Natural Heritage from East to West
Niki Evelpidou · Tomás de Figueiredo · Francesco Mauro · Vahap Tecim · Andreas Vassilopoulos
Editors

Natural Heritage from East to West

Case studies from 6 EU Countries

Springer
Cumulative global transformations, occurring daily, affect important aspects of our life. Characteristic cultural and natural heritage, including sites of priceless value, is under constant threat. There are growing pressures, of both natural and human origin, such as wars, conflicts, natural or technological disasters and the effects of global climate change. These provoke the continuous degradation of many sites included in the World Heritage List. In consequence, immediate strategic measures must be taken.

Natural heritage is our legacy from the past, that we inherited from our ancestors and pass on to future generations. It is vital to realize its value and protect it by all possible means, enforcing innovative and sustainable action plans that promote global international co-operation.

This book aims to address specific natural heritage sites in Europe, from West to East. The six countries of study interest are Portugal, Malta, Greece, Italy, Romania and Turkey. For each case, the corresponding current status is presented. This is accompanied by recommended action plans for protection and conservation, training initiatives that improve the public awareness of natural heritage issues and efforts to estimate the natural/environmental value of the sites. The book is the overall result of an interregional initiative aiming to promote convergence, provoke public interest and recommend action for radical changes in our attitude towards heritage conservation.
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Geomorphological Evolution of Santorini

Andreas Vassilopoulos, Niki Evelpidou, and Konstantia Chartidou

Santorini is an island of the Aegean Sea that belongs to the Prefecture of Cyclades. It is located southern of Ios Island and, along with Anafi, these are the southernmost islands of the Cyclades. Santorini is composed of Thera, with a crescent shape, and the islands of Therasia and Aspro (Aspronisi) in a circle. In the centre of the circle lies the caldera, which was formed by a volcanic eruption (or eruptions) and the simultaneous collapse of a part of the island. Santorini caldera is one biggest of the world, covering an area of approx. 83 km², with a length of 11 km (N–S) and a width of 7.5 km (E–W). The volcanic islands of Nea Kameni and Palaia Kameni have formed within the caldera. Nowadays Santorini is a volcanic island that belongs to the Aegean volcanic arc and, with its fumaroles, gases and a high temperature, is the only active volcano in the Eastern Mediterranean.

Santorini complex belongs to Cyclades islands situated into Aegean Sea

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The conceivable circle forming the caldera of Santorini. This circle is composed by Thera, Therasia and Aspro islands.

Santorini has been the subject of numerous studies undertaken by a wide variety of scientists (Lacroix, 1896; Padang, 1936; Marinatos, 1939, 1968; Galanopoulos, 1958 & 1971; Ninkovich et al. 1965; Heinek-Mac-Coy, 1984; Velitzelos, 1990; Skarpelis and Liati, 1987; Lagios et al. 1989; Fytikas et al. 1990). Nevertheless, geomorphological publications are still rare. Stratigraphically, the lithographic complex of Santorini consists of two main categories of rocks. At the base of the complex
the following formations are found: Triassic crystalline limestones and dolomites, Eocene phyllites and a Miocene granite intrusion. On top of these, a continuous sequence of volcanic rocks dominates the island; it began to form approximately 1.6 million years ago and continued up to modern times.

Within the caldera the volcanic islands of Nea Kameni and Palaia Kameni have been formed.

Hot springs in Thera island
Santorini’s volcanic sequence is characterised by an alternation of volcanic lavas and pumice. Literature often distinguishes three stratigraphic horizons of pumice, and refers to them as, lower, medium and superior pumice horizons. It should be noted that the superior pumice horizon is the result of the Minoan explosion, dating to around 1,500 BC.

The explosions of Santorini volcano began at the end of the Neocene period, about 2 million years ago, after Aigiida broke into pieces and sunk. The island that existed before the volcanic eruptions was residue of a crystalloschistosive mass. Residues of that pre-volcanic island are found in the Profitis Ilias area, which today has the higher altitude in the island (568 m). The most ancient volcanic centres are located on the southern part of the island. The historical eruptions of this volcano were first recorded in 197 BC (Strabo).

- Due to the explosion in 197–199 BC a small islet – Iera – appeared between Thera and Therasia.
- During the 19 AD explosion an islet named Thera was formed.
- With a powerful explosion in 46 AD, which lasted a few months, another islet near Iera was created.
- In 726 AD a violent explosion probably caused damages to agriculture due to the ash fall. The same explosion resulted in the merging of the Iera islet with the one created in 46 AD. None of these islets exists today and they are in no way relevant to the islands of Kameni.
- During the 1570–1573 explosion Palaia Kameni emerged 66 m above sea level.
- In 1650 an explosion took place 6.5 Km outside the caldera, eastern of Cape Columbo, and a small island formed. This island later sunk, leaving in its place Columbo reef, 19 m below the sea surface.
- The explosions of the 1707–1711 period created Nea Kameni.
- During the 1866–1870 explosions the “George I” (in honour of King George I) dome was created, 130.8 m high and constituting the highest altitude in modern Nea Kameni, accompanied by the Afroessa volcanic cone.
Profitis Ilias mountain has the higher altitude in the island and is a prevolcanic relict consisting mainly of crystallised limestones.

- The 1925 (August 11th) and 1926 (May 31st) explosions, created the Dafni dome (in honour of the cruiser who visited the island), that merged Palaia Kameni and Nea Kameni, which was already merged to Afroessa and George I.
- On January 23rd and March 17th 1928, a new explosion created the Nautilus dome (named after the ship of the Greek Hydrographical Service).
- From 1939 to 1941 new explosions in the area of George I and Nea Kameni created the domes Triton, Ktenas, Fouqué, Smith, Reck and Niki (named in honour of Greece’s victory in the Greek-Italian war).
- In 1950 the volcano’s reactivation resulted in the formation of Liatsikas dome (named after the Greek geologist Liatsikas who studied the Santorini volcano).

Part of the Minoan volcanic relief is smooth and has been formed by tuffs deposition.
Given the complexity of the volcanic evolution, various statistical methods have been used (Vassilopoulos et al., 2002) to analyse the diverse geomorphological units and various software programs were applied in order to visualise the alteration of the relief.

Five geomorphological units have been distinguished in Thera Island:

- The limestone–schist Unit (Prophitis Ilias – Vlychada). This formation is found in the south–eastern part of the island and mainly consists of crystalic limestones, dolomites and phyllites representing the pre-volcanic relief of Thera.
- The volcanic clusters (Mesa Vouno – Mikros Prophitis Ilias – Skarou) located in the Northern part of the island, mainly formed by andesitic lavas.
- The Minoan volcanic relief of Thera and Therassia shapes in the form of a crescent. This unit can be further divided in two sub-units, the one having a smooth relief and the other a rough one.
- The Caldera is the most impressive landform in Thera and has attracted many researchers over time.
- The Unit of the newer volcanic islands, Palaia and Nea Kammeni, whose creation expresses the most recent volcanic activity.

The newer volcanic islands, Palaia and Nea Kammeni, whose creation express the most recent volcanic activity. Figure a) has been taken from Nea Kammeni and shows Palaia Kammeni. Figure b) Show the volcanic crater of Nea Kammeni during a geological field work.
The Akrotiri area is believed to have been inhabited at least since the late Neolithic period (7,000 BC–3,500 BC). Akrotiri settlement is dated by ceramics to as far back as the mid 4th millennium BC. These ceramics are related to those of the Neolithic settlement of Saliagos, between Paros and Antiparos. Almost 50 years of excavations have brought to light a self-sufficient settlement with a network of water supply and sewerage, along with paved roads and houses.

Ceramic elements found in Akrotiri settlement, dated at 4th millennium BC

A very well sewerage system was developed in Akrotiri village

Thick volcanic material deposits covered the prehistoric village of Akrotiri and conserved two or even three floor buildings, with their whole contents intact. The excavated section is a very small part of the entire settlement. Akrotiri must have covered an area around 200,000 m². Nine buildings are known but none has yet been entirely studied. The southernmost part of the excavation is 250 m away from the current beach. The settlement spreads along the slopes of a small hill, it is arranged like an amphitheatre with slopes towards the S and E.

Buildings with two or even three floors were found in Akrotiri village
The choice of this particular position shows that it was a village whose inhabitants combined agriculture with fishery. The proto-Cycladic (3rd millennium BC) settlement is located under the ruins of the more recent city, which makes the assessment of its extent impossible. In places remains of proto-Cycladic walls have been located, while carved rooms inside the rock are found at several locations, probably tombs that were used by later inhabitants as stores. Thus, Santorini, having been incorporated in the Cycladic civilisation, followed the same course as the other islands during the proto-Cycladic period, and the Neolithic village evolved into a significant centre.

Archaeological data proves that during the last centuries of the 3rd millennium, Akrotiri had already adopted a urban character and its port was increasingly important for communication with the rest of the Aegean Sea. There is a possibility that this rapid evolution is linked to the abandonment, for unknown cause, of Poliochni, a city in Limnos referred to 1,000 years earlier. With Poliochni missing, no communication was possible between the Aegean and Pontus Euxinus, from where metals were supplied, especially from Colchis. Akrotiri soon took over Poliochni’s role – due to its favourable position between Crete and the Greek mainland. At this time, goods were not being transferred between the Aegean and the Pontus Euxinus; instead trade was between the Aegean and Cyprus. This would explain how a settlement, Akrotiri, located in a small arid island, became a rich city, but it is just a possibility, since no archaeological data confirms it yet.
During the mid-Cycladic period (2,000–1,600 BC) Akrotiri prospered. This is the era of all the residencies dug up by Marinatos and of the well known frescoes; seen nowadays in the National Archaeological Museum.

Akrotiri rose to be one of the most cosmopolitan merchant ports of the Eastern Mediterranean, but it was destroyed during the late-Cycladic phase (1,600–1,500 BC) and then abandoned.

**Palaeogeography**

There is a theory suggesting that the Minoan explosion alone caused the creation of the current caldera, (Marinatos, 1972; Pichler and Friedrich, 1980). According to this theory, Minoan Santorini was an almost round island, named Strogili with an average altitude of 500–600 m. However, calderas form due to collapsing, so the volume of the collapsing material should be equal to the volume of the caldera. This fact raised the first suspicions concerning the phases responsible for the formation of the current caldera. In order to prove the above-mentioned theory, the quantity of the collapsing magma should be equal to the volume difference between Strogili and modern Thera. Measurements made on the island as well as drilling specimens of Minoan tephra from the Eastern Mediterranean, showed that the tephra ejected during the Minoan explosion was somewhere between 8 and 13 km$^3$ (Watkins et al., 1978). Other researchers calculated the quantity of Minoan tuffs at 31 km$^3$ (Pyle, 1990). In further research the volume of the caldera was estimated to be 60 km$^3$. 
(Pichler and Friedrich, 1980). Many different studies have taken place from time to time, usually leading to contradictory results. The possibility of a northern caldera in the Santorini area, flooded with sea water during Minoan times should be noted. This hypothesis is mainly based on observations of the interior inclinations on the edge of the caldera in Therassia and Oia (Heiken and McCoy, 1984).

Views of the current caldera in Santorini island complex

Topographically, Minoan Santorini was, up to a point, the same as modern Santorini. For instance, the mountains of Profitis Ilias, Mesa Vouno and Mikros Profitis Ilias were, and are still, characteristic of the Minoan relief. In some parts the Minoan relief has been dramatically altered by the deposition of tuffs of significant thickness in the valley beds, as well as on the neighbouring coastline; in some areas this spreads for more than a kilometre, e.g. in Monolithos. However at a smaller scale, topography varies from place to place. For instance, the northern half of the island is dominated by volcanic cones that have strongly influenced the thickness of the tuff deposits and given it a rougher appearance than in other parts of the island. The edges of the caldera show an incredible resemblance to the rocky site that is drawn on the Anoixi (Spring) fresco, found in the Minoan city of Akrotiri. Of course, small scale features have completely disappeared under the layer of pumice. Small valleys like the ones located under Oia and low hills like the ones uncovered
in the Megalochori quarry (where the art of pottery-making had been developed in what was probably a colonised city) have vanished, leaving a new ground surface relatively flat and without any special characteristics. The only elements interrupting this flat surface come from deep erosion valleys and human land use (Gournellos et al. 1995).

Additional evidence of Thera’s palaeotopography may derive from the relationship between the middle tuff series and the Minoan sequence. On southern Thera, the middle tuff series comes, for the most part, from a phreatomagmatic eruption and forms hilly depositions located on cliffy slopes in the inside of the caldera. These elements combined with the middle tuff series distribution, reveal a 6 km diameter area of depression, now inundated by the sea. This caldera was most probably formed during the explosion that produced the lower pumice series, a tuff sequence fairly similar in size and origin to the Minoan tuff.

There are many theories concerning the old coastline in the Akrotiri area. One theory suggests that the prehistoric coast was located about 800 m towards the south (Marinatos, 1972). A rather different theory suggests that the shore was located 50 m inland from the current shore and that the sea was also covering the (modern) Agios Nikolaos plain. That is where the city’s port is believed to have been located (Doumas, 1983).

There is evidence demonstrating the divergence between the modern and the past coastline in certain areas. Such examples can be found around the high masses of
Mesa Vouno and Mikros Profitis Ilias. Everywhere else, the Minoan coastline has disappeared under very thick tuff depositions and the current coastline lies towards the sea. The previous cliff-like slopes still remain and can be seen on the road from Perissa to Kamari and around the crystalline limestone mass in Gavrilos. It is certain that on the pre-Minoan island the modern embayment seen from Perivolos was at least partly inundated by the sea, and the area of the modern city of Emporio was closer to the Minoan coastline. This fact could support the theory that the city of Emporio was probably an important trade centre during the Minoan Age (Aston and Hardy, 1990). Despite the fact that the Minoan coastline has been covered by tuffs, there are currently two places where Minoan slopes appear. Those are in the southwestern part of Therassia and under the city of Oia on the northwestern part of Thera. The slopes facing the Akrotiri peninsula must have vanished due to the enlargement of the caldera during the Minoan explosion. The visible series are evidence of slopes less steep than the ones currently existing in some areas.

Nowadays, there are many wide and relatively flat areas, such as the area near the airport and the coastal land strip on the north. During the Minoan Age the area north of Oia and the western side of Therassia clearly had little to no chance of being available for colonisation. It is possible that the Minoan coastline was 1–2 km beyond the present coastline and the land surface followed the slope that appears on the 100 m contour.

The area west of Akrotiri must be the place where the prehistoric port was located. Around the Profitis Ilias massif there were probably other ports, as at Kamari and near Emporio. It is considered probable that the sheltered caldera served as a port (Doumas, 1983).

As far as land use in the Minoan Age is concerned, it has been discussed by many researchers (Wagstaff, 1978, Hope Simpson and Dickinson 1979; Doumas 1983). The investigation of those areas has inevitably returned very poor results due to the fact that the probably pre-existing area does not exceed 72% of that currently seen. Settlements have been recognized by buildings, walls, graves and pottery items found beneath pumice layers as well as by pieces of pottery found on exposed palaeo-surfaces. Statistically it is rather unexpected that settlements have been discovered on the island, given the fact that only a small piece of the original island still stands and only a very small percentage of the palaeo-surface is exposed. There is a high possibility that significant number of yet unknown settlements exist on the rest of the island. The density of the known settlements, as in the Akrotiri area, could possibly occur elsewhere. In geologically similar islands like Milos (Renfrew and Wagstaff, 1982) the existence of almost 20 settlements, during the Bronze Age, on an area of 33 km², has been proven. Proportionately to the island of Milos, in Minoan Thera 62 settlements are expected, 39 of which would probably have been preserved.

It’s undoubted that systematic and intensive fieldwork will bring to light new settlements, even in the relatively limited areas available. For instance, the existence of settlements in relatively flat areas of the Minoan island, such as the slopes north of Oia and on the western part of Therassia, is considered highly probable.
The Minoan relief has been altered dramatically by the thick tuffs deposition all around the island.

References


The Petrified Forest of Lesvos
A Unique Natural Monument

Nickolas C. Zouros

The Petrified Forest of Lesvos covers an area of 15,000 ha and has been declared a Protected Natural Monument. Fossil sites with standing and lying petrified tree trunks are found in many localities on the western part of Lesvos Island. The Petrified Forest was developed during Late Oligocene to Lower-Middle Miocene, due to intense volcanic activity in the area. In order to protect the Petrified Forest and ensure its proper management, serious efforts have been made during the last decades, including the foundation of the Natural History Museum of Lesvos Petrified Forest, scientific research, geoconservation, site protection measures etc. All these elements comprise the main parameters for the operation of the Western Lesvos Geopark, a body whose aims are the protection of the geological heritage and sustainable local development. The Lesvos Petrified Forest geopark comprises the famous fossil sites of the Lesvos Petrified Forest as well as a variety of other important volcanic geosites. It also includes the establishing of a network of walking trails linking geosites of interest, creation of relevant information points and eco-tourism infrastructure as well as the organization of exhibitions, scientific events and congresses and environmental education programmes and activities.

Introduction

Located in NE Aegean Sea, Lesvos Island is one of the largest Greek islands, with an area of 1630 km². On the western coast of Lesvos, where the volcanic rocks meet the azure blue of the Aegean Sea, natural erosion has slowly revealed the petrified remains of plant life of the distant past. No description can do justice to the brilliance, the beauty and the vivacity of their colours, the real glory of the standing fossilized trunks or the wild beauty of the volcanic landscape.

The most noteworthy concentrations of petrified trunks, making up the renowned “Petrified Forest”, are located in the western peninsula of Lesvos between Sigri,

Antissa and Eresos villages over an area of 15,000 ha. As well as petrified trunks, one encounters perfectly preserved petrified roots, fruit, leaves and seeds.

The large number of standing petrified trunks with their root systems intact and in full development provides proof that these trees were petrified in their original growing position. In other words this is an autochthonous petrified forest.

Recognising the major environmental, geological and palaeontological value of the site, the Greek State has declared the Petrified Forest to be a preserved Natural Monument (Presidential Decree 443/85).

In order to deal with the study, research, preservation, conservation and protection of the Petrified Forest, the Museum of Natural History of the Petrified Forest of Lesvos was founded in 1994. The Museum is located in Sigri villages and coordinates all the research, educational and geotouristic activities in the Petrified Forest protected area.

Due to its great geological and ecological value, a great part of western Lesvos (16,600 ha) is included in the list of the “Natura 2000” areas of Greece under the name “Petrified Forest – Western Peninsula of Lesvos”. Furthermore, due to the significant presence of rare types of birds, the area is also included in the list of the most important bird habitats of Greece.

The year 2000 marked the establishment of the European Geopark Network, its objective being the cooperation of geologic parks and monuments at a European
level for the development of geotourism. The Lesvos Petrified Forest is a founding member of this network. In 2001, the Museum was awarded the Eurosite Management Award for its effective management of the Lesvos Petrified Forest. In February of 2004, the Petrified Forest of Lesvos joined, the Global Geopark Network of UNESCO.

Volcanic Activity and the Creation of the Petrified Forest

The creation of the Petrified Forest is related to the intense volcanic activity that took place in the Northern Aegean during Lower Miocene. Neogene volcanic rocks dominate the central and western part of the island. Lesvos is part of a belt of late Oligocene to middle Miocene calc-alkaline to shoshonitic volcanism of the northern and central Aegean Sea and western Anatolia. The main volcanic sequence consists of andesite, dacite, and basalt lavas, ignimbrites, and a thick pyroclastic sequence (Pe-Piper and Piper, 2002).

In the central part of the island a series of volcanic centres is located along a SW-NE axis. There are impressive volcanic domes, large dikes, volcanic necks and numerous other volcanic sites. Major craters are located in central Lesvos in the regions of Vatoussa, Agra and Lepetimnos.

Early Miocene volcanic eruptions resulted in the flow of pyroclastic material that covered the vegetation.

Gigantic petrified trunk, an ancestor of today’s Sequoia. This is the largest known standing trunk of a petrified tree in the world. The trunk stands 7.02 meters high and has a circumference of 8.58 meters. Here we can see the very well-preserved lower part of the trunk. The visible root system at the base of the trunk is proof that the tree is still in the same spot that it was 20,000,000 years ago. Prior to petrification the tree would have been over 100 meters high. This is trunk belongs to the species *Taxodiumalbertense*, which is the ancestor of the *Sequoia sempervirens* now found on the west coast of the United States (California and Oregon) along the Pacific where the necessary climatological conditions (humidity) prevail for this species to grow. This species along with the related *Taxodiumgysaeum, Sequoia abietina, Taxodiumpseudoalbertense, Cunninghamia miocenica* species formed the Sequoia forests of the Aegean during the Tertiary period.