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THE NEOLITHIC POTTERY OF RIO TANA (CENTRAL ITALY, ABRUZZO): NEW DATA FROM THE ARCHAEOMETRIC INVESTIGATIONS

Abstract: The paper presents the results of a preliminary petrographic study of a sample of pottery fragments from the site of Rio Tana (Abruzzo, Central Italy). The settlement, situated on a terrace of the ancient Fucino Lake, now artificially drained, is dated to the early phase of the Neolithic. The present study aims to provide new data on the raw materials and techniques used in the production of pottery at the site. Preliminary investigations on 11 selected samples allowed the identification of two main petrographic fabrics based on the nature, percentage and grain size of the inclusions. The ceramics were produced using calcareous clays with inclusions of calcite crystals, quartz and fragments of carbonate rocks. The optical activity of the matrix and the presence of calcareous inclusions indicate a maximum firing temperature lower than 650 °C. The colour, mainly in the tone of reddish-brown, of the matrix of the analysed ceramics testifies oxidizing conditions during the firing process, in which the control of the oxygen fugacity was not generally achieved by the Rio Tana craftspeople.

Keywords: Early Neolithic, Impressed Ware, Petrographic Analysis, Pottery Technology, Thin Sections

1. Introduction

Pottery is one of the most useful archaeological artefacts for reconstructing past human activities and can provide information on economic and technological choices, as well as intangible aspects such as cultural identity and artistic tradition. Since the second half of the 1970s, the enormous potential of the study of archaeological ceramics was highlighted, especially when investigated through macroscopic and microscopic observations, mineralogical and petrographic analysis, and spectroscopic investigations (Schneider, 1978; Picon, 1984; Mannoni, 1994; Maggetti, 1995; Tite,

1999; Baxter, 2006; Papageorgiou, 2020; Quinn, 2013). The understanding of this production, including manufacturing processes and raw materials provenance, can be achieved through the petrographic characterisation of the ceramics. Provenance studies contribute to the reconstruction of trade routes in ancient areas and can help to identify possible centres of production or redistribution. In addition, pottery can be investigated for its functional aspects (Braun, 1983). Although, in recent years answers to this question have also been obtained from the analysis of both surface wear and residues (Heron & Evershed, 1993; Isaksson & Hallgren, 2012; Regert, 2011; Skibo, 2015; Forte et al., 2018; D'Agostino et al., 2023), the identification of the types of temper used in ceramic bodies has long been considered a potential method to identifying the function of a particular ceramic form. According to some researchers (Tite, 1999; Rice, 1987, Müller, 2016, Roux, 2019), specific temper types were included in the clay mix to improve the performance of a vessel for a particular purpose.

Starting from the 6th Millennium BC, groups of farmers, carriers of technical and economic innovations, spread throughout the western Mediterranean (Guilaine, 2001; Zilhão, 2001; Guilaine & Cremonesi, 2003). Following this diffusion, communities characterised by pottery assemblages, consisting mainly of simple shapes, decorated with impressed and incised motifs (Impresso-Cardial Ware, Binder et al., 1993; Binder & Maggi, 2001; Guilain et al., 2007; Radi & Petrinelli Pannocchia, 2018; Hamon & Manen, 2021), spread first in the southern and then in the central part of the Italian Peninsula. Although there are common features, a complex scenario, influenced by different traditions and adaptations to the occupied territories (Tiné, 1983; Cipolloni Sampò et al., 1999; Fugazzola et al., 2001; Radi & Petrinelli Pannocchia, 2018; Natali & Forgia, 2018), is suggested by the variations in decorative patterns, vase morphology and raw material composition between regions and localities (Gabriele & Tozzi, 2017; Laviano & Muntoni, 2003; Muntoni, 2012; Michelaki et al., 2015).

This paper focuses on the preliminary petrographic characterization of pottery produced at Rio Tana, an Early Neolithic settlement located on a terrace of the Fucino basin (Abruzzo, Central Italy) to provide new data on the choices and techniques used in the production of ceramics during the earliest phase of the Neolithic in Central Italy. Fucino was an ancient lake that occupied a large tectonic depression drained at the end of the XX century. During the Neolithic period, villages were located on terraces overlooking the sides of the lake. The data collected allowed us to define Rio Tana as a Neolithic settlement. The site has all the characteristics of a sedentary settlement: pottery, structures remain, chipped and polished stone tools, as well as heavy industry (e.g. millstones), etc…

During the Neolithic, the production of pottery, like other tools, was a domestic activity. Specialized sites or structures were not identified. A unique case in this sense is Portonovo di Ancona, but it is still to be verified.

Thin section petrographic analysis of pottery sherds has been applied to gain new insights into raw materials exploitation and pottery production during the first half of the VI Millennium BC in Central Italy. The results of this preliminary petrographic characterization of the ceramics from the Rio Tana site can contribute to extending our knowledge on the pottery production during Early Neolithic in Central Italy.

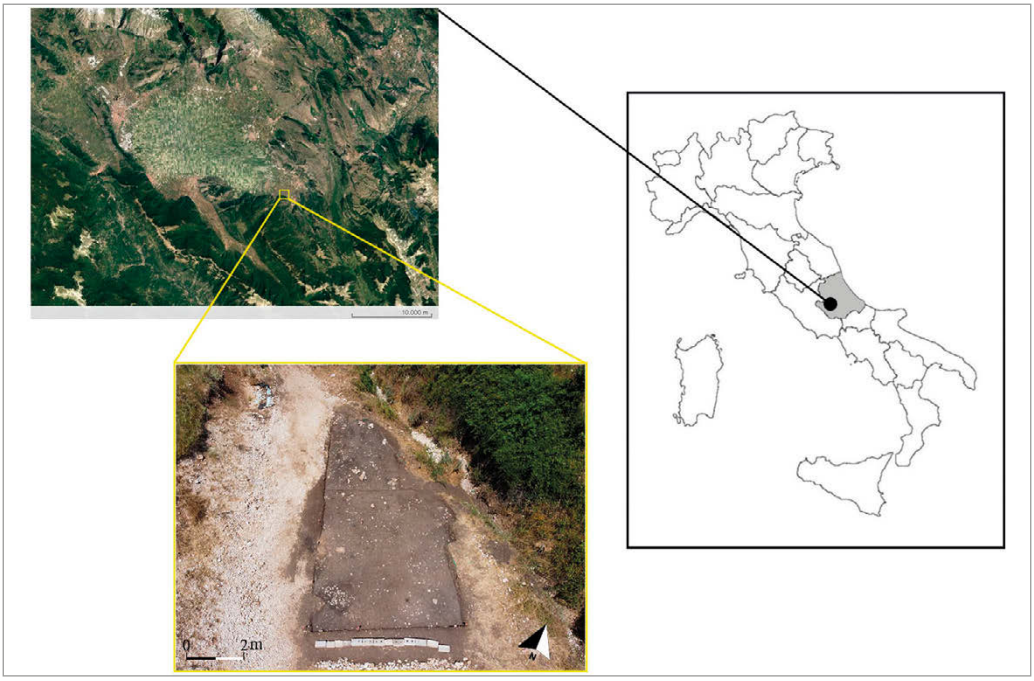

fig. 1. Localisation of the Rio Tana site (Abruzzo, Central Italy) in the ancient basin of the Fucino lake.

2. Archaeological context

Rio Tana is a settlement located on the southeastern terrace of the Fucino basin (fig. 1), near the modern town of Lecce nei Marsi, at an altitude of approximately 705 meters above sea level.

The site was first studied in 1993 during an exploratory campaign organised by the Archaeological Superintendence of Abruzzo, which allowed to a preliminary survey of the area (D'Ercole et al., 2001). In 2020, a research campaign was initiated by a team from the Department of Civilisation and Knowledge at the University of Pisa to determine the extent of the anthropic deposit and establish the chrono-cultural framework of the settlement.

The interventions impacted an area of approximately 290 m² to the west of the 1993 M3 test (Level 1, tab. 1). Based on the available evidence, it can be hypothesised that this area was used for a covered structure that served multiple purposes (Petrinelli Pannocchia et al., 2022).

According to Petrinelli Pannocchia et al. (2022), the data obtained from the faunal remains suggest that the village had a fully productive economy. The chipped stone industry was abundant, and the products were made of flint originating from the Monte Genzana sector. Some of the collected tools were made of obsidian, mainly imported from the island of Palmarola.

The pottery complexes (fig. 2), collected during the 1993 and 2021 archaeological campaigns, comprise 4767 pottery fragments (Petrinelli Pannocchia et al., 2023). The

LEVEL	LABORATORY	DATE BP
layer I	AECV-211C	6790 ± 70
layer II	AECV-2012C	6860 ± 60

tab. 1. Radiocarbon dates from Rio Tana (AQ, Italy, D'Ercole et al., 2001).

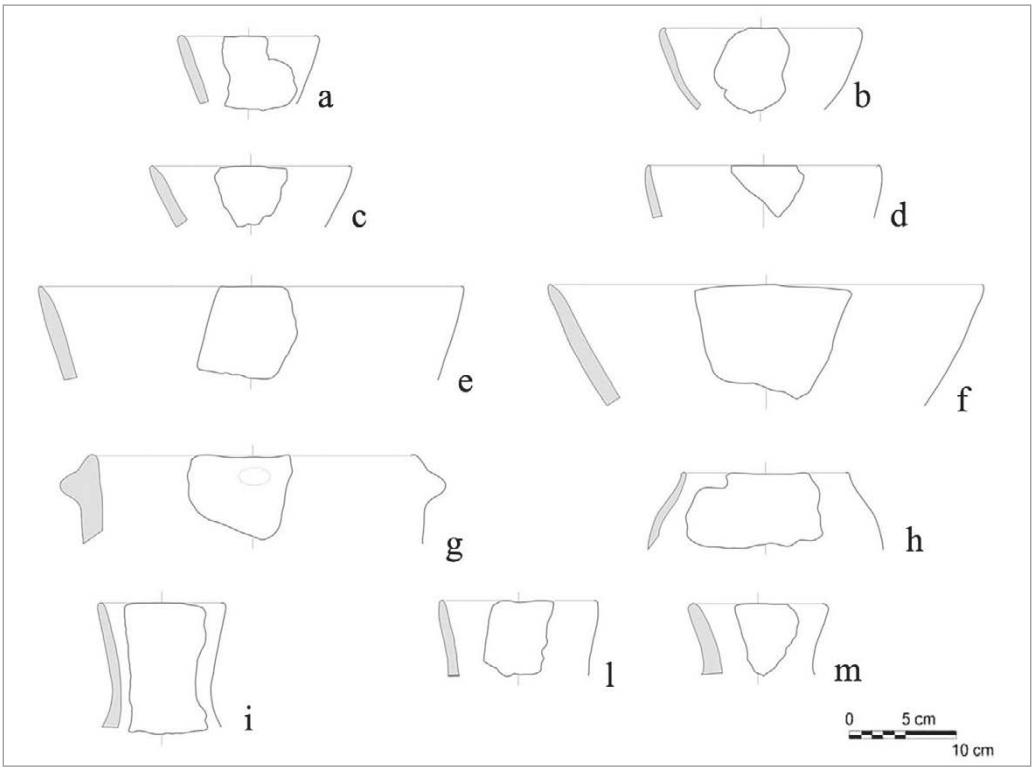

fig. 2. Typology of Rio Tana (AQ, Italy) pottery.

high degree of fragmentation of the finds and the characteristics of the underlying terrain have often made their recovery during excavation operations difficult, making the attribution of individual fragments to vessel shapes complex. However, most of the potsherds have intact surfaces and sections with clear edges, indicating excellent preservation.

The diagnostic elements such as rims, inflections, and handles were used to identify the pottery production from the studied level. The ceramic shape consists mainly of open forms, although closed forms are also present. The open forms are typically medium-low with a truncated conical section, simple with indistinct, thinned, or flattened edges, and indistinct bases (fig. 2a-f). This group includes a miniature vase with a cylindrical profile. Less common are the deep forms with semi-ellipsoidal and ellipsoidal bodies, which also have rather large diameters and heeled bases. Among the closed forms, there are a few specimens of globular and ovoid morphology (fig. 2g-h). The presence of articulated forms with a composite profile has been established through the numerous fragments of necks (fig. 2i-m). These forms include short and high-necked vessels such as ollas and flask vases. However, only a few examples have preserved the base of the vessel, which is usually indistinct and convex.

3. Materials and Method

A preliminary macroscopic classification of the Rio Tana archaeological ceramics was based on the granulometry of the ceramic paste by observing the collected samples by means of a stereomicroscope (LEICA model S9D). The observations indicated the existence of three main granulometric classes of the paste: coarse, semi-fine, and fine. To obtain a detailed analysis, eleven specimens representative of the three different classes of paste previously identified were subjected to mineralogical-petrographic analyses in thin section (tab. 2).

Petrographic thin-section analysis was performed by polarized light microscopy (Zeiss D-7082 Oberkochen microscope equipped with plane polarised light (PPL) and Cross polarised light (XPL), Department of Earth Sciences, Sapienza University of Rome, Italy) following the criteria of Whitbread (Whitbread, 1989) with the aim of acquiring details on the features of the groundmass, the nature and shape of the inclusions, and voids. PPL allowed to examine the characteristics of larger mineral inclusions, such as colour and pleochroism. XPL enabled the differentiation of isotropic minerals from anisotropic ones and the determination of the birefringence of the latter (Quinn, 2022).

A Leica microscope with a trinocular head and camera, instead was used to acquire photomicrographs and display a live view on the screen.

The Whitbread criterion mentioned above is a detailed system for the thorough description of archaeological thin section ceramics. It recognises the value of the clay

Sample	Archaeological structure	Ceramic texture	Petrographic Fabric	Inclusions size range as measured by POM	General petrographic description
2	Q53	Semi-fine	Fabric I	0.1-2 mm	Carbonate rocks are the most abundant mineralogical component and cover the entire size range. Few coarser crystals in smaller and more abundant crystals.
10	O53	Coarse		0.1-4.5 mm	Carbonate rocks are more abundant and cover the entire size range. In the same percentage abundance crystals of large/medium and smaller sizes.
11	M52	Coarse		0.1-4 mm	Carbonate rocks are the most abundant mineralogical component and cover the entire size range. Few coarser crystals mixed within more abundant smaller crystals.
3	I51	Semi-fine	Fabric III a	0.1- 2 mm	Carbonate rocks (cover the coarsest size range) are more abundant than pyroxenes (cover the medium-small size range).
7	O53	Coarse		0.1-4 mm	Pyroxenes and carbonate rocks are in the same percentage amount, but the carbonate crystals are coarser than the pyroxenes.
16	N51	Coarse		0.1-3.9 mm	Medium and small-sized carbonate rocks are the most abundant mineralogical class. In a smaller percentage, there are also medium-sized pyroxene crystals.
6	Q53	Semi-fine	Fabric III b	0.2 -2.5 mm	Fragments of carbonate rocks are the most abundant mineralogical component and cover the medium-small size range
17	I52	Fine		0.3 -1.24 mm	Fragments of carbonate rocks are the most abundant mineralogical component and cover the medium-small size range
20	I52	Fine	Fabric II	0.1 - 0.6 mm	Quartz and pyroxenes with small size and in the same percentage abundance.
21	P-Q 53 54	Fine		0.1-1 mm	Quartz is the most abundant size range and small in size. Pyroxenes are medium and small in size in a smaller percentage. Very rare small carbonate fragments.
22	Q51	Fine		0.1-1.2 mm	Quartz is the most abundant mineralogical class and covers the entire size range.

tab. 2. List of the eleven samples analysed.

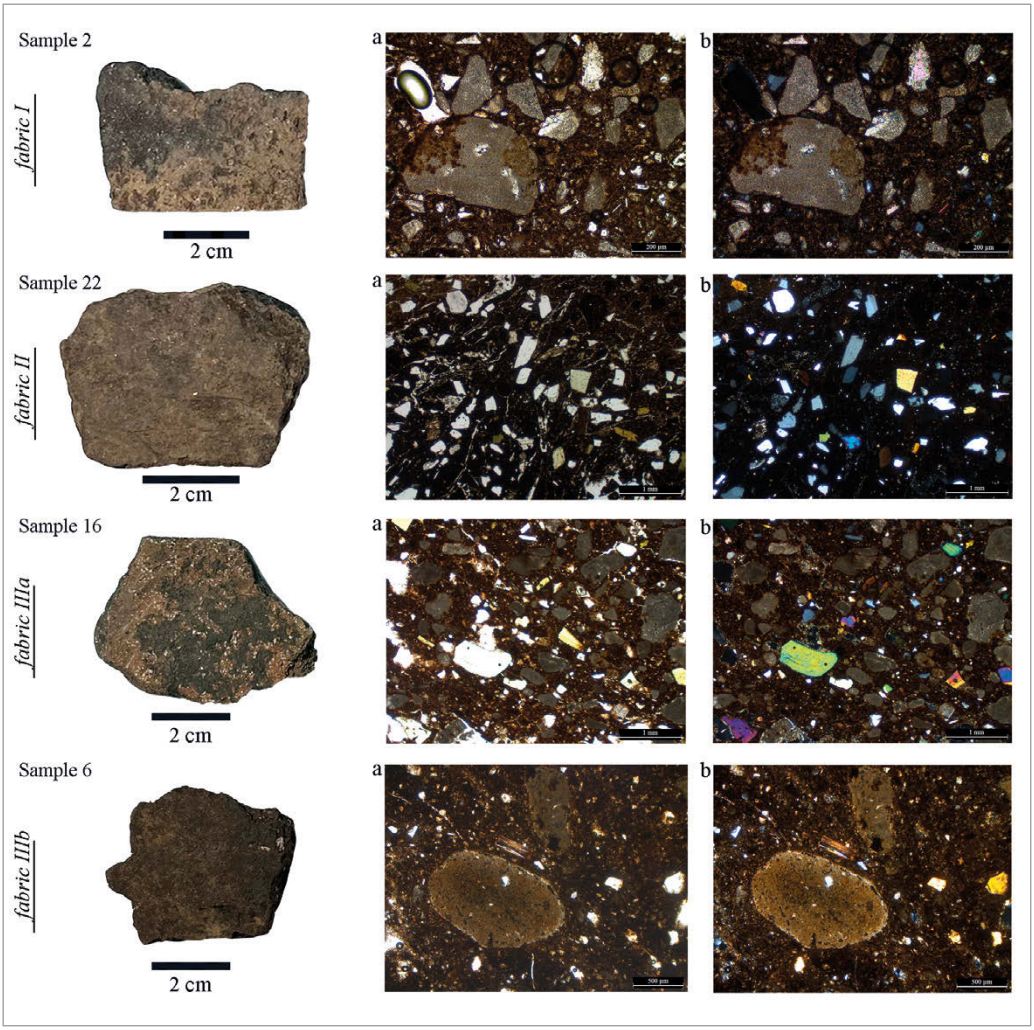

fig. 3. The different fabrics identified at Rio Tana. Left, Fabric I: Sample 2; Fabric II: Sample 22; Fabric III: Sample 16. Right, view of the related thin sections: a) Plane polarised light (PPL); b) Cross polarised light (XPL).

matrix and voids for distinguishing different petrographic fabrics and for interpreting aspects of ceramic technology (Quinn, 2022).

An assessment of the firing characteristics of the ceramics forming the fabric can be given, including an estimation of the temperature of firing determined from the optical activity of the matrix and the atmosphere of firing according to the colour of the groundmass (Maggetti et al., 2011; Thér et al., 2016; Quinn, 2022; Russo et al., 2022). Optical activity is a change in intensity in the birefringence of clay matrix in XPL, which is caused by the minute clay minerals going in and out of extinction. The birefringence and extinction of the matrix is affected by the processes of sintering and vitrification of the clay minerals in ceramics, and it is therefore important for the reconstruction of ancient firing technology (Quinn,

2022). Indeed, the vitrification of the clay matrix during firing leads to a change in the birefringence of clay minerals. As they fuse and melt, the optical activity of the matrix is reduced until it becomes anisotropic and glassy appearance. The point of the matrix vitrification is dependent on the types and proportions of clay minerals and their refractoriness.

4. Results

These results obtained (tab. 2) on the selected samples have been confirmed by the thin section analyses by using the Wentworth size scale (Quinn, 2022).

In the coarse ceramic paste, the size range of the inclusions varies from 0.1 to 4.5 mm with the most abundant size class is the very coarse sand.

The semi-fine ceramic paste is made by inclusions ranging in size from 0.1 to 2.5 mm and the most abundant size class consists of medium sand.

For the fine ceramic paste, the inclusions have sizes ranging from 0.1 to 1.24 mm and the most abundant dimensional class is the fine sand.

The inclusions have a temper function, according to the definition of Cuomo di Caprio (Cuomo di Caprio, 2007)

Petrographic analyses (fig. 3) allowed the identification of two main fabrics. Fabric I (fig. 3, sample 2) characterized by a coarse paste includes three out eleven ceramic samples (2, 10, 11). This is made up mainly of carbonate rocks with dominant coarse inclusions (45-50%) (Terry & Chilingar, 1955), calcite crystals, and quartz. The elements microfossils and charred organic residues, with micas and nodules of iron oxides present in traces are present in lower percentages . Very small inclusions consist of abundant calcite and quartz.

The ceramic matrix presents for 25-40% (common/frequent) (Terry & Chilingar, 1955) is heterogeneous and composed by clay and micritic calcite with a colour ranging from beige/red to orange, while the few (Terry & Chilingar, 1955) voids (representing 15% of the mixture) are macro, meso vesicles and vughs. The voids have no orientation, suggesting that the ceramics of this fabric have not been sanded and smoothed either manually or mechanically (Ther & Toms, 2016).

The fabric II (fig. 3; sample 22) is characterised by a fine ceramic paste consisting mainly of river sand coarse and pyroxene inclusions. It includes three out eleven ceramic samples (20, 21, 22). Most of the paste is made up of inclusions, which account for 45% (dominant) (Terry & Chilingar, 1955). In traces are visible nodules of iron oxides, micas, flint, and some charred organic residues.

Very small inclusions of quartz (river sand) and a few very fine inclusions of calcite are present too. The matrix (40% frequent) is homogeneous and consists of clay with a colour ranging from red/brown (brick) to brown/black. A few voids (15%) are macro, meso vesicles, and vughs. The voids, unlike fabric I, have a poor orientation which indicates a slight surface smoothing carried out manually.

Six samples out of eleven belong to these two fabrics. The remaining five samples (fabric III) show intermediate characteristics to the two previously mentioned fabrics (fig. 3; sample 16).

The first three samples (3, 7, 16: fabric IIIa) are in between fabric I and fabric II. They have the characteristics of both two fabrics, with the same inclusions, even though with a different abundance (30-60% frequent/dominant). The major inclusions are those that make up fabric I (quartz and calcite) and they have the same minerals percentage as fabric II (clinopyroxene, K-feldspar, plagioclase). The extremely heterogeneous matrix (30-60% frequent/dominant) consists mainly of calcite, clay and small percentages of iron oxide. The colour of the samples varies from orange reddish to dark brown/black by moving from the outer edges to the central core. Voids (10-30% common) are macro vughs and vesicles.

The last two samples (6 and 17: fabric IIIb) have features close to that of fabric I. They have, in fact, the same inclusions of fabric I (aggregates of carbonate rocks with calcite fragments on them and quartz) even though with different abundances (20% common). The inclusions are in a lower percentage than those of the samples of fabric I and II; they are also very degraded because of the presence of not well-defined contours. Lastly, the inclusions of pyroxenes that characterise fabric II are absent. The matrix (50-70% dominant) is heterogeneous and consists mainly of clay, calcite, and small percentages of iron oxides. In sample 6 the colour of the matrix varies, with the two outer surfaces reddish brown, while the centre is characterized by a brown/black colour. Sample 17, on the other hand, has a matrix with a colour that varies passing from reddish brown to light beige from one surface to another. The few voids (10%) are macro vughs and vesicles, although most of them are elongated, and due to plant residues (probably fragments of straw or grass). The sample 17 matrix displays a range of colours from reddish-brown to light beige. The sample contains macro vughs and vesicles, with only a small percentage (10%) of voids. The elongated shape of most of them is due to their production from burned organic matter, such as fragments of straw or grass. This item also shows a lighter colour of the surface compared to the other ten ceramic fragments analysed, with a powdery red layer on one of the two surfaces. In addition, the petrographic analysis revealed the presence of rounded sandstone fragments embedded in a heterogeneous clay matrix.

Groups 3a and 3b despite their heterogeneous composition could be considered as a third fabric, given that it is a preliminary study. A more accurate classification, with a higher number of analysed samples, will be carried out.

5. Discussion and conclusions

The results of the preliminary petrographic analyses allowed to investigate the nature of the raw materials and technology used to produce ceramics in the Neolithic site of Rio Tana. Two main fabrics containing ceramic specimens were identified. Fabric I includes mainly samples made by carbonatic rocks fragments with a coarse texture, while fabric II includes mainly quartz with fine-grained samples. Few sherds (fabric III) have differences in terms of relative abundances, size ranges, and nature of inclusions which do not allow them to be included in the afore mentioned fabrics I and II. The continuation of the investigations on a larger sample will allow us to better define the fabrics present in Rio Tana. The nature of the raw materials used to produce the

different ceramics is calcareous due to the abundant primary micritic calcite, which gives the matrix a characteristic appearance when oxidised. This is often an indication that a marine sedimentary clay source such as marl was used to make the artefacts, especially if microfossil inclusions are also present (Quinn, 2022).

In addition to calcite, the matrix has a heterogeneous composition due to the presence of clay and iron oxides, as suggested by the different colours, composition, and texture of the very fine inclusions (<10 μm) observed with XPL and PPL. The use of a heterogeneous matrix is plausible because deposits are often heterogeneous in terms of the distribution of clasts and local variation in weathering and bioturbation (Quinn, 2022). The data therefore show that at least two different sources were used by the Rio Tana craftspeople to produce pottery.

It was also possible to estimate the equivalent firing temperature of ancient ceramics by the observation of thermally induced changes in the clay matrix and specific mineral inclusions. The samples of Rio Tana with optically active clay matrices can be interpreted as having an approximate equivalent firing temperature lower than 800/850 °C.

The presence of calcareous inclusions (calcite crystals, carbonate rocks fragments, microfossils) indicates temperatures of firing lower than of threshold of decarbonation process at about 650-700 °C (Trindade et al., 2009; Bayazit et al., 2014). Additional components of ceramics that can provide useful information on the firing temperature are the charred organic residues that disappear at about 600 °C. Therefore, we can conclude that the maximum temperature reached during the firing of the artefacts is 600/650 °C. Plant residuals were found in all samples, but they were particularly numerous in the fragments belonging to fabric II. The presence of plant residues is quite common in the production of Early Neolithic pottery throughout the Mediterranean (Spataro, 2011; Tsuneki et al., 2017; Dzhanfezova, 2020). These residues were probably added voluntarily to make the clay paste leaner (Skibo et al., 1989; Mariotti Lippi & Pallecchi, 2016; Arobba et al., 2017) as has also been suggested for the nearby Colle Santo Stefano site (Angeli & Fabbri, 2017).

Concerning the firing process, the colour of the matrix depends on the atmosphere developed within the furnaces, as well as the maximum temperature reached, the firing time and the cooling rate (Lofrumento et al., 2004; Molera et al., 1998). The colour of the analysed samples shows a great variability, mainly in the tone of reddish-brown, thus testifying to a general oxidizing condition in which the oxygen fugacity was not completely controlled.

The inclusion sizes of the samples studied do not show a bimodal distribution. The presence of minerals (quartz, K-feldspar, and plagioclase whose function is that of tempers) in the samples of fabric II and fabric IIIa might suggest the possible selection of starting materials by the potter.

As mentioned before the voids of fabric II show a poor orientation suggesting that these samples have undergone a more refined process, before the firing process, than samples of fabric I that instead are more manufactured coarse.

Also, for sample 17 there was no bimodal distribution for inclusion sizes, indicating that the sandstone fragments were not intentionally added but were already present in the clay used to create the paste. Therefore, it can be assumed that the craftspeople

used a different starting clay than the one present in the remaining samples. A similar mixture, containing fragments of sandstone, was found in the open-air site of Maddalena di Muccia (province of Macerata, Italy), belonging to the same period (Spataro, 2002). The addition of the sandstone fragments in the matrix probably served to give greater hardness to the final product (Crandell et al., 2016). The provenance of the sandstone is probably local because of the presence of outcrops of Miocene sandstones near the Neolithic archaeological site. According to these observations the roundness of the inclusions might indicate that this material derives from a riverbed and the temper has not been obtained from crushed sandstone rocks (Medeghini & Nigro, 2017). Further analysis will be undertaken to determine the nature of the red layer observed in the thin section, which was deliberately applied to one of the surfaces of sample 17.

The results of this preliminary petrographic characterization, along with further investigation on a larger number of samples, of the ceramics from the Rio Tana site can contribute to extending our knowledge of the pottery production during the Early Neolithic in Central Italy.

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