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Full length article



Shell tool technology and new insights into techno-cultural strategies during the Neolithic in Eastern Arabia. An initial case study from Umm al-Quwain (United Arab Emirates)

Kevin Lidour^{a,b,c,*}, David Cuenca Solana^{a,d}, Jesús Setién Marquín^a, Ana Cimentada Hernández^e, Vincent Charpentier^c, Sophie Méry^c

^a Instituto Internacional de Investigaciones Prehistóricas de Cantabria (Universidad de Cantabria, Gobierno de Cantabria, Grupo Santander), Universidad de Cantabria, Edificio Interfacultativo, Avda. de Los Castros nº 52, 39005 Santander, Spain

^b UMR 7209 (AASPE), Muséum National d'Histoire Naturelle, 55 rue Buffon, 75005 Paris, France

^c UMR 7041 (ARSCAN), Maison des Sciences de l'Homme Mondes, 21 allée de l'Université, 92000 Nanterre, France

^d UMR 6566 (CREAAH), Université de Rennes 1, Campus de Beaulieu, bâtiment 24-25, 35042 Rennes, France

^e Laboratorio de la División de Ciencia e Ingeniería de los Materiales (LADICIM) (Universidad de Cantabria, Gobierno de Cantabria, Grupo Santander), Universidad de Cantabria, ETSI de Ingenieros de Caminos, Canales y Puertos, Avda. de Los Castros nº 44, 39005 Santander, Spain

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ABSTRACT

The production and use of shell tools has been reported from the Neolithic (c. 6500–3300 BCE) to the Late Bronze Age (c. 1600–1300 BCE) – or the Early Iron Age c. 1300–1000 BCE) – along the eastern shores of the Arabian Peninsula. The latter are described as large bivalve shells whose ventral margin has been retouched. However, to date, no functional analysis has been performed to understand the use of these unusual tools, despite the recognised importance of marine resources in the cultural development of Protohistoric societies in this region. This paper, therefore, aims to present the findings of a large number of worked shell valves collected from excavations at Neolithic sites in the Umm al-Quwain area in the Northern United Arab Emirates, over the past 20 years. It introduces the first functional study of shell tools in the Arabian Peninsula and contributes to the knowledge of techno-cultural processes among the Neolithic coastal communities of this area.

Comparisons with experimental specimens have allowed us to highlight the use of shell tools for various activities, including butchering and woodworking tasks, and the processing of animal skins in-line with the production and use of ochre. Most of the specimens studied evidenced use-wear resulting from the processing of vegetal fibres, suggesting basketry or rope production. Although further work is required on material retrieved from other sites in the region, the results from the Umm al-Quwain area already constitute a huge step forward in reconstructing past productive activities during the Neolithic, opening a new area of research for the Archaeology of Eastern Arabia.

1. Introduction

1.1. General

Arid and semi-arid climatic conditions in the Arabian Peninsula throughout the Holocene bound past human groups to adapt and migrate towards ecological refuges, including, and in particular, tropical coastal ecosystems consisting of significant biomass and biodiversity hotspots (e.g. mangroves, seagrass meadows, and coral reefs) (Fig. 1)

(Harold et al., 2010; Berger et al., 2013; Rose, 2022). These ecosystems provided abundant subsistence resources in the form of marine molluscs, crustaceans, fish, and marine mammals. Despite the lack of sufficient rainfall to support the development of rain-fed agriculture throughout the Neolithisation process, Arabian societies adapted their economies to their local environments. On the coast, this took the form of mixed economies mainly based on the exploitation of marine resources and small-scale herding (Uerpmann and Uerpmann, 2000). Indeed, oasian agriculture, based on innovative irrigation systems (using wells, run-off

* Corresponding authors at: Instituto Internacional de Investigaciones Prehistóricas de Cantabria (Universidad de Cantabria, Gobierno de Cantabria, Grupo Santander), Universidad de Cantabria, Edificio Interfacultativo, Avda. de Los Castros nº 52, 39005 Santander, Spain.

E-mail addresses: lidour01@gmail.com (K. Lidour), david.cuenca@unican.es (D. Cuenca Solana).

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channels, and the development of *falaj* technology), only developed from the Bronze Age onwards (Charbonnier, 2017). In that respect, the exploitation of marine resources took on a greater importance during the Neolithic, not only for procuring a staple food but also for the exploitation of hard marine animal materials. The latter having supported symbolic and technological productions in the form of personal adornments and shell tools (Lidour, 2023).

Up until now, shell adornments have been abundantly discussed in the literature – not only because they are related to past manifestations of aesthetic, symbolism, and cultural identity but because they consist of distinctive artefacts which abound in the form of grave goods. Apart from shell fish hooks, which have received great interest (Charpentier and Méry, 1997; Méry et al., 2008; Cavulli et al., 2009; Bavutti et al., 2015), shell tools remain poorly documented in the region. This can be explained by their presence within domestic assemblages where they are

often attributed as food discards.

In the early 2000s, Charpentier et al. (2004) recorded the use of shell tools in Eastern and Southern Arabia (United Arab Emirates (UAE), Sultanate of Oman, and Yemen) from the Neolithic (c. 6500–3300 BCE) to the Late Bronze Age (c. 1600–1300 BCE) – or the Early Iron Age c. 1300–1000 BCE). Most specimens were documented in Ruways and Suwayh (ash-Sharqqiyah, Sultanate of Oman). During the last few years, further examples have been documented in the region, especially at Ra’s al-Hamra (Muscat district, Sultanate of Oman), Sharbithat (Dhofar, Sultanate of Oman), Umm al-Quwain (Northern UAE), and on the islands of Marawah and Ghagha (Emirate of Abu Dhabi, UAE) (Marcucci et al., 2014: 242, fig. 5; Méry, 2015: fig.2/E; Marcucci et al., 2021: 114, fig. 6.13; Beech et al., 2022: fig. 8 n°3; Maiorano et al. in press; pers. com. N. Hamad Al-Hameli). Several specimens have also been identified from Masafi 5 in the hinterlands of the Emirate of Fujairah, UAE (Lidour

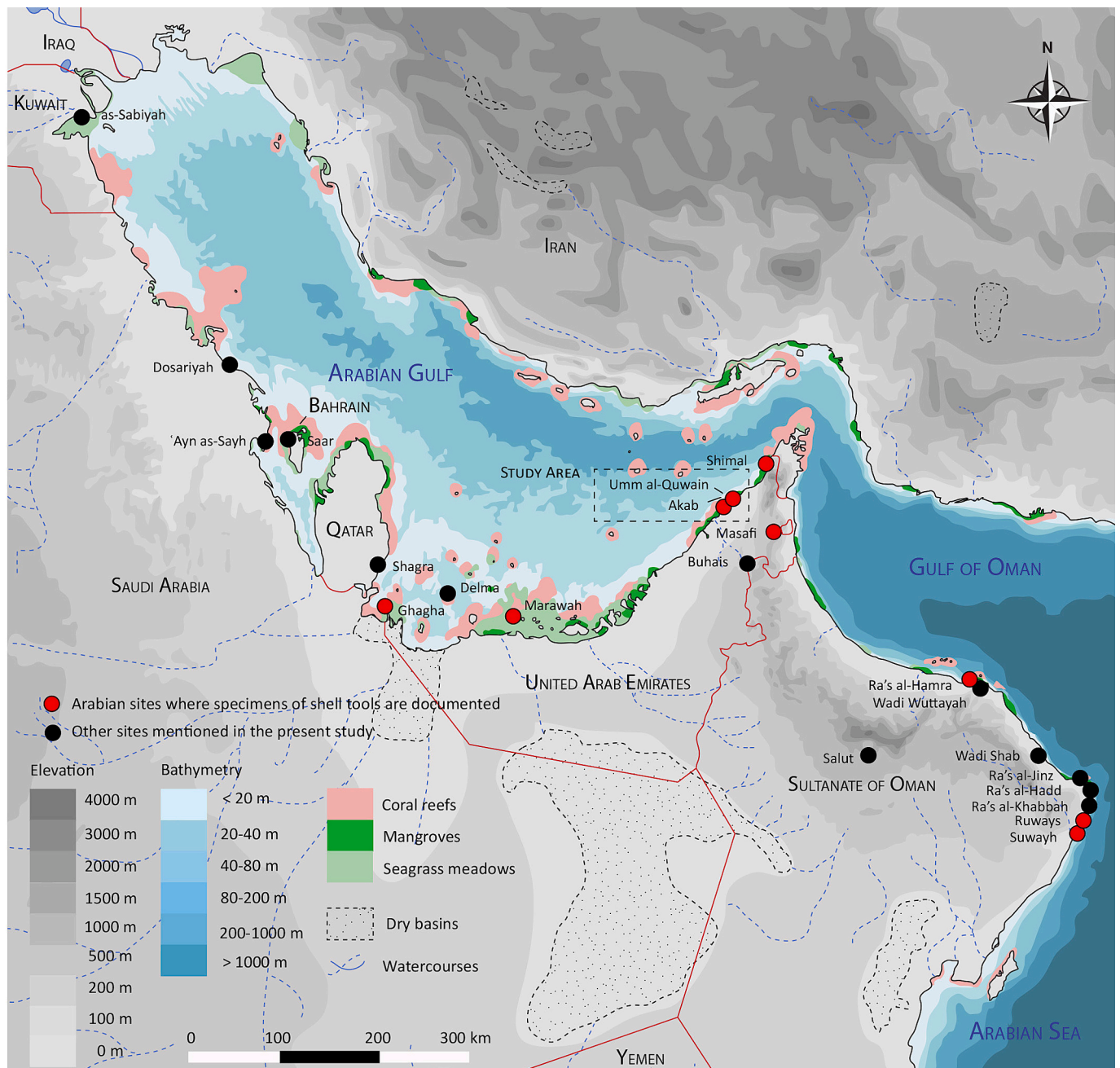


Fig. 1. Regional map with the location of the archaeological sites mentioned in the present study. Credits: K. Lidour.

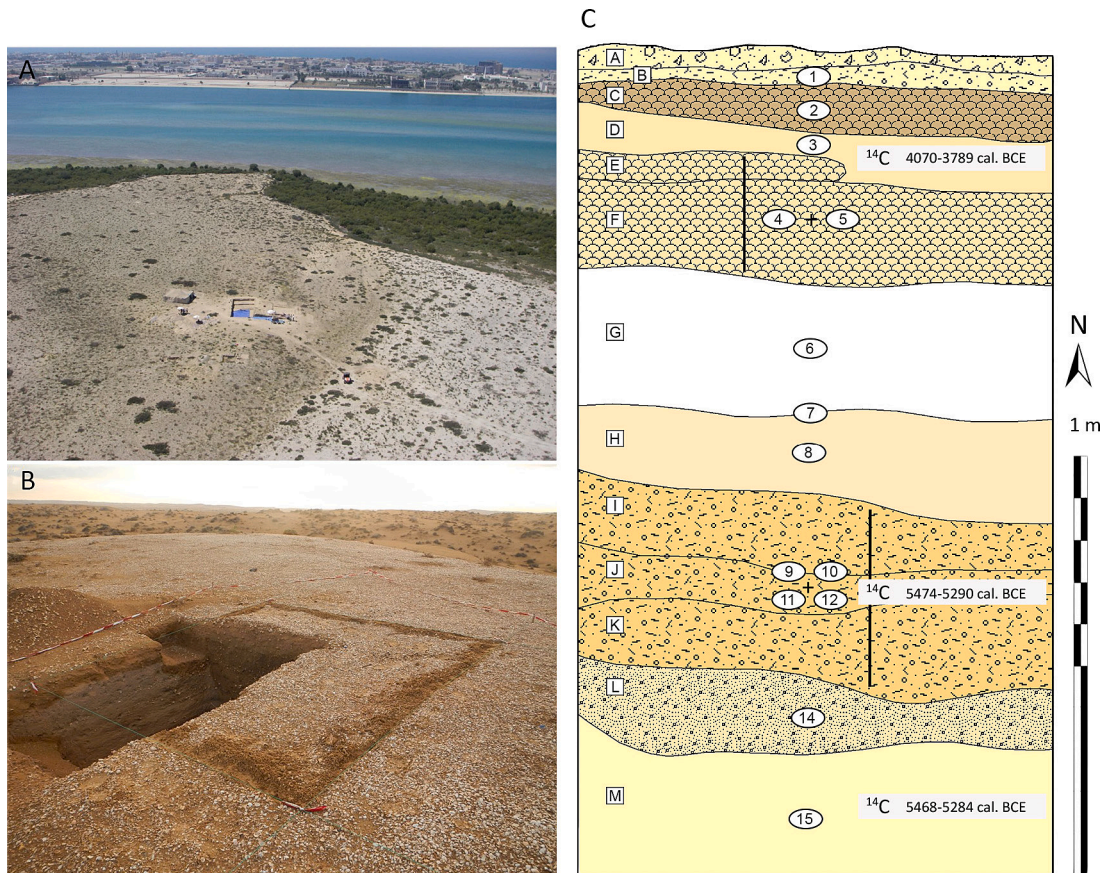


Fig. 2. A. Aerial view of the site of Akab during the 2009 field season on the Jazirat al-Ghallah (© T. Sagory for the French Archaeological Mission in the UAE); B. View of the UAQ36 shell midden's surface layer at the beginning of the excavations in 2018 (K. Lidour, French Archaeological Mission in the UAE); C. Stratigraphic sequence of the UAQ2 site with key radiocarbon dating from Méry et al. (2016).

et al., 2023). One can expect that these particular artefacts were also more widely used at other coastal sites; unfortunately, as the shells have probably not been systematically identified (and sorted) within the archaeological shell assemblages, this assumption remains unproven. Consisting of large bivalve shells showing distinctive scalar-like retouches along their ventral margins, species used include *Callista erycina* (Linnaeus, 1758), *Callista umbonella* (Lamarck, 1818) and, less frequently, *Meretrix* Lamarck, 1799, *Asaphis violascens* (Forsskål, 1775) and *Tivela ponderosa* (Koch in Philippi, 1844). It has been suggested that they were used as scrapers/knives for various purposes: butchering activities, the processing of animal skins, and woodworking. However, no proper functional analysis has been conducted to assert these hypotheses.

This paper presents the first detailed use-wear analysis of these valve tools. The study examined specimens from excavations conducted over the last 20 years by the French Archaeological Mission in the UAE on coastal Neolithic sites located in the Emirate of Umm al-Quwain (UAQ) in collaboration with the Department of Tourism and Archaeology. The sites studied include UAQ2, UAQ36, and Akab. Our approach aims to show the efficiency of the functional analysis method when applied to the material from our study area and to provide a representative sample of the range of activities conducted. In addition, the results will considerably enrich our knowledge of the socio-technological processes of the coastal Neolithic societies.

1.2. Archaeological setting

The coastal territory of the Emirate of Umm al-Quwain hosts an important semi-enclosed lagoon where human societies have developed continuously from the Neolithic onwards (from c. 5500–5300 BCE). The

earliest evidence of human presence in the area consists of Neolithic shell middens established on natural high points, such as Pleistocene megadunes. The peculiar nature of these sites expresses a strong reliance on the exploitation of local marine resources. The latter subsisted in tropical coastal ecosystems occurring in the lagoon or its vicinity (i.e. mangrove forests, seagrass meadows, and coral reefs). The shallowness of the lagoon (between 2 and 8 m depending on areas and tides) allowed access to extensive intertidal flats and shallow subtidal waters where the gathering of molluscs and crustaceans was facilitated, as well as the exploitation of juvenile fish (Department of Fisheries, 1984).

The site of UAQ2 (25°34'37"N; 55°39'16"E) is a Neolithic shell midden located on the top of a Pleistocene megadune overhanging a wide *sabkha* (an evaporitic salt flat corresponding to an ancient lagoonal area) which is situated along the eastern side of the lagoon. The occupation of the site is documented by a series of occupational layers chronologically ranging from the second half of the 6th millennium BCE and the end of the 5th millennium BCE (Fig. 2.C; Fig. 3) (Méry, 2015; Méry et al., 2016). The stratigraphy is remarkably preserved at a height of more than 2 m. The settlement identified on the site has provided numerous remains of post-frame structures, as well as hearths and food waste. The diet of the site's inhabitants confirms an economy based primarily on seafood (marine molluscs, crustaceans, and fish) and herds (domestic caprins and cattle) (Mashkour et al., 2016; Lidour et al., 2021). The material culture here is rich and diversified, comprising the main reference assemblage for the Neolithic in the Northern UAE. The lithic industry includes several types of arrowheads, scrapers, drills, and splintered pieces whose use has been linked with the production of personal adornments made of marine shells (beads, pendants, and rings). Groundstone implements comprise stone adzes, crushing stones, grinding stones, polishing stones, and net sinkers made from pebbles.

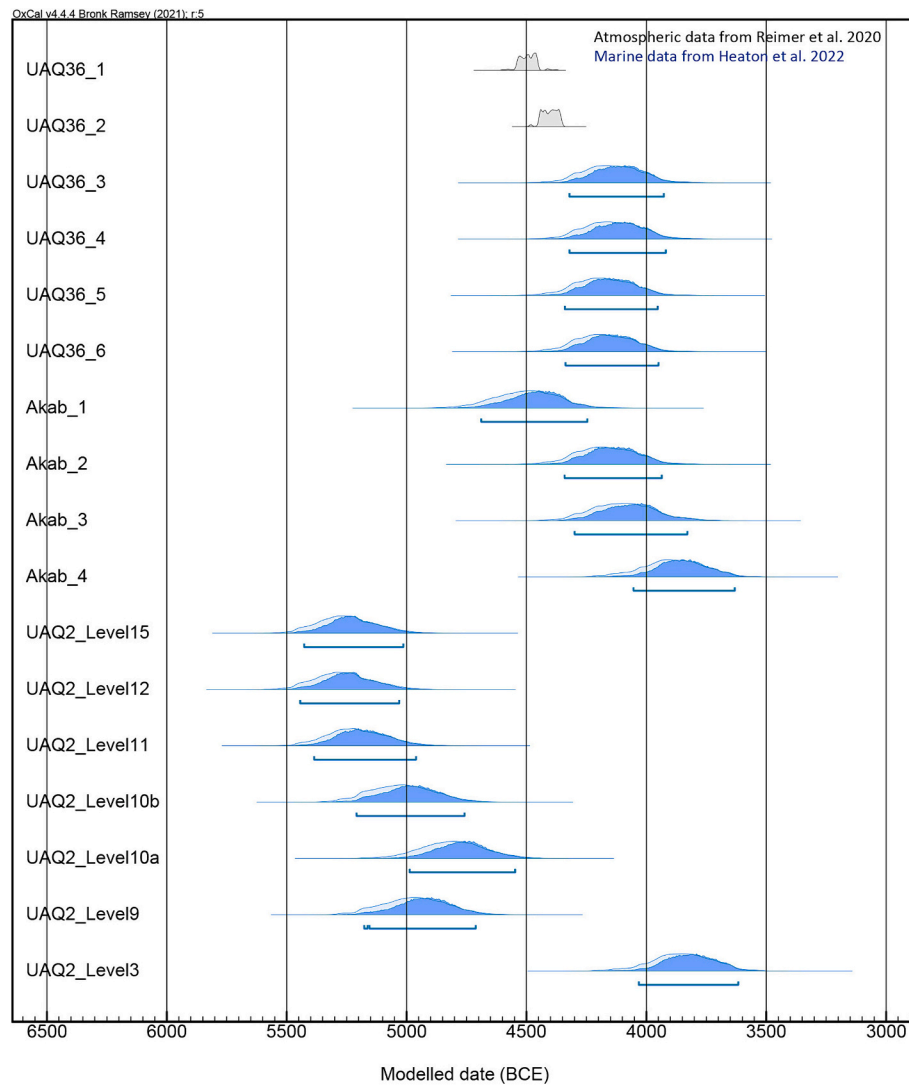


Fig. 3. OxCal v4.4.4 plot with the distribution of calibrated radiocarbon dates obtained for UAQ2, UAQ36, and the Akab settlement ($\Delta R = 68 \pm 91$ from Méry et al., 2019). Bayesian probability densities in blue correspond to radiocarbon dating made on marine shells; in light gray for charcoals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Shell tools are remarkably abundant on this site, consisting of over 150 shell valves currently identified as scrapers or knives. Several specimens of shell fish hooks have also been attested in the upper levels of the site's stratigraphy, corresponding to a late 5th millennium BCE occupation (Méry et al., 2008). Additionally, the site has provided a significant amount of pottery sherds belonging to Middle Chalcolithic Mesopotamian wares (known as 'Ubaid culture'). All this evidence suggests expansive transregional networks and the exchange of goods over around a thousand kilometres from Southern Iraq, as far back the 6th millennium BCE, across the Arabian Gulf. The site of UAQ2 is also famous for its graveyard, which has provided the remains of more than 40 individuals, mostly dated from the late 6th millennium BCE. This is currently the earliest documented graveyard in the UAE and the whole of the Arabian Gulf (Méry et al., 2016).

The site of UAQ36 (25°34'57"N; 55°39'35"E) is a shell midden located about 1 km north of UAQ2 (Méry et al., 2019) on another Pleistocene sand megadune. Archaeological deposits extend to 2 m of stratigraphy, arranged in shell-rich layers (Fig. 2.B). Although this site's material culture was surprisingly poor compared to UAQ2, radiocarbon dating has been possible on charcoal samples collected from several contexts, confirming an occupation by the mid-5th millennium BCE (Fig. 3). The uppermost part of the stratigraphy, therefore, probably belongs in part

to the 4th millennium BCE. The remains of post-frame structures, hearths, and food discards evidence a settlement and its associated domestic activities. As previously mentioned, material culture is scarce on this site: a small amount of lithic debitage, a few beads, and a unique shell scraper/knife found in the stratigraphy. It has been suggested that the mode of occupation of this site was more occasional or seasonally-based than at UAQ2, where evidence for an almost year-round presence has been evidenced (Mashkour et al., 2016: fig. 10). In contrast, the study of the fish remains has highlighted that the procurement of seafood was possible throughout the year at UAQ36 (Lidour et al., 2020b).

The site of Akab (25°34'09"N; 55°34'31"E) is located on a small sandy islet (Jazirat al-Ghallah) (Fig. 2.A) situated in the western half of the lagoon (Charpentier and Méry, 2008), on top of a lower Pleistocene dune. It is composed of a settlement occupied during the second half of the 5th millennium (Fig. 3) and a ceremonial area dating from the mid-4th millennium BCE where the remains of a structure built in dugong – *Dugong dugon* (Müller, 1776) – skeletal elements has been found (Méry et al., 2009; Méry and Charpentier, 2012). Although the site's stratigraphy is relatively reduced compared to UAQ2 and UAQ36 (only 25–35 cm thick at Akab), numerous remains of post-frame structures and domestic activities, in the form of hearths and ashy lenses, have been documented. The faunal assemblage comprises large quantities of

marine shells, fish bones, and crab remains (Lidour et al., 2020a; Lidour et al., 2021). Intensive fishing activities are highlighted by the discovery of several pebble net sinkers and shell fish hooks, produced on site (Méry et al., 2008). Shell technology is further documented by a significant amount of disc beads made from thorny oyster shell (*Spondylus spinosus* Schreibers, 1793), whose transformation into adornments has been related, as at UAQ2, to the use of microtools, such as lithic drills and splintered pieces. Examples of shell scrapers/knives have also been found within the settlement area. Although less abundant than at UAQ2, some Mesopotamian pottery sherds are also attested at Akab.

So far, no detailed analyses of the malacological assemblages have been conducted for the three sites presented above. Nevertheless, a preliminary assessment of the UAQ2 assemblage has highlighted a remarkable taxonomic diversity among the marine molluscs exploited (about 55 species identified by C. Dupont), including taxa consumed as seafood, taxa whose shells have been worked for the production of personal adornments and tools, and commensal taxa. However, there is little doubt that marine shells that are not locally available were obtained through exchange with other Neolithic groups living in the region – e.g. *Engina mendicaria* (Linnaeus, 1758) is not encountered in the Arabian Gulf but occurs in the Sultanate of Oman (Bosch et al., 1995: 128). We observed the recurrence of the same main edible taxa on the three sites studied, including small clam species (belonging mainly to the genus *Marcia* H. Adams & A. Adams, 1857), the hooded oyster *Saccostrea cucullata* (Born, 1778), the giant mangrove whelk *Terebralia palustris* (Linnaeus, 1767), the rock snail *Hexaplex kuesterianus* (Taparone Canefri, 1875), and the Gulf pearl oyster *Pinctada radiata* (Leach, 1814). The latter species evidence the ancient exploitation of a variety of coastal marine ecosystems encountered locally: mangrove fringes (for mangrove whelks and hooded oysters), intertidal coarse sands and gravels associated with the estuarine system (for clams), and shallow subtidal rocky flats (for pearl oysters and rock snails).

2. Material and methods

Sampling strategies were similar across the three sites discussed in this paper. All the excavated sediments were systematically dry-sieved using a 3 mm mesh (1/8 in.). Shell tools were identified and sorted from the sieve or found in situ during excavation. It is possible, however, that some shell tool fragments were not identified and remain to be sorted from the malacological assemblages. It should also be noted that the classification of a mollusc shell as a tool does not necessarily require the presence of a retouch. Unmodified shells may have been used as ‘expedient tools’ (sensu Binford, 1977). Indeed, there are various actions that do not require a cutting edge (e.g. smoothing a surface or spreading something onto it); therefore, it will be necessary to investigate larger samples of the shell assemblages recovered from archaeological sites in the future.

The assemblage comprises 149 specimens of shell valves or valve fragments from UAQ2, UAQ36, and Akab: 76 *C. erycina* valves, 71 *C. umbonella* valves, and 2 *A. violascens* valves (Table 1). Most of the specimens come from UAQ2 ($N = 142$, i.e. over 95% of the assemblage) and belong to all occupation levels, dated from the mid-6th millennium to the end of the 5th millennium BCE (from level 14 to level 1, including the surface, although most of the tools were concentrated in levels 8–11) (Table 1; Fig. 4). Six valves come from the backfill deposits of excavations conducted in the early 1990s (Phillips, 2002). At Akab, specimens also come from various occupational deposits (levels 2, 3, and 4 of the settlement area), though these only constituted a small sample ($N = 5$) of the total assemblage available for this site. A more complete study of the latter is planned in the future. Only two specimens were studied for UAQ36 (from the site’s surface). The assemblages from Akab and UAQ36 may be small, yet they are the sole specimens accessible within the limited timeframe of this study. Nevertheless, they hold significant value for comparative analysis.

Functional analysis is based on the observation of use-wear traces

Table 1
Distribution of material among the three sites studied.

		<i>C. erycina</i>	<i>C. umbonella</i>	<i>A. violascens</i>	Total
UAQ2	Level 1	1	1	–	2
	Level 2	6	1	1	8
	Level 3	3	–	–	3
	Level 4	9	–	–	9
	Level 5	7	1	–	8
	Level 6	12	3	–	15
	Level 7	2	–	–	2
	Level 8	9	1	–	10
	Level 9	2	11	1	14
	Level 10	2	15	–	17
	Level 11	1	12	–	13
	Level 12	3	2	–	5
	Level 13	–	4	–	4
	Level 14	2	5	–	7
Surface	10	9	–	19	
Backfilling	–	6	–	6	
Total	69	71	2	142	
UAQ36	Surface	1	–	–	1
	Surface	1	–	–	1
	Total	2	–	–	2
Akab	Level 2	1	–	–	1
	Level 3	2	–	–	2
	Level 4	1	–	–	1
	Level 6	1	–	–	1
	Total	5	–	–	5

produced on the active area of archaeological tools. This methodology was initiated by Semenov (1964) during the first half of the 20th century CE for the study of lithic tools. During the last few decades, use-wear studies have been extended to tools made of bone (e.g. Peltier and Plisson, 1986; Maigrot, 2003) and mollusc shells – in particular in the Caribbean, Oceania, and Western Europe for the latter (e.g. Lammers Keijsers, 2008; Szabó and Koppel, 2015; Manca, 2013; Cuenca Solana, 2013; Cuenca Solana et al., 2015).

Observations at low magnification (below 100×) (using stereomicroscopy) allow a general description of the surface modifications to be made, including human-made retouch, bioerosion and post-depositional traces, as well as a preliminary localisation of the active area – abrasions, rounding, and scarring confirm the presence of use-wear. Observations at high magnification – from 100×, using digital microscopy or scanning electron microscopy (SEM) (D’Errico, 1985; Carbonell et al., 1999; Tumung et al., 2015) – allow for a detailed description of use-wear. This includes the polish, the striations, the edge rounding, and fracturing (Kamminga, 1982). High-powered observations permit the processed material and the characteristics of the action performed to be specified (Keeley and Newcomer, 1977). Comparisons made with experimentally produced use-wear facilitate the identification of the material processed (Plisson, 1991; Gutiérrez Sáez, 1990; González Urquijo and Ibáñez Estévez, 1994; Cuenca Solana, 2013; Cuenca Solana et al., 2010). With this in mind, a reference collection of experimentally made use-wear traces has been recently prepared to assist the study of shell tools from Eastern Arabia (Lidour and Cuenca Solana, 2023) (Fig. 5). It comprises specimens of the same taxa as the archaeological shell tools retrieved from the study area (collected alive in their natural habitats or washed up on the shore), consisting mainly of *C. umbonella* and *C. erycina* valves whose ventral margins have been retouched. A total of 65 experiments have been analytically conducted, according to activities likely to have been carried out by coastal Neolithic fisher-herder communities living in the Arabian Peninsula – a representative selection of 23 experiments are documented and illustrated in Lidour and Cuenca Solana (2023), including the processing of various animal, vegetal, and mineral materials available in the region. Direct comparisons have been performed with the archaeological specimens from this study.

Use-wear observations were conducted using stereomicroscopy (Leica S8 APO) and digital metallurgical microscopy (Leica DM 2500

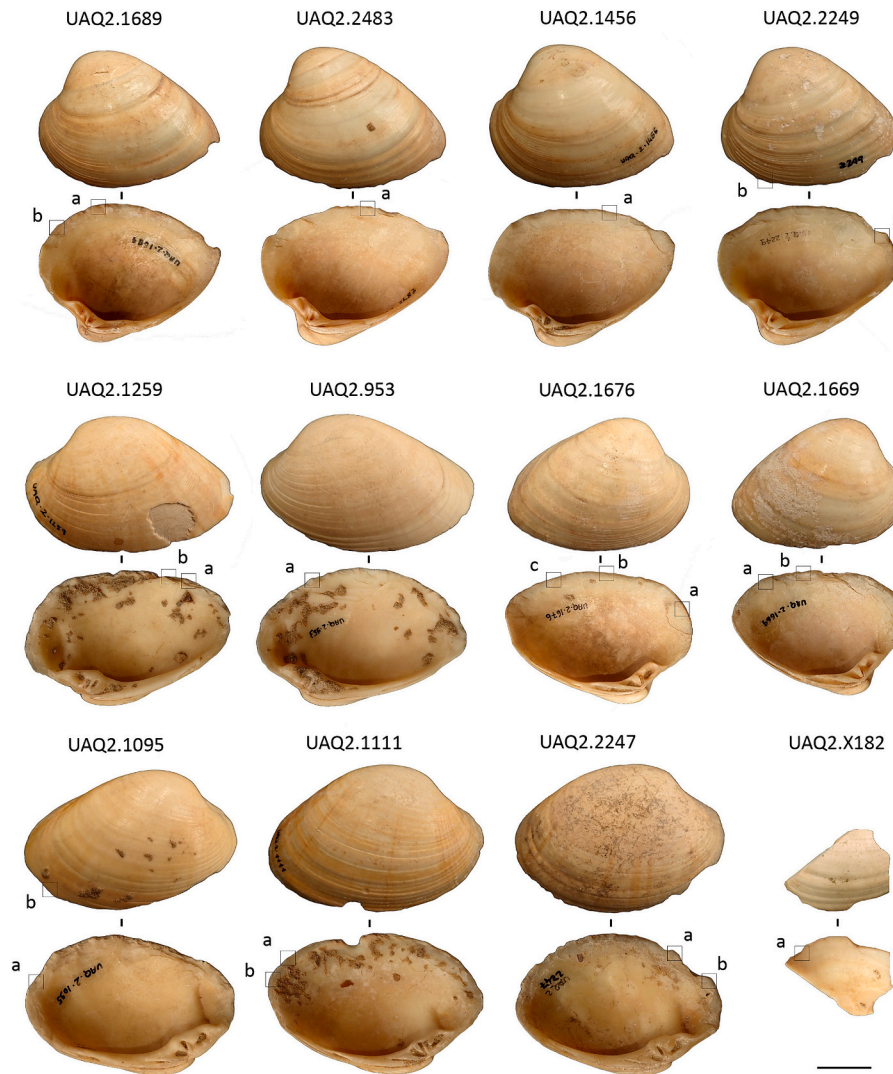


Fig. 4. Archaeological shell valves for which the use-wear is documented and illustrated in the present study – with the location of the photographs taken from the optical microscope. UAQ2.1689. Sector 2, Level 11, Square E2; UAQ2.2483. Sector 2, Level 13, Square H0; UAQ2.1456. Sector 2, Level 9, Square H1; UAQ2.2249. Surface; UAQ2.1259. Sector 2, Level 8, Square G4; UAQ2.953. Sector 2, Level 6; UAQ2.1676. Sector 2, Level 11, Square I0; UAQ2.1669. Sector 2, Level 10, Square D5; UAQ2.1095. Sector 2, Level 8, Square F1; UAQ2.1111. Sector 2, Level 4; UAQ2.2247. Sector 4, Level 5, Square O13; UAQ2.X182. Sector 2, Level 14, Square J0. Scale: 2 cm.

M), allowing magnifications from 10 to 200 \times . Photographs were taken with a digital microscope camera (Leica MC190 HD) linked to a computer using the Leica Application Suite v. 4.13.0. Multifocal pictures were processed using either the Leica software or the Helicon Focus v. 8.1.0. The elemental composition of residues found on some of the shell tools has been analysed using an energy-dispersive X-ray analyser (EDX). This analytical technique measures the X-rays emitted by a sample when excited by an energy source, such as an electron beam from a scanning electron microscope (SEM). The resulting energy spectrum is then analysed by comparing peak intensities with known standards, enabling the identification and quantification of the elemental makeup of the residues. This method provides valuable insights into the composition of the materials present on the shell tools, aiding in their characterisation and understanding of their use. Laboratory work was conducted at the Instituto Internacional de Investigaciones Prehistóricas de Cantabria (IIIPC) and at the Laboratorio de la División de Ciencia e Ingeniería de los Materiales (LADICIM) (Universidad de Cantabria, Santander, Spain).

3. Results

3.1. Collecting the valves

While *C. umbonella* and *A. violascens* are available in coastal intertidal waters (Bernard et al., 1993; Bosch et al., 1995: 259, 269), *C. erycina* is reported as strictly inhabiting offshore substrates (Bosch et al., 1995: 269). However, valves of the latter species could have easily been collected when they washed up on shore. About 96% of the *C. erycina* valves show abrasion, a distinctive smoothing on their cardinal teeth, or occasionally an accentuated modification of their shape; conversely, this concerns only 13.7% of the *C. umbonella* valves (Table 2). The combined action of marine sediments and wave movements is reported to cause fractures and abraded surfaces on shells. Modifications affecting the inner valve are generally post-mortem, indicating the valve has spent a certain amount of time in the sea after the mollusc's death. However, if the mollusc's death occurred recently, its shell would still theoretically look relatively fresh. The degree of bioerosion would also depend on the distance between the mollusc's habitat and the shore, which is greater for *C. erycina* than for those species available in intertidal substrates,

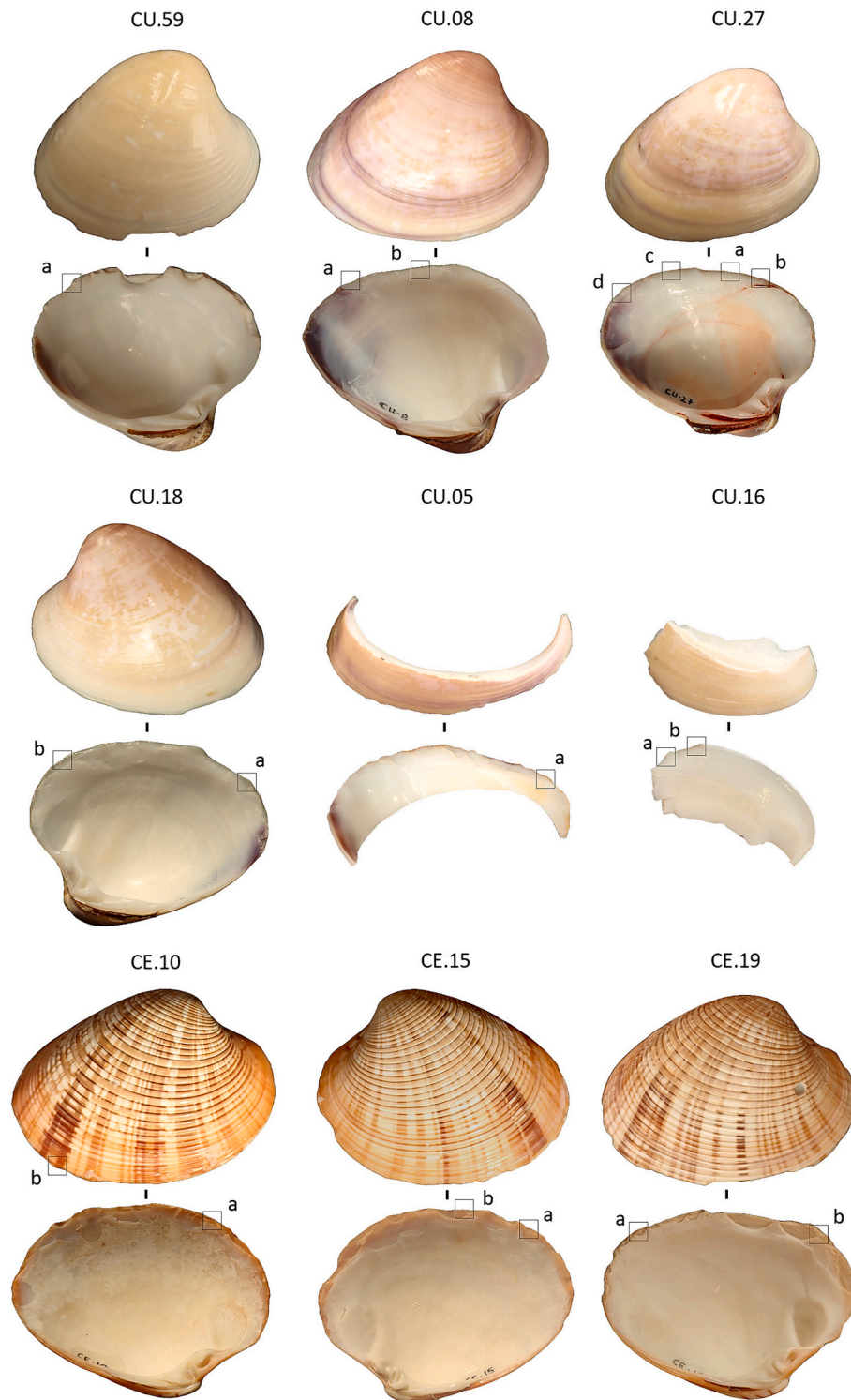


Fig. 5. Reference shell valves used for comparing archaeological and experimentally-made use-wear for the present study – with the location of the photographs taken from the optical microscope. CU.59. Debarking a branch of fresh false acacia (*Robinia pseudoacacia*), 10 min; CU.08. Cutting half-dry date palm leaves in bulk, 10 min; CU.27. Cleaning and treating a sheep skin with ochre, 35 min; CU.18. Cutting dry date palm leaves in bulk, 10 min; CU.05. Scraping a hard nodule of haematite, 10 min; CU.16. Debarking a branch of dry false acacia, 10 min; CE.10. Cutting date palm leaf sheath in bulk, 10 min; CE.15. Cutting meat on a lamb limb, 20 min; CE.19. Cutting a thread made from date palm leaf sheath, 5 min. Scale: 2 cm.

such as *C. umbonella* or *A. violascens*. The observation of such traces on archaeological specimens, however, is frequently complicated by both taphonomic alterations (e.g. post-depositional dissolutions and concretions) (Fernández López, 1999: 81; Gutiérrez Zugasti, 2008) and human-

made modifications (e.g. retouch on the ventral margin).

Another form of bioerosion consists of modifications related to the action of organisms that are parasitising or boring either the surface (epiliths) or inner the shell (endoliths) (Boekschoten, 1966; Álvarez

Table 2
General information on the shell valves studied.

	<i>C. erycina</i>	<i>C. umbonella</i>	<i>A. violascens</i>	Total
NISP	76	71	2	149
Left valves	40	36	2	78
Right valves	36	35	–	71
Length range (mm)	51.7–83.7	47.2–64.4	70.0–79.3	47.2–83.7
Marine abrasion	95.6%	13.7%	50%	61.9%
Bioerosion	5.26% (N = 4)	5.63% (N = 4)	50% (N = 1)	6.04% (N = 9)

Fernández, 2009; Cabral and Monteiro Rodrigues, 2015). In the material studied, these modifications consist of holes and furrows made by shell-boring worms (Polychaeta) (2 specimens), the presence of barnacle shells (Balanidae) (4 specimens), and tube-building annelids (Serpulidae) (2 specimens) at the surface of the valve. In the whole assemblage, only 6% of the valves show such types of bioerosion – concerning *C. erycina* and *C. umbonella* valves equally. Interestingly, two specimens of *C. umbonella* with barnacle shells in their inner valves showed no abrasion on their cardinal teeth, confirming that not all the shells washed up on the shore would evidence marine attrition. The cardinal teeth of many *C. umbonella* valve specimens personally collected (K.L.) on the shores of Marawah Island (Emirate of Abu Dhabi, UAE) looked relatively unchanged, supporting the previous assertion.

The fact that *C. umbonella* valves could have been collected washed up on the shore rather than fresh – considering a dietary purpose before being used as a raw material – is not surprising at Umm al-Quwain. In contrast to the Ruways and Suwayh areas, this species has never been exploited in large quantities in Umm al-Quwain, where most of the shellfish consumption was based on smaller bivalves of the *Marcia* H. Adams & A. Adams, 1857 species during the Neolithic (Méry et al., 2019). This is probably due to local differences in the mollusc populations available. Conversely, *A. violascens* valves were more abundantly observed as a food discard within the shell assemblages from the Umm al-Quwain sites. A few of the large specimens had been re-used as tools.

Charpentier et al. (2004: 6–7) have pointed out the preferential use of left valves as tools (96% on a corpus of 57 valves from the areas of Ruways and Suwayh, in the Sultanate of Oman) – interpreted as having a better grip for right-handers, who represent about 90% of any human population (Raymond and Pontier, 2004). In the present study, however, the assemblage comprised 78 left valves and 71 right valves (73 and 69 at UAQ2). Although the grip would not be the same for a left and right valve because of their non-superimposable shapes, it would also greatly depend on the activity conducted, the working angle, and the gesture it required (i.e. transversal vs. longitudinal; mono- or bidirectional, etc.). A similar observation has been made by Andrade Lima et al. (1986: 95), who found fairly balanced proportions of left and right valve tools from Ilha de Santana (Macaé, Brazil). They concluded that both left- and right-handed individuals could have used the same shell tools. In the case of the Ruways and Suwayh specimens, the preferential use of left valves seems to be directly correlated to the preferred location of the active area on the posterior edge of the ventral margin (Charpentier et al., 2004: tab. 2).

Conversely, specimens from the Umm al-Quwain area show retouches all along their ventral margin, suggesting either a wider active area or a non-specific location – a unique specimen of *C. erycina*, coming from level 2 at UAQ2 (ref. UAQ2.706) evidences a retouch limited to the posterior end of its ventral margin. The morphology of the working edge also shows some differences: more or less rectilinear for the valves that have been retouched on their posterior half, and curved for the valves that show retouches all along their ventral margin. These differences could be due to a distinct use of shell tools, but, unfortunately, no use-wear was preserved on the specimen from UAQ2, mentioned above. A study of the specimens from Ruways and Suwayh would be necessary to

specify differences with the shell tools from Umm al-Quwain in more detail.

Another parameter that should be pointed out is that *C. umbonella* and *Meretrix* sp. were abundantly exploited and consumed as food at Neolithic sites from the Ruways and Suwayh areas (Martin, 2004: 51, fig. 2; Martin, 2005: 172, figs. 3–4; Charpentier et al., 2000: fig. 8; Charpentier et al., 2003; Berger et al., 2020: 6). This suggests that the sites' inhabitants had some choice in the selection criteria of the better valves available to be used as tools (not only the largest ones but also regarding laterality). Conversely, as previously mentioned, the shell species used to produce tools at Umm al-Quwain were either gathered washed up on the shore or, when available locally, had never previously been exploited in comparable proportions. This would have induced a less selective pattern for the shell collection.

Whereas the height of the valve varies greatly after the retouch of the ventral margin, experiments have shown that the length remains about the same (less than 3% reduction). Our analysis shows that the shell collection studied includes specimens measuring between 51.7 and 83.7 mm in length for *C. erycina*, between 47.2 and 64.4 mm for *C. umbonella*, and between 70.0 and 79.3 mm for *A. violascens*. Although insufficient complete valves were available to provide a representative dataset, retouched *A. violascens* specimens were bigger than the unworked ones present within the shell assemblage of UAQ2 (the latter measuring between 42 and 71 mm in length). The shells were large enough to use the ventral margin as a working edge with a proper hand grip, regardless of the laterality of the valve.

3.2. Retouching the valves to produce tools

Potential techniques for retouching the valves have been discussed in detail in Lidour and Cuenca Solana (2023). Three main techniques have been described: Retouch type 1. 'Quina retouch' as suggested by Romagnoli et al. (2016), in the context of shell tools made from *C. chione* valves (Linnaeus, 1758) reported within Neanderthal-associated contexts in the Mediterranean; Retouch type 2. 'Flat retouch'; Retouch type 3. The 'block-on-block' technique or 'on resting hammer' (Cheynier, 1949: 190; Bordes, 1988: 25) (Fig. 6.D). They were all conducted using hard and direct percussion – small basalt pebbles weighing between 40 and 60 g have been used during the experiments.

Experiments have shown that all these retouch types are suitable for producing efficient cutting edges comparable to archaeological specimens evidencing distinctive scalar-like flaking and half-moon shaped fractures (Fig. 6). However, the type of retouch is frequently hard to identify on archaeological shell tools because of the attrition of retouched surfaces caused by their use as tools.

Most of the specimens studied showed retouch all along their ventral margin, which differs from that observed for specimens from the Ruways and Suwayh areas by Charpentier et al. (2004). Furthermore, the working edge always follows the natural curve of the ventral margin.

3.3. Using the valves as tools

The difference between the valves showing a visible attrition of the ventral margin and those evidencing a negligible reduction was relatively balanced, which could be linked to a progressive abrasion of the working edge or its over-fragmentation and re-sharpening – 48.6% and 51.4% of the 105 valves for which this analysis was possible (Table 3). The frequent attrition of the working edge tends to confirm the deliberate and prolonged use of shell tools within socio-economical activities at the sites.

Although most of the valves were preserved in a fairly complete form (65.4% of the assemblage), apart from the ventral margin being worked, many specimens evidenced a transversal or an oblique fracture which has caused the loss of their posterior end (22.8%) – only one specimen showed a fracture on its anterior end (0.7%). The preferential fracture of the posterior end seems to correlate to the fact that the shell is thinner on

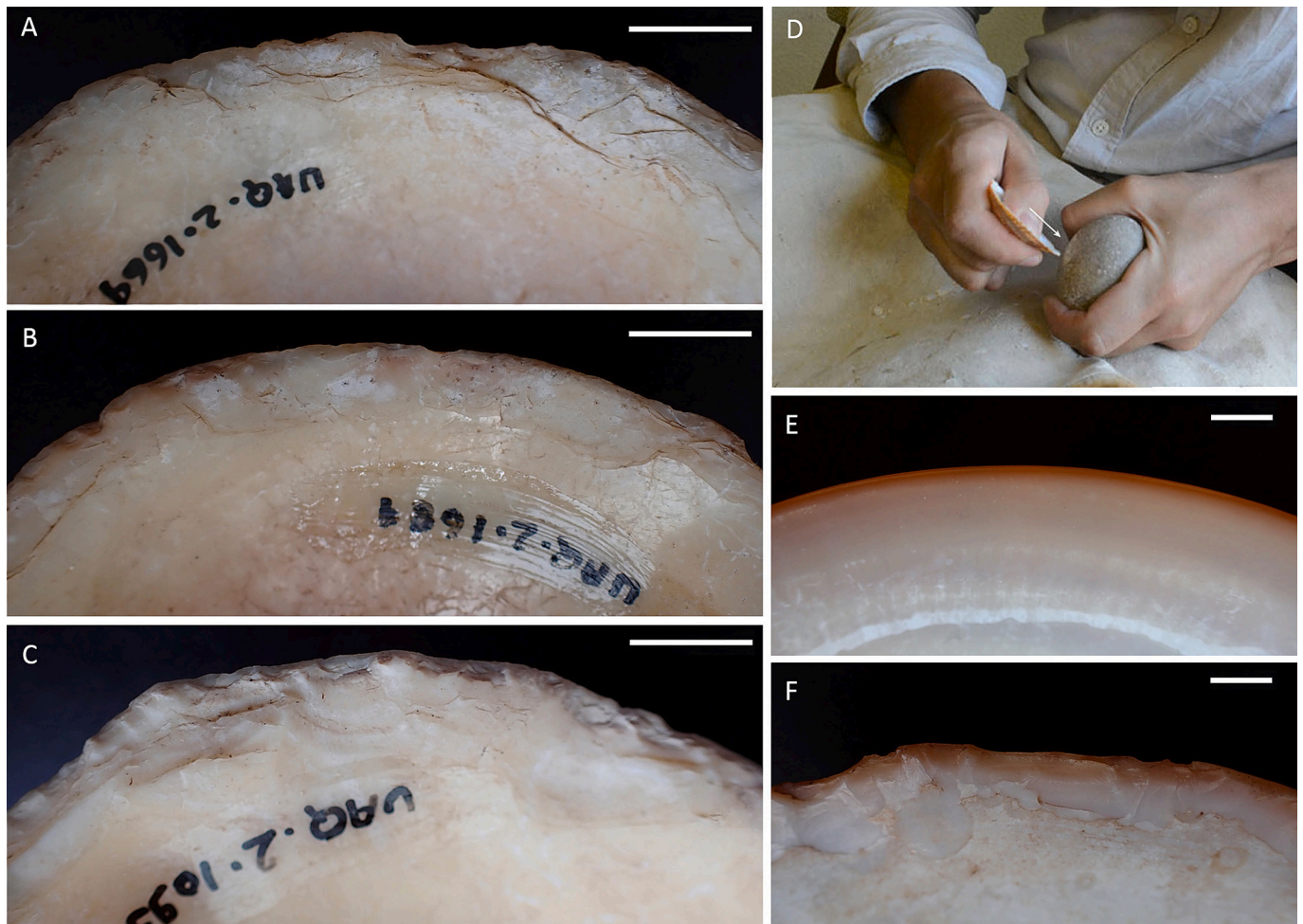


Fig. 6. A–C. Detail of scalar-like retouch on archaeological shell valves from UAQ2; D. Illustration of the ‘block-on-block’ retouch technique (Retouch type 3); E. Unmodified ventral margin of a modern *Callista erycina* shell valve; F. Detail of scalar-like retouch experimentally made using the ‘block-on-block’ technique on a modern *Callista erycina* shell valve. Scale: 1 cm.

Table 3

General information on the human-made modifications observed on the shell valves.

Completeness of the valve	
NISP	136
Almost complete	65.4%
Anterior end missing	0.7%
Posterior end missing	22.8%
Fragment	11.0%
Attrition of the ventral margin	
NISP	105
Important	48.6%
Low or non-existent	51.4%
Preservation of the micro-polish	
NISP	136
Class 1	26.5%
Class 2	27.2%
Class 3	46.3%
Localisation of the use-wear on the margin	
NISP	63
Anterior end	12.3%
Middle	15.8%
Posterior end	71.9%

this part of the valve and thus could have broken more easily during use. One can also suggest that any action was preferentially conducted with this part of the valve. In this sense, microscopic observations have confirmed that most of the use-wear traces are concentrated on the

posterior end of the valves, regardless of their laterality (in 71.9% of cases vs. 12.3% for the anterior end, and 15.8% for the middle).

A total of 13 specimens did not show any retouch or use-wear: 3 were complete valves (1C. *erycina* and 2C. *umbonella*) and 10 were fragments. This proportion may be higher, but remains to be confirmed by a complete analysis of the malacological assemblages. The remaining specimens were distributed into three categories according to the state of preservation of their use-wear (adapted from Schmidt et al., 2001: 69) and, more specifically, their micro-polish. In many cases, abraded surfaces and striations indicated the use of the shell as a tool, but they did not allow for detailed functional analysis (Keeley, 1980); therefore, the categories are described as follows: Class 1. No micro-polish is visible, although the valve is retouched; Class 2. The micro-polish is slightly visible and not exploitable; Class 3. The micro-polish is visible enough to be described and eventually interpreted. A total of 63 specimens have been classified within Class 3–46.3% of the worked valves. Classes 1 and 2 comprised 26.5% and 27.2% of the same corpus.

Among the 63 shell tools included in Class 3, only 40 have yielded definitive interpretations. They provide use-wear that can be directly compared with reference specimens. (Lidour and Cuenca Solana, 2023). Results show that various animal, vegetal, and mineral materials were processed during specific activities, such as butchering, the processing of animal skins and vegetal fibres, woodworking, and the scraping of ochre (Table 4).

Table 4

Productive activities evidenced by the use-wear analysis conducted in the present study.

Matter	Action	UAQ2	UAQ36	Akab
Animal meat	Longitudinal	2	–	–
Skin with ochre	Transversal	2	–	–
Wood or wood bark	Transversal and oblique	3	–	–
Vegetal fibres	Longitudinal	28	1	2
Ochre	Transversal	2	–	–

3.3.1. Animal materials

Use-wear interpreted as the result of butchering activities has been identified on two specimens from levels 4 and 9 at UAQ2. The micro-polish was more visible when positioning the valve horizontally to the microscope lens, indicating that the processed material was in full contact with the inner valve – the inclination of the valve is indicated in the top left of the illustrations (see Fig. 7). The micro-polish is developed moderately far from the edge on both sides of the valve and shows a loose pattern with blurred limits, a greasy texture, and a dull brightness (low reflectance). It also has a homogenous development in relief – the working surface is fluid, indicating the processing of a soft material. No roundings or other significant modifications of the edge and the relief were observed, suggesting that the material worked was not abrasive. Nevertheless, isolated surfaces on some of the micro-topography's high points show a micro-polish with a closer and brighter pattern (Fig. 7:

UAQ2.1111, a; CE.15, a). These have been interpreted as areas of contact with a harder material. Striations were rare but sometimes more visible in these areas, evidencing a longitudinal movement produced by a cutting action. These striations are generally short, thin, and shallow and have been interpreted as the result of butchering activities, such as cutting animal meat and contact with bones (areas showing a closer pattern). It is impossible to specify whether it was mammal or fish meat that was processed, although the former tends to produce a better-developed use-wear over time (Lidour and Cuenca Solana, 2023).

The use of ochre to treat animal skins is suggested on at least two specimens from levels 8 and 11 of UAQ2 (Fig. 8). The valves showed a micro-polish that had developed on various angles – visible in the inner valve when the shell tool was set almost horizontally to the microscope lens but more clearly visible when it was inclined. However, use-wear is limited to the edge when looking at the outer side of the valve; therefore, the action appears to have been mainly transversal on a moderately soft or flexible material. The micro-polish has a fairly wide extension on the inner valve, showing irregular or blurred limits. It has a bright and closed pattern with a grainy (sometimes greasy) aspect and develops well in relief. The latter shows an important rounding that tends to create continuous surfaces with a unified micro-polish, apart from the edge, which frequently shows fractures. The micro-polish also evidences either significant force applied to the edge or contact with a hard material. Striations are numerous, moderately long, deep, and of various thicknesses – some are in the shape of scratches, indicating contact with a mineral material. These striations are arranged transversally or

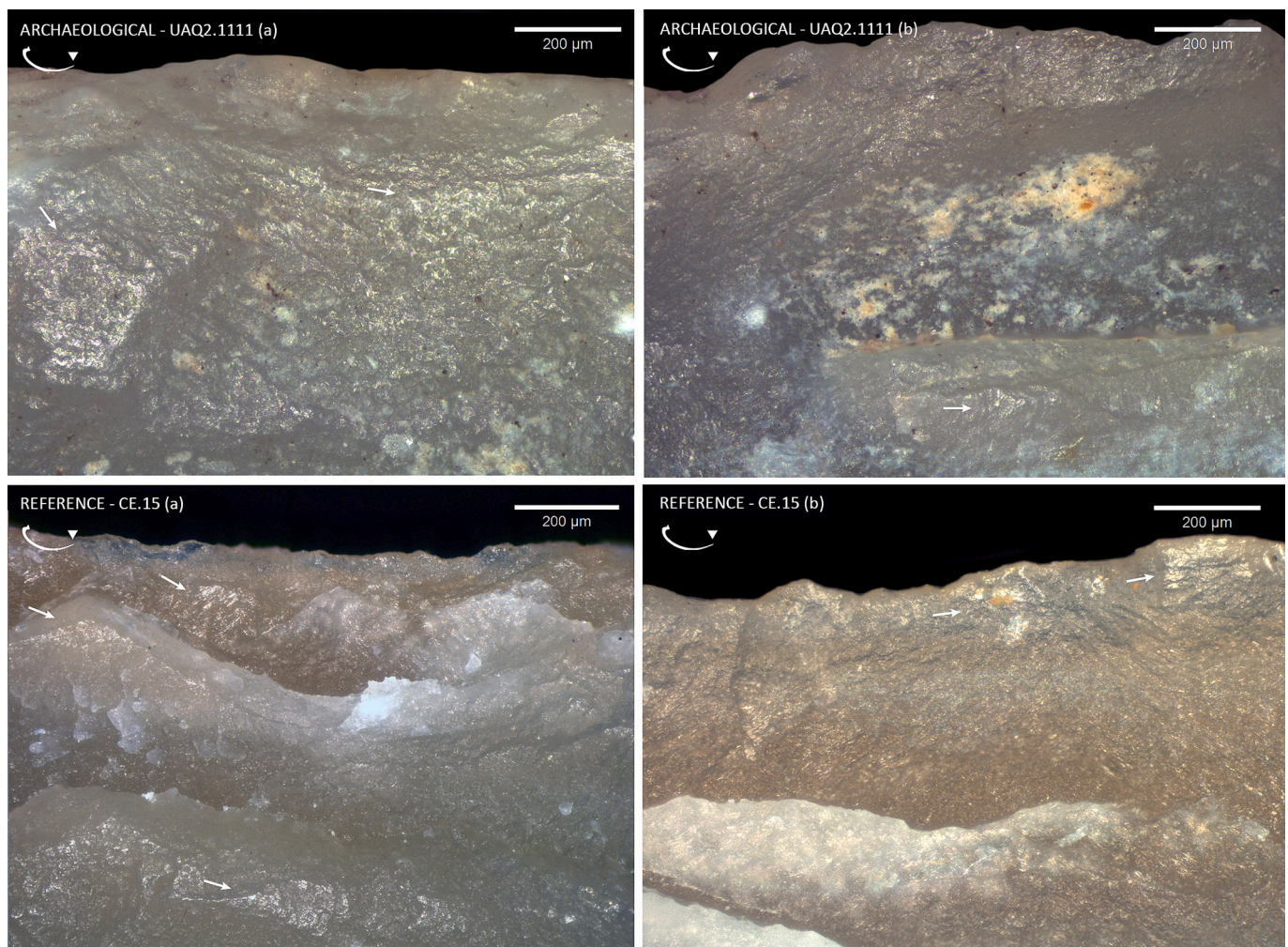


Fig. 7. Comparing archaeological and reference (experimental) use-wear produced by butchering activities, at 100 \times . CE.15. Cutting meat on a lamb limb, 20 min. White arrows highlight areas of contact with bone.

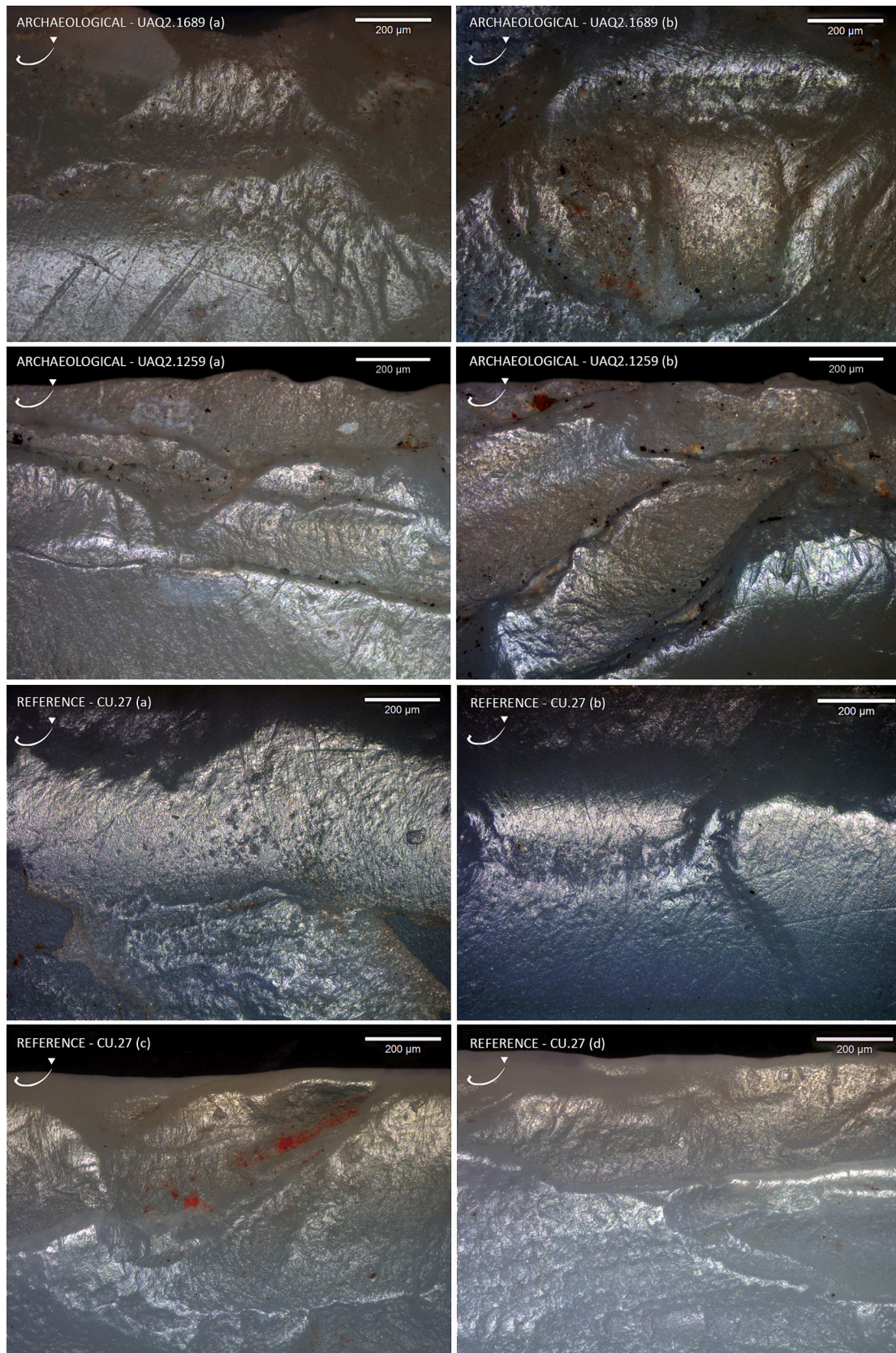


Fig. 8. Comparing archaeological and reference (experimental) use-wear produced by the processing of animal skin using ochre, at 100 \times . CU.27. Cleaning and treating a fresh sheep skin with an emulsified solution of lam brain mixed with ochre powder, 35 min.

obliquely to the edge of the valves, frequently intersected, suggesting a bi-directional movement – this was also confirmed by a moderate development of the use-wear on the outer side of the valve. The working area also showed numerous subcircular micro-holes (Fig. 8: UAQ2.1689 & CU.27, a and b). The latter have previously been reported as resulting from the processing of animal skins (González Urquijo and Ibáñez Estévez, 1994: 51; Cuenca Solana, 2013: 178, fig. 3.30.8). On the examples presented here, the micro-holes tend to be obliterated on surfaces where the abrasion is strong. Nevertheless, they are clearly visible on the periphery of the active area. The development of the micro-polish and its greasy aspect align with the interpretation of animal skin processing. The fracture of the edge suggests the use of a hard support where the skin was laid. The high brightness of the micro-polish, the strong abrasivity, and the presence of numerous striations showing various thicknesses suggest the use of a mineral additive in the treatment process of animal skins. According to experiments, and evidence from the same site (see below), the use of ochre powder can be suggested.

3.3.2. Vegetal materials

Woodworking activities were identified on at least three specimens from levels 3, 6, and 8 of UAQ2. On two of the valves, the micro-polish was developed on the edge – it was more clearly visible when inclining the valve at about 45°. This indicates little contact with the material worked, limited to the edge. The movement was mainly transversal. The reliefs located close to the edge are distinctly abraded and show micro-polishing characterised by a closed pattern, moderately bright, with a scratchy texture. These are moderately developed in relief, creating distinctive domed shapes (Fig. 9: UAQ2.1095, a; UAQ2.2247; CU.16). The latter evidences invasive striations, which are short, of various thicknesses and depths. These are arranged transversally to the edge, more often obliquely, and were also observed along the edge on the outer side of the valves (Fig. 9: UAQ2.1095, b). This use-wear has been interpreted as resulting from the removal of dry wood bark – possibly linked with the planing of a wood surface using the main part of the active area. Another valve shows use-wear generally associated with the removal of fresh soft bark (Fig. 9: UAQ2.953; CU.59). The micro-polish here shows a wide extension on the inner valve, well developed in relief. It presents a semi-closed pattern with a dull brightness and a characteristic varnish-like aspect (possibly produced by the natural “hydration” of the green wood or its bark). The reliefs are regularly and only slightly subdued – they do not show striations or scratches.

Most of the shell tools observed showed use-wear associated with the processing of vegetal fibres (non-woody vegetal materials) – 31 specimens retrieved from UAQ2, UAQ36, and Akab. Comparisons conducted with the experimental specimens have allowed us to suggest interpretations regarding the different types of fibres processed. However, it should be noted that these differences are often subtle and thus require further documentation. The research and analysis of phytoliths on archaeological shell tools would also greatly help the identification of the vegetal taxa processed.

The cutting of leaves was suggested by many valves (at least 10 specimens from levels 5, 8, 9, 12, 13, and 14 of UAQ2) (Fig. 10). The micro-polish was visible across a wide extension with irregular limits up to 5–10 mm from the edge and on both sides. It is better visible when the valve is set horizontally to the microscope lens, indicating a longitudinal movement created by processing soft or ductile material. It presented a closed pattern and a strong brightness. It was well developed in relief, evidencing the material's softness or flexibility. The latter must also have been quite abrasive, as shown by the strong flattening of the valve's relief, creating extensive flat surfaces with a unified micro-polish. The texture appeared slightly lumpy in some areas. Striations are invasive and clearly visible: long, deep, and of various thicknesses. They are arranged longitudinally to the edge of the valve (well visible on its outer side). According to our experiments, these features can be interpreted as resulting from the cutting or slicing of non-woody vegetal fibres, particularly leaves.

Another type of use-wear (Fig. 11) associated with the processing of vegetal materials was identified on at least nine shell tools from UAQ2 (levels 5, 8, 10, 11, 12, and 13), one from level 2 of Akab (Sector 1 of the settlement area), and one collected from the surface of UAQ36. The micro-polish presents a wide extension on the inner valve (and is also visible on its outer side) (Fig. 10: UAQ2.2249, b; CE.10, b). Its pattern is more gradual, being brighter and closer in the highest areas of the micro-topography and quite open (or even untouched) in the crevasses. It evidenced a less fluid working surface and, consequently, a material that was less soft or flexible than leaves – it is more comparable to what has been documented for wood (see above). In this sense, the edge and the relief are extensively rounded and domed, which again is more similar to woodworking use-wear. However, we did observe the formation of invasive striations on the working area – short, shallow, thin, and with a more regular shape in comparison to those present on tools used for the processing of leaves. The striations are also arranged longitudinally to the edge of the valve, confirming a cutting action. Experiments have permitted us to identify this use-wear as potentially resulting from the cutting of palm leaf sheath (i.e. the fibre covering the trunk of palm trees).

Some specimens have been associated with the processing of non-woody vegetal materials (probably leaves or leaf sheaths), without a more precise specification. They represent at least nine valves from levels 5, 6, 7, 8, 9, 10, 11 and 14 at UAQ2; another specimen came from the lowest occupation level of the settlement area at Akab.

3.3.3. Mineral materials

The obtention of ochre powder was distinctly documented on two specimens recovered from levels 11 and 14 of UAQ2 (Fig. 12). The use-wear is located to limited areas of the edge. The micro-polish is more clearly visible when the valve is 45° inclined to the microscope lens; therefore, the material worked must have been hard, making minimal contact with the edge of the valve. The micro-polish appeared very bright and showed a closed pattern. The edge was significantly rounded on one of the specimens (Fig. 12: UAQ2.1676), showing a strong abrasivity: numerous striations. The latter are long, thin, and of varying depth. They are arranged transversally or obliquely to the edge, indicating a scraping action. On both of their ends, we observed the presence of a red material residue – evidencing a short bidirectional movement.

Residue analyses were carried out by Energy-dispersive X-Ray spectroscopy (EDX), using SEM (Fig. 13; Table 5). The strong presence of iron oxide (FeO) on the surface of UAQ2.1676 can be interpreted as the result of scraping ochre (Cuenca Solana et al., 2013; Cuenca Solana et al., 2016). Experiments have shown that the reliefs would show more roundings if the worked ochre nodule had been ductile. In this study, the ochre seems to have been softer for the archaeological specimens than for the reference ones (being massive haematite) (Fig. 12: CU.05). The presence of alumina (Al₂O₃) associated with silicon (Si), magnesium (Mg), and potassium (K) in the sample analysed indicates the exploitation of an argillaceous rock (e.g. shale, mudstone) with a high iron oxide content. Shales and mudstones have a lower hardness (2–3 on the Mohs scale) than haematite (5–6.5), making them easier to work with a mollusc shell. The presence of iron-oxide residues on shell valves showing use-wear associated with the processing of animal skin (see UAQ2.1259 and UAQ2.1689 in Fig. 13 and Table 5) supports the hypothesis that ochre was deliberately used for this treatment.

4. Discussion

4.1. Butchering: mammal or fish?

Functional analysis has evidenced the use of shell tools as knives to cut animal meat, and experiments have confirmed their efficiency for cutting meat, tendons, and disarticulating; however, it remains hard to specify whether the meat concerned was mammals or fish. During the Neolithic, coastal subsistence was based primarily on the consumption

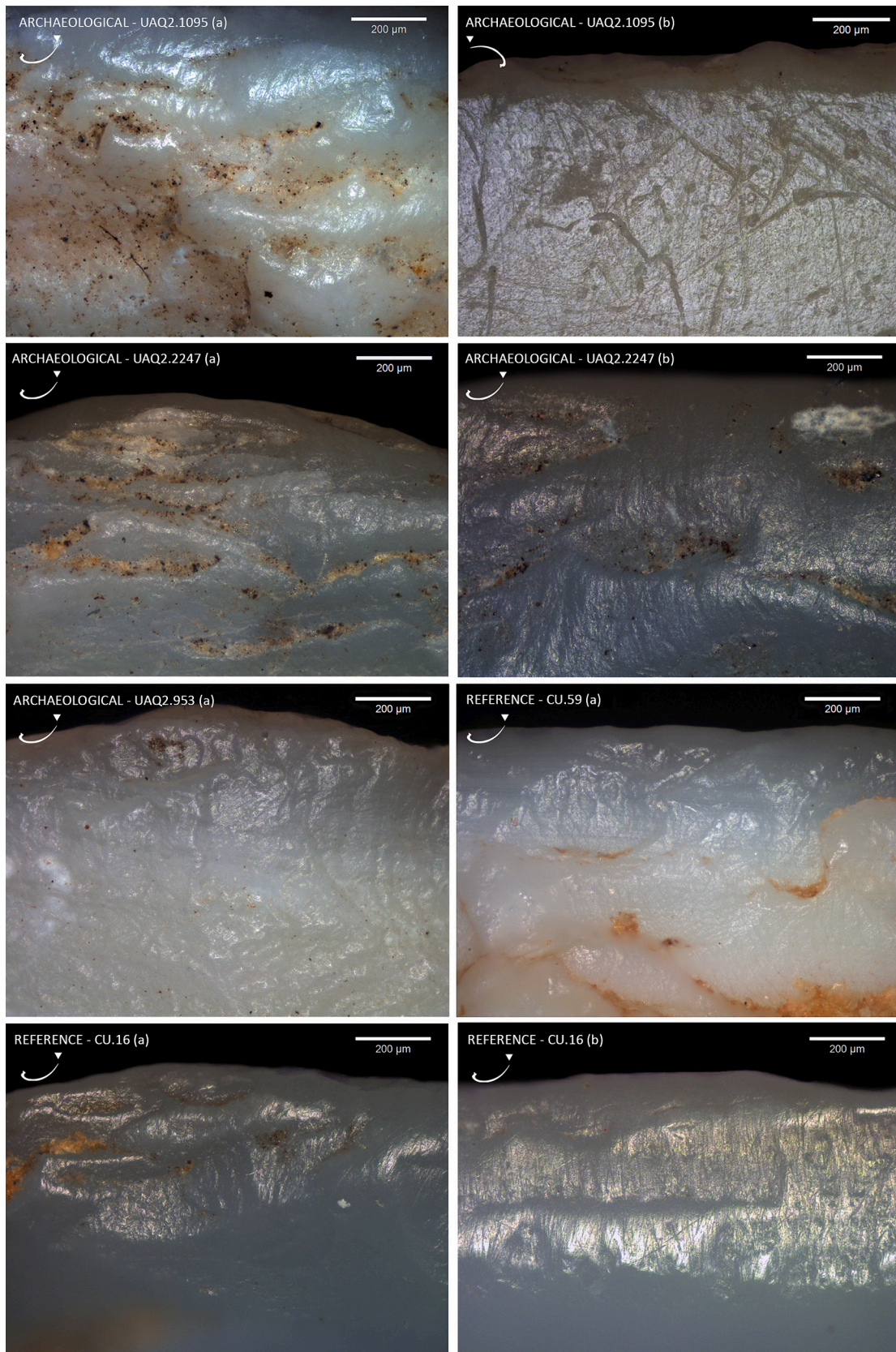


Fig. 9. Comparing archaeological and reference (experimental) use-wear produced by woodworking, at 100×. CU.59. Debarking a branch of fresh false acacia (*Robinia pseudoacacia*), 10 min; CU.16. Debarking a branch of dry false acacia, 10 min.

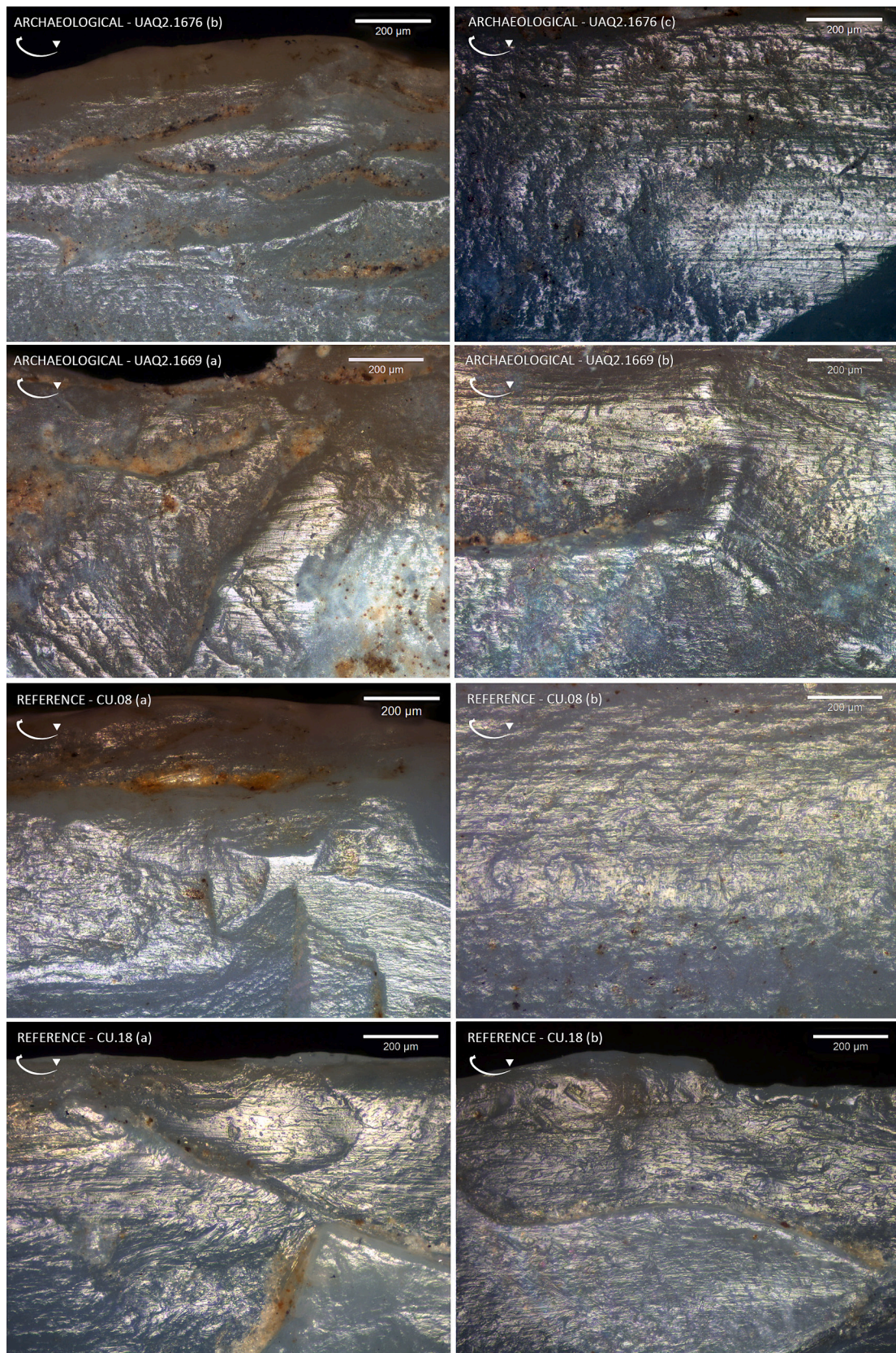


Fig. 10. Comparing archaeological and reference (experimental) use-wear produced by cutting leaves, at 100 \times . CU.08. Cutting half-dry date palm leaves in bulk, 10 min; CU.18. Cutting dry date palm leaves in bulk, 10 min.

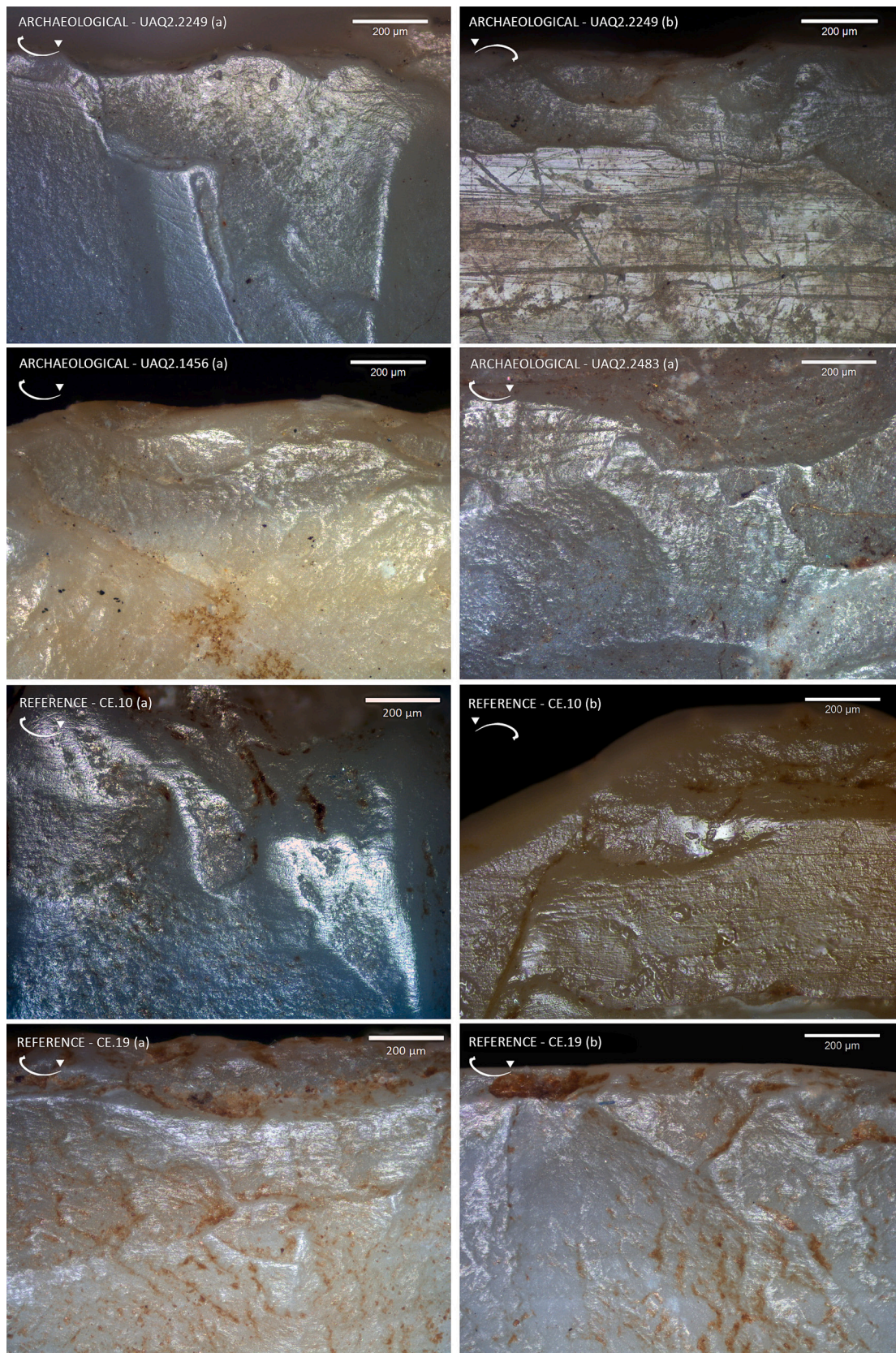


Fig. 11. Comparing archaeological and reference (experimental) use-wear produced by cutting leaf sheaths, at 100×. CE.10. Cutting dry date palm leaf sheaths in bulk, 10 min; CE.19. Cutting a thread made from dry date palm leaf sheath, 5 min.

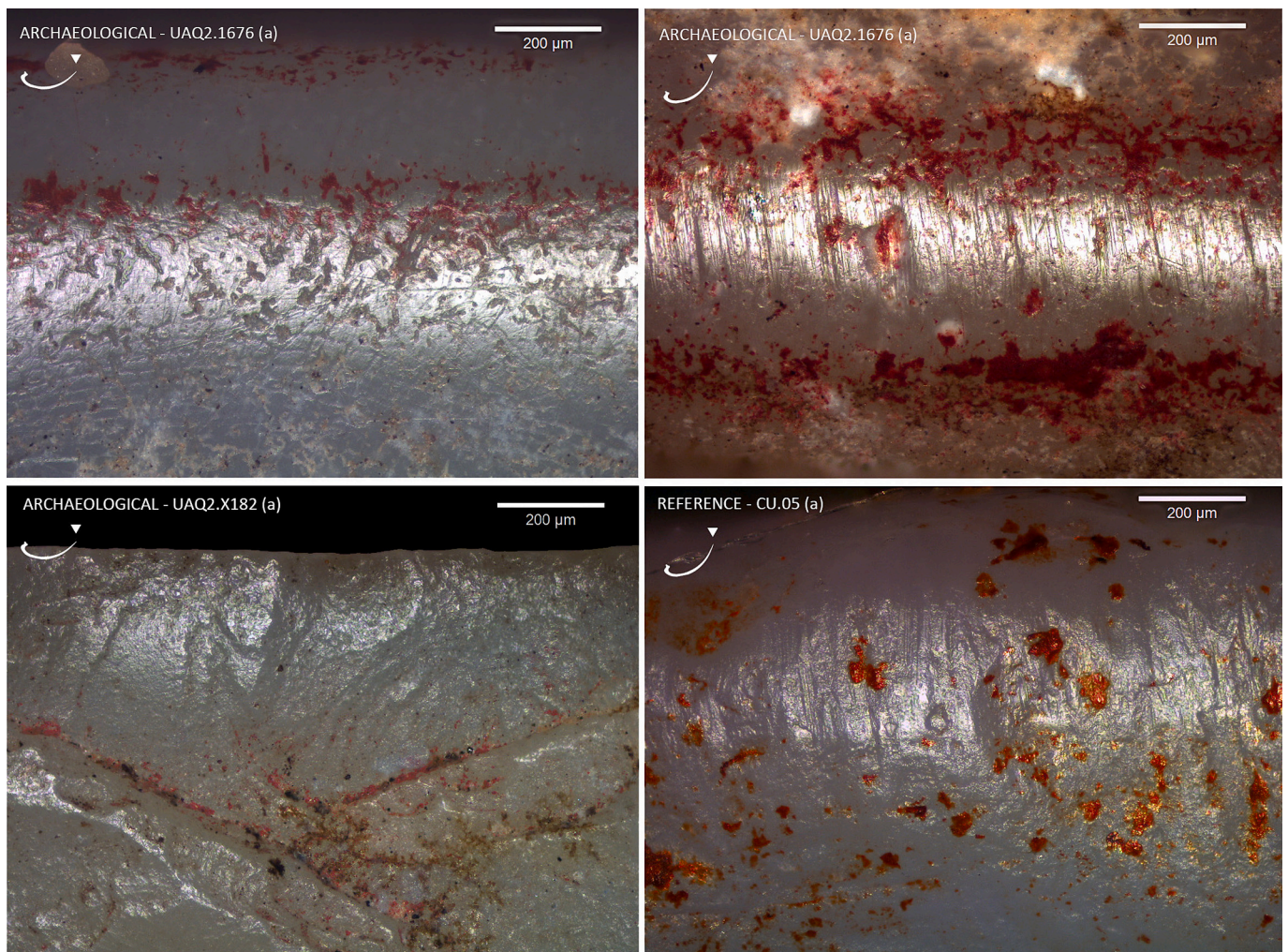


Fig. 12. Comparing archaeological and reference (experimental) use-wear produced by scraping ochre, at 100 \times . CU.05. Scraping a hard haematite nodule, 10 min.

of seafood, which included marine molluscs, fish, crabs, and, in lesser proportions, sea turtles and marine mammals (dolphins, dugongs, etc.) (Mosseri-Marlio, 2002; Lidour, 2023). While fish does not have to be cut prior to being cooked and eaten (or even scaled, just gutted), mammal meat generally requires a more complex process taking into account slaughtering, gutting, skinning, and butchering – especially for medium to large-sized mammals, such as caprines and cattle. The total absence of cut marks and the anatomical repartition of charred skeletal elements and fire marks (on spines and the less fleshy parts of the body, including the head) suggests that fish were directly grilled on coals in a relatively complete form. Until now, cut marks have been observed only on mammal bones within Neolithic faunal assemblages (Lidour, 2018: 328). A more detailed analysis of these marks, however, is necessary to confirm the use of shell knives alongside the corresponding tool kit in lithic material.

Although herding seems to have been performed mainly for the obtention of animal milk at UAQ2 (interpreting the kill-off patterns from Mashkour et al., 2016: fig. 6; see Vigne and Helmer, 2007). One can still expect livestock and game to have been slaughtered on special occasions, such as social or religious ceremonies, as El Mahi (2000: 108) reported in traditional Oman. Furthermore, hunting was more than likely also motivated by non-dietary purposes, including not only the obtention of valuable skins/furs, horns, trophies, traditional pharmacopoeia (Charpentier, 2014: 116; Desse and Desse-Berset, 2000: 91) but also warfare training and prestige.

4.2. Treatment of raw animal skins

Several shell tool specimens were associated with the processing of animal skins. The transformation of fresh animal skin into imperishable fur or leather involves the following steps: skinning the animal, scraping the flesh and the fat from the hypodermis (usually with a sharp and convex blade), unhairing and removing the epidermis (by scraping), tanning (spreading a conservative on the skin), softening (by stretching the skin and using smoothers), and drying. Most activities can be performed on the ground (with a flat and hard support) or on a frame. In this study, the processing of animal skins has been associated with the spreading of ochre using a shell valve, either for treatment or colouring. There is little doubt, therefore, that the shell tools in this study's assemblage were used for the diversified range of activities mentioned above.

The obtention of animal skins is directly correlated to Neolithic herding and hunting activities. The latter are expected to have taken on more importance inland rather than among coastal groups where the economy relied mainly on the exploitation of marine resources. However, animal skins and leather appear to have been important for the confection of various garments, textile reinforcements, bags, pouches, blankets, and tents, as well as for making batter heads and straps for drums, for instance. Whole goat skins are traditionally used as water bags (*qirba* in regional Arabic) and churning bags (*shikwa*), for making butter (*zibdeh*), fermented milk (*laban*), and other dairy products. Threads and strips made from leather can also be used for sewing or

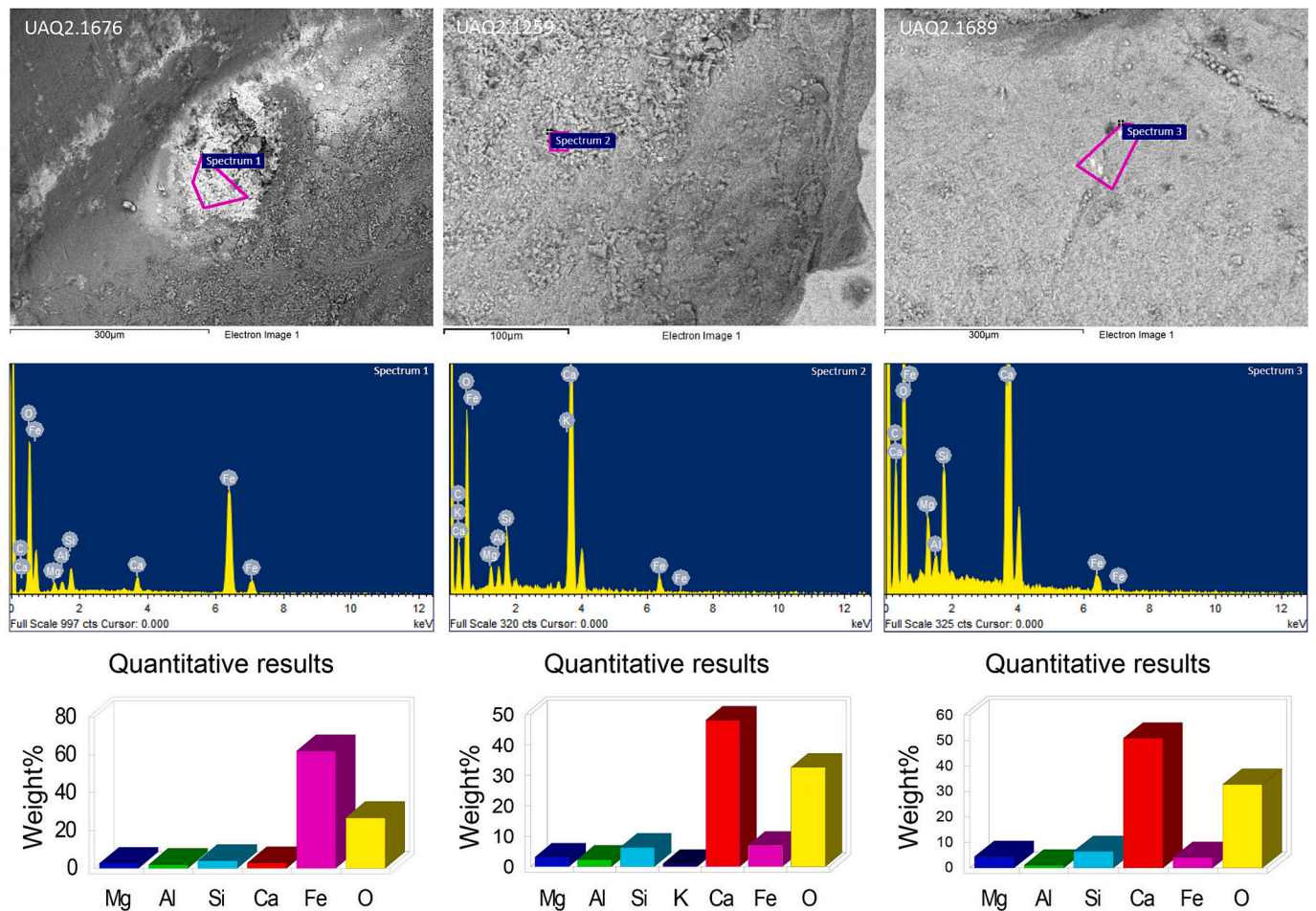


Fig. 13. Results of the residue analyses conducted by energy-dispersive X-ray spectroscopy (EDX) on archaeological shell valves from UAQ2 (UAQ2.1676, UAQ2.1259, and UAQ2.1689). Above. Sampling areas selected for residue analysis (SEM imagery); Middle. Corresponding energy-dispersive X-ray spectroscopy (EDX) spectra; Below. Corresponding bar charts of the elemental compositions performed on the selected sampling areas.

Table 5
Composition of the residues analysed by energy-dispersive X-Ray spectroscopy (EDX).

UAQ2.1676 (<i>C. umbonella</i> - Level 11)				
Element	Weight%	Atomic%	Compd%	Formula
Mg K	2.48	3.22	4.11	MgO
Al K	1.89	2.21	3.58	Al ₂ O ₃
Si K	4.03	4.53	8.62	SiO ₂
Ca K	2.71	2.13	3.79	CaO
Fe K	62.11	35.09	79.90	FeO
O	26.78	52.82		
UAQ2.1259 (<i>C. erycina</i> - Level 8)				
Element	Weight%	Atomic%	Compd%	Formula
Mg K	3.06	3.30	5.07	MgO
Al K	2.26	2.20	4.28	Al ₂ O ₃
Si K	6.28	5.86	13.43	SiO ₂
K K	0.90	0.60	1.08	K ₂ O
Ca K	48.08	31.47	67.27	CaO
Fe K	6.89	3.24	8.87	FeO
O	32.53	53.33		
UAQ2.1689 (<i>C. umbonella</i> - Level 11)				
Element	Weight%	Atomic%	Compd%	Formula
Mg K	4.47	4.77	7.42	MgO
Al K	1.05	1.01	1.99	Al ₂ O ₃
Si K	6.53	6.03	13.97	SiO ₂
Ca K	51.00	33.01	71.36	CaO
Fe K	4.10	1.90	5.27	FeO
O	32.85	53.27		

making necklaces, bracelets, etc. In the Musandam Peninsula (such as at Kumzar, Sultanate of Oman), the use of animal skins is also reported for the decoration of the bow and stern of a particular type of boat (*battil*) (Crocker Jones, 1991: 189).

Although doubts exist as to the materials used for making sails, ancient seafaring in Eastern Arabia is suggested from the Neolithic onwards by both open sea fishing and the colonisation of offshore islands located tens of kilometres off the mainland (e.g. Delma, Marawah, Masirah, and Hallaniyat Islands) (Beech et al., 2016; Charpentier et al., 2013; Charpentier et al., 2022). Although rarely attested in ethnographical records, the ancient use of animal skins for making boat sails is documented by Julius Caesar in *Commentarii de Bello Gallico* when describing the boats of the Veneti – a Gallic tribe from Brittany (Western France) he fought in 56 BCE: “[...] pelles pro velis alutaeque tenuiter confectae, [haec] sive propter inopiam lini atque eius usus inscientiam [...]” (Julius Caesar, 2024: III, 13) – “[...] for sails, they used skins and finely worked leather, [these] on account either of their lack of flax or their ignorance of its use [...]” (pers. trad.). Similarly, no native vegetal taxa encountered in Eastern Arabia consists of the type of material (such as flax, hemp or cotton) for producing fabrics that could have been used for making boat sails during the Neolithic. While animal skins are a serious hypothesis, boat sails could have also been made using goat or sheep wool as documented in medieval Norway (Lightfoot, 1996).

4.3. Woodworking

Woodworking includes various activities, such as debarking,

planing, or logging (transversal actions) and grooving (longitudinal action) – which can be performed either as a technique for separating wooden pieces or for a decorative purpose (engraving, for instance). Sculpting wood involves both transversal and longitudinal actions. Only transversal actions are documented with woodworking in the assemblage studied: debarking and planing activities. The latter could have been performed to produce shafts used for tools (handles) and weapons (spears, bows, arrows, etc.). Other products include furnishings (boxes, frames, containers and supports) and domestic and naval architectural elements (e.g. posts, rafters). In addition, shell tools could have been used to sharpen wooden points used as pikes, for instance.

The production and use of chisels made from the outer lip of *Cypraeassis rufa* (Linnaeus, 1758) have been reported by Charpentier et al. (2016: 358) in Southern Oman. The latter can be compared to specimens from Oceania (e.g. the Solomon Islands) whose use for woodworking tasks (splitting wood) is generally suggested (Tekarawa Radclyffe, 2021). However, technological and functional analyses are necessary to confirm a similar use in Arabia.

Functional analysis conducted on Late Palaeolithic (c. 12–8 ky BP) lithic implements (burins, in particular) from Dhofar (Southern Oman) has evidenced woodworking activities (Hilbert et al., 2018; Hilbert and Clemente Conte, 2021). The use-wear shows a bright polish located on the edge of the tools – described as showing an undulated micro-topography where rounded surfaces have developed on eminences. Striations are oriented perpendicularly to the edge of the tools, evidencing a transversal action. This has been associated with the planing or scraping of hardwood. According to the taxa locally available, worked wood could have belonged to multiple species of acacia-related (*Vachellia* Wight & Arnott, 1834; *Prosopis cineraria* (Linnaeus) Druce, 1914) trees. Other plausible species include the frankincense tree (*Boswellia sacra* Flück, 1867), whose bark and resin are still traditionally exploited as valuable odoriferous products in Southern Arabia.

Pollen and phytolith indices analysis from lacustrine sedimentation (at the Awafi palaeolake, in the Emirate of Ra's al-Khaimah) have shown the predominance of *Prosopis* and *Vachellia* taxa in the Northern UAE by c. 6300 BCE (Parker et al., 2004: 671, fig. 6). The development of an extensive scrub woodland of the latter taxa corresponds to the maximum peak activity of the Southwest Monsoon (or Indian Ocean Monsoon) in the Arabian Peninsula during the Early Holocene – dated between c. 6100 and 5600 BCE by Neff et al. (2001). Although the exploitation of a mangrove ecosystem is already documented by the second half of the 6th millennium BCE at UAQ2 (Méry, 2015; Mashkour et al., 2016), pollen data from the Umm al-Quwain coast documents an important increase in local *Avicennia marina* (Forsskål) Vierhapper 1907 and *Rhizophora* Linnaeus, 1753 populations towards 4500–4300 BCE, within a general context of aridification, as the concomitant development of herbaceous taxa shows (Méry et al., 2019: 231, fig. 8). This phenomenon seems to be correlated to a maximum marine transgression event in the Arabian Gulf (Dalongeville and Sanlaville, 2005; Berger et al., 2013, fig. 8), while a regional shift into a more open landscape is confirmed by both lacustrine and fluvial silt records, from the Awafi palaeolake and a tributary river of the Wadi Yudahay at Mleiha (Emirate of Sharjah) (García Antón and Sainz Ollero, 1999).

From the Neolithic onwards, charcoal assemblages show that the past exploitation of wood has relied mainly on locally available mangroves (both *Avicennia marina* and *Rhizophora* sp.) on the coasts of the UAE and Northern Oman (Willcox and Tengberg, 1995; Tengberg, 2005). In the hinterlands, the main taxa exploited belong not only to acacia-related trees but also to the Christ's thorn jujube (*Ziziphus spina-christi* Linnaeus, 1798) (Biagi and Nisbet, 1992; Tengberg, 1998). The ancient exploitation of the Christ's thorn jujube is also occasionally documented by the presence of fruit stones at some sites, such as at as-Sabiyah H3 (Kuwait) by the end of the 6th millennium BCE (Parker, 2010: 198) and Ra's al-Hamra RH5 during the 4th millennium BCE (Biagi and Nisbet, 1992: 575–576, tab. 3). Although mangrove trees are frequently reported as having small twisted trunks and branches,

straighter specimens are usually encountered on the landward zone (pers. obs.). The latter are suitable for the production of architectural elements, for instance. Date palm tree (*Phoenix dactylifera* Linnaeus, 1753) fronds and trunks were also probably used in the architecture; however, the trunk is not properly made of “real” wood (monocot) and thus needs special treatment prior to being worked for making planks or sculpted items.

4.4. Weaving, basketry, and ropes

Basketry is a very important handcraft in traditional Arabia. Ethnographic studies have reported the extensive use of date palm tree fibres to produce various everyday items. Palm leaflets are traditionally woven to make mats, baskets, and hand fans (Fig. 14.A), while the palm mid-ribs, which are stronger and more rigid, are mainly used for making fish traps (*gargur*). Palm fronds are cut from the tree using a pruning curved handsaw and are then left to dry in the sun for a few days. The palm leaflets are separated manually from the rachis (or mid-rib) and are generally split in two along their longitudinal axis. They may also have been dyed to make decorative patterns when weaving (Crocker Jones, 1991: 145–147), such as with ochre and other metal oxides-based pigments, during Protohistory. Palm work probably has its origins fairly far back in time in this region.

Palmae phytoliths have been identified from the Awafi palaeolake sequence, within deposits dated to 6000 BCE (Parker et al., 2004), and from the as-Sabiyah H3 site, occupied by the second half of the 6th millennium BCE (Parker, 2010: 192–193) – the latter are identified as belonging to the date palm (*Phoenix dactylifera*), as it is the only native species of palm tree present in the Arabian Gulf region (Western, 1989). The earliest evidence of the exploitation of wild populations of palm trees consists of charred or mineralised stones from 6th millennium BCE contexts at as-Sabiyah H3 (Parker, 2010: 198), as well as from the islands of Delma and Marawah, off the Abu Dhabi Emirate mainland (Beech and Shepherd, 2001; Beech et al., 2022). These stones are interpreted as the remains of dried fruits supposedly exchanged between the hinterlands and coastal sites (Gros-Balthazard et al., 2017).

Evidence of basketry is documented within Bronze Age contexts: imprints of mats and baskets made from vegetal fibres have been identified on bitumen coatings at Ra's al-Jinz RJ2 (late 3rd millennium BCE, Sultanate of Oman) (Cleuziou and Tosi, 2020: figs. 168, 179–180) and Saar (late 3rd or early 2nd millennium BCE, Bahrain) (Höjlund, 1995; Connan et al., 1998: fig. 6). A mineralised basket is also documented from Ra's al-Hadd HD6 (Cleuziou and Tosi, 2007: 93, fig. 81) – it is a round-based coiled basket comparable to traditional handcraft baskets made of palm spadix stems (*esqa* in regional Arabic) (inflorescences) (Crocker Jones, 1991: 174). Further evidence of baskets made from weaving date palm leaflets and, possibly, leaf sheaths have also been found from Iron Age contexts (occupied by c. 1200–1000 BCE) at Salut (Sultanate of Oman) (Bellini et al., 2011: 2783, fig. 3; Degli Esposti, 2021).

The leaf sheath (*leaf*) is a fabric-like fibre exploited from the surface of the palm trunk. It is used principally for the production of ropes (*kambar*). The fibre can be relaxed after being soaked in water or by using a wood or a stone hammer (pers. obs. KL). It is twisted in the fingers and rolled in the palms (Fig. 14.B). These ropes can be used for various purposes such as in domestic or naval architecture and for making fishing nets. The palm leaf sheath is traditionally used as a filter in coffee pots and for stuffing mattresses, cushions, and camel saddles (Heard-Bey, 2016: 176).

Imprints on bitumen coatings from Dosariyah (Saudi Arabia) (early 5th millennium BCE) (Drechsler, 2018: 336, fig. 16.4) and Ra's al-Jinz RJ2 (c. 2350 BCE) show that bundles of reed or palm rachis constituting the hull of boats were tied together using ropes; the latter were also used for sewn-plank boats from 2200 BCE (Cleuziou and Tosi, 2020: 294–295, figs. 181, 183). Mineralised pieces of rope have been documented from Neolithic and Bronze Age contexts at Ra's al-Hamra RH5



Fig. 14. A. Emirati woman braiding dry palm leaflets for making baskets (© Free_lancer / Dreamstime); B. Emirati man making ropes with palm leaf sheath at the Abu Dhabi Maritime Heritage Festival (© Charles O. Cecil / Alamy Stock Photo).

and RH6 (Munoz, 2020: 122–123, fig. 7.2; Marcucci et al., 2021: figs. 6.4 and 7.37), Ra's al-Hadd HD6 (Cleuziou and Tosi, 2007: 93, fig. 82), and possibly at Ayn as-Sayh site C (Saudi Arabia) (McClure and Al Shaikh, 1993: fig. 11).

4.5. The exploitation and uses of ochre

The use of shell tools for scraping and spreading ochre on animal skins is a newly documented activity within the Neolithic technological processes of Eastern Arabia. Ochre has a multi-purpose function. Its use as a pigment has been reported worldwide in both ethnographical and archaeological literature, but it is also known, for example, as a traditional body sunblock, insect repellent, and odour masker used by hunters. It can be used for colouring and softening animal skins, as documented among the Konso from Southern Ethiopia, when mixed with castor oil (*Ricinus communis*) (Weedman Arthur, 2010: 231). Similarly, among the Aonikenk and the Kawéskar from Patagonia, as well as the Selk'nam from Tierra del Fuego (Isla de Xátiva), ochre was mixed with grease and smeared on guanaco (*Lama guanicoe*) skins used to make clothes and tents (Musters, 1872: 197; Gallardo, 1910; Lothrop, 1928, Gusinde, 1982: 194; Gusinde, 1986: 400; Gusinde, 1991: 192; Emperaire, 1955). Ochre is also presented as a substitute for the tanning process by Belkin (2002: 17'10), although this is highly debated (Watts, 2002; Henshilwood and Marean, 2003). Natural tannins consist of polyphenolic biomolecules (mainly occurring in vegetal tissues) that bind to collagen proteins present in the skin precipitating them – ochre does not have these properties. Nevertheless, when associated with organic molecules, iron(III) oxide is responsible for producing peroxide and hydroxyl radicals (OH^{\bullet} radicals), which are highly reactive and efficiently eliminate viruses and bacteria, including *Escherichia coli* and *Salmonella* spp. (Tributsch, 2016). Ochre, therefore, has strong antibacterial and antifungal properties, which could partly replace the effects of tannins by preserving the skin from decay – see the experiments of Audouin and Plisson (1982). By extension, the antifungal effect of iron(III) oxide also finds application in wood and textile treatments – in Scandinavia and East Canada (Newfoundland and Labrador), ochre was traditionally mixed with vegetal, fish, or seal oil for painting houses, as

well as to put on boat sails and fishing nets for their long-term durability (Townsend, 1910: 72–73; Jarvis and Barrett, 2019).

The production and use of ochre have been reported on several occasions at Neolithic sites in Eastern Arabia. Haematite pebbles showing abrading facets have been interpreted as raw materials exploited for the obtention of ochre powder at Dosariyah (Drechsler et al., 2018: 302, fig. 13.1) – further examples are documented at other sites of the region, such as at Ra's al-Hamra RH5 (Marcucci et al., 2021: 153–154, fig. 7.33). Fragments of raw haematite have also been reported from Delma (Emirate of Abu Dhabi, UAE) (Beech et al., 2016: 14), Wadi Shab GAS1 (Sultanate of Oman) (Munoz and Usai, 2020: 67), and Suwayh SWY1 (Charpentier et al., 2003: 17). The production of ochre powder from raw haematite has been associated with the use of ground stone implements (e.g. identified as millstones, grinding stones, etc.) at Shagra (Qatar) (Inizan, 1988: 119, fig. 56 n°2) and Dosariyah (Drechsler et al., 2018: fig.13.3).

At Dosariyah, red stains were observed on the inner side of several Mesopotamian potsherds. These have been identified as being composed of iron(III) oxide by residue analysis using X-Ray micro-diffraction (Drechsler et al., 2018: fig.13.7, 13.8). It has been suggested that potteries were used for the storage either of raw haematite pebbles – in this sense, Carter (2010: 199) has listed 'red ochre' as a product potentially exchanged between coastal Arabians and Mesopotamians during the Neolithic – or of some products associated with ochre, such as food. Ochre is traditionally used as a conservative for preserving dried wild fruits by Aboriginals from Northern Australia (Berndt and Berndt, 1977: 114; Laudine, 2009: 70).

Several sherds with red stains on their outer side from Dosariyah have been interpreted as palettes. In addition, ochre-based paintings were used for the decoration of plaster vessels at Marawah and Delma (Beech et al., 2022: 14). Sharpened bone tools sometimes show red stains on their tips, suggesting their use as cosmetic applicators (Phillips, 2002: fig. 11; Salvatori, 2007: 38), possibly for tattooing (Duarte, 2014). There is also some evidence of the use of ochre in association with personal adornments – for instance, potential ochre stains have been observed on shell beads from Dosariyah (Drechsler, 2018: fig. 15.4.a) and Buhais BHS18 (Emirate of Sharjah, UAE) (De Beauclair, 2008: fig.

9). At the latter site, 18 disc beads evidenced red bands that have been interpreted as the residue left by (leather, sinew?) threads coated with ochre. A similar interpretation has been suggested for specimens from Middle Stone Age sites in Africa and the Middle East (D'Errico et al., 2010).

A distinctive red-coloured lens was exposed during the 2012–2013 excavations at Ra's al-Hamra RH6 (Area A) (Marcucci et al., 2014: fig. 2/I). The excavators interpreted it as either the result of an intense and localised burning activity or being associated with some taphonomical processes. Is there a possibility that this red patch is linked to the production or the use of ochre powder at the site? This remains uncertain, although activities involving the use of ochre are highly expected on Neolithic sites, especially when considering the evidence previously discussed. At the Magdalenian campsite of Pincevent (France), red-stained floors have been interpreted as the remains of ochre-coated animal hides used as floor covering. Residues of red staining were also identified on lithic end-scrapers retrieved from the same site, suggesting the use of ochre for processing animal skins (Keeley, 1980: 171). The deliberate spreading of an ochre solution has been observed on many dugong bones composing the lower level of the ceremonial structure at Akab (Méry et al., 2009: 702; Méry and Charpentier, 2012: 74), also indicating its use in ritual practices.

4.6. Comparisons with other tool technologies

The results of the present study show that the shell tools had a generalist function, although preferentially used for the processing of vegetal fibres at UAQ2, and were produced with minimal effort (showing a low cost of production in comparison to the lithic debitage). The shell collection cannot be considered opportunistic, since the large and complete valves were only selected from specimens washed up on the shore rather than from among readily available dietary discards. Many shell tool specimens show a significant reduction in volume, suggesting their use over a long duration and, potentially, their re-sharpening.

An 'expedient tool' is defined by Binford (1977) as not showing any modification of its original form (its natural shape in the case of a marine shell). It differs from a 'curated tool' concerned with preconceived modifications intended to improve its efficiency for specific activities. Curated tools, therefore, are more likely to be repaired or re-sharpened if their efficiency is reduced after an extended use. Conversely, when an unworked shell tool is altered beyond further use, because its characteristics of shape and robustness have been exploited to their maximum, it can be directly replaced by a new specimen (Cuenca Solana and Clemente Conte, 2017: 296; Cuenca Solana et al., 2011: 79). In this sense, the shell tools from this study should not be considered as 'expedient tools' because they could have sometimes (but not systematically) constituted a substitute due to the lack of raw lithic material (Toth and Woods, 1989).

However, the shell tools must be put into perspective with the parallel use of lithic implements at the same sites, particularly scrapers. Tile knives are large lithic tools showing a distinctive scalar-like retouch along one of their longest sides (frequently convex). They are made from large flakes or tabular flint and are attested at a great number of Neolithic coastal sites in the Arabian Gulf (Edens, 1982: pl. 102, B; Kapel, 1967: 21, fig. 44b; Méry and Charpentier, 2013: 75). Conversely, their total absence at interior sites (Edens, 1988: 21) suggests their use in activities exclusively carried out on the coast. Shell tools show a large and convex working edge compared to tile knives, suggesting similar uses. This assertion has, however, yet to be supported by proper functional analysis of the lithic tool technology. In contrast, bone tools are still poorly documented in the Arabian Peninsula despite the evidence of diversified products, particularly at Dosariyah: including points, punches, chisels, and needles made from long bone shafts (Drechsler, 2018: 310–317). It is also worth noting a remarkable optimisation of enamel-like structures obtained from sharks and stingrays: shark teeth,

sawfish rostral teeth, and stingray barbs (Charpentier et al., 2009), although more research is necessary to determine the precise nature of their use. Bone tools have yet to be linked to cutting or scraping functions and might constitute a distinct range of tools in themselves.

5. Conclusion

The present study constitutes the first insight into the function of ancient shell tools in the Arabian Peninsula. Functional analysis (Semenov, 1964) was performed to compare archaeological and reference shell tools, allowing us to highlight multiple productive activities among the coastal Neolithic groups within the study area. The latter are associated with butchering and woodworking tasks, cutting vegetal fibres (probably for basketry), and processing animal skins, linked to the exploitation and use of ochre. Further experiments are required for a complete reconstruction of the stages of operational sequence involved in extracting and treating animal skins to make furs and leather. This work should also focus on the documentation of a greater variety of animal and vegetal taxa processed, especially those found in the study area on the basis of ethnographical studies or, if required, personal interviews regarding traditional handicrafts.

The analysis only covered the assemblage of shell tools retrieved from Neolithic sites of the Umm al-Quwain area in the Northern UAE; therefore, further material needs to be investigated to provide a more diversified and complete knowledge of the production and use of shell tools in Eastern Arabia. To date, other available corpus include Marawah MR11, Ra's al-Hamra RH6, and Suwayh SWY1 for the Neolithic, as well as specimens from Bronze Age sites such as Shimal, Masafi 5, and Suwayh SWY3. On another note, as it is probable that not all the shell tools from the malacological assemblages of many other archaeological sites have yet to be identified and sorted, we hope that this study will motivate archaeologists working in the Arabian Peninsula to identify these peculiar artefacts and consider their importance in documenting the productive activities of past human societies.

A revised analysis of the malacological assemblages is also necessary for assessing the presence of unworked shell tools (corresponding to 'expedient tools'). Some tasks do not require the natural characteristics of a marine shell to be modified – transverse actions (such as for scraping or planing) do not generally require a sharp edge, whereas longitudinal ones do, especially when they are intended for cutting tasks (Cuenca Solana et al., 2011: 79). In this sense, preliminary observations have suggested the potential use of unmodified valves of ark (*Anadara* Gray, 1847), cockle (*Vasticardium lacunosum* (Reeve, 1845)), and scallop (*Mimachlamys sanguinea* Linnaeus, 1758) as shell tools. The future study of the latter would involve new experimental works. Smaller species of bivalve could also have been used and should therefore also be analysed.

Of course, further functional analyses should also cover other tool technologies, including lithic implements, as their functions are still greatly under-documented in the Arabian Peninsula. Comparisons with shell tools will allow a better understanding of their uses within technological processes. In addition, the persevering use of shell tools during the Bronze Age must be questioned for societies where copper-metallurgy was already well developed and allowed for the production of a wide range of efficient tools using a re-usable material (Lidour et al., 2023).

The Final Palaeolithic cultures should also be further investigated, particularly regarding their exploitation of marine resources. The Natif 2 cave (Dhofar, Sultanate of Oman) demonstrated a significant reliance on marine resources during the 9th/8th millennium BCE, preceding the regional Neolithic (c. 6500 BCE) (Charpentier et al., 2016). However, while shells were consumed and used as ornaments, there is no evidence of shell tools at this site. Similarly, two sea snail shells (Turbinidae) have been found in a level dated to c. 8500 BCE at the Faya FAY-NE1 (Emirate of Sharjah, UAE) rock-shelter (Armitage et al., 2011), supporting the hypothesis of a relatively recent development of coastal adaptation by human cultures in the Arabian Peninsula favoured by the onset of wetter

climatic conditions and a higher sea level at the beginning of the Holocene (Lidour, 2023). Further research still has a long way to go, however, in investigating the role of marine resources in the cognitive and cultural developments of past human groups in this region, especially given the established ancestry of marine adaptations in other regions of the world.

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Kevin Lidour: Writing – review & editing, Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation, Conceptualization. **David Cuenca Solana:** Writing – review & editing, Validation, Resources, Methodology, Investigation, Data curation. **Jesús Setién Marquínez:** Validation, Supervision, Project administration, Funding acquisition. **Ana Cimentada Hernández:** Resources, Investigation, Formal analysis. **Vincent Charpentier:** Validation, Supervision, Project administration, Funding acquisition. **Sophie Méry:** Validation, Supervision, Project administration, Funding acquisition.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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