

**Supplementary Information
For:**

Chapter 33

**Lower Bed II Olduvai Basin, Tanzania: Wetland sedge taphonomy, seasonal pasture, and
implications for hominin scavenging**

Charles R. Peters, Marion K. Bamford and John P. Shields

SI Part 1: Rainfall data for the Seekoeivlei Nature Reserve, South Africa, 1995-2011

This section details the rainfall levels of the modern wetland ecosystem on which the observations to inform the fossil marshland taphonomy of Lower Olduvai Bed II were based. Several years of monthly rainfall data were available for the rainfall gage at the District Government Office of the Seekoeivlei Nature Reserve in the town of Memel, Free State Province, South Africa, located a few kilometers south of the Klip River wetlands of Seekoeivlei on a rise between tributaries of the Klip River.

SI Table 1. Monthly rainfall (mm) at the Seekoeivlei Nature Reserve conservation headquarters in Memel, South Africa from 1995-2011. Under the southern hemisphere summer-rain climate the annual ecological calendar runs from July of one year through June of the following year. (Monthly totals with a 0.5 mm value have been rounded upward to 1.0 mm).

<i>From year</i>	<i>J</i>	<i>A</i>	<i>S</i>	<i>O</i>	<i>N</i>	<i>D</i>	<i>J</i>	<i>F</i>	<i>M</i>	<i>A</i>	<i>M</i>	<i>J</i>	<i>To year</i>	<i>Total</i>
2010	0	1	0	124	126	232	329	49	36	76	11	22	2011	1006
2009	0	66	38	123	70	232	251	58	56	125	0	0	2010	1019
2008	0	0	0	33	142	140	196	142	173	8	0	28	2009	862
2007	0	0	23	199	91	130	165	85	121	30	23	27	2008	894
2006	0	30	13	41	99	185	47	15	89	49	0	17	2007	585
2005	40	48	0	89	147	50	329	133	68	42	18	0	2006	964
2004	34	6	5	32	64	164	243	178	141	50	2	0	2005	919
2003	0	28	10	26	161	65	109	138	90	10	0	2	2004	639

2002	4	44	41	42	27	154	90	33	38	19	10	26	2003	528
2001	0	2	75	100	77	82	195	65	17	14	21	22	2002	670
2000	0	1	32	105	100	160	56	96	61	24	13	12	2001	660
1999	0	0	7	68	109	185	149	117	46	56	61	10	2000	808
1998	2	1	17	52	151	126	63	37	39	23	34	5	1999	550
1997	10	8	44	69	152	63	115	76	51	13	0	0	1998	601
1996	0	0	20	148	34	139	127	6	134	38	70	42	1997	758
1995	1	4	0	99	198	229	249	284	74	70	53	2	1996	1263

SI Part 2: The seasonal wetland root mat as a barrier and a net

This section describes the plant characteristics of the marsh root mat observed for the modern seasonal wetland at Seekoeivlei Nature Reserve, which is used to interpret the fossil evidence from Olduvai George, Tanzania. The two main structural components of the root system are perennial underground stems (rhizomes) and the roots that grow from them. (The exception to this is *Persicaria* which has a small tap root.) The rhizomes, with diameters of 2 mm to 1 cm, act as a kind of dense endoskeleton for the mat, ca. 2-10 cm below the ground surface. Its main roots are 0.5-2 mm in diameter. Branching off from these are numerous smaller roots and rootlets. Across the floodplain this root system forms a virtually continuous dense root mat from the surface to 5-7 cm below ground, which is underlain by a less dense subsystem of roots (10-15 cm farther down), with a few occurring at least as deep as 50 cm. This root system exists even under sparsely vegetated or temporarily bare patches of ground.

This root mat and its associated network of underground stems acts as a barrier to litter burial. This was surprising, since we presumed that the hooves of the equids buried pieces of litter by driving them down into the moist mud. In the relatively dry rainy season of 2002-2003 (see SI Table 1) the entire floodplain surface was exposed as a hoof-printed field, with some prints as large as 14-18 cm in diameter and 9-15 cm deep. Often mud was squeezed up to form rims around the hoof-print. In certain cases, hoof prints had pushed *Cyperus fastigiatus* culm fragments, and other litter, down several centimeters into the mud. While misleadingly appearing that the fragmented litter was being “buried”, in effect hoof-prints indented the soft mud, forcing some of it up through the root mat while pushing the root mat down, but without puncturing it. In effect, the litter is buried in the root mat.

Unvegetated river channels and oxbow ponds (former river channels) are the exception to the rule of a ubiquitous root mat. The oxbow pond banks are well-vegetated with floodplain species, but their deeper water is inhabited only by aquatic plants whose rhizomes and roots (relatively few in number) do

not form a root mat. Underwater shovel excavations and tube coring revealed that very little litter is buried in the oxbow mud, most of it within three meters of the bank, and that the layering of the mud was undisturbed, consistent with the absence of the large water loving and mud-wallowing mammals (such as hippopotamus, buffalo, and elephant).

SI Part 3: Unusual forms of microdamage to *Cyperus fastigiatus* at Seekoeivlei Nature Reserve

This section describes the unusual forms of microdamage observed at Seekoeivlei in these modern destruction-resistant sedges, both in tabular form and as descriptions of these categories. To date they have not been observed in the Olduvai sedge fossils.

SI Table 2. Unusual pre-burial neotaphonomic processes observed in a modern seasonal wetland: the features, their inferred causal agents/processes, and their micro-environmental space-time correlates. Based on data for *Cyperus fastigiatus*, at Seekoeivlei Nature Reserve, 2000-2010.

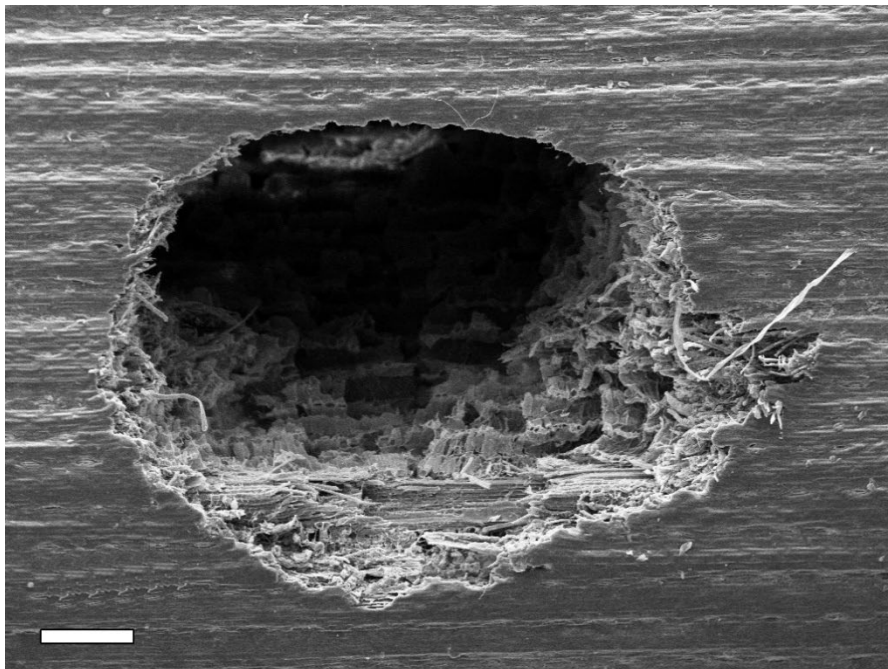
Taphonomic features	Inferred causal agents/processes	Spatial and temporal correlates
<u>round to oval borings</u> , ca. 125 μ m to 4.5 mm in width, through the cortex on into the pith where they terminate cup shaped, or continue for several millimeters as broad excavations in the pith under the cortex	insect damage	annual, wet season low density ubiquitous occurrence in green culms: restricted dense occurrence, seen one time in 10 years and only at one locality (in the western edge of the floodbasin)
<u>torn open sections of culm</u> exposing hollowed out sections of pith	bird damage: extracting insects from inside the standing culms (see round to oval borings)	during 10 years of observations only the 2005-2006 culm cohort in the western edge of the floodbasin suffered this form of damage (see round to oval borings)
<u>cone shaped micro-excavations</u> into the chlorenchyma, ca. 0.1-0.5 mm wide, on the lower culm	invertebrate (insect?) damage	occurring in patches of sedge that occupy the relatively high ground of the floodplain, not common in the floodbasin nor along the edge of the oxbow

Types of damage observed:

Round to oval borings. Approximately 10%-15% of the mature *C. fastigiatus* culms have 1-4 small insect holes in them (e.g., Figure SI.1). Most are cylindrical and ≤ 3 mm in diameter, and rarely, a small beetle carapace may be found inside the pith. Unusually large holes, only seen in the lower culm, are elongated in shape, e.g., 3 mm by 10-13 mm in size.

Our observations during our November 2007 field work showed that in the western edge of the floodbasin most of the standing-dead 2005-2006 culm cohort had insect damage and ripped open sections of culm, which was strikingly different to the more recently dead 2006-2007 cohort in the same location. As 2005-2006 was a very wet year (see SI Table 1), it had taller, more robust culms, while 2006-2007 was a relatively dry year, with smaller culms and less insect damage. The 2005-2006 culm cohort had suffered both more insect damage, and damage from insect-feeding birds (SI Table 2).

Figure SI.1. Extant round to oval boring ca. 1.1-1.2 mm wide through the culm cortex and on into the pith. From the edge of the epidermis (see upper edge of hole) on through the cortex, including the fiber strands (left and right edges of hole), the opening has the ragged ‘chewed’ appearance of insect damage. This damage continues well into the pith. Scanning electron micrograph in secondary electron mode. Extant sedge, *Cyperus fastigiatus*. Scale bar 200 μ m in length.

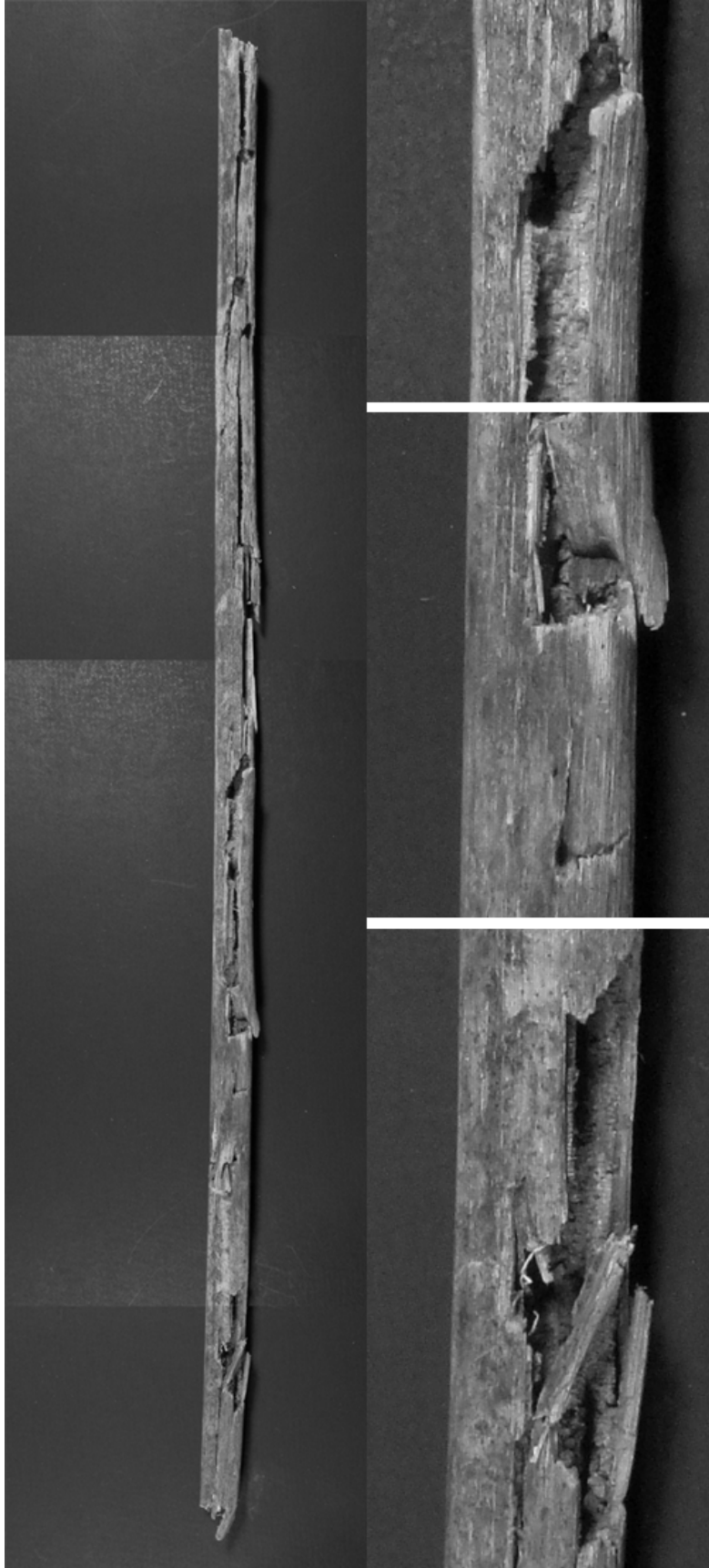


Torn open sections of culm. In November 2007 we observed in direct association with larger insect-holes, small sharp bird-beak-like punctures of the cortex along one side of the culm and ripped open sections of culm cortex (Figure SI.2). These torn up portions of culm corresponded to (insect) hollowed out sections of pith. Areas on the culm with smaller insect holes (ca. 125 μ m to 1mm in width), as well as some of the larger holes, remained untouched.

An apparent ancillary form of bird damage was also present. This consisted of small L-shaped depressions, (0.5) 1-2 (3) mm wide at the short, transverse end, with a sharp puncture at the corner of the L that depressed the cortex downward into the pith. The morphology of the damage indicates that it occurred when the culms were brittle, but not completely dry. This suggests that it occurred in the late rainy season or early dry season, and may be due to the red bishop (*Euplectes orix*), a common, small marsh bird which nests in the reeds (*Phragmites*). Although a seed eater, the female red bishop feeds the nestlings insects, during what is normally the second half of the (summer) rainy season (Maclean, 1985).

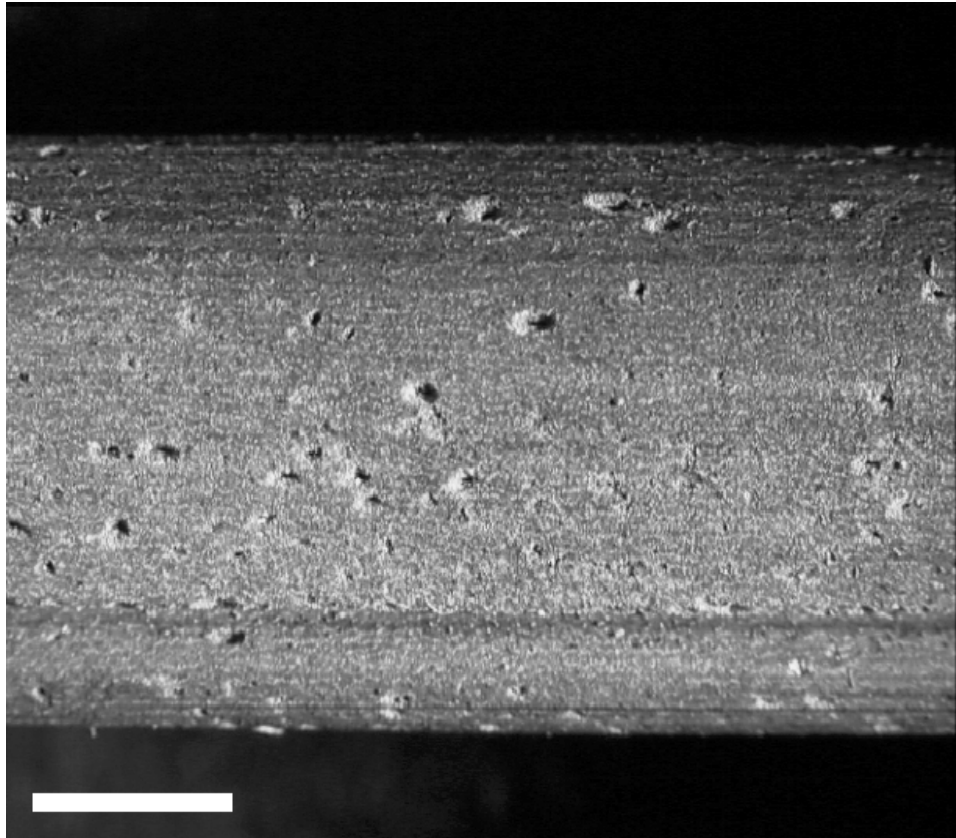
Figure SI.2. Extant torn open sections of a standing dead culm revealing hollowed out pith.

- SI.2A The left (composite) image is that of a 29 cm long midsection of damaged culm, oriented in its standing position. This midsection of culm is 7 mm wide at the top and 8 mm wide at the bottom. At least seven round to oval borings (holes inferred to be insect damage) occur along this specimen, and torn open portions (inferred bird damage to extract insects) can be seen along the lower two thirds of the specimen. Most of the pith is hollowed out as part of the insect damage. In the upper third of the specimen minor bird damage and drying of the hollowed culm has apparently caused the splits connecting the insect holes. Details of the more dramatic forms of bird damage to the lower two thirds of the specimen are seen in the three images to the right. Optical micrographs. Extant sedge, *Cyperus fastigiatus*.
- SI.2B Upper right image. Detail of inferred bird damage to extract insects from inside the culm. In this enlarged image the missing strip of ripped off cortex begins with an insect hole at the upper right. This rip-off exposes the hollowed out pith down its length, continuing another 2.8 cm below the area of this image. [The length of the entire ripped off strip is ca. 4 cm. It can be seen in the Figure 2A composite to the left, where it ends (at another insect hole) just above the area corresponding to the top of the middle enlarged image.] Optical micrograph. Extant sedge, *Cyperus fastigiatus*.
- SI.2C Middle right image. Detail of inferred ancillary bird damage. Sharply punctured L-shaped depressions. The apparent force applied in the upper example micro-folded the cortex down into hollowed pith, and dramatically displaced the side-wall laterally. Perhaps these punctures were exploratory, initiated but terminated (without rip ups) in favor of other locations on the culm. Optical micrograph. Extant sedge *Cyperus fastigiatus*.
- SI.2D Lower right image. Detail of inferred bird damage to extract insects from inside the culm. Section of multiple rip ups, beginning at an insect hole (viewed obliquely) at the upper right. The mid and lowermost parts of the damage appear to have been initiated by two separate punctures. Optical micrograph. Extant sedge, *Cyperus fastigiatus*.



Cone shaped micro-excavations. These are shallow excavations into the chlorenchyma which occur on the lower culm, up to ca. 35 cm from the base, on some of the standing dead (SI Table 2). At the surface of the culm their perimeter is usually approximately oval, sometimes round, and ca. (75)100-250 (500) μm in width (Figure SI.3). The unknown agent may be an aquatic beetle larvae. Usually, these cone shaped excavations are associated with a micro-wrinkled epidermis but not with cylindrical borings.

Figure SI.3. Extant cone shaped micro-excavations into the cortex of the lower culm. Apparently, quarrying of the chlorenchyma by an unidentified insect. Optical micrograph. Extant sedge, *Cyperus fastigiatus*. Scale bar 4 mm in length.



SI Part 4: Post-fossilization microdamage to Olduvai fossil sedge culm-species X

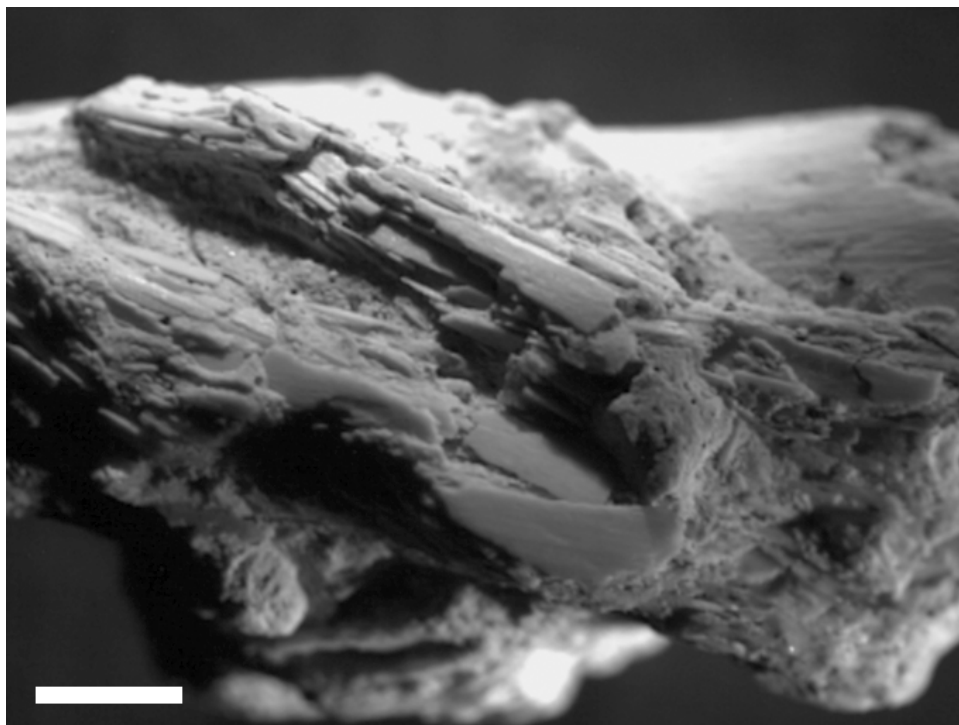
This section describes the different types of post-fossilization microdamage observed on the sedge fossils, and the likely causes.

In situ post-fossilization damage

In the earthy clay paleo-sediment adhering to some of the fossil specimens there are fossil shards of culm cortex, and/or sheath leaf, a few millimeters in size and smaller. On some specimens these shattered patches of cortex have micro-fault-block-like topography, including escalier sections of platy breaks (example shown in Figure SI.4). In orientation the fragments are sometimes a jumble, but not scattered as they might be if crushed by impact. In some cases, broken parts of what appear to have been one larger piece are partially pushed under one another. The edges of fragments are often covered by cemented sediment. Some fragments appear to have been pushed into the adhering sediment. The interpretation is that the breakage is compression fracture after fossilization, but before the sediment was fully lithified.

In the illustrated example (Figure SI.4) the platy shards include epidermis/hypodermis, but they do not appear in their orientation nor weathering stage to be anatomically part of the bulk of the specimen, which is a segment of culm. At one place in the breakage, observed at higher magnification, a thin layer of sediment could be seen between some of the shards and the underlying culm. The interpretation is that the tissues of more than one culm are present, and that the association was part of a patch of dense litter. Some of these composite specimens are very fragile, and others like them may have contributed fragments to the shattered component of the fossil collection.

Figure SI.4. Fragmented fossilized culm apparently compression fractured after fossilization, *in situ*, before recent exposure. Optical micrograph. Fossil sedge, Olduvai Gorge culm-species X. Scale bar 2 mm in length.



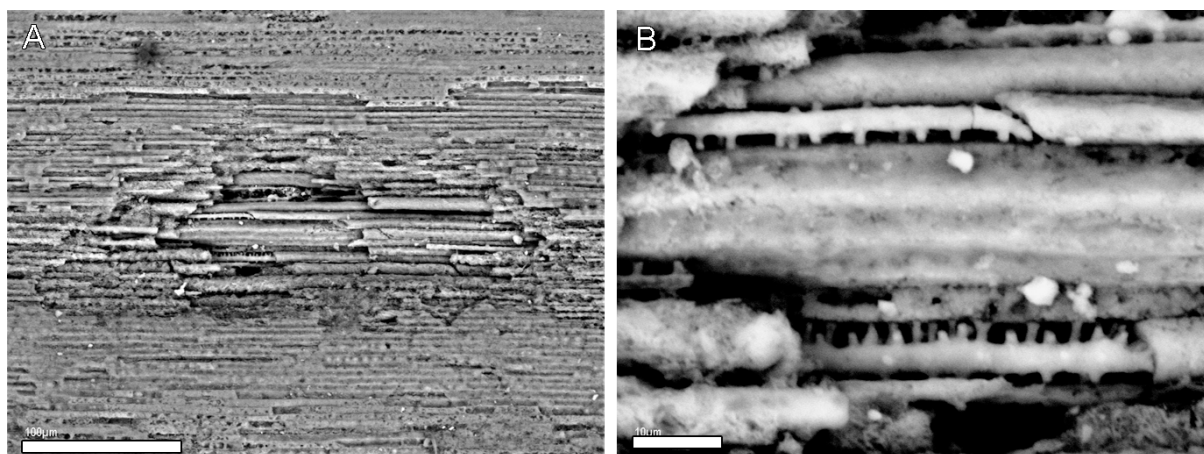
Chemical erosion is also apparent. It can be seen in the form of pitted cell walls of fossil epidermis, hypodermis and chlorenchyma, and ‘see-through’ layers of chlorenchyma cells where only the side walls remain. When initially viewed at low magnification in reflected light, small patches of this erosion were mistakenly thought to be examples of the cone shaped micro-excavations seen in the culms of the extant sedge *Cyperus fastigiatus* at Seekoeivlei (SI Table 2 and Figure SI.3). On closer examination, no unequivocal examples of that extant form of micro-damage were seen in the fossils.

In one case the chemical erosion of exposed hypodermis reveals that the sclerenchyma cells may have been fossilized in two stages. It appears that the thick walls of these cells may have been fossilized as a first stage. Then the voids at the center of the cells and ‘pore branches’ from the center of the cells to the cell surface were infilled as a second stage (Figure SI.5A, B). This second stage may also account for the infilling commonly seen in between the sclerenchyma cells of the hypodermis, giving it a massive (solid) appearance when viewed on end in snap-broken sections of fossilized culm. Since the fossils are silica it may be that their chemical erosion was related to ground water transgressions of the saline-alkaline Paleo-lake Olduvai.

Figure SI.5. Fossilized sedge culm damage interpreted as *in situ* post-fossilization chemical erosion.

SI.5A Fossilized culm cortex with a chemically eroded appearance. Both the epidermis (top and bottom of the image) and the hypodermis (broken open, central portion of the image) appear to have been chemically eroded after fossilization. Scanning electron micrograph. Fossil sedge, Olduvai Gorge culm-species X. Scale bar 100 μm in length.

SI.5B Detail of the hypodermis in Figure 5A revealing apparent complete post-fossilization dissolution of the walls of two of the sclerenchyma cells, only the infilled central void (and interior projections) of the cells remaining. Scanning electron micrograph. Fossil sedge, Olduvai Gorge culm-species X. Scale bar 10 μm in length.

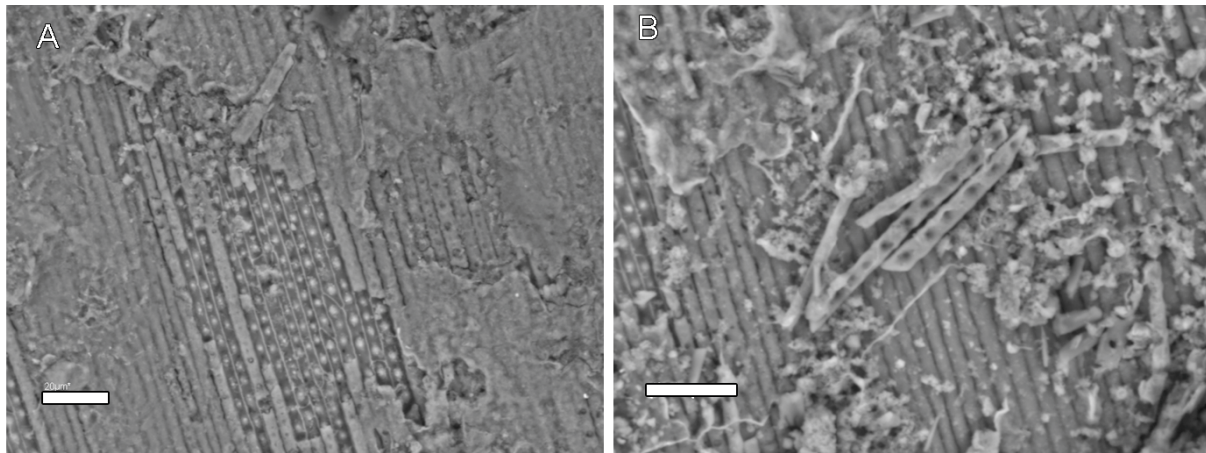


Recent damage

The fossil specimens derive from surface and near surface collections. Recent, coarse damage to the specimens is different in appearance from breakage resulting from pre-burial (pre-fossilization) snap-breaks and post-fossilization sediment-compression. The coarse damage is seen as rough jagged breaks at the millimeter scale. Some of these are fresh breaks, i.e. clean, shiny white surfaces, without adhering clay films and fine sand from modern surface ‘soil.’ Others appear to have occurred early after erosional exposure, being now partially covered with surface soil. This coarse damage is interpreted as caused by recent (modern) trampling by Maasai livestock, archeological surface-scrapes, and dry screening of sediments. Fine scale recent damage includes breakage revealing the cone shaped silica bodies inside, along with the side and end walls of the cells (Figure SI.6A). The epidermal cell tops are sometimes seen intact, scattered about nearby on the surface of the fossil culm as part of the modern micro-litter (e.g. Figure SI.6B).

Figure SI.6. Fossil sedge culm damage interpreted as recent breakage.

- SI.6A The tops of fossilized epidermal culm cells have recently broken away revealing the cone shaped silica bodies and side walls of the cell interiors (central lower portion of the image). The epidermal surface is partially covered by a paleo-film, part of which has also broken away (right of center in the image), revealing the top surface of intact epidermal cells with their single rows of dark depressions (which correlate with the silica bodies of the cell interior). Scanning electron micrograph. Fossil sedge, Olduvai Gorge culm-species X. Scale bar 20 μ m in length.
- SI.6B Two fossil culm epidermal cell tops (center of image) which are part of the culm surface micro-litter. Nearby to the damage seen in Figure 6A. Scanning electron micrograph. Fossil sedge, Olduvai Gorge culm-species X. Scale bar 20 μ m in length.



SI Part 5: Previously developed hominin land use models for the Lower Bed II Olduvai Basin

This section describes the different types of preliminary models of potential land use by hominins developed previously for Lower Bed II by Peters and Blumenschine (1995, 1996), which emphasize the possibilities of seasonal foraging for plant foods and scavengable carcasses. The primary landscape formulation is characterized by richly wooded mountain foot slopes in the east and southeast, woodland lined streams from there crossing the alluvial fan system to the lake, and marshes at the lakeshore stream mouths. This eastern part of the basin is reconstructed to have been able to support hominins. In the models, the eastern volcanic mountain foot slopes provided edible fruit and high-quality potable water. The wooded stream banks across the alluvial fans provided fruit, the occasional scavengable carcass from leopard kills, and relatively safe wooded corridors to the lakeshore. The lakeshore marshes posited for the mouths of the streams (minor deltas) provided edible rootstocks and opportunities for scavenging carcasses at freshwater sites that drew grazers (and their predators) from nearby lacustrine-plain grasslands (Peters and Blumenschine, 1995, 1996). A seasonal rainfall regime is assumed, and the implication for seasonal rounds of foraging are partially sketched for dry versus relatively wet climates.

A contrasting second formulation of the landscape is hypothesized in Peters and Blumenschine (1996) characterized by lake margin springs and a virtual absence of stream surface flow from the eastern

volcanic highlands across the alluvial fans to the lakeshore. This formulation is not reviewed here because our concern is with the implications of the earthy-clay marshlands, and those marshlands were broadly associated with stream systems, not associated with spring deposits (Hay, 1996; Stanistreet, 2012).

Blumenschine and Peters (1998) assert that for paleoanthropological model building purposes, the goal is prediction of the landscape distribution of stone tools and butchery-marked bone residues resulting from hominin scavenging of larger mammal carcasses, particularly where such sites could be excavated. In this predictive model, large-mammal carcass density from carnivore predation is greatest in the mid to upper eastern lacustrine plain, with its high-shoreline strip of grass pasture and its watering points where streams/rivers enter the lake. The model also recognizes that this lacustrine plain would have the highest hyena density in the basin, and that the resulting carnivore competition for carcasses would be intense. Scavengable parts likely to be found by hominins would be mostly trunks, heads/necks, and a few limbs, especially of grazers larger than wildebeest, such as the larger species of zebra and the buffalo, with their limb sizes beyond the bone-crushing capabilities of the hyenas of that time. Because the model postulates the scavenging hominins had very limited offensive/defensive capabilities and weaponry, carcass remains are reasoned to have been disarticulated by them for rapid transport to the relative safety of the nearest woodland. For the technology of that time the stone-tool kit was comprised of flakes (cutting and scraping implements), flaked cobble sized pieces of stone (also potentially chopping implements and projectiles), hammer stones, and unmodified rocks that could also serve as hand thrown projectiles. In the models, low densities of butchery-marked bones, and stone tools like flakes and hand thrown projectiles, would have been abandoned or lost while scavenging on the lacustrine plain and at lakeshore river mouths. Where complete processing of scavenged carcasses is predicted to have occurred, such as in prime stands of refuge trees, without impending threat from predators, complete processing would have included bone breakage for brains and marrow, and removal of all flesh scraps from bone surfaces, leaving inadvertent cut marks on shafts, bony projections and recesses. These stone tools lost or left behind would have been relatively clustered and dense. A full range of stone tools would be represented, possibly including unusually large stones used to break the larger bones that were scavenged and brought there.

References:

- Blumenschine, R.J., Peters, C.R. (1998). Archaeological predictions for hominid land use in the paleo-Olduvai basin, Tanzania, during lowermost Bed II Times. *Journal of Human Evolution* 34, 565-607.
- Hay, R.L. (1996). Stratigraphy and lake-margin paleoenvironments of lowermost Bed II in

Olduvai Gorge. *Kaupia* 6, 223-230.

Maclean, G.L. (1985). *Roberts' Birds of Southern Africa* (5th ed.). Cape Town: The Trustees of the John Voelcker Bird Book Fund.

Peters, C.R., Blumenschine, R.J. (1995). Landscape perspectives on possible land use patterns for Early Pleistocene hominids in the Olduvai Basin, Tanzania. *Journal of Human Evolution* 29, 321-362.

Peters, C.R., Blumenschine, R.J. (1996). Landscape perspectives on possible land use patterns for early Pleistocene hominids in the Olduvai basin, Tanzania: Part II, expanding the landscape models. *Kaupia* 6, 175-221.

Stanistreet, I.G. (2012). Fine resolution of early hominin time, Beds I and II, Olduvai Gorge, Tanzania. *Journal of Human Evolution* 63, 300-308.