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1 **ABSTRACT**

2 Lithic artefacts buried in the soil profile may be transported to the surface
3 during tillage-induced kinetic sieving, differential erosion or swell-shrink cycles
4 of clays and become part of a rock fragment mulch. Archaeologically these
5 manifestations are recognized as surface scatters. Although artefacts at the
6 soil surface are difficult to relate to the local stratigraphical context, surface
7 assemblages may provide information on lithic industries and the
8 archaeological significance of sparsely explored regions. Through in-situ
9 investigation of surface material in 60 1×1 m² plots in the Tembien district in
10 the northern Ethiopian highlands, we show that rock fragment mulches can
11 contain a significant number of lithic artefacts and provide evidence for mid-
12 Pleistocene occupation of a site. Considering that severe rill and gully erosion
13 may be a threat to the archaeological heritage and that well-dated African
14 Middle Stone Age sites are rare, we conclude that the region deserves more
15 attention for archaeological research.

16

1 INTRODUCTION

2 Stone mulches are superficial soil covers composed of rock fragments,
3 including all mineral particles >2 mm in diameter and with horizontal
4 dimensions less than about 1 m² (Poesen & Lavee, 1994). Typically
5 associated with (semi-)arid landscapes, they are also known as desert
6 pavement (e.g. Wood, Graham & Wells, 2005; Al-Farray, 2008; Adelsberger &
7 Smith, 2009; Matmon et al., 2009). In less arid parts of the world, surface
8 accumulation of rock fragments has been related to tillage-induced kinetic
9 sieving, differential erosion, upslope rock fall and swell-shrink cycles of clays
10 in soils with vertic properties (Oostwoud Wijdenes et al. 1997; Nyssen et al.,
11 2002; Moeyersons et al., 2006; Nyssen et al., 2006). In the highlands of
12 northern Ethiopia, rock fragments belonging lithologically to deposits
13 underlying active vertisols and other soils with seasonal desiccation cracks
14 appear continuously at the soil surface and at a rate high enough to form a
15 surface rock fragment mulch within a few decades or centuries (Nyssen et al.,
16 2000; Moeyersons et al., 2006). Large quantities of such surface rock
17 fragments of different sizes are frequently removed from arable land and
18 grazing land, when farmers consider rock fragment cover excessive, and for
19 building stone bunds and check dams to control soil erosion (Nyssen et al.,
20 2001).

21 As for other clasts present in the soil profile, prehistoric lithic artefacts
22 buried under vertic soils may also be squeezed up and accumulate on the soil
23 surface in the stone mulch (Moeyersons et al., 2006). Archaeologically these
24 manifestations are recognized as surface scatters. Surface stone artefact
25 deposits cannot be related directly to the local stratigraphical context, which

1 complicates the determination of their age. Even when different lithic
2 artefacts appear to be similar in character, they are not necessarily of similar
3 age (Fanning et al., 2009). In cropland and grazing land, rock fragment
4 removal, tillage and cattle trampling cause lateral and vertical displacement of
5 rocks on the soil surface, including lithic artefacts when present (Nyssen et
6 al., 2001; Navazo & Díez, 2008). Thus, surface deposits, in particular on
7 intensively used land, are likely to have lost spatial and temporal reliability
8 (Fanning & Holdaway, 2002). Therefore, excavations of stratified deposits are
9 usually preferred over surface finds (but see Ripley, 1998; Fanning &
10 Holdaway, 2001; Bintliff, 2005; de la Torre et al., 2007; Fanning et al., 2009).

11 Ethiopia has many important Pleistocene sites, including Middle
12 Awash, Gona and Hadar in the Afar Rift (Oldowan/Acheulean), Melka Konture
13 on the shoulder of the central Ethiopian Plateau (containing Early Stone Age
14 (ESA)/modes 1 and 2, or Developed Oldowan/Acheulean material) and
15 Konso-Gardula in the southern Main Ethiopian Rift (ESA/mode 2/Acheulean)
16 (e.g. Kalb et al., 1982; Asfaw et al., 1992; Semaw et al., 1997; Semaw, 2000;
17 Stout et al., 2005; Negash, Shackley, & Alene, 2006). Porc-Epic cave in Dire
18 Dawa and the Kibish formation in the Lower Omo Valley contain well-known
19 Middle Stone Age type or mode 3 material (Pleurdeau, 2005; Assefa, 2006;
20 Shea, 2008; Fig. 1). In northern Ethiopia, nearly all well-dated archaeological
21 sequences are associated with systematic archaeological surveys in and near
22 Aksum, which have largely been focusing on the settlement history of the pre-
23 Aksumite and Aksumite kingdoms (approximately 800 BC to AD 700) (Bard
24 et al., 1997; 2000; Michels, 2005; D'Andrea et al., 2008). The study of lithic
25 industries in the Aksum archaeological area also showed that stone tools

1 were manufactured and used since the Pleistocene and through the Holocene
2 until historical times (Finneran, 2000a; 2000b; 2001; L. Phillipson, 2000a;
3 2000b; Fattovich, 2002).

4 The rest of the northern Ethiopian highlands, however, remain largely
5 unexplored although earlier reports for the presence of early-mid Holocene
6 archaeological sites in the central-eastern Tigray region (Tembien) exist
7 (containing mode 4 and 5 lithic material; Negash, 1997). In the context of a
8 broader study of environmental degradation and rehabilitation of the Tembien
9 highlands, several sites containing lithic artefacts were observed (e.g. Nyssen
10 et al., 2000; Moeyersons et al., 2006). The objective of this study is to
11 demonstrate that rock fragment mulches, which are a common surface
12 feature throughout the northern Ethiopian highlands, can contain numerous
13 lithic artefacts. Investigating rock mulches may therefore facilitate the
14 identification of potential sites for the study and conservation of the
15 archaeological heritage of the region.

17 **STUDY AREA**

18 This study took place in a typical agricultural setting on the hillslope above the
19 village of Mai Ba'ati (13°39'14"N, 39°12'43"E, 2380-2460 m above sea level,
20 Fig. 1). The village belongs to the Dega Tembien district of Tigray, northern
21 Ethiopia, and is located 33 km northwest of the regional capital Mekelle and 4
22 km east of the district capital Hagere Selam. Tertiary flood basalts and
23 silicified lake deposits of limestone, sandstone and diatomites with gastropods
24 overlay early Cretaceous Amba Aradam sandstone and Jurassic Antalio
25 limestone (Moeyersons et al., 2006), both of which are extensively exposed

1 as cliffs in the typical *amba* or stepped mountain landscape of northern
2 Ethiopia (Asrat, 2002; Nyssen et al., 2006). Vertisols dominate the soilscape
3 in plateau situations wherever basaltic material is present in the soil profile.
4 Over the limestone basement, which is partially covered by transported vertic
5 clay material, vertic Cambisols were formed, while Leptosols formed on
6 shallower parent materials. The soils near Hagere Selam carry natural rock
7 fragment concentrations with 10 to 100 rock fragments m⁻² (Moeyersons et
8 al., 2006). Rain-fed agriculture and free range grazing are the major land
9 uses.

10

11 **METHODS**

12 Rock fragment mulches were investigated in fallow/grazing land on a slope
13 between a sandstone cliff at the upper end and a limestone cliff at the lower
14 end of the slope (Fig. 2). Surface rock fragments were examined in situ to
15 determine the density of lithic artefacts in the rock fragment mulch and to gain
16 insight into the artefact assemblage. We selected 60 1 × 1 m²-plots, laid out
17 randomly at three positions along the slope (3 × 20 clustered plots). In each
18 plot all surface rock fragments were counted and for all lithic artefacts
19 (including formal tools, flakes, cores and debitage) we recorded the raw
20 material and, when possible, documented reduction type and retouch. As all
21 rock fragments, including artefacts, were left in situ, no further detailed
22 measurements could be made. To determine the stratigraphical origin of the
23 artefacts in the rock fragment mulch, we investigated soil profiles which were
24 exposed in a > 2 m deep gully running down the slope (Fig. 2). We

1 investigated representative sections of the gully wall and looked for lithic
2 artefacts that had not yet been brought up to the soil surface.

3 Mean differences in total number of surface rock fragments, artefact
4 densities and relative proportions of artefact raw material among the three
5 positions along the slope were determined by use of Kruskal-Wallis non-
6 parametric analysis of variance (KW). The relation between total surface rock
7 fragment cover and number of artefacts was examined with Spearman rank
8 correlation (r_s). Data were analyzed using SPSS 15.0 (SPSS Inc., Chicago,
9 IL).

11 RESULTS

12 At the upper end of the slope, most rock fragments originated as
13 rockfall from the Amba Aradam sandstone cliff (Fig. 3, a) while at the lower
14 end of the slope (Fig. 3, c) most surface rock fragments were silicified
15 limestone (chert). Total rock fragment cover was significantly higher at the
16 upper end and in the middle of the slope (Fig. 4; KW $\chi^2 = 30.0$, $P < 0.001$). In
17 total, 835 lithic artefacts were observed in the 60 plots. Mean artefact
18 densities along the slope from upper end to lower end were 10, 19 and 13
19 artefacts m^{-2} corresponding to 5, 10 and 16% of the total rock fragment cover
20 (Fig. 4). The overall mean ($\pm$ SE) density was 14 ± 1 artefacts m^{-2} and artefact
21 lengths approximately ranged between 0.5 and $15 \cdot 10^{-2}$ m. The maximum
22 number of artefacts in a single plot was 37 m^{-2} , in the middle of the slope,
23 where absolute artefact densities were significantly higher (Fig. 4; KW $\chi^2 =$
24 9.5, $P = 0.009$). High numbers of artefacts were significantly correlated to
25 higher numbers of surface rock fragments ($r_s = 0.58$, $P < 0.001$). In the soil

1 profile, lithic artefacts were found in distinct stone layers underlying vertic
2 material at depths between 1 and 2.3 m below the surface (Fig. 5).

3 Chert was the main raw material source of artefacts, comprising 75%
4 of all examined artefacts (Table I). Before chertification, the initial lithology
5 consisted of fine-grained calcareous mudstone but coarser pelletoidal
6 wackestone also existed (Swennen, pers. comm., 2006). Some of the chert
7 artefacts have clearly been intensively weathered which explains the color
8 change from black to light grey. The second most utilized material was fine-
9 grained sandstone to siltstone (20%). Micro-crystalline quartzes
10 (chalcedony), as well as igneous rocks such as basalt and obsidian were also
11 used, but were on the whole relatively rare (Table I). Chert artefacts were
12 proportionally more numerous at the lower end of the slope (KW $\chi^2 = 12.2$, P
13 = 0.02), and sandstone artefacts at the upper end (KW $\chi^2 = 10.4$, P = 0.005).

14 Sandstone artefacts were too intensively weathered and/or damaged to
15 assess their reduction and retouch in situ. From all chert artefacts (excluding
16 debitage), approximately 10% had bifacial reduction and a distinctive yellow-
17 brown patina; these may be Mode 2/Acheulean elements of the Early Stone
18 Age (ESA), in particular the heavy bifaces or hand axes in this subset (as in
19 Fig. 6, a–c) (see Finneran 2007, 34). The probable ESA elements had
20 usually been retouched on both edges, in some cases with superposing
21 retouch (shallow intentionally produced dents, superimposed on much
22 rougher steep bifacial retouches). Reduced cores were very rare but we
23 found at least one single platform core. The majority of the artefacts were
24 flakes (detached pieces) and flake fragments, usually with a diagnostic
25 striking platform, a bulb of percussion and a clear release surface (as in Fig.

6, d–r). These artefacts had unifacial reduction, characteristic of Mode 3 flakes and Mode 4 blades of the Middle to Late Stone Age type-industries (hereafter MSA and LSA). In general, there was a wide variety of flake size and morphology, with few formal tools (but see Fig. 6, l–m for examples of end scrapers and Fig. 6, n for a Levallois flake).

DISCUSSION

Repeated Displacement of Artefacts

It is difficult to relate the artefacts of Mai Ba’ati to their original stratigraphical context, because all artefacts have been displaced laterally and vertically. Interpretation of the soil profiles suggests that the rock fragments have been transported to the surface from a stone line 1–2 m under the current soil surface (Fig. 5, a–c). In the subsoil, rock fragments are squeezed upwards via movements along slickensides and by seasonal opening and closure of desiccation cracks (Moeyersons et al., 2006). As rock fragments approach the soil surface, tillage-induced kinetic sieving may speed up the accumulation of coarser fragments at the soil surface (Oostwoud Wijdenes et al. 1997; Nyssen et al., 2002). The subsurface stock of rock fragments itself is most likely the result of colluviation and debris flows that occurred before the development of the vertic cambisol. Both mudstone and wackestone (being faecal pellets from gastropods) are lacustrine in origin. Therefore, the most likely source of the raw material used for the Mai Ba’ati artefacts are the interbedded silicified lake deposits on top of the Amba Aradam sandstone (above reference point A, Fig. 2), and not the silex nodules found in the Antalo limestone (a limestone bed with marine fossils) (below reference point C, Fig.

2). After reaching the rock fragment mulch, artefacts may have been further displaced repeatedly, by trampling, tillage and concentrated runoff (Poesen 1987; Nyssen et al., 2002). Nevertheless, the high density of artefacts in close proximity to the expected source area (0.5–1.5 km) indicates that chert nodules may have been shaped in situ or in rock shelters at the base of the Amba Aradam sandstone cliff. These are promising locations for future archaeological excavation aimed at yielding possible stratified occupation sequences.

Surface Scatter Assemblage

Despite the presence of heavy hand axes (Fig. 6, a–c), which are typical of the Early Stone Age (Mode 2) industries of the region and which appeared in East Africa 1–1.5 million years BP (Asfaw et al., 1992; Phillipson, 1993, 39), the lithic artefact assemblage at Mai Ba’ati is more likely of Middle to Late Stone Age origin. It primarily comprises retouched flakes, (end) scrapers on flakes and blades of the MSA and LSA types (Mousterian and Upper Paleolithic industry; 40ka–0.2Ma BP). Bladelets observed in the stone mulch (Fig. 6, q–r) are similar to the retouched flakes of the microlithic (Mode 5) ceramic phase of the Late Stone Age site of Baahti Nebait in Aksum (Finneran, 2000a). Bipolar blades (Fig. 6, e, h–i) and irregularly retouched elongated flakes (Fig. 6 j–k) which are abundant in the stone tool assemblage of Mai Ba’ati, were also encountered in other localities, including nearby settlements as Mheni but also as far as Dessa’a forest, 60 km to the east of the study site on the Eastern African Rift shoulder at the edge of the Danakil depression (pers. obs.). These artefacts are similar to the mudstone long-

1 blade (Mode 4) phase of the Late Stone Age site of Baahti Nebait, which was
2 dated to 9495-9975 BP based on carbon-dated charcoal samples, and to the
3 scrapers and blades found in Anqqa Baahti, both in Aksum (Finneran, 2000a;
4 2000b). But in general, blades in Mai Ba'ati are less elongated than the
5 Aksum long-blades, with mean breadth:length ratios in the order of 1:1-2
6 compared to 1:2-3 for long-blades.

7 There were very little formal patterns in retouch. The function and
8 degree of utilization could not be determined, because artefacts remained in
9 the field and microscopic analysis of microwear, residue and polish could
10 therefore not be performed. Many artefacts showed noticeable evidence of
11 edge damage, but it may be relatively recent, caused by tilling and repeated
12 displacement. Nevertheless, our observations are enough to classify most
13 flakes as scrapers, and for those with deliberate retouch on each edge,
14 double scrapers. Stone scrapers are often associated with hide working, a
15 technology that still persists with the Konso of southern Ethiopia (e.g. Brandt
16 & Weedman, 1997; Rots & Williamson, 2004) as well as with Ethiopian
17 Orthodox healer-priests specialized in the preparation of parchment for *ketab*
18 amulets (pers. obs.).

19 At the Porc-Epic cave in Dire Dawa, where the same extension of
20 Antalo limestone outcrops below the Adigrat sandstone, local raw materials
21 (flint and sandstone) and allochthonous materials (obsidian and basalt) were
22 used to produce flakes, blades, bladelets and points for retouched points,
23 scrapers, notched tools, backed tools and end scrapers (Pleurdeau, 2005). A
24 similar operational scheme, thought to be representative for the Middle Stone
25 Age artefacts, may have been used in Central Tigray. Our results therefore

1 suggest that this part of northern Ethiopia was occupied at least from the mid-
2 Pleistocene onwards.

4 **CONCLUSIONS**

5 In northern Ethiopia Stone Age lithic artefacts accumulate in rock fragment
6 mulches over soils with vertisols action or active desiccation cracks. The
7 upward movement of rock fragments in the soil profile means that the original
8 context of artefacts is lost, but the process generates rich surface
9 assemblages that are useful to provide preliminary information on lithic
10 industries of sparsely explored regions. The lithic artefact assemblage at Mai
11 Ba'ati mainly comprises retouched flakes, scrapers on flakes and blades of
12 Middle and Late Stone Age types. Considering that severe rill and gully
13 erosion may be a threat to the archaeological heritage (Wainwright, 1994) and
14 that well-dated and described African Middle Stone Age sites are rare
15 (Pleurdeau, 2005), we conclude that the region, in particular the Tembien
16 district with its many rock shelters and caves (Negash, 1997), deserves more
17 attention for archaeological research.

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REFERENCES

- Adelsberger, K.A. & Smith, J.R. (2009). Desert pavement development and landscape stability on the Eastern Libyan Plateau, Egypt. *Geomorphology*, 107, 178-194.
- Al-Farraj, A. (2008). Desert pavement development on the lake shorelines of Lake Eyre (South), South Australia. *Geomorphology*, 100, 154-163.
- Asfaw, B., Beyene, Y., Suwa, G., Walter, R.C., White, T.D., Woldegabriel, G., & Yemane, T. (1992). The earliest Acheulean from Konso-Gardula. *Nature*, 360, 732-735.
- Asrat, A. (2002). The rock-hewn churches of Tigray, Northern Ethiopia: a geological perspective. *Geoarchaeology*, 17, 649-663.
- Assefa, Z. (2006). Faunal remains from Porc-Epic: paleoecological and zooarchaeological investigations from a Middle Stone Age site in southeastern Ethiopia. *Journal of Human Evolution*, 51, 50-75.
- Bard, K.A., Fattovich, R., Manzo, A., & Perlingieri, C. (1997). Archaeological investigations at Bieta Giyorgis (Aksum), Ethiopia: 1993-1995 Field Seasons. *Journal of Field Archaeology*, 24, 387-403.
- Bard, K.A., Coltorti, M., DiBlasi, M.C., Dramis, F., & Fattovich, R. (2000). The environmental history of Tigray (Northern Ethiopia) in the Middle and Late Holocene: a preliminary outline. *African Archaeological Review*, 17, 65-86.
- Bintliff, J. (2005). Human impact, land-use history, and the surface archaeological record: a case study from Greece. *Geoarchaeology*, 20, 135-147.

- 1 Brandt, S.A. & Weedman, K.J. (1997). The ethnoarchaeology of hide working
2 and flaked stone tool use in southern Ethiopia. In K. Fukui, E.
3 Kurimoto, & M. Shigeta (Eds.), *Ethiopia in a Broader Perspective* vol. 1
4 (pp. 351–361). Kyoto: Shokado Books.
- 5 D'Andrea, C., Manzo, A., Harrower, M.J., & Hawkins, A.L. (2008). The pre-
6 Aksumite and Aksumite settlement of NE Tigray, Ethiopia. *Journal of*
7 *Field Archaeology*, 33, 151-176.
- 8 de la Torre, I., Benito-Calvo, A., Mora, R., Martínez-Moreno, J., Morán, N, &
9 Tibebe, D. (2007). Stone Age occurrences in the western bank of the
10 Bilate River (Southern Ethiopia) – Some preliminary results. *Nyame*
11 *Akuma*, 67, 14-25.
- 12 Fanning, P.C., & Holdaway, S.J. (2001). Stone artifact scatters in Western
13 NSW, Australia: geomorphic controls on artifact size and distribution.
14 *Geoarchaeology*, 16, 667-686.
- 15 Fanning, P.C., & Holdaway, S.J. (2002). Artifact visibility at open sites in
16 Western New South Wales, Australia. *Journal of Field Archaeology*, 29,
17 255-271.
- 18 Fanning, P.C., Holdaway, S.J., Rhodes, E.J., & Bryant, T.G. (2009). The
19 surface archaeological record in arid Australia: geomorphic controls on
20 preservation, exposure, and visibility. *Geoarchaeology*, 24, 121-146.
- 21 Fattovich, R. (2002). Excavations at Aksum. *Journal of African History*, 43,
22 316-317.
- 23 Finneran, N. (2000a). Excavations at the Late Stone Age site of Baahti
24 Nebait, Aksum, northern Ethiopia. *Azania*, 35, 53-73.

- 1 Finneran, N. (2000b). A new perspective on the Late Stone Age of the
2 northern Ethiopian highlands: excavations at Anqger Baahti, Aksum,
3 Ethiopia 1996. *Azania*, 35, 21-51.
- 4 Finneran, N. (2001). The Aksum long-blades: a Late Pleistocene/Early
5 Holocene (Mode 4) lithic industry from northern Ethiopia. *Nyame*
6 *Akuma*, 55, 23-31.
- 7 Finneran, N. (2007). *The Archaeology of Ethiopia*. London: Routledge.
- 8 Kalb, J.E., Jolly, C.J., Mebrate, A., Tebedge, S., Smart, C., Oswald, E.B.,
9 Cramer, D., Whitehead, P., Wood, C.B., Conroy, G.C., Adefris, T.,
10 Sperling, L., & Kana, B. (1982). Fossil mammals and artefacts from the
11 Middle Awash Valley, Ethiopia. *Nature*, 298, 25-29.
- 12 Matmon, A., Simhai, O., Amit, R., Haviv, I., Porat, N., McDonald, E.,
13 Benedetti, L. & Finkel, R. 2009. Desert pavement-coated surfaces in
14 extreme deserts present the longest-lived landforms on Earth.
15 *Geological Society of America Bulletin*, 121, 688-697.
- 16 Michels, J.W. 2005. Changing settlement patterns in the Aksum-Yeha region
17 of Ethiopia: 700 BC – AD 850. *Cambridge Monographs in African*
18 *Archaeology* 64/*British Archaeological Reports International Series*
19 1446. Oxford: Archaeopress.
- 20 Moeyersons, J., Nyssen, J., Poesen, J., Deckers, J., & Haile, M. (2006). On
21 the origin of rock fragment mulches on Vertisols: A case study from the
22 Ethiopian highlands. *Geomorphology*, 76, 411-429.
- 23 Navazo, M., & Díez, C. (2008). Redistribution of archaeological assemblages
24 in plowzones. *Geoarchaeology*, 23, 323-333.

1 Negash, A. (1997). Preliminary results of an archaeological reconnaissance of
2 Tigrai, Northern Ethiopia. *Nyame Akuma*, 47, 27-32.

3 Negash, A., Steven Shackley, M., & Alene, M. (2006). Source provenance of
4 obsidian artifacts from the Early Stone Age (ESA) site of Melka
5 Konture, Ethiopia. *Journal of Archaeological Science*, 33, 1647-1650.

6 Nyssen, J., Moeyersons, J., Deckers, J., Haile, M., & Poesen, J. (2000).
7 Vertic movements and the development of stone covers and gullies,
8 Tigray Highlands, Ethiopia. *Zeitschrift für Geomorphologie*, 44, 145-
9 164.

10 Nyssen, J., Haile, M., Poesen, J., Deckers, J., & Moeyersons, J. (2001).
11 Removal of rock fragments and its effect on soil loss and crop yield,
12 Tigray, Ethiopia. *Soil Use and Management*, 17, 179-187.

13 Nyssen, J., Poesen, J., Moeyersons, J., Lavrysen, E., Haile, M., & Deckers, J.
14 (2002). Spatial distribution of rock fragments in cultivated soils in
15 northern Ethiopia as affected by lateral and vertical displacement
16 processes. *Geomorphology*, 43, 1-16.

17 Nyssen, J., Poesen, J., Moeyersons, J., Deckers, J., & Haile, M. (2006).
18 Processes and rates of rock fragment displacement on cliffs and scree
19 slopes in an amba landscape, Ethiopia. *Geomorphology*, 81, 265-275.

20 Oostwoud Wijdenes, D., Poesen, J., Vandekerckhove, L., & de Luna, E.
21 (1997). Chiselling effects on the vertical distribution of rock fragments
22 in the tilled layer of a Mediterranean soil. *Soil and Tillage Research*,
23 44: 55-66.

24 Phillipson, D. (1993) *African Archaeology* (2nd edition). Cambridge: Cambridge
25 University Press.

- 1 Phillipson, L. (2000a). Aksumite lithic industries. *African Archaeological*
2 *Review*, 17, 49-63.
- 3 Phillipson, L. (2000b). Early and Middle Stone Ages. In: D.W. Phillipson (Ed.),
4 *Archaeology at Aksum, Ethiopia, 1993-7, Vol 1* (pp. 17-22). London
5 and Nairobi: British Institute in Eastern Africa and the Society of
6 Antiquaries of London.
- 7 Pleurdeau, D. (2005). Human technical behavior in the African Middle Stone
8 Age: the lithic assemblage of Porc-Epic Cave (Dire Dawa, Ethiopia).
9 *African Archaeological Review*, 22, 177-197.
- 10 Poesen, J., 1987. Transport of rock fragments by rill flow - a field-study.
11 *Catena*, S8, 35-54.
- 12 Poesen, J. & Lavee, H. (1994). Rock fragments in top soils: significance and
13 processes. *Catena*, 23, 1-28.
- 14 Ripley, J.L. (1998). A geoarchaeological approach to using surface sites for
15 paleoenvironmental reconstructions. *Geoarchaeology*, 13, 793-8118.
- 16 Rots, V. & Williamson, B.S. (2004). Microwear and residue analyses in
17 perspective: the contribution of ethnoarchaeological evidence. *Journal*
18 *of Archaeological Science*, 31, 1287-1299.
- 19 Semaw, S., Renne, P., Harris, J.W.K., Feibel, C.S., Bernor, R.L., Fesseha, N.,
20 & Mowbray, K. (1997). 2.5-Million-year-old stone tools from Gona,
21 Ethiopia. *Nature*, 385, 333-336.
- 22 Semaw, S. (2000). The World's oldest stone artefacts from Gona, Ethiopia:
23 their implications for understanding stone technology and patterns of
24 human evolution between 2.6-1.5 million years ago. *Journal of*
25 *Archaeological Science*, 27, 1197-1214.

- 1 Shea, J.J. (2008). The Middle Stone Age archaeology of the Lower Omo
2 Valley Kibish formation: excavations, lithic assemblages, and inferred
3 patterns of early Homo sapiens behavior. *Journal of Human Evolution*,
4 55, 448-485.
- 5 Stout, D., Quade, J., Semaw, S., Rogers, M.J., & Levin, N.E. (2005). Raw
6 material selectivity of the earliest stone toolmakers at Gona, Afar,
7 Ethiopia. *Journal of Human Evolution*, 48, 365-380.
- 8 Wainwright, J. (1994) Erosion of archaeological sites: Results and
9 implications of a site simulation model. *Geoarchaeology*, 9, 173-201.
- 10 Wood, Y.A., Graham, R.C., & Wells, S.G. (2005). Surface control of desert
11 pavement pedologic process and landscape function, Cima Volcanic
12 field, Mojave Desert, California. *Catena*, 59, 205-230.
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1 **TABLES**

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Table I. Raw material of lithic artefacts in rock fragment mulches in Mai Ba'ati, northern Ethiopia. Values are mean number of artefacts (and SE) m⁻² for 3 × 20 plots in three positions along the slope (n = 60).

Position along slope	Chert ¹	Sandstone ¹	Other ²
Upper end (Amba Aradam sandstone)	4.3 (0.7) ^a	4.8 (1.2) ^a	0.9 (0.3)
Mid-slope	16.2 (2.3) ^b	2.6 (0.5) ^a	0.6 (0.3)
Lower end (Vertic cambisol over Antalo limestone)	11.3 (1.0) ^b	0.8 (0.2) ^b	0.5 (0.2)
Overall mean	10.6 (1.1)	2.7 (0.5)	0.6 (0.2)

¹ Letters indicate significant differences between positions (Kruskal-Wallis ANOVA)

² Includes chalcedony, basalt and obsidian

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4 **3**

FIGURES

Figure 1. Map of Ethiopia showing the location of Mai Ba'ati with reference to key Pleistocene/Early Holocene archaeological sites in Ethiopia.

Figure 2. Photograph and diagram showing Mai Ba'ati, Central Tigray, Ethiopia and a catena from Amba Aradam sandstone (point A) to Antalo limestone (point C) along which the rock fragment mulch was investigated. North is to the right of the image. Scale varies with perspective: distance A–C 700 m; extent of horizon ~5 km. Altitudes are in m a.s.l.

Figure 3. Illustration of typical rock fragment mulches and 1-m² plots in strongly browsed rangeland in Mai Ba'ati, Ethiopia. Pen, knife and tip of *A/oe* leaf in (b) and pencil and knife in (c) mark artefacts. Position along the catena: (a) upper end, (b) mid-slope, (c) lower end. For location of the catena, see Fig. 2.

1
2 Figure 4. Number of lithic artefacts and total number of rock fragments (RF) m⁻² in
3 rock fragment mulches along a catena from Amba Aradam sandstone (upper end of
4 slope) to Antalo limestone (lower end of slope) in Mai Ba'ati, Ethiopia. Letters
5 indicate significant differences between groups. Note logarithmic vertical scale.

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Figure 5. Soil profiles exposed in a gully wall along a slope in Mai Ba'ati, Ethiopia, showing rock fragment layers with lithic artefacts underlying vertic material (a) at 100 cm below the surface in the middle of the slope and (b–c) at 200–230 cm below the surface towards the lower end of the slope. Artefacts (d) and burnt wood fragments (e) were also observed deeper in the soil profile, which reached the Antalo limestone parent material at ~300 cm.

Figure 6. Illustration of typical surface scatter artefacts in Mai Ba'ati, Central Tigray, Ethiopia (all are chert; images were enhanced to reveal details). (a–b) ESA-type, mode 2, biface/hand axe, (c) ESA-type, irregular hand axe, (d) MSA-LSA transitional-type, mode 4, denticulated/notched heavy blade, (e) MSA-LSA transitional-type, mode 4, bipolar long blade (distal damage), (f) MSA-LSA transitional-type, mode 4, heavy blade with cortex on distal extremity, (g) MSA-LSA transitional-type, mode 4, irregular scraper with recent edge damage, (h) possible MSA-type, mode 4, bipolar backed blade, (i) possible MSA-type, mode 4, bipolar blade with distal damage, (j–k) elongated flakes with irregular retouch, (l–m) end scrapers on flakes, m proximally broken, (n) Levallois-type flake with prepared butt and irregular retouch, (o–p) retouched flakes, (q–r) LSA-type, Mode 5, bladelets.