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POTTERY PRODUCTION AT THE MESOLITHIC SITE OF KABBASHI HAITAH (CENTRAL SUDAN): AN INTEGRATED MORPHOLOGICAL, PETROGRAPHIC AND MINERALOGICAL ANALYSIS

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ABSTRACT

This paper presents the results of an interdisciplinary archeometric study on Early Mesolithic pottery from the prehistoric site of Kabbashi Haitah, located 35 km north of Khartoum (central Sudan), along the Nile Valley. A large set of potsherds, selected after a preliminary macroscopic analysis of 1075 fragments representing the various vessels (mainly plain and globular in shape, with various rim diameter), macrofabrics and decoration types (either with or without incised or stamped decorations, i.e. *incisedwavy line* and *rocker stamp*) was analysed to define the type of the raw materials used and their manufacturing technology. The mineralogical and petrographic features, determined by optical microscopy and X-ray powder diffraction, indicate that the pottery was produced using an illitic clay tempered with quartz and/or K-feldspar derived from granite/syenite grinding, and fired in the temperature range between 750 and 900°C.

KEYWORDS: Mesolithic, Sudan, Kabbashi Haitah, pottery, archaeometric study.

1. INTRODUCTION

One of the oldest examples of ceramic production is represented by Mesolithic hunter-gatherers pottery – dating from about 8000-7000 years BP (Caneva, 1989; Salvatori 2012) – and attested in central Sudan. Although older productions are attested elsewhere in the word, such as those dated at 26.000 years BP in Europe (Verpoorte, 2001; Budja, 2006), 20.000 BP in China (Xu et al., 2012), 16.000 BP in Japan (Shelach, 2012), 10.000 BP in Africa (Huysecom et al., 2009; Jesse, 2010), and 7500 BP in South America (Roosevelt et al., 1996), the central Sudan pottery is of particular interest for the peculiar society to which it belongs.

This pottery is commonly believed to be homogeneous in nature, and lacking in sophisticated typological differences since it belonged to simple and poorly structured social groups. Indeed, every individual in a Mesolithic society is supposed to have supplied raw materials in similar ways and developed comparable, non-specialised, practical skills in all phases of the ceramic production techniques. However, since these groups were rather peculiar hunter-gatherers who lived in a semi-sedentary way in a particularly favourable riverine environment, their social organization might have been more complex than previously presumed (Salvatori, 2012 and literature therein; Iacumin et al., 2016). Pottery in such ancient cultures is, therefore, often presumed to have been locally made, without imported raw materials or finished products (Salvatori, 2012 and literature therein).

Two main elements are commonly used to macroscopically classify ceramics: form and decoration. The former cannot provide much help in contexts like the Sudanese Mesolithic ones, because the morphology of the containers, which can rarely be reconstructed completely, does not seem to vary significantly. The latter element, comprising decorative motifs and techniques, has therefore traditionally been adopted as the main criterion when classifying this kind of pottery, although observations also on the macrofabric (composition and texture of the paste) contribute to better define the pottery production over the time (Salvatori et al., 2012 and references therein).

Analogous archaeometric studies for characterization and provenance have been made earlier on pottery for early periods (Javanshah, 2018; Kilic et al., 2017; De Soto et al., 2014; Davit et al., 2014).

Although previous archaeometric analysis (most of them performed only using a chemical or a petrographic approach) were carried out on prehistoric pottery, both Mesolithic and Neolithic, found in several sites in central-northern Sudan (Arkell, 1949, Brandt, 1974; Hays and Hassan, 1974; Francaviglia and Palmieri, 1983; 1988; Caneva and Palmieri, 1990; De Paepe, 1986; 1988; Khabir, 1987; 1991a; 1991b; Ch1odnicki, 1989; Zedeño, 2001; Klein et al., 2004; D'Ercole et al., 2015), only the recent contribution of Dal Sasso et al. (2014), disclosed the relationship between the decorative systems, the macrofabrics and the petrographic composition of the paste. Following the first attempt of Miglioranzi et al. (2005) and bearing in mind the work by Dal Sasso et al. (2014), this study aims to analyse the Mesolithic pottery from Kabbashi Haitah, located 35 km north of Khartoum (central Sudan), taking into consideration, in addition to the macroscopic classification based on the decoration systems, also new standards of distinction criteria (e.g. raw material, added temper material, grain-size, firing conditions). The research is therefore addressed to: i) describe the production recipes; ii) define the firing temperature attained; iii) determine the origin of the raw materials used. From an anthropological point of view, the study aims to achieve a better definition of the social complexity of these ancient groups. The understanding of their ceramic production technology, the definition of the possible supplying area in which the raw materials were collected, and the trajectories of pottery exchanges may shed light on any distinctions within or between the groups. The study therefore also focused on identifying the possible shared traits between specific ceramic wares, vessel forms and decorative motifs, which might provide evidence of conscious technological choices made according to collectively recognized social functions.

2. THE POTTERY OF KABBASHI HAITAH

The Khartoum Mesolithic cultures, dating as early as the 9th millennium BP in central Sudan and previously in the Sudanese Nubia where is known as "Khartoum variant", covered an extensive area, from the site of Faras on the Egyptian border in the north, to the site of Jebel Moya, about 250 km south of Khartoum, on the Blue Nile, in the south (Caneva 1991; Garcea, 1993; Sadig, 2013). The vast majority of the settlements, where this material culture is attested, is located along the banks of the Nile and the Atbara Rivers, and only few are scattered inland, displaying more markedly seasonal characteristics (Caneva and Santucci, 2006).

Sudanese Mesolithic sites are typically characterised by an undulated surface, with concentrations of low mounds, formed by remnants of burial tumuli dating to the Meroitic (III-IV centuries AD) and later periods, located over and close to the prehistoric settlements. The surface above and around the tumuli is scattered with fragments of pottery, grinding stones and other archaeological materials, dated to various periods and dispersed by both human activity and wind/water deflation over a much wider area than that originally occupied by the Mesolithic settlements. The only remnants of the original settlements, in most cases, lie below the burial mounds, under which the settlements were sealed about 2000 years ago and which have been later damaged exclusively by the small pits leading to the deep funerary chamber.

The archaeological site of Kabbashi Haitah is located about 35 km north of Khartoum, at a distance of about 5 km eastern of the present course of the Nile (Caneva et al., 1993) (Fig. 1).

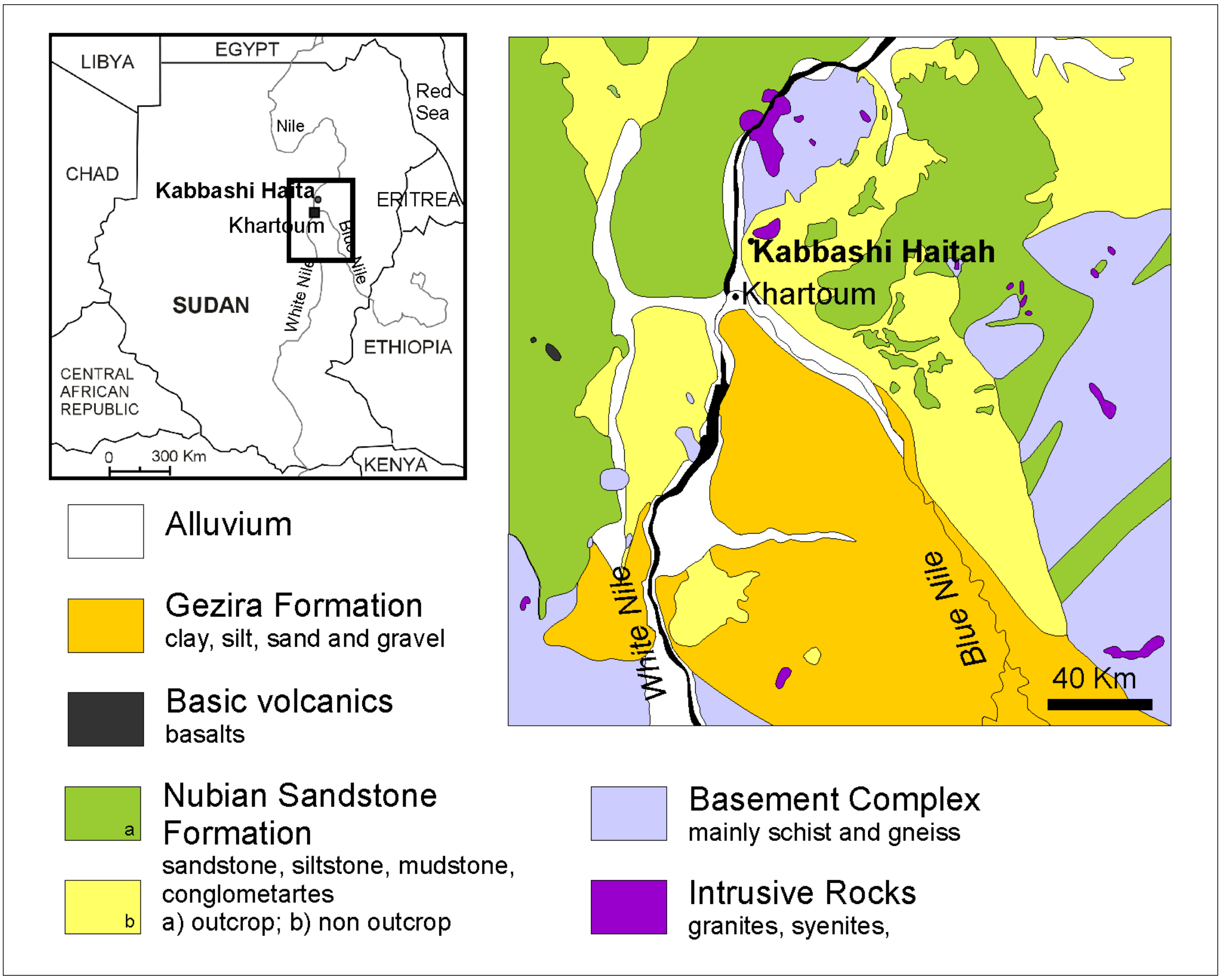

Figure 1.Geographic location of the Kabbashi Haita site (Khartoum, Sudan) and geological sketch of Central Sudan (modified after Ministry of Energy & Mining, Geological Research Authority of Sudan, 2004 and according to Dal Sasso et al., 2014).

At the beginning of the Holocene, the good climatic and environmental conditions favoured the intensive growth of plant and animal species in the Nile Valley (Gautier, 1983). About 9000 years BP, some groups of Mesolithic hunter-gatherers took advantage of this variety of flora and fauna to broaden their spectrum of food resources. The all-year round rational exploitation of various food resources allowed them to adopt seasonally-stable settlements, where also pottery is largely attested.

At Kabbashi Haitah, although no complete vessels have been found yet, the analysis of the fragments show that they were produced using the coiling technique. In terms of morphology, they are roughly globular open pots, with no neck, lugs or other applications, often with asymmetrical shape, irregular rim lines, variable wall thickness, uneven surfaces and the joints of the coils still visible. The bottom is prevalently rounded and indistinct from the walls, although fragments of thickened, undecorated, sometimes conical bases have also been found. The walls are usually simple and straight, with an average thickness of 8-9 mm, thinning slightly towards the rim. Undecorated pieces appear to be thicker, sometimes exceeding 15 mm, and probably belonged to the bottom of the containers. The internal surface is usually well smoothed, probably for practical rather than decorative reasons; only rarely is this treatment so crudely executed that the coiling can still be seen. The outer surface is almost entirely decorated, either by stamped or incised motifs.

Stamped decoration was almost exclusively executed using the *rocker* technique (Figs. 2a-c), by impressing a comb into the still soft clay surface and pivoting it alternately at the ends before impressing it again and again. The resulting decorative motifs thus vary according to the number of teeth in the comb, the distance between them and the size and shape of their tips (pointed, triangular, square, and straight) (Caneva, 1987; Caneva and Marks, 1990). Other significant factors include the angle at which the comb was held and pivoted, the distance between the decorative bands on the vessel and their shape, which could be either rectilinear or curvilinear. The curvilinear band, in particular, with the dotted wavy line motif (Fig. 2c), was discovered to be a key culture-specific element.

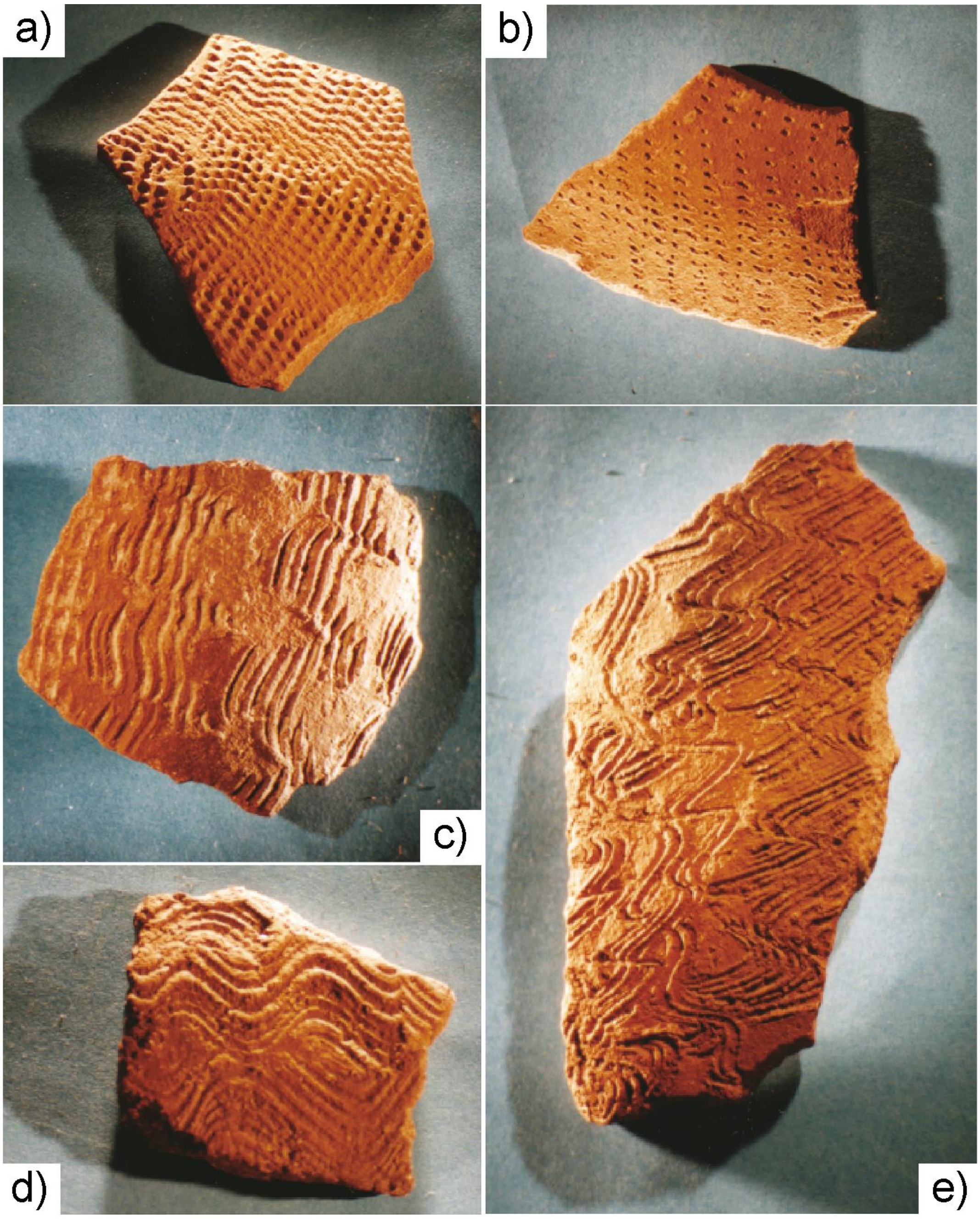

Figure 2.Macro-photographs of main types of decoration motifs: (a-b) rocker stamp decoration (samples KAH 902 and KAH 938, respectively); (c) rocker stamp decoration– "dotted wavy line" type (sample KAH 459); (d-e) incised decoration – "wavy line" type (samples KAH 200 and KAH 201, respectively).

Incised decoration consisted in drawing different types of combs around the circumference of the vessel, with curves and changes in direction used to create an infinite variety of wavy line patterns (Figs. 2d-e). In the collection analysed here, this decoration consisted mainly of shallow undulations that tended to flatten out into almost straight lines towards the lower part of the vessels.

The motifs and design composition vary considerably, with horizontal, oblique or vertical bands. The decoration was generally more carefully executed, with straighter lines, in the upper part of the vessel than towards the bottom, and only the upper two thirds of the vessels are likely to have been decorated (Arkell 1949).

3. GEOLOGICAL SETTING OF KABBASHI HAITAH

The site of at Kabbashi Haitah lays on an old alluvial terrace of the Nile, on its hydrographical right. The bedrock consists of the Umm Ruwaba Deposits, formed by unconsolidated gravel, sand, silt and clay laid down during the Tertiary and Quaternary (Fig. 1). The terrace deposits are bordered eastern by the Quaternary stabilized dunes, which represent the current limit of the desert conditions. Northern of the site, the Basement complex outcrops, composed of Proterozoic metamorphic rocks (mainly para- and orthogneiss), on which, eastern of the site, few-tens-metres hills of granite and syenite ring complexes rise, Jurassic in age (Whiteman, 1971; Yassin et al., 1984; Gras, 2004) (Fig. 1). On the western bank of the Nile at this latitude, the Nubian Sandstone Formation outcrops, and in particular the fluviate sandstones, siltstones and conglomerates of Cretaceous age (Fig. 1).

4. MATERIALS AND METHODS

A large set of potsherds (1075 pieces), selected to represent the entire area and depth of the excavation site, were analysed macroscopically, and ware type and decoration technique were considered to be the most prominent features insofar, as they reflect the main decisions of the potter in terms of quality and quantity of the raw materials, and the appearance of their product, respectively. On these basis, and after a detailed analysis of the repertoire from Kabbashi Haitah, the following features were selected for the macroscopic analysis:

I) *decoration type*: studies conducted in recent decades on decorative features of Mesolithic pottery from Sudan have resulted in somewhat different classification methods (Caneva and Marks, 1990; Mohammed-Ali, 1991; Salvatori, 2012). In the present study, a simplified classification of the decorative motives, divided in either stamped or incised motifs, yielded three groups: (i) *wavy line*, i.e. incised decoration; (ii) *rocker stamp*, i.e. impressed decoration, with a number of variables, including the *dotted wavy line* pattern and the two-dot, alternately pivoting stamps; (iii) *undecorated*, i.e. pieces with no surface decoration.

II) *size of the inclusions*: rock and/or mineral fragments macroscopically distinguishable from the finer groundmass (matrix) were divided into three main grain-size classes: (i) *small inclusions*, visible to the naked eye, but difficult to distinguish from the rest of the matrix and impossible to define as rounded or angular in shape; (ii) *medium-sized inclusions*, visible to the naked eye in the even matrix, and usually sub-rounded in shape; (iii) *large inclusions*, reaching few millimetres in length, and including both very large rounded or sub-rounded inclusions, and smaller angular inclusions, generally concentrated in the core of the ware.

III) *abundance of mica*: this feature can also easily be seen to the naked eye, as mica occurs in tabular crystals showing an intense pearly shining. Among the studied samples, three situations were identified: (i) *absence of mica*; (ii) *traces of mica*, where small mica flakes are scattered throughout the matrix but are easily distinguishable from the other materials (e.g. fragments of quartz); (iii) *abundant mica*, where mica is a distinctive mineral component, either scattered in large quantities of small flakes or in larger crystals up to 1-2 mm in size.

Mineralogical and petrographic analyses were performed on thirty potsherds, representative of the ware typologies macroscopically identified. The petrographic analysis was carried out by polarized-light optical microscopy (OM) on thin sections, using a Nikon Mod. TK-1270E microscope equipped with a digital camera for image acquisition, according to an ad-hoc modified descriptive method of Whitbread (1989; 1989; 1995) and Quinn (2013). The procedure focused mainly on the description of composition, abundance (using comparison charts for visual estimation; Baccelle and Bosellini, 1965) and grain-size (size class according to Wentworth, 1922) of inclusions, as well as the main feature of the micromass (matrix) and pores. X-ray powder diffraction (XRPD) was performed to analyze the bulk mineralogical composition of the ceramic bodies, using a Philips PW 1830 diffractometer in Bragg–Brentano geometry, equipped with a Cu–Kα tube, operating at 40 kV and 20 mA in the 3°-70° 2θ range, step size 0.02° and 1 s count per step. With the aim of better evidencing the possible presence of clay minerals in the micromass, orientated powder-mount XRPD of the matrix fine fraction (∅≤ 4 μm), as obtained after grinding the ceramic bodies on five potsherds representative of the various groups, was also performed, by placing a suspension in distilled water – attained after adequate settling rate according to the Stokes' law – of the *tout venant* of the sample on a glass slide, and drying at room temperature. For these latter, the acquisition was performed in the 3-20° 2θ interval.

5. RESULTS AND DISCUSSION

5.1 Macroscopic analysis

On the basis of the macroscopic analysis, most of the studied potsherds are decorated with the incised technique (*wavy line*) used as often as the stamped ones (*rocker stamp*). The ceramic paste is, in most cases, characterised by the presence of medium-sized inclusions (Table 1), whereas large inclusions are observed only in few cases (6%). This suggests that certain types of ware were more sought-after by early potters rather than others. Since large inclusions make the clay more difficult to be modeled and the decoration yields less accurate results (particularly when using the incised technique, where the comb would drag the inclusions or leave gaps if they fell away), the potters choose medium-sized paste to fit both aesthetic features and technological procedures.

Table 1. Results of the macroscopic analysis carried out on 1075 potsherds.

Size of inclusions	Number of sherds	Percent of total	Presence of mica	Number of sherds	Percent of total	Type of decoration	Number of sherds	Percent of total
large	61	6%	without	438	40%	*wavy line*	480	44%
medium	805	75%	traces	594	56%	*rocker stamp*	449	42%
small	209	19%	abundant	43	4%	not decorated	146	14%

As for the occurrence of mica, most of the potsherds are characterized by the presence of low quantities or completely lacking this mineral phase: only occasionally, micas represent abundant inclusions of the paste (Table 1).

When all these macroscopic features are compared, a significant distinction does emerge (Fig. 3).

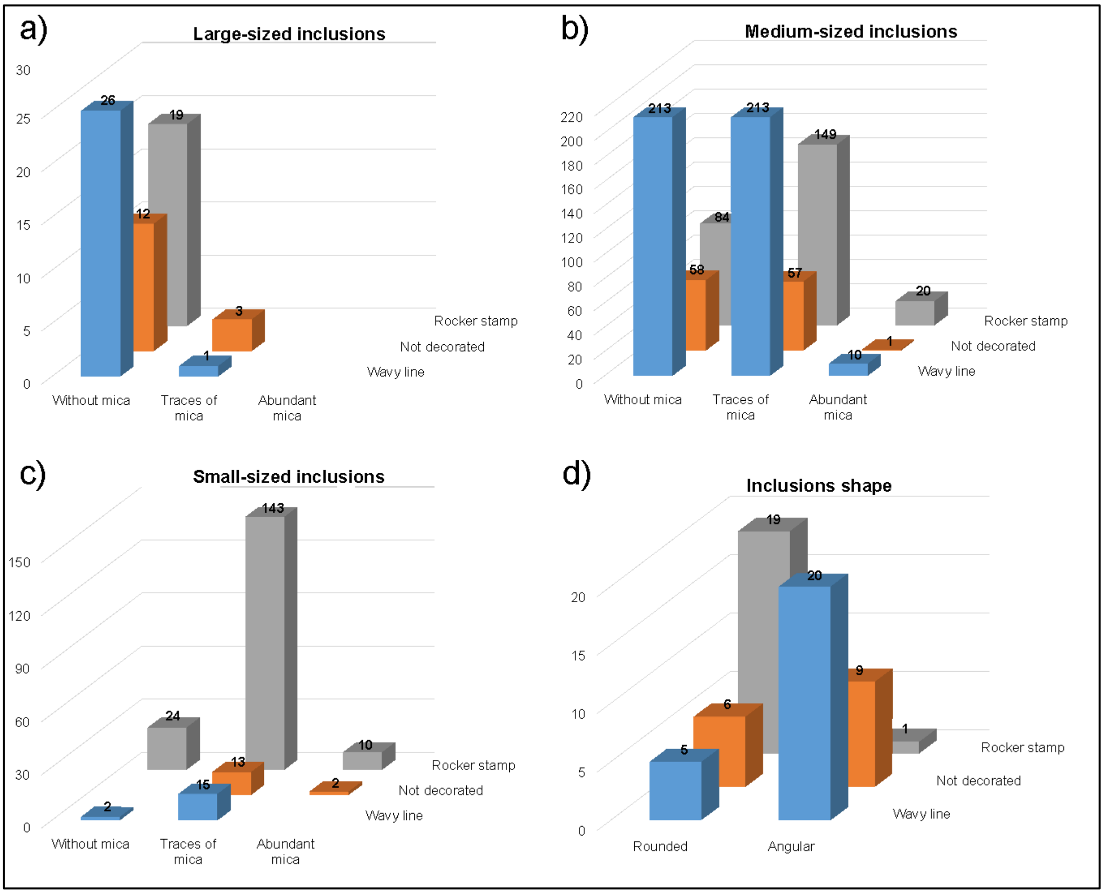

Figure 3. (a) Mica versus decoration in potsherds with large-sized inclusions. (b) Mica versus decoration ratio in potsherds with medium-sized inclusions. (c) Mica versus decoration ratio in potsherds with small-sized inclusions. (d) Decorations versus shape in potsherds with large-sized inclusions.

Pottery with large- and medium-sized inclusions is decorated by *wavy line* style as often as the *rocker stamp*, with the former prevailing slightly over the latter (Fig. 3a-3b). By contrast, in pottery with small inclusions the *rocker*-type decoration was used in the vast majority of the vessels (Fig. 3c). The same results emerged in the groups with large and medium-sized inclusions in relation to the presence of mica. A recurrent association between more refined ware types and a more sophisticated decoration technique, i.e. *rocker stamp*, can be observed.

Potsherds with large inclusions can be divided in two visibly distinct groups: i) potsherds with rounded inclusions, which may exceed 1 mm in size; ii) potsherds with angular inclusions, which are slightly smaller but more numerous within the groundmass. When this shape distinction is considered in relation to the decorative motives (Fig. 3d), it results that the incised type (wavy line) is associated with angular inclusions, whereas the impressed one (*rocker stamp*) is almost invariably found in shards with rounded inclusions.

Table 2. Summary of the mineralogical-petrographic characteristics of the ceramic bodies. Abbreviations: OA = Optically active; OI = Optically inactive; Hi = Hiatal; P = Polymodal; B = bimodal; M = Medium; H = High; L = Low; 2^a = secondary phase; ± = rare; + = present; ++ = abundant; +++ = very abundant.

GROUP	SAMPLE	GROUNDMASS	MICROSCOPIC ANALYSIS OF INCLUSIONS																					ROCK FRAGMENTS	POROSITY
			GRANULOMETRY	QUANTITY			GRAIN SIZE			QUARTZ						OTHER INCLUSIONS									
				Abundant	Medium	Low	Coarse sandy	Average sandy	Silty	Angular	Sub-angular	Sub-rounded	Polycrystallin	Chert	Total Quartz	K-FELDSPAR	PLAGIOCLASE	MUSCOVITE	BIOTITE	CALCITE	CLINOPYROXENE	AMPHIBOLE	OPAQUE MINERALS		
I a	219	OA	Hi/P	X			X	X		+	+++	++			+++	+++	+	±			±	±	±	+	MH
	309	OA	Hi/P	X	X		X	X		+	+++	++	±		+++	++	±	±			±		+	+	H
	351	OA	Hi/P	X			X	X		±	++	++			+++	+++	±	±		2^a	±		±	+	L-ML
	596	OA	Hi/P	X			X	X		+	+++	+			+++	++				2^a	±		±	+	MH-H
	699	OI	Hi/P	X			X	X		+	++	++			+++	+++	±			2^a	±		+	+	MB
	843	OA	Hi/P	X				X	X	++	++	+			+++	++	+	±			±	±	±	±	M-ML
	899	OA	Hi/P	X				X	X	++	++	+		±	+++	+++	+			2^a	±	±	±	±	A
	960	OA	Hi/P	X				X	X	+	++	+	±		+++	++	+	±			+		±	±	ML
	972	OA	Hi/P	X				X	X	++	+++	+			+++	++	++	±		2^a	±		+	±	L
	1022	OA	Hi/P	X	X		X	X		±	++	+++			+++	++	+				±		±	++	M
Ib	110	OA	Hi/P	X			X	X		+	+++	+			++	+++	±	±		2^a	±		±	+	M
	406	OA	Hi/P	X			X	X		+	+++	+			++	+++	±	±					±	+	ML
	425	OA	Hi/P	X	X			X	X	±	++	++		±	+++	+++	+	±			+		±	±	ML
	543	OA	Hi/B	X			X	X		++	+++	+	+	±	+++	+++	+	±			±		±	+	M
	976	OA	Hi/P	X				X	X	+	++	+			++	+++		±			±		+	±	L
	986	OA	Hi/P	X				X	X	±	++	+			++	+++	+	±		2^a	±		±	±	M-ML
	1063	OA	Hi/P	X	X		X	X		++	++	+			++	+++	±	±			±		±	+	M
	1065	OA	Hi/P	X	X		X	X		++	++	+			++	+++	+			2^a	±		±	±	M
II	83	OA	Hi/B	X				X	X	++	+	++	±		+++	+++	±	+			±		±	+	M-ML
	97	OA	Hi/P	X			X	X		+	++	+++	±		+++	++	+	++	+		±		±	++	M
	105	OA	Hi/P	X	X			X	X	++	++	+	±	±	+++	+++	±	±	++				±	±	ML
	107	OA	Hi/P	X			X	X		+	++	++	±		+++	+++	+	+	++		+		±	++	L
	1010	OA	Hi/P	X	X			X	X	+	++	++	±		+++	++	+	±	+	2^a	±		±	+	ML
	1012	OA	Hi/P	X			X	X		+	++	++			+++	+++	±	++	+				±	+	ML
III	642	OA	Hi/P	X				X	X	+	+++	+	±	±	+++	+				2^a	±		+	+	MH
	1015	OI	Hi/P		X		X	X		±	++	+++	+	±	+++	±		±		2^a	±		+	++	L
	1018	OA	Hi/P	X	X		X	X		+	+++	+	+	+	+++	±	±			2^a	±		+	+	L
IV	603	OA	Hi/P	X			X	X		+	++	++	±		+++	+++	±	±	±	+	±		±	+	L
	778	OA	Hi/P	X	X		X	X		++	++	++	±		+++	+++	++	±	+	++	±		+	++	M
	907	OA	Hi/P	X	X			X	X	+	++	++			+++	+++	±	±	+	++	±		±	++	ML

5.2 Petrographic analysis

On the basis of the minero-petrographic composition, the studied potsherds can be divided into four main groups (Table 2 and Figure 4):

- Group I: K-feldspar and quartz-rich potsherds

This group includes over half of the analysed potsherds. They are characterized by homogeneous and optically active groundmass, with a parallel striated birefringent fabric (b-fabric), in some cases showing a moderate orientation (Fig. 4) in which abundant inclusions are embedded (25- 40%), a hiatal grain-size distribution and a grain size reaching 0.5-1 mm. Inclusions are composed of abundant sand-sized crystals of partially kaolinitized microcline-pertite and quartz, associated to small fragments of plagioclase, granitoid rocks (alkaline granites) and rare crystals of biotite, muscovite, clinopyroxene, fragments of chert and opaque minerals, and occasionally also hornblende (Table 2). Pores, represented by planar voids and vughs, vary between 20% and 40% and are sometimes partially filled by secondary calcite. Based on the abundance of the various type of inclusions (in particular of quartz and microcline-pertite) and of their textural features, 2 subgroups can be distinguished:

Ia: (samples: KAH 219, 309, 351, 596, 699, 843, 899, 960, 972, 1022): in which quartz is more abundant and occurs mainly as sub-angular or angular (rarely sub-rounded) fragments, often with undulose extinction, occasionally polycrystalline, and the microcline-pertite is less abundant; these potsherds are also characterized by a lower percentage of inclusions (25-35) (Fig. 4a,b).

Ib: (samples: 110, 406, 425, 543, 976, 986, 1063, 1065): very similar to the previous group, but characterized by more abundant inclusions (30-40%), in some cases with a prevalence of microcline-pertite on the quartz grains (Fig. 4c), and lower porosity (≤ 20%).

Group II: K-feldspar-, quartz- and mica-rich potsherds

This group comprises six samples (83, 97, 105, 107, 1010, 1012) all characterized by abundant or very abundant inclusions (28-40%), with a hiatal grain-size distribution, ranging from silt- to very coarse-sand sizes. They are composed mainly of quartz, microcline-pertite and flackes of mica (biotite and muscovite), with a subordinate presence of crystals of plagioclase, fragments of granitoid rocks, opaque minerals and clinopyroxenes (Table 2). The relatively abundant biotite and subordinate muscovite (Fig. 4d), often disposed parallel to the body walls, is a distinctive feature of this group. Quartz is mostly subangular and subrounded, more rarely angular, often with undulose extinction and sometimes occurring in polycrystalline grains. The clasts of granitoid rocks are generally rounded and fresh and consist of quartz, microcline, plagioclase and mica. The micromass is micaceous and optically active with a striated b-fabric. Porosity ranges from medium-low to medium (20-30%), and is characterized mainly by vughs.

Group III: quartz-rich potsherds

Three samples of the studied repertoires (KAH 642, 1015, 1018) are clearly distinct from the former groups, owing to the presence of abundant (25-35%) and evenly distributed sandy-silty inclusions, mostly made up of clasts of sub-rounded or sub-angular (only very sporadically angular) quartz (Fig. 4e). In particular, inclusions show a hiatal and polymodal grain-size distribution due to the presence of coarse- (1-0.6 mm) or very coarse-grained (2-1.3 mm) clasts, essentially made of rounded fragments of extremely sialic – almost exclusively quartz-type – granitoid rocks, and by abundant clasts, from medium-fine sandy to silty in size, mainly consisting of mono- and poly-crystalline quartz, chert and, occasionally (less than 4-5% of the total) microcline-pertite, plagioclase and mica (Table 2). Rare crystals of clinopyroxene and iron oxides are also present. The micromass shows low mica and moderate quartz content, in some cases (642, 1018) with a striated b-fabric. Furthermore, it sometimes includes rare argillaceous rock fragments (ARFs; Whitbread, 1986) of small dimensions (1015). Porosity varies from low (1015 and 1018; < 20%) to medium (KAH 642; ca. 30%) and pores are sometimes partially filled by secondary calcite.

Group IV: potsherds rich in K-feldspar and bearing limestone

The three samples of this group (KAH 603,778, 907) are the only ones featuring inclusions comprising a significant primary carbonate fraction (Fig. 4f), along with the usual silicate components, which remain dominant (Table 2). Inclusions, which are from abundant to very abundant (30-40%), have a hiatal grain-size distribution, varying from very coarse sand- (Ø max = 1.48 mm) to silt-sized, and are composed of very abundant grains of quartz (usually sub-angular and sub-rounded, more rarely angular), abundant kaolinitized alkaline feldspar (microcline + pertites), subordinated calcareous and granitoid rocks, and scarce crystals of plagioclases, biotite, muscovite, opaque minerals and clinopyroxene. The carbonate clasts are composed of rounded fragments of micritic-pseudosparitic limestone, occasionally containing particles of detritic quartz. In some cases, their internal structure was obliterated from the firing, which determined also their reactions with the surrounding groundmass. The fairly rare fragments of granitoid rocks are similar in every respect to those already described in the samples of the previous groups. The matrix is generally optically active, with a striated b-fabric. Porosity is medium-low in terms of abundance (ca. 20-25%), and pores are formed mainly by channels and vughs.

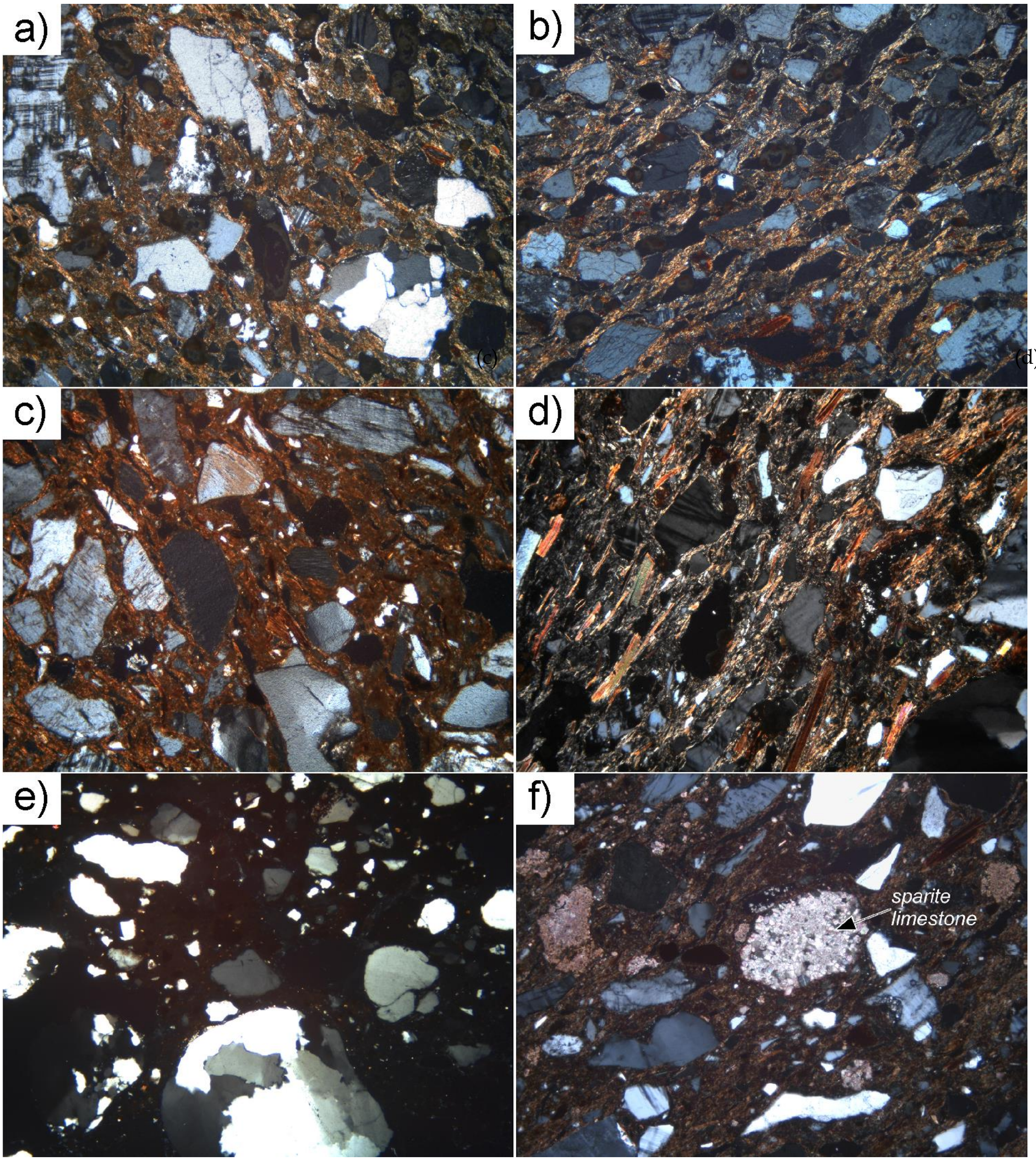

Figure 4. Photomicrographs of representative samples of petrographic sub-groups. Crossed polarized light; the long side of each picture is 2,35 mm. (a-b) sample KAH 351 (group Ia): clasts of pertite, quartz and granitoid rocks, sometimes moderately iso-oriented (b), into a striated groundmass; (c) sample KAH 406 (group Ib): abundant clasts of K-feldspar and quartz; (d) sample KAH 107 (group II): abundant presence of flakes of biotite and subordinate muscovite among the inclusions; (e) sample KAH 1015 (group III): abundant sub-rounded clasts of quartz and fewer clasts of granitoid rock in a optically inactive groundmass; (f) sample KAH 778 (group IV): fragments of carbonate rocks among the inclusions.

5.3 Mineralogical analysis

The XRPD analysis indicates that the Mesolithic pottery from Kabbashi Haitah is mainly composed of abundant quartz, associated to feldspar, plagioclase and, in most samples, also to muscovite/illite (Table 3). Primary calcite is present in potsherds of petro-group IV while secondary calcite figures in some samples of petro-groups I and II. Traces of clinopyroxene, amphibole, hematite and dolomite can be also observed in some potsherds (Table 3).

Basing on the mineralogical composition, it was possible to constraint the maximum firing temperature. Due to the dilution effect caused by the inclusions, the occurrence of peaks related to the survived clay minerals after firing was also explored for some standard and oriented samples. The diffractograms obtained from samples representative of each groups revealed the presence of the basal reflection of the muscovite/illite [d(001)], i.e. the 10Å peak, in all samples, indicating that this mineral phase did not decompose during firing.

Table 3. Results of the XRPD analysis of the selected potsherds.
Legend: Qtz = quartz; Kfs = potassic feldspar; Pl = plagioclase; Ill/Ms = illite/muscovite; Bt = biotite; Cal = calcite; Cpx = clinopyroxene; Amph = amphibole; Hem = hematite; Dol = dolomite.
+++ : very abundant; ++ : abundant; + : presence; ±: traces.

Group	Sample	Qtz	Kfs	Pl	Ill/Ms	Cal	Cpx	Amph	Hem	Dol
IV	KAH 603	+++	++	+		+				
	KAH 778	+++	+++	++	±	++			±	
	KAH 907	+++	+++	±	±	++				
III	KAH 1018	+++	±							
	KAH 1015	+++	±							
	KAH 642	+++	±							
II	KAH 83	+++	++	+	+					
	KAH 97	+++	++		+	+				
	KAH 105	++	+++	±	+	±				
	KAH 107	+++	++	+	+	+				
	KAH 1010	+++	++	+++	+	++				
	KAH 1012	+++	++	+	+	±				
Ib	KAH 110	++	+++	±		±				
	KAH 406	+++	+++	+	±	+				
	KAH 425	+++	+++	++	+		±			
	KAH 543	+++	+++	±	±		±			
	KAH 976	++	+++	±			±			
	KAH 986	++	+++	±	±	+				
	KAH 1065	+++	+++	±	±		+		±	
	KAH 1063	+++	+++	±		±	±			
Ia	KAH 219	+++	++	++			±			
	KAH 309	+++	+	±	±		±			
	KAH 351	+++	++	+	±	±			±	
	KAH 596	+++	++			±	±		±	±
	KAH 699	+++	++			±				
	KAH 843	+++	+	+	+			+		
	KAH 899	+++	++	+		+		±		
	KAH 960	+++	+	+	+		±			
	KAH 972	+++	++	+	±	+				
	KAH 1022	+++	+	+						

5.4 Discussion

The petrographic and mineralogical characterization of the 30 samples of Mesolithic pottery from Kabbashi Haitah highlights a number of interesting aspects about the provenance and the production technology of these materials. Although the pottery fragments belong to four distinct petro-groups, they display similar mineralogical compositional features, so that they can be considered closely related to the alluvial deposits or the formations surrounding the site (Marcolongo, 1983). As for the preparation process, basing on the hiatal or polymodal grain-size distribution of inclusions, the pottery was produced adding temper to the base clay. In particular, the angular shape of K-feldspar and quartz in potsherds of groups I, II and IV indicates that the temper was ground before being added to the ceramic paste. In the case of the quartz-rich potsherds of group III, the base clay was tempered with a quartz sand, since the quartz grains are sub-angular and sub-rounded in shape. Quartz sand was probably collected from the aeolian deposits, since the alluvial sand of the Main Nile contains, in addition to quartz grains, also fragments of volcanic rocks and mineral originating from the Ethiopian basalts transported from the Blue Nile (Garzanti et al., 2006). Most likely, the sand used for this pottery derives from the weathering of the Nubian Sandstone Formation, which extensively outcrops in most of the Sudanese territory, and also near the Kabbashi Haitah site; it is composed of predominant quartz grains associated to very scarce and rare heavy minerals. As for the nature of the inclusions, only three of the thirty samples contain significant (though not abundant) quantities of carbonate clasts (limestone ± calcite) in the temper, while all the others feature high contents of quartz, alkaline feldspar and some plagioclase. Due to the lack of limestone on the Nile hydrographic basin, these inclusions may derive from calcrete formations formed in the soil during the time (Dal Sasso et al., 2017). As for the microcline-pertite and plagioclase, they derive from the deterioration of the locally outcropping alkaline granites and syenite (Whiteman, 1971; Marcolongo, 1983; Jassin et al., 1984; Dal Sasso et al., 2014; Gravagna, 2017), which are composed, in different proportions according to the rock type, of microcline-pertite feldspar, albitic plagioclase, quartz, hornblende and biotite.

Although the maximum firing temperatures cannot easily be ascertained, due to the lack of newly formed mineral phases, generally typical of carbonate-rich base clays, the widespread optically active groundmass and the presence of illite/muscovite in most analysed samples, indicates that the firing did not exceed their breakdown temperature, therefore staying under about 900°C in open firing conditions (Maritan et al., 2006). Moreover, the lack of other clay minerals which should be present as important constituent of the Nile clays, and in particular of montmorillonite deriving from the alteration of the Ethiopian basaltic plateaux and kaolinite from the crystalline basement largely outcropping in the White Nile basins (Gravagna, 2017; Garzanti et al., 2015), indicated that the firing exceeded 750°C. Finally, the occurrence of unaltered limestone clasts in potsherds of petro-group IV, together with the absence of gehlenite, fassaite, wollastonite and of a vetrified structures, all point to a firing temperature lower than 800°C (Maggetti, 1982; Maritan et al., 2006). The data collected indicate that firing presumably took place in a fairly rudimentary structure. The studied fragments of pottery commonly feature a "black core", often visible to the naked eye, with pinkish or reddish-orange external edges. This indicates that after a reductive-type initial condition, final firing took place in an oxidizing atmosphere, probably related to the partial opening of the pit firing or to the complete combustion of wood and circulation of oxygen in open firing (De Bonis et al., 2017; Daszkiewicz and Maritan, 2016; Maritan et al., 2006; Nodari et al., 2004; Gosselain, 1992).

When the petro-groups are compared with the macrofabric defined on a large set of samples, it arises that fragments with large rounded inclusions belong to petro-group III, characterized by the presence of quartz sand, whereas those with angular inclusions relate to petro-groups I, II and IV, the differences among which can be considered as variants of the production, due to the collection of slightly different base clay (like clay of group IV containing also carbonate inclusion) or temper (like that of group II rich in mica). Taking into account the decoration motives, it is clear how the *rocker stamp* pottery was produced using a clay tempered with quartz sand, whereas most of the *wavy line* with a temper composed of K-feldspar and quartz.

6. CONCLUSIONS

Prehistoric pottery with similar paste composition was observed from a wide range of sites in the Nile valley and the western desert of Egypt and Sudan, as at Saggai and others (Francaviglia and Palmieri, 1983, Caneva and Santucci, 2006), Kadero (Ch1odnicki, 1989), Sarurab (Khabir, 1987), in the central-northern sites of Kadada (De Paepe, 1986), Dongola (Hays and Hassan, 1974), Karmakol (Gatto, 2006), in the region of Wadi Howar, Ennedi Erg, Jebel Tageru, Wadi Hariq and Laqiya (Jesse, 2003; Klein et al., 2004), Kerma (De Paepe, 1988), as well in sites located at Khartoum (Arkell, 1949) and south of the confluence between the White and the Blue Nile, at Al Khiday (Dal Sasso et al., 2014) and Shabona (Brandt, 1980).

Although confirming the existence of a general homogeneity in terms of production technology in this wide territory, the results of the mineralogical-petrographic analyses of the Early Mesolithic pottery from Kabbashi Haitah suggest that specific choices might have been made for what concerns paste and decoration. In particular, the two main types of decoration, *wavy line* and *rocker stamp*, which account for 25 % and 20-30 % of the total range of decorations respectively, were distinct from each other by different types of inclusions, angular in one case and rounded in the other (Fig. 3). In addition, the pottery decorated with the *wavy line* motifs was produced using only an illitic base-clay tempered with fragments of crushed granitic-syenitic rocks, available in the immediate vicinity of the site. The easy availability of granite and syenite clearly suggests a local production of this pottery. The strong connection between this decoration type (*wavy line*) and the ceramic paste, particularly the type of temper, suggests, however, that this raw material was deliberately selected for this specific vessel type, either as a sign of cultural identity or required by the specific function to which these vessels were intended. In other sites where this ceramic pastes (K-feldspar rich) are attested, the situation is different as the closest outcrops of the magmatic rocks are located many dozen kilometres far away (such as Al Khiday and Shabona). In such cases, the *wavy line* ceramics (as well as other decoration types, like the *rocker stamp dotted zig zag*, *rocker stamp drops deep*, and the *alternately pivoting stamp*: Salvatori, 2012; Dal Sasso et al., 2014) may represent an imported product, therefore witnessing contacts within a wide range of hunter-gatherer groups, one of them represented also by that settled at Kabbashi Haitah.

In the case of the quartz-tempered pottery, attested at Kabbashi Haitah mainly on the *rocker stamp* decorated vessels, the ubiquity of this type of temper (quartz sand) cannot help us to define whether this ceramic was univocally locally made or may also represent imports (exchanges) or frequentation of other areas in the Sudanese territory. Interestingly, while at Kabbashi Haitah *rocker stamp* pottery seems to have been produced using a quartz temper, in other sites analogous variants are characterised also by K-feldspar temper (such as *rocker stamp dotted zig zag*, *rocker stamp drops deep* at Al Khiday: Salvatori, 2012; Dal Sasso et al., 2014). It cannot be excluded that these variants of the *rocker stamp* may derive from other sites, rather than Kabbashi Haitah.

As for the other aspects of the pottery production, the ceramics from Kabbashi Haitah were realised with the use of the coiling technique and fired at temperatures of about 750-900 °C, which is quite high if we bear in mind that during the Mesolithic such values were not reached in a furnace but in a bonfire.

Generally speaking, the differences observed in the pottery seem to be the result of decisions taken by individuals, or possibly families, within a well-established technological and cultural tradition, with no hint of any craft, trade or social subdivision in the community. The range of pottery containers needed by a simple society whose requirements were associated almost exclusively with subsistence, such as the one analysed here, would have been limited not only because there was no differentiation between individuals, but also because the food resources were, albeit abundant, not highly varied. A more extensive study on the distribution of these production recipes versus the decoration type in the Nile valley may help to better interpret the dynamic of the pottery production in the Mesolithic, with particular focus on the relationships between communities dislocated in such a vast territory. This would contribute to the anthropological study of these hunter-gatherer-fishers in terms of their reciprocal relationships, mobility and metalanguage.

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