

1 **Title:** Birch bark tar in early Medieval England – continuity of  
2 tradition or technological revival?

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15

16 **Abstract**

17 Birch bark tar is a manufactured product with a history of production and use that reaches back to the  
18 Palaeolithic. Its sticky, water resistant and biocidal properties mean that it has a wide range of  
19 applications, for example, as a multipurpose adhesive, sealant and in medicine. Archaeological  
20 evidence for birch bark tar in the old world covers a broad geographic range from the UK to the Baltic  
21 and from the Mediterranean to Scandinavia. In the east and north of this range there is continuity of  
22 use to modern times but in western Europe and the British Isles the use of birch bark tar has generally  
23 been viewed as limited to prehistory, with gradual displacement by pine tars during the Roman period.

24 Here, we report new finds of birch bark tar from two early Medieval sites in the east of England.  
25 Analysis by HT-GC/MS to identify the tars also revealed fatty material, possibly added to modify the  
26 tar. The different contexts of the finds point to diverse applications of the material: in one case perhaps  
27 a medicine, the other associated with a ceramic container, possibly used for processing the tar. The  
28 results present the first identification of birch bark tar from early Medieval archaeological contexts in  
29 the UK. Together they indicate a later period of use for birch bark tar in the UK than has been

30 previously observed and raise the question of whether this indicates evidence of a longer continuity  
31 of use than hitherto recognised or a later reintroduction of the technology in the Medieval period, in  
32 which case the similarities between the find sites, both early Anglo-Saxon cemeteries with comparable  
33 assemblages of grave goods, may be significant.

34 **Keywords:** birch bark tar; early Medieval; HT-GCMS; lipids; betulin.

35

## 36 **1. Introduction:**

37 Birch bark tar is a manufactured product, synthesized by dry (destructive) distillation of birch bark  
38 (*Betula* sp.). Birch bark tar is found in many different contexts in the archaeological record. It has been  
39 used as both a waterproofing agent and an adhesive on a wide variety of artefacts, including hafting  
40 stone and bone tools (Binder *et al.*, 1990; Aveling and Heron, 1998; Regert *et al.*, 1998; Sauter *et al.*,  
41 2000; Koller *et al.*, 2001; Mirabaud *et al.*, 2015), for repairing, sealing and as a surface decoration on  
42 ceramic vessels (Charters *et al.*, 1993; Urem-Kotsou *et al.*, 2002; Regert, 2004; Morandi *et al.*, 2018)  
43 and for various other adhesive purposes such as assembling composite objects (Stacey, 2004; Ribechini  
44 *et al.*, 2011) or making jewellery (Courel *et al.*, 2018). The material has been used in medicinal  
45 preparations or perfumery (Karg *et al.*, 2014; Rageot *et al.*, 2019), for its odoriferous properties in  
46 funerary contexts (Lucquin *et al.*, 2007) and lumps with tooth impressions indicate that it was  
47 sometimes chewed (Heron *et al.*, 1991; Aveling and Heron, 1999; Van Gijn and Boon, 2006; Karg *et al.*,  
48 2014). It is also found in the form of ductile lumps or cakes/loaves in various contexts, including burials  
49 and settlements (Hayek *et al.*, 1990; Aveling and Heron, 1998; Dal, 1998; Regert *et al.*, 2003;  
50 Bergström, 2004).

51 In the old world, evidence for the use of birch bark tar is widespread across a geographical range that  
52 extends from the UK to Bulgaria (Aveling and Heron, 1998; Ribechini *et al.*, 2011) and from Corsica  
53 (Rageot *et al.*, 2016) and Greece (Urem-Kotsou *et al.*, 2002) to the north of Norway (Nordby 2008) .  
54 The earliest known production of the material dates back as far as the Early Palaeolithic c. 185–135 ka  
55 (Mazza *et al.*, 2006) and in Scandinavia and eastern Europe a tradition of manufacture and use  
56 continues to the present day (Kurzweil and Todtenhaupt 1990, 1991; Reunanen *et al.* 1993; Pesonen  
57 1999; Rajewski 1970). However, in northwest Europe, the use of birch bark tar has generally been  
58 considered to be restricted to prehistory, gradually being displaced by pine tars during the Roman  
59 period (Pollard and Heron, 2008) although recent analytical work (Regert *et al.*, 2019) and increasing

60 attention to tar in post-excavation reporting (e.g. Seager Smith 2015) has begun to challenge this  
61 theory.

62 Here, we report the first evidence from the British Isles of birch bark tar in early Medieval contexts,  
63 presented by finds from two different sites.

## 64 **2. The sites and finds (Archaeological background/context)**

### 65 **2.1 Hatherdene Close, Cherry Hinton, Cambridge**

66 In 2016, excavations by Oxford Archaeology in a field west of Hatherdene Close, Cherry Hinton,  
67 Cambridge, revealed a prehistoric crouched burial, Late Iron Age and Roman ditches, an early Roman  
68 funerary enclosure and cremation burials and a significant number of early Anglo-Saxon burials (Figure  
69 1; Ladd and Mortimer, 2018). The early Medieval remains at the site comprised an inhumation  
70 cemetery of 126 skeletons. Most were aligned SW-NE (head to the south-west) although notable  
71 variations point to possible changing practices or differential burial customs and were mainly lying  
72 supine (Ladd and Mortimer, 2018). The majority contained a single individual although others  
73 contained two or more individuals buried side by side or stacked. Many contained grave goods  
74 including weapons (iron spear heads and ferrules, shield bosses, and a set of arrowheads) and dress  
75 accessories (copper alloy brooches, wrist clasps, rings, pins, mounts, pendants, toilet items and a  
76 chatelaine). Although analysis of the finds is continuing, a substantial bead assemblage from across  
77 the cemetery, including amber, polychrome, monochrome and some faience beads, points to a 5-6<sup>th</sup>  
78 century date consistent with the initial radiocarbon dates from two skeletons. These were AD 417-569  
79 (95.4%, SUERC-71018) and AD 404-549 (95.4%, SUERC-71017) although it should be noted that the flat  
80 IntCal13 calibration curve (Reimer *et al.*, 2013) between AD 430 and AD 540 meant a broad date range.  
81 A small number of items are independently datable by typology (cruciform brooches, a great square-  
82 headed brooch and potentially some of the buckles) and fall into the broad bracket of the second half  
83 of the 5th century up to AD 550/60 (Hines, 1997; Hines and Bayliss, 2013; Martin, 2015), implying a  
84 relatively brief lifespan of the cemetery between the later 5th and first half of the 6th century.

85 The presence of several atypical iron artefacts and a near-complete glass-claw beaker suggest links  
86 with communities located in south-east England. A few burials also contained whole or part 5-6<sup>th</sup>  
87 century pottery vessels. Glass claw-beakers, which are expensive and exclusive drinking vessels, are  
88 often found in high-ranking burials such as Sutton Hoo, Snape and Mucking (Evison, 1982). The  
89 presence of this vessel in a grave may suggest a local elite group who had access to high status items.

90 In one burial, that of a child, an amorphous brown/black 'lump' of material, initially retained as a  
91 possible potsherd, was found (grave 293; Figure 2). The grave also contained an assortment of  
92 brooches and beads on the child's chest area and a variety of artefacts, including an iron knife, a copper  
93 alloy girdle hanger, an iron ring (possibly a small purse or bag ring), all likely contained, together with  
94 the amorphous 'lump' of material, in a bag hanging from a belt. The presence of these items might  
95 suggest a female burial. The skeleton was aged 7-9 years, based on epiphyseal fusion and dental  
96 development/eruption. Interestingly, there are some pathological indicators present, including *cribra*  
97 *orbitalia* present in the right orbit. This could be an indicator of general health stress, possibly iron  
98 deficiency anaemia/vitamin B<sub>12</sub> deficiency (Schutkowski 2008). There is also active periostitis on the  
99 inside surface of two of the left ribs, perhaps indicative of localised inflammation/infection of the  
100 adjacent soft tissue, although there is no evidence to point to a specific infection.

## 101 **2.2 Site context: Ringlemere Farm, Woodnesborough, Kent**

102 In 2001, a metal-detectorist discovered a fine early Bronze Age gold cup at Ringlemere Farm (Kent,  
103 UK). This triggered a broader excavation, led by the British Museum and Canterbury Archaeological  
104 Trust, the following year, continuing annually until 2006. During this work, archaeologists established  
105 that the cup had been placed in a large turf barrow mound (some 41.5m in diameter), with a  
106 substantial surrounding ditch (Needham *et al.*, 2006). The mound, termed 'M1', was prehistoric in date  
107 but in its north-western corner a fifth- to sixth-century ceramic pot (see below, 3.1) provided the first  
108 clear glimpse of early Medieval activity on the site. This was confirmed by the discovery of a sunken  
109 featured building dating to the seventh century, followed by a substantial early Anglo-Saxon cemetery,  
110 unearthed during successive excavations between 2004 and 2006 (Figure 3). It comprised fifty-one  
111 burials arranged in groups around the southern and western area of the prehistoric mound, with more  
112 graves likely in the unexcavated zones of the site. Most of the burials contained inhumations but ten  
113 cremations, a rare funerary rite in Anglo-Saxon east Kent, were also present (Parfitt 2009; Marzinzik  
114 2011; Marzinzik 2013).

115

116 The material assemblage at Ringlemere suggested that the cemetery was in use between the mid fifth  
117 to early sixth centuries. It also signalled a relatively affluent community, consuming glass and amber  
118 beads, belt buckles, purse mounts and brooches, some made from or incorporating precious metals –  
119 together with a degree of cultural diversity, reflected by connections with Continental populations  
120 across the Channel as well as the existing Romano-British milieu in Kent. The precise nature of these  
121 links awaits detailed study in a future publication; but the archaeological contexts present at  
122 Ringlemere raise the distinct possibility that at least some of the population buried there represent

123 very early, perhaps even first-generation, settlers from the Continent (Parfitt 2009; Marzinzik 2011;  
124 Marzinzik 2013).

125

### 126 **3. The samples.**

#### 127 ***3.1 Ringlemere vessel (1112)***

128 The ceramic vessel (1112) was discovered set into the side of the outer M1 mound in a small, ill-defined  
129 pit (Parfitt 2009). The vessel (Figure 4) is complete, 113mm diameter at the rim and c. 47cm in height.

130 Its form is a squat biconical jar or deep bowl with a rounded carination about half way up and  
131 decorated on the exterior with a chevron pattern. The fabric is a fine sandy ware and the whole exterior  
132 is lightly burnished. The form, fabric and decoration are consistent with other local examples dating to  
133 5<sup>th</sup>-6<sup>th</sup> century AD (Macpherson-Grant and Mainman 1995; Macpherson-Grant, 1999;) and suggest the  
134 vessel is a product of a Canterbury potter or workshop (Cotter 2003). Parallel vessels have been  
135 equated with similar decorated forms from Jutland and Frisia (Myres 1977). The interior of the vessel  
136 has a burnished appearance due to the presence of a shiny black residue which was sampled for  
137 analysis. Five samples (each approximately 2.5mg) were removed using a clean scalpel blade: one from  
138 already detached material on the interior (location unspecified) and two (from the rim and the bottom)  
139 on each surface (interior and exterior).

140

#### 141 ***3.2 Cherry Hinton lump***

142 The amorphous lump of brown/black material was found with other items interpreted as the  
143 contents of a bag hanging from a belt belonging to the child. The lump (Figure 5) was 4 cm in length,  
144 3 cm wide and less than 1 cm thick, with a weight of approximately 6 g. The material seemed quite  
145 pliable and was regular in shape being mostly square, with one rounded end, and the indentations on  
146 the surface suggested it had been manually moulded into shape. It contained white inclusions,  
147 possibly small pieces of plant fibre, and was elastic in nature, with an uneven, clay-like texture. No  
148 tooth impressions were present on the surface and it did not have the appearance of having been  
149 used as chewing gum. Approximately 10 mg of sample was sectioned from the main body for  
150 analysis.

151

### 152 **4. Methods of analysis**

153 Analyses of materials from the two sites were carried out separately at two different institutions (the  
154 Ringlemere residue at the British Museum (BM) and the Cherry Hinton lump at the University of Bristol  
155 using the same analytical techniques and comparable extraction procedures based on established

156 published protocols for lipid analysis (e.g. Charters *et al.*, 1993). In both cases the samples were  
157 extracted into a chloroform/methanol 2:1 (v/v) solution using ultrasonication. After decanting, the  
158 supernatant was concentrated under nitrogen and the samples were derivatised using *N,O*-  
159 bis(trimethylsilyl)trifluoroacetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) to form trimethylsilyl  
160 (TMS) derivatives. Laboratory blanks were prepared to monitor for analytical contamination and at the  
161 BM internal standards were added to enable calculation of extractable lipid yield. Analysis in both cases  
162 was by high temperature gas chromatography - mass spectrometry (HT-GC/MS) using on-column  
163 injection or pseudo on-column inlets, non-polar column and helium carrier gas. Analysis by HT-GC/MS  
164 enables separation, identification and quantification of the molecular components of the sample. For  
165 a detailed description of the procedure at each institution see Appendices 1 and 2.

166

## 167 **5. Results**

168 Analysis of the lipid extracts obtained from samples from both objects revealed a complex mixture of  
169 molecular components (Table 1; Figures 6, 7 and 8). In the samples from the Ringlemere vessel  
170 recovery of molecular material was low (less than  $10\mu\text{g}/\text{mg}^{-1}$  of sample).

171 In the Cherry Hinton lump the dominant compounds present included the pentacyclic triterpenoids  
172 betulin and lupeol along with lupenone and betulone, known together to be characteristic of birch  
173 bark (O'Connell *et al.*, 1988; Hayek *et al.*, 1989; Hayek *et al.*, 1990; Cole *et al.*, 1991; Hua *et al.*, 1991).  
174 These were identified by relative elution orders and characteristic mass spectra (see Charters *et al.*,  
175 1993 Aveling and Heron 1998, Binder *et al.* 1990, Charters *et al.* 1993, Regert *et al.* 1998). Other  
176 compounds regarded as characteristic of the degradation reactions undergone by bark during the  
177 heating processes necessary to produce birch bark tar were also present (Figure 6). For example,  
178 betulin is partially transformed into lupa-2,20(29)-dien-28-ol by dehydration and lupeol leads to the  
179 formation of lup-2,20(29)-diene (Aveling and Heron 1998; Regert 2004). Furthermore, the presence of  
180 the  $\alpha$ ,  $\omega$ -docosandioic acid, likely derived from the suberic polymer, suggests this tar may have been  
181 made using under specific heating conditions, such as the double-pot method (Rageot *et al.*, 2019).

182 Six of these pentacyclic lupane-type triterpenoid constituents were also identified in the Ringlemere  
183 residue. In contrast to the Cherry Hinton lump, they occur at low levels and only in the three interior  
184 samples. A partial extracted ion chromatogram ( $m/z$  189 and  $m/z$  203) showing these terpenoid  
185 derivatives is illustrated in Figure 7. Surprisingly, no lupeol and no lupa-2,20(29)-diene were identified;  
186 this absence has not been reported before and might be due here to the very low quantity of birch

187 bark tar present in the samples which meant that some of the triterpenoids could not be confidently  
188 identified.

189 In addition to typical birch bark tar triterpenoid constituents, higher molecular weight triterpenoid  
190 esters indicative of heating in the presence of acyl lipid (Dudd and Evershed 1999), were identified in  
191 both tars. These are prominent in the composition of the Cherry Hinton lump Figure 6, eluting between  
192 26 and 30 minutes, whereas in the Ringlemere residue only lup-2,20(29)-dien-28-yl palmitate could be  
193 confidently identified, although two further triterpenoid acyl fatty acids eluting between 35.5 and 36.5  
194 minutes were noted (Figure 7).

195 Free acyl lipid was also present in both tars, and in all of the Ringlemere samples the acyl lipid  
196 dominated the composition. Free saturated fatty acids from C<sub>9:0</sub> to C<sub>22:0</sub> were observed, with palmitic  
197 acid (C<sub>16:0</sub>) and stearic acid (C<sub>18:0</sub>) the most abundant. Monounsaturated oleic and palmitoleic acids  
198 were detected at low levels and acylglycerols were almost absent with only traces of triacylglycerols  
199 (TG) observed as indicated on the extracted ion chromatogram in Figure 8. Cholesterol, the major  
200 sterol in animal fats was also identified in all five of the Ringlemere samples. The Cherry Hinton lump  
201 also contained saturated and unsaturated fatty acids (Figure 6) but in a narrower range with only C<sub>16:0</sub>,  
202 C<sub>16:1</sub>, C<sub>18:0</sub> and C<sub>18:1</sub> fatty acids represented.

## 203 **6. Discussion**

204 The results provide evidence for the presence of birch bark tar at both sites and in both cases the  
205 manufactured tar product is accompanied by lipid. Nevertheless, there are differences in the chemical  
206 composition in each case that reflect the differing nature of the finds (lump vs surface residue) and the  
207 site contexts (grave good vs isolated find). It is therefore worth considering the composition of each  
208 find in its context before exploring the significance presented by the finds together.

209

### 210 **6.1 Local context: Ringlemere**

211 The acyl lipid in the Ringlemere samples seems to indicate the presence of some fatty residue as the  
212 profile of compounds is typical of highly degraded archaeological food lipid residues (Evershed et al.  
213 2001). However, caution in this interpretation is necessary because the acyl lipids are present in all the  
214 samples (interior and exterior) and these compounds, cholesterol in particular, can also be introduced  
215 during burial and as contaminants deriving from handling (Hammann et al 2018). The birch bark tar  
216 compounds occur only in samples from the interior of the vessel and therefore can be more confidently  
217 attributed to the black shiny interior coating on the vessel. The black colouration of the exterior  
218 residues must therefore be attributed to charring or sooting and indeed charred deposits may also

219 contribute to the interior surface blackening as the levels of birch bark tar triterpenoids detected are  
220 very low. The presence of triterpenoid fatty acyl esters imply that the tar and fat components must  
221 have been heated together during use of the vessel (Dudd and Evershed 1999).

222

223 Several scenarios can be envisaged which would give rise to this pattern of residues. The vessel could  
224 have been used for processing a mixture of fatty material with birch bark tar. Mixtures of animal fat  
225 and birch bark tar have been previously reported (Regert *et al.* 1998, Dudd and Evershed 1999) and  
226 this could have been practised intentionally to produce a tar/fat material for specific use or with  
227 desirable properties. Alternatively, the two materials could represent separate uses of the vessel. It is  
228 possible that the vessel was coated internally with birch bark tar to effect waterproofing/sealing and  
229 then subsequently used for processing fatty material. Sealing of ceramics with organic materials such  
230 as resins or waxes is not uncommon but only a few examples have been reported of birch bark tar used  
231 in this way, for example on Iron Age vessels at the site of Grand Aunay in France (Regert *et al.* 2003)  
232 and in vessels from the Neolithic settlement at Makriyalos in Greece (Urem-Kotsou *et al.* 2002). Birch  
233 bark tar has also been used as an adhesive to repair ceramics (Charters *et al.* 1993; Regert and Rolando  
234 2002) but, as the Ringlemere vessel is intact, this application can be discounted. The burnished exterior  
235 surface of the vessel suggests that sealing also would probably have been unnecessary, at least for  
236 practical reasons, and interior coatings are not described for other comparable vessels from the region  
237 (Macpherson-Grant 1999). The introduction of birch bark tar biomarkers during firing of the vessel  
238 should be considered, as recent research has demonstrated that pyrolytic products of fuel used in  
239 firing can penetrate low-fired ceramic fabrics (Reber *et al.* 2018). In this instance, the firing scenario  
240 would need to have produced a shiny black deposit localised on the interior of the vessel and excluded  
241 other resinous fuel sources such as pine, for which no chemical signatures were observed.

242

243 Reversing the use sequence, the vessel could have been used as a cooking pot before being used for  
244 processing tar, either for melting it prior to use or in primary production of the material. Much  
245 attention has been given to ancient methods of manufacturing of tar, ranging from industrial scale  
246 earth mounds which are attested archaeologically (Surmiński, J. 1997; Hennius, A. 2018) to theories of  
247 hearth pit production that could have been used by aceramic societies (Kozowyk *et al.* 2017; Groom *et al.*  
248 2015). The most productive method for small scale production uses a 'double-pot' method where  
249 the bark is sealed in a pierced vessel and the tar distillate drains into a sunken collection vessel beneath  
250 the fire (Piotrowski 1999). Although the excavated location of the Ringlemere vessel, sunk into the side  
251 of the outer M1 mound, might be consistent with such a small-scale tar-production activity, the tar  
252 deposits and the vessel argue otherwise. Retrieval of the tar would likely leave evidence of pouring on



253 the vessel, but more likely the collection vessel itself would have been taken away unless the tar was  
254 to be used at the production site. Moreover, it seems unlikely that at least some evidence of the  
255 associated hearth would not have survived. Two other complete Anglo-Saxon vessels were found in  
256 pits within the cemetery and it has been speculated that all the vessels were deposited as offerings  
257 (Parfitt 2009).

258

## 259 **6.2 Local context: Cherry Hinton**

260 The presence of saturated and unsaturated fatty acids in the Cherry Hinton lump might suggest some  
261 further processing of the tar post-manufacture, through the addition of animal fats or possibly plant  
262 oils. This would be consistent with the presence of terpenoid esters that form when tar and fat are  
263 heated together (Dudd and Evershed 1999). Mixing birch bark tar with tallow reportedly makes the tar  
264 thicker and prolongs its usability (Wrębiak 1971: 34, cited in Pietrzak 2012). However, the fatty acid  
265 profile is very similar to that which can be produced in birch bark tar (derived from the suberic polymer  
266 in the bark) when the tar is produced under certain conditions and thus could point instead to a tar  
267 that was produced using the double-pot method or similar process that separates the tar from residual  
268 bark products during manufacture (Rageot et al. 2019).

269 The purpose of the birch bark tar lump in the Cherry Hinton child burial is not known. However, the  
270 lump does not have the characteristic appearance of having been chewed. Consequently, it is possible  
271 that the birch bark tar found in the grave was kept for its medicinal/antiseptic properties. Certainly,  
272 the presence of birch bark tar in the grave of a child with pathological indicators present on the skeletal  
273 remains might well suggest that it was used for its medicinal properties whilst the child was alive. Birch  
274 bark tar has a long history of use in both pharmacology and veterinary medicine and is well-known for  
275 its antiseptic and antimicrobial properties (Langenheim, 2003; Šiman *et al.*, 2016). It has been used to  
276 treat colic and mange within veterinary contexts and skin diseases, such as eczema, psoriasis, shingles  
277 and atopic dermatitis, and malaria, dropsy and gout in folk medicine. Other applications have included  
278 the chewing of birch bark tar as a cleaning agent and disinfectant for the mouth (small amounts of  
279 disinfectants are released from the tar during mastication) and as an anaesthetic for toothache (Heron  
280 *et al.*, 1991; Charters *et al.*, 1993; Aveling and Heron, 1999; Aveling, 2005; Van Gijn and Boon, 2006;  
281 Kjellström *et al.*, 2010; Fuchs, 2012; Karg *et al.*, 2014). The pentacyclic triterpenoids present in birch  
282 bark have also proven to be useful bioactive compounds, particularly in modern-day medicine  
283 (Krasutsky, 2006). Interestingly, birch bark itself was used as an antiseptic in folk medicine to treat  
284 purulent wounds and various skin diseases. For example, betulin was known to exhibit antiseptic

285 properties and was used for the sterilization of plasters and bandages (Kuznetsova *et al.*, 2014). It  
286 should also be noted that birch bark tar gives off a distinctive and pleasant odour.

287 Birch bark tar is commonly reported from contemporary grave contexts in Early Iron Age Scandinavia,  
288 but it is typically present as a sealing material for lath-walled containers (Nordby 2008 and references  
289 therein) rather than among personal goods. A closer comparator comes from a burial of Late Roman  
290 Iron Age date at Bornholm (Denmark) which contained birch bark tar chewing gum inside a box (Karg  
291 *et al.* 2014). Amorphous lumps of bitumen were among the grave goods deposited in the 7th century  
292 ship burial at Sutton Hoo (Suffolk, UK) and although their significance is unclear, medicinal use is one  
293 possible interpretation (Burger *et al.* 2016).

### 294 **6.3 Connections between the sites**

295 The exceptional presence of birch bark tar at two broadly contemporary Anglo-Saxon cemeteries in  
296 different regional contexts poses questions about links between the sites. These are, to some degree,  
297 addressed by the wider archaeological record. Several grave goods recovered from Cherry Hinton are  
298 of types that occur more typically in southern and south-eastern England, including Kent, where  
299 Ringlemere is situated. They comprise arrowheads, lozengiform shield fittings, and types of shield boss  
300 and spearheads (Ladd and Mortimer 2018). Such finds in part reflect inter-regional contacts between  
301 eastern England and Kent at this time, which is nothing new; but another strikingly similar artefact  
302 unearthed at both cemeteries presents the possibility of a more direct link between the communities  
303 buried at Cherry Hinton and Ringlemere.

304 One grave at each cemetery contained an amber-coloured glass claw beaker of Evison's type  
305 3c. This in itself is not unusual: type 3c is the most common form of claw beaker, distributed across  
306 eastern and southern England; nor are amber-coloured examples especially rare, occurring for  
307 instance at Snape in Suffolk, East Shefford in Berkshire and even Dinas Powys in Glamorgan, Wales,  
308 among other sites (Evison 2008). However, the Cherry Hinton vessel has a distinctly Kentish flavour.  
309 Like the Ringlemere claw beaker and others found in Kent, it lacks a distinctive loop on the ridged trails  
310 decorating its claws, present on most examples found outside of Kent and taken as a sign of  
311 manufacture elsewhere (Evison 2008; Ladd and Mortimer 2018). The likelihood of a common point of  
312 origin for the two vessels is, for now, uncertain since finer points of comparison regarding style,  
313 proportions and chemical composition await ongoing research. However, the presence of two very  
314 similar claw beakers at sites already linked by the exceptional discovery of birch bark tar may add  
315 credence to the notion that the populations at Cherry Hinton and Ringlemere were, in some way,  
316 connected.

317           The precise nature of the link must remain a matter for speculation until research on both sites  
318 is completed. Scenarios that may explain the parallels range from direct interaction to mere  
319 coincidence, with a middle option being a more a diffuse connection in which both communities had  
320 access to similar cultural complexes, networks or exchange mechanisms that supported the sharing of  
321 resources, skills and knowledge including the making and use of birch bark tar. The likeliest scenario,  
322 based on current understanding of the sites, emerges from a broader comparative view of the issue.  
323 While both Cherry Hinton and Ringlemere have produced birch bark tar, the find contexts and uses of  
324 the material differs markedly between the sites: it is a grave good at the former, and a residue in a pot  
325 buried in the ground at the latter. The claw beaker at Cherry Hinton, meanwhile, sits comfortably  
326 within the Kentish-flavoured assemblage at the cemetery, its similarities to the Ringlemere beaker not  
327 necessarily reflecting a Ringlemere origin for the Cherry Hinton vessel, but a *Kentish* origin for *both*  
328 vessels. The proximity of prehistoric features at the cemeteries is also notable, but is best explained as  
329 part of a wider trend for siting Anglo-Saxon burial grounds close to ancient monuments (Semple, 2013).  
330 As research stands, on the balance of probabilities, the presence of birch bark tar at both Cherry Hinton  
331 and Ringlemere is likely to represent another example of diffuse, inter-regional connections between  
332 early medieval communities. For now at least, its exceptionality may be coincidental – and is perhaps  
333 a harbinger for further birch bark tar discoveries in future excavations of early medieval contexts.

334

#### 335 **6.4 Birch bark tar in northwestern Europe**

336 The two finds are the first examples of birch bark tar to be identified from early Medieval  
337 archaeological contexts in the UK. This is particularly interesting because, although in Scandinavia and  
338 eastern Europe birch bark tar has been used up to the present day, in northwest Europe its use has  
339 been considered to be more prevalent in prehistory. These two finds indicate a later period of use for  
340 this material in the region than has been recognised hitherto, raising the question of whether this is  
341 indicative of continuity of use or a later reintroduction of the technology.

342 It is likely that occurrences of birch bark tar have been overlooked in the archaeological record.  
343 Evidence from the Roman period in the UK is limited to two published chemically identified examples:  
344 an adhesive used to repair a Roman jar excavated at West Cotton, Northamptonshire (Charters et al.  
345 1993) and the contents of a small enamelled vessel from Catterick, North Yorkshire (Dudd and  
346 Evershed 1999). However, adhesive repairs on a range of Roman period vessels from Kent have been  
347 described as birch bark tar (Seager Smith 2015) at least some of which are supported by (unpublished)  
348 chemical analysis (Marter Brown and Seager Smith 2012). Other Roman period examples have been  
349 reported from Scandinavia (Bergström 2004; Karg et al. 2014) and from continental Europe (e.g.

350 adhesive on a spindle from Naintré, Ribechini et al. 2011 (first reported in Devière 2009)). The corpus  
351 of such material in France has been significantly extended by a recent study of Roman furniture inlays  
352 (Regert et al. 2019) which again underlines the likelihood of a larger body of material present in  
353 archaeological archive collections elsewhere that has, to date, gone unreported, because the  
354 published record depends upon chemical analysis.

355 Alternatively, the appearance of two new later finds in the east of England could signal a revival of the  
356 birch bark tar tradition in the early Medieval period coincident with the arrival of settlers from north  
357 eastern Europe where the continuity of the technology was unbroken. The etymology of the word 'tar'  
358 at least provides a Germanic link: the Old English *teoru*, *teru* meaning 'tar, bitumen, resin, gum' or  
359 literally 'the pitch of (certain kinds of) trees' derives from the Proto-Germanic *\*terw-* (also the source  
360 of the Old Norse *tjara*, Old Frisian *tera*, Middle Dutch *tar*, Dutch *teer*, German *Teer*) which is probably  
361 a derivation of *\*trewo-*, from Proto-Indo-European *\*derw-*, variant of root *\*deru-* "be firm, solid,  
362 steadfast," with specialized senses "wood, tree" and derivatives referring to objects made of wood  
363 (Tar n.d.). But this equally applies to pine tar, which, by Viking times, was produced on an industrial  
364 scale in Scandinavia and this burgeoning production of tar has been linked to its maritime use as timber  
365 preserver and caulking material for wooden boats (Hennius 2018). There are few preserved Anglo-  
366 Saxon boats and, of these, only from the Nydam boat (AD 310) has any tarry caulking material been  
367 described (McGrail 2004) although there is no published analysis to indicate if this is pine pitch or birch  
368 bark tar. Tar once attributed to the 7th century ship at Sutton Hoo (Suffolk, UK) has been shown to be  
369 imported bitumen associated with the grave goods rather than the ships timbers (Burger et al 2016).  
370 Distinct uses of birch bark tar and pine tar have been reported historically with pine tar extensively  
371 used as a timber preservative in Scandinavia (Hennius 2018) and birch bark tar favoured for tanning  
372 leather in Poland (Pietrzak 2012). Differentiation might be attributed to practical considerations, such  
373 as scale or locus of production as much as differences in physical properties of the materials. It is not  
374 clear to what extent black 'tarry' materials were differentiated by origin in ancient times; their  
375 properties and appearance may be similar in practical terms but cultural meanings may have deeper  
376 associations that would direct the use of these materials in funerary contexts or in propagating  
377 continuity of tradition. Tracking the occurrence of tar in the archaeological record is a means to  
378 examine these questions further with each new analysis extending our understanding of the economic  
379 and cultural significance of tar in different locations and periods.

380

## 381 **7. Conclusions**

382 New finds of tarry material from two early Medieval sites in the east of England have been analysed  
383 by HT-GC/MS and shown to comprise birch bark tar, a product manufactured by pyrolytic heating of  
384 bark. At Hatherdene Close (Cherry Hinton) a lump of birch bark tar in a child's burial may have been  
385 processed or mixed with fatty material, perhaps to modify its properties. The lump was found  
386 contained within a purse with other items and may have been for medicinal use. At Ringlemere a  
387 black coating on the interior surface of a ceramic pot may indicate the use of the vessel for  
388 processing, possibly even manufacturing, tar; although the application of the material as a surface  
389 sealant or coating cannot be ruled out. Fatty Lipid identified in the Ringlemere tar may have been  
390 mixed with the tar but could also represent a separate use of the vessel or more recent  
391 contamination.

392 The results reported here present the first identification of birch bark tar from early Medieval  
393 archaeological contexts in the UK. Together they indicate a later period of use for birch bark tar in the  
394 UK than has been previously observed based on published birch bark tar finds and raise the question  
395 of whether this indicates evidence of a longer continuity of use than hitherto recognised or a later  
396 reintroduction of the technology in the Medieval period, in which case the similarities between the  
397 find sites, both early Anglo-Saxon cemeteries with comparable assemblages of grave goods, may be  
398 significant.

399

#### 400 **Appendix 1 (BM analytical method)**

401 The samples (~ 2.5 mg) were solvent extracted using 1 mL of a chloroform / methanol 2:1 (v/v) solution  
402 after addition of two internal standards (tetratriacontane 20 µg and cholestane 20 µg). The samples  
403 were agitated in an ultrasonic bath for 15 minutes after which insoluble material was allowed to settle  
404 and the solvent was decanted to a fresh vial. This was repeated three times and the extracts combined.  
405 All of the total lipid extracts were evaporated to dryness under nitrogen. The dry residue was then  
406 derivatised by heating at 70°C for 30 minutes with 50 µL *N,O*-bis(trimethylsilyl)trifluoroacetamide  
407 (BSTFA) + 1% trimethylchlorosilane (TMCS) to form trimethylsilyl (TMS) derivatives.

408 The samples were analysed using an Agilent 6890N gas chromatograph (GC) coupled to an Agilent  
409 5973N mass spectrometer (MS). Samples of 1 µL were injected at on-column at 10.74 psi with the inlet  
410 temperature programmed to follow the oven cycle. The analytical column was an SGE HT-5, 12 m x 0.1  
411 mm, 0.1 µm film thickness, column fitted with a 1 m x 0.53 mm deactivated retention gap (J&W) was  
412 used. The carrier gas was helium in constant flow mode at 1.0 mL min<sup>-1</sup>. After a 2 minutes isothermal

413 hold at 40°C the oven was temperature programmed to 350°C at 10°Cmin<sup>-1</sup> with the final temperature  
414 held for 12 minutes. The MS interface temperature was 330°C. Acquisitions were made in full-scan  
415 mode (*m/z* 50–650) with a cycle time of 1.0 s after a solvent delay of 7 minutes. System control and  
416 data collection/manipulation were achieved using G1701DA Chemstation (G1701DA) software.

## 417 **Appendix 2 (Bristol analytical method)**

418 A small amount of material (~ 1g) was sectioned from the main lump of material and extracted *via*  
419 ultrasonication (10 min) with chloroform/methanol 2:1 (*v/v*). After allowing the particulate matter to  
420 settle, the supernatant was decanted and evaporated under a stream of nitrogen. Aliquots of the TLE's  
421 were derivatised using 30 µL BSTFA + 1% TMCS, excess BSTFA was removed under a gentle stream of  
422 nitrogen and the derivatised TLE was dissolved in hexane prior to HT-GC and HT- GC/MS.

423 The GC analyses were carried out using an Agilent Technologies 7890A GC system connected to a PC  
424 using Chemstation data acquisition software. Derivatised total lipid extracts (1.0 µL) dissolved in  
425 hexane were introduced by on-column injection. The analytical column was an Agilent J & W DB1 15  
426 m x 0.32 mm coated with dimethyl polysiloxane (film thickness, 0.10 µm). The temperature  
427 programming was from 50 to 350° at 25°Cmin<sup>-1</sup>, following a 1 min isothermal hold at 50° C. At the end  
428 of the temperature ramp the GC oven was maintained at 350° C for 5 minutes.

429 Compound identification was accomplished using gas chromatography-mass spectrometry (GC-MS).  
430 The TLE was introduced (1.0 µL) by autosampler via a programmable temperature vaporising (PTV)  
431 type injector into a GC-MS fitted with Agilent HT-1 0.3 m x 0.54 mm pre-column and, subsequently, an  
432 Agilent J & W DB-1 15 m x 0.32 mm analytical column, both coated with a stabilised dimethyl  
433 polysiloxane phase (film thickness, 0.10 µm). The instrument was a ThermoScientific Trace 1300 GC  
434 attached *via* a heated (400°C) transfer line to an ISQ MS operating in EI mode (electron energy 70 eV,  
435 scan time of 1.3 s<sup>-1</sup>). Samples were run in full-scan mode (*m/z* 50–650) and the temperature  
436 programme comprised an isothermal hold at 50°C for 2 min, ramping to 300°C at 10°Cmin<sup>-1</sup>.. Data  
437 acquisition and processing were carried out using XCalibur software (version 3.0, ThermoScientific).  
438 Peaks were identified on the basis of their mass spectra and gas chromatography (GC) retention times,  
439 by comparison with the NIST mass spectral library (version 2.0).

440

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## 452 **References**

- 453 Aveling, E. (2005). Characterisation of natural products from the Mesolithic of Northern Europe. In:  
454 Huseby klev. En kustboplats med bevarat organiskt material från äldsta mesolitikum till järnålder,  
455 Bohuslän, Morlanda socken, Husby 2:4 och 3:13, RAÄ nr 89 och 485, ed. B. Nordkvist, Mölndal. 135-  
456 146.
- 457 Aveling, E. and Heron, C. (1998). Identification of birch bark tar at the Mesolithic site of Star Carr.  
458 *Ancient biomolecules* 2(1): 69-80.
- 459 Aveling, E. M. and Heron, C. (1999). Chewing tar in the early Holocene: an archaeological and  
460 ethnographic evaluation. *Antiquity* 73(281): 579-584.
- 461 Bergström, L. (2004). The Roman Iron Age tar loaf from Albertsro, Sweden – and the Scandinavian Tar  
462 Loaves of the Bronze Age. *Acta Archaeologica* 75(2): 1-13.
- 463 Binder, D., Bourgeois, G., Benoist, F. and Vitry, C. (1990). Identification de brai de bouleau (*Betula*)  
464 dans le Néolithique de Giribaldi (Nice, France) par la spectrométrie de masse. *ArchéoSciences, revue*  
465 *d'Archéométrie* 14(1): 37-42.
- 466 Burger P., Stacey R. J., Bowden S. A., Hacke M., Parnell J. (2016). Identification, Geochemical  
467 Characterisation and Significance of Bitumen among the Grave Goods of the 7th Century Mound 1  
468 Ship-Burial at Sutton Hoo (Suffolk, UK). *PLOS ONE* 11(12): e0166276.
- 469 Charters, S., Evershed, R. P., Goad, L. J., Heron, C. and Blinkhorn, P. (1993). Identification of an adhesive  
470 used to repair a Roman jar. *Archaeometry* 35: 91-101.

471 Cole, B. J. W., Bentley, M. D., Hua, Y. and Bu, L. (1991). Triterpenoid Constituents in the Outer Bark of  
472 *Betula alleghaniensis* (Yellow Birch). *Journal of Wood Chemistry and Technology* 11(2): 209-223.

473 Cotter, J. (2003). 5.9 Anglo-Saxon Pottery, In: Ringlemere Farm, Woodnesborough, Kent, Spring 2002.  
474 Assessment Report and Updated Project Design. Ed: Keith Parfitt. Canterbury Archaeological Trust May  
475 2003 (unpublished).

476 Courel, B., Schaeffer, P., Féliu, C., Thomas, Y. and Adam, P. (2018). Birch bark tar and jewellery: The  
477 case study of a necklace from the Iron Age (Eckwersheim, NE France). *Journal of Archaeological*  
478 *Science: Reports* 20: 72-79.

479 Dal, L. (1998). Harpixkakor – med doft från bronsåldern. C-uppsats i arkeologi Arkeologiska  
480 institutionen, Lunds universitet (98).

481 Devière, T. (2009). Elucidating funeral rituals in burials from the end of the Roman Empire -  
482 Development of a multi-analytical approach, UPMC & Unipi: 250p.

483 Dudd, S. N. and Evershed, R. P. (1999). Unusual triterpenoid fatty acyl ester components of  
484 archaeological birch bark tars. *Tetrahedron Letters* 40: 359-362.

485 Evershed, R. P., Dudd, S.N., Lockheart, M. J. & Jim, S. (2001). Lipids in Archaeology. In D.R. Brothwell  
486 & A. M. Pollard (eds), *Handbook of Archaeological Sciences*. Chapter 28. John Wiley & Sons Ltd, pp.  
487 331 - 349.

488 Evison, V. I. (1982). II. Anglo-Saxon Glass Claw-beakers. *Archaeologia* 107: 43-76.

489 Fuchs, C. (2012). Die Birkenpechstücke aus der Pfahlbausiedlung Hornstaad-Hörnle IA am Bodensee.  
490 Werkstoff, Arzneimittel oder Beschäftigungstherapie?, Tübingen University. Unpublished Master  
491 Thesis.

492 Groom, P., Schenck, T. and Moéll Pedersen, G. (2015). Experimental explorations into the aceramic dry  
493 distillation of *Betula pubescens* (downy birch) bark tar. *Archaeological and Anthropological Sciences* 7:  
494 47-58.

495 Hammann, S., Cramp, L., Whittle, M. & Evershed, R. (2018) Cholesterol degradation in archaeological  
496 pottery mediated by fired clay and fatty acid pro-oxidants. *Tetrahedron Letters* 59: 4401-4404

497 Hayek, E. W. H., Jordis, U., Moche, W. and Sauter, F. (1989). A bicentennial of betulin. *Phytochemistry*  
498 28(9): 2229-2242.



499 Hayek, E. W. H., Krenmayr, P., Lohninger, H., Jordis, U., Moche, W. and Sauter, F. (1990). Identification  
500 of archaeological and recent wood tar pitches using gas chromatography/mass spectrometry and  
501 pattern recognition. *Analytical Chemistry* 62(18): 2038-2043.

502 Hennius, A. (2018). Viking Age tar production and outland exploitation. *Antiquity* 92(365): 1349-1361.

503 Heron, C., Evershed, R. P., Chapman, B. and Pollard, A. (1991). Glue, Disinfectant and Chewing Gum in  
504 Prehistory. *Archaeological Sciences 1989: Proceedings of a conference on the application of scientific*  
505 *techniques to archaeology, Bradford, September 1989.*

506 Hines, J. (1997). A new corpus of Anglo-Saxon great square-headed brooches. Reports of the Research  
507 Committee of the Society of Antiquaries of London. Woodbridge, Boydell Press.

508 Hines, J. and Bayliss, A. (2013). *Anglo-Saxon graves and grave goods of the 6th and 7th centuries AD:*  
509 *a chronological framework.* London: Oxbow Books.

510 Hua, Y., Bentley, M. D., Cole, B. J. W., Murray, K. D. and Alford, A. R. (1991). Triterpenes from the Outer  
511 Bark of *Betula nigra*. *Journal of Wood Chemistry and Technology* 11(4): 503-516.

512 Karg, S., Hansen, U. L., Walldén, A. M., Glastrup, J., Aerenlund Pedersen, H. and Sonne Nielsen, F. O.  
513 (2014). Vegetal grave goods in a female burial on Bornholm (Denmark) from the Late Roman Iron Age  
514 period interpreted in a comparative European perspective. *Danish Journal of Archaeology* 3(1): 52-60.

515 Kjellström, A., Nordqvist, B., Snäll, A. and Welinder, S. (2010). in *Socialisation: Recent Research on*  
516 *Childhood and Children in the Past.* In *Socialisation: recent research on childhood and children in the*  
517 *past,* ed. G. Lillehammer, Stavanger: Museum of Archaeology. 53-61

518 Koller, J., Baumer, U. and Mania, D. (2001). High-tech in the Middle Palaeolithic: Neandertal-  
519 manufactured pitch identified. *European Journal of Archaeology* 4(3): 385-397.

520 Kozowyk P. R. B., Soressi, M., Pomstra, D. and Langejans G. H. J. (2017). Experimental methods for the  
521 Palaeolithic dry distillation of birch bark: implications for the origin and development of Neandertal  
522 adhesive technology. *Scientific Reports* 7: 8033 DOI:10.1038/s41598-017-08106-7

523 Krasutsky, P. A. (2006). Birch bark research and development. *Natural product reports* 23(6): 919-942.

524 Kuznetsova, S. A., Skvortsova, G. P., Maliar, I. N., Skurydina, E. S. and Veselova, O. F. (2014). Extraction  
525 of betulin from birch bark and study of its physico-chemical and pharmacological properties. *Russian*  
526 *Journal of Bioorganic Chemistry* 40(7): 742-747.

- 527 Kurzweil, A. and Todtenhaupt, D. (1990). Teer aus Holz. Museumsdorf Duppel, Berlin.
- 528 Kurzweil, A. and Todtenhaupt, D. (1991). Technologie der Holzteergewinnung. *Acta Praehistorica et*  
529 *Archaeologica* 23, 63-79.
- 530 Ladd, S. and Mortimer, R. (2018). Late Iron Age and Roman features, a Roman and early Saxon  
531 cemetery, and Middle Saxon features, Hatherdene Close, Cherry Hinton, Cambridge. Post-excavation  
532 assessment, Oxford Archaeology East.
- 533 Langenheim, J. H. (2003). *Plant resins: chemistry, evolution, ecology, and ethnobotany*: Oregon, US:  
534 Timber Press.
- 535 Lucquin, A., March, R. J. and Cassen, S. (2007). Analysis of adhering organic residues of two “coupes-  
536 à-socles” from the Neolithic funerary site “La Hougue Bie” in Jersey: evidences of birch bark tar  
537 utilisation. *Journal of Archaeological Science* 34(5): 704-710.
- 538 Macpherson-Grant, N. (1999). The pottery vessel. *Archaeologia Cantiana* 119: 47-49.
- 539 Macpherson-Grant, N. and Mainman, A. (1995). Early to Late Saxon pottery. Excavation in the Marlowe  
540 Car Park and Surrounding Areas, *Archaeology of Canterbury*, v (ii) 818-97.
- 541 Marter Brown, K. and Seager Smith, R. (2012) What did the apocrypha know? Glued pottery vessels  
542 from Springhead and other Romano-British sites in south and eastern England. In: Jervis, B. and Kyle,  
543 A. (eds.) *Make Do and Mend: The Archaeologies of Compromise, Repair and Reuse*. Series: BAR  
544 international series (2408). Archaeopress: Oxford, UK, pp. 13-26. ISBN 9781407310060
- 545 Martin, T. F. (2015). *The cruciform brooch and Anglo-Saxon England*. Woodbridge: Boydell and Brewer.
- 546 Marzinzik, S. (2011). The earliest Anglo-Saxons? The burial site at Ringlemere Farm, East Kent, and  
547 early cross-Channel migration. In: S. Brookes, S. Harrington, A. Reynolds (eds.), *Studies in Early Anglo-*  
548 *Saxon Art and Archaeology: Papers in Honour of Martin G. Welch*. BAR British Series 527 (Oxford), 55-  
549 61.
- 550 Marzinzik, S. (2013). Les contacts trans-Manche revisités: Le cimetière anglo-saxon précoce de  
551 Ringlemere (Kent). In *La Gaule, le monde insulaire et l'Europe du Nord au haut Moyen Âge* ed. C.  
552 Lorren, Saint-Germain-en-Laye, Actes du XXVIIe Journées Internationales d'archéologie  
553 mérovingienne, AFAM Mémoires XXVIII: 31–39.

554 Mazza, P. P. A., Martini, F., Sala, B., Magi, M., Colombini, M. P., Giachi, G., Landucci, F., Lemorini, C.,  
555 Modugno, F. and Ribechini, E. (2006). A new Palaeolithic discovery: tar-hafted stone tools in a  
556 European Mid-Pleistocene bone-bearing bed. *Journal of Archaeological Science* 33(9): 1310-1318.

557 McGrail, S. (2004). *Boats of the World: From the Stone Age to Medieval Times*. Oxford: Oxford  
558 University Press.

559 Mirabaud, S., Pétrequin, A.-M., Pétrequin, P. and Regert, M. (2015). Système de production des  
560 adhésifs exploités à Clairvaux VII et Clairvaux XIV. In Clairvaux et le "Néolithique Moyen Bourguignon"  
561 eds. P. Pétrequin and A.-M. Pétrequin, Centre de Recherche Archéologique de la Vallée de l'Ain:  
562 Presses universitaires de Franche-Comté. 1001-1021.

563 Morandi, L. F., Porta, S. N. and Ribechini, E. (2018). Evidence for Birch Bark Tar Use as an Adhesive and  
564 Decorative Element in Early Iron Age Central Italy: Technological and Socio-Economic Implications.  
565 *Archaeometry* 60: 1077-1087.

566 Myres, J.N.L. (1977). *A Corpus of Anglo-Saxon Pottery of the pagan period*. Cambridge: Cambridge  
567 University Press.

568 Needham, S., Parfitt, K. and Vardell, G. (2006). The Ringlemere Cup: Precious Cups and the Beginning  
569 of the Channel Bronze Age. British Museum Research Publication 163. p.84-87.

570 Nordby, C. (2008). Continuity or change? The use and function of birch bark tar in Norwegian Early Iron  
571 Age. In: *Holding it all together. Ancient and modern approaches to joining, repair and consolidation*,  
572 eds. J. Ambers, C. Higgitt, L. Harrison and D. Saunders. London, Archetype Publications: 54-60.

573 O'Connell, M. M., Bentley, M. D., Campbell, C. S. and Cole, B. J. W. (1988). Betulin and lupeol in bark  
574 from four white-barked birches. *Phytochemistry* 27(7): 2175-2176.

575 Parfitt, K. (2009). The Anglo-Saxon cemetery, discovery and excavation. Unpublished draft report,  
576 supplied by the author.

577 Parfitt, K. and Needham, S. (forthcoming). *Ceremonial Living in the Third Millennium BC. Excavations*  
578 *at Ringlemere Site M1, Kent, 2002-2006*.

579 Pesonen, P. (1999). Radiocarbon dating of birch bark pitches in typical comb ware in Finland'. In *Dig It*  
580 *All: Papers Dedicated to Ari Siiriäinen*, Hurree, M. (ed.), 191–200. Helsinki: Finnish Antiquarian Society.

581 Pietrzak, S. (2012). Wood tar in the Dnieper and Elbe communities: vi – ii millenium bc

582 Piotrowski, W. (1999). In: Experiment and Design: Archaeological Studies in Honour of John Coles (ed.  
583 Harding, A.) Ch. 17, 149–155. Oxford: Oxbow Books.

584 Pollard, M. and Heron, C. (2008). *Archaeological Chemistry*. Cambridge: Royal Society of Chemistry.

585 Rageot, M., Pêche-Quilichini, K., Py, V., Filippi, J. J., Fernandez, X. and Regert, M. (2016). Exploitation  
586 of Beehive Products, Plant Exudates and Tars in Corsica During the Early Iron Age. *Archaeometry*: 58:  
587 315-32

588 Rageot, M., Théry-Parisot, I., Beyries, S., Lepère, C., Carré, A., Mazuy, A., Filippi, J.-J., Fernandez, X.,  
589 Binder, D. and Regert, M. (2019). Birch Bark Tar Production: Experimental and Biomolecular  
590 Approaches to the Study of a Common and Widely Used Prehistoric Adhesive. *Journal of*  
591 *Archaeological Method and Theory*, 26(1): 276-312.

592 Rajewski (1970) Pech Und Teer Bei Den Slawen. *Zeitschrift fur Archaeologie* 4: 46-53.

593 Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Ramsey, C. B., Buck, C. E., Cheng, H.,  
594 Edwards, R. L. and Friedrich, M. (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0–  
595 50,000 years cal BP. *Radiocarbon* 55(4): 1869-1887.

596 Reber, E. A., Kerr, M. T., Whelton, H. L., and Evershed, R. P. (2019) Lipid Residues from Low-Fired  
597 Pottery. 61: 131– 144.

598 Regert, M. (2004). Investigating the history of prehistoric glues by gas chromatography–mass  
599 spectrometry. *Journal of Separation Science* 27(3): 244-254.

600 Regert, M. and Rolando, C. (2002). Identification of Archaeological Adhesives Using Direct Inlet  
601 Electron Ionization Mass Spectrometry. *Analytical Chemistry* 74(5): 965-975.

602 Regert, M., Delacotte, J.-M., Menu, M., Pétrequin, P. and Rolando, C. (1998). Identification of Neolithic  
603 hafting adhesives from two lake dwellings at Chalain (Jura, France). *Ancient biomolecules* 2: 81-96.

604 Regert, M., Vacher, S., Moulherat, C. and Decavallas, O. (2003). Adhesive production and pottery  
605 function during the Iron Age at the site of Grand Aunay (Sarthe, France). *Archaeometry* 45(1): 101-120.

606 Regert et al (2019). Birch bark tar in the Roman world: the persistence of an ancient craft tradition.  
607 *Antiquity*

608 Reunanen, M., Holmbom, B. and Edgren, T. (1993). Analysis of archaeological birch bark pitches.  
609 *Holzforschung* 47: 175–7.

610 Ribechini, E., Bacchiocchi, M., Devièse, T. and Colombini, M. (2011). Analytical pyrolysis with in situ  
611 thermally assisted derivatisation, Py(HMDS)GC/MS, for the chemical characterization of archaeological  
612 birch bark tar. *Journal of Analytical and Applied Pyrolysis* 91: 219-223.

613 Sauter, F., Jordis, U., Graf, A., Werther, W. and Varmuza, K. (2000). Studies in organic archaeometry I:  
614 identification of the prehistoric adhesive used by the “Tyrolean Iceman” to fix his weapons. *ARKIVOC*  
615 735: 747.

616 Schutkowski, H. (2008). *Thoughts for Food: Evidence and Meaning of Past Dietary Habits. Between*  
617 *Biology and Culture*. Ed. H. Schutkowski. Cambridge Studies in Biological and Evolutionary  
618 Anthropology: Cambridge University Press. 141–64.

619 Seagar Smith, R. (2015). Late Iron Age and Roman pottery in Andrews. P, Booth, B., Fitzpatrick, A.P.,  
620 Welsh, K. (eds) *Digging at the Gateway: Archaeological landscapes of south Thanet: The Archaeology*  
621 *of the East Kent Access (Phase II) Volume 2: The Finds, Environmental and Dating Reports*. Oxford  
622 Wessex Archaeology, Monograph No.8: 374-377.

623 Semple, S. (2013). *Perceptions of the prehistoric in Anglo-Saxon England*. Medieval History and  
624 Archaeology. Oxford: Oxford University Press.

625

626 Šiman, P., Filipová, A., Tichá, A., Niang, M., Bezrouk, A. and Havelek, R. (2016). Effective method of  
627 purification of betulin from birch bark: the importance of its purity for scientific and medicinal use.  
628 *Plos One* 11(5): e0154933.

629 Stacey, R. (2004) Evidence for the use of birch-bark tar from Iron Age Britain. *PAST* 47,1-2.

630 Surmiński, J. (1997) Ancient methods of wood tar and birch tar production in Proceedings of the First  
631 International Symposium on Wood Tar and Pitch (eds. Brzeziński, W. & Piotrowski, W.) Ch. 31, 117–  
632 120 (State Archaeological Museum, 1997).

633 Tar. (n.d.) In *Online Etymology Dictionary*. Retrieved from <https://www.etymonline.com/word/tar>

634 Urem-Kotsou, D., Stern, B., Heron, C. and Kotsakis, K. (2002). Birch-bark tar at Neolithic Makriyalos,  
635 Greece. *Antiquity* 76(294): 962-967.

636 Van Gijn, A. and Boon, J. J. (2006). Birch bark tar. Schipluiden. A Neolithic Settlement on the Dutch  
637 North Sea Coast C. 3500 Cal BC. *Analecta Praehistorica Leidensia* 37-38: 261-266.

- 638 Wrębiak C. (1971). Produkcja i handel dziegiem we wsi Bielanka, pow. Gorlice. Materiały Muzeum  
639 Budownictwa Ludowego w Sanoku 15: 27-40.

640

641 **Figure Captions**

642 Figure 1: Site location and layout of the Anglo-Saxon cemetery at Hatherdene Close, Cherry Hinton,  
643 Cambridge.

644 Figure 2: Skeleton 294 from grave 293, Anglo-Saxon child burial

645 Figure 3: Site location and plan of Anglo-Saxon features around mound M1 at Ringlemere, (Kent) with  
646 location of vessel indicated (Parfitt and Needham, forthcoming).

647 Figure 4: Ceramic vessel 1112 from Ringlemere, side and interior views.

648 Figure 5: The amorphous lump found in grave 293.

649 Figure 6: Partial total ion chromatogram obtained by GC-MS analysis of the trimethylsilylated (TMS)  
650 total lipid extract from the amorphous brown 'lump' found in an Anglo-Saxon child burial at  
651 Hatherdene Close, Cherry Hinton, Cambridge. Compounds present are as labelled.

652 Figure 7: Partial extracted ion ( $m/z$  189 and  $m/z$  203) chromatogram from the data shown in Figure 8,  
653 showing triterpenoid compounds as labelled.

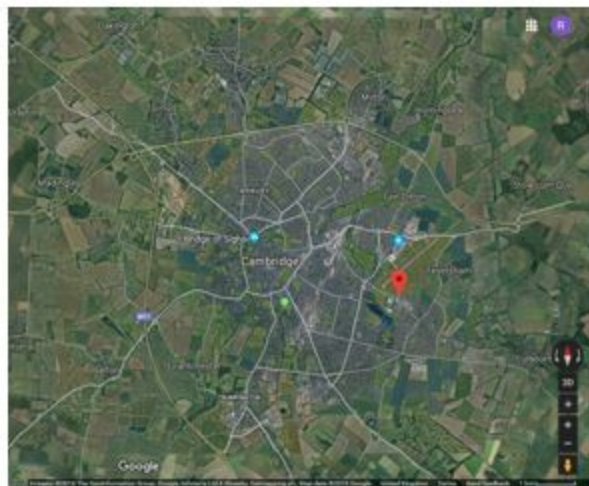
654 Figure 8: Partial total ion chromatogram obtained by GC-MS analysis of the trimethylsilylated (TMS)  
655 total lipid extract of one sample from the Ringlemere vessel. The partial extracted ion ( $m/z$  313, 341,  
656 371 and 399) chromatogram of area indicated by the orange box, reveals trace acylglycerols. Peaks  
657 labelled are fatty acids (FA) with carbon-chain length  $n$  and internal standards (IS) added prior to  
658 analysis.

659

Table 1: List of identified compounds labelled on chromatograms in Figures 6, 7 and 8. Samples marked \* were analysed and identified as TMS derivatives. CH = Cherry Hinton lump; R = Ringlemere pot.

Type	Compound	TMS	Sample
Pentacyclic triterpenoids	Lup-2,20(29)-diene	*	CH
	Lupa-2,20(29)-dien-28-ol	*	CH; R
	Lupenone		CH; R
	Lupeol	*	CH
	betulone		CH; R
	Betulin	*	CH; R
Triterpenoid esters	Lup-2,20(29)-dien-28-yl palmitate		CH; R
	Betulin myristate	*	CH
	Lup-2,20(29)-dien-28-yl stearate		CH; R?
	Betulin palmitate	*	CH
	Betulin stearate	*	CH
Acyl lipids	Dodecanoic acid (lauric acid); C12:0	*	R
	Tetradecanoic acid (myristic acid); C14:0	*	R
	Pentadecanoic acid (pentadecylic acid); C15:0	*	R
	(9Z)-hexadec-9-enoic acid (palmitoleic acid); C16:1	*	CH; R
	Hexadecanoic acid (palmitic acid); C16:0	*	CH; R
	Heptadecanoic acid (margaric acid); C17:0	*	R
	(9Z)-Octadec-9-enoic acid (oleic acid); C18:1	*	CH; R
	Octadecanoic acid (stearic acid); C18:0	*	CH; R
	Eicosanoic acid (arachidic acid); C20:0	*	R
	Docosanoic acid (behenic acid); C22:0	*	R
Sterols	Cholesterol	*	R







0

0.5

1

1.5

2 m







50 mm





0

1:1

50 mm

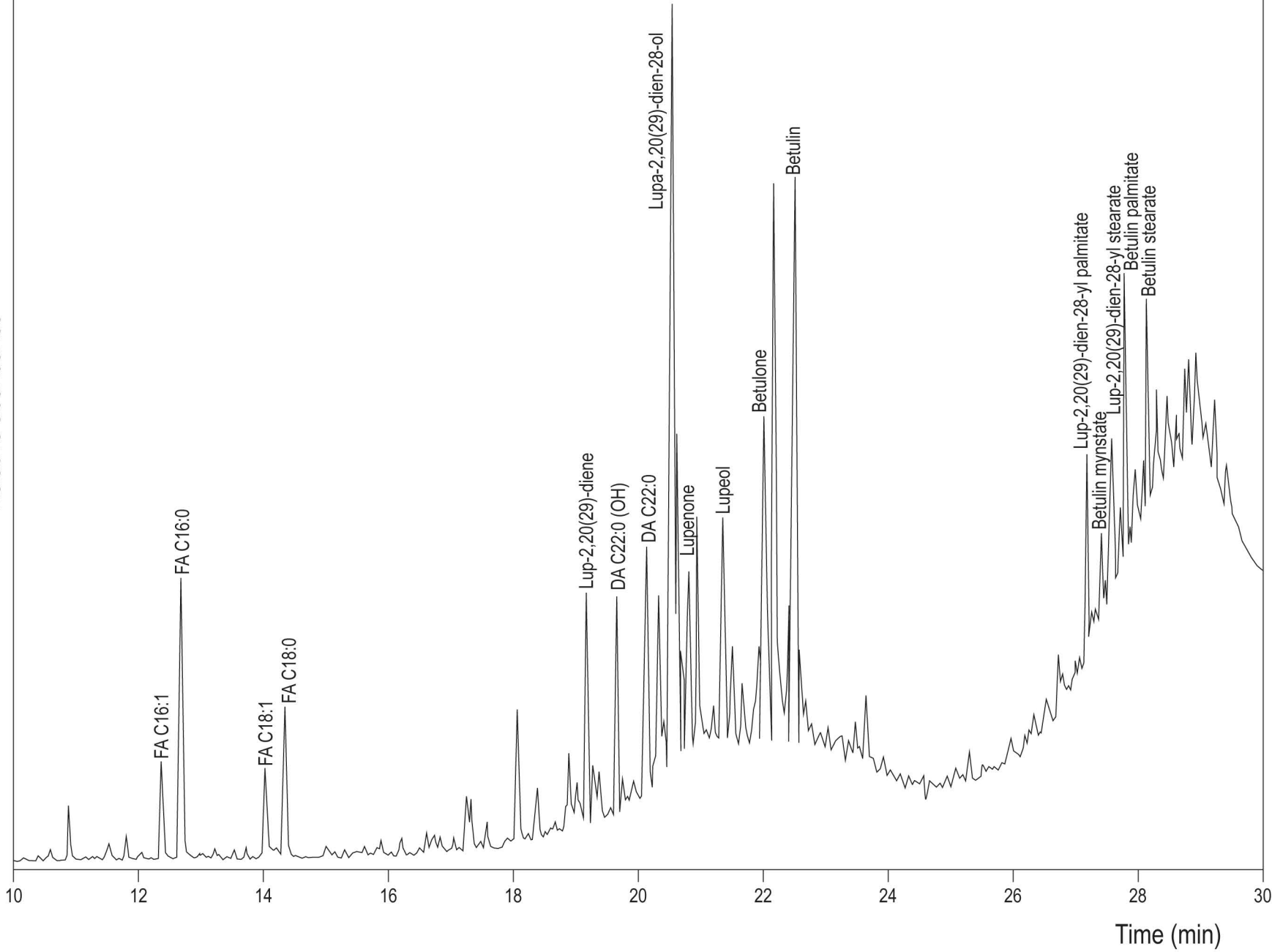


0

1:1

50 mm

Relative abundance



Time (min)

