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ORIGINAL RESEARCH

Early Holocene El-Ghorab Hunter-Gatherers of the Gebel Ramlah Playa, Egyptian South-Western Desert

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Abstract During the Holocene, diverse human groups of hunter-gatherers and pastoralists inhabited the Egyptian Western Desert. These Early Holocene populations were attracted by resources associated with numerous temporary lakes (*playas*) and related wetlands, which characterized the Western Desert during wet climatic oscillations at that time. The Gebel Ramlah region, adjacent to Nabta-Kiseiba, is one of the richest areas of Holocene settlement and has been recently investigated. This paper presents the results of research on a unique Early Holocene occupation associated with the so-called El-Ghorab Unit, dated to the 10th millennium BP. Our results interpret the investigated site as a seasonal, short-term hunting station primarily associated with dorcas gazelle hunting, most likely during the early spring season. Despite relatively favorable environmental conditions that allowed for the preservation of animal skeletal remains, there is no evidence of domesticated animals or pottery at the site. The evidence suggests that El-Ghorab Unit societies represent a primarily foraging mode of subsistence.

Résumé Pendant l'Holocène, divers groupes humains de chasseurs-cueilleurs et de pasteurs ont habité le désert occidental égyptien. Ces populations du début de l'Holocène étaient attirées par les ressources liées aux nombreux lacs temporaires (playas) et aux zones humides associées, qui caractérisaient le désert occidental lors des oscillations climatiques humides de cette période. La région du Gebel Ramlah, adjacente à Nabta-Kiseiba, est l'une des zones les plus riches en établissements holocènes et a fait récemment l'objet d'investigations. Cet article présente les résultats des

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recherches sur une occupation unique du début de l'Holocène associée à l'unité dite El-Ghorab, datée du 10e millénaire avant notre ère. Nos résultats interprètent le site étudié comme une station de chasse saisonnière et de courte durée, principalement liée à la chasse de la gazelle dorcas, très probablement au début du printemps. Malgré des conditions environnementales relativement favorables qui ont permis la conservation des restes squelettiques animaux, aucune trace d'animaux domestiqués ni de poterie n'a été retrouvée sur le site. Les données suggèrent que les sociétés de l'unité El-Ghorab représentaient un mode de subsistance principalement basé sur la cueillette et la chasse.

Keywords Early Holocene · Western Desert of Egypt · Gebel Ramlah · Hunter-gatherers · El-Ghorab Unit

Introduction

The Western Desert, part of the Eastern Sahara located west of the Nile Valley in Egypt, has been a subject of archaeological investigation for several decades. Intensive archaeological research on Stone Age occupation combined with paleoenvironmental studies has recently been conducted lately in the Western Desert's Oases: in Farafra by the University of Rome "La Sapienza" (Barich et al., 2014), in Dakhla within the Dakhleh Oasis Project (Bowen & Hope, 2019), and by several expeditions in Kharga, including the Combined Prehistoric Expedition (Wendorf & Schild, 1980), the Kharga Oasis Prehistory Project (Smith et al., 2004), and the Institut français d'archéologie orientale (IFAO; Dachy et al., 2018). Long-term research was also conducted in the areas outside the oases (Abu Muhariq Plateau, Abu Ballas Scarp, Great Sand Sea, and Gilf Kebir) by the University of Cologne within the B.O.S. and A.C.A.C.I.A. projects (Gehlen et al., 2002). Finally, the Southwestern Desert was investigated by the Combined Prehistoric Expedition (CPE).

CPE Research in the Egyptian Southwestern Desert Including the Gebel Ramlah Playa Area

Since the 1970s, the Egyptian Western Desert has been a primary research focus of the Combined Prehistoric Expedition (CPE). Research has concentrated on the Middle to Late Pleistocene and Holocene adaptations, as well as Quaternary paleo-environmental studies (Schild & Wendorf, 1977, 2013; Wendorf & Schild, 1980, 1993). Concerning the Holocene humid period, the investigations focused on the Southwestern Desert and on hunter-gatherers and pastoralists inhabiting the shores of wetland basins and paleo-lakes (*playas*) of the Nabta-Kiseiba area, dated to the Early and Middle Holocene. Extensive research by the CPE resulted in establishing a local chrono-climato-stratigraphic model characterized by the presence of five archaeological units. These units were identified by a set of unique artifactual characteristics associated with wetter climatic oscillations. The wet episodes were separated by dry periods during which human presence was impossible due to severe climatic conditions. These units are as follows: El Adam (ca. 11,200–9970 BP), El-Ghorab (ca. 9500–9150 BP), Early (ca. 8950–8200/8100 BP), Middle (ca. 8000–7500 BP), Late (ca. 7400–6600 BP), and Final Neolithic (ca. 6650–5500 BP) (Schild & Wendorf, 2013). Each unit is associated with distinct lithic and pottery production and, to some extent different settlement patterns, reflecting various adaptations and social organization (Schild & Wendorf, 2013; Wendorf et al., 2001).

In 2000, a new area for prehistoric research was identified near Gebel Ramlah, located about 25 km northwest of Gebel Nabta (Fig. 1). Intensive excavations and environmental studies have been conducted here since 2001 and continue to the present. During these CPE investigations, rich evidence of Middle-Late Pleistocene and especially Early and Middle Holocene occupations was recorded.

During the early years of Gebel Ramlah research, the CPE focused on numerous Holocene-age cemeteries discovered on the southwestern shore of the paleo-basin. Several burial sites were recorded and excavated, mostly dated to the Final Neolithic. These finds form an extensive mortuary complex, the only example known from the entire Western Desert of Egypt. Cemeteries varied in age and sex structure of the deceased, as well as grave goods. Some cemeteries (sites E-01–03; E-03-01; and E-03-02) contained rich burial inventories with distinct pottery, flint tools, ivory and shell jewelry, colorant containers, parts of weapons, and other items (Czekaj-Zastawny & Kabaciński, 2015; Kobusiewicz et al., 2004, 2010).

Fig. 1 Location of Gebel Ramlah (star) and main sites and areas mentioned in the text

Other cemeteries contained burials with only lumps or powder of red ochre. An exceptional example is a cemetery used exclusively for burying neonates, perinates, or children who died just after birth. In a few cases, these children were buried alongside mothers who died during childbirth (site E-09-02; Czekaj-Zastawny et al., 2018a; Kabaciński et al., 2019).

Another research phase involved recognizing the settlement context of these cemeteries, documenting numerous sites of various archaeological units previously known from the Nabta-Kiseiba region, chronologically ranging from the Early to Middle Holocene (Czekaj-Zastawny et al., 2018b; Fig. 2). During surveys along the northwestern edge of the Gebel Ramlah paleo-lake basin in the 2016 season, a scatter of chert cores, debitage, and tools was recorded on the surface of silt-dominated sediments, ca. 100 m south of the maximum extent of the paleo-lake or wetland. Initial examination revealed the artifact inventory could be assigned to the so-called El-Ghorab Unit (Fig. 3).

The Western Desert El-Ghorab Unit was first identified and described in 1984 when the first site of this type was excavated by the CPE on the margins of El-Ghorab Playa, one of many paleo-lakes discovered within the Nabta-Kiseiba region (Kobusiewicz, 1984; Wendorf & Schild 1984a). The unit is named after the playa basin. Several El-Ghorab sites have since been excavated, with radiocarbon dates ranging from the mid-10th to mid-9th millennium BP (Dachy et al., 2018; Kuper, 2023; Schild & Wendorf, 2013).

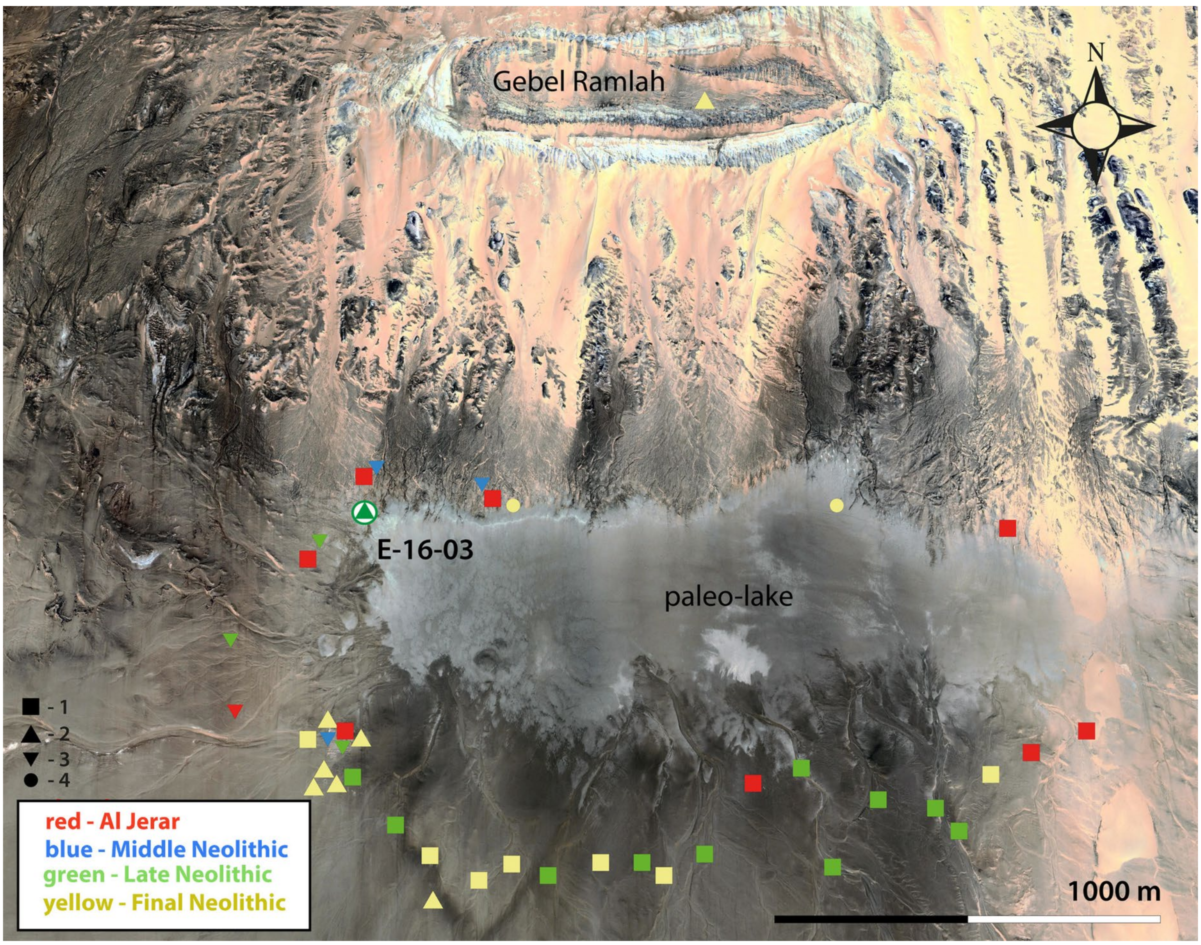


Fig. 2 Gebel Ramlah Playa and distribution of the Early and Middle Holocene sites (green triangle in the circle points to the location of El-Ghorab Unit E-16-03 site)

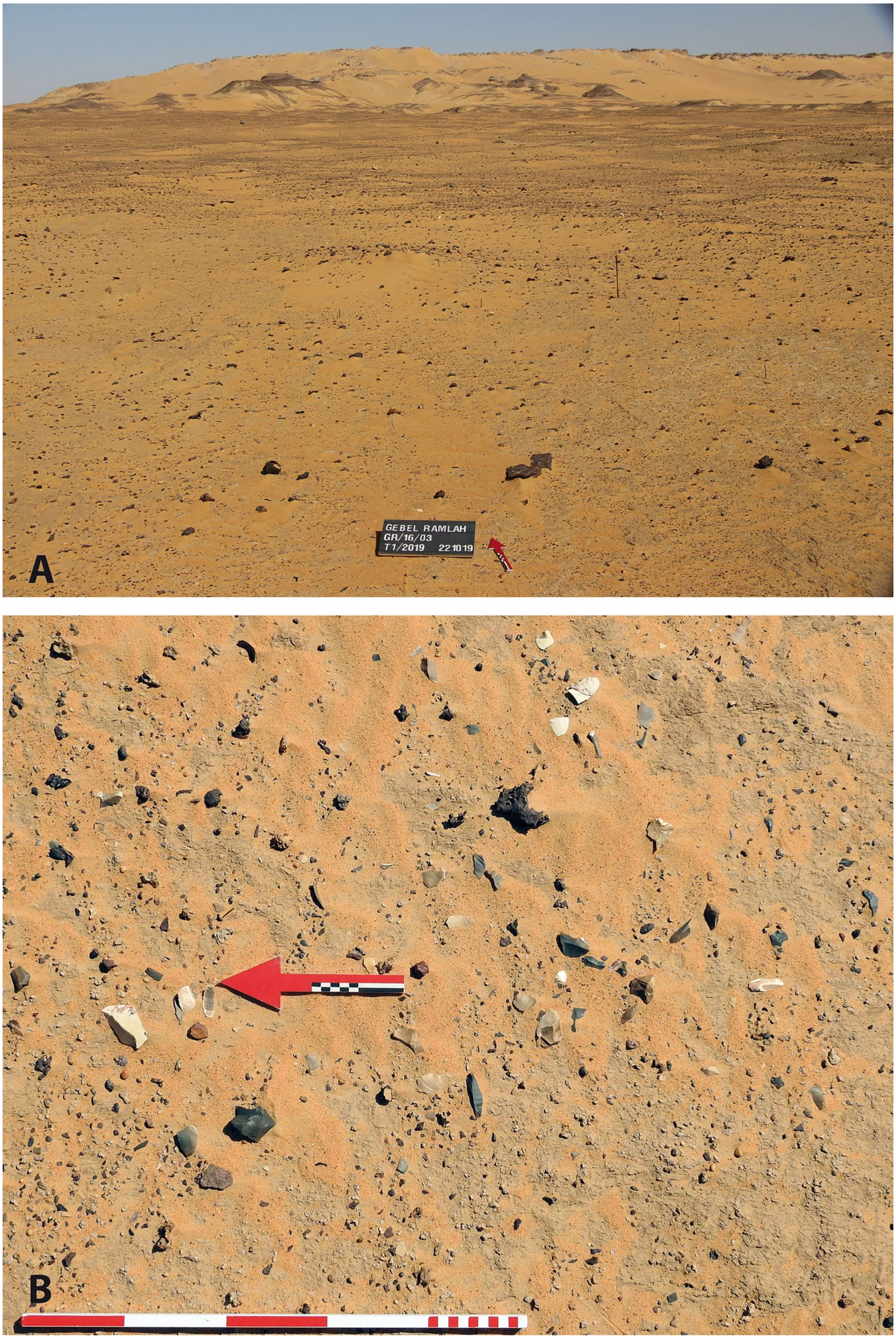


Fig. 3 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. **A** View on the site surface (note the western part of Gebel Ramlah in the background). **B** Scatter of chert artifacts on the surface (a close-up)

The site at Gebel Ramlah, designated E-16-03, was excavated by the CPE team in 2019. So far, E-16-03 is the oldest evidence of Holocene human presence in the area and the only El-Ghorab Unit site known from the Gebel Ramlah basin. This paper presents comprehensive research results from site E-16-03 discussed within the broader context of the Western Desert, including the subsistence of populations inhabiting the area at the beginning of the Holocene.

The Subsistence of the Early Holocene Societies in the Western Desert

It is generally agreed that in the Western Desert, the Holocene Humid Period began around 11,000 BP and lasted several millennia, depending on the region (Kuper & Kröpelin 2006; Schild & Wendorf, 2013). Rainfall filled erosional depressions, forming seasonal lakes and transforming the desert into semi-desert or dry savanna environments where people and various animal species could survive. Available evidence suggests that the subsistence of early settlers from the 11th to 9th millennium BP relied on hunting wild animals and gathering edible wild plants. However, due to poor preservation conditions, this evidence is scarce.

In the Farafra Oasis, the oldest Holocene occupation evidence, dated ca. 10,000–9000 BP, is linked to highly mobile Epipaleolithic hunter-gatherers (Barich, 2008), who likely hunted gazelle (*Gazella* sp.), hare (*Lepus capensis*), and Ammotragus (*Ammotragus lervia*) (Barich et al., 2012).

Holocene occupation in the Dakhla Oasis is associated with the Epipaleolithic Masara Unit, recognized in three chronologically comparable variants—Masara A, B, and C. Masara B is interpreted as workshops for secondary processing of MSA materials (McDonald, 2003), while Masara C represents a more sedentary lifestyle with evidence of stone structures. Radiocarbon dates place the Masara Unit between ca. 10,300 and 9000 BP (McDonald, 2009). Except for ostrich eggshells, present at all sites, only one Masara C site (Loc. 308) yielded larger faunal remains, including hartebeest (*Alcelaphus buselaphus*), gazelle (*Gazella* sp.), hare (*Lepus capensis*), ostrich (*Struthio camelus*), smaller birds, tortoise (*Testudinidae* sp.), lizard (*Lacertilia* sp.), and toad (*Bufo* sp.) (McDonald, 2009). Masara A site (Loc. 263 A) produced bones of dorcas gazelle (*Gazella dorcas*) and larger species. Charcoal and plant macrofossil analyses identified Sahelian flora species, such as *Acacia nilotica*, *Balanites aegyptiaca*, *Calotropis procera*, *Capparis decidua*, *Leptadenia pyrotechnica*, and *Salvadora persica*. Although tubers were not recorded, remains of various sedges and marsh plants suggest a broad spectrum of plant processing (Thanheiser, 2008, after McDonald, 2003, 2009). Masara C sites are considered long-term base camps of semi-sedentary groups (McDonald, 2009).

The earliest Holocene settlement in Kharga Oasis is linked to Masara A and C or Midauwara Units, primarily identified in the Dakhla Oasis (Dachy et al., 2018; McDonald, 2003, 2009). Radiocarbon dates from site KS192 LB (IFAO project) place Masara C Unit within 11,600–9900 BP, comparable to the El Adam Unit of Nabta/Kiseiba (Dachy et al., 2018; Schild & Wendorf, 2013), though typologically different due to the presence of Harif points. Several bovine bone remains identified as aurochs (*Bos primigenius*), hunted in Kharga, were found (Dachy et al., 2018).

A younger phase, called Kharga A in recent classifications, resembles El-Ghorab of Nabta/Kiseiba from a techno-typological perspective, but recent radiocarbon dates indicate only the earliest occupations may be related to El-Ghorab (Dachy et al., 2018). Scarce faunal remains from this phase include dorcas gazelle (*Gazella dorcas*), dama gazelle (*Nanger dama*), aurochs (*Bos primigenius*), and hare (*Lepus capensis*). Wild grass exploitation is also suggested as part of subsistence and mobility strategies (Dachy et al., 2018).

Limited information on subsistence exists for areas outside the oases. The earliest settlement is described by the ACACIA project as "Epipaleolithic" (Gehlen et al., 2002). Sites at Djara, dated between ca. 9700 and 8700 BP, contained only ostrich eggshells. Epipaleolithic sites at Abu Ballas also yielded ostrich eggshells; two sites produced bones of scimitar-horned oryx antelope (*Oryx dammah*), dama gazelle (*Nanger dama*), dorcas/leptoceros gazelle (*Gazella dorcas/leptoceros*), and hare (*Lepus capensis*) (Pöllath, 2009).

In the Regenfeld area of the Great Sand Sea, three settlement phases (Regenfeld A, B, and C) dated between ca. 10,700 and 8900 BP were identified. Units A and B are typologically close to Nabta/Kiseiba El Adam and El-Ghorab units (Gehlen et al., 2002). Ostrich eggshells, accompanied by bones of dorcas or leptoceros gazelle (*Gazella dorcas/leptoceros*) and less frequently bones of large dama gazelle (*Nanger dama*), addax antelope (*Addax nasomaculatus*), hare (*Lepus capensis*), and *Vulpes* sp., represent the faunal remains (Pöllath, 2009).

The largest set of faunal remains recorded so far comes from Nabta/Kiseiba sites in the Southwestern Desert, associated with the Early Holocene El Adam and El-Ghorab Units (Gautier, 2001; Schild & Wendorf, 2013). On each of eight El Adam sites, dorcas gazelle (*Gazella dorcas*) remains were identified, occasionally very numerous (e.g., 323 bone fragments at site E-79-8). Bones of dama gazelle (*Nanger dama*) were less numerous but present at seven sites. Most sites also contained hare (*Lepus capensis*) remains and ostrich eggshells. Single bones of porcupine (*Hystrix cristata*), jackal (*Canis aureus)*, wild cat (*Felis silvestris)*, and field rat (*Arvicanthis niloticus*) were likewise reported (Gautier, 2001). Similar faunal structures were recorded at four El-Ghorab sites: dorcas gazelle (*Gazella dorcas*) remains predominate, accompanied by hare (*Lepus capensis*). Single bones of wild cat (*Felis silvestris*), porcupine (*Hystrix cristata*), and several jackals (*Canis aureus*) were also present. What differentiates El-Ghorab from El Adam sites is the near absence of dama gazelle (*Nanger dama*) remains (only one bone at the E-79-4 site), which may suggest either more specialized hunting or environmental changes.

On six El Adam sites, *Bos* remains were present in low quantities and varied stratigraphic contexts. Two additional *Bos* bones were found at El-Ghorab sites (Gautier, 2001). These findings formed the basis of the hypothesis of local domestication of aurochs (*Bos primigenius*) in the Southwestern Desert proposed by A. Gautier (1984). This hypothesis, mainly ecological, has been intensely debated since its inception (for summary, see Brass, 2018; Schild et al. 2025). Currently, the issue remains unresolved, and new firm evidence from the Southwestern Desert may ultimately clarify it. Certainly, new data on aurochs' remains from Kharga (Dachy et al., 2018) weaken the crucial ecological argument that aurochs could not have existed in the Western Desert at the beginning of the Holocene without human assistance. However, even if some bones represent domesticated cattle, hunting was the primary method of obtaining food at this time.

Three bird remains come from El Adam sites, including single bones of helmeted guineafowl (*Numida meleagris*), bustard (*Otididae* sp.), and Passeriformes (unid.). The first two species were likely hunted. One bone of a small bird from the Pteroclid family (*Pterocles* sp.) was identified at an El-Ghorab site (Bocheński & Tomek, 2001).

Paleobotanical evidence from El Adam sites is limited. Only Tamarix taxa were identified in charcoals, suggesting a dry environment. Among a few plant remains, wild millet and some unidentified grass seeds accompanied by *Echinochloa colona*, *Setaria* sp., *Ziziphus* sp., and *Schouwia* were recorded. Most of these plants are suggested to be edible (Wasylikowa et al., 2001; Schild et al. 2025; Lityńska-Zając, 2025). No paleobiological data were collected from El-Ghorab sites.

This overview confirms a relatively uniform subsistence base of the earliest Holocene inhabitants of the Western Desert. They were principally hunters, focusing mainly on small- to medium-sized gazelle species—dorcas and dama gazelle (*Gazella dorcas/ Nanger dama*) and, less frequently, other species such as addax (*Addax nasomaculatus*) or scimitar-horned oryx (*Oryx dammah*) antelope. Hare (*Lepus capensis*) was also a common prey. A unique find is the aurochs (*Bos primigenius*), from Kharga, suggesting aurochs hunting in the Nabta area as well. Collection and processing of plant resources certainly occurred, but this evidence remains limited and likely underestimated.

Materials and Methods

The main archaeological materials recovered during excavations are lithics from three concentrations totaling 2726 artifacts. These are designated as concentrations 1, 2, and 3 and are located within 10 m of each other. The artifacts are composed almost exclusively of chert. For the technological analysis of the lithic artifacts, the so-called dynamic technology method was applied (Schild, 1980; Schild et al., 1975). Tool studies were based on the typology proposed by J. Tixier for Holocene collections from northwestern Africa (Tixier, 1963, 1967), adapted by the CPE for the Egyptian Western Desert Holocene context (Wendorf & Schild, 1980).

Functional studies of selected chert materials were conducted following principles initially defined by Semenov and Keeley (Keeley, 1980; Keeley & Newcomer, 1977; Semenov, 1964; Tringham et al., 1974). The methodology has since advanced alongside further technological and methodological developments (Marreiros et al., 2015). Because use-wear analysis focused on triangles, commonly considered parts of hunting equipment, different methodological approaches were reviewed. These included numerous experimental studies related to the European Mesolithic, which contains many types of triangles similar to those from site E-16-03 (Kozłowski & Kozłowski, 1975; Barton & Bergman, 1982; Fischer et al., 1984; Fisher, 1989; Crombie et al., 2001; Rots, 2010, 2016; Rots & Plisson, 2014; see also Winiarska-Kabacińska et al., 2024 for details).

Wear-trace observations were performed at the CPE field laboratory in Gebel Ramlah in 2021 using two microscopes: a digital microscope (Delta Optical Smart 5MP PRO) and a metallographic microscope (Zoom 100×–400×). The field results were later processed at the Traceological Laboratory of the Poznań Archaeological Museum.

The condition of the animal bones was poor, as indicated by a high percentage of remains lacking any diagnostic features relevant to taxonomy and anatomy (90.6% of remains). This was caused by destructive factors, especially during the biostratigraphic stages. Consequently, the skeletal elements of larger mammals were heavily fragmented and modified by biological, anthropogenic, and environmental factors. Most remains did not exceed 3 cm in size.

The animal remains underwent taxonomic and anatomical identification, size classification, and, where possible, identification of the side and part of the body. Assessments of age at death, sex, and morphological characteristics were also performed. Identification relied on morphological features of bones and teeth compared with a reference collection. Each fragment was classified into animal size classes (Gautier, 2001). Spearman's rank order was used to test the correlation between %MAU (minimum animal units) and bone mineral density (Lam et al., 1998).

The compact bone surfaces were analyzed for types of modification, accounting for biostratonomic influence (fracture types, fragmentation, tool marks, bite marks, high temperatures, pre-depositional environmental factors) and diagenetic effects (chemical, biological, and water-related) (Behrensmeyer, 1978; Binford, 1981; Capaldo, 1998). Faunal remains were examined in mechanical layers identified during archaeological investigation.

Remains were classified into three classes: (a) identified (taxonomic and anatomical identification); (b) indeterminate (anatomical identification and size classification only); and (c) unidentified (taxonomically and anatomically unrecognized). The following categories were used during the analysis: MSR, medium size ruminant (e.g., sheep/goat/gazelle/small antelope); LSR, large size ruminant (e.g., cattle, large antelope); MSM, medium size mammal (e.g., sheep/goat/gazelle/dog/taxa); and SSM, small size mammal (e.g., hare, porcupine, dik-dik). A similar methodology was applied by A. Gautier in analyzing osteological material from Nabta Playa (e.g. Gautier, 2001).

The E-16-03 Site

Geological and Geomorphological Overview

The E-16-03 site is situated on the northwestern margin of a deflation basin filled with silty-sandy deposits interpreted as a fossil paleo-lake, sometimes probably a wetland area (Fig. 2); this is one of many such Holocene basins known from the Egyptian Southwestern Desert. Geomorphologically, the site lies within a landscape featuring clastic basin sediments, alluvial fans, and eolian deposits. The southern and western parts of the area are characterized by an undulating plain intersected by wider and narrower wadis (dry tributary channels) that transported sediments into the paleo-basin from the south. To the north, two prominent alluvial fans (about 400–500 m wide) are separated by a roughly 380 m wide area of shallow gullies (Fig. 2). Numerous sedimentary remnants, including yardangs, occur along the northern shores and near the E-16-03 site, documenting the local stratigraphic sequence. These sediments consist of laminated silts containing trace fossils and sands, reflecting short- and long-term environmental dynamics. This stratigraphic context corresponds to the margin of a paleo-lake and wetland area that fluctuated seasonally according to monsoon-related rainfall cycles (Schild & Wendorf, 2010; Hill et al., 2018, 2020a, 2020b, 2022).

Studies of natural stratigraphic exposures (yardangs and sedimentary profiles along wadis) and sedimentary sequences from boreholes and trenches reveal episodic expansions and contractions of a waterbody within the Gebel Ramlah basin. Boreholes situated in the southern and northeastern parts of the paleo-lake show sedimentary sequences several meters thick, reflecting the dynamic basin development since the Last Interglacial (Schild & Wendorf, 2010; Hill et al., 2020a, 2020b, 2022). A Holocene transgressive and regressive phase within the basin is directly observed at site E-16-03; archaeological features embedded on the surface of lake sediments during waterbody contraction are occasionally overlain by silty sediments reflecting lake or wetland expansion in the basin.

Settlement Structures and Spatial Distribution of Lithics

Three trenches (numbers 1, 2, and 3) were excavated based on the densest surface clusters of lithics, designated concentrations 1, 2, and 3. Due to time constraints, excavation was conducted using trowels without sediment screening. Nevertheless, careful work recorded numerous small chips and flakes.

Excavations revealed stone artifacts within two different but geomorphologically connected layers: (1) thin, loose surface silty sands up to 1–3 cm thick (Fig. 3), and (2) the subsurface silty layer. The upper silty sands likely result from progressive erosion of underlying sediments, and the lithic distribution pattern in this upper bed matches that in the silty layer beneath. Thus, artifacts from both layers likely relate to the same occupation event and concentration.

After removing surface loose sands, several archaeological features were documented within lithic concentrations. In plan view, these appeared as oval, faintly visible areas of reddish burnt silt or sandy silt containing varying amounts of charcoal. These are remnants of deflated hearths, with maximum thicknesses of just several centimeters. Features 1 and 2 are adjacent within concentration 1 (trench 1); Feature 3 is in concentration 3 (trench 3); and Feature 4 is within concentration 2 (trench 2) (Fig. 4).

Feature 1 was a poorly distinguishable shallow, deflated basin, possibly a hearth remnant with partially burnt silt and some charcoal fragments. Feature 2, north of Feature 1, measured approximately 2 by 1 m and consisted of three shallow pits, possibly individual hearths filled with burnt sandy silt and charcoal fragments (Fig. 5). Feature 3, a shallow oval pit measuring 1.5 by 1 m, contained burnt sandy silt with numerous charcoal fragments and is located

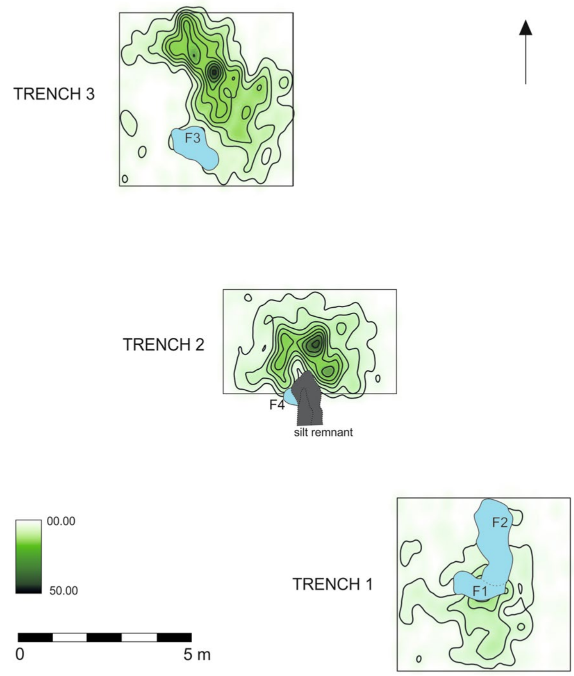


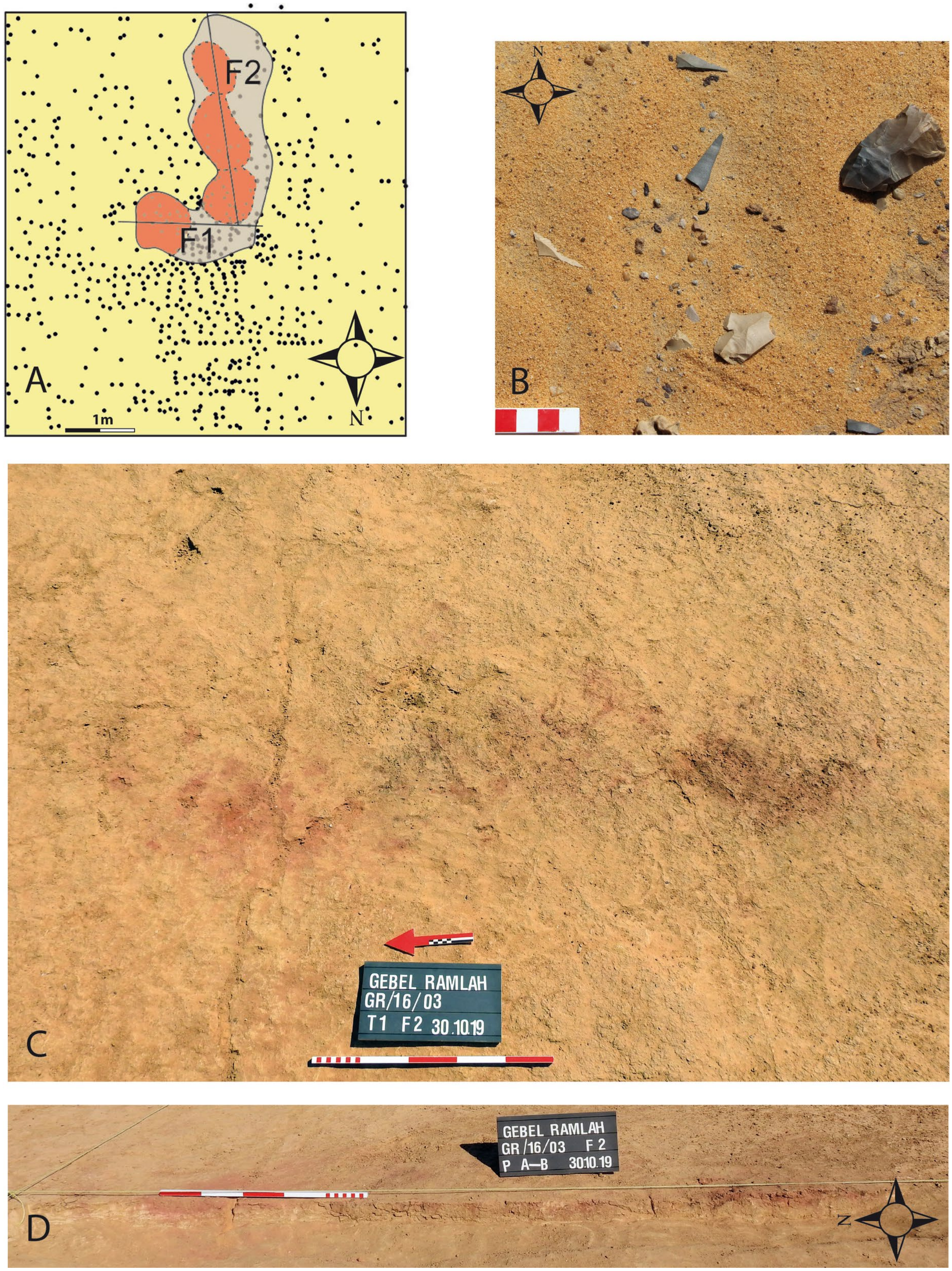
Fig. 4 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Spatial distribution of trenches and features (blue color) plotted on the density map of lithics, collected within surface and subsurface layers, estimated with the Kernel method. Isolines reflect the density of artifacts, from 0 to 50 artifacts. Gray color outlines silt remnant

in the southern part of the lithics concentration, outside the highest flint artifact density (Fig. 6).

Feature 4, approximately 1 by 0.5 m with a maximum thickness of about 0.15 m, is partially covered by a small yardang consisting of silts and sands deposited after the hearth's use (Fig. 7). It comprises burnt reddish silt with numerous large charcoal fragments. Excavations also uncovered burnt animal bones and burnt flint artifacts.

The lithic concentrations show distinct spatial structures often related to hearth features. Concentration 1 had the fewest artifacts and was most dispersed; its highest artifact density occurred centrally within trench 1, around Feature 1, and the southern part of Feature 2 (Figs. 4 and 5). No other clusters were detected nearby. By contrast, artifacts were evenly distributed throughout the rest of the excavated area.

Concentration 2 exhibits a similar distribution, with the highest density centrally north of Feature 4. A smaller sub-concentration occurs southeast of the main cluster (Fig. 4), although this pattern may be


F2
F1
A
1m
N
N
B
GEBEL RAMLAH
GR/16/03
T1 F2 30.10.19
C
GEBEL RAMLAH
GR/16/03 F 2
P A—B 30.10.19
N
D

◂**Fig. 5** Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Trench 1, feature no. 1 and 2. **A** A drawing showing the location of features no. 1 and 2 and the distribution of lithics (black dots) around features (concentration 1); profile lines in black. **B** Close-up photo of part of the surface concentration of lithics (concentration 1) around features no. 1 and 2; numerous triangles are visible. **C** Horizontal extension of feature no. 2. **D** N-S profile of feature no. 2

influenced by the unexcavated southern trench 2 area below the yardang, preserved for future paleoenvironmental studies (Fig. 7).

Nearly half of all artifacts come from concentration 3, which has a less regular spatial distribution. The concentration is oval-shaped (Fig. 4), with artifacts distributed along a northwest–southeast axis. The central densely occupied zone contains two sub-clusters: a smaller one dispersing northwest and a larger one southeast. Few artifacts occur between these sub-clusters (Fig. 6).

Feature 3 (the hearth) is located on the southwestern margin of the lithic concentration. In the northeastern part, a dense deposit of lithics within a small oval pit (~10 cm diameter and depth) contains over 100 tightly packed lithic artifacts, mainly blades (Figs. 6A, B). Such restricted density suggests lithics were stored in a container.

Lithic Concentrations

The three concentrations contain a total of 2726 specimens: 679 artifacts in concentration 1, 803 in concentration 2, and 1244 in concentration 3. The raw material used at the site is predominantly Egyptian chert (over 90%). Fresh, thin cortex on original slabs indicates extraction directly from geological beds. Limestone layers containing chert were initially identified in the rocky massif of Gebel Ramlah. However, due to its plate-like structure, it is believed that the raw material was not processed on site. Another potential Egyptian chert source is the Sin El Kaddab scarp, approximately 15 km north of Gebel Ramlah. The Eocene limestone beds exposed there are considered sources of Egyptian chert and other raw materials, but no direct evidence of quarry locations has yet been found. Based on the size of the largest debitage pieces, original nodules likely did not exceed several centimeters. Some specimens are composed of quartz, petrified wood, agate, quartzitic sandstone (quartzite), or other raw materials.

The general technological structure of the lithic assemblages is very similar across concentrations (Table 1). Cores appear rarely, making up 1–2% of specimens depending on concentration (eleven, eight, and fifteen specimens for concentrations 1, 2, and 3, respectively). Cores for flakes with changed orientation form the largest group (Figs. 8a–c), with five present in concentration 1, one in concentration 2, and six in concentration 3. Single-platform cores for flakes (Figs. 8d, e) appear only in concentrations 1 and 2 (three and one specimen, respectively). In the group of cores for blades, single-platform specimens predominate (one in concentration 1, two in concentration 2, and three in concentration 3; Figs. 9a–d). Other core types, such as opposed platform cores for blades, are rare (Figs. 9e, f).

Cores were usually well prepared for exploitation. Most platforms are lisse, formed by a single strike or sometimes natural. Striking platforms were prepared by removing core-trimming flakes (five to ten specimens depending on concentration) and crested blades (three, six, and seven in concentrations 1, 2, and 3, respectively). Cores were also repaired during exploitation, as evidenced by core tablets (one in concentrations 1 and 2, two in concentration 3) and seven rejuvenation flakes in concentration 3.

Debitage products dominate the assemblages, comprising between 80 and 88% of specimens (542, 661, and 1095 specimens for concentrations 1, 2, and 3, respectively; Table 1). Early core exploitation stages are indicated by cortical blanks. In concentration 1, the frequencies of cortical flakes and blades are balanced; in concentration 2, cortical flakes dominate; and in concentration 3, cortical blades are more common.

Chips constitute about 25% of the lithic inventories (180, 164, and 353 specimens in concentrations 1, 2, and 3, respectively). The two most dominant technological artifact categories are blades and flakes from single-platform cores, with blades being distinctly the most numerous group in all concentrations. Blades from single-platform cores make up 26–29% of the debitage (140, 192, and 316 pieces), while flakes from single-platform cores constitute approximately 22–25% of that group (129, 164, and 246 specimens). Blades and flakes from opposed platform cores or cores with changed orientation occur less frequently (a few percent per concentration). The average size of blades from single-platform

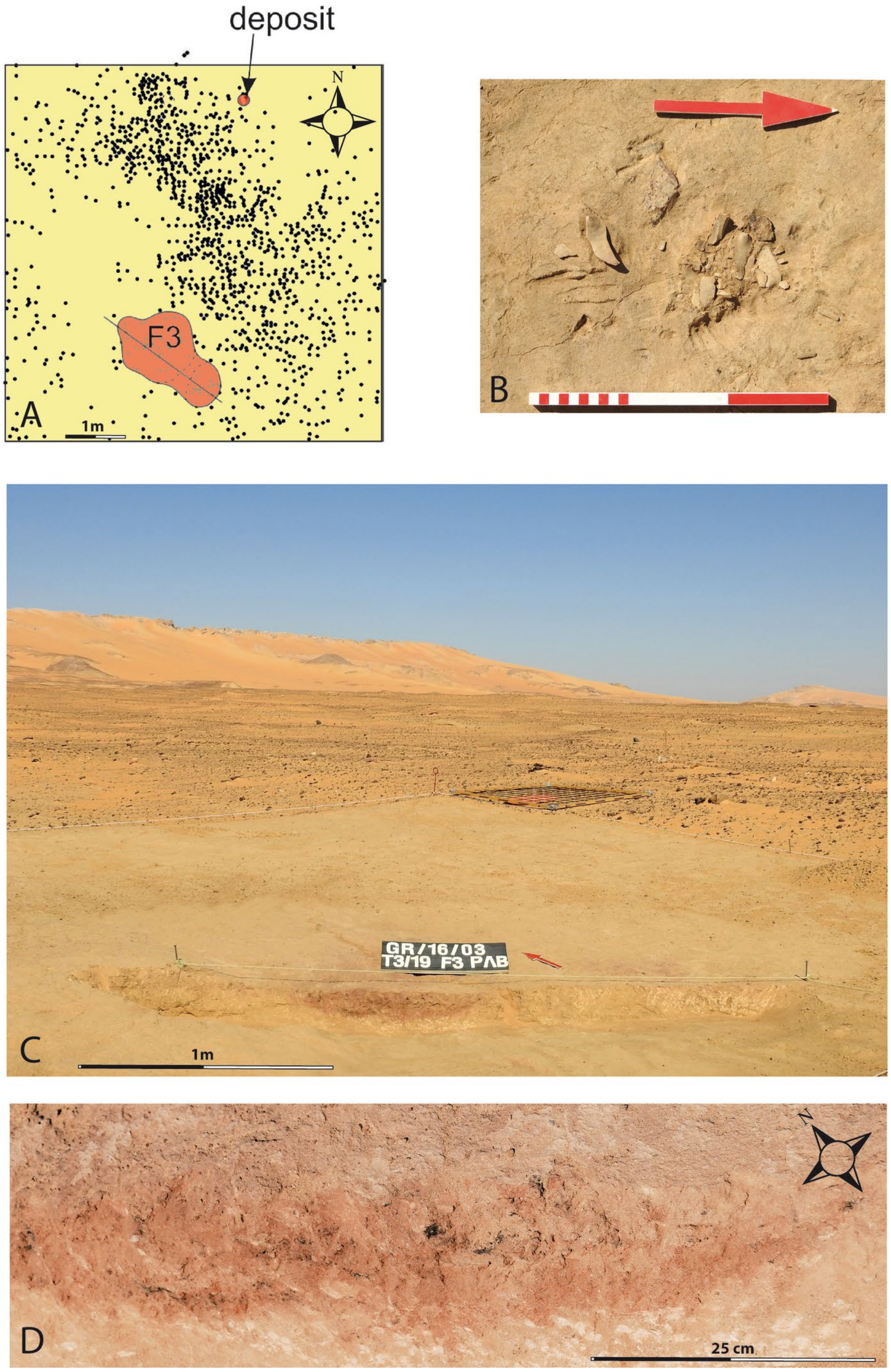


Fig. 6 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Trench 3, feature no. 3. **A** A drawing showing the location of feature no. 3 within the lithics of concentration 2. **B** Close-up photo of a deposit of lithics within concentration 2, north of feature no. 3. **C** NW-SE profile of feature no. 3. **D** A close-up of the profile of feature no. 3 showing numerous charcoals

cores varies by concentration but generally measures 32/38 × 11/13 × 3 mm. Flakes are slightly smaller, averaging 24 × 18/19 × 4/5 mm (Table 2).

Tools and waste products specifically derived from tool production range from 11 to 18% (126, 134, and 134 specimens in concentrations 1, 2, and 3, respectively; Table 3). The tool group is not very diverse and primarily includes triangles—the most characteristic tool type for the El-Ghorab Unit—and waste from their production (Fig. 10). The triangles are elongated, slender, with short sides, made from blades detached from single-platform cores.

The average size of triangles in concentrations 1 and 2 is 26×9×3 mm, and in concentration 3, it is 21×8×3 mm (Table 2). Triangles dominate the tool group in concentration 1, making up more than half of all tools. In concentrations 2 and 3, they constitute 26% (35 specimens) and 27% (36 specimens), respectively (Table 3).

Besides finished triangles, several other categories related to triangle production are present, primarily microburins. Microburins are the most numerous waste category in concentrations 2 and 3 and the second most numerous in concentration 1. Two types of microburins are distinguishable: (a) detached by striking (Figs. 11i–l) and (b) detached by snapping (Figs. 11g, h), with the former technique prevailing (82%; 113 specimens). Microburins were mostly removed from the proximal part of the blade (64% of cases; 88 specimens). A few Krukowski microburins occur within this group (Fig. 11l).

Other lithic forms potentially related to triangle manufacturing include notched blades/bladelets (Figs. 11e, f), segments, backed bladelets (Figs. 11a, b), and micro-truncations (Fig. 11c, d), often obliquely retouched. According to Tixier's typology used for Epipaleolithic/Neolithic inventories from Northern Africa (Tixier, 1963, 1967), these are designated as a separate type. However, it is probable that some of these forms are unfinished triangles.

Larger tools primarily include specimens with continuous retouch (Figs. 12c–j), as well as single end-scrapers (Fig. 12a), side-scrapers (Fig. 12b), perforators (including double perforators), a bifacial tool, and denticulate pieces (Table 3). Some of these forms, such as the bifacial tool and denticulated pieces, might belong to a younger, Late/Final Neolithic lithic scatter (Mugaj, 2016) located about 100 m to the north. This is probable for the discussed inventories due to the considerable metric distinctiveness of those specimens compared to the size of cores and debitage (Fig. 12).

The three analyzed lithic assemblages provide an opportunity to reconstruct the dynamics of stone reduction techniques applied at site E-16-03. Lithic production was strongly focused on producing slim blades. Small chert nodules were used for blank production, indicated by the average and maximum blade sizes: only two specimens across all inventories exceed 100 mm in length. Similarly, the lengths of cores' striking faces rarely exceed 50 mm.

Core preparation was limited to removing cortex from the future striking face and platform, while the core's back was left cortical. Few crested blades—mostly secondary—and some crests preserved on cores indicate only occasional regulation of the flaking surface during exploitation. Core platforms were rarely repaired, possibly due to their small size; platforms are flat or cortical, presumably prepared by a single blow, forming an acute angle with the flaking face, generally between 70 and 80 degrees. Direct impact with a stone hammer was used to detach blanks. The striking face was located on the narrower, longer side of the nodule. Some cores have two opposite platforms sharing a striking face, but the dominance of single-platform blades in the debitage indicates unidirectional exploitation, with the second platform used separately. Often, a new platform was placed perpendicularly on the side of the core relative to previous exploitation.

Lithic reduction was highly specialized, focusing on elongated blades later reworked into triangles. The tool assemblage is dominated by triangles and waste directly related to their production. The microburin technique was used to form triangles (Tixier, 1963; De Wilde & De Bie, 2011). Typically, a notch was made in the proximal blade part, then a semi-finished triangle was produced by removing a microburin, mostly by a stroke and sometimes by a snap at the notch. The tool was then retouched to the desired shape. Some Krukowski microburins removed from triangle tips indicate modification and repair using the microburin method. The number of microburins nearly equals that of triangles.

Microwear Analysis

Microwear analysis focused exclusively on triangles, considered the most characteristic typological feature of the El-Ghorab Unit and important functionally. A total of 140 triangle specimens were studied: 69 from concentration 1, 35 from concentration 2, and 36 from concentration 3. Five very small fragments were excluded due to heavy patination. Lithic artifacts, including triangles exposed for extended periods to wind-blown sand, can exhibit heavy post-depositional edge and surface modifications. However, triangles embedded in playa sediments were sufficiently preserved to retain microscopic traces of use. Details of microwear studies at Gebel Ramlah have been


GR 16/03
T2/2019 F4
A
N
GR/16/03
T2/19 F4 PΛB
B

◂**Fig. 7** Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Trench 2, feature no. 4. **A** The extension of the hearth under the yardang. Arrow points to the location of the triangle embedded in the hearth sediments. **B** W-E profile of feature no. 4 covered by the yardang. Numerous charcoals are visible in the hearth sediments

previously published (Winiarska-Kabacińska et al., 2024); here, basic results summarize the traceological investigations.

Of 140 specimens, 59 show no evidence of use. The remaining exhibit various wear traces. Seventy-three triangles displayed three types of diagnostic impact traces on their tips indicating target impact (Rots, 2010, 2016): burin-like fractures (n = 24), step-terminating bending fractures (n = 40), and spin-off fractures (n = 9). Several specimens showed combinations of burin-like and spin-off fractures. One concentration 1 specimen revealed microscopic linear traces (MILT) accompanying a burin-like fracture. Six triangles with impact fractures had their shorter retouched bases snapped. For 15 triangles, impact traces coincided with hafting polish traces dispersed along the longer retouched edge, partially on the longer edge and partially on the shorter base, or along the whole shorter retouched base.

Eight triangles showed modifications other than impact fractures, suggesting different uses: five were used to drill soft material, and one for scraping woody plants. Most exhibited secondary functions, as they also displayed impact traces. Finally, 59 triangles did not contain trace-wear evidence indicating use.

Osteological Materials

During excavations, 106 heavily mineralized animal remains were found within upper loose silty sands, subsurface silts, and archaeological features. The surfaces of these osteological materials were smooth, with colors ranging from dark gray/brown to black. Teeth, which comprised a small portion of the remains, were fragmented and exhibited mineralization similar to the bones. The overall preservation state of the faunal material was poor or very poor, limiting species-level taxonomic identification. In most cases, it was impossible to determine the age, sex, or evidence of bone working.

Poor preservation resulted from destructive taphonomic factors acting at different stages. A particularly unfavorable factor was extensive fragmentation causing the loss of diagnostic features. The degree of destruction prevents determining whether fragmentation occurred due to human activity at the biostratinomic stage or via depositional/post-depositional environmental conditions. Within anthropogenic factors leading to such a high fragmentation of faunal remains intentional bone breakage during consumption and post-depositional trampling should be considered. In the case of Gebel Ramlah, the condition of faunal materials likely results from a combination of several destructive factors.

The very poor preservation of post-cranial remains may indicate that bones left after human activity were exposed on the surface for some time. Actualistic research suggests that in dry, hot climates, animal remains tend to persist longer on the surface than in colder, wetter conditions, decomposing more gradually

Table 1 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. General structure of lithic assemblage (group of "technical flakes and blades" includes 4 core tablets, 22 core trimming flakes, 16 crested blades, and 7 rejuvenating flakes). Numbers in brackets in tools group refer to type numbers of J. Tixier (1963) taxonomy

	Concentration 1		Concentration 2		Concentration 3	
Debitage	*N*	%	*N*	%	*N*	%
Cores for blades	2	0.3	4	0.5	4	0.3
Cores for flakes	8	1.2	2	0.2	6	0.5
Unidentified cores	1	0.1	2	0.2	5	0.4
Blades	178	26.2	230	28.6	385	30.9
Flakes	169	24.9	246	30.6	322	25.9
Technical flakes/blades	9	1.3	14	1.7	26	2.1
Microburins	29	4.3	67	8.3	45	3.6
Chips	180	26.5	164	20.4	353	28.4
Chunks	6	0.9	7	0.9	9	0.7
Tools	97	14.3	67	8.3	89	7.2
Total	679	100.0	803	100.0	1244	100.0

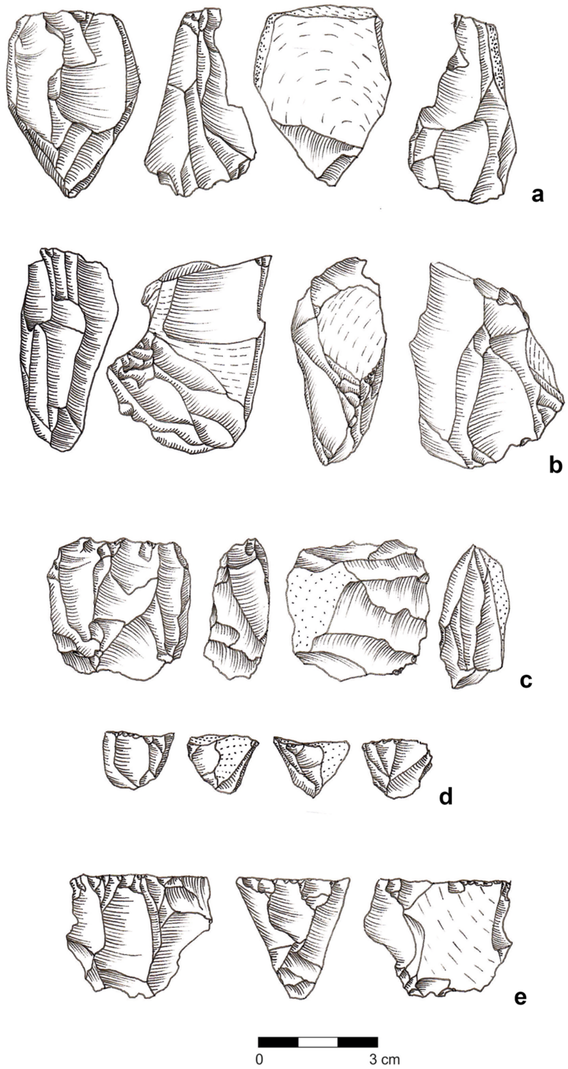


Fig. 8 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Cores. **a**–**c** Cores for flakes with changed orientation. **d**, **e** Single platform cores for flakes

over time. For example, large animal skeleton degradation may occur over approximately 25 years (Denys, 2002). Cracks in long bones can be longitudinal or irregular depending on location, and bone surfaces peel—characteristics observed in the Gebel Ramlah remains. Most unidentified bone fragments took the form of elongated splinters derived from long bone shafts.

However, post-depositional changes within the sediments were decisive for osteological preservation, leading to gradual bone mineralization. Over time, the osteological material underwent diagenetic alterations. Mineralogical sediment compositions and fluctuating hydrological conditions caused dissolution, precipitation, absorption, elemental exchange, and bone component recrystallization (Behrensmeyer, 1978; Lyman & Fox, 1989). The dark gray/brown and black colors of remains indicate iron and manganese deposition, and oxygen conditions accompanied gradual fossilization.

At site E-16-03, relatively numerous faunal remains were poorly preserved (Table 4). Diagnostic features permitting species-level identification were noted in only ten cases—all associated with dorcas gazelle (*Gazella dorcas*). Identified dorcas gazelle fragments belonged to various skeletal parts, including femur, metapodium, metacarpal, scapula, ulna, vertebrae, and teeth (Table 5). Detailed analysis of body parts and anatomical data suggests the remains may originate from a single individual. However, the spatial distribution of dorcas gazelle remains across two separate lithic concentrations suggests otherwise.

Among unidentified remains, seven belong to medium-sized ruminants (probably gazelle) and three to small-sized mammals (probably hare). The most numerous were unidentified mammal fragments (86). No bird, fish, or reptile skeletal elements were identified in the material. Archaeozoological results align with current knowledge about Early Holocene game and indicate exploitation of the semi-desert ecosystem by hunter-gatherers (e.g., Gautier, 2001).

Chronology

Charcoal from Feature 2 was radiocarbon dated to 8180 ± 50 BP (Poz-123918), and charcoal from Feature 4 was dated to 8270 ± 150 BP (Poz-153172) (Kabaciński et al. 2023). Calibrated radiocarbon ages of approximately 9400–9000 cal BP (Fig. 13) place these archaeological occurrences at Gebel Ramlah within the El-Ghorab Unit time range as defined by Schild and Wendorf (2013).

Discussion

Overview of Early Holocene Lithic Assemblages in the Western Desert

Despite the relatively limited archaeological evidence that can be dated with certainty—mostly indirectly—we

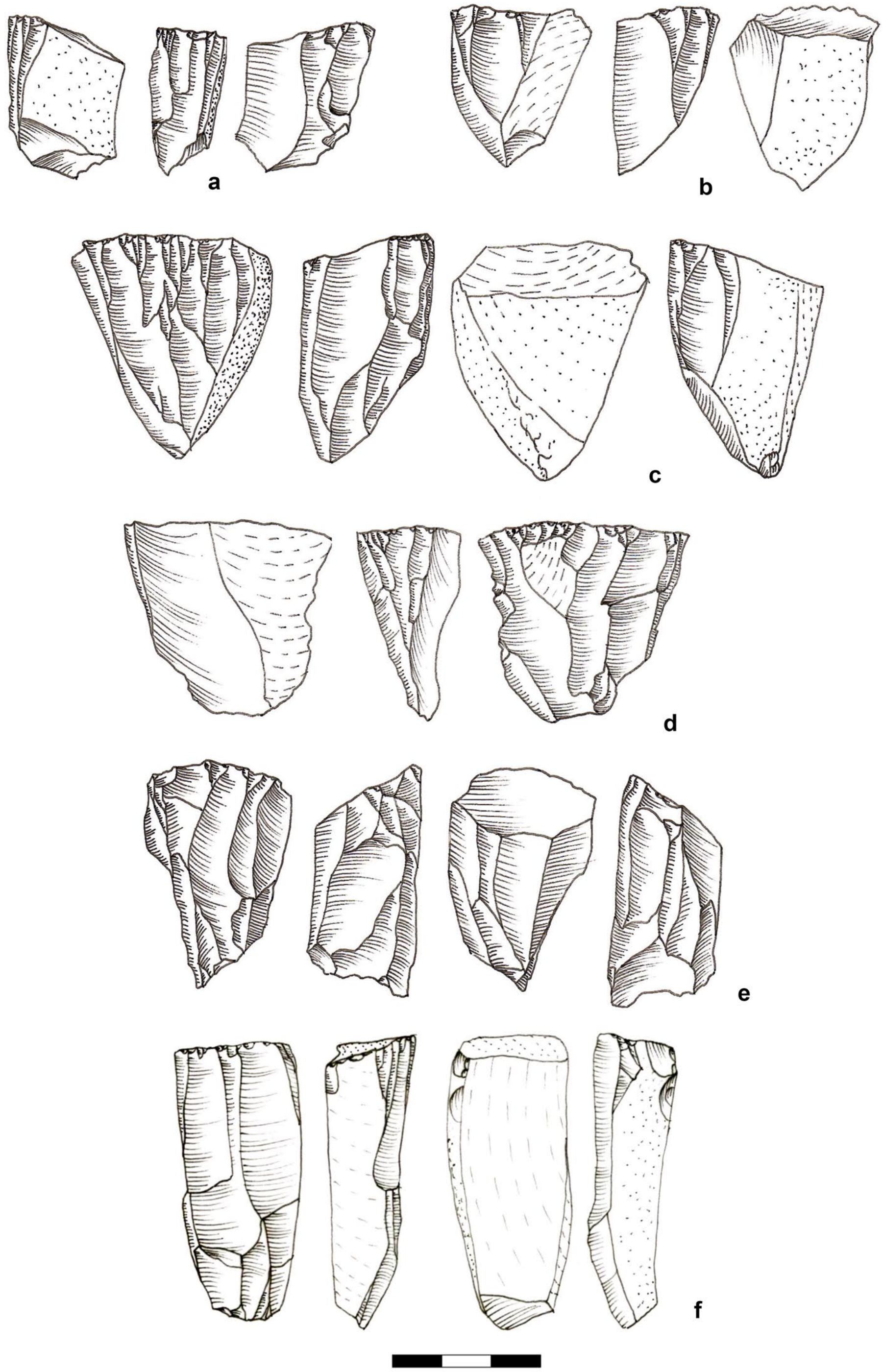


Fig. 9 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Cores. **a–d** Single platform cores for blades. **d**, **f** Opposed platform cores for blades

have a fairly well-established understanding of lithic technology and its evolution in the Western Desert during the Early Holocene. This period is associated with mobile hunter-gatherer groups whose traces have been found throughout nearly all of the region's formerly humid areas. The earliest settlements west of the Nile Valley date to the 11th and 10th millennia BP and are commonly linked to two distinct phases, though the

Table 2 Gebel Ramlah. Site E-16-03. Average size of the most numerous categories of lithics (s, standard deviation)

	Concentration 1						Concentration 2						Concentration 3					
	length (mm)	*s*	width (mm)	*s*	thickness (mm)	*s*	length (mm)	*s*	width (mm)	*s*	thickness (mm)	*s*	length (mm)	*s*	width (mm)	*s*	thickness (mm)	*s*
Blades from single platform cores	33	*14.3*	12	*5.1*	3	*1.7*	32	10.9	11	4.4	3	1.8	38	16.4	13	5.7	3	1.8
Flakes from single platform cores	24	*10.5*	19	*7.6*	5	*2.7*	24	9.3	18	8.8	4	2.6	24	8.4	18	7.8	4	2.0
Triangles	24	*5.0*	9	*1.3*	3	*0.6*	26	5.3	9	1.3	3	0.6	21	4.7	8	1.3	3	0.6

chronology and specific characteristics of lithic technology and toolkits may vary between regions (Fig. 1).

In the Dakhla Oasis, the earliest lithic assemblages belong to the Masara cultural unit, which is divided into two main groups: Masara A and Masara C (McDonald, 1991, 2003, 2009). Masara A flintknapping focused on producing flakes and blades. The toolkit is limited, mainly comprising backed bladelets, elongated triangles, and Ounan-Harif points. The short-term nature of these camps—typically represented by single, small concentrations and a high diversity of raw materials—suggests high mobility among Masara A groups. In contrast, Masara C settlements show evidence of longer occupation, indicated by larger inventories and greater typological diversity. The toolkit includes numerous perforators, including double-backed types, end-scrapers, and Ounan-Harif points. Geometric microliths such as triangles continue to appear, but elongated forms with short sides are absent. Backed bladelets become less common, while trapezes and segments begin to appear. The two phases overlap chronologically: Masara A dates to about 10,500–9500 BP, and Masara C to roughly 10,000–9000 BP (McDonald, 2003).

To the east, in the Kharga Oasis, the earliest Early Holocene horizon is Kharga A, which includes the Masara C phase (named for its typological similarity with the Dakhla Oasis) and the Midauwara phase (Dachy et al., 2018). Dating from 10,500–10,000 BP, this lithic technology is based on single-platform cores aimed at flake and blade production. The assemblage is dominated by geometric microliths, such as triangles (excluding elongated forms with small, short sides), trapezes, and Harif points, along with perforators and end-scrapers. Kharga A inventories (c. 9500–8400 BP) differ somewhat from earlier Masara C and Midauwara groups, consisting almost exclusively of blades and bladelets detached from conical and subconical cores. The toolkit primarily contains geometric microliths: elongated scalene triangles, trapezes, and several segments and backed bladelets. The use of the microburin technique is confirmed.

North of Dakhla, on the Abu Muhariq Plateau, the oldest Early Holocene artifacts are from the so-called Epipalaeolithic complex, dating between 9100 and 8700 BP (Gehlen et al., 2002; Kindermann, 2010). Although older dates exist from the late 10th millennium, these are not directly linked to archaeological

Table 3 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. General structure of tools. Numbers in brackets in tools group refer to type numbers of J. Tixier (1963) taxonomy

Tools (type no acc. to Tixier, 1963)	*N*	%	*N*	%	*N*	%
End-scrapers (1)			1	1.5	1	1.1
Perforators (12)	1	1.0	2	3.0		
Backed pieces (45)		0.0	2	3.0		
Denticulated pieces (75)	1	1.0	1	1.5		
Notched blades/bladelets (76)	4	4.1	5	7.5	1	1.1
Truncations (80)	1	1.0			3	3.4
Lunate (82)					1	1.1
Triangles (95)	73	75.3	36	53.7	36	40.4
Cont. retouched blades (105)			4	6.0	8	9.0
Side-scraper (106)	1	1.0				
Other retouched tools (108)	1	1.0	3	4.5	4	4.5
Retouched blades	11	11.3	8	11.9	19	21.3
Retouched flakes	4	4.1	4	6.0	16	18.0
Bifacial tool			1	1.5		
Total	97	100.0	67	100.0	89	100.0

material. Epipalaeolithic assemblages share characteristics with other Early Holocene technologies in the Western Desert, relying on unidirectional blade and bladelet production. The toolkit mainly includes geometric microliths such as elongated triangles, arch-backed bladelets, and straight-backed and pointed bladelets. In the neighboring Farafra Oasis, the onset of the Holocene is less well understood, but archaeological evidence confirms human settlements between approximately 9500 and 8700 BP (Barich, 2014; Mutri et al., 2020). These assemblages correspond to the earliest cultural complexes in the Western Desert. Tool production focused on straight-backed and pointed bladelets, as well as arch-backed forms, all crafted using the microburin technique. Numerous burins are also present.

A comparable Early Holocene settlement pattern is seen in the Great Sand Sheet area where the earliest habitation dates to the mid-11th millennium BP (Gehlen et al., 2002). Corresponding to the earliest Holocene evidence of the southern Western Desert, Regenfeld A assemblages are rich in straight-backed and pointed bladelets and arch-backed bladelets, but triangles appear only sporadically. During the later Regenfeld B phase (c. 9700–9500 BP), triangles become the dominant tool type—mainly elongated forms with small, short sides, alongside trapezes. In the subsequent Regenfeld C phase (c. 9400–8800 BP), geometric microliths continue to dominate but show greater variety in triangle types, including shorter scalene forms.

In the northernmost part of the region, in the Fayum Oasis, the oldest flint assemblages belong to the Qarunian culture (c. 9500–8100 BP). Although Qarunian assemblages are poorly known and discovered sites are not widely published, they primarily consist of backed bladelets (Wendorf & Schild 1976; Shirai, 2010). These resemble El Adam, Regenfeld A, and Masara A inventories elsewhere in the Western Desert.

For the southern Western Desert two areas are important: Gilf Kebir and Nabta-Kiseiba.

In the Gilf Kebir region, the earliest Holocene hunter-gatherer groups appear around 10,300–9700 BP (Schön 1996; Gehlen et al., 2002). Artifacts from this Gilf A period mainly consist of geometric microliths such as elongated triangles, trapezes, and various backed bladelets. Burins are also notable. After this phase, a long settlement hiatus occurs, followed by intensive Middle Holocene resettlement.

The oldest inventories from the Nabta-Kiseiba region, named the El Adam phase, spanning from the first half of the 12th millennium to the early 10th millennium BP (approximately 11,500–10000/9800 BP) (Wendorf & Schild 1998, 2013). El Adam flint technology is based on unidirectional blade production,

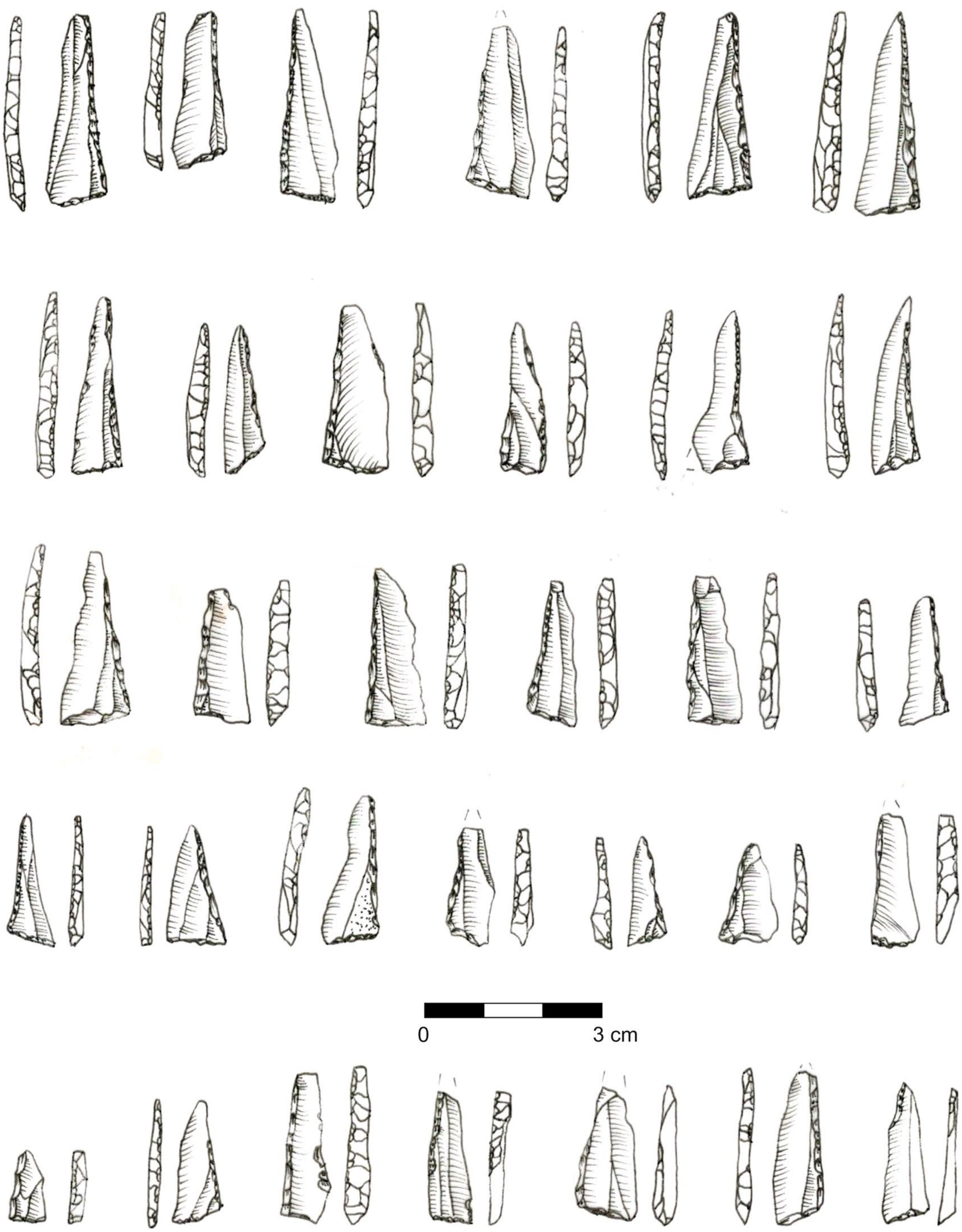


Fig. 10 Gebel Ramlah. Site E-16–03. El-Ghorab Unit. Triangles

focusing on microliths and tools made from blades and bladelets. The most common tools are straight-backed and pointed bladelets, arch-backed bladelets, and less numerous geometric microliths such as segments, short scalene triangles, and trapezes (Jórdeczka, 2021; Jórdeczka et al., 2015). The following

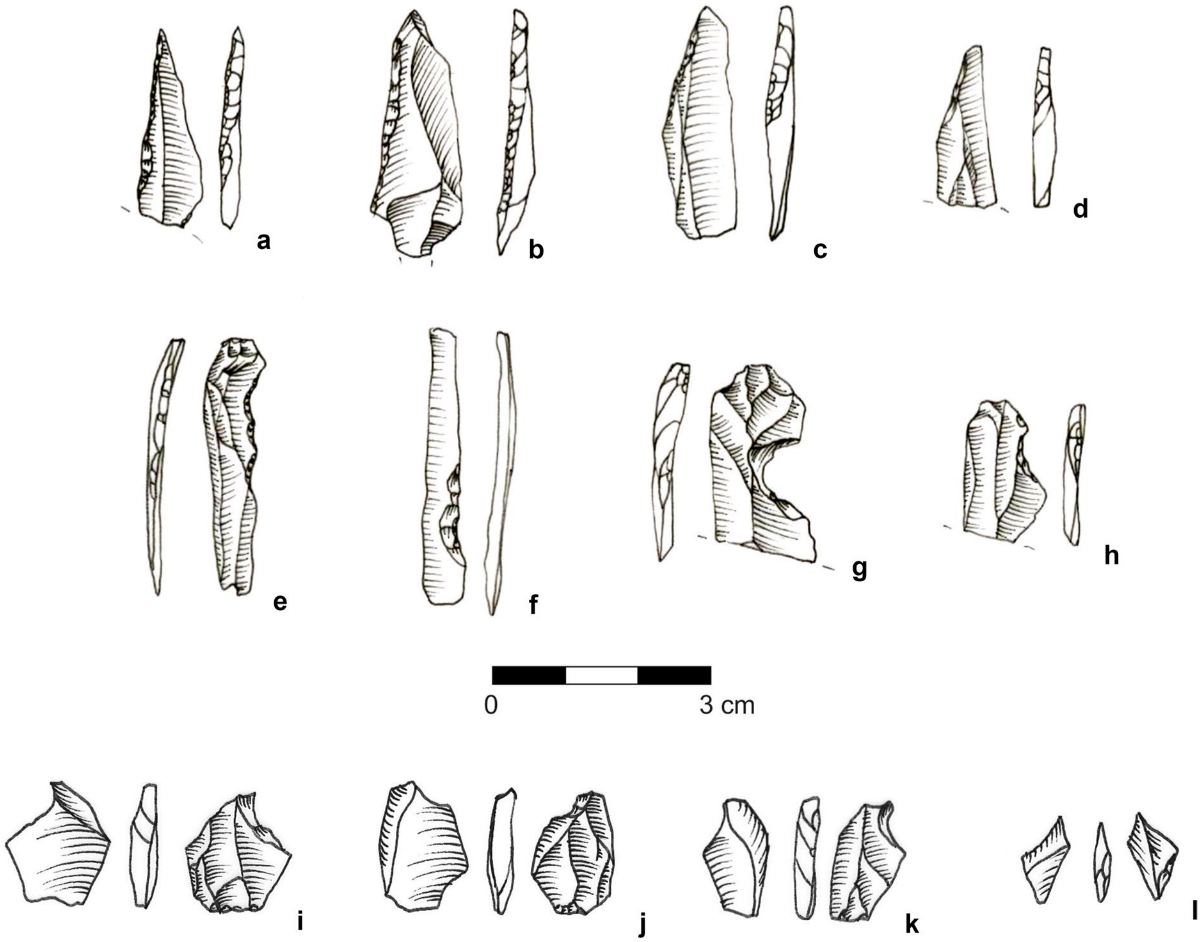


Fig. 11 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. **a**, **b** Backed bladelets. **c**, **d** Micro-truncations. **e**, **f** Notched blades. **g**, **h** Microburins detached by breaking (notched blades—wastes from microlithic production?). **i**–**l** Microburins detached by striking

cultural horizon (c. 9600–9000 BP), associated with the El-Ghorab settlement, also relied on unidirectional blade production but shows a decline in backed forms. Triangles—especially elongated scalene types produced using the microburin technique—dominate, supplemented by some perforators and end-scrapers. El-Ghorab represents short-term, episodic camps, typically marked by a single concentration of artifacts.

From a general perspective, the early Holocene lithic inventories of the Western Desert exhibit numerous similarities, both in the main technological pattern characterized by predominant unidirectional core exploitation and in the toolkit, where various types of backed bladelets and geometric microliths, including triangles, appear to form distinctive groups. However, closer examination reveals regional differences in the presence, proportion, and chronology of different tool types—sometimes striking, such as the early appearance of Ounan-Harif points in Dakhla and Kharga. On one hand, this may reflect clear regional variation across such a vast area; on the other, it highlights several methodological issues, including site homogeneity, dating accuracy, and functional diversity.

E-16-03 site and El-Ghorab Inventories in the Eastern Sahara

Site E-16-03 is one of several Early Holocene occurrences in the Eastern Sahara containing characteristic elongated triangles typical of the El-Ghorab

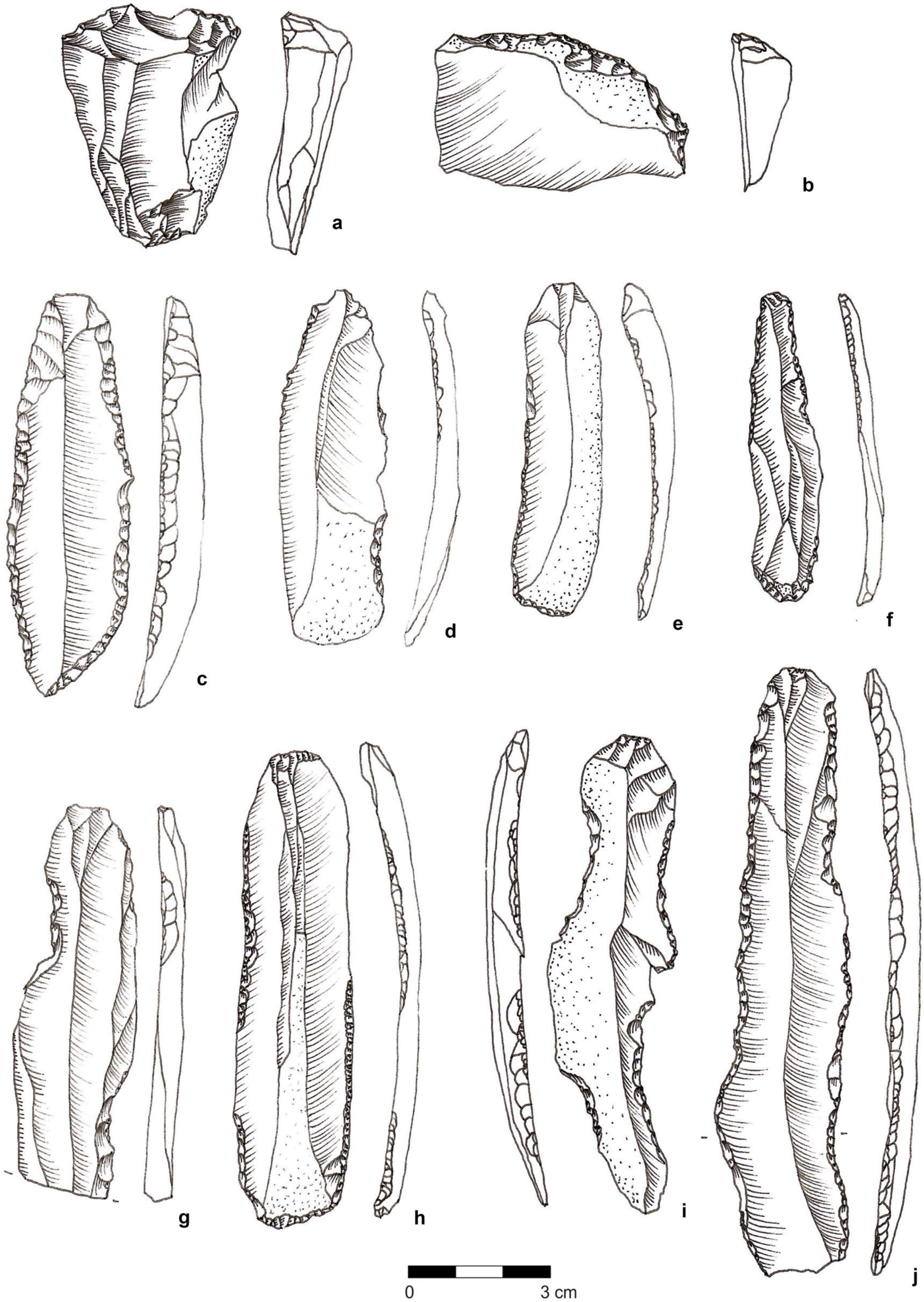


Fig. 12 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Tools: **a** end-scraper; **b** scraper; **c–j** continuously retouched blades

Table 4 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Structure of osseous remains

Taxon	*N*	%	MNE
Dorcas gazelle (*Gazella dorcas*)	10		9
NISP	10	9.4	9
Middle size ruminant (MSR)	7	6.6	7
Small size mammal (SSR)	3	2.8	3
Indeterminate	10	9.4	8
Unidentified	76	71.8	72
Total	106	100.0	99

Table 5 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Anatomical structure of remains of dorcas gazelle

Skeletal element	*N*	MNE
Tooth (*dentes*)	2	1
Vertebra (*vertebrae*)	1	1
Scapula *(scapula)*	1	1
Ulna (*ulna*)	1	1
Metacarpals (*o. metacarpalia*)	1	1
Femur (*femur*)	2	2
Metatarsals (*o. metatarsalia*)	2	2
Total	10	9

Unit, dispersed over the Western Desert and beyond (Fig. 1).

The two nearest examples, E-79-3 and E-79-4, lie along the Kiseiba Scarp (Wendorf et al., 1984). Site E-79-4, west of Gebel Ramlah on the El-Ghorab Playa edge, is associated with a wide tributary wadi within the El-Ghorab basin (Kobusiewicz, 1984). This settlement includes two areas of surface-scattered lithics, hearth remains, subsurface artifact layers, and some features. Several settlement phases from the Early and Late Neolithic were recorded. The oldest assemblages (Level II and III) dated ca. 9500–9000 BP contained flint similar to that from Gebel Ramlah. The technological and typological structure of Level II and III artifact inventories is highly homogeneous. Cores and blanks indicate a simple technology based on unidirectional exploitation of blade cores, with frequent orientation changes in late processing stages and limited preparation or repairs. Toolkit includes triangles, backed bladelets, double-backed perforators, and specimens with continuous retouch. Tool category frequencies vary significantly between stratigraphic units: the Upper Cultural Layer (UCL) and Surface East (SE) are dominated by perforators, backed blades, and continuous retouch specimens, while triangles are more abundant in the Lower Cultural Layer (LCL) and Surface West (SW) collections, at 28% and 32% of the tool group, respectively. The SW inventory contains numerous microburins. This assemblage, almost exclusively composed of triangles with numerous microburins, closely resembles site E-16-03. Schild and Wendorf (2001) identify the LCL with the El-Ghorab phase and the UCL with the El-Nabta Unit.

Neighboring site, E-79-3, located several kilometers from E-79-4, is interpreted as a short-term encampment where triangles are present but not dominant. Its tool group is diverse, mainly comprising burins and backed points. Single ostrich eggshell dating places the assemblage in the El-Ghorab phase (Wendorf & Schild, 1984). There is also another site from the Kiseiba area, E-75-6, considered belonging to El-Ghorab (Królik & Schild, 2001). However, that is only due to a single ostrich

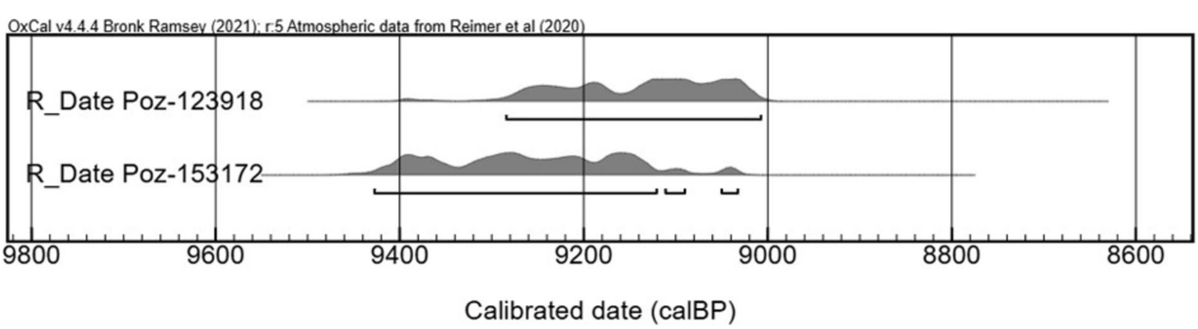


Fig. 13 Gebel Ramlah. Site E-16-03. El-Ghorab Unit. Calibration of radiocarbon determinations (see Kabaciński et al. 2023)

eggshell radiocarbon date that suggests such attribution while the lithic assemblage is likely associated with a younger El-Nabta horizon (Schild and Wendorf 2001:52).

Similar inventory was recorded in the Dyke Area, southwest of Dakhla Oasis, on site E-72-5 (Schild & Wendorf, 1977). Situated at the edge of a deflation basin filled with Early Holocene sediments, it featured several lithic concentrations dominated by debitage from single-platform cores. The toolkit contains numerous elongated triangles (almost 24%), microburins (10%), notched bladelets (22%), and shouldered blades (9%). Less abundant are different types of backed bladelets, trapezes, and burins.

To the east, two sites in Kharga are also considered as El-Ghorab. These are E-76-6, though triangles are less common there (Wendorf & Schild, 1980) and Ayn Manawir ML1. The latter contains lithic inventories similar to Nabta-Kiseiba El-Ghorab assemblages (Briois et al., 2008), with over half the assemblage composed of triangles and microburins. Ostrich eggshell dating indicates a slightly younger interval—the second half of the 9th millennium BP (Dachy et al., 2018). Elongated triangles also occur in the northern part of the Western Desert (Fig. 1). Several Sitra-Hatiyet sites in the Siwa-Qattara region (Cziesla, 1993; Kuper, 2023) contain such forms, usually a few percent of a toolkit, and inventories are dominated by burins and backed bladelets. Only on one site do triangles reach a quarter of all tools. Ostrich eggshell radiocarbon dates place this occupation at 9200–8900 BP (Kuper, 2023). In the Great Sand Sea, Abu Minqar 85/28-1 site (Regenfeld B phase; Gehlen et al., 2002) has toolkits dominated mainly by triangles and backed bladelets. Ostrich eggshell dating assigns this settlement to the mid-10th millennium BP (Kuper, 2023). Settlements with similar typological characteristics were also found in the Abu Muhariq Plateau (Djara site; Kindermann et al., 2006, 2010), Eastpans area (Gehlen et al., 2002) and the Gilf Kebir massif region (Wadi el Akhdar; Schön & Cziesla, 1996).

El-Ghorab-like assemblages were also recorded in the Sudanese eastern Sahara. Site 11-I-13, near the Egypt–Sudan border on the Nile Valley edge, yielded over 500 surface specimens. Similarities lie mainly in triangles, backed bladelets, and shouldered bladelets. Besides, the assemblage also contains numerous notched pieces and burins but lacks microburins. However, the debitage structure differs significantly from classic El-Ghorab assemblages: flakes predominate over less numerous blades, though most tools were blade-made. Lithic reduction involved single- and opposed-platform core exploitation (Usai, 2008). Still in Sudan, Selima Sandsheet features early Holocene types such as elongated triangles, microburins, shouldered blades, backed bladelets, segments, double-backed perforators, burins, and specimens with continuous retouch (Schuck, 1993). However, dates fall between 6900 and 5900 BP, much later than the Western Desert El-Ghorab Unit.

Analogies to early Holocene El-Ghorab settlements were suggested for Elkab in the Nile valley. Vermeersch (1978, 1984) notes Elkab materials techno-typologically resemble those from the Dyke Area and El-Ghorab Playa more than the Nile Valley Shamarkian Unit. However, Elkab's chronology is younger, coinciding with the El-Nabta/Al Jerar phase (Schild & Wendorf, 2013). Similarities between Nile Valley sites (Elkab, 11-I-13) prompt discussion on El-Ghorab groups' regional activity and population mobility scales (Usai, 2008). Vermeersch suggests seasonal movements of Early Holocene hunting groups along an east–west axis: desert sites served as winter camps. Nile Valley camps were in use during the summer season (Vermeersch, 1984:142). J. Kuper (2023) proposed a similar model, where desert areas were visited during post-summer rains and oases and Gilf Kebir massif during winter. Smaller camps would reflect seasonal group disintegration into smaller social units.

E-16-03 Site in Functional Perspective

The typology of lithic assemblages, its spatial distribution, and settlement features suggest site E-16-03 is an aggregation of short-term hunting camps specialized in manufacturing or repairing hunting equipment and processing game. This interpretation is strongly supported by wear-trace analysis (Winiarska-Kabacińska et al., 2024), showing nearly 70% of triangles display impact or hafting traces regardless of concentration. Combined with on-site triangle production, these data suggest that all three concentrations represent hunting stands—locations where El-Ghorab hunters focused on making and repairing weapons. Hafting traces suggest different mounting methods: (a) directly on arrow or spear tips or (b) obliquely along shafts forming barbed edges.

Osteological, technological, microwear, and geomorphological analyses inform on functional aspects and seasonality. Preserved osteological materials indicate dorcas gazelle (*Gazella dorcas*) as the main hunted species. Identified dorcas gazelle remains, though limited to ten fragments, represent all main skeletal parts, supporting the hypothesis that complete carcasses were brought to the site. Remains spread across trenches 2 and 3 suggest at least two individuals. Seven unidentified medium-sized ruminant fragments may be dorcas or dama gazelle (*Gazella dorcas/Nanger dama*), and three small mammal fragments most likely represent hare (*Lepus capensis*) (Gautier, 2001). Thus, prey variety was broader. Faunal evidence also includes several dozen ostrich eggshells, likely collected nearby, suggesting activities unrelated to hunting, as no ostrich bones were found.

Broken triangles may have been brought embedded in carcasses or hafted on shafts, damaged from missed shots. Numerous fractured triangles with impact traces suggest large-scale hunting contrasting with limited faunal remains, implying only a few prey (one or two dorcas gazelle and/or hare) were consumed on site. On the other hand, the above observation may be influenced by different post-depositional processes destructive to osteological materials. Therefore, further conclusions suggesting processing (drying?) parts of the tissues and/or transporting them elsewhere should be treated with caution.

Temporal relationships between the three concentrations are uncertain. It cannot be confirmed whether all represent simultaneous activity or sequential visits by the same or different groups over years or seasons. Lack of connecting artifacts between concentrations suggests separate groups or times. Their close spatial arrangement could indicate activities that did not coincide temporally. Supporting this, microwear studies found hafting traces only on triangles from concentration 1, indicating different weapon-manufacturing approaches and possibly different El-Ghorab hunter groups. Alternatively, this may reflect different, perhaps seasonal, hunting activities of one group.

Geological and geomorphological data add to seasonality understanding: all camps lie on silty sediments several dozen meters south of the basin's northern margins at maximum paleo-lake transgression. Occupations likely were short-term, occurring either before the rainy season (spring), when water remained centralized, or after (winter) during lake regression. The presence of ostrich eggshells but absence of bird bones suggests hunters collected eggs during their stay, supporting spring occupation since ostrich eggs can only be collected then.

Conclusions

The newly discovered and studied El-Ghorab Unit site E-16-03, located at the foot slopes' edge of Gebel Ramlah along the paleo-basin margin, significantly expands knowledge of Early Holocene human activity in the Eastern Sahara. From stratigraphic and taphonomic perspectives, it may be the most informative El-Ghorab site investigated in the Egyptian Western Desert, as archaeological materials were preserved in situ and stratigraphy remained undisturbed by younger Neolithic activity.

Current research outlines key future opportunities: (a) the geographic and spatial range of El-Ghorab populations. Characteristic El-Ghorab triangles suggest a wide range extending beyond lakes and wetlands of the Western Desert and northern Sudan, reaching at least the Nile Valley's left bank to the east, Siwa Oasis to the north, and as far west as Central Libya (Kuper, 2015, 2023); (b) issues of the exact chronology of El-Ghorab human presence. Some sites ascribed to El-Ghorab are clearly much younger than the Early Holocene (e.g., elongated triangles appear infrequently but regularly in subsequent phases such as El-Nabta).

Another major research challenge is understanding functional differences recorded across sites. Known sites exhibit diverse technological and typological characteristics: some represent highly specialized encampments (like E-16-03); others, such as E-79-4, may be base camps, indicating complicated settlement structures. These localities likely had varied functions tied to seasonal landscape and resource use. Improved chronological resolution and a broader understanding of landscape exploitation promise to contribute to better models of Early Holocene hunter-gatherer mobility and socio-cultural processes in the Eastern Sahara.

The most crucial question remains the El-Ghorab Unit's initial economic and cultural identity. Since the 1980s discovery of El-Ghorab sites, the unit has generally been interpreted as an early Neolithic phenomenon, characterized by triangle dominance combined with scant evidence for domestic animals and pottery (Kobusiewicz, 1984; Wendorf et al., 1984; Wendorf & Schild, 2001). The absence of pottery at E-16-03 aligns with a critical reassessment of early domesticated animal presence in the Southwestern Desert (Brass, 2018). Theoretical models emphasizing possible local domestication of cattle influenced interpretations of earliest domestic evidence related to El Adam and El-Ghorab Units (Wendorf et al., 1984). The E-79-04 site, with its sparse evidence of pastoralism and pottery, exemplifies this approach, possibly optimistically attributed to the Neolithic based on a single surface *Bos* bone and two potsherds from an uncertain context (Gautier, 1984; Kobusiewicz, 1984). Even if E-79-04 was multicomponent, its complexity has been insufficiently considered. Currently, available evidence does not convincingly support connecting El-Ghorab Unit with the pastoral Neolithic. New data from the homogenous settlement context at E-09-02 site in Gebel Ramlah strongly suggest domesticated cattle appeared no earlier than ca. 8200 BP, before the 8.2 ka cold event (Kabaciński et al., 2025).

The new E-16-03 site offers a clearer understanding of El-Ghorab-associated human groups. Emerging from evidence is a picture of highly specialized hunter-gatherers inhabiting southern Eastern Sahara during the 10th millennium BP.

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Data Availability The archaeological materials presented in this paper are stored in the magazine in the Gebel Ramlah. According to Egyptian law, access to any archaeological materials is granted by the Supreme Council of Antiquities upon the permission of the Director of the Mission (J. Kabaciński in that case). Documentation of research is available on request in the Institute of Archaeology and Ethnology PAS, Poznań Branch, ul. Rubież 46, 61–612 Poznań, Poland.

Declarations

Conflict of Interest The authors declare no competing interests.

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