Geologic Contexts of the Acheulian (Middle Pleistocene) in the Eastern Sahara

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The Bir Tarfawi and Bir Sahara East region of northeast Africa contains sedimentary remnants associated with Acheulian artifacts. The geology of these localities can be used to help examine paleobiogeographic and taphonomic contexts and paleoclimatic chronologies related to Middle Pleistocene hominids. Recognized by the presence of handaxes, Acheulian occurrences in the Eastern Sahara have been found with paleosols, cemented gravels, and tufas, and are often found as deflationary lags. In the Tarfawi region, handaxes were found embedded in sands overlain by carbonates, embedded in limestones, and in deflated contexts. These Acheulian sites likely date to before 300 ky B.P. The lithostratigraphic sequences indicate that paleoclimatic conditions in the Sahara during the Pleistocene were wetter than in the Holocene. The geologic context (stratigraphy, sedimentology, dating) of the Acheulian in the Eastern Sahara seems to indicate wet paleoclimatic intervals during the Pleistocene when biogeographic conditions were favorable for hominid habitation in the region. © 2001 John Wiley & Sons, Inc.

INTRODUCTION

Objectives

The geologic contexts of Acheulian (Lower Paleolithic) artifacts from southern Egypt (Figure 1) provide information useful for evaluating Middle Pleistocene landscape (paleobiogeographic) settings and site formation (taphonomic) processes connected with Middle Pleistocene hominids, as well as paleoclimatic chronologies of northeast Africa. The objectives of this article are to provide a succinct review of Acheulian sites in the Eastern Sahara, briefly describe and interpret the geologic context of Acheulian artifacts in the Bir Tarfawi-Bir Sahara region of southern Egypt, and place these discoveries in a tentative paleoclimatic chronologic framework.

The Bir Tarfawi-Bir Sahara area (Figure 2) is situated within the Darb el Arba’in Desert, a term applied by C. Vance Haynes, Jr. to distinguish the most hyperarid region of the Sahara (Haynes, 1987). The geologic record of this region preserves strong evidence for dramatic changes in paleoenvironmental conditions. These changes appear to have had an important influence on Pleistocene biotic populations that were sometimes able to exist in what is now the driest part of the largest desert on Earth (Haynes et al., 1997).
Review of Previous Work

The first systematic investigation of Pleistocene geology and Acheulian artifacts in the Egyptian Sahara was by Caton-Thompson in the early 1930s, at Kharga Oasis (Figure 1) (Caton-Thompson, 1932, 1952). At about the same time, Myers studied an Acheulian site at the Gilf Kebir as part of Bagnold’s 1937–1938 expedition (Bag- nold et al., 1939). In the Bir Tarfawi region, Acheulian artifacts were first studied by the Combined Prehistoric Expedition (CPE) in the early 1970s (Schild and Wen-
Acheulian sites have also been reported from other locations in the Western Desert of Egypt and in the Saharan portions of Sudan, Chad, and Libya. Figure 1 shows the general locations of selected Acheulian sites.

Acheulian sites from the Dakhla and Kharga region north of Bir Tarfawi (Figure 1) are typically found with fossils springs, indicating a relationship with wetter climates during the Middle Pleistocene (Caton-Thompson, 1952; Schild and Wendorf, 1977; Wendorf and Schild, 1980; Brookes, 1983; McDonald, 1982; Kleindienst et al., 1999; Kleindienst, 1999; Churcher and Mills, 1999; Nicoll et al., 1999). As an example, the Evolved Acheulian assemblage at spring mound KO10 (Kharga Oasis 10) is estimated to be older than 300 ky B.P. (Churcher et al., 1999). Wetter envi-
environments are also inferred along the eastern edge of the Kharga depression at Refuf Pass, where Acheulian artifacts are embedded in gravels capped with tufas (Caton-Thompson, 1952; Butzer and Hansen, 1968). The gravels seem to indicate increased wadi deposition (Wendorf and Schild, 1980) while the finer clastics and carbonates were deposited in slowly moving water, ponds, or springs. Tufa deposits at Refuf Pass and elsewhere near Kharga seem to be related to spring-fed alkaline stream environments (Nicoll et al., 1997). The Refuf Pass (Wadi el-Refuf) Acheulian assemblages are placed in two categories: an Evolved or Upper Acheulian perhaps older than 400 ky B.P., and an Acheulian-Levalloisian, older than 300 ky B.P. (Caton-Thompson, 1952; Churcher et al., 1999; Churcher and Mills, 1999). Higher water tables and tufa deposition seems to have occurred at Refuf Pass at around 240, 198, 174, 138, and 125 ky B.P. (Nicoll et al., 1997), providing an indication of when wetter environmental conditions may have prevailed.

Acheulian artifacts are found elsewhere in the Eastern Sahara in geologic contexts that also seem to imply paleolandscape with wetter climates during the Middle Pleistocene. For instance, in the vicinity of Wadi Midauwara, south of Kharga, Acheulian artifacts were reported as lags on tufa surfaces or in solution basins (Smith et al., 1999). North of Kharga, three Acheulian sites (KUWDE 30, 31, and 34) were found on alluvial terraces associated with Pleistocene wadi courses (Simmons and Mandel, 1985) (Figure 1). Closer to the Nile at Kurkur (Figure 1), Acheulian bifaces were recovered from within a tufa (Hester and Hoebler, 1965; Hoebler and Hester, 1969).

Between Bir Tarfawi and the Nile Valley, Late Acheulian bifaces are found on the pediments in the Nafta area, in lag position near Bargat el Shab, and on the surface of a red soil at the top of sands near Kiseiba. Late Acheulian artifacts are within basal sands along the southeastern bank of the Kiseiba Scarp (Wendorf et al., 1984), while other Acheulian artifacts are sand blasted (Haynes, 1985). An important set of sites in geologic context have been documented near Kiseiba, south of Two Hills playa (Haynes et al., 1997). One of these, Kiseiba Acheulian site no. 1 (KAS-1), contains Acheulian handaxes, cleavers, and other artifacts that do not appear to have been significantly redistributed by fluvial action (Haynes et al., 1997). Late Acheulian artifacts have also been reported on top of gravels at Bir Dibis southwest of Kiseiba (Wendorf and Schild, 1980).

In Egypt, south of Bir Tarfawi, Middle and Upper Acheulian artifacts were discovered near and in Wadi Arid, south of Wadi Arid, and around Bir Safsaf (Figure 1). Some of these sites have been dated, and some are possibly in primary context. Others are in lag position, such as Middle Acheulian artifacts found on a deflated petrocalcic paleosol (Haynes, 1985). Carbonate adhering to flakes dated by uranium series to 212 ky B.P. provides a minimum age for the Acheulian at Site 84212-A Area A (McHugh, 1988b; Szabo et al., 1989). At Site 84212-A Area Z (E-85-14 in Wendorf et al. [1987b]) Middle Acheulian artifacts were found embedded in slope-wash, which might indicate that, although in stratified geologic context, they have been transported to some degree. Acheulian artifacts were also found on top of the truncated calcified pebble gravel surface and partially embedded in gravels, and
Acheulian artifacts at Site S4M9-3 in the Bir Safsaf area were found on the surface surrounding a remnant capped by kunkar (a calcareous duricrust) with rhizoliths (McHugh et al., 1988a).

At Dagdag basin, southeast of Bir Safsaf, Acheulian artifacts occur on the surface and within the top of sands and gravels containing calcareous concretions and plates (Wendorf et al., 1987b). There are two taxonomic components at Site E-85-2; most of the abraded artifacts are Middle Acheulian, while less weathered and fresh artifacts are Upper or Final Acheulian. On the northern edge of the Dagdag basin, slope-wash deposits contain Late or Final Acheulian artifacts; artifacts from E-85-15 were embedded in slope-wash sands and redeposited gravels (Wendorf et al., 1987b).

Acheulian sites are known from the Gilf Kebir region and the Great Sand Sea (Figure 1). Site 1000 is an extensive Late Acheulian scatter along the base of the Gilf Kebir plateau (Hagstrold et al., 1959; Wendorf and Schild, 1980). It lies in the uppermost stratum of a gravelly alluvial fan (Wendorf and Schild, 1980; Haynes, 1983). The site may be contemporaneous with a period of increased wadi activity (Wendorf and Schild, 1980). In the Great Sand Sea region, Acheulian artifacts occur as surface lag and extend under sandy muds and derived sands reflecting playa conditions (Haynes, 1982, 1985; Roe et al., 1982). Acheulian artifacts are also associated with the contact between the surface of a dune ridge and alluvium, or older playa deposits transitional to the alluvium (Haynes, 1982). A handaxe made of Libyan glass was recovered in the Sand Sea area (Roe et al., 1982).

In Oyo, northwest Sudan (Figure 1), Late Acheulian handaxes and other Early Paleolithic artifacts have eroded from under lacustrine muds, diatomites, and marls capping a mesa (Haynes, 1985). The artifacts may have been deflated before the deposition of the Pleistocene lake sediments. In some places, an erosional contact of reworked sandstone contains late Acheulian artifacts. These artifacts were sandblasted while at the surface prior to burial (Haynes, 1985) or are in fluvial sands underlying the Pleistocene lake beds (Haynes, 1989). In north central Sudan, severely eroded Lower Paleolithic sites occur in the Laqiya Depression (Figure 1). At least one Late Acheulian site is known from Prendergast Valley. Handaxes and other artifacts occur in a soil developed in alluvial sands and gravel (Haynes, 1985).

In southern Libya and northern Chad, Acheulian occurrences include Upper
Acheulian (?) bifaces from the well at Sarra eroding from the surface of a soil covered by eolian sands (Arkell, 1964). Arkell found an assemblage that could be transitional between the Lower and Middle Paleolithic at Little Wanyanga Lake. Tillet (1985) considers that the sites near Wanyanga Kebir studied by Arkell represent a very evolved stage of Acheulian.

In summary, artifacts taxonomically affiliated with Middle, Upper, Late, and Evolved Acheulian have been discovered in both surface and subsurface contexts in the Eastern Sahara. Where there are unambiguous relationships between artifacts and geologic contexts, the pattern that seems to emerge is that Middle Pleistocene hominids lived in the Eastern Sahara during times when the climate conditions were substantially wetter than at present. Populations were widespread within the region but perhaps usually constrained to habitat settings connected with reliable sources of water. Acheulian artifacts within stratified deposits are rare. Detailed sedimentologic or taphonomic studies could help evaluate whether artifacts found within stratigraphic sequences are in primary context or assist in determining Pleistocene biogeographic settings.

METHODS

Studies of the geology of Acheulian sites in the Bir Tarfawi region were conducted as part of a broader project designed to (1) evaluate their paleogeographic setting ("landscape habitat"), (2) assess whether the patterns of artifact taxonomic composition and distribution could be directly attributed to Pleistocene hominids, and (3) place the sites within a paleoclimatic-chronologic framework. The field and laboratory techniques used are described in more detail by Hill (1992). Field examination and sampling included assessments of texture and composition, Munsell color (dry, Table I), coherence/cementation, prominent bedding or structures, thickness of deposits, character of stratigraphic boundaries, fossils, and artifactual content. Laboratory studies included particle size (wet sieving and pipette using sodium hexametaphosphate as a dispersant, after removal of carbonates and organics, Tables I – III), loss-on-ignition (weight loss after heating to 550°C and 1025°C to estimate organic and carbonate content, Table II), x-ray diffraction analyses, and petrographic thin-section studies. The thin-section descriptions follow the carbonate classification of Dunham (1962) and were provided by McGillis (1993).

RESULTS

Acheulian artifact assemblages, recognized by the presence of handaxes (mode 2 of Clark [1977]), were studied from three localities in the Bir Tarfawi-Bir Sahara region (Figure 2). Several other occurrences or isolated bifaces also were found. These include a set of handaxes recorded during a walking survey of the area between Bir Tarfawi and Bir Sahara East by Hill and J. Saunders during 1986, and Sites BS-5, BS-7, BS-9, BS-10, BS-20 discovered during the 1973 campaign of the CPE. Excavations recovered Acheulian artifacts in definitive subsurface geologic context at Site BS-14, situated at the south end of Bir Sahara East (Figure 2).
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Loss on Ignition (Organics)</th>
<th>HCl Soluble Fraction (Carbonate)</th>
<th>Carbonate Estimate Average</th>
<th>Plastic Component</th>
<th>Coarse</th>
<th>Fine</th>
<th>Munsell Color (dry)</th>
</tr>
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<td>BS 147188: 015</td>
<td>49.00</td>
<td>4.50</td>
<td>97.0</td>
<td>3.0</td>
<td>10YR 8/2, white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS 147188: 016</td>
<td>13.94</td>
<td>5.00</td>
<td>99.0</td>
<td>1.0</td>
<td>10YR 8/4, very pale brown</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>50.00</td>
<td>57.0</td>
<td>36.5</td>
<td>6.5</td>
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<td>67.0</td>
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<td>2.73</td>
<td>3.0</td>
<td>90.0</td>
<td>7.5</td>
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<td></td>
</tr>
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<td>93.0</td>
<td>5.0</td>
<td>4.0</td>
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<td>14.5</td>
<td>77.5</td>
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<td>BT-T87: 003</td>
<td>7.92</td>
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<td>78.0</td>
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<tr>
<td>E-88-12: A2</td>
<td>0.14</td>
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<td>E-88-12: A4a</td>
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<td>1.0</td>
<td>97.0</td>
<td>3.0</td>
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</table>
Table II. Particle weight-size distribution data.

<table>
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<th>Sample No.</th>
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<td></td>
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<td>Very</td>
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<tr>
<td></td>
<td>Gravel</td>
<td>Sand</td>
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<td>BS 14/T3/88: 015</td>
<td>0.74 31.65 34.53 17.10 8.58 5.24 1.85 0.93</td>
<td>BS 14/T3/88: 016</td>
</tr>
<tr>
<td>BS 14/T3/88: 017</td>
<td>3.65 19.24 16.25 18.41 15.27 12.14 5.23 9.62</td>
<td>BS 14/T3/88: 018</td>
</tr>
<tr>
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<td>BS 14/T3/88: 020</td>
<td>0.00 1.70 6.25 10.75 15.35 11.93 40.00 6.35</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>BS 14/T3/88: 023</td>
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<td></td>
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</tr>
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<tr>
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<td>0.74 31.65 34.53 17.10 8.58 5.24 1.85 0.93</td>
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<tr>
<td>BS 14/T3/88: 017</td>
<td>3.65 19.24 16.25 18.41 15.27 12.14 5.23 9.62</td>
<td>BS 14/T3/88: 018</td>
</tr>
</tbody>
</table>

Geologically in situ artifacts were recovered from Site E-88-12, on the south end of Bir Tarfawi (Figure 2). In other instances, Acheulian artifacts were found on the surface, although the artifacts were sometimes unweathered, presumably indicating their fairly recent erosion from sediments.

Bir Sahara East (Site BS-14 Area)

Site BS-14 is the most thoroughly documented Acheulian locality in the region (Schild and Wendorf, 1975, 1981; Wendorf and Schild, 1980; Hill, 1992). The sedimentary mound at BS-14 has a substantial (ca. thicker than 80 cm) cap composed of cemented sandy carbonate (sandy limestone, calcrite). The carbonate cap thins out toward the edges of the remnant and overlies clastic quartz sands (Figures 3 and 4). Acheulian artifacts were recovered on and in the sands underlying the carbonate (Figure 4). The excavations of M. Kobusiewicz as part of the CPE excavations in the early 1970s found ostrich eggshell fragments in these sands. Bifaces were recovered on top of the carbonate, and bones have been found embedded in the carbonate (Schild and Wendorf, 1981). Three trenches were excavated into the carbonate (Trenches 173, 273, and 988, Figure 3). Twelve other trenches (Trenches 373, 1888, and 10-1288) were placed on the edge of the carbonate cap or excavated into the sands (Figure 3). Descriptions and profiles of the trenches are available in Hill (1992).
### Table III. Grain-size statistics.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Mean</th>
<th>Sorting</th>
<th>Skewness</th>
<th>Kurtosis</th>
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<td>0.28</td>
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<td>1.93</td>
<td>1.52</td>
<td>-0.14</td>
<td>0.83</td>
</tr>
<tr>
<td>ET-T3/87: 006</td>
<td>5.38</td>
<td>1.83</td>
<td>-0.15</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Compositional and textural attributes representative of the stratigraphy observed at BS-14 are provided in Tables I–III and Figure 4. The lowest deposit consists of a quartz sand (sample 15, Figure 4) separated from the overlying deposits by an erosional unconformity. The basal sands are more than 90% coarse fraction clastics (sand-sized or larger particles).

The basal sands are unconformably overlain by an un cemented, poorly sorted gravelly sand (sample 16, Figure 4) that contains Acheulian handaxes, retouched flakes, debitage, and some faunal remains. Laminations suggest that the depositional energy regime was not uniform. At times, transporting and depositional energy levels were relatively high; these deposits have more than 3–4 times as much gravel as the basal sand. The detrital component also contains more muds, indicating lower energy depositional regimes on occasion. A trend from an overall higher energy to lower energy system is reflected by the decline in gravel content and an increase in the amount of very fine sand, silt, and clay. This decrease in energy is also reflected in the increased mean grain size and sorting indices (Figure 4). In terms of depositional mechanics, the detrital component of these sands represents a fluctuating, but gradually decreasing, energy regime. These clastic patterns are consistent with a depositional setting along the margin of a shallow deflational basin in which sands were being redeposited as wash or colluvium. The decreasing size of the clastic fraction could be an indication that the upper sediments were deposited in a quieter setting farther from the effective margin of the basin, possibly in a groundwater-fed pool. The fining upward sequence could also indicate that coarse clastics were not being transported into the basin because of increased vegetational cover. Trace fossils (rhizoconcretions) are present in the sands con-
Figure 3. Plan view of the Site BS-14 sedimentary remnant (situated in the southern part of Bir Sahara East, see Figure 2) showing the locations of stratigraphic test trenches. Trenches were excavated into the limestone cap, along the edge of the limestone, and in the sands surrounding the limestone. Acheulian artifacts were found on the limestone, in deflated position on the surrounding sands, and stratified within sands underlying the carbonates.

The upper deposits at BS-14 are sandy limestones. At Trench 1/88, the carbonate is about 30 cm thick, with medium blocky structure (sample 17, Figure 4). It is composed of about 60% carbonate. Based on petrographic thin sections (McGillis, 1993), this is a calcite mudstone with 3–30% detrital quartz grains. Typically, the clastic component is bimodal, with smaller angular and subangular quartz grains, and larger rounded to well-rounded grains. Bivalve fragments, rare calcispheres, and some ostracods are present. In some instances, the ostracod wall structure has recrystallized to equant calcite. There are some possible pelecypods, gastropods, and forams. Patchy hematite stains and equant calcite cement crusts occur on some of the quartz grains.

These carbonate-rich sediments could be related to a rising groundwater table.
Figure 4. Stratigraphy and sedimentology of Trench 1/88, providing a representative profile for Site BS-14 (Bir Shara East). Basal sands are represented by sample 15 and contain no artifacts. An erosional unconformity forms the boundary between the basal sands and the overlying deposits containing Acheulian artifacts. Basin wash sediments (sample 16) contain Acheulian artifacts and Pleistocene faunal remains. Trace fossils are also present. These sands are gradationally overlain by groundwater-formed carbonates (samples 17 and 18). See Tables I-III for compositional and particle size data (particle size statistics refer to clastic or detrital component of the sediments).

within a shallow basin. Based on studies of nearby sediments, Pachur et al. (1987) used the term “phreatogenic crusts” to distinguish calcareous crusts formed by groundwater or in lakes from pedogenic calcretes. The sandy limestones at Site BS-14 seem to be the result of carbonate deposition related to a groundwater seepage pool. The relatively high detrital content may indicate that the basin was small, that the groundwater level was not very high within the basin, or that there was not much vegetation surrounding the pool. The water level may have been just slightly higher than the ground surface or perhaps sometimes only saturating the surface, causing carbonate deposition within the previously deposited clastics. If the clastics represent ongoing deposition into the basin, they may reflect the absence of dense plant cover, perhaps indicating relatively low or highly sporadic local precipitation.

Other morphologically and lithologically different sedimentary remnants are near BS-14, and some have Acheulian artifacts scattered on them. These sedimentary
remnants consist of cemented clastics (mostly sandstones). Issawi (1978) designated remnants composed of a top section of carbonate as spring mounds, while those cemented by silica or Fe oxides were named ferrocrete mounds. Issawi suggested that the mounds were formed during a dry phase after a more humid interval associated with the deposition of carbonates that form the surrounding plateau. The lithologic differences between the mounds may relate to local deposition of Fe or carbonate minerals in continuously drying ponds that formed by seepage (Issawi, 1978). These mounds could represent phreatophyte-induced accretions around semipermanent pools (Neal and Motts, 1967).

Since the episode of wetter conditions, several processes have modified the sedimentary sequence. Some remnants are almost entirely lag features, the results of erosion by wind. Weathering has altered the top section of BS-14, the sandy limestone caprock. Where the underlying sands were not protected by indurated carbonates, the smaller-sized clastics were selectively removed by wind, leaving the larger particles (mostly handaxes and less resistant cemented rock fragments) as a deflational lag surrounding the mound. On the margins of the BS-14 mound, this lag deposit has helped to protect the underlying sands from further erosion.

No direct ages are available for BS-14, but some nearby deposits were dated. For example, Szabo et al. (1995) provided a uranium-series date of about 277 ky B.P. on sandy limestone from west of Bir Sahara, although the sample is not directly associated with artifacts. Churcher et al. (1999) correlate the BS-14 artifacts with the Upper Acheulian sensu stricto at Kharga dated at over 400 ky B.P., while Schild and Wendorf (1981) indicated some resemblance to the Acheuleo-Levalloisian from Refuf Pass. The Acheuleo-Levalloisian is estimated to be older than 300 ky B.P., but it may consist of a mixture of Lower and Middle Paleolithic artifacts in geologic context (cf. Churcher et al., 1999).

Central Bir Tarfawi

Acheulian bifaces were recovered from the surface of a sedimentary remnant in the central part of the Bir Tarfawi deflational basin (Figure 2), near several important Middle Paleolithic sites (Wendorf et al., 1993). The collection ranged from nearly unweathered to highly weathered, implying that the artifacts were exposed at the surface for varying amounts of time. Artifacts were not recovered from the stratigraphic trenches (Figures 5 and 6).

The remnant is a low plateau capped by very strongly cemented carbonates (limestones) and surrounded by small mounds composed of sandstones and mudstones (indurated, cemented clastics) (Figure 5). Loose to slightly cemented quartz sands underlie the carbonate cap and clastic-dominated mounds. Acheulian artifacts on the limestone and on the slopes of surrounding mounds were first mapped in 1974 (Wendorf and Schild, 1980). During the 1986–1988 CPE campaigns, the spatial distributions of the Acheulian artifacts were recorded (Hill, 1992) along with the description and sampling of the stratigraphic sequence and the surrounding mounds (Figures 5–7). No artifacts were recovered within these deposits, although...
Figure 5. Plan view of the Acheulian sedimentary remnant in the central part of Bir Tarfawi (see Figure 2). The limestone plateau is outlined in black. It is interpreted as a remnant of a Middle Pleistocene lake. Diagonal patterns represent sedimentary remnants composed of indurated clastics on and surrounding the limestone plateau, interpreted as spring mounds. Acheulian artifacts were found on the surface of the limestone plateau and associated with the spring mounds. Three trenches were excavated on the plateau under the direction of R. Schild in 1988. Trench 1/87 is on the west edge of the remnant, Trench 2/87 was excavated between Trench 1/87 and 3/87, and Trench 3/87 was placed further to the east closer to the center of the remnant. Two test pits (Trenches 1/88 and 2/88) were placed next to the two spring mound vents along the west side of the plateau (see Figure 6). Compositional and textural data for Trenches 2/88, 1/87 and 3/87 are shown in Tables I-III and Figure 7.
Figure 6. Plan view of two spring mound vents situated on the west side of the Acheulian sedimentary remnant in the central area of Bir Tarfawi. Trench 1/88 is situated on the north side of the south mound spring vent and Trench 2/88 is situated on the north side of the north spring mound vent. Compositional and textural data for samples G1 and G2 are shown in Tables I-III and Figure 7.
Figure 7. Sedimentology and stratigraphy of Trenches 2/88, 1/87, and 3/87, at the Acheulian-related sequence in the central part of Bir Tarfawi. Sediments from Trench 2/88 (samples G1 and G2) are representative of basal sands. Redeposited basal sands are also found in the lower sections of Trenches 1/87 and 3/87. The maximum lake stage near the margin of the basin is represented by sample 4 at Trench 1/87. Clay-rich sediments with high carbonate contents (samples 2-5, Trench 3/87) reflect deposition nearer the center of the lake basin. Vertical and horizontal scales are the same.
many of the handaxes found on the surface appeared to be slightly weathered and probably were embedded in sediments until exposed relatively recently by deflation.

The sedimentary sequence appears to represent the remains of a small Pleistocene lake with spring mounds. Compositional and textural information are provided in Tables I–III and Figure 7. The sequence consists of lower basal sands and redeposited basal sands, and overlying deposits representing transgressive, maximum, and regressive stages of a paleolake. The detrital component of the paleolake deposits appears to be reworked basal sands.

The detrital component and the abundance of carbonate seem to reflect slightly different depositional regimes within a deflationally formed basin. Initial sedimentation consisted of redeposited basal sands. These lowermost deposits are high in clastics; they seem to be sand that was washed into a deflational basin during a time when there was little vegetation. There is an increase in carbonate towards the center of the basin.

The edge of the plateau remnant (Trench 1/87, Figures 5 and 7) appears to have been near the margin of a lake. The sequence is dominated by clastics. The maximum lake stage is associated with high levels of carbonate deposition and ends with a return to clastic-dominated sedimentation of a regressive lake stage. The transgressive phase is indicated by a detrital component that shows an increase in the proportion of silt and clay.

Nearer the center of the paleolake, at Trench 3/87 (Figures 5 and 7), detrital sediments deposited prior to the maximum lake stage have a substantial portion of silt and clay. This supports the idea that this area was closer to the deeper part of the lake, in a lower depositional energy setting than deposits along the edge of the remnant. The lack of a "transgressive trend" might reflect a more stable depositional setting than deposits of the same lake stage nearer the lake margin.

The maximum lake phase represented by the high carbonate peak at the edge of the remnant (Trench 1/87, sample 4, Figure 7) is overlain by sediments that indicate a higher energy depositional regime and preserve evidence of a regressive lake stage. These deposits are dominated by clastics and seem to reflect deposition in shallower waters, perhaps caused by a reduction in the size of the paleolake. The coarse to fine ratio and the carbonate content of the deposit seem to indicate that the paleolake was larger than the lake before the maximum lake stage.

Mounds composed of indurated clastics (quartzitic sandstones and mudstones) surround the limestone remnant (Figures 5 and 6) and appear to overlie basal sands or slightly redeposited basal sands. In some places where the basal sands are exposed on the surface, an incipient soil horizon has developed. The top surfaces of these sands have a slightly increased fine fraction and carbonate (sample G2, Figures 6 and 7). Acheulian handaxes were found on the surfaces of the mounds.
Two types of mounds composed of siliceous minerals were described by Neal and Motts (1967). "Spring mounds" form where mineralized material is deposited when groundwater emerges at the surface. These mounds support vegetation and, ideally, the height of the mound will approximate the piezometric surface (the height of the water table). Small conical mounds composed of siliciclastics on and adjacent to playas also form as a result of continual accumulation around plants. When the phreatophyte dies, a conical hill remains. The mounds at Tarfawi are morphologically somewhat similar to ferrocrete mounds composed of quartz sandstone (Issawi, 1978) in the BS-14 area. Said (1975) describes freshwater springs in southern Egypt containing carbonates in solution. In their last stages of activity, these springs produce mounds made of sandstone cemented by carbonate or nodules that form in association with vegetation. Roberts and Mitchell (1987) describe similar conical hillocks with or without central craters consisting of carbonate-cemented sand and silt.

An estimate of the age of this sedimentary remnant, and the associated Acheulian artifacts, is approximately 450–500 ky B.P., based on uranium-series dating (Schwarcz and Morawska, 1993). This is about twice as old as the oldest remnant in the central area of Bir Tarfawi associated with Middle Paleolithic artifacts, estimated to date to around 220–233 ky B.P. based on samples 87BTF 21, 32, and 33 in Schwarcz and Morawska (1993) and sample 25-73Eg86 in Szabo et al. (1995).

South Bir Tarfawi (Site E-88-12)

Acheulian artifacts in the south area of Bir Tarfawi (Figure 2) were discovered by the CPE during the 1975 campaign (Wendorf and Schild, 1980; Schild and Wendorf, 1981). The artifact assemblage from Site E-88-12 was analyzed by R. Schild and Hill (Hill, 1994). The main part of this sedimentary remnant consists of two types of indurated deposits: limestones and sandstones. Acheulian artifacts were embedded within both lithologies as well as on the surface of the remnant. The sandstones (poorly sorted, slightly gravelly sands, sample A2, Figures 8 and 9) are extremely hard and very strongly cemented by calcium carbonate. Bulk mineralogy x-ray diffraction analyses indicate that quartz is the principal mineral. The surfaces are weathered or are covered by a thin clay film.

The limestones contain around 90% carbonate (sample A4a, Figures 8 and 9). Bulk mineral x-ray analyses indicates that calcite is the dominant mineral. The residual (clastic) component is a poorly sorted sandy mud. The exposed surface of these lithified carbonates are abraded and polished. Some surfaces are covered with a clay film. Impressions of mollusc shells and handaxes were preserved in the limestones. The mollusc impressions are probably Hydrobia or Melanoides. In thin section, the calcite mudstones contain bivalve shells and possible ostracods (McGillis, 1993).

The two sedimentary rock types found at E-88-12 are interpreted as different depositional regimes, both of which were associated with Acheulian occupations. The sandstones, which underlie the limestone remnant, may be sand-sheet depo-
Figure 8. Map showing geology of Site E-88-12, in the southern part of Bir Tarfawi (Figure 2) and sediment sample locations. Lithologies include limestones (sample A4a) and sandstones (sample A2). Acheulian handaxes are imbedded in the limestones and sandstones.

Postdepositional diagenetic processes cemented the deposits to form sandstones. The bimodal grain size distribution of these deposits is similar to sandsheets described elsewhere in Egypt and usually regarded to be eolian deposits (Bagnold, 1935; Maxwell, 1982; Breed et al., 1987).

The limestone at E-88-12 was probably biochemically precipitated as endogenic carbonate mud near the center of a freshwater lake or pond. About 79% of the detrital component consists of silt, indicating a very low-energy depositional regime. The impressions of what appear to be freshwater forms of gastropods may mean the paleolake had relatively low-salinity levels during at least some lake stages.

The highly indurated nature of these lithologies, the abraded and polished exposed surfaces, and the low relief of the exposed remnant all indicate that this locality has been subjected to a higher degree of weathering and diagenesis than
Figure 9. Compositional content (carbonate and clastic components) and grain-size histograms of the detrital fraction of sediments from Site E-88-12. Sample A2 is dominated by clastics and has a bimodal grain-size distribution, while sample A2 is composed almost entirely of carbonates and has a clastic component dominated by silt.
other Pleistocene remnants in the region. This could mean that the artifacts are perhaps some of the oldest recovered from the area. Two dating methods were used to estimate the age of the E-88-12 sedimentary remnant. Quartz thermoluminescence measurements of sand underlying the limestone provided an age of about 165 ky B.P. (Bluszcz, 1993). Uranium-series determinations indicate deposition of the limestone prior to 350 ky B.P., perhaps around 600 ky B.P. (Wendorf et al., 1994). Although both methods indicate a Middle Pleistocene age for the associated Acheulian artifacts, the older date may be more reasonable, or perhaps even a minimum age.

CONCLUSIONS: Paleogeographic Settings and Artifact Taphonomy

Based on the association of artifacts with particular geomorphic and depositional contexts, we can make inferences about (1) the landscape setting and resources associated with the hominid occupations and (2) the effect geologic processes might have on transforming the original patterns of the hominid occupations into the observable record (cf. Rapp and Hill, 1998). Inferences concerning landscape context, in turn, provide a framework for proposing models of adaptive systems (such as organizational and resource-use strategies, mobility patterns) employed by Paleolithic groups in the Eastern Sahara during the Middle Pleistocene. Likewise, attempts to determine how the archaeological record has been affected by postoccupational processes provide a way to evaluate whether the patterns expressed by artifact assemblages can be reliably attributed to Pleistocene hominid behavior. If the spatial distributions and artifact forms are probably related to the initial occupation, and not the result of postoccupation agencies of accumulation, these patterns can be used to evaluate the duration and intensity of occupation, and the size of the prehistoric group involved. Furthermore, the meaning of the absences or presence of specific forms of artifacts may become clear. Through these methods, it should be possible to begin to assess the prehistoric record in terms of its implications for Pleistocene hominid activities.

From the perspective of taphonomy and site integrity, some Acheulian artifacts at Site BS-14 may be essentially in primary context; it is possible that the initial hominid occupation record has not been severely affected by postdepositional processes. It may also be possible to evaluate the paleolandscape associated with the Acheulian occupations. At Bir Tarfawi and Bir Sahara East, the Acheulian occupations seem to be associated with emergent groundwater pools and the margins of perennial lakes. These localities are far removed from any known lithic resources, and at Site BS-14 the typology and technology of the assemblage appear to reflect its characterization as either a base camp or resource procurement locality (Hill, 1992). The apparent presence of Acheulian lithic assemblages indicating functionally specific reduction strategies in particular paleolandscape settings, may reflect Middle Pleistocene resource-based organizational strategies and mobility patterns in the Sahara, although more field studies need to be undertaken to test this idea.

Acheulian artifacts in North Africa have been found with a wide variety of sed-
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inventory deposits (Hill, 1992). These sediments indicate some of the processes by which the artifact accumulation was formed, and, depending on taphonomic trajectories, the landscape setting, and potential resources associated with the hominid occupation. In addition, some of the artifact accumulations are associated with other geologic resources, such as rock outcrops usable for obtaining raw material for the production of artifacts. A continuum of local geomorphic contexts and specific depositional regimes — ranging from eolian sandsheets to settings associated with playa and perennial lakes — appear to have been present in the Bir Tarfawi region during the Pleistocene (Hill, 1983). Paleolithic artifacts have been found embedded or associated with almost every kind of depositional setting that has been studied. These include settings associated with coarse siliciclastic deposition, with increased levels of mud (fine siliciclastics), and in settings associated with high carbonate deposition. For example, Acheulian artifacts are known to have been embedded in both sandstones and limestones.

Sands containing zones of thin, cylindrical calcite-cemented trace fossils occur in several contexts within the various Pleistocene sedimentary sequences. They may be the result of biologic activity and seem to imply the presence of nearby moisture. Trace fossil horizons were observed within basin sands and in basin-wash deposits. Many of the trace fossil horizons appear to be the lateral facies equivalents of hydromorphic deposits. These horizons could have developed as the result of plant root systems (composed of horizontal root mats) formed within or marginal to a shallow phreatic zone (Mount and Cohen, 1984). Others appear to be the result of the development of grasses and other vegetation on the edges of water basins and on nearby eolian deposits (cf. Glennie and Evamy, 1968; Plaziat and Mahmoudi, 1990). Some of the trace fossil horizons may be the result of aquatic macrophytes and other biologic activity (including insects and small burrowing organisms) within shallow lake margins.

Trace fossils were observed in the sands containing Acheulian artifacts at Site BS-14; these sands were overlain by carbonates related to a groundwater pool. In terms of paleogeographic interpretations, these trace fossil horizons imply stabilized land surfaces or basin margin settings. Taphonomically, artifacts embedded in these bioturbated zones may have been vertically displaced. Thus, as with other settings containing trace fossil concentrations, there is some question concerning the temporal relation of these structures and the deposition of the artifacts. The seemingly unabraded surfaces of the artifacts recovered within the sands, the presence of a wide range of artifact sizes (chips to handaxes), as well as the apparent technological coherence implied by the presence of different forms of artifacts, suggests that this locality could contain a relatively intact record of Acheulian presence in southern Egypt. If the sands are a result of basin-wash associated with deposition in a groundwater pool, the artifact record may have been less affected by postdepositional events than in a spring vent setting.

Coarse siliciclastic-dominated Pleistocene sediments can be separated into several sets based on specific microdepositional settings (Hill, 1993). One set consists of clastics derived from the redeposition of basal sands and deposits probably

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short

standard
initially derived from basal sands, such as eolian-related sediments. These include sands deposited along the margins of basins where only pelagic sedimentation occurred (playa-pan settings and early stage perennial lake settings), as well as sands deposited within the active beach/shore zones connected to maximum expansion stages of lakes where carbonate deposition was occurring deeper in the basin. Eolian deposition can also be related to the formation of dunes along the margins of the basins and eolian activity during drier climatic conditions.

Coarse-clastic-dominated deposits from the Acheulian Sites E-88-12 and BS-14 contain embedded artifacts. At Site E-88-12, the coarse siliciclastics appear to be sandsheet sediments deposited in a shallow basin and then buried by limestones. One set of Acheulian artifacts at Site E-88-12 may have been deposited in sandsheet deposits unrelated to the subsequent lake deposits, while another set can be directly connected to the presence of the limestone. At Site BS-14, the artifacts are embedded in sands deposited within and along the margins of a shallow basin, probably later submerged by a rise in the groundwater level. A calcareous sandstone cap (calcrete) overlies these artifact-bearing sands.

Artifacts of various sizes were deposited within the sands at BS-14. These sands could have been associated with the run-off of sporadic rains or with the edge of a small groundwater-charged basin. The calcrete cap may be the result of carbonate deposition after a period of increased moisture when rising water inundated the artifact-bearing sediments. The carbonate overlies these sands and appears to have formed as a result of evapotranspiration of a groundwater/vadose zone-formed pool. The carbonate cap helped protect the underlying sands from erosion.

Along the periphery of the carbonate cap at BS-14, the sands containing Acheulian artifacts were subsequently altered by the accumulation of pedogenic carbonates and reddened by incipient weathering and soil development. Unprotected areas of these sands were weathered and deflated, forming lag deposits of Acheulian handaxes around the periphery of the limestone remnant (see Figure 44 in Schöndorf and Wendorf [1981]). Smaller artifacts (debitage: chips) that were introduced into the sediments as a result of Middle Pleistocene hominid activity were destroyed or weathered to various degrees. Artifacts found on top of the BS-14 remnant could have eroded out from portions of carbonate removed by deflation, or from other sediments overlying the carbonate that were eroded away, or may remain where they were left by subsequent hominid activities.

The presence of apparently unabraded artifacts in basin-edge and basin-wash sands and the occurrence of concentrations of rhizoconcretions suggests that a relatively undisturbed Acheulian artifactual record may be present at Site BS-14. The occurrence of both large and very small artifacts within the sands suggests the likelihood that, assuming a groundwater pool context, the artifacts have not been substantially disturbed from their initial occupational context, at least in terms of horizontal displacement. For example, Schick (1992) used the absence of small debitage (less than 2 cm) as an indication of fluvial sorting at an Acheulian site; the presence of small debitage at Site BS-14 might support the contention that the site was not disturbed by water action.
Some vertical dispersal of the artifacts at BS-14 is suggested by an ascending vadose zone as well as by the presence of trace fossil concentrations, which indicate subsequent groundwater saturation of the deposits. The trace fossils likely indicate the presence of a stabilized vegetated surface contemporaneous with either the Acheulian occupation episode and the initial deposition of the artifacts or a period of vegetative cover after the initial deposition of the artifacts. Bioturbation could have affected the vertical placement of the artifacts.

The artifact component at Site BS-14 that was recovered embedded within the sands underlying the calcrete cap provides a critical record of the Acheulian occupation of southern Egypt. It provides an essentially undispersed and, at least, technologically coherent Acheulian assemblage from the Eastern Sahara. The presence of a technologically coherent assemblage (that is, an assemblage probably containing representative materials from all aspects of lithic reduction activities associated with the occupation at the site) presents an opportunity to compare the resource and mobility strategies at Site BS-14 with other Acheulian assemblages from southern Egypt. Succinctly, the artifacts at Site BS-14 could represent Acheulian occupations associated with strategies of raw material use apparently far from the sources of these materials, reflecting patterns related to mobility and curation. In contrast, other Acheulian localities reflect patterns associated with the direct presence of the lithic materials used to form the artifacts. The Site BS-14 Acheulian assemblage may reflect Pleistocene hominid activities associated with use of paleobiogeographic contexts located away from lithic raw material resources.

The depositional setting directly associated with the biochemical precipitation of carbonate is similar to the setting associated with the deposition of fine siliciclastics within a lake basin. Limestones and marls are generally deposited in quiet, low energy settings except for some types of travertines and tufas and spring vent settings. The presence of artifacts embedded within lacustrine carbonate sediments could imply that these surfaces were subaerially exposed at the time Middle Pleistocene hominids were present. Artifacts were found embedded in marls and limestones at the Acheulian locality of Site E-88-12 in the south part of Bir Tarfawi. The artifacts were buried by other lake sediments implying occupations during dry seasons, possibly near dry-season pools of groundwater-fed perennial water-bodies.

The Pleistocene archaeological sites associated with perennial lake contexts (lake basins containing evidence of chemical deposition) are situated in transitional, potentially high energy, depositional settings along the margins of lake basins (Hill, 1993). At the Acheulian sedimentary remnant in the central part of Bir Tarfawi, artifacts were found in several surface contexts. Bifaces were found on top of the limestone remnant, on the sands surrounding the remnant, and on the surface of mounds surrounding the remnant. These Acheulian artifacts, as well as those embedded in limestones at the south area of Bir Tarfawi (Site E-88-12) provide more evidence indicating that Acheulian occupations were associated with perennial lakes. The artifactual context at Site E-88-12 implies that some of these occupations coincided with regressive lake cycles, probably during the dry season.
when some of the carbonate deposits were exposed and the lake was reduced in size. These might represent later stages of hominid presence within a major lake phase, in contrast to the emergent groundwater pool at Site BS-14.

**Paleoclimatic and Chronologic Context**

The presence of perennial lakes associated with the Pleistocene archaeological and paleobiologic record in southern Egypt contrasts with evidence for only playa settings during the early Holocene. While Pleistocene sites are in contexts associated with both perennial lakes (e.g., carbonates deposited in groundwater-fed systems) and seasonal playas (dominated by clastic transported by local rains), Holocene sites seem to be confined to playa settings. Thus it seems that Pleistocene pluvial events may have been connected with wetter climates than the early Holocene in the Sahara (cf. Haynes, 1980, 1997; Hill and Wendorf, 1991, 1997; McKenzie, 1993).

The relative and absolute chronologic placement of the Acheulian in the Sahara has relied on specific local and regional geomorphic/stratigraphic associations, correlations with dated sequences outside North Africa, and coupling (correlation) of sedimentary sequences with paleoclimatic models. The Lower Paleolithic in North Africa extends back to at least the early Pleistocene (Clark, 1992; Sahnouni and de Heinzelin, 1998). In terms of absolute ages, Acheulian assemblages are estimated to have been present prior to a million years ago (e.g., Isaac, 1972; Clark, 1998; Dennell, 1998; Rolland, 1998). In Kenya, Upper Acheulian artifacts have been estimated to date to around 230 ky B.P. (Isaac, 1972), and final Acheulian artifacts (from near Lake Zway, Ethiopia) overlain by assemblages “similar to Typical Mousterian of Levallois Facies” are in deposits dated to about 181 ky B.P. (Wendorf et al., 1975). This can be compared to the transition from Acheulian to Middle Paleolithic in Europe, which may have occurred during isotope stage 6. Age estimates for the Acheulian of about 288–240 ky B.P. have been correlated with isotope stages 7 and 8 (Schwarz and Grün, 1983), while Middle Paleolithic artifacts have been dated to around 123 ky B.P. and correlated with isotope stage 5e (Schwarz and Blackwell, 1983). Along the eastern Mediterranean, at Tabun Cave, the latest Acheulian may date to around 300 ky B.P.; while the earliest Mousterian may be older than 250 ky B.P. (Mercier et al., 1995). Throughout North Africa, Pleistocene-age sedimentary sequences provide evidence of episodic changes in paleoclimatic conditions which, when securely dated, provide the potential for evaluating the chronologic context of Paleolithic artifacts. The chronologic placement of the Acheulian in the Sahara is complicated by the rarity of stratigraphically superimposed artifact sets, as well as the difficulties involved in developing sedimentological and paleoclimatological interpretations with adequate age constraints.

At Bir Tarfawi and Bir Sahara East, geochronometric dating has provided age estimates for deposits containing or related to the Acheulian that are at least 350 ky B.P., and perhaps with the range from 680–460 ky B.P. (Wendorf et al., 1994). Sedimentary remnants containing or associated with Middle Paleolithic artifacts...
range from more than 350 ky B.P. to less than 50 ky B.P.; however, the most feasible estimates range from slightly older than 200 ky B.P. to around 70 ky B.P. (Miller et al., 1991; Wendorf et al., 1994).

The potential for interpreting North African sedimentary deposits in paleoclimatic terms and correlating these with other chronoclimatic sequences has been recognized and attempted (especially along the Atlantic and Mediterranean coasts where direct connections with sea level changes can be made). These correlations have become more reliable with the increasing dependability of direct dating measurements. Using a model based on external forcing by fluctuations in solar insolation, threshold insolation values can possibly be used to predict the onset of monsoon conditions in North Africa, which would be recorded in the geologic record by the presence of lacustrine or other pluvial related deposits (e.g., Rossignol-Strick et al., 1998; Hill and Wendorf, 1991). An alternative approach is to correlate the sedimentary sequences with independently dated paleoclimatic sequences, such as the Vostock ice core or the Devils Hole chronology (Winograd et al., 1997). Based on these types of correlations, any potential succession from Acheulian to Middle Paleolithic in the southern Egyptian Sahara would have occurred during the interval from about 300–200 ky B.P.

A postulated age for the end of the Acheulian and the beginning of the Middle Paleolithic prior to 200 ky B.P. appears to conflict with other proposed chronologies for North Africa (Hill, 1999). While not negated by other age measurements from southern Egypt (e.g., Szabo et al., 1989, 1991; Crombie et al., 1997, Sultan et al., 1997; Churcher et al., 1999), this age model is different from the chronologies proposed elsewhere based on direct measurements or paleoclimatic correlations with isotope stages. For instance, along the Atlantic Sahara Upper and Evolved Acheulian artifacts are indirectly dated by correlation with isotope stage 5 (ca. 130–100 ky B.P. [Barbey et al., 1991]). In Libya, the Terminal Acheulian has been associated with lacustrine episodes centered on 130 ky B.P. (Petit-Maire, 1991; Petit-Maire et al., 1991), while in Tunisia the Final Acheulian may date to about 150 ky B.P. (Ballais and Hedouche, 1991). Whether the apparent differences in the ages of the end of the Acheulian and beginning of the Middle Paleolithic reflect actual spatial variation for the transition, the reliability of geochronologic measurements and correlations, or is a manifestation of the adequacy of existing lithic artifact taxonomic categories still needs to be resolved. There does seem to be, however, a growing amount of geochronometric information which links the timing of Saharan pluvial events with interglacial climates; it seems that these pluvials were the times when Middle Pleistocene biotic communities, including hominids using Acheulian artifacts, would have been most viable in the Eastern Sahara.

Summary
The three sedimentary remnants from the Bir Tarfawi region associated with Acheulian artifacts share the following characteristics: They overlie basal sands and/or redeposited basal sands constituting the lowermost part of the depositional
sequences; the boundaries between the basal sands and the basin fill that form the remnants are at relatively high elevations (ca. 246–248 m asl); and the remnants are composed of extremely indurated limestones or sandy limestones. The character of the carbonate deposit at Site BS-14 is somewhat different from the limestone deposits at the Bir Tarfawi Acheulian localities. At Bir Tarfawi, the central basin limestones are indurated lime muds while at Bir Sahara East they contain a much higher proportion of coarse detrital materials, probably indicating a shallower, smaller water body. Acheulian handaxes are commonly found in lag position on the surfaces of the indurated detrital remnants. Acheulian artifacts also occur on the surfaces of the carbonate remnants at all three localities and are embedded in carbonates at Site E-88-12. Acheulian artifacts were also recovered within sands at Site BS-14 and E-88-12 and on the surface of sands in central Bir Tarfawi. U-series measurements indicate that carbonates associated with the Acheulian in the Bir Tarfawi region may date to before 300 ky B.P. In terms of a paleoclimate chronology, the Acheulian in the Eastern Sahara seems to be linked to pluvial intervals associated with marine isotope stage 9 or older.

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