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Leave no mudstone unturned: Geochemical proxies for provenancing mudstone temper sources in South-Western Cyprus

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ABSTRACT

A variety of ceramic fabrics bearing mudstone inclusions (either naturally existing in the clay or added as temper) are attested in several sites in South-Western (SW) Cyprus. Within the Mamonia terrane of SW Cyprus mudstone-bearing lithologies are divided into two main groups. Sediments of the Ayios Photios group (sandstones, siltstones, mudstones, calcarenites, occasional limestones and chert) were deposited in marine conditions and close to the continental slope. In contrast, the contemporaneous Dhiarizos group contains radiolarian mudstones and cherts deposited in deep-sea conditions. Mudstones and cherts from both formations share similar macroscopic characteristics (distinctive red colour, fine texture) and can be confused for one another, especially when examined only as small-scale ceramic inclusions. Being able to differentiate between the different inclusion types and to link them to one of the two formations leads to useful conclusions regarding the provenance of ceramic samples within the Mamonia terrane.

In this case study, geological samples from relevant mudstone sources were analysed as reference materials to describe the possible types of mudstone inclusions. Sr and Pb isotopic data were the primary means for distinguishing between the two major formations, as they closely relate to the differences in depositional setting. Based on the established isotopic classification, microtextural analysis and elemental mapping data were also compared to determine if members of the two formations are distinguishable at this level. Finally, as the isotopic approach proved to be the one offering better results, a theoretical outline for utilizing this type of information to determine the provenance of mudstones in ceramic sherds is presented.

1. Introduction

Mudstones are fine-grained siliclastic sedimentary rocks composed predominantly of silt-sized (0.062–0.004 mm) and clay-sized (<0.004 mm) particles (Prothero and Schwab, 1996). When more than 50% of the constituents are silt-sized the term siltstone can be used, whereas if more than 50% of the particles are clay-sized the term claystone is more applicable. In both cases, individual grains are too small to be distinguished without a microscope. Few, if any, rock fragments are present, with quartz and feldspars being the predominant ones. Similarly, a sedimentary rock comprising more than 50% either silt- or clay-sized transported carbonate grains is referred to as a calcilutite.

Mudstones have been attested as major inclusions or intentional temper in various prehistoric contexts from the Eastern Mediterranean – pithoi from Messenia (Matson, 1972), Crete (Boileau and Withley, 2010; Day, 1988) and Cyprus (Jacobs and Borgers, 2009; Xenophontos et al., 2000), storage vessel fragments from Antikythera (Pentedeka et al. 2010) – and even later contexts — 7th–5th century B.C. Corinthian transport amphorae (Whitbread, 1995). A common parameter in all the above cases is the use of mudstone temper for large to medium, thick walled, hand-formed vessels. Thus, the use of mudstone (or shale) is associated with the need to reduce plasticity (improve workability) of the clays — allow shaping of the vessel and prevent collapse under the clay's own weight (Matson, 1972; Whitbread, 1995). Additionally, the same studies, argue that mudstones play a role in reducing cracking during the drying process. The preferential use of mudstone over other aplastics is considered to be a matter of its availability in the natural landscape and/or according to potting tradition (Matson, 1972).

In the context of Cyprus, mudstones are primarily found in ceramics attributed to sites within the Mamonia terrane, at the SW of the island. Mudstone outcrops are abundant in this region (Fig. 1b) meaning that mudstones will be both a natural constituent in the local clays but also readily available to potters as potential temper.

In the case of several Late Cypriot pithoi, studied by Xenophontos et al. (2000), the addition was intentional. Three models have been

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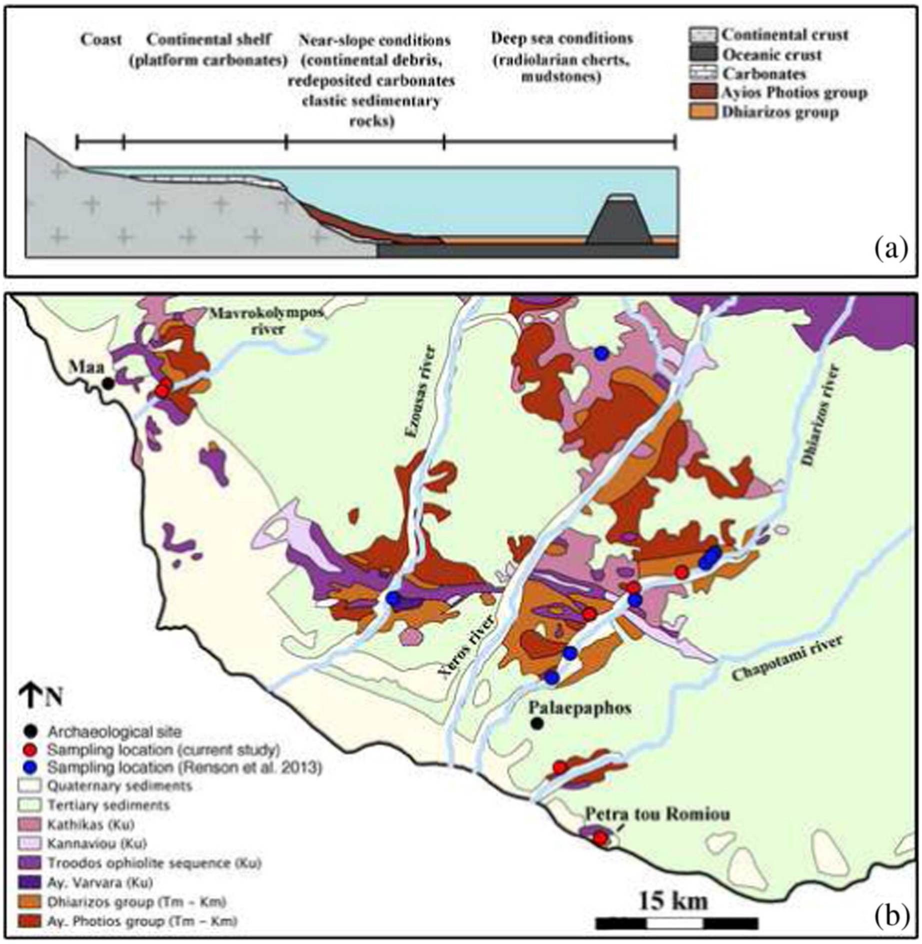

Fig. 1. (a) The contrasting depositional settings of the Ayios Photios (continental slope) and Dhiarizos (deep sea) sediments (modified after Edwards et al., 2010). (b) The geological setting of the Mamonia terrane and sampling locations — multiple samples were collected at each location. (The map was created using the 1:250,000 scale G.I.S. map of Cyprus provided by the Geological Survey Department of Cyprus).

proposed for Cypriot pithoi manufacture and distribution (Keswani, 2008): 'centralized' production, localized manufacture or itinerant potters. Within the Mamonia terrane, it is possible to define regions where mudstones of different origins are more prominent. Therefore, if pithoi were manufactured at one cluster of workshops the mudstone inclusions would be of one single origin. In the case of localized production and itinerant potters, pithoi from each site might exhibit a preferential use of the mudstone type that is in closest proximity. Based on the above arguments, mudstone inclusions could be used as an indicator of ceramic provenance within the Mamonia terrane if a strong proxy is defined for linking mudstone temper to a specific geological formation.

Most provenance studies of mudstones rely on chemical methods because the separation of individual minerals is difficult (Potter et al., 2005). Major element analysis has been a staple in mudstone provenance studies and is best employed to determine the extent of weathering of the source terrain. It constitutes a convenient approach as it can be conducted rapidly and inexpensively with methods such as X-ray fluorescence (XRF) or energy dispersive–scanning electron microscopy (SEM–EDX). Some trace elements may be above detection limit for these techniques, but many of those of greatest interest require techniques such as instrumental neutron activation analysis (INAA) and inductively coupled plasma-mass spectrometry (ICP-MS). Another indicator of provenance is the type of primary detrital material that was incorporated into the mudstones, and whether it originated from an igneous, sedimentary or crustal source. To this end, isotopic analysis provides a useful proxy, as isotopic ratios strongly differentiate between these categories of materials (Potter et al., 2005 and references therein).

The current case study focuses on effectively differentiating between the two major mudstone-bearing formations of the Mamonia terrane, the Ay. Photios group and the Dhiarizos group. Even though mudstones from both formations share macroscopic characteristics (colour, texture) they differ in relation to the depositional environment in which they were formed (Fig. 1a). Reference samples representing different mudstone types were collected and assigned to either of the two formations based on their Sr and Pb isotopic composition, as these two systems closely relate to the differences in depositional setting and source rock material. Once the samples were provenanced, additional data (microscopic appearance, grain-size, phase analysis using elemental maps — all collected using SEM–EDX) were compared to determine if they are distinctive enough to discriminate the two types of mudstone. The isotopic approach proved to be the one offering the best resolution between the formations. Therefore, a methodology to utilize this data to determine the provenance of mudstone inclusions from bulk isotopic measurements on ceramic samples is also presented. Within the limits of this work, this is just a theoretical demonstration. However, it shows sufficient potential and will be tested on relevant archaeological material within the context of future research.

2. Background to the present study

2.1. Geological context

The Mamonia terrane records the break-up of a preexisting continental margin (Fig. 1a) during a period of convergence with the Troodos microplate (Edwards et al., 2010). Mamonia lithologies are divided into