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Article *in* Quaternary Research · July 2008

DOI: 10.1016/j.yqres.2008.04.010

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ScienceDirect
Quaternary Research 70 (2008) 283–300
QUATERNARY RESEARCH
www.elsevier.com/locate/yqres

Middle Stone Age starch acquisition in the Niassa Rift, Mozambique

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Received 29 November 2007
Available online 13 June 2008

Abstract

The quest for direct lines of evidence for Paleolithic plant consumption during the African Middle Stone Age has led scientists to study residues and use-wear on flaked stone tools. Past work has established lithic function through multiple lines of evidence and the spatial breakdown of use-wear and microscopic traces on tool surfaces. This paper focuses on the quantitative analysis of starch assemblages and the botanical identification of grains from flake and core tools to learn about human ecology of carbohydrate use around the Niassa woodlands, in the Mozambican Rift. The processing of starchy plant parts is deduced from the occurrence of starch assemblages that presumably got attached to stone tool surfaces by actions associated with extractive or culinary activities. Specifically, we investigate starch grains from stone tools recently excavated in northern Mozambique at the site of Mikuyu; which presumably spans the middle to late Pleistocene and represents similar sites found along the Malawi/Niassa corridor that links East, Southern, and Central Africa. Starch was extracted and processed with a diverse tool kit consisting of scrapers, cores, points, flakes, and other kinds of tools. The microbotanical data suggests consumption of seeds, legumes, caryopses, piths, underground storage organs, nuts, and mesocarps from more than a dozen families. Our data suggest a great antiquity for starch use in Africa as well as an expanded diet and intensification.

Keywords: Africa; Middle Stone Age; Mozambique; Niassa; Starch grains

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Introduction

There are many sources of raw starch available in the African landscape (Laden and Wrangham, 2005); some of which are still gathered nowadays in sub-Saharan Africa for food and medicinal purposes. Ethnobotanical research on modern foraging societies indicates that some of these starch sources are unpalatable and indigestible, even toxic, without culinary modification (Watt and Breyer-Brandwijk, 1962; Fox and Young, 1982; Peters et al., 1992; Venter and Venter, 1996), and it shows the relevance that starch, and plant use in general, has among traditional groups (Lee and Devore, 1968). In relation to ecosystem type and human ecology, savanna groups are surrounded by a greater number of wild starch sources than their counterparts in rainforests (Laden and Wrangham, 2005: 485). Some authors believe that early hominin diets relied on foods high in soluble carbohydrates such as sugars, but not on starch (Stahl, 1984: 154), because of the indigestible constituents that could not be consumed by societies that did not control fire for cooking purposes. Others think that australopithecine species used starch resources from underground storage organs as fall-back foods, that cooking appeared very early on in human evolution, and that these behaviors determined the appearance of key body traits and that of cohesive social systems (Wrangham et al., 1999). However, others question whether such resources are just fall-back items to hominoids rather than staples (Hernández-Aguilar et al., 2007). A modern plant food reconstruction for Olduvai Gorge (Copeland, 2007) establishes the role that grains, legumes, starchy piths, and starch-rich underground plant parts played for Oldowan groups. During later phases of human evolution, in the reconstructions of early African *sapiens* diets, Desmond Clark (1988: 299) expected starchy plant foods to have been regularly obtained from grasses, bushes, and trees in the form of seeds, fruits, nuts, rhizomes, and tubers, and in fact grinding stones that could have been utilized to process carbohydrate-rich foods are common during the Acheulian and the early Middle Stone Age (Yellen et al., 1995; McBrearty and Brooks, 2000: 511; Mckinney, 2001; Van Peer et al., 2003: 191). Thus, it seems reasonable to assume that the earliest evidence for a significant reliance on starchy foods worldwide is to be found in Africa.

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doi:10.1016/j.yqres.2008.04.010

Modern ethnoarchaeobotanical work points to starch use as a critical step in human evolution with far-reaching effects; by improving dietary quality in the African savannas and woodlands where the hominin tribe first evolved (Clark, 2001; Bromage et al., 1995; White et al., 2003; Laden and Wrangham, 2005; Sponheimer et al., 2005, Peters and Vogel, 2005; cf. Hladik and Dounias, 1993). In this context, we ask when did modern humans exploit starches and made them into staples for the first time? Furthermore, to what extent did Middle Stone Age reliance on carbohydrate-rich foodstuff parallel Later Stone Age starch consumption? (Deacon and Deacon, 1999).

Actualistic predictions based on projections from modern ecology and plant use, whether they pertain to primitive, archaic or modern humans, have one thing in common: the lack of direct botanical evidence to support them. Confirmation remains dependent on the recovery of botanical remains. For decades, preservation biases have been invoked to argue that such recovery is impossible (Stahl, 1984: 151); particularly in forested ecosystems and regions of high rainfall. However, the advance in microbotanical analysis that would allow assessing the role of tubers, grains, piths and legumes in the past is now manifest (Torrence and Barton, 2006) and available. Researchers working outside the African savannas have made a substantial contribution to understanding early use of wild carbohydrates and demonstrated that starch preserves in the archaeological record for thousands of years in the Pacific region (e.g. Loy et al., 1992; Barton et al., 1998),

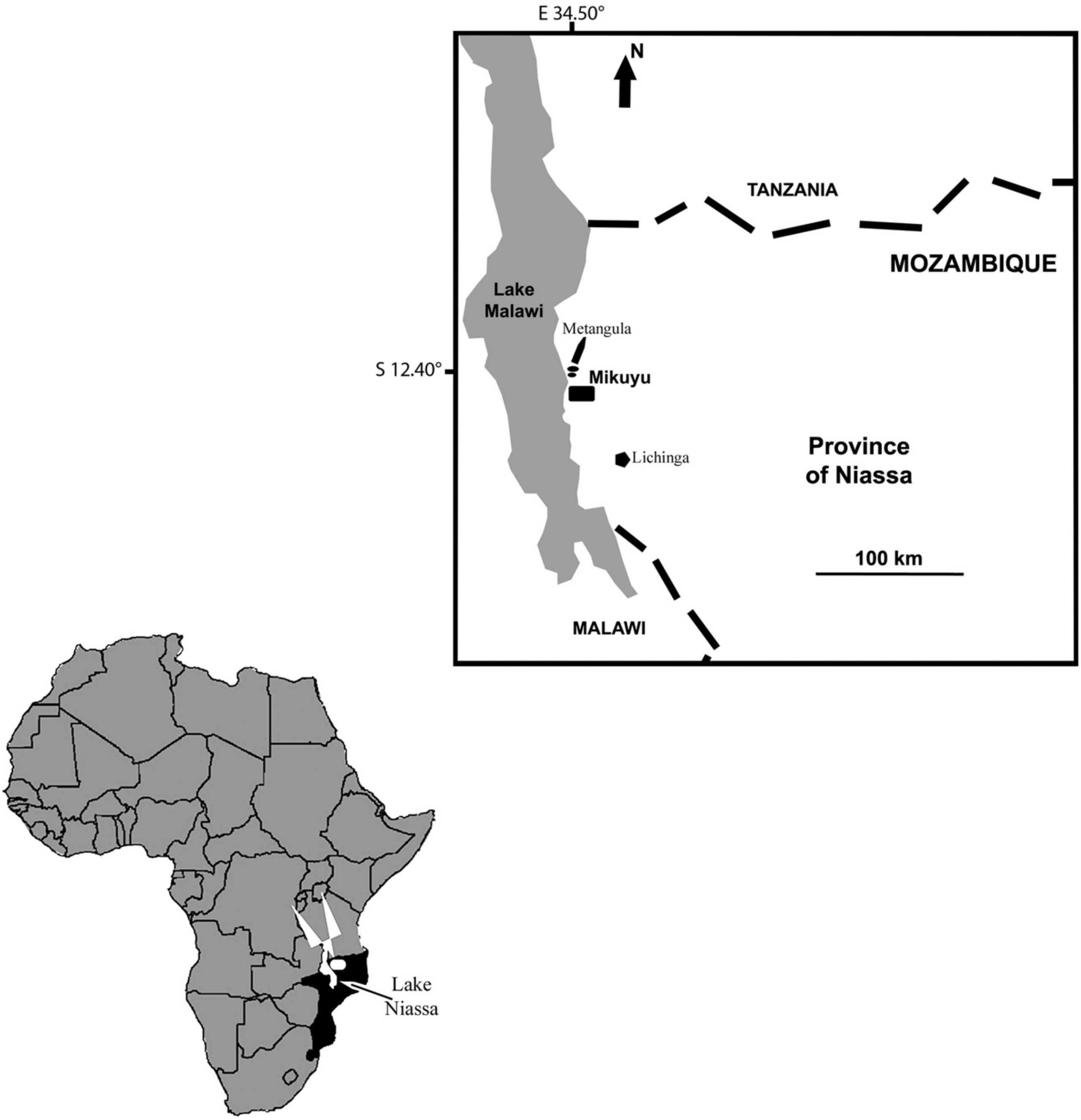

Figure 1. Location of the study area in relation to Lake Niassa (Malawi) and the international borders with Malawi and Tanzania.

South East Asia (e.g. Barton, 2005), the New World (e.g. Piperno et al., 2000; Pearsall et al., 2004; Zarrillo and Kooyman, 2006; Dickau et al., 2007; Perry et al., 2007), the Middle East (e.g. Piperno et al., 2004), South Africa (e.g. Langejans, 2006), and West Africa (e.g. Mercader et al., 2007).

The quest for direct lines of evidence for Paleolithic plant consumption has taken archaeologists to study residues and use-wear on flaked stone tools (Hardy et al., 2001; Williamson, 2004; Lombard, 2005; Wadley and Lombard, 2007). Past work has established lithic function through multiple lines of evidence and the spatial breakdown of use-wear and microscopic traces on tool surfaces (e.g. Lombard, 2005). This paper focuses on the quantitative analysis of starch assemblages and the botanical identification of grains from African Middle Stone Age flake and core tools to learn about the ancient processing of starchy plant parts. We look at plant residue in the form of starch granules that were attached to stone tool surfaces by actions associated with prehistoric processing activities such as digging, dibbling, augering (Dounias, 1993: Figure 52.3), cleaning, peeling, slicing, scraping, scooping, pounding, and grinding (Fullagar et al., 2006). The assemblage spans the early late Pleistocene along the geographical corridor that links East, Southern, and Central Africa, in the central Malawi/Niassa basin of northern Mozambique; around the archaeological site of Mikuyu, first surveyed by one of us (JM) in 2005 and excavated during 2006.

Geoarchaeological, geographical, and ecological background

The site of Mikuyu (34°49.505’535E; 12° 43.444’S) is located in the Mozambican province of Niassa (Figs. 1, 2). Mikuyu is part of a relict, erosional landscape on a hill whose divide at 535 m

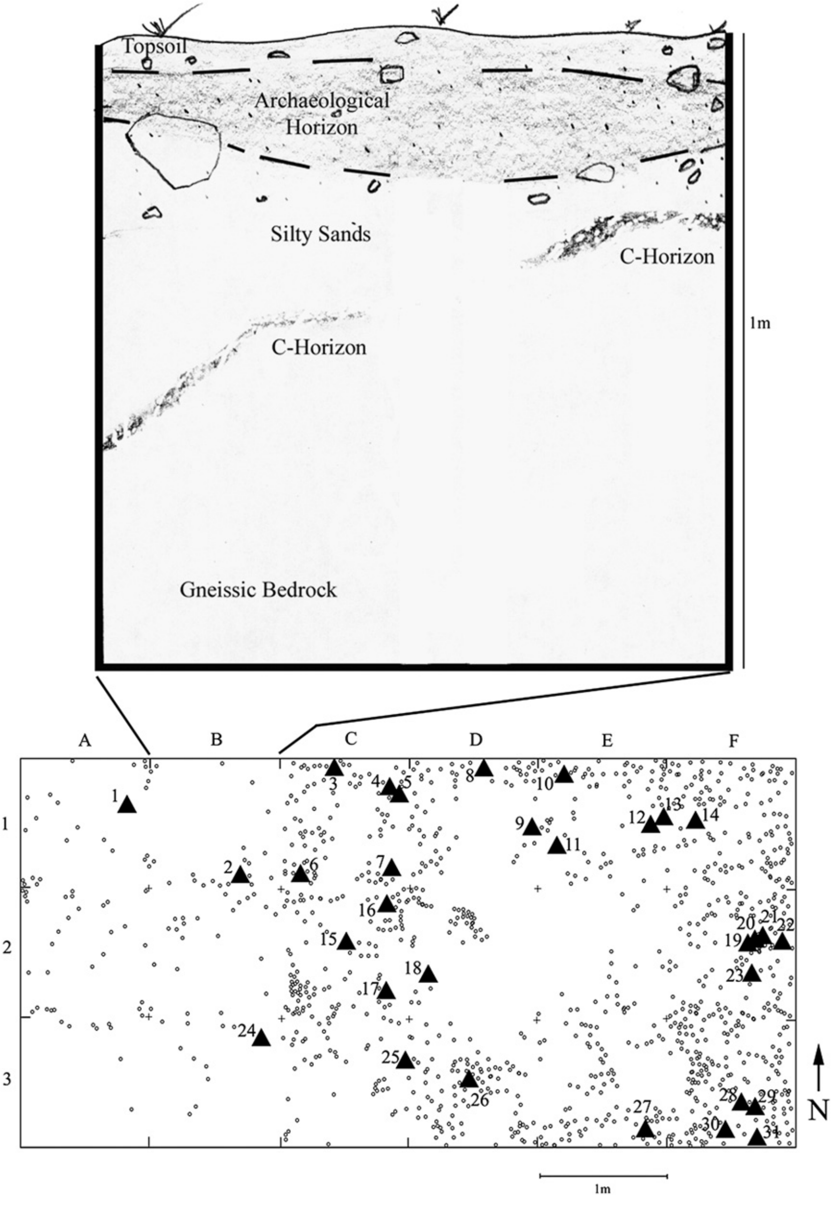

Figure 2. The upper graphic represents part of the stratigraphic section of Mikuyu (north wall of test pit T6). The lower graphic is a plan view of test pit T6 showing the general distribution of lithics (small circles) and those selected for residue analysis (numbered triangles; see Fig. 3).

Table 1
Techno-typological features of lithics and starch quantification

Stone tool ID as it appears in Fig. 3	Techno-typology	Raw material	Mass	Length	Width	Thickness	WB* residue, mass	S** residue, mass	Granules	Monodominant clusters	MNI per cluster
1	Levallois Point (This Study)	Quartz	6.1	30.82	22.92	7.92	0.00	0.003	0	0	0
2	Side Scraper (Clark and Kleindienst 2001)	Quartz	29.8	58.34	37.06	12.47	0.013	0.016	5	0	0
3	Drill (This Study)	Quartz	7.3	35.55	26.41	8.26	0.003	0.003	2	0	0
4	Scraper — Small Convex (Yellen et al. 2005)	Quartz	8.1	26.81	23.23	12.38	0.00	0.011	14	0	0
5	Point, Mousterian (Yellen et al. 2005)	Quartz	5.2	34.80	22.79	6.56	0.003	0.003	30	2	127
6	Scraper — Small Convex (Yellen et al. 2005)	Quartz	11.6	32.47	30.12	11.83	0.00	0.003	4	0	0
7	Point, Mousterian (Yellen et al. 2005)	Quartz	3.6	31.38	18.88	7.59	0.003	0.003	5	1	78
8	Side Scraper (Clark and Kleindienst 2001)	Quartz	23.5	47.39	37.10	12.49	0.00	0.009	2	0	0
9	Retouched Core Fragment (This Study)	Quartz	56.2	69.19	43.58	19.64	0.013	0.003	10	0	0
10	Point — Thick Base (This Study)	Quartz	8.4	32.62	32.67	10.93	0.00	0.003	11	0	0
11	Levallois Flake — Retouched (This Study)	Quartz	13.8	43.43	37.16	11.78	0.00	0.003	1	0	0
12	Discoidal Core (This Study)	Quartz	64.3	57.55	55.48	19.08	0.00	0.05	9	0	0
13	Core Scraper (Clark and Kleindienst 2001)	Quartz	42.5	43.73	28.56	28.51	0.01	0.012	12	0	0
14	Flake — Concave Retouch	Quartz	26.4	52.78	40.23	11.60	0.003	0.006	3	1	12
15	Side Scraper (Clark and Kleindienst 2001)	Quartz	16.5	45.44	32.50	12.04	0.00	0.006	1	0	0
16	Side Scraper (Clark and Kleindienst 2001)	Quartz	22.2	46.43	35.73	12.46	0.00	0.003	2	0	0
17	Backed Blade (Clark and Kleindienst 2001)	Quartz	9.9	39.53	21.57	9.76	0.00	0.016	3	0	0
18	Trapezoid (This Study)	Chert	3.8	32.43	20.84	4.88	0.00	0.003	1	0	0
19	Circular Scraper (Clark and Kleindienst 2001)	Quartz	20.5	33.93	40.00	15.39	0.00	0.003	3	0	0
20	Flake (This Study)	Quartz	10.4	43.49	29.58	8.68	0.00	0.003	4	1	26
21	Micro Levallois Core (Yellen et al. 2005)	Quartz	8.5	31.00	26.16	11.34	0.00	0.003	1	0	0
22	Levallois Flake — Retouched (This Study)	Quartz	9.2	37.21	27.81	8.47	0.00	0.003	3	0	0
23	Pointed Flake (This Study)	Quartz	14.7	46.66	30.00	10.76	0.00	0.003	4	0	0
24	Point, Classic MSA (Yellen et al. 2005)	Quartz	5.0	44.10	19.51	5.85	0.00	0.003	7	1	16
25	Discoidal Core (This Study)	Quartz	86.4	69.71	61.84	21.39	0.008	0.009	3	0	0
26	Discoidal Core (This Study)	Quartzite	20.1	47.15	28.08	14.56	0.06	0.003	4	1	75
27	Drill (This Study)	Quartz	5.0	27.93	23.10	7.67	0.003	0.003	8	0	0
28	Pointed Flake (This Study)	Quartz	22.2	54.40	41.96	11.87	0.005	0.011	8	0	0
29	Micro Levallois Core (Yellen et al. 2005)	Quartz	14.5	34.18	31.84	15.05	0.00	0.05	13	0	0
30	Burin (Clark and Kleindienst 2001)	Quartz	6.6	37.03	25.26	9.77	0.005	0.003	5	0	0
31	Levallois Core (Yellen et al. 2005)	Quartz	86.1	72.94	55.54	24.17	0.00	0.019	6	0	0
T7	Denticulate Scraper (Clark and Kleindienst 2001)	Quartz	13.5	35.07	30.04	11.59	0.00	0.003	23	0	0
North of T6, surface	Core Axe (Clark and Kleindienst 2001)	Quartz	575.1	147.15	76.86	61.15	0.00	0.2	1	0	0
									208	7	334
									(Type 1: $n=6$; Type 2: $n=1$)		

*Wet Brush
**Ultrasonic Cleaning

above sea level (a.s.l.) is 1 km from the present-day shoreline of Lake Niassa (Malawi). The archaeological site spreads across a ridge that overlooks the Chingamanje River watershed as well as the lake shore, and it sits on the Malawi Rift escarpment. The modern lake water level is at 465 m a.s.l. The site, although a lowland locus, is adjacent to the Lichinga Highlands and the third highest mountain range in Mozambique (Serra Jeci at 1841 m a.s.l). Mikuyu is part of a wider geological formation dated to the middle and late Pleistocene (Geological Survey of Norway, 2004). This formation appears in six spatially discreet, lake-bordering members that run 5–15 km parallel to the modern-day shoreline and cover 1–2 km transversally across on the east shore of the lake, 20–100 m above present-day lake level. At the site of Mikuyu, the flat platform on top of the hill is ideally suited for human occupation because of its proximity to abundant quartz outcrops as well as its elevation of 65 m above the lake and its hinterland. This plateau contains one geological layer with an undulating nature. This layer is 0.6 m thick and it houses a single archaeological horizon (0.3 m thick) with archaeological materials displaying an increase gradient to the east. The excavation of Mikuyu has yielded thousands of artifacts that denote Middle Stone Age affiliation (Clark and Haynes, 1970, Clark, 1995; Tryon et al., 2005; Tryon, 2006). The study of stone tools is on-going, and so far we have identified a quartz-dominated, flake-based industry mostly derived from radial cores. Large cutting tools such as hand-axes and cleavers are absent. Diagnostic stone tools, in order of frequency, include scrapers, points, drills, burins, and geometrics; but also core-axes, picks, hand-axe rough-outs, and small cleavers.

In the lowlands, red soils are shallow, neutral, and they have a silty sand texture (classified as Ferric Lixisols by FOA, 1998; Instituto Nacional de Investigação Agronómica, 1995). In the highlands, red clayey soils have alkaline to acidic pH, and are deep and oxic (also known as Rhodic Ferralsols, FOA, 1998). Mikuyu's sediments are dark yellowish brown. Current pH is slightly acidic

Unclassified morphotypes	Classified morphotypes	Morph. 1	Morph. 2	Morph. 3a	Morph. 3b	Morph. 3c	Morph. 4	Morph. 5	Morph. 6	Morph. 7	Morph. 8	Morph. 9	Morph. 10
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	3	2	0	0	0	0	0	0	0	0	0	0
0	2	1	1	0	0	0	0	0	0	0	0	0	0
0	3	0	0	0	0	0	10	0	0	3	1	0	0
1	6	16	7	2	1	2	1	0	0	0	0	0	0
0	3	1	0	0	0	0	2	0	0	1	0	0	0
2	2	1	1	0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	1	0	0	0	0	0	1
0	4	2	5	0	0	0	0	0	2	0	1	0	0
0	4	3	2	0	0	0	4	2	0	0	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0
0	4	2	3	0	0	0	1	0	3	0	0	0	0
0	5	2	6	0	0	1	0	2	0	1	0	0	0
0	2	2	0	0	0	1	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0
0	2	1	1	0	0	0	0	0	0	0	0	0	0
0	1	3	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	1	0	0	0
0	2	0	1	0	0	0	2	0	0	0	0	0	0
0	4	1	0	0	0	0	1	0	1	1	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0
0	2	2	1	0	0	0	0	0	0	0	0	0	0
1	1	3	0	0	0	0	0	0	0	0	0	0	0
0	3	4	2	0	0	0	0	0	0	0	0	1	0
0	3	1	1	0	1	0	0	0	0	0	0	0	0
1	2	6	4	0	0	0	0	0	0	0	0	0	0
0	3	2	4	0	0	0	2	0	0	0	0	0	0
0	4	1	3	0	0	0	3	1	0	0	0	0	0
1	4	1	2	0	0	0	3	0	0	6	0	0	0
0	3	1	1	0	0	0	3	0	0	0	0	0	0
0	3	1	3	1	0	0	0	0	0	0	0	1	0
0	5	13	4	0	0	0	2	1	3	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0	0	0	0
		73	57	3	3	4	35	6	9	13	2	2	1

to practically neutral (6.3 to 6.7). The excavated archaeological horizon contains<2% organic matter (1.87 at 375°C; loss on ignition; McKeague, 1976) and about 1% of organic carbon (1.09; conversion=0.58×% organic matter). The amount of phosphates and carbonates, as deduced from chemical attack with hydrochloric and nitric acids at 3 normal, is 12%. Sedimentary fabrics reflect low to medium competence as seen in poorly sorted matrix-supported silty sands in which <5% are coarse fractions such as gravels and pebbles (few cobbles reach 100 mm of maximum length). Particle size analysis of the <2 mm fraction (Particle Size Analyser: Malvern, Mastersizer, 2000; Sperazza et al., 2004) indicates a silty sand texture; silts comprise 30–35%. The sand fraction is made up of very fine, fine, and medium sands. Observation under stereo microscopy (Olympus SZX 12, 7–20 magnifications) of clast morphology (Rapp and Hill, 1998: 42) shows that 75% of the population (1–1.9 mm) has sub-prismoidal and sub-spherical geometry; of which 60–80% display subangular and subrounded shapes. These geoarchaeological features show sedimentary environments with variable depositional energies mostly of colluvial nature and associated sheet flow and rain wash. Because small lithics (<20 mm) are very abundant (in excess of 8000 pieces) and no unconformities or erosion features such as scour marks were documented, it must be assumed that high energy currents that would winnow out the fine fractions and create a spread out stone pattern did not sweep across the site.

The study area traverses two different climatic and vegetation zones as it transitions from the lowlands to the highlands. Rainfall in the lowlands totals 600–800 mm per year and 1400 mm in the highlands (Gama, 1990). The dry season spans June to December. Recent inventories of Mozambique's vascular flora (da Silva et al., 2004; Palgrave et al., 2007) document almost 4000 indigenous plants across more than 220 families of which about 150 are dicots. White (1983) includes Niassa in the Sudano-Zambezian phytogeographical region. The province's diverse

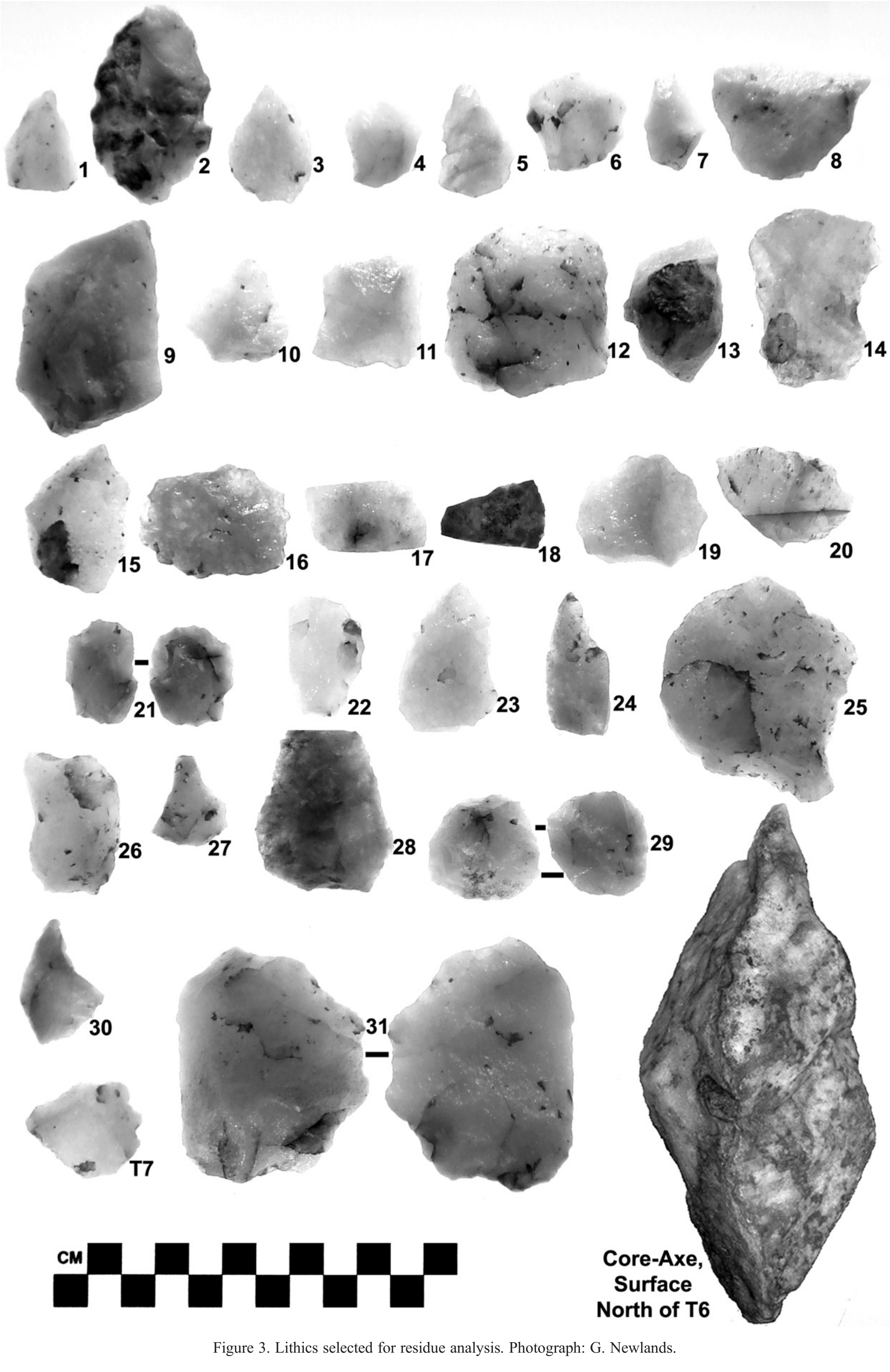

Figure 3. Lithics selected for residue analysis. Photograph: G. Newlands.

Table 2
Modern starch input in the study area

Domain and District	LOWLANDS (Lago district)				HIGHLANDS (Sanga District)		
HABITAT TYPE	Grassy Woodlands				Dense Miombo	Uapaca Forest	Dambo
Location	Chuanga 12° S 40.250′ 34° E 50.127′	Mikuyu, Cassava plot 1 12° 43.6′ 34° E49.6	Mikuyu, Cassava plot 2 12° 43.6′ 34° E49.6	Mikuyu Hill 12° 43.6′ 34° E49.6	Njawala 12° S54.414′ 35° E 09.620′	Road to Malulo 12° S53.469′ 35° E 10.792	Sefo 12° S 57.845′ 35° E 10.381′
Altitude a.s.l. (m)	496	500	500	500	1371	1385	1377
Sample mass	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Granules	2	0	2	3	34	1	4
Monodominant clusters	0	1	2	0	0	0	1
No. of unclassified morphotypes	1	1	1	1	4	1	1
Classified morphotypes	1	0	1	1	1	0	2
Morph. 1	0	0	1	2	0	0	2
Morph. 2	0	0	0	0	0	0	1
Morph. 3a	0	0	0	0	0	0	0
Morph. 3b	0	0	0	0	0	0	0
Morph. 3c	0	0	0	0	0	0	0
Morph. 4	0	0	0	0	0	0	0
Morph. 5	0	0	0	0	0	0	0
Morph. 6	0	0	0	0	0	0	0
Morph. 7	1	0	0	0	0	0	0
Morph. 8	0	0	0	0	3	0	0
Morph. 9	0	0	0	0	0	0	0
Morph. 10	0	0	0	0	0	0	0
	1	0	1	1	1	0	2

Table 3
Starch control samples from Mikuyu excavation

Location	Above arch. horizon	Arch. horizon	Underneath arch. horizon	Arch. horizon (VIII)		
Sample provenance	Column: no. IX	Column: no. VIII (at B2)	Column: no. VII	C3	D2	F1
Sample mass (g)	0.5	0.5	0.5	0.5	0.5	0.5
Granules	0	0	1	1	0	1
Monodominant Clusters	0	0	0	0	0	0
No. Unclassified Morphotypes	0	0	0	0	0	0
Classified Morphotypes	0	0	1	1	0	1
Morph. 1	0	0	0	0	0	0
Morph. 2	0	0	0	0	0	0
Morph. 3a	0	0	0	0	0	0
Morph. 3b	0	0	0	0	0	0
Morph. 3c	0	0	0	0	0	0
Morph. 4	0	0	1	1	0	1
Morph. 5	0	0	0	0	0	0
Morph. 6	0	0	0	0	0	0
Morph. 7	0	0	0	0	0	0
Morph. 8	0	0	0	0	0	0

climate allows for a mosaic of biomes and different broad vegetation types: 1) variably open savannas with a grassy layer and a discontinuous tree cover (Gibbs et al., 1991); 2) woodlands without an interlocking canopy but with some grass cover; 3) Miombo, characterized by a woody layer and a species composition dominated by members of three genera (*Brachystegia, Julbernardia, and Isoberlinia*) from the legume family Fabaceae (Exell, and Wild, 1963; Palgrave, 2002); and 4) forest/thicket, with both evergreen and deciduous species whose crowns and branches often interlock (Timberlake et al., 2004). In Niassa, because of its intermediate geographical and altitudinal location, these vegetation types display floristic connections with western savannas, woodlands, and Miombos from Malawi, Zambia and Zimbabwe (Mapaura and Timberlake, 2004; Phiri, 2005) as well as with forest formations to the north from Tanzania and Kenya (White, 1983; Lovett et al., 1988; Timberlake et al., 2004; Kamwendo, 2005; Hemp, 2006).

Niassa supports the largest conservation area of Miombo on the continent[1] with genera such as *Acacia, Adansonia*

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[1] Ribeiro, N., 2005. Report of the Field Trip to Niassa Reserve, Mozambique. Unpublished report.

Table 4
Starch morphotypes by tool type

	Morph 1	Morph 2	Morph 3a	Morph 3b	Morph 3c	Morph 4	Morph 5	Morph 6	Morph 7	Morph 8	Morph 9	Morph 10	Clusters
Scrapers													
Side Scraper	4	4	0	0	0	1	0	0	0	0	0	1	0
Scraper — Small Convex	1	0	0	0	0	12	0	0	4	1	0	0	0
Core Scraper	2	6	0	0	1	0	2	0	1	0	0	0	0
Circular Scraper	0	1	0	0	0	2	0	0	0	0	0	0	0
Denticulate Scraper	13	4	0	0	0	2	1	3	0	0	0	0	0
Totals by Morphotype	20	15	0	0	1	17	3	3	5	1	0	1	0
Total Number of Granules =	66												
Cores and Core Tools													
Discoidal Core	9	8	0	1	0	1	0	3	0	0	0	0	1 (MNI=75)
Micro Levallois Core	1	3	0	0	0	3	0	0	6	0	0	0	0
Levallois Core	1	3	1	0	0	0	0	0	0	0	1	0	0
Retouched Core Fragment	2	5	0	0	0	0	0	2	0	1	0	0	0
Core Axe	0	0	0	1	0	0	0	0	0	0	0	0	0
Totals by Morphotype	13	19	1	2	0	4	0	5	6	1	1	0	1
Total Number of Granules =	52												
Points													
Levallois Point	0	0	0	0	0	0	0	0	0	0	0	0	0
Point, Mousterian	17	8	2	1	2	1	0	0	0	0	0	0	3 (MNI=205)
Point, Classic MSA	4	2	0	0	0	0	0	0	0	0	1	0	1 (MNI=16)
Point, Thick Base	3	2	0	0	0	4	2	0	0	0	0	0	0
Totals by Morphotype	24	12	2	1	2	5	2	0	0	0	1	0	4
Total Number of Granules =	49												
Flakes													
Levallois Flake — Retouched	2	2	0	0	0	0	0	0	0	0	0	0	0
Flake, Concave Retouch	2	0	0	0	1	0	0	0	0	0	0	0	1 (MNI=12)
Flake	1	0	0	0	0	1	0	1	1	0	0	0	1 (MNI=26)
Pointed Flake	4	3	0	0	0	3	1	0	0	0	0	0	0
Totals by Morphotype	9	5	0	0	1	4	1	1	1	0	0	0	2
Total Number of Granules =	22												
Other Tools													
Drill	3	5	0	0	0	2	0	0	0	0	0	0	0
Burin	1	1	0	0	0	3	0	0	0	0	0	0	0
Backed Blade	3	0	0	0	0	0	0	0	0	0	0	0	0
Trapezoid	0	0	0	0	0	0	0	0	1	0	0	0	0
Totals by Morphotype	7	6	0	0	0	5	0	0	1	0	0	0	0
Total Number of Granules =	19												

Total Number of Individual Grains=208.
Total Number of Grains in Clusters=334.
Total Assemblage=542.

(limited to the drier lowlands), *Albizia, Annona, Brachystegia, Combretum, Cordyla, Isoberlinia, Kirkia, Lonchocarpus, Markhamia, Pseudolachnostylis, Pterocarpus, Securidaca, Sterculia, Terminalia, Treculia,* and *Uapaca* (common in the highlands) (Timberlake et al., 2004). Hydromorphic biomes, grasslands growing on seasonally waterlogged bottomlands known as "Dambos," typically intersperse with woodlands. The most important members of the Poaceae include Panicoids (C_4: *Andropogon, Eleusine, Heteropogon, Hyparrhenia, Hyperthelia, Loudetia, Melinis, Paspalum*), Arundinoids (C_4 *Aristida*; C_3: *Urochlaena*), Bambusoids (C_3: *Lepstaspis*, *Oreobambus*, *Oxytenanthera*) and Chloridoids (C_4: *Chloris*, *Eragrostis*, *Sporobolus*)[1] (Timberlake et al., 2004).

Sample collection procedures and laboratory methods

For this study we chose tools from all main types to take into account the broadest range of potential plant uses: scrapers (27%), cores (22%), points (22%), flakes (12%), and others (17%) (Table 1). We also selected tools from across the entire industrial scatter (Figs. 2 and 3). All samples were subject to minimal handling, and our protocols to avoid contamination are like those used in the majority of ancient starch research (e.g. Loy and Barton, 2006): removal of stone tools directly from the ground — except for instances of tools found in the sieve; use of non-powdered gloves; testing of all working surfaces, instruments, filters, and glassware prior to extraction; boiling of instruments used for analysis, and the isolation of samples and

Table 5
Plant specimens in reference collection

	Family	Genus	Species	Part analysed	Collector's name and no.	Provenance
1	Amaryllidaceae	*Amaryllis*	*belladona*	U.S.O.	De Kock, 105	South Africa
2	Amaryllidaceae	*Brunsvigia*	*radulosa*	U.S.O.	Leitulen, 42A	South Africa
3	Anacardiaceae	*Sclerocarya*	*birrea*	Seed	Rodin, 8962	South Africa
4	Annonaceae	*Annona*	*senegalensis*	Mesocarp	Lovett and Kayombo, 5025	Tanzania
5	Annonaceae	*Annona*	*senegalensis*	Seed	Lovett and Kayombo, 5025	Tanzania
6	Annonaceae	*Cleistopholis*	*glauca*	Pith	Mercader	Eq. Guinea
7	Anthericaceae	*Chlorophytum*	*triflorum*	U.S.O.	Acocks, 19762	South Africa
8	Apocynaceae	*Ceropegia*	*rendalii*	U.S.O.	Louw, 835	South Africa
9	Apocynaceae	*Fockea*	*angustifolia*	U.S.O.	Vorster and Jackson, 2164	South Africa
10	Apocynaceae	*Tabernaemontana*	*elegans*	Mesocarp	Rodin, 4603	South Africa
11	Apocynaceae	*Tabernaemontana*	*elegans*	Seed	Rodin, 4603	South Africa
12	Araceae	*Zantedeschia*	*aethiopica*	U.S.O.	Smook, 8703; Lettis, 1294	South Africa
13	Araceae	*Zantedeschia*	*rehmannii*	U.S.O.	Smook, 8703; Lettis, 1294	South Africa
14	Arecaceae	*Borassus*	*aethiopum*	Pith	Codd and Dyer, 4701	South Africa
15	Arecaceae	*Hyphaene*	*coriacea*	Pith	Rawya, 5305; Wild, 3100; Greenway, 8919	Kenya
16	Arecaceae	*Hyphaene*	*petersiana*	Pith	Rawya, 5305; Wild, 3100; Greenway, 8919	Kenya
17	Arecaceae	*Hyphaene*	*petersiana*	Nut	Rawya, 5305; Wild, 3100; Greenway, 8919	Kenya
18	Arecaceae	*Phoenix*	*reclinata*	Seed	Pope, 42	Zimbabwe
19	Arecaceae	*Phoenix*	*reclinata*	Pith	Pope, 42	Zimbabwe
20	Arecaceae	*Raphia*	*australis*	Pith	Strey and Noll, 3879	South Africa
21	Arecaceae	*Raphia*	*farinifera*	Pith	Wild, 3938	Zimbabwe
22	Asparagaceae	*Asparagus*	*stipulaceus*	U.S.O.	Watt and Brandwyk, 2135	Zimbabwe
23	Asphodelasceae	*Bulbine*	*frutescens*	U.S.O.	Marais, 1010	South Africa
24	Asphodelasceae	*Bulbine*	*sedifolia*	U.S.O.	n/a	unknown
25	Asphodelasceae	*Trachyandra*	*involucrata*	U.S.O.	Euston-Brown, 10/10/99/33	South Africa
26	Balanitaceae	*Balanites*	*maughamii*	Seed	WEJ6 sub J 27982	South Africa
27	Bignoniaceae	*Kigelia*	*africana*	Seed	Donaldson, 11	Swaziland
28	Bombacaceae	*Adansonia*	*digitata*	Mesocarp	Mercader	Mozambique
29	Convolvulaceae	*Ipomoea*	*bolusiana*	U.S.O.	Obermeyer, 40458	South Africa
30	Convolvulaceae	*Ipomoea*	*simplex*	U.S.O.	Mogg, 17399	South Africa
31	Cucurbitaceae	*Acanthosicyos*	*naudinianus*	Seed	Wild, 4764	Zimbabwe
32	Cucurbitaceae	*Coccinia*	*adoensis*	U.S.O.	Veerdorn, 618	South Africa
33	Cucurbitaceae	*Coccinia*	*rehmannii*	U.S.O.	Steyn, 325	South Africa
34	Cucurbitaceae	*Cucumis*	*africanus*	Seed	Quarre, 6859/Q	DR Congo
35	Cucurbitaceae	*Lagenaria*	*siceraria*	Mesocarp	Smith, 1347; Greenway, 5736	Botswana/Kenya
36	Cucurbitaceae	*Luffa*	*cylindrica*	Seed	Smith, 1347; Greenway, 5736	Botswana/Kenya
37	Cucurbitaceae	*Momordica*	*cardiospermoides*	Mesocarp	Chase, 8596	Zimbabwe
38	Cyperaceae	*Cyperus*	*tomaiophyllus*	U.S.O.	Leeuwenberg, 8048	Cameroon
39	Dioscoreaceae	*Dioscorea*	*bulbifera*	U.S.O.	Strey, 7497; Wells, 3781	South Africa
40	Dioscoreaceae	*Dioscorea*	*burkilliana*	U.S.O.	Hladik, 4234	Gabon
41	Dioscoreaceae	*Dioscorea*	*cayenensis*	U.S.O.	SB, 620	Central African Republic
42	Dioscoreaceae	*Dioscorea*	*diversifolia*	U.S.O.	Ward, 6339; Reynolds, 5891	South Africa
43	Dioscoreaceae	*Dioscorea*	*dumetorum*	U.S.O.	Hladik, 4244	Gabon
44	Dioscoreaceae	*Dioscorea*	*mangenotiana*	U.S.O.	Hladik, 5504	Central African Republic
45	Dioscoreaceae	*Dioscorea*	*prahensilis*	U.S.O.	Dounias,91–115	Cameroon
46	Dioscoreaceae	*Dioscorea*	*rupicola*	U.S.O.	Strey, 7497; Wells, 3781	South Africa
47	Dioscoreaceae	*Dioscorea*	*sansibarensis*	U.S.O.	Hladik, 4496	Central African Republic
48	Dioscoreaceae	*Dioscorea*	*schimperiana*	U.S.O.	Dounias, 90–333	Cameroon
49	Dioscoreaceae	*Dioscorea*	*smilacifolia*	U.S.O.	Hladik, 4475	Central African Republic
50	Dioscoreaceae	*Dioscorea*	*sylvatica*	U.S.O.	Ward, 6339; Reynolds, 5891	South Africa
51	Euphorbiaceae	*Ricinodendron*	*rautanenii*	Nut	Loeb, 47063	SW Africa
52	Euphorbiaceae	*Uapaca*	*kirkiana*	Mesocarp	Mercader	Mozambique
53	Fabaceae	*Acacia*	*erioloba*	Legume	Mercader, PRENBG	South Africa
54	Fabaceae	*Acacia*	*erioloba*	Mesocarp	Mercader, PRENBG	South Africa
55	Fabaceae	*Acacia*	*nilotica*	Legume	Leendertz, 439	South Africa
56	Fabaceae	*Acacia*	*sieberiana*	Legume	Banks, 68	Botswana
57	Fabaceae	*Afzelia*	*quanzensis*	Legume	McFerren, 61802	South Africa
58	Fabaceae	*Albizia*	*anthelmintica*	Legume	Codd, 6675	South Africa
59	Fabaceae	*Bauhinia*	*petersiana*	Legume	Van Wyk, BSA 9	Botswana
60	Fabaceae	*Brachystegia*	*spiciformis*	Legume	da Silva, 2843	Angola
61	Fabaceae	*Cajanus*	*cajan*	legume	Liengme, 162	South Africa
62	Fabaceae	*Cassia*	*petersiana*	Legume	Pienaar, 1011	South Africa
63	Fabaceae	*Colophospermum*	*mopane*	Legume	Straub, 697	South Africa

(continued on next page)

Table 5 (*continued*)

	Family	Genus	Species	Part analysed	Collector's name and no.	Provenance
64	Fabaceae	*Cordyla*	*africana*	Legume	Nel, 177	South Africa
65	Fabaceae	*Crotalaria*	*recta*	Legume	Killiam, 13	South Africa
66	Fabaceae	*Delonix*	*regia*	Legume	Mercader	Mozambique
67	Fabaceae	*Dolichos*	*kilimandscharicus*	U.S.O.	Lovett, Sidwell, Kayombo, 3786	Tanzania
68	Fabaceae	*Eriosema*	*preptum*	U.S.O.	Acocks, 13065	South Africa
69	Fabaceae	*Faidherbia*	*albida*	Legume	Gerstner, 6077	South Africa
70	Fabaceae	*Guibourtia*	*coleosperma*	Legume	Breitenbach, 1204	Mozambique
71	Fabaceae	*Lablab*	*purpureus*	Legume	Dlamini, 56193	Swaziland
72	Fabaceae	*Lotus*	*discolor*	U.S.O.	Ward and Rajh, 11691	South Africa
73	Fabaceae	*Macrotyloma*	*axillaris*	Legume	Haycroft, 449210	South Africa
74	Fabaceae	*Mucuna*	*pruriens*	Legume	Glen, 11554	South Africa
75	Fabaceae	*Mucuna*	*spp.*		Mercader	Eq. Guinea
76	Fabaceae	*Pterocarpus*	*angolensis*	Legume	Mercader, PRENBG	South Africa
77	Fabaceae	*Sphenostylis*	*stenocarpa*	U.S.O.	Banda, Chikuni, and Nachamba, 3513	Malawi
78	Fabaceae	*Tylosema*	*fassoglensis*	Legume	De Winter and Leistner, 5596	Namibia
79	Fabaceae	*Vigna*	*lobatifolia*	Legume	100a: Giess, 9875 100b: de Winter, 9182	South Africa
80	Fabaceae	*Vigna*	*lobatifolia*	U.S.O.	100a: Giess, 9875 100b: de Winter, 9182	South Africa
81	Fabaceae	*Vigna*	*unguiculata*	Legume	Van Zyl, B/68/2	South Africa
82	Hyacinthaceae	*Dipcadi*	*marlothii*	U.S.O.	Bradfield, 341	South Africa
83	Hyacinthaceae	*Urginea*	*altissima*	U.S.O.	Dahlstrand, 350	South Africa
84	Hypoxidaceae	*Hypoxis*	*hemerocallidea*	U.S.O.	56a: Jacobsen, 1068; 56b: Robertson, 2150	South Africa
85	Hypoxidaceae	*Hypoxis*	*iridifolia*	U.S.O.	57a: Turner, 1173; 57b: Van Wyk and Van Wyk, 1260	South Africa
86	Hypoxidaceae	*Hypoxis*	*rigidula*	U.S.O.	56a: Jacobsen, 1068; 56b: Robertson, 2150	South Africa
87	Hypoxidaceae	*Hypoxis*	*zeiheri*	U.S.O.	57a: Turner, 1173; 57b: Van Wyk and Van Wyk, 1260	South Africa
88	Iridaceae	*Gladiolus*	*gueinzii*	U.S.O.	53a: Viviers, 1239–53b: Hall, 4659	South Africa
89	Iridaceae	*Gladiolus*	*undulatus*	U.S.O.	53a: Viviers, 1239–53b: Hall, 4659	South Africa
90	Lamiaceae	*Plectranthus*	*esculentus*	U.S.O.	Velcich, 39866	South Africa
91	Lamiaceae	*Solenopithom*	*rotundifolia*	U.S.O.	Gerstner, 4454	South Africa
92	Malvaceae	*Abelmoschus*	*esculentus*	Seed	Monteiro and Murta, 305	Angola
93	Musaceae	*Ensete*	*ventricosum*	Mesocarp	Grewcock, 26435	South Africa
94	Moraceae	*Ficus*	*natalensis*	Mesocarp	Wells and Edward, 37	South Africa
95	Moraceae	*Ficus*	*sur*	Mesocarp	Flanagan, 767	South Africa
96	Moraceae	*Treculia*	*africana*	Mesocarp	Seempas, 27	DR Congo
97	Nymphaeaceae	*Nymphaea*	*caerulea*	U.S.O.	Ellery, 40	Botswana
98	Orchidaceae	*Ansellia*	*africana*	U.S.O.	Verdcourl, 769	Uganda
99	Orchidaceae	*Disa*	*polygonoides*	U.S.O.	Dielerlur, 489	Lesotho
100	Orchidaceae	*Satyrium*	*macrophyllum*	U.S.O.	Pegler, 395B	South Africa
101	Pandanaceae	*Pandanus*	*livingstonianus*	Pith	Chase, 2988	Mozambique
102	Poaceae	*Aristida*	*junciformis*	Caryopsis	Arnold	South Africa
103	Poaceae	*Arundinaria*	*alpina*	Pith	Schum, 7470	DR Congo
104	Poaceae	*Chloris*	*virgata*	Caryopsis	Gubb, 296–44	South Africa
105	Poaceae	*Digitaria*	*brazzae*	Caryopsis	Smith, 2228	Botswana
106	Poaceae	*Echinochloa*	*stagnina*	Caryopsis	Volk, 30723	SW Africa
107	Poaceae	*Eleusine*	*africana*	Caryopsis	Emson, 87	Tanzania
108	Poaceae	*Eragrostis*	*aspera*	Caryopsis	Pedrogoa, 879	Mozambique
109	Poaceae	*Eragrostis*	*racemosa*	Caryopsis	Arnold	South Africa
110	Poaceae	*Oreobambus*	*buchwaldi*	Pith	Christiaensen, 2471	Burundi
111	Poaceae	*Oxytenanthera*	*abyssinica*	Pith	Balsinhas and Marrime, 343	Mozambique
112	Poaceae	*Panicum*	*novemnerve*	Caryopsis	Smook, 9910	Namibia
113	Poaceae	*Pennisetum*	*purpureum*	Caryopsis	de Lemos and Macuacua, 23	Mozambique
114	Poaceae	*Setaria*	*spp.*	Caryopsis	Arnold	South Africa
115	Poaceae	*Sorghum*	*spp.*	Caryopsis	Mercader	Mozambique
116	Poaceae	*Sorghum*	*versicolor*	Caryopsis	Giess, 15079	SW Africa
117	Poaceae	*Sporobolus*	*panicoides*	Caryopsis	Fourie, 2541	South Africa
118	Poaceae	*Urochloa*	*mosambicensis*	Caryopsis	Torre and Paiva, 9255	Mozambique
119	Polygonaceae	*Polygonum*	*senegalense*	U.S.O.	Ward, 5945	South Africa
120	Proteaceae	*Protea*	*welwitschii*	U.S.O.	Davidse, 5982	South Africa
121	Ranunculaceae	*Ranunculus*	*multifidus*	U.S.O.	Hanekom, 2192	South Africa
122	Rubiaceae	*Canthium*	*mundianum*	Seed	Burrows and Burrows, 6599; Ward, 2672	South Africa
123	Rubiaceae	*Coffea*	*racemosa*	Seed	Burrows and Burrows, 6599; Ward, 2672	South Africa
124	Sapotaceae	*Englerophytum*	*magalismontanum*	Mesocarp	De Winter, 7533	South Africa
125	Strelitziaceae	*Strelitzia*	*nicolai*	Seed	Curator NH 50000 (PRE)	South Africa
126	Strychnaceae	*Strychnos*	*spinosa*	Seed	Buitendag, 858	South Africa
127	Strychnaceae	*Strychnos*	*spinosa*	Mesocarp	Buitendag, 858	South Africa
128	Taccaceae	*Tacca*	*leontopetaloides*	U.S.O.	Philcox, Leppard, and Dini, 8600	Zimbabwe

Table 5 (*continued*)

	Family	Genus	Species	Part analysed	Collector's name and no.	Provenance
129	Typhaceae	*Typha*	*capensis*	U.S.O.	Jacobsen, 2750	South Africa
130	Ulmaceae	*Celtis*	*africana*	Seed	Meyer, 1032	South Africa
131	Zamiaceae	*Encephalartos*	*fridericiguilielmi*	Pith	Mercader, PRENBG	South Africa
132	Zamiaceae	*Encephalartos*	*laevifolius*	Pith	Mercader, PRENBG	South Africa
133	Zamiaceae	*Encephalartos*	*lebomboensis*	Pith	Mercader, PRENBG	South Africa
134	Zamiaceae	*Encephalartos*	*natalensis*	Pith	Mercader, PRENBG	South Africa
135	Zamiaceae	*Encephalartos*	*princeps*	Pith	Mercader, PRENBG	South Africa
136	Zamiaceae	*Encephalartos*	*senticosus*	Pith	Mercader, PRENBG	South Africa
137	Zamiaceae	*Encephalartos*	*villosus*	Pith	Mercader, PRENBG	South Africa

Note. U.S.O. Underground Storage Organ.

specimens in separate sealed plastic bags or aluminum foil. We used multiple lines of control samples to test whether the residue from the tools studied here was the primary source of starch, rather than random contamination. We have compared starch grains from stone tools to those recovered off-site in modern soils ($n=7$) from across the region in four habitat types (Table 2). We also compared granules from the stones to granules found on-site in matrices above, beneath, and within the archaeological horizon, but not in contact with the archaeological specimens ($n=6$; Table 3). The collection of modern soils was carried out by placing transects across the habitat type to be studied. In the central part of it, an area of 1 m^2 was cleared of litter and one cm of the topsoil was scraped across the entire cleared area. Prehistoric sediments were sampled horizontally and vertically: aerial units covered 10 cm × 5 cm.

For starch analysis, we processed 33 lithics previously identified as formal tools from a typological standpoint (Table 4). Because many lithic specimens were unwashed we tried to see any residue directly on the stone tool surfaces under the stereomicroscope (Olympus SZX 12) but, like other researchers before us (Pearsall et al., 2004: 427), we found this procedure to be unproductive because of 1) masking by fine sediment, 2) reflectivity of the raw material (Wadley and Lombard, 2007: 1003); despite microscopy in dark field. We did not perform probe, spot sampling (Piperno and Holst, 1998: 768; Perry, 2004: 1074) or conventional use-wear analysis (Barton et al., 1998; Hardy et al., 2001; Lombard, 2005). Following a slightly modified procedure first presented by Pearsall et al. (2004: 427), we jet-bathed the stone tool with deionized water to ensure that no loose sediment would remain on its surface. This sediment in contact with the stone was analyzed separately and termed Wet Brush (WB). If stone tools were not collected directly from the ground, but found in the sieve, then no jet-bathing took place. A second set of residue was obtained through sonication (S), in which tools were subject to ultrasonic cleaning (unit: VWR, 750HT) for 15 min. The resulting residue was then allowed to concentrate and dry by natural evaporation. The mean weight of dry, sonicated residue is 0.008 g (all masses in this study were measured by a high-precision balance: Ohaus, Voyager Pro, Model no. VP413CN). In contrast, weight for free-standing matrices (control samples) is 0.5 g, which is 71.5 times the weight of the average residue obtained from stones through sonication. Extraction of starch from wet-brushed and sonicated sediments follows the methodology originally devised by Zarrillo and Kooyman (2006), with minor modifications (Mercader et al., 2007). Microscopy was employed to study starch (System Microscope, Olympus BX51: 400 magnifications) under polarized light, regular light microscopy, and Differential Interference Control (D.I.C.); which greatly enhances contrast and resolves fine structural details (e.g. Barton, 2005; Fullagar et al., 2006).

Ethnobotanical work carried by our team with the guidance of traditional doctors and people knowledgeable of local plants as well as that of other researchers (Morris, 1996; Venter and Venter, 1996; van Wyk and Gericke, 2000; Palgrave, 2002; Williamson, 2005) shows the plant parts currently used in Southern, Eastern, and Central Africa by traditional groups for carbohydrate extraction. We employed this baseline to guide the collection of local and herbarium specimens that constitute our reference collection. We used the resources from the largest herbarium in Africa (Pretoria, PRE; with>1,200,000 specimens; Victor et al., 2004). Using established herbaria as a source of reference material adds significant methodological strength through a systematic access to a much wider geographical referential, to rare plants, to taxa that were not readily available locally at the time of research, and to positively identified specimens. Matching of archaeobotanical specimens was secured by comparison with the African starch comparative collection housed at the Tropical Archaeology Laboratory, University of Calgary. The list of plant specimens used as reference materials for this study appears in Table 5. Our collection consisted of 129 species (96 genera) spread across 39 families found in dry forests, woodlands, and savannas from 18 sub-Saharan countries.

Starch analysis

Description of assemblages

On the basis of grain characteristics observed under microscopy the analyst estimates the botanical source. We described and quantified granules according to three dimensional shapes, bi-dimensional descriptors, surface textures (volumetric features), "Maltese cross" morphology and centricity under polarized light, as well as mean size and metric range (Table 1). A compilation of morphological features and other relevant classification data appear in Table 6 and Figure 4. The total number of granules is 208. An additional 334 grains from clusters forms a total

Table 6
Starch morphometrics, and estimated plant parts and families present in the archaeological sample

Type	3-D descriptor	2-D descriptor	Surface texture	Surface features	Arm morphology	Arm centricity	Mean max. length	Size range	*N*	Plant part	Producing families
1	Lenticular planoconvexe, biconvexe	Ellipsoid to orbicular	Lamellae, psilate	Slit, depression, Y, X, pocking, slit along edge	Diffuse, straight	Centric	23.52±6	8–36.6	73	**Seed**, legume, mesocarp	**Fabaceae**, Malvaceae, Apocynaceae
2	Subrounded parallelepiped	Suborbicular	Psilate, irregular	Slit, Y,V,T, stellated fissures	Sharp, straight, bent	Centric, slightly eccentric	17.2±3.5	11.5–28.7	57	**Caryopsis**, **legume**, mesocarp, pith, USO	**Fabaceae**, **Poaceae**, Strychnaceae, Apocynaceae, Cyperaceae
3a	Pear-shaped; one taper end	Ellipsoid	Lamellae, Psilate	Eccentric cuneiform slit	Sharp, Curved	Eccentric	41.1±10.3	30.2–42.4	3	**Pith**	**Arecaceae**
3b	Pear-shaped	Ovate	Lamellae	Eccentric slit °<	Sharp, straight, curved	Eccentric	60.7±14.1	51.2–77	3	**USO**	**Amaryllidaceae**
3c	Oblong sphere	Ellipsoid	Lamellae, psilate	Fissures, slit V	Sharp, curved	Eccentric	63.4±12.4	52.3–80	4	**Pith**	**Arecaceae**
4	Sphere; hemisphere	Orbicular, ellipsoid	Lamellae, psilate	Centric vacuole, fissure, pressure facets	Sharp, straight, curved	Centric, slightly eccentric	9.7±2.3	6.2–14	35	**Mesocarp**, pith, USO	**Bombacaceae**, Annonaceae, Cucurbitaceae,
5	Oblong sphere	Orbicular, ellipsoid	Lamellae, psilate	Centric fissuring ~, pressure facets	Sharp, straight, bent	Centric	21.1±4.2	15.7–26.3	6	**USO**, **legume**	**Polygonaceae**, **Fabaceae**
6	Tear drop	Subtriangular	Psilate	Featureless, centric vacuole	Sharp, curved, bent	Eccentric	9.5±1.5	7.0–12.0	9	**USO**	**Araceae**
7	Hemisphere, hyperhemisphere	Plano-ovoid	Psilate	Vacuole, pressure facets	Sharp, straight, curved, bent	Eccentric, centric	11.6±2.9	8.7–15.8	13	**USO**, legume, nut, **mesocarp**	**Fabaceae**, Lamiaceae, Arecaceae, **Annonaceae**
8	Pear-shaped	Ovate	Psilate	Featureless	Sharp, straight	Eccentric	18.5±3.1	16.3–20.8	2	**USO**, seed, pith	**Asphodelasceae**, **Nymphaeaceae**, Strychnaceae, Zamiaceae
9	Oblong sphere	Ellipsoid	Psilate, irregular	Centric fissuring ~	Diffuse, straight	Centric	22.3±6.7	17.6–27.1	2	**Legume**	**Fabaceae**
10	Bell-shaped	Subtriangular	Psilate	Centric vacuole, fissure, pressure facets	Sharp, curved, bent	Eccentric	28	28	1	**Pith**, USO	**Arecaceae**, Apocynaceae, Taccaceae, **Zamiaceae**

Bold captions indicate the plant part and family considered by the authors to be the most likely or abundant source of starch found in this study.

assemblage amounting to 542 grains. The mean number of classified morphotypes per stone tool is 2.6 (range: 1–6). Average number of unclassified morphotypes per tool is 0.18 (range: 1–2). Mean number of granules per tool is 6.3 (range: 1–30). Average mass per lithic sample is 21.3 g (range: 3.6–86.4 g). Mean maximum length of stone tools is 43 mm. The mean surface area per stone tool exposed to the matrix in which it was buried is 23 mm^2 (range: 11.5–45 mm^2). All 33 lithics represent a combined aerial surface of 738 mm^2, which implies that, on average, every 2 mm^2 per stone tool support 1 starch granule. All stone surfaces are quartz, except for two instances (chert, quartzite).

Clusters aside, only counting discreet, free-standing granules, we note that six stone tools yielded 0–1 granules, and an additional 15 tools yielded totals below average (<6 granules per tool). The remainder ($n=12$) were rich tools (ID no. 4, 5, 9, 10, 12, 13, 24, 27, 28, 29,31, and T7) for they yielded numbers above average; including three scrapers, four points, three cores, and one drill (Table 4). Seven of these rich lithics have masses and maximum lengths below average. We retrieved a total of seven clusters that may come from a single plant source. Six out of seven clusters represent one morphotype alone (Type no. 1). Two lithics classified as "points" support one or more clusters and also a high number of discreet granules while several tool types support the opposite trend: a high number of clusters, but low numbers of discreet granules. The morphotypes represented in these clusters and those represented by individual granules are not always the same. Moreover, the starch assemblages on stone tools are polytypic. In relation to lithic types, we note that scrapers provide 31.75% of the starch, followed by cores (25%), points (23.55%), flakes (10.59%), and other tools (9.13%). In all types the highest numbers belong to morphotypes 1 and 2, and only scrapers/flakes sustain a high proportion of morphotype 4; yet, in lower frequencies, all tool types support a variable number of morphotypes other than 1, 2, and 4 (range: 2–7).

Starch preservation in this assemblage is variable. About 30% of the assemblage is well preserved, displaying starch grains with features that resemble those seen in fresh specimens. The rest (~70%) suffers from at least one type of alteration (Table 7). The most common patterns are the disruption of the "Maltese cross" and a partial darkening. The least frequent types are pitting, breakage, and burrowing. Two morphotypes (no. 1, 2) exhibit all or almost all types of modifications, while eight (no. 3 through 10) show some alterations but not others. Morphotype no. 1 supports 40% of the individual number of instances in which alterations were recorded, and morphotype number two 22%. Morphotype no. 1 is less vulnerable to damage when preserved in clusters.

Starch input by local plants into the regional topsoils of four habitats (seven loci across highlands and lowlands) (Table 2) indicates that modern starch content in free-standing matrices is low: 0–4 grains, although one sample yielded 34 grains. Modern soils support several unclassified morphotypes, clusters are common, and two main morphologies associate: lenticular and tabular. After calculating equivalent weights we noticed that the mean number of granules on stone tools is 12 times larger than that retrieved from modern, off-site soils. The diversity of morphotypes seen on stone tools is also three and half times larger. Furthermore, most morphotypes from stone tools do not appear in modern soils, and in two instances ("Mikuyu cassava plot 1" and "Uapaca forest") none of the ten morphotypes seen on archaeological specimens is present in off-site topsoils. Additional controls consisted of free-standing sediments on-site. These samples came from immediately above the archaeological horizon, from the archaeological horizon itself at four locations, east/west, across the whole archaeological scatter (B2, C3, D2, and F1), and immediately underneath the archaeological horizon. Fifty percent of these samples tested negative ($n=0$) and the rest provided little starch (morphotype no. 4). The equivolumetric conversion of masses indicates that the average number of grains on stone tools is 1000 times larger than the average number in the site's sediments.

Taxonomic matching of prehistoric starch to reference collection materials

Although the discovery of a large starch assemblage on Middle Stone Age lithics is, on its own, of great archaeological and methodological significance, more interesting are the morphotypes that are known today to be produced by specific families, genera, and species. The identification of starch granules, however, is not straightforward. Redundancy and multiplicity were observed during the study of our reference collection. We provide granule identifications for ancient starch only if the several morphotypes produced by a certain plant part and species concur in a prehistoric target. For the sake of completeness the reader is also presented with an alternative identification for decontextualized, isolated types (see below).

Mikuyu's starch typology appears in Figure 4. Based on the geographical focus of this paper, the analogy with our modern reference collection, and published data, the taxonomic interpretation of Mikuyu's starch types is as follows: Type 1 is a hard endosperm starch which can be found in nuts, seeds, and grains. It, sometimes, associates with type 2. We have documented type 1 in *Delonix regia*'s legume (Fig. 4A) and in the caryopsis from *Sorghum spp*. It has also been documented in the seeds from *Abelmoschus esculentus* and in the mesocarp from *Tabernaemontana elegans*. Type 2 is a hard endosperm starch from nuts, seeds, and grains. It supports four variants, and together these four subtypes form a consistent, cohesive diagnostic type set that allows for the identification of cereals such as *Sorghum bicolor*. The most common variant (Type 2a) appears in sorghum (Fig. 4B1); but also in the endosperm from *Acacia erioloba*'s legume, the pith from *Oxytenanthera abyssinica*, the seed from *Strychnos spinosa*'s fruit, and the mesocarp from *Tabernaemontana elegans*. The second variant (Type 2b) consists of parallelepiped subspheres with tabular cross section which is part of the Sorghum type set but can also be found in the USOs from *Eriosema preptum* (Fig. 4B2) and the caryopsis from *Sporobolus panicoides*. A third variant from Type 2 (subspheres supporting a deeply incised Y or T at the hyllum) is found in sorghum and, alternatively, in the USO from *Cyperus tomaiophyllus* (Fig. 4B3). Type 2d is represented by subspheres with a sulcated surface that is common, but not exclusive, in the caryopsis of *Sorghum versicolor* (Fig. 4B4).

The study of our reference collection establishes that Types 3A and 3C are best described as trunk starch granules similar to those seen in the Asian swamp sago palm (Barton, 2007: 1756, Fig. 2). The closest taxonomic match for the several subtypes that fall under this category (3A,3C) is found in the African wine palm: *Hyphaene petersiana* (Figs. 4 C1–C3). Type 3B is exclusive to the bulb from *Amaryllis belladonna* (Fig. 4C2). Type 4 is mostly a mesocarp starch (*Adansonia digitata* — Figure 4 D, *Annona*

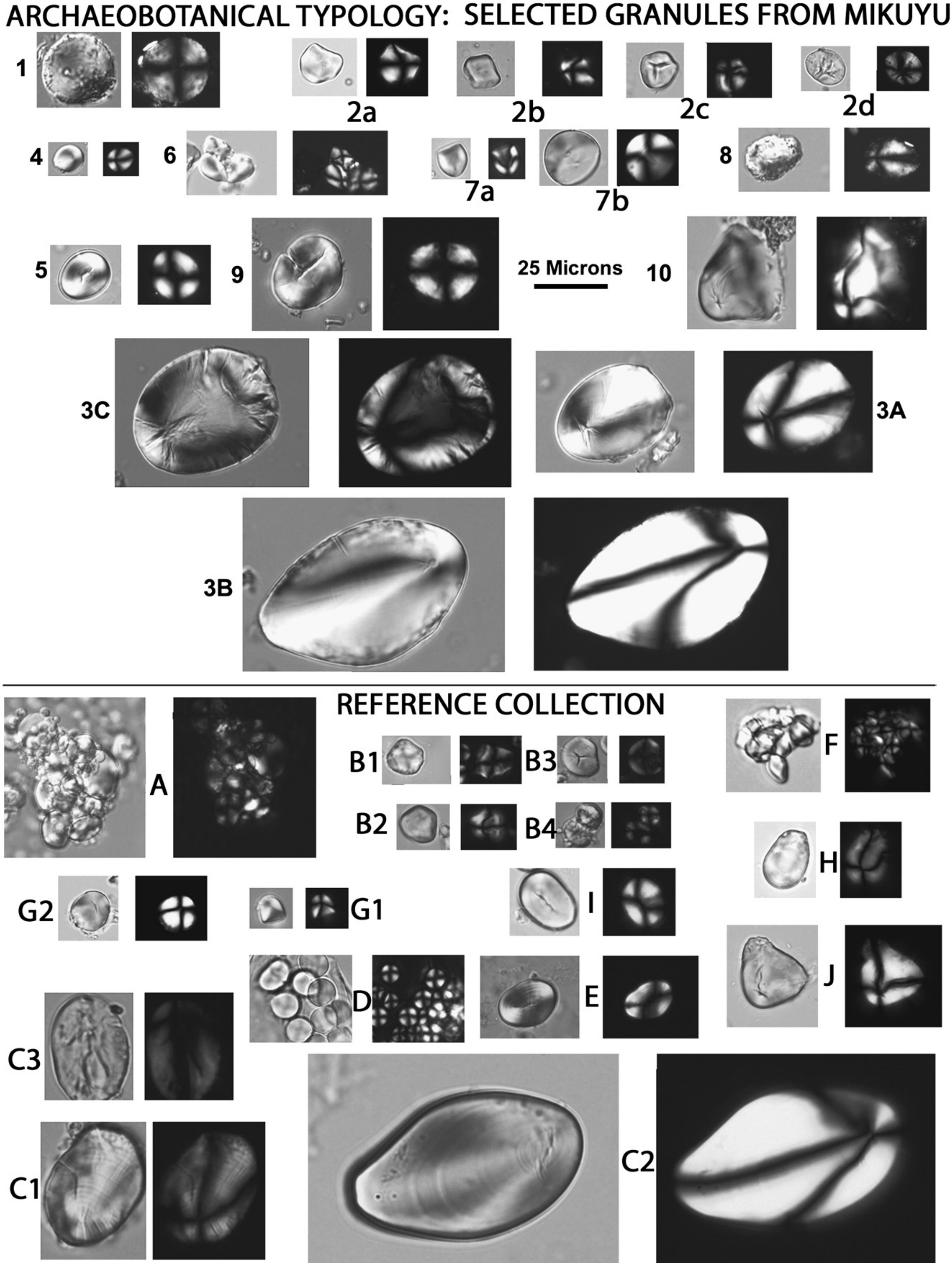

Table 7
Types of starch alteration

Morphotype	Cross barely visible	Arm disruption	Darkening	Incoming fissures	Granulation	Pitting	Creasing	Breakage	Burrowing
1	9	11	14	5	5	3	8	1	1
2	2	8	11	4	5	1	1	0	0
3A	0	2	0	0	0	0	3	0	1
3B	0	2	1	1	0	0	1	0	0
3C	1	4	3	1	0	0	1	2	0
4	0	1	1	1	4	0	1	0	0
5	0	2	2	0	0	0	0	0	0
6	0	1	1	0	0	0	0	0	0
7	0	2	3	0	1	0	0	0	0
8	0	1	0	0	1	1	0	0	1
9	0	1	2	2	0	0	0	2	0
10	0	0	0	0	0	0	0	0	0
SUBTOTALS	12	35	38	14	16	5	15	5	3

senegalensis, Lagenaria siceraria), but it is occasionally detected in USOs (*Coccinia adoensis*, *Hypoxis rigidula*, and *Hypoxis zeiheri*). Types 5 (*Vigna lobatifolia*) (Fig. 4E) and 9 (*Cajanus cajan, Faidherbia albida*) (Fig. 4I) are almost exclusively legume starches; yet, type 5 may occur in the USO from *Polygonum senegalense*. Type 6 has been documented in the USO from *Zantedeschia rehmannii* (Fig. 4F). Type 7 appears in the USOs from *Lotus discolor* (Fig. 4G1) and *Plectranthus esculentus*. It is present in the endosperm from *Cordyla africana*'s legume and in the nut from *Borassus aethiopum*. An additional variant of type 7 consists of smooth hyper-hemispheres whose correlate is found in the mesocarp from *Annona senegalensis* (Fig. 4G2). Type 8 is found in the USOs from *Bulbine sedifolia* and *Nymphaea caerulea*. It is also seen in the seed from *Strychnos spinosa*, and in the pith from *Encephalartos villosus* (Fig. 4H). Lastly, type 10 appears in the pith from *Hyphaene petersiana* (Fig. 4J), but similar shapes are found in the USOs from *Ceropegia rendalii* and *Tacca leontopetaloides* and the trunks of *Encephalartos fridericiguilelmi* and *Encephalartos natalensis*.

Discussion and conclusions

There is good reason to maintain a healthy skepticism about the behavioral interpretation of so-called plant "micro-fossils" from open air sites because there is so much of the geological, diagenetic, taphonomic, and food-processing history of ancient starch assemblages that the archaeologist does not know or remains untraceable. Yet, our multiple lines of evidence indicate that Mikuyu's granules derive from genuine prehistoric plant residue. Moreover, starch assemblages from open-air sites establish a benchmark against which future work from deep cave settings can be tested.

Although the taphonomic processes leading to the long-term preservation of crystalline, water-insoluble polymers are not understood in terms of enzyme digestibility and the millennial scale implied in Paleolithic archaeology, Haslam (2004: 1719–1720) has shown that without protection from enzymatic attack, starch cannot survive in free-standing matrices for long periods of time. It is possible that the sheltered loci provided by micro-crevices in various rocks may provide protection (Piperno et al., 2000: 896). Some authors, however, do not consider stone cavities and pores to be taphonomic mechanisms on their own (Barton, 2007: 1753), rather than just residue traps which do not explain how starch escapes hydrolysis. In a cogent review of bacterial gene transfer in the environment, Lorenz and Wackernagel (1994: 573–577) elucidate the factors favoring organic molecule preservation in soils, sediments, and on the surfaces of various minerals, including quartz. From this perspective, adsorption is the key (for starch preservation); as a process leading to the creation of a molecular film over the stone surfaces. Once adsorption (or transfer from a semi-fluid state to a rigid one) is complete the utilization of the adsorbate by microbes is retarded or abolished. Other factors that may be conducive to the long-term preservation of starch are the site location and the particle size prevalent in the matrix where stone tools have been buried. At Mikuyu, the high location of the site in the landscape partly determined the low contents of organic

Figure 4. For the reader to see a clear relationship between ancient starch from the archaeological assemblage and close matches from the reference collection we have divided our plate in two parts: archaeobotanical (top) and reference (bottom). In addition, numbers representing the archaeolobotanical types are correlated with their alphabetical counterparts from the reference collection. Therefore, archaeobotanical type 1 can be correlated with reference type A: *Delonix regia* (collecter Mercader, Niassa, Mozambique); archaeobotanical type 2a can be correlated with reference type B1: *Sorghum bicolor* (collector Mercader, Mozambique); archaeobotanical type 2b can be correlated with reference type B2: *Eriosema preptum* (collector Acocks, 13065); archaeobotanical type 2c can be correlated with reference type B3: *Cyperus tomaiophyllus* (collector Leeuwenberg, 8048); archaeobotanical type 2d can be correlated with reference type B4: *Sorghum versicolor* (collector Giess, 15079); archaeobotanical types 3a and 3c can be correlated with reference type C1 and C3: *Hyphaene petersiana* (collector Wild, 3100); archaeobotanical type 3b can be correlated with reference type C2: *Amaryllis belladonna* (collector De Kock, 105); archaeobotanical type 4 can be correlated with reference type D: *Adansonia digitata* (collector Mercader, Mozambique); archaeobotanical type 5 can be correlated with reference type E: *Vigna lobatifolia* (collector Giess, 9875); archaeobotanical type 6 can be correlated with reference type F: *Zantedeschia remahnnii* (collector Lettis, 1294); archaeobotanical type 7a can be correlated with reference type G1: *Lotus discolor* (collector Ward and Rajh, 11691); archaeobotanical type 7b can be correlated with reference type G2: *Annona senegalensis* (collector Lovett and Kayombo, 5025); archaeobotanical type 8 can be correlated with reference type H: *Encephalartos villosus* (collector Mercader, PRENBG); archaeobotanical type 9 can be correlated with reference type I: *Faidherbia albida* (collector Gerstner, 6077); archaeobotanical type 10 can be correlated with reference type J: *Hyphaene petersiana* (collector Wild, 3100).

matter and this alone could have brought about a reduced microbial attack. Because the matrix that encapsulated the quartz tools contain high proportions of silt (a particle size which makes possible a rapid molecular binding), Mikuyu's taphonomic setting would have been less hospitable to enzymatic degradation (Lorenz and Wackernagel, 1994). Haslam's (2004) observation that unbound starch gets destroyed quickly leads to another important observation: not many granules exist in flux within the matrix, but bound and immobilized. This alone deflates doubts about the authenticity of the residue because of modern transfer of free starch through the sediment column onto the lithics is not possible without direct contact (Williamson, 2006: Box 5.4). Should a fortuitous transfer be the main starch source, we would expect a direct correlation between tool aerial surface and starch richness. However, there are many examples of very small lithics containing more granules than larger tools. There is also the higher occurrence of starch on artifacts than in surrounding sediments and soils (Barton et al., 1998). If contamination was the most significant depositional agent, there should be a qualitative similarity between control and lithic samples. Moreover, the starch from control samples is typologically different and less diverse than its prehistoric counterpart.

We cannot assure that starch from stone tools represents direct tool function, for we have not carried out use-wear analysis, but we feel confident that the Middle Stone Age lithics from Mikuyu were exposed to starch-rich materials by either usage in the processing of foodstuff, ancient transfer of starch as a consequence of tool handling with hands that had starch on them, or by accidental direct contact with plant parts that were consumed at the site. Activities such as woodworking and hafting may also be responsible for contributing starch to the assemblage. Starch was extracted and processed with a diverse tool kit consisting of scrapers, cores, points, flakes, and other kinds of tools. The microbotanical data suggests the use of seeds, legumes, caryopses, piths, underground storage organs, nuts, and mesocarps from more than a dozen families. They represent sorghum grains, starchy sap, trunk flour, pigeon peas and beans as well as root crops. Whereas some of these plant parts are available only during specific times of the year, others can be obtained over a long period of time. These two types complement each other from a seasonal scheduling point of view. It is clear that an understanding of seasonal and phenological schedules was necessary to collect grains or fruits, while the extraction of tubers entailed time-consuming tasks and labor-intensive extraction (Dounias, 1993). The food value of some of the documented plants is well known. Many plants were once used for food, even though some of the starch sources documented here have now fallen in disuse and are toxic without pertinent removal of toxins through fire or other means. For example, cycads provide a high quality trunk starch that, nonetheless, has poisonous properties. Detoxification of flour is a lengthy complicated procedure (Thierret, 1958). The punching of Arecaceae trunks with pointed tools to access the pith from *Hyphaene petersiana* denotes an ancient manipulation of sap; one that in modern times is carried out to produce palm wine. In sum, the Middle Stone Age groups from Niassa had an expanded starch diet and practiced a related intensification. This signifies a fully modern behavioral pattern of food acquisition that somewhat parallels Later Stone Age practices.

Acknowledgments

This work could have not been accomplished without Arianna Fogelman, Lourenço Thawe, Justin Sondergaard, Sofia Sondergaard, and the numerous workers, friends, and authorities in Niassa. The authors thank the Dept. of Anthropology and Archaeology at Eduardo Mondlane University for the support, collegiality, and encouragement especially Professors Hilário Madiquida and Solange Maçamo. Work in Niassa was conducted under two permits to Julio Mercader from Eduardo Mondlane University and the Ministry of Education and Culture (03-2003 and 01-2007). Temporary export of materials was conducted under "Certificate of Origin no. 0134" from the Mozambican Chamber of Commerce, as well as the "Export License no. 24399" from the Mozambican Customs Service. We thank the Canada Research Chairs program and the Canada Foundation for Innovation for making much of this research possible through generous grants and research endowments (CFI grant no. 201550) to the lead author and the Tropical Archaeology Laboratory at the University of Calgary, the Faculty of Social Sciences, Dept. of Archaeology, and various internal programs at the University of Calgary made available financial and logistical support to the author. The Social Sciences and Humanities Research Council of Canada (File no. 410-2007-0697; CID: 148244), as well as the American Embassy in Maputo (Ambassador's Fund for Cultural Preservation) assisted this project with essential monetary aid. The Department of Anthropology at the George Washington University and the Human Origins Program at the Smithsonian Institution provided institutional support. A. Hladik kindly provided us with *Dioscorea* samples from several countries. The South African National Biodiversity Institute, specifically the Pretoria Herbarium, provided us with invaluable plant reference material, books, advice, specimen identification services, and a friendly and efficient work environment. We thank Richard Fullagar for his comments.

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