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1 Aridity, availability of drinking water and freshwater foods, and hominin and  
2 archeological sites during the Late Pliocene–Early Pleistocene in the western region of the  
3 Turkana Basin (Kenya): A review

4

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28

29 **Abstract**

30 Although the Turkana Basin is one of the driest regions of the East African Rift, its Plio–  
31 Pleistocene sediments are rich in freshwater vertebrates and invertebrates, providing evidence  
32 that freshwater foods were available in this region during the Plio–Pleistocene (4.2–0.7 Ma).  
33 Here we provide an overview of the hydroconnectivity of the Turkana Basin. We then review  
34 the period during which freshwater river and lake systems expanded into the western region of  
35 the Turkana Basin, where hominin and archeological sites have been discovered in sediments  
36 dating back to the Late Pliocene–Pleistocene. Freshwater conditions are reconstructed from  
37 river and lake sediments and the micro- and macrofauna they contain. Data synthesis suggests  
38 that drinking water and freshwater foods prevailed in the western region of the Turkana Basin  
39 at 4.20–3.98 Ma, 3.70–3.10 Ma, 2.53–2.22 Ma, then between 2.10–1.30 Ma and intermittently  
40 from 1.27 to 0.75 Ma. Milestones in hominin evolution occurred in this context, such as the  
41 first occurrence of *Australopithecus anamensis* (4.20–4.10 Ma) and *Kenyanthropus platyops*  
42 (3.50 Ma and 3.30–3.20 Ma), the presence of *Paranthropus aethiopicus* (2.53–2.45 Ma), early  
43 *Homo* (2.33 Ma), *Paranthropus boisei* (2.25 Ma and 1.77–1.72 Ma) and *Homo ergaster/Homo*  
44 *erectus* (1.75 Ma, 1.47–1.42 Ma and 1.10–0.90 Ma). Developments in hominin behavior also  
45 occurred during this timeframe, including the first known stone tools (3.30 Ma), the oldest  
46 Oldowan sites (2.34 Ma and 2.25 Ma) in the Turkana Basin, the earliest known evidence for  
47 the emergence of bifacial shaping in eastern Africa (1.80 Ma), and the first known Acheulean  
48 site (1.76 Ma). Our synthesis suggests that, diachronic variation in hydroconnectivity played a  
49 role on the amount of drinking water and freshwater foods available in the western region of  
50 the Turkana Basin, despite regional aridity.

51

52 **Keywords:** Hominin evolution; Paleoclimatology; Paleoenvironment; Hydroconnectivity;  
53 Omo Group deposits

54

55 **1. Introduction**

56 Over the past 25 years, numerous authors have linked climate change and hominin  
57 evolution based on the premise that resources essential to hominin development (e.g., brain  
58 size, cognition and behavior), such as water and food availability, have fluctuated in tandem  
59 with climate in the East African Rift (deMenocal, 1995, 2004, 2011; Vrba et al., 1995; Potts,  
60 1998, 2013; Bobe and Behrensmeyer, 2004; Wynn, 2000, 2004; Trauth et al., 2005, 2007, 2010,  
61 2015; Behrensmeyer, 2006; Bobe, 2006; Bonnefille, 2010; Levin et al., 2011; Cerling et al.,  
62 2011; Maslin et al., 2014, 2015; Levin, 2015; Potts and Faith, 2015; Cuthbert et al., 2017;  
63 Blumenthal et al., 2017; Timmermann et al., 2022). An important related debate about the  
64 relationship between climate change, hominin diet and behavior concerns landscape  
65 aridification in the Turkana Basin (Kenya, Ethiopia) (Wynn, 2004; Sommerfeld et al., 2014;  
66 Fortelius et al., 2016; Blumenthal et al., 2017; Quinn and Lepre, 2020, 2021; Lepre and Quinn,  
67 2022). During the Neogene, topographic uplift altered atmospheric moisture transport and  
68 distribution in the East African Rift, and the initiation of Northern Hemisphere glaciations at  
69 the end of the Pliocene intensified hydrological deficits in this region (Laporte and Zihlman,  
70 1983; deMenocal, 2004; Sepulchre et al., 2006; Blumenthal et al., 2017; Trauth et al., 2021).  
71 Along with hypotheses linking hominin adaptation to landscape aridification, the availability  
72 of water and food would also have been critical resources for their evolution (e.g., Cuthbert et  
73 al., 2017). The debate on aridification and drinking water and food availability is especially  
74 relevant to hominin evolution, as some previous hypotheses, such as the savanna and the  
75 turnover pulse hypotheses (Vrba et al., 1995; deMenocal, 2004) or the pulsed climate variability  
76 hypothesis (Maslin and Trauth, 2009; Maslin et al., 2015), considered climate instability to be  
77 key drivers of natural selection, adaptive divergence, and speciation in Plio–Pleistocene  
78 hominin evolution. Although the global climate changed during the Plio–Pleistocene transition,  
79 the responses of these changes on landscape, fauna and hominins are still debated in the East

80 African Rift and in the different regions of the Turkana Basin in particular (Blumenthal et al.,  
81 2017; Fortelius et al., 2016; Blumenthal et al., 2017; Villaseñor et al., 2020, 2023; Quinn and  
82 Lepre, 2020, 2021; Lepre and Quinn, 2022). The aims of this review are to examine the  
83 archeological and hominin records from the western region of the Turkana Basin (Kenya; Fig.  
84 1) and the evidence for the existence of freshwater conditions and resources in the western  
85 region of Turkana Basin between 4.20 and 0.70 Ma. This specific region of the Turkana Basin  
86 provides evidence of hominin and archeological sites dating back to the Late Pliocene–Early  
87 Pleistocene, raising new questions about the role of climate and environmental change on water  
88 and food resources and hominin evolution.

89         The western region of the Turkana Basin is unique, as the archeological site of Lomekwi  
90 3 has yielded the first lithic assemblage associated with Late Pliocene sediments, climate, and  
91 environment (Harmand et al., 2015; Lewis and Harmand, 2016; Quinn et al., 2021). Lomekwi  
92 3 is at least 300 kyr older than the earliest known Oldowan assemblages discovered at other  
93 localities (i.e., Gona, Ledi-Geraru, and Nyayanga; Semaw, 2006; Braun et al., 2019; Plummer  
94 et al., 2023). Other important archeological sites have been discovered in the same region of  
95 the basin over the past 30 years. For example, the Lokalalei 1A and 2C sites are among the  
96 oldest Oldowan assemblages known in Kenya and older than 2.2 Ma (Kibunjia et al., 1992;  
97 Roche et al., 1999; Delagnes et al., 2005; Harmand, 2009). The artifacts from Kokiselei 6 are  
98 the earliest known evidence for the emergence of bifacial shaping (Duke et al., 2021), and the  
99 archeological site of Kokiselei 4 has yielded the oldest Acheulean assemblage presently known  
100 (Lepre et al., 2011; Texier, 2018). These archeological sites provide some of the earliest  
101 evidence of hominin cognitive abilities in eastern Africa. As for the hominin record, the western  
102 region of the Turkana Basin has yielded some of the most important hominin fossils known,  
103 including *Australopithecus anamensis* (Leakey et al., 1995; Leakey et al., 1998; Ward et al.,  
104 1999, 2001, 2013, 2020), *Kenyanthropus platyops* (Leakey et al., 2001; Spoor et al., 2016),

105 *Paranthropus aethiopicus* (Walker et al., 1986) and *Paranthropus boisei* (Leakey et Walker,  
106 1988; Brown et al., 2001; Prat et al., 2003; Wood and Constantino, 2007), as well as specimens  
107 assigned to early *Homo* (Prat et al., 2005), *Homo ergaster* or *Homo erectus*, referred to here as  
108 *Homo ergaster/erectus* (Walker and Leakey, 1993; Prat et al., 2003; Wood and Leakey et al.,  
109 2011; Wood and Boyle, 2016), including the nearly complete skeleton of KNM-WT 15000  
110 ('Nariokotome Boy'; Walker and Leakey, 1993). This fossil record highlights the importance of  
111 the western region of the Turkana Basin in terms of hominin taxonomy and phylogeny (e.g.,  
112 Walker and Leakey, 1993; Leakey et al., 2001; Ward et al., 2020). The western region of the  
113 Turkana Basin is also very rich in freshwater micro- and macrofauna demonstrating that  
114 freshwater conditions expanded into this arid region of the East African Rift during the Plio–  
115 Pleistocene (e.g., Williamson, 1981; Harris et al., 1988; Meylan et al., 1990; Stewart, 2003;  
116 Martin and Trautwein, 2003; Storrs, 2003; Van Bocxlaer, 2011, 2020; Stewart and Rufolo,  
117 2020).

118         Similar, coeval records exist to the northern regions of the Turkana Basin in the  
119 Shungura, Mursi and Usno Formations (Ethiopia) along the Omo River and to the eastern  
120 regions in the Koobi Fora Formation (Kenya) and at Fejej and Konso (Ethiopia) (Williamson,  
121 1981; Howell et al., 1987; Stern et al., 1993; Isaac, 1997; Nagaoka et al., 2005; WoldeGabriel,  
122 et al., 2005; Chapon et al., 2005, 2011; Van Bocxlaer et al., 2008; Braun et al., 2010; Barsky et  
123 al., 2011; Delagnes et al., 2011; Leakey et al., 2012; Maurin et al., 2017; Fig. 1). Reviews of  
124 the Turkana Basin generally combine data from these different fluvial and lacustrine formations  
125 (i.e., located in the northern, western, eastern and southern regions of the Turkana Basin).  
126 However, this review covers only the western region of the Turkana Basin (Nachukui and  
127 Kanapoi Formations) and does not include data from the northern and northeastern regions of  
128 the basin (Shungura and Koobi Fora Formations). In these latter regions, freshwater conditions  
129 are more permanent, due to the presence of the Omo River delta. By contrast, in the western

130 and southern regions of the Turkana Basin, conditions have been more alkaline–saline since the  
131 closure of the outlet to the Indian Ocean at around 2.2 Ma (Boës et al., 2019a). Given the  
132 reorganization of the hydroconnectivity, it is important to consider the mosaic of landscapes  
133 with their own rhythms, hydroconnectivity and hydroclimatic influences from the northern,  
134 southern, eastern and western regions of the Turkana Basin. Here, we focus on understanding  
135 how landscapes changed regionally along the western region of the Turkana Basin, where the  
136 hydrology and limnology is substantially different from that of the Omo delta region. Moreover,  
137 in terms of hydroconnectivity, the upland river-lake systems in the western region of the  
138 Turkana Basin are associated with the hydroclimate of the Kenyan Highlands, while in the  
139 eastern region of the basin they are associated with the hydroclimate of the Ethiopian  
140 Highlands.

141         The various sources of data from the western region of the Turkana Basin (see Tables  
142 1–5) can be compiled in a reliable chronostratigraphic framework derived from  $^{40}\text{Ar}/^{39}\text{Ar}$  ages  
143 of volcanic tuffs and/or lateral correlations by geochemical signatures specific to each tuff (e.g.,  
144 Harris et al., 1988; Feibel et al., 1989; Brown and McDougall, 2011; McDougall et al., 2012).  
145 Plio–Pleistocene sediments and tuffs are outcropping in the Nachukui Formation, including  
146 Lothagam, Loruth Kaado, South Turkwel and in the Kanapoi Formation (Fig. 1; Table 2). The  
147 Nachukui and Kanapoi Formations offer ~700 m of strata with regularly intercalated tuffs that  
148 cover the period from 4.20 to 0.70 Ma without major chronostratigraphic gaps, although the  
149 interval between 3.1 and 2.7 Ma is represented by fewer outcrops. In this review, we consider  
150 that it is not possible at this time to provide accurate ages within the interval between 3.1 and  
151 2.7 Ma because there are no dated tuffs or paleomagnetic inversions, which considerably limits  
152 the reliability of sediment chronologies (and/or results in excessively large errors; see section  
153 3.6 below on methods for controlling chronology). In what follows, ages in Ma with two  
154 decimal places are argon–argon dated tuffs or ages that were directly interpolated from these

155 tuffs, whereas ages in Ma with one decimal place either were derived from paleomagnetism or  
156 were estimated.

157 We begin by introducing the impact of global climate change on eastern Africa during  
158 the Plio–Pleistocene and present our current understanding of the influence of regional climate  
159 on the Turkana Basin. We then provide an overview of the former hydroconnectivity of the  
160 Turkana Basin and highlight the topoclimatic effects on the regional hydroclimate system.  
161 Subsequently, we present the datasets and criteria we used to reconstruct the paleohydrological  
162 evolution of the western region of the Turkana Basin and the development of freshwater  
163 systems accompanied by freshwater micro- and macrofauna in this region. A synthesis is  
164 provided based on available datasets between 4.20 and 0.70 Ma and on field data verifications  
165 that were conducted between 2010 and 2023 in the western region of the Turkana Basin  
166 (Mission Préhistorique au Kenya; West Turkana Archaeological Project). We then relate our  
167 findings from this synthesis to the stratigraphic and spatiotemporal contexts of the archeological  
168 and paleoanthropological sites of the western region of the Turkana Basin. Along with the  
169 hypotheses linking increasing aridity to hominin evolution, we discuss the availability of  
170 drinking water and freshwater food resources for hominins occupying this arid region of the  
171 rift.

172

## 173 **2. Plio–Pleistocene climate change, aridity and hominin evolution in eastern Africa**

174 Until recently, it was thought that major climate change in eastern Africa began ~2.7  
175 Ma in response to the onset of Northern Hemisphere glaciations, and that the expansion of arid  
176 environments accompanied major developments in hominin evolution (deMenocal, 1995, 2004,  
177 2011; Trauth et al., 2007; Maslin and Trauth, 2009; Potts and Faith, 2015). Recent data do not  
178 corroborate a consistent stepwise transition from ~2.7 Ma onward but suggest that glaciations



179 were initiated before ~2.7 Ma, as discussed by Trauth et al. (2021), partly in connection with  
180 tectonic, radiative forcing and feedback over oceans. These involved changes in the circulation  
181 of the North Atlantic Ocean, due to the gradual closure of the Central American Seaway during  
182 the uplift of the Central American Isthmus between 4 and 3 Ma (Bartoli et al., 2005; O'Dea et  
183 al., 2016). Among the modifications of ocean circulation and air flow along the equator was the  
184 creation of the Gulf Stream, which initiated the storage of atmospheric humidity within the  
185 Northern Hemisphere ice cap. This new ocean circulation system explains global differences in  
186 the cyclicity of benthic  $\delta^{18}\text{O}$  records related to changes in astronomical forcing on atmosphere-  
187 ocean circulation after 3.5 Ma (deMenocal, 2004; Lisiecki and Raymo, 2005), while orbital  
188 parameters (Milankovitch cycles) were unaltered (Laskar et al., 2004). One of the earliest  
189 glacial events occurred at 3.30 Ma, i.e., during MIS M2 (Lisiecki and Raymo, 2005; Raymo et  
190 al., 2006; Tan et al., 2017). With the formation of the ice cap, a large amount of water was  
191 removed from the oceans, resulting in global sea-level drops (Miller et al., 2005). This sea-level  
192 fall would have expedited the tectonic closure of equatorial and tropical seaways (i.e., the  
193 Central American and Indonesian Seaways) and the associated alteration of ocean and  
194 atmospheric circulation (Cane and Molnar, 2001; Yan et al., 2021). As tropical ocean  
195 circulation declined, heat transfers reduced in the Indo-Pacific Ocean (Karas et al., 2009). The  
196 resulting establishment of atmospheric circulation cells (i.e., the Walker and Hadley cells)  
197 would have significantly weakened the East African monsoon (Yan et al., 2021) and thus  
198 promoted the expansion of more seasonal and arid environments in eastern Africa, with  
199 implications for mammalian evolution, including hominins (e.g. Cohen et al., 2022;  
200 Timmermann et al., 2022).

201 Multiple regional ecological indicators, such as the abundance of grazing bovids, C<sub>4</sub>  
202 plants, grass pollen, soil carbonate  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values, leaf wax  $\delta^{13}\text{C}$  values and phytoliths  
203 suggest a long-term trend toward aridification of eastern Africa during the Plio–Pleistocene

204 transition, including the Turkana Basin (e.g., Passey et al., 2010; Levin, 2015; Quinn and Lepre,  
205 2020, 2021; Lepre and Quinn, 2022), rather than several arid punctuations as previously thought  
206 (Wynn, 2004). Several studies have focused on climate change (mostly via temperature and  
207 precipitation proxies) at the scale of the paleontological and archeological sites in the Turkana  
208 Basin. For example, based on the distribution of  $^{13}\text{C}$ – $^{18}\text{O}$  bonds in soil carbonates, Passey et al.  
209 (2010) suggested that the temperature in the Turkana Basin has remained stable (30–35 °C)  
210 over the last 4 Myr. Based on faunal ecometric methods, Fortelius et al. (2016) suggested that  
211 the basin was already arid before 2.7 Ma and may have acted as a 'species factory', promoting  
212 ecological adaptations to aridity prior to widespread aridification in eastern Africa. Based on  
213 dietary changes of large herbivores, Cerling et al. (2015) suggested that  $\text{C}_4$ -grazing taxa  
214 (savanna biome) increased after 2.35 Ma in the Turkana Basin. However, sampling of coeval  
215 soil carbonate records from different regions in the basin shows that the distribution of  $\text{C}_3$  and  
216  $\text{C}_4$  plants varied by region (Levin, 2015). For example, Uno et al. (2016) showed that  $\text{C}_4$ -  
217 dominated ecosystems developed in the western region of the Turkana Basin only after 2.1 Ma.  
218 Blumenthal et al. (2017) argued that changes in paleoaridity and herbivore paleodiets were  
219 decoupled in the basin during the Plio–Pleistocene. Using  $\delta^{18}\text{O}$  values from tooth enamel, they  
220 suggested that changes in the abundance of  $\text{C}_4$  grass and grazing herbivores might reflect  
221 rainfall seasonality rather than general aridity. Recent drill-core studies along the rift (Cohen et  
222 al., 2022) do not extend beyond 700 ka, but drilling in the Turkana Basin at Kaitio (core  
223 WTK13) covers the interval between 1.9 and 1.4 Ma. Based on this drill-core, Lupien et al.  
224 (2022) proposed that the Turkana Basin experienced a dramatic and abrupt increase in  
225 precipitation (enrichment in  $\delta\text{D}_{\text{wax}}$  in WTK13 core in the western region of the Turkana Basin)  
226 at 1.71 Ma and that rapid changes in aridity/humidity likely affected the basin. Finally, again  
227 using soil carbonate  $\delta^{18}\text{O}$  values, Lepre and Quinn (2022) suggested that aridity increased after

228 2.1 Ma in the Turkana Basin following the strengthening of the Indo-Pacific Walker circulation,  
229 as seen in marine records (Van der Lubbe et al., 2021; Trauth et al., 2021).

230 Whereas soil temperature and moisture proxies suggest that the Turkana Basin has  
231 remained arid since the uplift of rift flanks, the interpretation of precipitation proxies recorded  
232 in the fluvio-lacustrine deposits seems to be more complex. Indeed, the basin sediments reflect  
233 inputs from the upper northern, northeastern and southwestern drainage basins as they connect,  
234 amplifying the hydroclimatic responses recorded in the Turkana Basin, especially when the  
235 basin has no outlet (i.e., when it is a terminal basin). In other words, there was a ‘decoupling’  
236 between basin aridity and the fluctuating/continuous presence of freshwater availability via  
237 distantly sourced lakes and rivers (=hydroconnectivity), especially for regions of the basin that  
238 are further away from the direct influence of the Omo River delta. This hydroconnectivity has  
239 enabled freshwater fauna to colonize the Turkana Basin at certain periods despite the ambient  
240 aridity (Williamson, 1981; Harris et al. 1988; Meylan et al., 1990; Stewart, 2003; Martin and  
241 Trautwein, 2003; Storrs, 2003; Van Bocxlaer, 2011, 2020; Stewart and Rufolo, 2020). To gain  
242 deeper insight into the paleolandscapes of the Turkana Basin, it is important to integrate the  
243 topoclimatic and hydroclimatic effects within the basin as well as adjacent regions of the East  
244 African Rift. Indeed, beyond the Omo River that supplies the region with freshwater, other  
245 drainage basins may have fed freshwater into the different regions of the Turkana Basin, as  
246 suggested by the periodic occurrence of freshwater micro- and macrofauna in the basin  
247 (Williamson, 1981; Harris et al. 1988; Meylan et al., 1990; Stewart, 2003; Martin and  
248 Trautwein, 2003; Storrs, 2003; Van Bocxlaer, 2011, 2020; Stewart and Rufolo, 2020).  
249 Moreover, it is necessary to examine the effects of volcano-tectonic activity on basin  
250 topography and the reorganization of paleohydrographic networks and outlets during the Plio–  
251 Pleistocene (Bruhn et al, 2011; Salzburger et al., 2014; Boës et al., 2019a).

252

253 **3. Hydroclimatic specifics and hydroconnectivity of the Turkana Basin within the East**  
254 **African Rift system**

255 *3.1. Topoclimatic effects*

256 In eastern Africa, precipitation is largely concentrated in a few uplifted mountain ranges  
257 (e.g., Nicholson, 2017). To the northeast and southwest of the Turkana Basin, the Ethiopian and  
258 Kenyan Highlands (Fig. 1) block atmospheric circulation and intercept most of the monsoon  
259 rainfall in the region (>1500 m.a.s.l.; >1500 mm annual precipitation; 19 °C mean  
260 temperature=tropical monsoon climate). The isotopic composition of water suggests that the  
261 Indian Ocean is the moisture source for the Kenyan monsoon rainfall, whereas the source for  
262 Ethiopian monsoon rainfall has oscillated seasonally between continental and Indian Ocean  
263 moisture sources (Levin et al., 2009). To a large extent, the continental monsoon is driven by  
264 increased evapotranspiration rates in equatorial Africa during summer insolation maxima  
265 (Rossignol-Strick, 1985; Wang, 2009; Prömmel et al., 2013; Zhisheng et al., 2015; Kuechler et  
266 al., 2018; see also e.g., Ashley, 2007 and Verschuren et al., 2009 for lake responses in eastern  
267 Africa). For the Indian Ocean moisture source, it seems that when the Indian monsoon is strong,  
268 it causes rainfall deficits in eastern Africa, especially in northeast Kenya (Camberlin et al.,  
269 2010). Located between the Kenyan and Ethiopian Highlands, i.e., two topographic barriers  
270 that intercept most of the atmospheric moisture, the Turkana Basin is a rainfall-deficient  
271 depression (<500 m.a.s.l.; <300 mm annual precipitation). The Turkana Jet, a low-level jet  
272 stream channeled by the topography of the Turkana Basin, also reinforces the permanent aridity  
273 at the foot of the uplifted highlands (Nicholson, 2016). Because of this configuration, the  
274 climate in the Turkana Basin remains warm and dry throughout the year (~30 °C mean  
275 temperature=hot desert climate). Isotope temperatures of paleosol carbonates from the  
276 Nachukui and Shungura Formations suggest that similar mean temperatures have prevailed in  
277 the basin since 4 Ma (Passey et al., 2010) and perhaps as early as the establishment of the

278 topographic barriers in the Middle Miocene (Wichura et al., 2015; Sommerfeld et al., 2014;  
279 Polissar et al., 2019).

280

### 281 *3.2. Paleohydrographic network*

282 Although the regional climate of the Turkana Basin is arid and decoupled from  
283 precipitation changes in the Kenyan and Ethiopian Highlands, the basin does receive water from  
284 these adjacent regions. Today, 80–90% of the permanent water inflow to the Turkana Basin  
285 comes from the Omo River drainage catchment in the Ethiopian Highlands (140,000 km<sup>2</sup>; >500  
286 m<sup>3</sup>/s; Kallqvist et al., 1988; Fig. 1). Most of the remaining 10–20% comes via inflow from the  
287 Turkwel and Kerio rivers (Fig. 1) that drain the southwestern side of the basin up to the Kenyan  
288 Highlands, supplemented by runoff from ephemeral streams along the western and eastern  
289 regions of the Turkana Basin. Beyond the river systems that currently contribute water to the  
290 basin, several paleohydrographic connections may have been activated at certain periods during  
291 the Pliocene and Pleistocene.

292 In the northeastern region of the Turkana Basin, along the Ethiopian branch of the East  
293 African Rift, a series of closed lake basins are currently separated from the Turkana watershed  
294 (Figs. 2–4). However, if precipitation intensifies in the Ethiopian Highlands, a cascading river-  
295 lake system may form that ultimately would overflow into the Turkana Basin (Garcin et al.,  
296 2009; Junginger, 2011; Bloszies, 2014). This system includes current lakes Abaya (1175  
297 m.a.s.l.; 1100 km<sup>2</sup>), Chamo (1110 m.a.s.l.; 310 km<sup>2</sup>) and Chew Bahir (498 m.a.s.l.; 120 km<sup>2</sup>).  
298 When overfilled with water, these systems spill into each other and finally into the Il Bakate  
299 paleoriver (Figs. 3d, f and 4d), which drains into the Turkana Basin in the paleodeltaic zone of  
300 Koobi Fora along the eastern region of the Turkana Basin (Fig. 4d; see also Grove et al., 1975;  
301 Cuthbert et al., 2017). When precipitation increases in the Ethiopian Highlands, the water level

302 of the last lake in this cascade system, Lake Chew Bahir, would need to rise up by 45 m before  
303 an outflow is established, expanding its surface area from 120 to 2100 km<sup>2</sup> (the outlet is situated  
304 at 543 m.a.s.l.; Fischer et al., 2020). The fluvio-lacustrine sediments along the Ethiopian branch  
305 of the East African Rift are consistent with the activation of this system at several periods in  
306 the Plio–Pleistocene (Trauth et al., 2005; Nagaoka et al., 2005).

307 In the southwestern region of the Turkana Basin, a similar series of currently closed lake  
308 basins exists along the Kenyan branch of the East African Rift (Figs. 2–4). Although these are  
309 currently hydrographically separated from the Turkana watershed, this hydrographic network  
310 may be activated and overspill into the Turkana Basin when precipitation intensifies over the  
311 Kenyan Highlands. This cascading river-lake system consists of lakes Elmenteita (1790  
312 m.a.s.l.; 18 km<sup>2</sup>), Nakuru (1758 m.a.s.l.; 45 km<sup>2</sup>), Bogoria (990 m.a.s.l.; 34 km<sup>2</sup>), Baringo (970  
313 m.a.s.l.; 168 km<sup>2</sup>) and Logipi-Suguta (275 m.a.s.l.; 30 km<sup>2</sup>). When overfilled with water, these  
314 systems overspill into each other and finally into the Kerio River (Garcin et al., 2009; Olaka et  
315 al., 2010; Junginger, 2011; Melnick et al., 2012; Bloszies, 2014; Dommain et al., 2022; Figs. 2,  
316 3d, f and 4c). Evidence for the activation of this cascading system comes from the presence of  
317 diatomite beds in the Baringo-Bogoria Basin (east of the Tugen Hills; Fig. 1), which indicate  
318 that deep lakes existed along the Kenyan branch of the East African Rift during the Plio–  
319 Pleistocene (Trauth et al., 2005; Kingston et al., 2007; Westover et al., 2021). In addition, the  
320 last lake in this cascade system, Lake Logipi-Suguta, is a volcanic-dammed lake that formed  
321 with the eruption of ‘the Barrier’ from 1.44–1.37 to 0.69 Ma (Fig. 4c; Dunkley et al., 1993;  
322 McDougall et al., 2012). When precipitation increased in the Kenyan Highlands, the water level  
323 of Lake Logipi-Suguta could rise up by 300 m before overflowing, reaching a lake surface of  
324 430 km<sup>2</sup> in contrast to the current 30 km<sup>2</sup> (=paleolake Suguta, with the outlet situated at 577  
325 m.a.s.l.; Fig. 4c; Garcin et al., 2009; Junginger, 2011; Bloszies, 2014). Before deposition of the  
326 Barrier, Lake Logipi-Suguta did not exist; instead, the Suguta paleoriver flowed directly into

327 precursors of Lake Turkana, which periodically were larger than the present-day lake (Figs. 3d,  
328 f and 4c). In other words, the redirection of the Suguta paleoriver into Lake Logipi-Suguta by  
329 volcanism drastically reduced the excess water input from the Kenyan Highlands to the Turkana  
330 Basin after 1.37 Ma (with the overflow of Lake Suguta reoriented towards the Kerio River and  
331 then into the Turkana Basin; Fig. 3d, f). Located next to the Suguta paleovalley, the Kerio River  
332 is today a major river system that drains the Kenyan Highlands (Kerio Basin, west of Tugen  
333 Hills). Sediments from the Kerio paleoriver formed the extensive Pliocene fossiliferous deltaic  
334 deposits at Kanapoi (Fig. 4b; Feibel, 2003a)

335         Activation of these cascading river-lake systems at various periods in the Plio–  
336 Pleistocene and the resulting enhanced hydroconnectivity would likely also have promoted  
337 dispersal of freshwater fauna into the Turkana Basin (Fig. 5a). This hydroconnectivity amplified  
338 the volume of water flowing into the Turkana Basin and would have caused the periodic  
339 formation of large, deep freshwater paleolakes, depending on the configuration of the basin  
340 outlet.

341

### 342 *3.3. Evidence for large, deep paleolakes in the Turkana Basin*

343         Today, the continuous water inflow of the Omo River into the Turkana Basin renders  
344 Lake Turkana the largest permanent ‘desert lake’ in a closed drainage system (lake surface area  
345 from 6800 to 7200 km<sup>2</sup>; water volume of 200–240 km<sup>3</sup>). The current lake occupies the central  
346 axis of the volcano–tectonic basin and is on average only 30 m deep, with a maximum depth of  
347 110 m in the central and southern basins (e.g., Dunkelman et al., 1989; Fig. 1). As a result of  
348 closed conditions, the lake water is saline (2500 ppm total dissolved solids [TDS]); Yuretich  
349 and Cerling, 1983) and alkaline (21–34 meq/L; Olago and Odada, 1996), except in the vicinity  
350 of the Omo River delta, where the conditions are fresher due to the continuous inflow of the

351 Omo River. The level of Lake Turkana is currently relatively stable ( $365 \pm 5$  m.a.s.l.),  
352 representing a balance between continuous inflow of the Omo River and high evaporation (2.5  
353 to 3.5 m/year resulting in a volume of 20 km<sup>3</sup>/year; Kallqvist et al., 1988).

354 Over the past 150 years the water level of Lake Turkana has fluctuated, reaching levels  
355 15 m above the present lake level when precipitation intensity increased in the adjacent Kenyan  
356 and Ethiopian Highlands (Bloszies and Forman, 2015; Bloszies et al., 2015). Reconstructions  
357 over the last 25 kyr suggest even larger fluctuations, with levels having reached 95 m above the  
358 present lake level (lake surface of nearly 10,000 km<sup>2</sup>; Garcin et al., 2012; Morrissey and Scholz,  
359 2014). Over the last 4 Myr, the sediments in various regions of the Turkana Basin reveal a  
360 succession of fluvio-lacustrine systems that confirm the existence of large, deep paleolakes  
361 (Feibel et al., 1993; Trauth et al., 2005, 2007; Feibel, 2011; Joordens et al., 2011; Lepre, 2014;  
362 Gathogo, 2017; Boës et al., 2019a; Nutz et al., 2020). Such changes in water volume may be  
363 caused by increased precipitation in the Kenyan and Ethiopian Highlands and by changes in the  
364 catchment size, due to the emergence of new connections extending to rivers and lakes in these  
365 two regions. The impact of tectonic subsidence on ‘accommodation space’ for sediment and  
366 water volume is limited for our time scale, considering the rate of basin extension (<500 cm/ka;  
367 Knappe et al., 2020) and the highest sedimentation supply during the Plio–Pleistocene (<55  
368 cm/ka). Thus, hydroconnectivity and water supply were the primary drivers of fluvio-lacustrine  
369 sedimentation and paleolake-level fluctuations in the basin. However, in our time interval,  
370 explosive volcanoes (Mount Kulal and the Barrier; Table 1) reorganized outlets and inlets  
371 across the southern region of the Turkana Basin (Dunkley et al., 1993; Bruhn et al., 2011; Boës  
372 et al., 2019a; Fig. 5b). These changes likely have influenced freshwater availability and the  
373 colonization of the Turkana Basin by freshwater fauna.

374



375 3.4. Evidence of paleo-outlets and reorganization of the drainage of the Turkana Basin by  
376 volcanism

377 During the Plio–Pleistocene, water outflowed from the Turkana Basin, first to the Indian  
378 Ocean and subsequently to the Mediterranean Sea, through the Loiyangalani and Ilemi outlets  
379 respectively (Figs. 2, 3c, e, 4e, f and 5b; Nyamweru, 1986, 1989; Feibel, 1993; Bruhn et al.,  
380 2011; Salzburger et al., 2014; Lepre, 2014; Boës et al., 2019a).

381 Situated on the southeastern region of the Turkana Basin, the Loiyangalani outlet, when  
382 active, connected the Turkana Basin to the Turkana paleoriver, which flowed into the Indian  
383 Ocean (Figs. 3f and 4e; Feibel, 1993; Van Damme and Van Bocxlaer, 2009; Bruhn et al., 2011;  
384 Feibel, 2011; Salzburger et al., 2014; Boës et al., 2019a). Major paleohydrographic changes  
385 occurred in this area between 3 and 2 Ma, with the onset of explosive volcanism in the  
386 southeastern region of the Turkana Basin and the damming of the Loiyangalani outlet by the  
387 Mount Kulal volcano and the Lenderit Basalt (Figs. 4e and 5b; Table 1; Frostick and Reid,  
388 1989; Bosworth and Maurin, 1993; Haileab et al., 2004; Bruhn et al., 2011; Boës et al., 2019a).  
389 This volcanic activity initiated the closure of the Loiyangalani outlet, resulting in a shift of the  
390 basin outflow sill towards the Ilemi outlet (Fig. 3d, f and 5b).

391 The Ilemi outlet is located in the northwestern region of the Turkana Basin, ~300 km  
392 distant from the Loiyangalani sill (Nyamweru, 1989; Bruhn et al., 2011; Feibel, 2011; Lepre,  
393 2014; Boës et al., 2019a; Figs. 1, 2 and 3d, f). The Ilemi outlet channel connected to the White  
394 Nile River and the Mediterranean Sea (Figs. 3d and 4e). Unlike the Loiyangalani outlet, which  
395 was blocked by explosive volcanism (see below; Figs. 3f, 4e), the Ilemi outlet can still be  
396 reactivated if the lake level rises by 100 m, as during the ‘African Humid Period’ (Bloszies,  
397 2014; Bloszies and Forman, 2015; Bloszies et al., 2015). The Ilemi outlet is located 95 m above  
398 the current lake level (364 m). The longitudinal profile of the paleovalley connected to the Sobat

399 River and then the White Nile River shows elevations from 455 to 440 m.a.s.l., respectively,  
400 through the Ilemi sill (Fig. 4f). However, these are modern altitudes, and the elevations may  
401 have been different in the past due to volcano-tectonic influences on topography and erosion,  
402 notably in the eastern and southeastern regions of the Turkana Basins. In the northwestern  
403 region of the basin, river erosion may have affected the Ilemi outlet channel after its opening,  
404 so this outlet was probably initially situated in a higher position (possibly ~465 m.a.s.l.). In  
405 comparison, the longitudinal profile of the Turkana paleoriver (Fig. 4e) shows elevations  
406 around 440 m.a.s.l. north of the basalt flows of Mount Kulal, which erupted ~3 Ma (Table 1).  
407 In other words, the outlet of the Turkana paleoriver to the Indian Ocean was lower than the  
408 outlet to the Nile River and the Mediterranean Sea. The activation of the Ilemi outlet in the Late  
409 Pleistocene has been demonstrated in numerous papers since the 1980s (Harvey and Grove,  
410 1982; Dumont, 2009; Johnson and Malala, 2009; Stewart, 2009; Van Damme and Van  
411 Bocxlaer, 2009; Garcin et al., 2012; Morrissey and Scholz, 2014; Williams, 2019). Some  
412 studies suggest that this hydroconnectivity already existed in the Early Pleistocene (Cerling,  
413 1979; Harris et al., 1988; Nyamweru, 1989; Haileab et al., 2004; Bruhn et al., 2011; Boës et al.,  
414 2019a). The presence of lake sediments east of Ilemi in the Shungura Formation (i.e., from  
415 submember G-14 to G-27; Feibel et al., 1989; Bobe and Eck, 2001) indicates that paleolake  
416 levels came close to the Ilemi outlet channel at 2.00–1.95 Ma. Harris et al. (1988) proposed that  
417 the basin was connected to the Nile as early as 1.7 Ma. However, ostracod data from the  
418 Shungura Formation indicate the presence of oligohaline conditions between 1.8 and 1.4 Ma  
419 and variable conditions after 1.4 Ma (i.e., appearance of *Limnocythere*; Carbonel and  
420 Peypouquet, 1979). This information suggests that if the basin opened to the Nile after 1.9 Ma,  
421 it must have been in alternation with closed alkaline–saline conditions in the Turkana Basin  
422 (see Boës et al., 2019a), although the Omo River and potentially the Il Bakate River provided  
423 freshwater in the northern and northeastern regions of the basin.

424

425 *3.5. Criteria and evidence for the expansion of freshwater systems into the western region of*  
426 *the Turkana Basin during the Plio–Pleistocene*

427 In contrast to the saline–alkaline conditions that prevail in Lake Turkana today, various  
428 lines of evidence indicate that freshwater systems existed and/or expanded repeatedly in the  
429 Turkana Basin during the Plio–Pleistocene. These lines of evidence, among others, include  
430 sedimentology, water paleochemistry, isotope records and freshwater micro- and macrofauna  
431 and flora (Cerling, 1979; Feibel, 1993; Stewart, 2001, 2003, 2009; Wood, 2003; Van Bocxlaer  
432 et al., 2008; Van Bocxlaer, 2011, 2020; Dumont, 2009; Vonhof et al., 2013; Boës et al., 2019a).  
433 These records indicate the existence of enhanced hydroconnectivity, and at least the periodic  
434 occurrence of freshwater conditions in the western region of the Turkana Basin despite  
435 persistent ambient aridity. As rivers transport water, they do not accumulate mineral salts and  
436 are essentially fresh, except for perhaps at the establishment of a lake outflow, when previously  
437 accumulated mineral salts are flushed. Given the aridity and high levels of evaporation within  
438 the Turkana Basin during the Plio–Pleistocene (Wynn, 2004; Passey et al., 2010; Blumenthal  
439 et al., 2017; Lepre and Quinn, 2022), the presence or absence of an outlet determines the  
440 physicochemical properties of water bodies (freshwater versus saline–alkaline). When an outlet  
441 exists (open drainage=exorheic basin), mineral salts are flushed from the Turkana Basin and  
442 freshwater conditions develop or are maintained within it. For example, freshwater biota  
443 colonize the basin when new rivers connect to the Turkana Basin and/or when the lake level  
444 develops an outlet; thus, shell beds and other micro- and macrofaunal assemblages could be an  
445 indicator of the existence of enhanced hydroconnectivity with upland river-lake systems and/or  
446 an outflow. In the absence of an outlet (closed drainage=endorheic basin), mineral salts  
447 accumulate within the basin and create saline–alkaline conditions. When a lake progressively  
448 becomes alkaline–saline, some freshwater organisms may persist for some time, or find refuge

449 in rivers, in this particular case near the Omo River delta, despite increasing alkalinity–salinity  
450 in the rest of the basin.

451 The development of enhanced hydroconnectivity and expansion of freshwater fauna into  
452 the Turkana Basin are evidenced by the occurrence of various freshwater vertebrates,  
453 invertebrates, microalgae and microbial structures in river and lake sediments. These include:  
454 the crocodile *Euthecodon*; turtles (Pelomedusidae and Trionychidae), fishes (*Sindacharax*,  
455 *Semlikiichthys*, *Polypterus*) and cartilaginous fish (*Dasyatis africana*); crabs of the family  
456 Potamonautidae, mollusks (such as various gastropod and bivalve species) and ostracods  
457 (*Stenocypris*, *Sclerocypris*); microalgae diatoms (*Stephanodiscus* spp. and *Aulacoseira* spp.)  
458 and sponge spicules; and stromatolite microbial structures (Wood, 1979, 2003; Williamson,  
459 1981; Schwartz, 1983; Harris et al., 1988; Meylan et al., 1990; Feibel, 1993; Brugal et al., 2003;  
460 Stewart, 2001, 2003, 2009; Harris et al., 2003; Martin and Trautwein, 2003; Storrs, 2003;  
461 Trauth et al., 2007; Van Bocxlaer et al., 2008; Tiercelin et al., 2010; Van Bocxlaer, 2011, 2020;  
462 Van Bocxlaer and Van Damme, 2009; Brochu, 2020; Stewart and Rufolo, 2020).

463 Among the freshwater macrofauna, the aquatic mollusks found throughout the western  
464 region of the Turkana Basin belong exclusively to freshwater mollusk families, although some  
465 taxa like *Melanoides* can tolerate enhanced salinity/alkalinity (see Mandahl-Barth, 1988;  
466 Brown, 1994; Van Bocxlaer, 2020; Graf and Cummings, 2021). Note that even under current  
467 conditions, some salt-tolerant ‘freshwater’ mollusks occur in Lake Turkana. The ostracods  
468 microfauna are likewise tolerant of various salinity/alkalinity levels and their ecological  
469 interpretations may be difficult without accurate species-level identification (Peypouquet et al.,  
470 1978; Carbonel and Peypouquet, 1979; Carbonel et al., 1988). Four ostracod assemblages have  
471 been identified in the Plio–Pleistocene sediments of the Turkana Basin (Cohen et al., 1983;  
472 Carbonel et al., 1988). Of these, the assemblage containing *Stenocypris* and *Hemicypris*  
473 (ostracods) reflects freshwater conditions with nutrient-rich water mixed by the wind, whereas

474 the ostracod *Limnocythere* is tolerant to saline–alkaline waters. The ecological interpretations  
475 of freshwater conditions based on ostracods are congruent with those based on some mollusks  
476 (Cohen et al., 1983), various fish taxa (Stewart et al., 2003) including cartilaginous fish (Feibel,  
477 1993) and reptiles, i.e., crocodiles and turtles (Meylan et al., 1990; Harris et al., 2003; Wood,  
478 2003; Brochu, 2020). With regard to microalgae, in closed systems within arid zones, changes  
479 in the diatom algal assemblage reflect the presence/absence of river inflow and/or the transition  
480 from an open to a closed lake basin (Gasse et al., 1997). Throughout the Plio–Pleistocene  
481 sediment series in the western region of the Turkana Basin, white diatomite beds occasionally  
482 occur and consist almost exclusively of diatom frustules (Trauth et al., 2007). This type of  
483 biogenic sediment only forms when a lake is sufficiently large and deep to be thermally  
484 stratified with seasonal nutrient upwelling caused by wind-driven mixing, resulting in diatom  
485 blooms (e.g., Owen, 2002). However, the ecology of Plio–Pleistocene diatoms is still not well  
486 known, most notably the ecological tolerances of the various taxa, since freshwater and saline-  
487 tolerant diatom taxa may have occurred at times in the Turkana Basin as in other basins in  
488 eastern Africa (Gasse, 1980; Gasse et al., 1997). As such, the diatom record of the western  
489 region of the Turkana is incomplete and requires further study.

490 Finally, stromatolite microbial structures provide additional information on the  
491 paleohydrological conditions that existed in the western region of the Turkana Basin at certain  
492 times. The stromatolites (and oncolites) are formed by accretions of thermophilic blue-green  
493 algae (fresh/brackish water cyanobacteria) and trapped sediment around nuclei (Abell et al.,  
494 1982). Blue-green algae may have enhanced CO<sub>3</sub> evasion and caused the direct precipitation of  
495 CaCO<sub>3</sub> onto their filaments (Riding, 1991). The association of stromatolites with saline-alkaline  
496 or freshwater environments is a complex issue. As a clue to stromatolite growth, mixing  
497 freshwater rivers with saline–alkaline lake waters results in carbonate dissolution. In other  
498 words, as the water is supersaturated with carbonate in the mixing zone, it is reprecipitated by

499 the microbial activity of carbonate reduction in stromatolites. The stromatolite beds therefore  
500 suggest the possibility that a freshwater river mixed with saline–alkaline lake waters. In some  
501 cases, stromatolites may also be related to thermal circulations channeled by faults (Casanova,  
502 1996).

503

504 *3.6 Definition of ‘freshwater episodes’ and enhanced hydroconnectivity in the western region*  
505 *of the Turkana Basin*

506 From the fossil record of the western region of the Turkana Basin, ‘freshwater episodes’ can be  
507 defined by the presence of river and lake sediments and the freshwater macrofauna they contain,  
508 such as: mollusks (Van Bocxlaer, 2011, 2020; Van Bocxlaer and Van Damme, 2009), fish  
509 (Stewart, 2001, 2003, 2009; Stewart and Rufolo, 2020), cartilaginous fish (Feibel et al., 1993)  
510 and crocodile (Harris et al., 1988; Brochu, 2020; Storrs, 2003). Freshwater microfauna  
511 (ostracods and diatoms) is also included in the definition of ‘freshwater episode’, despite some  
512 tolerance to alkaline and saline conditions and the absence of a biostratigraphy with accurate  
513 species-level identification for Plio–Pleistocene microfauna in the Turkana Basin (Peypouquet  
514 et al., 1978; Carbonel and Peypouquet, 1979; Carbonel et al., 1988; Harris et al., 1988; Trauth  
515 et al., 2007). As such, ‘freshwater episodes’ in the western region of the Turkana Basin can be  
516 expressed by the colonization of the region by freshwater macrofauna from upland river-lake  
517 systems via cascade hydroconnectivity. In the Turkana Basin, enhanced hydroconnectivity  
518 formed and disappeared from the Kenyan and Ethiopian Highlands and surrounding regions as  
519 observed in the Pleistocene records (Grove et al., 1975; Garcin et al., 2009; Olaka et al., 2010;  
520 Junginger, 2011; Melnick et al., 2012; Bloszies, 2014; Cuthbert et al., 2017; Dommain et al.,  
521 2022). Finally, ‘freshwater episodes’ express enhanced hydroconnectivity and the occurrence

522 of freshwater food chain with drinking water while there is a decoupling between the ambient  
523 aridity and the type of biota that colonized the region via distantly sourced lakes and rivers.

524

### 525 *3.7. Methods to develop chronological control*

526 In our review, it is important to revise the timing of various lines of evidence, and for  
527 this purpose, we created a Bayesian age model using ChronoModel v. 2.0. (Lanos and Dufresne,  
528 2019; Fig. 6). All of the argon-argon ages of the tuffs were plotted against the different  
529 geological members to verify the ages that have been proposed in the different papers and  
530 available datasets (Tables 2–5). Tuff ages and interpolated ages between tuffs are therefore  
531 considered in the same framework and all published ages for fossils can be verified taking into  
532 account uncertainty via error bars. In the published literature (Tables 2–5), the age of vertebrate  
533 and invertebrate fossils, microalgae, hominin remains and archeological sites is given either 1)  
534 in relation to the presence of a tuff, or 2) as an age calculated from the sedimentation rate  
535 inferred from the thickness of the sediments accumulated in between tuffs. The Bayesian age  
536 model allowed us to verify the distribution of the published ages and uncertainties (Fig. 6). The  
537 age modeling between 4.20 and 0.70 Ma shows that it is currently not possible to obtain an  
538 individual date with an accuracy of less than 50 ka for the chronostratigraphic interval between  
539 3.2 and 2.6 Ma. The error bars extend to 300 ka between 3.1 and 2.7 Ma (Fig. 6), due to the  
540 absence of tuffs (and paleomagnetic inversions). For this reason, as in most databases and  
541 papers on the western region of the Turkana Basin, the time interval between 3.1 and 2.7 Ma is  
542 not evaluated in this synthesis. For example, there is no soil carbonate nodules for the western  
543 region of the Turkana Basin (Nachukui Formation) between 3.1 and 2.7 Ma in the recent paper  
544 published by Lepre and Quinn (2022). However, note some soil carbonate datasets cover this  
545 interval for the western region of the Turkana Basin (e.g., Levin, 2015; Nutz et al., 2020).

546 Finally, note that the new ages recently proposed by Phillips et al. (2023) for the Chari and  
547 Malbe tuffs correspond to the ages obtained here with the Bayesian age model (Fig. 6).

548

#### 549 **4. Evolution of freshwater ecosystems in the western region of the Turkana Basin**

##### 550 *4.1. From 4.20 to 3.60 Ma*

551 The western region of the Turkana Basin is marked by the presence of river sediments  
552 between 4.17 and 4.12 Ma and around 4.07 Ma at Lothagam (Tables 2 and 3). In the Kanapoi  
553 Formation, lake sediments at 4.15–4.11 Ma are intercalated between a lower and upper fluvial  
554 sequence (i.e., between the Upper Pumiceous and Kanapoi Tuffs=Lonyumun paleolake; Fig.  
555 7). In the Lonyumun Member of the Nachukui Formation (Table 2), lake sediments occur  
556 between <4.20 and 3.98 Ma (i.e., from the basalts to above the Topernawi Tuff=paleolake  
557 Lonyumun). Note that paleolake Lonyumun sediments are in the Lonyumun Member (e.g.,  
558 Harris et al., 1988) and not in the Kataboi Member as indicated in Nutz et al. (2020; i.e., there  
559 is an error of 400 kyr in their section 3, as the Naibar Tuff at 40 m is not dated at 3.60 Ma but  
560 at 4.02 Ma). Diatomites occur in the Lonyumun Member, below the Naibar Tuff (Table 3; Fig.  
561 7). Diatomite beds occur in the same temporal context at Loruth Kaado, Lomekwi, and  
562 Nasechebun (Fig. 1; Harris et al., 1988). The end of paleolake Lonyumun is observed at 3.98  
563 Ma in the sediments of the Nachukui Formation (i.e., 3 m below the Moiti Tuff that contains  
564 pumice clasts). One brief lacustrine interval (lake muds and diatoms) is also present at ~3.7 Ma,  
565 i.e., 12 m above the Moiti Tuff (3.97 Ma) and below the Lokochot Tuff (3.60 Ma) in the middle  
566 of the Kataboi Member of the Nachukui Formation at Lomekwi (Tables 2 and 3; Fig. 7).  
567 Diatomites are also present at this level at South Turkwel (Tables 2 and 3; Fig. 7).

568 The development of an open freshwater system is demonstrated by the occurrence of  
569 freshwater crabs of the family Potamonautidae at 4.2 Ma (Martin and Trautwein, 2003) and



570 freshwater crocodile *Euthecodon* (Storrs, 2003) at Lothagam (Fig. 1; Tables 2 and 3).  
571 *Sindacharax* is also reported at 4.15–4.11 Ma at Lothagam (Table 3; Fig. 7). In addition, fossils  
572 of freshwater organisms are present in the Kanapoi Formation between 4.20 and 4.10 Ma,  
573 including ostracods such as *Sclerocypris* (Peypouquet, 1978); mollusks, such as *Bellamyia* and  
574 *Etheria* (Feibel, 2003a; Van Bocxlaer, 2020); the fishes *Sindacharax* and *Semlikiichthys*  
575 (Stewart, 2001, 2003, 2009; Stewart and Rufolo, 2020); the crocodile *Euthecodon* (Harris et al.,  
576 2003; Brochu, 2020), and freshwater turtles of the families Pelomedusidae, Testudinidae and  
577 Trionychidae (Meylan et al., 1990; Harris et al., 2003; Wood, 2003). In the Kanapoi Formation,  
578 freshwater mollusks have only been observed from shell beds between 4.15 and 4.11 Ma (i.e.,  
579 between the Upper Pumiceous and the Kanapoi Tuffs; Fig. 7). Some mollusks derive from river  
580 deposits, but most are from paleolake Lonyumun and in stratigraphic proximity to the Kanapoi  
581 Tuff (Fig. 7). *Etheria* is reported in a channel fill that cuts the Kanapoi Tuff (4.11 Ma).  
582 Freshwater ostracods (*Hemicypris*) occur between 4.20 and 3.98 Ma and freshwater mollusks  
583 are found at 3.99–3.98 Ma (i.e., from the Topernawi to the Moiti Tuffs; Fig. 7).

584

#### 585 4.2. From 3.60 to 3.1 Ma

586 The western region of the Turkana Basin is marked by the presence of river sediments  
587 in association with the Lokochot Tuff (3.60 Ma; Table 3; Fig. 7), succeeded by lake sediments  
588 at 3.58 Ma (i.e., 3 m below the burrowed fine-sandstone marker bed=paleolake Lokochot; Fig.  
589 7). This paleolake phase is marked by the presence of diatomites between 3.58 and 3.44 Ma  
590 (i.e., between the Lokochot and Tulu Bor  $\alpha$  Tuffs). Diatomites are well exposed at Loruth  
591 Kaado, South Turkwel, Lomekwi and Nasechebun (Fig. 1; Harris et al., 1988; Ward et al.,  
592 1999). An alluvial system developed between 3.30 and 3.2 Ma (Table 3; Fig. 7). Then, lake

593 sediments with diatoms occurred at about 3.2–3.1 Ma, in association with the Waru Tuff  
594 (=paleolake Waru; Table 3; Fig. 7).

595 The development of an open freshwater system is demonstrated by the occurrence of  
596 freshwater sponge spicules within the upper 12 m of the Kataboi Member (i.e., <3.60–3.44 Ma).  
597 Freshwater mollusks such as *Bellamya*, *Cleopatra* and *Melanoides* are present at 3.5 Ma. At  
598 Lomekwi, remains of *Euthecodon*, *Sindacharax*, mollusks and freshwater turtles are present in  
599 a paleo-beach complex at 3.30 Ma (LO-5 and LO-4w localities of fossil collection in Leakey et  
600 al., 2001; Table 3; Fig. 7). Harris et al. (1988) have already reported the presence of *Etheria* at  
601 3.30 Ma, in the same paleo-beach complex 23 m above the Tulu Bor  $\alpha$  Tuff. A similar sequence  
602 of freshwater biota including *Etheria* is observed at 3.30 Ma at Loruth Kaado in sediments of  
603 the lower Lomekwi Member (Tables 2 and 3; Fig. 7). The sediments of paleolake Waru include  
604 the mollusk trace fossil *Lockeia* (Gathogo, 2017) and sponge spicules (Harris et al., 1988).

605

#### 606 4.3. From 2.60 to 2.20 Ma

607 In the Lokalalei Member of the Nachukui Formation (Table 2), the development of river  
608 systems is reported at 2.53 Ma (Table 3; Fig. 7); this environment is replaced by a  
609 lagoonal/embayment environment that develops between the Lokalalei and Kokiselei Tuffs at  
610 2.53 and 2.44 Ma (Tiercelin et al., 2010; Table 3; Fig. 7). Then, lake sediments occur at 2.44  
611 Ma (i.e., 3 m above the Kokiselei Tuff=paleolake Kokiselei; Fig. 7). In the lower Kalocho  
612 Member of the Nachukui Formation (Table 2), lake sediments occur between 2.25 and 2.22 Ma  
613 (i.e., a few meters above Tuff G=paleolake Nasura; Fig. 7). The paleolakes Kokiselei and  
614 Nasura are separated by river sediments (2.33–2.25 Ma; Table 3; Fig. 7).

615 The development of an open freshwater system is demonstrated by the occurrence of  
616 *Etheria* deposited in channels with the Lokalalei Tuff at 2.53 Ma (Table 3; Fig. 7). Freshwater

617 mollusks occur between 2.34 and 2.32 Ma at Lokalalei. Other bioclastic facies with freshwater  
618 mollusks (lake-margin coquina) occur below and above the Ekalalei Tuff (undated), which  
619 contain, among others, *Melanoides* shell beds. At 2.25 Ma, the aquatic environment was  
620 inhabited by the freshwater mollusks *Melanoides* and *Potadoma*, which suggest malacofaunal  
621 continuity between 2.34 and 2.25 Ma. Siltstones and claystones in the Kokiselei drainage dated  
622 between 2.27 and 2.20 Ma contain ostracods (Table 3; Fig. 7). Geochemical studies (Sr/Ba  
623 ratio) suggest alternating saline–alkaline conditions at 2.22 Ma (Boës et al., 2019a). In the  
624 transition from freshwater to saline–alkaline conditions, inhospitable conditions appear to have  
625 occurred briefly, as suggested by a fish kill event at 2.22 Ma (Boës et al., 2019a). This event is  
626 probably associated with a destabilization of the thermal stratification, low water inflows, high  
627 evaporation and substantial algae and microbial activities, such as cyanobacteria blooms  
628 (expansion and proliferation of cyanobacteria toxins; Olilo et al., 2023). The initiation of the  
629 volcanic blockage of the outlet of the Turkana Basin to the Indian Ocean may partly explain  
630 changing limnological conditions as early as 2.26 Ma (Boës et al., 2019a).

631

#### 632 4.4. From 2.20 to 1.30 Ma

633 In the Kalochoro Member, lake sediments occur from 2.19 Ma onwards (i.e., 15 m above  
634 Tuff G=paleolake Lorenyang; Fig. 7). Diatomites occur above the KBS Tuff in the Kaitio  
635 Member of the Nachukui Formation (Table 2). Diatomites are also reported at 1.48–1.38 Ma  
636 within the Nattoo Member of the Nachukui Formation (Table 2) and river sediments are present  
637 in the upper Nattoo Member (Table 3; Fig.7), sometimes called the ‘Chari floodplain’ (Feibel,  
638 2011).

639 The development of an open freshwater system is demonstrated by the occurrence of  
640 the freshwater stingray *D. africana* (spine fragments), with fossils reported in the Kalochoro,

641 Nattoo and basal Nariokotome Members of the Nachukui Formation (i.e., from below the KBS  
642 Tuff at 1.87 Ma up to the Chari Tuff at 1.38 Ma; Table 3; Fig. 7). In the upper Kalochoro  
643 Member, ostracods occur between 2.10 and 1.95 Ma (i.e., from 40 to 15 m below the KBS Tuff  
644 at 1.87 Ma). In the Kaitio Member of the Nachukui Formation (Table 2), freshwater mollusks  
645 and ostracods occur above the KBS Tuff. Ostracods have also been reported at the top of the  
646 Kaitio Member at Kokiselei (Table 3; Fig. 7). The expansion of freshwater environments at  
647 1.8–1.7 Ma is supported by the presence of diverse freshwater mollusks including, for example,  
648 *Iridina* and *Chambardia* (Table 3; Fig. 7), and by the presence of *Euthecodon* and fossils of  
649 freshwater fish, including *Polypterus* (Brugal et al., 2003). Freshwater mollusks are also  
650 reported at 1.8 Ma near the archeological complex of Naiyena Engol, 16 m above the KBS Tuff  
651 (Table 3; Fig. 7). The earliest stromatolite beds of the Nachukui Formation occur between the  
652 Malbe Tuff (1.84 Ma) and the Orange Tuff (1.76 Ma). At Kokiselei and Kalochoro, other  
653 stromatolite beds occur at 1.6 Ma, in the upper Kaitio Member and the base of the Nattoo  
654 Member of the Nachukui Formation (Tables 1 and 3; Fig. 7). However, it is difficult to  
655 differentiate the upper Kaitio Member from the overlying Nattoo Member at this locality. Nutz  
656 et al. (2017) reported the presence of stromatolite beds at Kokiselei, but their dating seems to  
657 be erroneous due to the presence of erosional/chronological gaps in the upper Kaitio Member  
658 that have not been taken into consideration (Boës et al., 2019b). A stromatolite bed is also  
659 present at the base of the Nattoo Member (Table 2) at Lowarengak (Harris et al., 1988) and there  
660 is one stromatolite bed at ~1.4 Ma, 15 m below the Lower Nariokotome Tuff (1.30 Ma; Table  
661 3; Fig. 7). Note that in the stratigraphy of the Nachukui Formation, there are no stromatolite  
662 beds between 1.6 and 1.4 Ma in the Nattoo Member as has been suggested by Nutz et al. (2020;  
663 i.e., there is a 440 kyr error in their publication in section 16, as the Malbe Tuff at 60 m is not  
664 dated at 1.40 Ma but at 1.84 Ma). Stromatolites occur at the transition between the Kaitio and  
665 Nattoo Members and then at the top of the Nattoo Member only (Harris et al., 1988). At

666 Kokiselei, the period between 1.7 and 1.6 Ma (upper Kaitio Member) is characterized by  
667 mollusk coquina, including *Celopatra* and *Melanooides* with the preserved trace fossil  
668 *Pelecypodichnus* (bivalve burrows) at the base of the coquina (Table 3; Fig. 7). Ostracods occur  
669 in a tuff 9 m above the base of the Natoo Member (=Ebei Tuff at 1.48 Ma) and the freshwater  
670 gastropod *Pila* occurs at 1.47 Ma. Mollusks are also present at 1.47 Ma at Loruth Kaado (Harris  
671 et al. 1988). Fossils of freshwater fishes (*Sindacharax*) are abundant between 1.47 and 1.42 Ma  
672 in the Natoo Member.

673

#### 674 4.5. From 1.30 to 0.70 Ma

675 The Nariokotome Member of the Nachukui Formation (Table 2) is marked by the  
676 presence of river and lake sediments. Sediments contain ostracods at 1.29 Ma (i.e., between the  
677 Lower and Middle Nariokotome Tuffs), which are overlain by deposits enriched in shells of  
678 *Cleopatra* and *Melanooides*, at 1.27 Ma (Table 3; Fig. 7). Then ostracods and mollusks alternate  
679 with stromatolites in sediments of several river and lake systems between 1.20 and 0.75 Ma.  
680 Freshwater mollusks are common in sediments between these stromatolites. Notably, *Iridina*  
681 has been reported from the Nariokotome Member (Table 3), where the depositional  
682 environments evolved from river to lake systems (Fig. 7). *Etheria* is occasionally found  
683 associated with stromatolites (Harris et al., 1988). Mollusks and stromatolites are commonly  
684 found within a stratigraphic interval extending from 9 m above the Upper Nariokotome Tuff at  
685 1.23 Ma, up to 1 m below the Silbo Tuff at 0.75 Ma (Brown, unpublished data; Ward et al.,  
686 2014; Maddux et al., 2015). The biostratigraphy of the Nariokotome Member suggests that  
687 freshwater and saline–alkaline conditions fluctuated, notably between 1.27 and 0.75 Ma  
688 (=paleolake Nachukui; Table 3; Fig. 7). Four of the stromatolite beds occur from 23 m above  
689 the base of the member (Ward et al., 2014; Maddux et al., 2015). The stromatolites occur

690 between the Upper Nariokotome and Silbo Tuffs (1.23 and 0.75 Ma, respectively). As  
691 previously discussed, these stromatolites may have formed by the precipitation of  
692 calcium carbonate around nuclei trapped in sediment when freshwater rivers and saline–  
693 alkaline lake waters mixed. Stromatolites developed near lakeshore and river channels, where  
694 mollusks or rounded basalt cobbles frequently served as hard nucleating surfaces (Ekdale et al.,  
695 1989; Hargave et al., 2014). For the stromatolites observed 9 m above the Upper Nariokotome  
696 Tuff at Nadung’a (Delagnes et al., 2006; Maddux et al., 2015), these formed around rounded  
697 basalt cobbles, freshwater mollusks and even around a biface stone tool. The latest stromatolites  
698 of the Nariokotome Member found 1 m below the Silbo Tuff (0.75 Ma) can be very large (up  
699 to 1.5 m) immediately east of the fault at the Nariokotome Mission, or very small (<5 cm) west  
700 of the fault at Nadung’a. This variation suggests that factors other than the mixing of freshwater  
701 rivers with saline–alkaline lake waters played a role in stromatolite size, such as geothermal  
702 activity (Casanova, 1996).

703

## 704 **5. Archeological and hominin sites in the western region of the Turkana Basin**

### 705 *5.1. From 4.20 to 3.60 Ma*

706 The KNM-LT 329 mandibular fragment from the lowermost Apak Member is older than  
707 4.20 Ma and thus represents the earliest known hominin from the Turkana Basin (Leakey and  
708 Walker, 2003; Wood and Leakey, 2011; Kissel and Hawks, 2015). Hominin fossils attributed  
709 to the species *A. anamensis* (e.g., KNM-KP 29281, 29283, 29285, 29286, 29287; KNM-WT  
710 30498, 31712, 34725, 53160, 58759; Table 4; Fig. 8) have been found in the Kanapoi Formation  
711 (Leakey et al., 1995, 1998), from the Lower Pumiceous Tuff and in the unit above the Kanapoi  
712 Tuff, i.e., between 4.20 and 4.10 Ma (Table 4; Figs. 7 and 8; Feibel, 2003a). Note that in the  
713 original publication by Leakey et al. (1998), the Lower Pumiceous and Kanapoi Tuffs were re-

714 dated at 4.17 Ma and 4.07 Ma, respectively, but were later dated to between 4.20 and 4.11 Ma  
715 by McDougall et al. (2012). Thus far, the discoveries at Kanapoi represent the first occurrence  
716 of *A. anamensis* and likewise of the genus *Australopithecus*. However, remains found in the  
717 Koobi Fora region at Ileret may be 100,000 years older (Ward et al., 2023). The hominin fossils  
718 from Kanapoi are almost contemporaneous with the material of *A. anamensis* from Fejej, 4.18–  
719 4.0 Ma (Ward, 2014), and slightly older than the remains of *A. anamensis* from Allia Bay in the  
720 Koobi Fora Formation, 3.90 Ma (Leakey et al., 1995; Ward et al., 2001).

721

## 722 5.2. From 3.60 to 3.1 Ma

723 The period between 3.60 and 3.10 Ma coincides with the appearance of a new hominin  
724 genus and species, *Kenyanthropus platyops*, in the western region of the Turkana Basin (Leakey  
725 et al., 2001). The remains of *K. platyops* have been described only from the Kataboi and  
726 Lomekwi Members in the Lomekwi region (Leakey et al., 2001). The holotype (KNM-WT  
727 40000 cranium; Table 4; Fig. 8) of this species occurs at 3.50 Ma, whereas the paratype (KNM-  
728 WT 38350 maxilla) dates to 3.30 Ma (Leakey et al., 2001). The oldest fossils of *K. platyops*,  
729 including the holotype cranium, were found in nearshore lake deposits at 3.50 Ma in the Kataboi  
730 Member at Lomekwi (e.g., KNM-WT 38339, 38341; Table 4; Fig. 8). Other hominin remains,  
731 mentioned here as Pliocene hominins, have been discovered between 3.50 and 3.20 Ma at  
732 Lomekwi (Skinner et al., 2020), and at 3.5 Ma at Lothagam (KNM-LT 23181, 23182, 23183;  
733 Table 4; Fig. 8) and south of the Turkwel River (KNM-WT 22936 and KNM-WT 22944; Table  
734 4; Fig. 8). The hominin remains at South Turkwel have been found in the same spatiotemporal  
735 and depositional contexts as those at Lomekwi (see Ward et al., 1999 and Leakey et al., 2001).  
736 At Lomekwi, most of the remains of *K. platyops* and Pliocene hominins were found in the  
737 Lomekwi Member at 3.30 Ma and 3.30–3.2 Ma (e.g., KNM-WT 16003, 08556, 08557, 38343,

738 38344, 38345, 38346, 38356, 38357; see Leakey et al., 2001) and in the same spatiotemporal  
739 context as the archeological bed ('LOM3 bed') excavated at Lomekwi 3 (LO-5 locality of fossil  
740 collection), which has yielded the oldest known artifacts dated at 3.30 Ma (Table 4; Fig. 8). The  
741 stone artifacts at the archeological site of Lomekwi 3 (LOM3) are mainly large cores, some  
742 reaching more than 20 cm in length, as well as flakes, hammerstones and anvils (Harmand et  
743 al., 2015). Some specimens are multipurpose and were used both as cores to produce flakes and  
744 as anvils or percussors (Harmand et al., 2015). At present, the lithic artifacts from LOM3 at  
745 3.30 Ma are the earliest evidence of hominin cognitive abilities for tool making (Harmand et  
746 al., 2015; Lewis and Harmand, 2016). The LOM3 site and the *K. platyops* paratype were found  
747 in sediments of the same age, just above a paleo-beach complex topped by sand dunes, and only  
748 about 650 m apart (LO-5 locality of fossil collection; Harmand et al., 2015; Leakey et al., 2001).  
749 The paleo-beach and sand dune complex, the latter containing fossilized calcified roots and  
750 termite nests, lie a few meters above the Toroto Tuff at 3.31 Ma (Harmand et al., 2015).  
751 Nearshore river and alluvial fan deposits exclusively mark the periods at 3.60 Ma and 3.30–  
752 3.20 Ma.

753

### 754 5.3. From 2.60 to 2.20 Ma

755 Two specimens of *P. aethiopicus* have been found in the Lokalalei Member: the KNM-  
756 WT 17000 cranium at 2.53 Ma and the KNM-WT 16005 mandible at 2.45 Ma (Table 4; Fig.  
757 8). The chronostratigraphic position of these fossils is constrained by the Lokalalei Tuff at 2.53  
758 Ma. KNM-WT 17000 lies within river sediments a few meters below this tuff and KNM-WT  
759 16005 is positioned around 20 m above in river sediments (Walker et al., 1986). A tooth  
760 attributed to early *Homo* (KNM-WT 42718) was discovered 2.2 m above the Ekalalei Tuff  
761 (undated) at LA1 $\alpha$  (Prat et al., 2005), i.e., a paleoanthropological site located in the same



762 stratigraphic context as the Oldowan sites of Lokalalei (Prat et al., 2005). KNM-WT 42718 was  
763 subsequently dated at 2.33 Ma based on the fact that the Ekalalei Tuff is slightly younger than  
764 Tuff F (Shungura Formation) dated at 2.34 Ma. It was then shown that the Ekalalei Tuff lies  
765 four meters above the Kalochoro Tuff at Loakalalei (Tiercelin et al., 2010). Harris et al. (1988)  
766 correlated the Kalochoro Tuff with Tuff F dated at 2.33 Ma, but McDougall and Brown (2008)  
767 suggested that they are two different eruptions very closely spaced in time. Based on these  
768 assumptions, KNM-WT 42718 is probably slightly younger than 2.33 Ma. The lithic material  
769 excavated at the archeological site of Lokalalei 1A and 2C demonstrates a level of technical  
770 and manual skill that is exceptional for the early Oldowan, with high productivity flaking  
771 between 2.33 and 2.25 Ma (Delagnes and Roche, 2005; Harmand, 2009; Arroyo et al., 2020).  
772 Another archeological complex of early Oldowan sites named Nasura (Roche et al., 2018)  
773 contains in situ artifacts at 2.33–2.25 Ma (NAS2, 1, 3; Table 5; Fig. 8). The remains of one  
774 hominin allocated to *Paranthropus* (probably *P. boisei*, KNM-WT 64910) is also reported  
775 within the archeological complex of Nasura (Table 4; Fig. 8). There are currently no remains  
776 of *P. aethiopicus* associated with an archeological site in the western region of the Turkana  
777 Basin.

778

#### 779 5.4. From 2.20 to 1.30 Ma

780 No hominins or archeological sites have been discovered thus far from the period  
781 between 2.2 and 1.9 Ma, but more archeological surveys are needed for the upperpart of the  
782 Kalochoro Member. Note that the hominin cranium (KNM-WT 15001) previously identified as  
783 *Homo habilis* at Kangaki is from the Holocene (Harris et al., 1994). Remains of *P. boisei*  
784 (KNM-WT 37100, 37744, 37747, 37748; Table 4; Fig. 8) have been found from coeval  
785 sediments during the excavation of the Oldowan material at Kokiselei 1, dated at 1.79 Ma (KS1;

786 Tables 4 and 5; Fig. 8). Other remains of *P. boisei* at 1.77–1.72 Ma (KNM-WT 17400, 17396,  
787 18600) have been discovered in the same spatiotemporal context as the Kokiselei archeological  
788 complex. A tooth at 1.75 Ma attributed to *Homo* sp. aff. *H. ergaster* (KNM-WT 37745) was  
789 uncovered at the Oldowan site of Naiyena Engol 1 (NY1; Table 5; Fig. 8). The period after 1.7  
790 Ma is marked by the presence of *H. ergaster/erectus*, of which the most complete skeleton  
791 known (KNM-WT 15000) was unearthed at the Nariokotome III site at 1.47 Ma (Walker et  
792 Leakey, 1993). Another cranium of *H. ergaster/erectus* (KNM-WT 16001), discovered in the  
793 Nariokotome drainage, is dated at 1.44 Ma by McDougall et al. (2012). A metacarpal (KNM-  
794 WT 51260) has been discovered at 1.42 Ma in the Nattoo Member (i.e., at the level of the  
795 Lokapetamoi Tuff) at Kaitio, and allocated to the genus *Homo* and probably to *H. erectus* sensu  
796 lato (i.e., *H. ergaster/erectus*; Ward et al., 2014).

797         The following chronostratigraphic interval between 1.8 and 1.7 Ma yielded many  
798 Oldowan sites at Kokiselei and Naiyena Engol (KS3, KS2, KS5, KS1; Table 5; Fig. 8). At 1.80  
799 Ma, the archeological site of Kokiselei 6 (KS6) provides the earliest known evidence for the  
800 emergence of bifacial shaping in eastern Africa (Duke et al., 2021). At 1.76 Ma, the  
801 archeological site of Kokiselei 4 (KS4) contains the oldest known Acheulean industry (Lepre  
802 et al., 2011; Texier, 2018). The lithic material is characterized by large flakes and heavy tools  
803 obtained by splitting large cobbles, direct shaping (unifacially or bifacially) of flat cobbles, and  
804 by shaping smaller detached products. Kokiselei 4 includes picks with trihedral or square  
805 sections, unifacial or roughly shaped handaxes, as well as pieces left as rough outs (Roche et  
806 al., 2003; Texier, 2018). The chronostratigraphy of the upper Kaitio Member requires further  
807 investigation, especially at Naiyena Engol, an archeological complex currently under study  
808 (NY1, NY2; Table 5; Fig. 8).

809

810 5.5. From 1.30 to 0.70 Ma

811 Currently under study, the Acheulean site of Nachukui 6 at 1.27 Ma (NK6; Table 5; Fig.  
812 7) is located a few meters above the Middle Nariokotome Tuff (1.28 Ma) and intercalated  
813 between conglomerates and channels. It is for the moment the only archeological site at the  
814 base of the Nariokotome Member. Higher in this member, a left proximal tibia attributed to *H.*  
815 *erectus* (KNM-WT 19700; Table 4; Fig. 8) is dated approximately to 1 Ma (i.e., 45 m above  
816 the Lower Nariokotome Tuff and 8–8.5 m below stromatolite horizon S3; NC1 locality in  
817 Brown et al., 2001). A hominin molar (KNM-WT 51261) was uncovered in marginal lake  
818 deposits within the Acheulean complex of Nadung'a at 0.75 Ma (i.e., at the level of the Silbo  
819 Tuff) and was attributed to the genus *Homo* (African Middle Pleistocene *Homo*; Maddux et al.,  
820 2015). The Acheulean sites of Nadung'a 1, 2 and 3 (NAD1, 2, 3; Table 5; Fig. 8) were excavated  
821 just below the pumices of the Silbo Tuff at 0.75 Ma and Nadung'a 4 (NAD4; Fig. 7) lies just  
822 above the tuff (Delagnes et al., 2006; Maddux et al., 2015). As the Silbo Tuff is not a continuous  
823 bed, it is very difficult to find pumice clasts at Nadung'a; they were found in situ at NAD2  
824 (Brown, unpublished data, and fieldwork done by the WTAP in 2022).

825

## 826 **6. Discussion**

827

828 *6.1. A complex hominin habitat in the western region of the Turkana Basin, with interaction*  
829 *between hydroclimate, hydroconnectivity and ambient aridity*

830

831 Most of the known hominin genera (*Australopithecus*, *Kenyanthropus*, *Paranthropus*,  
832 *Homo*) appear approximately between 4.3 and 1.7 Ma in eastern Africa, notably in the western  
833 region of the Turkana Basin (Walker et al., 1986; Leakey and Walker, 1988; Walker and Leakey  
834 1988, 1993; Leakey et al., 1995, 1998, 2001; Ward et al., 1999, 2001, 2013, 2014, 2020; Brown  
835 et al., 2001; Prat et al., 2003, 2005; Wood and Leakey, 2011; Maddux et al., 2015; Skinner et

836 al., 2020; Table 4; Fig. 7). Explanations of these speciation events have focused on adaptations  
837 to climatic and environmental changes, with effects on landscape aridification (Wynn, 2004;  
838 Stewart, 2014; Levin, 2015; Blumenthal et al., 2017; Villaseñor et al., 2020; Quinn and Lepre,  
839 2020, 2021; Lepre and Quinn, 2022). For example, Villaseñor et al. (2020) has suggested that  
840 *K. platyops* exploited resources from both C<sub>3</sub> and C<sub>4</sub> environments and was no longer a  
841 primarily C<sub>3</sub> or dense forest/shrubland inhabitant. Stewart (2014) has suggested that climate  
842 variability is associated with early *Homo* and perhaps *P. boisei* broadening their diet to familiar  
843 but less preferred foods: vertebrates and invertebrates. These foods consistently provided early  
844 *Homo* with essential nutrients, which reduced selection pressures and allowed for increases in  
845 brain size (Stewart, 2014). This author suggested that in response to environmental fluctuations  
846 hominins adopted ecological and dietary patterns based on predictable terrestrial and C<sub>4</sub>/C<sub>3</sub>  
847 wetland resources. Broadly, the availability of water in arid regions of eastern Africa is a major  
848 limiting factor for vegetation growth and the development of terrestrial ecosystems in which  
849 hominins lived. The landscape of the Turkana Basin is currently arid due to the presence of  
850 topographic barriers that block atmospheric moisture. However, during the Plio–Pleistocene,  
851 former rivers and lakes that connected and disconnected in the Kenyan and Ethiopian Highlands  
852 created a mosaic of habitats with sufficient resources to sustain hominins. When connected,  
853 these hydrosystems modified the landscapes in certain regions of the Turkana Basin and altered  
854 the balance between water influx and evaporation. The paleohydrology of the Turkana Basin  
855 and the colonization of the different regions of the basin by freshwater fauna thus resulted from  
856 a complex interplay of cascading hydroconnectivity that formed and disappeared from the  
857 Kenyan and Ethiopian Highlands and surrounding regions, except near the Omo River delta  
858 where freshwater conditions are more permanent.

859 In addition to the climate decoupling and hydroconnectivity, inflows to the Turkana  
860 Basin and the outflow to the Indian Ocean and later to the Mediterranean Sea appear to have

861 been reorganized by volcano-tectonic activity and the deposition of various major basalts  
862 throughout the basin between 4.2 and 1.3 Ma (Table 1; Fig. 7). The closure of the Turkana  
863 paleoriver, among others, has increased the water retention capacity of the Turkana Basin after  
864 2.0 Ma, while the redirection of the Suguta paleoriver into Lake Logipi-Suguta drastically  
865 reduced the excess water input from the Kenyan Highlands to the basin after 1.4 Ma. The period  
866 between 2.0 and 1.4 Ma was thus favorable to large, deep lake formation, while the period after  
867 1.4 Ma was not (Fig. 7). These paleohydrographic and paleogeographic changes should be taken  
868 into consideration in paleoclimate and paleoenvironmental reconstructions for the Turkana  
869 Basin, as they certainly amplified or reduced water and freshwater food availability in the  
870 different regions around the basin. Thus, the influence of climate on the hominin environment,  
871 drinking water and food resources, in the western region of the Turkana Basin and the other  
872 regions, is a complex issue and cannot be isolated from the specifics of each region (e.g.,  
873 evolution of the Omo River delta in the northern region; volcanic closure of the Suguta and  
874 Turkana paleorivers in the south and southeastern regions; relocation of the basin outlet 300 km  
875 to the north; evolution of the Il Bakate River in the northeastern region; etc.).

876 In terms of climate and vegetation, published  $\delta^{13}\text{C}$  values from soil carbonate nodules  
877 sampled in the East African Rift system have been interpreted as a long-term C<sub>4</sub> vegetation  
878 trend in different publications (Wynn, 2000, 2004; Cerling et al., 2003, 2011; Levin et al.,  
879 2011,; Quinn et al., 2013; Quinn and Lepre, 2021; Fig. 8). However, recent studies (Polissar et  
880 al., 2019; Faith et al., 2019) have proposed that the long-term C<sub>4</sub> vegetation trend was likely  
881 responding to changing atmospheric CO<sub>2</sub> rather than aridity. Compared to  $\delta^{13}\text{C}_{\text{soil carbonate}}$  values,  
882  $\delta^{18}\text{O}_{\text{soil carbonate}}$  values reflect local rainfall source and amount, evaporation and temperature  
883 (Lepre and Quinn, 2022). The  $\delta^{18}\text{O}_{\text{soil carbonate}}$  values from the Turkana Basin (Fig. 8) suggest  
884 that evaporation and temperature (or the amount of water available for evaporation, see Fig. 8)  
885 increased after 2.1 Ma (Lepre and Quinn, 2022). Our synthesis on the western region of the

886 Turkana Basin suggests that hydrological conditions have developed repeatedly from 4.20 to  
887 2.22 Ma, then more permanently from 2.10 to 1.30 Ma and more intermittently from 1.27 to  
888 0.70 Ma (Fig. 7). New freshwater vertebrates and invertebrates (e.g., *Euthecodon* and  
889 *Potadoma*) arrived in the western region of the Turkana Basin when new hydrographic  
890 connections were made to the basin. Various biota, including ostracods and diatoms, among  
891 others, indicate the presence of freshwater conditions for the Late Pliocene, although ecological  
892 tolerance of Plio–Pleistocene diatoms and ostracods is still not well known and requires further  
893 study. The freshwater micro- and macrofauna suggest that paleolake Lonyumun was fresh and  
894 connected to the Indian Ocean, as perhaps were paleolakes Lokochot and Waru. It seems that  
895 paleolake Lorenyang expanded after the eruption of the Lenderit basalt, which closed the  
896 outflow of the Omo River and Turkana Basin to the Indian Ocean after 2 Ma (Fig. 7). In the  
897 western region of the Turkana Basin, the freshwater stingray *D. africana* is present between  
898 1.90 and 1.38 Ma, but in the Koobi Fora and Shungura Formations *D. africana* is known to  
899 occur at around 2 Ma and persisted until its extinction around 1.3 Ma (Feibel et al., 1993;  
900 Joordens et al., 2013). With the volcanic closure of the Turkana paleoriver, stingrays could no  
901 longer migrate to the Indian Ocean, and it appears that *D. africana* became endemic to the  
902 Turkana Basin. It is possible that the Omo River delta offered more perennial freshwater  
903 conditions and a refugium, even when conditions were alkaline–saline in the rest of the Turkana  
904 Basin. Paleolake Lorenyang potentially overspilled to the Nile outlet at 1.8–1.7 Ma, as  
905 suggested by the presence of *Euthecodon* and freshwater mollusks (Fig. 7). In the western  
906 region of the Turkana Basin, paleolake Lorenyang appears to have experienced fluctuating  
907 paleolimnological conditions from 1.9 to 1.3 Ma, resulting in the enrichment of sediments by  
908 various aquatic fossils, including stromatolites (Table 3; Fig. 7). After 1.4 Ma and the formation  
909 of the Barrier volcanoes, the southern drainage basin partially closed and it appears that the  
910 Turkana Basin became more unstable with alternating freshwater to saline-alkaline conditions,

911 as suggested by the extinction of *D. africana* and by the alternation of mollusks, ostracods and  
912 stromatolite beds between 1.27 and 0.70 Ma (Fig. 7).

913 With regard to the hominin environment, most *A. anamensis* remains were deposited in  
914 lakeshore and nearshore river environments between 4.20 and 4.11 Ma, when drinking water  
915 and freshwater foods were available in the western region of the Turkana Basin due to enhanced  
916 hydroconnectivity (Figs. 7 and 8), but no hominin remains have been found in the freshwater  
917 environment at 3.99–3.98 Ma (Fig. 8). The majority of *K. platyops* and Pliocene hominin  
918 remains occur when drinking water and freshwater foods were available at both ~3.50 Ma and  
919 3.30–3.2 Ma (Table 4; Figs. 7 and 8). Moreover, the lithic artifacts excavated at LOM3 occur  
920 when drinking water and freshwater foods were available at 3.30 Ma (Fig. 8), but no lithic  
921 artifacts have been unearthed in the freshwater environments at <3.60–3.44 Ma. Most *P.*  
922 *aethiopicus*, *P. boisei* and *Homo* sp. have also been found when drinking water and freshwater  
923 foods were available at 2.53, 2.33 and 2.25 Ma (Fig. 8). However, no lithic artifacts have been  
924 found at 2.53 Ma. The Oldowan complexes of Lokalalei (LA1A and LA2C; 2.34–2.25 Ma) and  
925 Nasura (NAS 2, 1, and 3; 2.33, 2.27 and 2.25 Ma, respectively) occur when drinking water and  
926 freshwater foods were available at 2.34–2.32 Ma and 2.25 Ma. NAS 3, dated at 2.25 Ma,  
927 appears to be positioned on the last beach with freshwater mollusks associated with a lake level  
928 whose outlet was still connected to the Indian Ocean (Boës et al., 2019a). At 2.19 Ma, the  
929 archaeological site of NAS 4 does not seem to be in an environment where freshwater was  
930 abundant (Fig. 8). Thereafter, there are no archaeological and hominin sites up to 1.8 Ma found  
931 to date; all the sites belonging to the archaeological complex of Kokiselei lie above a major  
932 paleo-beach complex dating from around 1.8 Ma (Lepre et al., 2011; Duke et al., 2021).  
933 Remains of *H. ergaster/erectus* and *P. boisei* and Oldowan and Acheulean sites occur when  
934 drinking water and freshwater foods were available between 1.8 and 1.7 Ma, with freshwater  
935 conditions that seem to have begun to alternate with saline–alkaline conditions as suggested by

936 the formation of stromatolite beds (Table 3; Figs. 7 and 8). The in situ skeleton of *H.*  
937 *ergaster/erectus* (KNM-WT 15000) excavated in sediments dated at 1.47 Ma occurs within the  
938 same stratigraphic context as the remains of the freshwater gastropod *Pila* (Table 3; Figs 6 and  
939 7). The Acheulean complex of Nadung'a is closely associated with environments where  
940 drinking water and freshwater foods are available sporadically, mostly with beach and sand  
941 dune deposits with fossilized calcified roots, except for NAD4, which is embedded in a paleosol  
942 at the top of a paleo-beach complex (Delagnes et al., 2006). African Middle Pleistocene *Homo*  
943 is present at the level of the Silbo Tuff, within the spatiotemporal context of the Nadung'a  
944 archeological complex (KNM-WT 51261; Table 5; Fig. 8).

945 Our synthesis suggests that hominins were mainly present in the western region of the  
946 Turkana Basin when drinking water and freshwater foods were available, despite the ambient  
947 aridity. However, as discussed below, several caveats complicate the assessment of an  
948 association between drinking water, freshwater foods and hominin occupation, and in  
949 particular, the existence of a preference for freshwater foods in the hominin diet and various  
950 adaptations to a decoupled landscape, i.e., occupation of the western region of the Turkana  
951 Basin by hominins when freshwater macrofauna that could supply their needs colonized this  
952 arid zone during episodes of enhanced hydroconnectivity.

953

## 954 6.2. Caveats and limitations

955 More quantitative explorations fall beyond the scope of this review paper. Rather, we  
956 focus on building the framework to develop future quantitative explorations and on caveats to  
957 consider upon undertaking such endeavors. A first caveat relates to how hominin and  
958 archeological sites are preserved. Does the recovery of hominin fossils from certain sediments  
959 imply hominins occupied the associated depositional environment? First, we need to consider  
960 that the location of freshly exposed fossils may be different from the area of primary occupation.



961 Postmortem transport may have occurred, and chances of preservation mainly exist in  
962 depositional centers, where the natural burial of remains occurs. Therefore, archeological,  
963 paleontological and paleoanthropological sites may be mainly found near aquatic environments  
964 because water effectively transports sediments (and biotic remains) toward areas of deposition.

965         Whereas the Turkana Basin arguably represents a Plio–Pleistocene depocenter within  
966 the East African Rift system, our synthesis indicates that the conditions of burial and  
967 preservation of fossil remains were not uniform throughout the period considered in the western  
968 region of the Turkana Basin. Two important factors toward preservation potential are  
969 physicochemical conditions at the depocenter and sedimentation rates, which affect the chance  
970 of preservation over time and the rate of burial, respectively. Biomineralized remains preserve  
971 better under neutral/alkaline conditions (less chance for demineralization) and in calmer  
972 depositional environments (less chance for fragmentation/abrasion; Kendall et al., 2018). In  
973 addition, environments where bone and water interactions remain static preserve bones better  
974 than do environments where cyclic wetting and drying occurs; increased temperatures also  
975 negatively affect collagen survival (Kendall et al., 2018). Therefore, we would expect a  
976 somewhat higher degree of bone preservation potential in alkaline than freshwater  
977 environments and in low energy depositional environments. Substantial variation in rates of  
978 deposition between 4.20 and 0.70 Ma primarily relates to hydroconnectivity and sediment  
979 influx into an open or closed basin. Interestingly, many hominin remains and archeological sites  
980 were found between 1.8 and 1.4 Ma (e.g., the archeological complex of Kokiselei; Figs. 7 and  
981 8), when sedimentation rates were very high (55 cm/kyr; Fig. 9). However, during the formation  
982 of the archeological complex of Nadung'a, between 0.8 and 0.7 Ma, the sedimentation rate was  
983 much lower (15 cm/kyr). Sedimentation rates were also lower between 2.4 and 2.2 Ma (10  
984 cm/kyr), when the sites of the archeological complex of Nasura were buried. Therefore, it  
985 appears that as long as deposition occurred through time, there was a potential to preserve

986 hominin remains and archeological sites, as well as freshwater vertebrates, invertebrates, and  
987 microalgae, although the formation and preservation of archeological sites may follow different  
988 depositional processes from those of fossil remains (see Fig. 9).

989 Another aspect to consider when examining association patterns is geochronology and  
990 dating uncertainty. First, if the confidence intervals for dates are large, existing associations  
991 may be blurred by noise derived from dating uncertainty. Second, age determinations of  
992 hominin fossils and archeological sites, as well as vertebrates, invertebrates, and microalgae,  
993 can be problematic when volcanic ash beds are too widely spaced. However, we consider the  
994 effect of geochronological constraints on our observations to be minimal for two reasons:  
995 firstly, because the presence of various tuff layers in the Turkana Basin, and the western region  
996 of the Turkana Basin in particular, provide unique opportunities to build a robust geochronology  
997 from 4.20 to 0.70 Ma and, secondly, geochronological uncertainty would obfuscate existing  
998 associations rather than create false associations (dating uncertainties <50 kyr; Fig. 6). That  
999 being said, there are two periods in the western region of the Turkana Basin, from 3.1 to 2.6  
1000 Ma and from 1.2 to 0.8 Ma, where fewer tuffs occur in the sedimentary series (Figs. 7–9). As  
1001 mentioned in the introduction, the chronostratigraphic interval between 3.1 and 2.6 Ma is not  
1002 well dated (and is represented by few outcrops) in the western region of the Turkana Basin and  
1003 was thus not evaluated in this synthesis. Furthermore, no hominin and archeological sites have  
1004 yet been discovered between 3.1 and 2.6 Ma. By contrast, there are a substantial number of  
1005 correlated outcrops to consider in the period between 1.2 and 0.8 Ma, as geological work has  
1006 been carried out on hominin and archeological sites found in this chronostratigraphic interval  
1007 (Delagnes et al., 2006; Maddux et al., 2015, and Brown, unpublished data).

1008 Despite the abovementioned considerations and caveats, the presence of different types  
1009 of fossils (microbial structures, diatom silica, bones, shell carbonate) throughout the Plio–  
1010 Pleistocene suggests that the conditions were quite favorable for their preservation. In the

1011 context of the quasi-continuous potential for fossil preservation, we consider our qualitative  
1012 observation of a possible association between hominin and archeological sites and the  
1013 development of drinking water and freshwater food resources for mammals, including hominins  
1014 across the western region of the Turkana Basin, as noteworthy.

1015         Considering our synthesis, we are tempted to provide a possible paleobiological  
1016 explanation, namely, that most hominin and archeological sites occur when drinking water  
1017 expanded into the arid zone and freshwater macrofauna colonized the region. The recurring  
1018 presence of freshwater micro- and macrofauna in the western region of the Turkana Basin  
1019 necessarily modified the food chain and the terrestrial environment in which hominins lived.  
1020 The presence of rivers and a large lake with an outflow has affected this arid landscape, enabling  
1021 colonization by new species adapted to freshwater and providing additional natural resources  
1022 (water, plants, fauna) that resulted in iterative occupation of the western region of the Turkana  
1023 Basin by various hominins. We highlight periods when freshwater was available, as well as  
1024 freshwater resources, indicated by the presence of river and lake deposits with freshwater  
1025 micro-and macrofauna they contain, during the following periods: 4.20–3.98 Ma, 3.70–3.10  
1026 Ma, 2.53–2.22 Ma, 2.10–1.30 Ma, then more intermittently after 1.27 Ma, as indicated by the  
1027 presence of stromatolite beds, which increase in number between 1.27 and 0.75 Ma (Figs. 7 and  
1028 8). Enhanced hydrological activity into the arid zone of the western region of the Turkana Basin  
1029 may have promoted 1) the growth of C<sub>4</sub> grasses and sedges, which are found on lake margins,  
1030 deltas, marshes, or floodplain, 2) the dispersal of freshwater foods and 3) the increased  
1031 accessibility of drinking water and food resources for mammals, including hominins. Thus, in  
1032 association with the arid environment, these hydrological conditions may have played a role in  
1033 driving hominin dietary and behavioral changes, as well as techno-cultural developments in this  
1034 region, as already suggested in the western region of the Turkana Basin by Stewart (2014) and  
1035 in the eastern region of the basin as well (Braun et al., 2010b; Archer et al., 2014).

1036 We do not have yet in-depth studies regarding the consumption of freshwater animals  
1037 in the western region of the Turkana Basin. However, with regard to the abundance of drinking  
1038 water, the regional isotopic studies from Lomekwi suggest that *K. platyops* shifted from  
1039 acquiring liquids directly from food toward drinking more water at 3.30 Ma (Quinn et al., 2021);  
1040 this could be a reflection of enhanced hydroconnectivity in this region associated with the  
1041 colonization of freshwater biota, which could have supplied the food needs of hominins in the  
1042 arid zone. In addition, isotopic study at Lokalalei 1A and 2C indicates that  
1043 woodland/bushland/shrubland was the dominant vegetation structural category. Notably, the  
1044 wooded grassland category was also present in abundance. Riparian woodlands near a large,  
1045 perennial river system may have provided shade, protection, floral food resources and drinkable  
1046 water to hominins at 2.34–2.32 Ma (Quinn et al., 2013). At Kokiselei 1–6, isotopic study  
1047 suggests the presence of wooded grasslands near a lake margin (Quinn et al., 2013), which may  
1048 have favored hominin resource use and tool-making behavior between 1.8 and 1.6 Ma.  
1049 According to these authors, it is possible that *Kenyanthropus*, *Paranthropus* and/or *Homo* used  
1050 tools for the extraction of freshwater invertebrate fauna and the processing of vertebrate  
1051 carcasses. However, to date, no taphonomic studies have found percussion or extraction marks  
1052 on invertebrate remains in the western region of the Turkana Basin.

1053 Along the eastern region of the basin, the consumption of aquatic foods has been argued  
1054 at Koobi Fora, for the archeological site of FwJj 20 at 1.95 Ma, based on taphonomic evidence  
1055 and the association of aquatic fauna with lithic assemblages (Braun et al., 2010b; Archer et al.,  
1056 2014). These authors suggest that hominins predating *Homo ergaster/erectus* may have  
1057 incorporated aquatic resources such as crocodiles and catfish into their diet, and that these  
1058 aquatic foods may have had a beneficial effect on brain development and function. Broadly,  
1059 several authors have suggested a potential link between the exploitation of aquatic resources  
1060 (vertebrates and invertebrates) and the evolution of hominin brain size and cognition

1061 (Wrangham et al., 2009; Archer et al., 2014; Joordens et al., 2014; Russon et al., 2014;  
1062 Hohmann et al., 2019; de Chevalier et al., 2022). In this context, our synthesis suggests that  
1063 diachronic variation in hydroconnectivity in the western region of the Turkana Basin explains  
1064 the occurrence of drinking water and freshwater macrofauna that could have supplied the food  
1065 needs of hominins despite the ambient aridity.

1066

## 1067 **7. Conclusions**

1068 In summary, our synthesis shows that there is a complex interaction between  
1069 topographic barriers along the Turkana Basin and changes in hydroconnectivity that result over  
1070 time in changes to how drinking water has been provided from the Ethiopian and Kenyan  
1071 Highlands to the arid Turkana Basin. The development of enhanced hydroconnectivity with  
1072 upland rivers and lakes, as well as the temporary establishment of outflows toward other  
1073 drainages, promoted the colonization of the western region of the Turkana Basin by freshwater  
1074 macrofauna, such as crocodiles, fish and mollusks. In the northern basin, freshwater conditions  
1075 are more persistent due to the presence of the Omo River delta, but in the rest of the basin,  
1076 conditions have at times been alkaline and saline, except when the lake had an outlet. The  
1077 paleogeography of basin outlets has been modified after 2 Ma by the volcanic closure of the  
1078 Turkana paleoriver that connected the southern region of the Turkana Basin to the Indian Ocean  
1079 (Bruhn et al., 2011; Boës et al., 2019), and by the opening of a new outlet connected to the Nile,  
1080 possibly from 1.9 Ma, as well as the obstruction of the Suguta paleoriver after 1.4 Ma. These  
1081 aspects are fundamental to understanding how freshwater conditions interacted with ambient  
1082 aridity in the Turkana Basin in relation to hominin occupation and faunal succession within a  
1083 constrained chronological framework. As such, periods of enhanced hydroconnectivity with  
1084 freshwater foods available to hominins may be assessed by the presence of macrofauna, such

1085 as freshwater mollusks, fish and crocodiles (the freshwater crocodile *Euthecodon*, with its  
1086 elongated jaw, fed exclusively on fish and could not be a predator for hominins).

1087 Our synthesis of these data in the western region of the Turkana Basin suggests that  
1088 river-induced hydrological changes and high-amplitude paleolake-level fluctuations may be  
1089 explained without ‘extreme and abrupt climate pulses’, but rather through the interactions of  
1090 various regional factors. These include a dormant cascading river-lake system and the  
1091 reorganization of the hydrographic network and outflows by volcanism. Secondly, our synthesis  
1092 suggests that hominin and archeological sites exist in the western region of the Turkana Basin  
1093 within this context of hydrological variability. In light of these insights, we consider that there  
1094 may be a direct causality between the variation and availability of drinking water and freshwater  
1095 foods and hominin occurrences through the increased total biomass productivity in freshwater  
1096 environments compared to periods of water stress in an arid environment with high evaporation  
1097 rates. However, several caveats are to be considered because the effective use of these data is  
1098 precluded by limitations of pattern-matching strategies to infer causal relationships between  
1099 ecological and evolutionary change (see e.g., Faith et al., 2021).

1100 The consumption of C<sub>4</sub> and aquatic resources by hominins has been hypothesized in the  
1101 western (Stewart, 2014) and eastern (Braun et al., 2010b; Archer et al., 2014) regions of the  
1102 Turkana Basin and a search for more direct evidence of interactions among hominins and  
1103 aquatic organisms may be warranted in the western region of the Turkana Basin. To what extent  
1104 such interactions affected the anatomical, cognitive and behavioral evolution of hominins in the  
1105 Turkana Basin remains an important question. Beyond a search for direct interactions, an  
1106 association between freshwater availability and hominin occupation in the western region of  
1107 the Turkana Basin requires in-depth quantitative comparisons, which should focus on  
1108 compiling independent datasets on fossil occurrences of freshwater biota and hominins for  
1109 subsequent correlative analyses. Such analyses could be undertaken at the scale of the western

1110 region of the Turkana Basin or of the Turkana Basin, but taking into account the mosaic of  
1111 landscapes and numerous paleohydrographic and paleogeographic parameters which interfere  
1112 with paleoclimatic interpretations of proxies. This new framework offers exciting prospects to  
1113 the study of the interrelationship between multifactorial paleoenvironmental changes and the  
1114 anatomical and cognitive evolution of hominins in the Turkana Basin.

1115

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1139

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- 1813

1814 **Figure legends**

1815

1816 **Figure 1.** a) Digital elevation model of eastern Africa. b) Map of the present-day Lake Turkana  
1817 watershed (dotted line), with the main Omo River watershed in the North and the Kerio and  
1818 Turkwel River watersheds in the South. c) Digital elevation model of the entire Turkana Basin  
1819 and Lake Turkana with the limit of the East African Rift and the extensional rift basin (white  
1820 dotted line. Sources: Shuttle Radar Topography Mission (SRTM-90 m) and bathymetric map  
1821 from Garcin et al. (2012). Locations: A=Gombe Group basalts; B=Loiyangalani sill (former  
1822 outlet channel to the Indian Ocean); C=Kulal Volcano and Lenderit basalts; D=Chalbi Basin;  
1823 E=Tirr TIRR; F=the Barrier and Suguta; G=Lothagam and Kerio; H=Nasechebun and Kataboi;  
1824 I=Ilemi sill (former outlet channel to the White Nile River); J=Lapur Range; K=Chew Bahir;  
1825 L=Abaya-Chamo lakes; M=Awash River Basin; N=Baringo-Bogoria Basin; O=Tugen Hills;  
1826 P=Elgeyo Escarpment and Kerio Basin. Plio–Pleistocene Formations affiliated with the Omo  
1827 Group: 1=Nachukui; 2=Shungura; 3=Koobi Fora and Allia Bay region; 4=Kanapoi; 5=Kibish;  
1828 6=Usno; 7=Mursi and Nkalabong; 8=Fejej—other localities affiliated with the Nachukui  
1829 Formation: 9=Lothagam, 10=South Turkwel, and 11=Loruth Kaado. The Konso Formation  
1830 (12) is considered separate from the Turkana Basin.

1831

1832 **Figure 2.** Schematic map of the Plio–Pleistocene drainage system of the entire Turkana Basin  
1833 with indication of cascading hydroconnectivity with upland rivers and lakes from the Ethiopian  
1834 and Kenyan Highlands. See text for explanations. Plio–Pleistocene formations affiliated with  
1835 the Omo Group: 1=Nachukui (4.2–0.7 Ma; McDougall et al., 2012); 2=Shungura (3.7–1.1 Ma;  
1836 McDougall et al., 2012); 3=Koobi Fora (4.4–0.70 Ma; McDougall et al., 2012) and Allia Bay  
1837 region (4.1–3.9 Ma; Wynn, 2000); 4=Kanapoi (4.3–3.9 Ma; McDougall et al., 2012 ); 5=Kibish

1838 (196–8 ka; McDougall et al., 2012); 6=Usno (3.4–3.1 Ma; Drapeau et al. 2022; Jolly and  
1839 Bonnefille, 203); 7=Mursi (>4.0 Ma; Drapeau et al. 2022) and Nkalabong (4.0–1.7 Ma;  
1840 Drapeau et al. 2022); 8=Fejej (4.3–1.8 Ma; Brown and McDougall, 2011)—other localities  
1841 affiliated with the Nachukui Formation: 9=Lothagam (>3.9 Ma; Feibel, 2003b), 10=South  
1842 Turkwel (>4.1–3.6 Ma; Ward, 1999), and 11=Loruth Kaado (3.6–3.2 Ma; Harris et al., 1988).  
1843 The Konso Formation=12 (1.9–1.4 Ma; Katoh et al., 2000) is considered separate from the  
1844 Turkana Basin.

1845

1846 **Figure 3.** Digital terrain model of the Omo-Turkana-Nile region (from the Shuttle Radar  
1847 Topography Mission, SRTM-90 m). Paleo-drainage system of the Turkana Basin (see Fig. 4  
1848 for the longitudinal profiles of the paleorivers). a and b) Present-day (Holocene) closed drainage  
1849 system with no outlet to the ocean, the sea, or other lakes (=endorheic and saline–alkaline  
1850 conditions); c and d) Early Pleistocene open drainage system with an outlet channel connected  
1851 to the Mediterranean Sea (=freshwater–exorheic conditions); e and f) Late Pliocene open  
1852 drainage system with an outlet channel connected to the Indian Ocean (=freshwater–exorheic  
1853 conditions).

1854

1855 **Figure 4.** Longitudinal profiles of elevation changes along major rivers and paleorivers of the  
1856 entire Turkana Basin (from the Shuttle Radar Topography Mission, SRTM-90 m). a) Omo  
1857 River; b) Kerio River and cascading connections from the Kerio Basin (West of Tugen Hills);  
1858 c) Suguta paleoriver and cascading connections from the Baringo-Bogoria Basin (east of Tugen  
1859 Hills); d) Il Bakate paleoriver and cascading connections between lakes Chamo, Abaya, and  
1860 Chew Bahir; e) Turkana paleoriver, i.e., Loiyangalani outlet connected to the Indian Ocean; f)

1861 the paleo-tributary to the White Nile and the Nile rivers, i.e., Ilemi outlet connected to the  
1862 Mediterranean Sea. (m.a.s.l.).

1863

1864 **Figure 5.** a) Map showing the maximum extension of Plio–Pleistocene paleolakes (shaded in  
1865 blue) when the size of the entire Turkana drainage basin is connected/disconnected (dotted  
1866 red/blue lines) from the watersheds of lakes in the Ethiopian and Kenyan branches of the East  
1867 African Rift (Abaya, Chamo, and Chew Bahir/Elmenteita, Nakuru, Borgoria, Baringo, and  
1868 Logipi-Suguta). Arrows show major inflows. b) Location of the volcanic eruptions of Gombe  
1869 ( $4.22 \pm 0.09$ – $3.95 \pm 0.10$  Ma; Haileab et al., 2004; Erbello and Kidane, 2018) and Kulal ( $3.01$   
1870  $\pm 0.55$ – $1.91 \pm 0.21$  Ma; Rundle, 1985; Dunkley et al., 1993; Gathogo et al., 2008;) near the  
1871 Loiyangalani outlet, connected to the Indian Ocean and influencing the evolution of the  
1872 drainage basin.

1873

1874 **Figure 6.** Bayesian Age model of the Nachukui Formation based on argon-argon dating of tuffs  
1875 and stratigraphy (after Harris et al., 1988; Brown and McDougall, 2011; McDougall et al.,  
1876 2012). Age model and error ranges calculated using Chronomodel v. 2.0 (software developed  
1877 by Lanos and Dufresne, 2019).

1878

1879 **Figure 7.** Compilation of geochronological data from the western region of the Turkana Basin  
1880 (Turkana Basin, Kenya). From left to right: Magnetostratigraphy (McDougall et al., 1992;  
1881 Lepre et al., 2011; Lepre, 2014; Harmand et al., 2015; Sier et al., 2017); volcano-tectonic  
1882 activity in the basin (Baker et al., 1971; Brotzu et al., 1984; Rundle, 1985; Nyamweru, 1986;  
1883 Key et al., 1987; Bosworth and Maurin, 1993; Dunkley et al., 1993; Haileab et al., 2004; Furman  
1884 et al., 2006; Kaeser, 2006 ; Gathogo et al., 2008 ; McDougall et al., 2012); tephrostratigraphy

1885 (Brown and McDougall, 2011; McDougall et al., 2012); geologic members (Harris et al., 1988;  
1886 Feibel et al., 1989; Feibel, 2003a; McDougall and Brown, 2008; Brown and McDougall, 2011;  
1887 McDougall et al., 2012); major Plio–Pleistocene river and lake systems in the entire Turkana  
1888 Basin (Harris et al., 1988; Feibel, 2011; Gathogo, 2017; Lepre, 2014; Boës et al., 2019a);  
1889 evolution of the aquatic fauna, including freshwater vertebrates, invertebrates and microalgae  
1890 (Wood, 1979; Williamson, 1981; Meylan et al., 1990; Feibel, 1993; Harris et al., 1988, 2003;  
1891 Stewart, 2001, 2003, 2009; Brugal et al., 2003; Martin and Trautwein, 2003; Storrs, 2003; Van  
1892 Bocxlaer et al., 2008; Tiercelin et al., 2010; Van Bocxlaer, 2011, 2020; Joordens et al., 2013;  
1893 Gathogo, 2017; Boës et al., 2019a; Brochu, 2020; Stewart and Rufolo, 2020). For the  
1894 tephrostratigraphy: U=upper; M=middle; L=lower.

1895

1896 **Figure 8.** From left to right: Woody canopy cover (%): combined published percentages of  
1897 woody canopy cover from the East African Rift (calculated from  $\delta^{13}\text{C}_{\text{soil carbonate}}$  values are  
1898 reported relative to Vienna Pee Dee Belemnite and are derived from Cerling et al. (2003), Wynn  
1899 (2000, 2004), Levin et al. (2011), Quinn et al. (2013), Levin (2015), and Quinn and Lepre 2021).  
1900 Soil carbonate  $\delta^{18}\text{O}$  values from the western region of the Turkana Basin (Lepre and Quinn,  
1901 2022). Hydrological changes: major hydrological changes induced by lake and river activity  
1902 and freshwater episodes with freshwater vertebrates, invertebrates and microalgae (based on  
1903 this synthesis). Lithic industries: archeological sites with lithic industries excavated by the  
1904 Mission Préhistorique au Kenya (Kibunjia et al., 1992; Roche et al., 1999, 2003, 2018; Brugal  
1905 et al., 2003; Prat et al., 2003, 2005; Delagnes and Roche, 2005; Delagnes et al., 2006; Harmand,  
1906 2009; Tiercelin et al., 2010; Harmand et al., 2015; Lewis and Harmand, 2016; Texier, 2018;  
1907 Boës et al., 2019a; Arroyo et al., 2020; Duke et al., 2021). Major hominin remains from (black)  
1908 work conducted by the Mission Préhistorique au Kenya (Prat et al., 2003, 2005) and from (gray)  
1909 major work conducted in the region by other teams (Walker et al., 1986; Walker and Leakey

1910 1988, 1993; Leakey and Walker, 1988; Leakey et al., 1995, 1998, 2001; Ward et al., 1999,  
1911 2001, 2013, 2014, 2020; Brown et al., 2001; Wood and Leakey, 2011; Maddux et al., 2015;  
1912 Skinner et al., 2020). For the hominins, the color gradient within each box takes into account  
1913 the estimated error range of the age estimates for the hominin remains and archeological sites.  
1914 Mission Préhistorique au Kenya/WTAP archeological sites: LOM3=Lomekwi 3 (Harmand et  
1915 al., 2015); LA1A=Lokalalei 1A and LA2C=Lokalalei 2C (Roche et al., 1999; Delagnes et al.,  
1916 2005; Harmand, 2009 ; Tiercelin et al., 2010); NAS1, 2, 3, 4=Nasura 1, 2, 3, 4 (Boës et al.,  
1917 2019a); KS1, 2, 3, 5, 6=Kokiselei 1, 2, 3, 5, 6 (Brugal et al., 2003 ; Roche et al., 2003;  
1918 KS4=Kokiselei 4 (Lepre et al., 2011; Texier, 2018); NY1, 2=Naiyena Engol 1, 2 (Brugal et al.,  
1919 2003; Prat et al., 2003; Roche et al., 2003, 2018); NAD4=Nadung'a 4 (Delagnes et al., 2006).

1920

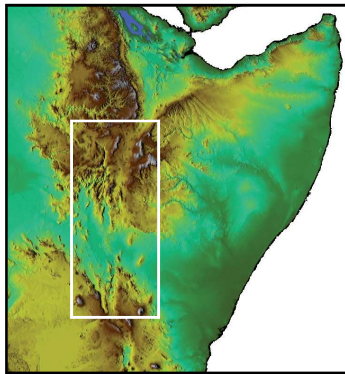
1921 **Figure 9.** Long-term variation in sedimentation rates in the western region of the Turkana Basin  
1922 (Nachukui Formation) and its influence on archeological site formation and preservation.  
1923 Archaeological and hominin sites are present where the sedimentation rate is high (>40 cm/kyr),  
1924 as at Kokiselei (KS) and Naiyena Engol (NY), but also where the sedimentation rate is lower  
1925 (<20 cm/kyr), as at Nasura (NS) and Lokalalei (LA). These results suggest that, as long as  
1926 deposition occurred through time, there was a potential to preserve hominin remains and  
1927 archeological sites in the Western region of the Turkana Basin. Sedimentation rates have been  
1928 calculated using Chronomodel v. 2.0 (software developed by Lanos and Dufresne, 2019).

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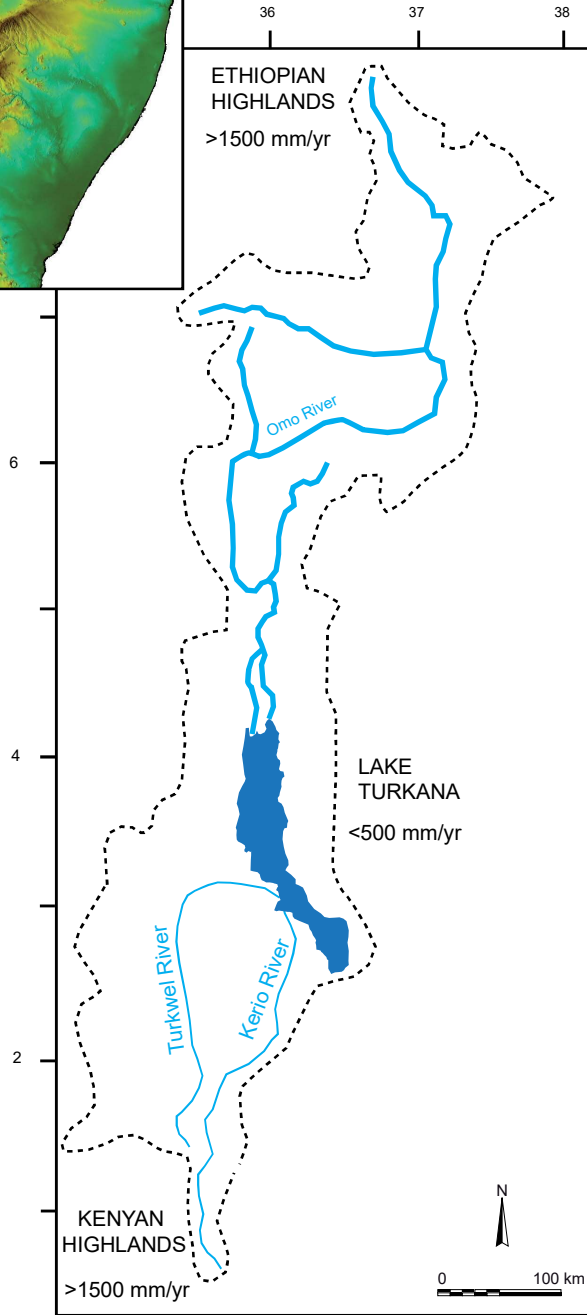
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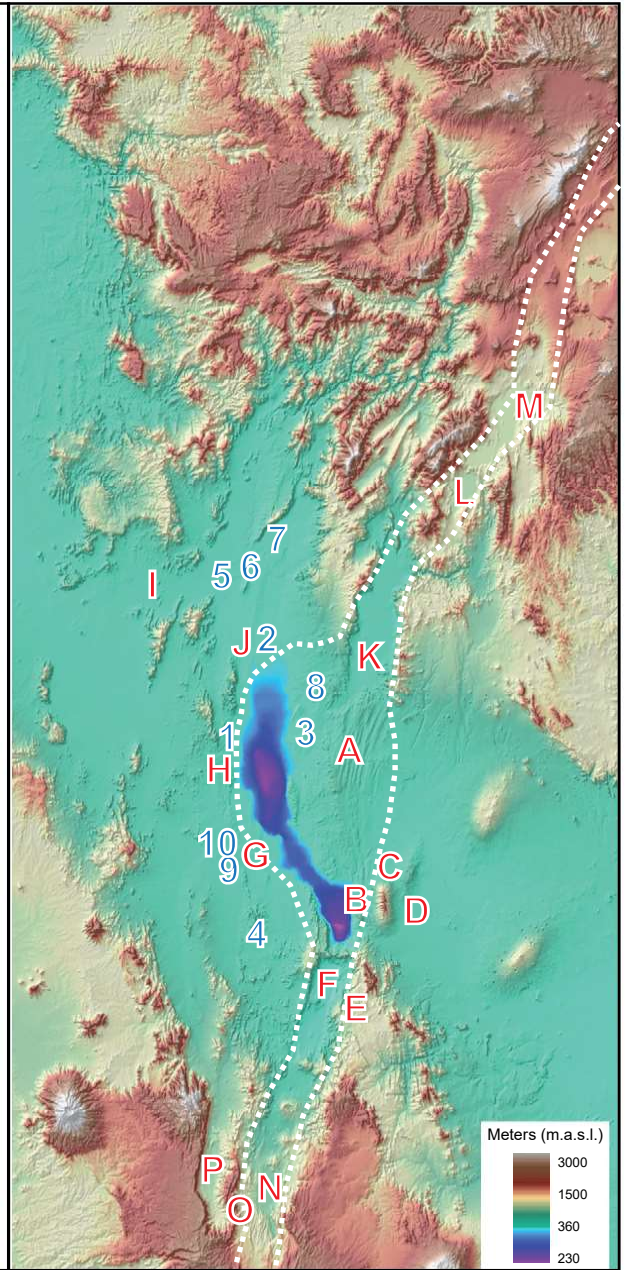




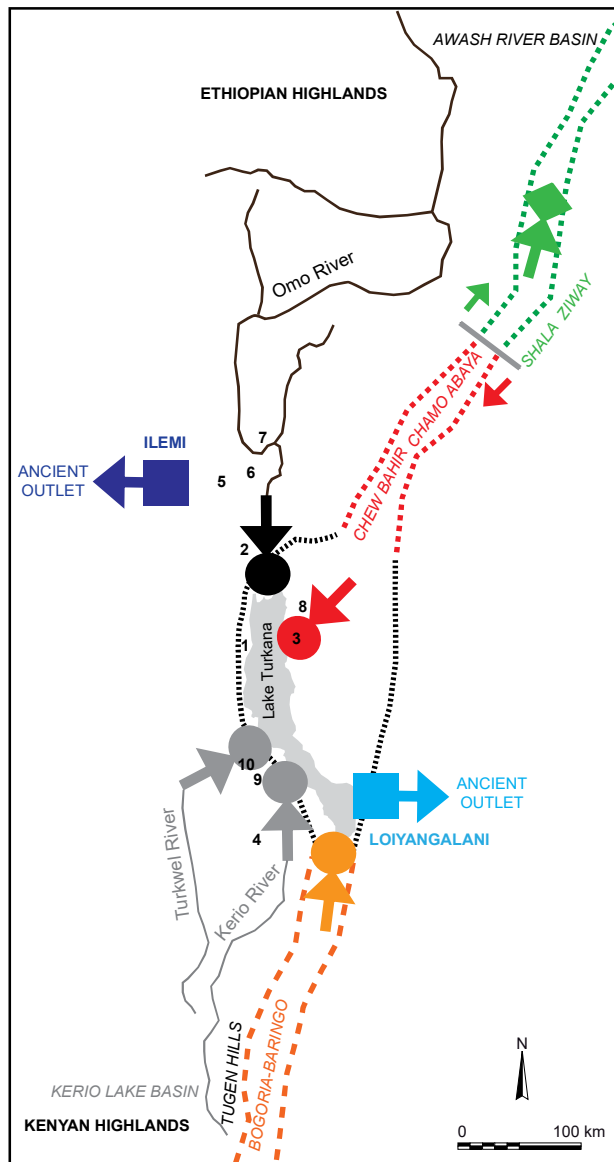
**a**















**b**



**c**

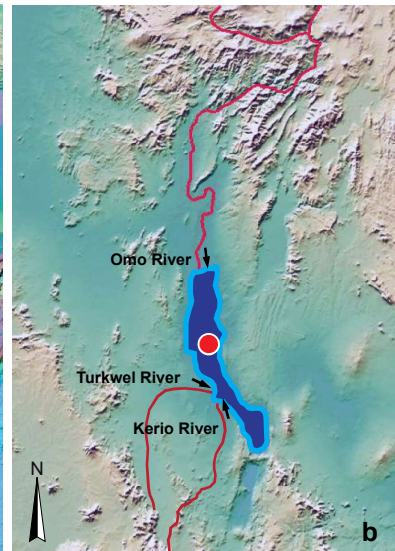
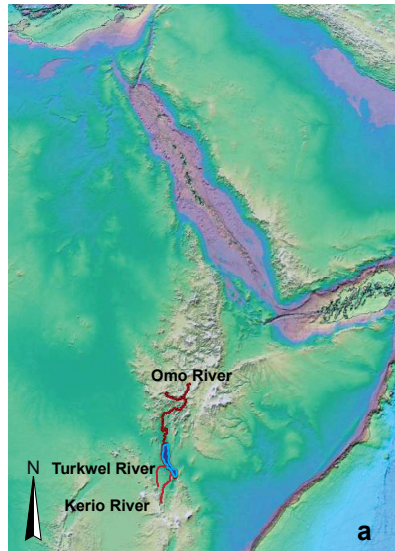


-  Awash drainage basin (Ziway-Shala lake basin system)
  -  Permanent drainage connection with the Omo River drainage basin in the Ethiopian Highlands
  -  Intermittent drainage connection with the Turkwel and Kerio rivers drainage basin in the Kenyan Highlands
- CASCADING CONNECTIVITY**

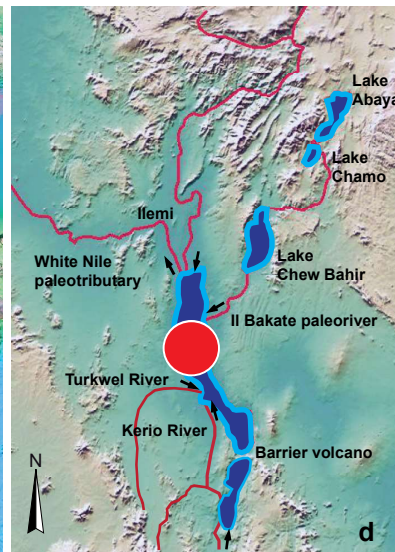
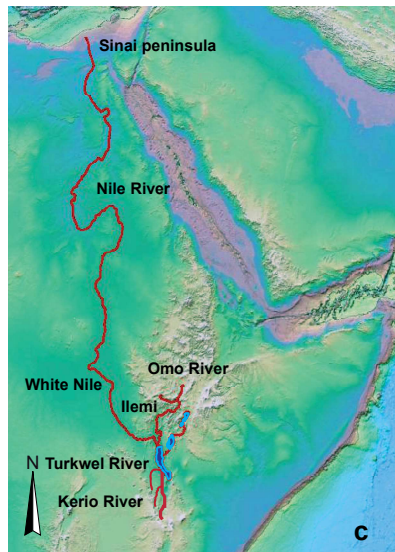
  -  Drainage connection with the Il Bakate palaeo-river drainage basin in the Ethiopian Highlands (Chamo-Abaya lake basins)
  -  Drainage connection with the Suguta palaeo-river drainage basin in the Kenyan Highlands (Baringo-Bogoria lake basins)
  -  Loiyangalani outlet connected to the Turkana palaeo-river and the Indian Ocean
  -  Ilemi outlet channel connected to the White Nile River and the Mediterranean Sea
-  Kenyan branch of the East African Rift (Kerio River and Suguta palaeo-river drainage basins)
  -  Ethiopian branch of the East African Rift (Il Bakate palaeo-river drainage basin)
  -  Ethiopian branch of the East African Rift (Awash River drainage basin)
  -  Present day Lake Turkana (reference point)
  -  Extensional basin of Lake Turkana (Turkana Basin)



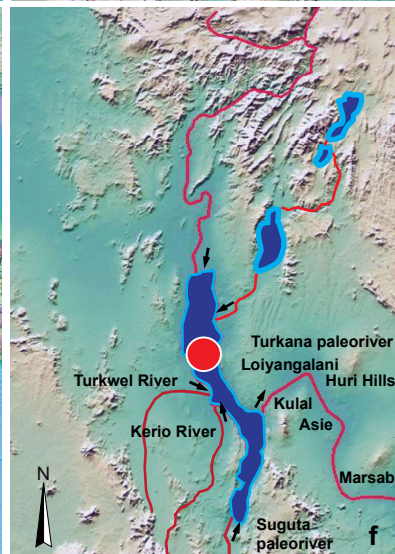
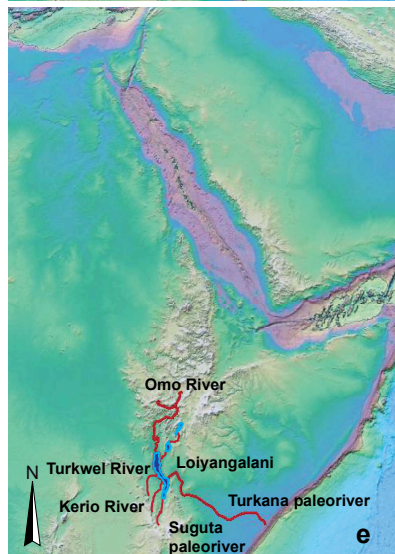
HOLOCENE



PLEISTOCENE



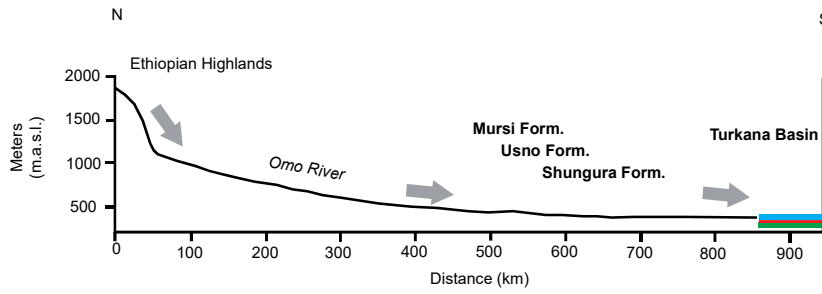
PLIOCENE



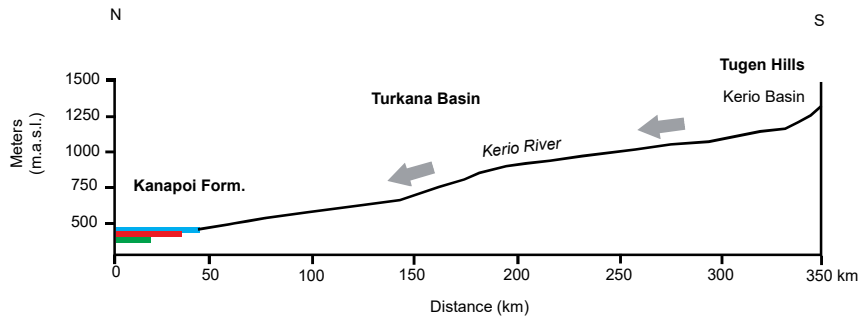
Lakes (m a.s.l.)	Number	Description
1	360	1 Actual lake (without outlet-endorheic system)
2	440 ?	2 Large paleolakes with outflows to the Indian Ocean (exorheic systems)
3	465-460	3 Mega paleolakes with outflows to the Mediterranean Sea (exorheic systems)



**CURRENT INFLOWS**

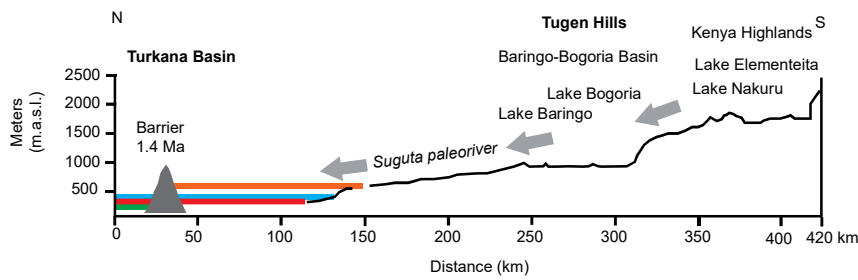


a

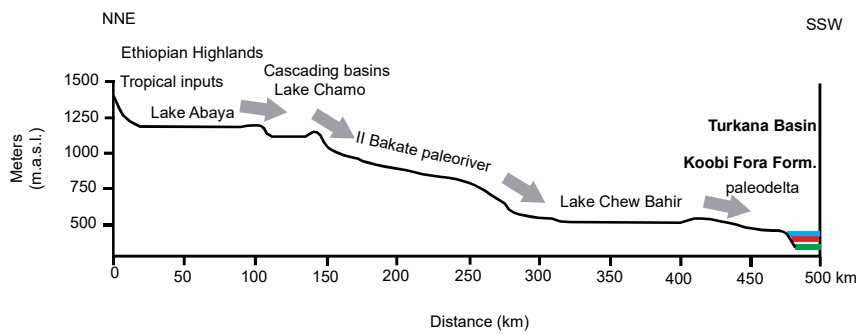


b

**ANCIENT INFLOWS**

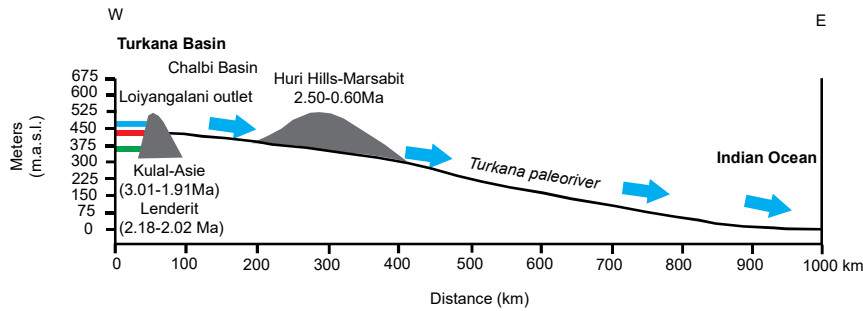


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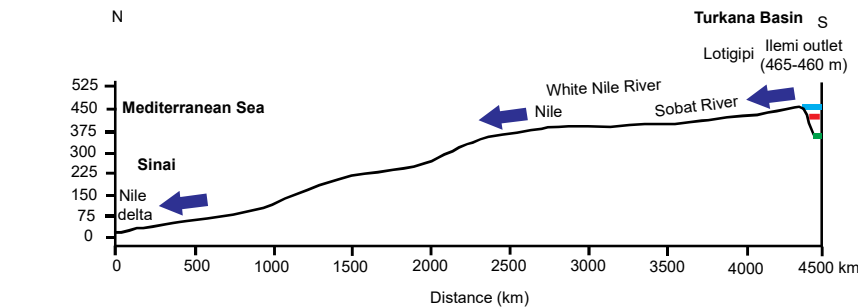
d

**ANCIENT OUTFLOWS**



**PLIOCENE**

e



**PLEISTOCENE**

f

- 360 m.a.s.l. Actual lake (low lake/closed-basin)
- 465-460 m.a.s.l. Pleistocene highest lake stand (outflows to the Mediterranean Sea)
- 577 m.a.s.l. Paleolake Suguta
- ~440 m.a.s.l. Pliocene highest lake stand (outflows to the Indian Ocean)
- Inflows (cascading river-lake systems)
- Pliocene outflows to the Indian Ocean
- Pleistocene outflows to the Mediterranean Sea
- Major early Pleistocene volcanoes (explosive volcanism)

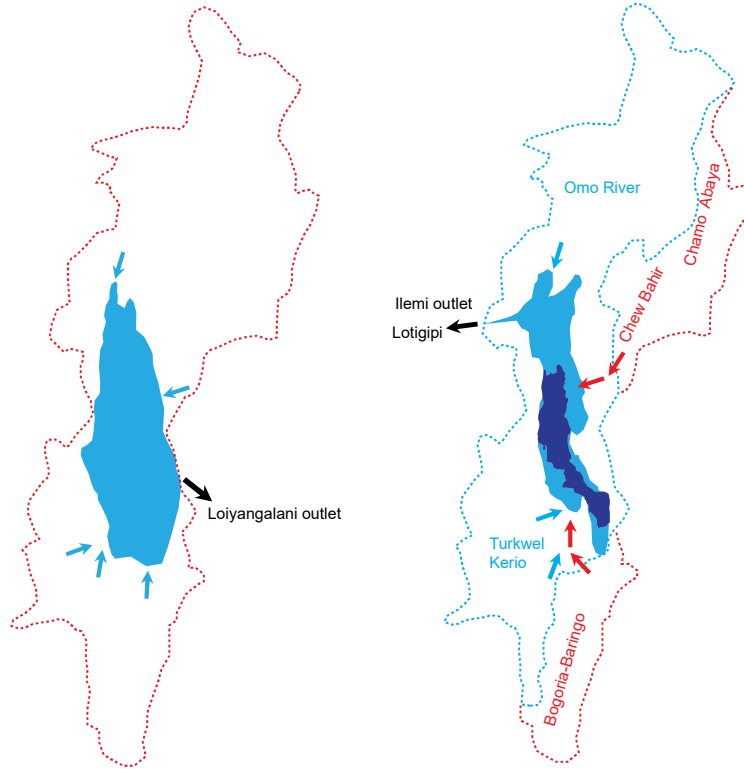
# EVOLUTION OF THE TURKANA DRAINAGE BASIN

## a) HYDROCLIMATE

### INCREASE OF EAST AFRICAN MONSOON VARIABILITY

PLIOCENE CLIMATE  
LARGE DRAINAGE BASIN

PLEISTOCENE CLIMATE  
VARIABLE DRAINAGE BASIN



## b) VOLCANISM AND TECTONICS

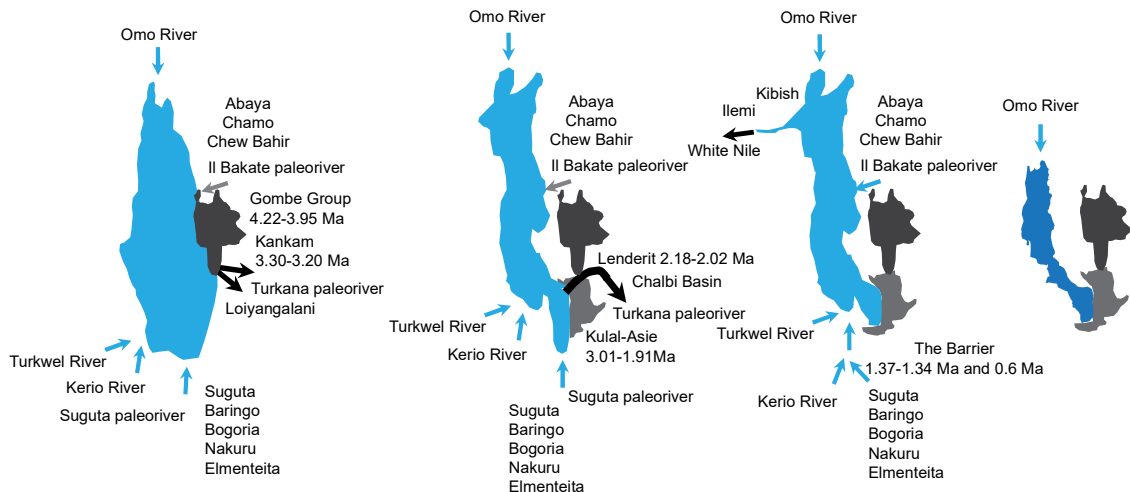
TRANSGRESSIONS TO THE WEST DUE TO VOLCANIC UPLIFT TO THE EAST

CENTRAL BASIN SUBSIDENCE

PLIOCENE

PLEISTOCENE

PRESENT



### Lonyumun paleolake phase

Large open-basin  
connected to the Indian Ocean

### Lorenyang paleolake phase

Volcanic closure of the primary outlet  
and opening of the secondary outlet

### Lake Turkana

Endorheic  
drainage basin

→ Inputs

■ Major Pliocene basalt deposition

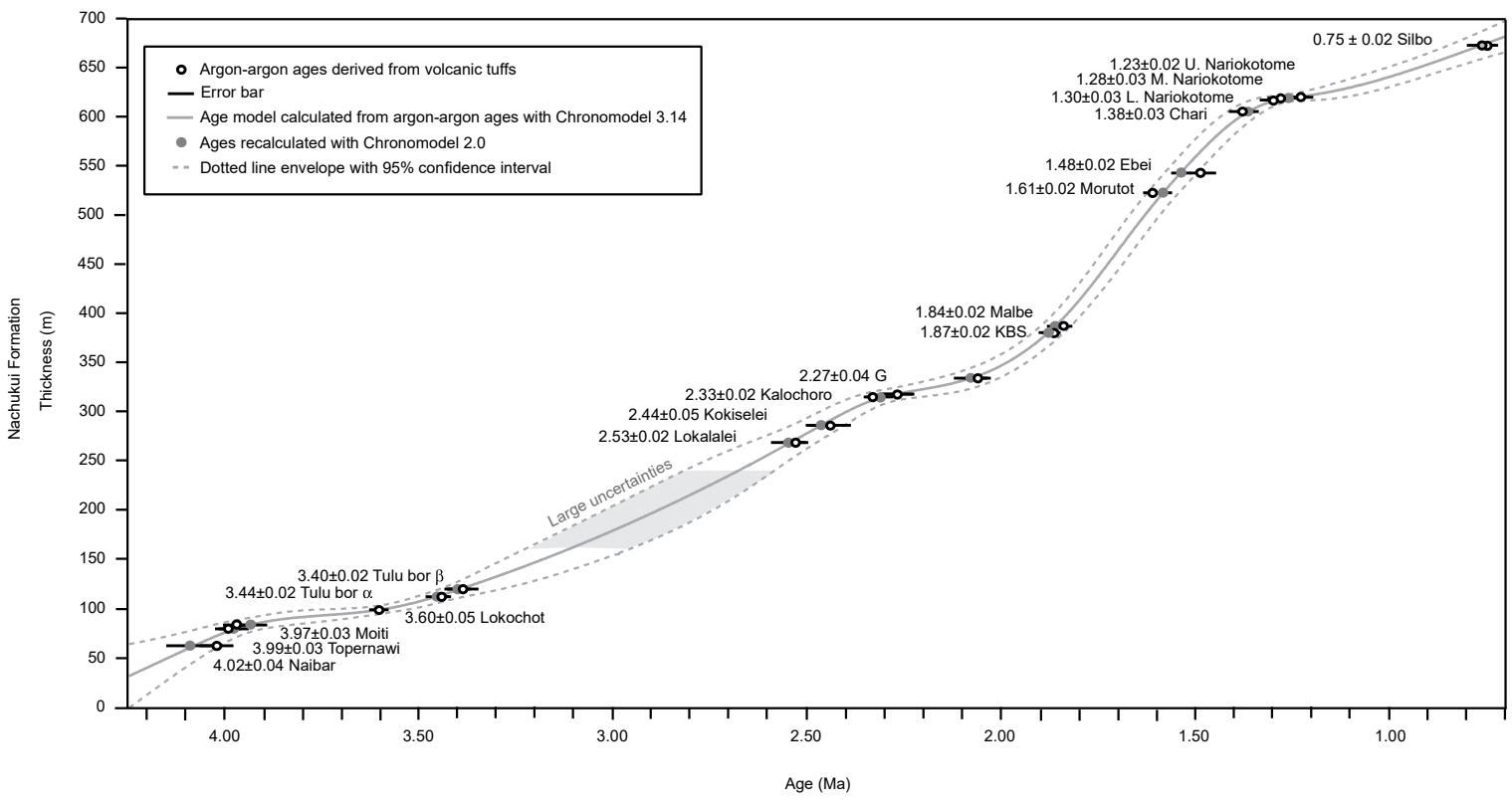
■ Major early Pleistocene basalt deposition

→ Outputs

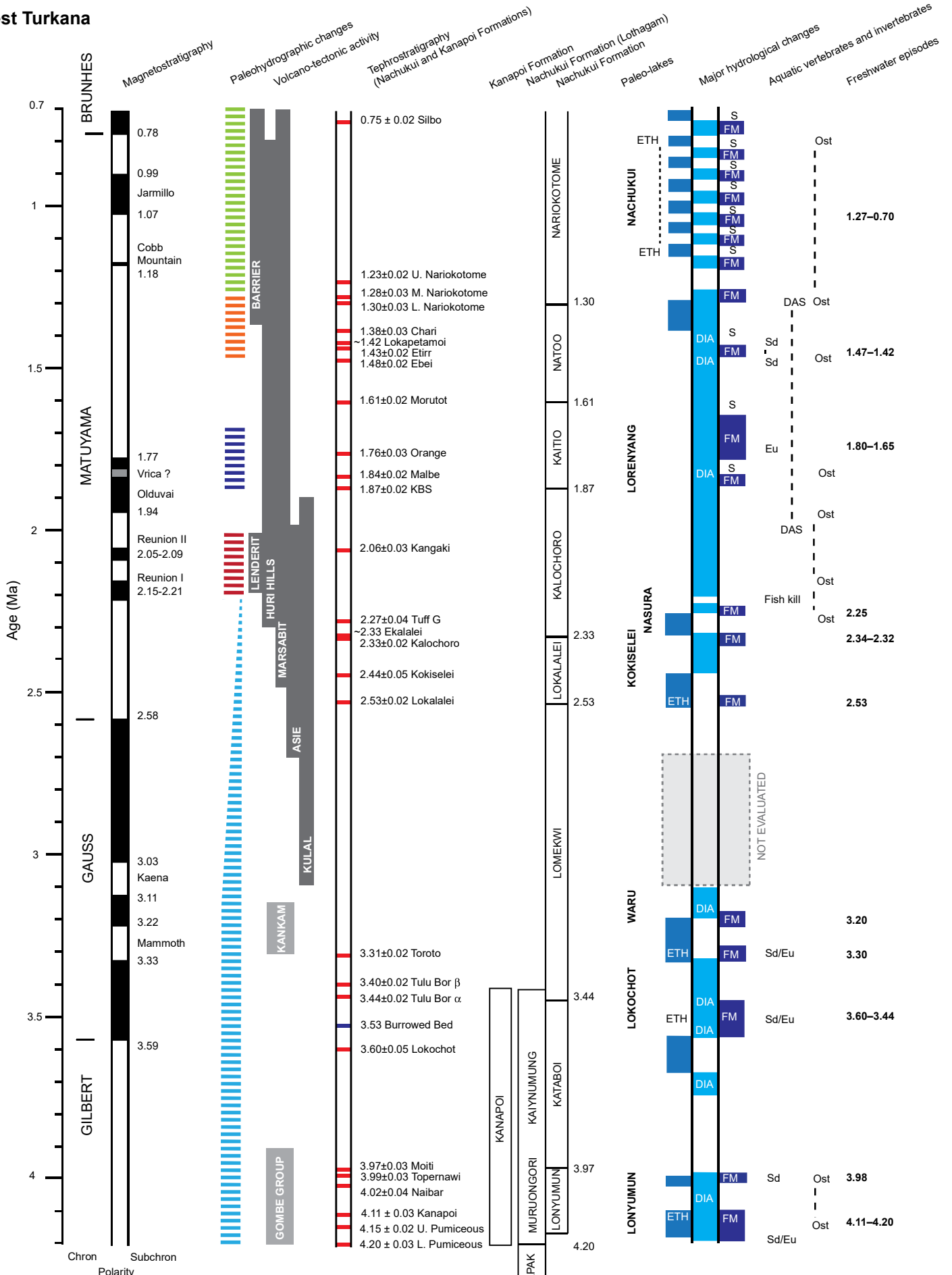
■ Plio-Pleistocene paleolakes

■ Modern Lake Turkana

0 200 km



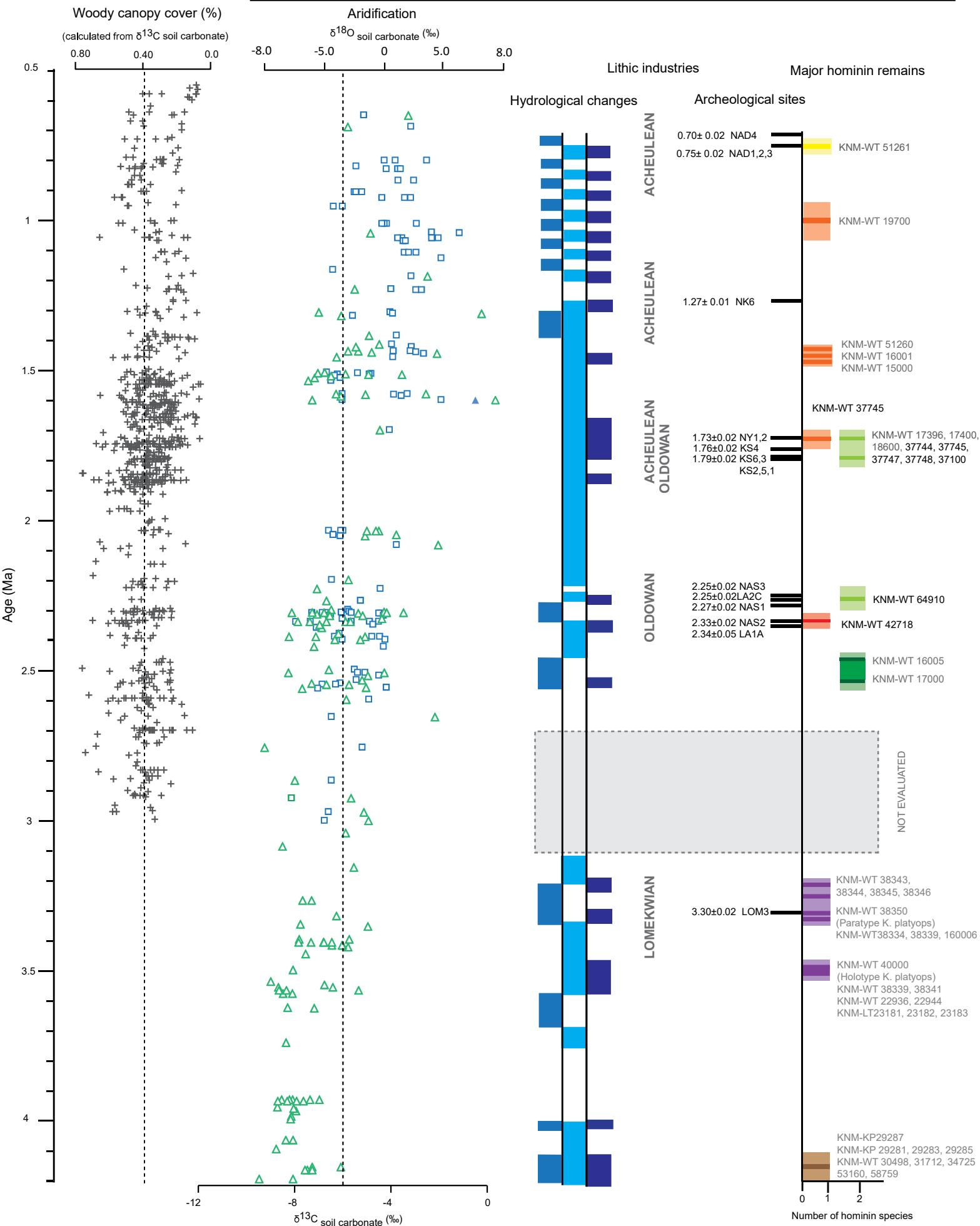
# West Turkana



- Normal
- Effusive volcanism
- Tuff
- Reversed
- Explosive volcanism
- Marker bed
- Opening and closing of the Omo-Turkana drainage outflows to the Nile and the Mediterranean Sea
- Volcanic closure of the southern basin - abandonment of the Suguta paleo-river and formation of Lake Logipi-Suguta
- First opening of the Ilemi outlet ? (Omo-Turkana outflows connected to the Nile and the Mediterranean Sea ?)
- Volcanic closure of the Loiyangalani outlet (Lenderit basalts) - abandonment of the Turkana paleo-river (Closure of the Omo-Turkana outflows to the Indian Ocean)
- Omo-Turkana drainage outflows connected to the Turkana paleo-river and the Indian Ocean
- Major rivers systems
- Freshwater fauna
- Major lake systems
- DIA Diatomites
- ETH *Etheria*
- FM Freshwater mollusks
- S Stromatolites and oncolites
- Sd/Eu *Sindacharax/Euthecodon*
- DAS *Dasyatis africana*
- Ost Ostracods

# East African Rift

# West Turkana



△  $\delta^{13}\text{C}$  soil carbonate (‰) from West Turkana (Lothagam, Kanapoi and Nachukui Formations)

□  $\delta^{18}\text{O}$  soil carbonate (‰) from West Turkana (Nachukui Formation)

■ Major rivers systems

■ Major lake systems

■ Freshwater fauna

■ *African Middle Pleistocene Homo*

■ *Homo ergaster/erectus*

■ *Homo sp.*

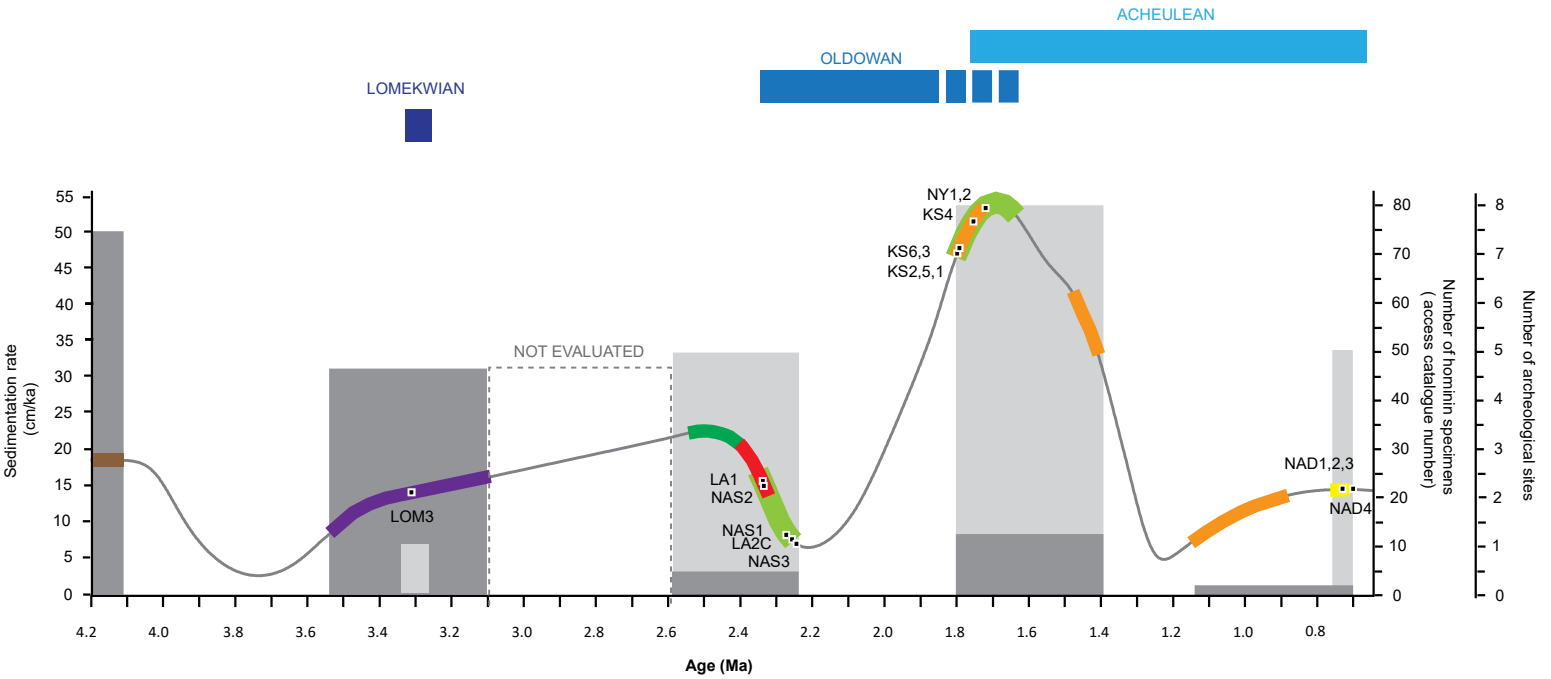
■ *Paranthropus boisei*

■ *Paranthropus aethiopicus*

■ *Kenyanthropus platyops* and Pliocene hominins

■ *Australopithecus anamensis*





- African Middle Pleistocene Homo*
  - Homo ergaster/erectus*
  - Homo sp.*
  - Paranthropus boisei*
  - Paranthropus aethiopicus*
  - Kenyanthropus platyops and Pliocene hominins*
  - Australopithecus anamensis*
- 
- Archeological sites
  - Number of archeological sites
  - Number of hominin specimens

**Table 1**

Geochronology of volcano-tectonic activity in the Turkana Basin during the Plio-Pleistocene.

<b>Volcanism</b>	<b>Type</b>	<b>Radiometric dating</b>
Gombe Group	Effusive	$4.22 \pm 0.09$ – $3.95 \pm 0.10$ Ma
Tirr Tirr	Effusive	$3.90 \pm 0.4$ Ma; $3.60 \pm 0.4$ Ma
Lothagam	Effusive	$3.71 \pm 0.23$ Ma
Longipi	Explosive	$3.50 \pm 0.27$ – $1.50 \pm 0.19$ Ma
Kankam	Effusive	3.30–3.20 Ma
Kulal	Explosive	$3.01 \pm 0.55$ – $2.60 \pm 0.02$ Ma; $2.40 \pm 0.03$ – $2.04 \pm 0.02$ Ma; $1.91 \pm 0.21$ Ma
Asie	Explosive	$2.70 \pm 0.35$ – $2.07 \pm 0.13$ Ma
Marsabit	Explosive	$2.50 \pm 0.3$ – $0.60 \pm 0.2$ Ma
Huri Hills	Effusive	$2.30 \pm 0.17$ – $0.8 \pm 0.3$ Ma
Lenderit	Effusive	$2.18 \pm 0.02$ Ma; $2.02 \pm 0.02$ Ma
Balo	Effusive	$1.79 \pm 0.02$ Ma
The Barrier	Explosive	$1.37 \pm 0.02$ – $1.34 \pm 0.01$ Ma (Likayu East); $0.69 \pm 0.05$ Ma (Likayu West)

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Haileab et al., 2004

Baker et al., 1971; Bosworth and Maurin, 1993

Baker et al., 1971

Furman et al., 2006

Gathogo et al., 2008

Rundle, 1985; Gathogo et al., 2008; Dunkley et al., 1993

Key et al., 1987

Nyamweru, 1986; Brotzu et al., 1984; Kaeser, 2006

Brotzu et al., 1984

Gathogo et al., 2008

Gathogo et al., 2008

Dunkley et al., 1993; McDougall et al., 2012

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**Table 2**

Geochronology of the Kanapoi Formation (Feibel, 2003a; Leakey et al., 1995; McDougall et al., 2012) and the Nachukui Formation (Harris et al., 1988; McDougall et al., 2012) in West Turkana.

<b>Kanapoi Formation (southwestern basin)</b>	4.2–3.4 Ma
<b>Members of the Nachukui Formation (western basin)</b>	
Apak*	4.9–4.2 Ma
Muruongori*	4.2–3.9 Ma
Kaiyumung*	3.9–3.4 Ma
Lonyumun	<4.2–3.97 ± 0.03 Ma
Kataboi	3.97 ± 0.03–3.44 ± 0.02 Ma
Lomekwi	3.44 ± 0.02–2.53 ± 0.02 Ma
Lokalalei	2.53 ± 0.02–2.33 ± 0.02 Ma
Kalochoro	2.33 ± 0.02–1.87 ± 0.02 Ma
Kaitio	1.87 ± 0.02–1.61 ± 0.02 Ma
Natoo	1.61 ± 0.02–1.30 ± 0.03 Ma
Nariokotome	1.30 ± 0.03–0.70 ± 0.02 Ma
Loruth Kaado	3.9–3.3 Ma
South Turkwel	4.1–3.3 Ma

Members found only at Lothagam (McDougall and Feibel, 2003; Schofield et al., 2021)

Notably, Loruth Kaado (northwestern basin) is attached to the Lomekwi Member

and South Turkwel (south of Nachukui and northwest of Lothagam) to the Lonyumun, Kataboi, and lower Lomekwi Members (Harris et al., 1988; Ward et al., 1999)

**Table 3**

Data from West Turkana on depositional environments and aquatic vertebrates

<b>Age (Ma)</b>	<b>Environment</b>
4.20–4.15	River deposits; Lothagam
4.15–4.11	Lakeshore environment and nearshore river deposits; Kanapoi Fm
4.20–3.98	Lake sediments; Lonyumun Mb
4.17–4.12	River sediments; Lower fluvial sequence; Lothagam
4.15–4.11	Lake sediments; Kanapoi Fm
4.11	River deposits, Kanapoi Fm
4.10–4.00	Lake sediments; Lonyumun Mb
4.07	River sediments; upper fluvial sequence; Lothagam
3.99–3.98	Lake sediments; Lonyumun Mb
4.02–3.98	Lake sediments; Lonyumun Mb
~3.7	Lake sediments; Kataboi Mb
3.65–3.60	River deposits; Kataboi Mb
3.58–3.44	Lake sediments; Kataboi Mb
3.50	Lake sediments; Kataboi Mb
3.30	Lakeshore environment, beach, sand dune, and river deposits; Lomekwi Mb
3.30–3.20	Alluvial deposits; Lomekwi Mb
3.20–3.10	Lake sediments; Lomekwi Mb
2.53	River deposits; Lomekwi/Lokalalei Mb
2.44	Lake sediments; Lokalalei Mb
2.34–2.32	Lakeshore environment and nearshore river deposits; Lokalalei Mb and Kalochoro Mb
2.25–2.22	Lake sediments; Kalochoro Mb
2.25	Lakeshore environment and nearshore river deposits; Kalochoro Mb
2.27–2.17	Lake sediments; lower Kalochoro Mb
2.22	Lakeshore environment; Kalochoro Mb
2.10–1.95	Lake sediments; upper Kalochoro Mb
1.85	Lakeshore environment; Kaitio Mb
1.8	Lakeshore environment; Kaitio Mb
1.80–1.70	Lakeshore environment and nearshore river deposits; Kaitio Mb
1.7–1.65	Lakeshore environment; Kaitio Mb
1.6	Lakeshore environment; Natoo Mb
1.48	Lake sediments; Natoo Mb
1.48–1.38	Lake sediments; Natoo Mb
1.47–1.42	Lakeshore environment and nearshore river deposits; Natoo Mb
1.4	Lakeshore environment; Natoo Mb
1.29–0.80	Lakeshore environment; Nariokotome Mb
1.27–0.75	Lakeshore environment and nearshore river deposits; Nariokotome Mb
0.80–0.70	Lakeshore environment, nearshore river deposits and beaches; Nariokotome Mb

tes and invertebrates, including freshwater fauna, bet

**Aquatic fauna**

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*Potamonautidae, Euthecodon*

*Euthecodon; Pelomedusidae, Testudinidae, and  
Trionychidae; Sindacharax, Semlikiichthys; Bellamya,  
Etheria; Sclerocypris  
Hemicypris*

Freshwater mollusks

*Etheria*

Diatomites

Freshwater mollusks

Pure diatomites and mollusks at 3.99–3.98 Ma

Diatoms

Pure diatomites; sponge spicules

*Bellamya, Cleopatra, and Melanoides*

*Etheria; Euthecodon; Sindacharax; turtles; mollusks*

Mollusks, *Lockeia*, sponge spicules and diatoms

*Etheria*

*Melanoides*

*Melanoides* and *Potadoma*

Ostracods

Fish kill

Ostracods

Mollusks overlain by ostracods and diatomites

Stromatolites

*Iridina, Chambardia; Euthecodon; Polypterus*

*Cleopatra* and *Melanoides*

Stromatolites

Ostracods

Diatoms

*Pila; Sindacharax*

Stromatolites

Ostracods

*Cleopatra* and *Melanoides* at 1.27 Ma; ostracods and mollusks (*Iridina*) interfinger with stromatolites in sediments of several river and lake systems between 1.27 and 0.70 Ma

Mollusks; small stromatolites (<5 cm) 1 m below the Silbo Tuff

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ween 4.20 Ma and 0.70 Ma. See text for explanations.

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- this study
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**Table 4**

Data from West Turkana on hominins between 4.20 Ma and 0.70 Ma. See text for explanation

Age (Ma)	Hominins
4.9–4.2	KNM-LT 329
4.2–4.11	e.g. KNM-KP 29281, 29283, 29285, 29286 ; KNM-WT 30498, 30500, 31712, 34725, 47951, 47952, 47953, 53160, 58759
4.1	KNM-KP 29287
3.53±0.01	KNM-WT 38341
~3.5 env	KNM-LT 23181,23182,23183
3.5	KNM-WT 22936, 22944
3.5	KNM-WT 40000 (Holotype), 38339
3.35±0.05	KNM-WT 16006
3.3±0.1	KNM-WT 38350 (Paratype)
3.3–3.2	e.g. KNM-WT 38332, 38334, 38335, 38337, 38338, 38345, 38342, 38343, 38344, 38345, 38346, 38347, 38348, 38349, 38352, 38358, 38359, 38360, 38361, 38362, 39949, 39950, 39951, 39952, 39953, 39954, 39955, 40001, 66289, 66290, 66291
3.26±0.01	KNM-WT 16003
3.26±0.01	KNM-WT 08556, 08557
3.2±0.1	KNM-WT 38356, 38357
2.53±0.02	KNM-WT 17000
2.45±0.05	KNM-WT 16005
2.33 ±0.02	KNM-WT 42718
2.25 ±0.02	KNM-WT 64910
1.79±0.02	KNM-WT 37100, 37744, 37747, 37748
1.77±0.1	KNM-WT 17400
1.75±0.05	KNM-WT 37745
1.72±0.07	KNM-WT 18600
1.72±0.07	KNM-WT 17396
1.47±0.03	KNM-WT 15000
1.42±0.01	KNM-WT 51260
1.44±0.03	KNM-WT 16001
1±0.15	KNM-WT 19700
0.75	KNM-WT 51261



tions.

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Brown et al., 2001

Maddux et al. 2015

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**Table 5**

Data from West Turkana archaeological sites between 3.30 Ma and 0.

<b>Age (Ma)</b>	<b>Archaeological site</b>	<b>Culture</b>
3.30±0.02	Lomekwi 3 (LOM3)	Lomekwian
2.34±0.05	Lokalalei 1A (LA1A)	Oldowan
2.33±0.02	Nasura 2 (NAS2)	Oldowan
2.27±0.02	Nasura 1 (NAS1)	Oldowan
2.25±0.02	Lokalalei 2C (LA2C); Nasura 3 (NAS3)	Oldowan
1.79±0.03	Kokiselei 6,3,2,5,1 (KS6,3,2,5,1)	Oldowan
1.76±0.02	Kokiselei 4 (KS4)	Acheulean
1.75±0.05	Naiyena Engol 1 (NY1)	Oldowan
1.73±0.02	Naiyena Engol 2 (NY2)	Oldowan
1.27±0.01	Nachukui 6 (NK6)	Acheulean
0.75±0.02	Nadung'a 1,2,3 (NAD1,2,3)	Acheulean
0.70±0.02	Nadung'a 4 (NAD4)	Acheulean

.70 Ma. See text for explanations.

## **References**

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this paper

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Delagnes et al., 2006

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**Table 6**

Comparison of number of hominins versus total number of mammalian fossils and collected surface area (where available, from information in Harris et al., 1988) (from the Turkana Database) for members of the Nachukui formations from West Turkana. See Table 1 for the geochronology.

<b>Geology</b>	<b>Hominins</b>	<b>Fauna</b>	<b>Hom %</b>	<b>Sq. km</b>
Kanapoi	75	958	7.83	-
Apak	1	225	0.44	-
Muruongori	0	0	0.00	-
Kaiyumung	4	124	3.23	-
Lonyumun	0	0	0.00	-
Kataboi	6	134	4.48	0.85
Lomekwi	40	1174	3.41	10.93
Lokalalei	2	70	2.86	0.59
Kalochoro	3	185	1.62	1.31
Kaitio	8	189	4.23	2.33
Natoo	4	185	2.16	2.34
Nariokotome	2	83	2.41	0.77