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## **Qaleh Kurd Cave (Qazvin, Iran): Oldest Evidence of Middle Pleistocene Hominin Occupations and a Human Deciduous Tooth in the Iranian Central Plateau**

Hamed Vahdati Nasab, Gilles Berillon, Seyyed Milad Hashemi, Jean-Jacques Bahain, Noémie Sévêque, Mozhgan Jayez, Stéphanie Bonilauri, Guillaume Jamet, Mohammad Akhavan Kharazian, Asghar Nateghi, et al.

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1 QALEH KURD CAVE (QAZVIN, IRAN): OLDEST EVIDENCE OF MIDDLE  
2 PLEISTOCENE HOMININ OCCUPATIONS AND A HUMAN DECIDUOUS  
3 TOOTH IN THE IRANIAN CENTRAL PLATEAU

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32 research design and the preparation of the manuscript.

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38

39 **Abstract**

40 The Iranian Central Plateau (ICP) with the Alborz and the Zagros Mountains is located at the crossroads between  
41 the Levant and the Caucasus to the west, and Central Asia and East Asia to the east. These two regions yielded  
42 key paleoanthropological and archaeological sites from the Middle Pleistocene period. These discoveries  
43 highlight a large human biological and cultural diversity in this area during the Middle Pleistocene, and raise  
44 questions about the interactions these humans had. Yet, despite decades of field research, no Middle Pleistocene  
45 assemblage in a clear chronological and stratigraphic context was known in the ICP, the Zagros and the Alborz  
46 Mountains that could contribute to this debate; so far, the earliest of the area is dated of 80ka. The Joint Iranian  
47 and French Paleoanthropological Project reinvestigated the cave of Qaleh Kurd (Qazvin). The Qaleh Kurd cave  
48 is located at 2137m asl at the very western limit of the ICP, at its boundary with the Zagros Mountains. Here we  
49 report on the discovery of *in situ* middle Pleistocene archaeological assemblages, including a human deciduous  
50 first upper molar associated with a rich lithic and faunal material, and a first description of the chrono-  
51 stratigraphic framework of the deposits. The excavation, the archaeological and geoarchaeological analyses  
52 show that humans occupied the site during the Middle Pleistocene, during a period ranging from ca  $452 \pm 32$   
53 and  $165 \pm 11$  ka . This chronology pushes back the earliest dated evidence of human settlement in the ICP by  
54 more than 300ka. The human deciduous first upper molar comes from the upper part of the middle Pleistocene  
55 sequence. The crown of the tooth is widely impacted by wearing and carries that limit taxonomic inferences. The  
56 study of the three upper archaeological assemblages shows that the cave was recurrently occupied by humans of  
57 early Middle Paleolithic cultures. These assemblages recall by some traits sub-contemporary assemblages known  
58 in the Caucasus and the Levant but also the later Middle Paleolithic of the Zagros. The faunal assemblage is  
59 mainly composed with horse's remains. The remains are very fragmented and show numerous anthropogenic  
60 stigmata that indicate important butchery activities on site. From a large regional and chronological perspective,  
61 these findings make Qaleh Kurd Cave a key site for the knowledge of early human settlements and dispersals  
62 between the Levant and Asia.

63

64 **Keywords:** Iranian Central Plateau, Hominin, Middle Pleistocene, Paleolithic, Qaleh Kurd Cave, Qazvin

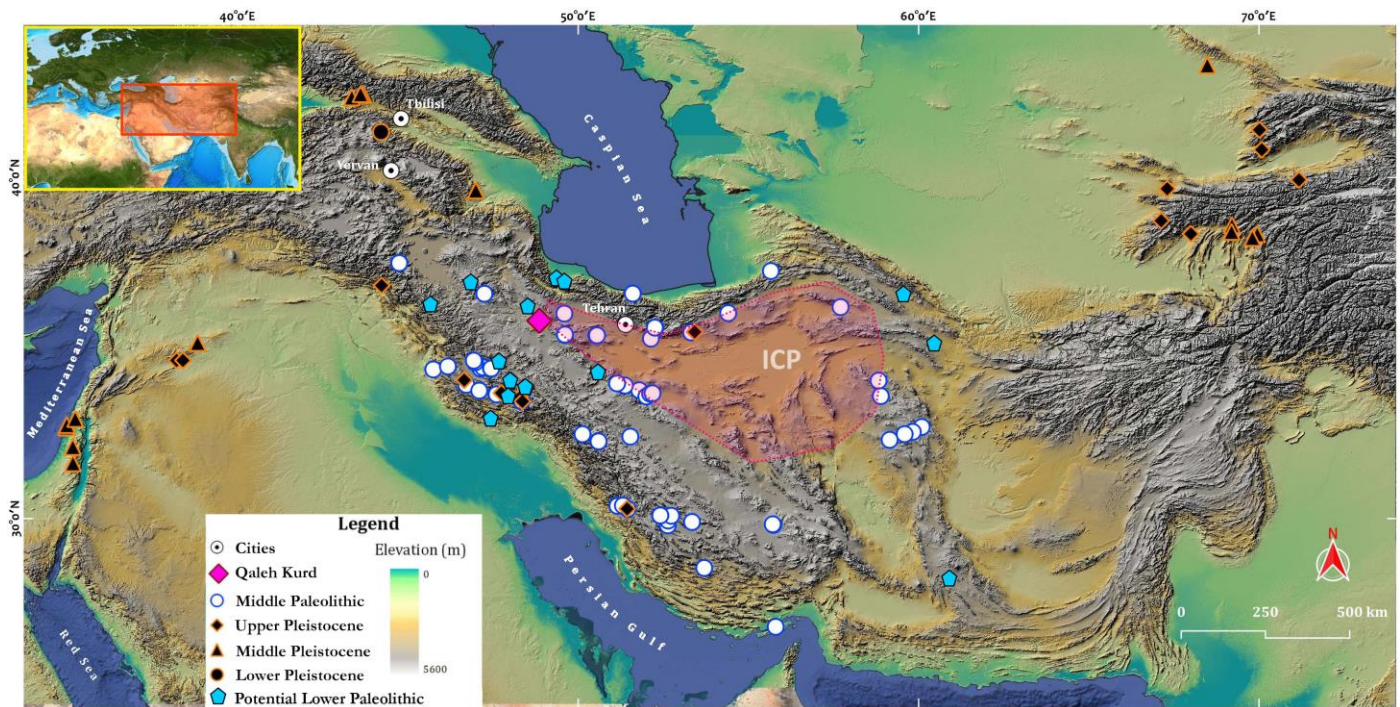
65

## 66 **Introduction**

67 The Iranian Central Plateau (ICP1) with the Alborz and the Zagros Mountains is located at the crossroads of two  
68 vast regions: the Levant and the Caucasus to the west, and Central Asia and East Asia to the east. These two  
69 regions have yielded numerous archaeological assemblages in chrono-stratigraphic contexts. These assemblages  
70 are essential for investigating hominin biological and cultural diversity and dispersal during the Early and  
71 Middle Pleistocene between the Levant (e.g., Bar-Yosef, 1994; Bar-Yosef and Belfer-Cohen, 2001; Bar-Yosef  
72 and Meignen, 2001), Europe (e.g., Mihailović et al., 2022) and Asia (e.g., Dennell, 2008; Narasimhan et al.,  
73 2019; Finestone et al., 2022) (Fig. 1). These researches demonstrate that several hominin species have settled  
74 this large area during the Middle Pleistocene, some of which may have interacted: late *Homo erectus*,  
75 Denisovans, Neanderthals and *Homo sapiens* in the east (e.g., Chen et al., 2019; Jacobs et al., 2019; Pan et al.,  
76 2020; Finestone et al., 2022; Han et al., 2022) and in the west, Neanderthals, *Homo sapiens* and possibly other  
77 species (e.g., Mercier and Valladas, 2003; Hershkovitz et al., 2021). However, despite decades of field research  
78 in the ICP and its immediate surrounding areas (the Zagros and the Alborz), no archaeological assemblage  
79 related to the Early and Middle Pleistocene in a clear chronological and stratigraphic context has been reported  
80 in this vast region so far. The earliest assemblage in a clear stratigraphic and chronological context is dated of  
81 80ka (Gareh Boof, Heydari et al., 2021). However, surface finds (such as Dehtal in the Southeast Zagros  
82 Mountains, Ganj Par in the Alborz Mountains and Kaftar Kouh of Ferdous in the Khorasan) as well as test  
83 excavations (such as Darband Cave in the Alborz Mountains) may advocate an early settlement of the region  
84 (e.g., Biglari and Shidrang, 2006; Biglari and Jahani, 2011; Sadraei et al., 2019, 2023; Biglari et al., 2014, 2023).  
85

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1 - The ICP is the large area surrounded by the Zagros Mountains to the west, the Alborz Mountains in the north, the Kopet Dagh Mountains in the east, and the central Iranian block (mainly the Lut Desert) in the south.



86

87 Figure 1. Location of the cave of Qaleh Kurd and the main Pleistocene archaeological sites of the Iranian Central  
 88 Plateau (ICP) and surrounding areas, from the Levant to Central Asia (© M. Alirezazadeh, QGIS). ICP: the large  
 89 area surrounded by the Zagros Mountains to the west, the Alborz Mountains in the north, the Kopet Dagh  
 90 Mountains in the east, and the central Iranian block in the south.

91

92 In contrast, the Upper Pleistocene from the Zagros Mountains to the northern part of the ICP and the Alborz  
 93 Mountains is relatively well documented by decades of excavations and discoveries. In the Zagros chain, they  
 94 allow addressing the existence of local facies of Middle and Upper Paleolithic, and how the Upper Paleolithic  
 95 originated (e.g., for early field works: Coon, 1951; Solecki, 1963; Braidwood et al., 1961; Hole and Flannery,  
 96 1967; McBurney, 1964; see Vahdati Nasab, 2010 for a synthesis; e.g., for more recent works: Otte et al., 2009,  
 97 2011, 2012; Jaubert et al., 2009; Tsanova, 2013; Shidrang et al., 2016; Bazgir et al., 2017; Becerra-Valdivia et  
 98 al., 2017; Ghasidian et al., 2017, 2019; Heydari et al., 2021; Heydari-Guran et al., 2021). In the Northern part of  
 99 the ICP and the Alborz chain, discoveries address the diversity of Middle and Upper Paleolithic cultures and  
 100 their relationships to those of the Zagros (e.g., Chevrier et al., 2006; Berillon et al., 2016; Bonilauri et al., 2019;  
 101 Vahdati Nasab et al., 2019). These debates are also supported by numerous surface finds, from the Zagros  
 102 Mountains (e.g., Roustaei et al., 2004), the Alborz chain (e.g., Biglari and Jahani, 2011), the northern ICP (e.g.,

103 Vahdati Nasab and Clark, 2014; Vahdati Nasab and Hashemi, 2016; Hariryani et al., 2021) to the eastern ICP  
104 (e.g., Nikzad et al., 2015). Finally, in a broader context, including the Caucasus and Central Asia, these decades  
105 of discoveries demonstrate the significance of the ICP and surrounding areas as a dispersal corridor for hominin  
106 populations during the Upper Pleistocene (e.g., Vahdati Nasab et al., 2013; Shoaee et al., 2021; Ghasidian et al.,  
107 2023).

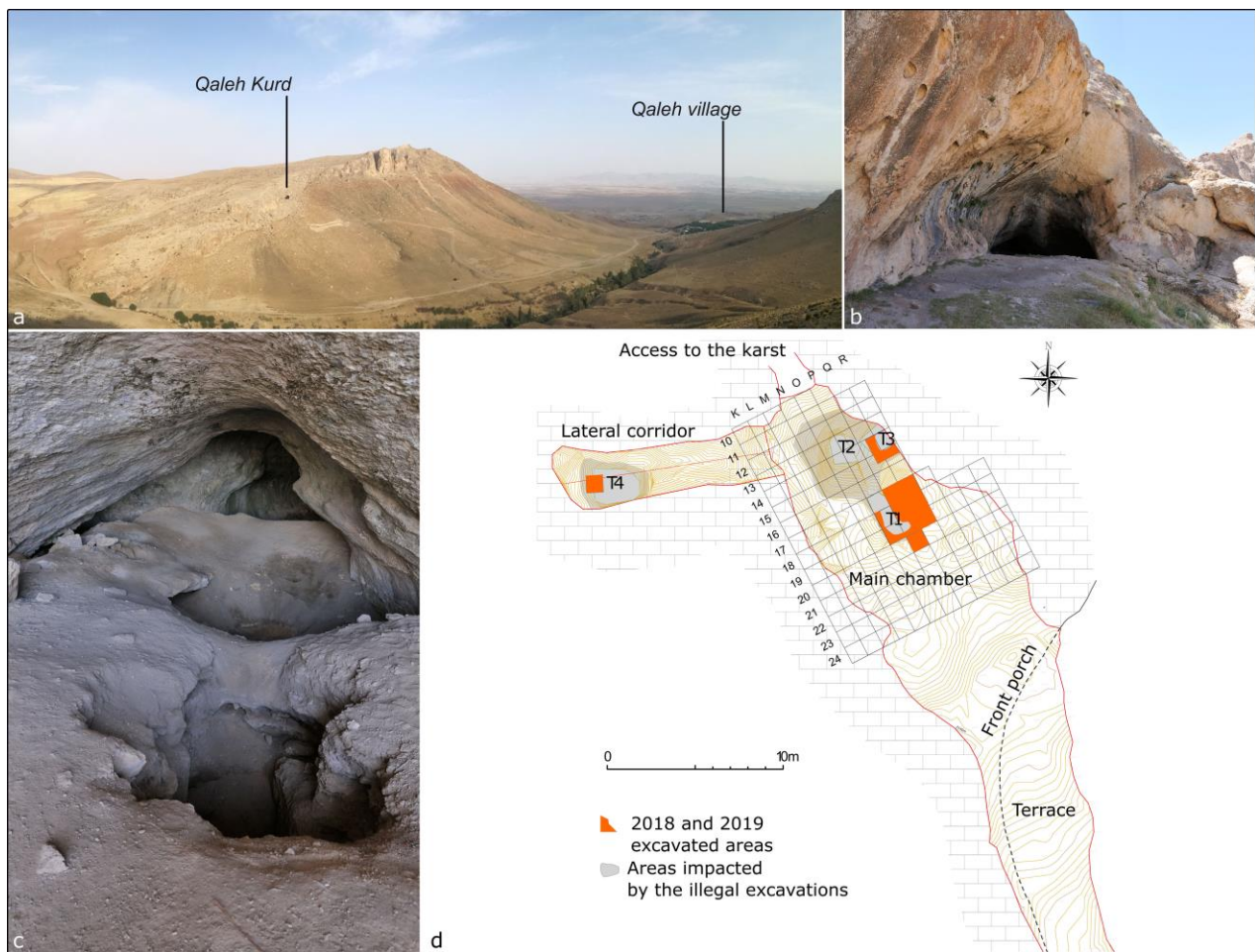
108 From the paleoanthropological point of view, human remains are scarce in the ICP, the Zagros Mountains and  
109 the Alborz Mountains, and they are all related to the Upper Pleistocene so far. The Neanderthals at Shanidar  
110 cave represent a large palaeoanthropological assemblage in a Middle Paleolithic archaeological context (Solecki,  
111 1959; Trinkaus, 1983). The other human fossils consist in isolated bones and teeth: the right radius proximal  
112 diaphysis at Bisitun rock shelter (Trinkaus and Biglari, 2006), a deciduous canine at Bawa Yawan (Heydari-  
113 Guran et al., 2021), an isolated unerupted P3 at Wezmeh 1 (Trinkaus et al., 2008; Zanolli et al., 2019). Finally,  
114 one possibly Upper Paleolithic modern human lower molar was reported at Eshkaft-e Gavi (Scott and Marean,  
115 2009) as well as nine specimens from the Epipaleolithic sequence. Such scarcity in Upper Pleistocene human  
116 remains in this wide area, contrasts with the paleoanthropological corpus in the Levant (e.g., Tobias, 1966;  
117 Vandermeersch, 1981; Hershkovitz et al., 2021), the Caucasus (e.g., Vekua et al., 2002; Ferring et al., 2011;  
118 Vasilyev and Amirkhanov, 2018), Central and East Asia (e.g., Glantz et al., 2008; Glantz, 2010; e.g., Reich et  
119 al., 2010; Chen et al., 2019). This corpus represents several human species dated from the Lower Pleistocene to  
120 the Upper Pleistocene.

121 In this context, the Joint Iranian and French Paleoanthropological Project reinvestigated the cave of Qaleh Kurd  
122 (Qazvin). Located at the western edge of the ICP and its boundary with the Zagros (Fig. 1), its potential  
123 prehistoric significance was recently demonstrated (Soleymani and Alibaigi, 2018). Here we report on the  
124 discovery of *in situ* Middle Pleistocene archaeological assemblages, including a human deciduous tooth  
125 associated with a rich lithic and faunal material, and the first description of the chrono-stratigraphic framework  
126 of the deposits.

127

128 **The Qaleh Kurd Cave and excavation methodology**

129 Qaleh Kurd cave (35°47'50"N 48°51'26"E) is located near the village of Qaleh Kurd (Avaj district) at the  
130 northwestern limit of the ICP, in the southwestern boundaries of Qazvin province. The cave belongs to a wide  
131 karstic network that developed in the Oligo-Miocene Qom Formation (Fig. 2) (Mehterian et al., 2017). The  
132 entrance of the cave opens at 2137m. It faces toward the southwest, and is located 140m above a seasonal creek  
133 that follows the valley. The archeological deposits are preserved in two chambers (Fig. 2): the main chamber of  
134 the cave that is 8m wide, 6m high, and 20m long (maximum dimensions) and oriented south-east-northwest, and  
135 at the back, a narrow corridor of 12m length and 1.5m high on average that deviates toward the west.



136  
137 Figure 2. The Qaleh Kurd cave: Context, mapping and excavated areas. The Qaleh Kurd Valley (a); the entrance  
138 (b) and the damages visible in the main chamber (c) at the time of first visit by the joint Iranian and French team;  
139 mapping of the cave and the excavated areas (d) (© FIPP 2019).

140

141 The Qaleh Kurd cave is originally known among the cavers for its active karstic network and calcareous  
142 concretions. S. Alibaigi noticed its archaeological potential in 2011. Surface lithic artefacts were then collected  
143 and analyzed by Soleymani and Alibaigi (2018). Based on Middle Paleolithic diagnostics (e.g., the presence of  
144 Mousterian and Levalloisian artifacts), they proposed similarities with the surface Middle Paleolithic assemblage  
145 of Mirak known in the northern ICP (Vahdati Nasab et al., 2013). Qaleh Kurd cave has also been investigated for  
146 oxygen isotopes based palaeoclimatic reconstruction of the last Interglacial and early glacial periods (73–127ka)  
147 and early Holocene (6500–7500 BP) (Mehterian et al. 2017). At the time we reinvestigated Qaleh Kurd, the  
148 deposits had been extensively damaged by recent illegal human activities. Four large clandestine pits revealed a  
149 stratigraphy of at least 2.5m depth, including Paleolithic archaeological deposits with well-preserved faunal  
150 remains and lithic artifacts.

151 The excavations allowed to investigate the nature of archaeological deposits and their chrono-stratigraphic  
152 context. For some preservation and safety reasons, the excavation strategy was adapted to the presence of the  
153 clandestine pits. Indeed, they largely affected the deposit of the main chamber on a surface of 25m<sup>2</sup> and 2.5m in  
154 depth. We first dry-sieved the whole reworked sediment next to the pits; several thousand objects were collected  
155 in this reworked sediment. We then initiated the excavation by enlarging two pits located in the main chambers  
156 (labelled Trench 1 T1 and Trench 3 T3, see Fig.2). The excavation was then conducted by m<sup>2</sup> following the  
157 stratigraphic main units and 3D referencing the archaeological finds. A total area of 11m<sup>2</sup> and an average depth  
158 of 130cm were excavated in T1 and 250cm in T3; trench 4 (T4) was additionally prepared for ongoing  
159 geological investigation. The whole excavated sediments underwent dry and wet sieving using 1mm mesh sizes  
160 in order to collect microfauna, small chips, and debris.

161

## 162 **Depositional setting and chrono-stratigraphic framework of Qaleh Kurd**

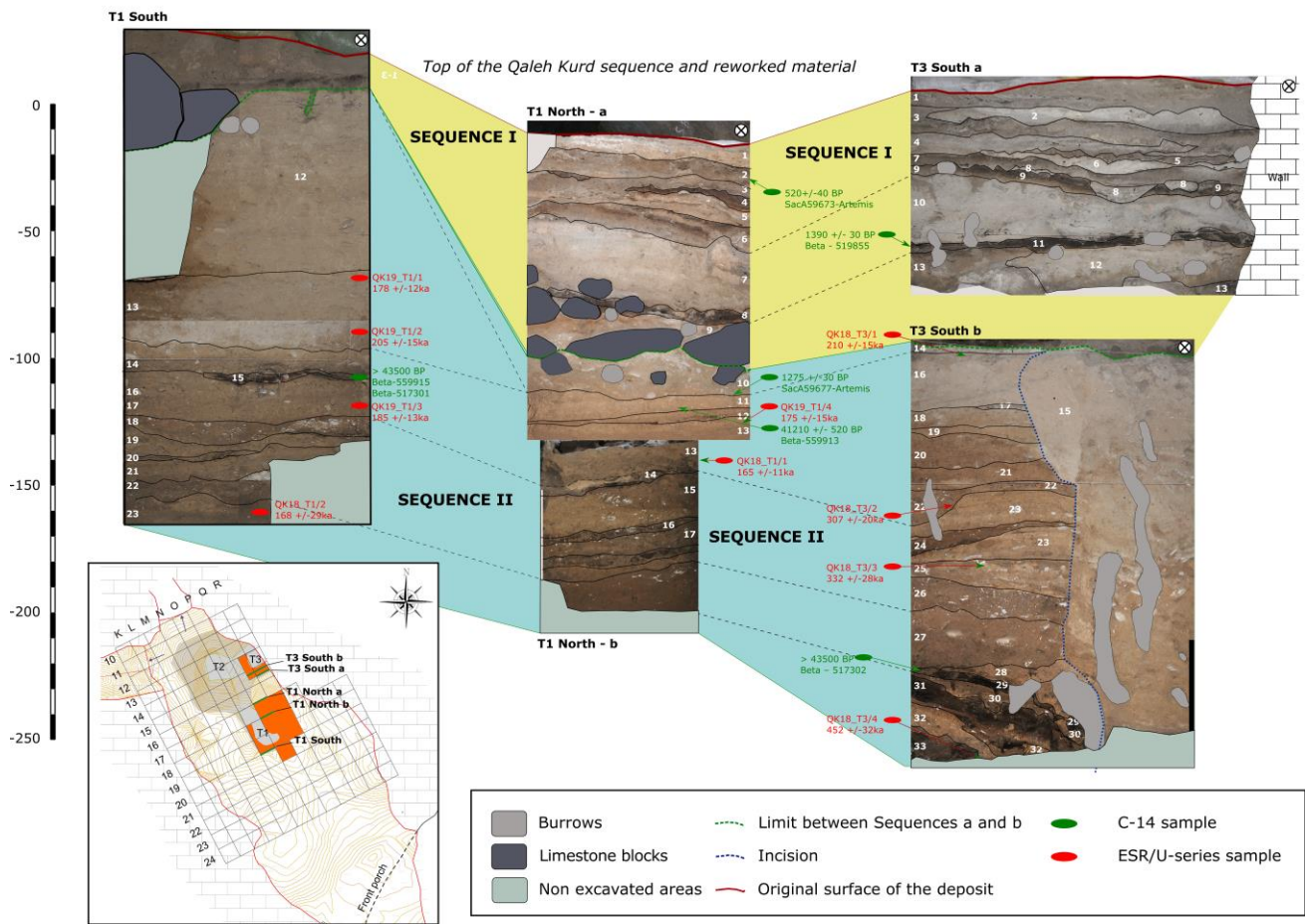
163

### 164 **The Qaleh Kurd stratigraphic sequence**

165 The excavations enabled us to observe the stratigraphy of the deposits in three trenches. Concerning T4, deposits  
166 at the bottom take the form of broad, wedge-shaped sheets characteristic of secondary deposits. Some of these



167 sheets have also been extensively reworked in a second step by recent human activities. Concerning T1 and T3,  
 168 Figure 3 and Table 1 provide a synthesis of the results of the fieldwork analysis of the deposits, auger drilling,  
 169 and laboratory analyses (including grains size analysis, micromorphology; see SI1). These analyses reveal a  
 170 sedimentary succession represented by a 6 m-thick karstic and clastic record made up of two sequences:  
 171 Sequence I and Sequence II, separated by a discontinuity (an incision surface and limestone blocks). The  
 172 deposits are in the form of centimetric to decimetric-thick sheets. These sheets correspond to laterally non-  
 173 continuous units (unit numbers are proper to each section). Descriptions of the units are given in SI2 for T3  
 174 (where the excavation reaches its maximum depth and the sequence is observed continuously). Correlations have  
 175 been made secondarily based on field and sedimentological data (see Table 1).



176  
 177 Figure 3. Synthetic stratigraphy of the Qaleh Kurd sequence and chronological data. (Full page, landscape) (©  
 178

G. Berillon, J.-J. Bahain, M. Akhavan Kharazian and G. Jamet).

179

Table 1 – Simplified stratigraphic succession of the Qaleh Kurd deposits (See SI2 for the description of the units).

QALEH KURD SEQUENCE	T1 southern section	T1 northern section	T3 southern section	Proposed age
SEQUENCE I	T1S U1-3	T1N U1-6	T3 U 1-9	Holocene
		T1N U 7-8	T3 U 10-13	
		T1N U 9		
SEQUENCE II	T1S U12-13	T1N U10	T3 U14-15	Late Pleistocene??
	T1S U14-16	T1N U11-13	T3 U16-21	MIS 7-6
	T1S U17-21	T1N U14- 17	T3 U22-26	MIS 9
	T1S U22-23		T3 U27	??
			T3 U28-33	MIS12-11

180

181 Sequence I consists of 8 units (1–8) in T1 (Northern Section, where it is best preserved) and 13 units (1–13) in  
 182 T3. Its thickness varies laterally; from high in T3 and the northern T1 section (80cm on average) it thins towards  
 183 the entrance of the cave on the southern T1 section (10cm). Sequence I exhibits a granular to massive structure.  
 184 It contains predominantly whitish-grey ashy silt-sized sediments with episodic occurrence of cobbly to  
 185 gravelly erosional surfaces and local calcareous flat stones, with inclusions of dark humic lenses. Anthropogenic  
 186 components are frequent, such as shepherd deposits (charcoals, spherulites, animal dung, ashy remains, and  
 187 occasionally pot fragments). The boundary with sequence II corresponds to a roof- and/or wall-collapse deposit  
 188 (Units 9 and 10 in T1 northern section, unit 13 in T3) that is characterized by angular to subangular calcareous  
 189 clasts of varying sizes, from gravel to large blocks.

190 Sequence II consists of a ca. 170 cm-thick deposit in both trenches; its basis has not been reached yet. It was  
 191 subdivided into 12 units (12–23) in T1 (Southern Section, where it is best preserved) and 20 units (14–33) in T3.  
 192 It is composed mainly of silt-sized material and displays a generally slightly granular to massive structure.  
 193 Micromorphological traits, such as strongly degraded calcic clasts reduced to very coarse sand (as observed in  
 194 Unit 15), are indicative of post-depositional alterations of the units linked to fluctuating seasonal temperature  
 195 and water levels in the karst. This sequence has also recorded several cryoclastic episodes (e.g., Unit 15 in the  
 196 Northern T1 section, within Units 13, 26 and 27 in T3) and display lenticular humic silty layers (e.g., Unit 17,  
 197 20, 22, 24 in Upper Sequence II of T3). Humic lenses are also numerous in the lowest units of T3 as well (Units  
 198 29, 31, 33) where they superimposed with lenticular gravelly silt layers. These humic lenses contain abundant

199 charcoal, heated bones and vegetal remains. They could represent paleosoils and may be in relation with  
200 anthropic activities. These traits are indicative of a long time-range deposition.

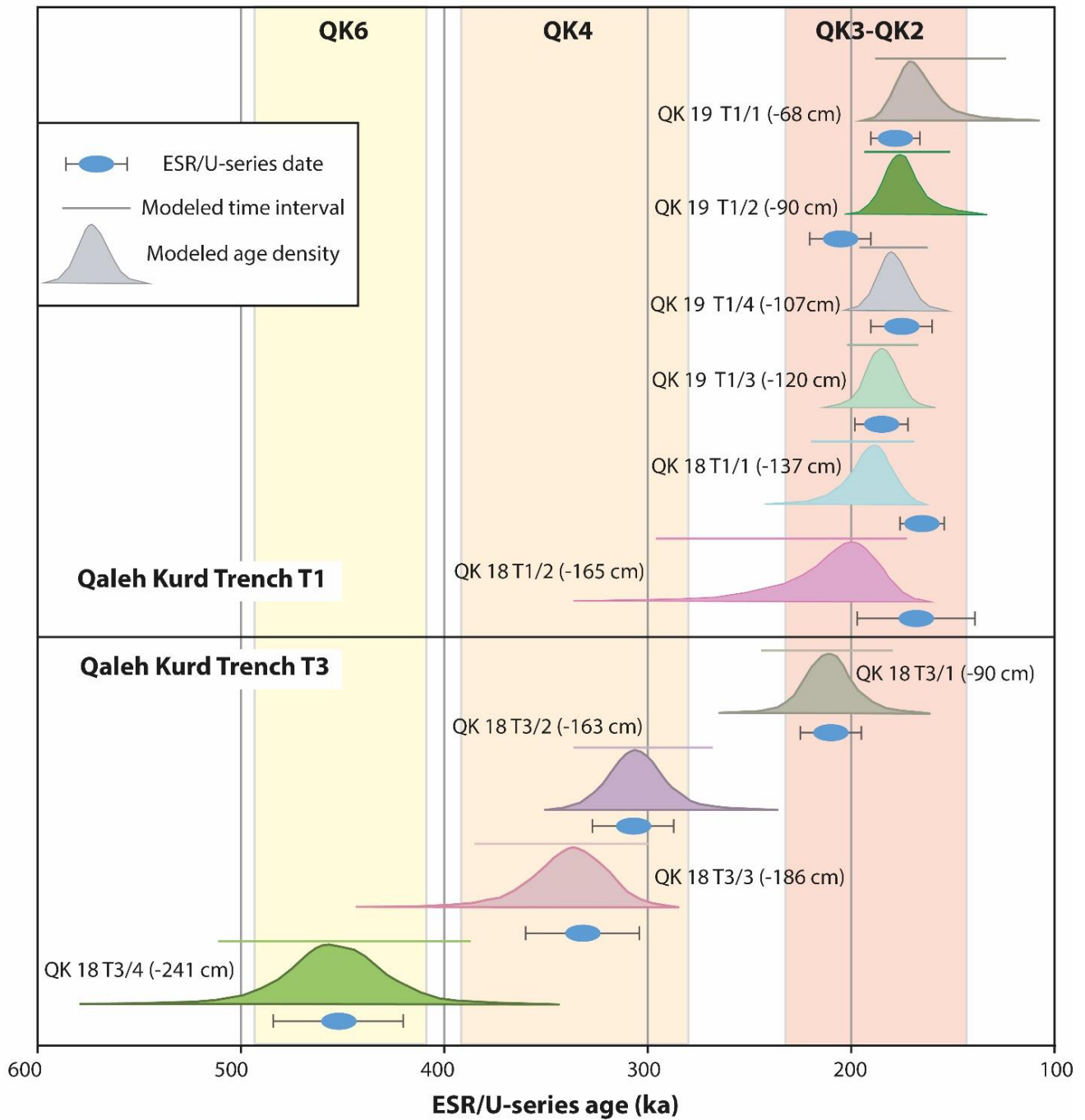
201 Generally speaking, sequence II delivered numerous archaeological levels and remains, including the human  
202 deciduous tooth recovered in the upper part of Unit 13, close to the T1 Northern section. The upper units of  
203 sequence II appear truncated from the entrance to the back of the chamber. Together with the roof-collapse  
204 episode with large blocks (units 9 and 10 of the T1 northern section), this indicates a major sedimentary hiatus  
205 between sequences I and II.

206

### 207 Chronology of the Sequences based on AMS and ESR/U-series dating

208 Numerous samples were collected for chronological analysis. The obtained ages, when applicable, are provided  
209 in Figure 3. Concerning Sequence I, two radiocarbon dates were obtained on organic sediments and micro-  
210 charcoals from the lower and upper units, which provided ages of 1390 +/- 30 BP (Beta-519855) and 520 +/-40  
211 BP (SacA59673). Such recent dates are in agreement with the general composition of the collected  
212 archaeological assemblages and sediments, indicating the recent nature of the sequence.

213 Concerning Sequence II, five samples of organic sediments from the upper to the lower units were analysed by  
214 radiocarbon and provided an age above the limit of the AMS method (> 43500 BP). In parallel, 10 equid teeth  
215 were also sampled for C14 analysis, but the low collagen content made it impossible to attempt any radiocarbon  
216 dating. They were then used for analysis by the ESR/U-series dating method using the analytical protocol  
217 described by Bahain et al. (2021) and detailed in SI3. The obtained results are displayed in Table 2 and Figure 4.  
218 They range from 205 ± 15 ka to 165 ± 11 ka in T1, and from 452 ± 32 to 210 ± 15 ka in T3. These results allow  
219 assigning the whole sequence II to the Middle Pleistocene and a period that spans at least 300 ka.



220

221 Figure 4. Bayesian model (Chnonomodel, 95% of confidence) of the ESR/U-series ages obtained on analyzed

222

Qaleh Kurd teeth. (© J.-J. Bahain).

Table 2 – ESR/U-series ages of the analyzed Qaleh Kurd teeth. Uncertainties are given at  $2\sigma$  (95% of confidence).

Samples (laboratory number)	Samples (Excavation number)	Trench	Unit	Depth	ESR/U-series ages (ka)
QK19 T1/1	Tooth n°5118	T1	12	-68cm	178 ± 12
QK19 T1/2	Tooth n°5353	T1	15	-90cm	205 ± 15
QK19 T1/4	Tooth n°4895	T1	13	-107cm	175 ± 15
QK19 T1/3	Tooth n°6158	T1	23	-120cm	185 ± 13
QK18 T1/1	Tooth n°2381	T1	C3	-137cm	165 ± 11
QK18 T1/2	Tooth n°2500	T1	C4	-165cm	168 ± 29
QK18 T3/1	Tooth n°495	T3	C1	-90cm	210 ± 15
QK18 T3/2	Tooth n°3148	T3	C1	-163cm	307 ± 20
QK18 T3/3	Tooth n°3310	T3	C1	-186cm	332 ± 28
QK18 T3/4	Tooth n°1721	T3	C1	-241cm	452 ± 32

223

## 224 Context and history of the deposits

225 The stratigraphic and sedimentary characteristics of Sequence II support the idea of low-energy sheet deposits in  
 226 which seasonal temperature variations as well as human activities played an important role. Some features  
 227 indicate contrasted climatic conditions along the sequence with colder periods marked by cryoclastic deposits  
 228 and more temperate ones, marked by humic deposits. These humic deposits may represent palaeosoils and may  
 229 be in relation with anthropic activities (see above). According with the ESR/U-series chronology, these climatic  
 230 changes can correspond to the local record of the late Middle Pleistocene climatic cyclicity. This first phase of  
 231 sedimentation started prior 450ka and lasted at least 300 ka. It seems to have ended during the late Middle  
 232 Pleistocene. No further deposits were recorded until the late Holocene (around 1.5 ka).

233 This long sedimentary gap between Sequence II and Sequence I could be linked to the closure of the cave  
 234 leading a decrease in sedimentation or karstic processes within the cave, as well as the end of anthropic  
 235 activities. The top part of the Pleistocene sequence (T1 South) in the central current main chamber has been  
 236 eroded. No data is available so far to date this event precisely and to address its possible natural causes, yet  
 237 recent human activities cannot be excluded. The cave opened up during the last two millennia. A level of

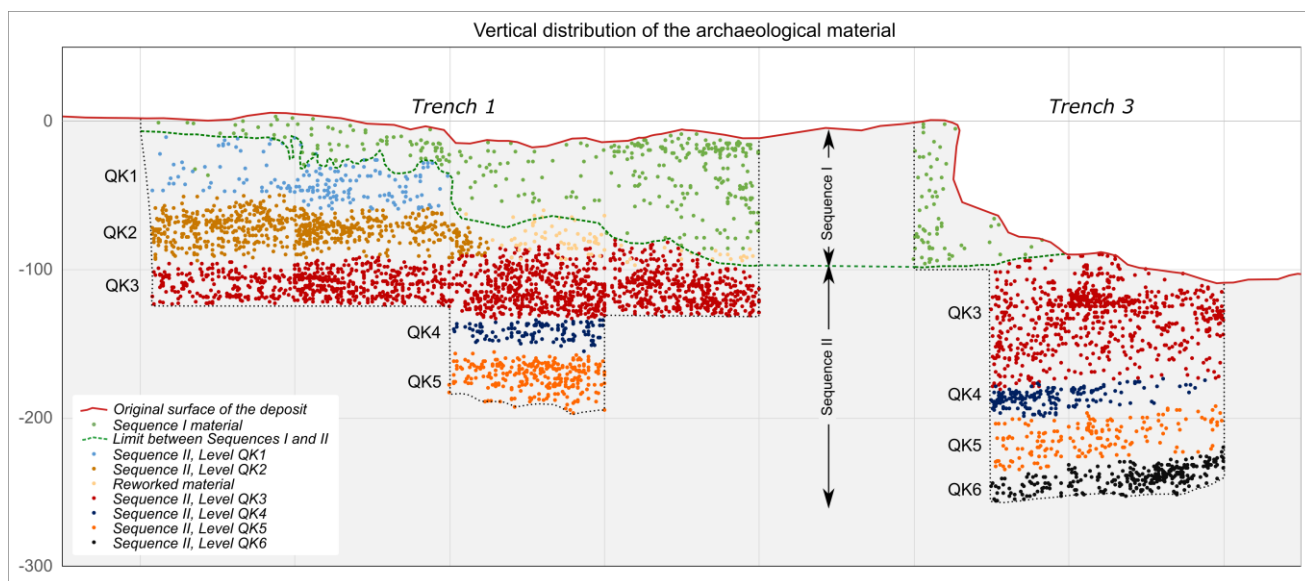
238 gelifracts and large blocks that presumably collapsed from the ceiling, covers the eroded Pleistocene sequence in  
239 this area; it seems to signify the restart of sedimentation. The cave has since been used by humans.

240

## 241 The archaeological assemblages

### 242 The archaeological levels

243 Excavations at T1 and T3 yielded more than 5800 *in situ* finds, within which around 2/3 are large mammals'  
244 bones and teeth, 1/3 are lithic artifacts, and one is a human tooth. Figure 5 represents the vertical distribution of  
245 the finds in both trenches across the whole sequence. Sequence I delivered isolated remains, mainly pottery  
246 fragments and remains of wild and domesticated animals. Isolated artifacts of Paleolithic affinities were also  
247 collected in reworked contexts, such as animal burrows or the units 8–10 of T1 at the contact of the collapsed  
248 rocks.



249

250 Figure 5. Vertical distribution from South to North of the *in situ* collected archaeological material in Trench 1  
251 and Trench 3 of Qaleh Kurd (© G. Berillon, M. Hashemi and H. Vahdati Nasab). Full page, landscape.

252

253 In sequence II, finds are distributed in at least six archaeological levels, named QK1 to QK6, from the top of the  
254 sequence in T1 (around 10cm in depth) at the entrance of the cave until the deepest excavated area in T3 (around  
255 250 cm in depth). Archaeological levels extend sub-horizontally, with a depth of several decimeters. Both lithics

256 and faunal materials show fresh ridges and are very well preserved. The fauna is locally covered with carbonated  
257 encrustation. The upper part of sequence II (until 90cm depth) is preserved in the southern half of T1 only where  
258 the deposits have not been incised (see above). QK1 appears largely impacted by animals' burrows and as a  
259 consequence, appears fragmented with a low average density of objects. QK2 could be observed in the southern  
260 part of T1 only as well, while QK3 was preserved in all excavated areas of T1. The lower material has been  
261 allocated to at least 3 levels, QK4 to QK6. These lower deposits could be observed on a very limited surface;  
262 these allocations thus need to be improved based on new excavations. The bottom of the sequence has not been  
263 reached by the excavations. Auger drillings down to the depths of 6m in both T1 and T3 indicates that older  
264 archaeological layers are preserved in the non-excavated part of the sequence (at least 3m depth).

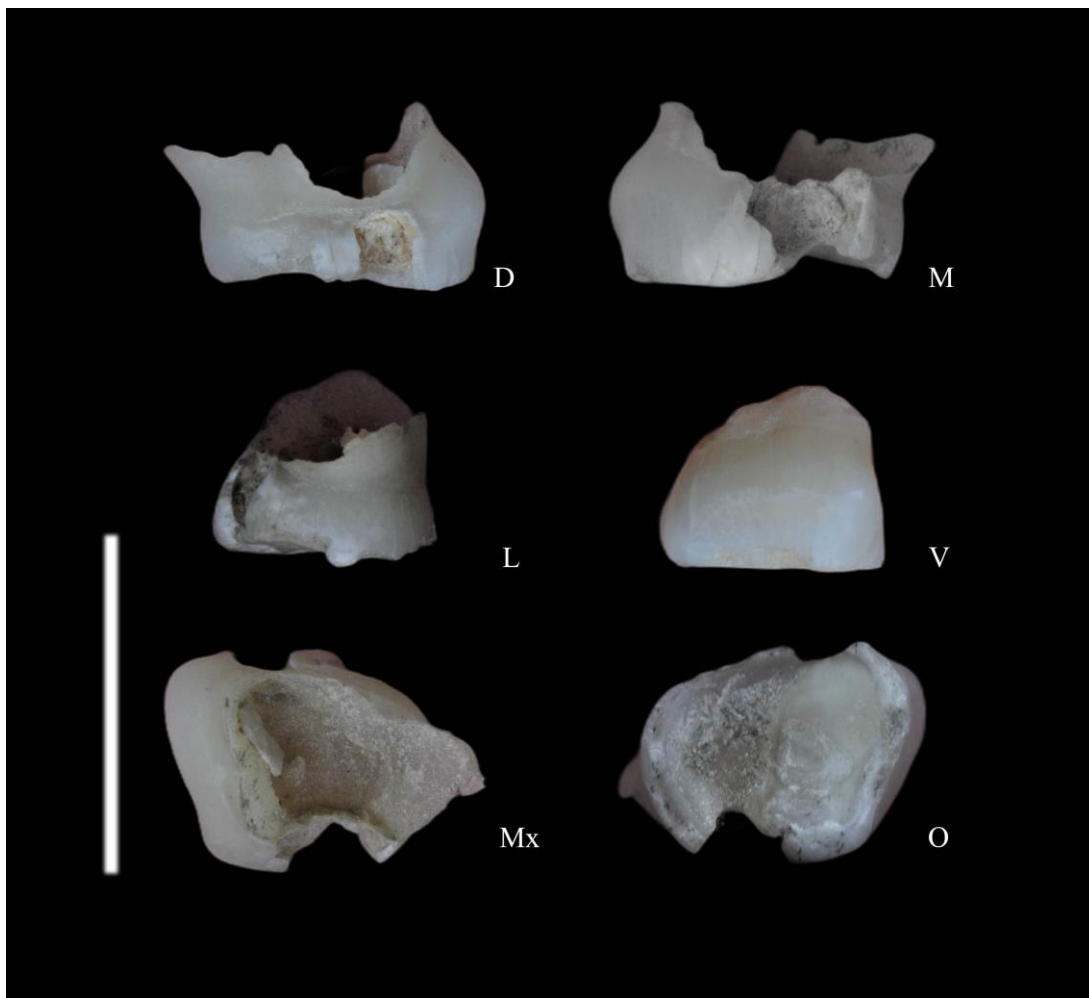
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## 266 The deciduous human tooth

267 A human deciduous left first upper molar (n°QK19-6169) was discovered in Trench 1, square R17, at a depth of  
268 105cm. This tooth was deposited in unit 13 (Section T1 North). It belongs to the upper half of the QK3 level that  
269 spreads from unit 13 to unit 16 of the stratigraphy (Section T1 North). The current chronological framework  
270 places thus this human tooth between  $205 \pm 15$  ka and  $165 \pm 11$  ka. Here we present the preliminary results of  
271 the analysis of this tooth.

272 The morphology of the tooth is widely impacted by wearing, root resorption and caries (Fig. 6). In occlusal  
273 view, the outline of the crown is trapezoidal and asymmetrical. The occlusal surface of the crown shows  
274 extensive wear (stage 5) (Molnar, 1971); only a small chip of enamel is preserved and no cuspid can be  
275 identified. At the mesial and distal levels, the crown is affected by two large millimetric lacunae, from the  
276 enamel to the dentine; the largest (mesial) communicates with the pulp cavity. Both lacunae appear to be caries:  
277 the edges and inner surfaces are smooth, and neither enamel nor dentine show any signs of abrasion or breakage.  
278 The resorption of the root appears almost achieved with some remaining flaps at the vestibular and linguo-distal  
279 borders. The state of resorption of the root suggests that this tooth was close to be shed if not shed naturally  
280 during the child's life; by way of comparison, in modern humans, this upper first molar (if not been shed) would  
281 come from a child around the age of 11 (AlQahtani et al., 2014). However, the life history evolution may be

282 dissociated with the timing of tooth eruption within hominins; if the tooth represents for example a Neanderthal  
283 or an archaic *Homo sapiens* then the individual was probably younger (e.g., Smith et al., 2007). Such degrees of  
284 crown wear and root resorption suggest that the tooth may have been functional for a long period of time.  
285



286  
287 Figure 6. The human deciduous first upper left molar QK19-6169 in distal (D), mesial (M), lingual (L),  
288 vestibular (V), occlusal (O) and maxillary (Mx) views (scale, 10mm). (© FIPP 2019, G. Berillon).

289  
290 A prominent *tuberculum molare* is observed at the mesiodistal corner that accentuates the asymmetrical shape of  
291 the crown in occlusal view. *Tuberculum molare* is a trait variably observed or described in archaic humans,  
292 Neanderthals and modern humans, including extant humans. By way of comparison, it is well developed in  
293 archaic humans such as Tighenif, Le Lazaret 12 and 27 and Arago 27 and moderate on Arago 12 (Tillier, 1980;



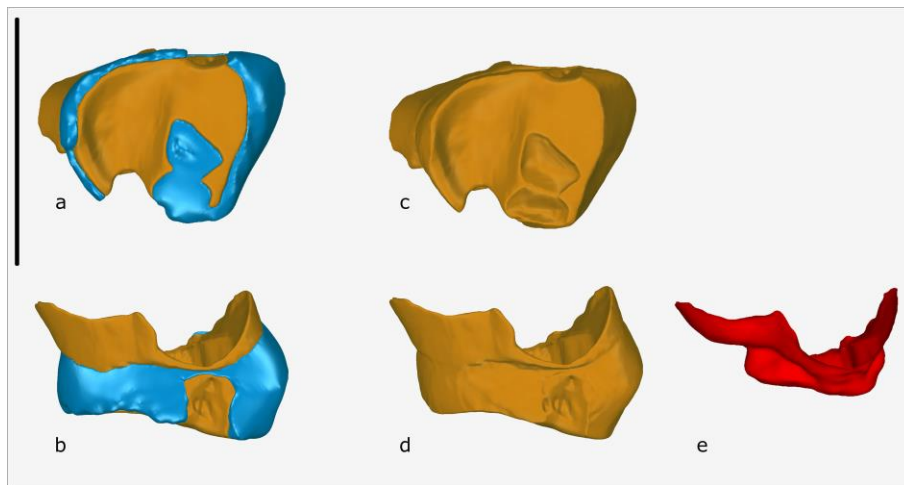
294 Lumley de, 2018, 2022). It is also well-developed in Neanderthals such as Shanidar 7, Chateaufort 2 (Tillier,  
295 1979a, Trinkaus, 1983) and Pech de l’Azé (personal observation), as well as in early *Homo sapiens* such as  
296 Qafzeh 12 and 4 (Tillier, 1979b, 1999), while it is moderate to absent on Kebara KMH25, KMH30, KMH1 and  
297 Subalyuk (Thoma, 1963; Tillier et al., 2003), as well as in Qafzeh 14, 10 and 15 (Tillier, 1999). The occurrence  
298 of a *tuberculum molare* and its prominence naturally affect the shape of the crown. In general, the outline of the  
299 crown is highly variable in archaic humans, Neanderthals and early modern humans, from elongated to  
300 quadrangular and trapezoidal, from symmetrical to asymmetrical (see above references).

301 The mesiodistal diameter being affected by the caries has a minimal value of 6.1mm, thus below the  
302 distributions of modern humans (European Upper Paleolithic and Near Eastern modern humans) and  
303 Neanderthals (see e.g. Becam and Chevalier, 2019 and Tillier, 1999: 6.4–9.5 mm MH and 7.1–11 mm NEA; and  
304 comparative metrics in table SI4). However, it is very likely that its actual value would fall within the lower  
305 range of both species. The buccolingual diameter is 7.2mm and falls within the lower range of the known  
306 variation for Neanderthals and below that of modern humans (see Becam and Chevalier, 2019 and Tillier, 1979a:  
307 7.4–9.6 mm MH and 6.8–9.9 mm NEA; see table SI4). The crown diameters of the Qaleh Kurd deciduous first  
308 upper molar fall within the lower range of the known variation of Middle and Upper Pleistocene humans.

309 In order to observe the endostructure of the tooth, a  $\mu$ CTScan has been performed at the Tehran University  
310 Medical Science Preclinical Core Facility (LOTUS-inVivo  $\mu$ CtScan, Behin Negareh Company). A 3D  
311 reconstruction was carried out on 17.5 $\mu$ m-thick sections (Fig. 7). The 3D reconstructed model shows that the  
312 important crown wear and both caries deeply affect the enamel-dentin junction. The pulp cavity appears as well  
313 profoundly affected by the whole resorption process. As a consequence, reproducible measurement and  
314 morphological inference as well as quantified analyses cannot be realized as done on better preserved specimens  
315 (e.g., Fornai et al., 2014; Slimak et al., 2022).

316 In summary, the high degree of wear on the crown and the presence of two large caries significantly affect the  
317 morphology of the tooth, impacting the metrics and potentially taxonomically informative traits.

318



319

320 Figure 7. 3D reconstruction of the enamel (in blue), the dentine (in brown) and the pulpar cavity of the human  
 321 deciduous first upper left molar QK19-6169 in occlusal (a, c) and distal (b, d, e) views (scale, 10mm). (© J.

322

Özçelebi).

323

### 324 The Lithic assemblages, QK1-3

325 The three upper levels (QK1-3) are directly associated with the human tooth and could be observed in T1 on a  
 326 large surface (contrary to the lower deposits that were excavated on less than 1m<sup>2</sup>) (Fig. 2). In total, the QK1-3  
 327 assemblages on which we focus here count for 2145 pieces of lithic artifacts collected *in-situ*.

328 The percentages of different raw materials is shown in Table 3. Raw materials in QK1–3 are mainly represented  
 329 by sedimentary rocks comprising limestone and silicified limestone (64.3%), the chert category (24.9%,  
 330 including chert and jasper, as well as flint and agate), radiolarite (1%), siltstone and sandstone (1%), and others  
 331 (1.25%). Volcanic (igneous) rocks (including tuff and lithified pyroclastic debris, as well as basalt, andesite,  
 332 dacite, rhyolite, and rhyodacite in very low proportions) make up about 4.68% of the assemblage. Quartzite was  
 333 also used for making some few pieces (0.7%).

334

Table 3 – Lithic raw materials at Qaleh Kurd levels QK1-3.

Raw material	QK1		QK2		QK3	
	N	%	N	%	N	%
Limestone	6	31.58	16	26.23	131	40.18
Silicified limestone	5	26.32	19	31.15	84	25.77
Chert	6	31.58	4	6.56	56	17.18
Jasper	1	5.26	5	8.20	8	2.45
Quartzite	1	5.26			2	0.61
Flint			6	9.84	14	4.29
Tuff			4	6.56	5	1.53
Pyroclastic			1	1.64		0.00
Igneous			2	3.28	6	1.84
Silicified stone			2	3.28	7	2.15
Radiolarite			2	3.28	2	0.61
Dolomite					1	0.31
Andesite					1	0.31
Calcareous tufa					1	0.31
Agate					1	0.31
Bio Micrite					1	0.31
Siltstone					3	0.92
Sandstone					1	0.31
Opal					2	0.61
<b>Total</b>	<b>19</b>	<b>100</b>	<b>61</b>	<b>100</b>	<b>326</b>	<b>100</b>

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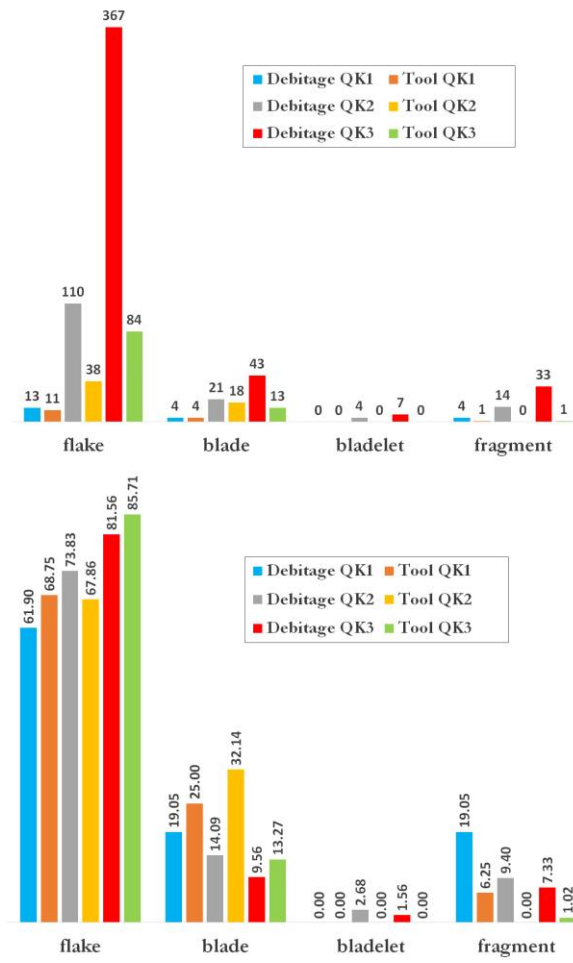
Table 4. General techno-typological summary for QK1–3.

QK1	#	%	QK2	#	%	QK3	#	%	Total
Débitage	19	15.57	Débitage	149	59.60	Débitage	450	25.38	618
Tool	16	13.11	Tool	56	22.40	Tool	98	5.53	170
Core	-	-	Core	4	1.60	Core	11	0.62	15
Debris	87	71.31	Debris	28	11.20	Debris	1186	66.89	1301
Indeterminate	-	-	Indeterminate	13	5.20	Indeterminate	28	1.58	41
<b>Total</b>	<b>122</b>	<b>100</b>	<b>Total</b>	<b>250</b>	<b>100</b>	<b>Total</b>	<b>1773</b>	<b>100</b>	<b>2145</b>
Intensity of toolmaking		45.7	Intensity of toolmaking		27.3	Intensity of toolmaking		17.89	
Side scraper	3	18.75	Side scraper	19	33.93	Side scraper	26	27.08	
Mousterian Point	3	18.75	Double side scraper	8	14.29	Double side scraper	7	7.29	
simple retouched point	2	12.50	Mousterian Point	6	10.71	Mousterian Point	21	21.88	
Déjeté scraper	1	6.25	simple retouched	1	1.79	simple retouched	3	3.13	

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			<b>point</b>			<b>point</b>		
<b>Levallois point</b>	1	6.25	<b>Levallois point</b>	2	3.57	<b>Levallois point</b>	5	5.21
<b>Convergent Scraper</b>	1	6.25	<b>Convergent Scraper</b>	6	10.71	<b>Convergent Scraper</b>	11	11.46
<b>Endscraper</b>	2	12.50	<b>Déjeté point</b>	1	1.79	<b>Déjeté point</b>	2	2.08
<b>Retouched Piece</b>	2	12.50	<b>Endscraper</b>	2	3.57	<b>Endscraper</b>	4	4.17
<b>Other</b>	1	6.25	<b>Retouched Piece</b>	10	17.86	<b>Retouched Piece</b>	13	13.54
<b>Total</b>	<b>16</b>	<b>100.00</b>	<b>Notched</b>	1	1.79	<b>Naturally backed knife</b>	1	1.04
			<b>Total</b>	<b>56</b>	<b>100.00</b>	<b>Notched</b>	1	1.04
						<b>Multiple tool</b>	2	2.08
						<b>Total</b>	<b>96</b>	<b>100.00</b>

The level QK1 is characterized by the production of large and elongated flakes, triangular flakes/points and, by laminar blanks. The removals were made by both non-Levallois and Levallois methods. The lithic assemblage is made up of 15.6% of débitage, 13.4% of tools and 71.3% of debris (Table 4). No core has been recovered from QK1. Flakes and blades represent 61.9% and 19% of the débitage respectively (Fig. 8). The predominance of flake production is also seen in the tool category: 68.7% of them are made on flakes, while 25% are made on blades. No bladelet tool was recorded from QK1. Elongated flakes ( $L/W$  ratio  $\geq 1.5$ ) make up about 45.4% of the flake blanks. The tool assemblage consists of simple side to transverse scrapers and retouched points. They are usually made on thick blanks, mainly with moderate to invasive retouch, and sometimes of invasive stepped types reminiscent of the Quina-type retouch (Fig. 9, g). Mousterian points are also present. Basal trimming of convergent tool types is common, perhaps for hafting purposes (Fig. 9, see b, d, f, j–l).

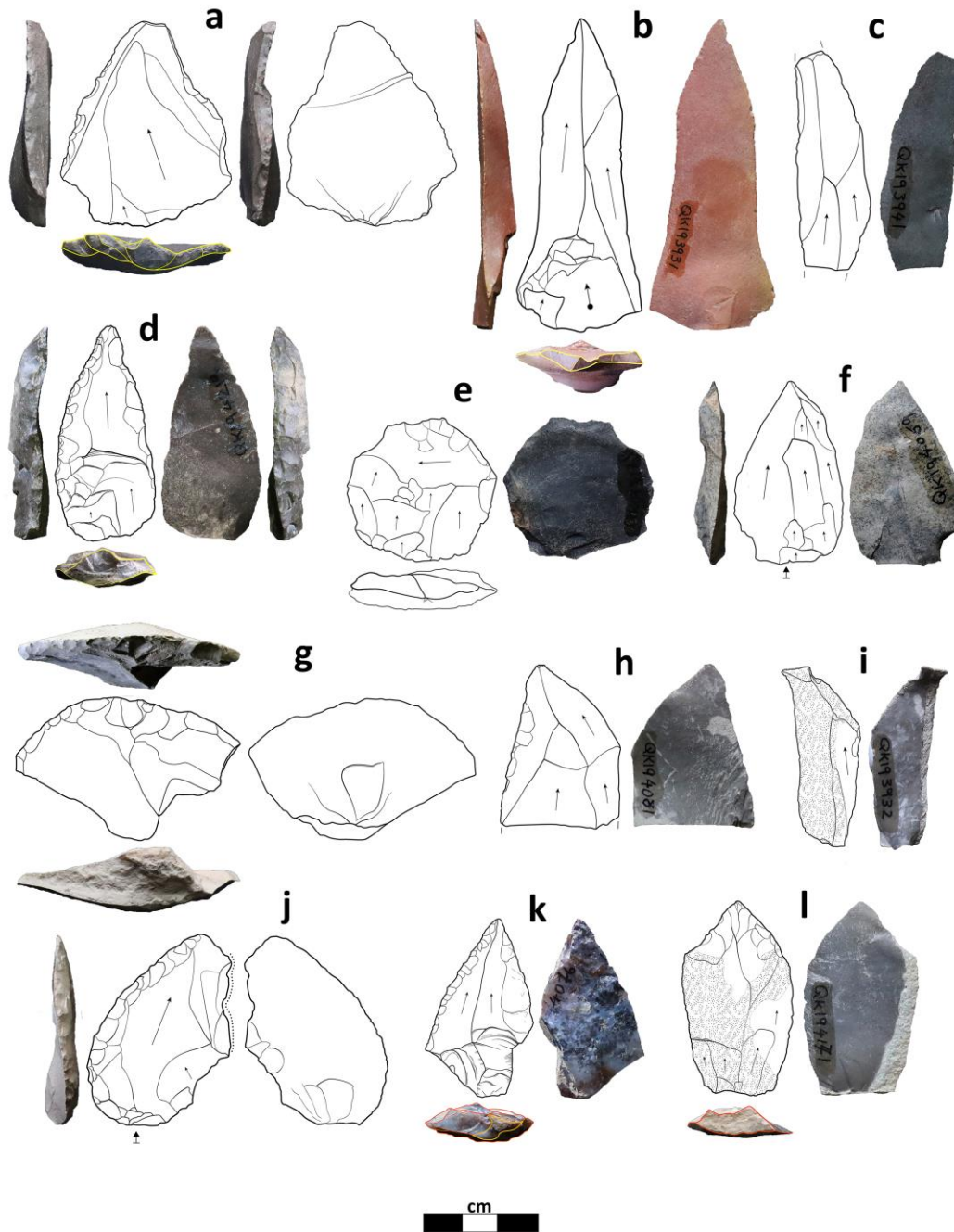


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360 Figure 8. The composition of débitage and tools in QK1-3. Guide: the upper bar chart is based on absolute

361 numbers, while the lower bar chart is based on percentages.

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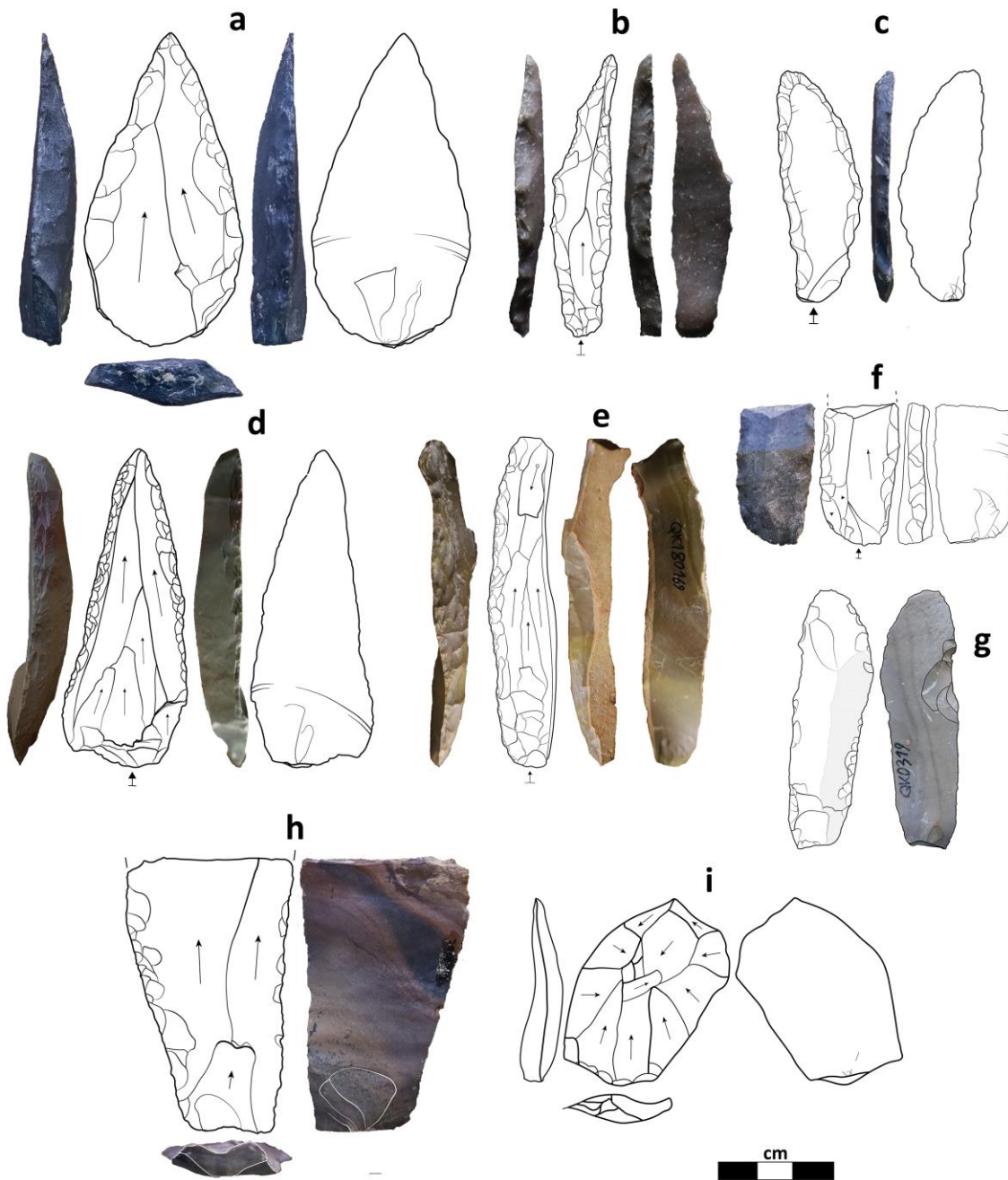
364 Figure 9. selected lithic artifacts from QK1. a. Retouched Levallois point; b. Pointed Levallois blade with basal  
 365 thinning; c. Medial part of a blade; d. Mousterian point on an elongated thick flake with basal thinning; e. End  
 366 scraper on a Levallois flake; f. point/subtriangular flake; g. Transverse scraper on a wide thick flake; h. distal  
 367 part of a side-retouched piece; i. An atypical cortical plunging blade; j. Déjeté scraper; k. Mousterian point on a  
 368 relatively elongated flake with basal thinning/chipping; l. Retouched point on an elongated flake. © M. Hashemi,

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Full page.

370

371 The general structure of the QK2 lithic assemblage displays a mixed production of broad and elongated flakes,  
372 point or triangular flakes, and blades (Fig. 10), as in QK1. The débitage is made of both Levallois and non-  
373 Levallois, as well as laminar methods. Concerning the production of blanks, elongated varieties such as blades  
374 with convergent edges or elongated points, are more numerous here than the QK1. The assemblage is fairly  
375 retouched: more than 25% of the flakes and 46% of the blades. Cortical surfaces are observed in 27.7% of the  
376 lithics. The débitage accounts for 60% of the lithic assemblage while tools represent 22.4%. In addition to debris  
377 (11.2%), four cores were recovered in QK2. Flakes represent 73.8% of the débitage, while blades account for  
378 about 14.1% (Fig. 8). 67.9% of the tools are made on flake, and 32,1% are made on blade blanks. In addition,  
379 elongated flake blanks in QK2 are numerous (51.6%), higher than QK1.



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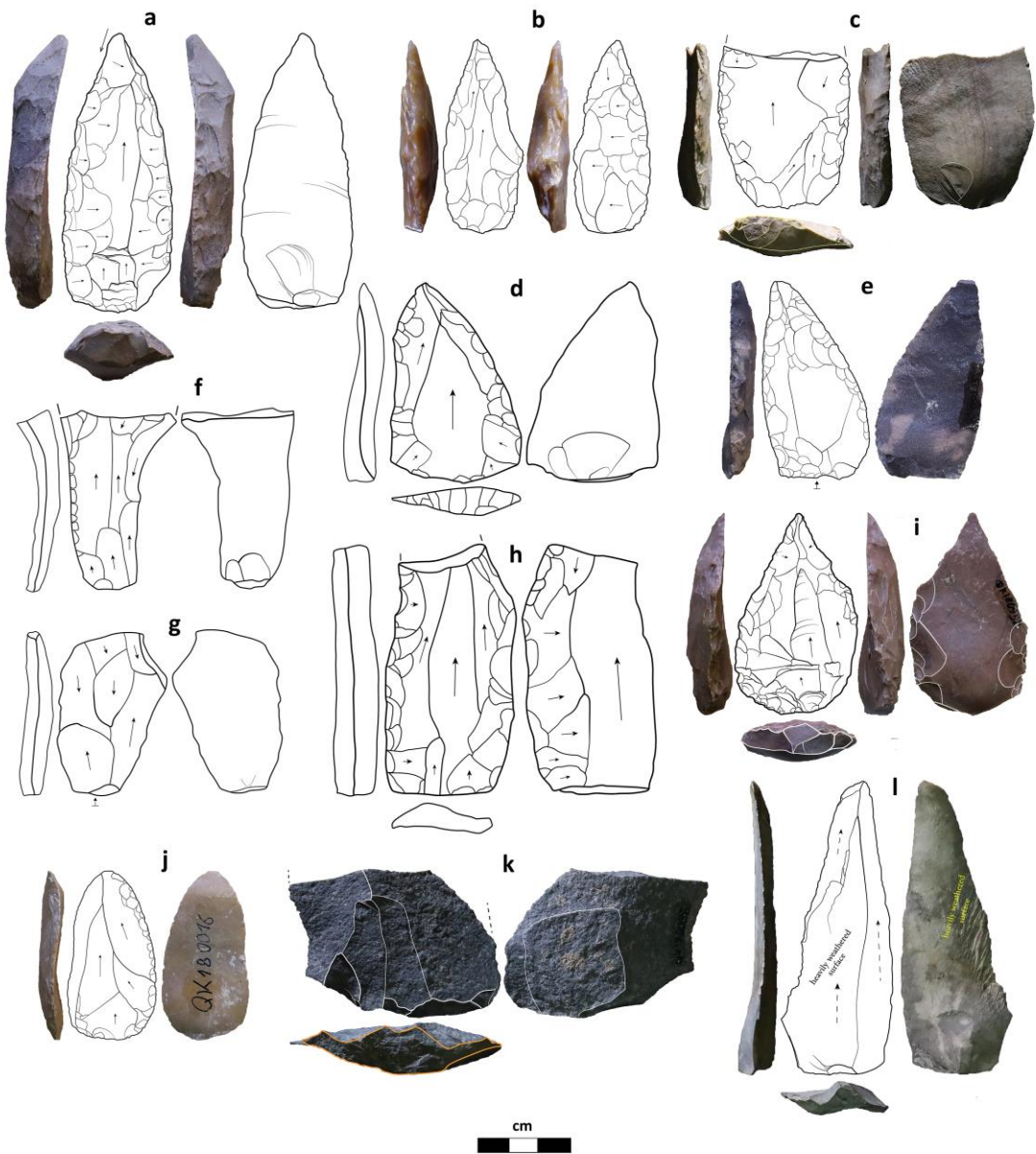
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Figure 10. Selected lithic artifacts from QK2. a. Mousterian point on an elongated flake; b. Elongated point on an elongated thick blade with basal thinning; c. Double side and convergent scraper on a blade with basal chipping; d. Elongated Mousterian point with stepped retouch and basal thinning; e. Side scraper on an elongated narrow and thick cortical blade with stepped retouch; f. Double side scraper on a thick blade; g. Retouched piece made on a cortical blade with basal thinning; h. Side scraper with stepped retouch on a massive elongated flake or wide blade; i. A preferential Levallois flake with centripetal scars. © M. Hashemi.



QK3 is characterized by high occurrences of flakes and bulkier flakes and the presence of some large laminar products. Some of these laminar products were retouched to become pointed blades/elongated points (Fig. 11). The débitage is usually of non-Levallois design and laminar, which differ from the upper levels. A few signs of the discoid method are also discernible in QK3 (see the discoid core in Fig. 12a), albeit such a method is not common. The débitage accounts for 81,5% of flakes and about 9.5% of blades. 85.7% of the tools are made on flakes and 13.3% are made on blades (Fig. 8). Some bladelet débitage specimens have been recorded (as in QK2). Elongated flakes constitute 40.2% of the flake removals, and cortical pieces represent 18.9% of the lithics.



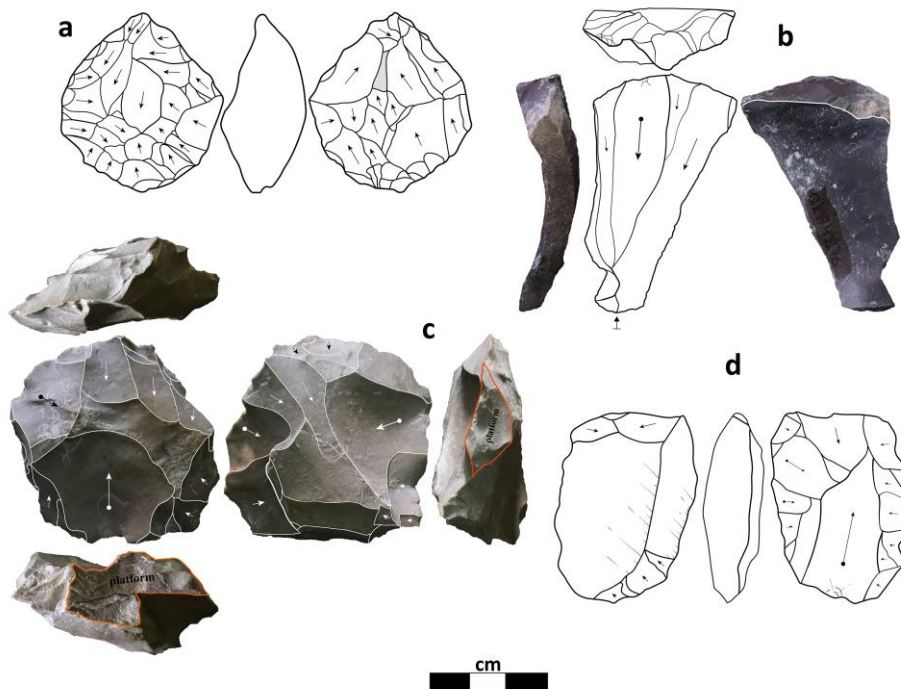
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388 Figure 11. Selected lithic artifacts from QK3. a. Elongated Mousterian point with invasive stepped retouch on a  
 389 massive elongated thick flake and with basal thinning; b. Bifacially retouched point on an elongated flake with  
 390 invasive scaled-stepped retouch and ventral and basal thinning; c. Double side scraper (point?) on a massive  
 391 elongated thick flake with basal thinning; d. Retouched Levallois point on a flake; e. Mousterian point with  
 392 invasive scaled-stepped retouch and basal thinning (bifacially-thinned base); f. Retouched piece made on an  
 393 atypical blade (laminar core trimming element of débitage surface; bidirectional opposed scheme); g. Core  
 394 trimming flake (trimming of débitage surface, bidirectional scheme); h. Elongated Mousterian point made on an  
 395 elongated thick flake or wide thick blade with basal and ventral thinning (invasive scaled-stepped retouch); i.

396 Mousterian point on a Levallois flake with invasive scaled-stepped retouch and basal-ventral thinning; j. Side  
 397 scraper/retouched point on an elongated Levallois flake; k. Proximal part of an atypical massive flake; l.  
 398 Elongated subtriangular flake/elongated point with (Levallois ?) with ventral nibbling in the left lateral side (not  
 399 visible in the picture due to the weathering effect). © M. Hashemi.

Cores are mainly flake cores except one with mixed scars of flake-blade and one with blade scars (Figure 12). The complete cores are small ( $L \leq 4\text{cm}$ ) to large ( $>7\text{cm}$ ) in dimension in both QK2 and QK3. All cores are reduced using hard hammer technique. The number of core's negative scars range from one to two-digit flake scars (Figure 12a). The platforms are prepared both by a single blow or faceting. Most of the cores are atypical (amorphous); however, the assemblage counts also discoid cores, flat ones, Levallois cores, narrow-fronted platform cores, and core-on-flake (Figure 12). Levallois cores are recorded from both QK2 and QK3; both depict the two modes of preferential and recurrent débitage removal (Figure 12c, d). These cores usually show radial/centripetal preparations and none of them bear traces of advanced faceting for platform preparations.

400



401

402 Figure 12. Lithic cores of Qaleh Kurd, Trench 1. QK2: a. discoid core; b. core-on-atypical blade with faceted  
403 platform of the core; c. recurrent Levallois core with centripetal preparation; QK3: d. preferential Levallois point  
404 core with centripetal preparation (Nubian type II core). © M. Hashemi.

405  
406

## 407 The large mammal assemblages

408 Excavations at Qaleh Kurd delivered 4,014 faunal remains mostly in an excellent state of preservation, among  
409 which 1,886 pieces belong to large mammals. The sequence I has yielded 132 bone remains representing wild  
410 and domestic species of similar size. Cows (*Bos taurus*), sheep (*Ovis aries*), and domestic goats (*Capra hircus*)  
411 are identifiable. Small, undetermined bovids, which could be domestic or wild goats or sheep, are mainly  
412 represented by young individuals. Cutmarks made with metal knives and lithic industry attest to both recent and  
413 potentially older butchery activities.

414 The sequence II has yielded 1,465 *in-situ* teeth and bone remains. All long bones are fragmented pieces. As for  
415 the lithic assemblage, focus was made on the material from QK1 to QK3. Complementary observations were  
416 made on pieces from the lower levels regarding the represented taxa in the environment and the depth for time  
417 purposes. In total, nine taxa could be identified at gender or species level (Table 5), representing 408 remains  
418 (28,9 % of the total faunal material). The other remains are identified on a sub-level of gender, or undetermined.  
419 Large mammals are largely dominated by herbivores. Generally speaking, Equids represent the large majority of  
420 the fauna of each levels. At least 2 species are represented: a large horse (*Equus ferus*) (Fig. 13A) and the  
421 hydruntine (*Equus hydruntinus*), representing all age classes. The deer (*Cervus elaphus*) remains (Fig. 13D) are  
422 also common in all the deposits. Although the horse is largely dominant, some differences in faunal composition  
423 exist between levels.

424 QK1 yielded 123 remains, of which 26 have been identified at the species level, representing 5 taxa; each taxa is  
425 represented by a single individual (Table 5 and SI5a). The horse remains are represented by numerous pieces of  
426 limb bones and skull. The other identified species are the hydruntine, the red deer, the wild goat and the hare;  
427 they are represented by a few pieces. Marrow exploitation was particularly intense at this level, with 35.6% of  
428 the remains showing anthropogenic fractures (Fig. 14A). The stigmata visible on cortical surfaces (cutmarks,

429 scraping and retouch zones on bone tools) are also numerous (Fig. 13B). Their location and identification were  
 430 first assessed macroscopically; when requested, we proceeded to microscopic observations using dino-lite.  
 431 Carnivore trimming marks were observed on 7% of the material, which indicates a very low contribution of  
 432 carnivores compared to humans in the deposit.

433

434 Table 5. Faunal list of Pleistocene levels at Qaleh Kurd

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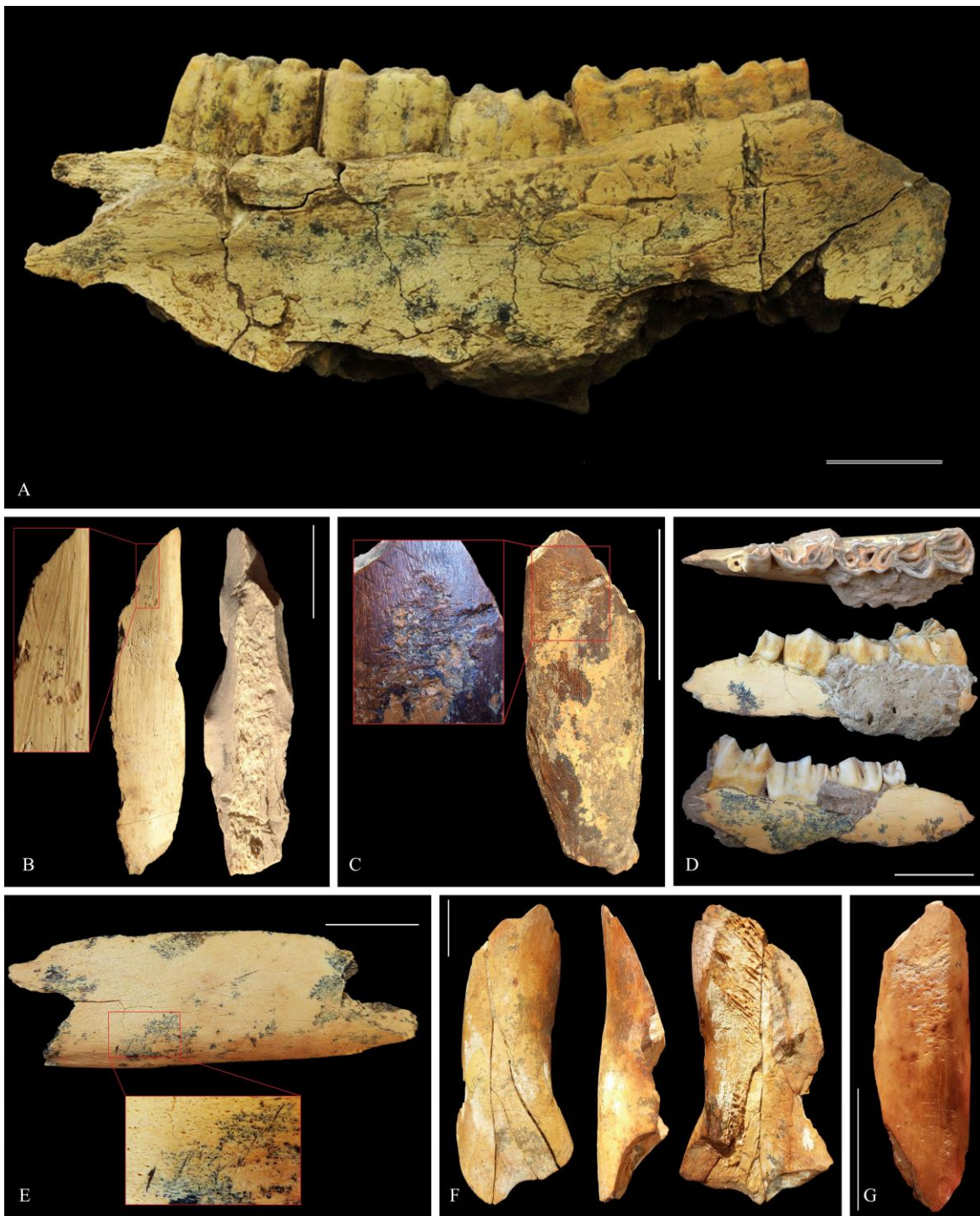
Archaeological levels	QK1		QK2		QK3		QK4-6		TOTAL	
	NR	%NISP	NR	%NISP	NR	%NISP	NR	%NISP	NR	%NISP
<i>Stephanorhinus hemitoechus</i>	-	-	-	-	-	-	1	7,7	1	0,3
<i>Bos primigenius</i>	-	-	1	0,7	3	1,3	-	-	4	1
<i>Equus</i> sp.	21	80,7	114	82,6	173	74,9	12	92,3	320	78,4
<i>Equus hydruntinus</i>	2	7,7	2	1,5	9	3,9	-	-	13	3,2
<i>Cervus elaphus</i>	1	3,9	15	10,9	27		-	-	43	10,5
<i>Capreolus capreolus</i>	-	-	1	0,7	3	1,3	-	-	4	1
<i>Capra</i> cf. <i>aegargus</i>	1	3,9	4	2,9	13	11,7	-	-	18	4,4
<i>Ursus arctos</i>	-	-	-	-	2	0,9	-	-	2	0,5
<i>Lepus</i> sp.	1	3,9	1	0,7	1	0,4	-	-	3	0,7
Total identified pieces	26		138		231		13		408	
Cetartiodactyla	2		5		9		-		16	
Indeterminate equid	6		23		21		4		54	
Indeterminate carnivore	1		1		-		1		3	
Large size herbivore	17		98		55		7		177	
Large/middle size herbivore	-		21		106		7		134	
Middle size herbivore	4		6		4		-		14	
Middle/small size herbivore	3		31		30		2		66	
Small size herbivore	16		20		26		3		65	
Indeterminate	48		195		262		20		525	
<b>TOTAL</b>	<b>123</b>		<b>538</b>		<b>744</b>		<b>1357</b>		<b>1465</b>	

436

437 NR=Total number of remains

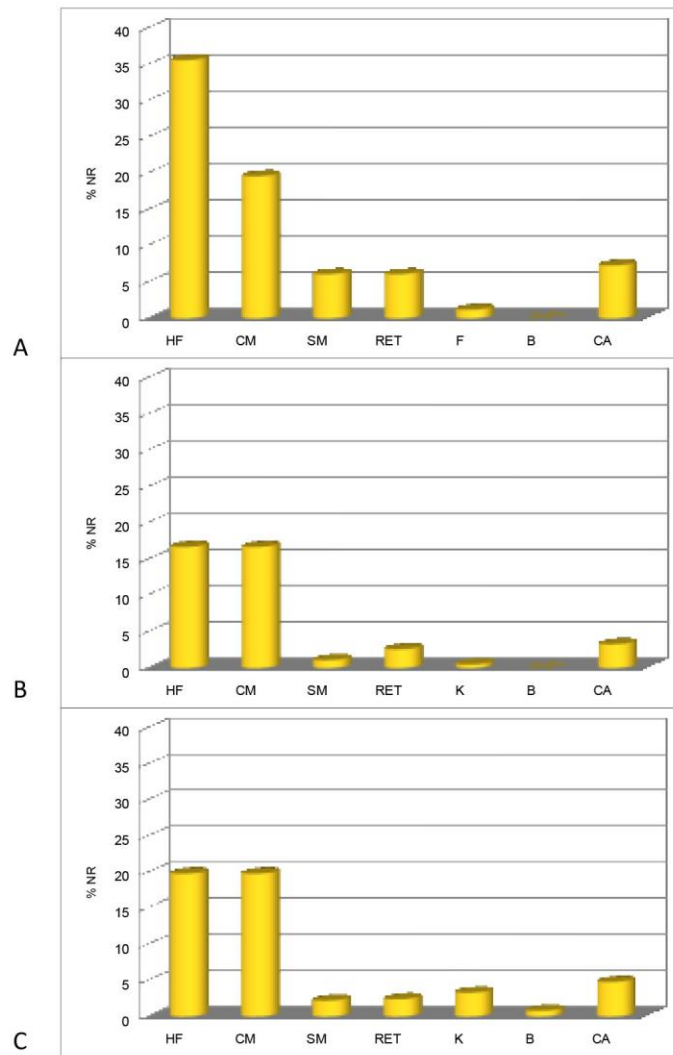
438 %NISP=number of identified specimens

439



440

441 Figure 13. Mammals' remains collected at Qaleh Kurd. A. Right mandible of a horse with P2-M2. B. Long bone  
 442 of a horse showing helical fracture, cutmarks and scrape marks; C. *Retouchoir* on a horse metapod associated  
 443 with numerous cutmarks and scrape marks. D. Left mandible of an adult deer. E. Cutmarks on the mandible of a  
 444 horse, for skin removal. F. Horse humerus with helical fracture and impact point. G. Double *retouchoir* on a deer  
 445 tibia. Scale, 3cm.



447

448 Figure 14. Percentage of remains with stigmata at Qaleh Kurd, from QK1 on top and QK3 at the bottom.

449 HF=helical fracture; CM=cutting marks; SM=scraping marks; RET=*retouchoirs*; F=flakes; B=burnt bones;

450

CA=carnivore marks.

451

452 QK2 yielded 538 remains representing 7 taxa (Table 5 and SI5b). The horse remains (82% of the corpus) are

453 represented by a juvenile and an adult. All anatomical parts are represented. The deer represents 10% of the

454 corpus and consists of a 4-5 years-old adult (Fig. 13D) and a juvenile; only the cranial parts and limbs are

455 represented. The other species are the hydruntine (*Equus hydruntinus*), the aurochs (*Bos primigenius*), the wild

456 goat (*Capra cf. aegargus*), the roe deer (*Capreolus* sp.) and the hare (*Lepus* sp.) are represented by few remains or

457 single individuals. The observed stigmata, although less numerous than in QK1 (Fig. 14B), support the  
458 anthropogenic origin of this accumulation (Fig. 13F).

459 QK3 has been more widely excavated and yielded 744 remains, of which 231 are identified, with large majority  
460 being horses, but also the red deer, the wild goat, the hydruntine, the brown bear (*Ursus arctos*), the roe deer, the  
461 aurochs and the hare are also present (Table 5 and SI5c). The horse remains are represented by one juvenile and  
462 one adult; all anatomical parts are present in the cave, including the spine and belts, except the phalanges. The  
463 deer is represented almost exclusively by the limb bones of one adult individual. The wild goat is represented by  
464 a 6-month-old juvenile and an older adult; the cranial skeleton is particularly well represented. This suggests that  
465 both species may have been treated differently, although their masses are quite similar. The hydruntine is also  
466 represented by a juvenile and an adult. The brown bear is a juvenile, presented only with two dental remains; it is  
467 impossible to determine the cause of death. Anthropogenic stigmata are numerous, including burnt bones, helical  
468 fracturing (Fig. 13F) and cutmarks on almost 20% of the material (Fig. 14C). Percussion flakes are numerous as  
469 well, which bears witness to the in-situ location of percussion activities.

470 The lower deposits (QK4-6) have been little excavated. They yielded mainly horses remains that represent at  
471 least 3 individuals, one juvenile and two adults. Several helical fractures and cutmarks have been observed. Note  
472 that a steppe rhinoceros (*Stephanorhinus hemitoechus*) remain has been identified (QK4) and that some scarce  
473 remains show carnivore trimming marks (QK6).

474 Across the sequence, the horse appears to be the main exploited taxon. However, from a general view, for all the  
475 herbivore taxa, the skeleton is fully represented in the assemblage. Limb portions and cranial skeleton as well as  
476 the rachis are well represented. The animals therefore appear to have been transported to the site in their entirety.  
477 However, concerning the horses, given the size of these animals and the topography of the cave, they were  
478 probably dismembered prior they were brought back to the cave. The joints of the long bones and metapods have  
479 been intensely and systematically fractured, whatever the size of the animals. This is evidenced by the large  
480 quantity of bone fragments combined with the presence of numerous percussion flakes. Several mandibles are  
481 also fractured. The number of pieces with helical fractures (N=266) and cut marks (N=259) are numerous in all  
482 levels. These stigmata are indices of butchering practices. All the striations were caused by the cutting of the  
483 meat. However, the number of pieces with scraping are rarer (N=27). In summary, these first observations show



484 the anthropogenic nature of the faunal assemblage, for each archaeological levels, and that all herbivorous taxa  
485 and their carcasses were subject to intensive food exploitation, for meat or for the yellow marrow of the long  
486 bones or the marrow of the mandibular canal.

487 Moreover, some bones were also used as *retouchoirs*. Ten *retouchoirs* have been collected *in situ* (29 others  
488 were collected in the reworked sediments) (Fig. 13C and 13G). The stigmata on the cortical surfaces that allow  
489 identifying *retouchoirs* are numerous and can be observed macroscopically and microscopically (e.g. see  
490 Daujeard et al., 2014). They consist in characteristic cupules and notches (Fig. 13C and SI6c). These bones were  
491 used to rearrange lithic edges, and the stigmata result of the several impact points produced against the lithic  
492 material. Almost only diaphyseal fragments of long bones and metapodials of horse, deer and wild goat were  
493 used. These species are the most commonly represented in the assemblage; this indicates an opportunistic  
494 tendency and not a choice toward a given species in the collection of pieces as *retouchoirs*. Most of the  
495 *retouchoirs* have a single retouching area; this indicates that they were generally used only once.

496

#### 497 Microvertebrate remains

498 Microvertebrate remains were collected through water sieving. To date, only preliminary observations were  
499 made on two test samples from T3. They revealed an interesting diversity, including several rodents (*Allactaga*,  
500 *Mesocricetus*, *Calomyscus*, *Meriones*, various voles including *Ellobius* and *Microtus* species) and, to a lesser  
501 extent, lagomorphs (Ochotonidae and Leporidae), bats, lizards (including Agamidae), snakes (including  
502 Colubridae) and small birds (See SI6). The anatomical representation of rodents is good, including small and  
503 fragile elements such as ribs and phalanges. A few traces of weak digestion have also been observed. This  
504 indicates that we are in the presence of a primary assemblage accumulated, at least in part, by predation (most  
505 probably owls). An in-depth study of the more abundant material collected during the excavation, will help to  
506 obtain more precise information on the species identifications, on the taphonomic history of the assemblages, as  
507 well as on the biochronological and palaeoenvironmental context of the human occupations.

508

## 509 **Discussion**

510

### 511 **A Middle Pleistocene sequence**

512 The archaeological and paleoanthropological corpus available from the Levant to the Caucasus and East Asia  
513 question the modalities and temporalities of the hominin dispersal over Eurasia during the Middle Pleistocene, as  
514 well as the diversity of hominins, their cultural traditions and possible interactions. Despite this rich regional  
515 context, no large assemblages in a clear chrono-stratigraphic framework that could be allocated to the Middle  
516 Pleistocene were available for the ICP and surroundings areas (the Zagros and the Alborz). Regarding the  
517 chronology, the Mousterian layer of Humian I, a rock shelter located in the Zagros delivered the single available  
518 date for the area; a single Th/U-series date on bone gave an age of  $148\pm 35$  ka (Bewley, 1984). More recently, a  
519 late Middle Pleistocene age has been proposed for the Darband Cave assemblage based on Th/U-series analysis  
520 of two bear teeth (Biglari and Jahini, 2011; Biglari et al., 2014). However, caution is requested regarding U-  
521 series dating of faunal remains since bones and teeth are open systems for uranium; this is particularly true in  
522 case of dating a bone based on a single sample, as done on Humian I (see Grün, 2006, for a review). Concerning  
523 U-series dating of a tooth, it is also acknowledged that for a same tooth, the ages vary according to the tissues.  
524 This led to couple U-Series with ESR analyses in order to model the kinetics of U-uptake on the tissues of a  
525 same tooth and provide a single age (see Grün et al., 1988). Finally, recent works have yielded more reliable  
526 dates for the edges of the northern ICP (Heydari et al., 2020) and for the Zagros (see Becerra-Valdivia et al.,  
527 2017 for a review of available radiocarbon original dates and Bayesian models for large archaeological  
528 sequences). So far, the oldest dates for the area was reported at Gareh Boof where the Middle Paleolithic  
529 deposits of the large archaeological sequence are dated from 81 to 45ka using optically stimulated luminescence  
530 (OSL) (Heydari et al., 2021).

531 At Qaleh Kurd, analyses have revealed a sedimentary succession represented by more than 2.5m thick record  
532 made up of two main sequences: a karstic and clastic sequence during the Middle Pleistocene including at least  
533 six archaeological levels (Sequence II), and a Holocene sequence including isolated archaeological material  
534 (Sequence I). The 10 ESR/U-series dates obtained on equid teeth collected in the excavated archaeological

535 levels, provide the first chronological framework for the deposit. Although other analyses (ESR/U-series in  
536 progress and TL) are requested in order to consolidate this framework, it is consistent with the stratigraphy and  
537 supports a middle Pleistocene occupation of the cave since ca 450ka (and most probably earlier since deeper  
538 archaeological deposits could not be excavated yet) that lasted at least ca 300ka, despite the high elevation of the  
539 site (2137m asl) and the large climatic fluctuations that occurred during this period. These results would push  
540 back to more than three hundred thousand years the earliest dated evidence of human settlement in the ICP and  
541 its direct surroundings (The Zagros and the Alborz Mountains). This framework is consistent with what is  
542 known in the Levant and Central Asia for the Middle Pleistocene, where human settlements are well documented  
543 by large and well dated archaeological sequences (e.g. Mercier and Valladas, 2003; Jacobs et al., 2019; Pan et  
544 al., 2020; Finestone et al., 2022; Hershkovitz et al., 2021).

545

#### 546 The hominins of Qaleh Kurd

547 Excavations at Qaleh Kurd yielded to the discovery of a deciduous human left first upper molar in the QK3  
548 level. The crown is highly worn and the root is almost totally resorbed, suggesting that it has probably been lost  
549 naturally during the child's life and was functional for some time. The crown is also affected in depth by two  
550 large caries. Caries have long been associated with agricultural diets; yet, several Pliocene and Pleistocene cases  
551 have been described in the literature, including decidual teeth, even if they represent only a small proportion of  
552 these cases. One can quote some cases of Pliocene specimens attributed to Early *Homo* and *Paranthropus*  
553 *robustus* from South Africa (Towle et al., 2019, 2021) or in the Levant, on specimens of Neanderthals at Kebara  
554 (Tillier et al., 1995) and modern humans from the late Middle Pleistocene at Qafzeh (e.g., Tillier, 2021).  
555 Although diet is the primary factor in caries formation (Sheiham and James, 2015), many other contexts can lead  
556 to caries formation including fatigue of the enamel due to a high level of mastication (Sanchez-Gonzalez et al.,  
557 2020) and/or high attrition (Hillson, 2008). In the state of analysis (paleoenvironmental and surface study of the  
558 tooth) it is premature to draw any conclusions on the origins of the caries of the Qaleh Kurd's deciduous tooth;  
559 nevertheless, given the high level of attrition, apart from diet, some functional insights could be proposed.

560 In terms of taxonomic affinities, the high degree of wear of the crown and the presence of two large caries  
561 significantly impact the metrics (Becam and Chevalier, 2019) and the potential taxonomically informative traits  
562 (Fornai et al., 2014). Although the bucco-lingual diameter corresponds to the range of variation known for  
563 Neanderthals and is below that of modern humans, this single measurement cannot be considered as conclusive  
564 in a taxonomic perspective. The morphology of the crown is also highly variable in archaic humans,  
565 Neanderthals and early modern humans, in occlusal view, from elongated to quadrangular and trapezoidal, from  
566 symmetrical to asymmetrical (e.g. Tillier, 1979b, 1980; Trinkaus, 1983; Tillier, 1999; Lumley de, 2018) with or  
567 without a *tuberculum molare*, as it is observed on the Qaleh Kurd specimen. This tubercle is inconstant and  
568 variably located (e.g. Thoma, 1963; Tillier, 1979b, 1980; Tillier, 1999; Tillier et al., 2003; Lumley de, 2018,  
569 2022). In summary, the crown of deciduous upper molars is highly variable in middle Pleistocene humans, both  
570 in metrics and morphology. Given the wear of the crown, the caries and the root resorption that affected the  
571 Qaleh Kurd specimen, the taxonomic attribution of the isolated Qaleh Kurd deciduous left first upper molar  
572 appears premature.

573 Finally, the whole chronology of the Qaleh Kurd archaeological sequence covers more than 300 thousand years  
574 of recurrent occupations during the Middle Pleistocene, starting at least from around 450 ka. During this large  
575 period of time, the presence of archaic humans, Denisovans and Neanderthals at the east and early Modern  
576 Humans, Neanderthals and possibly other species at the west have been reported (Mercier and Valladas, 2003;  
577 Chen et al., 2019; Jacobs et al., 2019; Pan et al., 2020; Hershkovitz et al., 2021; Finestone et al., 2022; Han et al.,  
578 2022). One cannot thus exclude that several human species could have occupied the cave of Qaleh Kurd, from  
579 archaic humans (*Homo erectus*?) to Denisovans, Neanderthals and/or early modern humans.

580

### 581 Early Middle Paleolithic Cultural affinities

582 Lithic tools in the upper Qaleh Kurd assemblages (QK1-3) are usually formal (see Andrefsky, 1994), made on  
583 flake and blade blanks. There are also some opportunistic, sparsely retouched pieces made on atypical flake or  
584 blade blanks. Typologically speaking, the overall picture of tool typology depicted in table 4 is the types  
585 expected from Middle Paleolithic contexts (see, e.g., Bordes, 1961; Debénath and Dibble, 1994; Geneste, 1985).

586 These include side scrapers and retouched convergent tools (including retouched points and convergent scrapers)  
587 made on flakes that are the dominant tool types across QK 1–3. Within the retouched convergent tools,  
588 Mousterian points are the most recurring tool type across all the three archaeological deposits. Some of the  
589 Mousterian points in Qaleh Kurd and most of them in QK3 are elongated. Endscrapers and Déjeté  
590 points/scrapers exist, but with much lower frequencies than side scrapers and retouched points. In addition,  
591 notched pieces are unpopular across all archaeological strata in Qaleh Kurd, denticulates are absent, and this is  
592 also the case for truncated-faceted pieces.

593 In comparison to local assemblages, QK 1-3 appear to share typological and technological traits with the Upper  
594 Pleistocene Middle Paleolithic assemblages of the Zagros (Bisitun rock shelter: Coon, 1951; Lindly, 1997;  
595 Warwasi rock shelter and Qobeh Cave: Braidwood et al., 1961; Dibble and Holdaway, 1993; Lindly, 1997; Gar  
596 Arjeneh rock shelter: Hole and Flannery, 1967; Lindly, 1997; Mar-Tarik cave: Jaubert et al., 2009; Kaldar:  
597 Bazgir et al., 2014). These shared traits are related to the high frequency of scrapers (especially side-scrapers) and  
598 points, few notches and denticulates and the comparable extent of the application of the Levallois method  
599 (Kamrani et al., 2022). In that respect, it is less similar to the ICP where these facies are unknown so far (Chahe-  
600 Jam: Vahdati Nasab and Hashemi, 2016; Mirak: Vahdati Nasab et al., 2019).

601 However, the QK 1-3 assemblages show also some traits that are known in the Early Middle Paleolithic of the  
602 Levant and the South Caucasus. These concern the high frequency of retouched points, either made on blades or  
603 elongated flakes (Meignen and Tushabramishvili, 2006, 2010; Mercier et al., 2010). As in the Levant and the  
604 Caucasus (Meignen and Tushabramishvili, 2010), such retouched elongated points are highly variable in their  
605 size, morphology, and retouch localization (e.g., Fig. 9a, d, j–l; Fig. 3a, b, d; Fig. 4a, b, d, e, h–j; Fig. 6). In  
606 addition, the assemblage displays symmetrical to asymmetrical points; they are sometimes reminiscent of what  
607 Neuville has called “pointes incurvées” (1951: 51, 52) or curved triangular points (Fig. 11e). In addition, in  
608 QK3, inverse retouching and hence, bifacial shaping, is observed on few points (Fig. 11h, i) as in the Caucasian  
609 early Middle Paleolithic (Meignen and Tushabramishvili, 2010). Ventral retouching/thinning, especially in the  
610 proximal and dorsal parts of the points, is less common at Qaleh Kurd than in the South Caucasus (Beliaeva and  
611 Lioubine, 1998; Golovanova and Doronichev, 2003). At QK 1-3, thinning usually occurs in proximal-basal parts

612 and with direct retouching/chipping; this suggests preparation for hafting (Figures 9, 10, 11). Finally, broad-  
613 based Levallois points with chapeau de gendarme striking platforms are rare in QK 1-3 contrary to the later so-  
614 called Tabun-B assemblages in the Levant (e.g., in Kebara units IX-X, Tor Faraj, Tabun I 1-17; Bar-Yosef and  
615 Meignen, 2001).

616 The other feature of the retouched tools at QK 1-3 is the presence of thick narrow retouched blades especially in  
617 QK2 (Figure 10b, e, f). These are similar to those recorded in the Levant in the Amudian entity in Tabun XI  
618 (Meignen and Tushabramishvili, 2010), and the early Middle Paleolithic assemblages of Abou Sif C–D  
619 (Neuville, 1951), Hummal Ia (Copeland, 1985), Hayonim lower E and F (Meignen, 1998; Meignen and Bar-  
620 Yosef, 2020), but also those of the early Middle Paleolithic “Kudaro-Djruclian” entity in the South Caucasus  
621 (e.g., Tushabramishvili, 1963 in Meignen and Tushabramishvili, 2010). Such thick elongated blades could have  
622 been struck from narrow cores with highly oblique lateral sides in cross section (Meignen, 1998). This technic  
623 has not yet been identified at Qaleh Kurd. Regarding elongation, the lithic blanks of QK 1–3’s tools mostly  
624 resemble those of Tabun-D type (Phase I Mousterian in Jelinek, 1982). They are elongated and  
625 convergent/pointed elongated and they differ from the suboval-subquadrangular blanks of the Tabun-C type  
626 (Bar-Yosef, 2008). Such blanks at Qaleh Kurd does not represent sub-parallel lateral edges, contrary to what in  
627 observed in Tabun-D type assemblages such as Abou Sif C and B (Copeland 1975, 1981). Albeit there are  
628 instances of non-elongated flake blanks in QK 1–3, they were not retouched for the most part. Preliminary  
629 analysis indicates that the flintknappers were strongly selective in choosing more elongated and thicker flakes  
630 for further retouching. This recall the Amudian as well as the Early Middle Paleolithic entities of the Levant and  
631 the Caucasus (see e.g., Meignen, 2007; Meignen and Tushabramishvili, 2010).

632 Few transverse and end-scrapers with Quina-like retouch and named here as demi-Quina scrapers (Figure 8g),  
633 are recorded from QK 1 to QK 3. They are made on thick and broad flakes. They belong to the Mousterian lithic  
634 type-lists of Europe (see e.g., Bordes, 1981; Bourguignon, 1997; Peresani et al., 2023). They are almost absent in  
635 the Levantine Mousterian (Agam and Zupancich, 2020), while they are known in the Acheulo-Yabrudian  
636 complex from late Lower Paleolithic or Lower-Middle Paleolithic boundary (Agam and Zupancich, 2020;  
637 Malinsky-Buller, 2016; Meignen and Bar-Yosef, 2020; Shimelmitz et al., 2014; Zaidner and Weinstein-Evron,  
638 2006). In the South Caucasus, they are recovered from both Acheulo-Yabrudian-like lithic assemblages as in

639 Tsopi (Grigolia, 1963 in Golovanova and Doronichev, 2003) and early Middle Paleolithic assemblages as in  
640 sites of Kudaro-Djruchulian context (Golovanova and Doronichev, 2003). Finally, Upper Paleolithic tools types  
641 are not common in Qaleh Kurd while they are prevalent in some of the Levantine early Middle Paleolithic sites  
642 (such as Hayonim lower E and F, Hummal Ia, Abou Sif; see Meignen and Tushabramishvili, 2010; Neuville,  
643 1951).

644 Blade production (laminar and elongated blanks) is significant in Qaleh Kurd but does not dominate other  
645 productions as it is the case in the Levantine early Middle Paleolithic (see e.g., Wojtczak and Malinsky-Buller,  
646 2022). In addition, like the Levantine early Middle Paleolithic (e.g., Wojtczak, 2022; Wojtczak and Malinsky-  
647 Buller, 2022), reduction schemes in Qaleh Kurd were diverse, with the presence of Levallois, laminar, and core-  
648 on-flake strategies. However, the Levallois method is not preferably used for blade production in Qaleh Kurd  
649 Cave contrary to what is reported for the Levantine early Middle Paleolithic (see Wojtczak and Malinsky-Buller,  
650 2022).

651 In summary, this first comparative analysis of the QK 1-3 lithic assemblages highlights some affinities with the  
652 Middle Pleistocene Early Middle Paleolithic of the Levant and the Caucasus that places it in an early Middle  
653 Paleolithic tradition. However, it highlights as well some affinities with the Upper Pleistocene Middle Paleolithic  
654 known in the Zagros that opens new insights in the origin of the Zagros Mousterian. Conducting new  
655 excavations and analyses at Qaleh Kurd are thus of great importance for our knowledge on the diversity of the  
656 early Middle Paleolithic cultures in the area as well as on the origin of local Mousterian facies.

## 657 658 Biochronological and Paleoenvironmental overview and perspectives

659 The Pleistocene upper units at Qaleh Kurd have yielded a faunal assemblage from which a first biochronological  
660 overview and some perspectives can be proposed. Several large mammals have been identified, including large  
661 horse (*Equus ferus* sensu lato) but also the red deer (*Cervus elaphus*), the hydruntine (*Equus hydruntinus*), the  
662 wild goat (*Capra* cf. *aegargus*), the roe deer (*Capreolus* sp.), the aurochs (*Bos primigenius*), the brown bear  
663 (*Ursus arctos*) and also the steppe rhinoceros (*Stephanorhinus hemitoechus*). Most of these taxa have a broad  
664 temporal distribution; their relevance for biochronological purposes is thus limited. They correspond to

665 "modern" taxa resulting from the major faunal renewal observed at the Lower-Middle Pleistocene transition. The  
666 brown bear *Ursus arctos*, identified in QK3, although known from the very beginning of the Middle Pleistocene  
667 in Asia (Zhoukoudian, Jiangzuo et al., 2018) is only described in the region in the Upper Pleistocene site of  
668 Wezmeh (Mashkour et al., 2009; Monchot et al., 2020). Aurochs is a taxon of African origin; its dispersal in  
669 Eurasia dates back to 0.7 Ma (Martinez-Navarro et al., 2007). *Bos sp.* and *Cervus elaphus* are notably identified  
670 around 0.8 Ma in the Levant (Gesher Benot Ya'aqov, Rabinovich and Biton, 2011). *Stephanorhinus*  
671 *hemitoechus*, identified in the lower archaeological deposit, is a species recognized mainly in Europe, although it  
672 may have spread to the Near East and North Africa (Pandolfi et al., 2021). Rhinoceros is reported from Wezmeh  
673 and Gilvaran at the west-central Zagros (Mashkour et al., 2009; Bazgir et al., 2014). It has also recently been  
674 determined in recent Middle Pleistocene deposits in Jordan (Pokines et al., 2019) and in Azerbaijan (Van der  
675 Made et al., 2016). The oldest record of *S. hemitoechus* is in Western Europe at around 0.55 Ma (Caune de  
676 l'Arago, Chen and Moigne, 2018). In Qaleh Kurd, in state of research, it is represented by a single remain which  
677 makes impossible any biochronological inference as it has been done for the Middle Pleistocene of Europe  
678 (Lacombat, 2009). Moreover, the lack of fossils makes it impossible to know whether the model is valid in  
679 Central Asia. Concerning the equids, two species have been described at Qaleh Kurd: a caballine horse and  
680 *Equus hydruntinus*, related to present-day hemiones. The later is more common in early Holocene in Iran but has  
681 also been determined in Pleistocene context (Orlando et al., 2006; Benett et al., 2017; Eisenmann and Mashkour,  
682 1999). The two species are frequently found in sympatry. Biochronological indications could be deduced from  
683 the study of horses by combining certain evolutionary and ecomorphological characters (Boulbes and van  
684 Asperen, 2019). As a preliminary approach, a comparative analysis of the medium to large dimensions of the  
685 teeth (See SI7 for comparative metrics and clustering analysis) places the Qaleh Kurd specimens closer to the  
686 Middle Pleistocene populations (including *Equus mosbachensis* and late Middle Pleistocene caballine equids)  
687 (Forsten and Moigne, 1998; Boulbes, 2010; Uzunidis-Boutillier, 2017). However, the available material is not  
688 yet statistically representative enough to confidently address this topic. In addition, although horses in Eurasia as  
689 a whole underwent a decline in size that accelerated at the beginning of the Upper Pleistocene (Nobis, 1971;  
690 Forsten, 1991; Boulbes and van Asperen, 2019), this global reduction is not absolute (Eisenmann, 2022), and  
691 such trend remains to be verified in Central Asia and the ICP. Thanks to new excavations, Qaleh Kurd, with its



692 assemblages rich in horses, could constitute a key site for this topic as well. Finally, it is interesting to note that  
693 all the species present at Qaleh Kurd are also recorded in the large revised faunal list of Middle Pleistocene  
694 levels dated to 0.3-0.2 Ma from Azokh Cave in the Lesser Caucasus in Azerbaijan (Van der Made et al., 2016).  
695 In summary, although preliminary, given the number of pieces collected so far, the composition of the faunal  
696 sample and the metrics of the horse are consistent with a Middle Pleistocene settlement of the cave as supported  
697 by the chronological data. Given the quantity of horse material collected during the first excavations at Qaleh  
698 Kurd spanning all over the stratigraphic sequence, additional fieldwork could yield sufficient material in support  
699 of a biochronological model for the area.

700 In a paleoecological perspective, the composition of the well represented large mammals and their relative  
701 abundance do not vary in the Pleistocene deposits of Qaleh Kurd. However, the samples by levels is not  
702 numerous enough yet to allow any statistical modelling. The horse, which is the dominant taxon at Qaleh Kurd,  
703 is generally considered a highly specialized "grazer". However, palaeontological evidence shows that horse  
704 experienced a wide range of habitats from interglacial open forests to grassy steppes during glacial episodes  
705 (Pushkina et al., 2014; Rivals et al., 2015; Saarinen et al., 2016; Uzunidis, et al., 2017). Like the hemiones,  
706 *Equus hydruntinus* was adapted to semi-arid and steppe conditions with a preference for temperate climates,  
707 although it could tolerate a moderate cold (Boulbes and van Asperen, 2019). Among cervids, *Cervus elaphus* is a  
708 eurytopic species with considerable dietary flexibility. The roe deer is tolerant of temperature variations but it is  
709 more limited to a browser-type diet and prefers wooded areas (Rivals and Lister, 2016; Sommer et al., 2009).  
710 Aurochs are most often linked to interglacial contexts, and their numbers generally increase in phases of  
711 Pleistocene climatic improvement (Brugal et al., 2020). The steppe rhinoceros (*Stephanorhinus hemitoechus*)  
712 which is identified in the lower level QK4-6, inhabited temperate open forest environments rich in low  
713 vegetation. It appears to be the most ubiquitous and least moisture-dependent species of the genus; the species  
714 tend to follow the Mediterranean environment during interglacial periods (Pandolfi et al., 2017; Lacomat, 2009;  
715 Fortelius et al., 1993). Finally, the ibex *Capra aegargus* is one of the most widely dispersed rock mammals in  
716 many habitats in Iran. The species is highly dependent on rocky substrates and steep slopes to avoid predators  
717 (Sarhangzadeh et al., 2013). As a preliminary overview, the large fauna which is relatively similar from QK3 to  
718 QK1 is consistent with interglacial (or interstadial) depositional conditions although the assemblage is not rich

719 enough to allow any robust inferences. However, the composition of the fauna of these levels implies a diversity  
720 of biotopes around the site.

721 The microvertebrate assemblages from Qaleh Kurd are still under study. However, preliminary observations  
722 demonstrate the presence of *Allactaga*, *Meriones*, *Ellobius* and *Mesocricetus* which indicates steppe  
723 environments. *Calomyscus* frequents rocky mountain steppe and shrubland habitats. These observations is  
724 consistent with the high elevation of the cave (over 2100m asl). Numerous samples from the whole sequence are  
725 available for sorting and study, and it makes no doubt that future investigations will provide significant  
726 biochronological and palaeoenvironmental information for the Middle Pleistocene settlement of Qaleh Kurd and  
727 the Northern ICP.

728

#### 729 Subsistence behaviours: Intensive exploitation of the fauna by humans

730 Carnivores are known to be agents of bone accumulation in Pleistocene sites where they may compete with  
731 humans. This has been demonstrated from the Lower Pleistocene (e.g., in Barranco León, Spain, Courtenay et  
732 al., 2023) to the Upper Pleistocene (e.g., in Wezmeh, Zagros, Iran, Mashkour et al., 2009). However, in Qaleh  
733 Kurd, beside the two teeth of *Ursus arctos*, few pieces with carnivore traces have been collected so far,  
734 suggesting that the role of carnivores in the accumulation of the deposit was very limited.

735 Conversely, for the 3 levels mainly investigated, the role of humans in the accumulation of the deposits appears  
736 to be essential for food purpose as in other Pleistocene sites (e.g., Daujeard, 2008; Romandini et al., 2014;  
737 Sévêque, 2017). For all herbivore taxa, animals appear to have been transported to the site almost in their  
738 entirety. Concerning the horses, considering the size of these animals and the topography of the site, it could  
739 have been brought in pieces into the cave. The analysis of the assemblage show that anthropogenic stigmata are  
740 numerous and indicate that humans in Qaleh Kurd intensively exploited herbivor and their carcasses for meat or  
741 for the yellow marrow of the long bones or the marrow of the mandibular canal. This feature is common to both  
742 past and present hunter-gatherer populations (e.g., Binford, 1981; Abe, 2005 for present-day groups, Delpéch  
743 and Villa, 1993; Farizy et al., 1994; Auguste, 1995 for Pleistocene groups). Apart from bone marrow and  
744 mandibular canal marrow, one cannot exclude that humans have recovered fat from bone tissue (joints,

745 phalanges, short bones) (Delpech and Villa, 1993; Brink, 1997; Speth, 2012; Costamagno and Rigaud, 2014).  
746 This process, considered universal (Outram, 2001), involves boiling, as ethno-archaeological work shows (e.g.,  
747 Binford, 1981; Nelson, 2010). Nevertheless, to date, no deposits that could be interpreted as slurry discharge  
748 have been identified at Qaleh Kurd.

749 Bones can also be exploited as tools (e.g., Vincent, 1993; Moncel et al., 2012; Blasco et al., 2013; Daujeard et  
750 al., 2014; Moigne et al., 2016; See Hutson et al., 2018 for a review). This study show that it has been the case at  
751 Qaleh Kurd where numerous bone *retouchoirs* have been collected in the Middle Pleistocene sequence, from the  
752 earliest deposits to the most recent (Fig. 13 and SI2c). This is the first mention of *retouchoirs* in Paleolithic sites  
753 of the ICP and immediate surroundings. Finally, the *retouchoirs* at Qaleh Kurd appear consistent with those  
754 known in Pleistocene Eurasian series. As in Qaleh Kurd, almost exclusively diaphyseal fragments of long bones  
755 and metapodials were used in these Eurasian series (Vincent, 1993; Armand and Delagnes, 1998; Daujeard et al.,  
756 2014; Sévêque and Auguste, 2018).

757

## 758 **Conclusion**

759 Excavations at Qaleh Kurd cave, have yielded one of the largest anthropogenic assemblages of the ICP, the  
760 Zagros and the Alborz, in a precise chrono-stratigraphic framework. So far, our studies have focused on the first  
761 extensively excavated archaeological assemblages. The consistent chrono-stratigraphic framework for the whole  
762 deposit and the faunal and lithic characteristics of the upper levels, demonstrate that the cave, which is located at  
763 2130m asl, was recurrently occupied by humans during the middle Pleistocene from ca 450ka and during at least  
764 300ka. This makes Qaleh Kurd the oldest evidence so far of Middle Pleistocene human settlements in the ICP  
765 and immediate surroundings (the Alborz and Zagros Mountains) and pushes back the earliest evidence of human  
766 settlement in this region to more than 300ka. This fieldwork and multidisciplinary analysis at Qaleh Kurd  
767 strongly support the need of systematic surveys, including high elevated region, as well as long term excavations  
768 in the ICP and surroundings.

769 The reported early Middle Paleolithic cultures recalls in some traits those known in the Caucasus and the Levant  
770 but also suggest resemblance to later Zagros Mousterian facies known from the region. This opens new insights  
771 in the early stages of Middle Paleolithic cultures in the area as well as in the origin of the Zagros Mousterian.  
772 Regarding the hominin species that may have occupied the site, the taxonomic attribution of the discovered  
773 human tooth cannot be specified in state of analysis. However, the chronology of the site and the  
774 paleoanthropological knowledge from the Levant to Central Asia for this trench of time, may support the idea  
775 that several hominin species could have occupied the site, at least successively.

776 From a general point of view, chronological, archeological, paleontological and paleoanthropological findings  
777 make Qaleh Kurd of great interest for the knowledge of early hominin settlements, as well as biological and  
778 cultural diversity from the Levant to Central and East Asia. Fieldworks and analysis are currently conducted to  
779 enrich what we started to investigate in this contribution, and to improve our knowledge of earlier periods  
780 recorded in the Qaleh Kurd sequence.

781

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802

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804

### 805 **Ethical Approval**

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807

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820

821 **Availability of data and materials**

822 No data outside the submitted manuscript file

823 Data and materials may be made available on demand to first authors; archaeological materials being under the care  
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825

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1291



## 1 SUPPLEMENTARY INFORMATION

### 3 SII: Geoarcheological laboratory analysis – Applied Methods

4 Field naked eye observations and sketches of the deposits allowed *in situ* identification of the main units.  
5 In addition, several laboratory analyses have been started at the UMR7194's laboratories in Paris, after  
6 the samples have been exported with the authorization of the Iranian Center for Archaeological Research  
7 (ICAR).

8 Grain-size analysis - Grain-size Analysis gives information of transport, sorting and hence genesis for  
9 the sediment. A total of 117 sediment samples were made every 5cm accordingly to the units in both  
10 sections of T1 and the northern section of T3. The particle size distribution was then measured on crude  
11 and acid treated samples by laser granulometry using a Mastersizer 3000 from MALVERN at the  
12 sedimentology laboratory of the Musée de l'Homme (UMR 7194) in Paris. The USDA scale was used  
13 as a basis for classification of the grain sizes.

14 Micromorphological Analysis – In order to specify the nature and the attributes of sediments,  
15 microscopic observations of the soil micromorphology were made. Four blocks of sediments from the  
16 southern and western walls of T1 and four blocks from the southern wall of T3 were extracted, from  
17 which 10 petrographic thin sections were prepared at the sedimentology laboratory of the Institut de  
18 Paléontologie Humaine (UMR 7194) in Paris. The thin sections are described using a polarizing  
19 microscope at the sedimentology laboratory of Musée de l'Homme (UMR 7194) in Paris.  
20 Micromorphological analyses allowed recognizing some forming factors, post-depositional changes and  
21 impact of human on deposits. Thin sections are still under analysis and should allow as well contributing  
22 to some paleoenvironmental inferences.

23 Complementary ongoing analyses - FTIR (Fourier Transform Infrared) analysis aims at identifying  
24 organic and inorganic materials in the sediments. Seven powder samples were analyzed by FTIR-ATR,  
25 on a Bruker Vertex 70 spectrometer equipped with a global source, a KBr beamsplitter, and a DLaTGS  
26 detector. The analyses were carried out at the *Plateau de Spectroscopie Infrarouge – Plateau Analytique*  
27 *du Muséum*, at Musée de l'Homme in Paris. Determination is conducted after comparison with the  
28 Plateau de Spectroscopie internal database (to be published). To complete our knowledge on  
29 mineralogy, nature and provenance of the sediments, a series of XRD analyses is implemented on 6  
30 sediment samples from the northern section of T1 using a Bruker XRD (D2) device. Finally, the  
31 magnetic susceptibility variations along the North Section of Trench I is measured. The magnetic  
32 susceptibility is the capacity of a body to acquire an induced magnetisation in an applied magnetic field.  
33 In the sediment, the magnetic susceptibility provides information on the proportions of carbonates  
34 (diamagnetic), clays (paramagnetic) and magnetic oxides (ferro- and ferrimagnetic). Its variations

35 indicate changes in the mineralogy, concentration and size of magnetic grains. These magnetic minerals  
36 are sensitive to the paleoclimatic and paleoenvironmental variations. The magnetic susceptibility ( $\chi$ ) of  
37 sediment samples is measured with a Bartington MS-2 Susceptibility Meter coupled with a MS2B dual  
38 frequency sensor. Low frequency ( $\chi_{lf}$ , 0.46 kHz) is applied and measured 3 times in an ambient  
39 temperature room; the average value is used for analysis.

40

41 **SI2 : Stratigraphic divisions and character of the sediments in the trench T3**

42

<i>Sequence</i>	<i>Unit</i>	<i>Thickness (cm)</i>	<i>Nature</i>	<i>Structure</i>	<i>Comments</i>
<i>I</i>	1	~ 15	Brown gravelly sandy silt	Reworked	Polygenetic superficial soil cover containing root traces, whitish gray slightly granular centimetric interbeds of ash and charcoal.
	2	~ 10	Whitish gray silt	Massive	Thin interbeddings of ash with lenticular geometry containing dark organic nodules.
	3	~ 7	Brown silt	Slightly granular	Polygenetic calcareous soil containing white calcareous nodules.
	4	~ 10	Light gray silt	Slightly granular	Subangular (local) gravel and centimetric charcoal.
	5	~ 7	Brown sandy silt	Slightly granular to massive	Contains soil nodules.
	6	~ 5	Light gray silt	Massive	Contains millimetric interbeddings of gray ash and charcoal. Lenticular geometry.
	7	~ 8	Brown to gray silt	Slightly granular	Contains charcoal and evidence of Fe migration. Probably a paleosol with eroded upper limit.
	8	~ 2	Whitish gray silt	Slightly granular	Contains brown soil nodules.
	9	~ 8	Black slightly sandy silt	Slightly granular	Contains reddish brown silt with granular structure that resembles a Fe segregation zone, at the bottom.
	10	~ 25	White to light gray gravelly silt	Slightly granular to massive	Contains subangular gravels and flat cobbles, interbeddings of gray sediment (ash). Affected by large bioturbation.
	11	~ 6	Black organic silt	Slightly granular	Probably an aggregated humic paleosol, with a facies of reddish brown silt with granular structure that resembles a Fe segregation zone at the bottom.
	12	~ 20	Very light gray silty sand	Slightly granular	Probably resulted from degradation of some calcareous beddings.
	13	~ 10	Cobbly gravelly sandy silt	Crudely stratified	Calcareous flat gravels (medium to coarse) and clasts.
<i>II</i>	14	~ 5	Gray silty sand	Granular	Consolidated by calcareous cement.
	15	~ 20	Very light brown sandy silt	Massive	Composed of very loose and well-sorted infilling sediments (loess).
	16	~ 20	Light brown gravelly sandy silt	Crudely stratified	Flat calcareous gravels.
	17	~ 2	Very dark brown organic silt (loess)	Slightly granular	Eroded top horizon of a paleosol formed in loess deposits.
	18	~ 10	Light brown silt (loess)	Slightly granular	Weakly stratified calcareous gravels.
	19	~ 6	Brown sandy silt	Slightly granular	Coarse grain and humic.
	20	~ 5	Dark brown organic silt	Slightly granular	Contains millimetric charcoal.
	21	~ 23	Greenish brown silt	Slightly granular	Evidence of gley distribution, contains Fe oxide migration zones.

22	~ 5	Gray to dark brown organic silt (ash)	Massive	Contains calcic precipitation at the bottom.
23	~ 10	Greenish brown silt	Slightly granular	Evidence of gley distribution, contains Fe oxide migration zones.
24	~ 2	Gray to dark brown organic silt	Massive	
25	~ 10	Brown silt	Granular	Calcareous flat clasts with crude stratification. This unit is probably a paleosol.
26	~ 10	Brown gravelly silt	Crudely stratified	Gravelly erosion near the top.
27	~ 30	Brown cobbly gravelly silt	Granular	Unstratified calcareous clasts.
28	~ 5	Yellowish brown silt	Granular	White calcareous gravels and sand-sized nodules.
29	~ 3	Dark brown to black organic clayey silt	Granular	Eroded.
30	~ 7	Yellowish brown gravelly silt	Granular	White calcareous gravels with lenticular geometry. Very eroded.
31	~ 5	Dark brown to black organic clayey silt	Granular	Contains yellow colored nodules of consolidated mudstone.
32	~ 7	Yellowish brown gravelly silt	Granular	White calcareous gravels. Very eroded and irregular at the upper limit.
33	~ 8	Dark brown to black organic clayey silt	Granular	
34	~ 10	Brown gravelly clayey silt	Granular	

43

44 **Table S12** – Stratigraphic divisions and character of the sediments in the trench T3. (© M. Akhavan Kharazian and G. Jamet)

45

46 **SI3: ESR/U-series dating**

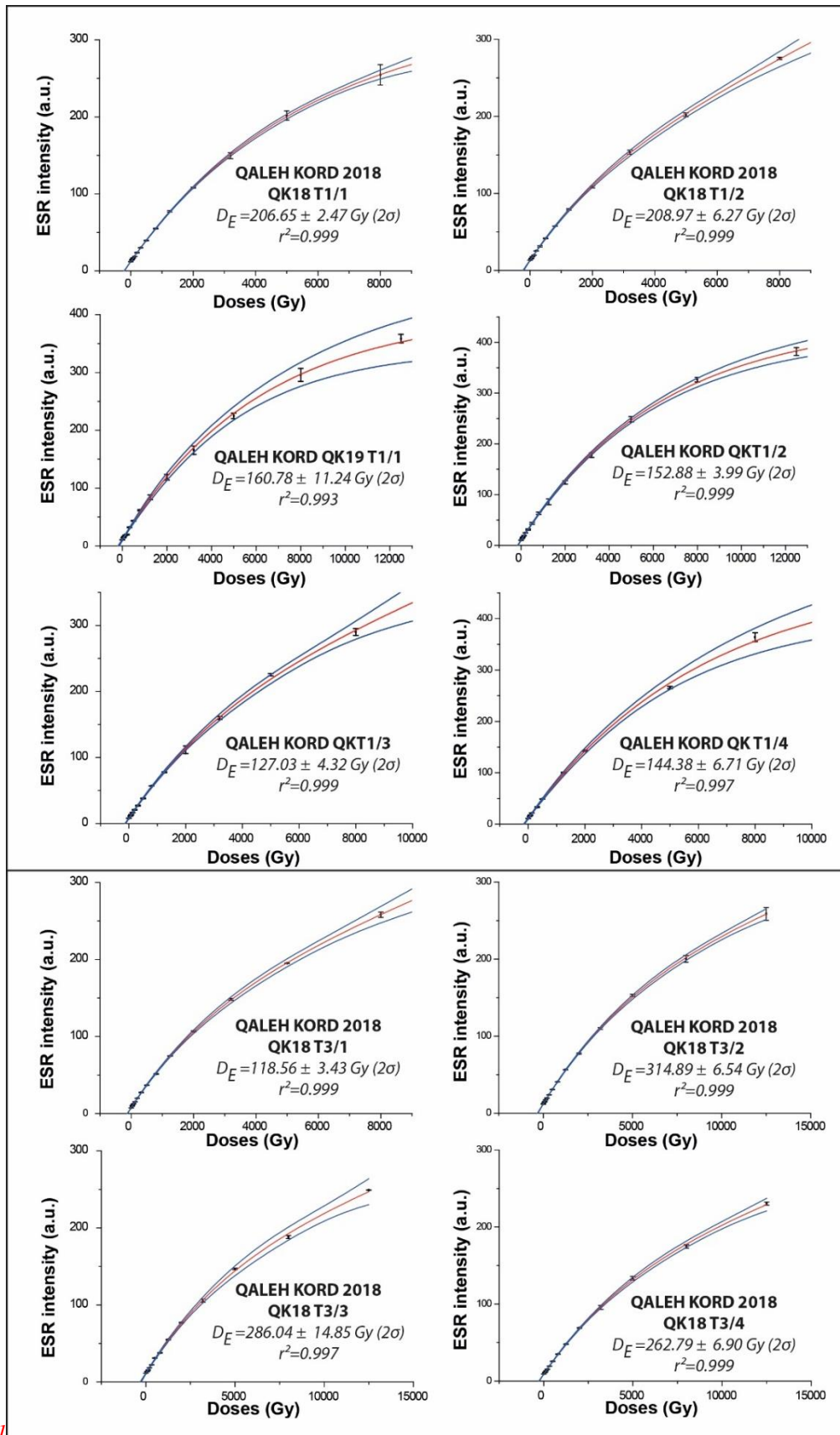
47 Preparation - Part of an external enamel layer was mechanically extracted from each tooth, then cleaned  
 48 on each side with a dental drill to avoid any contamination by sediment, cement or dentine. The cleaned  
 49 enamel fragments were then grounded and sieved in order to extract the 100-200  $\mu\text{m}$  grain-size fraction.  
 50 This fraction was split into fourteen aliquots, thirteen of them were irradiated at the CENIEH (Burgos,  
 51 Spain) using a  $^{60}\text{Co}$  gamma source at different gamma doses ranging from 32 to 8,000 or 12,500 grays  
 52 (Gy) depending on the aliquot and the sample.

53 ESR measurements -The fourteen aliquots, for each enamel sample, were measured using a Bruker EMX  
 54 spectrometer using the following parameters: 10 mW microwave power, 0.1 mT modulation amplitude,  
 55 room temperature, 10 mT scan range, 4 mins scan time and 100 kHz frequency modulation, at least four  
 56 measurements for each aliquot were performed on different days. The ESR intensities were measured  
 57 on each obtained spectrum from the  $g = 2.00018$  enamel ESR peak-to-peak (T1-B2) signal according to  
 58 Grün (2000).

59 Equivalent doses determination -The equivalent doses  $D_E$  were extrapolated from the obtained dose-  
 60 intensity data sets. The growth curves were built for each sample using three different fitting functions:  
 61 single saturating exponential, SSE; double saturating exponential, DSE; exponential plus linear, E+L.  
 62 The obtained results are displayed in **Table SI3a** and the best fitting curves displayed on **Figure SI3a**.  
 63 For the Qaleh Kurd samples, depending of the obtained curve descriptions, SSE or E+L equivalent doses  
 64 were used for the age calculation.

Samples	SSE	$r^2$	E+L	$r^2$	DSE	$r^2$
QK18 1/1	<u>206.65 ± 2.47</u>	<u>0.99974</u>	205.36 ± 3.38	0.99973	205.05 ± 5.57	0.99970
QK18 1/2	223.25 ± 6.27	0.99857	<u>208.97 ± 6.27</u>	<u>0.99926</u>	208.97 ± 8.94	0.99917
QK19 T1/1	<u>160.78 ± 11.24</u>	<u>0.99275</u>	157.07 ± 14.01	0.9922	157.07 ± 18.05	0.99134
QK19 T1/2	<u>152.88 ± 3.99</u>	<u>0.99896</u>	151.49 ± 4.96	0.99888	148.98 ± 7.07	0.99884
QK19 T1/3	131.31 ± 6.71	0.99893	<u>127.03 ± 4.32</u>	<u>0.99906</u>	125.64 ± 6.02	0.99901
QK19T1/4	<u>144.38 ± 3.66</u>	<u>0.99741</u>	140.33 ± 8.93	0.99725	140.34 ± 12.62	0.99669
QK18 3/1	124.55 ± 3.51	0.99870	<u>118.56 ± 3.43</u>	<u>0.99920</u>	117.47 ± 4.93	0.99912
QK18 3/2	324.88 ± 5.74	0.99944	<u>314.89 ± 6.54</u>	<u>0.99960</u>	314.70 ± 9.44	0.99955
QK18 3/3	298.58 ± 11.65	0.99737	<u>286.04 ± 14.85</u>	<u>0.99755</u>	286.04 ± 20.84	0.99727
QK18 3/4	272.34 ± 6.14	0.99913	<u>262.79 ± 6.90</u>	<u>0.99935</u>	262.79 ± 6.90	0.99928

65  
 66 **Table SI3a** – Equivalent doses determined for the Qaleh Kurd teeth using different mathematical extrapolation functions. The  
 67 underlined values were used for the age calculation. SSE= single saturated exponential function; E+L=function composed by  
 68 a linear and an exponential terms; DSE = function composed by two single saturated exponential terms. Uncertainties are given  
 69 at 95% ( $2\sigma$ ) of confidence.



71

72

Figure S13a – Dose growth curves obtained for the Qaleh Kurd samples.

73 U-series analyses - U-series analyses were performed on each dental tissue in order to determine the U-  
74 uptake parameters necessary to the dose rate contributions and age calculations (see details in [Shao et](#)  
75 [al., 2015](#)). In this work, two kinds of analyses were realized. The enamel samples were analysed on a  
76 Thermo Electron Neptune Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-  
77 ICPMS) at Nanjing Normal University, China, and the dentine and cement samples were performed on  
78 a Thermo Electron iCAP-RQ Quadripole Inductively Coupled Plasma Mass Spectrometer (Q-ICP-MS)  
79 at MNHN, Paris. The chemical protocol of [Shao et al. \(2011\)](#) was used for all the analyses. The obtained  
80 results are displayed in [Table SI3b](#).

Sample	Tissue	U (ppm)	<sup>230</sup> Th/ <sup>232</sup> Th	<sup>234</sup> U/ <sup>238</sup> U	<sup>230</sup> Th/ <sup>234</sup> U	Apparent U-series age (ka)	<sup>222</sup> Rn/ <sup>230</sup> Th	Initial thickness (μm)	Removed thickness Internal side (μm)	Removed thickness External side (μm)
QK18 T1/1	enamel	0.242 ± 0.005	288	1.473 ± 0.032	0.889 ± 0.020	192 + 13/-11	0.249	1031 ± 103	79 ± 8	172 ± 17
	dentine	8.576 ± 0.195	>9800	1.333 ± 0.029	0.668 ± 0.015	113 ± 5	0.562			
	cement	6.041 ± 0.159	>1200	1.414 ± 0.034	0.785 ± 0.021	149 +9/-8	0.058			
QK18 T1/2	enamel	0.300 ± 0.006	309	1.526 ± 0.031	1.053 ± 0.023	319 +43/-32	1.000	1580 ± 158	206 ± 21	238 ± 24
	dentine	7.824 ± 0.214	>15000	1.339 ± 0.030	0.685 ± 0.015	118 ± 5	0.352			
	cement	7.333 ± 0.157	>2400	1.403 ± 0.030	0.813 ± 0.017	160 ± 8	0.101			
QK18 T3/1	enamel	0.127 ± 0.003	75	1.394 ± 0.030	0.596 ± 0.017	94 ± 4	0.749	1180 ± 118	10 ± 1	190 ± 19
	dentine	3.987 ± 0.084	>3500	1.350 ± 0.028	0.555 ± 0.012	85 ± 3	1.000			
	cement	5.018 ± 0.141	250	1.348 ± 0.036	0.716 ± 0.019	127 +7/-6	0.080			
QK18 T3/2	enamel	0.132 ± 0.003	311	1.515 ± 0.032	0.784 ± 0.018	146 ± 7	1.000	1518 ± 152	133 ± 13	306 ± 31
	dentine	5.445 ± 0.116	>3800	1.486 ± 0.031	0.835 ± 0.018	167 +9/-8	0.912			
	cement	6.000 ± 0.154	720	1.482 ± 0.038	0.823 ± 0.021	162 +10/-9	0.880			
QK18 T3/3	enamel	0.164 ± 0.004	210	1.484 ± 0.034	0.825 ± 0.020	163 ± 9	1.000	1335 ± 134	200 ± 20	34 ± 3
	dentine	7.865 ± 0.175	>4700	1.365 ± 0.029	0.823 ± 0.018	166 +9/-8	0.357			
	cement	7.120 ± 0.156	401	1.379 ± 0.029	0.874 ± 0.019	189 +12/-11	0.616			
QK18 T3/4	enamel	0.086 ± 0.002	67	1.411 ± 0.035	0.801 ± 0.021	155 +10/-9	1.000	1596 ± 160	150 ± 15	292 ± 29
	dentine	7.593 ± 0.178	>3700	1.273 ± 0.027	0.858 ± 0.018	186 +12/-11	0.303			
	cement	5.005 ± 0.106	79	1.290 ± 0.027	0.894 ± 0.021	205 +16/-14	1.000			
QK19 T1/1	enamel	0.243 ± 0.006	150	1.309 ± 0.034	0.575 ± 0.015	89 ± 4	1.000	1366 ± 137	49 ± 5	49 ± 5
	dentine	7.490 ± 0.057	>3000	1.246 ± 0.009	0.614 ± 0.005	100 ± 1	0.404			
	cement	7.107 ± 0.051	>1600	1.358 ± 0.009	0.807 ± 0.006	159 ± 3	0.377			
QK19 T1/2	enamel	0.224 ± 0.006	>500	1.432 ± 0.037	0.640 ± 0.017	104 ± 5	1.000	1310 ± 131	16 ± 2	14 ± 1
	dentine	8.727 ± 0.066	>3000	1.371 ± 0.010	0.774 ± 0.006	146 ± 3	0.277			
	cement	7.546 ± 0.052	>3000	1.421 ± 0.009	0.815 ± 0.006	160 ± 3	0.350			
QK19 T1/3	enamel	0.127 ± 0.004	70	1.280 ± 0.036	0.648 ± 0.019	108 ± 6	1.000	1681 ± 168	43 ± 4	144 ± 14
	dentine	5.675 ± 0.043	>12000	1.186 ± 0.008	0.624 ± 0.005	103 ± 1	0.369			
	cement	5.491 ± 0.040	>800	1.268 ± 0.009	0.954 ± 0.009	252 ± 9	0.392			
QK19 T1/4	enamel	0.443 ± 0.012	150	1.210 ± 0.031	0.566 ± 0.015	88 ± 4	1.000	556 ± 56	18 ± 2	17 ± 2
	dentine	5.446 ± 0.046	>20000	1.192 ± 0.010	6.636 ± 0.005	106 ± 2	0.440			
	cement	6.038 ± 0.041	250	1.278 ± 0.008	0.715 ± 0.006	128 ± 2	0.470			

81 **Table SI3b** - U-series data obtained by ICP-MS, <sup>222</sup>Rn/<sup>230</sup>Th ratios determined by check-crossing of gamma and ICP-MS data  
82 and thicknesses (measured before and after cleaning of both sides of the enamel layer) used for the ESR/U-series age  
83 calculations on the Qaleh Kurd teeth.

84

85 Dose-rate estimations - The radioelement contents of sediment samples associated to each tooth were  
 86 determined by high resolution low background gamma spectrometry using a germanium crystal (**Table**  
 87 **SI3c**). The water content of the sediments was estimated after one week drying in 40°C oven and the  
 88 mean value of these measurements,  $10 \pm 5 \%$ , was used for the age calculations. TL Al<sub>2</sub>O<sub>3</sub> dosimeters  
 89 were also placed on the different dated levels during 2018 excavation campaign but it was not possible  
 90 to get access to the site since this date and external gamma dose rate cannot be measured in situ. The  
 91 cosmic dose rate was estimated using the formula of [Prescott and Hutton \(1994\)](#) using the following  
 92 parameters: F=0.24; J=0.76; h=2.137 km; H=4.1. Limestone roof thicknesses of 10m above T1 and 12  
 93 m above T3 and the depth of the samples were considered in the cosmic dose rate evaluation. The  
 94 following parameters were also used in the dose rate determination: k-value ( $\alpha$  efficiency) of  $0.13 \pm 0.02$   
 95 ([Grün and Katzenberger-Apel, 1994](#)); enamel water content of 0 wt%; dentine and cement water content  
 96 of 7 wt%; radioelement contents-doses conversion factors from [Guérin et al. \(2011\)](#). For each dental  
 97 tissue, Rn loss was estimated from both gamma and ICP measurements as preconized by [Bahain et al.](#)  
 98 [\(1992\)](#) and the beta dose contributions were corrected from the enamel part destroyed on each side of  
 99 the enamel layer during the preparation process (according to [Brennan et al., 1997](#)) (**Table SI3b**).

100  
101

Samples	Depth	<sup>238</sup> U (ppm)	<sup>230</sup> Th (ppm)	<sup>40</sup> K (%)
QK18 T1/1	-137cm	2.23 ± 0,09	6,52 ± 0,14	2,34 ± 0,02
QK18 T1/2	-165cm	2.30 ± 0,07	4,63 ± 0,10	1,68 ± 0,01
QK18 T3/1	-90cm	1.72 ± 0,07	2,05 ± 0,09	0,76 ± 0,01
QK18 T3/2	-163cm	1.94 ± 0,09	5,18 ± 0,14	1,95 ± 0,02
QK18 T3/3	-186cm	1.97 ± 0,07	3,61 ± 0,10	1,35 ± 0,01
QK18 T3/4	-241cm	2.01 ± 0,07	1,98 ± 0,09	0,69 ± 0,01
QK19 T1/1	-68cm	1.88 ± 0,07	4,44 ± 0,10	1,42 ± 0,01
QK19 T1/2	-90cm	1.48 ± 0,06	3,10 ± 0,09	1,01 ± 0,01
QK19 T1/3	-120cm	1.73 ± 0,06	3,15 ± 0,07	0,99 ± 0,01
QK19 T1/4	-107cm	1.92 ± 0,06	2,94 ± 0,07	0,99 ± 0,01

102 **Table SI3c** – Radioelement contents of the sediments from Qaleh Kurd determined by high resolution low background gamma  
 103 spectrometry.

104



105 ESR/U-series age calculation - Lastly, ESR/U-series ages, U-uptake parameters and dose-rate  
 106 contributions were calculated by US model (Grün et al., 1988) or AU model (Shao et al., 2012) using  
 107 “USESR”, “AUESR” and “combined ESR” computer programs, in which the age uncertainty ( $2\sigma$ ) is  
 108 calculated with Monte Carlo approach (Shao et al., 2014). Results are displayed in **Table SI3d**.

109

Samples	Tissue	U (ppm)	Equivalent dose (Gy)	U-uptake parameter $p$ or $n$ (a. u.)	$D_a$ ( $\mu\text{Gy/a}$ )	$D_\beta$ ( $\mu\text{Gy/a}$ )	$D_{(\gamma + \text{cosm})}$ ( $\mu\text{Gy/a}$ )	$D_a$ ( $\mu\text{Gy/a}$ )	ESR/U-series ages US or AU (ka)
<b>QK18 T1/1</b>	enamel	$0.242 \pm 0.005$		$-0.0089 \pm 0.0009$					
	dentine	$8.576 \pm 0.195$	$206,65 \pm 2,47$	$-0.6827 \pm 0.0632$	$55 \pm 43$	$102 \pm 59$	$1089 \pm 43$	<b><math>1245 \pm 85</math></b>	<b><math>165 \pm 11</math></b>
	cement	$6.041 \pm 0.159$		$-0.9315 \pm 0.0457$					
<b>QK18 T1/2</b>	enamel	$0.300 \pm 0.006$		$-0.0093 \pm 0.0165$					
	dentine	$7.824 \pm 0.214$	$208,97 \pm 6,27$	$-0.7100 \pm 0.1575$	$106 \pm 205$	$52 \pm 57$	$1097 \pm 46$	<b><math>1255 \pm 218</math></b>	<b><math>168 \pm 29</math></b>
	cement	$7.333 \pm 0.157$		$-0.0082 \pm 0.0023$					
<b>QK19 T1/1</b>	enamel	$0.243 \pm 0.006$		$-0.2868 \pm 0.0905$					
	dentine	$7.490 \pm 0.057$	$160,78 \pm 11,24$	$-0.4461 \pm 0.0794$	$46 \pm 34$	$84 \pm 45$	$774 \pm 31$	<b><math>903 \pm 63</math></b>	<b><math>178 \pm 12</math></b>
	cement	$7.107 \pm 0.051$		$-0.9187 \pm 0.0452$					
<b>QK19 T1/2</b>	enamel	$0.224 \pm 0.006$		$-0.3656 \pm 0.0888$					
	dentine	$8.727 \pm 0.066$	$152,88 \pm 3,99$	$-0.7557 \pm 0.0580$	$48 \pm 28$	$107 \pm 44$	$592 \pm 25$	<b><math>746 \pm 58</math></b>	<b><math>205 \pm 15</math></b>
	cement	$7.546 \pm 0.052$		$-0.8379 \pm 0.0514$					
<b>QK19 T1/3</b>	enamel	$0.127 \pm 0.004$		$-0.5131 \pm 0.0764$					
	dentine	$5.675 \pm 0.043$	$127,03 \pm 4,32$	$-0.4475 \pm 0.0818$	$19 \pm 20$	$49 \pm 36$	$610 \pm 25$	<b><math>687 \pm 54</math></b>	<b><math>185 \pm 13</math></b>
	cement	$5.491 \pm 0.040$		$-0.0078 \pm 0.0006$					
<b>QK19 T1/4</b>	enamel	$0.443 \pm 0.012$		$-0.2829 \pm 0.1173$					
	dentine	$5.446 \pm 0.046$	$144,38 \pm 3,66$	$-0.5495 \pm 0.0931$	$73 \pm 47$	$132 \pm 59$	$621 \pm 26$	<b><math>825 \pm 80</math></b>	<b><math>175 \pm 15</math></b>
	cement	$6.038 \pm 0.041$		$-0.7576 \pm 0.0734$					
<b>QK18 T3/1</b>	enamel	$0.127 \pm 0.003$		$0.0076 \pm 0.1131$					
	dentine	$3.987 \pm 0.084$	$118,56 \pm 3,43$	$0.0571 \pm 0.1170$	$19 \pm 20$	$44 \pm 32$	$503 \pm 24$	<b><math>565 \pm 44</math></b>	<b><math>210 \pm 15</math></b>
	cement	$5.018 \pm 0.141$		$-0.5861 \pm 0.0684$					
<b>QK18 T3/2</b>	enamel	$0.132 \pm 0.003$		$-0.4068 \pm 0.0624$					
	dentine	$5.445 \pm 0.116$	$314,89 \pm 6,54$	$-0.5746 \pm 0.0508$	$40 \pm 37$	$72 \pm 47$	$915 \pm 37$	<b><math>1026 \pm 70</math></b>	<b><math>307 \pm 20</math></b>
	cement	$6.000 \pm 0.154$		$-0.5415 \pm 0.0533$					
<b>QK18 T3/3</b>	enamel	$0.164 \pm 0.004$		$-0.4792 \pm 0.0720$					
	dentine	$7.865 \pm 0.175$	$286,04 \pm 14,85$	$-0.4952 \pm 0.0716$	$54 \pm 49$	$91 \pm 63$	$718 \pm 30$	<b><math>862 \pm 85</math></b>	<b><math>332 \pm 28</math></b>
	cement	$7.120 \pm 0.156$		$-0.6491 \pm 0.0575$					
<b>QK18 T3/4</b>	enamel	$0.086 \pm 0.002$		$-0.0866 \pm 0.0791$					
	dentine	$7.593 \pm 0.178$	$262,79 \pm 6,90$	$-0.3871 \pm 0.0573$	$22 \pm 18$	$55 \pm 32$	$505 \pm 24$	<b><math>581 \pm 44</math></b>	<b><math>452 \pm 32</math></b>
	cement	$5.005 \pm 0.106$		$-0.4504 \pm 0.0520$					

110 **Table SI3d** - Equivalent doses, U-uptake parameters, dose rate contributions and ESR/U-series ages obtained for the Qaleh

111 Kurd teeth. Data obtained through AU model use are indicated in italics.

112

113 Discussion - The equivalent doses determined for the Qaleh Kurd teeth range between 120 and 315 Gy  
 114 and are quite high if we consider the relatively low U-content determined for the different dental tissues.  
 115 The external dose rate estimated from the sediments varies quite highly from a level to another and  
 116 impacts greatly the obtained ESR/U-series ages, ranging from ca 160 to 220 ka for T1 samples and from  
 117 195 to 485 ka for T3 ones. A Middle Pleistocene age is so confirmed for the whole set of samples and  
 118 associated archaeological levels. It is however important to take in consideration that the age calculation  
 119 is greatly impacted by the external dose, representing more than 75 % of the dose rate (**Figure SI3.b**)

120 and leading to the reconstruction of U-uptake kinetics quite different for the teeth issued from the two  
121 trenches. Hence, for T1 teeth, some leaching behaviors were hence determined while for T3 samples  
122 relatively recent U-uptake behaviors are reconstructed (Figure SI3c). These results need to be  
123 consolidated by in situ dosimetric measurements.

124

125

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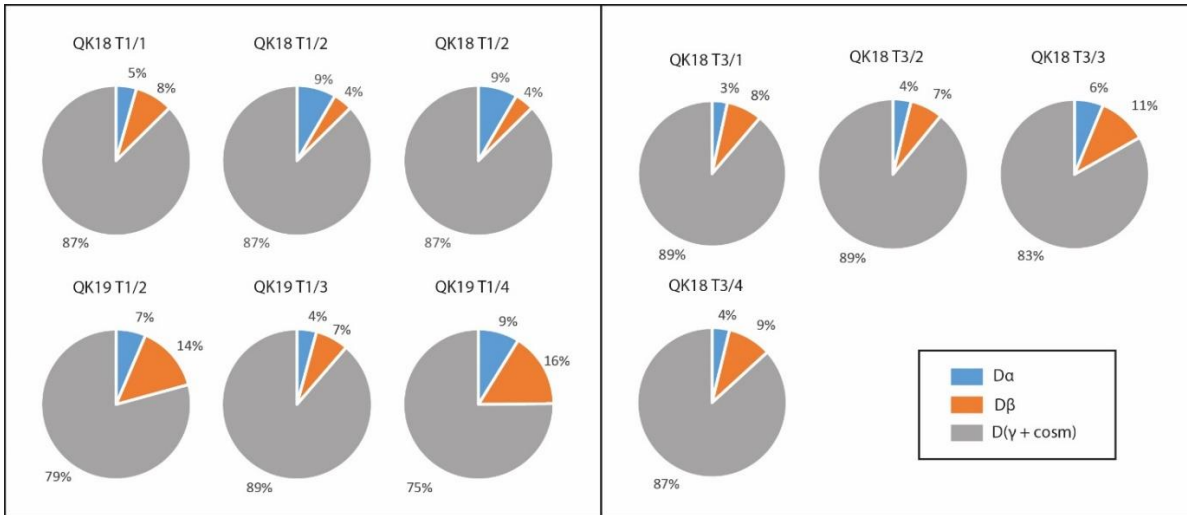
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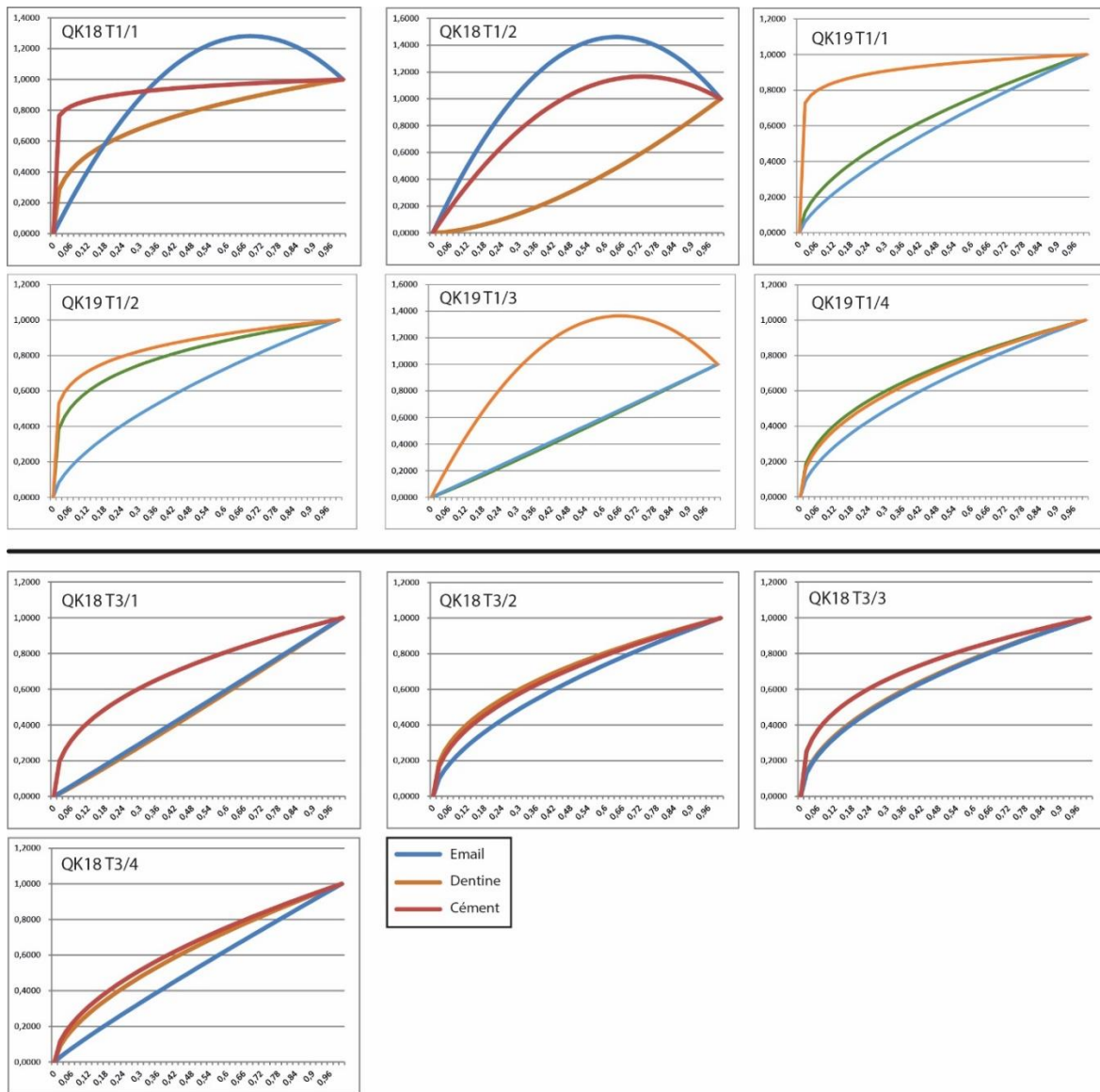
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Figure SI3b – Dose contributions reconstructed for the Qaleh Kurd teeth.



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152

Figure SI3c – U-uptake kinetics reconstructed for the Qaleh Kurd teeth.

			Mesiodistal diameter (mm)	Buccolingual diameter (mm)	Sources
<b>Qaleh Kurd</b>	<b>QK19-6169</b>	<b>L</b>	<b>(6.1)</b>	<b>7.2</b>	
Near Eastern Neanderthals	Dederiyeh cave 1 (2)	R	7.6	9.5	Tillier et al., 2003
		L	7.4	9.3	
	Dederiyeh cave 2 (1)	R	7.6	9.3	Tillier et al., 2003
	Kebara KMH 1 (2)	R	7.4	9.0	Tillier et al., 2003
		L	7.6	9.3	
	Kebara KMH 3 (1)	R	7.7	9.4	Tillier et al., 2003
	Kebara KMH 4 (1)	R	7.9	9.7	Tillier et al., 2003
	Kebara KMH 25 (1)	L	7.3	9.7	Tillier et al., 2003
	Kebara KMH 13 (1)	L	7.4	9.6	Tillier et al., 2003
	Kebara KMH 30 (1)	L	7.1	9.8	Tillier et al., 2003
	Shanidar 7 (1)	L	7.8	8.8	Trinkaus, 1983
Amud III (1)	L	7.4	8.6	Tillier, 1979	
	Range		7.1-7.9	8.6-9.8	
Near Eastern Early Modern humans	Skhul I (1)	R	8.4	7.9	Tillier et al., 2003
	Qafzeh 21 (1)	L	8.8	(7.8)	Tillier, 1999
	Qafzeh 12 (1)	R	8.8	10.0	Tillier, 1999
	Qafzeh 10 (2)	R	8.5	9.2	Tillier, 1999
		L	8.2	9.4	Tillier, 1999
	Qafzeh 4 (2)	R	8.4	8.7	Tillier, 1999
		L	8.5	9.4	Tillier, 1999
	Qafzeh 15 (2)	R	8.5	9.7	Tillier, 1999
		L	8.2	9.9	Tillier, 1999
	Range		8.2-8.8	7.9-10.0	
European Neanderthals (21)	Devil's Tower (2), Fate (1), Krapina (6), La Ferrassie 8 (1), La Quina H18 (2), Meridionale (1), Pech de l'Azé (2), Le Portel (2), Roc de Marsal (2), Subaluk (1), Teshik Tash (1)		7.1-11.0	6.8-9.9	Becam & Chevalier, 2019; Tillier, 1979, 1093; Lumley de, 2018, 2022
European Upper Paleolithic Modern Humans (30)	Abri Pataud (1), Arene Candide (4), Bruniquel (2), Dolni Vestonice (1), Hohlenstein (1), La Madeleine (1), La Roquette (1), Laugerie-Basse (2), Le Morin (1), McKay Cave (1), Muge (Arruda) (4), Muge (Moita) (3), Ofnet (8)		6.4-9.5	7.4-9.6	Becam & Chevalier, 2019
Western Middle Pleistocene humans	Lazaret 12 & 27, Arago (4), A-TD6-14 (1), Tighenif (2)		7.0-8.8	9.2-10.7	Tillier, 1980; Lumley de, 2018, 2022

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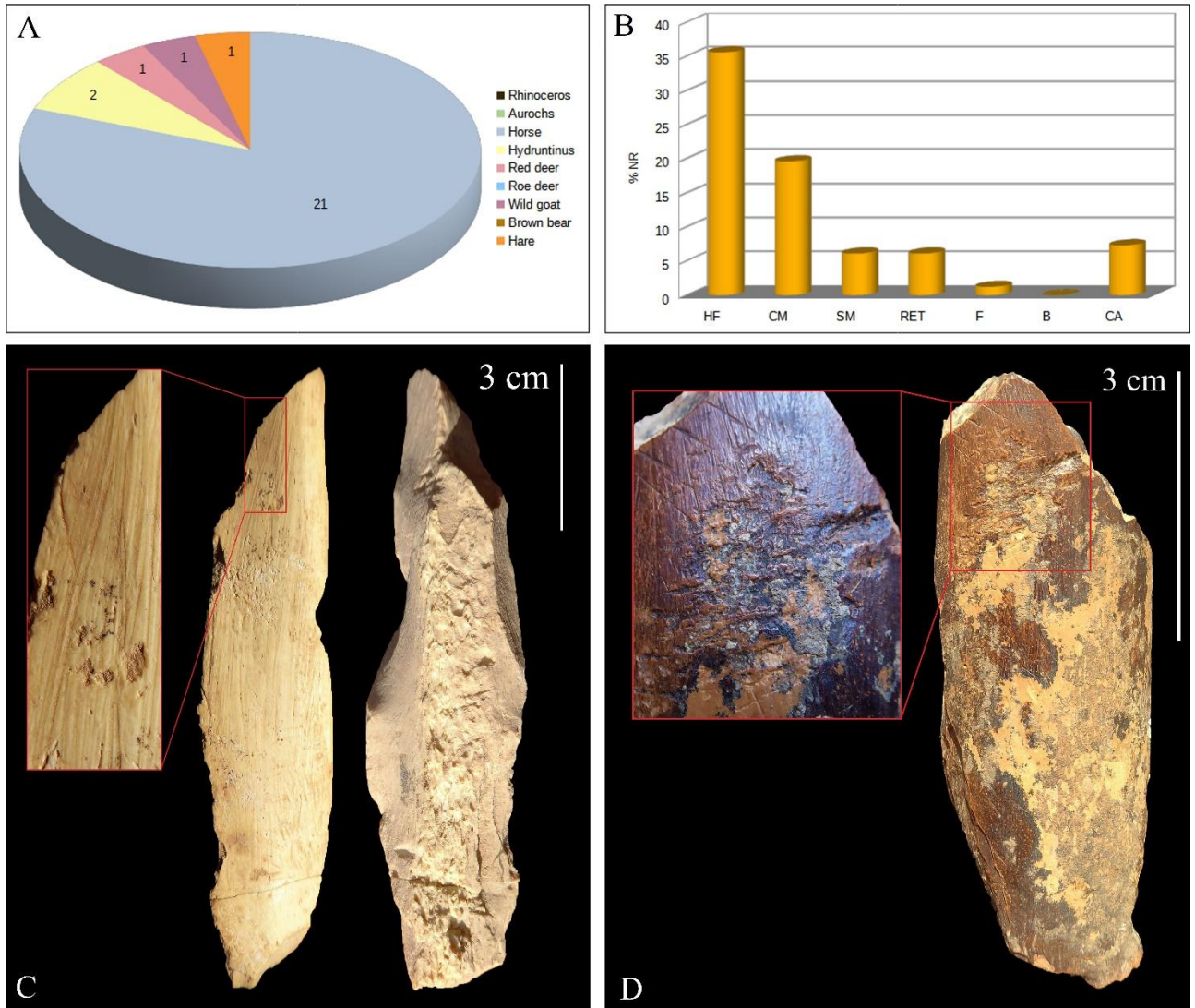
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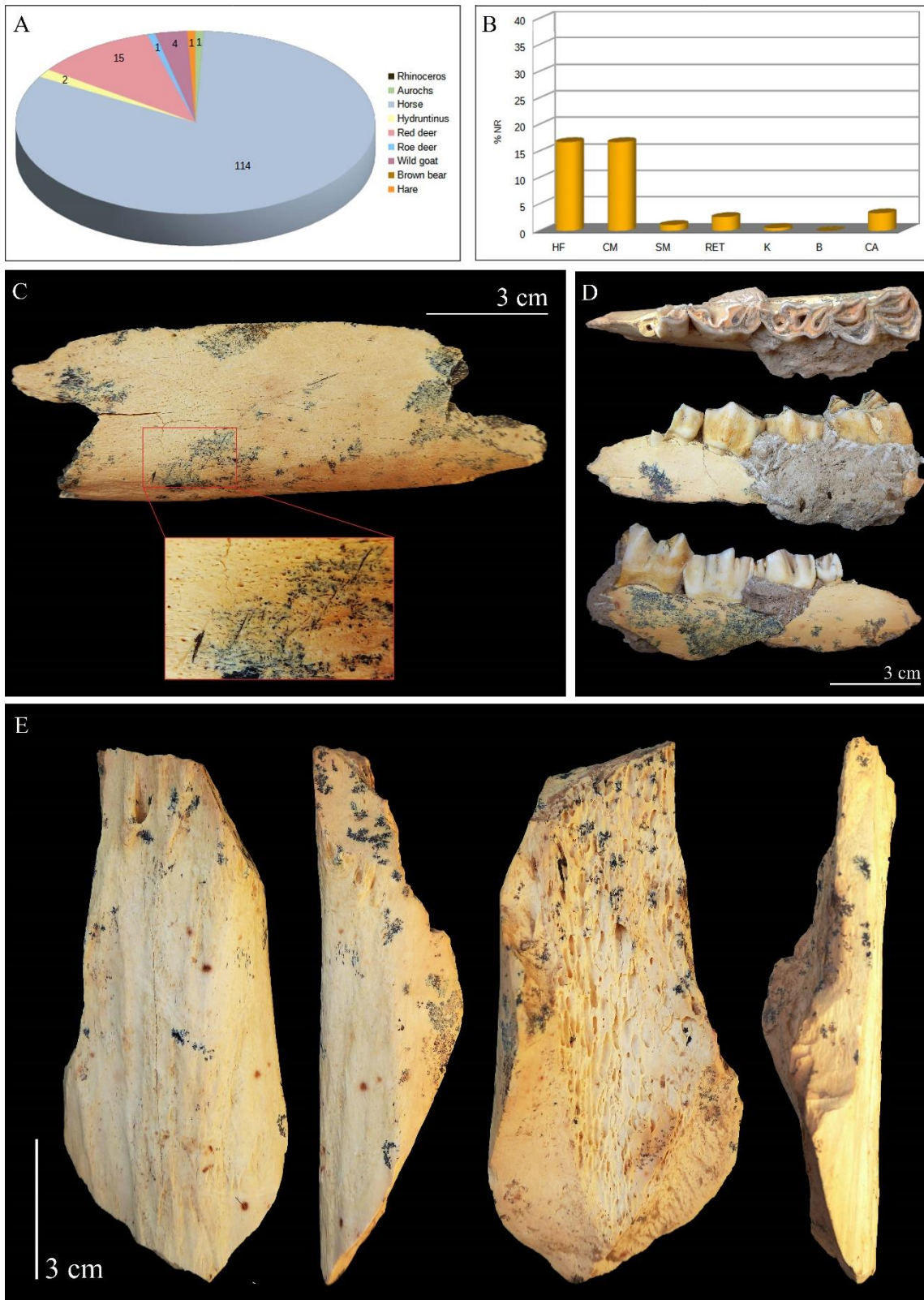
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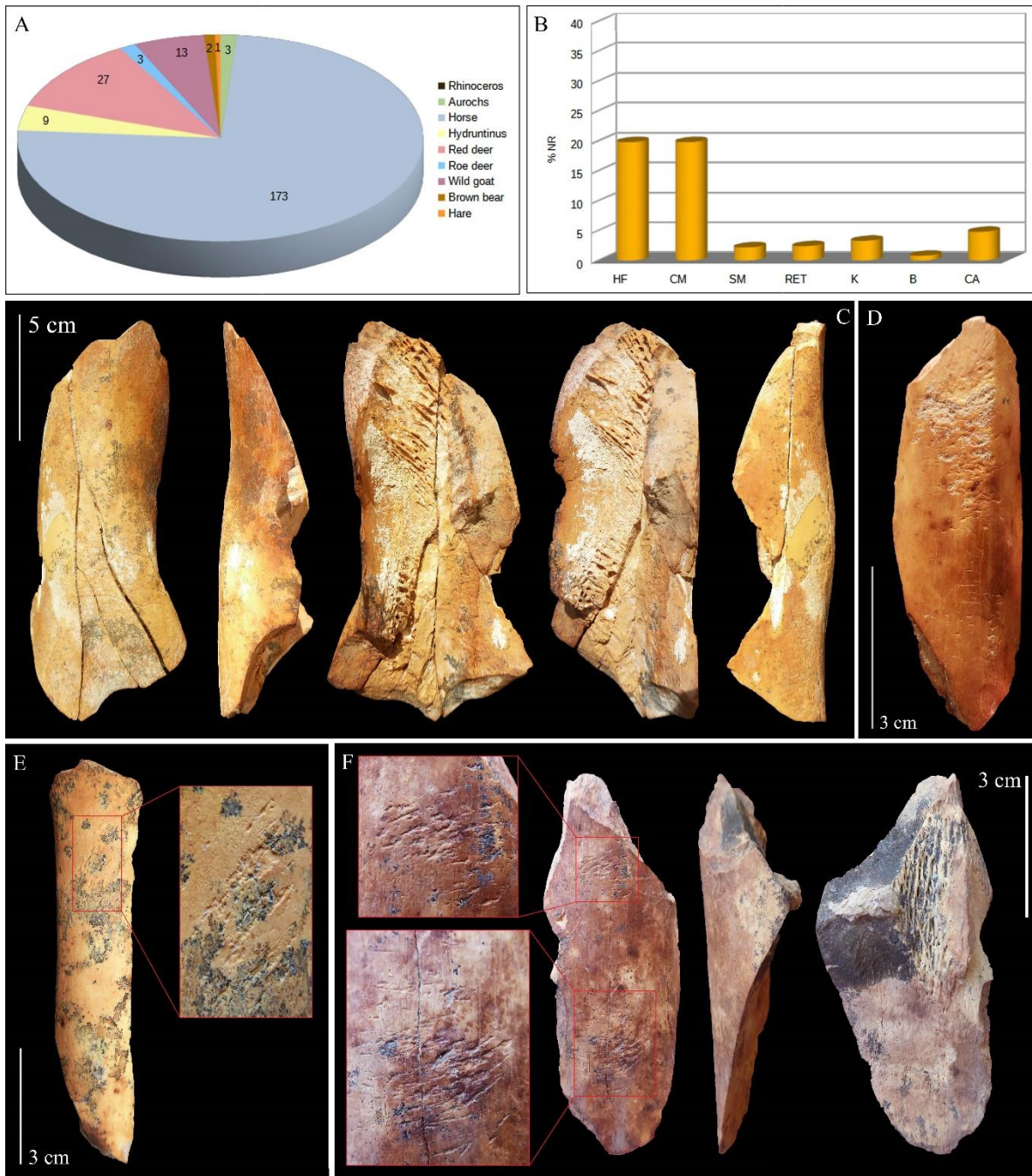
176 SI5: The faunal assemblages of QK1, QK2 and QK3  
 177



178  
 179 SI5a: LEVEL QK1. A. General inventory, number of rests. B. Percentage of rests with stigmata.  
 180 HF=helical fracture; CM=cut marks; SM=scrapping marks; RET=*retouchoirs*; F=flakes;  
 181 B=burned bones; CA=carnivore marks. C. Horse's long bone with helical fracture, cut marks  
 182 and scrapping marks; D. *Retouchoir* on a horse's metapodial. Associated with a lot of cut marks  
 183 and scrapping marks. (© N. Sévêque)  
 184

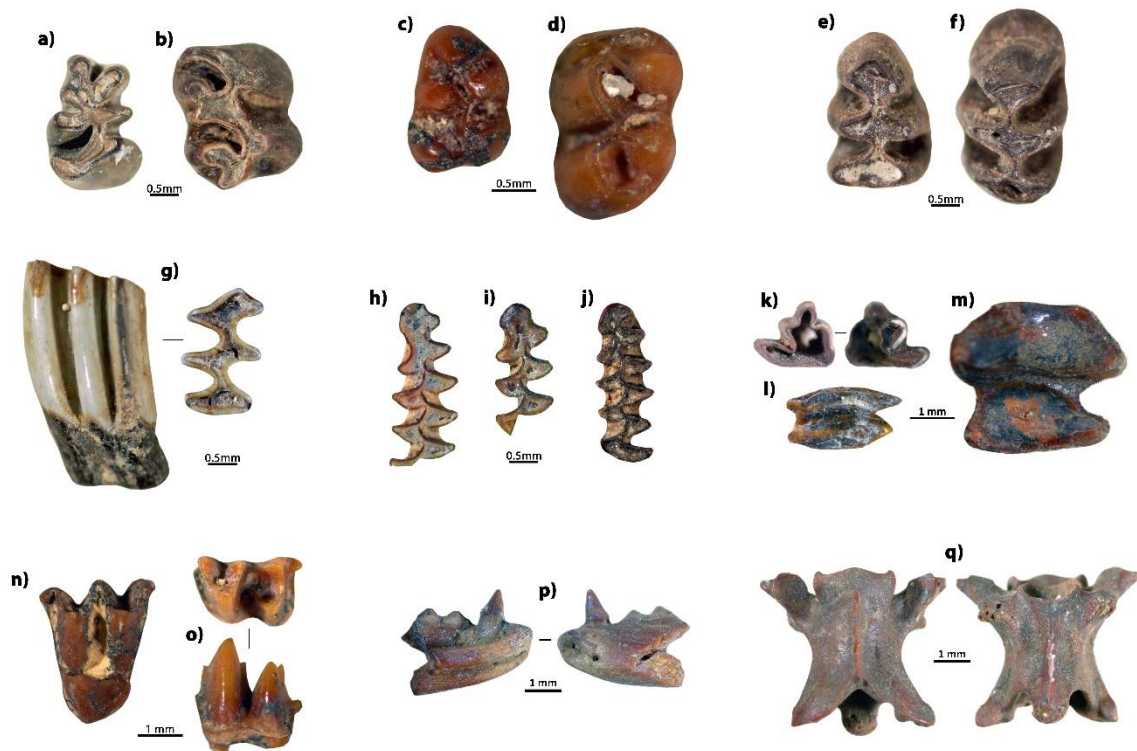


185  
 186 SI5b : LEVEL QK2. A. General inventory, number of rests. B. Percentage of rests with  
 187 stigmata. HF=helical fracture; CM=cut marks; SM=scraping marks; RET=*retouchoirs*;  
 188 F=flakes; B=burned bones; CA=carnivore marks. C. Cut marks on a horse's mandible, for skin  
 189 taking. D. Left mandible of an adult red deer. E. Helical fracture on a horse's tibia. (© N.  
 190 Sévêque)  
 191



192  
 193 SI5c : LEVEL QK3. A. General inventory, number of rests. B. Percentage of rests with stigmata.  
 194 HF=helical fracture; CM=cut marks; SM=scraping marks; RET=*retouchoirs*; F=flakes;  
 195 B=burned bones; CA=carnivore marks. C. Horse's humerus with a helical fracture and an  
 196 impact point. D. Double *retouchoir* on a red deer's tibia. E. *Retouchoir* on a red deer's  
 197 metapodial. F. Double *retouchoir* on a fractured horse's long bone. (© N. Sévêque)  
 198  
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- 202  
 203  
 204 Examples of microvertebrate remains from Qaleh Kurd:  
 205 a) *Allactaga* sp. m1 (QK18\_Trench3\_Unit24-25)  
 206 b) *Allactaga* sp. M1 (QK18\_Trench3\_Unit29-31)  
 207 c) *Calomyscus* sp. M1 (QK18\_Trench3\_Unit29-31)  
 208 d) *Mesocricetus* sp. m3 (QK18\_Trench3\_Unit24-25)  
 209 e) *Meriones* sp. m1 (QK18\_Trench3\_Unit24-25)  
 210 f) *Meriones* sp. M1 (QK18\_Trench3\_Unit24-25)  
 211 g) *Ellobius* sp. m2 (QK18\_Trench3\_Unit24-25)  
 212 h) i) j) *Microtus* spp. m1s (QK18\_Trench3\_Unit24-25)  
 213 k) *Ochotona* sp. p3 (QK18\_Trench3\_Unit29-31)  
 214 l) *Ochotona* sp. upper molar (QK18\_Trench3\_Unit24-25)  
 215 m) Leporidae lower molar (QK18\_Trench3\_Unit29-31)  
 216 n) Chiroptera upper molar (QK18\_Trench3\_Unit24-25)  
 217 o) Chiroptera lower molar (QK18\_Trench3\_Unit24-25)  
 218 p) Agamidae dentary fragment (QK18\_Trench3\_Unit29-31)  
 219 q) Colubridae tronc vertebrae (QK18\_Trench3\_Unit29-31)  
 220  
 221

222 SI7 : The caballine horse at Qaleh Kurd (Sequence II). Comparative metrics of the lower  
 223 teeth.  
 224  
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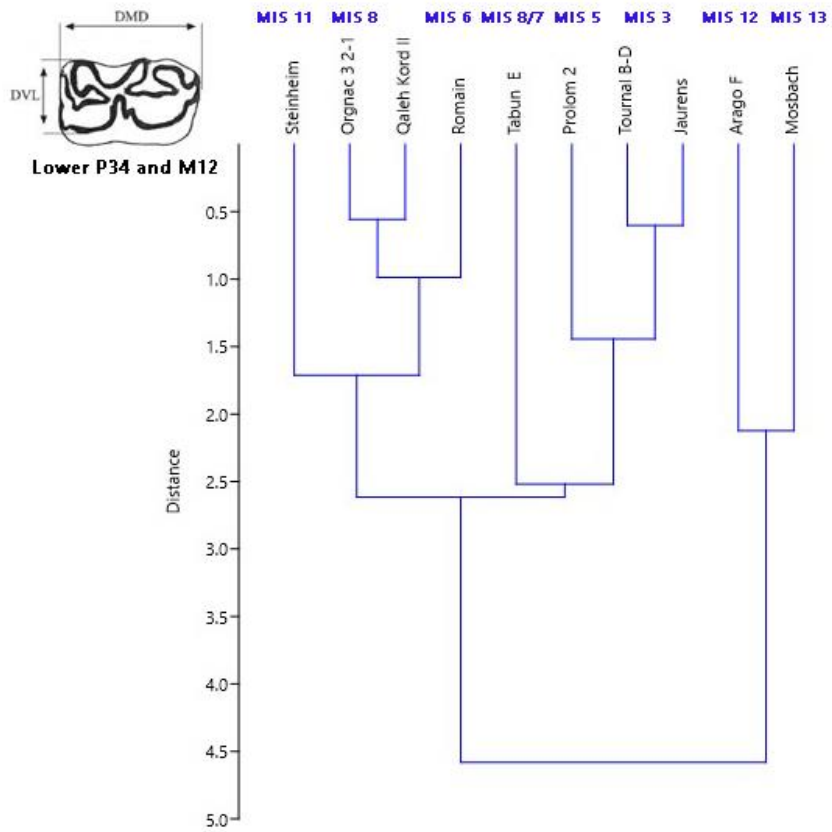
		<b>P<sub>34</sub></b>			<b>M<sub>12</sub></b>		
		DMD	DVL	(DMD+DVL)/2	DMD	DVL	(DMD+DVL)/2
	n	6	6	6	9	9	9
Qaleh Kurd	x	<b>30,5</b>	<b>17,2</b>	<b>23,9</b>	<b>28,1</b>	<b>15,8</b>	<b>21,9</b>
	s	1,3	1,6	1,0	2,0	1,7	1,5
Mosbach <sup>a</sup>	n	46	45	45	44	43	43
SIM 15/13	x	<b>32,4</b>	<b>17,9</b>	<b>25,2</b>	<b>29,8</b>	<b>15,9</b>	<b>22,8</b>
	s	1,5	1,0	1,0	1,7	1,1	0,9
Caune de l'Arago F <sup>b</sup>	n	42	43	42	47	48	47
SIM 12	x	<b>33,4</b>	<b>18,5</b>	<b>26,0</b>	<b>30,7</b>	<b>16,8</b>	<b>23,8</b>
	s	1,1	1,0	0,8	1,4	0,8	0,9
Steinheim <sup>c</sup>	n	49	49	47	60	62	60
SIM 11	x	<b>31,0</b>	<b>17,5</b>	<b>24,3</b>	<b>29,7</b>	<b>15,7</b>	<b>22,7</b>
	s	1,9	1,1	1,2	2,0	1,3	1,0
Orgnac 3 [2-1] <sup>b</sup>	n	29	35	29	34	39	34
SIM 8	x	<b>30,6</b>	<b>17,1</b>	<b>23,9</b>	<b>28,4</b>	<b>15,3</b>	<b>21,8</b>
	s	1,1	0,8	0,7	1,1	1,0	0,7
Tabun E <sup>a</sup>	n	5	6	4	2	2	2
SIM 8/7 ?	x	<b>31,0</b>	<b>16,0</b>	<b>23,5</b>	<b>26,8</b>	<b>16,4</b>	<b>21,6</b>
	s	1,4	1,5	0,4	-	-	-
Romain-la-Roche <sup>b</sup>	n	39	38	38	27	28	27
SIM 6	x	<b>31,2</b>	<b>17,5</b>	<b>24,3</b>	<b>28,5</b>	<b>15,6</b>	<b>22,1</b>
	s	2,0	1,0	1,3	1,5	0,7	0,8
Prolom 2 <sup>a</sup>	n	31	31	31	20	20	20
SIM 5	x	<b>29,6</b>	<b>17,6</b>	<b>23,6</b>	<b>27,5</b>	<b>16,4</b>	<b>22,0</b>
	s	1,3	1,0	0,8	1,2	0,8	0,6
Tournal B-D <sup>b</sup>	n	31	32	31	29	30	28
SIM 3	x	<b>29,0</b>	<b>17,5</b>	<b>23,3</b>	<b>27,1</b>	<b>15,6</b>	<b>21,4</b>
	s	1,70	0,82	1,08	1,9	0,9	1,0
Jaurens <sup>a</sup>	n	26	25	26	26	26	26
end SIM 3	x	<b>28,9</b>	<b>17,3</b>	<b>23,3</b>	<b>26,6</b>	<b>15,7</b>	<b>21,2</b>
	s	1,8	1,2	1,6	1,4	0,8	0,9

a: Eisenmann, web site

b: Boulbes, pers. datas

c: van Asperen, com. pers.

226  
 227 SI7a – Comparative metrics of the lower teeth of Middle and Upper Pleistocene caballine horses.  
 228 DMD = Mesio-distal diameter (length); DVL = vestibulo-lingual diameter (breadth). Measurements are  
 229 taken from the enamel (without cement) on the occlusal surface of the tooth.  
 230  
 231



232  
 233 SI7b – Hierarchical clustering analysis based on the mean dimensions of the teeth (Table SI7a).  
 234 Algorithm=paired group (UPGMA), Similarity index=Euclidean).  
 235