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## The first use of olives in Africa around 100,000 years ago

Laurent Marquer, Thierry Otto, Eslem Ben Arous, Emmanuelle Stoetzel,  
Emilie Campmas, Antoine Zazzo, Olivier Tombret, A Seim, W Kofler,  
Christophe Falguères, et al.

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1 **Title:** The first use of olives in Africa around 100,000 years ago

2

3 **Author list:** L. Marquer <sup>1,2\*</sup>, T. Otto <sup>3</sup>, E. Ben Arous <sup>4,5,6</sup>, E. Stoetzel <sup>4</sup>, E. Campmas <sup>7,†</sup>, A.  
4 Zazzo <sup>8</sup>, O. Tombret <sup>4,8</sup>, A. Seim <sup>1,9</sup>, W. Kofler <sup>1</sup>, C. Falguères <sup>4</sup>, M. Abdeljalil El Hajraoui <sup>10</sup>,  
5 R. Nespoulet <sup>4</sup>

6

7 **Affiliations:**

8 <sup>1</sup> Institute of Botany, University of Innsbruck, Innsbruck (Austria).

9 <sup>2</sup> Research Group for Terrestrial Palaeoclimates, Max Planck Institute for Chemistry, Mainz  
10 (Germany).

11 <sup>3</sup> Laboratoire écologie fonctionnelle et environnement, Université de Toulouse, CNRS, INPT,  
12 UPS, Toulouse (France).

13 <sup>4</sup> Histoire Naturelle de l'Homme Préhistorique (HNHP, UMR 7194), Sorbonne Universités,  
14 Muséum national d'Histoire naturelle, CNRS, UPVD, Paris (France).

15 <sup>5</sup> PanEv Lab, Max Planck Institute for the Science of Human Evolution (MPI-SHH), Jena  
16 (Germany).

17 <sup>6</sup> Centro nacional de investigación sobre la evolución humana (CENIEH), Burgos (Spain).

18 <sup>7</sup> UMR 5608 TRACES du CNRS, Université Toulouse Jean Jaurès, Toulouse (France).

19 <sup>8</sup> Archéozoologie, Archéobotanique : Sociétés, Pratiques et Environnements (AASPE, UMR  
20 7209), Sorbonne Universités, Muséum national d'Histoire naturelle, CNRS, Paris (France).

21 <sup>9</sup> Chair of Forest Growth and Dendroecology, Institute of Forest Sciences, Albert-Ludwigs-  
22 University Freiburg, Freiburg (Germany).

23 <sup>10</sup> Institut National des Sciences de l'Archéologie et du Patrimoine, Rabat (Morocco).

24

25 \*Correspondence to: [Laurent.Marquer@uibk.ac.at](mailto:Laurent.Marquer@uibk.ac.at)

26 † Deceased, March 8th, 2019.

27 **Abstract:**

28       The olive tree was an iconic plant for most of the past Mediterranean civilizations, for  
29 which it had important economic values. Here, we report the earliest use of fruits and wood  
30 from olive trees in Africa so far, around 100,000 years ago. These findings suggest the presence  
31 of olive trees in the Atlantic coast of Morocco during most of the last glacial, and the use of  
32 olives by the early *Homo sapiens* for fuel management and most likely for consumption.

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52 **Main Text:**

53 Across the Mediterranean Basin, two varieties of olive trees (*Olea europaea*) exist: a wild  
54 *O. europaea subsp. europaea* L. var. *sylvestris* and a cultivated *O. europaea subsp. europaea*  
55 L. var. *europaea*. The oldest wild olive findings were recovered at the Acheulean site Gesher  
56 Benot Ya'aqov (Israel), dating back to ca. 790 ka (1; ka: kiloanni). Since then, few  
57 archaeological evidence has been retrieved (2-5): ca. 62–55, 49 and 43-41 ka in Greece, Israel  
58 and Spain, respectively. From ca. 30 ka onwards, archaeological occurrences of olive remains  
59 rather rare until the Epipalaeolithic (4, 6). It is only from the Neolithic onwards that wild olives  
60 were intensively used by Mediterranean human groups, for the direct use of the entire tree (e.g.  
61 food, fuel, lighting, medicine and cosmetics) and its conceptualization in mythology and  
62 religion (7, 8). The olive was one of the first cultivated trees ca. 6 ka ago owing to its valuable  
63 oil derivatives from its fruit (9).

64 The sporadic use of wild olives during the Palaeolithic may be due to its scarcity or absence  
65 in the vegetation. However, DNA analyses and species distribution modelling (10)  
66 demonstrated the capacity of the wild olive to survive the last glacial period in the  
67 Mediterranean, although its presence would have been confined to refuge zones (4, 10, 11).  
68 One of the largest refuge zones were probably situated on the Atlantic coasts of Morocco and  
69 the southern part of the Iberian Peninsula (Fig. 1). Here, we present a ca. 100-ka-old evidence  
70 of the presence of wild olives during the last glacial period in the Rabat-Temara region of  
71 Morocco (Fig. 1).

72 In the Rabat-Temara region, El Mnasra and El Harhoura 2 caves were discovered in 1956  
73 and 1977, respectively (Extended Data Fig. 1). Archaeological material from the Middle Stone  
74 Age (MSA; from ca. 120 ka) and Iberomaurusian (Late Stone Age, LSA) is preserved in these  
75 caves (12, 13). The findings from the MSA correspond to the Aterian culture with  
76 Levallois/micro-Levallois debitage, side scrapers and the presence of tanged tools (tanged tools

77 only in El Mnasra). Bone tools associated with the Aterian culture have also been recovered at  
78 El Mnasra. The Aterian MSA groups at El Mnasra showed some cultural originalities; they  
79 produced the largest known *Nassaridae* perforated shells in Africa and used pigments such as  
80 hematite. Human remains were discovered in the Aterian MSA levels at both sites. These  
81 stratified coastal sequences with well-preserved successions of Aterian MSA occupations are  
82 rare in North Africa, and the Rabat-Temara caves are thus of crucial importance for our  
83 understanding of the evolution and dispersal of early *Homo sapiens* within and outside Africa  
84 (12).

85 Early *Homo sapiens* are considered hunter-gatherers. The animal and lithic remains found  
86 in archaeological contexts provide information about the hunter behaviour. However, the  
87 findings corresponding to the gatherer behaviour (i.e. collect of plants) are uncommon for the  
88 Palaeolithic, in particular those related to human diet and plant processing (14, 15, 16). In order  
89 to recover plant remains at our sites, a specific methodological approach has been used (12) to  
90 optimize the extraction of poorly preserved plant materials. Thus, charcoal (both sites) and  
91 charred seed fragments (El Mnasra) from the Aterian MSA levels were recovered (Extended  
92 Data Table 1; 12). Seventy-two percent of all charcoal fragments were identified as *Olea*  
93 *europaea* (12); they can be attributed to the wild variety of *Olea europaea* by considering the  
94 ages of the corresponding cultural levels. Due to the poor preservation of the plant remains  
95 (12), twenty-four percent of the charcoal fragments can only be identified as dicots, which  
96 includes wild olive and other wood taxa. The remaining charcoal fragments (4% of the  
97 fragments) are determined as *Quercus sp.* (evergreen oak), *Juniperus/Tetraclinis* and  
98 *Phillyrea/Rhamnus*. Regarding the seed fragments, eighty-one percent of all fragments are  
99 charred olive stones (Extended Data Table 1); sixteen percent cannot be identified due to their  
100 poor preservation. Wild olive stones were identified based on their morphology which strongly  
101 resembles their modern counterparts (Fig. 2). Charcoal from wild olive was also found in an

102 Aterian MSA combustion feature at the nearby Contrebandiers site (12). This suggests the  
103 widespread use of wild olives during the Aterian MSA in the Rabat-Temara region. Although  
104 charcoal taphonomy needs to be considered carefully (12), there is no doubt that wild olives  
105 were used by prehistoric hunter-gatherers.

106 Optically stimulated luminescence and combined U-series/Electron Spin Resonance dating  
107 (12, 17) from Aterian MSA levels that include the plant fragments range from ca. 115 to 46 ka  
108 (Extended Data Table 1). Accelerator Mass Spectrometry dating of a selection of charred olive  
109 stones and olive charcoal fragments confirms that the ages of these samples are beyond the  
110 limits of radiocarbon dating (> 50 ka) for El Mnasra and near the limit for El Harhoura 2 (12).

111 The sole presence of seed fragments in the Aterian MSA levels does not necessarily mean  
112 that olive fruits were consumed. However, olive fruits are a key alimentary resource, and since  
113 they are easy to collect, one can naturally assume that the Aterian MSA groups likely used the  
114 fruits in their diet. One could argue that olive fruits may also have come attached to branches  
115 which were used as fuel. The charred olive stones would have therefore resulted from an  
116 involuntary action. However, the use of entire branches with fruits and leaves as fuel would  
117 not be efficient. Since dry fruits quickly fall off branches and thus, being lost before reaching  
118 the fireplace, the material would have been used when it was freshly collected and burnt green.  
119 Greenwood, however, has a high moisture content resulting in a lower heating value and high  
120 pollutant content during combustion among other disadvantages of its burning properties (see  
121 below). The species forms also hardwood which would make its collection by cutting difficult,  
122 especially without specific tools. Finally, complete olive stones would have been recovered  
123 when burnt on its branches. All this points to a conscious use of olive fruits for consumption at  
124 El Mnasra.

125 It is not entirely clear why the olives stones were broken and charred, which raises  
126 important questions about human subsistence strategies. A first hypothesis would be that the

127 fruit could have been crushed for consumption and the leftovers thrown into the fireplace to  
128 avoid the accumulation of alimentary detritus. However, eating crushed fruits would be  
129 difficult. A second hypothesis would be that after consuming the fruit, the stones were thrown  
130 into the fire to eliminate alimentary waste. In that case, a mixture of fragmented (during  
131 charring) and whole charred stones would have been recovered. Breakage via heat exposure  
132 would have resulted in sharp fractures along the edges of the stones (18), because of the  
133 splitting of the stones into two halves (19, 20). A third hypothesis would be a deliberate  
134 breakage of the stones by humans after consuming the fruits. This would have resulted in an  
135 almost total fragmentation without specific breakage patterns, as it was observed in our  
136 samples.

137 The third hypothesis appears to be most plausible. However, why would humans have  
138 crushed the stones after the consumption of olives? We assume that they used the stones to  
139 create a residue to enhance combustion. Olive stones and their seeds have a high lignin and oil  
140 content (21-22). Therefore, the crushed olive stone residue would result in a slow combustion  
141 with long-lasting flames, favoured for cooking. When dried, the residue produces smokeless  
142 flames (21), which is a major advantage for prehistoric groups living in caves. Furthermore,  
143 olive wood is a good firewood by holding high heat for a long time. Wild olive (wood and  
144 stones) may thus be related to fuel management here. The specific use of wild olive as fuel  
145 could also be influenced by its abundance in the region. While oak and juniper are also good  
146 combustibles and present in the landscape, they have not been much considered by the  
147 prehistoric groups as only few charcoal fragments from these plants have been recovered.

148 Wood and fruits from wild olive trees were likely collected from the vegetation around  
149 Rabat-Temara. Wild olive is an abundant evergreen sclerophyllous tree/shrub in the present-  
150 day regional vegetation characterized by a thermo-Mediterranean bioclimate (12). Pollen  
151 archives show that *Olea* was present in the Mediterranean vegetation since the Miocene and

152 survived the Quaternary glaciations (4, 23, 24). Our findings demonstrate the presence of wild  
153 olive on the Atlantic coast in Morocco during the Aterian MSA and most of the last glacial  
154 period. This region has already been considered as a refuge for animals during the glacial  
155 period, such as the Algerian mouse (12).

156 There exists no other Aterian MSA archaeological sites for comparison so far. In northern  
157 Morocco, the archaeobotanical remains recovered at Taforalt, Ifri el Baroud, Kehf el Hammar  
158 and Ghar Cahal (25-29; Fig. 1) are much younger, i.e. from some 35 ka ago. There, it has been  
159 shown that MSA and LSA groups used different species including *Juniperus/Tetraclinis*,  
160 *Quercus* sp., *Pinus* sp., *Phillyrea/Rhamnus* and *Pistacia* sp. At Taforalt from ca. 15 ka onwards,  
161 acorns from oak, pistachios and seeds from pine, juniper, legumes and wild grasses were found;  
162 it is assumed that they were consumed (26, 27). These observations might underline two  
163 different gathering behaviours between the Aterian MSA groups living from ca. 115-46 ka ago  
164 in the Rabat-Temara region and the later MSA and LSA groups living from ca. 35 ka onwards  
165 in northern Morocco. The first would be related to fuel management where a species-specific  
166 selection of plants is considered due to their burning characteristics and/or their abundance in  
167 the vegetation, as found in the case for the Rabat-Temara populations. The second would be  
168 related to food consumption, for which a large variety of plants are used for the diet.

169 The early use of wild olives in Africa by Aterian MSA groups from ca. 100,000 years ago  
170 might represent improvements in cooking, technological innovations for wood processing and  
171 social organization, among other aspects. This finding provides new insights into the  
172 understanding of Aterian MSA hunter-gatherer economies, and complete the story of the iconic  
173 olive tree in the Mediterranean.

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177 **Methods:**

178 **Sampling strategy.** The recovery of archaeobotanical remains during the excavations was very  
179 challenging at both El Mnasra and El Harhoura 2. In particular, since the charcoal fragments  
180 ‘disintegrated’ as soon as they were in contact with water (12). Therefore, instead of using  
181 water flotation, we followed a ‘dry sampling protocol’ to optimize the collection of  
182 archaeobotanical remains. In a first step, all dark-colored objects (i.e. potential  
183 archaeobotanical remains) observed during the excavation have been collected with their  
184 coating sediments. These samples have been dried and sent to the laboratory (Laboratoire  
185 écologie fonctionnelle et environnement (Université de Toulouse, CNRS, INPT, UPS, France)  
186 for the extraction of archaeobotanical remains with a sieve of 0.25 mm mesh size and for  
187 botanical identification. In a second step, the residual sediments (resulting from the excavation)  
188 have been dried and gently sieved with a 1mm sieve mesh size. A visual inspection under a  
189 stereomicroscope was performed on the dried-sieved sediments equal to or larger than 1 mm;  
190 this to collect all visible dark-colored objects elements with the coating sediments that have  
191 then been sent to the laboratory for sieving (0.25 mm sieve mesh size) and botanical  
192 identification. The pros and cons of using the dry sampling *versus* the water flotation protocol  
193 is discussed in the Supplementary Materials (12).

194 The potential archaeobotanical remains with their coating sediments correspond to spatially  
195 dispersed combustion residues spread over the archaeological levels and combustion features  
196 (12). These remains were essentially recovered during the 2009, 2010 and 2017 excavations  
197 from the Aterian MSA and LSA levels and few were archived from previous excavations (2001  
198 and 2004), which are also included in this study.

199 The present study focused on the Aterian MSA levels, for which a total volume of sediment  
200 of 414 litres has been analyzed (Table S1); 162 litres correspond to the sediments of  
201 combustion features and 252 liters to archaeological sediments retrieved from outside the

202 combustion features (Table S2). A detailed overview of the sediments analyzed per  
203 archaeological level is given in Table S1. For comparison, the total volume of sediment  
204 processed for the MSA-LSA archaeological site Taforalt (northern Morocco) is 561 litres  
205 including both LSA and MSA levels (28).

206

207 **Observation of charcoal and seed fragments.** The anatomical wood characteristics of the  
208 charcoal from the archaeological sites were analysed under a reflected light microscope (200x  
209 to 500x magnification). Botanical identification was possible when the wood anatomy was  
210 observed in three dimensions, i.e., cross or transverse, radial and tangential sections (12). For  
211 comparison and aiding the identification modern *Olea europaea* charcoal reference samples  
212 (Fig. S4) were produced by placing a piece of modern olive wood in an aluminium container,  
213 which was covered by pure sand (e.g., Fontainebleau sand) and exposed to heat at 550 °C in  
214 an oven. This approach mimics the burning process in fireplaces by avoiding the complete  
215 combustion of samples as the supply of oxygen is limited.

216 Most charcoal samples contained high accumulations of iron oxides and minerals in the  
217 vessels and parenchyma (Fig. S5; 12), which made the identification of the wood taxa difficult.  
218 The charcoal fragments were chemically cleaned to improve the observation of the main  
219 anatomical features. Oxalic acid solutions were used as they do not dissolve the carbonates  
220 from the sediments which are incorporated in the wood structure of the charcoals and thus, no  
221 mechanical stress is applied due to possible gas releases (i.e. CO<sub>2</sub>) when using hydrochloric  
222 acid solutions.

223 Fragments of seeds and stones were analysed under a stereomicroscope for botanical  
224 identification (12). Modern stones from *Olea europaea* were used for comparisons with the  
225 fossil findings (Fig. 2).

226 A selection of samples (fossil and modern; charcoal and stones from *Olea europaea*) was  
227 analysed using a Scanning Electron Microscope (SEM) in order to observe anatomical details  
228 of wood and olive stone morphological features (Fig. 2; Figs S4, S5 and S6).

229

230 **Dating of fragments of charcoal and charred olive stones.** Dating of the fragments of  
231 charcoal and charred olive stones from Aterian MSA levels was expected to result in ages near  
232 50-45 ka or >50 ka as samples are assumed to be older than the range of radiocarbon dating  
233 (i.e., ca. 50 ka). This would confirm the contemporaneity of these findings and the  
234 archaeological levels in which they were found.

235 A total of fourteen fragments of charcoal and olive stones were used for dating (Table S4).  
236 Six Aterian MSA fragments correspond to charcoal and two to charred olive stones. For  
237 comparison with more recent archaeological levels, five fragments from LSA and one from the  
238 Neolithic were also dated.

239 Charred olive stones and charcoal fragments were prepared following the routine pre-  
240 treatment acid-alkali-acid protocol at the radiocarbon lab (UMR 7209, AASPE) of the Museum  
241 national d'Histoire naturelle (MNHN, Paris, France). Samples were pretreated using  
242 hydrochloric acid (HCl, 1M, 20°C, 1h) to remove exogeneous carbonates and then rinsed with  
243 MiliQ water. A few drops of sodium hydroxide solution (NaOH, 0.125 M, 20°C, 15 min) were  
244 added to the MiliQ water to eliminate humic acids and then rinsed again with MiliQ. A final  
245 HCl wash (1M, 1h) was applied to remove the remaining contamination from modern CO<sub>2</sub>  
246 taken up by alkali (NaOH). Samples were combusted at temperatures superior to 700 °C. CO<sub>2</sub>  
247 gas extractions were carried out using a carbon extraction line. Graphitization and AMS dating  
248 were carried out at the *Laboratoire de Mesure du Carbone 14* (CEA, Saclay, France). Dates  
249 were calibrated using IntCal20 and OxCal software.

250

251 **Statistics and Reproducibility.** Two hundred four fossil charcoal fragments and 55 seed  
252 fragments from *Olea europaea* have been observed. They all show the same anatomical  
253 characteristics. Three of the fossil seed fragments, four of the fossil charcoal fragments, two  
254 modern olive seeds and one modern charcoal fragment from *Olea europaea* were observed by  
255 using a scanning electron microscope, which resulted in the micrographs shown in figures 2b-  
256 d, 2f-h and supplementary figures 4a-f, 5a-d, 6d. Each of the four charcoal fragments was  
257 broken to create fresh surfaces to observe the anatomical features at the three anatomical wood  
258 sections.

259

260

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266 project El Harhoura-Témara. We further thank the three anonymous reviewers for their  
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268

269 **Author contributions:** Project conceptualization was initiated by L.M. and T.O. Identification  
270 of plant macro-remains was performed by T.O. Sampling was carried out by L.M., E.B.A, E.C.  
271 and R.N. Dating and faunal data were compiled by E.B.A., E.S., E.C. and C.F. Samples for  
272 dating were prepared by E.B.A., A.Z. and O.T. Excavations were led by R.N. and M.E.H. SEM  
273 images were taken and interpreted by A.S., W.K., L.M. and T.O. All authors have contributed  
274 to the writing of the manuscript and approved the final version.

275

276 **Competing interests:** The authors declare no competing interests.

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278

279 **Figure Legends/Captions (for main text figures):**

280 **Fig. 1. Location of the archaeological sites in Morocco and suitable areas for wild olive**  
281 **tree growth during the last full glacial cycle in the Mediterranean. (A)** Location of the  
282 Aterian Middle Stone Age and Iberomaurusian Late Stone Age sites cited in the text: 1) sites  
283 in the Rabat-Temara region, 2) Ghar Cahal, 3) Khef el Hammar, 4) Ifri el Baroud and 5)  
284 Taforalt. **(B)** Location of the Rabat-Temara sites. **(C)** Map of potential long-term refugia (red  
285 colour), i.e., regions considered as continuously suitable for the growth of wild olive trees  
286 during the last full glacial cycle (10). The names of El Harhoura 2 and El Mnasra caves are  
287 highlighted in bold.

288 **Fig. 2. Morphological characteristics of a modern (wild) olive stone and of fragments of**  
289 **a charred olive stone (sample E12-DYJSQ) found in the Aterian MSA level 7 at El**  
290 **Mnasra. (A)** Modern stone (stereomicroscope). **(B) (F)** A furrow (SEM). **(C) (G)** Detailed  
291 view of a furrow (SEM). **(D) (H)** Ladder-like structure in the furrow (SEM). **(E)** Fragment of  
292 Aterian MSA charred olive stones (stereomicroscope). SEM: Scanning Electron Microscope.  
293 Fu: Furrow. Note different scales.

294

295

296 **Data Availability:**

297 **Archaeobotanical material.** All data and code that are used in the main text and  
298 supplementary materials are presented in the file Supplementary Information. The material is  
299 housed at the Department of Botany of the University of Innsbruck, Austria.

300 **Pollen data.** The percentages of *Olea* pollen from three marine sedimentary cores (12) are  
301 available in the PANGAEA database:

302 A4-M15627-3: <https://doi.pangaea.de/10.1594/PANGAEA.55037>

303 A3-M16004-1: <https://doi.pangaea.de/10.1594/PANGAEA.55039>

304 A2-M15669-1: <https://doi.pangaea.de/10.1594/PANGAEA.55038>

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