Conservation of structure material of Greek fossilized forests

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Monuments and works of art in the world are separated in two basic groups, those of nature and those of culture. The first group (monuments and works of art of nature) has been created via physicochemical process and ideally aesthetics and apprehension. The second group (monuments and works of art of culture) has been created via artistic process and humankind activities. Fossilized forests belong to the first group. They have been created by volcanic activities, which beyond the accuracy and perfection that appear they also gave an incredible aesthetic to the subjects - monuments that have been created. In fossilized forests we can distinguish macroscopically and microscopically the structure of the tree's trunks, even though the chemical structure has totally changed with the replacement of carbon with silicon. Cellulose and lignin have also been replaced with minerals of silicon, like quartz, tridymite, and cristobalite. As a result, the process of conservation and restoration and the process of exhibition of monuments of nature, which are moreover protected by international charts and organizations, are equally important in order to be given for observation, for studies and for admiration for the present and future.

Greece, which has a strong monumental character of nature and culture, has the important privilege to dispose at least five fossilized forests that have been discovered until now, as appears in the map:

Map of Greece with the presence of fossilized forests in Lesvos (1), Kastoria (2), Evros (3), Evia (4), Limnos (5)

The fossilized forest in Lesvos, which is aged in the lowest Miocene (~20 million years), lies in the northwestern part of the island and according to latest researches, it takes up the half of the territory that is delimited from the intelligible line between Molivos and Plomari. The fossilized trunks are found in massive deposits and the level of petrification is the maximum. The fossilized forest of Kastoria, which is aged in the lowest Miocene (~20 million years), it covers an extended area in the range of Nostimo and Asprokklisia. The fossilized trunks are found in non-massive deposits and the level of petrification is some times maximum and some times incomplete.

The fossilized forest of Evros, which is aged in the upper Oligocene (25 million years), it covers an extended area in the range of southeastern ward of Thraki. The fossilized trunks are found in non-massive deposits and the level of petrification is some times maximum and some times incomplete.

The fossilized forest of Evia, which is aged in the upper Miocene (~5-9 million years), it covers an extended area in the range of the northwestern Evia. The fossilized trunks are found in non-massive deposits and the level of petrification is some times maximum and some times incomplete.
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**The fossilized forest of Limnos**, which is aged in the lowest Miocene (~20 million years), it covers an extended area in the range of Moundros in South Limnos. The fossilized trunks are found in non-massive deposits and the level of petrification is some times maximum. From a general review, corrosion in the fossilized materials is caused by:

**Water.** Mechanisms of water's action in the fossil's aluminosilicates minerals are the following:

- Expansion of clays - thixotropy: Most of the argils have thixotropic characteristics, which is developed as diastole during wetting. As a result argils during desiccation turn in thin powder. Ionexchange alteration: When the fossil's aluminosilicate minerals come in contact with water, some reactions of hydrolysis and ionexchange of the alkaline of the clay's lattice take place.

**Frost damage.** Some forms of corrosion that are related with the formation of ice could be caused, when the material's temperature is below 0℃ and the water content in the tubes of the net frost. The corrosion that is created from ice has to do with the growth of the specific capacity of ice towards water, on the order of 9.2%. **Soluble salts.** The sub-surface crystallization and the efflorescences of soluble salts create forces in the fossil's layers under its surface and the result is to create scaling. Efflorescences always appear in the boundaries between wet and dry area, where some cracks exist that are followed by alveolar corrosion.

**Temperature variations alteration.** The level of corrosion is depended by the size of the fossil's grain. As a conclusion, materials with big size of grain are inclined to change much quicker compared to those with smaller size of grain. In materials with small grain size, creation of cracks is observed. The reduction of the grain's number produces the increase of the specific surface something which favors its chemical alteration. **Biological factors.** The most common microorganisms that developed in the fossil's surface are algae, lichens, plants and two kinds of bacteria, fungus and actinomycetes. The conservation procedure of fossils can be separated in analysis of structural materials, cleanings, consolidation, protection, joining and completion.

**Analysis of structural materials.** Analyses of structural materials are accomplice with microscopically observation, special prestandardization chemical analyses (compleximetry, gravimetric analyses etc.) and with physicochemical analyses (X-R.D., S.E.M. - E.D.X.A., X-R.F., atomic absorption spectroscopy etc.) of the elementary, mineralogical, qualitative and quantitative analyses of the materials.

Overall, for the fossilized forests of Greece, we have the following physicochemical data:

**Procedure of petrification:** Volcanic action - ionexchange between silicon (Si) and carbon (C), (replacement of the tree's carbon by silicon). **Degree of petrification:** Lesvos: very high, Kastoria: high - medium, Evros: high, Evia: high - medium, Limnos: very high - high. **Porosity (average):** Lesvos: 19.24 mm³/g. Kastoria: 22.1 mm³/g. Evros: 20.4 mm³/g. Evia: 22.7 mm³/g. **Hardness (average):** Lesvos: 7.2 Mohs. Kastoria: 6.9 Mohs. Evros: 7.1 Mohs. Evia: 6.8 Mohs. Limnos: 7.4 Mohs.

**Analysis S.E.M. - E.D.X.A.. Analysis X-R.D..** Existence of silica and small quantities of Fe, Al, K, Na, Cl, Ti, Ca, Mg, Mn oxides.

**Cleaning.**

**Water spray:** This is a relatively easy method that it is used especially for the removal of soluble salts, which are extremely dangerous for the porous fossils. It is used basically when we have to deal with water-soluble depositions, which are not strongly connected with the surface of the stone. Water dissolves calcium carbonate that hard crust contents. **Microblasting:** In this method is used a very good smoothing powder made by alumina or by small beads of glass in powder, with lower hardness of that of silicon dioxide and with lower size. That means that we have gentle mechanical action. **Laser:** Cleaning with laser is a method based in high temperature (4,000 -5,000 K), which is developed for very little time, in materials with low thermal conduction and big absorbeny when the laser rays hit them. Crust as a material like that, because of the powder that contains, can be removed by this method.

**Detergent materials - soaps.** Surfactant materials are used for many years as detergents upon materials. They are organic molecules which are constituted by chains of carbon atom with one or more hydrophilic units and high pole energy in one edge. As a result of this structure, they are compatible with the aqueous and organic nature.

**Carbonate salts.** The characteristics of carbonate salts as detergents are known. In conservation of fossilized materials is used for cleaning basically the ammonium bicarbonate (NH₄HCO₃), which its pH is increased with the addition of ammonia.

**Pulpes.** What is being used in pulpes with carbonate salts of ammonium and sodium (NH₄HCO₃ - NaHCO₃) and ethylenediamin-tetraacetic acid (E.D.T.A.) or the disodium salt, which is more soluble compared to E.D.T.A..

**Pulpes of this category,** which are used for cleaning the surface of materials are:

a. Mora pulpe: H₂O: 100 cc, NH₄HCO₃, and NaHCO₃: 6 gr, E.D.T.A.: 2.5 gr, Desogen: 1 gr and carboxymethylcellulose or neutral paper: 6 gr.


c. AB57 pulpe: H₂O: 100 cc, NH₄HCO₃: 3 gr, NaHCO₃: 5 gr, E.D.T.A.: 2.5 gr, Desogen: 1 cc and carboxymethylcellulose or neutral paper: 6 gr.

**Use of absorbent clays.** In this method two types of clays are used, sepiolite and attapulgite, which are aluminosilicate minerals of magnesium. **Removal of biological depositions.** The most common and effective biocides that exist in the market are hydrogen peroxide solution (H₂O₂) 10 - 30% w/v (perhydrol), Desogen which acts basically in bacteria, algae and fungus, Primatal M50 of Ciba Geigy, Primatol 3588 of Ciba Geigy, Vancide 51 of R.T. Vanderbilt Co. Inc. - U.S.A. and many more.

**Removal of soluble salts from the material's surface and porosity.** If the subject is small and has unstable surface, then the subject can be soaked in deionized water so the constant flow and the frequent changes of water could give a result much
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quicker and better. The collected water, is measured for its conductivity and when the measurement is stabilized in low levels, the subject can be removed from the water and let dry.

Consolidation of fossils. When we have to do with portable fossils and we can easily carry them in the laboratory, the methods that are used because they allow a better access of the consolidant solution in the fossil's mass are the following:

Total immersion of fossil in the consolidant solution. The subject is soaked in a special tank, which contains the consolidant solution, under pressure and temperature of the environment. If the subject's surface is unstable there is a danger of dissolution, abrasion or break of the unstable parts. In that case it is necessary to put on the surface some kind of protective material, such as thin layer of paper.

Immersion of fossil with the consolidant solution in vacuum. This is a method by which we have the best access of the consolidant in the fossil material mass. For this method it is necessary to have a cabin with air pocket with two entrances, one for outgo and the one for entrance of the consolidant. Firstly, the fossil's surface is coated with the dissolver of the consolidant, which is very volatile and liquid and it can penetrate in depth. Secondly the consolidant solution is applied. To consolidant materials which are commonly used have their base on silicon. The variety of those materials is very big and it contains organic, inorganic and materials in between those two categories. The consolidant materials of silicon are used for consolidation and for repellent result for all kinds of fossilized materials.

Joining and connection of pieces. For the connection of the detachment pieces, some kind of mortars with or without dowels could be used. The last few years, it is preferred the use of metallic dowels, such as titanium dowels or stainless steel dowels, that cannot be oxidized and they give big stability to the fossilized material and to the joining. A structural mortars vests many times metallic dowels.

Completion of cracks, gaps and missing parts. Completion of gaps and cracks is very important because is the only way to close any gap bigger than 0,1 - 0,2 mm. Generally, completion must be clear-sighted and to have tone lighter in the color compared to the original color. The measure of the extent of the completion is judged according to the fossil's characteristics and those of the subject's. For the completion of big missing parts, a copy of the missing part is demanded, to used as a mold for the appropriate completion material.
BIBLIOGRAPHY

Amoroso G.G., Fassina V.,

Arnold A.,


Furland V., Pancella R.,
"Proprietes d'un gres tendre traite avec des silicates d'ethyle et un polymere acrylique", Proceedings "2nd international symposium for the corrosion of stone in constructions", Athens, September 1976.

Howie F.M.,

Lampropoulos V.N.,

Lampropoulos V.N.,

Lampropoulos V.

Lampropoulos V.,

Lampropoulos V., Panagiaris G., Tsamasfyrou I., Bika D., Velitzelos E..

Lazzarini L.,

Pauly J.P.,

Selmeier A., Velitzelos E..

Siuss H., Velitzelos E..

Velitzelos E., I. Petrescu, Symeonidis N..


Velitzelos E., Zouros N..