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To cite this version:

Rebecca Stacey, Julie Dunne, Sue Brunning, Thibaut Deviese, Richard Mortimer, et al.. Birch bark tar in early Medieval England – Continuity of tradition or technological revival?. Journal of Archaeological Science: Reports, 2020, 29, pp.102118. 10.1016/j.jasrep.2019.102118 . hal-03196739

HAL Id: hal-03196739

https://amu.hal.science/hal-03196739v1

Submitted on 15 Mar 2023

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Journal of Archaeological Science: Reports 29 (2020) 102118

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Birch bark tar in early Medieval England – Continuity of tradition or technological revival?

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ARTICLE INFO

Keywords:
Birch bark tar
Early Medieval
HT-GC/MS
Lipids
Betulin

ABSTRACT

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

Here, we report new finds of birch bark tar from two early Medieval sites in the east of England. Analysis by HT-GC/MS to identify the tars also revealed fatty material, possibly added to modify the tar. The different contexts of the finds point to diverse applications of the material: in one case perhaps a medicine, the other associated with a ceramic container, possibly used for processing the tar. The results present the first identification of birch bark tar from early Medieval archaeological contexts in the UK. Together they indicate a later period of use for birch bark tar in the UK than has been previously observed and raise the question of whether this indicates evidence of a longer continuity of use than hitherto recognised or a later reintroduction of the technology in the Medieval period, in which case the similarities between the find sites, both early Anglo-Saxon cemeteries with comparable assemblages of grave goods, may be significant.

1. Introduction

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

In the old world, evidence for the use of birch bark tar is widespread across a geographical range that extends from the UK to Bulgaria (Aveling and Heron, 1998; Ribechini et al., 2011) and from Corsica (Rageot et al., 2016) and Greece (Urem-Kotsou et al., 2002) to the north of Norway (Nordby, 2008). The earliest known production of the material dates back as far as the Early Palaeolithic *c*. 185–135 ka (Mazza et al., 2006) and in Scandinavia and eastern Europe a tradition of

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https://doi.org/10.1016/j.jasrep.2019.102118
Received 10 June 2019; Received in revised form 18 November 2019; Accepted 21 November 2019
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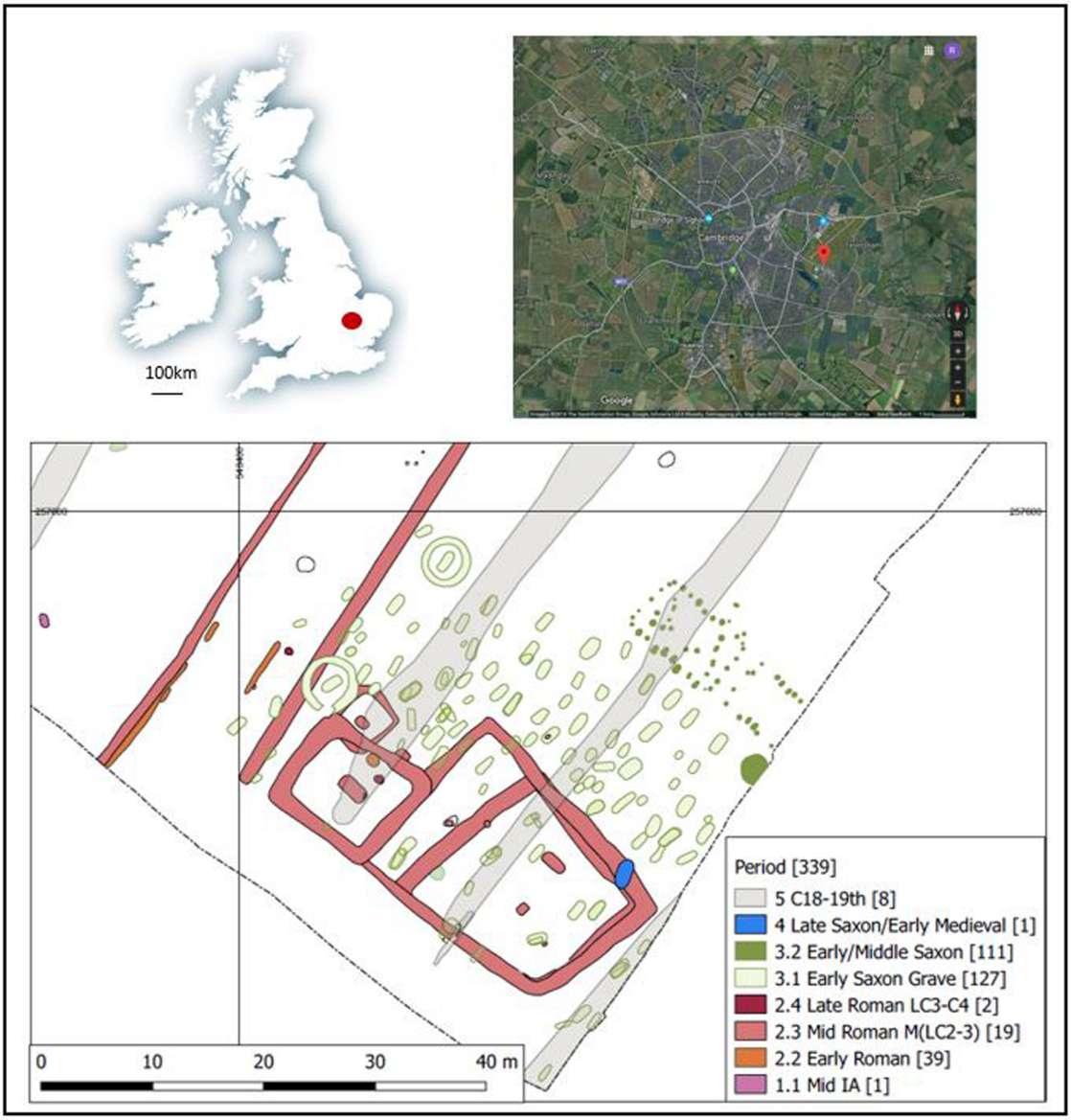

Fig. 1. Site location and layout of the Anglo-Saxon cemetery at Hatherdene Close, Cherry Hinton, Cambridge.

manufacture and use continues to the present day (Kurzweil and Todtenhaupt, 1990, 1991; Reunanen et al., 1993; Pesonen, 1999; Rajewski, 1970). However, in northwest Europe, the use of birch bark tar has generally been considered to be restricted to prehistory, gradually being displaced by pine tars during the Roman period (Pollard and Heron, 2008) although recent analytical work (Regert et al., 2019) and increasing attention to tar in post-excavation reporting (e.g. Seagar Smith, 2015) has begun to challenge this theory.

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

2. The sites and finds (archaeological background/context)

2.1. Hatherdene Close, Cherry Hinton, Cambridge

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

Fig. 2. Skeleton 294 from grave 293, Anglo-Saxon child burial.

fall into the broad bracket of the second half of the 5th century up to AD 550/60 (Hines, 1997; Hines and Bayliss, 2013; Martin, 2015), implying a relatively brief lifespan of the cemetery between the later 5th and first half of the 6th century.

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

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

2.2. Site context: Ringlemere Farm, Woodnesborough, Kent

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

The material assemblage at Ringlemere suggested that the cemetery was in use between the mid fifth to early sixth centuries. It also signalled a relatively affluent community, consuming glass and amber beads, belt buckles, purse mounts and brooches, some made from or incorporating precious metals – together with a degree of cultural diversity, reflected by connections with Continental populations across the Channel as well as the existing Romano-British milieu in Kent. The precise nature of these links awaits detailed study in a future publication; but the archaeological contexts present at Ringlemere raise the distinct possibility that at least some of the population buried there represent very early, perhaps even first-generation, settlers from the Continent (Parfitt, 2009; Marzinzik, 2011; Marzinzik, 2013).

3. The samples

3.1. Ringlemere vessel (1112)

The ceramic vessel (1112) was discovered set into the side of the outer M1 mound in a small, ill-defined pit (Parfitt, 2009). The vessel (Fig. 4) is complete, 113 mm diameter at the rim and c. 47 cm in height. Its form is a squat biconical jar or deep bowl with a rounded carination about half way up and decorated on the exterior with a chevron pattern. The fabric is a fine sandy ware and the whole exterior is lightly burnished. The form, fabric and decoration are consistent with other local examples dating to 5th-6th century CE (Macpherson-Grant and Mainman, 1995; Macpherson-Grant, 1999) and suggest the vessel is a product of a Canterbury potter or workshop (Cotter, 2003). Parallel vessels have been equated with similar decorated forms from Jutland and Frisia (Myres, 1977). The interior of the vessel has a burnished appearance due to the presence of a shiny black residue which was sampled for analysis. Five samples (each approximately 2.5 mg) were removed using a clean scalpel blade: one from already detached material on the interior (location unspecified) and two (from the rim and the bottom) on each surface (interior and exterior).

3.2. Cherry Hinton lump

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

4. Methods of analysis

Analyses of materials from the two sites were carried out separately at two different institutions (the Ringlemere residue at the British Museum (BM) and the Cherry Hinton lump at the University of Bristol using the same analytical techniques and comparable extraction procedures based on established published protocols for lipid analysis (e.g. Charters et al., 1993). In both cases, the samples were extracted into a chloroform/methanol 2:1 (v/v) solution using ultrasonication. After decanting, the supernatant was concentrated under nitrogen and the samples were derivatised using *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) to form

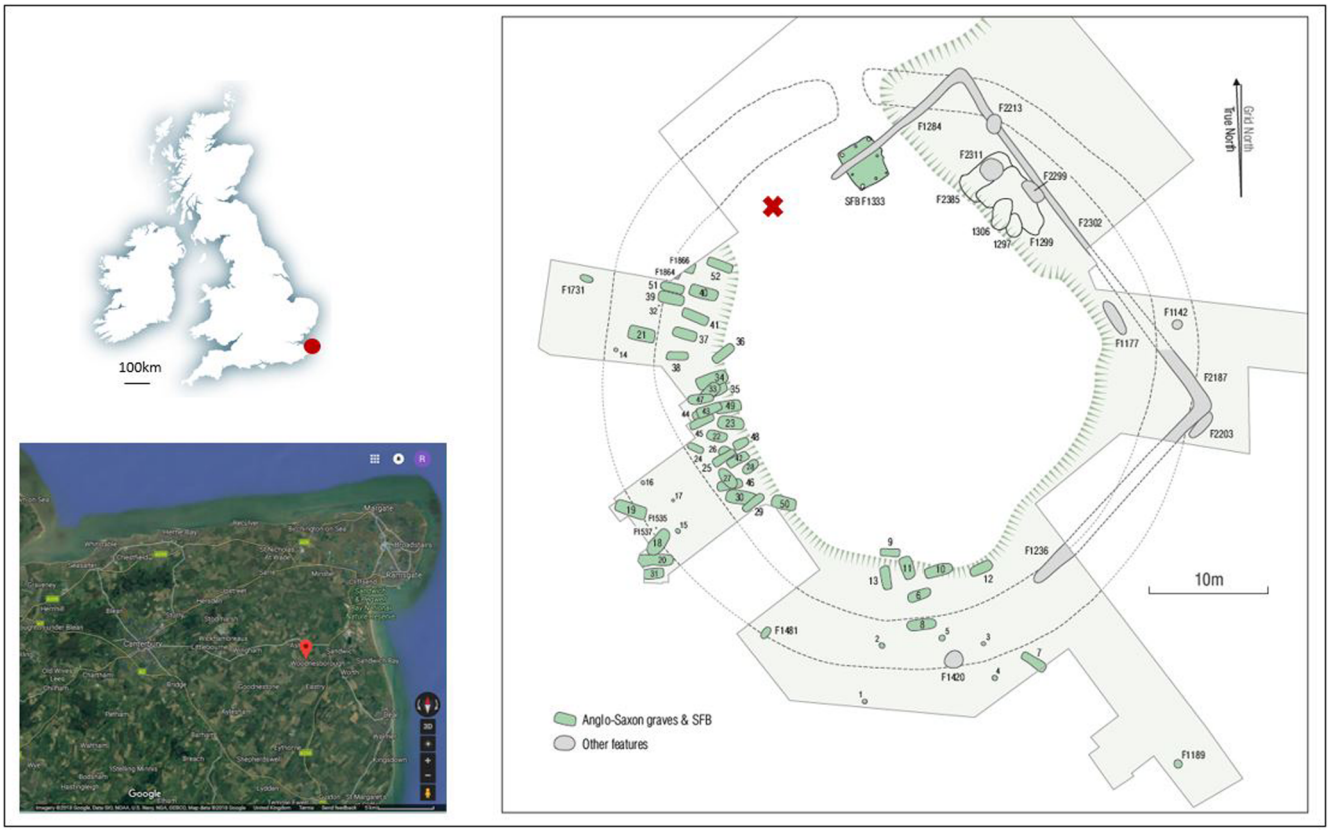

Fig. 3. Site location and plan of Anglo-Saxon features around mound M1 at Ringlemere, (Kent) with location of vessel indicated (Parfitt and Needham, forthcoming).

trimethylsilyl (TMS) derivatives. Laboratory blanks were prepared to monitor for analytical contamination and at the BM internal standards were added to enable calculation of extractable lipid yield. Analysis in both cases was by high temperature gas chromatography - mass spectrometry (HT-GC/MS) using on-column injection or pseudo on-column inlets, non-polar column and helium carrier gas. Analysis by HT-GC/MS enables separation, identification and quantification of the molecular components of the sample. For a detailed description of the procedure at each institution, see Appendices 1 and 2.

5. Results

Analysis of the lipid extracts obtained from samples from both objects revealed a complex mixture of molecular components (Table 1; Figs. 6–8). In the samples from the Ringlemere vessel, recovery of molecular material was low (less than 10 μg/mg^{-1} of sample).

In the Cherry Hinton lump, the dominant compounds present included the pentacyclic triterpenoids betulin and lupeol along with lupenone and betulone, known together to be characteristic of birch bark (O'Connell et al., 1988; Hayek et al., 1989; Hayek et al., 1990; Cole et al., 1991; Hua et al., 1991). These were identified by relative elution orders and characteristic mass spectra (see Charters et al., 1993 Aveling and Heron, 1998, Binder et al., 1990, Charters et al., 1993, Regert et al., 1998). Other compounds regarded as characteristic of the degradation reactions undergone by bark during the heating processes necessary to produce birch bark tar were also present (Fig. 6). For example, betulin is partially transformed into lupa-2,20(29)-dien-28-ol by dehydration and lupeol leads to the formation of lup-2,20(29)-diene (Aveling and Heron, 1998; Regert, 2004). Furthermore, the presence of the α, ω-docosandioic acid, likely derived from the suberic polymer, suggests

Fig. 4. Ceramic vessel 1112 from Ringlemere, side and interior views.

Fig. 5. The amorphous lump found in grave 293.

Table 1
List of identified compounds labelled on chromatograms in Figs. 6–8. 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); $C_{12:0}$	*	R
	Tetradecanoic acid (myristic acid); $C_{14:0}$	*	R
	Pentadecanoic acid (pentadecylic acid); $C_{15:0}$	*	R
	(9*Z*)-hexadec-9-enoic acid (palmitoleic acid); $C_{16:1}$	*	CH; R
	Hexadecanoic acid (palmitic acid); $C_{16:0}$	*	CH; R
	Heptadecanoic acid (margaric acid); $C_{17:0}$	*	R
	(9*Z*)-Octadec-9-enoic acid (oleic acid); $C_{18:1}$	*	CH; R
	Octadecanoic acid (stearic acid); $C_{18:0}$	*	CH; R
	Eicosanoic acid (arachidic acid); $C_{20:0}$	*	R
	Docosanoic acid (behenic acid); $C_{22:0}$	*	R
Sterols	Cholesterol	*	R

this tar may have been made using under specific heating conditions, such as the double-pot method (Rageot et al., 2019).

Six of these pentacyclic lupane-type triterpenoid constituents were also identified in the Ringlemere residue. In contrast to the Cherry Hinton lump, they occur at low levels and only in the three interior samples. A partial extracted ion chromatogram (*m/z* 189 and *m/z* 203) showing these terpenoid derivatives is illustrated in Fig. 7. Surprisingly, no lupeol and no lupa-2,20(29)-diene were identified; this absence has not been reported before and might be due here to the very low quantity of birch bark tar present in the samples which meant that some of the triterpenoids could not be confidently identified.

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

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

6. Discussion

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

6.1. Local context: Ringlemere

The acyl lipid in the Ringlemere samples seems to indicate the presence of some fatty residue as the profile of compounds is typical of highly degraded archaeological food lipid residues (Evershed et al., 2001). However, caution in this interpretation is necessary because the acyl lipids are present in all the samples (interior and exterior) and these compounds, cholesterol in particular, can also be introduced during burial and as contaminants deriving from handling (Hammann et al, 2018). The birch bark tar compounds occur only in samples from the interior of the vessel and therefore can be more confidently attributed to the black shiny interior coating on the vessel. The black colouration of the exterior residues must therefore be attributed to charring or sooting and indeed charred deposits may also contribute to the interior surface blackening as the levels of birch bark tar triterpenoids detected are very low. The presence of triterpenoid fatty acyl esters imply that the tar and fat components must have been heated together during use of the vessel (Dudd and Evershed, 1999).

Several scenarios can be envisaged which would give rise to this pattern of residues. The vessel could have been used for processing a mixture of fatty material with birch bark tar. Mixtures of animal fat and birch bark tar have been previously reported (Regert et al., 1998, Dudd and Evershed, 1999) and this could have been practised intentionally to produce a tar/fat material for specific use or with desirable properties. Alternatively, the two materials could represent separate uses of the vessel. It is possible that the vessel was coated internally with birch bark tar to effect waterproofing/sealing and then subsequently used for processing fatty material. Sealing of ceramics with organic materials such as resins or waxes is not uncommon but only a few examples have

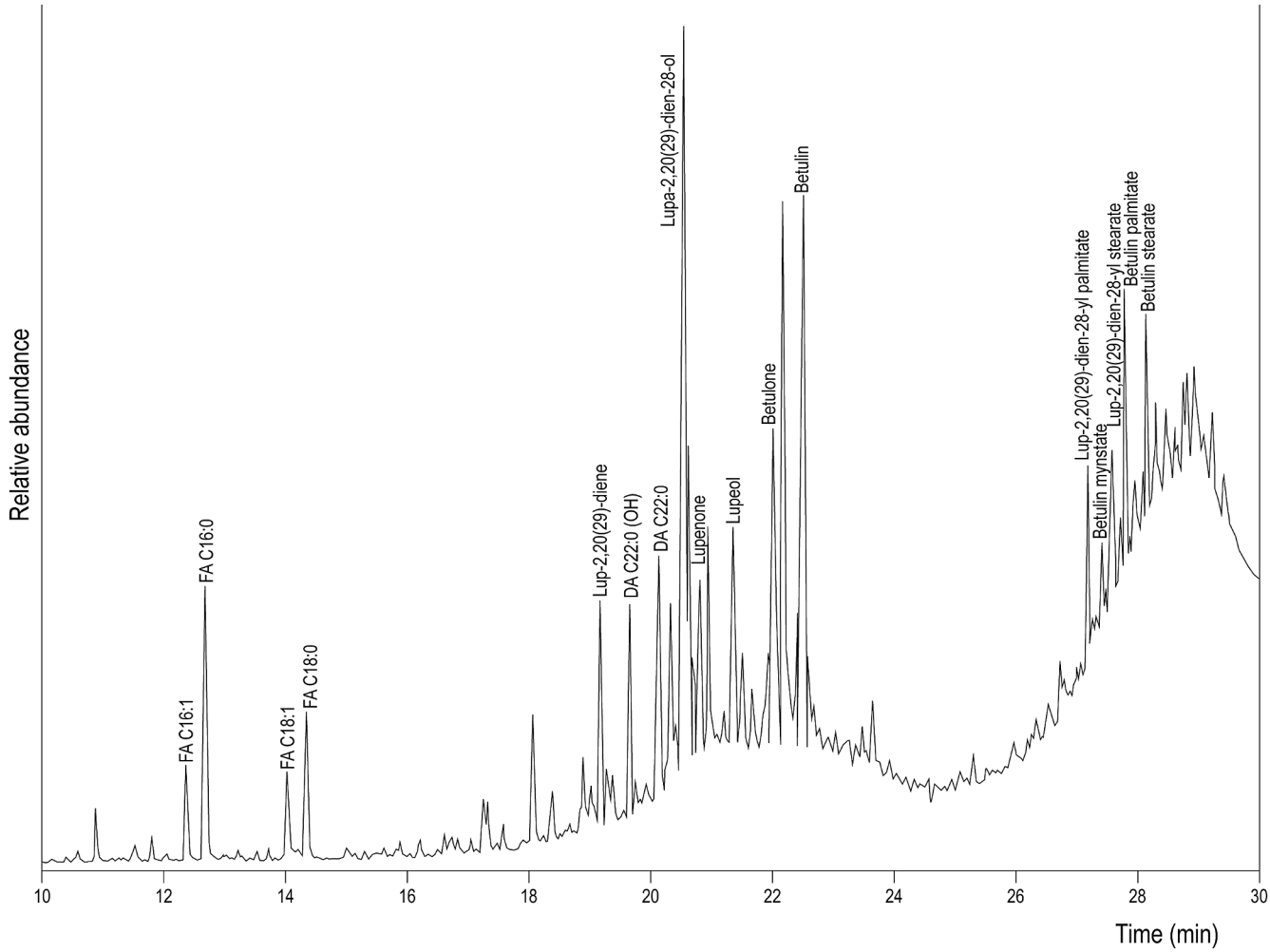

Fig. 6. Partial total ion chromatogram obtained by GC–MS analysis of the trimethylsilylated (TMS) total lipid extract from the amorphous brown 'lump' found in an Anglo-Saxon child burial at Hatherdene Close, Cherry Hinton, Cambridge. Compounds present are as labelled.

been reported of birch bark tar used in this way, for example on Iron Age vessels at the site of Grand Aunay in France (Regert et al., 2003) and in vessels from the Neolithic settlement at Makriyalos in Greece (Urem-Kotsou et al., 2002). Birch bark tar has also been used as an adhesive to repair ceramics (Charters et al., 1993; Regert and Rolando, 2002) but, as the Ringlemere vessel is intact, this application can be discounted. The burnished exterior surface of the vessel suggests that sealing also would probably have been unnecessary, at least for practical reasons, and interior coatings are not described for other comparable vessels from the region (Macpherson-Grant, 1999). The introduction of birch bark tar biomarkers during firing of the vessel should be considered, as recent research has demonstrated that pyrolytic products of fuel used in firing can penetrate low-fired ceramic fabrics (Reber et al., 2019). In this instance, the firing scenario would need to have produced a shiny black deposit localised on the interior of the vessel and excluded other resinous fuel sources such as pine, for which no chemical signatures were observed.

Reversing the use sequence, the vessel could have been used as a cooking pot before being used for processing tar, either for melting it prior to use or in primary production of the material. Much attention has been given to ancient methods of manufacturing of tar, ranging from industrial scale earth mounds which are attested archaeologically (Surmiński, 1997; Hennius, 2018) to theories of hearth pit production that could have been used by aceramic societies (Kozowyk et al., 2017; Groom et al., 2015). The most productive method for small scale production uses a 'double-pot' method where the bark is sealed in a pierced vessel and the tar distillate drains into a sunken collection vessel beneath the fire (Piotrowski, 1999). Although the excavated location of the Ringlemere vessel, sunk into the side of the outer M1 mound, might be consistent with such a small-scale tar-production activity, the tar deposits and the vessel argue otherwise. Retrieval of the tar would likely leave evidence of pouring on the vessel, but more likely the collection vessel itself would have been taken away unless the tar was to be used at the production site. Moreover, it seems unlikely that at least some evidence of the associated hearth would not have survived. Two other complete Anglo-Saxon vessels were found in pits within the cemetery and it has been speculated that all the vessels were deposited as offerings (Parfitt, 2009).

6.2. Local context: Cherry Hinton

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

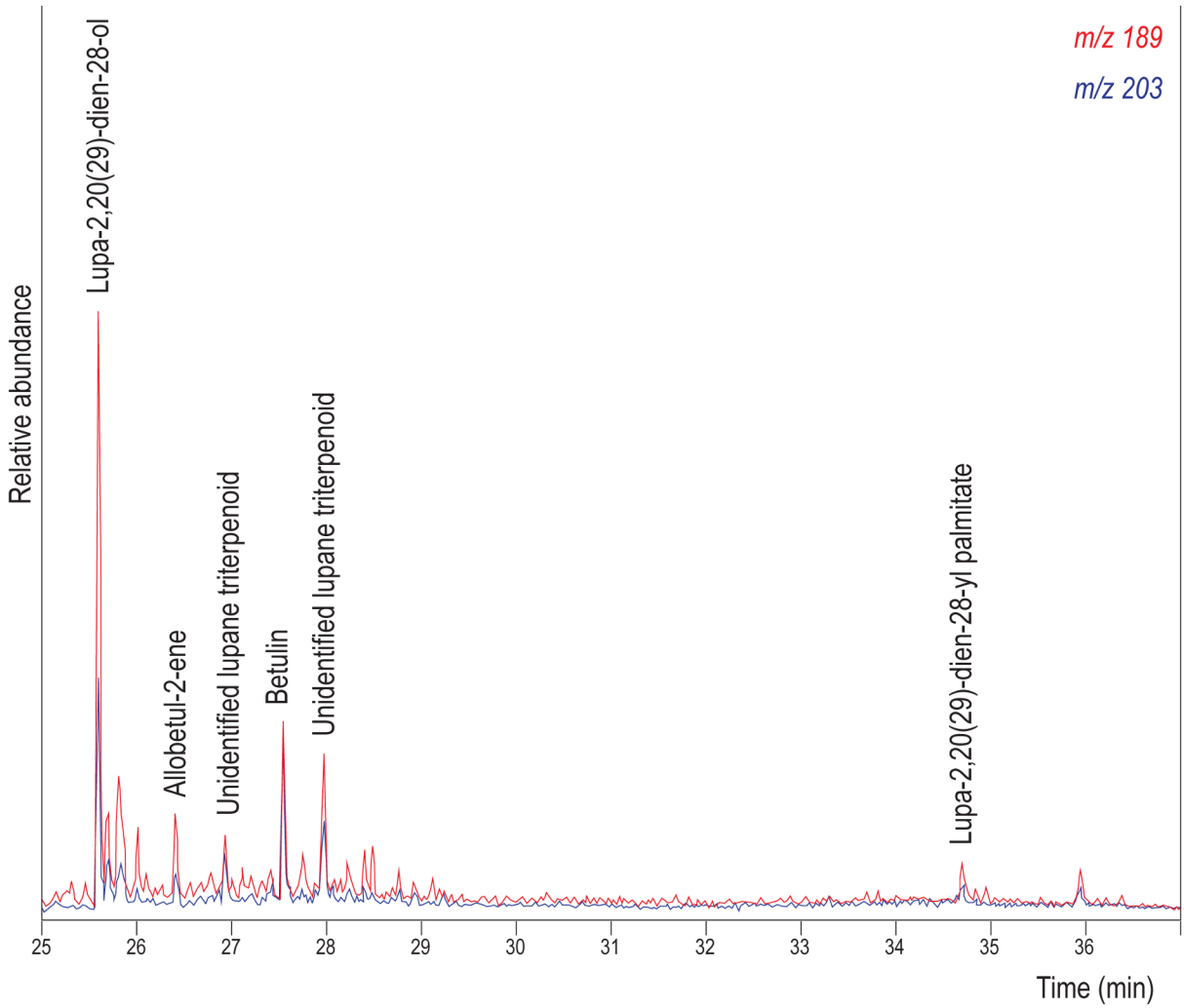

Fig. 7. Partial extracted ion (*m/z* 189 and *m/z* 203) chromatogram from the data shown in Fig. 8, showing triterpenoid compounds as labelled.

similar process that separates the tar from residual bark products during manufacture (Rageot et al., 2019).

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

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

6.3. Connections between the sites

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

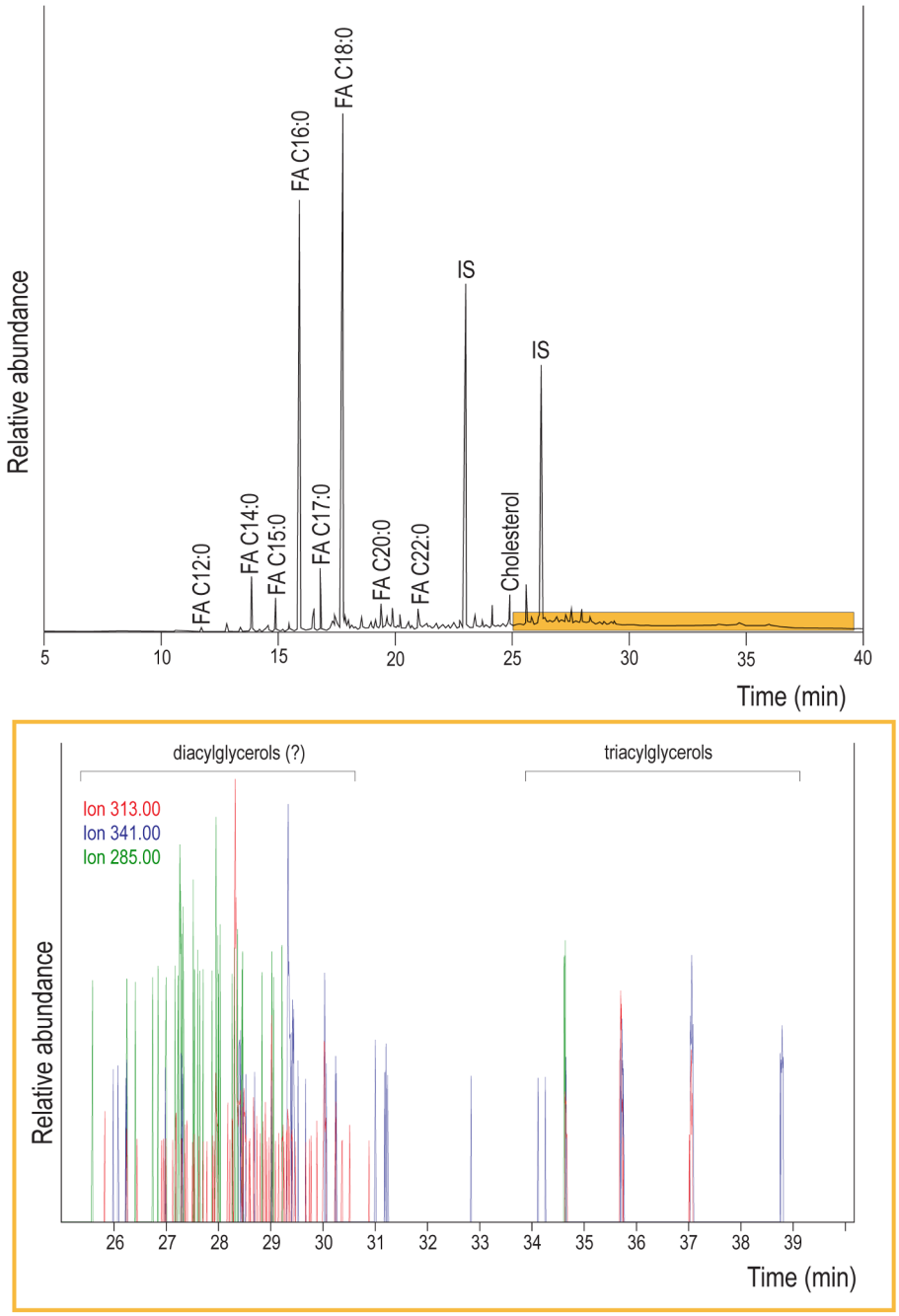

Fig. 8. Partial total ion chromatogram obtained by GC-MS analysis of the trimethylsilylated (TMS) total lipid extract of one sample from the Ringlemere vessel. The partial extracted ion (*m/z* 313, 341, 371 and 399) chromatogram of area indicated by the orange box, reveals trace acylglycerols. Peaks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

more direct link between the communities buried at Cherry Hinton and Ringlemere.

One grave at each cemetery contained an amber-coloured glass claw beaker of Evison's type 3c. This in itself is not unusual: type 3c is the most common form of claw beaker, distributed across eastern and southern England; nor are amber-coloured examples especially rare, occurring for instance at Snape in Suffolk, East Shefford in Berkshire and even Dinas Powys in Glamorgan, Wales, among other sites (Evison, 1982). However, the Cherry Hinton vessel has a distinctly Kentish flavour. Like the Ringlemere claw beaker and others found in Kent, it lacks a distinctive loop on the ridged trails decorating its claws, present on most examples found outside of Kent and taken as a sign of manufacture elsewhere (Evison, 1982; Ladd and Mortimer, 2018). The likelihood of a common point of origin for the two vessels is, for now, uncertain since finer points of comparison regarding style, proportions and chemical composition await ongoing research. However, the presence of two very similar claw beakers at sites already linked by the exceptional discovery of birch bark tar may add credence to the notion that the populations at Cherry Hinton and Ringlemere were, in some way, connected.

The precise nature of the link must remain a matter for speculation until research on both sites is completed. Scenarios that may explain the parallels range from direct interaction to mere coincidence, with a middle option being a more a diffuse connection in which both communities had access to similar cultural complexes, networks or exchange mechanisms that supported the sharing of resources, skills and

knowledge including the making and use of birch bark tar. The likeliest scenario, based on current understanding of the sites, emerges from a broader comparative view of the issue. While both Cherry Hinton and Ringlemere have produced birch bark tar, the find contexts and uses of the material differs markedly between the sites: it is a grave good at the former, and a residue in a pot buried in the ground at the latter. The claw beaker at Cherry Hinton, meanwhile, sits comfortably within the Kentish-flavoured assemblage at the cemetery, its similarities to the Ringlemere beaker not necessarily reflecting a Ringlemere origin for the Cherry Hinton vessel, but a *Kentish* origin for *both* vessels. The proximity of prehistoric features at the cemeteries is also notable, but is best explained as part of a wider trend for siting Anglo-Saxon burial grounds close to ancient monuments (Semple, 2013). As research stands, on the balance of probabilities, the presence of birch bark tar at both Cherry Hinton and Ringlemere is likely to represent another example of diffuse, inter-regional connections between early medieval communities. For now at least, its exceptionality may be coincidental – and is perhaps a harbinger for further birch bark tar discoveries in future excavations of early Medieval contexts.

6.4. Birch bark tar in northwestern Europe

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

It is likely that occurrences of birch bark tar have been overlooked in the archaeological record. Evidence from the Roman period in the UK is limited to two published chemically identified examples: an adhesive used to repair a Roman jar excavated at West Cotton, Northamptonshire (Charters et al., 1993) and the contents of a small enamelled vessel from Catterick, North Yorkshire (Dudd and Evershed, 1999). However, adhesive repairs on a range of Roman period vessels from Kent have been described as birch bark tar (Seagar Smith, 2015) at least some of which are supported by (unpublished) chemical analysis (Marter Brown and Seager Smith, 2012). Other Roman period examples have been reported from Scandinavia (Bergström, 2004; Karg et al., 2014) and from continental Europe (e.g. adhesive on a spindle from Naintré, Ribechini et al., 2011 (first reported in Devièse, 2009)). The corpus of such material in France has been significantly extended by a recent study of Roman furniture inlays (Regert et al. 2019) which again underlines the likelihood of a larger body of material present in archaeological archive collections elsewhere that has, to date, gone unreported, because the published record depends upon chemical analysis.

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

7. Conclusions

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

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

CRediT authorship contribution statement

Rebecca J. Stacey: Conceptualization, Supervision, Visualization, Writing - original draft, Writing - review & editing. **Julie Dunne:** Supervision, Visualization, Writing - original draft, Writing - review & editing. **Sue Brunning:** Writing - original draft, Writing - review & editing. **Thibaut Devièse:** Investigation, Formal analysis, Validation, Visualization, Writing - original draft, Writing - review & editing. **Richard Mortimer:** Project administration, Resources. **Stuart Ladd:** Project administration, Resources. **Keith Parfitt:** Project administration. **Richard Evershed:** Funding acquisition. **Ian Bull:** Investigation, Formal analysis, Validation, Visualization, Writing - original draft, Writing - review & editing.

Acknowledgements

The authors wish to thank NERC for partial funding of the National Environmental Isotope Facility (NEIF; Bristol laboratory). JD thanks The Leverhulme Trust (RPG-2016-115) for funding and Alison Kuhl for technical help. RJS thanks the Wellcome Trust (097365/Z/11/Z) for funding and Chris Mussell for technical support. We thank Helen Grant

of the NEIF (Lancaster laboratory) for stable isotopic characterisation of reference standards and derivatising agents. We thank Tony Simpson (British Museum) for help with formatting the figures. We are indebted to Sonja Marzinzik for instigating analysis of the Ringlemere vessel when she was curator of early Medieval European collections at the British Museum; analysis of the birch bark 'lump' was commissioned by Oxford Archaeology. We are grateful to our colleagues who read and commented on the manuscript in draft and to our anonymous reviewers for their helpful suggestions.

Declarations of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. (BM analytical method)

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

The samples were analysed using an Agilent 6890 N gas chromatograph (GC) coupled to an Agilent 5973 N mass spectrometer (MS). Samples of 1 μL were injected at on-column at 10.74 psi with the inlet temperature programmed to follow the oven cycle. The analytical column was an SGE HT-5, 12 m × 0.1 mm, 0.1 μm film thickness, column fitted with a 1 m × 0.53 mm deactivated retention gap (J&W) was used. The carrier gas was helium in constant flow mode at 1.0 mL min^{-1}. After a 2 min isothermal hold at 40 °C the oven was temperature programmed to 350 °C at 10°$Cmin^{-1}$ with the final temperature held for 12 min. The MS interface temperature was 330 °C. Acquisitions were made in full-scan mode (*m/z* 50–650) with a cycle time of 1.0 s after a solvent delay of 7 min. System control and data collection/manipulation were achieved using G1701DA Chemstation (G1701DA) software.

Appendix 2. (Bristol analytical method)

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

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

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

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