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Dating fossil root cast (Black Sea coast, Turkey) using thermoluminescence: Implications for windblown drift of shelf carbonates during MIS 2

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A B S T R A C T

Rhizoliths are mostly sub-aerially exposed root prints which appear through removal of the rock units that cap them. A horizontal-lying residual of a rhizolith, consisting purely of soft inner core material of white color was recovered 10 km west of Şile, Istanbul, in northwest Turkey within laminated oolithic massive aeolianite. The inner part, consisting purely of calcium carbonate, was dated by applying thermoluminescence, while for the outer shelves optically stimulated luminescence of quartz was used for age assessment. The age of the $CaCO_3$ infill occupying the original place of the decayed plant roots was found to be 26.8 (±5.0) ka, corresponding to MIS 2. When compared with the ages of the middle (105.2 ± 15.6 ka) and outer (127 ± 9 ka) layers, corresponding to the later stage of MIS 5e or early stage of MIS 5d, the inner core coincides with the last glacial period when the sea-level was lower than the present, promoting transportation of ooids by offshore winds in conjunction with the exposed shelf carbonates. Based on the results yielded, rhizolith is much younger than the host rock aeolianite and witnesses to last glacial sea level lowstand when removal of shelf carbonates by offshore winds was promoted from the exposed shallow shelf plain. The results provide strong evidence that rhizoliths may not be coeval with the aeolianites within which they are embedded.

1. Introduction

Contributing to illumination of paleo-pedogenesis conditions in sedimentary rocks of various origins and ages, rhizoliths are footprints of decayed roots. These occurrences are preferably retained within Pleistocene carbonate dunes or aeolianites and are simply defined as organo-sedimentary formations produced by roots, providing evidence of higher plant colonization of sub-aerially exposed sediments and rocks (Klappa, 1980). The generic term rhizolith, derived from the Greek rhizo = root + lith = stone, was adopted in 1980 by Klappa to include accumulation and/or cementation around, cementation within, or replacement of, higher plant roots by minerals.

Rhizoliths are mostly sub-aerially exposed root prints which appear through removal of the rock units that cap them. Their size is usually on a centimetric scale with the exception of those having a length of 1 m or more, recently defined as megarhizoliths (Alonso-Zarza et al., 2008). In their field appearance, these occurrences have some constitutive properties, such as several downward bifurcations similar to those in living tree roots with decreasing diameters of second, third and higher order branches, distinguishing thus rhizoliths from animal burrows. In general, they can be categorized into five different morphological types: root

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tubules, root casts, root molds, rhizocretions and root petrifactions (Klappa, 1980).

Rhizoliths retain a record of paleo-environmental conditions (Retallack, 2001). Therefore, their characteristics as facies, age and isotopic attributes could provide extremely valuable information. Despite the abundance of preserved records, fossil root marks and casts have received little attention from geologists, and their paleo-ecological potential has scarcely begun to be examined. In previous studies, carried out on both continental and coastal aeolianites all around the world, many authors were solicitous about the significance of rhizolith formation as it accompanies paleo-pedodiagenesis as an organic component (Abegg et al., 2001; Kraus and Hasiotis, 2006; Frébourg et al., 2008). However, most of these citations go no further than merely listing their presence in the field. For further evidence supporting the aforementioned statement, the authors could refer to Gocke et al. (2010; 2011; 2014) and references therein.

A limited number of studies were carried out concerning the morphological and petrological features and the mineralogical composition of the aeolianites and the presence of rhizoliths as paleo-environmental indicators. However, the majority of these are focused on the morphological characteristics of the rhizoliths. Among these, only a scarce number of studies are focused on the structure and composition of the rhizoliths and even fewer use X-ray diffraction techniques to determine their mineralogical composition (Gocke et al., 2010, 2011, 2014). Moreover, there is no literature data concerning direct luminescence dating of the calcium carbonate based rhizolith inner part, with only limited reports of rhizolith dating by ^{14}C (Gocke et al., 2011).

In this paper, the microfacies, compositional characteristics as well as the thermoluminescence (TL) age are presented for a rhizolith ascertained within coastal aeolianites 10 km west of Şile on the western Black Sea coast of Turkey. The formation of these aeolianites was recently dated by both optically stimulated luminescence (OSL, Erginal et al., 2013) and TL (Polymeris et al., 2012). Besides some recent publications (Erginal et al., 2010, 2013; Kiyak and Erginal, 2010; Polymeris et al., 2012), the knowledge for the existence of both aeolianites and rhizoliths on either Turkey's long (8483 km) coastline or the Black Sea is greatly restricted. For instance, in Brooke's (2001) review, listing the global distribution of aeolianites pinpointing 89 different locations, no record was included from either the Turkish coastline or the Black Sea coast.

The present study is based mainly on direct observations ranging from field to microscopic. The morphological and mineralogical features of the rhizolith, as well as its chemical composition, are examined in this paper using optical microscopy, X-ray powder diffraction (XRPD) and energy dispersive X-ray spectroscopy/scanning electron microscopy (EDX/SEM) techniques, respectively. For the age of the formation, two independent luminescence approaches were applied, depending on the composition. To the best of the authors' knowledge, this is the first study dealing with the simultaneous compositional and dating examination of a rhizolith sample around the Mediterranean Sea.

2. Regional settings – site description

The studied rhizolith sample was collected within highly indurated fossil terrestrial carbonate dunes (aeolianites) 10 km west of Şile (Fig. 1), Istanbul, in northwest Turkey (41°11′53″N, 29°26′46″E). The host rock has a maximum of 6 m thickness and backs onto a sandy beach containing abundant bioclastic material such as *Venus gallina* and *Ostrea edulis*. The aeolianite overlies disconformably Pliocene-aged clay-rich terrestrial deposits, consisting of clayey sands with lignite intercalations (Okay, 1948). From a climatological point of view, the area under study falls within a semi-humid region based on data from Şile meteorological station (41°10′N 29°36′E). The area receives an annual precipitation of 749 mm. The average annual temperature is 13.6 °C and the predominant wind activity is from the northeast (Erginal et al., 2013).

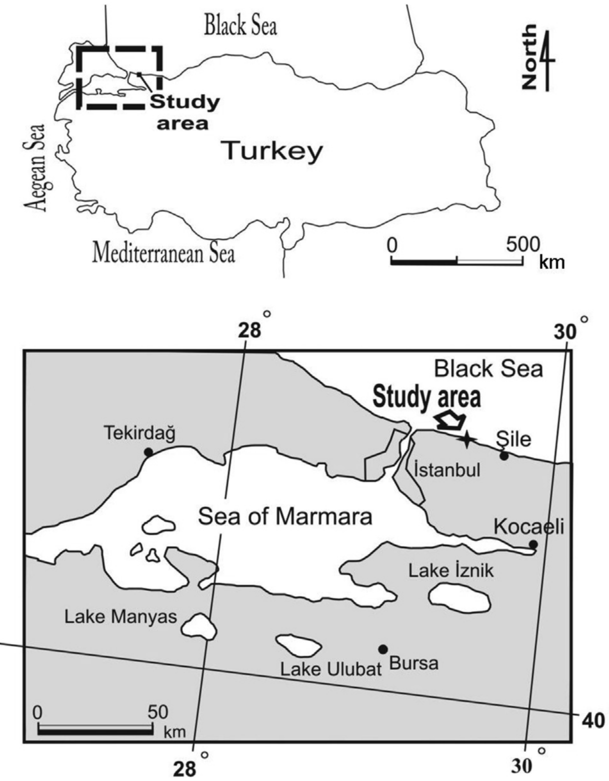

Fig. 1. Location map of sampling site.

3. Materials and methods

3.1. Micro-analytical examination

The samples of rhizolith were thin sectioned and subsequently examined under a CHEBIOS microscope. Energy dispersive X-ray spectroscopy (EDX) was used to determine the elemental composition of the samples. The micro-morphological characteristics of the rhizolith were studied using a scanning electron microscope (Phillips XL–30 S FEG). The XRPD patterns of the different layers (inner core, middle, and outer layers) observed in the sample were acquired on a Phillips PW 1820/00 X-ray diffractometer, equipped with a PW 1710 microprocessor and using PC-APD software. Operating conditions for the samples were 35 kV and 25 mA using Ni-filtered $CuK_{\alpha ave}$ radiation. The 2theta (2θ) scanning range was between 3 and 63° and the scanning speed was 1.2°/min. Identification of the samples was made using the JCPDS-ICCD 2003 database.

3.2. Luminescence apparatus and protocols

All luminescence measurements were acquired using a RISØ TL/OSL reader (model TL/OSL-DA-15) equipped with a 0.075 Gy/s $^{90}Sr/^{90}Y$ beta particle source (Bøtter-Jensen et al., 2000). The reader was fitted with a 9635QA photomultiplier tube. In the case of OSL, the stimulation wavelength was 470 (±20) nm, emitting at the sample position a maximum of 40 mW cm^{-2}, while the detection optics consisted of a 7.5 mm Hoya U-340 (λp ~ 340 nm, FWHM 80 nm) filter. However, all TL measurements were performed using