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Evidence for Quaternary climate change in East Africa has been derived from outcrops on land, lake cores and from marine dust, leaf wax and pollen records. These data have previously been used to evaluate the impact of climate change on hominin evolution, but correlations have proven to be difficult given poor data continuity and the great distances between marine cores and terrestrial basins where fossil evidence is located. Here we present the first continental coring evidence for progressive aridification since about 575 thousand years ago (ka), based on Lake Magadi (Kenya) sediments. This long-term drying trend was interrupted by many wet-dry cycles, with the greatest variability developing during times of high eccentricity-modulated precession. Intense aridification apparent in the Magadi record took place between 525–400 ka, with relatively persistent arid conditions after 350 ka and through to the present. Arid conditions in the Magadi Basin coincide with the Mid-Brunhes Event and overlap with mammalian extinctions in the South Kenya Rift between 500–400 ka. The 525–400 ka arid phase developed in the South Kenya Rift between the period when the last Acheulean tools are reported at about 500 ka and prior to the appearance of Middle Stone Age artefacts by about 320 ka. Our data suggest that increasing mid-late Pleistocene aridification and environmental variability may have been drivers in the physical and cultural evolution of *H. sapiens*in East Africa.

Quaternary | paleoclimate | paleolimnology | hominins | Lake Magadi

Several hypotheses have attempted to explain human evolution and its possible relationship with environmental change (1, 2). The savannah hypothesis suggested that bipedalism resulted from hominins moving from forests to grassy savannas (3). Other theories emphasized climate as an evolution driver, including the aridity, turnover pulse, variability selection and accumulated plasticity hypotheses (4–7). Evaluation of these ideas has been hindered by a lack of basin-scale records that can provide a high-resolution environmental context. The Hominin Sites and Paleolakes Drilling Project (HSPDP) has attempted to fill this gap by providing continental sedimentary records that can be linked to nearby hominin fossils and artefacts in Ethiopia and Kenya (8).

Here we present evidence from the southernmost HSPDP site, at Lake Magadi (Fig. 1), that is relevant to debates about the climatic context of human evolution, from an area close to some of the most important records of hominin prehistory. The Lake Magadi record spans the past one million years (Fig. 2; see SI Appendix text, Figs. S1–3 and Tables S1–7 for details of dating methods) and can be compared with --a 1.2 million-year (Ma) sequence at Olorgesailie, 25 km to the northeast (9–11). The Olorgesailie deposits and archeological record document a transition from Acheulean to Middle Stone Age (MSA) toolkits (12–14), with the Magadi core, and cores from the neighboring Koora Basin drilled by the Olorgesailie Drilling Project (8, 15), covering the period when *H. sapiens* emerged in Africa (16). The Magadi and Olorgesailie records also span a turnover in large mammals before 320 ka (14), which has also been documented at Lainyamok between 500–400 ka, 15 km west of Magadi (17). Thus, Lake Magadi is located in a region containing archeological and paleontological Middle Pleistocene sites that provide critical information about the relationships between climate dynamics and human prehistory.

Lake Magadi is a seasonally flooded saline alkaline pan about 606 m above sea level in the South Kenya Rift (Fig. 1a) surrounded by poorly correlated cherts, silts and evaporites (18–19). Core HSPDP-MAG14-2A (hereafter MAG14-2A, Fig. 1b) includes trona, zeolitic mud, chert, tuff, and carbonate grainstone deposited in a regional tectonic sump that has been occupied by a lake since eruption of the underlying lavas (1.08 Ma). This study combines geochemical, mineralogical, diatom and pollen analyses that indicate a trend towards a more saline, alkaline lake and a more arid climate from about 575 ka to the present. This progressive change was interrupted by wetter episodes, but was directional in overall character towards increasing aridity.

Results

Progressive changes in geochemistry and mineralogy. Loss on Ignition (LOI) at 1,000°C (Fig. 2a; SI Appendix, Table S7) indicates combustible carbonates (calcite, trona) and organic matter. High LOI values before 950 ka, or 187 meters below surface (mbs), reflect shallow water carbonate grainstones. LOI (550°C) is low (<3%) between 950–800 ka (187–178 mbs) with higher val-

Significance

Previous research hypotheses have related hominin evolution to climate change. However, most theories lack basin-scale evidence for a link between environment and hominin evolution. This study documents continental, core-based, evidence for a progressive increase in aridity since about 575 ka in the Magadi Basin with a significant change from the Mid-Brunhes Event (~ 430 ka). Intense aridification in the Magadi Basin corresponds with faunal extinctions and changes in toolkits in the nearby Olorgesailie Basin. Our data are consistent with climate variability as an important driver in hominin evolution, but also suggest that intensifying aridity may have had a significant influence on the origins of modern *H. sapiens* and the onset of the Middle Stone Age.

Reserved for Publication Footnotes

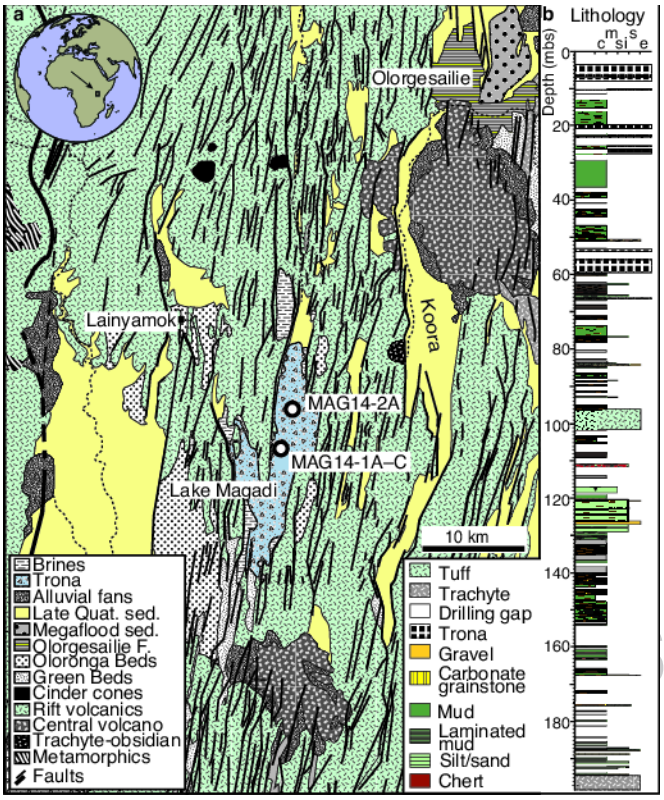

Fig. 1. Core location and lithology. a, Location of MAG14-2A and 1A and geology. **b,**Sediment log for MAG14-2A; c=clay, m = mud, si = silt, s = sand, e = evaporites.

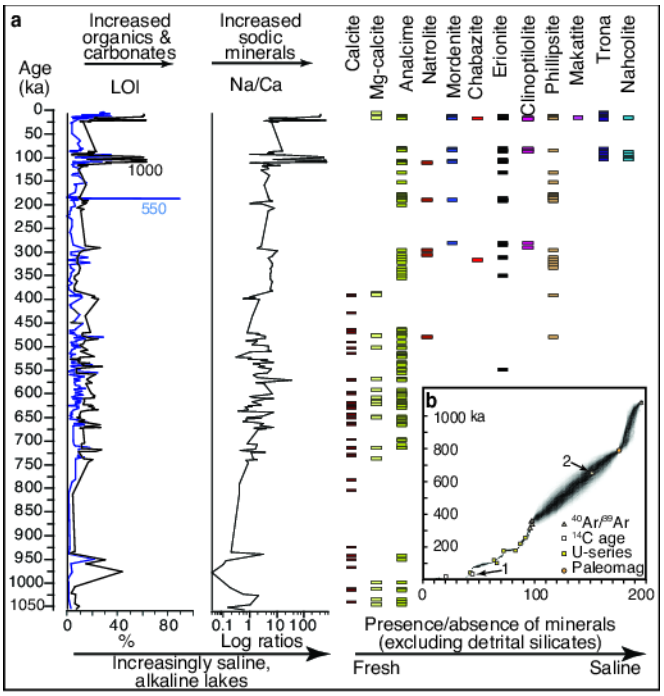

Fig. 2. Core chronology, geochemistry and mineralogy. a, Geochemistry and mineralogy. LOI (550/1000) = Loss on Ignition and ignition temperatures (centigrade). Profile of Na/Ca ratios. Major authigenic minerals (excluding clays, quartz, feldspar) determined by X-ray diffraction. Minerals ordered to reflect generally higher salinities to the right. **b,**Bayesian chronological model. 1 = Excluded ^{14}C date that fails to follow a monotonic ordering. 2 = Excluded ^{40}Ar/^{39}Ar date from a single crystal. Two chert dates from samples later found to contain secondary chalcedony were also excluded from the model. See SI for details.

ues (5–20%) in younger sediments suggesting greater lake floor anoxia. Major increases in LOI in sediments <111 ka (65 mbs) reflect increases in organics and trona, which accumulated in highly saline alkaline, anoxic waters. Na/Ca ratios increased with time (Fig. 2a) as a result of a shift from calcium-rich (calcite, Mg-calcite) to Na- and K-rich (erionite, trona) chemical sediments. The upward decline in Ca probably reflects early precipitation of $CaCO_3$ near shorelines where streams entered an alkaline paleolake and relative increases in groundwater contributions, as drier conditions developed, which would have favored lower Ca through subsurface precipitation.

Mineralogical data also document progressive changes (Fig. 2a). Authigenic minerals are dominated by calcite and Mg-calcite in sediments >385 ka (103 mbs), indicating fresh to mildly saline groundwater. Analcime occurs throughout the core with other zeolites accumulating since 375 ka, indicating a shift towards more saline alkaline conditions. The zeolites formed from Na-Al-Si alkaline spring gels washed into the basin or by alteration of aluminosilicate minerals or volcanic glass (20). Trona was deposited after 111 ka (65 mbs) in highly saline, alkaline water.

Diatom and pollen stratigraphy. Diatoms are absent in MAG14-2A sediments >545 ka (132 mbs), but are present in basal limestones in a second core, MAG14-1A (Fig. 1a), where benthic and epiphytic taxa indicate freshwater swamps. A few cherts contain *Anomoeoneis sphaerophora*, a moderate to high salinity taxon present in shallow springs today (21). The occurrence of diatoms only in well-cemented chert and limestone suggests they may have dissolved from unlithified deposits. The dominant taxa in the diatomaceous interval (about 545–16 ka; 132–38 mbs) include mixed planktonic freshwater (*Aulacoseira granulata*, *A. agassizi*) and saline species (*Cyclotella meneghiniana*, *Thalassiosira faurii*; details in SI Appendix, Fig. S4 and Dataset S1), suggesting a deep meromictic lake with permanent saline waters that were periodically overtopped by fresh fluvial inputs. The evidence for flooding is supported by intermittent freshwater benthic taxa (22) such as *Cocconeis placentula*, *Encyonema muelleri* and *Epithemia* spp.

Mean transfer functions for all diatoms indicate pH of about 7.4–11.4 and conductivities of 300–40,000 µS cm^{-1} (Fig. 3). However, given the evidence for episodic meromixis, there is a need to recalculate the data separately for surface freshwater and deeper saline water taxa (Fig. 3), which suggests that the pH of freshwater inputs ranged between 7.3–8.5 with conductivities of 200–2,000 µS cm^{-1}. The saline floras document increased pH after about 385 ka (103 mbs), from 9.2–10 to 9.4–11.5. An absence of diatoms after about 18 ka suggests that pH and conductivity exceeded tolerance limits or resulted in dissolution.

Grasses (Poaceae) dominated with a smaller sedge (Cyperaceae) component before about 900 ka (184 mbs), with pollen not preserved between 900–735 ka (184–168 mbs) (Fig. 4; detailed floras in SI Appendix, Figs. S9–S10 and Dataset S2), possibly due to oxygenated conditions. Cyperaceae increased relative to Poaceae between about 735–520 ka (168–127 mbs) and dominated between 605–568 ka (143–136 mbs), with other minor aquatics (*Typha, Potamogeton*), suggesting shallow fresh waters (21). There were also significant increases in *Podocarpus* (735–520 ka) and *Olea* (698–635 ka; 160–147 mbs) with *Juniperus* appearing after 735 ka. *Podocarpus* is common in modern upland forests in Kenya and, where abundant, has been used to infer expansion of Afromontane forests or changes in fluvially-transported regional pollen (23, 24). The parallel trends for *Podocarpus*, Cyperaceae and the other aquatic indicators imply a climatic control. Although broadly the wettest interval in the last million years, climate varied with a drier episode at about 662–625

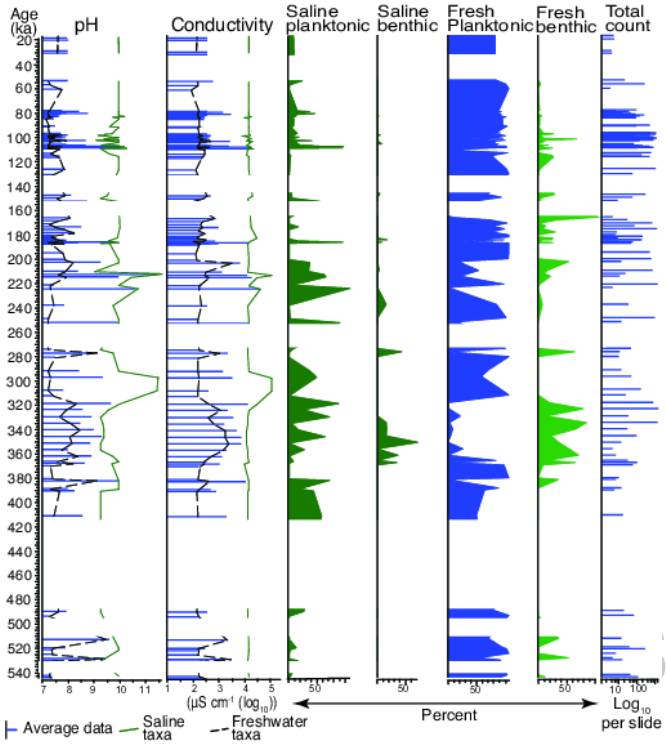

Fig. 3. Diatom-based environmental data. Diatoms accumulated in a meromictic lake so separate conductivity and pH transfer functions are shown for mixed, saline and fresh water taxa. Habitats indicated separately for saline and fresh taxa.

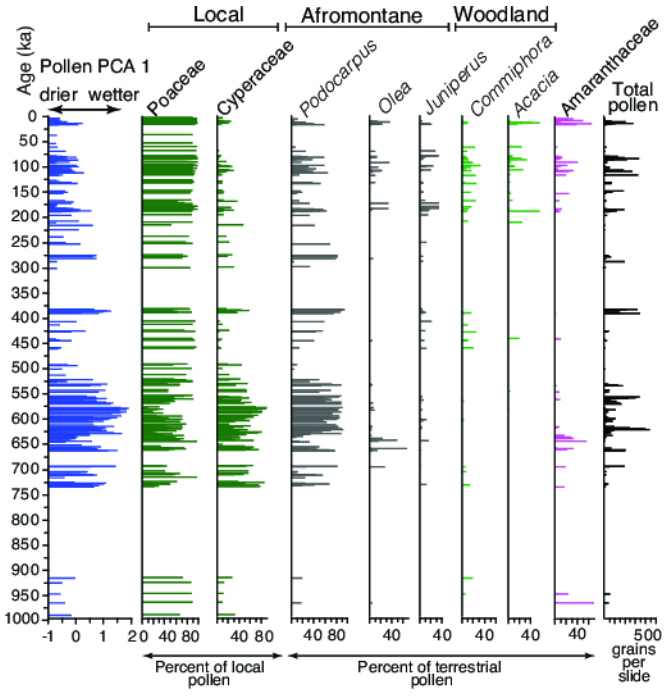

Fig. 4. Pollen stratigraphy. Selected taxa shown. Pollen PCA 1 summarizes all pollen data and shows a long-term reduction in PCA values from ~575 ka that reflects increased aridity. Poaceae increase upwards with Cyperaceae and *Podocarpus*declining. Other taxa suggest increasing aridity during the last half million years.

ka (153–146 mbs) marked by increased Amaranthaceae, with the wettest conditions at 575 ka (137 mbs) (Fig. 4).

Cyperaceae and *Podocarpus* declined between about 520–400 ka (127–105 mbs), suggesting greater aridity at a time when diatoms indicate a meromictic lake and/or alternating saline and freshwater lakes. A recovery in *Podocarpus* and Cyperaceae between 400–275 ka (105–94 mbs) suggests a wetter interval that was followed by a decline in these taxa. During the last 275 ka (94 mbs) a variety of taxa expanded and contracted, reflecting wetter and drier settings, but with an overall trend towards greater aridity. *Olea*, for example, is derived from wet and dry upland evergreen forests and varies in abundance between about 275–5 ka (94–7 mbs) when it disappears. *Commiphora* and *Acacia* increase after 205 ka (87 mbs) suggesting dry semi-deciduous dense bushland, with drought-related Amaranthaceae and *Juniperus*, associated with drier upland forests (25), also common. Increases in Cyperaceae along with herbaceous pollen such as *Hydrocotyle* between about 12–8 ka (17–12 mbs) suggest fresher waters. Afromontane and woodland species were replaced by herbaceous pollen and Poaceae through the last 8 ka with Poaceae forming nearly 100% of the flora after 4 ka (6 mbs).

Na/Ca ratios, PCA data for all pollen, and grass to aquatic pollen ratios indicate an overall progressive change during the last half million years (Fig. 5). Prior to 575 ka the basin had trended towards wetter conditions, but then there was an overarching shift towards greater aridity superimposed on multiple wet-dry cycles. Independent terrestrial and aquatic datasets that varied in unison indicate that this change was not simply due to lake hydrology and local tectonics, but was driven by a directional climate shift. Intermittent positive spikes in diatom PCA data between 350–70 ka reflect increases in shallow, freshwater, diatoms. The strong contrast in habitat preferences between the dominant mixed saline and fresh, deep-water planktonic taxa (*Thalassiosira* spp., *Aulacoseira granulata* and variety *valida*) and episodic shallow, freshwater, lake/wetland (*A. agassizi*, *A. granulata* v. *angustissima*) and benthic floras (Fig. 3) suggest that the latter may have been transported intermittently by floods from nearby swampy and/or fluvial settings to the core site (22). Many of the younger spikes also match pollen evidence for wetter periods (195, 170, 125, 95, 80 ka) and interglacial episodes. The amplitude of the spikes decrease with time, as does their temporal spacing. A lack of diatoms after about 16 ka reflects the formation of an ephemeral hypersaline playa.

Discussion

Climate change. On a global scale a major inflection point in Pleistocene climate, the Mid-Brunhes Event (MBE), close to the boundary between Marine Oxygen Isotope stages 12 to 11, took place about 430 ka. Subsequently, there was increased climate variability with the development of colder glacial periods and warmer interglacial episodes (26, 27), although it has been suggested that the MBE is regionally inconsistent. Terrestrial data from the UK (28), for example, have been used to infer no significant change across the MBE, whereas continental evidence from Spain (29) supports a climate transition.

The continental pollen record from equatorial Lake Magadi provides strong support for a climate transition at the MBE (Fig. 5), suggesting a potential link to global CO_2/glacial cyclicity, with a major change from wetter conditions to greater aridity after about 430 ka. The overall trend towards dryer conditions was initiated about 575 ka, with particularly intense aridity developing between 525–400 ka, which partially overlaps with Marine Oxygen Isotope Stage 11 (424–374 ka), the warmest interglacial of the last 500 ka (30). Subsequently, many wetter and drier cycles were superimposed on progressive aridification, with diatomaceous parts of the core documenting a tendency towards increased flood inputs of benthic taxa (increased PCA values) during interglacial episodes (Fig. 5).

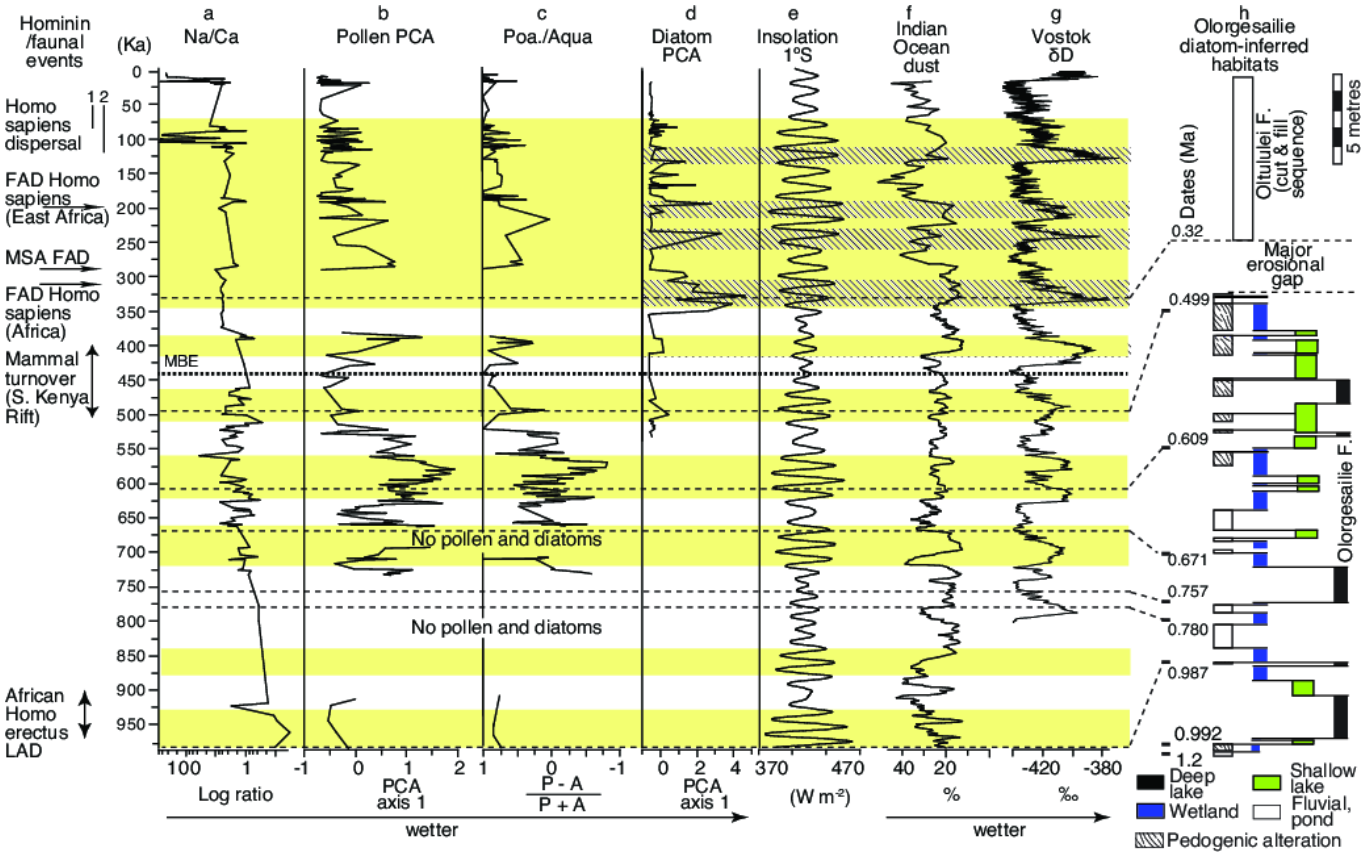

Fig. 5. Temporal environmental change in the Magadi basin and regional comparisons. Major hominin/faunal events in eastern Africa (except where noted) to left (8). First appearance of *H. sapiens* in Africafrom Morocco data (16). *H. sapiens*dispersal: 1 = genetic data (41), 2 = fossil data (39, 40).FAD = First Appearance Datum; LAD = Last Appearance Datum. Thick dashed line shows the Mid-Brunhes Event (MBE). **a,**Na/Ca ratios. Decline reflects change from fresh to saline alkaline lake. **b,**Pollen PCA 1. Low values reflect increased aridity. **c,**Poaceae to aquatic pollen ratios (P-A/P+A). High values indicate wetter episodes. **d,**Diatom Principal Component Analysis. High values reflect benthic taxa introduced to a meromictic lake by flooding. Note that many of these flood events broadly correlate (diagonal shading) with interglacial episodes in "g". **e,**Insolation (1°S) from AnalySeries 2.0. High variability periods shaded. **f,**Northwest Indian Ocean dust record (26). Note long-term increasing aridity through the last 400 ka. **g,**Change in deuterium in Vostok ice core, East Antarctica (27). Note increased variability in glacial-interglacial cycles after the MBE. **h,**Diatom-inferred environmental change, Olorgesailie Basin(47).

This directional increase in aridity since ~575 ka has not previously been documented in continuous continental cores from East Africa, although there is support from pedogenic carbonate carbon isotopes in outcrops (31) and eolian dust records from the northwest Indian Ocean (7, 26) (Fig. 5), which suggest a similar pattern of increasing aridity and intermittently wetter intervals through the last half million years. Limited pedogenic carbonate carbon isotope data from Olorgesailie indicate an overall increase in C4 grasslands during the last 800 ka (14). Oxygen and carbon isotopes from several sites within a 990 ka Olorgesailie Formation paleosol, for example, suggest an abundance of wooded grassland in a cooler and moister environment at that time compared with the modern grassy semi-arid basin (32).

There are also clear correlations for specific intervals in the Magadi record with other African regions. For example, the deposition of trona and intermittent severe reductions in aquatic pollen between about 110–80 ka indicate a series of very dry phases that alternated with wetter intervals. The termination of this drought period lies close to a transition from megadroughts to wetter conditions at Lake Malawi and more widely across tropical Africa (33, 34). However, in contrast, the overall drying trend at Magadi is inconsistent with an inferred shift towards wetter conditions noted at Lake Malawi (35) indicating regional African contrasts in vegetation and climate patterns. However, pollen data (36) show some similarities with high percentages of *Podocarpus* between 455–325 ka at Malawi coinciding with increased *Podocarpus* at Magadi after 455 Ka.

Climate and hominin evolution. The nearby Olorgesailie Basin provides detailed information on hominin evolution for the last million years with evidence for a major transition in stone technologies (Fig. 5). The Olorgesailie Formation (~1,200–500 ka) includes Acheulean tools (14) whereas MSA artefacts (12) are present in the Oltulelei Formation (~320–36 ka) (11), with the transition between these toolkits taking place during a period of erosion at Olorgesailie that has been related to faulting and base-level change (10). New environmental data from Magadi show increasing aridity during the period of hiatus at Olorgesailie with intense desiccation between 525–400 ka. This suggests that erosion at Olorgesailie might partly reflect climatic conditions, with aridity lowering lake and base levels and changing/reducing the vegetation cover, which would, in turn, tend to enhance erosion of more exposed land surfaces (37). Magadi pollen data (SI Appendix, Fig. S5), for example, indicate an expansion of grasslands and reduction in aquatic pollen after about 525 ka. The arid interval also closely overlaps with a major overturn in mammal faunas with local extinction of large-bodied specialized grazing mammals reported from both Olorgesailie (14) and Lainyamok (17).

The 525–400 ka dry phase and environmental variability would likely have had a significant impact on contemporary hominin populations regionally. It has been hypothesised (14), for

example, that environmental pressures and variability can lead to an uneven distribution of resources that could drive hominins to travel more widely and to interact increasingly with other groups for both raw materials and information. In turn, this would help to drive technological change and its dissemination, resulting in increased foraging success rates and ability to survive.

The Magadi terrestrial pollen record suggests that the interval with greatest climate variability took place between about 650–350 ka with moister periods tending to be linked to high-amplitude insolation variability and with drier episodes developing at times of low-amplitude insolation (e.g., 655–620, 560–510, 455–410, <75 ka; Fig. 5). Similarly, changes in toolkits overlap with the 650–350 ka period, with modest reductions in Olorgesailie Acheulean stone tool sizes reported between 615 and 499 ka (14) and with the smaller toolkits of the MSA developing by about 320 ka (12–14). This increased environmental variability, and the intense period of aridity, also overlap with a major turnover in mammal faunas with several large-bodied specialized grazing mammals becoming locally extinct and being replaced by related species with smaller body sizes (14, 17). As the earlier fauna was already arid-adapted, the progressive increase in aridity was unlikely to have led to any turnover. However, a change in variability, that very specialized grazers couldn't adapt to, may have led to the turnover. It is also possible that increased aridity, or more variable environmental conditions in the context of increasing aridity may have impacted hominin populations during this transitional period by selecting for cognitive abilities to, for example transport increasingly diversified toolkits over greater distances, as is evidenced in the nearby Olorgesailie archeological record (12).

Major steps in Quaternary hominin evolution have also been linked to eccentricity-modulated high-amplitude insolation cycles specifically associated with extreme climate variability during moist intervals, rather than low-amplitude periods when monsoons are weakened and climate becomes drier (38). However, the possible overlap between intense aridity, major changes in toolkits, and mammal extinctions in the Magadi-Olorgesailie region argue against this version of a climate-evolution linkage.

The period between 350–50 ka represents the longest episode of eccentricity-modulated high amplitude insolation variability in the Middle to Late Pleistocene (Fig. 5). This coincides with significant environmental change when MSA tools emerged, symbolic cultures developed, *H. sapiens* appeared and the Late Stone Age commenced (2). Early anatomically modern human fossils from Asia indicate that they dispersed from Africa between 120–50 ka (39, 40) with genetic data suggesting that ancestral modern non-African populations originated from Africans that dispersed between 75–50 ka (41). Gulf of Aden leaf wax isotopes, close to a possible southern migration route, indicate multiple wet-dry cycles set against an overall drying trend (42). Our continental record indicates arid climates that were punctuated by moist episodes, which may have supported a greener Sahara, opening the possibility of northern routes.

Recent hominin studies have noted that *H. sapiens* and the cultural materials that they produced may have a polycentric African origin with reproductively semi-isolated populations adapting to local environments alongside genetic drift (43). In the South Kenya Rift, the 300-ka period of high-amplitude insolation variability was characterized by major environmental and hominin changes, providing support for hypotheses such as variability selection, which advocates adaptive evolutionary change during periods of increased environmental variability (4, 38, 44–46). However, it is important to note that this variability was superimposed on a strongly directional long-term trend towards increased aridity, especially during the critical 525-–400 ka interval of drying documented here, which coincides with major technological and evolutionary events in the regional human prehistory. The Magadi record thus suggests that the species and technological changes in the South Kenya Rift were occurring against a backdrop of both increased aridity and enhanced variability, both of which could have acted as strong selective agents during the transition from the Early to Middle Stone Age and in the evolution of anatomically modern humans.

Methods

Details of the drilling (June 2014) are presented in the SI Appendix text. Three holes were drilled at Site 1 with one (MAG14-2A) recovered from Site 2 (Fig. 1a). Core recovery for MAG14-2A was 65% with drilling terminated in trachyte at ~194mbs.

The chronology model (Fig. 2b) made use of one radiocarbon date from humate fractions of bulk organic matter in the upper core, nine replicate $^{40}Ar/^{39}Ar$ dates from mid core tephra, one $^{40}Ar/^{39}Ar$ date on a basal trachyte lava and seven U-series dates from chert. An $^{40}Ar/^{39}Ar$ date for a single feldspar grain from ash at 151 mbs was treated as supplementary and not included in the model, but plots within the 0.95 probability range for this depth (see SI Appendix for dating techniques). One ^{14}C date did not follow a monotonic sequence and was excluded from the model, but is shown in Fig. 2b. In addition, the model includes the Brunhes-Matuyama boundary in the lower core.

Samples for geochemical (n=343) and LOI (n=332) analyses were collected at about 32 cm intervals and where distinctive lithologies were present (see SI Appendix for techniques). Diatom samples (n=355) were collected every 32 cm with additional sampling at 10–15 cm intervals for diatomaceous sections, yielding 113 samples and 62 diatom taxa between 43–132 m (18–472 ka in SI Appendix, Fig. S4; Datasets S1, S2). A minimum of 400 diatoms were counted per slide, except where diatoms were rare, in which case all diatoms were included. Environmental reconstructions are based on the "Combined Salinity Dataset" in the European Diatom Database (EDDI) (http://craticula.ncl.ac.uk/Eddi/jsp/index.jsp) with taxa matched to the EDDI classification system. Pollen taxa (n=105) were identified in 354 samples with common pollen shown in SI Appendix, Figs. S5 and S6 and Datasets S3 and S4. Pollen and spores were mounted on slides and counted at 400x magnification. Pollen identification was made to the lowest possible taxonomic level, although some pollen types could only be identified to family level. The total count per sample generally ranged between 250–500 grains, except in a few samples where preservation was poor.

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Figures

Fig. 1. Core location and lithology. a, Location of MAG14-2A and 1A and geology. **b,** Sediment log for MAG14-2A; c=clay, m = mud, si = silt, s = sand, e = evaporites.

Fig. 2. Core chronology, geochemistry and mineralogy. a, Geochemistry and mineralogy. LOI (550/1000) = Loss on Ignition and ignition temperatures (centigrade). Profile of Na/Ca ratios. Major authigenic minerals (excluding clays, quartz, feldspar) determined by X-ray diffraction. Minerals ordered to reflect generally higher salinities to the right. **b,** Bayesian chronological model. 1 = Excluded ^{14}C date that fails to follow a monotonic ordering. 2 = Excluded ^{40}Ar/^{39}Ar date from a single crystal. Two chert dates from samples later found to contain secondary chalcedony were also excluded from the model. See SI for details.

Fig. 3. Diatom-based environmental data. Diatoms accumulated in a meromictic lake so separate conductivity and pH transfer functions are shown for mixed, saline and fresh water taxa. Habitats indicated separately for saline and fresh taxa.

Fig. 4. Pollen stratigraphy. Selected taxa shown. Pollen PCA 1 summarizes all pollen data and shows a long-term reduction in PCA values from ∼575 ka that reflects increased aridity. Poaceae increase upwards with Cyperaceae and *Podocarpus* declining. Other taxa suggest increasing aridity during the last half million years.

Figure 5. Temporal environmental change in the Magadi basin and regional comparisons. Major hominin/faunal events in eastern Africa (except where noted) to left (8). First appearance of *H. sapiens* in Africa from Morocco data (16). *H. sapiens* dispersal: 1 = genetic data (41), 2 = fossil data (39, 40). FAD = First Appearance Datum; LAD = Last Appearance Datum. Thick dashed line shows the Mid-Brunhes Event (MBE). **a,** Na/Ca ratios. Decline reflects change from fresh to saline alkaline lake. **b,** Pollen PCA 1. Low values reflect increased aridity. **c,** Poaceae to aquatic pollen ratios (P-A/P+A). High values indicate wetter episodes. **d,** Diatom Principal Component Analysis. High values reflect benthic taxa introduced to a meromictic lake by flooding. Note that many of these flood events broadly correlate (diagonal shading) with interglacial episodes in "g". **e,** Insolation (1°S) from AnalySeries 2.0. High variability periods shaded. **f,** Northwest Indian Ocean dust record (26). Note long-term increasing aridity through the last 400 ka. **g,** Change in deuterium in Vostok ice core, East Antarctica (27). Note increased variability in glacial-interglacial cycles after the MBE. **h,** Diatom-inferred environmental change, Olorgesailie Basin (47).