should be included in a future Geopark. The profit from the promotion and utilization of its geological wealth with the aim of its integration in the world environment of the Geoparks, is obvious. In general, it is estimated that the benefit to the island as a whole will be particularly significant.

The long-term objective is to formally establish a geopark on the island of Syros which would claim the status of a UNESCO Global Geopark. The key requirements set for Global Geoparks, such as the presence of outstanding geo-heritage and local community engagement, are or may be met in the near future. Achieving the UNESCO Global Geopark status would provide valuable international recognition, thereby helping to strengthen the residential and tourist appeal of the region, a lever for local economic development that will protect these assets. The designation of Syros island as a geological monument of global importance and its integration in the Global Geoparks will result in the attraction of tourism on the island, with direct positive consequences for local development, in terms of competitiveness, employment growth, enhancing living standards and social welfare.

The ambition of the local authorities is to develop a responsible geotourism and actions concerning geo-education which are going to contribute to the economic development of the Cyclades islands. The development of geotourism on the island of Syros through the use of geological morphology, with the principles of sustainable development through tourism and educational activities will contribute to the economic development of the wider region. The development of geotourism is intertwined and complementary with the operation of the geopark as well as with the establishment of a geological exhibition (geo-museum) where the geological history of Syros will be presented.

In order to achieve the goals mentioned above, a lot of related work has to be done including:

1. Geosite inventory: An inventory comprising the various geosites of Syros island, must be created and discussed. Regarding the geological information and the interests of geodiffusion, we plan to show, describe and explain the preserved evidence of processes active in deep levels of orogens, and, then, explain the birth and development of an orogeny. Geo-diffusion activities undertaken encompass concepts and configuration of geological trails along the most impressive and indicative cross sections, most of which are dedicated to displaying characteristics of these processes.
2. Capacity building: Geological experts obtain information through literature collection and on-the-spot investigations, and then translate scientific data into popular materials that the public can understand. Through continuous and hierarchical training including the seed narrator training, environmental education for students of primary and high school, etc., to learn about the land where you live, and to introduce the story of their hometown;
3. Networking activities: In order to continuously improve the ability of community residents to promote the geopark, to share the experience promoted by domestic and foreign geoparks. Networking activities involve the organization of conferences, workshops, training courses, field studies, production and presentation of local geo-products, among others. Moreover, through interviews with community cadres and the public, surveys and inventory of resources will be conducted with the community

 doi:10.20944/preprints202101.0305.v1

to understand the geology, landscape, human history, ecology, and agricultural specialties that they own, as applicable resources for the geopark;

4. Development and production of promotional material: To promote the geopark, increase the elements and characteristics of the territory, scholars and community residents jointly carry out the LOGO design of the Syros Geopark, and make folding, postcards, bags, books, brochures, among others.

There are many prospects for the future, including improvement of sustainable development plans, continuing to build capacity for local communities, seeking support from local governments, providing guided tours and developing geo-products.

Following these first moves, further actions will involve the combination of scientific processes and methodologies, along with geosite-based items, as well as museum collections, scientific displays and nature trails.

In addition, multimedia and virtual reality approaches are designed to visualize and communicate this remarkable natural heritage as widely as possible to an audience. Last but not least, the creation of geodiversity action plans, including educational impacts and promotion of a "geodiversity economy" are further steps in the activity.

5. Conclusions

Syros is a chest full of fascinating, rare and well-exposed geological and archaeological features, something that attracts geologists and archaeologists from all over the world every year. The geological heritage of Syros represents a wide spectrum of unique phenomena. Syros Island is a world-class reference for the preservation of HP–LT metamorphic rocks such as eclogite and glaucophane schist. Scientists from many universities worldwide have been studying the island's geology and have published many of their research results with topics ranging from mineralogy to petrology, tectonics and so much more. Together with the development of the Cycladic culture, all the treasures are locked up in the rocks of Syros waiting to be unlocked. For this to happen, a Geopark must be created on Syros aiming to bring both the Earth history and Ancient Greek Scientific Tradition into worldwide awareness and appreciation and make Syros a unique cultural and scientific park for the entire world to admire.

In both contexts – geology and archaeology – rocks serve as cultural archives. The Syros Geopark will aim to highlight and protect the heritage treasures

- of fundamental processes operating in an oceanic subduction zone
- of the geological evolution of Syros over some 60 million years
- of human culture and evolution on Syros over 8,000 years.

The links between the natural geological heritage in Syros and its human history must be exposed to the public, and the cultural treasures as well as particularly valuable geological sites must be protected.

The preliminary SWOT analysis revealed that the great strength of the locality is the integration of different themes and features, the high accessibility and the connection with other existing tourism attractions. This might result in drastic opportunities for networking and boosting the number of tourists. This can largely promote local people and economic development. However, the analysis further illustrated the weaknesses (e.g. lack of an integrated management system) and the threats to be faced (e.g., completion of all the necessary actions depending on irregular funding and results connected to an integrated management, which should overcome overlapping management from local bodies). On this basis, the geological heritage of Syros is intended as a resource and instrument to contribute to the popularization and enhancement of the cultural heritage of human and geological history of one of the key areas of the island of Cyclades. Last but not least, by improving sustainable tourism based on valuable and lesser-known sites, Syros aims to increase awareness of the themes of natural hazards and territorial risks, increasing the development and resilience of the inner regions of Syros.

Author Contributions: Conceptualization, H.D.; methodology, H.D.; investigation, H.D., T.T., M.P., G.P., C.P., A.M.; resources, M.P., C.P. and A.M.; writing—original draft preparation, H.D.; writing—

review and editing, H.D., T.T. and A.M.; supervision, H.D. and A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Acknowledgments: The authors gratefully thank the journal editor and the three reviewers for their thorough consideration of this paper. They also express their sincere thanks to Professor Martin Engi for his kind and very professional advices as well as his continuous efforts for the promotion and development of the Syros Geological Museum.

Conflicts of Interest: The authors declare no conflict of interest.

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