doi:10.1038/nature14464

PART A. THE LO5 HOMININS AND IMPLICATIONS FOR HUMAN-LIKE MANIPULATION CAPACITIES

The artefacts from LOM3 are in the same spatiotemporal range as the hominin fossils found in paleontological collecting area LO5[26], including the paratype of *Kenyanthropus platyops* (KNM-WT 38350)[27], hominin specimens generally referred to *cf. Kenyanthropus platyops*[28] (Supplementary Table 1) and one unpublished tooth found by the West Turkana Archaeological Project in 2012 (KNM-WT 64060; left lower third molar). In 1982, a mandible (KNM-WT 8556) was discovered in this area. This specimen was initially assigned to *Australopithecus afarensis*[65], and is now more generally referred to *cf. Kenyanthropus platyops*[27,66]). The right upper third molar (KNM-WT 16003) discovered in 1985, previously allocated to *Australopithecus cf. afarensis*[65], is now also more generally referred to *cf. Kenyanthropus platyops*[27].

For the last decade, palaeoanthropological discoveries highlight an increased diversity of hominin species between 4.2 and 3.0 Ma. Indeed, during this period four hominin species are recognised in East and Central Africa (*Au. anamensis, Au. afarensis, Au. bahrelghazali* and *K. platyops*) although the question of the validity and the patterns of temporal and geographic variation of these taxa is still debated[67-71]. Furthermore, LOM3 predates the oldest known specimens attributed to the genus *Homo* in West Turkana[7], as well as in other localities in Kenya[72], Ethiopia[8,73] and Malawi[74]. The age and location of the LOM3 artefacts confirm that the earliest stone tools were made by a genus other than *Homo*.

The discovery of LOM3 shows that the human-like manipulative capabilities discussed for the mid-Pliocene hominin *Au. afarensis* is not prior but contemporaneous to the appearance of stone tools in the archaeological record. The hand structure for *Au. afarensis* has been proposed to be a reasonable model for that of early stone-tool makers[75] or at least stone tool-users[76], which has been further suggested by the publication of the 3.39 Ma cut-marked bones from Dikika[20] (but see refs 77 and 78). However, the functional morphology of the hand of fossil hominins (especially *Au. afarensis*) must be further investigated in terms of adaptation for stone tool making to better understand this important milestone in human evolution.

Indeed, the timing of emergence of human-like manipulative capabilities (i.e. pad-to-pad precision grasping *sensu* Napier[79,80] and, in a broader sense, forceful precision grips and precision handling *sensu* Marzke[76]) in the hominin lineage is currently under debate[81]. With the absence of any associated stone tools, the possible oldest occurrences of human-like manipulative functions have been interpreted as possible adaptations to locomotor, social and feeding behaviours, that might be secondarily compatible with substantial tool-using and tool-making in later hominins. With the Late Miocene ape *Oreopithecus bambolii* (from Baccinello and Monte bamboli localities, faunal units V1 and V2, 8.2-6.7 Ma), human-like manipulative abilities have been proposed[82,83] but these adaptations have been interpreted as a convergence with later hominins in response to harvesting feeding behaviours in a resource-limited (insular) environment[82]. Pad-to-pad precision grasping has been inferred in the late Miocene hominin *Orrorin tugenensis* (from Kapsomin site, Kapsomin Member, 5.8-5.9 Ma)[84,85]. Such a hand function may have been either advantageous to hand-assisted bipedalism[84] or a consequence of a reduction in locomotor constraints on the hands[85]. The *Ardipithecus ramidus* hand (from ARA-VP-6 and -7 localities, Lower Aramis Member, 4.4 Ma), which is the best known morphologically, exhibits generalized morphology that likely allowed enhanced grasping functions. Such condition may have been compatible with the emergence of more frequent non-locomotor grasping behaviours (including extractive foraging, tool using and making) in later hominins[86].

Mainly based on the remains from localities A.L. 333/333w, A.L. 1044 (Denen Dora Member, 3.2 Ma) and A.L. 438, A.L. 444, A.L. 724 (Kada Hadar Member, 3 Ma), *Au. afarensis* is characterized by mostly human-like hand functions as supported by organization of hand musculature, substantial mobility of carpometacarpal joints, overall morphology of the distal pollical phalanx[87] and modern human-like manual proportions with a relatively long thumb and short medial digits[80,87-90]. However, the *Au. afarensis* hand is also considered as being functionally more limited (for instance, due to thumb slenderness) but allowing some forceful precision grips (pad-to-side and three-jaws chuck pinches) and precision handling that might be used to apply pressure to tools in activities such as cutting, probing or digging, or even pounding, chopping and stone-throwing[76,91]. More recently, the view of a more functionally restricted *Au. afarensis* hand is proposed by Rolian and Gordon[92] who highlight that *Au. afarensis* manual

doi:10.1038/nature14464

proportions are intermediate between gorillas and humans, and suggest that *Au. afarensis* was able to produce tip-to-tip precision pinches but not the more efficient pad-to-pad grasp typical of modern humans.

Based on the specimens classically put into Member 4 deposit from Sterkfontein excavation (dated according to different methods from 2.8 to 2.0 Ma, for a review see ref. 93), *Au. africanus* likely used a human-like pad-to-pad precision grasp[94] and one type of forceful precision grip (pad-to-side grip) and handling grips[76] in various behaviours such as hammering, striking, chopping, scraping, gouging and throwing[76,95]. However, the slenderness of metacarpal I suggests that *Au. africanus* was not able to use the full range of human-like manipulative behaviours seen in later hominins[94]. More recently, the analysis of the internal structure of metacarpals confirms that this hominin was capable of habitual and forceful human-like opposition of the thumb and fingers during precision and power (squeeze) grips[96].

After 2 Ma, tool using and tool making have been directly inferred from the morphology of the Olduvai and Swartkrans hominin hands, having been discovered near stone tools. In the former (Olduvai Hominid [OH] 7) from FLK NN of the Olduvai Gorge, Bed I, 1.75-1.8 Ma[97] classically attributed to *Homo habilis* (but see ref. 98 for a potential attribution to *Paranthropus boisei*), human-like precision grips are associated with pad-to-pad precision grasping[98-101]. Similarly, adaptations for tool-using and tool-making are observed in the Swartkrans hominins mainly from Member 1, dated between 1.7 and 2.25 Ma[102] and putatively attributed to *Paranthropus robustus*[103-105]. Forceful precision gripping and possibly stone tool production have been also proposed for *Au. sediba*[106] (from Malapa site, facies D, 1.977 Ma). Lastly, the recent description of a third metacarpal (Kaitio area, West Turkana, Natoo Member, 1.42 Ma) from West Turkana, with a styloid process typical of modern humans seems to confirm that enhanced hand function for tool-making and tool-using took place very early in the evolution of the genus *Homo*[107].

SUPPLEMENTARY TABLE 1. Hominin specimens from LO5 paleontological area (1982-1998) (R: right side; L: left side).

KNM-WT	Year	Element(s)	Taxonomic designation	Reference
8556	1982	Mandible	*Australopithecus afarensis*	65
			unassigned	27
			cf. *Kenyanthropus platyops*	28, 63

16003	1985	RM^3	cf. *Australopithecus afarensis* unassigned cf. *K. platyops*	65 27 28
38345	1998	Middle phalanx	cf. *K. platyops*	28
38346	1998	Partial RM^1 or RM^2	unassigned cf. *K. platyops*	27 28
38347	1998	Crown LdM_2	unassigned cf. *K. platyops*	27 28
38348	1998	Mandibular symphysis with unerupted L & R I_1s	cf. *K. platyops*	28
38349	1998	Crown M_1 or M_2	unassigned cf. *K. platyops*	27 28
38350	1998	Left Maxilla fragment with P^3 and P^4 roots and M^1 fragment	*Kenyanthropus platyops* (paratype)	27
38352	1998	Partial RM_1 or RM_2	unassigned cf. *K. platyops*	27 28
38357	1998	RM_1 or RM_2	unassigned cf. *K. platyops*	27 28
38358	1998	Associated RI^2, RM^3 fragment; LM_3, fragment LM_2 fragment, 4 crown fragments	unassigned cf. *K. platyops*	27 28
38359	1999	Associated RM_1 and RM_2	unassigned cf. *K.platyops*	27 28
38361	1998	Associated (partial) germs of I^1, LI^2, R$\underline{C}$, RP^3, LP^3, RP^4, LP^4	unassigned cf. *K. platyops*	27 28
38362	1998	Associated partial LM^1 or LM^2 and RM^1 or RM^2	unassigned cf. *K. platyops*	27 28
39949	1998	LP_4 fragment	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39950	1998	RM_3	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39951	1998	RM_1 or RM_2 fragment	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39952	1998	LM_1 or LM_2	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39953	1998	LM_1 or LM_2 fragment	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39954	1998	Two tooth fragments	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
39955	1998	L_C fragment	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*
40001	1998	Right temporal	unassigned cf. *K. platyops*	27 M. Leakey *pers. comm.*

PART B. GEOLOGY AND GEOARCHAEOLOGICAL CONTEXT OF THE LOM3 SITE

Geology

The LOM3 site (SASES# GaJg1 - not to be confused with paleontological collecting locality Lomekwi III, abbreviated LO-3[26,27]) lies in paleontological collecting area LO5[26], in the southern part of the Lomekwi drainage and just to the north of the Topernawi laga. In this region, badland exposures of the Nachukui Formation are extensive and present a rugged topography with some 80 m local relief. The western limit of Nachukui Formation sedimentary strata in this area is marked by a major boundary-fault complex. This feature generally forms a sharp delineation between Miocene to Pliocene volcanic rocks to the west and the sedimentary sequence on the east, extending from well south of the Topernawi to the northern end of the Labur Range[26]. Within the sedimentary exposures, a series of relatively minor faults offset strata locally.

Stratigraphy. Strata exposed in LO5 all lie within the uppermost Kataboi and lowermost Lomekwi Members of the Nachukui Formation[26]. In northerly sections, a conspicuous marker sandstone, referred to as the 'burrowed bed' underlies a pair of grey vitric tephra that are geochemically demonstrated to be the α-Tulu Bor Tuff (Supplementary Table 2; Extended Data Fig. 2). The β-Tulu Bor Tuff occurs as a prominent white bed 4 m higher in the section. In sections to the south of LOM3, the β-Tulu Bor Tuff is also recognized and above it, a lenticular vitric tephra occurs that geochemically correlates with the Toroto Tuff. Ten meters above the base of the α-Tulu Bor Tuff couplet is a thick flat-pebble conglomerate (interpreted as a beach gravel) with interbeds of molluscan sandstone. Comparable flat-pebble conglomerates can be traced to the south. The basal contact of this conglomerate is locally an arcuate erosional surface (Extended Data Fig. 2). The archaeological level at LOM3 lies a few meters above this beach complex, within a pebbly sand and claystone sequence. Overlying strata are dominated by upward fining cycles, beginning with polymictic sandstones, including lenses of volcanic pebbles and capped by vertic claystones (Extended Data Fig. 2).

doi:10.1038/nature14464

Supplementary Table 2. Electron Microprobe analyses of tephra collected in 2011 around LOM3. Analyses were completed in the microprobe facility in the Department of Earth and Planetary Sciences at Rutgers University. All values are wt %.

Sample	SiO2	Al2O3	Fe2O3	CaO	K2O	Na2O	MgO	MnO	TiO2	Cl	F	Total	N	ID	Locality
K11-8218	70.30	9.75	4.74	0.20	0.96	5.76	0.03	0.18	0.21	0.16	0.07	104.44	20	Toroto	LOM, 2012-9
K94-5437	64.29	9.59	4.57	0.21	4.23	4.53	0.00	0.13	0.26	0.18	0.00	87.54	12	Toroto	Area 204
K11-8219	71.34	12.26	1.53	0.29	2.05	5.81	0.05	0.04	0.10	0.10	0.11	103.56	20	Tulu Bor b	LO5
K11-8196	70.27	11.92	1.51	0.30	2.88	4.44	0.05	0.05	0.13	0.11	0.00	93.14	29	Tulu Bor b	LOM
K11-8215	70.03	11.97	1.51	0.29	2.42	5.19	0.05	0.05	0.13	0.11	0.00	93.24	31	Tulu Bor b	LOM, 2011-1
K13-8363	75.71	12.54	1.60	0.31	1.42	1.68	0.05	0.04	0.14	0.14	0.05	93.68	21	Tulu Bor b	LOM, 2013-1
K11-8212	68.66	12.29	1.29	0.46	2.71	5.13	0.11	0.04	0.18	0.10	0.00	92.24	30	Tulu Bor a	LOM, 2011-1
K11-8214	69.06	12.29	1.32	0.46	2.83	5.17	0.11	0.04	0.19	0.10	0.00	92.86	26	Tulu Bor a	LOM, 2011-1
K99-7103	68.99	12.83	1.45	0.54	3.55	4.44	0.12	0.05	0.20	0.09	0.00	93.69	14	Tulu Bor a	Area 129
K10-8142	70.62	12.54	1.32	0.45	4.40	5.26	0.11	0.04	0.13	0.09	0.07	95.04	29	Tulu Bor a	Area 129
K11-8195	71.51	10.65	3.01	0.17	2.33	5.72	0.01	0.08	0.12	0.14	0.16	105.34	15	Lokochot/2	Topernawi
K11-8194/1av	72.02	10.80	2.67	0.19	2.77	4.86	0.01	0.07	0.11	0.12	0.13	104.42	7	Moiti/1	Topernawi
K11-8194/2av	67.92	12.09	3.14	0.69	1.71	4.61	0.06	0.15	0.17	0.07	0.16	101.29	10	co-Moiti/1	Topernawi

Sedimentary facies analysis and context demonstrate that the burrowed bed and associated strata of the upper Kataboi Member (below the α-Tulu Bor Tuff) represent the lake margin assemblage of the Lokochot Lake, a basin-wide lacustrine phase that preceded deposition of the Tulu Bor Tuff[108]. The lake margin package 10 m above the tuff represents a fan delta on the margin of a successor lake phase, possibly the Waru Lake.

The type section of the Lomekwi Member (158.5 m) was measured beginning just to the east of the localities discussed here[26]. The base of the Member is placed at the base of the α-Tulu Bor Tuff, and the β-Tulu Bor Tuff lies a few meters above. Other tephra reported from the lower Lomekwi Member include the Waru Tuff (outcropping to the southeast along laga Topernawi), and an unnamed tephra (K82-750) observed at Loruth Kaado. Correlative strata at Koobi Fora also include the Toroto and Allia tuffs[109]. The lithological description of the lower Lomekwi Member[26] notes that two distinctive lithofacies associations are represented: one dominated by orthomictic volcanic-clast conglomerates, the other by upward-fining cycles based on quartz-rich sandstones.

These facies associations broadly reflect two distinct depositional systems: marginal alluvial fans and an axial meandering river system (NB - the reconnaissance geology reported in ref. 26 did not distinguish the relatively short lacustrine sequences discussed here). Strata at LO5 largely reflect the distal end of the alluvial fan association. Coarse conglomerates reflecting a true alluvial fan setting are present below the site, but most of the gravels encountered in the area are best characterised as representing the distal toes of alluvial fans.

Geoarchaeological context and site formation processes

The LOM3 site was revealed by a concentration of two-dozen knapped blocks discovered on the surface during the 2011 WTAP field-season. These pieces were located on the lower half of a hillside in the process of erosion, in the southern portion of the Lomekwi complex. This situation allowed us to hypothesize that the archaeological level was situated halfway down the hillside, which justified the placement of a 4 m^2 test excavation at that level during the 2011 season (Extended Data Fig. 5). A dozen lithic artefacts found in the sediment beneath the superficial pavement confirmed the presence of an *in situ* archaeological layer in these Pliocene deposits (Figs 2a and 2b). The continuation and extension of the excavation during the 2012 fieldwork (Extended Data Fig. 1) allowed for more detailed documentation of the *in situ* character of the archaeological pieces and the site formation processes.

The site's stratigraphic position within the Lomekwi Member demonstrated above shows that it is located in the lower portion of the series of pebble, gravel, sand and silt beds constituting the distal alluvial fan deposited on the border of a lacustrine plain. Several units are recognised at the level of the hillside where the LOM3 site is located (Fig. 2). They are deposits of well sorted fine quartzo-feldspathic sands forming a paleodune that covered and regularised the topography left by the lake paleobeach; overlain by a series of massive silt beds alternating with lenses of sand and granules, and capped by a level of clays attributable to a paleosol.

The section exposed by the excavation allowed for refined identification of the deposits containing the archaeological material (Fig. 2). The first sediments encountered by the excavation form a plaque of slope deposit. The sediments forming this slope deposit present several characteristics that clearly distinguish them from the underlying *in situ* Pliocene deposits. The principle characteristics are:

- a high proportion of unsorted coarse elements;
- the presence, within this fraction, of numerous thermoclastic flakes. Thermoclastism is currently a very active process that causes the fragmentation of blocks and cobbles that make up the surface pavement and produces numerous natural angular debris. Such fragments have not been observed in the Pliocene deposits of the Nachukui formation.

Under this slope deposit lie the sandy-granully indurated sediments in which the *in situ* artefacts were found. The section preserved along bands I and J of the excavation allowed for the description of these sediments (Fig. 2c). There are three types:

1. interdigitating lenses of silts, and fine, medium, and coarse sands, including granules;
2. brown (7.5YR 5/4) sandy silts;
3. lenses of coarser sands and granules.

The facies documented by this section are comparable to those making up the overall alluvial sequence, in which the silt, sand, and granule lenses represent temporally distinct sedimentation episodes within the fan system. The maximal competence of the transport flow can be estimated by the coarsest fraction of the bed load deposited, in this case <4 cm diameter granules. The small marginal fan deposit in which the artefacts are preserved appears to have been minor vis-a-vis the other portions of the alluvial fan system.

The discovery of archaeological material within this distal fan deposit poses questions about the primary or secondary archaeological context of LOM3 stone tools. Several geoarchaeological observations made at the excavation are pertinent to this point. They are:

- the presence of artefacts of different sizes, ranging from ~1 cm wide flake fragments to very large worked cobbles and cores;
- the nature of the artefacts, larger and heavier than could be carried by the energy of the alluvial system that deposited the sediments (the maximal competence of the transport flow can be inferred by the coarsest fraction of the bed load deposited, i.e. <4 cm diameter granules);

doi:10.1038/nature14464

- a vertical distribution of the archaeological material throughout the deposit, but meanwhile unequal in the sense that the majority of pieces come from the lower portion.

In this context, the archaeological material represents a double granulometric anomaly vis-a-vis the encasing sediment because: 1) it is unsorted, and 2) it includes cobbles larger than can be carried by the competence of the flows at the origin of the observed natural deposits. These two arguments indicate the archaeological material has not been reworked by flowing water. It is also appropriate, however, to consider the significance of the freshness of the material and its observed lack of sorting. The development of abrasion on lithic materials, in flowing water or in an alluvial setting, is less a function of the distance of displacement of the pieces than the length of time objects remain in the active environment[110-112]. The low degree of post-depositional mechanical alteration to LOM3 artefact edges and surfaces excludes the pieces having been transported within the alluvial fan for a extended duration, but does not exclude their displacement. The factors conditioning the sorting of lithic assemblages have been documented by Schick[111]. This experimentation demonstrates that size sorting of pieces is under the double-control of: 1) the location of the assemblage with reference to its place of knapping (primary or secondary archaeological position), and; 2) the number of remobilisation episodes. An unsorted assemblage can thus result either from a temporally discrete redistribution over a short distance during one or more flow episodes, or a situation in which lithic pieces remain in their original discard positions but a part of the assemblage is laterally redistributed by episodic water flow. Based on observations at and around the LOM3 excavation, the most parsimonious interpretations are thus limited to remarkable preservation of the site and most of the assemblage, or a slight redistribution in close proximity to the original activity location.

doi:10.1038/nature14464

PART C. AGE DETERMINATION FOR THE LOM3 SITE

Age Constraints. Paleontological assemblages collected from LO5 were attributed to the lower Lomekwi Member, just above the Tulu Bor Tuff[26]. Intensive prospecting throughout the Lomekwi drainage, and the discovery of numerous hominin specimens attributed to *Kenyanthropus platyops*[27], led to the recognition of nearby fossiliferous strata in the uppermost Kataboi Member as well as within the lower Lomekwi Member. In the local section, LOM3 lies 19 m above the base of the first α-Tulu Bor Tuff and 15 m above the β-Tulu Bor Tuff. The site is thus < 3.44 Ma based on the age of the former as reported in ref. 29 (this age was attributed initially to the Tulu Bor Tuff *sensu lato*; subsequently identified as the α-Tulu Bor[30]). Five meters above the β-Tulu Bor Tuff is a lenticular tuff that is a geochemical correlate of the Toroto Tuff. Above these tephra is a thick beach-gravel with interbeds of molluscan sandstone, capped by dune sand. The archaeological level at LOM3 lies two meters above this beach complex, within a pebbly sand and claystone sequence. The site is thus some 19 m above the base of the first α-Tulu Bor Tuff (3.44 ± 0.02 Ma[29,30]), 15 m above the β-Tulu Bor Tuff (<3.44 and >3.41 Ma[29,30]), and 10 m above the Toroto Tuff (3.31 ± 0.02 Ma[29,30]). The nearby type section of the Lomekwi Member is 158.5 m thick, and sediment accumulation rates estimated for the Member (17.4 cm/ky, based on section thickness and age constraints on the bounding stratotypes[26,30]) suggest an age of 3.3 Ma for LOM3.

Paleomagnetic Data.

Supplementary Table 3. Paleomagnetic data for samples from the lower Lomekwi Member.

Sec.	Meters	ID	MAD	bDec	bInc	bLat	Range	N
1	1	LMK-1	2.1	9.6	-9.4	77	400-550	5
1	2	LMK-2	2.2	9.5	8.6	80.5	400-550	5
1	3	LMK-3	1.8	8.5	-13.3	76.3	400-550	5
1	4	LMK-4	4.4	11.1	7.2	78.9	400-550	5
1	5	LMK-5	10.3	47.5	0	42.4	400-550	5
1	6	LMK-6	3.8	12.7	-18.9	71.3	400-550	5
1	6	LMK-6b	5.9	16.5	-14.8	69.9	400-550	4
1	7	LMK-7	8.5	358.7	-8.1	81.8	400-550	5
1	8	LMK-8	3.9	7.2	-3.5	80.8	400-550	5
1	9	LMK-9	3.6	1.8	12.3	87.1	400-550	5
1	10	LMK-10	10.1	22.9	-6.1	66.1	400-550	5

1	11	LMK-11	37.4	41.4	-12.8	47.4	400-550	5
1	12	LMK-12	2.5	359.6	3.2	87.6	400-550	5
1	11.9	LMK-13	9.5	353.2	-5.8	80.3	400-550	5
1	14	LMK-15	4.2	9.5	-7.8	77.6	400-550	5
1	15	LMK-16	5.9	5.7	7.9	84.3	400-550	5
1	15	LMK-16b	4.7	9	6.8	81	400-550	4
1	16	LMK-17	12.8	32.4	14.7	57.6	400-550	5
1	17	LMK-18	17.5	343.2	-10	70.9	400-550	5
1	18	LMK-19	5.3	18	-2.2	71.3	400-550	5
1	19	LMK-19b	11.2	20.1	4.9	69.9	400-550	4
1	19	LMK-20	4.6	3.1	-5.1	82.7	400-550	5
1	20	LMK-21	3.2	3.1	3.1	86.1	400-550	5
1	21	LMK-22	9	358.7	-5.4	83.2	400-550	5
1	22	LMK-23	5.8	3.5	-15.3	77.7	400-550	5
1	23	LMK-24	2.2	11.1	1.1	78.4	400-500	3
1	23	LMK-24b	6.3	2.3	10.3	87.4	400-550	4
1	24	LMK-25	4.2	7	-6	80.1	400-550	5
1	24	LMK-25b	3.4	17	1.2	72.7	400-550	4
1	25	LMK-26	1.5	340.9	-11.5	68.6	400-550	5
1	25	LMK-26b	3	339.9	-11.3	67.7	400-550	4
1	26	LMK-27	3.8	358.6	11.4	87.8	400-550	5
1	27.2	LMK-28	14.8	45.4	-41.6	37.7	400-550	5
1	29.2	LMK-29	14.5	181.7	43.7	-60.4	400-550	5
1	29.2	LMK-29b	8.3	210	9	-58.8	400-550	4
1	30.2	LMK-30	14	197.6	11.9	-69.8	400-550	5
1	32.4	LMK-31	5.3	184.8	35.7	-65.8	400-550	5
1	33.8	LMK-32	4.5	192.9	33	-64.6	400-550	5
1	36.3	LMK-33	20.3	159.6	12.3	-67.2	675-700	3
1	38	LMK-34	11.7	159.3	2.6	-68.6	680-700	3
1	40	LMK-35	14.5	166.1	19.2	-70.4	675-690	3
1	41.6	LMK-36	3.3	169.3	3.7	-77.8	675-690	3
1	43	LMK-37	13.5	168.1	3.8	-76.7	675-690	3
1	43.8	LMK-38	14.4	159.5	-12.1	-69.5	675-690	3
1	45.2	LMK-39	5.2	165	-14.5	-74.7	675-690	3
2	0	tt0x	3.4	12	-26.6	68.4	600-660	5
2	1	tt1	13	174.8	4.3	-81.9	600-660	4
2	2	tt1.5	6.9	163.8	21.8	-67.8	600-660	4
2	3	tt2	8.8	151.7	23.2	-57.6	600-660	4
2	4	tt2.5	7.3	161.9	12.6	-69.2	600-660	4
2	5	tt3	6.4	156.4	10.1	-64.7	600-660	4
2	6	BB1	8.2	172.8	20.3	-73.8	625-670	4

2	7	BB2	6.7	173	8.5	-79.2	625-670	4
2	10	LOM3	14.9	168.3	17.1	-72.7	625-670	4
2	10.5	wt65	5.7	165.8	0.8	-75.1	600-660	4
2	10.5	wt68	21.6	147.2	-10.2	-57.3	600-660	4
2	10.8	wt116	8.3	172.4	-0.6	-81.6	600-660	4
2	11	LOMup	9.8	168.6	19.9	-71.8	625-670	4
2	11.6	wt72	9.6	151.6	4.1	-61	625-670	4
2	11.6	wt73	42.3	35.2	1.5	54.7	600-660	4
2	11.95	wt117	11.6	182.7	2.7	-84	600-660	5
2	11.95	wt118	10	194.2	7	-73.9	650-675	4
2	12.3	wt69	4.2	157.1	7.4	-65.9	650-670	3
2	12.3	wt71	30.9	33.4	-36.5	49.2	600-660	4
2	13	wt115-1	7.5	170.3	6.7	-77.8	600-660	4
2	13.7	wt103	9.9	155.4	11.7	-63.5	600-660	4
2	13.7	wt106	18.4	140.7	-47.6	-45.3	600-660	4
2	14.7	wt75	34.7	125.8	28.5	-33	600-660	4
2	14.7	wt76	31.8	124.7	37.4	-30.4	600-660	4
2	15.7	wt77	6.8	178.4	10.7	-80.5	600-660	4
2	16.7	wt80	10.9	174	5.8	-80.9	600-660	4
2	16.7	wt81	33.3	160.2	43	-55.2	600-660	4
2	17.7	wt82	7.3	162.6	3.1	-71.7	600-660	4
2	17.7	wt84	39.6	156.1	6.2	-65.1	600-660	4
2	18.2	wt100	5.4	157.9	7.5	-66.6	600-660	4
2	18.2	wt101	15.4	163.3	-44.9	-62.4	600-660	4
2	18.7	wt85	9.1	156.7	4.2	-65.9	600-660	4
2	18.7	wt86	42.3	164.2	67.1	-34.5	600-660	4
2	19.2	wt95	5.5	154.2	11.5	-62.4	600-660	4
2	19.2	wt98	10.2	204.4	11.8	-63.7	650-675	4
2	20.2	wt92	6.9	167.3	0.8	-76.6	600-660	4
2	20.2	wt93	17.4	162.7	-47.5	-60.4	600-660	4
2	21.2	wt88	7.1	158.7	13.7	-66.1	625-670	4
2	21.2	wt89	44.2	189.1	75.3	-23.3	600-660	4
2	22.2	wt62	5.5	160	14	-67.2	600-660	4
2	22.2	wt63	13.4	173	6.8	-79.8	600-660	3
2	23.6	wt114-1	12.5	166	25.9	-67.5	600-660	4
2	23.6	wt59	8.3	148.7	13.3	-57	600-660	4
2	23.6	wt60	11.6	130.1	-4.2	-40.1	600-660	4
2	25	wt56	5.2	130.4	0.2	-40.3	600-650	3
2	26.4	wt113	12.3	167.2	7	-75.2	600-660	4
2	26.4	wt53	14.7	165.8	17.9	-70.7	600-660	4
2	27.8	wt50	6.7	165.9	18.8	-70.4	600-660	4

2	27.8	wt51	6.4	169.1	12.4	-75	600-660	4
2	29.4	wt112	7.1	177.6	12	-79.7	600-660	4
2	29.4	wt46	3.8	163.4	10.9	-70.9	600-660	4
2	29.4	wt49	5.7	171.2	2.9	-79.7	600-660	4
2	30.8	wt44	9.3	174.2	6.6	-80.7	600-660	4
2	30.8	wt45	5	167	12.1	-73.5	600-660	4
2	31.2	wt39	7.1	162.6	6.2	-71.2	600-660	4
2	31.2	wt40	9.3	169	8.3	-76.3	600-660	4
2	32.5	wt111-1	11.1	168.4	7	-76.2	600-660	4
2	32.5	wt36	5.3	166.1	14.5	-72.1	600-660	4
2	32.5	wt37	19.3	157.8	17.7	-64.3	600-660	4
2	33.8	wt31	4.8	169	11.8	-75.2	600-660	4
2	33.8	wt32	16.4	160.5	54.8	-46.6	600-660	4
2	34.2	wt28	9.2	171	3.6	-79.3	600-660	4
2	34.2	wt30	18.8	161.8	64.1	-37.6	600-660	4
2	34.6	wt110	7.5	169.3	7.2	-76.9	600-660	4
2	35.2	wt26	10.4	186.5	10.5	-78.7	650-675	4
2	36	wt21	24.2	177.7	56.5	-48.9	600-660	4
2	36.7	wt107	6.2	165.8	4.4	-74.5	600-660	4
2	36.7	wt108	37.2	333.8	-69.8	28.3	600-660	4
2	37.4	wt18	11.3	162.7	67.9	-33.1	600-660	4
2	38.4	wt12	10.3	164.5	-7.4	-74.5	600-660	4
2	38.4	wt15	13.3	147.2	74.3	-20.5	600-660	4
2	39.9	wt8-1	6.8	154.5	3	-63.9	625-670	4
2	39.9	wt9	11.1	142.2	64.1	-29.9	600-660	4
2	40.9	wt5	11.2	170.7	0	-79.9	650-680	4
2	40.9	wt6	21.4	163.9	21.3	-68	600-660	4
2	41.9	wt1	9.9	283.7	-61.6	7.2	600-660	4
2	41.9	wt3	9.8	179.1	5	-83.4	650-675	4

Notes. All samples are from independently orientated and analysed hand-cut blocks, except those with lowercase "b" that indicate samples split from the same block (e.g., LMK-6 and LMK-6b). Sec. = Section 1 or Section 2. Meters are the stratigraphic level of the oriented sample upwardly from base of Section 1 (Section 1 samples), or from the Toroto Tuff (Section 2 samples). ID is the sample ID. MAD = maximum angular deviation in degrees. Data with MAD values larger than 15° were not used for magnetostratigraphic interpretations. bDec = ChRM declination in bedding coordinates in degrees. bInc = ChRM inclination in bedding coordinates in degrees. bLat = latitude of virtual geomagnetic pole of ChRM in degrees. Range is for temperature range in degrees Celsius of the thermal demagnetization experiments used to isolate the ChRM direction. N = number of temperature steps in the temperature range used for principal component analysis.

doi:10.1038/nature14464

PART D. PALEOENVIRONMENTAL RECONSTRUCTION THROUGH PEDOGENIC CARBONATE STABLE CARBON ISOTOPIC ANALYSIS

Stable carbon isotopic analyses of pedogenic carbonate nodules (n=24, 47 analyses) located stratigraphically above, below and at LOM3 yielded mean $\delta^{13}C_{VPDB}$ values of -7.3±1.1‰, ranging from -9.5 to -4.7‰ (Extended Data Fig. 4). These results indicate a mean f_{wc} of 47%, ranging from 26-65% woody cover and 18-52% C_4 biomass. Results indicate that the woodland/bushland/thicket/shrubland structural category was most abundant, but wooded grasslands were also present. Forest and grassland structural categories are not indicated.

We statistically compared LOM3 paleosol $\delta^{13}C_{VPDB}$ values to those of the Oldowan lithic site from the Busidima Formation at Gona[33,54] and to those of comparably aged paleosols (3.2-3.4 Ma) in the Koobi Fora[56,57] and Nachukui[57,58] Formations (Kenya), in the Chemeron Formation[59] (Kenya), and in the Hadar Formation (Ethiopia) from Gona[54], Hadar[60], and Dikika[32,61]. East African pedogenic carbonate isotopic values are compiled in a single database[55]. Summary statistics for $\delta^{13}C_{VPDB}$ values (‰) and estimated f_{wc} (%) are reported in Extended Data Fig. 4c. Box and whisker plots are shown in Extended Data Fig. 4b. LOM3 $\delta^{13}C_{VPDB}$ values are significantly lower than those from the Busidima Formation at Gona (t test, $p < 0.001$) and have a mean value that indicate 18% more woody canopy cover. East African hominin habitats underwent a transition from woodland- to grassland-dominated ecosystems throughout the Plio-Pleistocene and an increase on this order has been documented[32]. When compared to paleosol $\delta^{13}C_{VPDB}$ values of the Koobi Fora, Nachukui, Chemeron, and Hadar formations from 3.2 to 3.4 Ma, LOM3 $\delta^{13}C_{VPDB}$ values are not significantly different (One-way ANOVA, $p > 0.05$). All Pliocene East African hominin localities used in this comparison produced f_{wc} percentages indicating that the woodland/bushland/thicket/shrubland structural category was most abundant, but wooded grasslands were also present.

PART E. PALAEONTOLOGY AND ZOOARCHAEOLOGY OF THE LOM3 AND LO5 LARGER VERTEBRATE FOSSILS

Over 25 large vertebrate species are present in the LO5 collecting area[113], of which 5 were found in the LOM3 site's surface or excavation: elephant and hippopotamus (a molar enamel plate and a premolar fragment, respectively), a crocodile of small size, an alcelaphine, and a large felid (distal tibia fragment). The most remarkable piece found *in situ* in the excavation is a set of horn cores of an alcelaphine of medium size, provisionally attributed to *Parmularius*. Primate remains are present, especially *Theropithecus*. Within the Equidae, fossils of *Eurygnathohippus* aff. *hasumense* were recovered, comprising an interesting range of size variation which is to be further studied. As for the Bovidae, remains of Alcelaphini are dominant, with a large bodied species (aff. *Megalotragus*) and a smaller one represented both by isolated teeth but also a few intact mandibles, with a high proportion of young adults (teeth only beginning to wear). *Aepyceros shungurensis* is also well represented. An isolated tooth of a small bovine confirms the presence of *Ugandax*, and a very small bovine, represented by a distal tibia, conforms favourably with Neotragini.

A total of 75 bones and teeth, including identifiable specimens, were collected in the zone around the LOM3 site; 33 come from the LOM3 site itself: 11 *in situ* and 22 from the surface. The latter are mainly fragments, primarily from a large mammal. Some ~40 very small fragments were found during screening (mammal micro-flakes, fish micro-plaques, and micro-fragments of hippopotamus and crocodile teeth). Overall this fossil association suggests a paleoenvironment that had a high vegetal biomass with important tree cover, probably riverine forest and wooded savannah nearby. The presence of *Theropithecus brumpti* supports the former, and several open or semi-open bovid species support the latter.

In the main, the LOM3 bone material is well preserved, often white in colour, but sometimes presenting sandy concretions. We have systematically examined all fossil element/fragment surfaces in the field in order to observe any possible hominin-inflicted modifications (stone tool cut marks, impact marks, etc). No anthropic marks were detected, but we did identify several elements presenting carnivore tooth marks (both furrows and pits). Additionally, certain fragments display green-bone (spiral) fracture, sometimes associated with carnivore tooth marks, and some coprolites are present.

The fossil faunal assemblage from the LO5 collection area has not yet been inspected for surface marks indicative of hominin interaction, but the fossil faunal assemblage from the LO10 collection area, just a kilometre to the east, was inspected for surface marks. None preserved hominin inflicted cut or percussion marks, though carnivore tooth marks were observed.

PART F. 3D SCANS OF THE LOM3 ARTEFACTS

3D laser scans of all of the lithic artefacts pictured in the Article and accompanying Extended Data can be freely viewed on http://africanfossils.org/search.

PART G. REFERENCES CITED IN SUPPLEMENTARY INFORMATION SECTIONS

65. Brown, B., Brown, F. H. & Walker, A. New hominids from the Lake Turkana Basin, Kenya. *J. Hum. Evol*. **41**, 29-44 (2001).

66. Kimbel, W. H. & Delezene, L. K. ‘‘Lucy’’ Redux: A Review of Research on *Australopithecus afarensis*. *Year. Phys. Anthropol*. **52**, 2-48 (2009).

67. Senut, B. D'*Australopithecus* à *Praeanthropus* ou du respect de la nomenclature internationale. *Ann. Paleontol.* **81**, 281-283 (1995).

68. Strait, D. S., Grine., F. E. & Moniz, M. A. A reappraisal of early hominid phylogeny. *J. Hum. Evol*. **32**, 17-82 (1997).

69. White, T. D. 2003. Early hominid-diversity or distortion? *Science* **299**, 1994-1997 (2003).

70. Kimbel, W. H. *et al.* Was *Australopithecus anamensis* ancestral to *A. afarensis*? a case of anagenesis in the hominin fossil record. J. Hum. Evol. **51**, 134-152 (2006).

71. Spoor, F., Leakey, M. G. & Leakey, L. N. Hominin diversity in the Middle Pliocene of eastern Africa: the maxilla of KNM-WT 40000. *Philos. Trans. R. Soc. B-Biol. Sci*. **365**, 3377-3388 (2010).

72. Hill, A., Ward, S., Deino, A., Curtis, G. & Drake, R. Earliest *Homo*. *Nature* **355**, 719-722 (1992).

73. Howell, F. C., Haesaerts, P. & de Heinzelin, J. Depositional environments, archaeological occurrences and hominids from Members E and F of the Shungura Formation (Omo basin, Ethiopia). *J. Hum. Evol*. **16**, 665-700 (1987).

74. Schrenk, F., Bromage, T. G., Betzler, C. G., Ring, U. & Juwayeyi Y. M. Oldest *Homo* and Pliocene biogeography of the Malawi Rift. *Nature* **365**, 833-836 (1993).

75. Tocheri, M., Orr, C., Jacofsky, M. & Marzke, M. W. The evolutionary history of the hominin hand since the last common ancestor of *Pan* and *Homo*. *J. Anat.* **212**, 544-562 (2008).

76. Marzke, M. W. Precision grips, hand morphology, and tools. *Am. J. Phys. Anthropol.* **102**, 91-110 (1997).

77. Dominguez-Rodrigo, M., Pickering, T. R. & Bunn, H. T. Configurational approach to identifying the earliest hominin butchers. *Proc. Nat. Acad. Sc. USA* **107**, 20929-20934 (2010).

78. McPherron, S. P. *et al.* Tool-marked bones from before the Oldowan change the paradigm. *Proc. Nat. Acad. Sc. USA* **108** E116 (2011).

79. Napier, J. R. The prehensile movements of the human hand. *J. Bone Joint Surg*. **38B**, 902-913 (1956).

80. Almécija, S. & Alba, D. M. On manual proportions and pad-to-pad precision grasping in *Australopithecus afarensis*. *J. Hum. Evol*. **73**, 88-92 (2014).

81. Marzke, M. W. Tool making, hand morphology and fossil hominins. *Phil. Trans. R. Soc. B* **368**, 20120414 (2013).

82. Moyà-Solà, S., Köhler, M. & Rook, L. Evidence of hominid-like precision grip capability in the hand of the Miocene ape *Oreopithecus*. *Proc. Nat. Acad. Sc.* **96**, 313-317 (1999).

83. Almécija, S., Shrewsbury, M., Rook, L. & Moyà-Solà, S. The morphology of *Oreopithecus bambolii* pollical distal phalanx. *Am. J. Phys. Anthropol.* **153**, 582-597 (2014).

84. Gommery, D. & Senut, S. The terminal thumb phalanx of *Orrorin tugenensis* (Upper Miocene of Kenya). *Geobios* **39**, 372-384 (2006).

85. Almécija, S., Moya-Sola, S. & Alba, D. M. Early origin for human-like precision grasping: A comparative study of pollical distal phalanges in fossil hominins. *PLoS One* **5**, e11727 (2010).

86. Lovejoy, C. O., Simpson, S. S., White, T. D., Asfaw, B. & Suwa, G. Careful climbing in the Miocene: the forelimbs of *Ardipithecus ramidus* and humans are primitive. *Science* **326**, 70 (2009).

87. Ward, C. V., Kimbel, W. H., Harmon, E. H. & Johanson, D.C. New postcranial fossils of *Australopithecus afarensis* from Hadar, Ethiopia (1990-2007). *J. Hum. Evol.* **63**, 1-51 (2012).

88. Latimer, B. Locomotor adaptations in *Australopithecus afarensis*: the issue of arboreality. in *Origine(s) de la Bipédie chez les Hominidés* (eds Y. Coppens & B. Senut) 169-176 (CNRS, Paris, 1991).

89. Alba, D. M., Moyà Solà, S. & Köhler, M. Morphological affinities of the *Australopithecus afarensis* hand on the basis of manual proportions and relative thumb length. *J. Hum. Evol.* **44**, 225-254 (2003).

90. Drapeau, M. S., Ward, C. V., Kimbel, W. H., Johanson, D. C. & Rak, Y. Associated cranial and forelimb remains attributed to *Australopithecus afarensis* from Hadar, Ethiopia. *J. Hum. Evol.* **48**, 592-642 (2005).

91. Marzke, M. W. & Shackley, M. S. Tools and the Morphology of Hominid Hands. *Am. J. Phys. Anthropol.* **69**, 237-237 (1986).

92. Rolian, C. & Gordon, A. D. Reassessing manual proportions in *Australopithecus afarensis*. *Am. J. Phys. Anthrop.* **152**, 393-406 (2013).

93. Reynolds, S. C. & Kibii, J. M. Sterkfontein at 75: review of palaeoenvironments, fauna and archeology from the hominin site of Sterkfontein (Gauteng Province, South Africa). *Paleont. Afr.* **46**, 59-88 (2011).

94. Green, D. J. & Gordon, A. D. Metacarpal proportions in *Australopithecus africanus*. *J. Hum. Evol.* **54**, 705-719 (2008).

95. Ricklan, D. E. Functional anatomy of the hand of *Australopithecus africanus. J. Hum Evol.* **16**, 643-664 (1987).

96. Skinner, M. M. *et al.* Human-like hand use in *Australopithecus africanus*. *Science* **347**, 395-399 (2015).

97. Walter, R. C., Manega, P. C., Hay, R. L., Drake, R. E. & Curtis, G. H. Laser-fusion $^{40}Ar/^{39}Ar$ dating of Bed 1, Olduvai Gorge, Tanzania. *Nature* **354**, 145-149 (1991).

98. Moyà-Solà, S., Köhler, M., Alba, D. M. & Almécija, S. Taxonomic attribution of the Olduvai hominid 7 manual remains and the functional interpretation of hand morphology in robust Australopithecines. *Folia Primatol.* **79**, 215-250 (2008).

99. Napier, J. Fossil hand bones from Olduvai Gorge. *Nature* **196**, 409-411 (1962).

100. Susman, R. L. & Creel, N. Functional and morphological affinities of the subadult hand (O.H.7) from Olduvai Gorge. *Am. J. Phys. Anthropol*. **51**, 311-332 (1979).

101. Susman, R. L. & Stern, J. T. Functional Morphology of *Homo habilis*. *Science* **217**, 931-934 (1982).

102. Pickering, R., Kramers, J. D., Hancox, P. J., de Ruiter, D. & Woodhead, J. Contemporary flowstone development links early hominin bearing cave deposits in South Africa. *Earth Planet. Sci. Lett*. **306**, 23-32 (2011).

103. Susman, R. L. Hand of *Paranthropus robustus* from Member 1, Swartkrans: Fossil evidence for tool behavior. *Science* **240**, 781-784 (1988).

104. Susman, R. L. Fossil evidence for early hominid tool use. *Science* **265**, 1570-1573 (1994).

105. Susman, R. L. Hand function and tool behavior in early hominids. *J. Hum. Evol.* **35**, 23-46 (1998).

106. Kivell, T. L., Kibii, J. M., Churchill, S. E., Schmid, P. & Berger, L. R. *Australopithecus sediba* hand demonstrates mosaic evolution of locomotor and manipulative abilities. *Science* **333**, 1411-1417 (2011).

107. Ward, C. V., Tocheri, M., Plavcan, J. M., Brown, F. H. & Manthi, F. K. Early Pleistocene third metacarpal from Kenya and the evolution of modern human-like hand morphology. *Proc. Nat. Acad. Sc. USA* **111**, 121-124 (2014).

108. Feibel, C. S. A Geological History of the Turkana Basin. *Evol. Anthropol*. **20 (6)**, 206-216 (2011).

109. Brown, F. H. & Feibel, C. S. Revision of lithostratigraphic nomenclature in the Koobi Fora region, Kenya. *J. Geol. Soc.* **143**, 279-310 (1986).

110. Harding, P., Gibbard, P. L., Lewin J., Macklin, M. G. & Moss, E. H. The transport and abrasion of flint handaxes in a gravel-bed river. in *The Human Uses of Flint and Chert* (eds. de G. Sieveking, G. & Newcomer, M. H.) 115-126 (Cambridge University Press, 1987).

111. Schick, K. D. Experimentally-Derived Criteria for Assessing Hydrologic Disturbance of Archaeological Sites. in *Natural Formation Processes and the Archaeological Record* (eds. Nash, D. T. & Petraglia, M. D.) 86-107 (British Archaeological Reports, 1987).

112. Lenoble, A. *Ruissellement et formation des sites préhistoriques: référentiel actualiste et exemples d'application au fossile* (British Archaeological Reports, 2005).

113. Bobe, R. Fossil Mammals and Paleoenvironments in the Omo-Turkana Basin. *Evol. Anthropol.* **20**, 254–263 (2011).