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A Window into the Early–Middle Stone Age Transition in Northeastern Africa—A Marine Isotope Stage 7a/6 Late Acheulean Horizon from the EDAR 135 Site, Eastern Sahara (Sudan)

Grzegorz Michalec [a], Marzena Cendrowska [a,b], Eric Andrieux [c,d], Simon J. Armitage [c,e], Maciej Ehlert [a,b], Ju Yong Kim [f], Young Kwan Sohn [g], Joanna Krupa-Kurzynowska [h], Piotr Moska [i], Marcin Szmit [j], and Mirosław Masojć [a]

[a]University of Wrocław, Wrocław, Poland; [b]Archeolodzy.org Foundation, Wrocław, Poland; [c]University of London, London, United Kingdom; [d]Durham University, Durham, United Kingdom; [e]University of Bergen, Bergen, Norway; [f]Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, Republic of Korea; [g]Gyeongsang National University (GNU), Jinju, Republic of Korea; [h]Wroclaw University of Science and Technology, Wrocław, Poland; [i]Silesian University of Technology, Gliwice, Poland; [j]Gdańsk Archaeological Museum, Gdańsk, Poland

ABSTRACT
This paper presents the results of the analysis of a late Acheulean horizon from the EDAR 135 site, which was discovered in the Eastern Desert, Sudan, in an area heavily transformed by modern mining activity. A lithic assemblage was discovered there, within a layer of gravel sediments formed by a paleostream in a humid period of the Middle Pleistocene. This layer is OSL dated between 220 ± 12 and 145 ± 20 ka (MIS 7a/6). These dates indicate that the assemblage could be the youngest trace of the Acheulean in northeastern Africa. Technological analysis of the lithics reveals different core reduction strategies, including not only ad hoc ones based on multiplatform cores, but also discoidal and prepared cores. The use of prepared core reduction methods has already been confirmed at other Late Acheulean sites in Africa and the Middle East. Microwear traces observed on lithic artifacts could relate to on-site butchering activities.

KEYWORDS
Sudan; Acheulean; Middle Pleistocene; lithic technology; Large Cutting Tools; fluvial sediments; OSL dating

Introduction

Together with the Arabian Peninsula, the Eastern Sahara region (Egypt and Sudan) played an important role in the development and dispersal of hominins from the African continent to Eurasia, especially in the context of Middle (*Homo erectus/ergaster*) and Late Pleistocene (*Homo sapiens*) migrations (Van Peer 1998; Bar-Yosef and Belfer-Cohen 2001; Lycett and von Cramon-Taubadel 2008; Scerri et al. 2018; Petraglia, Breeze, and Groucutt 2019). In the period dated to the end of Marine Isotope Stage (MIS) 7 and the beginning of MIS 6, considerable changes in cultural adaptations occurred in this area (Van Peer 2016; Scerri and Spinapolice 2019; Usai 2019; Garcea 2020). Technological innovations connected with the Early Middle Stone Age appeared here later than in other parts of the continent (Deino et al. 2018; Scerri and Spinapolice 2019). Archaeological material displays the evidence of an ongoing presence of the Acheulean tradition at sites located along the Nile and the Atbara Rivers (Caton-Thompson 1952; Chmielewski 1968, 1987; Vermeersch et al. 2000; Abbate et al. 2010; Van Peer et al. 2003; Van Peer 2016; Masojć et al. 2020; Masojć 2021), in the Egyptian Oasis (Schild and Wendorf 1977), on the Red Sea coast (Beyin, Chauhan, and Nassr 2019), and in the Red Sea Mountains (Kobusiewicz et al. 2018). The Acheulean is one of the Early Stone Age cultural complexes, lasting for over 1.5 million years and covering the territory of Africa, Europe, and Asia (Kuman 2014). This complex is mainly characterized by the production of Large Cutting Tools—handaxes, cleavers, picks, and choppers (Gallotti and Mussi 2018; Shipton 2020).

At the same time, the emergence of a new technological tradition known as the Sangoan is observed (Van Peer 2016; Scerri and Spinapolice 2019; Garcea 2020; Masojć 2021). There is still considerable debate over the origins, technological features, and adaptation methods of the Sangoan complex in Africa and its differences from the Lupemban (Clark 1982; McBrearty 1988; McBrearty and Brooks 2000; Taylor 2016; Van Peer 2016). Generally, this complex is defined as a post Acheulean, Early Stone Age–Middle Stone Age transitional complex connected with the adaptation to forest/humid environments (Clark 1982; McBrearty 1988; McBrearty and Tryon 2006; Tylor 2016). Core-axes—small, oval bifacial tools with considerably retouched distal edges—are the *fossile directeur* of this complex (McBrearty 1988; Carlson 2015; Van Peer 2016), and their emergence is attributed to the arrival of anatomically modern humans (Van Peer 2016; Garcea 2020; Masojć 2021). However, the oldest *Homo sapiens* skeletal remains, which were discovered at the Jebel Irhoud site in Morocco, are associated with the Levallois–early Middle Stone Age (MSA) assemblage (Richter et al. 2017).

Sangoan assemblages have been recorded at a few sites located in Sudan, mainly along the Nile Valley, including Sai-8-B-11 (Van Peer et al. 2003), Khor Abu Anga (Carlson 2015), and al-Jamrab, whose cultural attribution is not clear

CONTACT Mirosław Masojć miroslaw.masojc@uwr.edu.pl University of Wrocław, Institute of Archaeology, Laboratory for Non-European Archaeology, Szewska 48 street, 50-139 Wrocław, Poland

and can also be connected to the Late Acheulean (Spinapolice et al. 2018). Apart from these, early MSA assemblages, which are characterized by the lack of Large Cutting Tools (LCTs), a bifacial component, and the dominance of discoidal, Levallois reduction methods with retouched tools (points, denticulate, etc.) and therefore described as Mousterian or Early Stone Age assemblages associated with the Levallois method, were discovered in the Eastern Sahara (Scerri and Spinapolice 2019). The oldest MSA settlements in northeastern Africa are the "larged-sized MSA" unit from Dakhleh Oasis and the "lower Levallois" site from Kharga Oasis Locus IV, which are dated similarly to 220 ± 20 ka (Churcher, Kleindienst, and Schwarcz 1999, 305; Kleindienst et al. 2008, 35). Previous dating results for the sites of Bir Sahara East and Bir Tarfawi indicate a similar chronology for the early MSA assemblages discovered in this area (Wendorf, Schild, and Close 1993); however, new correlation of OSL (Optically Stimulated Luminescence) dating results shows that the oldest assemblages were buried within sediments dated to MIS 5 (Schild, Hill, and Bluszcz 2020).

This article presents the results of research on the lower horizon discovered in 2019 during the excavations carried out at site EDAR 135. The artifacts were found at a depth of ca. 2.6 m from the contemporary ground level in fluvial deposits dated to the MIS 7/6 transition. Above this stratigraphic level, a horizon with Levallois material was recorded, which will be discussed elsewhere (Ehlert et al. in press).

History of research in the Atbara River region

The first identification of Acheulean sites in the Atbara River region (Khor Hudi and Khashm el Girba) comes from J. Arkell (1949). Subsequently, the mid-Atbara River area in the vicinity of Khashm el Girba was investigated by W. Chmielewski in February 1967, as part of the Combined Prehistoric Expedition (Chmielewski 1987). He discovered 26 new sites which yielded Abbevillian or Acheulean and Levallois artifacts and documented their stratigraphy. Site 102 is particularly noteworthy, as artifacts determined by W. Chmielewski to be Abbevillian handaxes were discovered in gravel deposits ranging from 50–300 cm in thickness. Acheulean and Levallois artifacts were recovered at sites 106 and 109. W. Chmielewski's conclusions were revised in 2005–2008 by the team headed by E. Abbate (Abbate et al. 2010), who succeeded in describing a 50 m thick sequence of Pleistocene deposits along the mid-Atbara River between Khashm el Girba and Halfa al Jadida. The deposits were dated on the basis of Pleistocene faunal remains and artifacts, but also with the use of U/Th and paleomagnetic methods. Two main geological synthems were identified in the research area: the Butana Bridge Synthem (BBS)—older, dating from the Late Early Pleistocene to the Early Middle Pleistocene—and the Khashm el Girba Synthem (KGS), dated from the Late Middle Pleistocene to the Late Pleistocene. The BBS sediment layers provided Acheulean handaxes and an *Elephas recki recki* cranium, among others. The KGS was divided into three subsynthems; the oldest, KGS

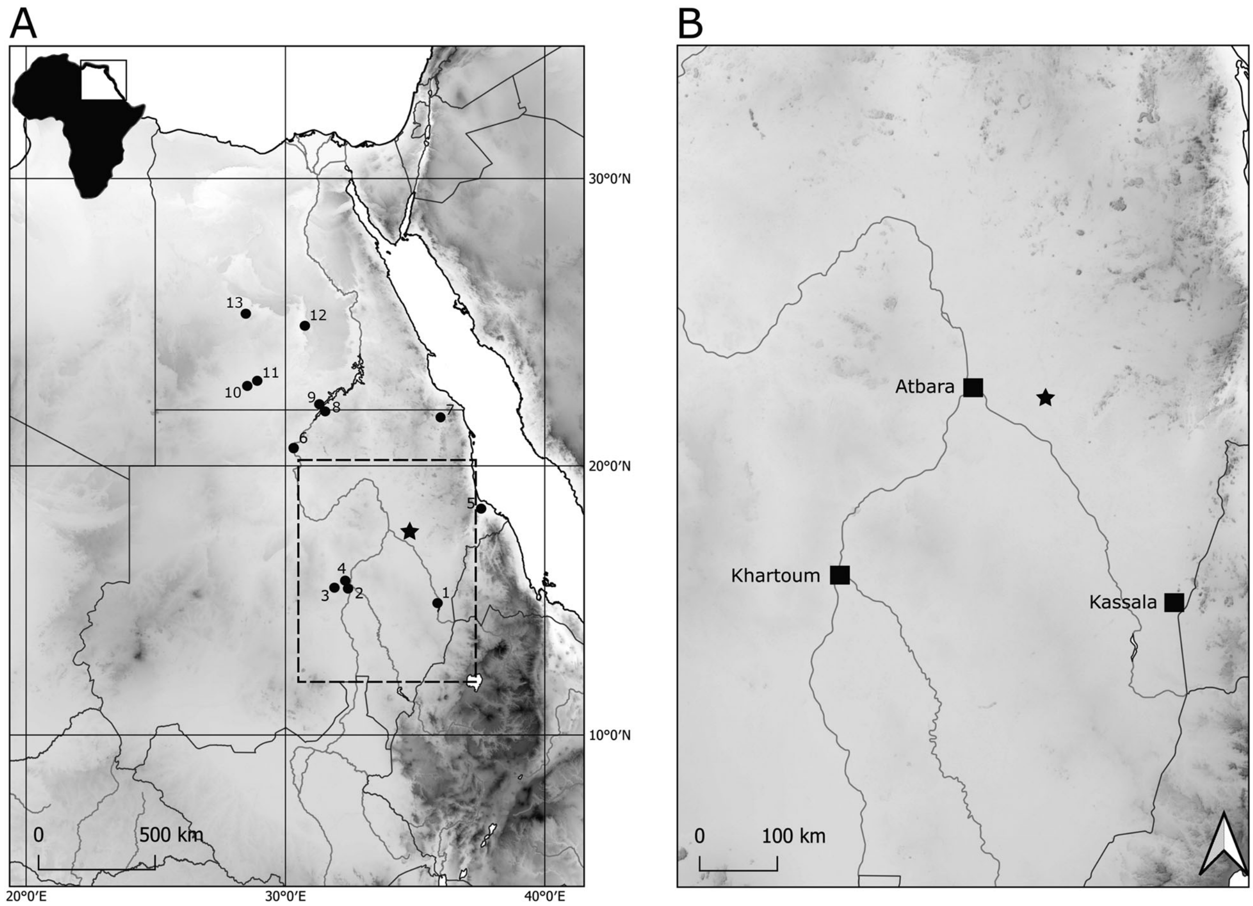

Figure 1. Location of sites in Sudan and Egypt mentioned in the text (EDAR sites marked with a star). 1—Khashm el Girba; 2—Khor Abu Anga; 3—Al-Jamrab; 4—Khor Shambat; 5—Hayna and Tagrada; 6—Sai Island 8-B-11; 7—Gebel Karaiweb; 8—Wadi Halfa; 9—Arkin 8; 10—Bir Sahara; 11—Bir Tarfawi; 12—Kharga Oasis; 13—Dakhla Oasis.

1, where Acheulean evidence was recorded, was dated to MIS 7. The remaining two, KGS 2 and 3, were dated to 126 ± 1 ky and 92.2 ± 0.7 ky, respectively, which correlates to MIS 5. Buried Levallois assemblages were recorded within these stratigraphic units.

EDAR project

The Eastern Desert Atbara River (EDAR) Project aimed at identifying new Middle and Upper Pleistocene archaeological sites in a stretch of the Sudanese Eastern Desert (N17.68500° E34.77448°) located ca. 70 km to the east of Atbara city (Figures 1, 2) (Nassr and Masojć 2018; Masojć et al. 2019, 2021a, 2021b; Masojć 2021). The project was carried out by the Institute of Archaeology, University of Wrocław, Poland in cooperation with the Faculty of Archaeology & Tourism, Al Neelain University, Khartoum, Sudan, the Korea Institute of Geoscience and Mineral Resources (KIGAM), Republic of Korea, and the Research Institute of Natural Science of the Gyeongsang National University, Republic of Korea.

The project comprised four consecutive seasons of fieldwork starting in 2016. It began with extensive surface prospection, which resulted in finding more than 150 sites situated on the Atbara River and in the Eastern Desert. Several among them contained strata connected with the late Acheulean (EDAR 6, EDAR 7, EDAR 133, and EDAR 135) and MSA (EDAR 134, EDAR 135, and EDAR 155) (Masojć et al. 2019, 2021b). All these sites were discovered in contemporary mining shafts concentrated in an area of over 2 ha. The shafts had been dug by prospectors searching for gold present in quartz dykes (see Figure 2). Although gold has been mined in Sudan since antiquity, the contemporary gold rush began in 2008 (Klemm and Klemm 2013; Chevrillon-Guibert 2016). On the one hand, intensive mining in archaeologically unexplored parts of the desert results in the discovery of new sites (e.g. the EDAR site complex). On the other hand, it has had a destructive impact on the local environment and heritage, damaging not only sites which were already located and protected by the National Corporation for Antiquities and Museums (NCAM), like the Jabar Maragha site in the Bayuda Desert, destroyed in 2020, but also eradicating a great multitude of new ones before they had a chance to be recorded.

Apart from determining the archaeological context of Pleistocene settlement, three seasons of fieldwork (2017–2019) carried out as part of the EDAR study were aimed at recognizing the geological situation in the region, stratigraphic description of the profiles, and collecting samples of deposits for OSL dating and Be-10

Figure 2. EDAR 135 site. A) Aerial photography of mining shaft complex; EDAR 135 marked with black arrow; B) aerial photography of the EDAR 135 site; C) eastern profile of mining shaft with marked (red dots) places of OSL S4 and S5 (below) sampling places; D) northern profile; E) northern profile before upper level excavations (MSA); F) removing sterile sediments above the lower horizon; and, G) excavating lower horizon (Acheulean).

(atmospheric cosmogenic nuclides Beryllium 10) analysis. Excavations were carried out at sites EDAR 6, 7, 133, 134, 135, and 155.

Geological description of site location

The studied area is a plain with a flat surface situated at an altitude of 350–400 masl. The western border is marked by the vast Nile Valley between the Fifth and Sixth Cataracts, and the southern border is the valley depression of the Atbara River. The main component of the geological structure of the analyzed area is metamorphosed Proterozoic rocks with rhyolite intrusions breaking through them. A long-lasting denudation process, driven and influenced by climate change, began in the early Quaternary and led to the formation of the basic framework of the relief: isolated hills and weathered covers of various thicknesses. These covers are derived from various sedimentary rocks. The contemporary surface of the plateau is covered mostly by aeolian formations and wide valleys (Wadi), poorly visible in the morphology of the area.

Materials and Methods

Optically Stimulated Luminescence dating (OSL)

OSL samples were taken from sands immediately above and below the artifact-bearing fluvial gravels in each of two different sections: the Northern section (samples EDAR-135-1 and 2) and the Eastern section (samples EDAR-135-S4 and S5). The samples coded EDAR-135-1 and EDAR-135-2 were measured at the Korean Institute of Geoscience and Mineral Resources (KIGAM), while those coded EDAR-135-S4 and EDAR-135-S5 were analyzed at the Gliwice Absolute Dating Method Centre (GADAM) laboratories. The results from the KIGAM samples were previously published (Masojć et al. 2019, 2021b), but the equivalent dose and dose rate data are reanalyzed here for consistency with the GADAM data, which are partly presented for the first time in this study. Sample preparation and measurement conditions for the KIGAM samples were presented by Masojć and colleagues (2019).

The samples were prepared under subdued red-light conditions, where the outer, light-exposed portions of each sample were removed and used for environmental dose rate measurements and estimation of the sample's moisture content. The remaining sediment was treated with hydrochloric acid (1M HCl) and hydrogen peroxide (H_2O_2) to remove carbonate and organic matter, respectively. Quartz was extracted from the 90–212 µm (KIGAM) or the 90–125 µm (GADAM) fractions using density separations at 2.62 and 2.70 g/cm^3 and a subsequent HF acid etch (23M HF for 40 minutes, followed by a 10M HCl rinse). Refined quartz was deposited as a monolayer on aluminum discs using Silkospray silicone oil.

The samples were measured on a Daybreak Model 2200 luminescence reader using the single-aliquot regenerative-dose (SAR) procedure (Murray and Wintle 2000, 2003). Optimal measurement conditions were determined using dose recovery tests, and a preheat combination of 220 °C for 10 s prior to measurement of the natural/regenerated luminescence intensity (PH1) and 160°C for 10 s prior to measurement of the test dose luminescence intensity (PH2) was adopted. Irradiations were carried out using a $^{90}Sr/^{90}Y$ beta source. Stimulations were carried out at 125 °C for 60 s using blue light emitting diodes. Aliquots were heated at 5 °C/s during all heating steps, and a 10 second pause at 125 °C prior to optical stimulation was used. The OSL intensity is that recorded during the first 1.5 seconds of stimulation with a background signal subtracted. The EDAR samples display a rapidly decaying OSL signal. All growth curves were fitted using a saturating exponential plus linear function. The performance of the SAR procedure was monitored via recycling ratios and recuperation (Murray and Wintle 2000, 2003). Aliquots not yielding recycling ratios consistent with unity or displaying recuperation greater than 5% of the natural signal were rejected.

For both the KIGAM and GADAM samples, the optimal statistical model for determining the sample burial dose (D_b) was determined via the analysis of the D_e distribution following Bailey and Arnold (2006). The Central Age Model (CAM) (Galbraith et al. 1999) was found to be appropriate for all samples. Published D_b values for EDAR-135-1 and EDAR-135-2 (Masojć et al. 2019) were calculated as the mean value of the accepted aliquots, resulting in D_b estimates ca. 10% larger than those determined using the CAM. For consistency, we use CAM D_b estimates hereafter. Radial plots showing the equivalent dose distribution and CAM D_b for each sample are presented in Figure 3.

Radioisotope concentrations for each sample were determined using high resolution gamma spectrometry and imply secular equilibrium in the ^{238}U and ^{232}Th decay series. Beta and gamma dose rates were calculated from the radioisotope concentrations using the conversion factors of Guérin, Mercier, and Adamiec (2011). Beta dose rates were corrected for grain size using the attenuation factors of Guerin and colleagues (2012) and an etch attenuation factor after Bell (1979). A moisture content of 8 ± 3% was assumed for all samples to account for the plausible range of past conditions and humidity changes. Cosmic ray dose rates were calculated based on the altitude, latitude and longitude, present-day burial depth, and overburden density of the sample (Prescott and Hutton 1988). Overburden densities of 1.8 g/cm^3 were assumed. Dose rates and ages for each sample were calculated using DRAC (Durcan, King, and Duller 2015) x and are presented in Table 1.

Geology and stratigraphy

Paleogeographic reconstructions synthesize the results of local observations with general paleoclimatic assumptions. Sedimentological and lithofacial (structural and textural) analyses carried out in the field, supplemented with OSL dating, were the main methods of paleogeographic research. The profile of EDAR 135 was thoroughly sampled (50 points in ca. 10 cm intervals). The samples were analyzed under laboratory conditions on the basis of their particle size and geochemical features (Figure 4B–C).

Fieldwork methods—archaeological excavations

Fieldwork at the EDAR 135 site was carried out for three seasons, beginning in 2017 with the discovery of lithics in the walls of a 5 m deep mining shaft (see Figure 2). In the same season, all profiles were cleaned with geological hammers. A preliminary geological and geomorphological

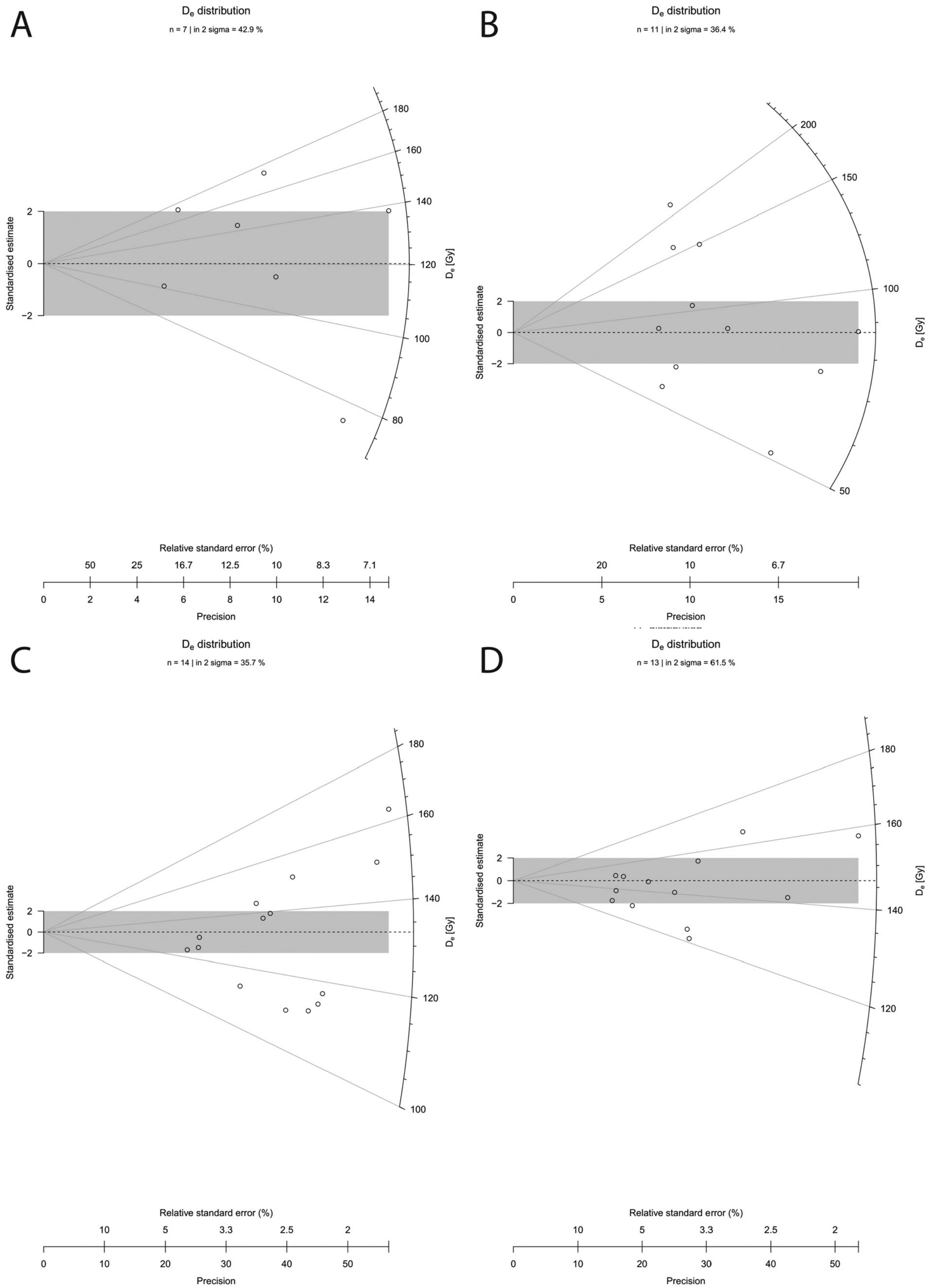

Figure 3. Radial plots of EDAR samples. The dark grey bar is centered at the CAM Dose (broken black line), and all the points that lie within the bar are consistent (at 2σ) with this dose. A) EDAR135-1; B) EDAR135-2; C) EDAR135-S4; and, D) EDAR135-S5.

description was made, and the first artifacts and six OSL samples were collected from the northern section. In 2018, the eastern section was described, and four dating samples were collected. The excavation proper started in 2019. A trench was located in the northern section of the mining shaft (see Figure 1). Hoes and pickaxes were used to remove the sterile, purely geological layers of units III and IIB. After reaching archaeological horizons, large

Table 1. OSL dating results.

Sample (EDAR- …)	Radionuclide Concentrations[1] K (%)	U (ppm)	Th (ppm)	Depth (m)	Profile	Grain Size (μm)	Cosmic Dose Rate (Gy/ka)[2]	Total Dose Rate (Gy/ka)[3]	Burial Dose D_b (Gy)[4]	Age (ka)[5]
135-1	0.30 ± 0.02	0.62 ± 0.20	1.12 ± 0.48	2.75 ± 0.05	Northern	90–212	0.151 ± 0.015	0.65 ± 0.04	125.7 ± 13.7	194.8 ± 25.1
135-2	0.37 ± 0.02	0.48 ± 0.11	0.81 ± 0.04	2.60 ± 0.05	Northern	90–212	0.154 ± 0.015	0.66 ± 0.03	94.9 ± 12	144.7 ± 19.4
135-S4	0.46 ± 0.04	0.25 ± 0.02	1.48 ± 0.15	2.20 ± 0.05	Eastern	90–125	0.161 ± 0.016	0.75 ± 0.04	129.9 ± 4.4	173.2 ± 10.7
135-S5	0.35 ± 0.03	0.22 ± 0.03	1.72 ± 0.15	2.60 ± 0.05	Eastern	90–125	0.154 ± 0.015	0.65 ± 0.02	142.4 ± 3.8	220.6 ± 12.4

[1]Radioisotope concentrations were measured using high resolution gamma spectrometry and converted to dose rates following Guérin, Mercier, and Adamiec (2011).
[2]Cosmic dose rates were calculated following Prescott and Hutton (1988) and using overburden densities of 1.8 g/cm^3.
[3]The total dose rates were corrected for grain sizes of 90–212 or 90–125 μm and moisture content (8 ± 3%) following Guérin and colleagues (2012).
[4]Burial doses were calculated using the Central Age Model (CAM; Galbraith et al. 1999).
[5]The datum of the age calculation is 2019.

tools were swapped for brushes, geological picks, and small trowels. The excavated sediment was dry sieved through a 5 mm mesh.

The excavation covered an area of over 5 m^2 and was divided using a square meter local grid system (see Figures 2, 5). All artifacts larger than 15 mm were plotted using a total station, given an ID number, and packed separately in plastic bags labelled with all necessary data (ID no., layer, etc.). Artifacts extracted from the sieving of sediments were grouped within their respective square meters.

Lithics analysis

The implemented method of typological classification of artifacts and analysis of techno-morphological features is syncretic; it was based on various approaches to Acheulean materials from Africa and the Middle East (Schild and Wendorf 1977; de la Torre and Mora 2018; Goren-Ibnar et al. 2019). Stone artifacts were divided into two main technological groups characterized by different sequences of reduction: Large Cutting Tools (LCTs) and core reduction products. The LCTs are defined (see García-Medrano et al. 2020) as more or less standardized forms of unifacial and bifacial tools (choppers, cleavers, handaxes, etc.). The techno-morphological analysis was adjusted to consider the attributes specific to particular artifact groups (cores, tools, and debitage), as well as features common to each artifact (e.g. platform type, percentage of natural surface, number and direction of scars, physical state, completeness, and heat damage). A detailed scar pattern analysis was conducted for selected artifacts (cores and handaxes) whose physical state allowed it. Selected lithic artifacts were drawn and photographed.

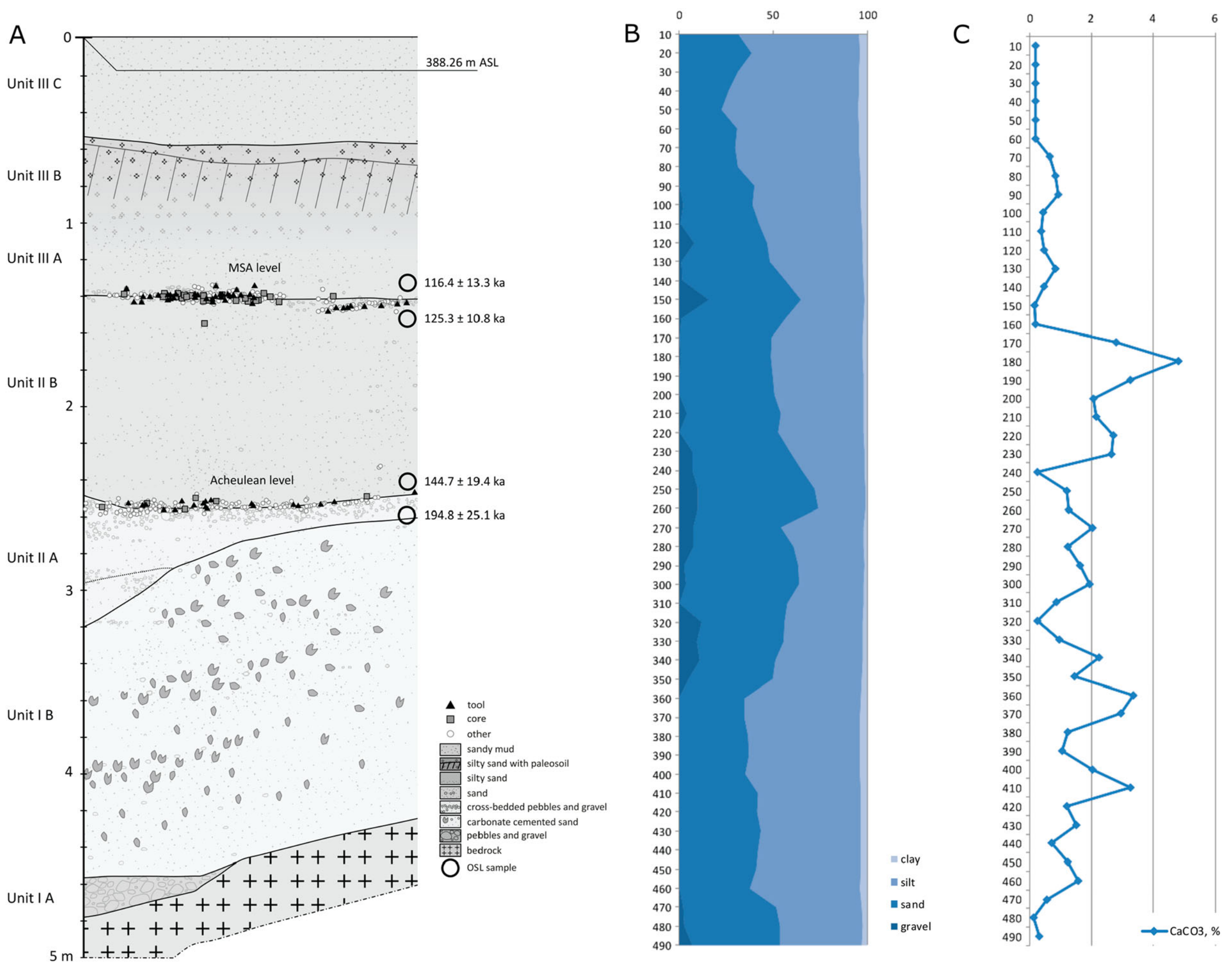

Figure 4. Northern profile and chronology of EDAR 135. A) Stratigraphy and two cultural horizons with OSL results; B) results of granulometry analysis; and, C) calcium carbonate content.

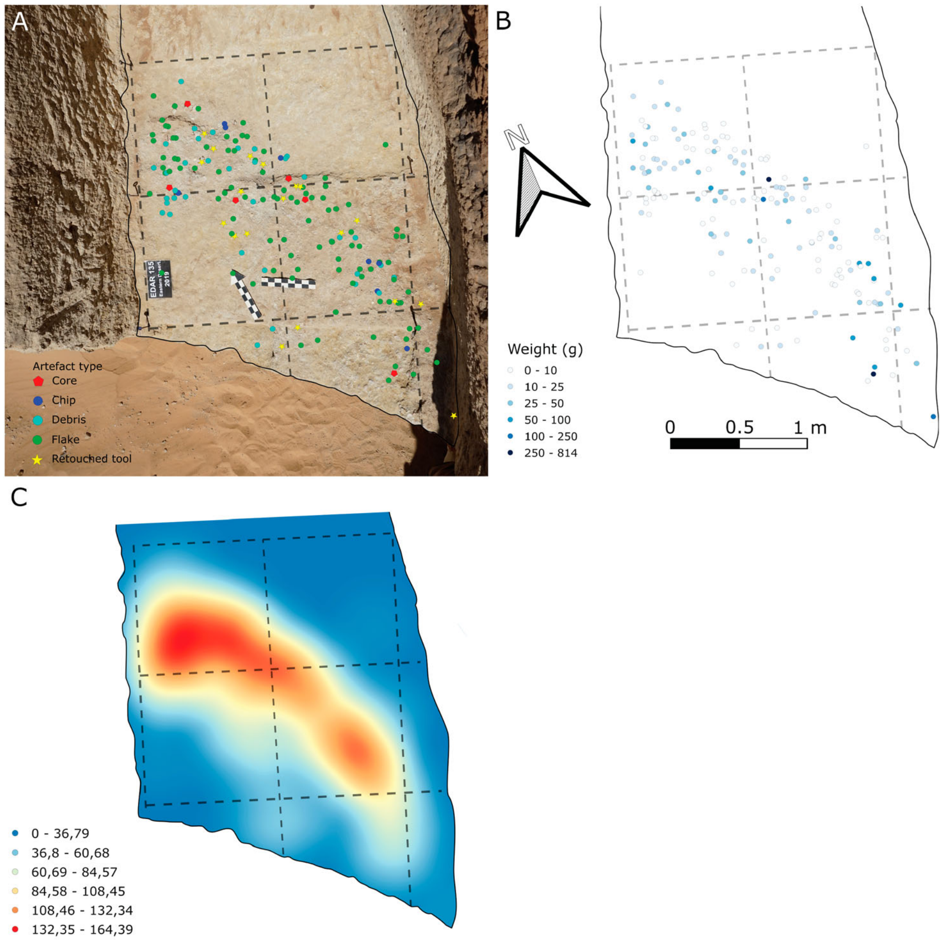

Figure 5. Spatial analysis results. A) Spatial distribution by artifact type; B) distribution of artifacts by weight; and, C) Kernel density.

All artifacts were weighed on an electronic scale (0.1 g resolution), but only those longer than 15 mm were measured (max. length, width, and thickness) with an electronic caliper (0.01 mm resolution). Shorter forms of flakes were classified as chips. The length of debitage was measured along the technological axis (see Inizan et al. 1999; Andrefsky 2005).

EDAR Acheulean and MSA assemblages, including the one from the lower horizon of EDAR 135, were almost exclusively based on two raw materials: quartz and rhyolite. Samples of these rocks were subjected to petrographic analysis. Mineral composition of the rocks used as raw material for the production of artifacts was determined via X-ray powder diffraction analysis (XRD). The X-ray diffraction measurements were made using a Siemens D-5005 diffractometer. Additionally, transmitted light preparations for representative rocks were made. Observations were carried out with the use of a standard petrographic microscope.

Metric and technological data, as well as basic information about the artifact context, were collected in a Microsoft Access database. Spatial analysis of artifacts, including distribution and Kernel density (bandwidth = 0.25), was conducted in QGIS (v. 3.10.1 La Coruna). Scale of colors was used in Kernel density analysis to identify potential clusters.

Microwear analysis

Quartz is a heterogeneous, macrocrystalline rock. Because of this quality, traces form irregularly in small areas, most frequently on crystals and higher parts of artifact surface topography (Clemente Conte, , and Gibaja Bao 2009; Leipus 2014; Clemente Conte et al. 2015). Additionally, the features caused by use-wear and post-depositional alterations may occur together on different parts of the tool. Therefore, careful observation of each edge under magnifications between 200x and 500x is required to detect specific surface features (Taipale 2012; Lemorini et al. 2014). All typological tools made of small flakes were designated for use-wear analysis. Of these, 11 artifacts without heavy edge and ridge rounding or micro-chipping and at least one intact, functional working edge were selected.

The study was conducted in the laboratory of the Institute of Archaeology, University of Wroclaw. The artifacts were cleaned for 2–5 minutes in an ultrasonic bath (water) and subsequently observed and documented with the use of a NIKON Eclipse LV 100 under 200–500x magnification. Image focus was enhanced by picture stacking. This same microwear analysis protocol was previously applied in studies of lithics from the EDAR 7 site (Masojć et al. 2021a).

Results

Stratigraphy

The sedimentary cover within which the EDAR sites were documented reaches a maximum thickness of 5 m and is composed of sand/silt sediments with interbedding of gravel and rock fragments (see Figure 4). The bedrock is composed of weathered rhyolite and is overlain by thin alluvial and colluvial pebbly gravel with a diameter of up to 20–30 cm and coarse-grained sands dated to older than 391 ± 30 ka (Masojć et al. 2021a). The thicker silty sand layers (0.5–1.5 m) are the result of decreased aeolian accumulation; there are carbonate concretions of secondary calcium carbonate within them. Gravel sediments are a remnant of paleochannels formed during wet periods. Thin layers of gravel and pebbles (0.2–0.4 m) are the result of erosive wind activity in cold and dry periods forming a deflation pavement. Three main units of sediments can be distinguished in the geological structure of the sedimentary cover of the EDAR sites: Unit I—composed of gravel and layered pebbles (IA) and coarse-grained sands with carbonate concretions (IB), Unit II—composed of sand and layered gravel (IIA) and carbonate silty sands (IIB), and Unit III—composed of fine sediments with individual rock fragments and fossil soil remains.

Units I and II represent two separate wet periods (gravel) and the subsequent dry periods (cemented sand) dated to the Middle Pleistocene period (≥ MIS 11–MIS 6) (Masojć et al. 2019, 2021a). Stone artifacts have been documented within the gravel series (Unit IIA) and a thin erosive layer within sand and pebble fragments (Unit II B) (see Figure 4). The layer (Unit IIA) analyzed in detail lies at the depth of 240–300 cm and presents a series of cross-stratified fluvial sediments dated to MIS 7/6 (221 ± 12 ka, 145 ± 19ka). Fossil channels are cut in boulder-gravel-sand covers (Unit IB) dated to the period between 391 ± 30 ka and 199 ± 12 ka (Masojć et al. 2021a). The width of the paleochannel ranges from several to several dozen meters, and they are shallowly incised into the substratum. From the frequent lateral accretions of the braided stream, as shown in the lithology of Unit IIA, it may be postulated that the paleocurrent direction was variable.

OSL dating

Ages within each section are in stratigraphic order (see Table 1). Samples underlying the artifact-bearing braided stream deposit yielded ages of 194.8 ± 25.1 ka (EDAR-135-1) and 220.6 ± 12.4 ka (EDAR-135-S5), while those above it were dated to 144.7 ± 19.4 ka (EDAR-135-2) and 173.2 ± 10.7 ka (EDAR-135-S4). These ages bracket the deposition of the fluvial deposit and imply that the river was active during MIS 7 or at the transition between MIS 7 and 6.

Site formation and spatial analysis

Lithic artifacts were buried in a ca. 25 cm thick layer of fluvial gravels at depths ranging between 2.40 and 2.65 m below the surface. They occurred in gravels only—none were found in sand, and therefore their distribution in the northeastern part of the trench reflects the boundary between these two sediment types (Figure 5A). The distribution of artifacts by weight, especially the lightest products of core reduction, indicates uniform and ubiquitous positioning of the lithics (Figure 5B). Kernel Density reveals an artifact cluster which extends along the north-south axis and reflects the flow direction of a paleostream (Figure 5C).

The horizontal distribution of the artifacts is probably the result of fluvial processes, which secondarily displaced archaeological material. Higher density of the artifacts in the northern part of the trench is probably the consequence of a natural depression in the paleostream bed, not a cluster created by human activity. The collected data suggest that the artifacts were redeposited by a meandering watercourse, which is substantiated by the presence of artifacts only within gravel deposited at the bed of the paleostream and their absence in the adjacent sand deposits. Experiments testing the possibility of flaking milky quartz proved that block reduction results in a great number of micro-splinters (dust and chips) (Manninen 2016; Masojć et al. 2021a). A similar effect could probably have been achieved by a strong watercourse current, carrying quartz and chipping it during transport. Ubiquitous fine material (chips) at the site is the consequence of two main factors: human activity and transport by flowing water. Due to the lack of a conclusive basis to determine unequivocally how many chips are geofacts or artifacts, all fine materials were included in the assemblage.

Table 3. Dimensions of all artifacts.

Attribute		Flakes	Tools	Cores
Length	Min.	15.9	16.2	20.8
	Max.	63.2	79.7	118.5
	Mean	31.4	37.6	56.4
	Median	28	32.3	33.4
	St. Dev.	10.8	18.5	41.5
Width	Min.	9.3	13.2	33.8
	Max.	79.2	62.5	104.2
	Mean	30.1	34.4	56.7
	Median	26.8	32.7	40.3
	St. Dev.	12.6	12.4	28.8
Thickness	Min.	2.5	5.8	20.8
	Max.	27.3	40.3	57.7
	Mean	12.9	14.8	36.9
	Median	12.4	13	34
	St. Dev.	5.7	8.8	14.4
Weight	Min.	2	2.5	33.1
	Max.	89	227.8	813.8
	Mean	16.65	32.1	236.9
	Median	9.3	14.2	37.1
	St. Dev.	18.1	52.3	346.1
Platform width	Min.	5.5	7.1	
	Max.	51.8	48.2	
	Mean	20.1	23.2	
	Median	18.5	19.2	
	St. Dev.	9	13.8	
Platform length	Min.	2.5	3.3	
	Max.	47.3	35.4	
	Mean	10.8	12.1	
	Median	9.8	9.9	
	St. Dev.	6.6	8.2	

Table 2. Structure of lithic assemblage—number and weight of artifact classes by raw material.

		Rhyolite				Quartz			
Artifact Type	Total n	N	%	Weight (g)	%	n	%	Weight (g)	%
Handaxes	2	1	0.1	48.2	0.7	1	0.1	391.2	5.5
Choppers	1	1	0.1	1108	15.7	-	-	-	-
Cores	7	-	-	-	-	7	0.9	1658.4	23.5
Flakes	119	7	0.9	136.1	1.9	112	15.2	1746.2	24.7
Chips	549	11	1.5	22.6	0.3	538	73.0	773.6	10.9
Debris	36	-	-	-	-	36	4.9	456.2	6.5
Retouched tools	23	3	0.4	106.4	1.5	20	2.7	623.2	8.8
Total	737	23	3.1	1421.3	20.1	714	96.9	5648.8	79.9

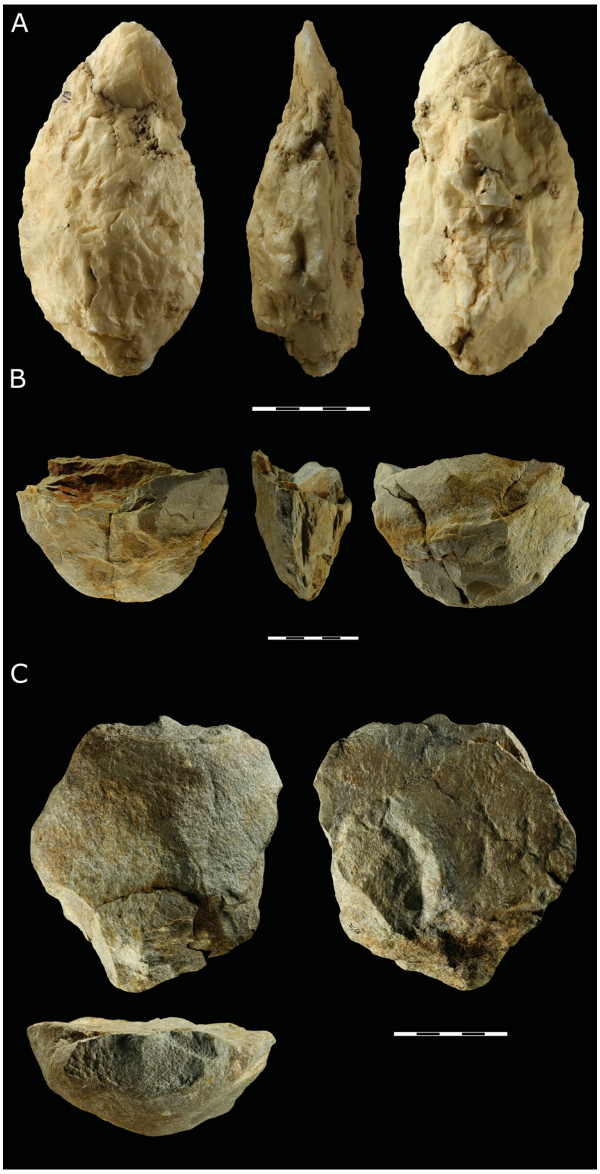

Figure 6. Large Cutting Tools from EDAR 135: A) handaxe, quartz; B) basal fragment of a handaxe, rhyolite; and, C) chopper made from a rhyolite cobble.

In the case of the assemblage analyzed here, the composition of the sediment and the distribution and properties of the artifacts (high fragmentation, abrasion of artifacts, and post-depositional traces visible on artifacts) seem to suggest that such dynamic processes did take place. In view of the above, the recorded spatial arrangement should be considered a consequence of dynamic natural processes (surface flowing water, stream water, and aeolian process) and does not reflect a fragment of a functional spatial arrangement formed by the activities of the Acheulean artifact producers.

Lithic assemblage

The lithic assemblage discovered at the lower horizon of the EDAR 135 site contains 737 artifacts (Table 2). Most of them (n = 565) were found during dry sieving, six during profile cleaning, and the rest were discovered and plotted while excavating. Table 3 contains the dimensions of measured artifacts.

Raw material and preservation state

Only local raw materials were used in lithic production at the lower level of EDAR 135. Quartz and rhyolite occur as large blocks and cobbles within close vicinity of the EDAR sites. Most of the artifacts were made of quartz (n = 714), with only 23 of rhyolite. As far as completeness is concerned (debris and chips excluded), almost 56% of the artifacts are complete, and 44% are preserved only in fragments. A significant proportion of artifacts (82.9%) have heavily or slightly abraded surfaces; the remaining ones are fresh.

LCTs

The analyzed assemblage includes just three LCTs: two handaxes and one chopper, all discovered during profile cleaning. The handaxes are made of quartzite and rhyolite. One was crushed by gold mining machinery—only the base part was found in the profile, heavily abraded and weathered (Figure 6B). The second specimen is complete and slightly abraded, cordiform in shape and plano-convex in cross-section (Figure 6A). It is shaped by numerous invasive, centripetal removals and has bifacial retouching on both sides and the tip. The presence of few hinged scars from the first stages of shaping probably results from the raw material properties. The chopper found at the site is made of a rhyolite cobble and is badly preserved (Figure 6C).

Cores

Seven cores were collected from the lower level of EDAR 135. All were made of quartz pebbles and cobbles, are preserved completely, and were discarded at the advanced stage of reduction. Miniaturized cores made on pebbles prevail in

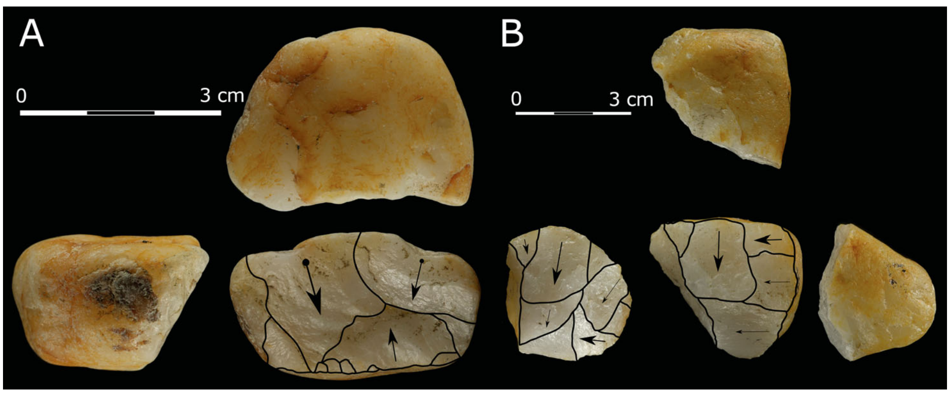

Figure 7. Cores made from quartz pebbles: A) bipolar and B) flake core with changed orientation.

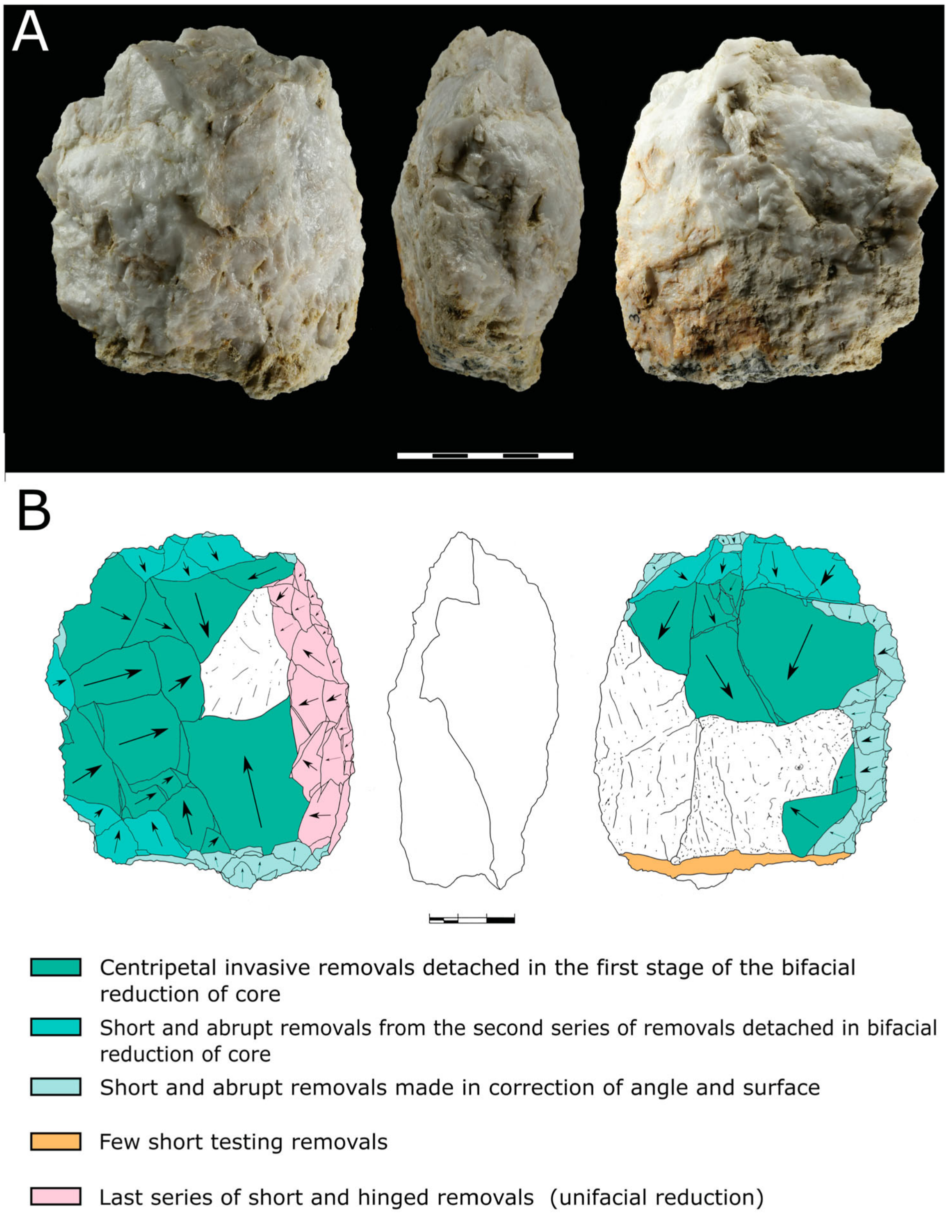

Figure 8. A) Levallois core (quartz) from EDAR 135, lower horizon and B) graphic presentation of scar pattern analysis results.

the assemblage (n = 5); their average dimensions are 32 × 40 × 28 mm. Their morphological features show a variety of reduction approaches. The first two specimens are a bipolar core (Figure 7A) and a bidirectional core with changed orientation (Figure 7B). The natural surface without preparation was used as the striking platform in both cases. The third small core is multiplatform. The two remaining ones are unidirectional: one has the striking platform prepared with a series of centripetal removals, whereas the platform of the other bears no signs of preparation.

The two larger cores represent different concepts of reduction. One is discoidal, has a non-hierarchized structure, and shows no traces of predetermination (Figure 8). Early on, the exploitation of this core focused on bifacial, centripetal removals. The flaking angle was then corrected with a series of short removals preparing the striking platform. The last stage aimed at unifacial reduction with the natural surface of the less transformed side used as the striking platform. Both surfaces display different degrees of exploitation, which results from variation of raw material properties (e.g. inclusions).

The other core is a prepared centripetal flake core, characterized by hierarchization of structure and a high degree of preparation (Figure 9). The main flaking surface is completely decorticated by centripetal removals. The second surface, with more cortex left, was used as the striking platform. Scar pattern analysis enables three stages of core reduction to be distinguished. The early stage aimed at preparing the flaking surface by unifacial removals, with a 75–90° flaking angle. The following stage involved using two surfaces and included striking platform preparation and control of the main flaking surface. Removal of invasive and long flakes was the final step.

Debitage and waste

Debitage and waste is the most numerous artifact group in the assemblage. It comprises 704 specimens, mostly chips (n = 549) and flakes (n = 119), while debris (n = 36) is less numerous. There are only 7 flakes and 11 chips made of rhyolite; the rest (n = 686) are quartz.

The flakes were mostly preserved in a complete state (n = 77). Analysis of dorsal side attributes shows that 37

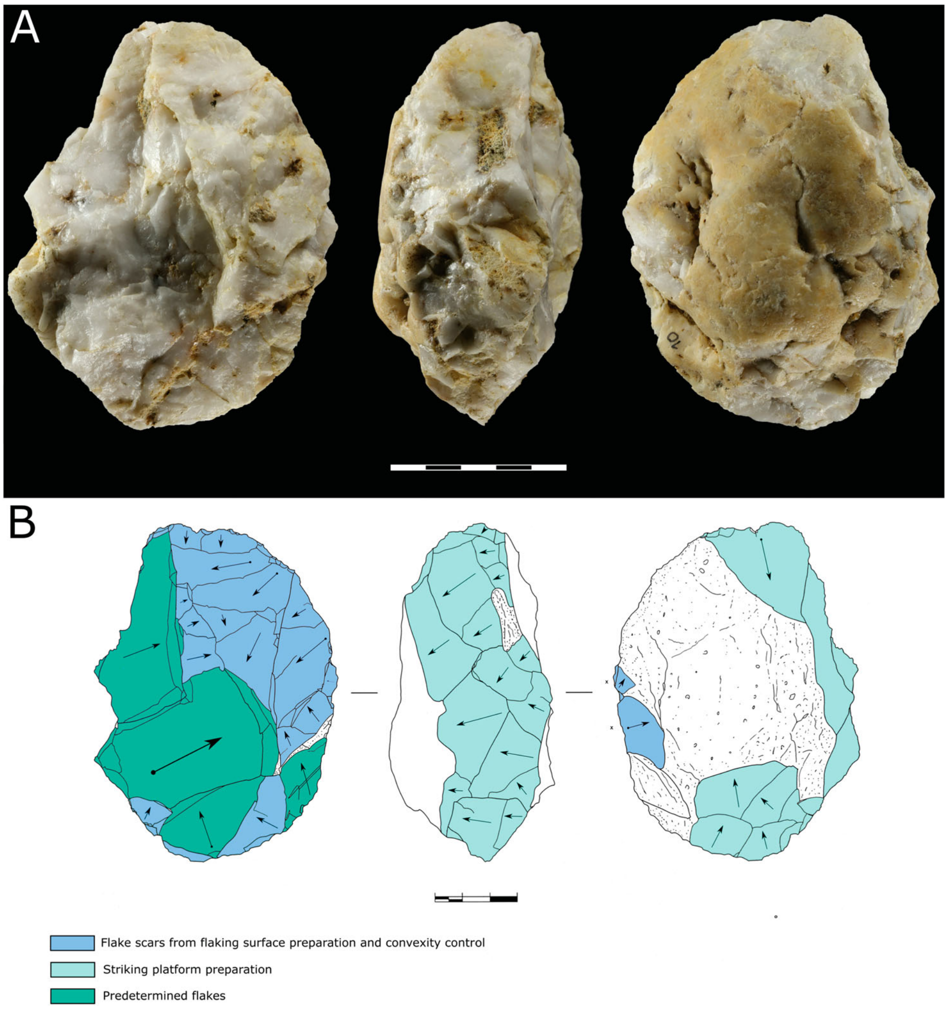

Figure 9. A) Discoidal core (quartz) from EDAR 135, lower horizon and B) graphic presentation of scar pattern analysis results.

specimens have between 75 and 100% of the natural surface left and thus can be defined as primary flakes detached at the first stage of reduction. The majority of flakes came from later stages of reduction and are either non-cortical (n = 33) or have up to 25% (n = 34) or 26–75% (n = 15) of the natural surface on the dorsal face. Unidirectional scars are the most common pattern (n = 46), while multidirectional (n = 14) and bidirectional ones (n = 26) are less frequently represented. Two predominant platform types are plain (n = 37) and natural (n = 39). Other types represented in the assemblage are punctiform (n = 11), linear (n = 7), and dihedral (n = 2). The remaining 23 flakes had missing or undetermined platforms.

Retouched tools

There are 23 retouched tools made on flakes in the assemblage, including 21 intact and two fragments (Figures 10, 11). Only 2 tools are made of rhyolite, which again makes quartz the most frequent raw material. Eight tool types were distinguished: denticulates (n = 6), sidescrapers (n = 4), flakes with simple retouch (n = 2), notches (n = 3), perforators (n = 3), endscrapers (n = 2), combined tools with mixed retouch (n = 2), and one Levallois flake (see Figures 10, 11). Flakes detached at the advanced stage of core reduction were the most frequently used blanks: the majority of tools have less than 25% (n = 14) or 26–75% (n = 7) of the natural surface on their dorsal faces (n = 14). Only two tools were made from primary flakes.

As with flakes, unidirectional scars predominate (n = 11), and bidirectional or multidirectional (centripetal) are less frequent. In the case of the two strongly abraded tools, scar directions could not be distinguished. Platform type frequencies are analogous with the flakes, too: plain (n = 15), linear (n = 2), cortical, and facetted (one of each). The remaining four lack or have a nonidentifiable platform.

Microwear Analysis

Macro-traces suggesting possible wear were detected on 7 out of 11 artifacts. Edge rounding and chipping were the most frequently observed traits. Despite that, identification of worked material was possible only for one tool (Figure 12A: 1, 2). Rough and matt polish, together with concentrations of impact pits and grooves of varying depths, were observed alongside one edge of this denticulate. Patches of brighter and smoother polish with sleek parallel striations were also visible. The former pattern could be linked with meat and hide cutting. The more pronounced traces could have formed when the tool had contact with bone. Combined, the observed use-wear suggests the possibility of use in butchering.

Post-depositional alterations (PDP) were observed on the surface of all analyzed tools (Figure 12B: 3). In three cases,

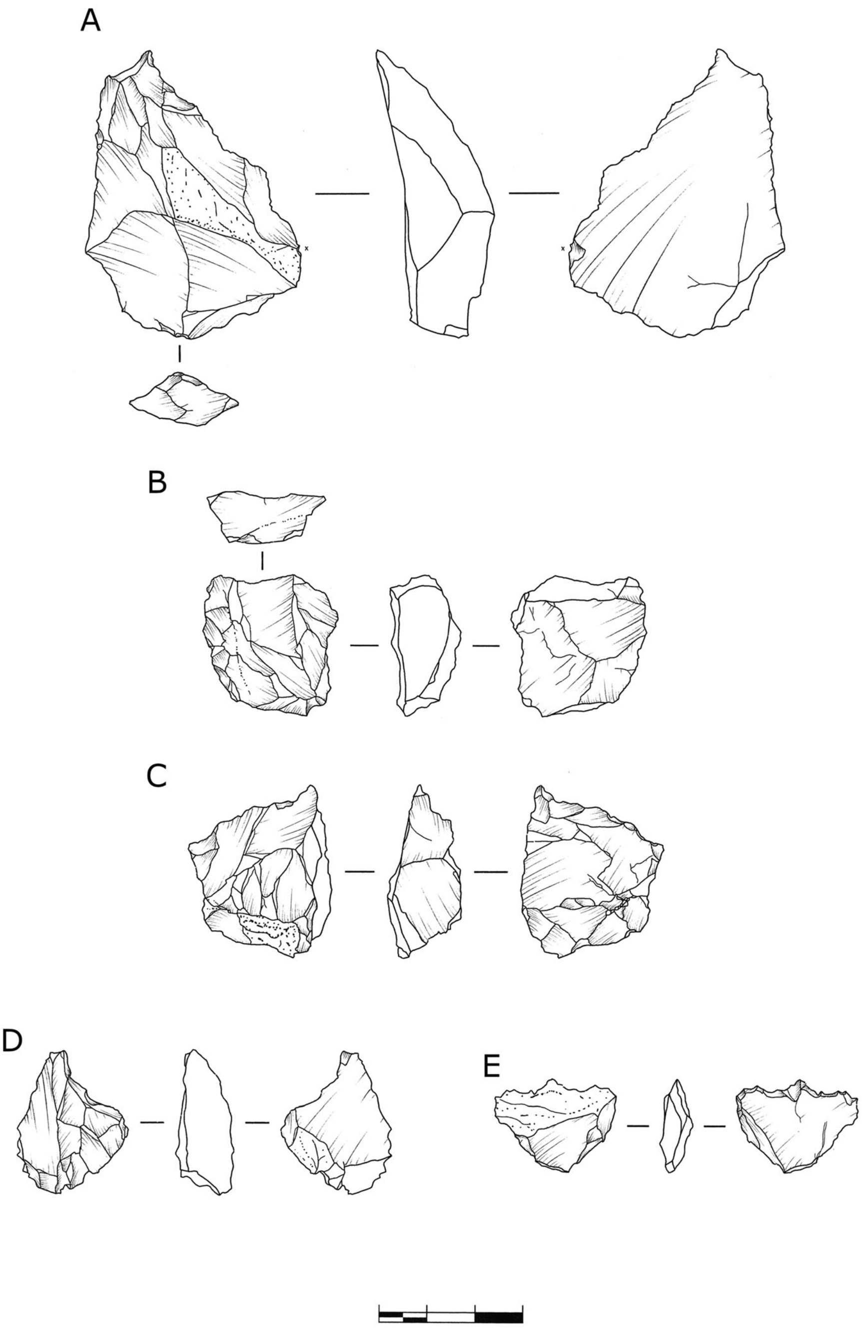

Figure 10. Retouched tools: A–B) sidescrapers and C–E) perforators. A) Rhyolite and B–E) quartz.

almost the entire surface was affected by PDP, which made the interpretation of function impossible. Several characteristics distinguish PDP from other traces. In micro-scale, they include striations of varying depths, scattered impact pits, and matting of surface. The patterns formed by such traces depend on post-depositional conditions. Water transport and rolling lead to strong and covering abrasion; the edges and other protruding parts of the artifact become rounded. Stabilization during that process would limit the damage to parts of the specimen. Coarseness of sediment also plays an important role: the rougher the sediment, the more pronounced the chipping (Petraglia and Potts 1994; Venditti, Tirillò, and Garcea 2016). Such a pattern of PDP alterations was most frequently observed on the EDAR 135 sample. Additionally, some traces, such as numerous impact pits, flat fractures, and cracks, could be linked with aeolian abrasion (Knuttson and Lindé 1990).

Discussion

Technological behaviors in the lower horizon of EDAR 135

The assemblage from the lower level of EDAR 135 is not particularly numerous. This factor is responsible for the limitation in our picture of the technological activities of its Acheulean manufacturers. These activities were aimed at the production of two types of tools: LCTs and flake tools (see Figures 6, 10, and 11). The former is rudimentarily represented in the assemblage: two complete tools and four flakes detached in various phases of flaking or repair of bifacial forms.

Flake production was diversified and based mainly on opportunistic reduction of miniaturized cores made of quartz pebbles. Miniaturization is a common phenomenon on a global scale, recorded in different assemblages dated

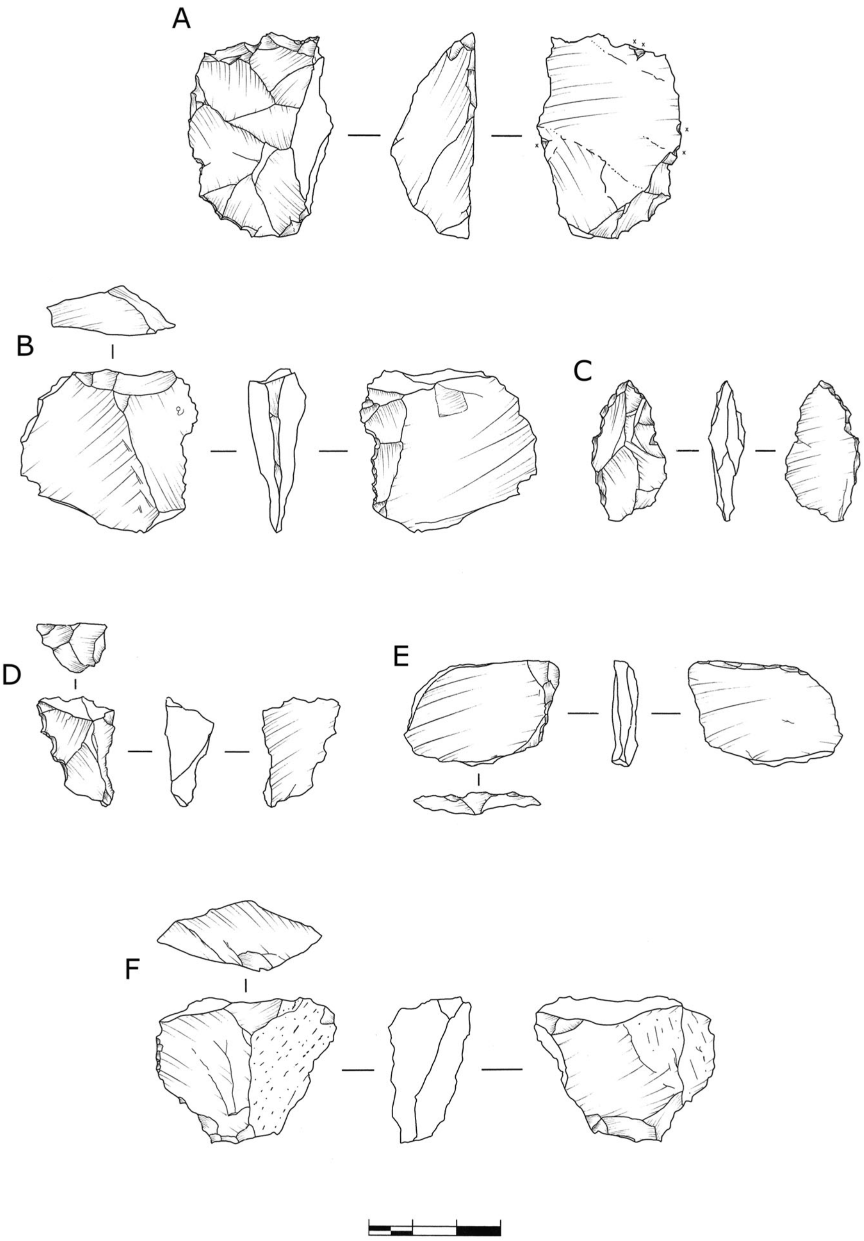

Figure 11. Retouched tools: A–D) denticulate; E) Levallois flake; and, F) retouched flake. A) Quartz; B) rhyolite; and, C–F) quartz.

to the Pleistocene, and it might be the result of raw material economy or technological behaviors and strategies (Pargeter and Shea 2018). The morphological features of these cores testify to four different variants of their reduction. The first was based on multi-surficial reduction of blocks by free-hand percussion. Another, avoiding substantial economic losses with the production of more cutting edges per unit of raw material (Eren, Greenspan, and Sampson 2008; Pargeter and de la Peña 2017) and employing the same striking technique, involved core orientation changes and adapted natural surfaces for striking. The remaining two methods relied on unidirectional reduction but used different platform preparation methods and reduction techniques: one specimen displayed evidence of striking platform preparation with a series of centripetal blows and could be flaked by direct percussion with a hard hammerstone (Pargeter and de la Peña 2017), while the other (see Figure 7A) adapted a natural surface for the flaking platform and was most probably reduced on an anvil, using the bipolar technique (de Lombera-Hermida et al. 2016; Pargeter and de la Peña 2017). The size of discarded miniaturized cores suggests that flakes acquired from these cores did not exceed 4 cm in length. These debitages have mainly unidirectional negatives or natural surface on the dorsal face and natural or flat platforms.

In the case of the discoidal core, the method implemented for flake production displays a considerable difference in reduction dynamics at individual stages. It seems that bifacial reduction with surfaces displaying evidence of weak hierarchization was applied at the early exploitation stage (Terradas 2003). Then, as imperfections in raw material were encountered, the reduction strategy was changed and led towards partial, unifacial reduction of one of the surfaces in the last phase.

Morphological features of the core from Figure 9 did not meet all the criteria (Boëda 1993, 1995, 2014) of a recurrent Levallois core, among others, predetermination and normalization of the final products, and should therefore be defined as a prepared centripetal core. The prepared core method has been observed in Acheulean assemblages from Africa and the Near East, e.g. at Maunagidze (Zimbabwe), sites near

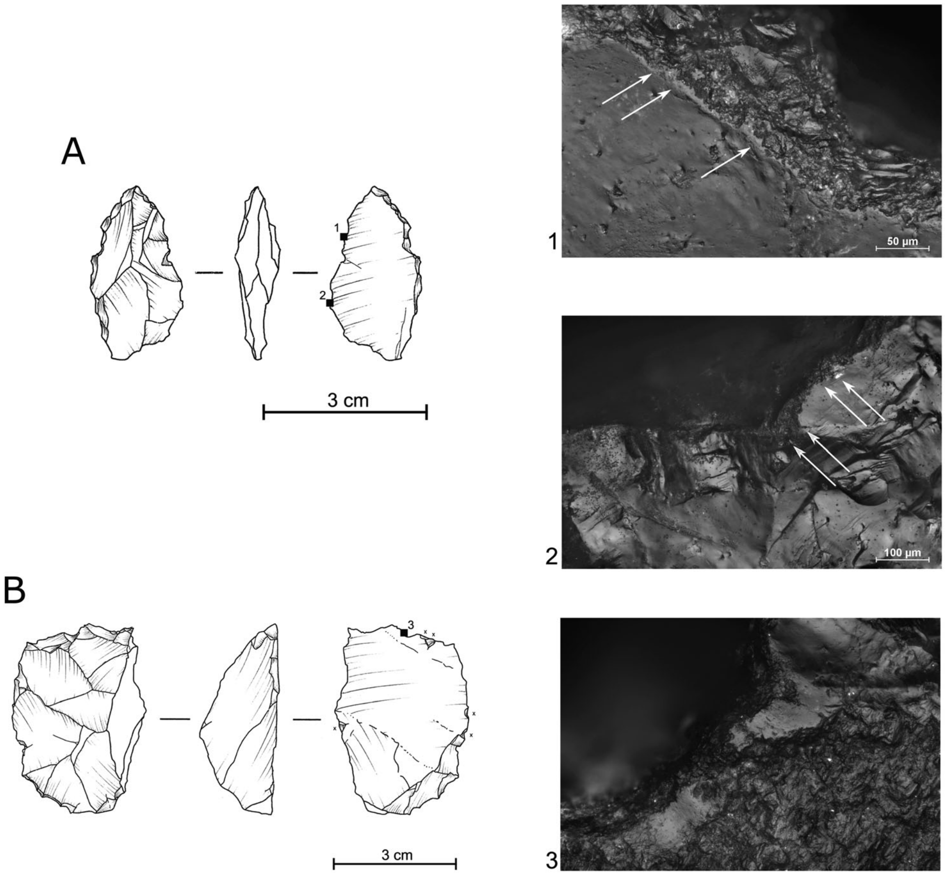

Figure 12. Use-wear analysis of artifacts from EDAR 135, lower horizon. A) Traces left by 1) contact with bone and 2) hide working. B) PDP alterations 3) covering almost the entire surface of the artifact.

Victoria West (South Africa), and Jaljulia and Revadim (Kuman 2001; Mercader et al. 2016; Li et al. 2017; Rosenberg-Yefet, Shemer, and Barkai 2021).

Flakes classified as products of discoidal core reduction display mainly flat and dihedral platforms, while scars on their dorsal faces are multi- or bidirectional. They were also larger, which made them more likely to be transformed into tools (Figure 11A–D). Besides that, the assemblage contains one flake tool with a faceted platform (Figure 11E). The presence of products with features of preparation or even predetermination does not unequivocally imply that the Levallois method of core reduction was used.

The analyzed tools have regular and continuous formal retouch. This indicates that the edges had been primarily modified before post-depositional alterations occurred. Despite that, use-wear analysis was implemented to a highly limited degree due to heavy post-depositional damage: irregular crushing and edge rounding, as well as strong surface abrasion (Venditti, Tirillò, and Garcea 2016; de la Peña and Witelson 2018). In the micro-view, the so-called pseudo-retouch could be distinguished from intentional edge modifications based on the regularity and typical trace location.

Microtraces of use were more frequent on the artifacts from other EDAR assemblages, especially the Acheulean from EDAR 7, which yielded the most diverse set of tools used on animal and plant materials in an ad hoc manner, being supplementary to the Large Cutting Tools (Masojć et al. 2021a). The direction and pattern of linear features suggested that using these artifacts involved more than one type of movement, though each was used on one material type only. Traces connected with butchering activities were discovered on small tools from the upper (MSA) level of EDAR 135 (Ehlert et al. in press). It could be inferred that small tools from the site discussed here were used in a similar manner.

Early Stone Age–Middle Stone Age transition in northeastern Africa—chronology and cultural attribution

The assemblage from the lower horizon of the EDAR 135 site was found within fluvial sediments laid down by a braided stream flowing there in humid climatic conditions. Spatial analysis and post-depositional traces on the artifacts' surfaces unambiguously indicate that this position of the assemblage is secondary. Initially, the artifacts were extensively transported horizontally as a result of fluvial processes. Subsequently, deflation slightly relocated them vertically. Unfortunately, these factors prevent reaching an unequivocal conclusion as to whether the assemblage is homogenous or a palimpsest resulting from several consecutive instances of hominin presence.

The results of dating the lower EDAR 135 horizon fall within the chronological framework established for this part of Africa, where the MIS 7 period was inferred to be the time of transition from the ESA to the MSA (Van Peer et al. 2003; Van Peer 2016; Scerri and Spinapolice 2019; Masojć et al. 2021b). The available archaeological data suggest that dynamic cultural changes of a mosaic rather than linear nature took place during that time in northeastern Africa (Van Peer 2016; Scerri and Spinapolice 2019;

Table 4. Late Acheulean and Sangoan sites mentioned in the paper.

Site	Country	Chronology	Cultural Attribution	LCTs	Cores	References
Kharga Oasis - K10	Egypt	ca. 400–300 kya	Late Acheulean	Handaxes, cleavers, trihedral picks, choppers	Discoidal, Levallois, miniaturized cores	Caton-Thompson 1952; Kleindienst 2006
Dakhla Oasis E-72-1, E-72-2	Egypt	ca. 400–300 kya	Late Acheulean	Handaxes, cleavers	Discoidal, Levallois, unidirectional, bidirectional multiplatform, globular, miniaturized cores	Schild and Wendorf 1977; Kleindienst 2006
Wadi Halfa	Sudan	?	Late Acheulean	Choppers, handaxes, trihedral picks	Discoidal, Levallois, multiplatform cores	Guichard and Guichard 1968
Khashm el Girba	Sudan	Older than MIS 7 and MIS 7	Late Acheulean/ Early MSA	Choppers, handaxes, cleavers, trihedral picks	Discoidal, Levallois, multiplatform cores	Chmielewski 1968; Abbate et al. 2010
Khor Shambat	Sudan	?	Late Acheulean	Handaxes, cleavers	Discoidal, Levallois	Masojć et al. 2020
Sai Island 8-B-11	Sudan	$\geq 223 \pm 19$; 223 ± 19–183 ± 20	Late Acheulean and Sangoan	Handaxes, core-axes	Discoidal, Levallois, single platform, bidirectional, Kombewa cores	Van Peer et al. 2003; Van Peer, Rots, and Vroomans 2004
Khor Abu Anga	Sudan	?	Late Acheulean and Sangoan	Choppers, handaxes, cleavers, core-axes	Levallois, discoidal, multiplatform, single platform, bidirectional cores	Carlson 2015
al-Jamrab	Sudan	older than MIS 5e	Late Acheulean or Early Sangoan	Handaxes	-	Spinapolice et al. 2018
Arkin 8	Egypt	?	Late Acheulean or Early Sangoan	Handaxes, ovates	Single platform, multiplatform, discoidal, "oval" cores	Chmielewski 1968
Mieso	Ethiopia	ca. 220 kya	Late Achuelean	Handaxes, cleavers	"Giant cores for flakes," centripetal miniaturized cores, bidirectional cores	de la Torre et al. 2014

Masojć 2021). The archaeological sites discovered in this region and dated to MIS 7 and 6 are connected with three main cultural units/complexes: Late Acheulean, Sangoan, and Early MSA with Levallois/Mousterian.

The late Acheulean supposedly disappeared from Eastern Saharan Africa by ca. 200 ka (Spinapolice et al. 2018; Garcea 2020; Masojć et al. 2021b), and assemblages described as such have been discovered in northeastern Africa. The results of Optimal linear estimation (OLE) modelling show that the Late Acheulean phase in North Africa and the Near East could even have ended between 175 and 160 kya, which fits in with OSL dating results of the lower horizon from the EDAR 135 site (Key, Jarić, and Roberts 2021). However, reconstruction of the chronological framework for the final Acheulean in northeastern Africa is limited due to the existence of a small number of sites with accurate dating results.

Most Late Acheulean sites from Sudan and Egypt were discovered within deposits connected with watercourses or spring wells (Caton-Thompson 1952; Chmielewski 1968; Schild and Wendorf 1977; Spinapolice et al. 2018; Masojć et al. 2020). Consequently, the material at these sites may have been transported from their original locations and redeposited by fluvial processes, as is the case with EDAR 135.

Late Acheulean assemblages were also discovered in fluvial contexts at the Arabian Peninsula site of Saffaqah (Scerri et al. 2018). Remains of production of LCTs from flake blanks were discovered there within fluvial sediments of watercourses flowing in the area during the wet period of MIS 7. This is some of the youngest evidence of the Acheulean tradition in the region neighboring northeastern Africa, next to Mieso sites discovered in Ethiopia (de la Torre et al. 2014). Evidence of even younger (MIS 6/5e) Acheulean was discovered within the sediments dated by OSL to ca. 140–125 ka at the Bamburi 1 and Patpara sites in the Middle Son Valley in northern India (Haslam et al. 2011). Mieso sites are an appropriate analogy to EDAR 135. These sites are dated to around 212 kya, and small lithic assemblages were discovered there (Mieso site 7 assemblage contains 112 artifacts; Mieso site 31 contains 339 artifacts) (de la Torre et al. 2014). Clusters of artifacts reflected lower density scatters and covered more space than in EDAR 135. Spatial analysis, refitting studies, and the physical state of the artifacts suggest a weak impact of post-depositional processes, with the artifacts remaining in a direct position. Some similarities are visible in production methods: lack of Levallois method and miniaturization of flake production. The difference is, however, a significant proportion of LCTs in the assemblage and the use of flakes as a blank for their production.

The exceptional nature of Late Acheulean assemblages in northeastern Africa (Table 4) stems mainly from the presence of highly elaborated handaxes along with discoidal cores and, less frequently, elements of Levallois technology (Caton-Thompson 1952; Guichard and Guichard 1968). The presence of the Levallois method in the Late Acheulean of northeastern Africa is not exceptional for this specific region and has also been recorded in other assemblages, e.g. in eastern Africa (Tryon and McBrearty 2002; Clark et al. 2003; Tryon 2003). Assemblages with such traits are known from sites in northeastern Africa and can serve as analogies to EDAR 135. The first reliable data on this cultural horizon were presented among the results of excavations at the complex of Kharga Oasis sites in Egypt (Caton-Thompson 1952). An assemblage determined as Acheulean-Levallois and found in situ in gravel deposits was recorded on the Eastern Scarp (K 10 site). Cherts from local outcrops were mainly used as raw material for production in the site area. Handaxes are the most numerous type of artifact in the assemblage and were produced only from cobbles; using flakes as blanks for the production of handaxes has not been observed in the assemblage. Similar to EDAR 135, miniaturized forms of cores have been reported here (Caton-Thompson 1952, 68). Acheulean assemblages containing Levallois elements were also recorded in the vicinity of two sites in Dakhla Oasis: E-72-1 and E-72-2 (Schild and Wendorf 1977). Also, in the case of these two sites, production was based on local raw material—chert. Most of the handaxes in the assemblage are well elaborated, with circular thinning retouch, and were produced from chert cobbles. Besides the Levallois method, other cores represent similar methods of reduction observed at the EDAR 135 site: multiplatform, unidirectional, discoidal, and single miniaturized forms. Nevertheless, there is no sign of using the bipolar method. These materials from Dakhla and Kharga Oasis are connected with the Terminal Acheulean-"Balat Unit" defined by M. Kleindienst and dated to ca. 400–300 Kya (Kleindienst 2006). In all three cases, human activity was connected with mound springs active in the region in the mid-Pleistocene.

An Acheulean-Levallois horizon was recorded in the vicinity of Wadi Halfa (Guichard and Guichard 1968), which prompted the conclusion that the Levallois method appeared as early as the middle phase of the Acheulean tradition and became quite common in the Upper Acheulean. The last phase was characterized by regular handaxes with a considerable degree of surface processing, mainly amygdaloid and shouldered in shape. Other sites were discovered in the vicinity of Khashm el Girba (Chmielewski 1987; Abbate et al. 2010). Assemblages of handaxes and cores were recorded within gravel and solidified gravel-sand deposits at stratified sites 106 and 109 identified by W. Chmielewski (1987). Recent research dates the KGS1 deposit complex, which contains Acheulean assemblages with Levallois elements, to MIS 7 (Abbate et al. 2010).

More recently, an assemblage of artifacts displaying Late Acheulean traits was discovered on the surface of fluvial deposits in Khor Shambat, situated within the city limits of Omdurman (Masojć et al. 2020). It consists mostly of handaxes, a few big flakes, discoidal, and Levallois cores mainly of the preferential type.

So far, four sites containing remains of activity identified as the Sangoan complex have been recorded in Sudan (Van Peer 2016). It is a technocomplex which combines Mode 2 bifacial elements with Mode 3 core reduction methods (Tylor 2016; Van Peer 2016). The Sangoan is mainly characterized by oval, symmetric core-axes with flat-convex cross-section and considerably retouched distal edges, accompanied by Levallois technology (Clark and Kleindienst 2001; Van Peer 2016). Certain analogies to the assemblage examined in this paper can be found at the Sai Island 8-B-11 site in northern Sudan. This site is particularly well-preserved, and two in situ horizons have been identified there. Because of that, it is considered a reference site for the Late ESA and Early MSA in the general area (Van Peer et al. 2003; Van Peer, Rots, and Vroomans 2004). The site's three oldest cultural horizons provide a suitable analogy here. The sands lying above the lowest horizon of gravel deposits have an OSL terminus ante quem of 223 ± 19 ka. A small assemblage of artifacts, discovered in the interface of gravel and sands, included a few products of discoidal reduction and lanceolate handaxes. Such forms are considered to be the fossile directeur of the Late Acheulean (Van Peer et al. 2003; Van Peer, Rots, and Vroomans 2004; Rots and Van Peer 2006). Lower and Middle Sangoan assemblages were discovered within the subsequent horizons of gravel and gravel-sand deposits. A sample collected from the sandy deposits situated above yielded an OSL age of 183 ± 20 ka. Like the Late Acheulean one, the Sangoan assemblages relied on local quartz for tool production. This corresponds directly to the situation at the lower horizon of EDAR 135. Single and double platform cores, often small and made of pebbles, were reduced into polyhedral forms in an ad hoc manner (Van Peer, Rots, and Vroomans 2004). The Sai assemblage also includes numerous disc cores (n = 55). The role of the Levallois method seems marginal, as evidenced by few cores and products. Oval core-axes, a Sangoan essential, constitute the majority of bifacial tools (Van Peer, Rots, and Vroomans 2004; Rots and Van Peer 2006).

Late Acheulean and Sangoan horizons have also been discovered at two sites further south in Sudan. The first site is Khor Abu Anga in Omdurman (Arkell 1949; Carlson 2015). Stone artifact assemblages were discovered mainly in fluvial gravel, silts, and clay deposits. The oldest assemblage representing the Late Acheulean phase is characterized by the presence of triangular, cordiform, and long ovoid handaxes with a high degree of *façonnage* (Carlson 2015). In the case of the Early Sangoan horizon, the site also includes numerous ovate core-axes, as well as much less numerous Levallois cores and products of their reduction (Carlson 2015). Contrary to EDAR 135, quartz was rarely used at the site; the production process was based on Nubian sandstone, instead.

Another site displaying certain similarities is al-Jamrab, situated to the west of Khor Abu Anga, 10 km from the White Nile in the vicinity of what is now Wadi al-Hambra (Spinapolice et al. 2018). Two cultural horizons were discovered there in a series of fluvial deposits. The older assemblage, probably Late Acheulean or Early Sangoan, includes only 12 sandstone handaxes with well-developed surfaces. The younger horizon represents the manufacturing based on the Levallois and laminar technology, which testifies to a younger chronology connected with the MSA, probably the Lupemban or Sangoan complex (Spinapolice et al. 2018). The Arkin 8 site, where bifacial oval tools identified as core-axes were discovered (Chmielewski 1968; Van Peer 2016), is also associated with the Sangoan. However, Levallois elements are absent there (Chmielewski 1968).

The earliest MSA assemblages from Africa, e.g. Jebel Irhoud (ca. 315 ka), Olorgesailie Basin (ca. 305 ka), and Gademotta Formation (≥ 275 ka) contain evidence of innovative predetermined technologies attributed to the emergence of anatomically modern humans (Schild and Wendorf 2005; Sahle et al. 2014; Richter et al. 2017; Deino et al. 2018). The oldest traces of the Levallois from the Eastern Sahara come from the sites of Bir Tarfawi and Bir Sahara. They were found in the context of limnic deposits older than ca. 210 ka (Wendorf, Schild, and Close 1993). A similar, early chronology (ca. 230 ka) was determined for the "Lower Levalloisian" assemblages from Kharga Oasis (Churcher, Kleindienst, and Schwarcz 1999, 305). A site in the Bayuda Desert, BP 177, may confirm the early chronology of these complexes in Sudan (Masojć et al. 2017). Although OSL dates of ca. 60–20 ka point toward a very late chronology of its two cultural horizons, there are premises that suggest a much older age. One of them, the so-far-unpublished dating results of sample TL-3, which determined the terminus post quem for the lower horizon as 332 ± 106 ka (Lub-5152). Besides that, the structure and technology of assemblages from both horizons—handaxes and Nubian and centripetal Levallois cores, as well as bifacial foliates of petrified wood and volcanic rock—have compelling analogies dated to MIS 5e from Sai Island (Groucutt 2020). Nonetheless, clear-cut interpretations are exceedingly difficult and rare. Besides that, despite some differences existing especially at the early stage, the MSA assemblages from northern Africa generally show considerable manufacturing conservatism. Thus, the MSA tradition in northeastern Africa seems to have originated from the merging of two components: Mousterian and bifacial elements (Scerri and Spinapolice 2019).

The presence of handaxes and lack of sufficient arguments for the use of the Levallois method in the lower horizon of EDAR 135 offer no possibility of connecting this assemblage with the Early MSA. Moreover, it seems that, due to the absence of core-axes, the EDAR 135 lower horizon assemblage should be identified with the late phase of the Acheulean Eastern Sahara, rather than the early phase of the Sangoan (Van Peer 2016; Garcea 2020).

Conclusions

Excavations at EDAR 135 resulted in the discovery of two lithic assemblages buried in fluvial sediments (Units IIA and IIB) deposited by braided streams in wet periods of the Pleistocene. The lower cultural horizon discussed here, relocated by post-depositional processes, is dated to the MIS 7a/6 transition and constitutes the youngest evidence for the presence of groups identified with the Acheulean tradition in the eastern Sahara. Its dating corresponds with the chronology of the Late Acheulean sites from eastern Africa, the Arabian Peninsula, and the Indian subcontinent and suggests a wider chronological framework of this technocomplex.

The analysis of the lower horizon from EDAR 135 revealed traces of various activities carried out by groups inhabiting this area in the Middle Pleistocene. Quartz and rhyolite, occurring locally as pebbles and cobbles, were used to manufacture stone tools. Apart from LCTs, flake blanks were produced using different methods of core reduction: the ad hoc variant based on multidirectional cores, the non-hierarchical discoidal method, and prepared centripetal cores. Even though the artifact surfaces displayed numerous changes caused by post-depositional processes, it was possible to observe some traces resulting from the use of tools for butchering.

The presence of prepared and predetermined technology is by no means an exception in the Late Acheulean material. EDAR 135 notwithstanding, it has already been observed at the earlier sites connected with the Late Acheulean and located in Africa and the Near East.

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Geolocation Information

Eastern Desert, Sudan, Africa, N17°41’06.0” E34°46’28.1”.

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Disclosure Statement

No potential competing interest was reported by the authors.

Notes on Contributors

Grzegorz Michalec (M.A. 2020, University of Wrocław, Poland) is a Ph.D. student at the University of Wroclaw, Poland. His research focuses on the lithic technology and lifestyle of Pleistocene hunter-gatherer groups. He specializes in experimental knapping, statistical analysis, and microscopic use-wear analysis. He conducted studies of the lithic assemblages and participated in fieldwork in the EDAR project. ORCID: https://orcid.org/0000-0002-5794-5334.

Marzena Cendrowska (M.A. 2016, Aarhus University, Denmark) is a Ph.D. candidate at the Institute of Archaeology of the University of Wrocław, Poland. She specializes in microscopic use-wear analyses of stone artifacts, with an emphasis on those made of quartzite and quartz. ORCID: https://orcid.org/0000-0002-6140-555X.

Eric Andrieux (Ph.D. 2017, University of Bordeaux, France) is a postdoctoral research associate in luminescence dating at Royal Holloway University of London and Durham University. He conducted the luminescence dating data analyses and calculations. ORCID: https://orcid.org/0000-0003-1688-0543.

Simon J. Armitage (Ph.D. 2003, University of Wales, Aberystwyth, United Kingdom) is a Professor in Quaternary Science at Royal Holloway University of London (United Kingdom) and a PI of the Centre for Early Sapiens Behaviour (SapienCE) at the University of Bergen (Norway). He uses luminescence dating to better understand the relationship between climate change and early human behavior, particularly in dryland environments. He supervised the analysis of luminescence data in the EDAR project. ORCID: https://orcid.org/0000-0003-1480-9188.

Maciej Ehlert (Ph.D. 2015, University of Wrocław, Poland) is the chair of Archeolodzy.org Foundation. Lithic technologies, especially of the MSA of northeastern Africa and the Neolithic and Bronze Age of Europe, are his main field of expertise. He participated in fieldwork and lithic analyses in the EDAR project. ORCID: https://orcid.org/0000-0001-9690-6971.

Ju Yong Kim (Ph.D. 1990, Seoul National University, Korea) is an Honorary Research Fellow at the Korea Institute of Geoscience and Mineral Resource (KIGAM). He carried out geoarchaeological investigations for the EDAR project as a principal research fellow of KIGAM. ORCID: https://orcid.org/0000-0003-4782-8262.

Young Kwan Sohn (Ph.D. 1992, Gyeongsang National University, Jinju City, Republic of Korea) is a Professor in Sedimentology at the College of Natural Sciences, Gyeongsang National University (GNU), Jinju City (Republic of Korea), and a member of the EDAR geoarchaeological team. ORCID: https://orcid.org/0000-0002-1811-0545.

Joanna Krupa-Kurzynowska (Ph.D. 2013, Jan Kochanowski University of Kielce, Poland) is an Assistant Professor at the Faculty of Geoengineering, Mining and Geology of the Wrocław University of Science and Technology, Poland. She is a geomorphologist, and her work in the EDAR project was focused on issues related to paleoenvironment. ORCID: https://orcid.org/0000-0002-1196-9912.

Piotr Moska (Ph.D. 2007, Silesian University of Technology, Gliwice, Poland) specializes in luminescence dating in geology and archaeology. He is interested in luminescence properties of quartz and feldspar for creating an absolute chronology of the Quaternary sediments. His main research topics are Polish loess stratigraphy and the reconstruction of the evolution of inland dunes in Poland during the end of the last glaciation. Since 2014, he is a head of the Gliwice luminescence dating laboratory. His entire professional career is connected with the Institute of Physics, Division of Geochronology and Environmental Isotopes, Silesian University of Technology in Gliwice. ORCID: https://orcid.org/0000-0001-6114-9595.

Marcin Szmit is the head of the Digitalisation and Archiving Department of Gdańsk Archaeological Museum, Poland. He has 20 years of experience in archaeological fieldwork in Sudan. He was the main technician and surveyor of the EDAR project. ORCID: https://orcid.org/0000-0002-2331-1245.

Mirosław Masojć (Ph.D. 2002, University of Wrocław, Poland) is an Associate Professor at the Institute of Archaeology of the University of Wrocław, Poland. His principal research interests lie in studying Pleistocene and early Holocene hunter-gatherers in Europe and north-eastern Africa and flint knapping in the Late Bronze Age. He is the PI of the EDAR project. ORCID: https://orcid.org/0000-0001-7779-5014.

ORCID

Grzegorz Michalec http://orcid.org/0000-0002-5794-5334
Marzena Cendrowska http://orcid.org/0000-0002-6140-555X
Eric Andrieux http://orcid.org/0000-0003-1688-0543
Simon J. Armitage http://orcid.org/0000-0003-1480-9188
Maciej Ehlert http://orcid.org/0000-0001-9690-6971
Ju Yong Kim http://orcid.org/0000-0003-4782-8262
Young Kwan Sohn http://orcid.org/0000-0002-1811-0545
Joanna Krupa-Kurzynowska http://orcid.org/0000-0002-1196-9912
Piotr Moska http://orcid.org/0000-0001-6114-9595
Marcin Szmit http://orcid.org/0000-0002-2331-1245
Mirosław Masojć http://orcid.org/0000-0001-7779-5014

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