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# A Mismatched Piece in a Cultural Middle Stone Age Puzzle: Traces of Human Activity Dated to 90 kya (MIS 5) at Sites EDAR 134 and 155 in the Eastern Sahara, Sudan

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## ABSTRACT

This article presents the results of research carried out at two previously unreported Eastern Desert Atbara River project (EDAR) Middle Stone Age (MSA) sites—EDAR 134 and EDAR 155. Luminescence dating results indicate human activity in this area during the Marine Isotope Stage 5 period (MIS 5), approximately 90 kya. Discussion concerning the affiliation of both analyzed inventories will be provided, including another MSA site from the EDAR area, where an assemblage dated to MIS 6/5e does not have technological features known from other technocomplexes in the eastern Sahara region (EDAR 135). Microscopic analysis of traces of tool use for the EDAR 155 assemblage shows the high impact of post-depositional (aeolian) processes on the state of preservation of lithic material. Sites EDAR 134 and 155 provide evidence for hominin activity during the late Pleistocene within an area only episodically accessible, due to arid conditions prevailing in the Saharan deserts.

## ARTICLE HISTORY

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## Introduction

The term Middle Stone Age (MSA), alongside the Early and Later Stone Age (ESA/LSA), was introduced by Goodwin (1928) based on the archaeological record from southern Africa (Goodwin and van Riet Lowe 1929). The current definition of the MSA includes a specific chronological framework based on material culture, paleoanthropology, and environmental data (Basell and Spinapolice 2024; McBrearty and Brooks 2000; Scerri and Spinapolice 2019).

The beginning of the MSA in northern Africa is currently dated to ca. 300 kya and its end to ca. 50 kya (Garcea 2020a; Leplongeon 2021; Masojć 2021; Richter et al. 2017). This period is marked by the emergence of anatomically modern humans, resulting in significant behavioral changes reflected in the archaeological material (McBrearty and Brooks 2000; Scerri and Will 2023). The new behavioral package, in addition to complex cultural phenomena (burials, symbolism, and the use of pigments), also included changes in subsistence strategies and technology (McBrearty and Brooks 2000).


The eastern Sahara region (Egypt and Sudan) played a key role in the context of the northern migration route of *Homo sapiens* towards Eurasia in the upper Pleistocene, which is dated to 130–90 kya (Armitage et al. 2011; Beyin 2011; López, Van Dorp, and Hellenthal 2015; Petraglia et al. 2010). When assessing its role in that dispersion, two important factors should

be considered: 1) the land connection with the Levant and 2) favorable climatic conditions in MIS5 (130–70 kya)—a period humid and warm enough to sustain an extensive network of watercourses and lakes (Beyin 2011; Drake et al. 2011, 2022; López, Van Dorp, and Hellenthal 2015; Williams et al. 2015).

Research on the MSA in the eastern Sahara has resulted in the identification of several technological units (Ben Arous, Boisard, and Leplongeon 2024; Garcea 2020a; Guichard and Guichard 1965; Leplongeon 2021, 2022; Marks 1968a, 1968b; Masojć 2021; Scerri and Spinapolice 2019; Schild and Wendorf 1977; Van Peer 1998, 2016). The characterization of these units was based on technological features (Van Peer 2016), the presence of *fossile directeur*, or the proportion of tool types in the assemblages (Marks 1968a). The units include the Sangoan or Sangoan-Lupemban (Van Peer 2016), Nubian (Van Peer 1998), and Aterian complexes (Garcea 2020b). Due to the high similarity of technological features and the lack of a precise chronological framework, the current reconstructed cultural image of the MSA in the eastern Sahara shows many complexities. Some of them are reflected in the ongoing debate on the Nubian complex (Groucutt 2020; Hallinan and Marks 2023) and the lack of consensus on the original assumptions proposed by Van Peer (1998).

Similar to other regions of Africa, numerous MSA lithic assemblages lacking technological features that would allow

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them to be clearly connected with particular complexes have been discovered in the eastern Sahara (Garcea 2020a; Kleindienst 2019, 2020; Kleindienst, Smith, and Adelsberger 2009; Scerri and Spinapolice 2019). These assemblages are most often found on the surface, rarely in a stratigraphic context (Garcea 2020a; Scerri and Spinapolice 2019). Their technological markers are the classic Levallois core method (recurrent and preferential cores with centripetal preparation) and opportunistic methods of flake core reduction (single and multiplatform). Moreover, they lack the fossile directeur typical of other units, such as core axes, foliates, and lanceolate bifacial points.

The following article presents two sites from the Eastern Desert of Sudan: EDAR 134 and 155. The technological features of their lithic assemblages do not fit into the previously known picture of the eastern Saharan MSA. Optically stimulated luminescence (OSL) dating of quartz grains at both sites indicates that they were occupied in Marine Isotope Stage (MIS) 5, around 88–90 kya. This was a relatively warm and semi-humid period when today's desert was covered with green savanna (Drake et al. 2011; Tierney, deMenocal, and Zander 2017). Micro- and macroscopic wear analyses show the impact of aeolian processes on the condition of the lithic artifacts.

## Materials

### Geology of the area

The area investigated by the EDAR project is a plain ranging from 350–400 masl. It is delineated by the expansive Nile Valley, spanning the Fifth and the Sixth Cataracts, in the west and the lowland of the Atbara River in the south (Nassr and Masojć 2018). Metamorphosed Proterozoic rocks intermingled with intrusive rhyolite formation predominate in the geological substrate (Masojć et al. 2019, 2021b, 2024). Enduring erosion began in the early Quaternary and was significantly influenced by climatic fluctuations (Masojć et al. 2019, 2021b, 2024). This contributed to developing the dominant topographical features: isolated hills and weathered sedimentary rock coverings of varying thicknesses and diverse origins. Most of the modern plateau surface is covered by aeolian formations intersected by broad and not prominently discernible valleys (wadis).

### Sites' location

The sites are located approximately 70 km east of the city of Atbara in Sudan (Figure 1) in an area strongly transformed by modern gold mining (Masojć 2023; Masojć et al. 2021a, 2021b). This destructive activity led to the creation of massive mining shafts and allowed the location of several Pleistocene sites deep below the current ground level. The oldest sites (EDAR 6, 7, and 135) are associated with the Acheulean (Masojć 2023; Masojć et al. 2019, 2021a, 2021b, 2023, 2024; Michalec et al. 2021). Traces of human activity dated to the MSA, in addition to the two sites discussed in the text, were discovered in the younger horizons of sites EDAR 7 and EDAR 135 (Ehlert et al. 2022; Masojć et al. 2019, 2021a, 2021b).

EDAR 134 (N17°68'12" E34°77'66") was found in the southern part of the largest mining shaft concentration, at 376 masl. The gold miners' heavy equipment destroyed the top stratigraphic units, exposing a cluster of lithic artifacts in the uppermost part of Unit IIIB (Figure 2A). The other site (EDAR 155) is located 2.7 km south of EDAR 134 (N17°65'68" E34°77'92") at 384 masl, next to a smaller concentration

of mine shafts (Figure 1C). The topmost stratigraphic unit was removed entirely, which revealed a concentration of artifacts.

## Methods

### Fieldwork

At both sites, trenches were opened where the largest clusters of artifacts were visible on the post-mining surface. The excavation area was then divided into a local grid of 1 × 1 m. At EDAR 134, the trench covered 16 m<sup>2</sup>. In its central part, two squares were excavated to a depth of 1.6 m (see Figure 2). In the remaining squares, excavations reached a depth of ca. 35–40 cm. In 2019, the site was destroyed by a large mining shaft, and the fieldwork was discontinued (Figure 2D).

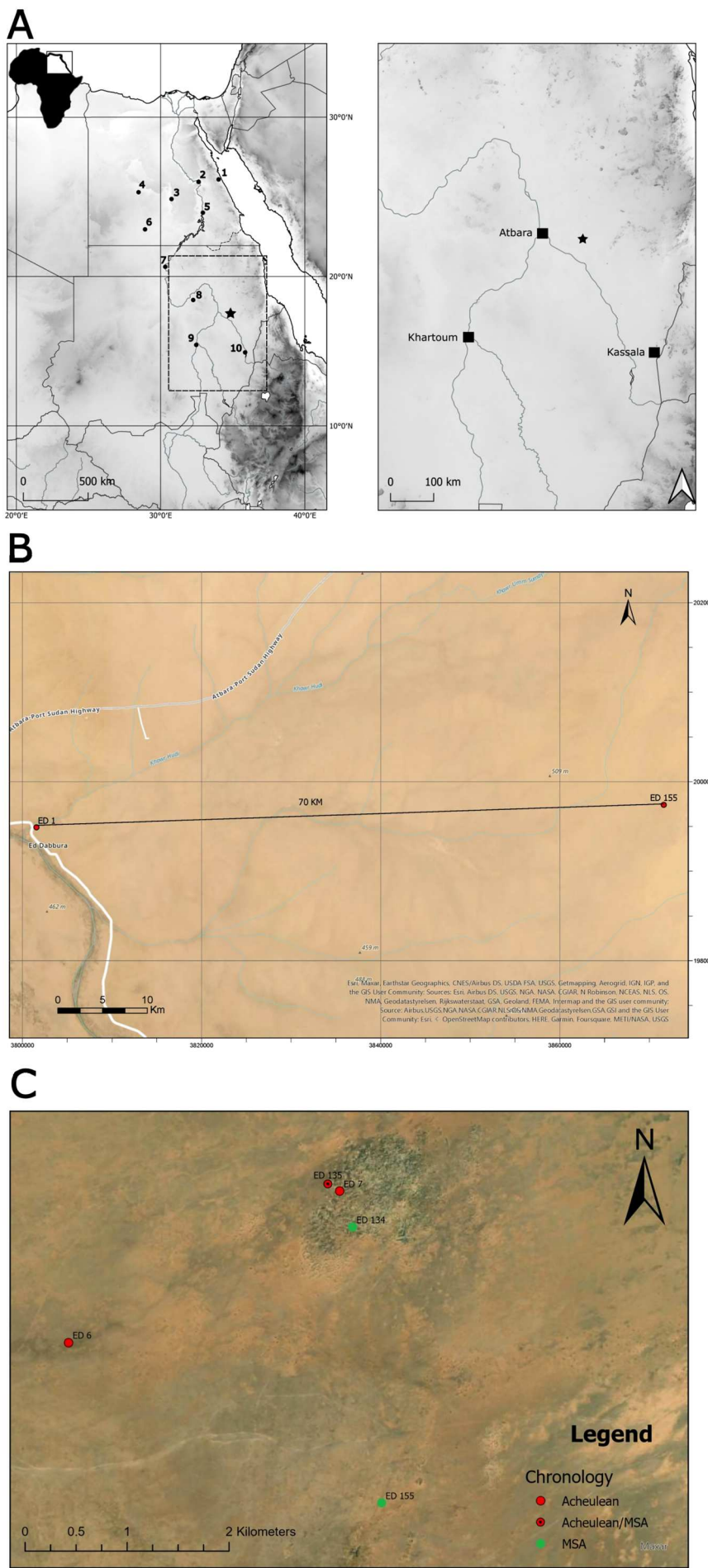
Two trenches (I/2017 and II/2018) covering 18 m<sup>2</sup> in total were excavated at EDAR 155 (see Figure 2). The stratigraphic sequence of the site was revealed in two squares in the southern part of trench I/2017, excavated to the depth of 1 m. The remaining squares in both trenches were stopped at a depth of 30 cm, where sterile sediment without artifacts was reached.

Samples for granulometric analysis and OSL dating were collected from geological cross-sections at both sites. All artifacts larger than 15 mm were plotted using a total station and collected from the surface and during the exploration of sediments. Each was given an ID number, packed separately, and labeled (ID, layer, etc.). Excavated sediments were dry-sieved with a 3 mm mesh. Artifacts extracted from the sieves were grouped within their respective square meters and depths.

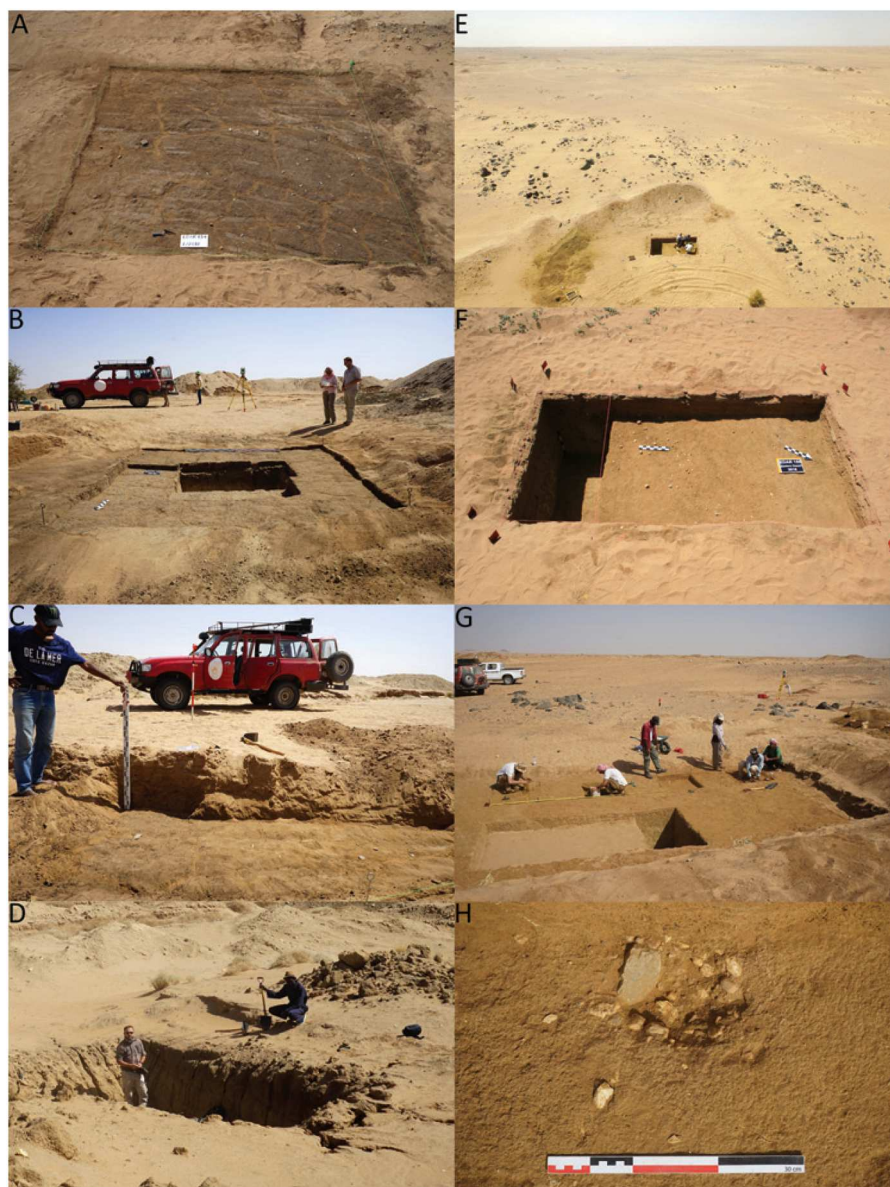
### Luminescence dating

Optically Stimulated Luminescence (OSL) dating is a technique used to estimate the time since mineral grains were last exposed to sunlight, which is usually assumed to be the burial age of the sediment. After being buried, mineral grains absorb a constant level of radiation from cosmic rays and naturally occurring radioactive isotopes such as U, Th, Rb, and K. In mineral grains such as quartz and feldspar, this radiation results in the progressive accumulation of electrons in traps (areas of positive charge) within the crystal lattice, creating a record of the total dose received. When the minerals are exposed to light or heat, these trapped electrons are released, during which a proportion dissipates energy as light, known as luminescence. The amount of light emitted is proportional to the number of trapped electrons, which is in turn proportional to the total radiation dose received (the natural dose). The equivalent dose ( $D_e$ ) is the laboratory estimate of the natural dose and is calculated using the luminescence intensity of the natural sample, usually via comparison with the luminescence intensity in response to a calibrated laboratory radiation dose. When combined with the dose rate received during burial, the time since the last exposure to light or heat can be determined using the equation: Age (kya) = Equivalent dose (Gy) / Dose rate (Gy/kya).

At EDAR 134, six samples were collected spanning both archaeological and archaeologically sterile levels. Only one sample, from Unit IIIB, which contained a lithic assemblage, was collected at site EDAR 155 (Figure 3). Previous research identified different stratigraphic levels in the EDAR area, of which several were dated using luminescence methods (Ehlert et al. 2022; Masojć et al. 2019, 2021a, 2021b; Michalec et al. 2021). The results of dating and sediment analysis from



**Figure 1.** Maps with location of sites. A) Location of sites in Sudan and Egypt mentioned in the text (EDAR sites marked with a star). 1) Sodmein Cave, 2) Taramsa 1, 3) Kharga Oasis, 4) Dakhla Oasis, 5) Wadi Kubbanyaia, 6) Bir Tarfawi, 7) Sai Island 8-B-11, 8) BP 177, 9) Khor Abu Anga, and 10) Khashm el Girba. B) Location of the EDAR area in Eastern Desert. C) Location of all EDAR sites mentioned in text.



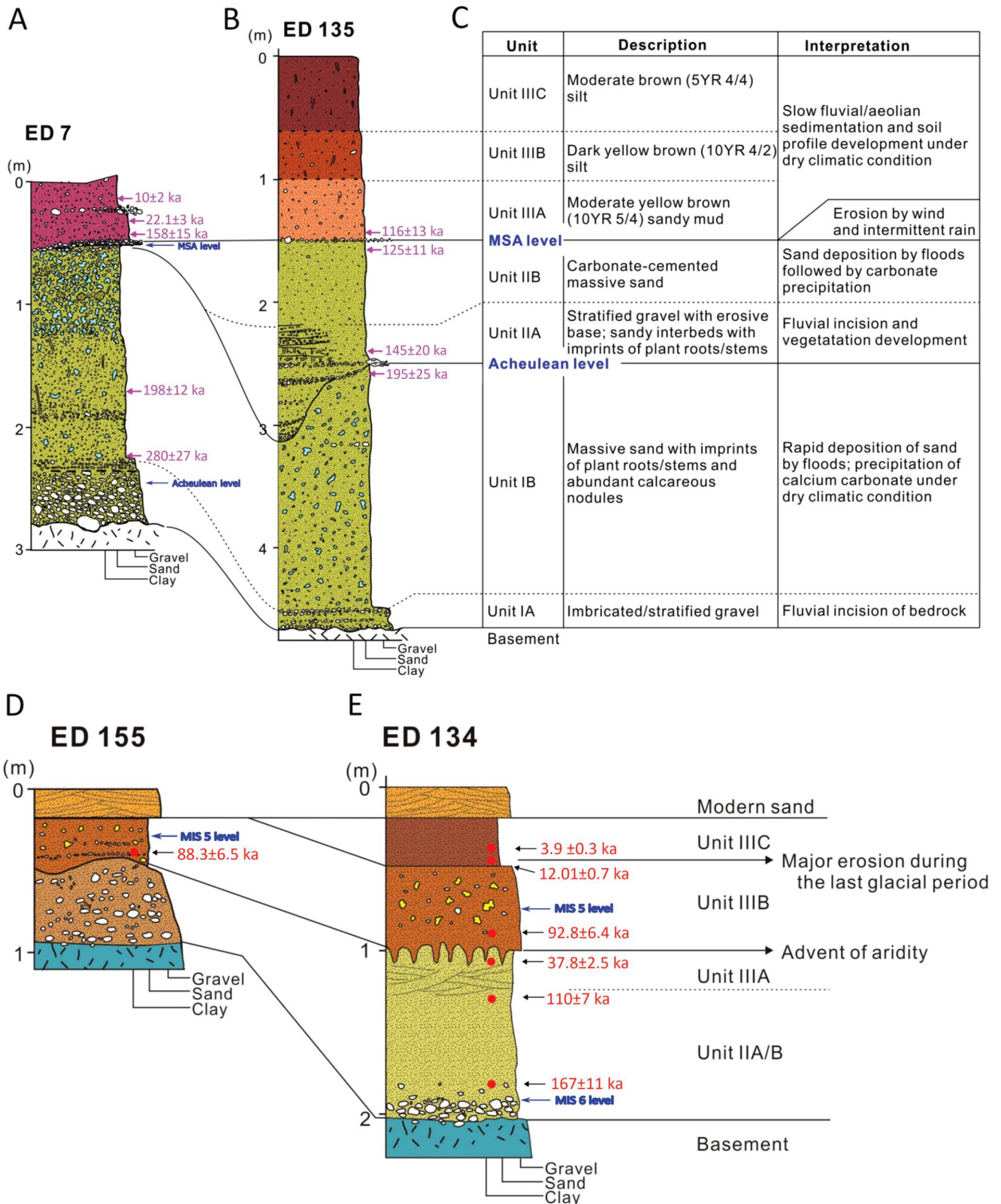
**Figure 2.** EDAR 134 and 155 sites. A) Surface of opened trench before exploration at site 134, field season 2017. B) Trench at site EDAR 134, season 2018. C) Photo of the profile at site EDAR 134, the remaining top sediment untouched by gold miners, season 2018. D) EDAR 134, site destroyed by gold miners in 2019. E) Aerial photography of site EDAR 155 in 2018. F) Trench II/2018 at site EDAR 155. G) Excavations at site EDAR 155 within trench II/2019. H) Unidirectional core discovered in trench II/2019, EDAR 155.

EDAR sites 134 and 155 were compared with the data obtained at EDAR sites 7 and 135.

Luminescence samples were measured by the Gliwice Absolute Dating Method laboratory (GADAM) (Moska et al. 2021), and the data from these measurements was later analyzed at Royal Holloway, University of London. Measurements were performed on a Daybreak Model 2200 reader using a  $^{90}\text{Sr}/^{90}\text{Y}$  beta source for irradiations. Stimulation was carried out at  $125^{\circ}\text{C}$  for 60 seconds, using blue light emitting diodes. Aliquots were heated at  $5^{\circ}\text{C}/\text{s}$  during all heating steps, and a 10 second pause at  $125^{\circ}\text{C}$  prior to optical stimulation was used. The OSL intensity is recorded during the first 1.5 seconds of stimulation with a background signal subtracted. The EDAR samples displayed a rapidly decaying OSL signal. All growth curves were fitted using a saturating exponential plus the linear function. The performance of the SAR procedure was monitored via recycling ratios, and recuperation was calculated to monitor its performance (Murray and Wintle 2000, 2003). Aliquots not yielding recycling ratios consistent with unity ( $2\sigma$ ) or displaying recuperation greater than 5% of the natural signal were rejected.

Radioisotope concentrations for each sample were measured using high-resolution gamma spectrometry (Canberra gamma spectrometers with HPGe detectors). These data imply secular equilibrium in the  $^{238}\text{U}$  and  $^{232}\text{Th}$  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 Guérin and colleagues (2012) and the etch attenuation factor after Bell (1979). A moisture content of  $8 \pm 3\%$  was assumed for all samples to account for the plausible range of past conditions and humidity changes affecting the samples. 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  $1.8 \text{ g}/\text{cm}^3$  were assumed.

The optimal statistical model for determining the equivalent dose was determined after analyzing the degree of skewness, the kurtosis, and the overdispersion of the De distributions following Bailey and Arnold (2006). The Central Age Model (CAM) was found to be appropriate for all samples (Galbraith et al. 1999). Abanico plots showing the



**Figure 3.** Stratigraphy description at the EDAR sites. A) Site EDAR 7, B) site EDAR 135, C) description and interpretation of stratigraphy units, D) EDAR 155 with the height of OSL sampling marked with a red dot, and E) EDAR 134 with the height of OSL sampling marked with red dots.

equivalent dose distribution and the calculated CAM  $D_e$  for each sample are presented in Supplemental Material 1, SM Figure 1. More detailed information regarding sample preparation is presented in Supplemental Material 1.

### Lithic studies

All lithic assemblages discovered during the three seasons (2017–2019) of fieldwork carried out at both sites were

subjected to techno-typological analyses. Generally, detailed analyses of MSA and Middle Paleolithic assemblages include only artifacts larger than 20 mm (Prévost and Zaidner 2020; Schild and Wendorf 1977). However, because of the lack of consensus on “miniaturization” in lithic production (Pargeter and Shea 2019), we decided to move the threshold down to 15 mm. Smaller specimens were classified as chips (metrical, not technological), and only raw material type was specified for them.

Lithic studies were based on the chaîne opératoire conceptual framework (Pelegrin, Karlin, and Bodu 1988; Sellet 1993; Shott 2003). This approach aims to reconstruct technological behaviors, from raw material procurement to discarding used tools, and studying lithic materials related to respective stages of the operation sequence (Pelegrin, Karlin, and Bodu 1988; Shott 2003; Tixier 2012). Moreover, it allows the analysis of different aspects of the raw material economy at the site. The concept of chaîne opératoire has certain limitations and has been criticized by Bar-Yosef and Van Peer (2009), who pointed out its weaknesses: restricting oneself to a rigidly technological framework and over-formalized typological description and emic relevance—the illusion of being able to read the minds of prehistoric knappers.

All the artifacts from both sites (cores, tools, debitage, and waste) were classified according to the syncretic typological list following the categories defined, among others, by Schild and Wendorf (1977) and Van Peer (1992) and applied in previous studies of other lithic assemblages from EDAR sites. Specific features were studied for each artifact group (see Supplemental Material 1 for a list of attributes). The maximum length, width, and thickness of all artifacts over 15 mm were measured with an electronic caliper (0.01 mm resolution). The lengths were measured along the technological axis (see Andrefsky 2005). All artifacts were weighed using an electronic scale (0.01 g resolution). Detailed Scar Pattern Analyses were conducted for all the cores whenever the preservation state allowed it. Selected artifacts were photographed and drawn. Conjoining studies of these assemblages have not yet been carried out.

The Levallois method was defined according to the six criteria proposed by Boëda (1993, 1995, 2014: 1) presence of two asymmetrical convex faces, with the intersection defining a plane; 2) hierarchization of two faces which are related to each other—one produces predetermined products and the other is conceived of as a surface of the striking platform; 3) predetermination and production of convexities on the main flaking surface; 4) the plane of predetermined products is parallel to the plane of intersection of a core; 5) the prepared/faceted striking platform is located perpendicular to the main axis of a core with a proper flaking angle; and, 6) application of hard hammer direct percussion technique in the production of the determined Levallois products. To distinguish the recurrent and preferential Levallois method from the Nubian method, we used the criteria proposed by Usik and colleagues (2013): triangular and subtriangular shape of cores, distal ridge preparation, and faceted and dihedral striking platforms. Spatial analysis, including scatter of objects in terms of artifact type, weight, and Kernel density (bandwidth = 0.25), was conducted using QGIS (3.34 Lima version) software.

### Usewear analysis

The sample of 20 artifacts selected for usewear analysis included only flake tools with at least one intact, functional working edge. All came from EDAR 155. Artifacts with heavily rounded or micro-chipped edges and ridges were excluded. The study was conducted in the laboratory of the Institute of Archaeology, University of Wrocław. The artifacts were cleaned for 2–5 minutes in an ultrasonic bath and observed under a NIKON Eclipse LV 100 microscope with magnifications between 200x and 500x. The traces

were documented with the same microscope. Image focus was enhanced using picture stacking.

The physical proprieties of quartz, especially its high reflectivity and irregularity in trace formation, make usewear analysis quite challenging. Traces appear on small areas, more frequently on crystals and elevated topography parts (Clemente Conte et al. 2015, 64–65); Leipus 2014, 230–233). Additionally, features typical of usewear and post-depositional alterations may co-occur on different parts of one tool. Therefore, careful observation of each edge under magnifications between 200x and 500x is required to observe specific surface features (Lemorini et al. 2014; Taipale 2012, 94).

## Results

### Stratigraphy

Multiple sedimentary sequences ranging from 1–5 m in thickness have been excavated in the EDAR area (Masojć et al. 2019, 2021b). Detailed sedimentary profiles were obtained from sites EDAR 7 and EDAR 135 (Ehlert et al. 2022; Masojć et al. 2021a; Michalec et al. 2021), and these provide a stratigraphic context for EDAR 134 and EDAR 155 (see Figure 3). Generally, the sedimentary deposits at these sites can be divided into three units (I–III) bounded by fluvial or aeolian erosion surfaces. Unit I consists of stratified and imbricated gravel in the lower part (IA) and massive sand with abundant calcium carbonate nodules in the upper part (IB). Unit II overlies Unit I with an unconformity-boundary and comprises planar- to cross-stratified gravel interbedded with sandy deposits with imprints of plant roots/stems in the lower part (Unit IIA) and carbonate-cemented massive sand in the upper part (Unit IIB). Unit III comprises yellow to dark brown silt and sandy mud with subtly different grain sizes. It is underlain by a thin and continuous gravel layer, representing a desert pavement which resulted from the removal of sand and dust by wind and intermittent rain. At EDAR 7, Unit III directly overlies Unit I, suggesting the complete removal of Unit II by deflation or other wind erosion processes.

The lower two units (Units I and II) are interpreted to have resulted from fluvial incision of the bedrock or the earlier sedimentary deposits followed by sand deposition by floods and subsequent calcium carbonate precipitation. The predominance of fluvial features and the imprints of plant roots/stems in these units suggest that the climatic conditions were relatively wet during the Acheulean and the MSA. Afterwards, the area was subject to aeolian erosion, and a desert pavement formed, probably because of the advent of aridity. Deposition of the finer-grained Unit III occurred during a period of reduced clastic sediment input by aeolian and rare overland flow processes, followed by soil profile development under semi-arid climatic conditions. In general, sedimentary facies changes of EDAR are characterized by both fluvial and aeolian processes, with unconformity boundaries indicating an erosional episode or transitional period. This is demonstrated by periodic transitions from a stream channel-dominated alluvial plain in the lower part to an arid savanna or grassland in the upper part.

Very thin (< 1 m) sedimentary deposits are preserved at EDAR 155 (see Figure 3), making it difficult to define and

correlate the depositional units. However, the dark yellow-brown sand upon the gravelly sand and bedrock is inferred to correlate with Unit IIIB of the EDAR 135 site. At EDAR 134, carbonate-cemented massive sand and gravel occur upon the weathered bedrock. An OSL age from the deposit suggests that it is coeval with Units IIA and IIB. The overlying deposits of dark yellow-brown and brown silty sands have textures and colors similar to those of Units IIIB and IIIC, respectively. Unit IIIA is presumed to be intercalated between Unit IIA/B and Unit IIIB/C but is poorly identified by sedimentary features.

### OSL dating

Dose rates were calculated using the DRAC online calculator (Durcan, King, and Duller 2015) which, in combination with CAM  $D_e$  values, was also used to calculate ages (Table 1).

For EDAR 134, dating results confirm the stratigraphic situation associated with strong erosion of sediments in the late Pleistocene (see Figure 3, Table 1). Sample EDAR\_134\_S1\_2019 yielded an age of  $12 \pm 0.7$  kya and was collected in the bottom part of Unit IIIA. However, another sample (EDAR-134-S1) was taken from a depth of approximately 40 cm within the same stratigraphic unit and yielded a younger age of  $3.9 \pm 0.3$  kya. Overdispersion of aliquots of this sample is relatively high, possibly indicating bioturbation, though it is equally possible that Unit IIIC accumulated over a considerable period of time.

Sample EDAR-155-S1, collected below the archaeological horizon in Unit IIIB, was dated to  $88.3 \pm 6.5$  kya (see Figure 3). Chronologically similar dating results ( $92.8 \pm 6.4$  kya) were also obtained for sample EDAR-134-S2 from the same stratigraphic unit (IIIB) at EDAR 134, which is also below the location of the lithic assemblage. Moreover, the dating results of sample EDAR-134-S4, taken from the bottom of Unit IIA/B, where three artifacts were discovered, confirm older traces of human presence in MIS6.

The age of sample EDAR134-S3, collected from the uppermost part of Unit IIIA, yields a younger age ( $37.8 \pm 2.5$  kya) than the underlying sample EDAR134-S2 (Unit IIIB,  $92.8 \pm 6.4$  kya), EDAR134-S4 (top of Unit IIA/B,  $167 \pm 11$  kya), and basal ages for Unit IIIA at sites EDAR 7 ( $158 \pm 15$  kya) and 135 ( $116 \pm 13$  kya, see Figure 3) (Ehlert et al. 2022; Masojć et al. 2021a, 2021b; Michalec et al. 2021). Sample EDAR134-S3 was taken from the layer affected by desiccation cracks (Unit IIIA), which extended from the layer above. These cracks contain sediment from the overlying layer and may have caused significant mixing. Moreover, cracks are often used by vegetation for roots and infiltrating water, potentially resulting in the inclusion of younger intrusive grains in the lower layers. Therefore, it is possible that the equivalent dose for this sample is an

underestimate of the burial dose for the material of interest (i.e. Unit IIIA), as the measurements were conducted on small aliquots containing hundreds of grains, some of which are younger than and not derived from Unit IIIA. Consequently, we do not regard the age for sample EDAR134-S3 as indicative of the age for Unit IIIA.

### EDAR 134 lithic assemblage

The lithic assemblage includes 379 artifacts with a combined weight exceeding 5 kg (Table 2). Of these, 233 were found and plotted in the squares, while 146 came from the sieves. Debitage and waste—flakes, blades, chips, and debris—were the most numerous artifact group ( $n = 351$ ). Thirteen of them were identified as technical products from Levallois core reduction, mainly debordant flakes. Retouched tools ( $n = 19$ ) were the next most numerous category, followed by cores and precores ( $n = 8$ ) (see Table 2).

### Preservation and spatial distribution

Although most artifacts (69.8%) were preserved completely, as much as 95% of the assemblage bears traces of considerable abrasion. This suggests a strong influence of post-depositional processes, such as wind erosion, without much influence of ones that could result in high fragmentation rates. Most artifacts were recorded in the dark yellow-brown sandy dust sediments of Unit IIIB (see Figures 3, 4). A horizontal cross-section reveals the distribution of the objects becomes less dense along the west-east axis (see Figure 4). As the relative height difference between the artifacts is up to ca. 30 cm, they might have been deposited on the surface of a gentle slope.

The results of the vertical Kernel density analysis revealed two clusters: a larger one in the southeastern part of the trench and a smaller one in the northwestern part (Figure 5). All artifact categories are present in both concentrations (see Figure 5). The analysis of the distribution of objects relative to their weight does not suggest post-depositional material sorting. The partial, horizontal, and vertical redeposition probably resulted from floating water and soil expansion and shrinkage during seasonal rainfalls. Besides that, the artifacts probably remained on the surface for a long time, which allowed aeolian erosion to transform their surfaces to such a degree that in some cases the negatives are barely visible. Considering that and the OSL dating results, it should be assumed that the deposition of the assemblage occurred in the warm period with strong seasonal rainfall—MIS 5c. Then, from MIS 5b–MIS 2, during dry periods with strong wind erosion, the artifacts remained exposed on the surface.

### Raw material

Lithic production was based on local raw materials, mainly rhyolite ( $n = 280$ ) and quartz ( $n = 98$ ); only one artifact was made from sandstone (see Table 2). Pebbles and cobbles occurring on the surface were the most commonly exploited raw material form. They came from fragments of bedrock (consisting mainly of dacite and rhyolite intruded by quartz dykes) that were shaped and modified during fluvial transport in humid climatic conditions, as well as aeolian processes during dry climatic periods.

**Table 1.** Dose rates, equivalent doses, and ages of the EDAR samples.

Sample	Dose Rate (Gy/kya)	Equivalent Dose ( $D_e$ ) (Gy)	Age (kya)
EDAR-134-S1	$0.76 \pm 0.04$	$3 \pm 0.2$	$3.9 \pm 0.3$
EDAR-134-S2	$0.69 \pm 0.03$	$64.3 \pm 3.2$	$92.8 \pm 6.4$
EDAR-134-S3	$0.84 \pm 0.04$	$31.6 \pm 1.4$	$37.8 \pm 2.5$
EDAR-134-S4	$0.67 \pm 0.03$	$111 \pm 5$	$167 \pm 11$
EDAR-155-S1	$0.72 \pm 0.03$	$63.1 \pm 3.6$	$88.3 \pm 6.5$
EDAR_134_S1_2019	$0.92 \pm 0.03$	$11.1 \pm 0.5$	$12 \pm 0.7$
EDAR_134_S3_2019	$0.7 \pm 0.03$	$77 \pm 3.8$	$110 \pm 7$



**Table 2.** EDAR 134, structure of lithic assemblage—number and weight of artifact classes by raw materials.

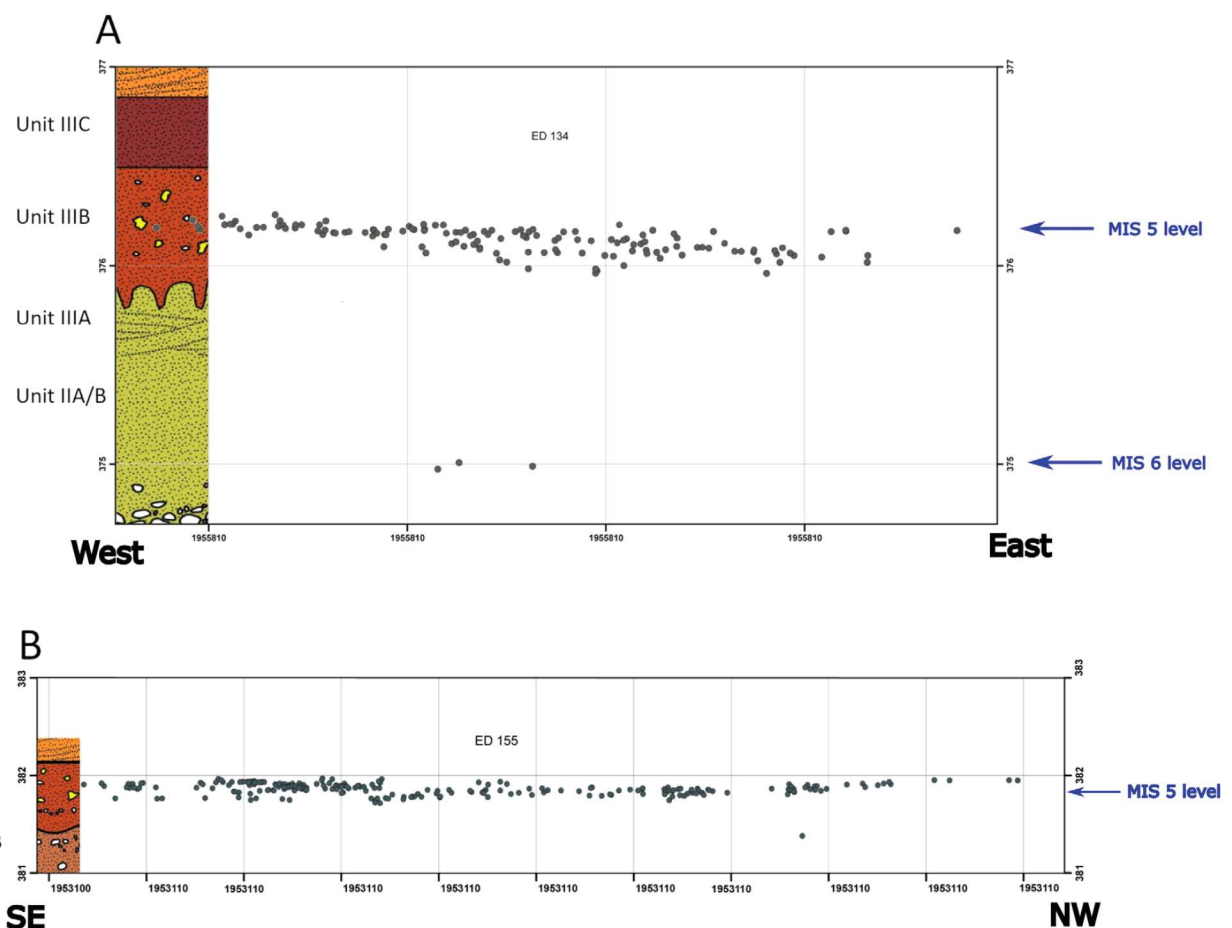
Artifact type	Total n	Rhyolite				Quartz				Sandstone				Total weight	
		Total %	n	%	Weight (g)	%	n	%	Weight (g)	%	n	%	Weight (g)		%
Precore	1	0.3	1	0.26	1043	19.17	-	-	-	-	-	-	-	1043	
Cores	7	1.8	5	1.32	807	14.83	2	0.53	157.9	2.9	-	-	-	964.9	
Blades	16	4.1	12	3.17	215.9	3.97	-	-	-	-	-	-	-	215.9	
Flakes	143	36.8	109	28.76	1667.1	30.64	26	6.86	250.5	4.6	1	0.26	5.9	0.1	1923.5
Chips	154	39.6	101	26.65	83.6	1.54	53	13.98	40.6	0.75	-	-	-	124.2	
Debris	30	7.7	26	6.86	245.4	4.51	4	1.06	37.1	0.68	-	-	-	282.5	
Levallois trimming elements	13	3.3	11	2.9	342	6.29	2	0.53	11.1	0.2	-	-	-	353.1	
Levallois core products	6	1.5	6	1.58	71.5	1.31	-	-	-	-	-	-	-	71.5	
Retouched tools	19	4.9	9	2.37	281	5.16	10	2.64	181.5	3.34	-	-	-	462.5	
<b>Total</b>	<b>389</b>	<b>100</b>	<b>280</b>	<b>73.88</b>	<b>4756.5</b>	<b>87.42</b>	<b>97</b>	<b>25.59</b>	<b>678.7</b>	<b>12.47</b>	<b>1</b>	<b>0.26</b>	<b>5.9</b>	<b>0.1</b>	<b>5441.1</b>

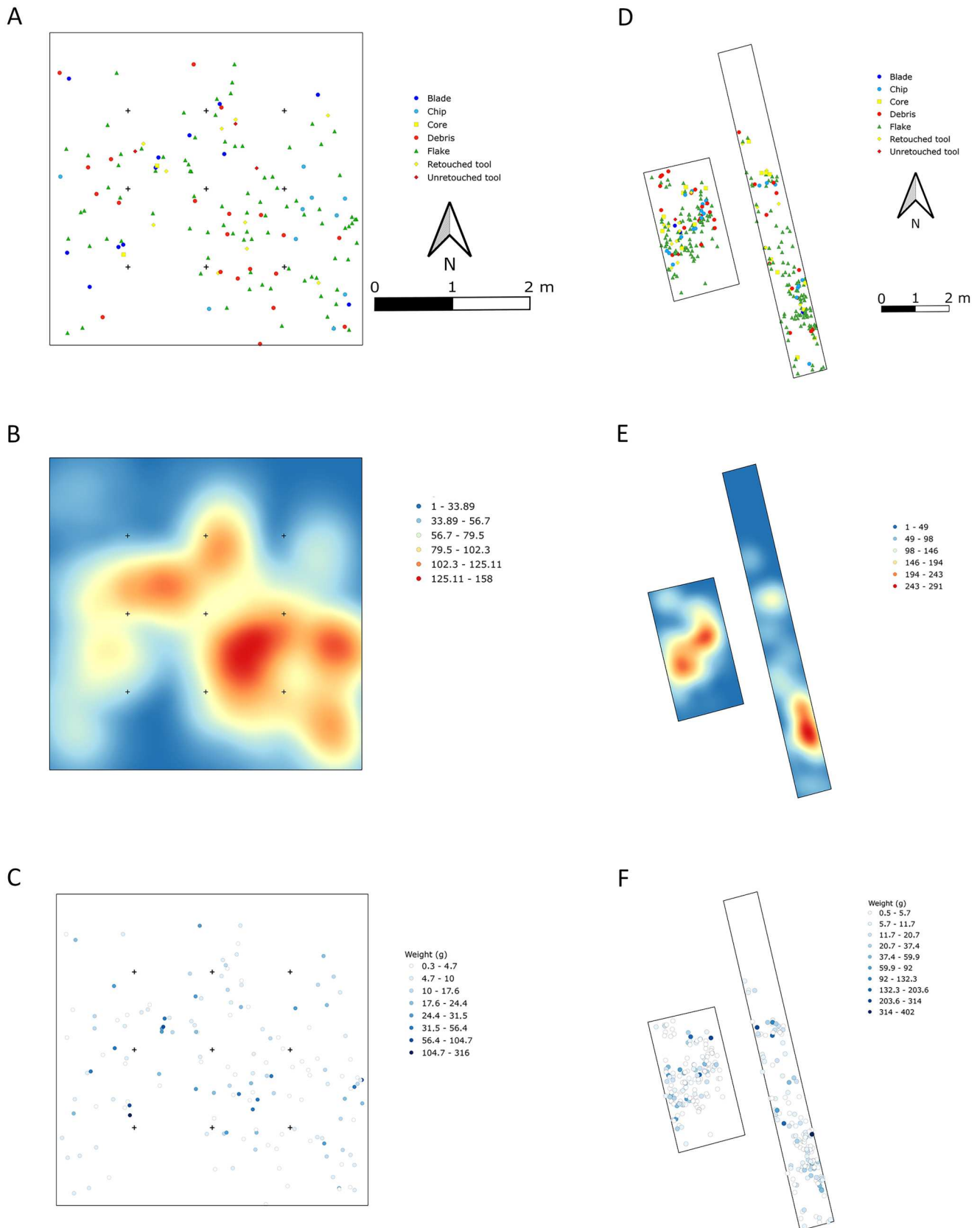
### Cores

Eight cores were discovered—six from rhyolite and two from quartz. A cobble with a single negative on one of the faces was classified as a precore (Table SM1, Supplemental Material 1). Two rhyolite cores represent different variants of the predetermined method—recurrent Levallois and Nubian Levallois (Figure 6A). The Nubian core, triangular and with a faceted platform, is characterized by bilateral preparation (opposing negatives, perpendicular to the main axis) of both the flaking surface and the second face (see Figure 6A). Such features are those of the type 2 Nubian (Van Peer 1998), according to Usik and colleagues (2013). Apart from that, the flaking surface displays the evidence of a last, unsuccessful attempt at making a Nubian point: a negative with a hinge termination obliterating the middle of the flaking surface. The angle between core surfaces is

60–70 degrees. The other predetermined core is the Levallois recurrent unidirectional type (Figure 6D). The main flaking surface and lower face display centripetal preparation negatives. The former displays three leading negatives resulting from the effort to obtain Levallois flakes, originating in the main faceted platform of the core.

The next two rhyolite cores are classic discoidal with centripetal negatives (Figure 6B–C). The remaining three forms result from the use of opportunistic single-platform ( $n = 1$ ) and multi-platform ( $n = 2$ ) reduction methods (see Figure 6). One of the multidirectional cores, made from a quartz pebble, shows traces of a simple change of reduction surfaces without their prior preparation. The other (made from rhyolite) employed a different reduction strategy (Figure 6E). The negatives from the initial flaking phases suggest that at this stage, a method similar to the one seen on the previous

**Figure 4.** Spatial analysis results for vertical position of assemblage. A) EDAR 134 and B) EDAR 155.

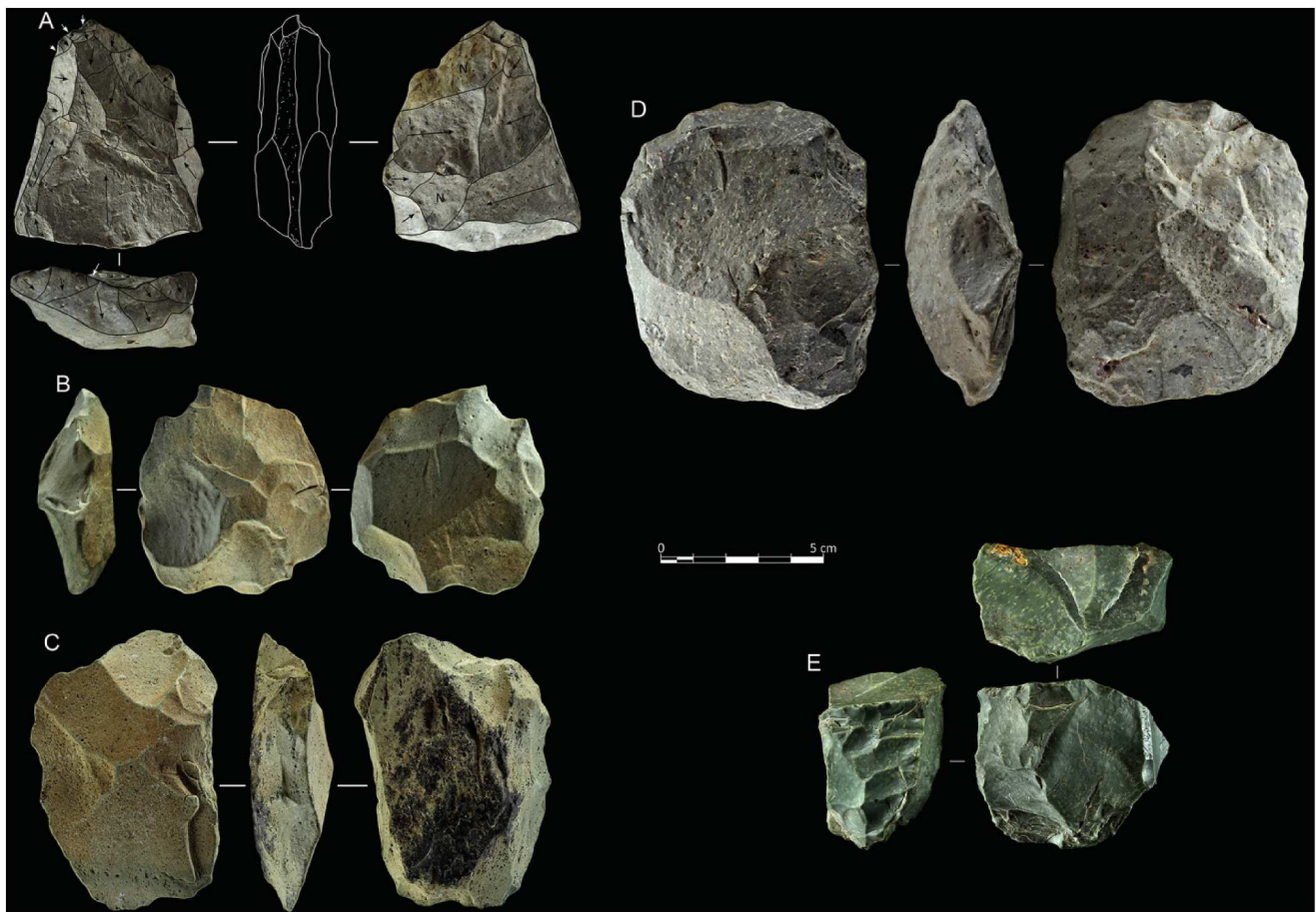


**Figure 5.** Spatial analysis results for EDAR 134 and 155. A) Spatial distribution by artifact type, EDAR 134; B) distribution of artifacts by weight, EDAR 134; C) Kernel density, EDAR 134; D) spatial distribution by artifact type, EDAR 155; E) distribution of artifacts by weight, EDAR 155; and, F) Kernel density, EDAR 155.

core was employed: multidirectional reduction of unprepared surfaces and free-hand direct knapping. The strategy then changed to bipolar on an anvil, as evidenced by the chipping and impact traces on the core's surface.

The mean sizes of the cores are  $70.9 \times 58.9 \times 39.2$  mm. The medians do not differ substantially, which suggests the absence of a wide range of sizes and excessive values in the

set (Table SM7, Supplemental Material 1). The two smallest cores were quartz, and their sizes suggest the use of small pebbles in flake production. The sizes of predetermined and discoidal cores based on rhyolite cobbles suggest that the selection of the raw material at the early stage was aimed at finding the appropriate volume necessary to successfully execute these methods.



**Figure 6.** EDAR 134, cores. A) Nubian II Levallois, B–C) discoidal, D) recurrent Levallois, and E) multidirectional; rhyolite. Photos: M. Jórdeczka.

### Debitage and waste

This category consists of 351 artifacts: 143 flakes, 12 blades, 13 Levallois core trimming elements, and six Levallois flakes, as well as 154 chips and 30 debris pieces (Table SM2, Supplemental Material 1). Most artifacts were made from rhyolite, including all flakes with metric features fitting the blade category. Only 28 flakes were made from quartz; the remaining 114 were rhyolite (see Table SM2, Supplemental Material 1). Almost 70% of all flakes were fully preserved. Most of them (76.7%) have less than 50% of the natural surface on the upper side—they were removed during the final stages of core reduction. The two most frequent directions of dorsal negatives are unidirectional (45.1%) and multidirectional (19.7%); two-directional perpendicular (8.5%) and opposite (1.4%) patterns are less common. Dorsal negatives of the remaining 25.3% were too strongly abraded. Flakes with a natural and plain platform were the most numerous, while the dihedral and faceted ones were less frequent.

The technical products ( $n = 13$ ) of Levallois core reduction are debordant flakes, controlling and changing the convexity of the distal and lateral parts of the cores (Figure 7). They are characterized by prepared platforms and dorsal sides with original core preparation scars partially removed by the detachment of a final product. Six debordant flakes meet the metrical blade criterium (2:1 length to width ratio). All the blades have regular unidirectional dorsal negatives (see Figure 7). Two of them have a faceted platform, one plain. Platforms of all the remaining blades are unidentified due to the degree of abrasion. Of six Levallois flakes, four were fragments and only two were preserved

completely; all had faceted platforms. Based on the triangular shape of its distal part, one of them was described as a Levallois point. Perpendicular ( $n = 2$ ) and centripetal ( $n = 3$ ) dorsal scar directions dominate, as only one flake had unidirectional negatives.

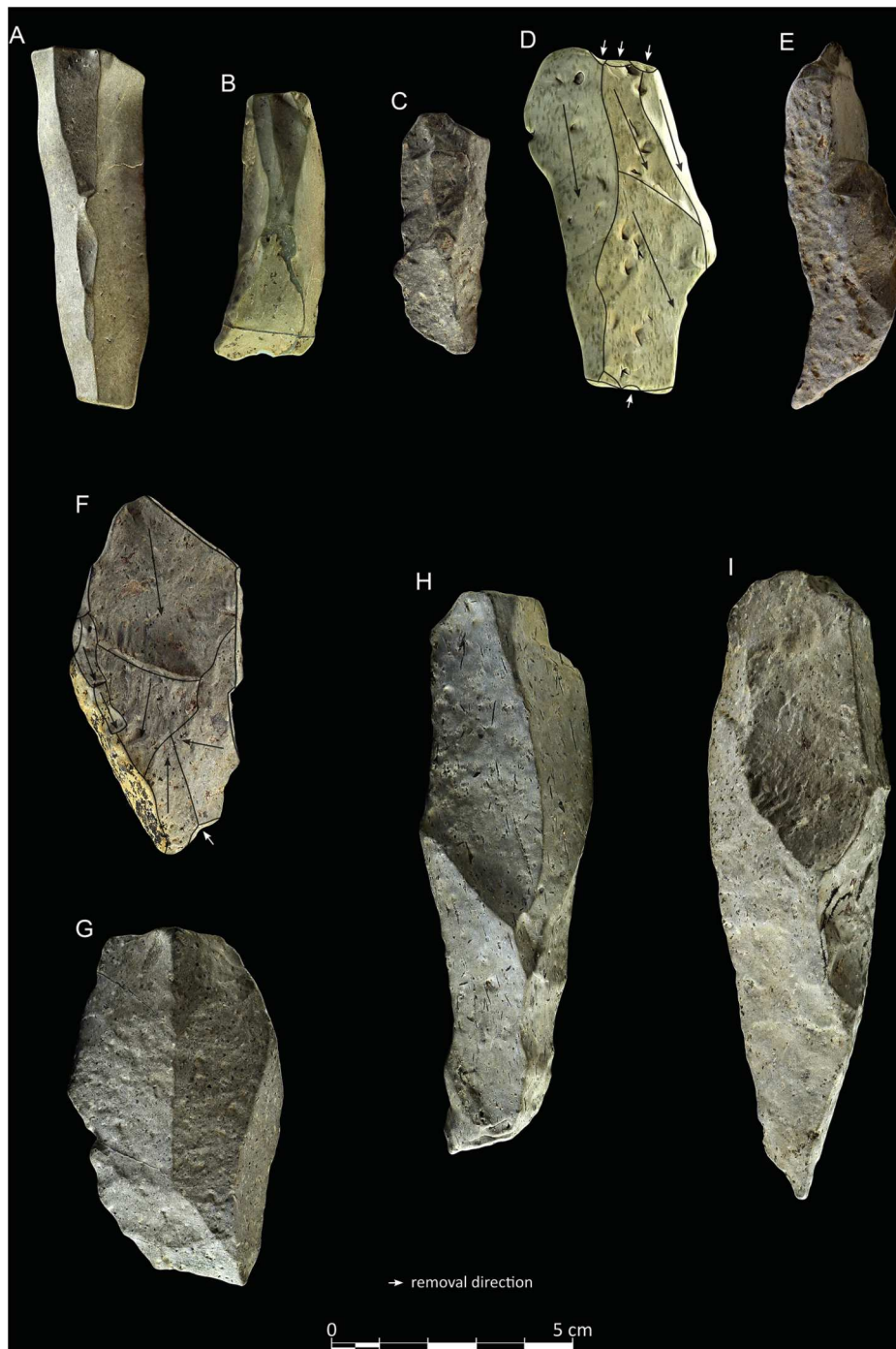
### Retouched tools

Nineteen tools were discovered—13 complete ones and six fragments (Table SM3, Supplemental Material 1; Figure 8). Ten were made from quartz, and the remaining ones were from rhyolite. Most tools ( $n = 18$ ) display technological features of domestic tools used mainly within the encampment and not as hunting weapon elements: five denticulates, three endscrapers, three sidescrapers, two notched tools, and one retouched Levallois flake, as well as one blade and five flakes with simple edge modification.

The tools were made mainly from flakes without much natural surface on the dorsal side—less than 25% ( $n = 15$ ) and 50% ( $n = 2$ ). Most of them come from multidirectional ( $n = 8$ ) cores; unidirectional ( $n = 2$ ) and two-directional perpendicular negatives ( $n = 2$ ) were also recorded. In two cases, dorsal sides were damaged beyond recognition. Five tools had their platforms missing; among the remaining ones, the most frequent type was plain ( $n = 9$ ), while natural and prepared ones were less frequent, and only one was punctiform.

### EDAR 155 Lithic assemblage

The EDAR 155 assemblage consists of 1111 specimens (Table 3); 546 were found in the squares, and 565 were found while sieving. The combined weight of the whole



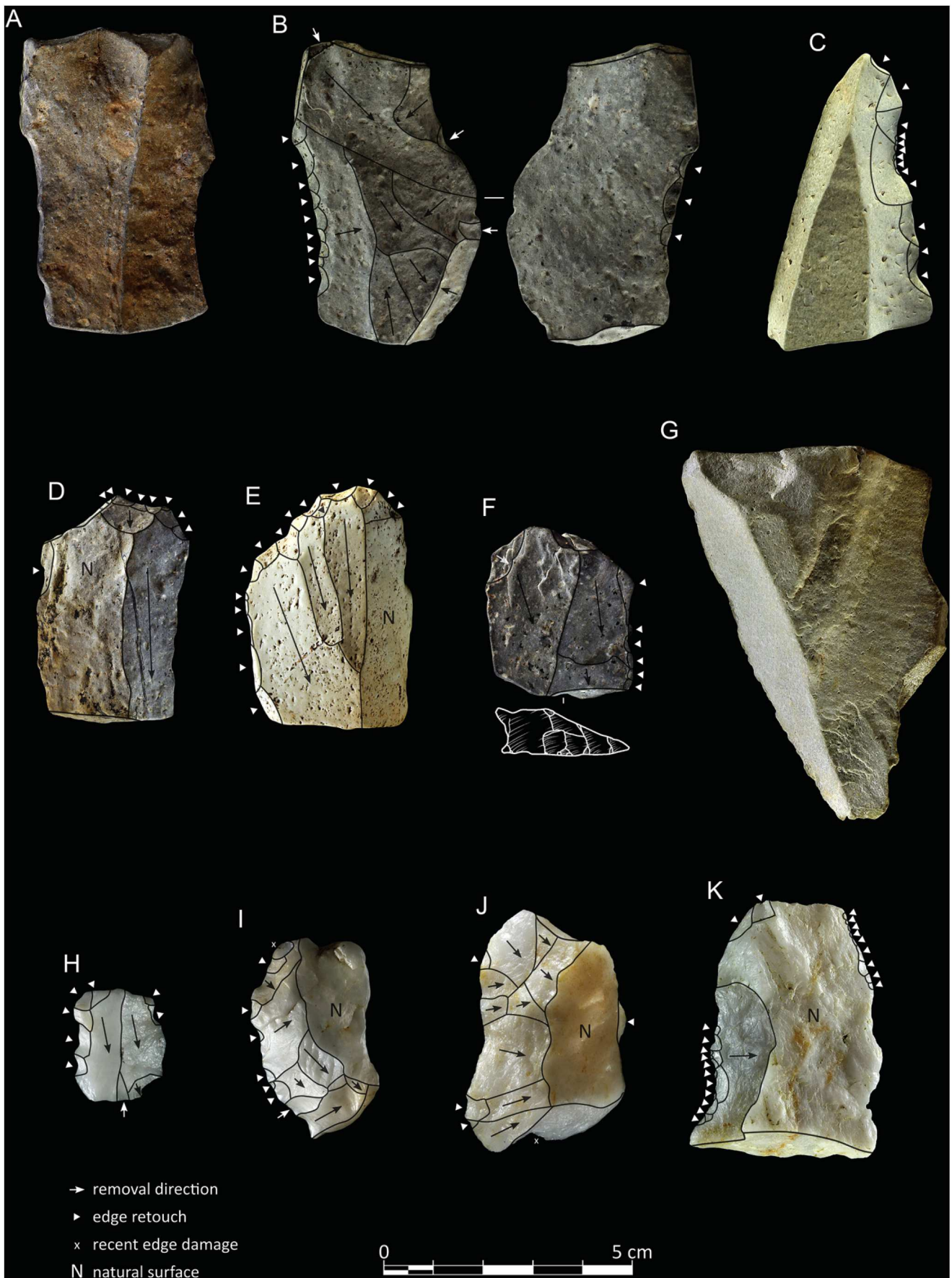
**Figure 7.** EDAR 134, debitage. A–C) Blades and D–G) debordant flakes and blades; rhyolite. Photos: M. Jórdeczka.

assemblage exceeds 8 kg (see [Table 3](#)). Again, debitage and waste dominate. Among the former, flakes ( $n = 352$ ) were the most common, followed by blades ( $n = 7$ ) and bladelets ( $n = 2$ ) (see [Table 3](#)). The latter are mostly chips ( $n = 616$ ), with 52 debris pieces. Apart from that, nine technical products from core preparation, nine Levallois flakes, and 31 retouched tools were classified.

#### **Preservation and spatial distribution**

77.7% of the artifacts were preserved completely. Surface condition is diverse: 47% had fresh surfaces with clearly visible negatives, while 53% were abraded to some degree. The artifacts were situated mainly within the top of a layer of dark-yellow sands with a fine fraction of gravel (Unit IIIB). In the vertical projection, they formed a 20 cm thick concentration (see [Figures 3, 4B](#)).

The horizontal projection reveals the absence of artifacts in the northern part of the 10 × 1 m (eastern) trench (see [Figure 5](#)). The results of Kernel density analysis show two clusters preserved within the site: one in the southern part of the eastern trench and the other mainly in the northeastern part of the western (4 × 2 m) trench, with some possible remains in the northern part of the eastern trench. The northwestern cluster contains a significant number of cores and retouched tools, which are hardly present in the other one. Weight class analysis revealed no post-depositional material sorting. These results indicate that post-depositional processes impacted mostly artifact surfaces, which show abrasion caused by aeolian processes. However, they did not cause significant spatial redeposition. This confirms the fact that they were found in the original position of their deposition, perhaps after minimal vertical displacement.



**Figure 8.** EDAR 134, tools. A) Unretouched and B) retouched Levallois products, C) denticulate, D–F) endscrapers, G, K) retouched flakes, and H–J) sidescrapers; A–F) rhyolite and H–K) quartz. Photos: M. Jórdeczka.

### Raw material

Most artifacts at the site were made from local raw materials (see Table 3): quartz (n = 871), rhyolite (n = 223), and

quartzitic sandstone (n = 13); only four were made of Hudi chert, not found in the near vicinity of the site. Surface prospection revealed Hudi chert outcrops (site EDAR 1) near

**Table 3.** EDAR 155, structure of lithic assemblage—number and weight of artifact classes by raw materials.

Artifact type	Total n			Total %			Rhyolite			Quartz			Quartzitic Sandstone			Hudi Chert			Total weight
	n	%	Total %	n	%	Weight (g)	n	%	Weight (g)	n	%	Weight (g)	n	%	Weight (g)	n	%	Weight (g)	
Precore	6	0.5	0.5	1	0.1	89	1.1	4	0.4	594.2	7.3	1.6	1	0.1	131.3	1.6	-	-	814.5
Cores	27	2.4	2.4	4	0.4	714.7	8.8	21	1.9	1015.8	12.5	2.3	1	0.1	187	2.3	0.1	98.5	2016
Blades	7	0.6	0.6	6	0.5	52.7	0.6	1	0.1	2.8	0	-	-	-	-	-	-	-	55.5
Bladelets	2	0.2	0.2	-	-	-	-	2	0.2	2.3	0	-	-	-	-	-	-	-	2.3
Flakes	352	31.7	31.7	110	9.9	1045	12.8	230	20.7	2242.6	27.5	1.7	10	0.9	137.7	1.7	0.2	68	3493.3
Chips	616	55.4	55.4	72	6.5	61.6	0.8	543	48.9	403.1	4.9	-	-	-	-	-	0.1	1.8	466.5
Debris	52	4.7	4.7	15	1.4	132.7	1.6	37	3.3	300.3	3.7	-	-	-	-	-	-	-	433
Levallois trimming elements	9	0.8	0.8	6	0.5	74.9	0.9	3	0.3	66.1	0.8	-	-	-	-	-	-	-	141
Levallois core products	9	0.8	0.8	7	0.6	70.2	0.9	2	0.2	84.3	1	-	-	-	-	-	-	-	154.5
Retouched tools	31	2.8	2.8	2	0.2	26.5	0.3	28	2.5	531.7	6.5	0.3	1	0.1	22.3	0.3	-	-	580.5
Total	1111	100	100	223	20.1	2267.3	27.8	871	78.4	5243.2	64.3	5.9	13	1.2	478.3	5.9	0.4	168.3	8157.1

the Ad-Daburra village on the Atbara riverbank, ca. 70 km from EDAR 155 (see [Figure 1B](#)). Such a long distance seems to have prevented this raw material from being regularly used at the site, restricting it to single precores or raw material lumps.

### **Cores**

This category includes 27 cores and six precores, most made of quartz ( $n = 25$ ) (Table SM4, Supplemental Material 1; [Figure 9](#)). The majority ( $n = 30$ ) are preserved in a complete form; only three were fragmented. Most were abandoned at the late stages of reduction. Three such cores were classified as residual due to the insufficient block volume preventing further reduction. Forms connected with the use of opportunistic production methods predominate in the assemblage: unidirectional cores ( $n = 8$ ) and multiplatform cores ( $n = 11$ ) ([Figures 9D](#), [10A](#)). The unidirectional cores mainly have platforms prepared with one removal or are completely natural. Technological features of two cores meet the criteria for discoidal cores, including the absence of hierarchization between two flaking surfaces and centripetal scar directions ([Figure 9C](#)). Another core is bipolar, showing opposing negatives with splintered scarring on the flaking surfaces, along with Hertzian cones on one of the platforms ([Figure 9D](#)).

Two cores represent different Levallois methods of production. The first one, made of Hudi chert, is recurrent with centripetal preparation of both surfaces and one main, hinge-terminated negative was created by detaching a Levallois product ([Figure 9A](#)). Main flaking surface preparation scars are visible in the proximal part near the platform and partly in the distal part; the rest is left natural and unprepared. The platform is unidirectionally faceted. The other core is centripetal recurrent and made of rhyolite. The scar pattern of the flaking surface shows two series of Levallois product negatives. The two main faceted platforms are located on the opposing sides of the core. The second face is centripetally prepared with ca. 50% of the natural surface left intact.

Mean core sizes are  $45 \times 42.2 \times 31.8$  mm (Table SM8, Supplemental Material 1). Only three cores have maximum dimensions exceeding 60 mm. The medians and means for the maximum sizes are similar, which testifies to the absence of considerably excessive values in the assemblage. The smallest core measures  $17.8 \times 20.7 \times 9.3$  mm. This size range proves that in most cases, raw material of small size was used, e.g. cobbles or pebbles. Additionally, the cores were normally abandoned at a late use stage, with much of their original volume exploited. In this case, the apparent miniaturization seems to result from economic issues and the raw material availability of a particular volume rather than intentional technological behavior.

### **Debitage and waste**

The EDAR 155 assemblage includes 352 flakes (230 quartz, 110 rhyolite, 10 quartzitic sandstone, and two Hudi chert), 616 chips (72 rhyolite, 543 quartz, and one Hudi chert), and 52 debris (including 15 rhyolite) (Table SM5, Supplemental Material 1). Most flakes were preserved completely ( $n = 271$ ; 81 fragmented) and have less than 50% of their natural surface on the dorsal face ( $n = 231$ ), which means that they come from late core reduction stages (see Table SM5, Supplemental Material 1). Only 17 flakes have

more than 50% of the natural surface, and 66 are completely cortical; 36 remained undetermined due to surface damage. Four different types of dorsal patterns occurred (see Table SM5, Supplemental Material 1): unidirectional ( $n = 168$ ), perpendicular ( $n = 44$ ), multidirectional ( $n = 44$ ), and opposite ( $n = 10$ ). The most frequent platform types are plain ( $n = 146$ ) and cortical ( $n = 111$ ), while dihedral, linear, punctiform, and faceted ones were much less common (see Table SM5, Supplemental Material 1).

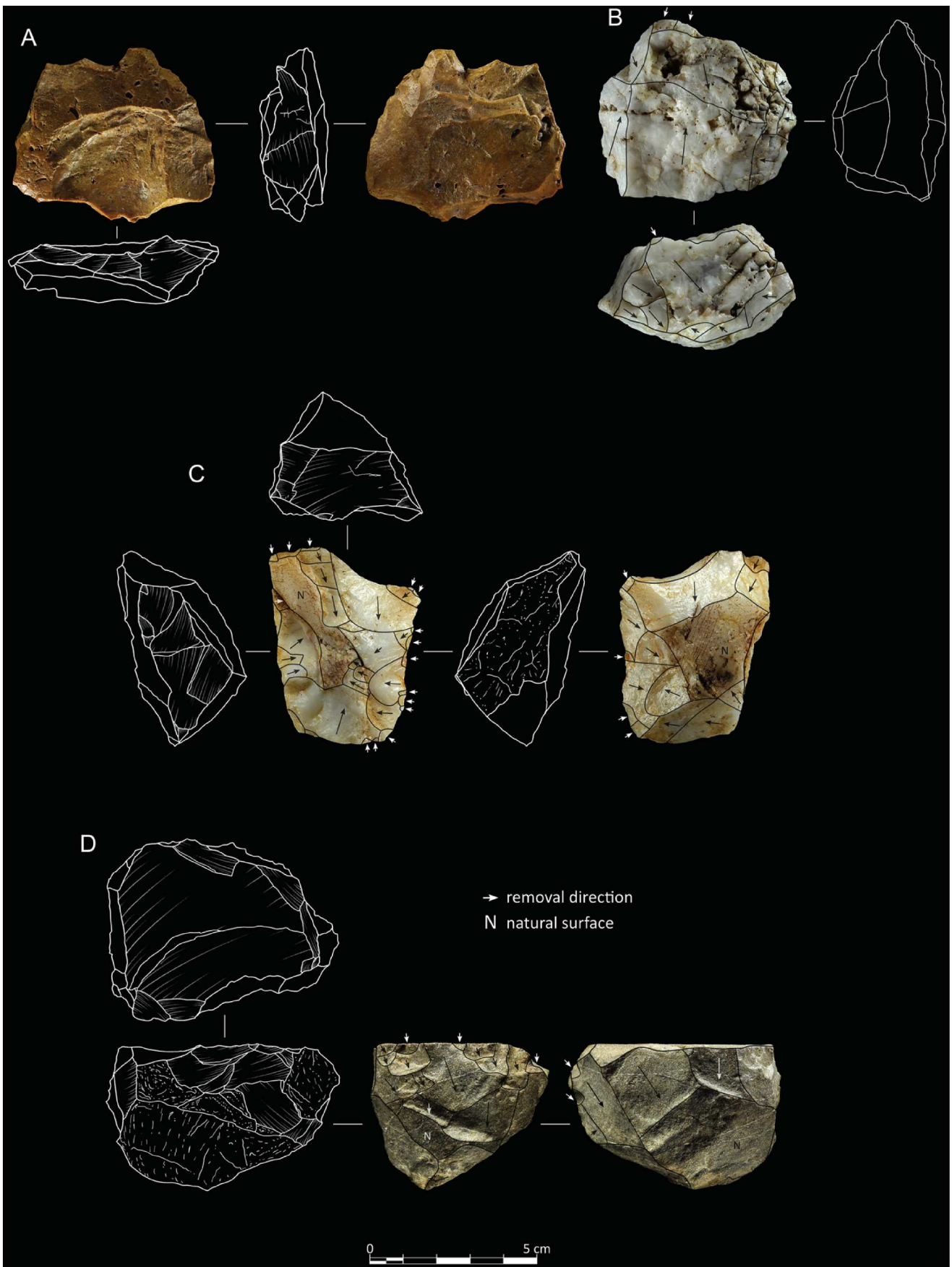
Nine flakes were classified as core trimming elements (see [Figure 10](#)). Four of them bear the features typical of primary debordant flakes—multidirectional scars of a flaking surface preparation, as well as faceted and plain platforms. The other five are secondary debordant flakes with perpendicular dorsal negatives created during the preparation of the flaking surface and detaching of preferential flakes; two with plain and three with faceted platforms. The last category of core reduction products is represented by nine Levallois flakes: seven rhyolite and two quartz (see [Figure 10](#)). Typologically, six of them are Levallois flakes, one is a Levallois point, and two are Nubian points (a complete one and a fragment), all with faceted platforms. Their dorsal scar patterns are centripetal ( $n = 4$ ), unidirectional ( $n = 2$ ), and perpendicular ( $n = 1$ ).

### **Retouched tools**

As with the remaining artifact groups, the retouched tools were predominantly made of quartz ( $n = 28$ ), with the addition of rhyolite ( $n = 2$ ) and quartzite sandstone ( $n = 1$ ) (Table SM6, Supplemental Material 1; [Figure 11](#)). Except for one retouched Levallois flake, all these retouched tools can be associated with various simple domestic activities within the encampment: flakes with simple retouch ( $n = 12$ ), denticulates ( $n = 4$ ), sidescrapers ( $n = 6$ ), endscrapers ( $n = 5$ ), perforators ( $n = 3$ ), combined tools ( $n = 2$ ), and one unidentified tool fragment. Most tools ( $n = 21$ ) were made on flakes from advanced core reduction stages with less than 50% dorsal cortex; only two have more than 50% of the natural surface and three are fully cortical (see Table SM6, Supplemental Material 1). The retouched tool blanks have unidirectional ( $n = 14$ ), multidirectional ( $n = 5$ ), perpendicular ( $n = 6$ ), and opposite ( $n = 3$ ) scar patterns. Six platform types have been observed on tools: plain ( $n = 9$ ), cortex ( $n = 5$ ), dihedral ( $n = 4$ ), faceted ( $n = 3$ ), punctiform ( $n = 2$ ), and one linear.

### **Usewear analysis**

Macroscopic examination of 10 sample artifacts revealed slight to heavy rounding of at least one working edge. On three, small, irregular, overlapping negatives were observed; these could be the first indicators of use for cutting. A multitude of traces was discovered in microscale. Unfortunately, the vast majority of them may be attributed to post-depositional processes. Two types of polish appeared on otherwise dull surfaces. The first type, covering larger areas, was rough and matt ([Figure 12A](#)). The other manifested itself as scattered, brighter, more translucent, and smoother patches ([Figure 12B](#)). Other micro-traces included short, crisscrossing sleeks and striations of varying depth. Numerous impact pits were visible, especially on tool edges and ridges. In many cases, they formed large concentrations. A series of small cracks and chips could also be observed. All the described traces may be linked to aeolian abrasion, suggesting that

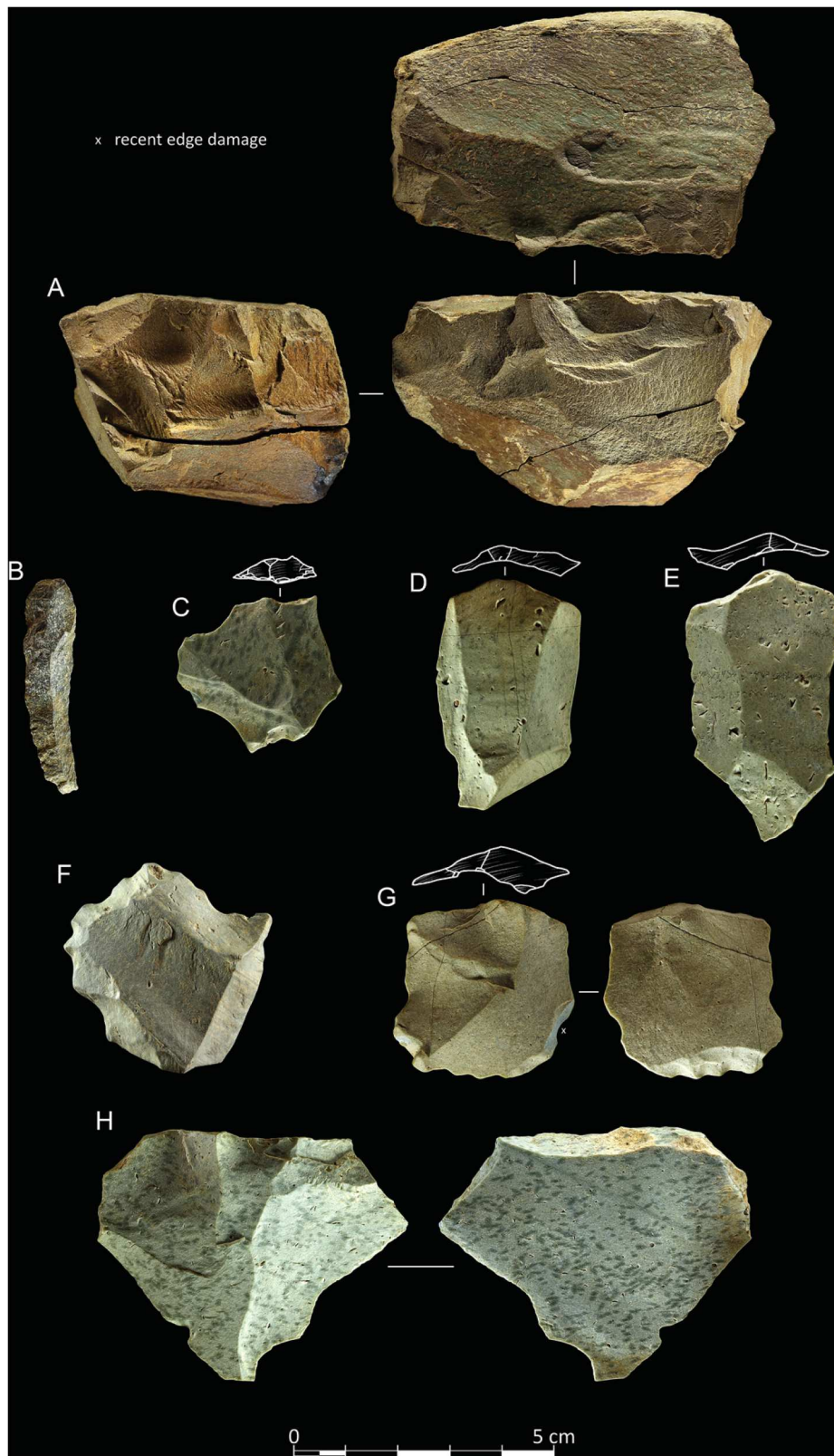


**Figure 9.** EDAR 155, cores. A) Recurrent Levallois, B) multiplatform core, C) discoidal, and D) unidirectional; A) Hudi chert, B–C) quartz, and D) rhyolite. Photos: M. Jórdeczka.

the analyzed artifacts were temporarily uncovered and exposed to sandblasting. This, together with tumbling, would have caused fractures, cracks, impact pits, and irregular scratching of the surface (Knutsson and Lindé 1990).

Due to heavy post-depositional alterations, it was almost impossible to identify traces related to specific tasks. Indicators of possible use—regular edge rounding caused by overlapping microfractures—were identified in two cases.





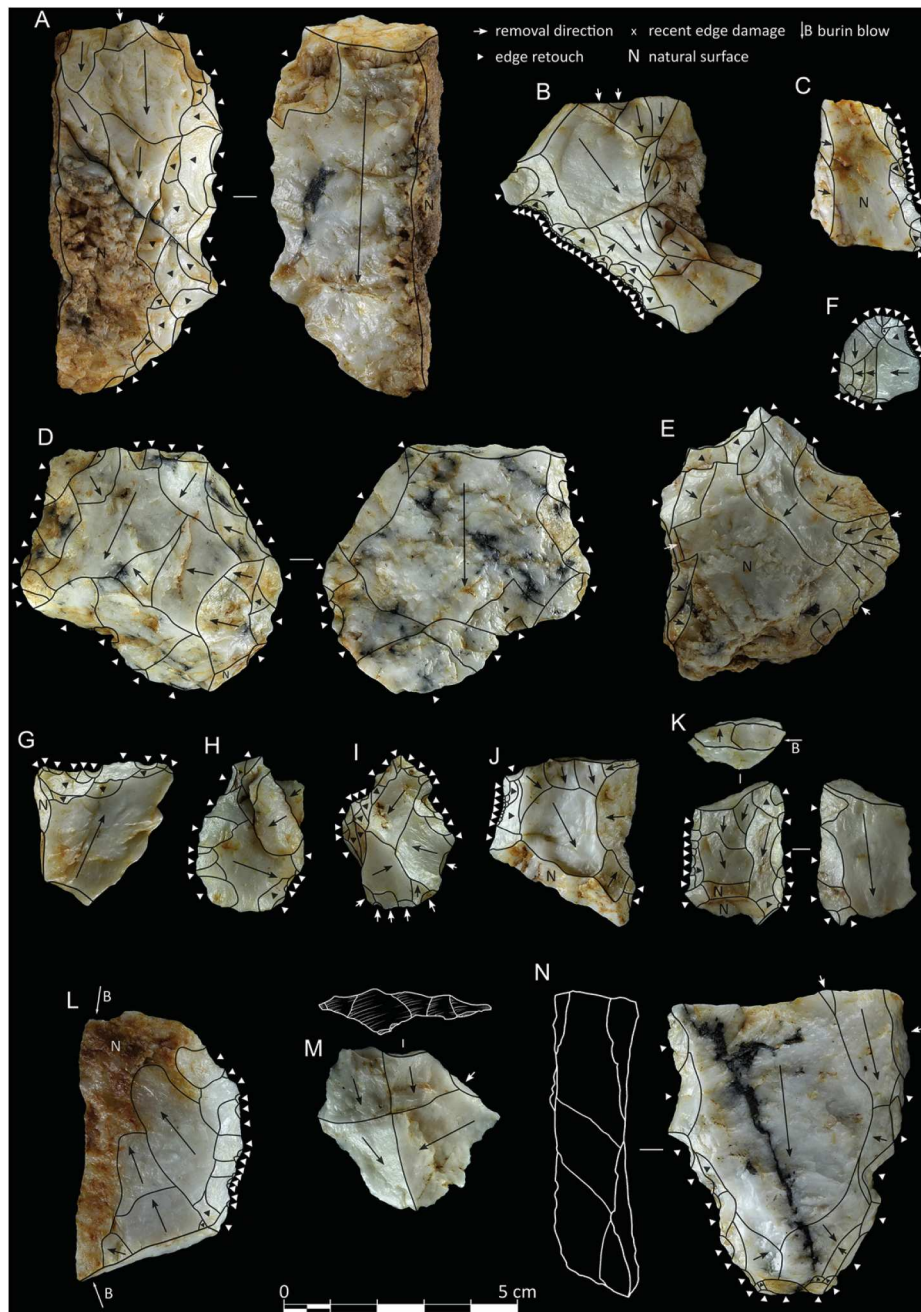
**Figure 10.** EDAR 155. A) Unidirectional core, B) blade, C–E) Levallois flakes, F) denticulate, G) retouched Levallois flake, and H) multidirectional flake; all rhyolite. Photos: M. Jórdeczka.

This, together with several perpendicular striations, could hint at the use for scraping (Figure 12C–D). Such interpretation is by no means certain, as similar patterns could be created by post-depositional wear (Taipale 2012, figs. 2.1, 2.2).

## Discussion

A strong connection between human settlement and changing environmental conditions during MIS5 in the

EDAR area is visible in the data obtained at the sites. This period is characterized by climate variability and the occurrence of several humid, semi-humid, and semi-arid periods (Williams 2020; Williams et al. 2015). Environmental data confirm the climatic conditions referred to as the Green Sahara, where the modern desert was a grassland/savanna biome with numerous lakes and seasonal watercourses (Ait Brahim et al. 2023; Drake et al. 2011, 2022)

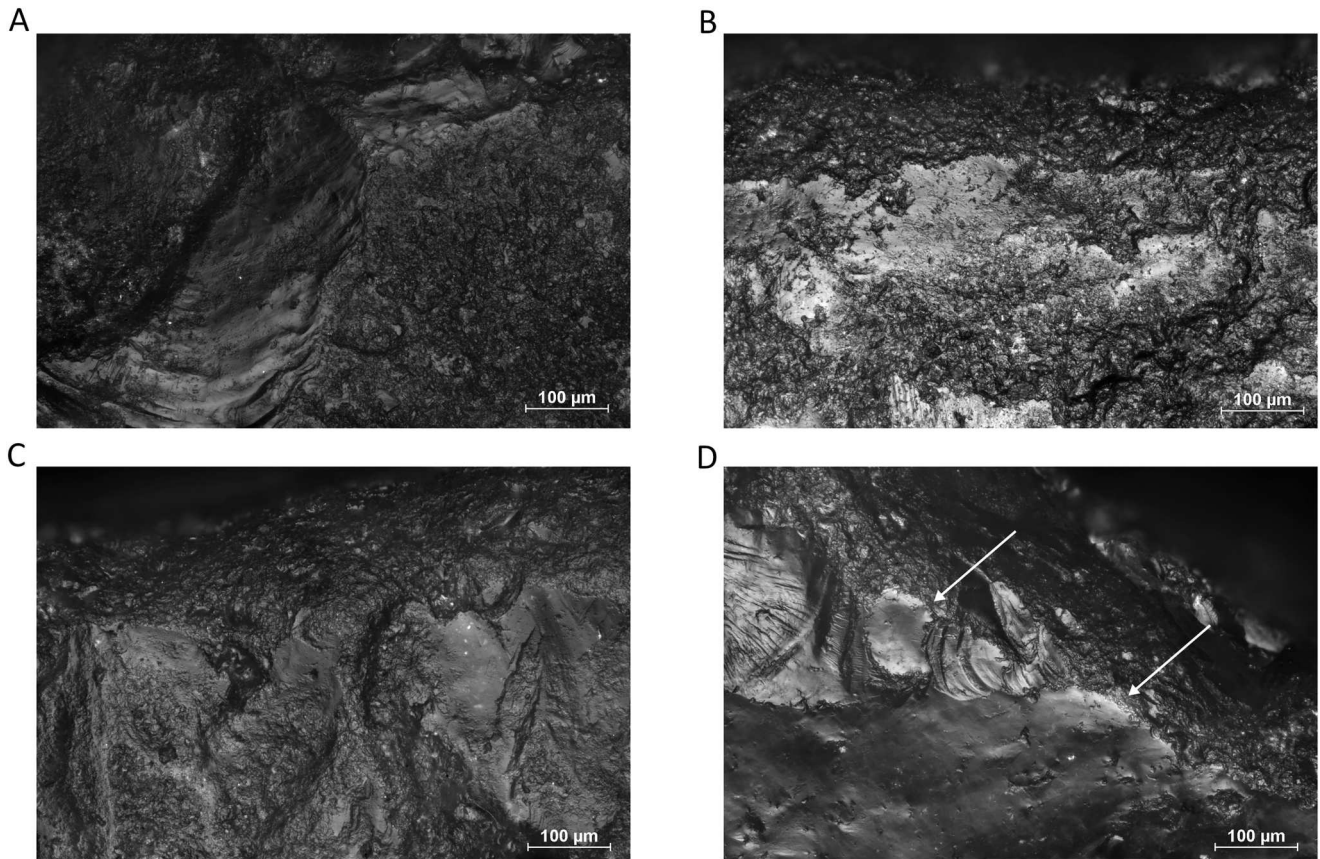


**Figure 11.** EDAR 155, tools. A, C) Denticulates, B, D, H) sidescrapers, E, I) perforators, F) endscraper, G, J) retouched flakes, K–L) composite tools, M) Levallois flake, and N) Nubian Levallois flakes; all quartz. Photos: M. Jórdeczka.

The occurrence of a warm and humid period during MIS 5e associated with Sapropel Event 5 was confirmed by correlating marine and Nile basin sediment data (Williams 2020; Williams et al. 2015). Similarly, the analysis of Wadi Midauwara silts in the Kharga Oasis confirmed the presence of a lake in the MIS 5e period, around which human settlements existed (Kieniewicz and Smith 2007; Smith et al. 2007). One of the EDAR sites fits in that timeframe—the younger archaeological horizon from EDAR 135 was discovered in sand and gravel deposited during strong erosion episodes occurring between sedimentation periods at the turn of MIS 6 and MIS 5e (Ehlert et al. 2022; Masojć et al. 2021b).

The dating of sediments from EDAR 134 and 155 indicate human presence at the turn of MIS 5c and 5b. MIS 5c was a relatively warm and humid period, which is confirmed by the studies of the middle reaches of the Atbara River, where paleosol remains dated to  $98 \pm 10$  and  $90 \pm 10$  kya were

discovered in Khashm El Ghirba 2. Their grain size and chemical composition show conditions corresponding to a sub-humid and semi-arid climate (Mohammednoor et al. 2023). Further confirmation of humid or semi-arid conditions in this period is found in lake sediments from Bir Sahara and Bir Tarfawi (Schild, Hill, and Bluszcz 2020), as well as in studies of Nile Valley sediments (Williams et al. 2015). It should be noted that compared to the MIS 5e and MIS 5a stages, MIS 5c is characterized by much lower humidity (Schild, Hill, and Bluszcz 2020; Williams 2020; Williams et al. 2015). It cannot be ruled out that the deposition of the lithic assemblage occurred during the period when the EDAR area was covered with green savanna. Macro- and microscopic observations recorded a large share of post-depositional traces and abrasion visible on the surfaces of the stone artifacts. This indicates that the assemblage remained on the surface for a long time, which



**Figure 12.** EDAR 155. A–B) Features interpreted as post-depositional wear: irregular striations and patches of polish and C–D) possible usewear mixed with post-depositional damage. Noticeable edge rounding, some short perpendicular streaks; visible weak polish (marked by arrows).

resulted in the objects being exposed to post-depositional processes, mainly aeolian ones, occurring during dry periods such as MIS5b (Schild, Hill, and Bluszcz 2020; Williams et al. 2015).

### **Technological behaviors and cultural attribution**

The data obtained so far does not allow us to determine unequivocally which subsistence-settlement model, e.g. foragers or collectors as proposed by Binford (1980), was adopted by the communities occupying the EDAR area. Mobility models of hunter-gatherer societies are influenced by many factors: environmental and climatic conditions, group size, subsistence strategy, or access to resources (Binford 1980; Grove et al. 2023; Johnson 2014). Two main site formation processes that influence data acquisition should also be considered: cultural and noncultural (environmental) formation processes (Schiffer 2010).

Despite similar dating, there is no certainty that the same group settled both EDAR 134 and 155, either simultaneously or at a similar time. There are, however, several important aspects differentiating both assemblages. Firstly, a much smaller number of artifacts was discovered at EDAR 134. Secondly, the percentage of retouched tools is higher on that site. Thirdly, there are artifacts made of non-local Hudi chert raw at EDAR 155. Based on that, EDAR 155 can be considered as a part of a larger network of seasonal camps and lithic workshops. This seasonality should probably be associated with favorable environmental conditions during the rainy season, when it was possible to hunt the fauna that migrated to savanna areas away from the permanent riverbeds, e.g. the Atbara River. According to the

models proposed by Binford (1980), EDAR 134 should be considered a cache or station, where special tasks were performed by small groups. In this case, this task might have been establishing a small outpost near an easily accessible outcrop of high-quality rhyolite.

Both the EDAR 134 and 155 assemblages are characterized by the predominance of one local raw material, i.e. quartz at EDAR 155 and rhyolite at EDAR 134. One of the behavioral innovations of the MSA is the long-range transport of raw materials (McBrearty and Brooks 2000; Scerri and Will 2023). The four Hudi chert artifacts from EDAR 155, probably brought from the EDAR 1 outcrop near Ad Daburra on the bank of the Atbara River ca. 70 km away, could be evidence of such behavior (see Figure 1B). Of course, without XRF analyses, we cannot state unequivocally that Hudi chert came from this particular outcrop. Either way, it seems that the long distance from its sources prevented a more regular use of this raw material. This is evident in the MIS 6/5e EDAR 135 assemblage, where only quartz and rhyolite were found (Ehlert et al. 2022).

The diversity of the properties of raw materials occurring in the EDAR area was explored during an experiment involving large cutting tools and large flake production (Masojć et al. 2021a). This may be the cause of intentional raw material selectivity according to various production methods. It seems that, due to its properties, rhyolite was more willingly used when the Levallois method was applied—most of the Levallois cores and their reduction products were made of this raw material.

Quartz has the tendency to shatter during detachment, which makes controlling and maintaining the expected shape of the product problematic (Pargeter and De La

Peña 2017). This raw material was mainly used in opportunistic core reduction methods aimed at obtaining as many working edges as possible while using all block volume: unidirectional, multidirectional, and discoidal. It should also be noted that such a technological orientation is reflected in the high frequency of simple domestic tools (retouched flakes, notches, scrapers, denticulates, etc.), used for various activities related to working with organic raw materials (bones and wood) and butchering (Ehlert et al. 2022).

Insufficient data on the chronological range of individual complexes makes relating the assemblages from EDAR 134 and 155 to technological complexes known from northeastern Africa somewhat difficult (Garcea 2020a; Leplongeon 2021, 2022; Masojć 2021). Therefore, any attempts at placing them in the broader context of the local cultural mosaic must focus on their techno-typological features. The Levallois, discoidal, and opportunistic core reduction methods mentioned above are not distinctive features—they are common in various technological units of the MSA in northeastern Africa (Garcea 2020a; Leplongeon 2021, 2022; Masojć 2021; Scerri and Spinapolice 2019; Van Peer 2016). Therefore, attention should be paid to the individual Nubian Levallois cores and Nubian points from EDAR 134 and 155. These artifacts are the fossile directeur for the broadly defined Nubian complex (Van Peer 1998). The nature of the Nubian complex, as well as the Nubian Levallois technology itself, occurring not only in northeastern but also in southern Africa and the Arabian Peninsula, are hotly debated issues in the literature on the subject (Blinkhorn et al. 2021; Hallinan and Marks 2023; Hallinan et al. 2022; Masojć et al. 2017; Rose et al. 2011; Usik et al. 2013; Van Peer 1998). The Nubian complex was originally defined by Van Peer (1998) and includes local technological units previously identified in Sudan and Egypt (Van Peer 1998; Van Peer and Vermeersch 2000), including the Denticulate Mousterian (Marks 1968a), Khormusan (Marks 1968b), and Nubian Middle Paleolithic (Guichard and Guichard 1965). So far, two development phases of this complex have been distinguished: Early Nubian, characterized by bifacial foliates and predominance of Nubian Levallois cores, and Late Nubian, with Nubian core reduction methods (type I) focused on the production of Nubian points and no bifacial foliates (Van Peer 1998, 2016; Van Peer and Vermeersch 2000). Nubian sites in the Nile Valley are found both in the main area of floodplain edges and deep in today's desert; the latter are interpreted as sites associated with special activities (Van Peer 1998, 2001, 2016).

Only a few Nubian sites from Egypt and Sudan have had the ages of their sediments determined so far (Garcea 2020a; Leplongeon 2021, 2022; Masojć 2021). Three key sites from Egypt should be mentioned. Taramsa 1 (Van Peer, Vermeersch, and Paulissen 2010; Vermeersch 2023b), with two Nubian phases (II and III), is OSL dated to ca. 103 and 69 kya (Vermeersch 2023b). Phase II is a small cluster of artifacts originating during the production of Nubian Levallois points and blades (Vermeersch 2023b). The technological features of Phase III, discovered above a human burial, are strictly related to type I Nubian Levallois point production (Van Peer, Vermeersch, and Paulissen 2010; Vermeersch 2023b). The next two sites are Sodemein Cave and Bir Tarfawi (Hill 1993; Vermeersch 2023a). At the Sodemein Cave site, horizon six was associated with the Nubian complex (Vermeersch 2023a). Luminescence dating of the sediments

indicates a chronological range from ca. 87–121 kya (Vermeersch 2023a). The techno-typological features of the lithic assemblage from this level indicate a large share of Levallois and Nubian cores (Vermeersch 2023a). The Nubian assemblage from the Bir Tarfawi E-87-3 site is associated with a MIS5a lake (Hill 1993).

There are two important Sudanese Nubian complex sites: BP177 and Sai Island 8-B-11 (Masojć 2018; Masojć et al. 2017; Van Peer 2023; Van Peer, Rots, and Vroomans 2004; Van Peer et al. 2003). At BP 177, two archaeological horizons related to this complex (I and II) were discovered on the top of a hill in the Bayuda Desert (Masojć 2018; Masojć et al. 2017). The assemblages show a large share of classic Levallois cores, along with the Nubian ones. Additionally, numerous bifacial foliates were recorded within horizon I at the site. The dating is younger than the previously mentioned sites: horizon I = < 24 kya, horizon II = > 60 kya (Masojć et al. 2017). In the case of Sai Island, the youngest horizon was discovered within a layer dated to ca. 40–25 kya (Van Peer 2023). This assemblage was assigned to the Khormusan—a regional unit strongly associated with the Nubian complex (Van Peer 2023; Van Peer, Rots, and Vroomans 2004)—and characterized by the exclusive use of quartz and the presence of type I Nubian cores and numerous bifacial foliates (Van Peer 2023).

All the examples above show that defining the Nubian complex is not an easy task. The dating of the youngest horizons from Sai Island and BP 177 indicate that it lasted much longer, beyond MIS5 (Masojć et al. 2017; Van Peer 1998, 2023). The techno-typological picture is also very complex, with the two main components being the Nubian Levallois core reduction method and foliate points. The latter were not discovered at EDAR 134 and 155, while the former do not have a large share in the assemblages. Additionally, unlike in Sodemein Cave (Vermeersch 2023a), there is no clear tendency to produce blades and points using the classic Levallois and Nubian Levallois methods, even though some metrical blades were found (Bar-Yosef and Kuhn 1999).

The Sangoan or Sangoan-Lupemban is another technological unit of the northeastern African MSA (Van Peer 2016). It was first described in sub-Saharan Africa (McBrearty 1988; Taylor 2016, 2022). Besides Levallois and discoidal cores, it is defined by characteristic core-axe tools: plano-convex, most often bifacial, with one or two opposed working edges (Clark and Kleindienst 2001; Van Peer 2016). The key Sangoan reference site is Sai Island 8-B-11, dated from MIS 7–MIS 5 (Van Peer 2023; Van Peer, Rots, and Vroomans 2004; Van Peer et al. 2003). The techno-typological features of the assemblages indicate that production was focused on core-axes and foliate points, as well as blanks using classic Levallois and Nubian Levallois methods (Van Peer 2023; Van Peer, Rots, and Vroomans 2004). In addition, a fragment of a lanceolate point was discovered within horizon III (Van Peer 2023).

The Sangoan-Lupemban complex has also been associated with four stratigraphic units at the Khor Abu Anga site in Sudan (Carlson 2015; Nassr and Carlson 2023). Like on Sai Island, numerous core-axe tools, as well as lanceolate and foliate points, were discovered there, along with a large share of Levallois points and classic and Nubian Levallois cores. No techno-typological elements (core-axes and lanceolate and foliate points) that would justify connecting them with the Sangoan-Lupemban were present in EDAR 134 and 155.

Furthermore, it seems that the structure of both the EDAR 134 and 155 assemblages do not fit the technological features defined for the Aterian (Garcea 2020b; Scerri 2013a). This complex is characterized by tanged points (Garcea 2020b; Scerri 2013a, 2013b), small Levallois and discoidal cores (Garcea 2020b; Spinapolicc and Garcea 2013), and bifacial foliates and lanceolate points (Garcea 2020b). Aterian sites occur mainly outside the Nile Valley, e.g. in the Western Desert in Egypt (Kleindienst, Smith, and Adelsberger 2009; Schild and Wendorf 1993). The only site recorded within the valley is Wadi Kubbania (Schild and Wendorf 1989). The chronological framework for the Aterian in northeastern Africa, assuming the dating from the vicinity of the Kharga oasis, can be presumed to be MIS 5–3 (Kleindienst, Smith, and Adelsberger 2009; Scerri 2013a; Smith et al. 2004).

Although most of the non-diagnostic MSA sites in the eastern Sahara region come from the surface (Bicho, Haws, and Honegger 2020; Leplongeon, Bailly, and Graff 2024; Scerri and Spinapolicc 2019), some of them have been discovered in stratigraphic contexts (Garcea 2020a; Leplongeon 2021; Masojć 2021). Both sites presented in this article do not fit into the technological picture of the complexes previously defined in northeastern Africa. The younger horizon from EDAR 135, OSL dated to MIS 5e and containing both recurrent and preferential Levallois and opportunistically reduced single and multiplatform cores, as well as simple retouched tools (retouched flakes, denticulates, and scrapers), is very similar in this regard (Ehlert et al. 2022). Another Sudanese site which can be associated with a general/non-diagnostic MSA is Affad 23 in the Southern Dongola Reach (Osypiński et al. 2016). It was dated with luminescence methods to ca. 60–57 kya years ago, although electron spin resonance dating of faunal remains indicate an older, MIS 5 chronology (Osypiński et al. 2021). Here, the pattern of use of different types of the Levallois method and the production of simple retouched tools is evident, too (Osypiński et al. 2016). Moreover, numerous localities described as generalized MSA have been discovered near the Dakhla and Kharga Oases in the Western Desert, Egypt (Kleindienst 2019, 2020). Most of them are surface clusters of lithics, and the few that have come from stratified contexts are dated to MIS 5–7 (?) (Kleindienst 2019, 2020).

When addressing the phenomenon of non-diagnostic MSA, it is necessary to mention the recently raised issue of generic MSA: assemblages with technological features not fitting the established image and dating to a very wide time scale of ca. 300–30 kya (Basell and Spinapolicc 2024; Taylor 2024; Will and Scerri 2024). As Will and Scerri (2024) point out, research still places a strong emphasis on determining the spatiotemporal occurrence of the respective complexes and connecting that with other issues, such as the emergence of technological innovations, social learning processes, and human dispersal. Thus, “generic MSA” should be used to describe a research problem, not as a broadly understood archaeological taxon. Critical comments on the use of this term as a formal name for an industry or technocomplex have been presented by Shea (2024). As he rightly notes, this can result in the oversimplification of the complex picture of human activity reconstructed based on archaeological, paleontological, and environmental data.

## Conclusions

Functionally, both sites are interpreted as workshop remains, although there are some differences between the assemblages: EDAR 155 probably belonged to a larger camp, while EDAR 134 was a so-called station related to performing a specific activity. Both functioned during MIS 5, when the area was covered with green savanna. Traces discovered on artifacts during usewear studies indicate that factors such as aeolian processes influenced the state of preservation of the site.

The technological features of these sites do not fit into the image of the northeastern African technological complexes. The scarcity of Nubian cores and points in the assemblage, as well as technological features different from other sites from the eastern Sahara region, do not allow us to link EDAR 134 and 155 to the Nubian Complex (Van Peer 1998, 2016). It cannot be ruled out that both the sites’ specific functional characters and the fact that only small areas were excavated may be responsible for the dearth of Nubian Levallois elements.

Blank production methods at both sites involved the use of different variants of the Levallois method and less sophisticated, opportunistic methods (unidirectional, multidirectional, and bipolar). The reason for the use of the latter ones probably stems from block reduction economy—using the largest possible volume of raw material while producing an appropriate number of working edges. The tools discovered at the sites were mainly classified as simple retouched tools used to perform various activities in the camp.

## Geolocation Information

Eastern Desert, Sudan, Africa, N17°68'12" E34°77'66" and N17°65'68" E34°77'92".

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