Journal of Archaeological Science: Reports 57 (2024) 104581

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Neolithic arrowheads and Bronze Age industry at Saruq al Hadid, UAE

Amal Al Kassem [a,b,*], Huw S. Groucutt [a,c,d,e], Felix Reize [f], Mariam Ali Alsuwaidi [g], Badar Mohamed Abdulla Al Ali [g], Mansour Boraik Radwan Karim [g]

[a] *Institute of Prehistoric Archaeology, University of Cologne, Cologne, Germany*
[b] *ARCO Research Center, Abu Dhabi, United Arab Emirates*
[c] *Department of Classics and Archaeology, University of Malta, Msida, Malta*
[d] *Extreme Events Research Group, Max Planck Institutes for Geoanthropology, Chemical Ecology, and Biogeochemistry, Jena, Germany*
[e] *Department of Archaeology, Max Planck Institute of Geoanthropology, Jena, Germany*
[f] *Institute for Integrated Natural Sciences, University of Koblenz, Germany*
[g] *Antiquities Department, Dubai Culture & Arts Authority, Dubai, United Arab Emirates*

ARTICLE INFO

Keywords:
Neolithic
Arrowheads
Microliths
Bronz Age
Techno-typological analyses
Saruq Al Hadid
Dubai
Arabia

ABSTRACT

Among growing indications of human occupation in the coastal regions of southern and southeastern Arabia extending into the Neolithic and beyond, this study introduces new archaeological evidence, namely bifacial arrowheads and trihedral points, suggesting human presence at the Saruq Al-Hadid site in the fringe of Rub' Al Khali during the mid-Holocene period. Human activities in the site are dated to the 'Dark Millennium' and Bronze Age. We suggest that Contexts 10 and 8 are an extension of the activities of the Horizon IV, located 20 m to the West. This is evidenced by the similarity in the simple reduction strategies applied in both to produce microliths, which are dated in both as well to the Wadi Suq and Late Bronze Age periods. However, there is a notable difference in bone density, with Horizon IV exhibiting higher density. Moreover, the almost complete absence of end products in Contexts 10 and 8 contrasts with their prevalence in Horizon IV. And the absence of final products in Contexts 10 and 8, with their high percentage in the Horizon IV. Taken together, these indications, coupled with the low density of lithics in Contexts 10 and 8 as well as those unearthed in area F, suggest that Horizon IV was the focal point of activities during the Wadi Suq period and the Late Bronze Age.

1. Introduction

Several researchers propose that the clustering of archaeological sites along the southeastern Arabian Gulf coast can be attributed to periods of aridity, which compelled inhabitants of the inland to contract into the coast, highlands (Hajar Mountains), and oases during various phases of the Holocene (Potts, 1990, 2001; Uerpmann, 2003; Parker et al. 2006a, 2006b, 2016; Drechsler, 2009; Casana et al., 2009; Rose, 2010; Rose et al., 2019; Preston et al., 2015; Petraglia et al., 2020). The archaeological record from the inland and coastal regions of southeastern Arabia consistently indicates the presence of the Fasad point during humid periods of the early Holocene across southern and southeastern Arabia, despite variations in technology between these archaeological contexts (Kallweit et al., 2005; Uerpmann et al., 2009; Casana et al., 2009; Charpentier and Crassard, 2013; Uerpmann et al., 2013). Drechsler (2009) links the climatic downturn recorded between 8.2 – 8.0 ka BP to the transition between earliest Holocene "Qatar B/Fasad" and the preceding Neolithic "Arabian Bifacial Tradition" (ABT), which was interpreted as a shift from hunting and gathering to herding. A significant rise in the number of archaeological sites dated to the mid Holocene is observed, which are characterized mainly by the Arabian Bifacial Tradition (referring to trihedral point and bifacial arrowheads). While both bifacial arrowheads and trihedral points are found together in the mid sixth millennium BC in Marawah 11 (MR11) in Abu Dhabi (Beech et al., 2008), only bifacial arrowheads were found in Ghagha (GHG0014) in Abu Dhabi dating to mid seventh millennium BC (Al Hameli et al., 2023). Trihedral points occur in Yemen and spread across southern Arabia, from the Red Sea to the Gulf coast dating back to the mid-seventh millennium BC (Charpentier, 2004; Crassard et al., 2006; Crassard and Petraglia, 2014), which are bifacially, and sometimes trifacially, shaped, with a triangular cross-section (Crassard and Petraglia, 2014). The sudden disappearance of the ABT was noted at the beginning

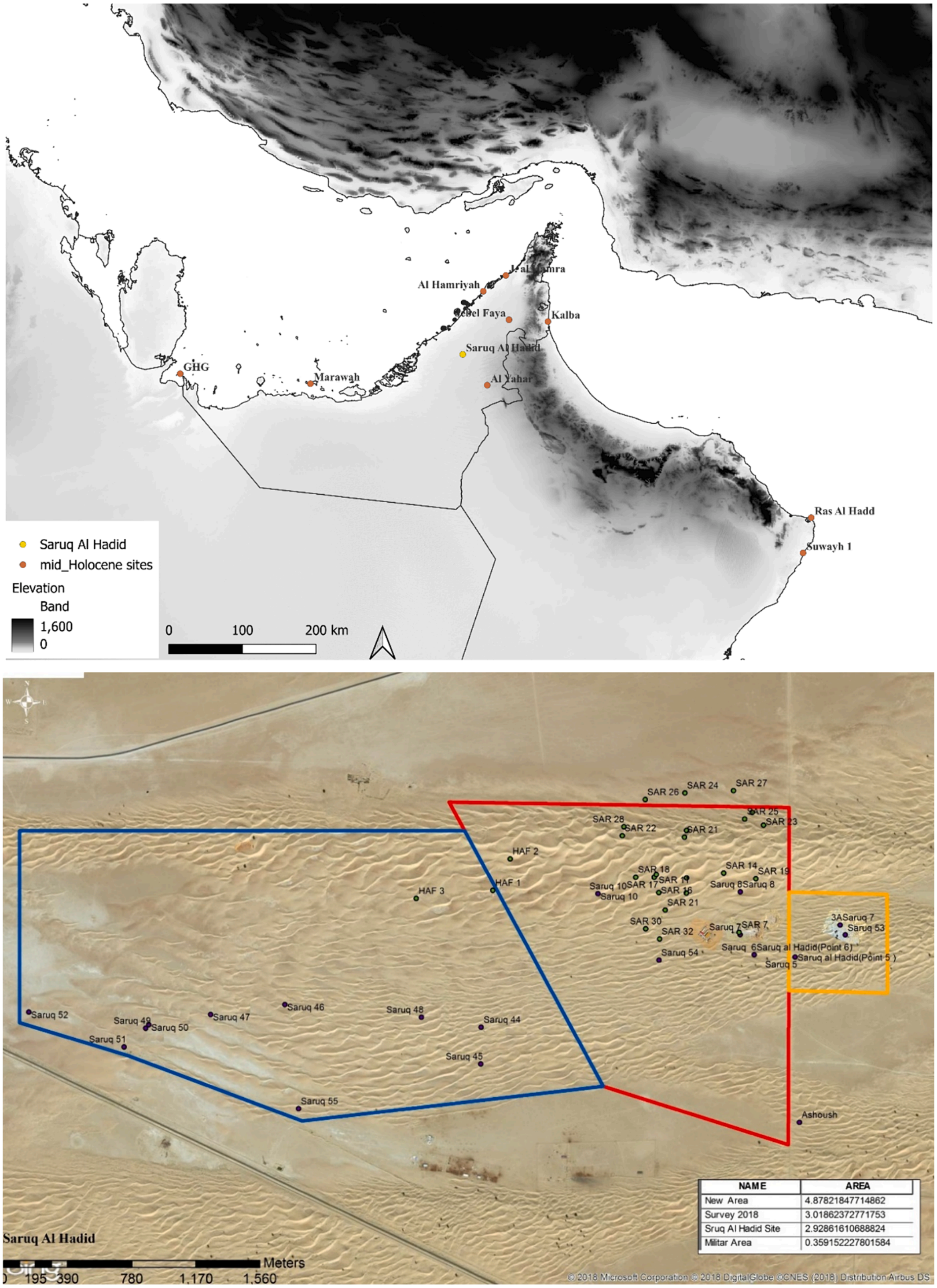
---

* Corresponding author.
E-mail addresses: aalkass3@uni-koeln.de (A. Al Kassem), huw.groucutt@um.edu.mt (H.S. Groucutt), freize@uni-koblenz.de (F. Reize), mariam.alsuwaidi@dubaiculture.ae (M. Ali Alsuwaidi), bader.alali@dubaiculture.ae (B. Mohamed Abdulla Al Ali), mansour.radwan@dubaiculture.ae (M. Boraik Radwan Karim).

https://doi.org/10.1016/j.jasrep.2024.104581
Received 25 December 2023; Received in revised form 5 May 2024; Accepted 6 May 2024

of the Dark Millennium c. 5.9 – 5.2 ka, followed by a scarcity of archaeological evidence in the inland (Uerpmann, 2003). The use of lithics reappeared in the Bronze Ages and Iron Age in Yemen and UAE, where a microlith industry has been recorded (Crassard, 2008; Contreras et al., 2016; Rempel et al., 2019; Moore et al., 2022).

The Saruq al-Hadid 7 (henceforth SH) is located on the fringe of the Rub Al-Khali desert (Fig. 1). Since 2002 the SH and its vicinity have been the focus of research (Qandil, 2003). Architecture Heritage and Antiquates Department (henceforth AHAD) – Dubai Municipality carried out sporadic surveys in the SH and Al Ashoosh sites in the 2000 s (Fig. 1) (Qandil, 2003). The surveys resulted in recording scattered artefacts amidst an expansive area attributed to different chronological periods embedding in dunes towering up to 6 m in height, including Neolithic stone artefacts. Since then, SH has been subjected to intense archaeological investigations by national and international expeditions, of which the Jordanian Department of Antiquities in cooperation with AHAD (Al-Khraysheh and Nashef, 2007), the German team during two seasons 2015 and 2015–2016, the University of New England, Australia



NAME	AREA
New Area	4.87821847714862
Survey 2018	3.01862372771753
Sruq Al Hadid Site	2.92861610688824
Militar Area	0.359152227801584

Fig. 1. Top. Location of SH site among some of mid Holocene sites (diva-gis.org) Ras Al Hadd and Suwayh 1 (Oman), Al Yahar, Marawah, GHG, Jebel Faya, Al Hamriyah, Al Hamra, Kalba and Saruq Al Hadid (UAE). Coordinate System used: WGS 84/EPSG 4326. Below. The main map show distribution of SH sites based on frequent surveys in 2000 s (by AHAD).

from 2015 to 2016 (Weeks et al., 2017,2019), the University of Sanisera Archaeological Institute between 2016 and 2018 (Valente et al 2019; 2020), and the University of Seville in 2019.

In 2006, the University of Arkansas-USA, in collaboration with AHAD, undertook an extensive survey in the Dubai desert, including SH and Al-Ashoosh sites. The region's near-total lack of Lower Palaeolithic artifacts makes the discovery of a lone handaxe particularly noteworthy, meriting considerable attention (Casana et al., 2009), along with the presence of Neolithic arrowheads (Casana et al., 2009, p. 35; Contreras et al., 2016).

The excavation efforts have unearthed diverse phases of human activity, predominantly dating back to the Bronze and Iron Ages. Although the early Iron Age witnessed a dramatic change in the nature and intensity of human activities, SH was a 'persistent place', continually inhabited from the Umm an-Nar period through the early Iron Age. There is also evidence suggesting earlier use during the Hafit period and possibly later use from the late first millennium BC to the early Islamic period. However, the Bronze age layers confined to areas G and F of the site (Herrmann et al., 2012; Rempel et al., 2019; Weeks et al., 2017; Valente et al., 2020). SH has been the subject of numerous studies, however, the majority of them did not delve into the lithic industry. One notable exception is the work published by Moore et al. (2020, 2022).

For a long time, SH and its vicinity have remained a focal point for studies concerning the Bronze Ages and Iron Ages, yet there has been a notable scarcity of research on the site during the mid-Holocene. As a response to the growing body of studies positing an increase in occupation of the coast, upland, and oases during the mid-Holocene and post-Dark Millennium, attributed to contraction into coastal areas prompted by aridity, we undertake an examination of a sample of trihedral points and bifacial arrowheads sourced from the SH site. This analysis aims to situate the site within the broader context of relevant discoveries in the region. Additionally, we describe the stone-flaking technology in Contexts 10 and 8 unearthed during our excavation of SH in the season 2022–2023, dating back to the Bronze Age. We propose that our sample is an extension of the microlithic industry identified within dense middens of animal bone in Horizon IV (Moore et al., 2020, 2022), which is the centre of Bronze Age hunting activities. Finally, the common theory suggests that interior regions were abandoned during the Dark Millennium. Nevertheless, this site presents evidence of human activities dating back to the fourth millennium.

2. Materials and methods

AHAD discovered over 200 bifacial arrowheads and trihedral points in surveys of Saruq Al-Hadid, we were provided with 12 samples for an initial examination, with the understanding that further analyses will be conducted in subsequent studies. The sites where Neolithic materials were discovered are in close proximity to Saruq Al-Hadid-7, which underwent excavation in the 2000 s (refer to Map 1 and Table 1).

The term "Arabian Bifacial Tradition" (ABT) was established to describe a wide range of projectile points and diverse bifacial pieces after the discovery of numerous surface artifacts in various areas of Arabia, primarily in the Rub' Al-Khali (Edens, 1982). The ABT is delineated as involving the utilization of pressure retouch on bifacial blanks and tanged points with barbs (Edens, 1982).

However, the term ABT is unreliable typologically because it covers a broad array of products and materials (Crassard and Drechsler, 2013). Charpentier (2004) discriminates between two different types of the projectile points in Marawah site, "Arabian Bifacial Tradition" and trihedral points based on definition of trihedral point descripted by Caton-Thompson (1953), Sordinas (1978) and Méry and Charpentier (2002). From their descriptions, we summarize the definition of the trihedral arrowhead in points have a slender silhouette, formed by trihedral semi-abrupt retouch results in a triangular cross-section. Following this discrimination, we identified 9 arrowheads attributed to type "Arabian Bifacial Tradition", and 3 Trihedral arrowheads from SH (Table 1).

Bronze Age lithics were uncovered during our investigation of SH in season 2022–2023. We conducted excavations in squares W3, W2, X3, and X2, with partial excavation also carried out in areas X1 and W1 within Area G (Fig. 2).

We labelled the identified stratigraphic units as Contexts following the AHAD documentation method. There are 12 distinct archaeological Contexts (Fig. 3), each briefly described. Then, we will provide detailed explanations of the lithics-related Contexts (Contexts 10 and 8).

The uppermost Contexts (1–5) were formed by sand accumulation during the Islamic and Iron Ages periods. The limited occurrence of the thin Context 7 in small parts of the excavated areas, coupled with the mixing of materials from Contexts 6 and 8, prompted us to infer that Contexts 6 and 8 likely belong to the same chronological phase. Distinguishing between them was challenging due to excavation difficulties in the sandy site.

After the removal of Context 8, a homogeneous layer of pure sand, identified as Context 9, became apparent across all squares, covering the underlying gravel layer of Context 10. While removing Context 10 in the East represented by X2, two rows of stones were revealed, exposing a well drilled into the gypsum layer, as later identified. Context 11 consists of the backfill accumulation from the well, distributed solely adjacent to the well on its south, west, and north sides. Lastly, Context 12 refers to the virgin gypsum crust, showing slight indications of human activity directly on its surface (further formation about archaeological layers and their interpretation see Alkhalid et al., submitted).

Stone artifacts were exclusively discovered within Contexts 10 and 8, which were collected from 3 mm sieves or collected from the deposits at the moment of discovery. Context 8 shows a horizontally expansive occupation layer visible across all squares, abundant with discarded materials such as bone fragments, pottery sherds, and stone artifacts. The layer's thickness varies across squares, ranging between 5 and 15 cm, with an irregular distribution of discarded materials, exhibiting varying concentrations. Notably, within Context 8, the most prominent

Table 1
Bifacial arrowheads and trihedral points collected from SH.

Nr.	GR	type	Length cm	Width cm	Thickness cm	Year of discovery	site	Raw material
1	308	Bifacial arrowhead	2.9	1.8	0.3	2004	SH 45	Flint
2	480	Bifacial arrowhead	2.1	1.8	0.3	2005	SH 49	Flint
3	378	Bifacial arrowhead	2.8	1.6	0.4	2005	SH 49	Flint
4	520	Bifacial arrowhead	3.1	1.4	0.5	2005	SH 52	Flint
5	525	Bifacial arrowhead	2.8	1.4	0.5	2005	SH 51	Flint
6	799	Bifacial arrowhead	4.5	1.6	0.3	2006	SH 49	Flint
7	4305	Bifacial arrowhead	2.9	1.7	0.5	2009	SH 7	Flint
8	1610	Bifacial arrowhead	2.5	1.5	0.4	2005	SH 52	Flint
9	1611	Bifacial arrowhead	3.0	1.6	0.3	2005	SH 52	Flint
10	319	Trihedral arrowhead	3.1	0.7	0.5	2004	SH 47	Flint
11	195	Trihedral arrowhead	3.9	0.8	0.4	2005	SH 51	Flint
12	521	Trihedral arrowhead	2.7	0.9	0.4	2005	SH 52	Flint

Fig. 2. The position of our excavation (W1, W2, W3, X1, X2, X3) in relation to the excavation of University of New England, Australia (the photo taken by AHAD using the Drone).

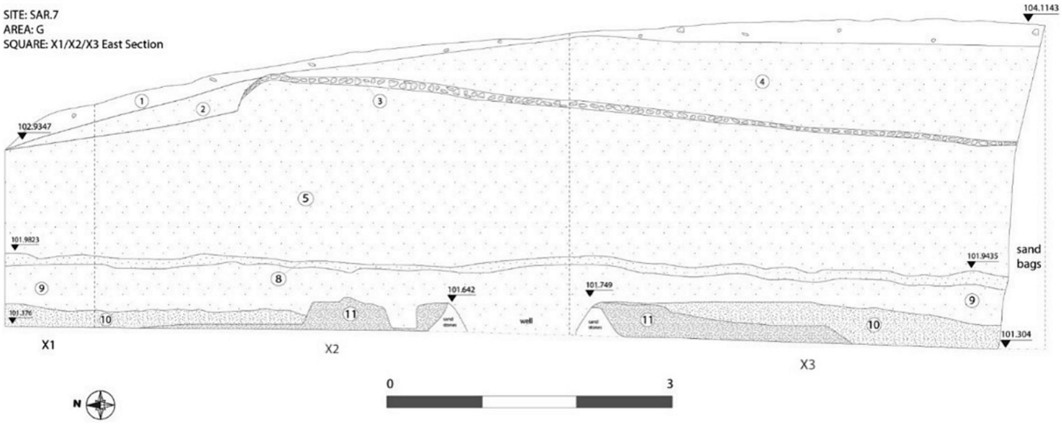


Fig. 3. The eastern section of the excavated area provides clarity on the extent of the archaeological Contexts uncovered across squares X1, X2, and X3 (Alkhalid et al., submitted).

artifacts recovered include pottery fragments and stone tools.

Context 10 is primarily distinguished by its nearly horizontal arrangement and displays a color spectrum ranging from light grey to beige. Comprised of sand particles, this context is notable for its diverse stone inclusions, varying in size from 1 mm to 5 cm and encompassing a range of colors. Additionally, frequent sandy concretions containing calcium carbonate are observed within this stratum. It is believed that these concretions formed following multiple episodes of water evaporation. Our analysis indicates that this stratum likely formed due to seasonal alluvial rainwater activity. The stratum exhibits a uniform thickness, ranging from 5 to 15 cm, with its highest elevation observed at the eastern ends of excavation units X2 and X3.

The total sample size for both contexts is about 250 stone artefacts. Because both contexts exhibit microlithic industries, a low frequency of lithics, and nearly absent end products aside from a few ones, we have regarded them as a single assemblage. We analyse only 157 stone artefacts out of 250 since the rest are undiagnostic debitage. Techno-typological analysis was carried out. Typological analysis follows the type of list for the Upper Palaeolithic and Epipalaeolithic of the Southern Levant compiled by Goring-Morris (1987). Technological analysis follows the '*chaîne opératoire*' approach (Leroi-Gourhan, 1964; Inizan and Tixier, 1978; Geneste, 1985; Pelegrin et al., 1988) which involves classifying artefacts into technological types according to their inferred position in the reduction sequence. The concept encompasses all stages from acquiring raw materials to final disposal, including manufacturing, and using various components, allowing for a comprehensive understanding of tool production.

The present results of radiocarbon dating of seven samples mixed with sand (Table 2) reveal a timeline of human activity spanning from the early Forth millennium to the first half of the first millennium BC.

3. Result

3.1. Trihedral points and bifacial arrowheads

Trihedral points and bifacial arrowheads are components of south and southeastern Arabian tool kit during mid Holocene (e.g. Hellyer, 1998; McCorriston et al., 2002; Cremaschi and Negrino, 2002; Crassard et al., 2006; Beech et al., 2008; Uerpmann et al., 2013). As can be seen in Fig. 4, the three trihedral points collected from SH were produced from high quality raw material and shaped by the pressure retouching technique. While they vary morphologically, there is some affinity in their

Table 2
Summary table of Radiocarbon analysis done in seven samples collected in different levels.

ID	Context and square	Lab Code	Sample	C14 Age (BP)	δ^{13}C (‰)	Cal. BC
AR.S.206	Context 6 Sq: W2	LTL31812	Charcoal	2791 ± 40	−24.5 ± 0.3	1045–1029 cal. BC (2.5 %) 1019–830 cal. BC (92.9 %)
AR.S.212	Context 8? Sq: X3	LTL31813	Charcoal	2816 ± 40	−12.3 ± 0.7	1108–1064 cal. BC (4.5 %) 1058–894 cal. BC (86.0 %) 875–838 cal. BC (4.9 %)
AR.S.213	Context 8 Sq: X3	LTL31814	Charocal	3013 ± 45	−30.2 ± 0.8	1401–1121 cal. BC (95.4 %)
AR.S.217	Context 10 Sq: W1	LTL31815	Charcoal	3555 ± 45	−14.1 ± 0.5	2025–1991 cal. BC (7.4 %) 1984–1749 cal. BC (88.0 %)
AR.S.257	Context 12 Sq: W1	LTL31816	hearth	3971 ± 40	−20.9 ± 0.4	2578–2342 cal. BC (95.4 %)
AR.S.260	Context 12 Sq: X3	LTL31817	Ash with Sand	4994 ± 45	-23.2 ± 0.1	3945–3856 cal. BC (25.1 %) 3844–3834 cal. BC (1.1 %) 3818–3651 cal. BC (69.1 %)
AR.S.261	Context 12 Sq: X3	LTL31818	Ash with Sand	4449 ± 50	-23.5 ± 0.3	3339–3004 cal. BC (86.1) 2990–2928 cal. BC (9.4 %)

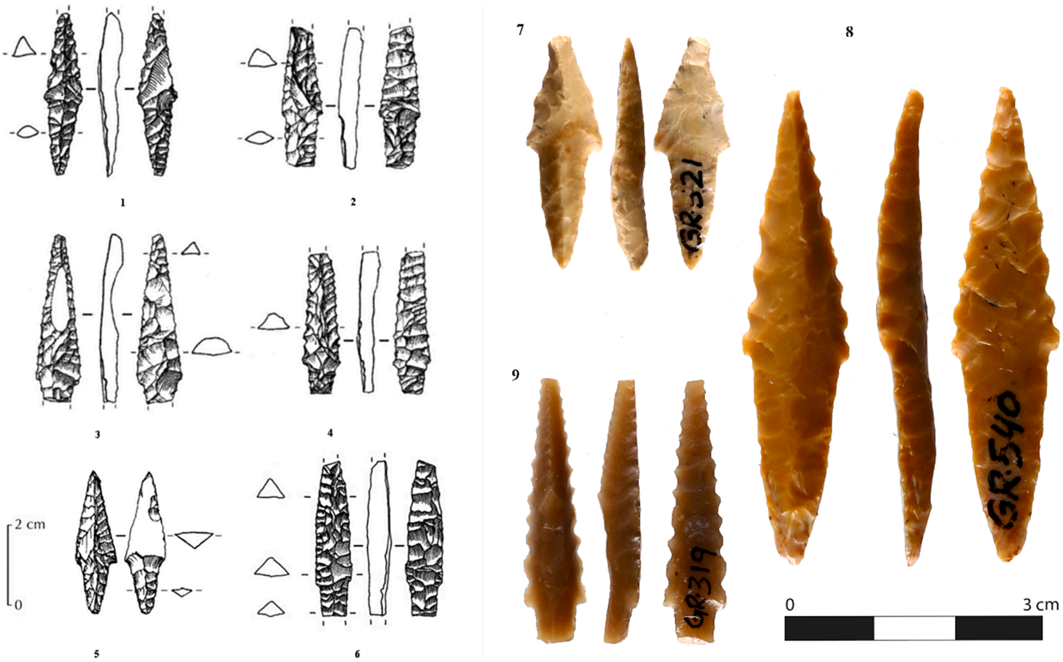


Fig. 4. Trihedral points from different SH and other sites in southern and southeastern Arabia.1–5 From Marawah MR-1, Abu Dhabi, UAE (Charpentier, 2004) 6. From Manayzah, Yemen (Crassard et al., 2006).7–9. Trihedral points with number of.1. GR. 521. 2. GR. 319. 3. GR. 540 from SH site, Dubai, UAE.

dimension, particularly the thickness and width (Table 3). This This may be a result of the affinitive size of the shaped blanks. These points have tiny protrusions/spurs formed during the shaping of the tangs. If the toolmaker had narrowed the tangs further, the spurs would likely have protruded, forming barbs. The angles of notches created by shaping the tangs are obtuse in the three samples. While two trihedral points are symmetrical and their edges give the impression of being denticulated, the other point shows irregular-shaped edges (Fig. 4; 8 and 9). The length of the tangs s varies relative to the length of the shaft in these points, with tangs being shorter in two of them (Fig. 4; 8 and 9), the other makes up more than half of the entire length of the piece (Fig. 4; 7), which was observed in trihedral points in MR-1 (Charpentier, 2004) and al-Ain (Hellyer, 1998). The faces of the trihedral points underwent complete pressure retouch, unlike some samples from the MR-1 and Suwayh SWY-1 (Charpentier, 2003, 2004), where the ventral surface of the blank is still visible (Fig. 4; 5).

Table 3
Mean length, width, thickness and standard deviations (SD) of trihedral points and bifacial arrowheads.

Type	Length		width		thickness	
	mean	sd	mean	sd	mean	sd
Bifacial arrowhead	2.9	0.6	1.6	0.15	0.39	0.1
Trihedral points	3.23	0.61	0.80	0.10	0.43	0.06

The barbed and tanged bifacial arrowheads collected from SH reflect the morphometric diversity observed among arrowheads in Arabia (Edens, 1982; Crassard and Petraglia, 2014; Charpentier, 2004; Cremaschi and Negrino, 2002; Crassard et al., 2006; Crassard et al., 2013; McCorriston et al., 2000; Beech et al., 2005; Uerpmann et al., 2012; Alghamdi, 2011; Kallweit, 2004; Crassard et al., 2013). These arrowheads are triangular in form and were bifacially shaped by pressure retouch on flakes (Fig. 5). Distinctive in having a short to medium pointed or rounded tang, mostly have asymmetrically set either side of which are the barbs. Some exhibit broken barbs, especially those that seem to be perfectly shaped, thin and have symmetrical barbs (Fig. 5; 2,4, and 5).

Although this study includes a few samples of mid-Holocene components that limit our analysis, each type (i.e trihedral points and

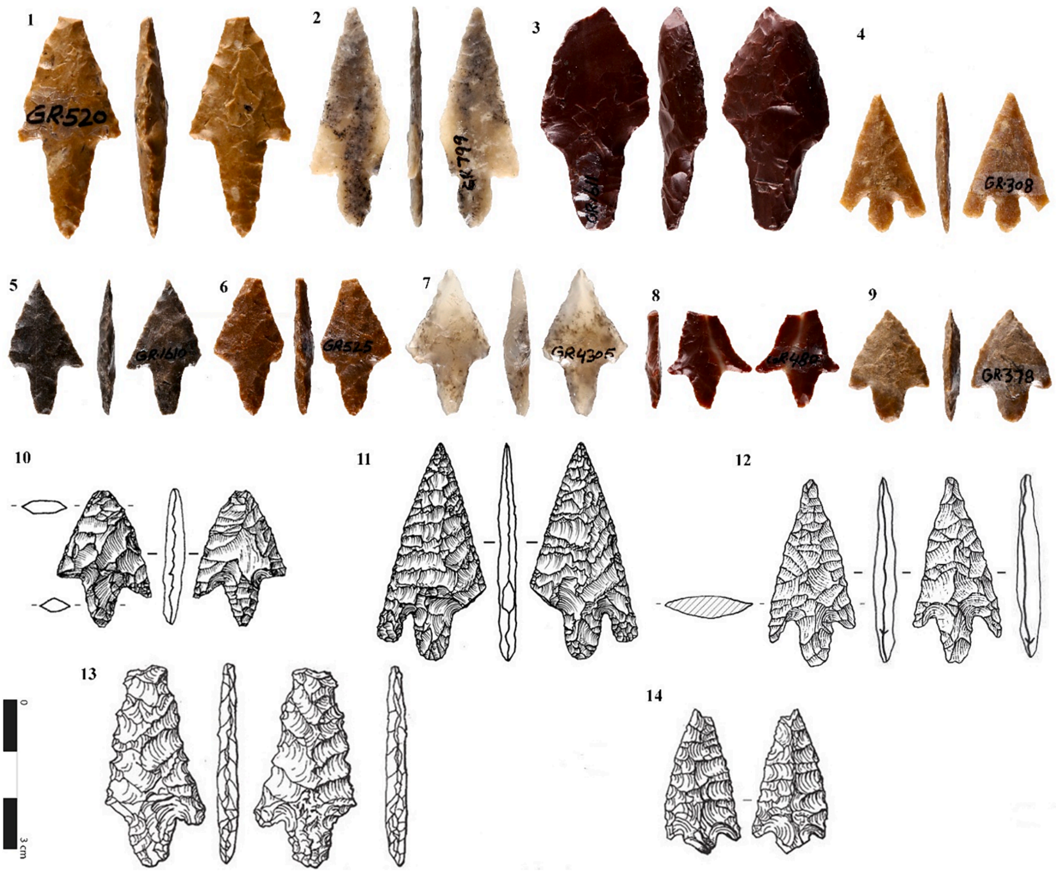


Fig. 5. A set of arrowheads collected from SH (1—9), Dubai, UAE. 10. Marawah MR-1, Abu Dhabi, UAE (Charpentier, 2004). 11. Mundafan site, Saudi Arabia (Crassard et al., 2013). 12. Ghagha, Abu Dhabi, UAE (Al Hameli at al., 2023). 13–14. Al Ashoosh (Casana et al., 2009).

bifacial arrowheads) has its own unique characteristics. Using different angles during shaping resulted in variable morphometric characteristics of both types. Some bifacial arrowheads were shaped by a series of bifacial removals from an angle close to 90°, which helped the thinning process and gave them an almost foliate shape as in Fig. 5: 2 and 4. In contrast, while trihedral points were shaped by a series of removals from an angle less than 90° to form the lateral faces (sides of the triangle) on the dorsal surface, shaping the hypotenuse/triangular's base (ventral surface) of the trihedral points were shaped by series of removals from an angle close to 90° which resulted in forming a more flat face. Likewise, some bifacial arrowheads were shaped using pressure with less than 90° angle resulting in biconvex arrowheads as in Fig. 5: 1, 5 and 6. Despite the use of pressure retouch technique in shaping, both types show metric variability that might be related to the diversity of available raw material or ballistic and hafting requirements. The sample sizes are too small for the trihedral points to support statistical analyses. However, the standard deviation SD for thickness of trihedral arrowheads in Table 3 compared to bifacial arrowheads indicates that trihedral arrowheads display less variability in thickness.

These bifacial arrowheads from SH show common characteristics (i.e. having triangular shape with barbs and tangs) with those discovered in stratified sites in different regions of Arabia dating back to the mid-seventh and mid sixth millennium BC despite the morphological variability. These include sites like MR-1, Ghagha, and Al Ashoosh in UAE, Mundafan in Saudi Arabia, Khuzmum site or HDOR-538 and HDOR-561 sites in Yemen (Charpentier, 2004; Casana et al., 2009; Al Hameli et al., 2023; Crassard et al., 2013; Crassard et al., 2013; Crassard, 2008; Gopher, 1994; Rollefson et al., 2014) In addition, they share the use of the pressure retouch technique.

3.2. Bronze Age industry

3.2.1. Condition and raw material procurement

The site attests to a clear variability of the raw material used. Five categories of stone were identified in both contexts according to Vinx (2014) and Schön (2015). Chert (108 artefacts) is the most common material used with clear variability in colour, texture, and inclusion, followed by chalcedony (36 artefacts), quartz (4 artefacts) and 9 undiagnostic material which might be dolerite. Other geological types were identified, but without anthropogenic fractures such as metamorphic stone pebbles. The natural surfaces of some materials appear largely eroded by wind and show clear signs of aeolian erosion, in the form of wind abrasion. A few rock fractures appear as if the surface has been eroded by water. The edges of stone artefacts are in very fresh condition, devoid of any indications of, wind erosion, or other forms of taphonomic damage. Notably, evidence of material recycling behaviour is apparent, wherein discarded lithics, possessing adequate volume for further reduction, demonstrate a clear behaviour of re-exploitation. This can be evident through double patina on two artefacts and the frequent appearances of cores on flakes among uncovered lithics (Fig. 6). The raw material of the uncovered sample in both contexts show similarity to those studied by Moore et al. (2020, 2022), who indicates that this raw material was noted in colluvial deposits of Jebel Faya near the modern town of Mleiha (Moore and Weeks, pers. obs. 2016, cited in Moore et al., 2022).Patina was detected on some cores uncovered in Area F dating back to the Wadi Suq period, suggesting a potential period of abandonment before subsequent reuse (Rempel et al., 2019).

3.2.2. Lithic analysis

Table 4 presents the main categories of the analysed 157 stone

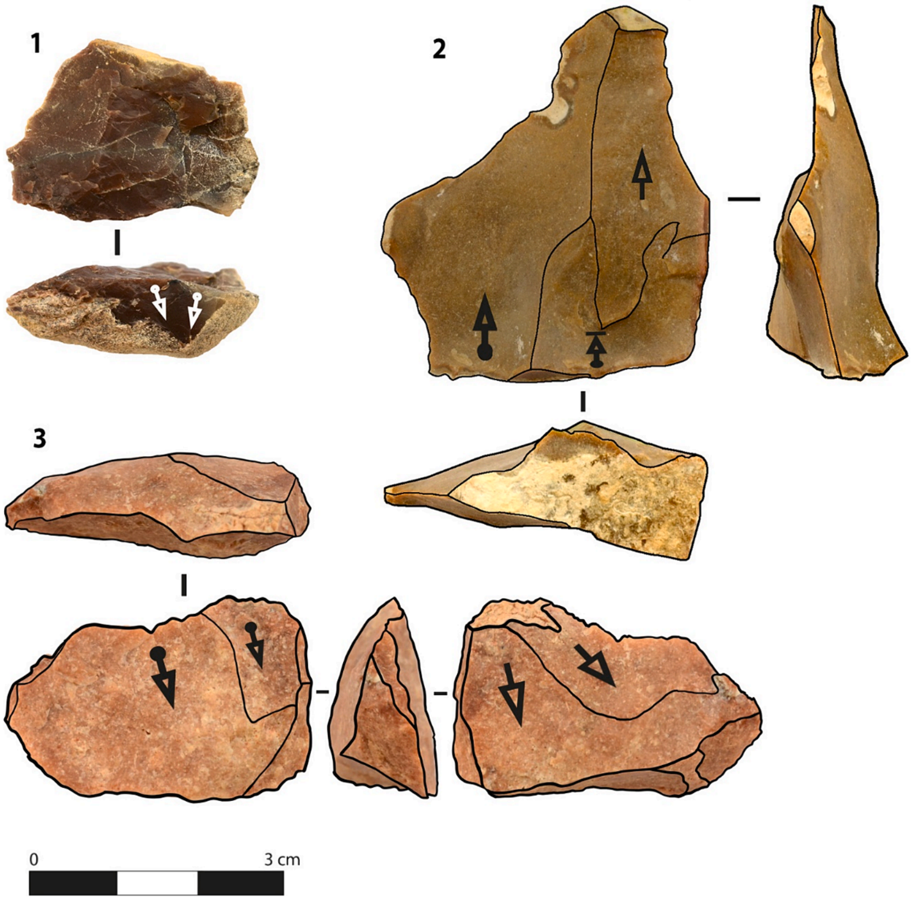


Fig. 6. Example on recycling: 1. Core on cortical flake. 2. Core on flake. 3. Core of on flake (quartz).

Table 4
Classification of the analysed cores and debitage from Contexts 10 and 8 in area G of SH.

Type	N.	%
Flake	1	0.6
Elongated point	3	2
Backed microlith	2	1.2
Burin	1	0.6
Tablet	1	0.6
Partly cortical flake	21	13.4
Full cortical flake	4	2.5
Fragment	3	2
Undignostic	78	50.8
Cores	26	16.5
Hammer	2	1.2
Raw material	14	9
Total	157	100 %

artefacts. By techno-typological analysis of the discarded cores and debitage, a simple, low-effort and relatively low-skilled approach to core reduction was documented in Contexts 10 and 8, dated c. 1983——1401 BCE (Wadi Suq and Late Bronze Age) through radiocarbon dating, resembling to approach seen in Horizon IV, located about 20 m westward, presents low-effort and relatively low-skilled approach to core reduction (Moore et al., 2022). However, it shows highly skilled techniques for transforming flakes into microliths within a dense midden of animal bones dated to the Wadi Suq to Late Bronze Age period, c. 1750–1300 BCE (Moore et al., 2020, 2022, Weeks et al., 2019).

The density of stone artefacts in Contexts 10 and 8 is low compared to those uncovered in Horizon IV, numbering 1011 artefacts (Moore et al., 2022). However, there is at similar density of lithics to those discovered to the north in area F, dating to the Wadi Suq period (Rempel et al., 2019 and 2020). In both Contexts, lithics mainly show features of the flake industry, utilizing a hard hammer and direct percussion. This is evident from final removals on cores and fractures on some cores' striking platform edges (Inizan et al., 1995). Despite their small size, analysed by-products exhibit pronounced bulbs, indicating the use of a hard hammer as defined by Inizan et al., (1995), with core negatives reflecting their size.

Two possible hammerstones of different materials were found. One, a quartz hammer, displays a scar that might have resulted from repeated blows (Fig. 7), while the other, made of dolomite cobble, lacks fracture marks. Despite its small size and no fracture marks, the dolomite cobble

Fig. 7. An elongated hammer showing negative of fracture, which could be broken during striking.

likely served as a hammer but was not used frequently given the low number of artefacts uncovered on-site. Although Moore et al. (2022) documented hammers in Horizon IV, none showed signs of use on their ends.

A relatively small number of cores, only 26 in total, were found in both contexts (Table 5). Various core reduction methods were employed, as follows:

1. Single platform: Products were extracted from a single flaking surface utilizing a single striking platform, they are nearly perpendicular.
2. Two opposite platforms: Products were removed from a single flaking surface but from two opposite striking platforms.
3. Two orthogonal platforms were utilized to extract products from a single flaking surface, each originating from striking platforms positioned perpendicular to each other.
4. Multiplatform: Refers to the extraction of products from multiple striking platforms through the rotating of the core.
5. Bifacial or unifacial exploitation: Products were removed from almost tabular raw material. The material is treated similarly to forming bifaces. If the products are extracted from both surfaces, it becomes bifacial; if from a single surface, it is termed unifacial.

Although variability in core reduction methods, opportunistic exploitation behaviour is predominant across most cores, aligning with the simple core reduction techniques observed in Horizon IV (Moore et al., 2022). The single platform approach, where removals are made after selecting the appropriate flaking surface (Fig. 8:1–4), is the most commonly used strategy, while multiplatform cores were rotated according to the material's convexity (Fig. 8:5). Cores with two platforms, showing opposite or orthogonal platforms, were infrequent (Fig. 9:1).

Bifacial reduction involved flipping nearly flat cores to exploit convexities on both faces. bifacial or unifacial exploitation was seen on tabular-shaped materials. We see applying these methods associated with insufficient volume for flaking (Fig. 8:6 and 9:2).

The exploitation of natural or existed convexities in cores is evident not only in the predominance of very small pieces of debitage which are undiagnostic, but also in the lack of standardization in core and flake morphology, even among those reduced using the same method. This was documented in Horizon IV (Moore et al., 2022) and showing expedient behaviour which is very common technological behaviour seen in other periods like Middle Palaeolithic (e.g. Vaquero et al., 2012; Al Kassem, 2021). Additionally, the low frequency of negatives on cores, averaging 2.5 scars compared to the 9.8 ± 4.4 scars recorded on discarded single platform cores in Horizon IV (Moore et al., 2022), suggests cores did not undergo systematic preparation. Instead, knappers likely exploited the natural or existed convexity for a few removals before discarding the core, rather than systematically preparing cores which causes more scar counts and produces diagnosable by-products. Interestingly, exploitation of discarded blanks as cores or the natural convexity of the raw material is a common behaviour observed through time (e.g. Groucutt, 2014; Vaquero et al., 2014).

The convergence between stone flake technology in Horizon IV and lithic material in Contexts 10 and 8 is evident in core size. Moore et al., (2022: 13) state that exploited cores were generally small, mostly under 60 mm in size. The varying sizes of cores in both (Fig. 10), along with an average of 2.5 negatives, indicate core exploitation based on convexity without surface preparation. This is supported by the lack of faceted or dihedral butts on flakes and preparation of core striking platforms (Tables 6 and 7). Only five cores exhibit hinge fractures despite the absence of core striking platform preparation, suggesting the high skill of toolmakers and low fracture accident frequency relative to raw material size. Additionally, similar volumes between discovered cores and raw material in the same contexts (Fig. 9) imply a short core reduction lifespan.

Table 5
Distribution of cores based on the number and direction of the striking platform.

core type	Context 8	Context 10
Single platform	8	10
Two opposite platforms	–	1
Two orthogonal platforms	1	–
Bifacial or unifacial exploitation	1	2
indet.	3	–

Of the total stone artefacts, 115 blanks were analysed. They are mostly byproducts_undiagnostic debitage, and fully/partially cortical flakes_(Table 4), except for a flake, two backed microliths and a microburin. The high frequency of partially cortical flakes compared to other debitage, together with the low number of negatives on cores, is consistent with an assumption of exploiting the convexity of cores for a few removals.

The size of by-products recovered from both contexts are larger than the negatives left on discarded cores (Fig. 11), particularly partially cortical blanks representing the early stage of core reduction. On the contrary, the length to width (L/W) ratio of by-products is lower than L/W of scars on cores, 1.3 and 1.5 respectively, suggesting the last stage of core reduction tends to produce more elongated flakes despite the difference is very small. The distribution of scars on cores implies that the removals reached the second-third of some core's length at maximum. Location of the cortex as can be seen in some instances (Fig. 12:1–3, 5–7) is additional evidence for the exploitation of small raw material, where the cortex is situated on the distal termination of the cortical flakes.(See Fig. 13).

Scar patterns on by-products are difficult to be evaluated since undiagnostic debitage are the most frequent elements identified in both contexts. However, flakes bearing parallel or sub-parallel scars are the most common patterns, followed by flakes with a single scar pattern.

Two backed microliths were identified among the debitage. While one was found in context 10, the other was recognized in the archaeobotanical sample during the flotation process, which belongs to a hearth in the gypsum Context 12 and has no damages (Fig. 14). Both backed microliths differ morphometrically, one lunate shape with a size of 30 × 16 × 9 mm and the other a geometric microlith with a size of 19 × 5 × 2.5 mm (Fig. 14). The former was manufactured directly on a flake, where the plain butt of the flake is still visible. Whereas the latter was truncated from a distal part of a blank, which still has the feather termination. Both of them were abandoned in the early stage of backing, where different parts of the blanks are not backed. Single backing was carried out to opposite platforms discontinuously in different areas of the backed microlith. Scars of backing are relatively large and irregularly shaped. Moore et al. (2022) suggests a shift in backing technique from early/middle stage marked by single-backing to final stage finishing characterised by double-backing, clarifying that broken or rejected microliths in manufacture, attributed to the early stage of microlith, are more likely to be single-backed, but finished microliths are often double-backed. Unfortunately, the absence of microliths in our excavation does not allow us further analysis.

In Context 10, we record a single tablet characterized by a pointed tip, which was formed through abrupt retouching of the edges that converge at the distal end (see Fig. 15). This method of backing is the strategy of backing in forming backed microliths in Horizon IV. Notably, the tablet shows varying thicknesses, progressively increasing towards the pointed tip. Interestingly, tables were, made of chert, discovered in Horizon IV, which display bifacial flaking creating bifacial edges with relatively steep edge-angles (Moore et al., 2022).

Two cortical flakes of 8 stone artefacts were refitted together (Fig. 16: 7 and 8). The 8 stone artefacts were examined macroscopically (Weißmüller, 1995). This allowed distinguishing common principal features of the raw material: lustre, opacity, inclusion, and type of cortex, suggesting their production from the same core in Context 10 (Fig. 16).

Fig. 8. Cores. 1–4 Core bearing a single striking platform. 5. Multiplatform on a core stroked by rotating the core following the convexity. 6. Bifacial core stroked following the convexity.

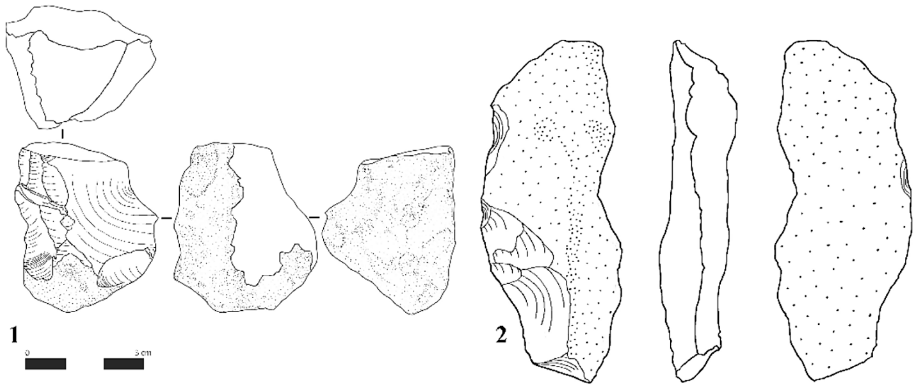


Fig. 9. 1. Core with two orthogonal platforms. 2. Unifacial core applied on tabular-shaped material (Drawing by Al Kassem).

Despite the absence end products, we could notice remarkably the analogous technical behaviour between both contexts by setting the striking platform based on the convexity of the flaking surface and the volumetric characteristics of cores impacted the strategy of core reduction. The convexity and thickness of cores specified the direction of exploitation, where small volumes forced knappers to extract a few removals after selecting the appropriate convexity for exploitation.

Both the size of discarded cores and debitage reflect the production of microliths, where two to three microliths were detached from a single convex surface, then the core was abandoned though its volume still allows for further exploitation. Therefore, we think that the small size of the raw material was not an obstacle to meeting their needs, but rather reduced and facilitated their loads during mobility. We see that the low-cost and relatively low-skilled approach to core reduction, resembling Horizon IV, documented in both contexts, resulted from the characteristics of the available raw material to meeting their simple requirement for obtaining a flake that would otherwise be subject to the highly skilled process of backing into geometric microliths. Additionally, the large number of bones discovered in Context 8, dated to the Late Wadi Suq and Late Bronze Age (1401–1121 cal. BC), could be the extension of the dense midden of bone (Horizon IV) placed a few meters to the west and northwest of our excavation (Fig. 2). Horizon IV contained more than 1 ton of bones of wild fauna (Gazelle and Oryx) and some species of fish and plenty of microliths (Roberts et al., 2018) and more than two hundreds of backed microliths (Moore et al., 2022), indicating large-scale hunting activities.

Context 10 attested to human activities related to a few knapping events dated to the late Umm Al Nar and Wadi Suq periods (2025–1749 cal. BC). Alkhalid et al., (submitted) suggest that human activities were carried out in Context 12 and these stone artefacts with other material were deposited in Context 10 because of the slow movement of the seasonal rainwater. However, an alternative possibility is that some knapping events related to human activities were carried out in Context 10 since the lithics are unweathered and stone artefacts are in very fresh

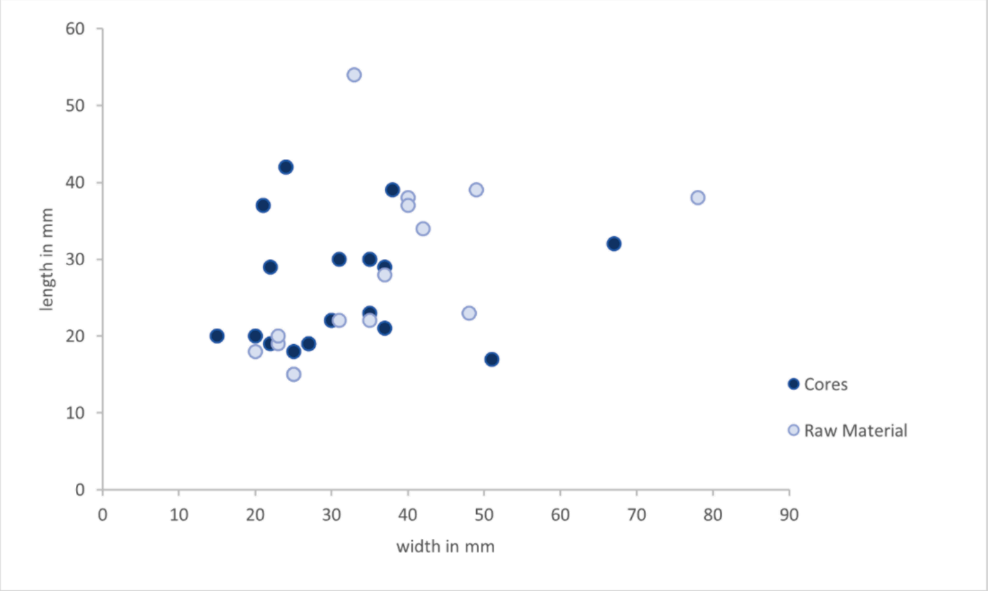


Fig. 10. Scatterplot comparing size of core to discovered raw material, which is mainly chert and some chalcedony, Contexts 8 and 10.

Table 6
Type of striking platforms on cores.

Context	Faceted platform	Plain platform	Cortical platform
8	1	2	5
10	0	11	7

Table 7
Type of butts on debitage.

Context	Abscent platform	Plain platform	Cortical platform
8	34	4	8
10	28	30	11

condition. Context 12, specifically the hearth containing a backed microlith, is related to human activities dated to the late third millennium c. 2574–2342 cal. BC (Umm an-Nar period).

4. Discussion

The scarcity of mid-Holocene and post-Dark Millennium sites in the interior remains a subject of debate until additional evidence emerges to challenge this notion. Recent research attributes the decline of inland occupations and the movement of populations to resource-rich coastal areas along the Arabian Gulf in southeastern Arabia, to periods of downturn rainfall (Preston et al., 2015; Petraglia et al., 2020). However, the Saruq Al-Hadid site and Al Ashoosh (Casana et al., 2009), situated on the fringe of the Rub Al Khali desert, serve as illustrative examples of human activity during the mid-Holocene, Bronze Ages and Iron Ages in the Dubai desert.

Our sample of trihedral points and bifacial arrowheads found at SH are components of the mid-Holocene toolkit in southeastern Arabia. The archaeological records indicate variations in their temporal and spatial distribution. Charpentier (2004, 2008) discussed the difference in the occurrence of trihedral points, their earliest occurrence in Yemen was recorded in Mahadi to about 6450–6360 BCE (Charpentier and Inizan, 2002:44) and at Khuzmum rock shelter and Manayzah site dated to 7th millennium (McCorriston et al., 2002; Crassard, 2008). At Suwayh SWY-

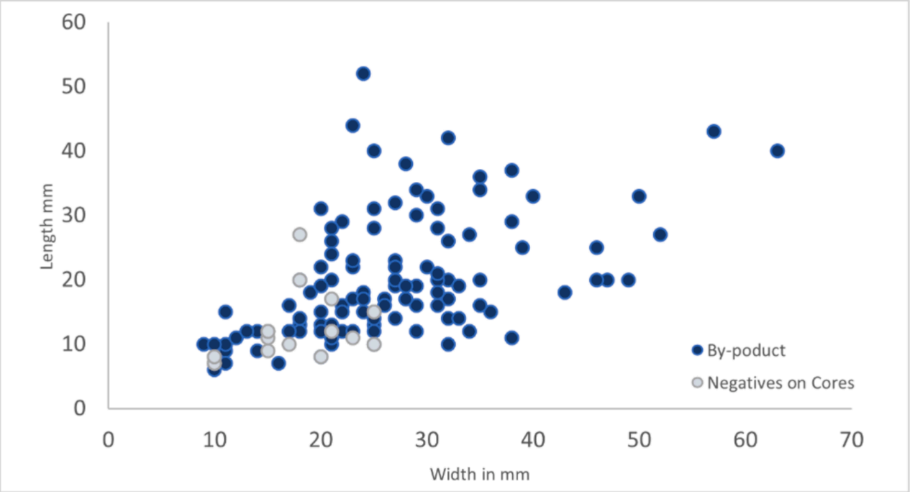


Fig. 11. Scatterplot comparing by-product sizes to sizes of scars on discarded cores, Contexts 10 and 8.

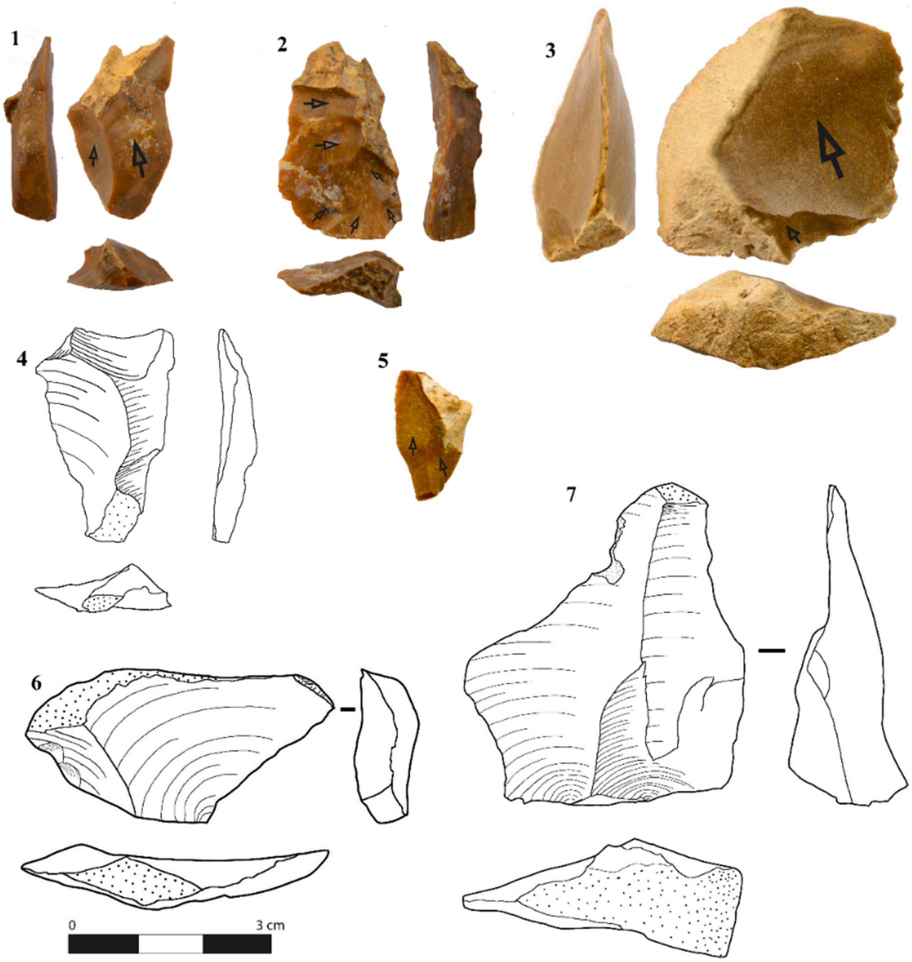


Fig. 12. 1–6. Cortical flakes. 7. Core on flake applied on cortical flake (Drawing by Al Kassem).

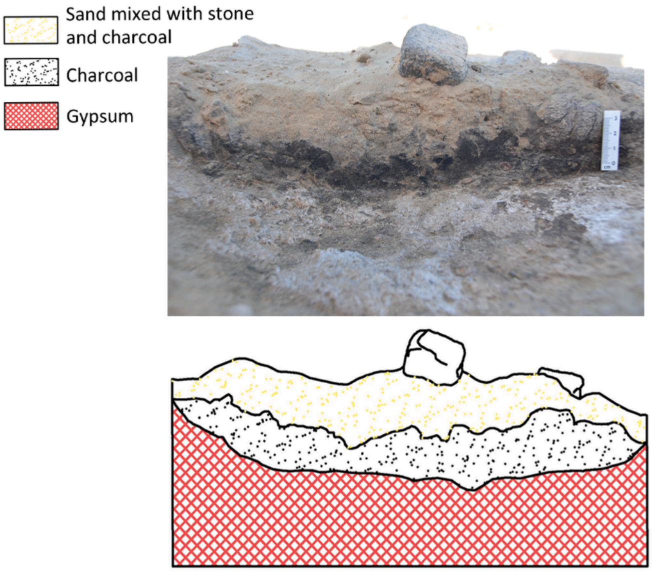


Fig. 13. Detail of a fireplace discovered in Context 12 where the backed microlith found.

1 in Oman, trihedral points situated around 5500–5400 BCE, and they disappeared from the sequence during the second half of the 5th millennium BC. It is thus highly probable that trihedral points appeared from the middle of the 7th millennium and disappeared during the second half of the 5th millennium BC (Charpentier, 2004).

In UAE, the best-dated sites are MR1 and MR11, where both bifacial arrowheads and trihedral points were dated back to the 6th and 5th millennia (Beech et al., 2005, 2019), Ghagha presents also the earliest occurrence of bifacial arrowheads dating to 6500 BCE (Al Hameli et al., 2023). With our sample being surface collections and considering the wide range of chronological records of trihedral points and bifacial arrowheads, we can only infer that the SH site in Dubai desert may have witnessed human activities during humid periods in the mid-Holocene.

Crassard (2009) attributes Early/mid-Holocene industries in different geographical regions of eastern Yemen to endemic development. He clarifies that trihedral points have been found in Oman to Sa'da in Yemen and along the Jawf-Hadramawt palaeo-river, which demonstrates a connection between the central desert's bordering regions, at least between the 7th and 6th millennia BC (Crassard 2013; Charpentier, 2004; Inizan et al., 2007; Cleuziou et al., 1992). This led us to propose that Saruq Al-Hadid, on the fringe of Rub Al Khali, might have been in connection with neighbouring sites, whether located in the coastal or inland areas, or that the inhabitants of Saruq Al-Hadid were moving between the coast and the interior, alternating between pluvial and aridity periods.

For a long time, it has been thought that the inland remained vacant during and after the Dark Millennium (Potts, 2001; Uerpmann, 2003).

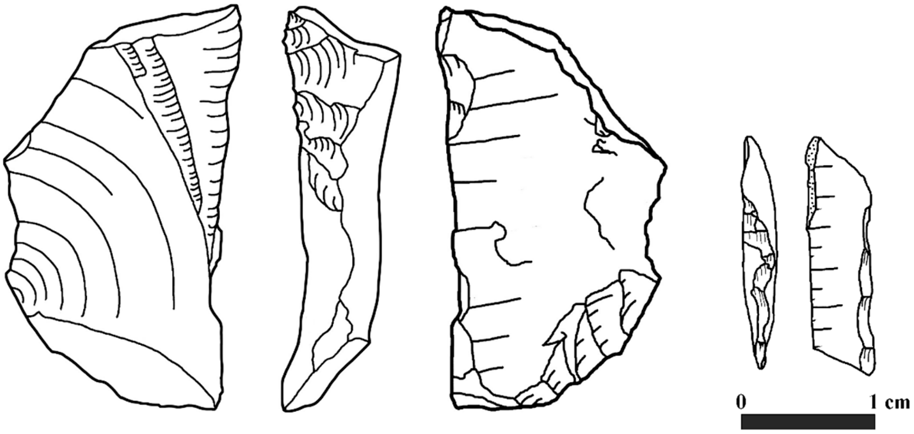


Fig. 14. Left: backed microlithic, context 10. Right: backed microlith revealed from the fireplace in context 12 (Drawing by Al Kassem).

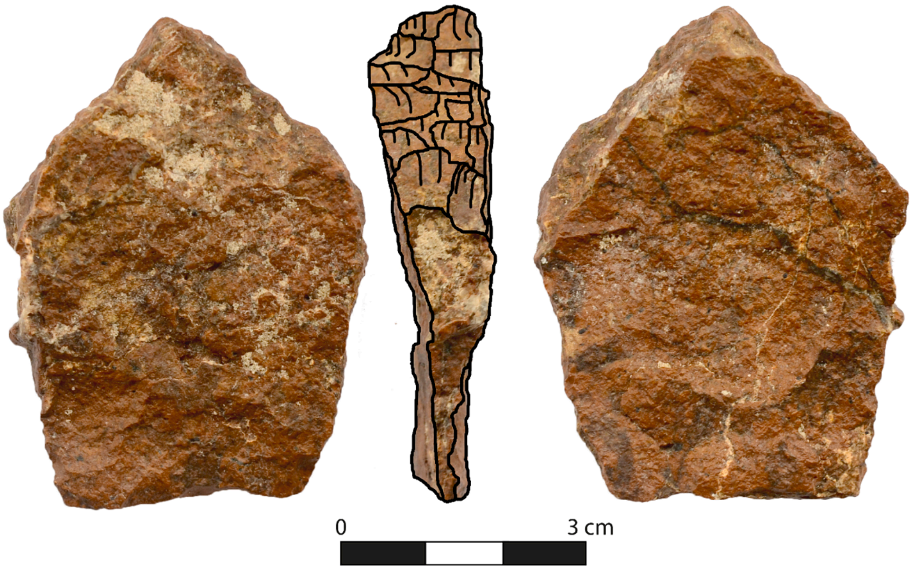


Fig. 15. A tablet with a pointed tip formed by abrupt retouch.

However, the unusual site of SH presents evidence of persistent re-occupation during the Bronze Age and continuing into the Iron Age (Qandil, 2003; Weeks et al., 2017, 2019; Valente et al., 2020). Additionally, the site presents new evidence of human activity dating to the fourth millennium BC. The repeated seemingly temporary use of SH (Weeks et al., 2019) is consistent with the terrestrial records of both Awafi and Wahalah Lakes in the northern Emirates, which indicate a decrease in humidity between 4.2 – 3.9 ka years ago and corresponds in the archaeological record to the period of shift from Early Bronze Age Umm al-Nar to Middle Bronze Age Wadi Suq (Parker et al., 2006a, 2016), which is represented by Context 9 in our excavation. It is also consistent with Parker and colleagues', (2006a) mention that there was a reversion to moist conditions after the Dark Millennium between 5.0 – 4.2 ka cal BP during the Hafit and Umm al-Nar phases. Radiocarbon dating of SH Contexts 12, 10 and 8 suggests that the site saw human activity in the Early Bronze Age (Umm Al Nar), the Middle Bronze Age (Wadi Suq) and the Late Bronze Age, during which SH witnessed the microlithic industry.

Moore et al. (2020) seek to determine the origin of the microlithic industry in Saruq Al-Hadid Horizon IV by reviewing microlithic industries across the Arabian Peninsula and its surroundings from the Late Pleistocene to the Bronze Ages. Their analysis of the large quantity of backed microliths suggests that the lithic technology observed at Saruq al-Hadid exhibits few close parallels in the region, suggesting a distinctive aspect of indigenous stone-tool technology development in Bronze Age southeastern Arabia. The almost total lack of end products and low density of lithics in Context 10 and 8 well as in Area F to the north of our excavation compared to those uncovered in Horizon IV support us to believe infer that the center of hunting activity during the Wadi Suq period and Late Bronze Age lies within Horizon IV.

5. Conclusion

The Saruq Al-Hadid site, situated near the Rub Al Khali, presents new evidence of mid-Holocene occupation, highlighted by the discovery of trihedral points and bifacial arrowheads. This distinguishes it as one of the rare mid-Holocene sites within eastern Arabia's interior regions. However, the varying chronological distribution of these Neolithic components across southern and southeastern Arabia complicates pinpointing a specific timeframe for our findings. Nevertheless, the presence of trihedral points suggests that Saruq Al-Hadid shares endemic developments with other mid-Holocene sites in the southern and southeastern regions of the peninsula.

The site provides evidence of human activities during the fourth millennium when the archaeological record suggests that populations contracted to the coast, uplands and oases. The persistent temporal

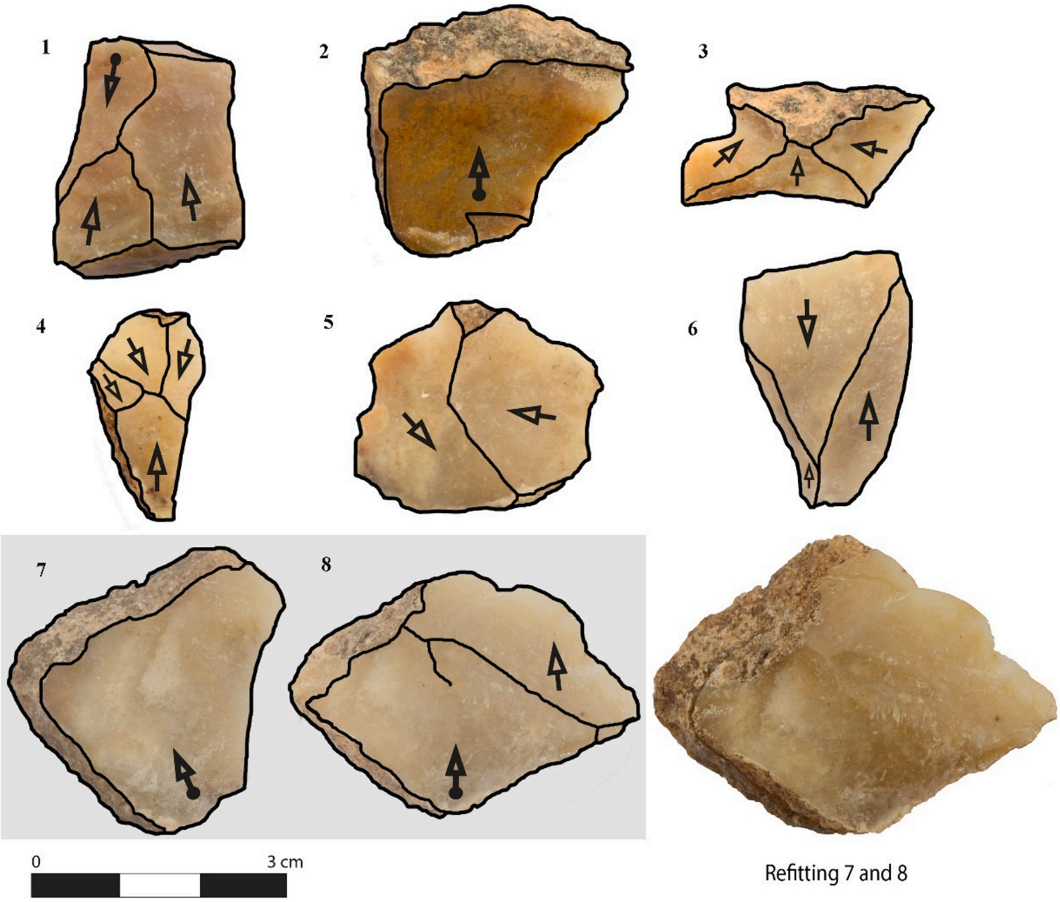


Fig. 16. Stone artefacts produced from the same core, number 7 and 8 refitting together.

occupations of the site during Bronze Ages, perhaps related to the pluvial periods during Umm Al Nar, Wadi Suq, Late Bronze Age phases and beyond. The microlithic industry of Wadi Suq and the Late Bronze Age, discovered in area G (Context 10 and 8 and Horizon IV), indicates that the cores in Saruq al-Hadid were reduced to obtain flakes through a simple, low-cost, and relatively low-skilled approach to using a simple hard-hammer percussion technique. However, transforming flakes into backed microliths attested high skill in Horizon IV.

This similarity indicates, on the one hand, that our contexts are an extension of the Horizon IV, but on the other hand, the scarcity of end products, as well as the low density of lithics in our contexts, as well as those discovered in area F, indicate that the Horizon IV is the center of activities during the Wadi Suq and the Late Bronze Age.

CRediT authorship contribution statement

Amal Al Kassem: Writing – original draft, Visualization, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Huw S. Groucutt:** Writing – review & editing, Writing – original draft, Investigation. **Felix Reize:** Writing – original draft, Investigation, Data curation. **Mariam Ali Alsuwaidi:** Writing – original draft, Investigation. **Badar Mohamed Abdulla Al Ali:** Writing – original draft, Investigation. **Mansour Boraik Radwan Karim:** Writing – original draft, Investigation.

Declaration of Competing Interest

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.

Data availability

The data that has been used is confidential.

Acknowledgment

We would like to express our thank to the Dubai Municipality – Architecture Heritage and Antiquates Department in Dubai, UAE, specifically to the Director Eng. Badar Mohamed Abdulla Al, the Archaeologist Mansour Boraik Radwan Karim and the excavator Mariam Ali Alsuwaidi, to the surveyor Jamal Safi, and to Ms. Noora Abdul Ghani Ali AlKhoori for their permanent support. Many thanks for ARCO team represented by the Manager Director Mazen Al Khayrat, the topographer Maria Perri, GIS specialist Marco Moderato, Archaeobotanist Alessia D'auria, the Zooarchaeologist Younes Naime, the Archaeologists Mohamad Alkhalid, Alessandro Colantoni, Margheita Scuteri, Gaia Perego, Jasmin Vese, and Giovanni Barco. All artefacts are stored at the Architectural Heritage and Archaeology Department, Dubai, United Arab Emirates. All research work was undertaken under the auspices of contract 12221576 between the Dubai Municipality and the ARCO Research Center, UAE.

References

Al-ghamdi, A., 2011. *The Neolithic Archaeology of the Southwest of the Kingdom of Saudi Arabia*. Doctoral thesis, Durham University.

Al Hameli, N., Cuttler, R, Beech, M., Crassard, R., al-Hajj al-Faki, A., Magee, P., Lidour, K., 2023. New light on the Neolithic Fertile Coast: Recent excavations on Ghagha Island (Abu Dhabi Emirate, UAE) and the emergence of domestic architecture in ancient Arabia. *Proceedings of the Seminar for Arabian Studies* 52, 139–157.

Al Kassem, A., 2021. Variability of core reduction strategies of the late Middle Palaeolithic of assemblages 6 and 4 of Yabroud I (Syria): An analytical and comparative study. PhD thesis, Universität zu Köln.

Alkhalid, M., Alkassem, A., D'auria, Alessia., Naime, Y., Reize, F., Alsuwaidi, M., Boraik, M., (submitted). Archaeological Excava/ons at Saruq Al Hadid Area G Preliminary Results of 2022-2023 Season. *Arabian Archaeology and Epigraphy*.

Al-Khraysheh, F. and Nashef, K., 2007. Dubai: Civilization and Progress throughout Three Thousands Years. Five Seasons of Joint Archaeological Excavations between the Emirate of Dubai and the Hashemite Kingdom of Jordan at Sarouq al-Hadeed. Department of Tourism and Commerce Marketing, Government of Dubai. United Arab Emirates.

Beech, M., Cuttler, R., Moscrop, D., Kallweit, H.,Martin. J., 2008. Excavations at the Neolithic settlement of MR11 on Marawah Island, Abu Dhabi, United Arab Emirates: 2004 season. Pages 25–53 in P. Hellyer & M. Ziolkowski (eds), *Emirates Heritage Vol .2 – Proceedings of the 2nd annual symposium on recent archaeological discoveries in the Emirates and of the symposium on the history of the Emirates,* Al Ain, 2004. Al Ain: Zayed Center for Heritage and History.

Beech, M., Kallweit, H., Hellyer, P., 2004. New archaeological investigations at Abu Dhabi Airport, United Arab Emirates. Proceedings of the Seminar for Arabian Studies 34, 1–15.

Beech, M., Cuttler, H.T.R., Al Kaabi, K.A., El Faki, A.A., Martin, J., Al Hameli, N., Roberts, M.H., Spencer, P., Tomasi, D., Brunet, O., Crassard, R., 2019. Excavations at MR11 on Marawah Island (Abu Dhabi, UAE): new insight into the architecture and planning of Arabian Neolithic settlements and early evidence for pearling. Arab. Archaeol. Epigr. 31, 1–13. https://doi.org/10.1111/aae.12148.

Casana, J., Herrmann, J., Qandil, H., 2009. Settlement history in the eastern Rub al-Khali: Preliminary Report of the Dubai Desert Survey (2006–2007). Arab. Archaeol. Epigr. 20 (1), 30–45. https://doi.org/10.1111/j.1600-0471.2008.00306.x.

Caton-Thompson, G., 1953. Some Palaeoliths from South Arabia. Proc. Prehist. Soc 19, 189–218. https://doi.org/10.1017/S0079497X00017953.

Charpentier, V., 2003. From the Gulf to Hadramawt: Fluting and Plunging Processes in Arabia. In: Potts, D., Al Naboodah, H., Hellyer, P. (Eds.), Archaeology of the United Arab Emirates: Proceedings of the First International Conference on the Archaeology of the UAE.

Charpentier, V., 2004. Trihedral points: A new facet to the 'Arabian Bifacial Tradition'. Proceedings of the Seminar for Arabian Studies 34, 53–66.

Charpentier, V., 2008. Hunter-gatherers of the 'empty quarter of the early Holocene' to the last Neolithic societies: chronology of the late prehistory of south-eastern Arabia (8000–3100 BC). Proceedings of the Seminar for Arabian Studies 38, 59–81.

Charpentier, V., Crassard, R., 2013. Back to Fasad… and the PPNB controversy. Questioning a Levantine origin for Arabian Early Holocene projectile points technology. Arabian Archaeology and Epigraphy 24 (1), 28–36. https://doi.org/10.1111/aae.12011.

Charpentier, V., Inizan, M.-L., 2002. Diagnostic Evidence of the Fluting Technique in the Old World: The Neolithic Projectile Points of Arabia. Lithic Technol. 27 (1), 39–46.

Cleuziou, S., Inizan, M.L., Marcolongo, B., 1992. Le peuplement pré- et protohistorique du système fluviatile fossile du Jawf-Hadramawt au Yémen (d'après l'interprétation d'images satellite, de photographies aériennes et de prospections). Paléorient 18 (2), 5–28.

Contreras, F., Carcacer, N., Thomas, J., Koljic, D., Murray, M., Bukhash, R.M., Al Abbar, S.O., Boraik, M., Zein, H., 2016. Al-Ashoosh: a third-millennium BC desert settlement in the United Arab Emirates. Antiquity 90 (354), 1–6. https://doi.org/10.15184/aqy.2016.219.

Crassard, R., 2009. Modalities and characteristics of human occupations in Yemen during the Early/Mid-Holocene. C. R. Geosci. 341, 713–725. https://doi.org/10.1016/j.crte.2009.05.003.

Crassard, C., Drechsler, P., 2013. Towards new paradigms: multiple pathways for the Arabian Neolithic. Arab. Archaeol. Epigr. 24 (1), 3–8. https://doi.org/10.1111/aae.12021.

Crassard, R., McCorriston, J., Oches, E., bin 'Aqil, A., et al., 2006. Manayzah, early to mid-Holocene occupations in Wadi Sana (Hadramawt, Yemen). Proceedings of the Seminar for Arabian Studies 36, 151–173.

Crassard, R., and Petraglia, M. D., 2014. Stone Technology in Arabia. Helaine Selin. Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures, Springer.

Crassard, R., Petraglia, M.D., Parker, A.G., Parton, A., Roberts, R.G., et al., 2013. Beyond the Levant: First Evidence of a Pre-Pottery Neolithic Incursion into the Nefud Desert, Saudi Arabia. Plos ONE 8 (7), e68061. https://doi.org/10.1371/journal.pone.0068061.

Crassard, R., 2008. *La Préhistoire du Yémen. Diffusions et diversités locales, à travers l'étude d'industries lithiques du Hadramawt.* British Archaeological Reports International Series 1842. Oxford, UK: Archaeopress.

Cremaschi, M. and Negrino, F., 2002. *The Frankincense of Sumhuram: paleoenvironmental 325-363.* In Avanzini, A. (ed.), Khor Roh Università di Pisa.

Drechsler, P. 2009. The Dispersal of the Neolithic over the Arabian Peninsula (Archaeopress).

Edens, C., 1982. Towards a definition of the western ar-Rub' al-Khali "Neolithic''. Atlal 6, 109–123.

Geneste, J.-M., 1985. Analyse lithique d'industries moustériennes du Périgord: Une approche technologique du comportement de groupes humains au Paléolithique moyen. Ph.D. dissertation, University of Bordeaux.

Gopher, A., 1994. Arrowheads from the Neolithic Levant: A Seriation Analysis. Eisenbrauns, Winona Lake, IN.

Goring-Morris, A. N., 1987. At the Edge: *Terminal Pleistocene Hunter-Gatherers in the Negev and Sinai.* BAR International Series, 361. Oxford: British Archaeological Reports.

Groucutt, H.S., 2014. Middle Palaeolithic point technology, with a focus on the site of Tor Faraj (Jordan, MIS 3). Quat. Int. 350, 205–226.

Hellyer, P., 1998. Hidden Riches: An archaeological introduction to the United Arab Emirates. Abu Dhabi.

Herrmann, J.T., Casana, J., Qandil, H., 2012. A sequence of inland desert settlement in the Oman peninsula: 2008–2009 excavations at Saruq al-Hadid, Dubai, UAE. Arab. Archaeol. Epigr. 23, 50–69. https://doi.org/10.1111/j. 1600-0471, 2011.00349.x.

Inizan, M.L., Rachad, M., 2007. Art rupestre et peuplements préhistoriques au Yémen. Paléorient 35 (1), 137–152.

Inizan, M.-L., Reduron-Ballinger, M., Roche, H., Tixier, J., 1995. Technologie de la pierre taillée. CREP, Meudon.

Inizan, M.L., Tixier, J., 1978. Outrepassage intentionnel sur pieces bifaciales neolithiques du Qatar (Golfe arabo-persique). Quaternaria 20, 29–40.

Kallweit, H., 2004. Lithics from the Emirates: the Abu Dhabi Airport sites. Proceedings of the Seminar for Arabian Studies 34, 139–145.

Kallweit, H., Beech, M., Al-Tikriti, W.Y., 2005. Kharimat Khor al-Manahil and Khor Al Manahil — New Neolithic sites in the south-eastern desert of the UAE. Proceedings of the Seminar for Arabian Studies 35, 97–113.

Leroi-Gourhan, A., 1964. Le geste et la parole: II, Technique et langage. Albin Michel, Paris.

McCorriston, J., Oches, E., Walter, D.E., Cole, K.L., 2000. Holocene paleoecology and prehistory in Highland Southern Arabia. Paléorient 28 (1), 61–88.

McCorriston, T., Walter, D.E., Oches, A.E., Cole, K.L., 2002. Holocene Paleoecology and Prehistory in Highland Southern Arabia. Paléorient 28 (1), 61–88.

Méry, S., Charpentier, V., 2002. Around Suwayh (Jacalan): a summary of some recent discoveries from coastal shell-middens of Eastern Arabia. Journal of Oman Studies 12, 181–195.

Moore, M. W., Weeks, L., Cable, C. M., Al-Ali, Y.Y., Boraik, M., 2020. Bronze Age microliths at Saruq al-Hadid, Dubai. In Bretzke K, Crassard R, Hilbert YH, editors. Stone Tools of Prehistoric Arabia. *Proceedings of the Seminar for Arabian Studies* 50, 149–166.

Moore, M.W., Weeks, L., Cable, C., Al-Ali, Y., Boraik, M., Zein, H., 2022. Bronze age stone flaking at Saruq al-Hadid, Dubai, southeastern Arabia. PLoS One 17 (7), e0270513. https://doi.org/10.1371/journal.pone.0270513.

Parker, A.G., Preston, G.W., Walkington, H., Hodson, M.J., 2006a. Developing a framework of Holocene climatic change and landscape archaeology for southeastern Arabia. Arab. Archaeol. Epigr. 17, 125–130.

Parker, A.G., Goudie, A.S., Stokes, S., White, K., Hodson, M.J., Manning, M., Kennet, D., 2006b. A record of Holocene climate change from lake geochemical analyses in south-eastern Arabia. Quat. Res. 66, 465e476.

Parker, A.G., Preston, G.W., Parton, A., Walkington, H., Jardine, P.E., Leng, M.J., Hodson, M.J., 2016. Low-latitude Holocene hydroclimate derived from lake sediment flux and geochemistry. J. Quat. Sci. 31 (4), 286–299. https://doi.org/10.1002/jqs.2859.

Pelegrin, J., Karlin, C., Bodu, P., 1988. "Chaînes opératoires":un outil pour le préhistorien. In Technologie Préhistorique, J. Tixier (ed.), pp. 55–62. Centre National de la Recherche Scientifique, CRA Notes et monographies techniques no. 25, Paris.

Petraglia, M.D., Groucutt, H.S., Guagnin, M., Breeze, P.S., Boivin, N., 2020. Human responses to climate and ecosystem change in ancient Arabia. PNAS 117 (15), 8263–8270. https://doi.org/10.1073/pnas.1920211117.

Potts D.T., 1990. A prehistoric mound in the Emirate of Umm al-Qaiwain, U.A.E.: Excavations at Tell Abraq in 1989. Copenhagen: Munksgaard.

Potts, D.T., 2001. Before the Emirates: An Archaeological and Historical Account of Developments in the Region c. 5000 BC to 676 AD. In: Ghareeb, E., Al-Abed, I. (Eds.), Perspectives on the United Arab Emirates, London, pp. 28–69.

Preston, G.W., Thomas, D., Goudie, A.S., Atkinson, O., Leng, M.J., Martin, M.J., Walkington, H., Charpentier, V., Mery, S., Borgi, F., Parker, A.G., 2015. A multi-proxy analysis of the Holocene humid phase from the United Arab Emirates and its implications for southeast Arabia's Neolithic populations. Quaternary International 382, 277.

Qandil, H., 2003. Survey and Excavations at Saruq al Hadeed, 2002–2003. Pages 120–138 in P. Hellyer & M. Ziolkowski (eds), Emirates Heritage Vol. 1 — *Proceedings of the First annual Symposium on Recent Palaeontological & Archaeological Discoveries in the Emirates (Al Ain, 2003)* (Al Ain, Zayed Center for Heritage and History).

Rempel, S., Wygnańska, Z., Juchniewicz, K., 2019. *Polish Mission, Saruq al-Hadid 2019 Final Report.* 380 p.

Rempel, G. S., Wygnanska, Z., Bagi, O., Woźniak, M., Rądkowska, J., Bajtler, M., 2020. Polish Mission Final Report for the 2020 Season at Saruq al-Hadeed (SAR-7).

Roberts, J., Weeks, L., Cable, C., Fillios, M., Youssef al Aali, Y., Radwan, M.R., Zein, H., 2018. The Role of Wild Terrestrial Animals in Late Prehistoric Societies of South-Eastern Arabia: New Insights from Saruq al-Hadid. Arab. Archaeol. Epigr. 29, 1–20. https://doi.org/10.1111/aae.12112.

Rollefson, G., Rowan, M. Y., Perry, M., 2014. *A permanent late neolithic residential structure in the eastern desert of Jordan.*

Rose, J.I., 2010. New light on human prehistory in the Arabo-Persian Gulf Oasis. Current Anthropology 51, 849–883. https://doi.org/10.1086/657397.

Rose, J.I., Hilbert, Y.H., Usik, V.I., Marks, A.E., Jaboob, M.M.A., Černý, V., Preusser, F., 2019. 30,000-year-old geometric microliths reveal glacial refugium in Dhofar, southern Oman. Journal of Paleolithic Archaeology 2 (3), 338–357. https://doi.org/10.1007/s41982-019-00027-3.

Schön, J. H., 2015. Rocks—Their classification and general properties. *Developments in petroleum science* 65, 1-19. Elsevier.

Sordinas, A., 1978. Contributions to the Archaeology of Saudi Arabia. III. The Zimerman Collection from the Northern fringe of the Rubc al-Khali. Coconut Grove, FL: Field Research Projects.

Uerpmann, H.-P., Potts, D., Uerpmann, M., 2009. Holocene (re-)occupation of eastern Arabia. In: Petraglia, M.D., Rose, J.I. (Eds.), Evolution of human populations in Arabia: paleoenvironments, prehistory and genetics. Springer, Dordrecht, pp. 205–214.

Uerpmann, M., Beauclair, R., Händel, M., Kutterer, A., Noack, E., Uerpmann, H, P., 2012. The Neolithic site FAY-NE15 in the central region of the Emirate of Sharjah (UAE). *Proceedings of the Seminar for Arabian Studies* 42, Papers from the forty-fifth meeting of the Seminar for Arabian Studies held at the British Museum, London, 28 to 30 July 2011, 385-400.

Uerpmann, H.P., Uerpmann, M., Kutterer, A., Jasim, S.A., 2013. The Neolithic period in the Central Region of the Emirate of Sharjah (UAE). Arab. Archaeol. Epigr. 24 (1), 102–108. https://doi.org/10.1111/aae.12019.

Uerpmann, M., "The Dark Millennium: remarks on the final Stone Age in the Emiratesand Oman" *in Archaeology in the United Arab Emirates: Proceedings of the First International Conference on the Archaeology of the UAE*, D. Potts,et al., Eds. (TridentPress, 2003), pp. 74–81.

Valente, T., Contreras, F., Mahmud, A., Yousif Ali Al Ali, Y., Boraik Radwan Karim, M., 2019. Anthropomorphic figurines from Area 2A of Sārūq al-Ḥadīd, Dubai, UAE. Proceedings of the Seminar for Arabian Studies 49, 283–292.

Valente, T., Contreras, F., Mahmud, A., Boraik, M.,Al Mansoori, M. S., Zein, H., 2020. "Five Seasons of Excavations in Areas 2A and G of Saruq al Hadid (Dubai, UAE): Iron Age II Evidence of Copper Production, Workshop Area, and Ceremonial Activities." *Isimu* 23, 169-195. https://doi.org/10.15366/isimu2020.23.010.

Vaquero, M., Bargallo, A., Chacon, G.M., Romagnoli, F., Sanudo, P., 2014. Lithic recycling in a Middle Paleolithic expedient context: Evidence from the Abric Romaní (Capellades, Spain). Quat. Int. 361, 1–17. https://doi.org/10.1016/j.quaint.2014.05.055.

Vaquero, M., Chaon, M.G., Cuartero, F., García-Ant_on, M.D., Gomez de Soler, B., Martínez, K., 2012. The lithic assemblage of level J. In: Carbonell, E. (Ed.), *High Resolution Archaeology and Neanderthal Behavior. Time and Space in Level J of Abric Romaní (Capellades, Spain)*. Springer, Dordrecht, pp. 189e311.

Vinx, R., 2014. Gesteinsbestimmung im Gelände. Springer-Verlag.

Weeks, L., Cable, C., Franke, K., Newton, C., Karacic, S., Roberts, J., Stepanov, I., David-Cuny, H., Price, D., Bukhash, R.M., Boraik, M., Zein, H., 2017. Recent Archaeological Research at Saruq al-Hadid, Dubai, UAE. Arab. Archaeol. Epigr. 28, 31–60. https://doi.org/10.1111/aae.12082.

Weeks, L., Cable, C.M., Karacic, S., Franke, K.A., Price, D.M., Newton, C., Roberts, J., Stepanov, I., McRae, I.K., Moore, M.W., David-Cuny, H., Al Aali, Y.Y., Boraki, M., Zein, H., 2019. Dating persistent short-term human activity in a complex depositional environment: Late prehistoric occupation at Saruq Al-Hadid, Dubai. Radiocarbon 00, 1–35. https://doi.org/10.1017/RDC.2019.67.

Weißmüller, W., 1995. *Die Silexartefakte der Unteren Schichten der Sesselfelsgrotte. Ein Beitrag zum Problem des Mousterien.* Quartar-Bibliothek 6. Saarbrucken.