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Original article

Micro-morphological, physical and thermogravimetric analyses of waterlogged archaeological wood from the prehistoric village of Gran Carro (Lake Bolsena-Italy)

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ABSTRACT

Oak disks from pile dwellings of the prehistoric site of Gran Carro (lake Bolsena, Italy) were analysed in order to estimate wood degradation. Micro-morphological observations showed that the microbial decay could be mainly attributed to erosion bacteria. The most important physical properties, i.e. Maximum Water Content (MWC), Residual basal Density (RDb), and the calculation of the Lost Wood Substance (LWS) highlighted that heartwood (HW) was moderately preserved, with MWC values slightly higher or comparable to that of recent oak, whereas sapwood (SW) was very degraded. Thermogravimetric analysis (TGA) was tested as an alternative method for the chemical characterisation of archaeological wood. The TGA profiles were critically discussed taking into account the results of the physical and micro-morphological analyses. Potentialities and drawbacks of TGA were underlined.

1. Introduction

The definition "waterlogged archaeological wood" includes all wooden remains recovered from submerged archaeological sites (in lakes, rivers, wetlands and the sea) or from terrestrial waterlogged sites. At these sites, wood is subjected to slow biodegradation depending on the oxygen concentration, which influences the types of microorganisms involved in the process (erosion bacteria, tunnelling bacteria and/or soft-rot fungi) [1–3]. They mostly degrade cellulose and hemicellulose, however partial deterioration of lignin has also been reported [4–8]. Selective degradation of cellulose and hemicellulose leads to increased lignin content in wood and considerable loss in mechanical flexibility and a general change in other physical properties [4,9].

Over the last number of years, the characterisation of waterlogged archaeological wood has assumed a significant importance in correct conservation and restoration practices. This topic is becoming more and more significant because of the recent problems with wooden pilings in certain European cities, like Venice and Amsterdam (e.g. [10]). Guidelines for wood characterisation established by European Technical Standards [11] define a diagnostic protocol for wood conservation, including microscopic, physical and chemical analyses. Physical and chemical characterisation of wood, which is one of the main tasks when planning the appropriate methods for conservation and/or restoration, is sometimes very time-consuming. Chemical techniques using classic extraction systems, for instance, require specialised equipment and are

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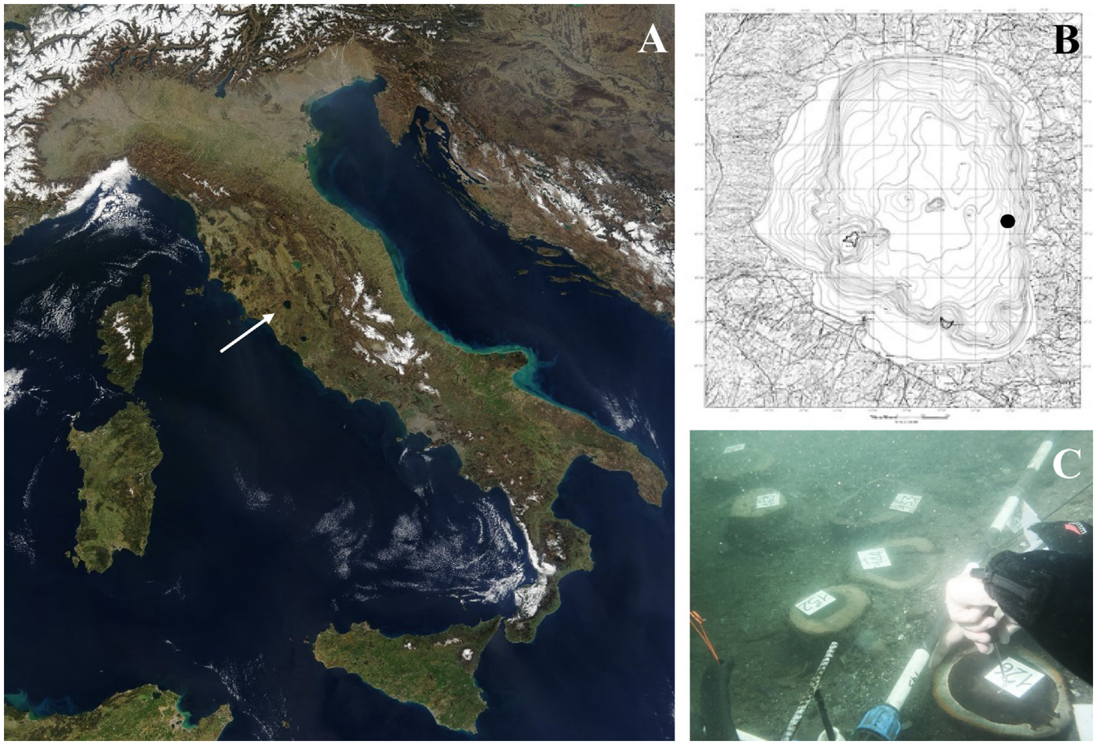

Fig. 1. The archaeological site of Gran Carro, Italy. A. Location of Lake Bolsena (white arrow) (satellite image from NASA). B. Bathymetric map of the lake (1:40,000); the black dot indicates the position of the site (photo from Istituto italiano di Idrobiologia). C. Underwater photo of the poles of the village taken after cleaning operations.

usually associated with considerable consumption of chemicals and time [12–14]. Recently, several spectroscopic and chromatographic techniques, like FT-IR, GC-MS-Py, SEM-EDX, NMR, and UV-microspectrophotometry (UMSP) have been applied to refine data on wood degradation [6,15–20]. Furthermore, they are very helpful for the chemical identification of wood remnants. Usually, application of one method is not sufficient; hence, it is convenient to combine several different techniques to gain as much information as possible. All these methods are micro-destructive and yield detailed results, but a number of them are quite expensive and the obtained data are not always easily comparable to each other and to the data collected by traditional techniques [13]. Thermogravimetric analysis (TGA) is a well-known thermal procedure, which provides information about the residual components of wood. TGA is not expensive, can be performed at high speed, and requires only a small amount of material. In the field of archaeological wood, TGA has been previously applied primarily to demonstrate the effectiveness of wood consolidation [21,22], but few examples have been seen regarding characterisation of wood degradation in waterlogged wood [23–25].

The major aim of the present study was to define the state of degradation of pile-dwelling poles from the lake Bolsena in Italy. A peculiarity of the studied samples is that the majority of the poles contained both sapwood (SW) and heartwood (HW) so it was possible to compare the performance of these two parts of the trunk, which usually have different resistances to decay. The second goal was to test the potential of TGA as a technique in the characterisation of decayed waterlogged wood. To establish the effectiveness of the technique, the obtained results were evaluated taking into account those of physical and micro-morphological analyses.

2. Materials and methods

2.1. Site description

The wood analysed in the present work was sampled from the underwater archaeological site of Gran Carro. The site lies at a depth of 4–5 m, about 100 m off the Point of Grancarro on the east coast of the volcanic lake Bolsena (42°35′ N 11°59′ E) (Fig. 1A, B). It was studied for approximately twenty years, from 1959, by a group of volunteers coordinated by Alessandro Fioravanti [26–30] and by institutions including the University of Pennsylvania and the Superintendence of Southern Etruria (excavation campaigns: 1965–66, 1981). Extended research, started in 2012, has allowed in-depth examination of the structure of the village [31] and seeks to establish an accurate chronology.

The site consists of two predominant remains: the “Aiola” and the residential area. The former, dated from the Bronze Age, is an elliptical mound (60 × 80 m) of unknown function that was built with different sized stones. The residential area, located farther south, covers an area of 8000 m^2 and consists of the remains of a Villanovan village dating from the 9th century B.C. It was discovered by A. Fioravanti in 1959 based on the presence of ceramic and metallic finds, bones, wooden remains and more than 400 poles pounded into the lake bottom, in most cases almost completely buried into the sediment (Fig. 1C). The poles, 17–22 cm in diameter, are arranged in parallel and placed at intervals of 3 m in the area facing the lake while having an irregular distribution in the part of the site nearest to dry land. This arrangement has led to the hypothesis that the village was made of quadrangular houses located alongside the ancient lake bank in a first phase, while at a later stage of the settlement, pile dwellings were constructed to confront rising water levels (from 297 to 304 m altitude) [30,32].

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