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Heating mollusc shells - A radiocarbon and microstructure perspective from archaeological shells recovered from Kalba, Sharjah Emirate, UAE

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ABSTRACT

This publication aims to shed light on the influence that prior heating (burning) of mollusc shells during human activity may have on the results of radiocarbon dating. We compare the geochemical and mineralogical composition of heated and unheated shells of *Anadara uropigimelana* and *Terebralia palustris* recovered from Neolithic and Bronze Age archaeological contexts at Kalba, Sharjah Emirate, in the United Arab Emirates (UAE). Our research examined whether the heating of shells impacts on the determination of reservoir effects, or whether in spite of heating, this material remains a viable material for precise ^{14}C measurements. Our results show that both heated and non-heated shells of *A. uropigimelana* and *T. palustris* provide consistent results, although the mineral composition of the shells changes from aragonite to calcite. Our results are important, since some of our selection of shells did not initially appear to have been heated. A heating process will then usually be detected as a greyish, marble like structure when cutting the shells. As a result of this work, we have also developed insights into prehistoric cooking practices of shells collected in Arabia. Our results provide archaeologists and associated researchers with confidence when assessing the results of radiocarbon dating during their studies of shells that might have been heated.

1. Introduction

Shells provide valuable sources of information within archaeology, whether for establishing chronologies for archaeological sites by means of radiocarbon dating and AAR (Kosnik et al., 2017) or through palaeoclimate and palaeoenvironmental studies (Biagi, 1994; Lindauer et al., 2017; Zazzo et al., 2016). This is especially so in arid environments where other organic matter such as peat or humic silt and clay are poorly preserved. Given the abundance of burnt shells in archaeological deposits (Barker et al., 2010; Stringer et al., 2008; Taylor et al., 2011), it is fundamental to understand the effect of heating on the geochemical composition of the shelly material, which in turn, may have consequences for the determination of reservoir effects during radiocarbon dating.

Depending on the species, shells can provide high-resolution information about palaeoenvironments over decades, centuries or millenia (Andrus, 2011; Hallmann et al., 2013; Lindauer et al., 2017; Paul and Mauldin, 2013; Scourse et al., 2012; Wanamaker Jr et al., 2008). The information stored in the shell material contains evidence about environmental conditions and food resources throughout their complete lifetime (Culleton et al., 2006; Hallmann et al., 2013; Leng and Lewis, 2016; Twaddle et al., 2017). Furthermore, shells can aid our understanding of strategies of food procurement by hunter-gatherer communities (Burchell et al., 2013). In archaeological contexts, large quantities of aquatic shells are found along contemporary or past coastlines, either as discrete shell midden deposits, or associated with settlements (Biagi, 1994, 2013; Biagi and Nisbet, 1999; Fernández-López de Pablo, 2016; Parker and Goudie, 2007; Uerpmann, 1990). Sometimes shells are also found in excavations further inland, e.g. as grave goods (Kutterer, 2013). In all these contexts, it is critical to know whether or not heated (burnt) shells can still be used to provide chronological control. Furthermore, sometimes it is not obvious at first sight whether shell remains have been heated or not. The most obvious way that shells would be heating is during the cooking process.

In an earlier paper, Milano et al. (2016) focused upon species *Phorcus turbinatus*. The behaviour of shell microstructures and changes associated with the temperature of heating were explored; it was shown that above a temperature of 500 °C a mineralogical transformation from

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aragonite into calcite and major structural alterations occurred. Milano et al. (2016) also found that exposure to high temperatures resulted in a systematic shift in the oxygen stable isotope content ($\delta^{18}O$), which has significant implications for palaeoclimatic interpretations of sea surface temperatures. The information on altered microstructures is relevant when interpreting the radiocarbon data on heated shells as a change in microstructure might lead to an incorporation of surrounding carbon sources like atmosphere or ash.

When investigating ancient shell midden sites or settlements, shells are often used for radiocarbon dating. However, shells that show evidence of burning are generally excluded from such studies. However, it is important to remember that in some cases it may not be possible to detect burning features at first sight. Thus, cooked shells could unintentionally be selected for dating. It is therefore important to know how heating affects the dates that may potentially result when using shells for radiocarbon dating.

In this paper, we build upon the studies of Milano et al. (2016) and explore the role that heating of mollusc shells may have on radiocarbon analyses based on (shell) material recovered from an archaeological site, Khor Kalba in the United Arab Emirates (UAE).

1.1. *Shells from archaeological sites in Kalba*

Khor Kalba in the Sharjah Emirate, United Arab Emirates, is a city that lies on the Gulf of Oman, between the Hajar Mountains and the present-day coast (Fig. 1). Since the Neolithic, there has been a lagoon near Kalba where mangroves, mostly *Avicenna marina*, are abundant, providing the local population with food and wood. In Kalba, shell middens dating back to the Neolithic are located in the vicinity of the mangroves and the surrounding sabkha (salt flats), thus providing potential information about human dietary strategy (Magee, 2014; Phillips and Mosseri-Marlio, 2002). However, no Neolithic settlements have been found. Nonetheless, north of the shell middens and the city of Kalba, ancient settlement structures, including mudbrick walls, houses and a tower dating from the Bronze Age and the Iron Age have been discovered (Fig. 1) and investigated archaeologically (Carter, 1997; Phillips and Mosseri-Marlio, 2002).

In the present study, we focus on two species of marine shell, *Anadara uropigimelana* (Bory de Saint-Vincent, 1827) and *Terebralia palustris* (L), that were identified in large quantities from a shell midden and archaeological settlement near the mangrove at Kalba. These shells show a species-specific radiocarbon reservoir effect, as their lifestyle and diet differ significantly, although both are found in or near mangrove forests (see also Section 1.2.). *Anadara uropigimelana* is a filter feeder and lives buried in the sand (Azzoug et al., 2012; Murray-Wallace et al., 2000), whilst in contrast, *Terebralia palustris* feeds on leaf litter (Fratini et al., 2008; Slim et al., 1997) and can be found on the surface of sediments, or attached to mangrove roots. Hence, each of them utilizes different carbon sources. This leads to a different species-specific reservoir effect, as suggested by other studies, for example, in the United States (Culleton et al., 2006).

For this study, we sampled a shell midden of late Neolithic date, but with two distinct phases (site code KK1): once in 2013 and again in 2015 (Fig. 1). We also collected younger specimens of Bronze Age date from a settlement northwest of the modern city of Kalba (site code K4); near a mudbrick wall, we located two shell layers, one on top of the other, and sampled each of them separately. The lower layer, referred to as MBZ1 (Middle Bronze Age 1) turns out to be around 100 years older than the overlying layer MBZ2. The younger layer (MBZ2) consisted mainly of shells, in contrast to the older layer (MBZ1), which comprised a mix of shells, ash and sediment. The age correlations follow those of Carl Philipps (pers. Comm., Phillips and Mosseri-Marlio, 2002, Lindauer et al., 2017).

The environmental conditions of shell growth as well as seasonal patterns are usually investigated using sclerochronology and stable isotopes ($\delta^{13}C$ and $\delta^{18}O$). Kalba is a settlement along a lagoon with occasional inputs of freshwater as a result of heavy rainfall events, which makes $\delta^{13}C$ signals difficult to interpret due to the several overlapping sources of carbon influencing the signal. Shell $\delta^{13}C$ mirrors processes like ecosystem metabolism as well as estuarine mixing, but for marine shells, it is mainly influenced by dissolved inorganic carbon (DIC) in the water (McConnaughey and Gillikin, 2008). In contrast, the $\delta^{18}O$ signature is easier to interpret, since it mainly reflects sea surface temperature and salinity.

For *A. uropigimelana*, its shell grows continuously from autumn until spring but its growth ceases in the summer. The seasonality of shell growth and hence the ability to reflect seasonal environmental changes in *A. uropigimelana* from Kalba had been investigated using growth lines

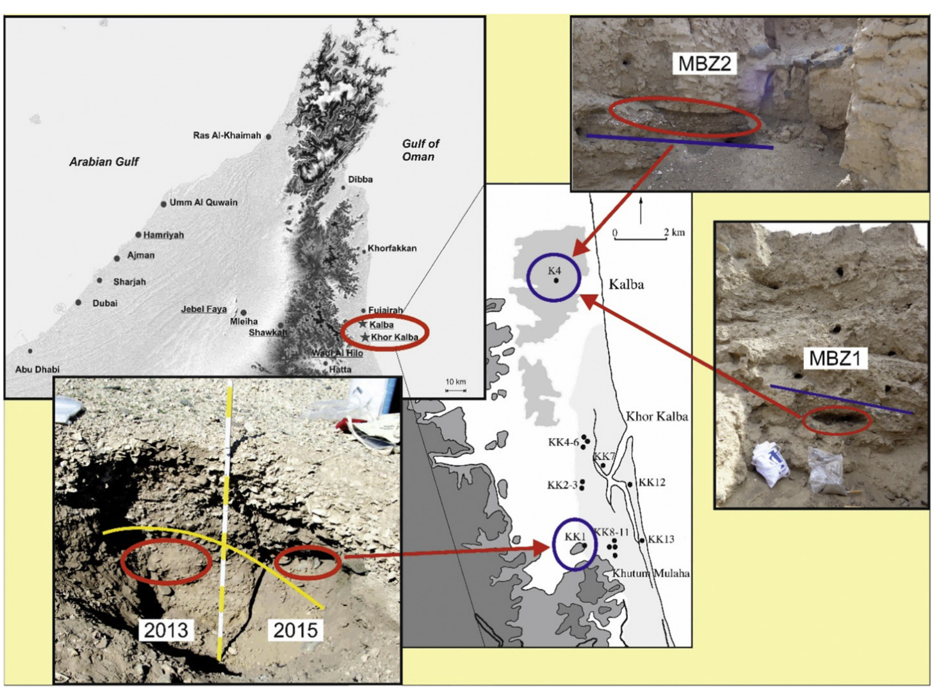

Fig. 1. Map of Kalba with sampling sites. KK1 is a late Neolithic shell midden covering two different phases (below and above the yellow line); K4 is a settlement from the Middle Bronze Age where two shell layers on top of each other were sampled (MBZ1 and MBZ2). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)