



## **Analysing deterioration of marble stones exposed to underwater conditions**

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The peculiar conditions of the marine environment make the conservation of underwater archaeological sites an extremely complex procedure. This is due to the fact that the prevailing conditions in this environment promote the development of deterioration phenomena in submerged artefacts through the synergistic action of physical, chemical and biological factors.

The objective of the present investigation was to determine how petrophysical properties of cultural heritage materials can be affected by being exposed to the specific underwater conditions of the sea bottom, and so, to evaluate how this can affect, in a long term, in their durability and evolution when they part of an archaeological site.

For this purpose, two types of marble (the Italian Carrara and the Spanish Macael) were subjected to an experiment consisting of exposing stone materials for one and a half year to underwater conditions. The experimental test was located in an archaeological site in the Bay of Cadiz (southern Spain), Bajo del Chapitel (recognized as Cultural Interest), which includes remains of shipwrecks from different periods. In this site, samples were submerged to 12 m depth and placed in the sea bottom simulating the different positions in which underwater archaeological objects can be found (fully exposed, half buried and covered). Petrophysical characterisation involved determination of the apparent and bulk densities, water saturation (maximum water content a material may contain), open porosity (porosity accessible to water), chromatic parameters and ultrasonic velocity. Before measuring, samples were subjected to mechanical cleaning (in those samples with biological colonization) and to removal of salt deposits. Results showed significant differences in these petrophysical properties after underwater submersion, which were directly related to the type of underwater exposure condition. Comparative analysis of petrophysical properties, like the one conducted in this study, provides useful information for evaluation of the deterioration processes of heritage stones in a marine environment, and for conservation measures aimed at the in situ preservation of archaeological sites.

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