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ORIGINAL ARTICLE

A Holocene Ceramic Sequence in the Central Sahara: Pottery Traditions and Social Dynamics Seen from the Takarkori Rockshelter (SW Libya)

Rocco Rotunno · Lucia Cavorsi · Savino di Lernia

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Abstract This article presents the Early and Middle Holocene pottery repertoire of the Takarkori archaeological site, a rockshelter in the Tadrart Acacus massif in southwestern Libya, Central Sahara. This long sequence, extending from 10,200 to 4300 cal BP, is one of the best preserved Holocene contexts in North Africa, recording much of Holocene cultural evolution and chronologically framed by a large number of radiocarbon dates. The study of the assemblage resulted in a well-defined seriation of the pottery sequence, supported by statistical and comparative methods. Following an integrated approach, the study identifies continuities and changes in ceramic production that enhance our understanding of the human occupation of Takarkori and its cultural variations. The multi-scalar and multi-dimensional perspectives highlight technological traditions and cultural dynamics and provide new insights into the origin and use of pottery, first among Late Acacus hunter-gatherers and later among Pastoral Neolithic herders and their regional interconnections. This study clarifies the position of the Takarkori ceramic sequence within the broader regional and interregional contexts from the Early to the Middle Holocene. By indicating contacts and interrelationships among different areas of the Sahara and neighboring regions, from the massifs of Central Algerian Sahara to the plains of the Eastern Sahara, the study adds new insights into North Africa's prehistory. It contributes to an increasingly accurate reconstruction of the Holocene's chronological and cultural sequences.

Résumé Le présent article décrit le répertoire de poteries de l'Holocène ancien et moyen du site archéologique de Takarkori, un abri sous roche situé dans le massif de Tadrart Acacus, dans le sud-ouest de la Libye, au Sahara central. Cette longue séquence, qui s'étend de 10200 à 4300 cal. BP, est l'une des mieux préservées de l'Holocène nord-africain dans son ensemble, enregistrant une grande partie de son évolution culturelle et garantie par un grand nombre de dates radiocarbones. 'étude de l'assemblage a achevé à une sériation bien définie de la séquence de poterie, soutenue par des méthodes statistiques et comparatives. En suivant une approche intégrée, l'étude a identifié des continuités et des changements dans la production de céramique qui améliorent notre compréhension de l'occupation humaine de Takarkori et de ses variations culturelles. La perspective multi-scalaire et multi-dimensionnelle a mis en évidence des attributs fournissant des données sur les traditions

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technologiques et la dynamique culturelle, offrant de nouvelles perspectives sur l'origine et l'utilisation de la poterie, d'abord chez les chasseurs-cueilleurs de l'Acacus Tardif (Late Acacus), puis chez les éleveurs du Néolithique pastoral et sur leurs interconnexions régionales. Cette étude clarifie la position de la séquence céramique de Takarkori dans le contexte régional et inter-régional plus large de l'Holocène précoce à l'Holocène moyen. En indiquant les contacts et les rapports entre les différentes zones du Sahara et les régions voisines, des massifs du Sahara central algérien aux plaines du Sahara oriental, elle ajoute des nouvelles informations à notre connaissance actuelle de la préhistoire de l'Afrique du Nord et contribue à une reconstruction et à une définition de plus en plus précise de ses aspects chronologiques et culturels.

Keywords Pottery · Holocene · Foragers · Herders · Central Sahara

Introduction

Africa is home to one of the world's oldest pottery traditions. The archaeological sequences in Africa have yielded very early dates that place the emergence of this material class at around the beginning of the Early Holocene (Huysecom, 2020; Huysecom et al., 2009; Jesse, 2010). The origin of pottery in Africa is still disputed, both chronologically and geographically. It is generally accepted that the earliest African pottery was produced by human groups with an extractive economy, an occurrence that finds parallels elsewhere in the world (Craig, 2021; Craig et al., 2013; Jordan & Zvelebil, 2010; Kim & Seong, 2022; Wu et al., 2012).

To date, the oldest African pottery comes from sites in the Sahel, southern Sahara, and the Nile Valley (D'Ercole, 2021; Huysecom, 2020). Potsherds from Ounjougou in Mali are associated with dates as early as 11,400–10,800 cal BP (e.g., Huysecom, 2020; Huysecom et al., 2009 [All dates in this article are calibrated using OxCal 4.4, with the last calibration curve IntCal20—95.4% probability, Bronk Ramsey, 2009; Reimer et al., 2020]). Tagalagal and Adrar Bous in southern Sahara, Niger (Jesse, 2003a; Roset, 2000) and Sarourab and Bir Kiseiba, in Sudan's Nile Valley and Egypt's Western Desert, respectively, have yielded pottery specimens in layers dated to between 11,000 and 10,100 cal BP (Hakem & Khabir, 1989; Jordeczka et al., 2011).

In the Central Sahara, specifically the Tadrart Acacus, pottery-bearing contexts can also be placed in the early Holocene. However, the dates are more recent and probably related to population diffusion dynamics and migratory drifts (for a recent synthesis, see di Lernia, 2022). The lowest pottery-bearing layer at Takarkori is dated ca. 10,200 cal BP (Cherkinsky & di Lernia, 2013), matching those at Ti-n-Torha Two Caves, Ti-n-Torha East, Uan Afuda, and Uan Tabu (Barich, 1974, 1987a; di Lernia, 1999; Garcea, 2001a). Ti-n-Hanakaten and Amekni, in the Algerian Tassili and Ahaggar, respectively, date roughly to the late tenth millennium and early ninth millennium cal BP (Aumassip & Delibrias, 1982; Camps, 1969, Fig. 1).

Pottery represents an extraordinary material through which the various social and cultural entities in the Holocene greater central Sahara can be disentangled. Presenting some degree of stylistic and technological similarity over large geographical and temporal areas, yet regionally diversified, the ceramic production from the earliest Holocene up to the Middle Holocene serves as an indicator of cultural spheres, mobility strategies, settlement organizations, and exchange patterns (e.g., Caneva & Marks, 1990; Jesse, 2010; Keding, 2017; Salvatori, 2012). The study of pottery allows us to answer numerous questions regarding chronology, regional and inter-regional contacts and traditions, resource exploitation, and social formation processes. Here, we present an account of the pottery assemblage of the Takarkori rockshelter, which offers information on one of the longest and most complete sequences of the Holocene Central Sahara, thanks to its well-preserved deposits, the meticulous excavation strategy employed, and the large dataset of ^{14}C dates.

The Takarkori Rockshelter: Archaeological and Cultural Sequence

The Takarkori rockshelter is located in the wadi of the same name, which connects the Tanezzuft valley with the eastern foothills of the Tadrart Acacus massif, near the current Libyan-Algerian border. The shelter is roughly 70 m long and runs north-south on a terrace of over 2200 m^2. It opens to the west and

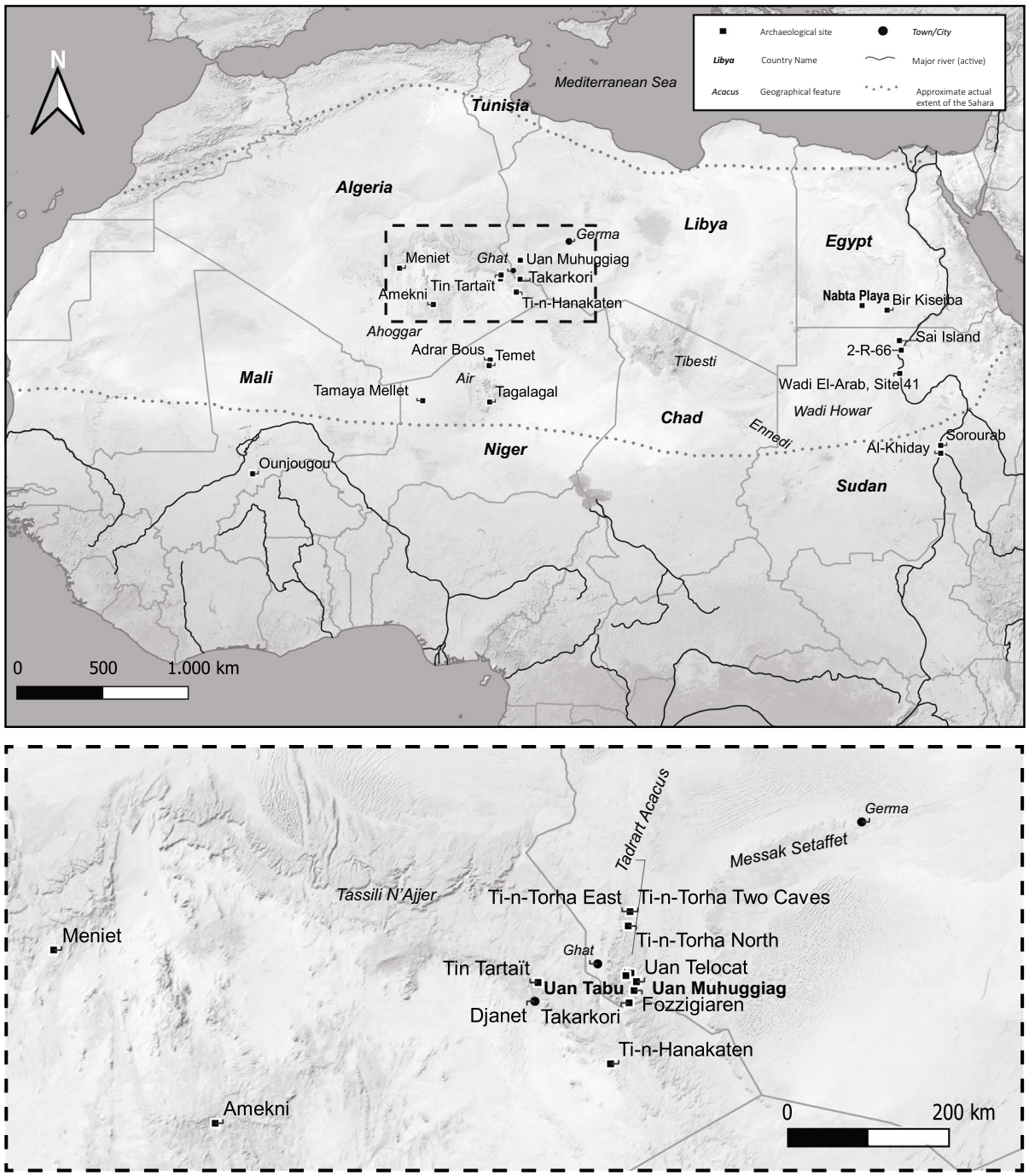


Fig. 1 Map of North Africa with the location of places mentioned in the text and the Tadrart Acacus and Tassili N'Ajjer area (by RR)

is bounded to the east by a 30-m-high rock wall. The location at 1100 m above sea level, and 150 m above the valley below, is in correspondence with a major mountain pass between the Tadrart Acacus in Libya and the Algerian Tadrart and adjacent to a paleolake basin (Biagetti & di Lernia, 2013). The depression,

currently filled by an endorheic basin, was fed by a complex hydrographic system originating from the Algerian Tassili that remained active until the onset of more arid climatic conditions at the end of the Middle Holocene (Cremaschi et al., 2014). During the African Humid Period (AHP), the area was home to a rich variety of flora and fauna thanks to the moist conditions, very different from the current hyper-arid climate with annual precipitation below 25 mm (Cremaschi et al., 2014; Fornaciari et al., 2018; Zerboni et al., 2015).

The archaeological deposits were excavated during four field seasons (2003–2006) in four areas: Main, Northern, Western, and Southern Sectors (Fig. 2). The bedrock was reached only in the Northern Sector, where the stratigraphy was 1.6 m thick, whereas the excavation stopped in the other sectors before reaching the bedrock because of conservation considerations (Biagetti & di Lernia, 2013, Fig. 2c). The excavations brought to light the remains of a long human occupation divided into four principal cultural phases: Late Acacus (LA), Early Pastoral (EP), Middle Pastoral (MP), and Late Pastoral (LP), covering the Early and Middle Holocene.

An analysis of the differences in the numerical distribution of archaeological features, the sequence and relationships between stratigraphic units, and the statistical analysis of ^{14}C measurements (Cherkinsky & di Lernia, 2013; Table 1) made it possible to further divide the main cultural horizons into sub-phases (Biagetti & di Lernia, 2013; Table 2). These form the main chronological framework referred to in this article. The occupation started with the so-called Late Acacus dwellers, subdivided into three sub-phases. The bottom of the sequence relates to the LA1 occupation, which, though reached only in the Northern Sector, contained important features indicating an intensive occupation of the shelter by hunter-gatherer-fishers. The dates associated with this sub-phase fall within 10,200–9500 cal BP. The subsequent Late Acacus 2 (LA2) and Late Acacus 3 (LA3) occupations, respectively 9500–8600 and 9000–8000 cal BP, represent the bulk of the early Holocene occupation (Cherkinsky & di Lernia, 2013). Characterized by a complex palimpsest of long-lasting

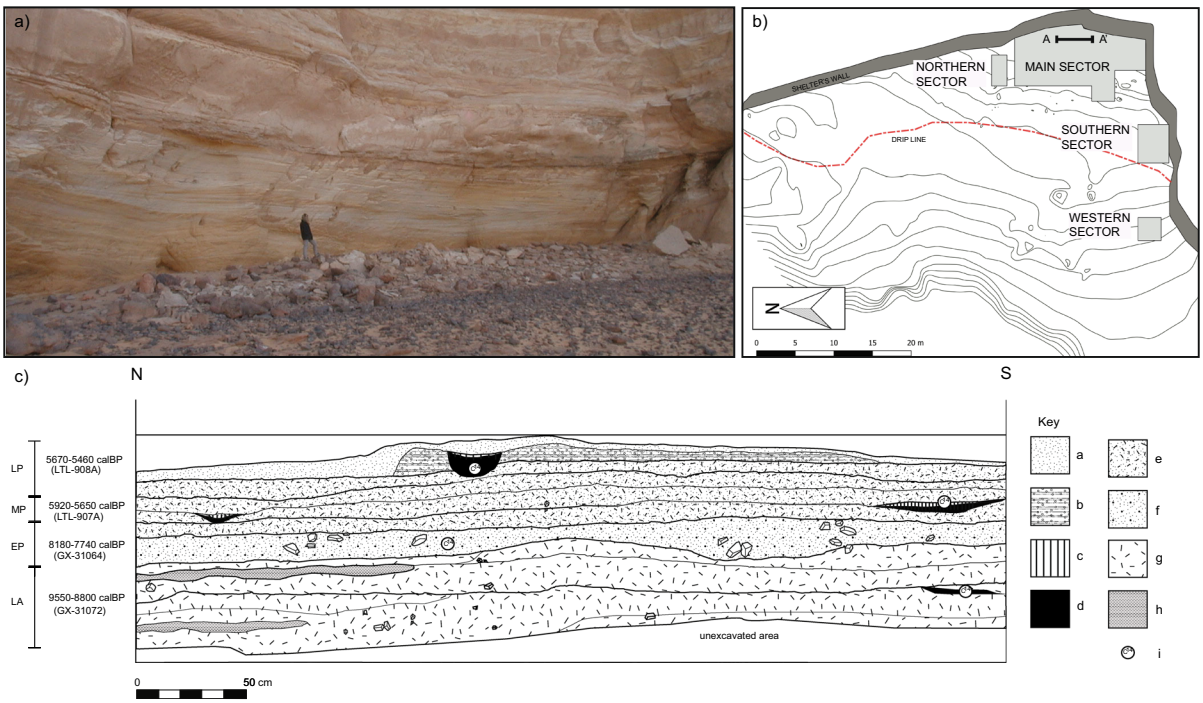


Fig. 2 The Takarkori rockshelter: **a** general view from the East (photo: The Archaeological Mission in the Sahara); **b** DEM and location of the excavated sectors; **c** main sector N-S stratigraphic profile (key: a eolian sand; b dung; c ash layer; d hearth; e organic sand with a variable amount of organics; f humified organic sand; g organic sand; h floor, hardened organic sand; i radiocarbon dates) (see Table 1)

Table 1 Selection of radiocarbon dates and calibrations (according to OxCal online version 4.4.4 (Bronk Ramsey, 2009), and calibration curve IntCal 20 (Reimer et al., 2020)) from the Takarkori rockshelter (modified from Biagetti & di Lernia, 2013; Cherkinsky & Di Lernia, 2013; Cremaschi et al., 2014)

Lab sample	Material	Age	Calibrated yrs BC (95.4% confidence)	Calibrated yrs BP (95.4% confidence)	Cultural attribution/subphase
LTL670A	Human bone	4291±50	3090–2700	5040–4650	Late Pastoral (LP1)
GX-30325	Dung	4800±70	3710–3370	5660–5320	Late Pastoral (LP1)
LTL908A	Coprolite	4841±50	3750–3510	5670–5460	Late Pastoral (LP1)
LTL907A	Charcoal	5064±55	3970–3710	5920–5650	Middle Pastoral (MP2)
UGAMS#10149	Dung	5170±25	4003–3951	5990–5900	Middle Pastoral (MP2)
UGAMS#01841	Collagen	5340±50	4330–4040	6280–5990	Middle Pastoral (MP2)
GX-31077	Bone collagen	5600±70	4600–4330	6550–6280	Middle Pastoral (MP1)
GX-30324-AMS	Human bone	6090±60	5210–4840	7160–6790	Middle Pastoral (MP1)
UGAMS#01842	Collagen	6230±90	5470–4940	7420–6890	Early Pastoral (EP2)
GX-31074-AMS	Human bone	6540±70	5630–5370	7570–7310	Early Pastoral (EP2)
GX-31073-AMS	Human bone	6740±70	5760–5520	7710–7470	Early Pastoral (EP2)
LTL1585A	Human bone	6763±55	5750–5560	7700–7510	Early Pastoral (EP2)
GX-31075-AMS	Human bone	6900±70	5980–5660	7930–7610	Early Pastoral (EP1)
LTL911A	Human bone	7068±100	6210–5730	8160–7670	Early Pastoral (EP1)
GX-30326	Dung	7070±100	6210–5730	8160–7680	Early Pastoral (EP1)
GX-31064	Soil	7130±100	6230–5800	8180–7750	Early Pastoral (EP1)
LTL1586A	Human bone	7155±65	6210–5890	8160–7840	Early Pastoral (EP1)
GX-31069	Soil	7580±110	6650–6230	8590–8180	Late Acacus (LA3)
LTL369A	Charcoal	7694±60	6640–6440	8590–8390	Late Acacus (LA3)
LTL364A	Charcoal	7801±35	6700–6510	8650–8450	Late Acacus (LA2)
LTL368A	Charcoal	8031±65	7140–6690	9090–8640	Late Acacus (LA2)
LTL366A	Charcoal	8049±40	7140–6820	9030–8760	Late Acacus (LA2)
GX-31072	Charcoal	8290±140	7600–6850	9550–8800	Late Acacus (LA2)
UGAMS#10150	Charcoal	8410±30	7553–7452	9520–9400	Late Acacus (LA2)
UGAMS#01844	Charcoal	8820±60	8220–7720	10,170–9670	Late Acacus (LA1)

Table 2 Chronology of the main chrono-cultural phases and their sub-phases identified in the Takarkori area (modified after Cherkinsky & di Lernia, 2013, and Biagetti & di Lernia, 2013). The calibrated dates express the maximum chronological range and overlap are statistically possible. For the calibration: OxCal online version 4.4.4 (Bronk Ramsey, 2009; Reimer et al., 2020)

	Cultural phase	Sub-phase	uncal BP	cal BCE	cal BP*
Chronology	Late Pastoral (LP)	LP1	5000–4000	3950–2350	5900–4300
	Middle Pastoral (MP)	MP2	5500–5000	4450–3700	6400–5600
		MP1	6100–5500	5200–4250	7100–6200
	Early Pastoral (EP)	EP2	6900–6400	5900–5300	7800–7300
		EP1	7400–6900	6400–5700	8300–7600
	Late Acacus (LA)	LA3	7900–7400	7050–6100	9000–8000
		LA2	8500–7900	7600–6650	9500–8600
		LA1	8900–8500	8250–7500	10,200–9400

occupations, the study of the social and economic aspects of this phase greatly enhanced our understanding of this cultural entity within a broader regional context. Highly formalized stone structures identified as huts, pens, and stone alignments indicate a structured site arrangement (Biagetti & di Lernia, 2013; Rotunno et al., 2019; Scancarello et al., 2022). These, together with floors and organic sand accumulations yielding numerous artifacts and ecofacts, testify to an intense and prolonged occupation (Biagetti & di Lernia, 2013). An advanced delayed-return strategy of resource exploitation distinguishes the LA, as attested by the penning of wild Barbary Sheep (Rotunno et al., 2019) and the cultivation and storage of wild cereals (Dunne et al., 2016; Mercuri et al., 2018). This cultural phase sees the introduction and widespread use of pottery and lithic assemblages characterized by microliths, increased macrolithic components, and grinding equipment (di Lernia, 2022).

The Early Pastoral (8300–7200 cal BP) is linked with the first, and among the oldest, evidence for domesticated animal species in the African continent, dated to the arid interval of 8300–8000 cal BP (di Lernia, 2021). The herding of domestic livestock is complemented by multispectral resource exploitation (Van Neer et al., 2020), which, together with specific funerary customs, represents one of the principal features of this cultural phase (di Lernia & Tafuri, 2013). The Takarkori rockshelter was used intensively as a burial ground throughout this occupational phase, differentiated into two sub-phases, Early Pastoral 1 (EP1) (8300–7600 cal BP) and Early Pastoral 2 (EP2) (7800–7300). Alongside the funerary evidence, the occupation features pits, fireplaces, stone structures, and a varied and rich material culture (Scancarello et al., 2022).

A short arid phase separates the Early from the Middle Pastoral, signaled by decreased hygrophilous plants in the sequences (Cremaschi et al., 2014). The Middle Pastoral is divided into two sub-phases: Middle Pastoral 1 (MP1) and Middle Pastoral 2 (MP2). The Middle Pastoral chronology ranges from 7100 to 5600 years cal BP. This highly distinctive cultural phase saw the presence of mobile herders with a settlement strategy focused on the intensive use of lakeside areas during the wet season (summer) and a move to the mountain ranges during the dry winter, indicating vertical seasonal transhumance (di Lernia & Biagetti, 2007). A fully pastoral economy is attested by dairy products, as suggested by the analysis of lipid residues on pottery (Dunne et al., 2012, 2013). The funerary evidence is heterogenous (di Lernia & Tafuri, 2013). The Takarkori sequence ends with a Late Pastoral occupation, here limited to Late Pastoral 1 (LP1, 5900–4300 cal BP), one of the two sub-phases into which this period is subdivided in the regional context (e.g., Biagetti & di Lernia, 2013; Cremaschi & di Lernia, 1998; Garcea & Sebastiani, 1998). Groups of nomadic shepherds accompanied by their herds occupied the shelter for short periods on a seasonal basis, as evidenced by hearths, burials, artifacts, and numerous ecofacts (e.g., Rotunno et al., 2020).

Materials and Methods

A total of 2944 potsherds were retrieved from all the excavation sectors and are considered here, excluding the surface collection already studied (Biagetti et al., 2004; Table 3).

The analysis of the pottery assemblage adopted a holistic and integrated approach, combining typo-stylistic, morpho-technological, and contextual aspects of ceramic production. This multifaceted approach combines methods and insights from ceramic ecology,

Table 3 Potsherds distinguished by sector and chronology (the number of samples used in the archaeometric study is in brackets, modified after Eramo et al., 2020)

No. of potsherds (samples)	Main sector		Northern sector		Western sector		Southern sector		Surface collection	Total		
	2149	(63)	173	(6)	202		18		402		2944	(69)
LA	490	(15)	130	(5)	23	-	-	-	29	-	-	(20)
EP	635	(19)	16	(1)	-	-		-	34	-	-	(20)
MP	829	(22)	28	-	179	-	-	-	187	-	-	(22)
LP	172	(7)	-	-	-	-	18	-	36	-	-	(7)
Unclassified	25	-	-	-	-	-	-	-	116	-	-	-

behavioral archaeology, and chaîne opératoire (e.g., Duistermaat, 2017; Garcea, 2005; Rice, 2015; Roux, 2016, 2019; Skibo & Schiffer, 2008, 2001) to identify diachronic changes in the production system within social groups and technological variations between social entities at a regional and macro-regional scale. Reconstructing pottery production may help to evaluate the social behavior underlying technical and social choices made in different spatiotemporal contexts and provide information about the people who produced and used the resulting items.

The technological features were analyzed using macroscopic and microscopic approaches, following the principles and parameters of the relevant literature (e.g., Orton & Hughes, 2013; Rice, 2015; Roux, 2019; Rye, 1981; Skibo, 2015). An in-depth study of tempers and fabrics based on archaeometric and petrographic characterization has already been published elsewhere (Eramo et al., 2014, 2020), and it underpins the observations on technology and manufacturing reported here. That study used standard pottery analyses (optical microscopy, X-ray powder diffraction, X-ray fluorescence) and digital image processing of polarized light photomicrographs to address issues relating to provenance and the technology of pottery production combined with the characterization of clay sediment samples (Eramo et al., 2020).

The decorations and typologies of the repertoire were studied following the guidelines established by Caneva (Caneva, 1987; Caneva & Marks, 1990), used in studies of North African pottery (e.g., D'Ercole, 2017; Garcea, 2008, 2013; Gatto, 2002; Jesse, 2003b, 2010; Mohammed-Ali & Khabir, 2003; Nelson, 2002), appropriately expanded and adapted to reflect the specificities of the assemblage under consideration. This method emphasizes the role of technique, assuming that the object or the tool, together with the gesture and the method employed, may reflect stylistic and technological differences arising from social and cultural choices (Caneva, 1989; Gosselain, 1992b, 2000; Livingstone Smith, 2007; Roux, 2019). These attributes can be easily identified even on small fragments, which comprise most Saharan collections, consisting of partially to highly fragmented ceramics. Additionally, this system, more or less modified by various scholars and adopted in many Africanist pottery studies (Ashley & Grillo, 2015; Caneva et al., 1993; CISEM II, 2004; Commelin et al., 1992; di Lernia, 1999; Dittrich, 2015; Jesse, 2003b; Keding, 2006; Salvatori, 2012), aims to create a shared language and framework to facilitate cross-cultural and trans-geographical comparisons and thus permit broad chrono-cultural evaluations.

The analysis of vessel shapes followed a geometric approach, where the terms used refer to figures of the solid geometry and to intended functional classes (for example, Orton & Hughes, 2013; Shepard, 1974). Shapes are defined as closed or restricted (R) when the orifice is smaller than the total height, as open or unrestricted (U) when it is not. These are estimates based on comparing the few more or less complete forms and the diagnostic sherds' inclination and wall layout, given the limited and highly fragmented state of the sherd assemblage.

Descriptive and multivariate statistical analyses were performed on the dataset using specific software (SPSS vs. 27; PAST vs.4.2; ([Hammer et al., 2001]) to assess the principal attributes of the pottery, including shape, decoration, and technological features. Specifically, correspondence analysis was used because it offers an easy and accurate way of analyzing and quantifying multivariable data by bringing data into the sequence when they follow a unimodal model (Bellanger et al., 2006; Greenacre, 2010; Nielsen, 1991; Smith & Neiman, 2007). It has the potential to assess the reliability of the chronostratigraphic reconstruction and to increase its chronological resolution. In addition, the correspondence analysis in this article seeks to scrutinize the seriation proposed and some of the significant associations between the attributes of the pottery. Sherds are the units of observation in association with other independent variables/attributes, including the type of decoration, the pertaining layer, and the occupation phase deduced from the stratigraphic context. This allows us to assess the chronological-diagnostical significance of the various decoration techniques, and the sequence of decorations obtained from the stratigraphic analysis (Peeples & Schachner, 2012).

Results

Attributes, Frequency, and Descriptive Statistics

Technological Features

The pottery from Takarkori is made by hand without employing rotating kinetic energy (Roux, 2019). Firing processes were directly and indirectly

evaluated. The estimated firing temperature, assessed based on mineralogical analysis and microstructural alterations (Eramo et al., 2020), was 500–800 °C. The oxidation patterns on the potsherds indicate a reducing atmosphere during the firing and cooling stages. The surface colors signal differences between the Early and the Middle Holocene assemblages. The surfaces of Late Acacus pots range from dark brown to gray (from 2.5 YR 3/3 to 10YR 3/2), indicating a reducing firing and cooling atmosphere; those of the EP range from dark brown (7.5YR 3/2) to dark reddish brown (5YR 3/2 to 5YR 4/3). MP and LP potsherds are more heterogeneous in color, in the red and brown range (from 5YR 3/4 to 10YR 3/4), related to a more oxidizing atmosphere. The frequent presence of a "black core" among the specimens indicates that after initial reducing conditions, the vessels underwent an oxidizing stage, either when the fire was opened or during the final cooling process (Gliozzo, 2020; Gosselain, 1992a; Maritan et al., 2006).

The fabrics presented considerable variability and were assigned to macro-fabric groups based on the macroscopic observation of (i) the amount and quality of inclusions and (ii) the degree of refinement (Orton & Hughes, 2013, p. 74 ff.; 273 ff.; Fig. 3a). The five groups are as follows:

(1) Fine: Fine-grained and compact fabric with a minimal quantity of small mineral (sandy) and fibrous (vegetable) inclusions barely visible to the naked eye (up to 0.1 mm).

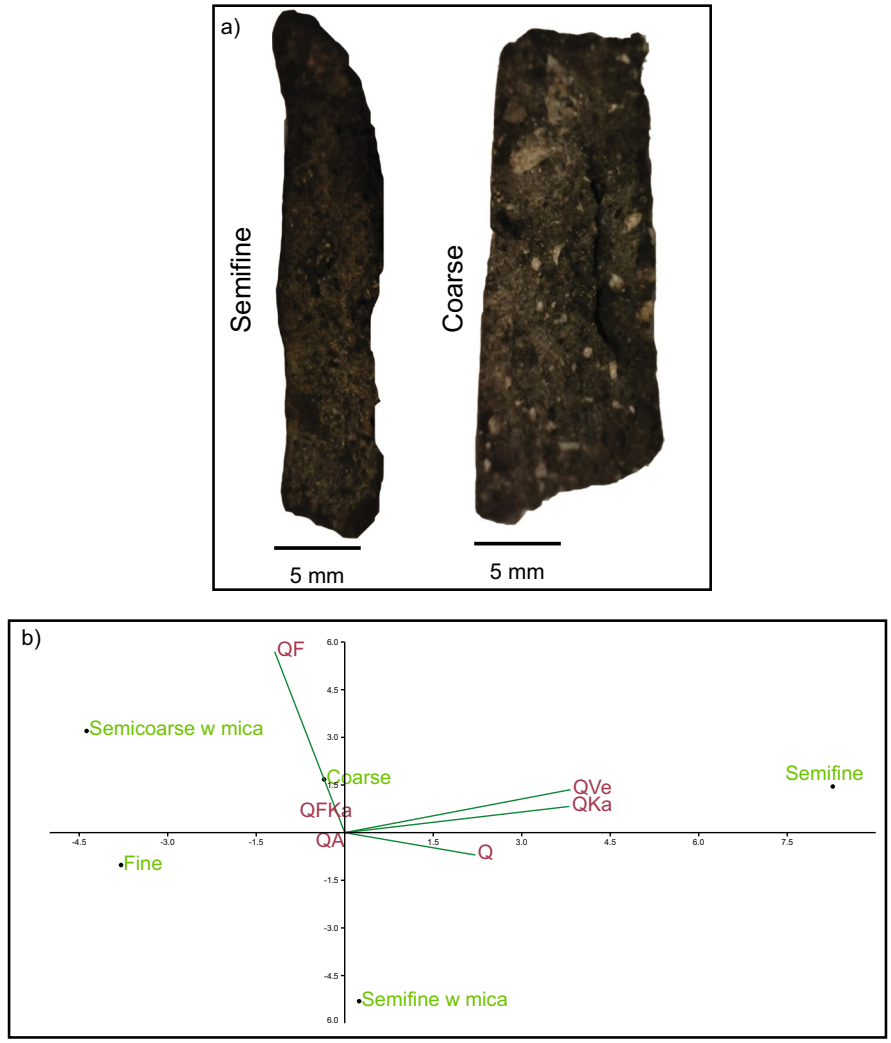


Fig. 3 Technological and manufacturing features: **a** examples of semi-fine and coarse fabrics; **b** biplot graph of correspondence between macro-fabrics and petrofabrics (processing on Past v.4.3 by RR)

(2) Semi-fine: fine and compact groundmass with a medium quantity of small/fine (0.1–0.25 mm) to medium (0.25–05 mm) vegetable and mineral (sandy) inclusions and fairly sorted.
(3) Semi-fine with mica: a low to medium quantity of small/fine (0.1–0.25 mm) to medium (0.25–0.5 mm) vegetable and mineral inclusions with significant mica flakes scattered in the matrix and fair sorting.
(4) Semi-coarse with mica: a medium to high quantity of small medium to large (0.1–1 mm) vegetable (rare) and/or mineral inclusions with frequent mica flakes (biotite) and poor sorting.
(5) Coarse: large quantities of small to large (0.2–1.5 mm) vegetable (sporadic) and mineral inclusions and poor sorting.

As shown in the biplot graph (Fig. 3b), these groups broadly match the six petrofabrics identified by archaeometric analysis (see Eramo et al., 2020 and references therein for further discussion):

- Q* (Q, QVe, QA, QKa): quartz and sandstone-related raw materials, with the differential preponderance of quartz (Q), carbonized vegetable (Ve), mudstone (A), or calcareous (Ka) inclusions.
- QF* (QF, QFKa): plutonic rock-related raw materials, with the prevalence of some calcareous (Ka) inclusions distinguishing between the two sub-groups.

Overall, Q* petro-fabrics compare with Groups 1, 2, and 3 of the macro-fabrics, and QF* petro-fabrics with groups 3, 4, and 5, suggesting a time- and culture-sensitive polarization in the production and use of specific raw materials and fabrics. The Early Holocene production of the LA tradition is mostly characterized by semi-coarse and coarse fabrics with sub-millimetric and millimetric micaceous and mineral inclusions. Finer fabrics, more often organic-rich matrixes and inclusions, are mostly used in the Middle and Late Pastoral (Fig. 3). Body thickness also presents a chronological trend, with LA and EP specimens having thicker walls on average. In contrast, the Middle Pastoral production shows a clear decrease in wall thickness linked to the presence of slightly more closed and lighter vessels (Table 4).

Table 4 Principal technological attributes of the Takarkori pottery production by chronological phase (percentage refers to the grand maximum of 2542 with the exclusion of surface collection

	Preparation					Forming			Color (firing)				
	Macro fabric 1/fine	Macro fabric 2/semifine	Semifine mica	Semicoarse mica	Coarse	Average body thickness	Max body thickness	Min body thickness	Grays from 2.5 YR 3/3 to 10YR 3/2	Dark browns (7.5YR 3/2)	Dark reddish brown (5YR2,5/2-3/4)	Browns (2,5 YR 2,5/1–7,5YR5/4)	Reds (10YR ¾)
LA	0%	9%	10%	50%	31%	10	24	7	19%	37%	21%	16%	7%
EP	4%	58%	10%	17%	11%	8	27	4	14%	24%	34%	23%	5%
MP	5%	74%	9%	10%	3%	7	18	3	12%	20%	22%	27%	19%
LP	5%	67%	14%	12%	1%	7	13	4	13%	25%	27%	27%	8%

Shapes and Morphology

During the LA, the main shapes are simple, slightly restricted vessels with a spherical (Rs, 36%) or conical (Rc, 45%) profile (Fig. 4 and Table 5). Both are also present in the EP when a good percentage is represented by restricted Rr vessels with a short collar. Though less frequently, these simpler shapes, Rs and Rc, are also present in the subsequent MP and LP phases. The bulk of the assemblages in the MP and LP phases could be assigned to Rr (50% and 38%, respectively), with a reverted expanded rim often forming a short collar. These shapes are typical of Middle Pastoral chronologies and are also attested in other contemporaneous assemblages together with rare necked types (Barich, 1987a; Cremaschi & di Lernia, 1998; Garcea & Sebastiani, 1998; Ponti et al., 1998). Necked jars are also representative of Pastoral

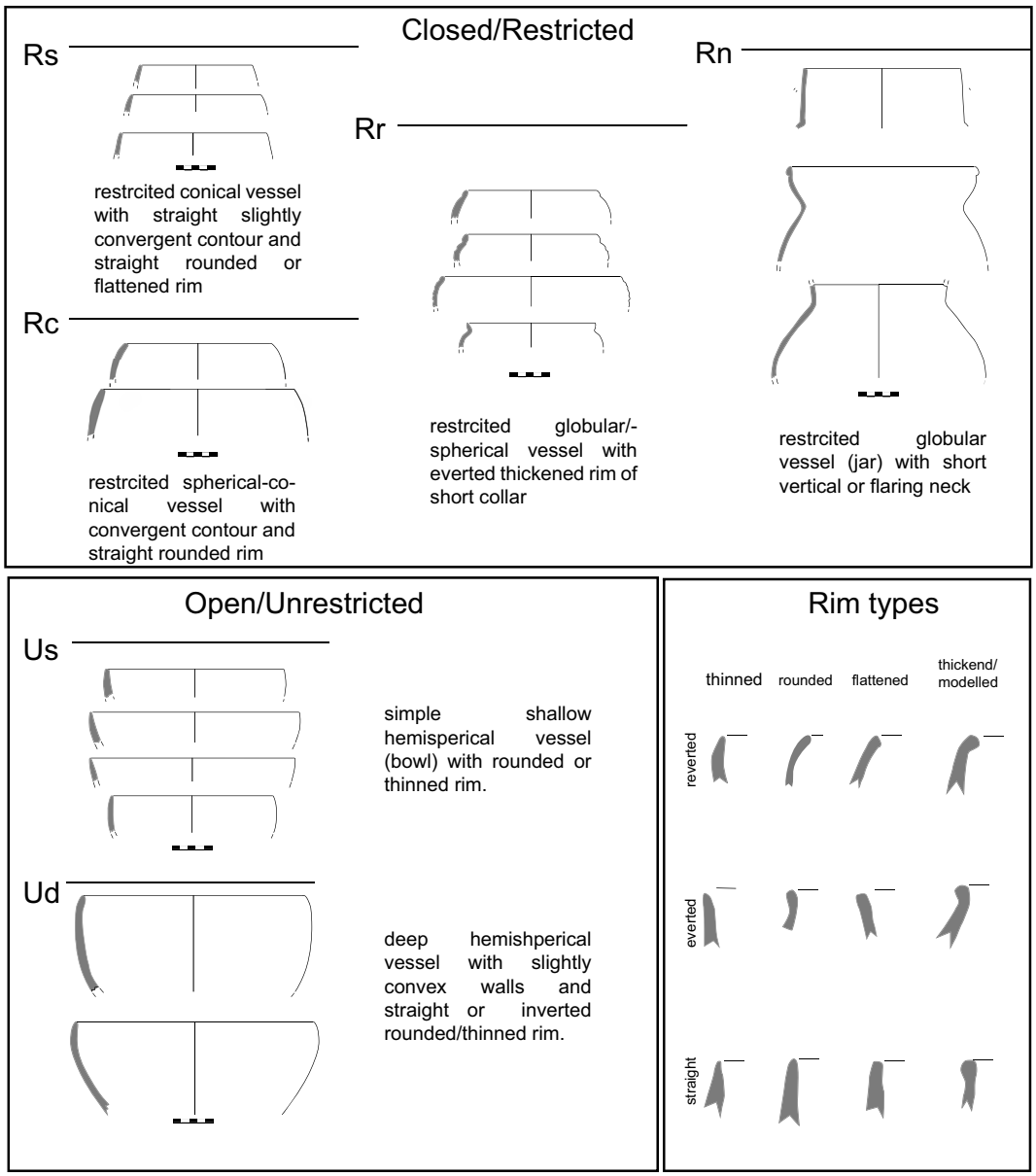


Fig. 4 Shapes and morphology of the Takarkori pottery (scale 5 cm)

Table 5 Relative percentages of vessel shapes, diameters, and rim shapes

Chronology	Vessel Shapes						Diameter (mm)			Rim shapes		
	Rs	Rc	Rr	Rn	Us	Ud	Average	Min	Max	Straight rounded	Everted/ thickened	Other
LA	36%	45%	5%	0%	9%	5%	23	10	38	55%	2%	43%
EP	24%	26%	33%	0%	9%	7%	20	5	34	59%	12	29%
MP	12%	19%	50%	2%	12%	4%	19	6	30	43%	22%	35%
LP	12%	27%	38%	8%	15%	0%	19	10	30	50%	10%	40%

pottery, in particular of the MP and LP phases. There are fewer open forms, though almost evenly spread among the principal chronological phases (under 10% in every phase, Table 5). Two kinds can be distinguished (Fig. 4): a shallow, medium-sized (18–20 cm in diameter) bowl (Us) and a medium-sized (12–30 cm in diameter) hemispherical deep bowl (Ud). Chronological trends are also apparent in the rim outline: LA production is characterized by a preponderance of simple rounded straight or slightly reverted rims, features which also partially characterize the EP vessels. The Middle Pastoral and Late Pastoral pottery present more everted or thickened rims.

Decoration

The decorative types include impressed and incised decorations, with a clear preponderance of the former. Among the impressions, the rocker technique is common in the earlier production, whereas alternately pivoting stamp (APS) is common in the Pastoral phases. These two techniques and the implements used (multiple-toothed combs, 2-toothed comb, and plain edge tools) determine the main decorative types identified. They are inserted into the taxonomic tree, following the Caneva system, with motifs and structures defining the varieties (Table 6).

The LA1 assemblage presents a limited number of types and varieties, with rocker-packed dotted zigzags (RPD) being the most common (>86%, Table 7) (Fig. 5). The patterns are created with evenly serrated edge tools and belong to two varieties: small rounded dots and large coarse dots (Fig. 6: 1–3). The comb teeth used for the decorations are large, 3–9 cm long, and have many notches. The LA2 subphase yielded numerous potsherds. The most common decoration is rocker-packed dotted zigzags in continuous lines, RPD_ct (>39%), with a slight preference for variety b with coarser and larger dots, created by an instrument with ten or more notches (Fig. 6: 4). The Dotted Wavy Line (DWL) is the second most frequent decoration (~13%), present in all its varieties (Fig. 6: 5–7), in particular, DWL_b (long waves, Fig. 6: 6) and DWL_c (short flat wave, Fig. 6: 7). DWL_a, with very short and small wave impressions applied to the rim band area, is relatively rare and sees its peak in the subsequent LA3. Like the sherds bearing the RPD pattern, numerous potsherds present a rocker plain-edged decoration on the lips. DWL-decorated vessels sometimes have an RPL motif on the rim band (the area just below the rim) followed by the wavy decoration, sometimes combined with the typical RPD decoration. The combs used to make both RPD and DWL, especially for the long wave varieties (DWL_b and DWL_c), are fairly large (average of seven indentations and up to 4 cm long), but the depth of the impression is shallow with light pressure over the surface. Simple impressions are present but rare. Undecorated pottery sherds are frequent; although this may be linked to zonal decoration, it is difficult to ascertain because of the absence of diagnostic rim sherds.

LA3 is characterized by the significant presence of undecorated sherds, but the few with decorations have the same attributes as LA2 pottery. Among the DWL varieties, the most common is the "a-variety," often framed by a horizontal line of simple impressed dots without further decoration on the ceramic body. Rocker-packed dotted zig zags are the main motif found on LA3 vessels, principally in the variety with large dots (Fig. 6: 8). Other decorative motifs include simple impressions, such as SI_wt, an impression of a wolftooth pattern created by applying a stylus/reed implement obliquely to form a pattern organized in a wolftooth fashion. It is always combined with the DWL_a variant on the upper register or rim band (Fig. 6: 9).

Table 6 Classification scheme and attributes of main decorative types

Technique	Name	General description	Variety	Variety description
Alternately pivoting stamp	APS_ct	Alternately pivoting stamp in a continuous regular pattern	a	Small dots
			b	Large dots
			c	Tiny dots
	APS_r	Alternately pivoting stamp, return technique	a	Small
			b	Small fine dots
			c	Tiny dots, sometimes in irregular fashion
Rocker	RPD_ct	Rocker packed dotted zigzags in continuous bands	a	Fine dots
			b	Large dots
			c	Very fine dots
	RS	Rocker spaced dotted zigzags		
	DWL	Dotted wavy line	a	Very short, small angular waves
			b	Long waves
			c	Short and flat waves
			d	Angular short waves
			e	Juxtaposed fanlike arches
	RPLs_ct	Rocker, plain edge straight continuous zigzags.		
	RPLc_ct	Rocker, plain edge curved continuous zigzags.		
	RPL_fn	Rocker plain edge, fishnet pattern.		
Simple impression	SI_CRD	SI_crd- simple impression with a cord implement.		
	SI_wt	Juxtaposition of two oblique dashed impressions connected at one end to form lines of "chevrons" or wolf-teeth.		
	SI_varia	Simple impression of various patterns, mainly single dots or lines.		
Incision	SInc	Varia-simple incisions.		

The EP1 pottery presents a discontinuity in the relative and absolute quantities of some decorations compared to the previous phase. RPD (Fig. 6: 11) declines in frequency (8%), and the most common variety is that with fine rectangular impressions. DWL is rare, as is undecorated pottery. Rocker decorations of straight and curved motifs, made with a plain edge tool increase (Fig. 6: 12). The most frequent decoration is APS continuous, mainly with small and very small irregular dots, though the latter variety is mostly restricted to the EP phase. APS return is also well represented. Another type, restricted to the EP phase, is what we have termed SI_crd, created when a simple cord or a cord-wrapped stick is applied to the surface of the vessel. The result is a syntactical chevron design (Fig. 6: 13–14). The EP2 shows a clear increase of APS (Fig. 6: 15–16) in both its continuous regular (Fig. 6: 16) and return technique variants. DWL is absent, and the formerly typical RPD becomes rare, continuing the trend already seen in the preceding subphase. Rocker plain edge, both straight and curved, decorative motifs have become common, especially the loosely-spaced varieties (Fig. 6: 17).

The MP1 sub-phase has yielded few potsherds due to severe post-depositional disturbance processes (Biagetti & di Lernia, 2013). The assemblage mainly consists of sherds decorated with APS continuous (Fig. 6: 18) and using the return technique (Fig. 6: 19). It indicates a clear pertinence to the Pastoral horizon, though with some archaic features, such as the irregular fine dots in some patterns, such as variety C (di Lernia, 2021; Garcea, 2003, 2005). By contrast, APS return is mainly attested in its fine (a) and

Table 7 Relative percentages of main diagnostic decorative types per sub-phase

		LA1		LA2		LA3		EP1		EP2		MP1		MP2		LP1	
		%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Alternately pivoting stamp	**APS_ct**	**0%**		**1%**	**3**	**3%**	**12**	**14%**	**34**	**37%**	**140**	**33%**	**23**	**35%**	**328**	**32%**	**57**
	a	*0%*		*0%*	*1*	*2%*	*8*	*4%*	*11*	*18%*	*70*	*16%*	*11*	*19%*	*175*	*14%*	*25*
	b	*0%*		*1%*	*2*	*1%*	*3*	*7%*	*16*	*8%*	*30*	*7%*	*5*	*10%*	*98*	*11%*	*20*
	c	*0%*		*0%*		*0%*	*1*	*3%*	*7*	*10%*	*37*	*10%*	*7*	*6%*	*55*	*6%*	*10*
	APS_r	**0%**		**3%**	**7**	**2%**	**7**	**17%**	**42**	**25%**	**94**	**28%**	**19**	**36%**	**336**	**24%**	**43**
	a	*0%*		*1%*	*2*	*1%*	*4*	*10%*	*25*	*11%*	*42*	*16%*	*11*	*15%*	*145*	*12%*	*21*
	b	*0%*		*2%*	*4*	*1%*	*2*	*4%*	*11*	*7%*	*27*	*10%*	*7*	*16%*	*147*	*9%*	*16*
	c	*0%*		*0%*		*0%*		*0%*		*1%*	*3*	*0%*		*0%*		*1%*	*2*
	APS_tr_ct	**0%**		**0%**	**1**	**0%**	**1**	**2%**	**4**	**4%**	**17**	**9%**	**6**	**6%**	**59**	**6%**	**11**
	APS_tr_r	**0%**		**0%**		**0%**		**0%**		**2%**	**6**	**0%**		**0%**	**1**	**0%**	
Dotted wavy line	**DWL**	**5%**	**1**	**13%**	**29**	**6%**	**22**	**4%**	**9**	**0%**		**0%**		**0%**		**1%**	**1**
	a	*0%*		*4%*	*9*	*4%*	*15*	*3%*	*8*	*0%*		*0%*		*0%*		*1%*	*1*
	b	*5%*	*1*	*5%*	*11*	*1%*	*2*	*0%*		*0%*		*0%*		*0%*		*0%*	
	c	*0%*		*2%*	*5*	*1%*	*2*	*0%*	*1*	*0%*		*0%*		*0%*		*0%*	
	d	*0%*		*1%*	*3*	*1%*	*3*	*0%*		*0%*		*0%*		*0%*		*0%*	
	e	*0%*		*0%*	*1*	*0%*		*0%*		*0%*		*0%*		*0%*		*0%*	
Rocker packed dots	**RPD_ct**	**86%**	**18**	**39%**	**89**	**12%**	**43**	**8%**	**20**	**5%**	**18**	**4%**	**3**	**3%**	**30**	**3%**	**6**
	a	*48%*	*10*	*12%*	*27*	*3%*	*11*	*3%*	*7*	*2%*	*8*	*3%*	*2*	*1%*	*14*	*1%*	*2*
	b	*38%*	*8*	*26%*	*60*	*8%*	*28*	*3%*	*8*	*2%*	*7*	*1%*	*1*	*1%*	*7*	*2%*	*3*
	c	*0%*		*1%*	*2*	*1%*	*4*	*2%*	*5*	*1%*	*3*	*0%*		*1%*	*9*	*1%*	*1*
Rocker plain edge	**RPLc_ct**	**0%**		**0%**		**0%**	**1**	**3%**	**7**	**1%**	**4**	**1%**	**1**	**1%**	**12**	**2%**	**3**
	RPLs_ct	**0%**		**2%**	**4**	**3%**	**10**	**6%**	**14**	**8%**	**29**	**6%**	**4**	**6%**	**54**	**6%**	**10**
	RPLs_fn	**0%**		**0%**		**0%**		**0%**		**1%**	**2**	**0%**		**2%**	**18**	**3%**	**5**
Rocker spaced	**RS**	**0%**		**3%**	**8**	**3%**	**9**	**4%**	**10**	**6%**	**22**	**1%**	**1**	**2%**	**22**	**3%**	**5**
Simple impression	**SI_varia**	**0%**		**3%**	**6**	**3%**	**12**	**3%**	**7**	**2%**	**6**	**1%**	**1**	**1%**	**10**	**3%**	**6**
	SI_wt	**0%**		**0%**		**1%**	**2**	**0%**	**1**	**0%**		**0%**		**0%**		**0%**	
	SI_crd	**0%**		**1%**	**3**	**1%**	**3**	**13%**	**31**	**2%**	**8**	**0%**		**1%**	**9**	**1%**	**1**
Simple incision	**Sinc_varia**	**0%**		**0%**	**1**	**0%**	**1**	**0%**		**0%**		**0%**		**0%**		**2%**	**3**
Undecorated	**UND**	**10%**	**2**	**32%**	**73**	**64%**	**224**	**26%**	**64**	**5%**	**19**	**16%**	**11**	**6%**	**55**	**16%**	**28**
Total		*100%*	*21*	*100%*	*230*	*100%*	*351*	*100%*	*245*	*100%*	*379*	*100%*	*69*	*100%*	*942*	*100%*	***179***

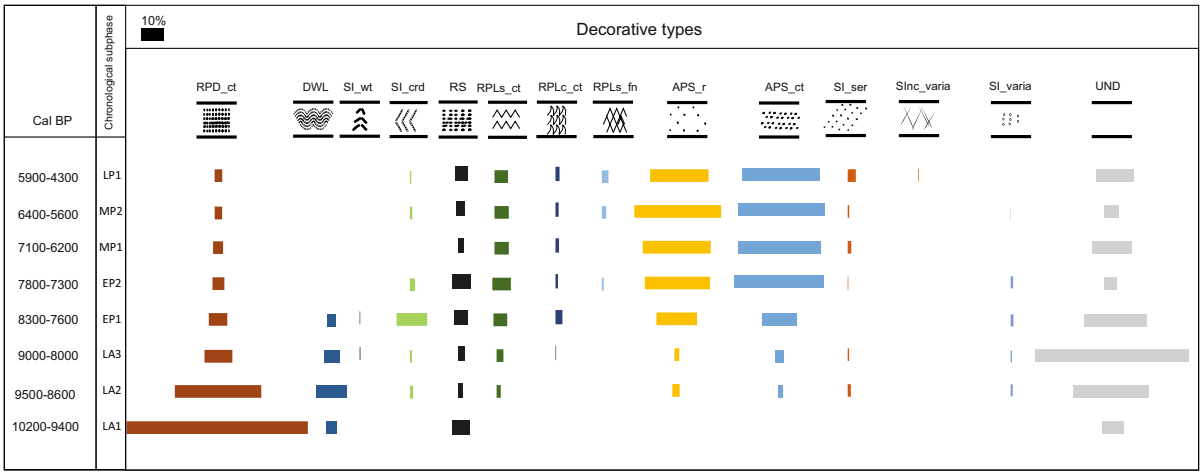


Fig. 5 Battleship graph of the main diagnostic decoration types, by sub-phase

thick (b) dotted variety. The MP2 is epitomized by the APS technique in both the continuous and return variants (Fig. 6: 21–25), which make up more than 70% of the assemblage. Both are created with fine or large dots with a slight preponderance of the former. RPL fishnet (Fig. 6: 26) is also well represented.

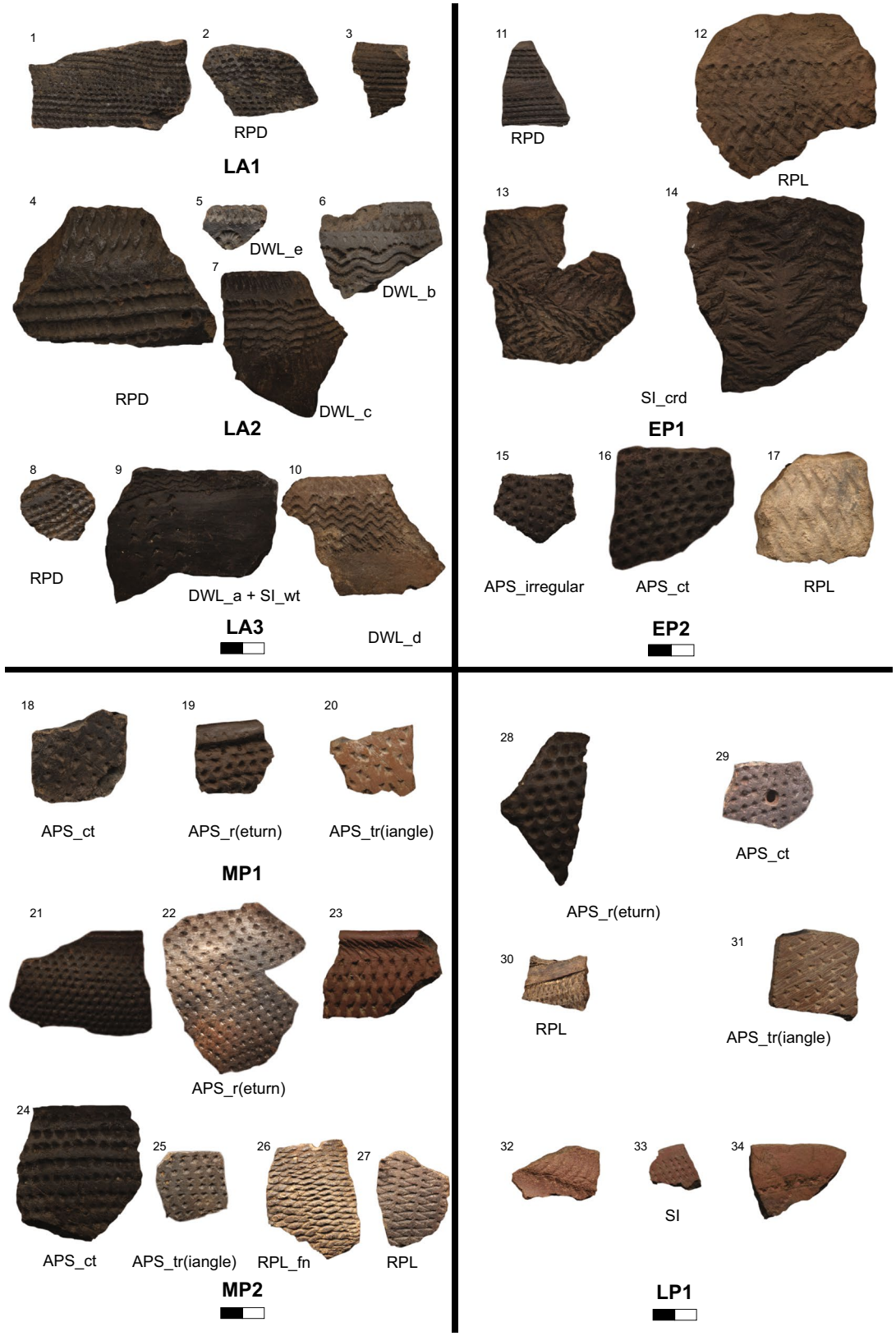
The LP1 layers yielded relatively few sherds compared to the other sub-phases (Fig. 6: 28–34). The repertoire mainly consists of APS_continuous decorations (~34%, Fig. 6: 29), APS_return (24%, Fig. 6: 30), and undecorated, sometimes burnished, pottery (~15%). APS with triangular impressions (Fig. 6: 32) is also more frequent than other subphases. Other decoration types appear in small quantities. These include the simple impressed pattern made with a serrated edge implement, which in its oblique (herringbone) form, is the most frequent here (Fig. 6: 34). Simple incised motifs are also present, including an oblique application mostly near the rim band area.

Combining Multivariable Data

The correspondence analysis performed on the dataset highlights the use of tempering materials and fabrics. Although a general homogeneity of production technology in the main cultural phases is confirmed, there is relatively high variability in the proportions of the various fabrics. These two observations are consistent with a household level of production, where choices are made by individuals (potters), albeit within a well-defined technological and cultural tradition (e.g., Arnold, 1985; Dietler & Herbich, 1994; Eerkens & Lipo, 2005; Wenger, 1999). These features fully match the socioeconomic ways of hunter-gatherers and pastoralists living in small communities where societal and labor specialization were virtually absent (e.g., Costin, 1991; di Lernia, 2022).

The correspondence analysis's biplot (Fig. 7) combining the macro-fabrics and the main decoration types shows a clear polarization in the assemblage. RPD and DWL are found mainly in association with semi-coarse fabrics with a significant quantity of micaceous inclusions, corresponding to fabrics made from granite-derived raw materials as determined by the microscopic analysis (QF* group fabrics; Eramo et al., 2020). Undecorated (UND) pottery sherds are likewise predominantly ascribed to semi-coarse wares, like the simple impressed pottery (e.g., SI_sd: simple impression single dots and SI_wt: simple impression wolftooth). Rocker plain edge straight zig-zag (RPLs_ct) motifs are associated with semi-fine fabrics with a sandy and vegetable component. Subsequent thin-section analyses may suggest the use of particular tempering agents like crushed sheep/goat dung mixed with clay. By contrast, the same motifs made using a curved edge implement (RPLc_ct) are associated with more specimens made in semi-coarse fabrics, a pattern with chronological

Fig. 6 Main diagnostic pottery decorations divided by sub-phase (scale 2 cm) ▶


1
2
3
RPD
LA1
4
5
6
DWL_e
7
DWL_b
RPD
DWL_c
LA2
8
9
10
RPD
DWL_a + SI_wt
LA3
DWL_d
11
12
RPD
RPL
13
14
SI_crd
EP1
15
16
17
APS_irregular
APS_ct
RPL
EP2
18
19
20
APS_ct
APS_r(eturn)
APS_tr(iangle)
MP1
21
22
23
APS_r(eturn)
24
25
26
27
APS_ct
APS_tr(iangle)
RPL_fn
RPL
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APS_tr(iangle)
32
33
34
SI
LP1

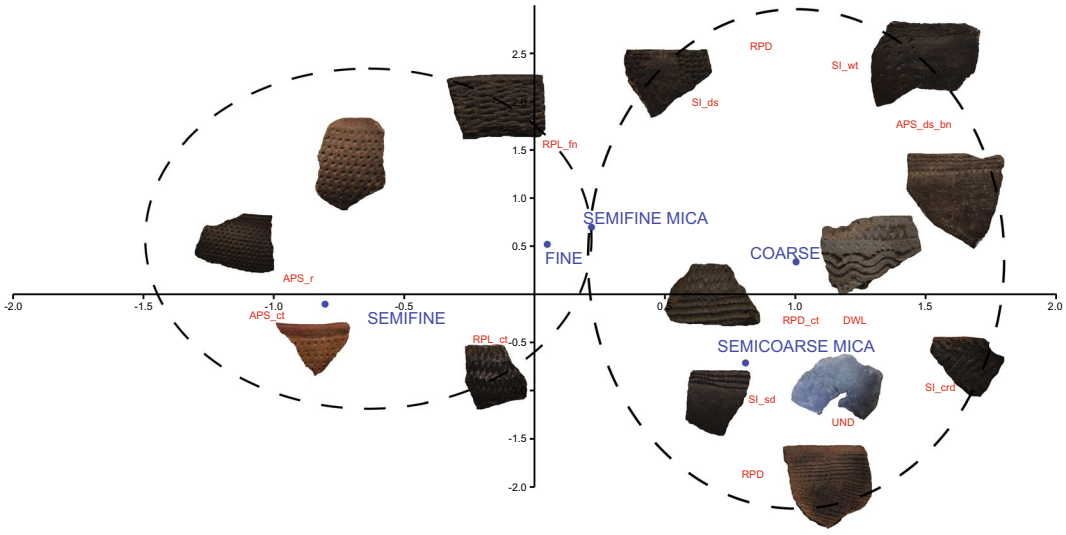


Fig. 7 Biplot graph of main decoration types and macroscopic fabric groups

significance. Fishnet motifs were also associated with semi-fine pastes. A separate cluster is represented by the APS pottery with continuous dotted motifs (APS_ct) and the typical return variant (APS_r), associated with distinctive semi-fine fabrics with fine to medium mineral and vegetable inclusions. Like most Pastoral pottery, this production uses Q fabrics made from locally-procured raw materials, with differing amounts of quartz and organic inclusions (e.g., QVe) interpreted as a dung-related tempering material.

The correspondence analysis scatterplot (Fig. 8) also shows a chronological arrangement of the decoration

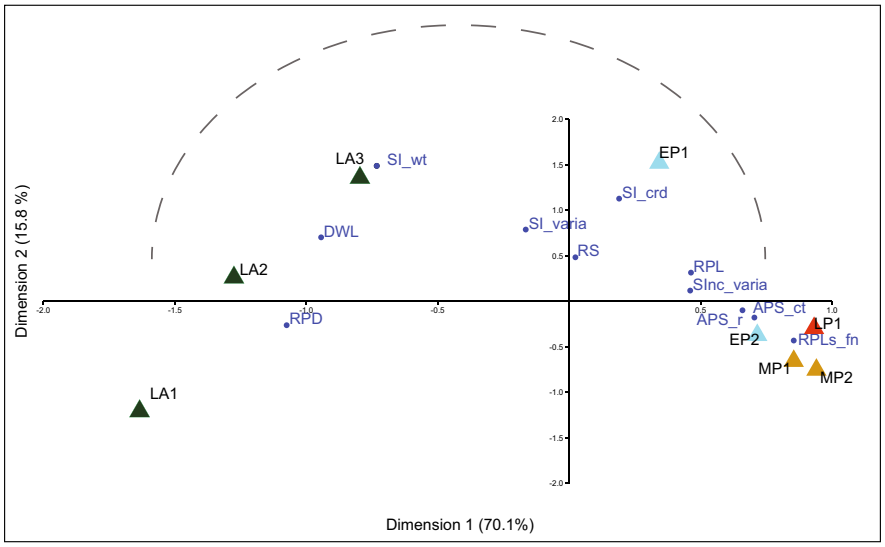


Fig. 8 Correspondence analysis of main decoration type elaborated on the matrices of decorations and layers pertaining to each sub-phase; note that the data shown are simplified and aggregated to facilitate the reading of existing relationships (processing on Past v.4.3, by RR). Colored triangles indicate chronological sub-phases (green: Late Acacus; sky-blue: Early Pastoral; yellow: Middle Pastoral; red: Late Pastoral), and blue dots indicate main decorative types. Note the horseshoe arrangement of data underlined by the dashed black line

types along the displayed sequence, which indicates time as the organizing parameter in its parabolic, or horse-shoe, layout. The plot of cultural subphases and decorative types shows two dimensions that account for 85.9% of the assemblage's overall variability. The first dimension (70.1%) demonstrates a correlation between APS decorative types and pastoral cultural phases (EP, MP, and LP). The second dimension (15.8%), on the other hand, emphasizes a correlation between DWL, RPD, and Late Acacus (LA) contexts. The APS patterns are separate from the RPD patterns. The latter are associated with DWL, emphasizing their shared chronological and cultural horizons.

Discussion: The Takarkori Pottery in Regional Context

The Early Holocene Sequence

Pottery production, a distinctive lithic assemblage, and a diverse array of cultural, economic, and social features distinguish the Late Acacus hunter-gatherer-fishers of the Tadrart Acacus mountains from the previous Early Acacus specialized hunters and the later Early Pastoral herders (e.g., Barich, 1987a; di Lernia, 2022; Garcea, 2001a). Late Acacus pottery presents semi-coarse or coarse-textured fabrics with mainly mineral tempers. The few organic inclusions, deliberately added or naturally present in the clay, are represented by vegetable macro-remains (chaff/stems). The external and internal surfaces are generally smoothed, with some specimens of rougher appearance. As to whether the raw material selection should be seen as a consequence of deliberate choices or as determined by the geopedological configuration of the area, the associations discussed above appear to favor the former explanation. On a high-resolution scale, we can plausibly assume the *habitus* (sensu Gosselain, 2000, p. 189) of individual potters to be the cause of high variability in the pottery fabrics (where no pot is completely equal to another); the same is true of the decorative motifs (especially for the widespread presence of unique variations). On the other hand, higher-level social processes—interaction, technical identity, and community of practices—of historical and cultural significance may explain the dichotomy between Late Acacus and Pastoral Neolithic productions (e.g., Gosselain, 2011; Wallaert-Pêtre, 2001; Wenger, 1999). Coarse vs. fine fabrics are chronologically situated, and their association with diagnostic decoration types reinforces the typological designation, the overall chronostratigraphic reconstruction of the site, and the resulting cultural attribution (Casanova et al., 2020).

Late Acacus pottery production is probably multifunctional. Simple hemispherical or conical vessels fashioned with coarse-grained clay fabrics may have been used in food processing, cooking, and storing. Mineral-tempered fabrics with some macro-organic inclusions enable "performance characteristics" (e.g., coarseness and porosity of the fabrics) suitable for this task, namely good heat transfer and reduced thermal stress (e.g., Braun, 1983; Rice, 2015; Skibo, 2013). The weakly closed profiles hinder boiling over but ease access to the contents, whereas the textured surfaces may ease grip and shock resistance (Schiffer et al., 1994; Tite et al., 2001; Fig. 9). The use of such pots for cooking and the processing of plant materials is also supported by the analysis of organic residues (Dunne et al., 2016).

Stylistically, the pottery repertoire of the LA horizon at Takarkori is characterized by the predominance of rocker impressions of dotted zigzags arranged to form various motifs and structures. These comprised simple outlines on mostly restricted conical/spherical pots and simple wide-open hemispherical bowls. The lowest layers (LA1) present sherds decorated with evenly serrated edge combs (small to medium circular teeth). Some have long-wave DWL combined with RPD. These are followed in the subsequent periods (LA2 and LA3) by increased decoration types and more varied combinations of motifs and structures. All the variants of DWL are present in the LA2 subphase, which is also characterized by the greatest variety of decoration types in the entire Late Acacus horizon. The use of shorter combs distinguishes the LA3. Short, wavy, and fine, sometimes steep and angular, decoration in the rim band area (DWL_a) is the main variety in this group. The fabrics and the choices of raw materials remain the same across the subphases, with mainly mineral-tempered fabrics, from semi-fine with abundant mica and quartz inclusions to semi-coarse and coarse.

Overall, these decoration types fit within the Early Holocene horizon of the Tadrart Acacus and the neighboring massifs of Central Sahara, characterized mainly by rocker stamp impressions of

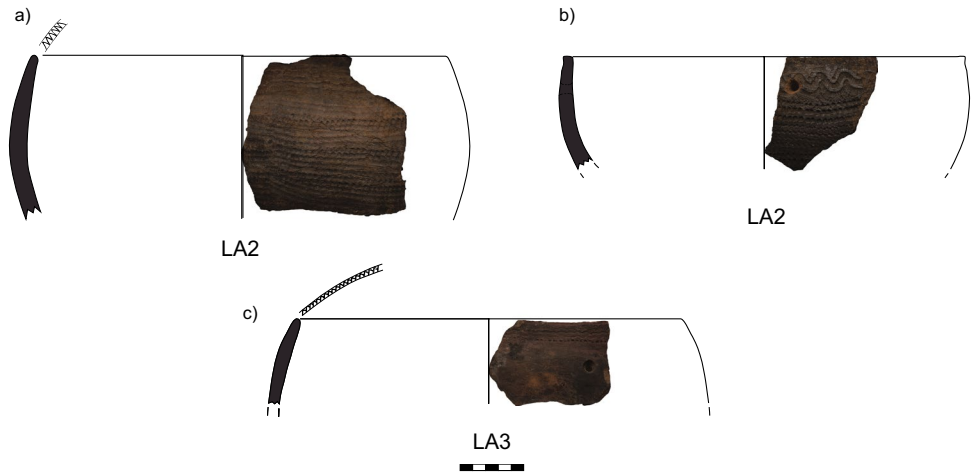


Fig. 9 Three Late Acacus reconstructed vessels: **a** LA2 RPD decorated vessel; **b** LA2 DWL_b decorated vessel; **c** LA3 DWL_a decorated sherd (scale 5 cm)

dotted zigzags, persisting in the sequence with few stylistic changes. These stylistic features shed light on some cultural connections and allow us to glimpse social and cultural implications and interrelationships. The closest similarities are with the adjacent regions of the Central Saharan Massifs, namely the Tadrart Acacus and the Tassil N'Ajjer. The stratigraphic contexts dated between 10,200 and 8000 cal BP at sites like Ti-n Torha East (levels C), Uan Tabu (Units II and I), and Uan Afuda (Layers 5meso to Layer 1) present repertoires with decoration types and techno-morphological features comparable to the LA at Takarkori (Barich, 1974, 1987c; di Lernia, 1999; Garcea, 2001b, 2001c; Livingstone Smith, 2001). Decorations are mostly RPD and DWL with some variations, compared to the Takarkori assemblage. From a technological perspective, significant similarities can be attributed to a shared identity in the form of communities of practice (Wenger, 1999). Mineral, micaceous inclusions and the use of specific raw materials of plutonic origin are also attested in other contemporary repertoires from sites of the Tadrart, like Uan Tabu (Eramo et al., 2020; Livingstone Smith, 2001). The stability of the manufacturing tradition suggests cultural continuity in the communities that lived at Takarkori over several centuries and with other communities that shared their "way of doing" and belonged to the same social network. As shown by the presence of raw materials from different and non-local geological environments, communities from various locations in the Tadrart Acacus were connected in a common interrelationship represented by the persistence of a single shared technical tradition.

The same can be said regarding the adjoining Tassili N'Ajjer and further west to some assemblages from the Hoggar. Ti-n Hanakaten, in the Tassili, presents RPD decorated pottery accompanied by some DWL in Sequence 8, dated to ca. 9000 cal BP (8100 ± 130 bp) (Aumassip et al., 2013; Aumassip & Tauveron, 1993). Further important evidence comes from the site of Ti-n-Tartait, a rockshelter in the Meddak of the Tassili. Thick, coarse, and low-fired sherds decorated with RPD, DWL, and simple impressions were directly dated and ascribed to the Pre-Pastoral, with chronologies comprised between the late tenth and the mid-ninth millennium cal BP, fully overlapping with the LA subphases at Takarkori (Messili et al., 2013). In the Hoggar, the site of Amekni has yielded fairly similar repertoires. The lower layers of the site excavated by Gabriel Camps and dated to around 8900 cal BP (*couche inférieur:* 8050 ±80 bp*)* contained pottery with comparable motifs and techniques, with RPD and DWL in similar variants (Camps, 1969).

Moving further away from the core area represented by the Central Saharan Massifs of the Hoggar, the Tassili, and the Tadrart, other localities feature pottery of similar age with comparable attributes. Layers ascribed to the tenth millennium cal BP at

Tagalagal in Niger Republic present pottery with RPD and DWL in the assemblage (Echallier & Roset, 1986; Roset, 1983). The Pre-Pastoral production from the well-known areas of the Adrar Bous and the Aïr, dated to around the tenth to ninth millennium cal BP, presents pottery with mainly medium-grained fabrics made from local raw materials, with very variable inclusions. The principal decoration types, represented by RPD and sometimes combined with a DWL in the rim-band area, are comparable with the Takarkori LA assemblage (Garcea, 2008, 2013).

Other correlates and similarities can be found in areas distant from the principal core area, across the Sahara and North Africa, from assemblages of the Nabta-Kiseiba region in Egypt to the shores of the Sudanese Nile, up to the Tibesti and Ennedi in Chad (Bailloud, 1969; Gabriel, 1978; Jesse, 2003a, b). For instance, the appearance of the wolftooth pattern (*SI_wt*), often complemented by the DWL_a (Fig. 6), is significant. This suggests some connections with areas to the east, where it is attested in the repertoire of the Nabta-Kiseiba area in a slightly earlier phase (Gatto, 2002; Nelson, 2002, p.10-13, figs. 2.1, 2.2). The motifs are similar in the esthetic pattern but differ in the technique and general arrangement, perhaps implying a mechanism of "imitation" rather than direct cultural transmission and suggesting distinct social boundaries within a broader, fairly uniform "cultural horizon" (Gosselain, 2011; Wallaert-Pêtre, 2001). This, together with the widespread dissemination of other decorative types like RPD and DWL, may corroborate the existence of an extensive network of contacts and connections over the vast Sahara-Sahel area facilitated by eco-geographical features and active throughout the Holocene though with different routes and timings (Brass et al., 2018; Caneva, 1987; Mohammed-Ali & Khabir, 2003). The result is regionalization within a common cultural tradition, as exemplified in the re-interpretation of some decorative patterns which, though similar, are never identical (Garcea, 2013; Jesse, 2010).

The wide dissemination of the rocker stamp decoration, in particular of the packed zigzags, together with the "wavy" motifs (the so-called Incised Wavy Line (IWL) in eastern Northern Africa and the DWL in western North Africa seem to characterize the Early Holocene or more accurately the HGF horizon (for further discussion on this topic, see Jesse, 2002; Keding, 2017; Mohammed-Ali & Khabir, 2003). In some areas, like the southern part of the Central and Eastern Sahara (i.e., the Wadi Howar or the Ennedi), the associated chronology is much later and dated to the Middle Holocene (Jesse, 2004; Jesse & Keding, 2007). However, these areas are always related to an HGF socioeconomic milieu more as a cultural occurrence than a strictly chronological one.

The existence of a common cultural milieu is evident in the distribution pattern of motifs on the pot's surface and the way the motifs were executed, but with understandable local and regional differences and traditions (e.g., Brass et al., 2018; Jesse, 2010; Keding, 2006, 2017). Style-based arguments regarding social identity rely on numerous aspects of sociocultural variability and are thus neither straightforward nor easy to simplify (Gosselain, 2000; Hodder, 1982; Plog, 1983; Shanks & Tilley, 1992; Shennan, 2003). An example is the decorations applied to the rim top and rim-band area: simple "linear" decorations on rim tops are found throughout the vast "impressed horizon" of the Early Holocene Sahara, but they are created in different "modes" throughout the various cultural-regional areas, from milled rims (straight thin linear impression at the lip: cf. Gatto, 2002, p. 70) to the RPL impressions at Takarkori.

Style is understood as a technological attribute, and decoration is regarded as a highly visible feature that may convey information and suggest various social and cultural dynamics of transmission: common craftsmanship, knowledge, and vertical transmission on the one hand (Eerkens & Lipo, 2005; Gosselain, 2000; Roux, 2019) and more horizontal processes, from imitation to deliberate manipulation, on the other (Carr, 1995; Gosselain, 2011; Sackett, 1977). A shared cultural background may have facilitated, supported, and substantiated stylistic similarities. At the same time, their dissemination, if not directly linked to local and independent innovations or inventions, may be the result of processes based on a network of social and cultural ties (di Lernia, 2022; Garcea & Hildebrand, 2009; Keding, 2017).

The Middle Holocene Sequence

The seriation proposed for the Middle Holocene sequence, corresponding to the Pastoral Neolithic, features pots with thinner walls, more closed shapes, and the most decoration types, such as APS—the

most widespread throughout this horizon. (Fig. 10). The EP1 assemblage exhibits elements of continuity with the earlier LA horizon regarding technological and decorative attributes. This is particularly the case with the preceding LA3 sub-phase. However, the overall impression is of a different pottery, where even the old rocker stamp-packed zigzag pattern seems to be executed using different and finer combs. Here and in the subsequent EP2, some specific decorations seem highly distinctive and circumscribed to these two subphases, i.e., the simple impressed cord decoration resulting in a vaguely diagonal (herringbone-like) pattern (SI_crd). Executed on pottery quite similar in texture and fabric to the earlier LA pottery and made from local raw materials (Eramo et al., 2020), it may respond to mechanisms of imitation or hybridization rather than actual imports. If so, this would further substantiate the explanatory paradigm of the Neolithization process advanced for such periods (di Lernia, 2021). Connections to the east can be inferred based on similarities with some productions of the Nabta-Kiseiba area dated around or slightly before 8000 cal BP (Gatto, 2002; Nelson, 2002). Other examples can also be seen in the Al Khiday site sequence in central Sudan (Salvatori, 2012; Salvatori et al., 2018).

The successive appearance of similar decorative schemes and patterns apparent in more southerly and later areas may suggest complex movements and trajectories active between the final Early and initial Middle Holocene periods. This is true of the Laqiya pottery of the Wadi Howar in northern Sudan, which strongly recalls our cord-impressed motifs, especially in the so-called older variant, albeit associated with some slightly more recent dates (Jesse, 2003b). The EP2 sees an increase in the APS decorative technique, as well as in the rocker stamp impression now made using a plain instrument (RPL s), also identified as typical of the Early Pastoral in other assemblages such as Uan Telocat and Uan Muhuggiag in the Tadrart Acacus (di Lernia, 2021; Garcea, 2003). The return variant continues to demonstrate its significance in this sub-phase. Similar to EP1, the primary type consists of either fine dots (APS r a) or very fine dots (APS r c).

In the Middle Pastoral sub-phases, there is a general shift toward "homogeneity" in ceramic decoration, with a notable decrease in the variety of decorative patterns and a predominance of APS continuous and APS in the *return* (APS r) variant. While in the Early Pastoral, the fabrics had "transitional" characteristics, with coarse and semi-coarse fabrics coexisting with finer ones, and the Middle Pastoral pottery is made primarily from locally gathered (sandstone-derived) raw materials with semi-fine to fine fabrics, with compact texture and fine sand or organic inclusions (Eramo et al., 2014, 2020). The preference for local raw materials and the use of readily available materials (e.g., dung) as a tempering agent (Eramo et al., 2020) may suggest an attempt to speed up production, though without compromising quality. There appears to be an attempt to obtain low porosity and compactness, perhaps confirming the use of vessels for storage purposes (Rice, 2015, p. 411-32). The

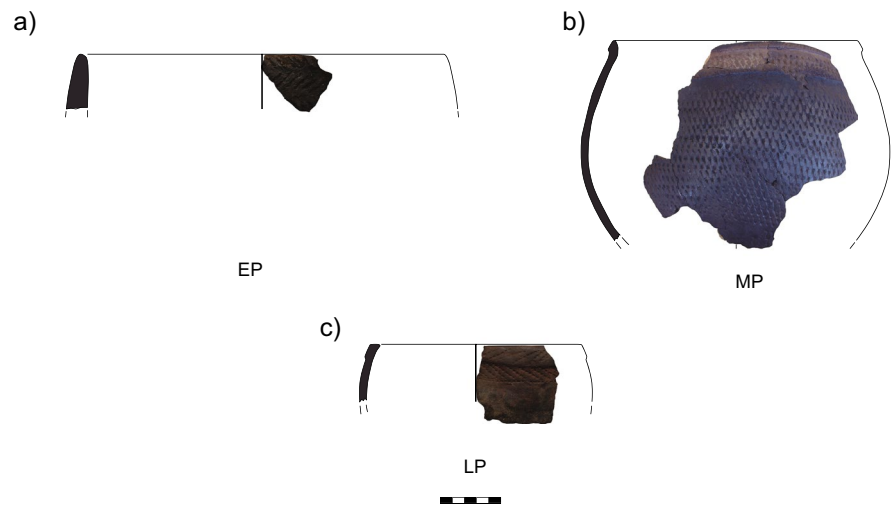


Fig. 10 Pastoral horizon vessels: **a** EP, SI_crd decoration; **b** MP, APS_r decoration; **c** LP, SI decoration (5 cm)

vessel forms mainly feature collared or necked bowls or jars suited to holding liquids. The walls are fairly thin to reduce the weight and increase portability.

These circumstantial data may be linked to the more mobile settlement strategies of the full Pastoral horizon, characterized by a complex pattern of major settlements in the vast plains of the Erg Uan Kasa and vertical seasonal transhumance camps in the mountain ranges, especially in the Middle Pastoral phase (Cremaschi & di Lernia, 1999; 2001; di Lernia, 2002). Numerous sites of comparable date present pottery repertoires similar to those of Takarkori. Sites like Uan Muhuggiag, Ti-n-Torha North (Barich, 1974, 1987b, c; Caneva, 1987), Wadi Athal (Barich & Mori, 1970), and Uan Telocat (Garcea & Sebastiani, 1998) in the Tadrart Acacus all preserve assemblages with same features and trends in the development of decorative and technological styles: the pre-eminence of the APS decoration, especially in the return technique variant, together with the RPL, and the creation of mostly closed and fine-walled pots made from local and sub-local raw materials. This type of pottery is consistently present in almost all sites, both sheltered and open-air, located in the explored areas of the Tadrart Acacus and the surrounding ergs and neighboring massifs such as Messak Setaffet (Cremaschi & di Lernia, 1998, 1999; Gallin & Le Quellec, 2008; Ponti et al., 1998).

Stylistic similarities can be observed in the ceramic production of the Tassili-n-Ajjer, where sites like Ti-n Hanakaten present pots with analogous motifs (Aumassip & Delibrias, 1982; Aumassip & Tauveron, 1993). Given other cultural features, this may suggest the existence of a relatively uniform cultural area encompassing the Hoggar, where sites like Amekni and Meniet (both in the upper layers) have yielded pottery similar to those of the Pastoral horizon (Camps, 1969; Hugot, 1963). Some analogies might also be sought in the Pastoral production in northern Niger, specifically in the Aïr and the surroundings of the Adrar Bous (Garcea, 2008, 2013).

In the Late Pastoral, the increasing aridity of the earl[y] sixth millennium BP fostered an economic change toward exploiting small livestock and large-scale mobility. In this period, human occupation indicates nomadic, highly mobile groups at mountain sites (Cremaschi & di Lernia, 1998; Cremaschi & Zerboni, 2009; Garcea & Sebastiani, 1998; Rotunno et al., 2020) and relatively sedentary communities in the river valleys with increased exchange between groups as a further adaptive strategy (Tafuri et al., 2006). The few pottery at Takarkori are mainly made from fine and semi-fine fabrics. This testifies, on the one hand, to the more temporary use of shelters as part of a nomadic settlement system (e.g., Rotunno et al., 2020), and, on the other hand, to the focus of this system on the Acacus range, the main source of raw materials for pottery production. Decorations are still mostly APS, but undecorated burnished/polished pottery is also present. APS motifs with impressed triangular elements are present and decorative patterns with simple impressed or incised lines below the rim were also found.

Similar decorative typologies can be observed in other Late Pastoral sites of the Tadrart Acacus (Cremaschi & di Lernia, 1998). At Uan Telocat, for instance, especially in Levels I and II (the former dated to around 5590–5280 cal BP), the potsherds present similar attributes: APS as the dominant technique, simple impressions with serrated-edge combs used to create diagonal and herring-bone motifs, and a steady increase in undecorated sherds from bottom to the top of the sequence (for a detailed discussion see Garcea & Sebastiani, 1998). Likewise, in the comparable upper levels (level 1) of Uan Muhuggiag, dated to around 4500 cal BP, the assemblage presents similar traits, such as the scarce presence of the return technique and the increase in undecorated sherds (Barich, 1987b, c; Cremaschi & di Lernia, 1998). Other sites recorded in the mountain range of the Acacus and neighboring regions present similar assemblages (Cremaschi & di Lernia, 1998). Further specific decorative types present in this period (e.g., the triangular impressed decoration) are known in the eastern Messak and Erg Uan Kasa, indicating that the Late Pastoral settlement system covered a very large territory (Cremaschi & di Lernia, 1998; Cremaschi & Zerboni, 2009). Trans-Saharan networks can be traced for these periods, as also testified by the much more frequent presence of "exotic" raw materials and tools in the lithic repertoires compared to the preceding phases (Cremaschi & di Lernia, 1998, 1999; di Lernia & Cremaschi, 1997; Garcea, 2001a). Further southeast, there are some similarities with decoration types identified in the Wadi Howar area and the Handessi Horizon, all within a comparable

chronological range (Jesse, 2006; Jesse & Keding, 2007; Keding, 2006), indicating the high mobility of these groups and the presence of an intricate network of contacts and exchanges.

Conclusion

This paper offers new data on the pottery assemblages from a well-documented site in Central Sahara with a long-lasting Holocene occupation. The radiocarbon chronology helped to situate variations and changes in the ceramic repertoire within a secure chronological framework, indicating cultural and technological modifications over time. The quantitative and qualitative analysis allowed us to elucidate variations in decorative techniques and pottery manufacturing processes. The relative frequencies of decoration types and tempers allowed us to better determine different spheres of use and production chains, deepening our understanding of the cultures studied, their likely changes in economic strategies, and degrees of mobility. At the same time, numerous issues remain to be clarified, from the questions surrounding the origins and spread of pottery to the reasons for the homogeneity apparent over vast expanses of space and time. The non-exhaustive comparative outline aimed to provide comparable chronological data for situating the Takarkori pottery sequence in its broader cultural context. Given the long history of research involved and the lack of new excavations and reliable radiocarbon dates in certain crucial localities, North African pottery studies and the resulting sequences are still puzzling. How some pivotal decorative styles disseminate geographically and chronologically, cutting across socioeconomic and cultural entities and terminologies, needs further refinement. This can be achieved with high-resolution studies of old and new collections. Novel approaches to re-examining old assemblages may help clarify some of these issues without forgetting the pressing need for new data and fieldwork.

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing Interests The authors declare no competing interests.

References

Arnold, D. E. (1985). *Ceramic theory and cultural process*. Cambridge University Press.

Ashley, C. Z., & Grillo, K. M. (2015). Archaeological ceramics from eastern Africa: Past approaches and future directions. *Azania: Archaeological Research in Africa, 50*, 460–480.

Aumassip, G., & Delibrias, G. (1982). Ages des depots neolithiques du gisement de Ti-n-Hanakaten (Tassili-n-Ajjer. AlgeÌrie). *Libyca, 30-31*, 207–211.

Aumassip, G., Jungner, H., & Schvoerer, M. (2013). Le site de Tin Hanakaten (Tassili Azjer, Algérie) et la chronologie de l'art rupestre saharien. *Ikosim, 2*, 49–60.

Aumassip, G., & Tauveron, M. (1993). *Le Sahara central à l'Holocène.Memorie della Societa Italiana di Scienze Naturali e del Museo Civico di Stroria Naturale di Milano, 1993, XXVI (II), pp* (pp. 63–80). MNM.

Bailloud, G. (1969). L'évolution des styles céramiques en Ennedi (République du Tchad). Actes du 1er Colloque international d'archéologie africaine, Fort-Lamy, 11-16 Déc. 1966 (pp. 31-45). Fort-Lamy, Institut national tchadien pour les sciences humaines.

Barich, B. E. (1974). La serie stratigrafica dell'uadi Ti-n-Torha (Acacus, Libia): Per una interpretazione delle facies a ceramica saharo-sudanesi. Origini. *Preistoria e Protoistoria delle Civilta Antiche Roma, 8*, 7–157.

Barich, B. E. (1987a). Archaeology and environment in the Libyan Sahara. The excavations in the Tadrart Acacus, 1978. BAR International Series.

Barich, B. E. (1987b). The Uan Muhuggiag Rockshelter. In B. E. Barich (Ed.), *Archaeology and Environment in the Libyan Sahara. The Excavations in the Tadrart Acacus, 1978-1983* (pp. 123–219). BAR International Series.

Barich, B. E. (1987c). The wadi Ti-n-Torha facies. In B. E. Barich (Ed.), *Archaeology and Environment in the Libyan Sahara:*

The Excavations in the Tadrart Acacus, 1978-1983 (Vol. 368, pp. 97–112). BAR International Series.

Barich, B. E., & Mori, F. (1970). Missione paletnologica italiana nel Sahara libico. Risultati della campagna 1969. *Origini, 4*, 79–142.

Bellanger, L., Husi, P., & Tomassone, R. (2006). Statistical aspects of pottery quantification for the dating of some archaeological contexts. *Archaeometry, 48*, 169–183.

Biagetti, S., & di Lernia, S. (2013). Holocene deposits of Saharan rockshelters: The case of Takarkori and other sites from the Tadrart Acacus Mountains (Southwest Libya). *African Archaeological Review, 30*, 305–338.

Biagetti, S., Merighi, F., & di Lernia, S. (2004). Decoding an Early Holocene Saharan stratified site: Ceramic dispersion and site formation processes in the Takarkori rockshelter (Acacus Mountains, Libyan). *Journal of African Archeology, 2*, 3–21.

Brass, M., Adam, A. H., & Wellings, J. (2018). New data from Jebel Moya and Shaqadud (central Sudan): Implications for Late Mesolithic interconnectivity with the Sahara. *Libyan Studies, 49*, 21–49.

Braun, D. P. (1983). Pots as tools. In J. A. Moore & A. S. Keene (Eds.), *Archaeological hammers and theories* (pp. 107–134). Academic Press.

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*, 337–360.

Camps, G. (1969). *Amekni*. Neolithique ancien du Hoggar.

Caneva, I. (1987). Pottery decoration in prehistoric Sahara and Upper Nile: A new perspective. In B. E. Barich (Ed.), Archaeology and environment in the Libyan Sahara. In *The excavations in the Tadrart Acacus* (pp. 231–254). BAR International Series.

Caneva, I. (1989). Typological notes: The Sudanese case. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Late Prehistory of the Nile Basin and the Sahara* (pp. 375–379). Polish Academy of Sciences.

Caneva, I., Garcea, E. A. A., Gautier, A., & Van Neer, W. (1993). Pre-pastoral cultures along the Central Sudanese Nile. *Quaternaria Nova, 3*, 177–252.

Caneva, I., & Marks, A. (1990). More on the Shaqadud pottery: Evidence for Saharo-Nilotic connections during the 6th-4th millennium BC. *Archéologie du Nil Moyen, 4*, 11–35.

Carr, C. (1995). Building a unified middle-range theory of artifact design: Historical perspectives and tactics. In C. Carr & J. Neitzel (Eds.), *Style., Society, and Person* (pp. 151–170). Plenum Press.

Casanova, E., Knowles, T. D. J., Bayliss, A., Dunne, J., Barański, M. Z., Denaire, A., et al. (2020). Accurate compound-specific 14 C dating of archaeological pottery vessels. *Nature, 580*, 506–510.

Cherkinsky, A., & Di Lernia, S. (2013). Bayesian approach to 14C dates for estimation of long-term archaeological sequences in arid environments: The Holocene site of Takarkori Rockshelter. *Southwest Libya. Radiocarbon, 55*(2), 771–782.

CISEM II. (2004). Mise en place d'un protocole de description des décors céramiques. *Préhistoires Méditerranéennes, 13*, 110–113.

Commelin, D., Garcea, E. A. A., & Sebastiani, R. (1992). A review of the archaeological material from Tintan and Chami (Atlantic coast of Mauritania). *Quaternaria Nova, 2*, 111–159.

Costin, C. L. (1991). Craft specialization: Issues in defining, documenting, and explaining the organization of production. *Archaeological Method and Theory, 3*, 1–56.

Craig, O. E. (2021). Prehistoric fermentation, delayed-return economies, and the adoption of pottery technology. *Current Anthropology, 62*, S233–S241.

Craig, O. E., Saul, H., Lucquin, A., Nishida, Y., Tache, K., Clarke, L., et al. (2013). Earliest evidence for the use of pottery. *Nature, 496*, 351–354.

Cremaschi, M., & di Lernia, S. (1998). The geoarchaeological survey in the central Tadrart Acacus and surroundings (Libyan Sahara): Environment and cultures. In M. Cremaschi & S. di Lernia (Eds.), *Wadi Teshuinat: Palaeoenvironment and Prehistory in South-Western Fezzan, Libyan Sahara* (pp. 243–296). CNR and All'Insegna del Giglio.

Cremaschi, M., & di Lernia, S. (1999). Holocene climatic changes and cultural dynamics in the Libyan Sahara. *African Archaeological Review, 16*, 211–238.

Cremaschi, M., & di Lernia,S. (2001).Environment and settlements in the Mid-Holocene palaeo-oasis of Wadi Tanezzuft (Libyan Sahara) *Antiquity 75 (290),* 815–825.

Cremaschi, M., & Zerboni, A. (2009). Early to Middle Holocene landscape exploitation in a drying environment: Two case studies compared from the central Sahara (SW Fezzan, Libya). *Comptes Rendus Geoscience, 341*, 689–702.

Cremaschi, M., Zerboni, A., Mercuri, A. M., Olmi, L., Biagetti, S., & di Lernia, S. (2014). Takarkori rockshelter (SW Libya): An archive of Holocene climate and environmental changes in the central Sahara. *Quaternary Science Reviews, 101*, 36–60.

D'Ercole, G. (2017). *Ceramic manufacturing techniques and cultural traditions in Nubia from the 8th to the 3rd*. Examples from Sai Island, Archaeopress.

D'Ercole, G. (2021). Seventy years of pottery studies in the archaeology of Mesolithic and Neolithic Sudan. *African Archaeological Review, 38*, 345–372.

di Lernia, S. (1999). The cultural sequence. In S. di Lernia (Ed.), *The Uan Afuda Cave. Hunter Gatherer Societies of Central Sahara* (pp. 57–130). All'Insegna del Giglio.

di Lernia, S. (2002). Dry climatic events and cultural trajectories: Adjusting middle holocene pastoral economy of the Libyan sahara. In F. A. Hassan (Ed.), *Droughts, food and culture* (pp. 225–250). Springer, Boston, MA.

di Lernia, S. (2021). Earliest herders of the Central Sahara (Tadrart Acacus Mountains, Libya): A punctuated model for the emergence of pastoralism in Africa. *Journal of World Prehistory, 34*, 531–594.

di Lernia, S. (2022). *Saharan hunter-gatherers: Specialization and diversification in Holocene southwestern Libya*. Taylor & Francis.

di Lernia, S., & Biagetti, S. (2007). Reflections on the Takarkori rockshelter (Fezzan, Libyan Sahara). *Prés du bord d'un abri: Les histories, Théories et Méthodes de Recherches Sur Les Abris Sous Roche, 14*, 125.

di Lernia, S., Cremaschi, M., & Notarpietro, A. (1997). Procurement, exploitation and circulation of raw material: Analysis of the Early and Middle Holocene lithic complexes from South-Western Libya (Tadrart Acacus and Messak Settafet). Man and Flint. Proceedings of the 7th

International Flint Symposium (pp. 233-242). Institute of Archaeology and Ethnology, .

di Lernia, S., & Tafuri, M. A. (2013). Persistent deathplaces and mobile landmarks: The Holocene mortuary and isotopic record from Wadi Takarkori (SW Libya). *Journal of Anthropological Archaeology, 32*, 1–15.

Dietler, M., & Herbich, I. (1994). Ceramics and ethnic identity: Ethnoarchaeological observations on the distribution of pottery styles and the relationship between the social contexts of production and consumption. In M. Dietler & I. Herbich (Eds.), *Terre cuite et société. La céramique, document technique, économique, culturel(pp.459-472) Editions APDCA*. Juan-les-Pins.

Dittrich, A. (2015). Dating the neolithisation process in the Middle Nile valley–A critical approach. In J. Kabacinski et al. (Eds.), *Hunter-gatherers and early food-producing societies in northeastern Africa. Studies in African Archaeology, 14* (pp. 15–64). Poznan Archaeological Museum.

Duistermaat, K. (2017). The organization of pottery production: Toward a relational approach. In A. Hunt (Ed.), *The Oxford handbook of archeological ceramic analysis* (pp. 114–117). Oxford University Press.

Dunne, J., Evershed, R. P., Cramp, L. J. E., Bruni, S., Biagetti, S., & di Lernia, S. (2013). The beginnings of dairying as practised by pastoralists in 'Green' Saharan Africa in the 5th millennium BC. *Documenta Praehistorica, 40*, 118–130.

Dunne, J., Evershed, R. P., Salque, M., Cramp, L., Bruni, S., Ryan, K., et al. (2012). First dairying in green Saharan Africa in the fifth millennium BC. *Nature, 486*, 390–394.

Dunne, J., Mercuri, A. M., Evershed, R. P., Bruni, S., & di Lernia, S. (2016). Earliest direct evidence of plant processing in prehistoric Saharan pottery. *Nature Plants, 3*, 16194.

Echallier, J. C., & Roset, J. P. (1986). La Céramique des gisements de Tagalagal et de l'Adrar Bous 10 (Aïr, Republique du Niger). *Cahier Sciences Humaines, 22*, 151–158.

Eerkens, J. W., & Lipo, C. P. (2005). Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. *Journal of Anthropological Archaeology, 24*, 316–334.

Eramo, G., Aprile, A., Muntoni, I. M., & Zerboni, A. (2014). Textural and morphometric analysis applied to Holocene pottery from Takarkori rockshelter (SW Libya, Central Sahara): A quantitative sedimentological approach. *Archaeometry, 56*, 36–57.

Eramo, G., Muntoni, I. M., Aprile, A., Pallara, M., Rotunno, R., Zerboni, A., et al. (2020). Networking through pottery characterisation at Takarkori rockshelter (Libyan Sahara, 10,200–4650 cal BP). *Archaeological and Anthropological Sciences, 12*, 1–33.

Fornaciari, R., Fornaciari, S., Francia, E., Mercuri, A. M., & Arru, L. (2018). Panicum spikelets from the Early Holocene Takarkori rockshelter (SW Libya): Archaeo-molecular and -botanical investigations. *Plant Biosystems, 152*, 1–13.

Gabriel, B. (1978). Gabrong-Achttausendjährige Keramik im Tibesti-Gebirge. *Sahara, 10*, 189–196.

Gallin, A., & Le Quellec, J. L. (2008). Les ensembles céramiques du Bassin de Murzuq-une contribution de l'archéologie préventive à la connaissance du Messak. *Les Cahiers De L'AARS, 12*, 71–88.

Garcea, E. A. A. (2001a). Cultural adaptations at Uan Tabu from the Upper Pleistocene to the Late Holocene. In E. A. A. Garcea (Ed.), *Uan Tabu in the settlement history of Libyan Sahara* (pp. 219–235). All'Insegna del Giglio.

Garcea, E. A. A. (2001b). The Early and the Late Acacus material cultures after the 1960-63 and the 1990-93 excavations. In E. A. A. Garcea (Ed.), *Uan Tabu in the Settlement History of the Libyan Sahara* (pp. 97–112). All' Insegna del Giglio.

Garcea, E. A. A. (2001c). The Pleistocene and Holocene archaeological sequences. In E. A. A. Garcea (Ed.), *Uan Tabu in the Settlement History of the Libyan Sahara* (pp. 1–14). All'Insegna del Giglio.

Garcea, E. A. A. (2003). Animal exploitation and pottery technology during pastoral times: The evidence from Uan Telocat, Libyan Sahara. *Journal of African Archaeology, 1*, 111–126.

Garcea, E. A. A. (2005). Comparing chaînes opératoires: Technological, cultural and chronological features of pre-pastoral and pastoral ceramic and lithic productions. In A. Livingstone Smith, D. Bosquet, & R. Martineau (Eds.), *Pottery manufacturing processes: Reconstitution and interpretation* (pp. 215–228). Archaeopress.

Garcea, E. A. A. (2008). The ceramics from Adrar Bous and surroundings. In J. D. Clark, D. G. Gonzalez, & J. Batkin (Eds.), *Adrar Bous: Archaeology of a Central Saharan granitic ring complex in Niger* (pp. 245–289). Royal Museum for Central Africa.

Garcea, E. A. A. (2013). Manufacturing technology of the ceramic assemblages. In E. A. A. Garcea (Ed.), *Gobero: The no-return frontier: Archaeology and landscape at the Saharo-Sahelian borderland* (pp. 209-240). Africa Magna Verlag.

Garcea, E. A. A., & Hildebrand, E. A. (2009). Shifting social networks along the Nile: Middle Holocene ceramic assemblages from Sai Island, Sudan. *Journal of Anthropological Archaeology, 28*, 304–322.

Garcea, E. A. A., & Sebastiani, R. (1998). Middle and Late Pastoral Neolithic from the Uan Telocat rockshelter, Tadrart Acacus (Libyan Sahara). In M. Cremaschi & S. di Lernia (Eds.), *Wadi Teshuinat - Palaeoenvironment and Prehistory in South-Western Fezzan, Libyan Sahara* (pp. 201–216). CNR.

Gatto, M. C. (2002). Early Neolithic pottery of the Nabta-Kiseiba area: Stylistic attributes and regional relationships. In K. and A. Nelson (Eds.), *Holocene settlements of the Egyptian Sahara. Vol. II The Pottery of Nabta Playa* (pp. 65–78). Plenum Press.

Gliozzo, E. (2020). Ceramic technology: How to reconstruct the firing process. *Archaeological Anthropological Science, 12*, 260. https://doi.org/10.1007/s12520-020-01133-y

Gosselain, O. (1992a). Bonfire of the enquiries. Pottery firing temperatures in archaeology: What for? *Journal of Archaeological Science, 19*, 243–259.

Gosselain, O. P. (1992b). Technology and style: Potters and pottery among Bafia of Cameroon. *Man*, 559–586.

Gosselain, O. P. (2000). Materializing identities: An African perspective. *Journal of Archaeological Method and Theory, 7*, 187–217.

Gosselain, O. P. (2011). Fine if I do, Fine if I don't: Dynamics of technical knowledge in Sub-Saharan Africa. In B. W. Roberts & M. Vander Linden (Eds.), *Investigating archaeological cultures: Material culture, variability, and transmission* (pp. 211–227). Springer.

Greenacre, M. J. (2010). Correspondence analysis. *Wiley Interdisciplinary Reviews: Computational Statistics, 2*, 613–619.

Hakem, A. A., & Khabir, A. R. M. (1989). Sarourab 2: A new contribution to the Early Khartoum tradition from Bauda site. In L. Krzyzaniak & M. Kobusiewicz (Eds.), *Late prehistory of the Nile Basin and the Sahara* (pp. 381–385). Poznań Archaeological Museum.

Hammer, Ø., Harper, D. A., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica, 4*, 1–9.

Hodder, I. (1982). *Symbols in action*. Cambridge University Press.

Hugot, H. J. (1963). Recherches préhistoriques dans l'Ahaggar nord-occidental, 1950-1957. In *Mémoires du Centre de Recherches Anthropologiques, Préhistoriques et Ethnographiques I*. Arts et Métiers Graphiques.

Huysecom, E. (2020). The first emergence of ceramic production in Africa. In Aldenderfer et al. (Eds.), *Oxford Research Encyclopedia of Anthropology* (pp. 1–14). Oxford University Press.

Huysecom, E., Rasse, M., Lespez, L., Neumann, K., Fahmy, A., Ballouche, A., et al. (2009). The emergence of pottery in Africa during the 10th millennium calBC: New evidence from Ounjougou (Mali). *Antiquity, 83*, 905–917.

Jesse, F. (2002). Wavy line ceramics: Evidence from northeastern Africa. *Holocene settlement of the Egyptian Sahara, 2*, 79–96.

Jesse, F. (2003a). Early ceramics in the Saharan and the Nile Valley. In L. Kryzaniak (Ed.), *Cultural markers in the later prehistory of northeastern Africa and recent research* (pp. 35–60). Archaeological Museum.

Jesse, F. (2003b). *Rahib 80/87*. Heinrich Barth Institute.

Jesse, F. (2004). The development of pottery design styles in the Wadi Howar Region (northern Sudan). *Préhistoires Méditerranéennes, 13*, 97–107.

Jesse, F. (2006). Pastoral groups in the southern Libyan desert: The Handessi horizon (c. 2400–1100 BC). In K. Kroeper, M. Chlodnicki, & M. Kobusiewicz (Eds.), *Archaeology of early Northeastern Africa: In memory of Lech Krzyzaniak* (pp. 987–1004). Poznań Archaeological Museum.

Jesse, F. (2010). Early pottery in Northern Africa. *An overview. Journal of African Archaeology, 8*, 219–238.

Jesse, F., & Keding, B. (2007). Holocene settlement dynamics in the Wadi Howar region (Sudan) and the Ennedi Mountains (Chad). In O. Bubenzer, A. Bolten, & F. Darius (Eds.), *Atlas of cultural and environmental change in arid Africa* (pp. 42–43). Heinrich-Barth-Institut.

Jordan, P., & Zvelebil, M. (2010). *Ceramics before farming: The dispersal of pottery among prehistoric Eurasian hunter-gatherers*. Left Coast Press.

Jordeczka, M., Krolik, H., Masojć, M., & Schild, R. (2011). Early Holocene pottery in the Western Desert of Egypt: New data from Nabta Playa. *Antiquity, 85*, 99–115.

Keding, B. (2006). Pottery of the Wadi Howar: Traditions, transformations and their cultural implications. In K. Kroeper, M. Chlodnicki, & M. Kobusiewicz (Eds.), *Archaeology of early northeastern Africa*. In memoriam of Lech Krzyżaniak. Poznań Archaeological Museum.

Keding, B. (2017). Middle Holocene fisher-hunter-gatherers of Lake Turkana in Kenya and their cultural connections with the north: The pottery. *Journal of African Archaeology, 15*, 42–76.

Kim, J., & Seong, C. (2022). Final Pleistocene and early Holocene population dynamics and the emergence of pottery on the Korean Peninsula. *Quaternary International, 608*, 203–214.

Livingstone Smith, A. (2001). Pottery manufacturing processes: Reconstruction and interpretation. In E. A. A. Garcea (Ed.), *Uan Tabu in the Settlement History of the Libyan Sahara* (pp. 113–152). All'Insegna del Giglio.

Livingstone Smith, A. (2007). *Chaîne opératoire de la poterie: Références ethnographiques, analyses et reconstitutions*. MRAC Musée Royal de l'Afrique Centrale.

Maritan, L., Nodari, L., Mazzoli, C., Milano, A., & Russo, U. (2006). Influence of firing conditions on ceramic products: Experimental study on clay rich in organic matter. *Applied Clay Science, 31*, 1–15.

Mercuri, A. M., Fornaciari, R., Gallinaro, M., Vanin, S., & di Lernia, S. (2018). Plant behaviour from human imprints and the cultivation of wild cereals in Holocene Sahara. *Nature Plants, 4*, 71.

Messili, L., Saliège, J.-F., Broutin, J., Messager, E., Hatté, C., & Zazzo, A. (2013). Direct 14C dating of early and mid-Holocene Saharan pottery. *Radiocarbon, 55*, 1391–1402.

Mohammed-Ali, A. S., & Khabir, A.-R. M. (2003). The wavy line and the dotted wavy line pottery in the prehistory of the Central Nile and the Sahara-Sahel belt. *African Archaeological Review, 20*, 25–58.

Nelson, K. (2002). Ceramic types of the Nabta/Kiseiba area. In K. Nelson (Ed.), *Holocene settlement of the Egyptian Sahara, vol. II: The pottery of Nabta Playa*. Kluwer Academic / Plenum Publishers.

Nielsen, K. H. (1991). The application of correspondence analysis: Some examples in archaeology. In H. H. Bock & P. Ihm (Eds.), *Classification, data analysis, and knowledge organization* (pp. 343–351). Springer.

Orton, C., & Hughes, M. (2013). *Pottery in archaeology*. Cambridge University Press.

Peeples, M. A., & Schachner, G. (2012). Refining correspondence analysis-based ceramic seriation of regional data sets. *Journal of Archaeological Science, 39*, 2818–2827.

Plog, S. (1983). Analysis of style in artifacts. *Annual Review of Anthropology, 12*, 125–142.

Ponti, R., Aurisicchio, G., Damiotti, R., & Guidi, G. (1998). Pottery from the Tadrart Acacus (Libyan Sahara): Decoration, distribution and manufacture. Wadi Teshuinat. *Palaeoenvironment and Prehistory in South-Western Fezzan (Libyan Sahara), 7*, 183–200.

Reimer, P. J., Austin, W. E., Bard, E., Bayliss, A., Blackwell, P. G., Ramsey, C. B., et al. (2020). The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon, 62*, 725–757.

Rice, P. M. (2015). *Pottery analysis: A sourcebook* (Second ed.). University of Chicago Press.

Roset, J. P. (1983). Les plus vieilles céramiques du Niger. *Archéologia, 183*, 42–50.

Roset, J. P. (2000). Céramique et néolithisation en Afrique saharienne. In J. Guilaine (Ed.), *Premiers paysans du monde: naissances des agricultures* (pp. 263–290). Errance - Collection des Hespérides.

Rotunno, R., Mercuri, A. M., Florenzano, A., Zerboni, A., & di Lernia, S. (2019). Coprolites from rockshelters: Hunter-Gatherers "herding" Barbary sheep in the Early Holocene Sahara. *Journal of African Archaeology, 17*, 76–94.

Rotunno, R., Mercuri, A. M., Florenzano, A., Zerboni, A., & di Lernia, S. (2020). The visibility of mobility: Coprolites, dung and Neolithic herders in Central Saharan rockshelters. *Environmental Archaeology*. https://doi.org/10.1080/14614103.2020.1777057

Roux, V. (2016). Ceramic manufacture: The Chaîne Opératoire approach. In A. Hunt (Ed.), *The Oxford handbook of archaeological ceramic analysis* (pp. 101–113). Oxford University Press.

Roux, V. (2019). *Ceramics and society: A technological approach to archaeological assemblages*. Springer.

Rye, O. S. (1981). *Pottery technology: Principles and reconstruction*. Taraxacum.

Sackett, J. R. (1977). The meaning of style in archaeology: A general model. *American Antiquity, 42*, 369–380.

Salvatori, S. (2012). Disclosing archaeological complexity of the Khartoum Mesolithic: New data at the site and regional level. *African Archaeological Review, 29*, 399–472.

Salvatori, S., Usai, D., & Zerboni, A. (2018). New evidence from the prehistoric sites at Al Khiday and Al Jamrab, Central Sudan. 24. In J. Kabacinski et al. (Eds.), *Desert and the Nile. Prehistory of the Nile Basin and the Sahara. Papers in honour of Fred Wendorf Studies (pp. 71-94). African Archaeology 15*. Poznań Archaeological Museum.

Scancarello, O., Gallinaro, M., & di Lernia, S. (2022). Site organization and mobility strategies: The Early and Middle Holocene stone structures from Takarkori Rockshelter (Southwestern Libya). *Journal of Field Archaeology, 47*(2), 1–19.

Schiffer, M. B., Skibo, J. M., Boelke, T. C., Neupert, M. A., & Aronson, M. (1994). New perspectives on experimental archaeology: Surface treatments and thermal response of the clay cooking pot. *American Antiquity, 59*, 197–217.

Shanks, M., & Tilley, C. Y. (1992). *Re-constructing archaeology: Theory and practice*. Psychology Press.

Shennan, S. J. (2003). *Archaeological approaches to cultural identity*. Routledge.

Shepard, A. O. (1974). *Ceramics for the Archaeologist* (Vol. 609). Carnegie Institution of Washington.

Skibo, J. M. (2013). *Understanding pottery function*. Springer.

Skibo, J. M. (2015). Pottery use-alteration analysis. In J. M. Marreiros et al. (Eds.), *Use-wear and residue analysis in archaeology* (pp. 189–198). Springer.

Skibo, J. M., & Schiffer, M. (2008). *People and things: A behavioral approach to material culture*. Springer.

Skibo, J. M., & Schiffer, M. B. (2001). Understanding artifact variability and change: A behavioral framework. In M. B. Schiffer (Ed.), *Anthropological perspectives on technology* (pp. 139–149). University of New Mexico Press.

Smith, K. Y., & Neiman, F. D. (2007). Frequency seriation, correspondence analysis, and Woodland period ceramic assemblage variation in the Deep South. *Southeastern Archaeology, 26*(1), 47–72.

Tafuri, M. A., Bentley, R. A., Manzi, G., & di Lernia, S. (2006). Mobility and kinship in the prehistoric Sahara: Strontium isotope analysis of Holocene human skeletons from the Acacus Mts. (southwestern Libya). *Journal of Anthropological Archaeology, 25*, 390–402.

Tite, M. S., Kilikoglou, V., & Vekinis, G. (2001). Strength, toughness and thermal shock resistance of ancient ceramics, and their influence on technological choice. *Archaeometry, 43*, 301–324.

Van Neer, W., Alhaique, F., Wouters, W., Dierickx, K., Gala, M., Goffette, Q., et al. (2020). Aquatic fauna from the Takarkori rockshelter reveals the Holocene central Saharan climate and palaeohydrography. *Plos One, 15*, e0228588.

Wallaert-Pêtre, H. (2001). Learning how to make the right pots: Apprenticeship strategies and material culture. A case study in handmade pottery from Cameroon. *Journal of Anthropological Research, 57*, 471–493.

Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Wu, X., Zhang, C., Goldberg, P., Cohen, D., Pan, Y., & Arpin, T. (2012). Early pottery at 20,000 years ago in Xianrendong Cave, China. *Science, 336*, 1696–1700.

Zerboni, A., Perego, A., & Cremaschi, M. (2015). Geomorphological map of the Tadrart Acacus Massif and the Erg Uan Kasa (Libyan Central Sahara). *Journal of Maps, 11*, 772–787.

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