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A wild boar dominated ungulate assemblage from an early Holocene natural pit fall trap: Cave shaft sediments in northwest England associated with the 9.3 ka BP cold event

Tom C Lord,[1] John A Thorp[2] and Peter Wilson[3]

Abstract

A highly unusual pit fall ungulate assemblage dominated by wild boar (*Sus scrofa*) was recovered during the recent exploration of a cave shaft in the upland karstic landscape of northwest England. Both the opening of the cave shaft to the surface and its infilling by clastic sediments are attributable to accelerated landscape erosion associated with the 9.3 ka BP climatic deterioration. Evidence that wild boar had died in winter or spring suggests that their deaths relate to the prolonged periods of annual snow cover experienced by the uplands of northwest England during the 9.3 ka BP event. The dominance of wild boar in the pit fall assemblage is explained by the snow pack concealing the open shaft and turning it into a baited trap for wild boar whenever it contained carrion. Wild boar bones splintered and chewed by wild boar demonstrate carrion cannibalism. Human presence is attested by slight butchery to an aurochs (*Bos primigenius*). How Mesolithic people adapted to climate change associated with the 9.3 ka BP event is a subject well worth pursuing.

Keywords

9.3 ka BP event, animal bones, karstic caves, northwest England

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Introduction

The Lower Carboniferous limestones of northwest England (Figure 1) contain almost one half of all the known karstic caves in Great Britain in terms of their number and length (Waltham et al., 1997). Cave systems are typically multi-level with relict phreatic passages above deeper active stream passages interspersed with deep vertical shafts (Waltham, 2013). The higher level passages are frequently obstructed by collapsed limestone blocks and speleothem, and infill from clastic deposits derived from surface materials.

Around 40 caves in the region have undergone systematic excavation, however most of the investigations took place before the development of modern dating techniques and very few of the obtained samples were accurately dated. It is only now with the application of direct AMS dating to key specimens that a secure chronology for final late Pleistocene and Holocene cave deposits in northwest England is beginning to take shape (Hetherington et al., 2006; Jacobi et al., 2009; Leach, 2008; Lord et al., 2007; Lord and Howard, 2013; O'Connor and Lord, 2013; Smith et al., 2013).

For over a century, the caves of northwest England have attracted sporting cavers who, as well as exploring accessible cave systems, attempt to discover new ones by digging likely places at the surface. These explorations are rarely recorded other than in caving publications (Murphy and Chamberlain, 2008). A recent initiative by Natural England, the statutory agency responsible for cave conservation in England, involves liaison with landowners and cavers intending to dig on protected areas designated as Sites of Special Scientific Interest (Hinde et al., 2012). This paper reports the results of radiocarbon dating of early Holocene ungulate bones recovered by cave explorers digging out sediments filling a cave shaft known as the Cupcake (Figure 1).

The remains of at least five wild boar (*Sus scrofa*), one aurochs (*Bos primigenius*) and a wolf (*Canis lupus*) were recovered from the shaft which had acted as a natural pit fall trap. The AMS dates for the wild boar and the aurochs correlate with the cold 9.3 ka BP climatic oscillation. The dominance of wild boar, the non-anthropic taphonomy, and the potential relationship to climate change make this a significant early Holocene record. It demonstrates the potential for cave shafts in northwest England to preserve rich environmental archives. Previously, clastic sediments in these shafts had been considered to be glacial or periglacial deposits (Waltham, 1974; Waltham and Murphy, 2013).

[1]Lower Winskill, UK
[2]High Bentham, UK
[3]Environmental Sciences Research Institute, School of Environmental Sciences, Ulster University, UK

Corresponding author:
Peter Wilson, Environmental Sciences Research Institute, School of Environmental Sciences, Ulster University, Coleraine, Co. Londonderry BT52 1SA, UK.
Email: p.wilson@ulster.ac.uk

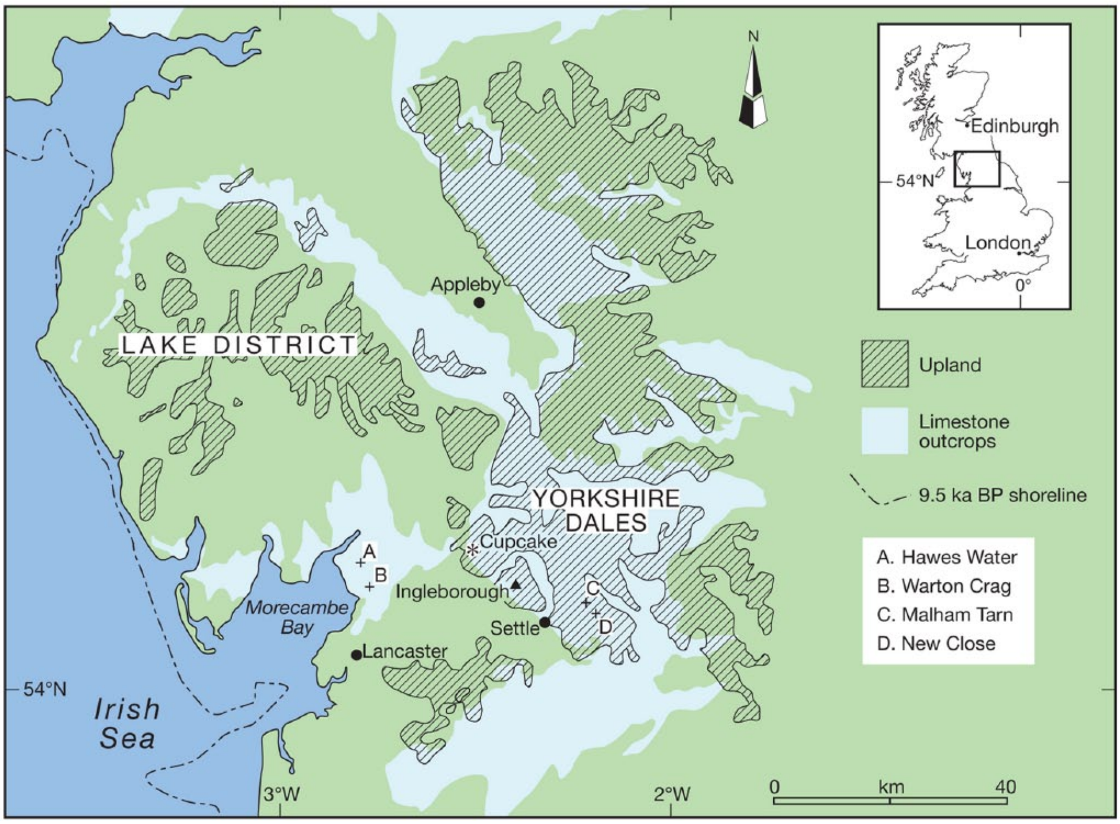

Figure 1. Location map showing the Cupcake in relation to the limestone outcrops of northwest England and other sites referred to in the text. The 9.5 ka BP shoreline is from Sturt et al. (2013).

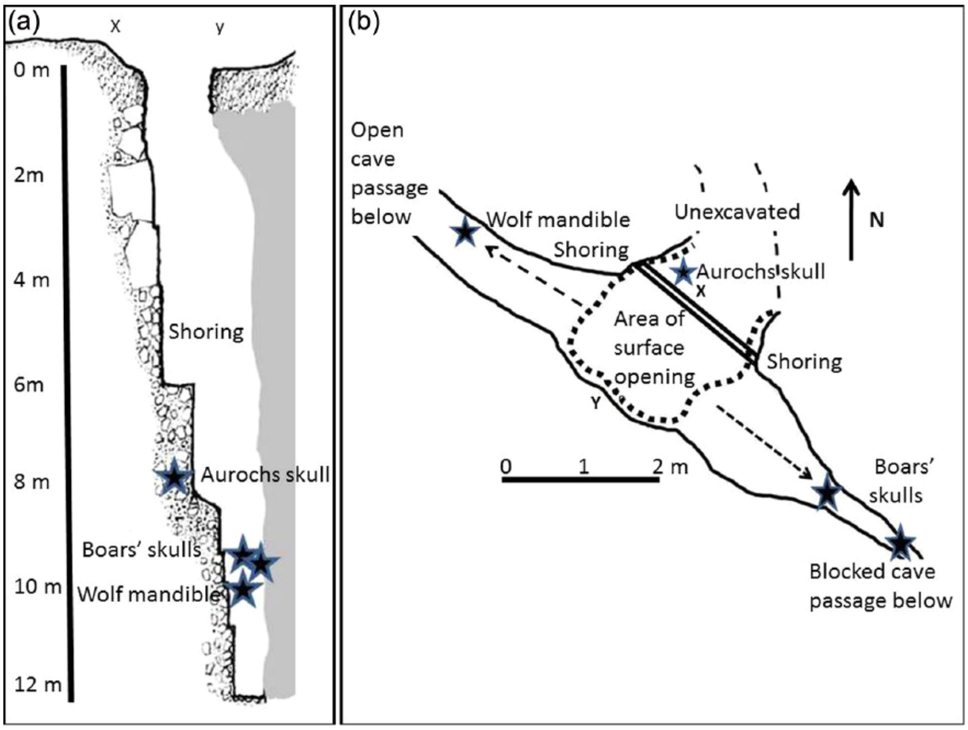

Figure 2. (a) The Cupcake shaft showing sediments, stratigraphy and find spots of bones recorded during the excavation. X–Y is line of section shown in (b). (b) Ground plan of the Cupcake showing the area of sediments excavated and the intact sediments held back by shoring.

The Cupcake

The Cupcake (so-called because of the shape of an associated stalagmite) is a vertical sediment-filled cave shaft ~12 m deep (Figure 2a) in Lower Carboniferous limestone at National Grid Reference SD 6665 7835 and 325 m OD on the southwest-facing slopes of Leck Fell, northern Lancashire (Figure 1). The Cupcake is part of the most extensive network of hydrologically linked caves in Great Britain known as the Three Counties System (Waltham, 2013; Waltham et al., 1997). With some 88 km of interconnected passages and more than 50 entrances, this system is a

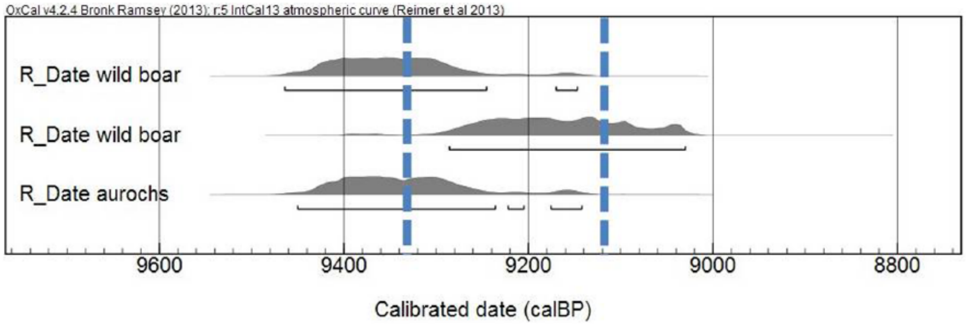

Figure 3. Probability distributions of calibrated radiocarbon dates from the Cupcake in relation to the start and end dates of the 9.3 ka BP event (vertical dashed lines) as defined by Rasmussen et al. (2014).

magnet for cave explorers. The Cupcake shaft was found in 2010 during attempts to extend a small passage that caused a partial collapse of the sediments blocking the route and subsidence at the surface which suggested the presence of an infilled shaft (Ramsey, 2011).

At the surface, the bedrock is covered by a thin diamicton containing sandstone, shale and limestone clasts, consistent with derivation from the Lower Carboniferous Yoredale Series, on the upper slopes of Leck Fell, and the local limestones. The diamicton is most likely of glacial or periglacial origin. A shallow dry valley/glacial meltwater channel (<5 m deep) occurs 30 m east of the site; local ground slope rises to the north and is marked by several small (1–2 m high) limestone scars.

Speleogenesis of the Cupcake shaft

The Cupcake shaft was formed by the collapse of a subsidence doline or shakehole (Sweeting, 1972) into an aven in an underlying cave system. Shakeholes capture overland flow and snow melt, focussing the runoff on the rock beneath them, accelerating both dissolution and the downward transport of fine sediment. Frost- and snow-related weathering processes act on any limestone bedrock exposed at their base. If there is a void near to the surface beneath them, a shakehole might suddenly collapse into it (Ford and Williams, 1989). An example ~1 km south of Cupcake occurred during the winter of 1946 when the floor of a shakehole collapsed, unroofing a 14-m-deep shaft accessing a cave system subsequently called Notts Pot (Gemmel and Myers, 1952).

Sediments and stratigraphy

A group of experienced sporting cavers excavated the Cupcake shaft in 2010–2011 so as to get direct access into this part of the Three Counties System. The sediments were removed back to solid rock walls on three sides of the shaft, leaving intact sediments on the remaining side held back by shoring (Figure 2). Bone deposits were recognised at depths of between 8 and 10 m (Thorp, 2011). The upper ~8 m of sediment in the shaft consisted of sub-angular gravel- to boulder-sized clasts, mainly of limestone and sandstone, in a sticky silt–clay matrix. The bone bearing sediments were noticeably finer, although large clasts were still present. In the centre of the shaft, the bone deposits were separated by ~0.5 m of fine sediment. The explorers discovered well-preserved specimens near to the walls of the shaft. Cancellous skeletal elements in the damper sediments in the more central area were soft and fell apart on touch. Beneath the fossiliferous sediments, the deposits consisted of loosely packed boulders and coarse sand. An aurochs metapodial and another bone found between the boulders had evidently worked down from higher in the sequence. The floor of the underlying cave passage was reached at a depth of ~12 m from the surface.

Sediment adhering to large bones was progressively wet sieved down to a 2-mm-sized mesh, as was a bulk sample of sediment of approximately 300 kg taken from the spoil heap at the end of the excavations. The wet sieving yielded a micro-vertebrate fauna and occasional small pieces of charcoal.

A single flint blade was found on the spoil heap. The flint resembles Wold-type material from east Yorkshire with white patination and grey–brown inclusions. It is 33 mm long, 8 mm wide and 3 mm thick. It has sharp edges with signs of use wear, just above mid-point on the ventral face, in the form of discontinuous scalar retouches. Ridges on the dorsal face indicate that the blade was struck from a blade-producing flint core.

Radiocarbon dating

Three samples were selected for AMS ^{14}C dating: an aurochs metatarsal OxA-25887: 8312 ± 39 bp (9.45–9.14 ka cal. BP) and the right humerus from two adult wild boar OxA-25889: 8323 ± 39 bp (9.47–9.15 ka cal. BP) and OxA-25888: 8210 ± 39 bp (9.29–9.03 ka cal. BP). Calibration of the ^{14}C ages to calendar age ranges BP was performed with the OxCal online program (v.4.1) using the IntCal09 calibration dataset. All three calibrated ages reveal deposition in the shaft contemporaneous with the 9.3 ka BP event (Figure 3). The Greenland Ice Core chronology (Rasmussen et al., 2014) places the 9.3 ka BP event between 9.36 ka B2k (9.31 ka BP) and 9.23 ka B2k (9.18 ka BP). It began abruptly triggered by a massive surge of freshwater from the Lake Superior basin into the North Atlantic (Yu et al., 2010).

The large vertebrates

The wild boar

The wild boar remains represent a minimum of five animals. Four adult wild boar are represented by a variety of skeletal elements, especially from the head and front limbs, and a piglet is evidenced only by an upper tooth row and two lower teeth. Tooth morphology, eruption and wear (Bull and Payne, 1982; Legge, 2013; Magnell, 2002; Magnell and Carter, 2007; Viner-Daniels, 2014) indicate two adult males more than 35 months old (Figure 4a), two adult females around 31–35 months old (Figure 4b), and a neonatal piglet. In temperate conditions, wild boar generally give birth only in the spring, so estimates of their age at death provide a guide to the season of the year when the animals died. Assuming the wild boar were born during March or April (Wright et al., 2014), the three wild boar whose age at death can be estimated from their dental morphology and tooth wear died during the winter or spring.

A number of wild boar limb bones have been chewed, splintered and reduced to fragments by wild boar (Figure 4c). Wild boar feeding on bones make distinctive patterns of tooth pits and scores (Domínguez-Solera and Domínguez-Rodrigo, 2009). Wild boar are opportunistic carrion eaters, and carrion cannibalism is

Figure 4. (a) Well-preserved male adult wild boar skull and mandible, tooth wear on the third lower molar indicates an animal more than 35 months old. (b) Female adult wild boar mandible with tooth wear similar to Bull and Payne (1982) Group 3, probably 31–35 months old. (c) Splintered and chewed fragment of an adult wild boar tibia with dense tooth pitting and scoring characteristic of wild boar feeding on bone (Domínguez-Solera and Domínguez-Rodrigo, 2009).

believed common (Ballari and Barrios-Garcia, 2014). There is no evidence of butchery on any wild boar bones.

The aurochs

Parts of most of the skeleton were recovered apart from the horn-cores. Skull fragments and cheek teeth found behind the shoring suggest more specimens lie in the unexcavated sediments there (Figure 2b). Biometric indices reveal that the Cupcake aurochs was a large male (Degerbøl and Fredskild, 1970; Wright and Viner-Daniels, 2015). Tooth wear and incomplete epiphysial fusion by reference to data for domestic cattle (Grigson, 1982; Silver, 1970) suggest an animal aged around 3–4 years old.

There are no tooth marks from scavenging animals on the aurochs bones. However, there are visible cut marks on parts of two ribs. The extent of any butchery is difficult to assess because of the poor preservation and recovery of cancellous elements in the axial skeleton of the aurochs. The well-preserved surfaces of the denser limb bones display no evidence of butchery. The latter is very different to butchered Mesolithic aurochs from open sites where discarded skeletal elements frequently display cut marks, chop marks and smashed open bones (Prummel and Niekus, 2011; Street, 1991). With a withers height of around 1.6–1.8 m (Van Vuure, 2005), an adult male aurochs is a substantial beast. Such a large carcass lodged in the confines of the Cupcake shaft would be difficult to access and butcher. The most likely scenario is that an attempt at butchery was made after the aurochs had first fallen into the cave shaft. Fairly complete Holocene aurochs skeletons are recorded from natural pit fall traps in caves in the Jura Mountains (Chaix and Arbogast, 1999).

The wolf

Part of a mandible with dentition, three upper teeth, and two limb bones are attributable to one adult wolf (*Canis lupus*). The upper and lower carnassial teeth permit biometric comparison with datasets from mainland Europe confirming that it is a wolf and not a dog (Degerbøl, 1961; Detry and Cardoso, 2010; Musil, 2000; Napierala and Uerpmann, 2010). This material is currently being analysed for ancient DNA at Oxford University.

The smaller vertebrates

Occasional specimens of badger (*Meles meles*), pine marten (*Martes martes*) and hare (*Lepus sp.*) were recovered in the initial stages of wet sieving. Micro-vertebrate remains recovered by the wet sieving include: Bechstein's bat (*Myotis bechsteini*), wood mouse (*Apodemus sylvaticus*), bank vole (*Clethrionomys glareolus*), field vole (*Microtus agrestis*), common shrew (*Sorex araneus*) and a lizard (*Zootoca cf. vivipara*). All these species would be at home in a Boreal environment (Yalden, 1999). There are no small mammals diagnostic of the late Glacial and Pre-Boreal Holocene (Price, 2003) to indicate the shaft was open to the surface before the Boreal. Common shrew was most frequent in the sediment associated with the aurochs bones (Thorp, 2011).

A natural pit fall trap

Clearly, the shaft and the collapse feature at the top of the shaft acted as a natural trap (Simms, 1994). But what accounts for wild boar being the numerically dominant ungulate? We have been unable to find published accounts of natural trap cave assemblages with wild boar the most abundant ungulate. All three ^{14}C ages on ungulates from the Cupcake are coincident with the 9.3 ka BP event, and in the absence of secure evidence, linking animal deaths to hunting or for substantial post-mortem butchery of the carcasses by humans, a climatic cause for their death and rapid incorporation in the cave sediments warrants serious consideration.

Early Holocene climate change

Climate during the Holocene epoch has often been viewed as being temperate and relatively stable, but evidence from North Atlantic sediments (Bond et al., 1997; Kleiven et al., 2008) and

Greenland ice cores (Meese et al., 1994; O'Brien et al., 1995; Rasmussen et al., 2007) indicates that widespread and pronounced millennial-scale oscillations (downturns) of decadal–centennial duration occurred around 11.4, 10.1, 9.2, 8.2, 5.9, 4.2, 2.8, 1.4 and 0.6 ka BP. Cool oscillations around 11.4, 11.2, 10.7, 10.4, 9.3 and 8.2 ka BP have been recorded by Lang et al. (2010) from chironomid assemblages in carbonate sediment at Hawes Water, 19 km west of the Cupcake (Figure 1).

These early Holocene cool events show good correlation with major and sudden inputs of freshwater into the North Atlantic Ocean from lakes associated with the Laurentide (North American) Ice Sheet and the Scandinavian Ice Sheet, and with periods of reduced solar activity. Freshening of the ocean caused a slowdown in the thermohaline circulation and a marked temperature reduction in Europe (Fleitmann et al., 2008). Two of these events, at 9.3 ka BP and 8.2 ka BP, are strongly expressed in both the oxygen isotope and chironomid records from Hawes Water (Lang et al., 2010; Marshall et al., 2007). At these times, the inferred mean July temperatures at Hawes Water were reduced by ~1.7 and ~1.6°C respectively, and these values suggest that mean annual air temperatures (MAATs) were depressed by more than 2°C. If accompanied by an increase in sea ice at these times, winters would have been significantly colder (Alley and Ágústsdóttir, 2005).

Applying an environmental lapse rate of 0.65°C/100 m (Wheeler and Mayes, 1997), the MAAT at the Cupcake is ~2.1°C lower than at sea level. With an ~2°C cooling during the 9.3 and 8.2 ka BP events, the Cupcake would have been ~4.1°C colder than at modern sea level. Based on 20th-century records for Malham Tarn (Manley, 1957, 1979; Figure 1), 25 km southeast of the Cupcake, this MAAT reduction indicates that for sites at 325 m OD, like the Cupcake, the annual number of days with snow cover could have been ~150.

Landscape instability during early Holocene cold events

Vincent et al. (2011) and Wilson et al. (2013) have argued that one impact of these early Holocene cold events on the landscape of northwest England was accelerated erosion. From six sites between 100 and 415 m OD, Vincent et al. (2011) reported a clustering of optically stimulated luminescence (OSL) dates from loessic sediments at around 8.2 ka BP and, using the palaeoclimate data of Marshall et al. (2007) and the Malham Tarn climate data (Manley, 1957, 1979), argued that the upland environment during that cold event was likely to have been one in which sediment reworking, due to greater snow accumulation, a greater intensity of frost-related processes, and more frequent meltwater flooding, was widespread. OSL dating has identified loessic silt colluviation coincident with the 9.3 ka BP event at two sites in northwest England; the upland site of New Close Malham dated 9.2 ± 0.8 ka BP (Wilson et al., 2008) and the lowland site of Warton Crag dated 9.2 ± 1.2 ka BP (Vincent et al., 2011).

As discussed by Vincent et al. (2011) and Wilson et al. (2013), early Holocene cold events in northwest England are likely to have been characterised by long-lasting snow cover, frequent and intense frost action, and copious meltwater runoff in spring and summer. A direct consequence of these conditions is likely to have been destruction of the ground vegetation and accelerated erosion of superficial sediments. Elsewhere in upland Britain, examples of sediment redistribution by snowpatch meltwater have been described by Tufnell (1971), Vincent and Lee (1982) and Ballantyne (1985).

Waltham (1974) and Waltham and Murphy (2013) discuss how clastic sediments enter cave systems via open shafts, and consider that glacial and periglacial processes are directly responsible. Because the sediment in the Cupcake contains the remains of early Holocene mammals, this hypothesis can be rejected at this site, at least for ~10 m of the sediment. Our hypothesis is that the sediment was originally glacial or periglacial surface material that was reworked by soliflual and fluvial processes soon after the unroofing of the shaft during the 9.3 ka BP climatic deterioration. Wilson et al. (2013), on the basis of cosmogenic isotope (^{10}Be) surface exposure dating, associate erosion of mountain top debris and exposure of underlying bedrock on Ingleborough (724 m OD; Figure 1), 8 km southeast of the Cupcake, with early Holocene cold events.

Snow cover: The smoking gun?

We further hypothesise that the wild boar remains from the Cupcake derive from animals that died attempting to access carrion in the snow pack overlying the shaft in the winter or spring, whereas the aurochs fell directly into the shaft possibly at a different time of year. The mosaic of mixed woodland and open areas that characterised the Boreal vegetation on the limestone uplands (Atherden, 2013; Simmons, 1996; Spikins, 1999) would have experienced a prolonged period of annual snow cover during the 9.3 ka BP event. We estimate snow lying for ~150 days a year in the vicinity of the Cupcake.

Deep snow and frozen ground hinder wild boar rooting in the soil for food (Okarma et al., 1995). Their distribution in northern Eurasia coincides with the 30- to 40-cm snow depth isoline (Rosvold and Andersen, 2008). Shakeholes filled and covered over by deep snow would be invisible to foraging ungulates. Blown snow would accumulate more quickly in these protected locales and on thawing would persist there longer than on more exposed areas. Carrion in a snow-filled shakehole turns it into a baited trap for wild boar rooting for food. Deep snow restricts their mobility, and a boar getting stuck might perish from cold and hunger. As the snow melts, gravity and meltwater would take the carcass down to the bottom of a shakehole, and deeper still if there was an open shaft at the base. Meltwater would moisten the carcass and hasten decomposition (Lyman, 1994).

Conclusion

It is possible that the wild boar deaths were part of a much wider pattern of increased mortality among ungulates in northwest England because of starvation and disease as a result of the 9.3 ka BP climatic deterioration. The rapid onset of the 9.3 ka BP event may have disrupted biological adaptions to early Holocene environments. In western Ireland, *Corylus* and other frost sensitive vegetation declined at this time (Ghilardi and O'Connell, 2012). The climatic deterioration coincides with the demise of early Mesolithic lithic traditions in parts of continental Europe fringing the North Sea Basin (Robinson et al., 2013), and possibly too in Britain, although here the chronology is less precise (Waddington et al., 2007). It may not be coincidence that the only plausible evidence for human cannibalism in Britain during the Mesolithic is a cut marked and culturally smashed human ulna from Kent's Cavern, in southwest England, dated 9.26–9.04 ka BP (Schulting et al., 2012). Stable isotope analysis shows that this individual relied upon terrestrial foodstuffs, a dietary pathway vulnerable to the abrupt climate change occasioned by the 9.3 ka BP event.

The results from the Cupcake clearly demonstrate the scientific potential of clastic infill in cave shafts in northwest England. Until now, these deposits have been routinely excavated by cave explorers with little attempt to record what they find. The work at the Cupcake will improve the understanding, significance and conservation of these hitherto neglected karstic features. Closer relationships between sporting cavers and Quaternary scientists should be encouraged.

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