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VULNERABLE GEOSITE PROTECTION AND MANAGEMENT IN GEOPARKS - A CASE STUDY OF TAFONE IN LESVOS PETRIFIED FOREST GEOPARK

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Abstract: Geoparks consists of a number of adjacent geosites which have different attributes in terms of value (scientific, educational, aesthetics) and vulnerability. In the Lesvos Petrified Forest Geopark area, beyond the fossilized plants which constitute a natural monument of international value, there are many other sites of interest in terms of geology, geomorphology, ecology and local traditions. Coastal geosites of the Lesvos Petrified Forest are of significant geomorphological, aesthetic, educational and touristic value including cliffs, collapsed boulders, tafoni structures and cavernous weathering forms. Tafoni are widespread on the Miocene volcanic formations on Sigri coast. Miocene volcanics are hosting the silicified plants of the Petrified Forest; a protected natural monument of international value and beauty. Due to their importance and fragility the Natural History Museum of the Lesvos Petrified Forest adopted special measures for the protection and conservation of the tafoni structures of the territory. The research activity in the costal area of western Lesvos island led to the inventory of tafoni. As a consequence of the research some endangered tafoni were brought to the museum for protection, conservation and exhibition. This tafoni exhibition introduces the museum visitors to the processes forming the external surface of our planet.

Keywords: Geopark, Vulnerable geosite management and protection, Lesvos Petrified Forest, Tafoni, Cavernous weathering

1. Introduction

Till recently nature management, protection and conservation attempts were mostly concerned with the biotic environment (flora and fauna). The non-living earth heritage was somehow neglected from the management priorities, even if included were not because of their geological or geomorphological importance but the visual appeal as scenery.

A Geopark is a nationally protected area containing features of geological significance, rarity or beauty, which safeguards and sustainably manages the geological heritage of the earth (Zouros, 2008). Geoparks consists of a number of adjacent geosites which have different attributes in terms of value (scientific, educational, aesthetics) and vulnerability.

Vulnerability is a debate surrounded concept because of the semantics of and the understanding of the term (Mcfadden et al., 2007). In environmental aspects; vulnerability is related to the magnitude of the impact, the adaptation or toleration capacity of the receiver, and the acceptable level of decomposition. Geoparks have a holistic approach in protected areas conservation and management. Geoparks in order to ensure a comprehensive protection of the Earth heritage sites adopt a management plan including the recognition, assessment and protection of the earth heritage monuments present in their territory.

2. Lesvos Petrified Forest Geopak

The Petrified Forest Geopark is situated on the western part of Lesvos island in the North Aegean Sea. The Lesvos Petrified Forest Geopark is one of the four founders of the European Geoparks Network established in 2000 (Zouros et al., 2008). It is well known for its large numbers of petrified trunks in immense beauty. The outstanding fossil of the Petrified Forest which indicates an ancient subtropical eco-

system reveals the last 20 million years history of the Aegean area (Velitzelos and Zouros, 2007). In the Lesvos Petrified Forest Geopark area, beyond the fossilized plants which constitute a natural monument of international value, there are many other sites of interest in terms of geology, geomorphology, ecology and local traditions. Coastal geosites of the Lesvos Petrified Forest are of significant geomorphological, aesthetic, educational and touristic value including cliffs, collapsed boulders, tafoni structures and cavernous weathering forms. The Lesvos Petrified Forest is awarded by a number of international awards on protection and conservation of the earth heritage as far as its successful management on geotourism development which has concrete socio economic results for local development.

3. Tafoni structures

"Tafoni" (singular: tafone) is a Corsican word that means window (Tschang, 1969). Tafoni have caused human curiosity for a long time. One of the oldest known depictions of such features are presented in the "Spring Fresco" excavated in Akrotiri, Greece dating 3500 years ago (Hejl, 2004). Tafoni are characteristic cavernous weathering features in various sizes and have arch shaped entrances, concave inner walls, overhanging margins and fairly smooth gently sloping, debris-covered floors (Mellor et al., 1997).

Science arbitrarily classifies tafoni according to their size, shape and location. The nomenclature for pitted and cavernous weathering was not harmonized throughout most of the twentieth century, but the word 'tafoni' has now become standard for all such pits, large and small (Norwick and Dexter, 2002). The same method is followed in this study that 'tafoni' refers to all cavernous weathering features. Several attempts were made to classify and explain tafone formation (Turkington, 2005; Uzun, 1995 and Tschang, 1969).

Although they are characteristic to the Mediterranean region they are found in many parts of the world, particularly in dry semi-arid environments but also hyper arid and cold arid desert environments as well as in the mild coastal zones, and even on the Mars surface as proved by the observation made by the Viking 1 Landers (Parsons et al., 2005).

The origin of the tafoni formation is a long debate. In 1930's scientist believed that tafoni were aeolian formations (Popoff and Kvelberg, 1938), however Young (1986) argued that salt weathering was the effective factor.

New researches claims tafoni formation as a self-reinforced weathering process characterized by positive feedback of mineral disintegration (ie.carbonates) and salt crystallization (Philips, 2004; Turkington, 2005; and Erginal, 2007).

Last of all, tafoni formation is result of selective or differential weathering on the rock surface driven by inherit internal variations of the rock structure (composition, strength, lithology) and the external exploiting effects of physical, biotic and chemical factors (Dragovich, 1969).

4. Materials and methods

The research area is situated at the Sigri Village; the western coast of Lesvos Island. Although the whole coastline seems to have tafoni features; for an intense survey, the research area was limited from the Plaka Petrified Forest Park till the peninsula of Sarakina, south of Sigri village (Fig. 1).

The tafoni evaluation and validation process mostly depends on field observations. More than 200 tafoni were measured in dimensions, directions and locations and the gained data were extracted to the tables and diagrams for further analyses (Fig. 2).

These statistical data were used to understand the development phases of the cavernous weathering in the research area. Directional (compass) measurements were used analyze the effect of the insolation and sea as a salt source on the tafoni development. Lichen effects on tafoni of the shaded areas were examined by stereoscopic microscopes. Finally the tafoni on the Sigri Castle walls were measured in order correlate the speed of the coastal tafoni development.

5. Tafoni of the Lesvos Petrified Forest Geopark

Cavernous weathering forms have a wide distribution in the warm and partly arid coastal regions of Greece (Kelletat, 1980). Lesvos Petrified Forest Geopark protected area as well bears wide variety of tafoni in terms of origin, size, distribution, parent material. Dimensional measurement comprises two different rock types and locations; one of them is on the coarse ignimbrite layers, the other one is on the bedrocks. Most of the tafoni that were sub-

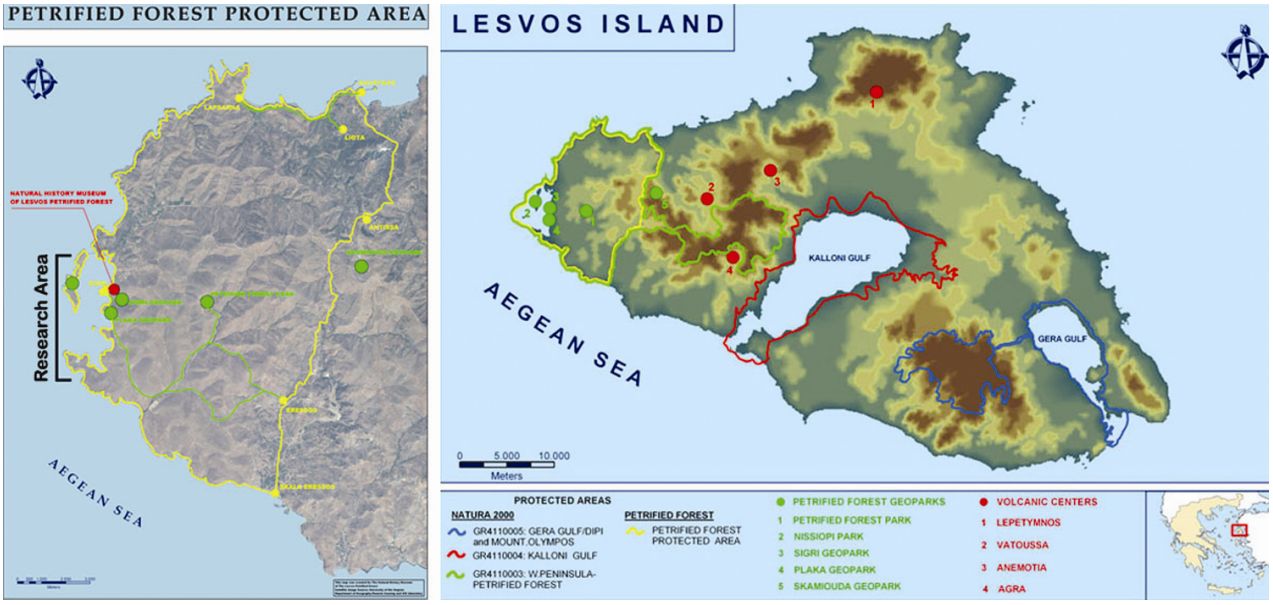

Fig. 1. Location map of research area and Lesvos Petrified Forest Geopark.

jected to this research were less than one meter in scale. As they represent different stages of cavernous weathering they are invaluable clues to understand the phases of erosion processes. The two of them shown below are characteristic samples of tafoni development on andesitic rocks (Fig. 3).

Tafone distribution is highly variable in Lesvos Petrified Forest Geopark coastal area. They develop on the ground rocks, at the lateral surfaces of bedrocks or overhanging over the cliffs (Fig. 4).

The microclimatic conditions and variety of the parent material led the development of very distinct types of tafoni in a relatively small area. Thus in one side of a cliff, salt crystallization can be the driving force, while biogenic activities of the lichens and the wind are dominant on the shaded side.

Most of the tafoni are in a zone not more than 10 meters far from the shoreline. This zone is the most prominent environment for tafoni development due to the strong insolation and splashing water as a salt source. This zone is also under mechanical erosion of waves. Tafoni structures similar to those formed on volcanic boulders along the Sigri coast are also formed on the stones walls of the Sigri castle walls, which was built by the Ottoman navy admiral Suleyman Pasa in 1760 (fig.5).

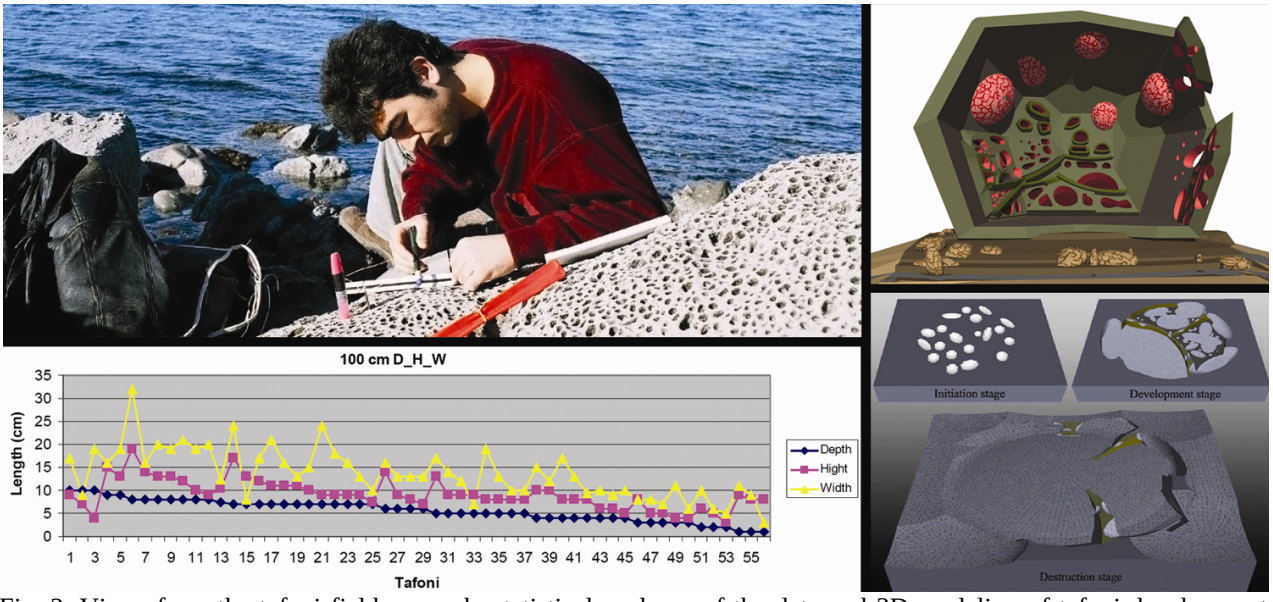

Fig. 2. Views from the tafoni field research, statistical analyses of the data and 3D modeling of tafoni development phases on the coastal geosite of Lesvos Petrified Forest Geopark.

Fig. 3. Two characteristic tafoni formations on andesitic rocks on Plaka Park coastal geosite.

The Sigri castle was mostly build with local volcanic rocks which enabled to create a relative dating of the coastal tafoni and their development phases. The mesurements assumed 0.2 mm weathering per year for the coastal tafoni according to the size/date correlation of Sigri Castle wall tafoni.

6. Protection of vulnerable tafoni in Lesvos Petrified Forest Geopark

Lesvos Petrified Forest Geopark launched a broad initiative for the identification and mapping of the various sites of interest in its territory (Zouros, 2007).

The geosite inventory provides an overall image for the tafoni in terms of distribution, threads and vulnerability. Tafoni which developed on the pyroclastic cliffs were very unstable and continuously collapsing. Tafoni bearing andesitic boulders along the Sigri coast are much less solid than they seem. The pyroclastic formation including andesitic boulders which are in the range of the waves were continuously eroded before the tafoni complete their development phases. The erosion process results in falling or rolling of tafoni bearing rocks. Due to the inner cavities, micro scale decomposition caused by salt crystallization, dissolution and removal of the rock cement by capillarity mechanically weakens the rock. In order to protect some of the spectacular tafoni boulders were carried to the museum (Fig. 6).

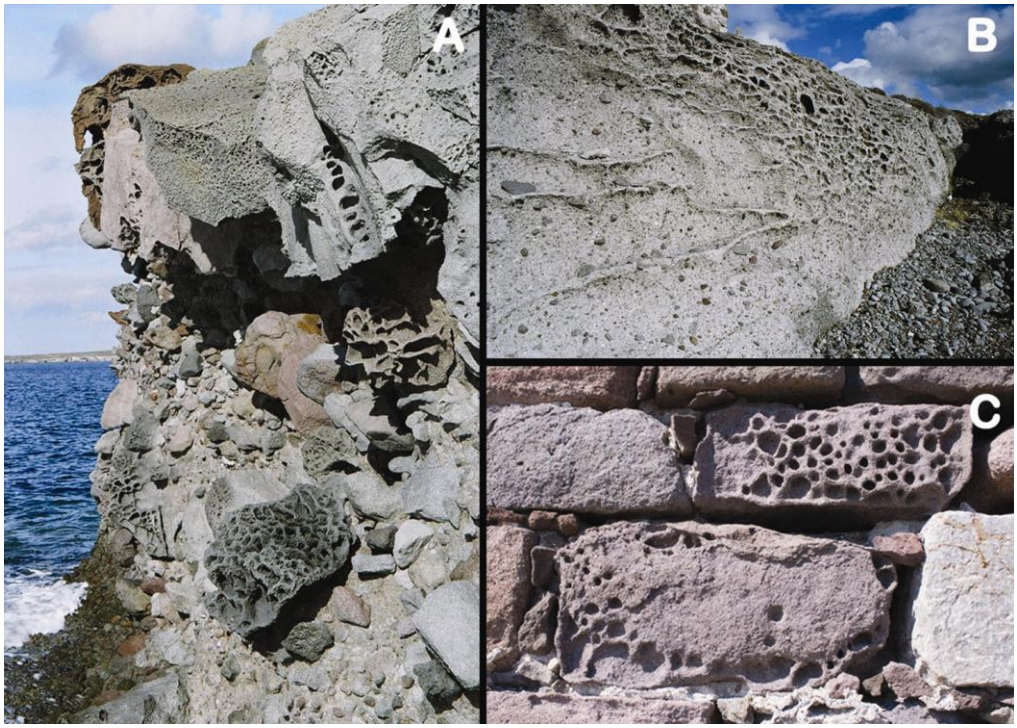

Fig. 4. Various tafoni distribution on the coastal geosite of Lesvos Petrified Forest Geopark (A: Andesitic boulders on cliffs, B: Coarse-grained pyroclastic layer, C: Sigri Castle wall).

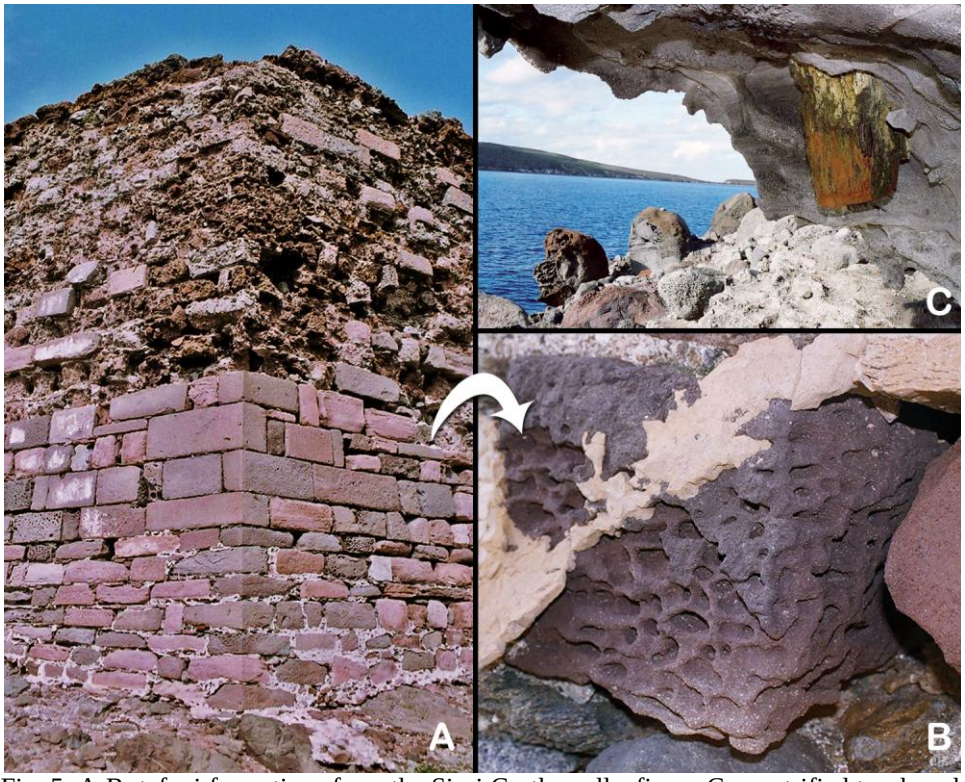

Fig. 5. A-B: tafoni formations from the Sigri Castle walls, figure C: a petrified trunk and tafoni on the same formation. A unique image of Geoparks comprehensive perspective.

A big boulder with tafone structures was found on the coastal area of the Plaka Park, 4.20 m above sea level. It has a large visor and the inside was almost eroded and removed. Just some merged inner alveols and the outer crust remained over time. The vertical circumference was 1.8 m and the horizontal circumference was 2.20 m. The entrance was 50 cm in height, 65 cm in width and 40 cm in


Fig. 6. Andesitic boulders with tafoni structures at the museum.

depth. Its inward buckled cavern floor was so fragile that in some parts the thickness of the rock separating two different tafoni development surfaces was less than 5 mm. The tafone was very thin in the crust and become almost empty with the successive weathering processes. It was connected with the cliff on a small neck less than 20 cm^2 thick. Another endangered tafone boulder was on the cliff of Plaka Park. This tafone bears well developed samples of honey comb cavities and a characteristic surface crust created by the precipitation of internal minerals carried to surface by capillarity. This sample was also about to collapse to the sea but because of its size and weight. The tafone was also carried to the museum without any considerable damage of the very fragile honey comb cavities. Both tafoni are now being visited in the museum.

7. Discussion

The tafoni structures of the Lesvos Petrified Forest Geopark are geosites with aesthetic, educational and scientific value. Moreover, different aspects of tafone development in the Geopark reveal strong linkage to the cultural and geological history of the territory.

The "Tafoni" approach of the Lesvos Petrified Forest Geopark was a successful instance of vulnerable geosite protection and management. The tafoni of the Petrified Forest protected area was documented and depending on this inventory, threatened or vulnerable tafoni were carried to the museum for protection and exhibition.

Beside the scientific importance, Tafoni have other benefits to be used as a touristic attraction or as an educational material for the students.

References

Dragovich D., 1969. The origin of cavernous surfaces (tafoni) in granitic rocks of southern South Australia: Zeitschrift fuer Geomorphologie, 13, 163-181.

Erginal A.E., Gonuz A., Bozcu M., Ates S.A. and Cetiner Z., 2007. The first findings on the origin of alveolar disintegration at the western shores of Gelibolu. Mineral Resource Exploration. Bulletin, 134, 27-34.

Gumus E. and Zouros N., 2008. Cavernous Weathering in Sigri Area, Lesvos Island, Greece, Proceedings of International Conference on Studying, Modeling and Sense Making of Planet Earth, 1-11.

Hejl E., 2005. A pictorial study of Tafoni development from the 2nd millennium BC. Geomorphology, 64, 87-95.

Kelletat D., 1980. Studies on the age of honeycombs and tafoni features. Catena, 7, 317-325.

Mcfadden L., Nicholls J.R and Rowsell P.E., 2007. Managing Coastal Vulnerability.Elsevier, London, 262p.

Mellor A., Short J. and Kirby S.J., 1997. Tafoni in the El Chorro area, Andalucia, Southern Spain. Earth Surface Processes and Landforms, 22, 817-833.

Norwick S.A. and Dexter L.R., 2002. Rates of development of tafoni in the Moenkopi and Kaibab Formations in Meteor Crater and the Colorado Plateau, Northeastern Arizona. Earth Surface Process and Landforms, 27, 11-26.

Parsons R.L., Head J. W. and Marchant, D.R., 2005. Weathering pits in the Antarctic dry valleys, insolation-induced heating and melting and application to Mars. Lunar and Planetary Science, 36, 1138.

Tschang H., 1969. Geomorphological observations on the tafoni forms of Honk Kong. The Chung Chi Journal, 9, 32-51.

Turkington V.A. and Jonathan D.P., 2004. Cavernous Weathering, Dynamical Instability and Self-Organization. Earth Surface Processes and Landforms. 29, 665-675.

Uzun A., l998. Weathering Forms on Sandstones Directly Exposed to Sea Effects in Gelincikburnu and Its Surroundings (South Coast of the Black Sea). Z. Geomorphology, 42, 233-244.

Velitzelos E. and Zouros N., 2007. The Petrified Forest of Lesvos, Topio Publications, Athens, 155p.

Young R.W., 1986. Tower karst in sandstone: Bungle Bungle massif, northwestern Australia. Z. Geomorphol. 30, 189-202.

Zouros N., 2005. Assessment, protection and promotion of geomorphological and geological sites in the Aegean area, Greece. Géomorphologie: relief, processus, environment, 3, 227-234.

Zouros N., 2007. Geomorphosite assessment and management in protected areas of Greece. The case of the Lesvos island – coastal geomorphosites. Geographica Helvetica. 3, 169-180.

Zouros N. 2008. Guide to the Plaka and Sigri Petrified Forest Park. Natural History Museum of the Lesvos Petrified Forest, Lesvos, 136p.

Zouros N., Ramsay T., Mc Keever P. and Patzak M., 2008. European Geoparks, Natural History Museum of the Lesvos Petrified Forest, Lesvos, 163p.