

The Petrified forest of Lesvos – Protected Natural Monument

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ABSTRACT: Remains of fossil plants, which form the famous «Petrified forest of Lesvos», declared as Protected Natural Monument, have been found in many localities on the western part of Lesvos island. The fossilised forest of Lesvos was developed during Late Oligocene to Lower - Middle Miocene, due to the intense volcanic activity in the area. Neogene volcanic rocks dominate the central and western part of the island, comprise andesites, dacites and rhyolites, ignimbrite, pyroclastics, tuffs and volcanic ash. The products of the volcanic activity covered the vegetation of the area and the fossilisation process took place due to favourable conditions. The fossilised plants in Lesvos are silicified remnants of a sub-tropical forest that existed on the north-west part of the island 20-15 million years ago.

1 INTRODUCTION

The island of Lesvos, which is the third largest Greek island after Crete and Euboea, is located to the NE of the Aegean sea and covers an area of 1630 square kilometres. The East coast of Lesvos Isl. is separated from the West coast of Asia Minor by the Mytilene strait.

Lesvos can be divided into four main physiographical provinces: a. The south-eastern part where the Olympus mountain range, reaching a maximum height of 967 m, dominates; b. The Kalloni Gulf grabben; c. The central mountainous region, including the chain of the main volcanic centres, this region starts west of Kalloni Gulf and extends to the northern shores of the island, hosting also the highest peak of the island, Lepetymnos (968 m); d. The hilly western part which is composed of pyroclastic rocks, and is characterised by irregular peaks that reach heights of 600 m.

The western part of the island is infertile and presents an undulating wavy regional geomorphology due to the intense erosion of the pyroclastic rocks.

It is also in this part of the island where remains of fossil plants appear within the volcanic rocks. The fossilised tree trunks comprise the well known «Petrified forest of Lesvos», which has been declared a Protected Natural Monument.

2 GEOLOGY OF LESVOS ISLAND

The geology of Lesvos Isl. has been described by Hecht (1971, 1974, 1975), Pe-Piper (1978), Katsikatsos et al. (1982, 1986). Hecht (1971, 1974) presented the geological map of the island (1: 50,000 scale).

Lesvos island belongs to the Pelagonian geotectonic zone (Mountrakis 1983). According to the published data and our survey, the geological structure of Lesvos island consists of the following rock-units:

- An autochthonous unit of Permo-Triassic age, including schists, quartzites, metasediments, phyllites and intercalation of marbles and crystalline carbonates. These rocks are widely extended on the Southeast part of the island, while in the Northwest part have a rather small extension.

- An ophiolitic nappe, comprising basic and ultrabasic rocks and associated deep-sea fine-grained sediments, as well as metamorphic rocks, amphibolites and amphibole schists, metabasites and metasediments, parts of the sole, overthrusting the metamorphic basement.

All these alpidic and pre-alpidic rocks were covered later by post-alpine volcanic rocks and Neogene marine and lacustrine deposits such as whitish marls, marly limestone, silts and sandstone, as well as Tertiary deposits.

The Neogene volcanic rocks, dominate the central and western part of the island. Lesvos is part of a belt of late Oligocene - middle Miocene calc-alkaline to shoshonitic volcanism of the northern and central Aegean Sea and western Anatolia. In the central part of the island there is a series of volcanic centres, situated along a SW-NE direction.

Several volcanic rock units can be distinguished. The oldest igneous rocks are andesites of the Lower Lava unit, dated by Borsi et al. (1972) as 18.0 m.y. The Acid volcanics unit overlies the former, comprising the Sigri pyroclastics, ignimbrite and rhyolite domes. Sigri pyroclastics are connected with the development of the Petrified forest. The Skoutaros Lava unit, consisting of basalt and andesite, overlies the acid volcanics.



Plate 1



Geological map of Lesvos island showing the main volcanic rock units (Pe - Piper 1978).

The volcanic activity was continuous into the Sikaminea unit of andesites, dacites and rhyolitic pyroclastics. The younger volcanics, Eressos andesitic dykes, dated by Pe-Piper (1978) at 16.2 m.y., are widespread in western Lesvos. The last volcanic manifestation took place later with the local basaltic-shoshonitic lavas of eastern Lesvos, in Mytilene area, around 11 m.y. ago (Pe-Piper, 1978). The intense volcanic activity in the area left a large number of active surface thermal manifestations (hot springs, various geothermal fields, etc).

Kinematic analysis carried out in Lesvos, showed that several successive tectonic events took place during

Cainozoic. The neotectonic stress pattern in the area was determined with quantitative methods, using tectonic striations and other kinematic indicators. Taking into account published results of regional neotectonic studies in the North Aegean (Mercier et al. 1989, Pavlides et al. 1990) as well as local studies (Dotsica et al. 1994) we conclude that Lesvos suffered at least three post-volcanic tectonic events since Miocene. The first one produced E-W to ENE-WSW trending sinistral strike-slip faults in Late Miocene. The second during Pliocene, caused NW-SE trending normal faults and NNE-SSW trending sinistral strike-slip faults. Finally during Pleistocene the orientation

Plate 1

1. *Pinoxylon paradoxum* SUSS & VELITZELOS (sp.nov.) fossilized tree trunk belonging to the *Protopinaceae* family, with distinct annual growth rings. This is a new species of conifer widely distributed in the region of the Petrified Forest of Lesvos
2. *Pinoxylon paradoxum* SUSS & VELITZELOS (sp.nov.) and *Taxodioxylon* sp.(lying) fossilized tree trunks from two species which are widely distributed in the Petrified Forest park at «Pali Alonia». The lying tree trunk is the longest trunk found in excavations at more than 20 meters in length.
3. Detail of a fossilized conifer tree trunk showing the impressive colours and excellent preservation of the morphology and structure of the wood.
4. *Pinoxylon paradoxum* SUSS & VELITZELOS (sp.nov.) Standing fossilized tree trunk, 1.28 m in height, in the the Petrified Forest park at «Pali Alonia». The considerable frequency of fossilized tree trunks preserved standing with their root systems fully developed confirms that they were petrified *in situ*.



Plate 2

of the strain ellipsoid changed and an extensional event in the N-S direction took place. It produced E-W trending normal faults and the reactivation of the pre-existing structures. This tectonic regime seems to be still active in the area (Papazachos et al. 1990).

3 PALAEOLOGICAL RESEARCH

Greece, provides a great deal of information about present plants. This fact was noticed very early on by renowned palaeobotanists who visited Greece and studied the past flora of Euboea, Lemnos, Thessaloniki and Lesvos. It was then, in fact, when the scientific study of the fossil forest of Lesvos began.

F. Unger, reports in 1844 fossil tree trunks from the petrified forest of Lesvos, without, however, being certain about their relative age. He believes that they belong perhaps to the Tertiary. These are the first scientific data about the anatomy of wood in the Mediterranean area. He identified the following species: *Peuce lesbia* UNG. (= *Cedroxylon lesbium* KR.), *Taxoxylon priscum* UNG., *Junglandinium mediterraneum* UNG., *Mirbelites lesbicus* UNG., *Brongiarites graecus* UNG. In 1898, Flinche in a book by de Launay dealt with the identification of fossil tree trunks from the petrified forest of Lesvos and reported the genera *Cedroxylon* and *Pityoxylon*. He also reported on the carbonised genera: *Cedroxylon*, *Palmoxylon* and *Ebenoxylon*. Berger (1953) in his palaeobotanical studies of Greece, made special reference to the fossil tree trunks from the area of the Aegean Sea. Krausel (1965) during a brief visit to the petrified forest of Lesvos, between Eressos and Sigri, recognised its high scientific value. He suggested that many tree trunks could belong to the family *Taxodiaceae* (*Sequoia*) and that an isolated piece of wood possibly belonged to oak. Krausel, even though he did not make a detailed analysis of the flora, was convinced that the relative age of the petrified forest was older than Pliocene, possibly close to lower Palaeogene. In addition, he suggested that the correct relative age of the petrified forest could be determined by the precise taxonomic identification of the palaeoflora.

Plate 2

1. *Pinoxylon paradoxum* SUSS & VELITZELOS (sp. nov.) Standing twin fossilized tree trunk, belonging to the *Protopinaceae* family, with distinct annual growth rings on both trunks.
2. *Taxodioxylon gypsaceum* (GOPPERT) KRAUSEL Standing fossilized tree trunk, with excellent preservation of the morphological features and the structure of the wood. 2 m in height, 1.05 m diameter, it is a precursory form of the modern species *Sequoia sempervirens*, which grows on the west coast of the USA (California, Oregon).
3. *Taxodioxylon gypsaceum* (GOPPERT) KRAUSEL Standing fossilized tree trunk in the Petrified forest park at «Pali Alonia». 2.60 m high, 1.15 m diameter. It is petrified *in situ* on account of the intense volcanic activity in the area 20 million years ago.
4. *Taxodioxylon gypsaceum* (GOPPERT) KRAUSEL Standing fossilized tree trunk, exposed by natural erosion of the volcanic rocks. It is preserved in excellent condition to this day. 4.30 m in height, 1.15 m diameter, it is the tallest standing tree trunk of the Petrified Forest of Lesvos.

Since 1979, the Division of Historical Geology and Palaeontology of the Department of Geology at the University of Athens, conducts palaeobotanical research in the petrified forest of Lesvos. Even though the research is not complete yet, important conclusions have been reached about the scientific value of this natural monument, its extent, relative age and palaeofloral constitution.

4 DEVELOPMENT OF THE PETRIFIED FOREST

The area enclosed by the villages of Eressos, Antissa and Sigri, exposes large accumulations of fossilised tree trunks comprising the Petrified forest of Lesvos. Isolated plant-fossils have been found in many other places of the island, including the villages Molyvos, Polichnitos, Plomari and Akrafi. The formation of the petrified forest is directly related to the intense volcanic activity in Lesvos island during late Oligocene - middle Miocene. The volcanic eruptions during this time, produced lavas, pyroclastic materials and volcanic ash, which covered the vegetation of the area. The rapid covering of tree trunks, branches, and leaves lead to isolation from atmospheric conditions. Along with the volcanic activity, hot solutions of silicon dioxide penetrated and impregnated the volcanic materials that covered the tree trunks. Thus the major fossilisation process started with a molecule by molecule exchange of the organic plant by inorganic materials. In the case of the Petrified forest of Lesvos, the fossilisation was perfect due to favourable fossilisation conditions. Therefore morphological characteristics of the tree trunks such as the annual rings, barkers, as well as the internal structure of the wood, are all preserved in excellent condition.

5 PALAEOFLOA OF THE PETRIFIED FOREST

The study of the fossil tree trunks, leaves and seeds gives useful data about the Palaeoflora, the climate and the relative age of the petrified forest. In addition to the large number of fossilised leaves, the genus or the species of the trees, can also be determined from the micro-analysis of

the internal structure of the fossil wood. The erect tree trunks, with their roots and branches, give evidence that the fossilisation took place *in situ*.

Despite the fact that the systematic study of the petrified forest has not yet been completed, the classification of the fossils permits certain conclusions to be drawn. All of the genera and species determined, belong to higher plant groups: *Angiospermae* and *Gymnospermae*. Complete development of the flora was achieved in the presence of Angiosperms, the most evolved plants.

The following taxa have been determined:

1. *Cinnamomum polymorphum* HEER sensu GRANGEON
2. *Laurus* sp.
3. *Litsea primigenia* (UNG.) TAKHT.
4. *Lindera ovate* KOLAK.
5. *Oreodaphne heeri* GAUD.
6. *Quercus apocynophyllum* ETT.
7. *Quercus crutiata* AL. BR.
8. *Carpinus pliofaurei* RATIANI forma *helladae* n. f.
9. *Carpinus uniserata* (KOLAKOVSKI) RATIANI (?)
10. *Alnus cycladum* UNGER fo *parvifolia* n. f.
11. *Populus balsamoides* GOEPP.
12. *Populus* sp.
13. *Tilia* sp.
14. *Diospyros brachysepala* AL. BR.
15. *Myrsinites* sp.
16. *Rhus* sp.
17. *Daphnogene polymorpha* AL. BR.
18. *Pinoxylon paradoxum* SUSS & VELITZELOS (sp. nov.)
19. *Pinoxylon pseudoparadoxum* SUSS & VELITZELOS (sp. nov.)
20. *Taxodioxylon biseriatum* SUSS & VELITZELOS (sp. nov.)
21. *Taxodioxylon gypsaceum* (GOPPERT) KRAUSEL.

From phytogeographical point of view the above mentioned plants can be distinguished into two main groups. The first group contain subtropical plants like *Laurus* (laurel), *Cinnamomum* (cinnamon), whose related species are found in the forests of south-eastern Asia. The second group includes plants which prefer mild temperatures like *Alnus* (alder), *Carpinus* (hornbill), *Populus* (poplar), *Quercus* (oak), *Pinus* (pine), *Taxodioxylon gypsaceum* (sequoia), etc. Related vegetation flourishes today in the warm continental zones of South-eastern Asia and North America.

A comparison of the stratigraphic expanse of the plant fossils with other European flora and with the Palaeoflora of Greece leads us to the conclusion that the Palaeoflora of Lesvos developed during Late Oligocene - Lower Miocene, under subtropical or warm temperate seasonal climatic conditions.

6 PROTECTION AND PRESERVATION

The Greek State recognised the exceptional palaeontological and geological value of this unique natural monument.

In order to protect the Petrified forest and ensure its proper management, five terrestrial and marine areas with fossil accumulations, as well as all the isolated fossils were declared as Protected Natural Monument with a special Presidential Decree (443 /1985).

The need for further research and protection of the fossils led to the establishment of the Natural History Museum of Lesvos' Petrified Forest in 1994. Its scope is to undertake scientific research on the Petrified forest as well as to preserve and to promote this monument.

In addition the Museum will organize special environmental education programs in order to cultivate a widespread sense of respect to the Earth's Heritage and the Natural monuments, among young students.

The recently established Natural History Museum of Lesvos' Petrified Forest, therefore, has the potential to be a centre for scientific research. Further research in the Petrified Forest will provide new data concerning the palaeontology, stratigraphy, palaeoecology, palaeoclimatology, and palaeogeography of the Southeast Mediterranean, at the Cross-roads of Europe and Asia.

7 THE SIGNIFICANCE OF THE PETRIFIED FOREST

The high proportion of upright petrified tree trunks, with well preserved roots in the fossilised soil, allows us to infer that the petrified forest of Lesvos Isl. represents a complete autochthonous (fossilised *in situ*) ecosystem.

The fossilised forest was developed during the time period from the end of the Late Oligocene to Lower - Middle Miocene (ca. 20 - 15 million years before present), in contrast to most well known fossilised forests on Earth, which developed in earlier geological periods. According to recent scientific data, the composition of the fossil flora is characterised by a high proportion of angiosperms (flowering plants) and gymnosperms (conifers), and a low proportion of Pteridophytes (ferns). The silicified tree trunks and their organs - especially the wood - are very well preserved. Furthermore, fossilised leaves, cones and seeds provide the raw data for important scientific studies. Taxonomic study of the flora shows that they do not grow today in the Mediterranean, but only in tropical to subtropical regions such as Asia and America.

All of the above mentioned criteria certify that the petrified forest of Lesvos represent an important stage of the earth's evolutionary processes. It is considered a unique natural geological monument offering rare scientific data, as no other analogous monument from this time period and stage of plant development exists.

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