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The Environmental Context and Function of Burnt-Mounds: New Studies of Irish *Fulachtaí Fiadh*

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Burnt mounds, or fulachtaí fiadh *as they are known in Ireland, are probably the most common prehistoric site type in Ireland and Britain. Typically Middle–Late Bronze Age in age (although both earlier and later examples are known), they are artefact-poor and rarely associated with settlements. The function of these sites has been much debated with the most commonly cited uses being for cooking, as steam baths or saunas, for brewing, tanning, or textile processing. A number of major infrastructural development schemes in Ireland in the years 2002–2007 revealed remarkable numbers of these mounds often associated with wood-lined troughs, many of which were extremely well-preserved. This afforded an opportunity to investigate them as landscape features using environmental techniques – specifically plant macrofossils and charcoal, pollen, beetles, and multi-element analyses. This paper summarises the results from eight sites from Ireland and compares them with burnt mound sites in Great Britain. The fulachtaí fiadh which are generally in clusters, are all groundwater-fed by springs, along floodplains and at the bases of slopes. The sites are associated with the clearance of wet woodland for fuel; most had evidence of nearby agriculture and all revealed low levels of grazing. Multi-element analysis at two sites revealed elevated heavy metal concentrations suggesting that off-site soil, ash or urine had been used in the trough. Overall the evidence suggests that the most likely function for these sites is textile production involving both cleaning and/or dyeing of wool and/or natural plant fibres and as a functionally related activity to hide cleaning and tanning. Whilst further research is clearly needed to confirm if* fulachtaí fiadh *are part of the 'textile revolution' we should also recognise their important role in the rapid deforestation of the wetter parts of primary woodland and the expansion of agriculture into marginal areas during the Irish and British Bronze Ages.*

Keywords: fulachtaí fiadh, burnt mound, environmental evidence, dyeing, deforestation, Bronze Age, Ireland

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Burnt mounds and associated pits or troughs, are one of the most ubiquitous monument types throughout the British Isles and Ireland and yet they remain enigmatic in terms of function and cultural significance (O'Sullivan & Downey 2004; Ó Néill 2009). This paper presents a summary of environmental analyses (plant macrofossils, charcoal, pollen, fossil insects, and multi-element analysis) of eight burnt mound sites from Ireland with the aim of inferring environmental context and, if possible, shedding light on their probable functions. In Ireland alone burnt mounds number over 6000 (Fig. 1) and are known to reach densities as high as 1 per 11 km^2. In parts of England, Wales, and Scotland, where detailed surveys have occurred, even higher densities have been recorded (eg, 1 per 1.5 km stream length) prompting the strong suspicion that the known distribution is almost entirely a product of the differential intensity of fieldwork (Barfield & Hodder 1987; Buckley 1990). Burnt mounds also occur throughout the length of the British Isles and Ireland from Tangwick in Shetland (Moore & Wilson 1999) to Hampshire (Boismier 1995). Even in areas with atypical landscape histories such as the New Forest they remain one of the most common site types (Pasmore & Pallister 1967). Although examples are recorded from as early as the Neolithic they generally date to the Middle–Late Bronze Age (Brindley & Lanting 1990; Buckley 1990; Bradley 2007; Ó Néill 2009). They usually comprise a mound of fire-cracked stone, classically crescentic in shape and located adjacent to a source of fresh water, most commonly streams, but also springs and occasionally lakes. Often, the 'arms' of the crescent enclose a trough or pit which may be lined with a variety of material, including wattle, stone, clay, or planks; sometimes a moss lining or 'corking' is also recovered (Ó Néill 2009). Burnt mounds are frequently present in large concentrations over relatively small areas, for example the recent review of the archaeology of Clare Island, Co. Mayo lists over 40 examples (Gosling *et al.* 2007).

Despite this abundance, the function of these sites remains disputed beyond the clear indication that they were used for heating water by the addition of fire-heated stones and so constitute a 'hot-stone technology' (Barfield 1991). The most cited interpretation is that they are the remains of cooking places and this is reinforced by the use in Ireland of the term *fulht fiadh* (singular) or *fulachtaí fiadh* (plural) which means cooking place in Gaelic; but the term was only coined in the 17th century by Geoffrey Keating in his history of Ireland (in Bradshaw *et al.* 1993). Experimental reconstructions by O'Kelly in 1952 demonstrated that meat could be cooked by this method and this practice is known from the ethnographic record (O'Kelly 1954; Fahy 1960; Hurl 1990) and has been replicated experimentally (Irish National Heritage Park, Wexford). However, a number of other functions have been proposed including: the rendering of animal fats (Monk 2007); bathing – either conventional bathing places or the remains of 'sweat lodges' or 'saunas' (Barfield & Hodder 1987; O'Driscoeil 1988); and tanning of hides and brewing (Quinn & Moore 2007). Fabric processing (including cleaning and dyeing) has also been proposed (Denvir 2002; Reilly & Brown 2013) and it is conceivable that boiled water was used as safe or uncontaminated drinking water. The general lack of both archaeozoological and artefactual evidence usually associated with these sites, even where animal bone and other artefacts could be preserved due to non-acidic soils, has led to a lack of consensus as to their function and, therefore, their role in Bronze Age society.

We approached this study with the hypothesis that each postulated function could have a characteristic environmental signal or 'profile' associated with it, for example: cooking and rendering of animal fats might be expected to leave traces of carrion and so carrion-related coleopteran or dipteran taxa. Tanning might be expected to leave a characteristic environmental profile of both insects and geochemistry indicative of carrion and foul or toxic conditions (cf. Hall & Kenward 2003); bathing, traces of human ectoparasites (ie, fleas and lice); brewing potentially traces of grain, cereal pollen, and grain-related insect taxa or taxa, associated with flavouring plants; and textile processing could potentially result in traces of mordants, dye-plants, and dependant taxa such as the concentrations of *Apion difficile* postulated to indicate the use of *Genista tinctoria* (Dyer's Greenweed), at Coppergate, York, UK (Kenward & Hall 1995).

PREVIOUS ENVIRONMENTAL STUDIES

Several environmental studies of single burnt mounds have been published including West Row, Mildenhall, Suffolk (Murphy 1986), Feltwell Anchor, Norfolk (Bates & Wiltshire 2001), Burlescombe, Devon (Best & Gent 2007), and Clifton, Worcestershire (Head 2007). One of the most comparable to this study is Feltwell where the pollen diagram shows a largely cleared landscape with evidence for both pastoral and arable agriculture (Bates & Wiltshire 2001). However, the diagram does

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not show the local deforestation event or post-mound woodland regeneration, except possibly in *Tilia* (lime) and the reason for this is probably the uncertain temporal relationship between the monolith column, trough, and burnt mound. Excavations at Watermeade Country Park, Leicestershire, of an early Late Neolithic burnt mound revealed a groundwater-fed trough on the bank of a palaeochannel which was first lined with a withy basket and later alder planks (Ripper 2004). An atypical aspect of the site was the preservation of contemporary faunal remains which included *Bos primigenius* (wild cattle or aurochs) and *Bos taurus* (domesticated cattle) which had undergone butchery, probably on site. However, they were not found *in situ* and their association with the trough and mound remains speculative, prompting the excavator to suggest alternative uses such as wool processing (Ripper 2004). The palaeobotanical evidence indicated undisturbed local woodland with mixed *Tilia*, *Quercus* (oak), and *Ulmus* (elm) of drier land and oak and *Alnus* (alder) carr on the valley floor. The results suggest that the trough and burnt mound were in a small clearing by the waterside on marshy ground surrounded by wet woodland (Monkton & Grieg in Ripper 2004). No cereal remains were recovered and no insect remains preserved.

More recently, excavations for the N9/N10 Carlow Bypass revealed 18 burnt mounds, 12 of which contained animal bone. An analysis of the assemblages by Tourunen (2008) revealed a dominance of domesticated cattle but also horse, deer, sheep, pig, and sheep/goat. The anatomical distribution of the cattle and deer bones suggested on-site slaughter, tanning, and antler-working rather than consumption. A burnt mound, excavated as part of the multi-period spring-head site at Burlescombe, Devon, provided a full pollen sequence and abundant insect material (Best & Gent 2007). The pollen evidence suggested that the burnt mound and pit were in oak-dominated wet woodland interspersed with rough pasture and clearings and some *Avena* (oat) or *Triticum* (wheat) cultivation nearby. Beetle analyses from the plank lined pit (C654) and the pollen revealed that the pit was constructed adjacent to woodland and received debris from it either naturally, or as part of fodder production. Both beetles and pollen indicate that both open land and woodland were present and that grazing was being undertaken in the vicinity. Also found was a rare weevil *Hylobius transversovittatus*, which is monophagous on *Lythrum salicaria* (purple loosestrife), which is a well known dye plant. There was also evidence for storage of animal food contemporary with mound construction in the form of a small wood-lined pit apparently filled with leafy material, primarily *Ilex aquifolium* (holly), apparently sealed in the manner observed in ethnographic silage-making methods (Best & Gent 2007). At Clifton, a burnt mound site adjacent to a palaeochannel of the River Severn was dated to the Early Bronze Age. Beetle analysis revealed little, if any, indication of human activity although pollen analysis from the palaeochannel revealed arable cultivation on the floodplain island (Head 2007; Davis *et al.* 2008). This relative lack of anthropogenic impact on the beetle faunas associated with burnt mounds has also been noted at Willow Farm, Castle Donington and Girton, Nottinghamshire (Smith pers. comm.).

The analytical approach of this study was designed to pick up any use-traces but, notwithstanding this, burnt mounds also existed in a landscape and as part of both a natural and human ecology. This palaeoenvironmental landscape approach formed the basis of the study reported here of eight Irish burnt mound sites excavated between 2002 and 2007. The term *fulacht fiadh*/*fulachtaí fiadh* is used throughout this paper to refer to a site which contains one or more mound sites or stone-spreads containing burnt or heated stones with, or without, an associated trough or pit, but with no connotation as to function.

METHODS AND SITES

The eight sites discussed here comprise three from Section 3 (Co. Clare–Co. Limerick) of the Bord Gáis Eireann's (BGE) 'Gas Pipeline to the West' project (Cahiracon, Inchagreenoge, Cragbrien) in 2002, and four from National Road Authority (now Transport Infrastructure Ireland) excavations undertaken in 2002–2007 (Killescragh and Caraun More, Coonagh West, Jigginstown, and Ballygawley, Fig. 1). Details of another site sampled as part of the same BGE project can be found in Brown *et al.* (2004). Although most of the sub-sampling was from columns and monoliths, in order to allow sampling between and adjacent to timbers, one trough (Inchagreenoge) was quartered and one-quarter crated and shipped to the laboratory. All the samples were stored in a cold store at 4°C prior to sampling. For methods descriptions see Supplementary Data.

Site descriptions

The site at Cahiracon Co. Clare was located in a bowl-shaped valley overlooking the Shannon Estuary and

Fig. 1.
Map of Ireland, burnt mound sites from the Irish Burnt Mound Database and sites used in this study

supplied by shallow groundwater (Grogan *et al.* 2007). The site was initially identified as a thin spread of burnt mound material 5.2 × 3.8 m overlying a peat deposit whilst a larger *fulacht fiadh* was identified beneath the peat. The latter comprised a 11.5 m N–S × 10.75 m E–W × 0.80 m high horse-shoe shaped mound centred on a rectangular trough (C.56, Fig. 2a). The trough which was cut into clay, was constructed of oak planks with alder pegs. A small wooden platform was constructed to the south of the trough and several large stepping-stones lead to it from the north (Dennehy 2003). The Inchagreenoge site consisted of two burnt mounds with troughs (C28 & C69) constructed in a small area of bog at the base of a hill adjacent to a stream and several springs (Taylor 2004). The mounds were sandwiched between peat deposits and the high water-table had lead to the preservation of the timber lined troughs of Early–Middle Bronze Age date. Close to the site, at the spring that fed one of the troughs, was found a human skull (young male adult) suggesting ritual associations. Trough C28, (Fig. 2b) was sub-rectangular and lined by planks of alder, *Fraxinus* (ash) and *Corylus* (hazel) held in place by stakes. Below the adjacent stone spread (C24) was found one post-hole and 13 stake-holes (0.07–0.13 cm in diameter). Trough C69, which lay under two overlapping stone spreads, was also lined by alder planks. The Cragbrien burnt mound was located on flat boggy ground 25 m to the east of a small stream and at only 1.3 m OD. Part of the burnt mound, the majority of which was buried by alluvial sediments, was excavated and a thin monolith taken from adjacent to the mound (Fig. 2c). The mound was made up of laminated deposits of woody peat and organic clay with burnt limestone. No evidence for a trough was recorded although it is possible it lay nearby but outside the area of excavation. Seven phases of deposition/activity were identified with contexts 12, 14, 15, 20, and 21 being the deposition of the burnt stone. Two burnt mounds excavated at Killescraigh Townland and Cauran More (Fig. 2d) lay at the foot of an esker ridge with a small river to the south. The deposits consisted of a spread of burnt stone and a series of associated wooden features including trackways and worked wood dated to the Late Bronze Age. A substantial minerogenic layer separated phases of activity probably due to flooding which may have caused temporary abandonment. At the second mound (A024/23), associated wooden features, included parts of a trough lining, a stake alignment, a wood-working area, and a number of felled/split timbers associated with a wooden platform structure. It is suggested that two phases of activity occurred after the inundation of the site during the Late Bronze Age. The burnt mound and trough at Jigginstown, located on the southern edge of a small peat-infilled basin close to a stream, was stratified within a peat bed sealed under 03–0.5 m of clay (Bolger 2005). Two burnt mounds, located either side of a stream-bed, were excavated at Coonagh West (site E2093 (was A005/2021)) as part of the Limerick Southern Ring Road Phase II in 2005 (Fig. 2e, Bermingham 2013; Reilly & Brown 2013). A pit, and alder and stone-lined trough were found under mound 2 (Reilly 2010). Archaeological excavations at Ballygawley revealed a complex of 26 burnt mounds and spreads. The mounds were located on a flood plain next to a series of palaeochannels with burnt mound activity seen to move chronologically with the shifting channel courses (Fig. 3). The results of 65 radiocarbon dates taken from features and sediment profiles suggest continuous activity took place on the site from the Neolithic to the Late Iron Age followed by a 900-year hiatus to

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Fig. 2.
Selected site photographs; (a) Cahiracon (6), (b) Inchagreenoge trough C28(3/45/1); (c) Cragbrien, (d) Killescragh (e) Coonagh West trough (f) Ballygawley (9869)

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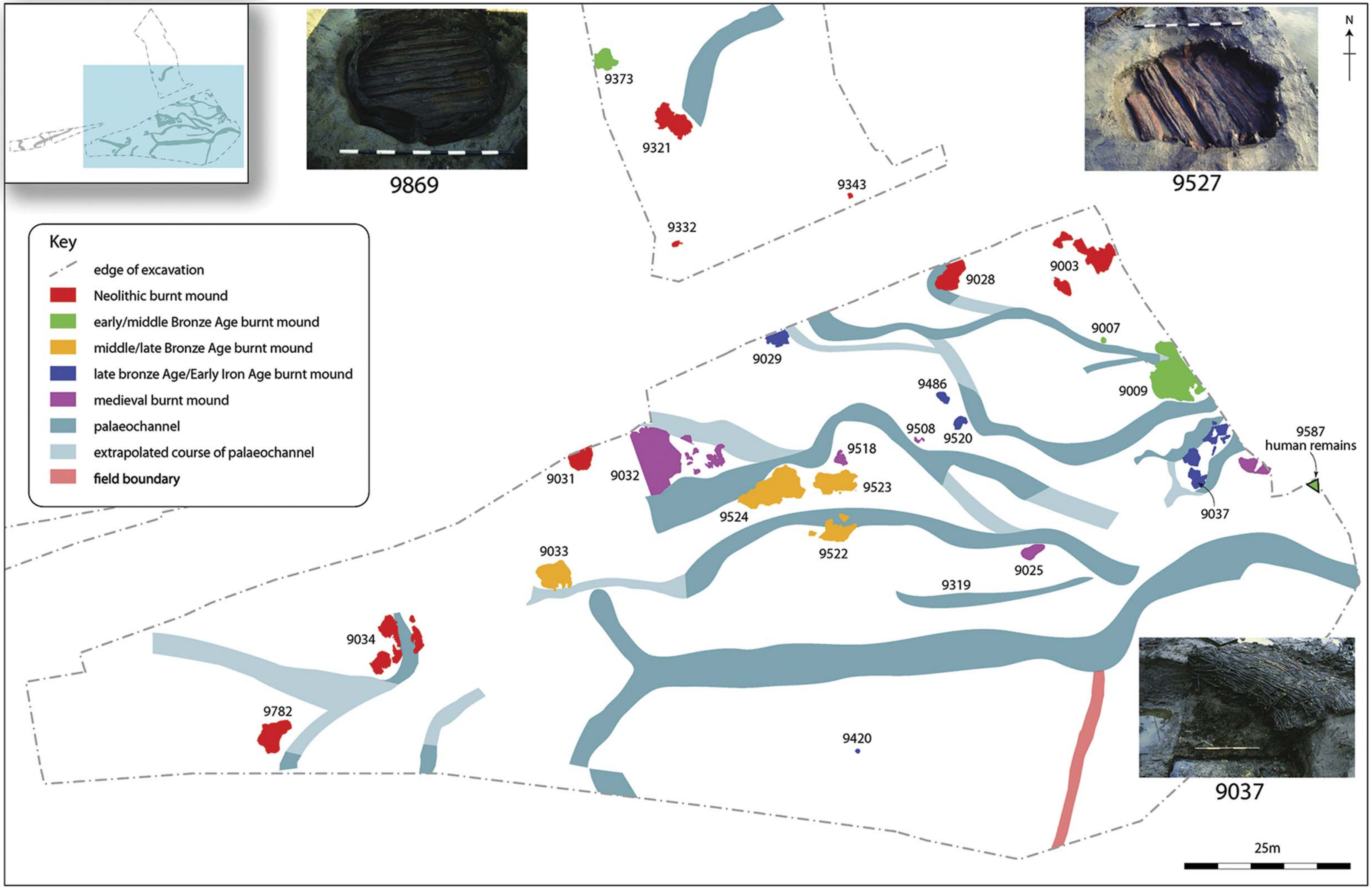

Fig. 3.
Plan of the Ballygawley burnt mounds, palaeochannels and selected troughs

the early medieval period. Sixteen of the mounds had circular, oval, or rectangular troughs. Ten of these were lined and eight styles of construction using wood, wicker, or a combination of both were used with no radiocarbon dating evidence of chronological preferences in style, although there was some elaboration in the design of the early medieval trough, where a channel connecting it to the stream was dug in order to bring water directly into the trough.

RESULTS

The Irish Burnt Mound Database

As part of this project a database was constructed of Irish sites reported as 'burnt mounds' or *fulachtaí fiadh* (Fig. 1). The database was compiled from the Irish Excavations Database (http://www.excavations.ie) as it was at the end of 2015, using the search terms 'burnt mounds', '*fulachtaí fiadh*', and 'burnt spread' in the site type field. This returned 465, 775, and 200 hits respectively. In each case Townland, excavation licence number, grid reference, publications(s) arising, excavator, excavation.ie reference number, were recorded along with the abstracted material from the site description including dimensions of the mound, dimensions and construction material of the trough, and dates where available. The distribution map was created through the use of similar search terms through the Irish National Monuments website (http://www.archaeology.ie) which were exported as a shape file which was then overlain on the base map.

Charcoal, plant macrofossils and pollen analyses

Charcoal from Cahiracon included oak, with some birch (*Betula*), hazel, ash, alder, Maloideae sp. (apple family), *Prunus spinosa* (blackthorn), holly and *Salix* sp. (willow). Radiocarbon dating of charcoal from the burnt mound dates the site to the Late Bronze Age (Table 1). Two monoliths (M7 & M5) were taken for environmental analysis; M7 from the west-facing edge of the baulk directly above the trough which would relate to post-trough use activities and M5 from the north end of the same excavation. The pollen diagram from M7 (Fig. 4) which has been divided into five pollen zones (CC7P1-CC7P5) is dominated by mixed deciduous woodland of alder, hazel, and oak. However, there are dramatic changes with the lower zones dominated by oak which is replaced after a partial clearance by oak, alder and hazel. The basal zone (CC7P1) indicates a large clearing or partially open landscape with significant heathland or bog. The rise in hazel and alder in zone CC7P2 indicates the regeneration of woodland over, or close to, the site continued into zone CC7P3. The fall in oak early in zone CC7P4 represents a second clearance phase and late in zone CC7P4 a second regeneration of woodland occurs over the site or area which on this occasion is dominated by oak rather than hazel and alder. The remarkably high oak values (80% TLP) strongly suggest its presence on site. Lastly, in zone CC7P5 there is another phase of woodland clearance with some expansion of heathland and cereal cultivation appears restricted to this last clearance phase. From the stratigraphy the pollen and spore zone CC7P1 is correlated with the abandonment of the trough and the later zones with archaeological phases 5–7 which include the use of the hearth and mound site to the north, east, and west of the trough and the eventual abandonment of the entire site. Monolith M5 provides a sequence from pre- to post-*fulacht* activity as it spanned two natural units, a lower peat and an upper peat with in-between sediment from the edge of the burnt mound. The pollen diagram, although allocated a single zone, shows a muted clearance signal similar to that in CC7P1 but with cereal type pollen (Supplementary Fig. S1). Given the high levels of oak and alder it suggests that the site was very close to or, more likely within, oak woodland, with some alder trees nearby. During the period covered by the diagrams there is a partial clearance of woodland associated with burning on site corresponding with the construction of the mound. After the burning oak regenerates, but there are also species characteristic of disturbed woodland such as holly and birch. The episode is also associated with arable cultivation of oats or wheat which ceases during the regeneration phase.

From Inchagreenoge charcoal identifications are dominated by alder, with lesser amounts of ash, hazel, birch, blackthorn, *Prunus avium/padus* (wild/bird cherry), Maloideae, elm, *Taxus* (yew), and willow. The monolith section (0.58 × 0.10 m) was taken through the stratigraphy of the southern baulk of the site which comprised a base of natural boulders, a peat unit, the edge of the burnt mound, another peat unit, a thin clay, and finally a soil A horizon. In addition, a large section of the trough (C28, fill C35) was cut *in situ* and shipped to the laboratory (Fig. 5). The pollen diagram from the core profile (Supplementary Fig. S2) has a basal pollen zone (ISCP1)

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TABLE 1: POLLEN COUNTS FROM COOHAGH WEST EXPRESSED AS % OF TOTAL LAND POLLEN SUM (%TLP) AND % OF TOTAL LAND POLLEN SUM-*ALNUS* (%TLP-A) IN CASES WHERE *ALNUS* WAS VERY HIGH

Type	*CWA1 Top of fill*	*CWB1 Mid fill*		*CWC1 Base of fill*		*CWG2 Below trough stones*	*CWH1 Deeper below stones*	*CWF5 Under trough timber V*
	%TLP	*%TLP*	*%TLP-A*	*%TLP*	*%TLP-A*	*%TLP*	*%TLP*	*%TLP*
Trees								
Betula	1.1	0.5	2.2	0.5	1.2	0.6	0.8	1.0
Pinus	15.4	1.6	7.2	7.1	18.4	39.1	37.2	29.9
Ulmus	4.3	0.9	4.0	2.1	5.5	5.8	5.4	9.6
Quercus	17.1	5.9	26.8	6.6	17.3	13.5	14.4	11.0
Alnus	31.7	77.7	348.5	61.4	159.6	17.0	18.8	25.5
Fraxinus	2.8	+	1.2	0.5	1.2	0.6	+	0.6
Malus sylvestris	+	+	1.1	+	+	0.5	+	+
P. spinosa			+					
Taxus				+	+			
Acer campestris						+		
Total Trees	*72.7*	*87.3*	*391.6*	*78.5*	*203.8*	*77.7*	*77.5*	*77.9*
Shrubs & epiphytes								
Corylus	10.8	5.1	23.1	11.6	30.2	15.7	15.1	12.3
Salix	0.9	+	+					+
Hedera	2.5	1.2	5.4	2.3	5.9	+	3.0	1.4
Ilex				+	+	+	0.5	+
Ericales und.				+	+	+	+	+
Total shrubs & epiphytes	*14.2*	*6.4*	*29.0*	*14.1*	*36.7*	*16.5*	*18.8*	*14.4*
Herbs								
Poaceae	4.3	0.6	2.5	1.7	4.6	2.3	0.9	1.5
Cerealia	+	+	1.2	+	0.5			
Cyperaceae	2.8	+	0.7	0.5	1.4	1.7	0.5	1.1
Artemisia				+	+			+
Anagallis t.		+	+					
Anemone t.				+	+			
Asteraceae	+	+	0.9	+	0.5	+	+	+
Cannabis t.				+	+			
Caryophyllaceae	+	+	+					
Chenopodiaceae	0.7	+	+			0.6	0.6	0.7
Filipendula	+	1.1	5.1	+	0.9	+		
Chelidonium	+							
Lactuceae		+	+	+	+		+	+
Linum bienne t.		+	+	+	+			
Lysimachia	+							
Plantago lanc.	0.9	0.6	2.5	1.2	3.1	+	+	1.1
P. coronopus		+	+	+	+			
P. media/major				+	+			+
Potentilla t.		+	+					

TABLE 1: Continued

Type	*CWA1 Top of fill*	*CWB1 Mid fill*		*CWC1 Base of fill*		*CWG2 Below trough stones*	*CWH1 Deeper below stones*	*CWF5 Under trough timber V*
	%TLP	*%TLP*	*%TLP-A*	*%TLP*	*%TLP-A*	*%TLP*	*%TLP*	*%TLP*
Rununculaceae	0.9	0.6	2.5	1.5	4.0	+	+	1.4
Rumex acetosa	0.7	2.3	10.4	0.6	1.6		+	+
R. acetosella		+	+					
Umbellifereae	+	+	+				+	
Scrophularia	+							
Stellaria				+	+			
Total herbs	*12.9*	*6.2*	*27.9*	*7.3*	*19.0*	*5.6*	*3.7*	*7.5*
Aquatics								
Nuphar				+	+			
Typha und.	+	+	+	+	0.5	+		+
Total aquatics	+	+	+	+	*0.7*	+		+
Spores								
Polypodium	5.2	+	1.6	5.6	14.5	4.1	5.6	9.8
Pteridium	2.5	+	2.0	0.5	1.2	0.5	0.5	1.0
Filicales und.	4.1	+	2.3	1.6	4.2	4.8	6.7	11.0
Sphagnum	+					+	0.5	0.7
Total Spores	*12.4*	*1.3*	*6.0*	*8.0*	*20.8*	*9.7*	*13.3*	*22.7*
Unid.	*0.9*	+	+	*1.1*	+	+		+
Total Counts								
Total no. types recorded	29	31		33		25	24	28
Total no. types recorded per 100 grains	4.6	1.2		2.1		3.5	3.4	2.9
Total land pollen (excl Alnus)	378	548		542		526		572
Total land pollen	554	2458		1407		634		768
Total pollen+ spores	624	2493		1520		696		943

For further elaboration see text

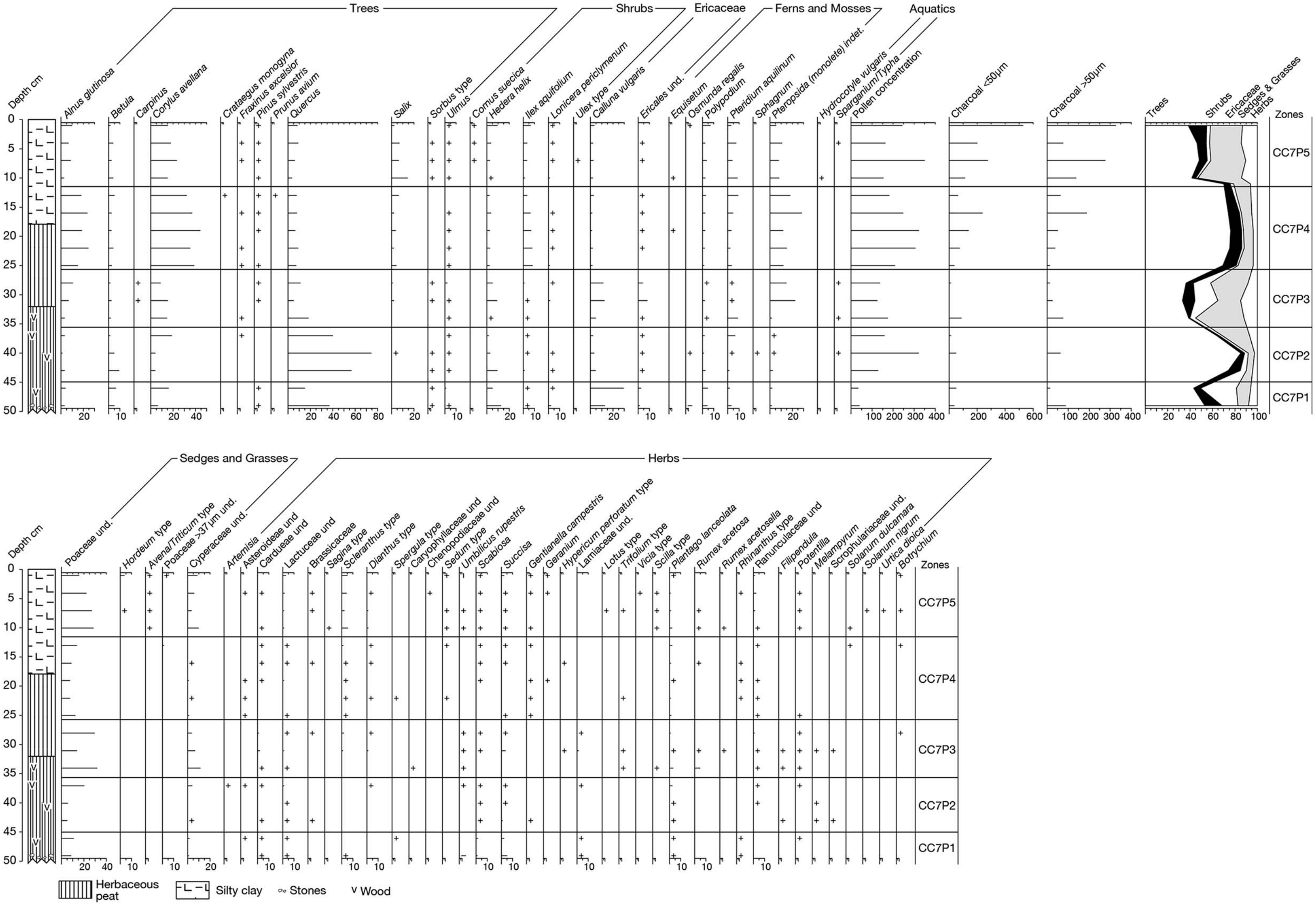

Fig. 4.
Cahiracon monolith 7 pollen diagram

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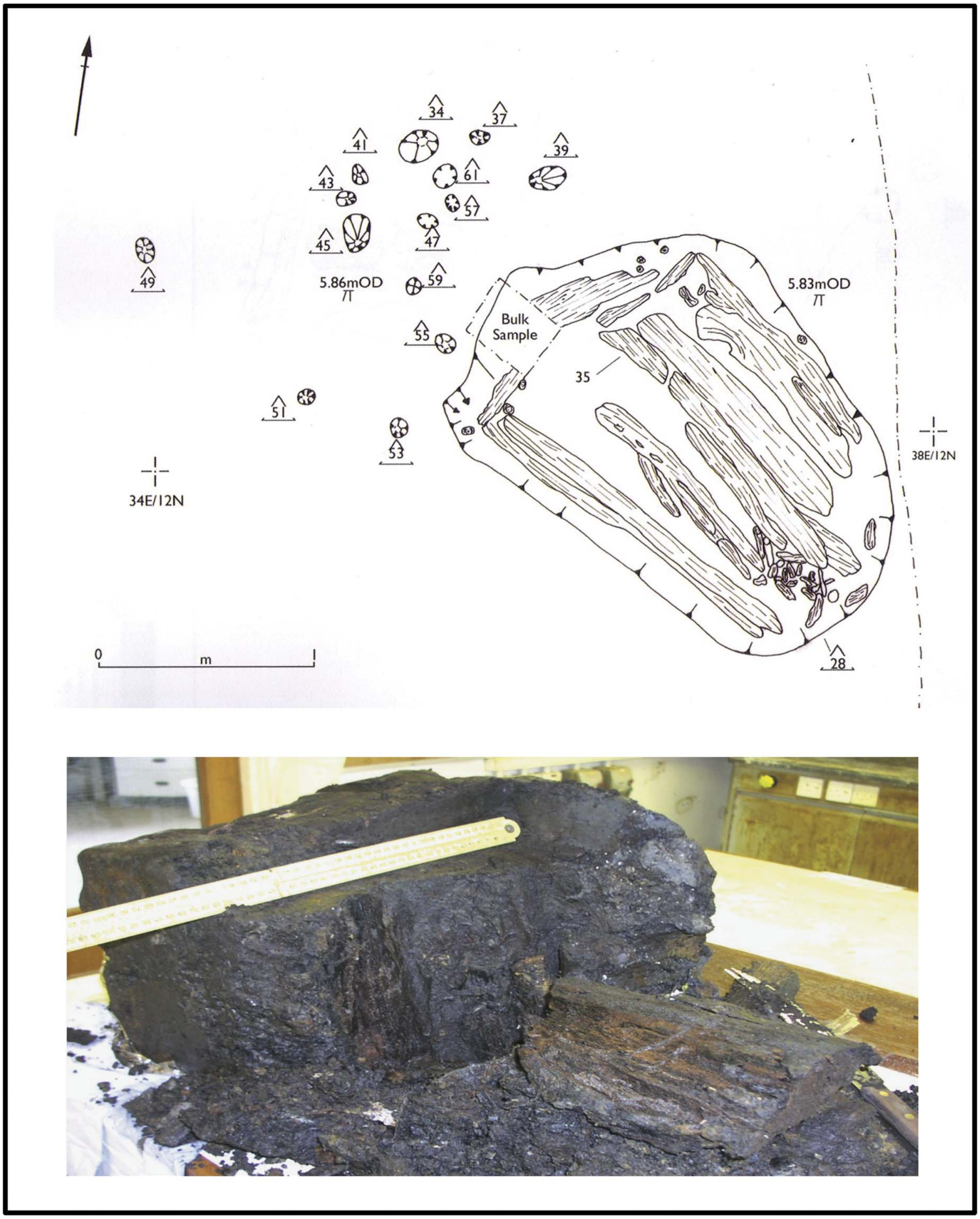

Fig. 5.
Inchagreenoge trough C28 plan showing stake-holes and location of the large *in situ* bulk sample

dominated by *Pinus* (pine) but this almost completely disappears at the level of the *fulacht fiadh* sediments. The pine is difficult to interpret due to its highly efficient dispersal of pollen, however, at approximately 30% TLP it is high enough to regard as of local or extra-local origin. The high common *Polypodium* (polypody) and other *Pteropsida* (ferns) but low *Pteridium* (bracken) also indicate that the site was at the edge of or close to a woodland. In zone ISC2 the spectra is dominated by grass, herbs and sedges indicative of grazed pasture or meadow. Oats (*Avena)* or wheat also appear at 32 cm which corresponds with the *fulacht fiadh* sediments (context 21). The simplest interpretation of the data is that pine woodland was felled and/or burnt prior to the construction of the *fulacht fiadh* and the site or land nearby used for both cereal cultivation and pastoral activity. The Holocene decline in pine is highly diachronous in Ireland being earlier (*c*. 2400–2100 cal BC) in northern Ireland (Hall *et al.* 1994) but later in central and western Ireland where it can be as late as *c*. 600 BP (Molloy & O'Connell 2007). Pine is also known to survive in refugia with locally favourable conditions long after its regional decline due to a combination of competition driven by climate change and human activity (Brown 1988). Inchagreenoge is Early Bronze Age in date and this relatively early date helps explain the existence of pine woodland which must have been growing on the slopes surrounding the bog in which the two *fulachtaí fiadh* were constructed. Animal bones from the fill of this trough included large domestic ungulates (cattle).

Charcoal data from Cragbrien (C21) indicates that hazel, alder, blackthorn, oak and wild/bird cherry were growing in the vicinity. The high-resolution pollen sequence (Fig. 6) is directly correlated with the base of the mound, and so start of its accumulation at 84 cm. The basal zone (CBP1) indicates wet alder-dominated woodland with both pine and mixed oak/hazel woodland. That the woodland was not completely closed and had gaps or clearings is indicated by the high *Hedera* (ivy) and the wide range of herb types present many of which are light demanding. The fall in alder pre-dates construction of the burnt mound, but by how much is unknown. The reduction in pine and oak are later and immediately pre-date the burnt mound level and an interesting increase/spike in willow (zone CBP2a). This could be due to these trees having been left by the streamside (25 m to the east) or possibly by willow branches with catkins (male) being brought onto the site. By the level of the mound in zone CBP2b the local area is open with scattered trees and the herbs are dominated by pastoral indicators. The apparent rise in pine in zone CBP2a is almost certainly an artefact of the opening up of the local canopy allowing far more regional and long distance pollen to reach the ground surface. The *Hordeum* (barley) type record is difficult to interpret as it could be *Glyceria* (reed grass) which is typical of such wet locations, however, the correspondence with oat/wheat type and *Secale* (rye) in zone CBP3 and early zone CBP4 suggests that the clearing was used for arable cultivation immediately after the deposition of the mound sediments. The construction of the mound also seems to be associated with a high grass to sedge ratio and a peak in *Plantago lanceolata* (ribwort plantain) suggesting grazing. Zone CBP3 largely post-dates the burnt mound levels and covers a reversal in the Poaceae/Cyperaceae (grass/sedge) ratio which suggests either/or a reduction in grazing pressure or an increase in local surface wetness. The final zone CB4 shows a peak in bracken suggesting a reduction in grazing pressure. The simplest interpretation of the vegetation sequence is: clearance of an area of alder carr and oak woodland close to the river at a time when there was still a largely wooded landscape. The burnt mound is then created in an open environment characterised by rough pasture and some heathland of bracken and heather. After the mound has gone out of use and is being buried by alluvial sediment, grazing pressure decreases and cereal cultivation increases only to be abandoned at the end of the sequence. This suggests that the construction of the burnt mound is not unreasonably associated with a pastoral economy but with some cereal cultivation in the vicinity.

The pollen analysis and plant macrofossils from Killescragh and Caraun More (A024/22 and A024/23, Hatton unpublished, Supplementary Data Table S1) reveal that the earliest peats analysed from site A024/22 (F22 & F8) indicate a local landscape dominated by open wet woodland comprising alder, birch, hazel, ash, bird cherry and yew. Pine and elm were also growing in the vicinity and may have occupied the well-drained slopes of the nearby esker ridges. The plant macrofossil assemblages from the earliest deposits analysed indicate the presence of open fen woodland with a diverse wetland understorey, which is likely to have occupied the low-lying area between the River Craughwell and the esker. The expansion of yew is thought to be associated with reductions in intensive

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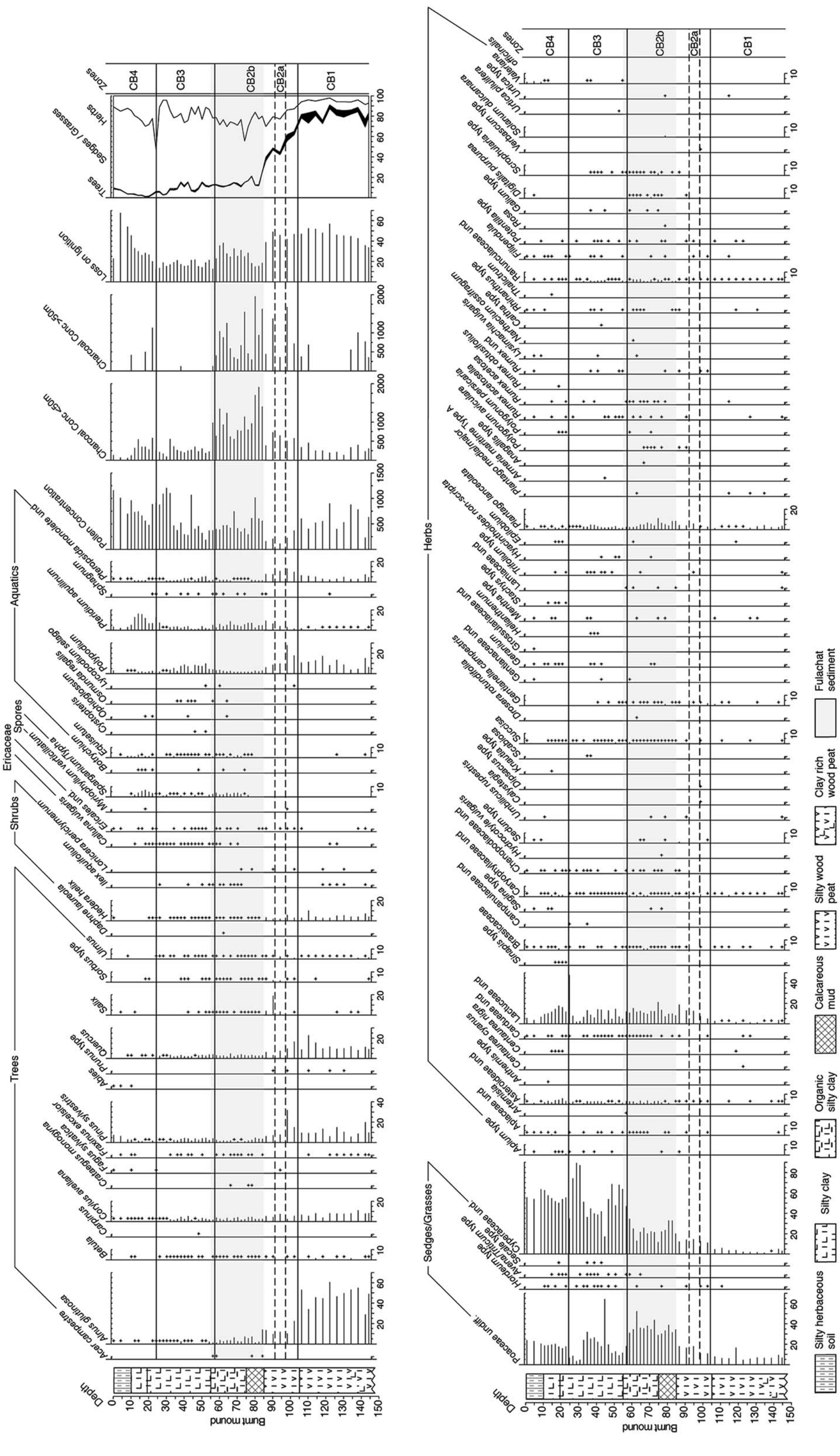

Fig. 6.
Craigbrien pollen diagram

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woodland clearance in the Neolithic (O'Connell & Molloy 2001) and Iron Age although it is regarded as over-represented in pollen diagrams (Newman *et al.* 2007). The possibility of immediate post-burnt mound anthropogenic activity in the area is also suggested by the presence of a single charred grain of barley and charcoal fragments of hazel, ash and elm, however, this context (F8), although above and close to the burnt mound (Killescragh 2), is not in direct stratigraphic association. Plant remains from the peat horizon underlying a wooden trackway (F21) suggest the continued presence of wet woodland, although some of the arboreal remains may relate to the trackway construction. Charcoal from the burnt mound deposit suggests that hazel and ash may have been used for fuel for fires associated with the feature. Plant macrofossils from the overlying peat deposit reflected open fen vegetation with little woodland cover. Samples from below a possible trough base at A024/23 indicate the presence of local wet woodland comprising alder, birch, hazel, and yew. Birch and hazel charcoal from the peat above the possible trough base may derive from fuel associated with the burnt mound.

At Coonagh West, pollen was extracted from six contexts from the excavation respectively top, middle, and base of the trough fill, and below the trough stones, deeper below the trough stones, and under a basal timber (Table 1, Supplementary Data Fig. S3). These were all counted to an unusually high count (>600 grains) in order to improve statistical inferences. The concentration of pollen and spores was high (20,000–100,000 grains ml) and very few showed signs of degradation or corrosion. The site has therefore almost certainly not suffered from differential preservation and the counts can be taken as an accurate reflection of the pollen and spore influx to the site. All six samples are dominated by trees, but this is where the similarity ends. It is apparent that the three levels beneath the stones and timber (CWG1, CWH1, CWF5) are all very similar to the point of having almost exactly the same percentage values of major types such total trees (77.7%, 77.5% & 77.9% TLP) and the same frequency order of trees. It is reasonable to suggest that these three samples came from an alder-oak-hazel dominated woodland surrounded by mixed woodland with a significant component of pine. The other samples have significant differences. Sample CWA1 is dominated by alder annd oak with high pine, hazel, elm, and ash. As with all the samples elm is surprisingly high (>4% TLP) and suggests that it was a significant component of the regional woodland (see later discussion). Birch and willow, although present, do not appear to be major components of the woodland, however, the Salicaceae, due to their dioecious biology, are generally under- and rather erratically represented in pollen diagrams even from hazel-willow carrs. A clearing is also indicated by high holly, which only flowers in sunlight and most prolifically at the edges of woodland, and a range of herbaceous pollen types including grasses and sedges but also Lactuceae (dandelions family), Chenopodiaceae (goosefoot family), ribwort plantain, *Rumex acetosa* (common sorrel) and bracken spores. A single grain of cereal type pollen (oat/wheat type) was also recorded. The closed nature and close proximity of the surrounding woodland is also indicated by the high levels of polypody and the occurrence of *Chelidonium* (celandine). Sample CWB1 is also dominated by alder and oak with high hazel, pine, and ash. The extremely high alder value (1910 grains counted) and the presence of clusters of alder grains clearly indicates that anthers had blown into the trough from either overhanging or adjacent trees. An unusual occurrence is *Malus sylvestris* (crab apple) at 1.1% TLP-A along with even higher holly than in sample CWA1 at 5.4 %TLP-A. The non-tree component is significantly higher at 27.9% TLP-A with unusually high levels of common sorrel at 10.4 %TLP-A, *Filipendula* (meadowsweet) at 5.1 %TLP-A and *Ranunculus* (buttercups) at 2.5% TLP-A. Cereals (oat/wheat type) are also high at 1.2 &TLP-A and one grain of *Linum bienne* type (pale flax) was recorded. Sample CWC1 is also dominated by alder and oak with high hazel, pine, and ash. Alder is still very high (865 grains counted) but no clusters were observed and both the herbaceous total at 19% TLP-A and unusually high holly (nearly 6% TLP-A) indicate a clearing or forest gap. The high herbs are again buttercup family, ribwort plantain, common sorrel and meadowsweet. Cereals are present, *Cannabis* type (hemp, 1 grain), pale flax type and *Stellaria holostea* (greater stitchwort). A similar gap or clearing was recorded at Leahy which also had unusually high *Lonicera* (honeysuckle; Brown *et al.* 2004). The remarkably high concentration of alder pollen in the lower levels of the Coonagh West trough suggests deliberate collection and deposition especially when we consider that it was possible that the trough was not cleaned out after its final use (Reilly 2010). Alder, common sorrel, and meadowsweet were commonly used in dyeing in Ireland.

Plant macrofossil analysis conducted on columns 1 and 3 from Coonagh West all produced a similar plant assemblage (Supplementary Table S2; Durham Archaeological Services 2007) and this can be compared with the pollen data from samples CWA1, CWB1, and CWC1 (Table 2). This is meaningful in this case because of the undoubtedly localised source area for most of the pollen and spores. There is a strong correspondence amongst both the common elements (e.g. alder, oak, etc) but also some rarities such as greater stitchwort. It reinforces the inference of a small damp grass-dominated clearing within wet/damp alder-hazel-oak woodland within the regional woodland with pine, elm, and ash. The composition of the local woodland matches unusually well the main wood types used in the construction of the trough with alder (51%), oak (23%), hazel (10%), Maloideae (8%), ash (5%), and willow (3%). In particular it is rare to be able to match less common species, in this case crab apple, which is also a potentially important prehistoric food resource. The slight mismatch with willow is probably due to the un-representivity of pollen influx value as mentioned earlier. The interesting difference is a lack of any elm or pine in the macrofossils, supporting the contention that they were growing in the region but not on the flood plain or in the immediate vicinity of the site.

The pollen sequence from Jigginstown is unusually complex given its limited depth (Fig. 7). The basal zone, JG1, almost certainly represents the end of the Lateglacial and very beginning of the Holocene and the succeeding zone, JG2, covers a period during which the Boreal woodland of the Early–Midle Mesolithic is established as is confirmed by radiocarbon dates. This woodland becomes richer after the appearance of hazel in zone JG4. There are indications of disturbance, both natural and later human, to this open and probably fragmented, woodland. Pollen zone JG5 covers a period when a clearing is created in the pine-hazel dominated woodland, perhaps with the aid of fire and this is initially used for grazing. Subsequently arable cultivation occurs in the close vicinity of the site. The definite presence of *Linum catharticum* (purging flax) in three consecutive levels at the base of the zone JG6 strongly suggests that it is being grown or processed near the site. It can be used as a yellow dye-plant but is also well known for its medicinal properties as it is anthelmintic (expels parasites from the gut), diuretic, emetic, and purgative. Macrofossil remains have been found at a number of Bronze Age sites in the British Isles including Knights Farm (Berkshire), Runnymede (Surrey), Stackpole Warren (Pembrokeshire), Wilsford Shaft (Wiltshire), and from several crannogs including Oakbank Crannog, Loch Tay, Tayside (Tomlinson & Hall 1996). The unusually high representation of *Centaurea nigra* (black knapweed) throughout zone JG6 (at over 5% TLP) could be due to the close proximity of a rough, damp knapweed-infested meadow or, alternatively, it may have been being encouraged/cultivated or brought onto site due to its well-known use in fabric dyeing (it produces a yellow dye). This is an unusual pollen and spore diagram, as it appears that oak dominated temperate woodland never developed around this site and the activities associated with the *fulachtaí fiadh* occurred in a pine and hazel dominated landscape. The evidence of purging flax and the anomalous levels of black knapweed suggest that one function, or at least usage, of the *fulachtaí fiadh* may have been related to the manufacture and dyeing of textiles.

TABLE 2: PLANTS FOUND BOTH AS MACROFOSSILS IN COLUMNS 1 & 3 & AS POLLEN IN SAMPLES CWA1, CWB1, OR CWC1

Plant	*Macrofossils*	*English name*
Alnus glutinosa	wood, fruit, female cone	alder
Corylus avellana	nut fragment, charcoal	hazel
Ilex aquifolium	fruitstone	holly
Prunus spinosa	fruitstone	sloe
Quercus sp.	bud, charcoal, cupule fragment, wood fragment	oak
Ulmus	wood fragment	elm
Ranunculus sp(p).	achene	lesser spearwort, buttercups
Apiaceae sp.	fruit	carrot family
Carex sp.	biconvex nutlet, trigonus nutlet	sedge family
Poaceae sp(p).	caryopsis	grass family
Rumex sp.	nutlet	docks
Stellaria holostea	seed	greater stitchwort

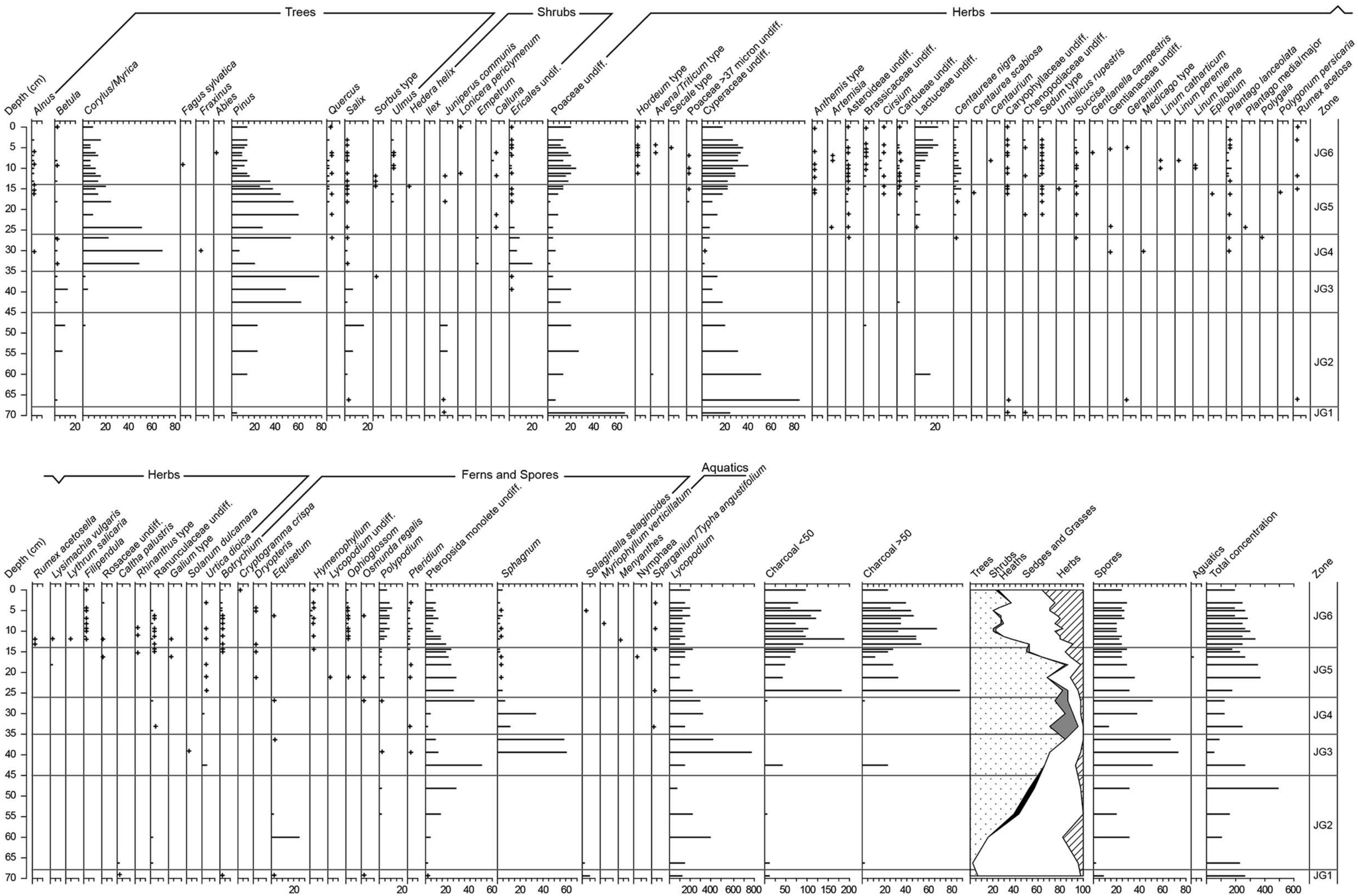

Fig. 7.
Jigginstown pollen diagram

At Ballygawley, a total of 2530 macroscopic charcoal identifications were carried out from features and deposits across all periods of site use. Alder and hazel were identified as the most abundant timbers used through each period with other arboreal taxa more popular as fuel wood in varying periods, eg, oak was utilised mainly in the Neolithic, while holly was resourced in the Late Bronze Age–Early Iron Age. Other tree and shrub types used for fuel include: wild cherry, Maloideae, willow, blackthorn, and ash. Ring-curvature shows fragments mainly had strong and moderately curved growth rings suggesting that branch wood was the main timber size used as wood fuel (Wheeler *et al.* in press). Fragments with weakly curved growth rings were present in low numbers which, together with the worked (waterlogged) wood from the trough linings, shows that large-sized timbers (eg, trunk wood) were also used on occasion. A total of 37 bulk samples were analysed for macroscopic plant remains from archaeological features and palaeochannel deposits. The overall assemblage from Ballygawley changes little chronologically, consisting largely of wet/damp loving plants indicative of fen conditions that are typical of stream side assemblages including: *Viola palustris* (marsh violet), *Potentilla palustris* (marsh cinequefoil), *Potamogeton* sp. (pond weed), and *Persicaria hydropiper* (water pepper), together with a range of sedge species. Evidence of the local woodland is limited with only *Sambucus nigra* (elder) fruits present, suggesting the area around the mound activity was cleared. The presence of pasture land near to the site is also indicated from the presence of a number of meadowland plants such as *Persicaria maculosa* (redshank), buttercups, *Galeopsis tetrahit* (hemp-nettle), Chenopodiaceae, and *Stellaria* sp. (chick weed). There is some evidence for cultivation during the prehistoric period with the presence of charred cereal grain of naked barley recovered from a pit (9539) associated with burnt mound (9009). The grains have been dated to the Middle Bronze Age (1610–1410 cal BC; SUERC-20608; 3215 ± 35 BP and cereal-type pollen is also present in the upper layers of Monolith 2 (LPAZ S1II4).

The pollen sequence from Ballygawley monolith 2 has been divided into four local pollen assemblage zones (LPAZ S1II1–4) (Fig. 8). The pollen diagram shows local alder carr with willow and birch, formed in the valley bottom, river banks, and flood plain terraces while dryland woodland of oak, hazel, and elm was present on the drier valley slopes and surrounds. The herbaceous pollen assemblage shows the field layer consisted mainly of grasses and damp grassland taxa such as sedges, *Peucedanum* type (probably wild angelica), and *Urtica* sp. (nettles). Within LPAZ S1ii1 and at the beginning of LPAZ S1ii3, regular fluctuations in the pollen of oak, alder, and hazel appear as a zig-zag pattern during and following the end of activity at burnt mound 9031. It is suggested this zig-zag pattern reflects some form of woodland management (eg, coppicing cycles) of the local woodland in association with the sampled burnt mound and one 40 m to the south-west (9034), dated to 2460–2200 cal BC (SUERC-20634; 3850 ± 35 BP). This potential pattern of managed woodland exploitation has been replicated at another burnt mound site at Roughan, Co. Tyrone. This zig-zag pattern seen in the arboreal and shrub pollen is absent within some levels from the burnt mound in LPAZ S1II2, and after the mound material has been deposited (upper LPAZ S1II3 and LPAZ S1II4); this is likely to be an effect of poor preservation through the mound material and counting at increased intervals in the upper levels. Poor pollen preservation might also explain the decrease in total arboreal pollen from 103 cm to 95 cm although a phase of woodland clearance cannot be discounted. Any impact on woodland cover is short-lived as arboreal pollen percentages recover to close to their pre-burnt mound values during the early stages of LPAZ S1ii3. Peaks in microscopic charcoal of all sizes (<21– >50 µm) are seen during the levels of the burnt mound activity reflecting the local burning taking place. Non-pollen palynomorph and spore data from levels in the lower and upper parts of burnt mound material show peaks in the presence of *Gloeotrichia* (HdV-146) implying increased levels of eutrophism at the site, which could be the result of water used in the troughs for cooking or other purposes, or from stagnant water lying close by. *Sphagnum* was probably used to line the troughs and its spores peak in the burnt mound material. Peaks in coprophilous fungi *Cerocophora*-type (HdV-112) and *Sordaria*-type (HdV-55A) are also recorded during and following the burnt mound activity suggesting the presence of animals around the site.

Beetles (Coleoptera)

Coleoptera fragments were high enough for meaningful analysis throughout the Cahiracon monolith M7 (Supplementary Data Table S3). The basal sample (0.3–0.5 m) was the most diverse of three with the

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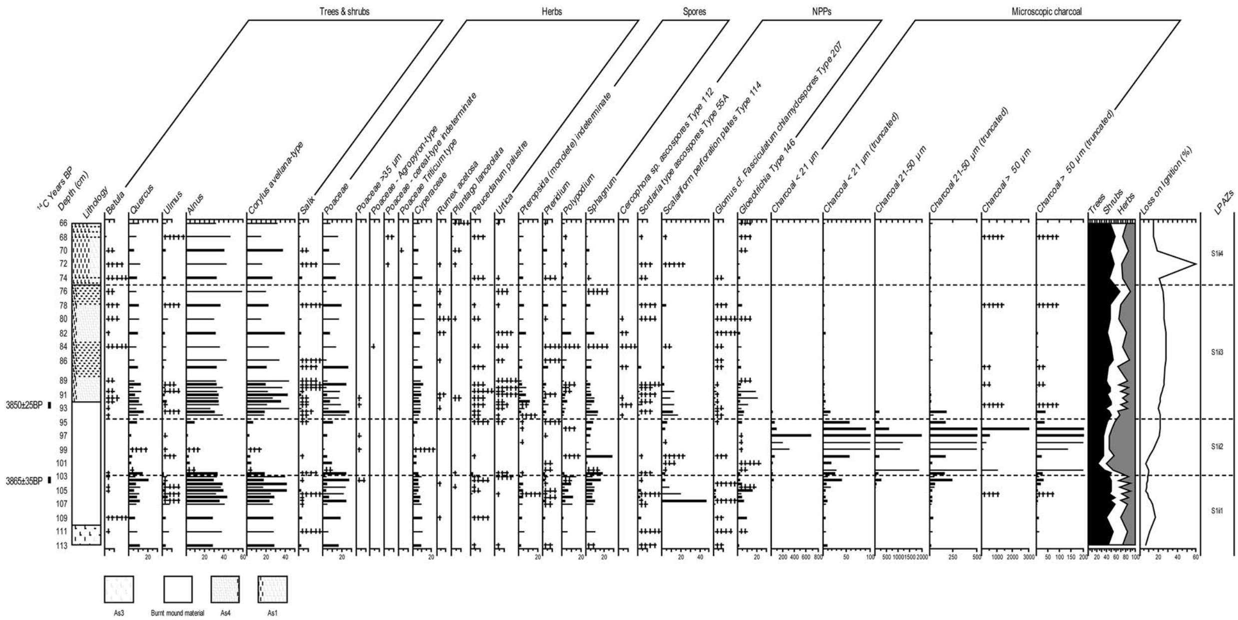

Fig. 8.
Pollen and spore diagram from Monolith 2 at Ballygawley

assemblage comprising 102 individuals from 45 taxa. A number of taxa characteristic of swampy or waterside environments are present (15%). These include the scirtid *Cyphon* sp., the pselaphid *Reichenbachia juncorum*, and the cryptophagid *Paramecosoma melanocephalum*. The water beetles present (*Hydraena riparia*, *Anacaena globulus*) strongly suggest a slow-flowing water body and the most abundant ecological grouping in this sample is indicative of accumulations of foul, rotting organic matter (*c*. 20% of all individuals present). These include a wide variety of staphylinids such as *Micropeplus fulvus*, *Tachinus laticollis*, *Philonthus varians*, and *Rugilus rufipes*. In addition, four dung-specific taxa are present, including two species of *Aphodius* (*A. contaminatus* and *A. sphacelatus*) with a preference for the dung of cattle or horse (Koch 1989), numerous fragments of *Geotrupes* (at least one individual), and the staphylinid (*Anotylus sculpturatus*) which may also inhabit carrion. Two woodland edge taxa seen in the other samples are again present; *Stenichnus collaris* and *Othius punctulatus*. In addition three genuine woodland taxa are recorded; the relatively non-specific weevil *Strophosoma melanogrammum*, the weevil *Curculio pyrrhoceras*, which is oligophagus on oak, its larvae living in the galls of the oak gall wasp *Cynips quercusfolii* (Koch 1992), and the cossonine weevil *Mesites tardii*. This is the largest species of cossonine weevil in the British Isles and has a preference for firm dead wood in coastal locations (Warren & Key 1991), so it may result naturally from the proximity of the site to the Shannon Estuary or from the import of driftwood for fuel. *M. tardyi* seems surprisingly common in Irish prehistoric samples compared with the UK where it is almost entirely driftwood related. Why this might be is not clear. In addition the presence of the weevil *Anthonomus rubi* is characteristic of woody members of the Rosaceae, probably *Rubus fruticosus* agg. (blackberry) of which a number of seeds were evident in sorting.

The sample stratigraphically above (0.2–0.3 m) contained a moderately diverse fauna (62 individuals from 37 taxa) relative to sample size. Again, the principal component of the assemblage indicates a swampy or stream-side locality as is once again indicated by the inclusion of members of the Pselaphidae and Carabidae of the genus *Pterostichus*. The water beetle fauna present is characteristic of slow-moving water bodies (*Anacaena globulus*, *Helophorus brevipalpis*, *Hydraena riparia*). The staphylinid *Olophrum consimile* is of particular interest in that it has traditionally been considered an upland species in the British Isles (eg, Joy 1932; Tottenham 1954). However, a number of continental European studies suggest it is often also

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present at the edges of lakes, ponds, bogs, and streams with luxuriant vegetation (eg Böcher 1995; Koch 1989). Several taxa present are characteristic of woodland or woodland edge environments including the staphylinid *Othius punctulatus*, the carabid *Bembidion harpaloides* (which mainly lives under bark of logs and dead trees; Luff 1998), and the cantharid *Rhagonycha femoralis*. The only obligate woodland species is once again the non-specific, deciduous tree dwelling *Strophosoma melanogrammum*. Four taxa characteristic of rotting vegetable matter are present; the hydrophilids *Megasternum boletophagum* and *Cercyon* sp. and the staphylinids *Philonthus* sp. and *Tachyporus hypnorum*. Dung beetles of the genera *Geotrupes* and *Aphodius* are present, the latter represented by *A. fimetarius* which may be found in dung and more rarely in compost and stable manure heaps and rotting vegetation, especially Brassicaceae (Koch 1989). A single phytophagous species is present; a weevil of the genus *Gymnetron*, the majority of which favour plantains as a host plant. The uppermost sample (0–0.1 m) also contained a moderate to highly diverse fauna (97 individuals from 42 taxa), strongly dominated by taxa of swampy or stream-side localities (eg, the pselaphids *Bryaxis bulbifer*, *Brachygluta haematica*, *Reichenbachia juncorum*, and the carabids *Pterostichus anthracinus*, *P. gracilis*, and *P. vernalis*), comprising approximately 30% of all taxa present. The limited water beetle community indicates a slow flowing water body (*Hydraena riparia* and *Anacaena globulus* both prefer such environments) with vegetation probably including *Scirpus lacustris* (common club-rush), upon which the larvae of *Limnobaris t-album* feed (Hoffman 1954). Some of the taxa present suggest local woodland or the presence of woodland litter, such as the scydmaenid *Stenichnus collaris*, which is usually found in damp woodland or woodland margins and the staphylinid *Lordithon exoletus* which lives on agaric fungi in similar environments (Koch 1989). Two taxa are strongly associated with woodland; the elaterid *Prosternum tesselatum* which has a strong preference for oak and pine (Laibner 2000), both of which are common within the pollen diagram at this time, and the weevil *Strophosoma melanogrammum* which lives upon a wide range of deciduous tree taxa. Several taxa indicate the presence of foul, rotting organic matter (eg, the staphylinids *Gyrohypnus punctulatus*, *Proteinus ovalis*, and *Tachinus laticollis*, in addition to members of the Hydrophilidae). This may have been in the form of dung, as fragments of two Aphodius dung beetles were present (too degraded to identify to species). Also present are two carabids characteristic of open localities which exhibit a preference for cultivated ground; *Bembidion obtusum* and *Trechus quadristriatus*. This is in concurrence with the pollen diagram which records both barley- and oat/wheat type within this zone (CC7P5).

All three samples have a broadly similar character in that they imply a swampy area in proximity to both a slow moving water body and an area of woodland (Fig. 9). More specifically the upper two samples both include some taxa of open cultivated ground which, in conjunction with the pollen evidence, strongly suggests arable cultivation. This element is absent from the lower sample, which has a more extensive dung and refuse fauna, possibly suggesting a switch from a pastoral system with the presence of cattle or horses in the vicinity to a mixed system. Also, marginally more woodland taxa are present towards the base of the column, which is in keeping with the pollen evidence of local woodland. Also in agreement is that this woodland included oak as is indicated by *Curculio pyrrhoceras*. This beetle is associated with oak galls which have a long use of history in the cloth dyeing industry. It is possible that the cossonine weevil *Mesites tardii* would have arrived on the site as a result of human activity, as its preferred habitat is driftwood which, given the apparently regular burning of such sites, may well have been an exploitable resource.

The Coleoptera from the Inchagreenoge monolith was sparse but the sample from 0.57–0.42 m included taxa of slow waters (*Agabus bipustulatus* and *Helophorus brevipalpis*), emergent vegetation (*Donacia* sp.), and shaded locales (*Olophrum* sp.). The leg of an *Aphodius* dung beetle is present. In the sample from 0–0.2 m depth one Dytiscid head (*Agabus* sp.) suggested slow water and there were carabids of open ground (*Pterostichus* sp.) and hygrophilous staphylinids (*Stenus* sp.). This is in agreement with the pollen and spore diagram but due to the low concentration and poor state of preservation prohibited further inference.

The coleoptera from the earliest peats from Killescragh and Caraun More (A024/22) are suggestive of a predominantly wet, but open environment with occasional trees (Fig. 9). One sample in particular demonstrates the presence of woody Rosaceae and possibly elm. The predominant vegetation type appears to have been aquatic grasses, with the field chafer, *Phyllopertha horticola* present in each of the three samples analysed from this phase. The presence

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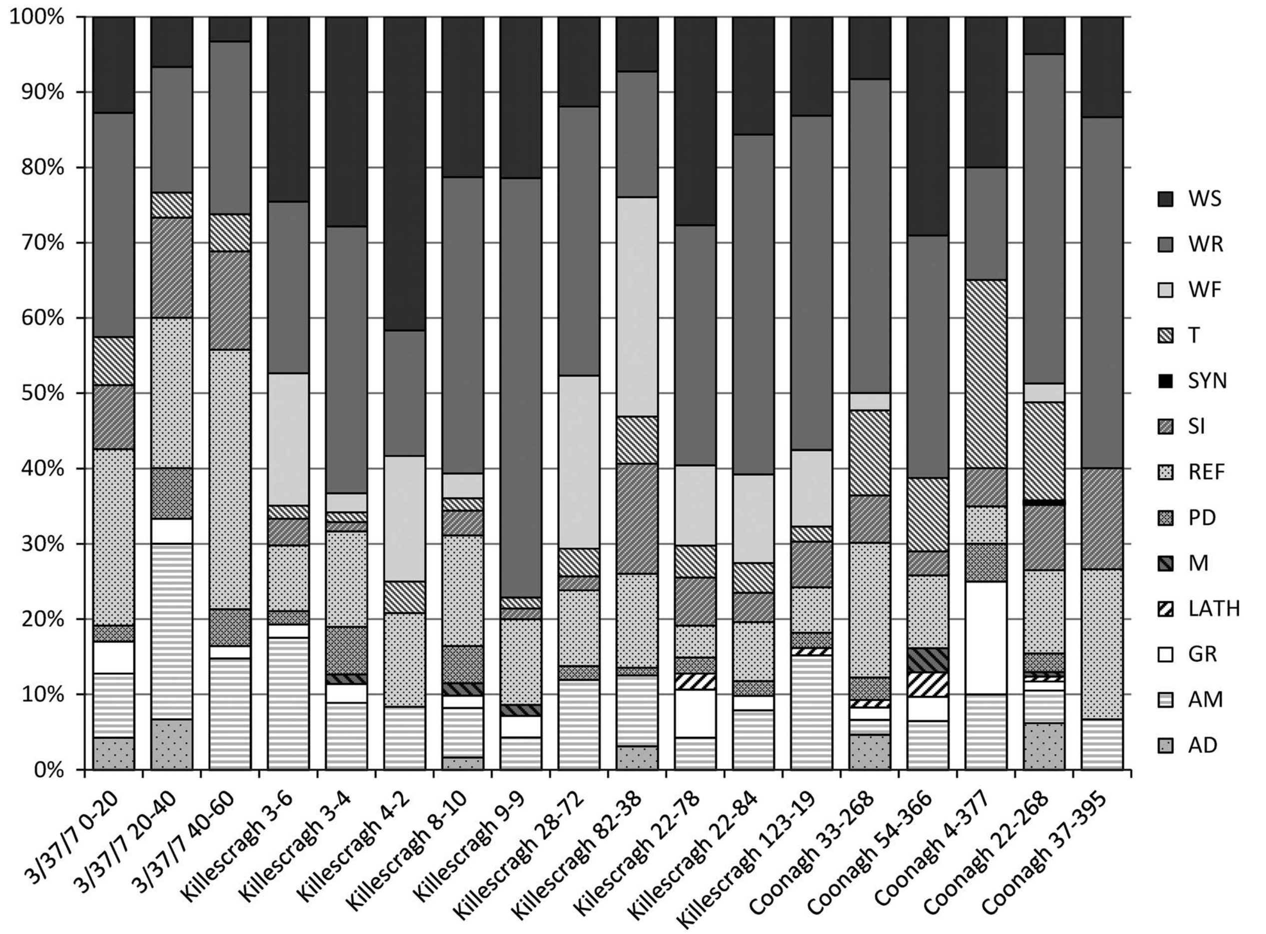

Fig. 9.
Sample by sample ecological comparison for site Cahiracon 3/37/7(M7), Killesraigh. and Coonagh West site A005 2021 and (b) Ecological categories are: WS (Slow water), WR (Running water), T (woodland), SI (Silvicolous), REF (Refuse/rotting vegetable matter), PD (Pasture/dung), M (Meadow), LATH (Lathridiidae – mould beetles), GR (Grassland), AM (Aquatic/marsh) and AD (Arable/disturbed)

of large herbivores is indicated in some samples, but the evidence does not suggest these were abundant or that pastoral agriculture represented a factor in the landscape at this time. Of the three samples analysed contemporary with the burnt mound, two indicate a more or less open flood plain landscape, the phytophages indicating plant taxa capable of rapid regeneration (e.g. rosebay willowherb: *Chamerion angustifolium*) and disturbed conditions (eg, ribwort plantain). Grazing indicators are sparse and the overall impression is of a landscape not dissimilar to that indicated in samples prior to mound construction, perhaps wetter with the elaterid *Prosternon tesselatum* living at distance on higher ground. However, the third sample analysed from this phase, which underlay a trackway remnant, provided a wealth of information regarding local and extra-local woodland at the site. In addition to the suite of aquatic and marshy taxa present in the majority of the other samples, it included five woodland taxa no longer found in Ireland, including the first record here of elm bark beetle, *Scolytus scolytus*, two species of *Cerylon*, and the chrysomelid *Oomorphus concolor,* indicative of ivy. It is probable that many of these woodland indicators arrived with the construction materials for the trackway itself, but they provide a picture of a diverse primary local woodland with oak, ash, willow, elm and *Prunus*/*Crataegus*. The presence of

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this diverse woodland assemblage has obvious implications for the availability of fuel for the mound itself; despite being situated in a largely cleared local landscape, diverse secondary woodland was still present in close enough proximity to allow its harvest for trackway building. The post-mound assemblages comprise what appears to be a more or less cleared flood plain environment, not unlike that observed in the pre-mound state but with some indication of local woodland or occasional tree presence. The moderate diversity of dung taxa and the presence of indications of ribwort plantain suggest a disturbed and grazed environment, typical of many later period lowland flood plains. Two assemblages recovered from this phase include a high proportion of fast water taxa and possible allochthonous taxa (ie, dryland species within a predominantly wetland assemblage) and may represent increased severity of floods.

Only one sample (Feature 27; Sample 43) from Caraun More produced insect remains. The sample yielded a sparse assemblage of 24 poorly preserved individuals from 14 taxa. This was dominated by the throscid *Trixagus dermestoides*, present as a total of eight individuals. *T. dermestoides* is primarily a woodland taxa, often found in clearings and leafy debris. The material processed, while devoid of leafy remains, clearly incorporated a large proportion of fine woody debris, reminiscent of wood shavings. The assemblage also included a few aquatic taxa of slow or stagnant waters, two dung beetles (one *Aphodius* sp. and one *Geotrupes* sp.), and a chrysomelid of the genus *Longitarsus*. Interestingly the assemblage also included a small potentially synanthropic element. A single *Ptinus* sp. was recovered, many species of which are strongly synanthropic, alongside two individuals of the *Lathridius minutus* group. *L. minutus*, while typically synanthropic, is not an obligate synanthrope and may be recovered from woodland debris where it lives upon fungal hyphae. As such, its presence in this assemblage appears to relate to the decomposing wood 'shavings' which were home to *Trixagus dermestoides*. It is conceivable that this debris was created during working of wood for trough construction.

Two pre-mound samples from the palaeochannel fill stratigraphically below a trough at Coonagh West were analysed and found to be extremely rich beetle assemblages. Numerically these were dominated by taxa of slow or running waters, with taxa of fast-flowing waters conspicuously absent (Fig. 9). Refuse taxa were well represented, with *Anotylus rugosus* the most common species of this ecotype. A range of the taxa represented are typical of a waterside location and dung taxa are present in frequencies suggesting moderate presence of large herbivores. Numerically these are dominated by *Aphodius sphacelatus/prodromus* type, but the presence of *A. depressus* is suggestive of a shaded, possibly woodland environment. In contrast, *A. merdarius* is predominantly a taxon of open environments with a preference for dung of cattle, though infrequently found in woodland margins; this suggests the local presence of woodland, possibly providing considerable shade in places. Of particular interest is the diverse woodland assemblage preserved within these samples. These include a range of silvicolous taxa exemplified by the carabids *Nebria brevicollis* and *Agonum assimile*. This latter is a nocturnal woodland floor predator, resting during the day under loose bark (Stork *et al.* 2001). The most common woodland taxon present is the large cossonine weevil *Mesites tardyi*. Other woodland taxa included two species of bark beetles (Scolytidae), *Scolytus mali* and *S. rugulosus*, neither of which are currently recorded in Ireland, although *S. mali* has been recorded from early medieval Dublin (cf. Whitehouse 2006); both of these taxa are typical of woody plants of the Rosaceae, earning *S. mali* the English name of the orchard bark beetle. Other woodland components indicated include oak (the weevil *Curculio pyrrhocerras* lives upon oak galls) and ash (of which the Scolytid *Leperisinus varius* is typical). Several taxa suggest an abundance of local dead wood, including the Eucnemid *Melasis buprestoides* and the Cucujid *Pediacus dermestoides*, which is characteristic of freshly cut or broken tree stumps but rare in Ireland (Alexander 1994). Several taxa present suggest the local presence of grassland or pasture. These include the Elaterid *Adrastus pallens*, usually found on stream and river meadows, in pastures and at woodland margins, in addition to many individuals of the Carabid *Trechus quadristriatus*, typical of open, rather dry country with short vegetation, including agricultural land. Non-woodland phytophagous taxa are relatively sparse, but include the Nitulid *Brachypterus glaber*, characteristic of stinging nettle and hence increased nitrogen input, the Chrysomelid *Hydrothassa marginella*, found on a range of plants by fresh water (including *Caltha palustris* (marsh marigold) and buttercups) and the weevil *Thryogenes festucae*, found in sedges in waterside locations. In summary, the assemblages while diverse (particularly as regards the woodland element), are not unlike many modern flood plain assemblages, indicating

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an area of mixed oak woodland, possibly secondary in nature (suggested by the presence of ash), adjacent to a largely cleared flood plain environment. This may have been agricultural pasture (implied by the presence of nettles and some dung taxa), possibly with the presence of some cattle.

Two samples investigated from a trough fill at Coonagh West (C395 & C366) were dominated by taxa of slow-moving waters or waterside locations. A few woodland taxa are present, including a single woodworm (*Anobium punctatum*) and the weevils *M. tardyi* and *Strophosoma melanogrammum*. The latter common, feeding on the leaves of a wide range of tree species (Harde 1984). Phytophages are restricted to a single individual of *H. marginella* and the weevil *Apion hydrolapathi*, the latter of which is oligophagous on *Rumex* spp. (docks). This small assemblage possessed a fairly generic waterside character, though the presence of some dead wood and possible local woodland is implied. The reduced woodland component of the fauna is in keeping with it being of potentially later origin. While elements of this assemblage may originate from the trough itself (ie, the dead wood component), the fauna probably derive in part from post-use infilling resulting from overbank sedimentation.

Two samples from the post-mound phase of the Coonagh West site yielded worthwhile assemblages. In contrast to previous samples discussed, the aquatic fauna represents a relatively small fraction of this which, coupled with indifferent preservation, suggests a potentially drier depositional environment. However, several waterside taxa are present and a number of woodland taxa, once again including *M. tardyi* and *Leperisunus varius*. These are accompanied by *Cerylon histeroides* and *Scolytus rugulosus*, primarily a taxon of woody Rosaceae. Several taxa also suggest the presence of local open ground, including the field chafer, *Phyllopertha horticola* and dung beetle *Aphodius prodromus/sphacelatus*. Despite comprising an appreciably smaller assemblage, the overall impression is of an environment not unlike that of the pre-mound conditions; a wooded area (including ash and woody Rosaceae) adjacent to a partially cleared flood plain. This suggests that, following mound use, either some woodland remained or that this deposit represents a significantly later accumulation following growth of secondary woodland. The construction and use of the trough/mounds appears to be marked by a change in the beetle fauna that is indicative of high woodland component being replaced by more grassland and refuse species (Fig. 10). This is a more pronounced picture of the changes to the forest than is given by the pollen and plant macrofossils. This is probably due to the bias towards very local changes that is typical of beetle assemblages, whereas the extra-local and regional component of the pollen remains a major part of that spectra. No carrion beetles were noted and dung beetles were not high enough to support any concentration higher than some grazing, such as the corralling of stock at the site. It is clear from these case studies that synanthropic taxa are conspicuous by their absence and statistical analyses reveals that the burnt mound samples cluster well together but show little overlap with a variety of modern and ancient samples (Fig. 10). Woodland taxa are at times extremely common and diverse, reflecting the likely presence of remnants of primary woodland at the time of monument construction, becoming more fragmentary over the course of mound use. However, canopy taxa are sparse, suggesting that many of these woodland taxa may be arriving with fuel rather than directly from overhanging trees. Dung beetles are, in comparison to late Holocene flood plain assemblages, poorly represented and indicate low stocking levels (or indeed the complete absence of pastoral agriculture) in the regions in which these sites were constructed and used.

Thirty-seven samples from Ballygawley were analysed for insect remains, again taken from archaeological features such as wicker trough lining and palaeochannel deposits. The overall assemblage is similar to that of the macroscopic plant remains including many stream side indicators, such as *Colymbetes fuscus* and *Hydroporus palustris* together with taxa indicative of the presence of damp/wet plants including *Sitona hispidulus* and *Leiosoma deflexum* (Tetlow & Davis 2009). The occurrence of insects, such as *Geotrupes* sp., *Aphodius* sp., and *Megasternum obscurum*, associated with decaying matter (probably decaying vegetation) and sometimes dung, is of interest and suggests that animals were present around the site (*ibid.*). The potential presence of domesticates is also shown in the Bronze Age faunal bone assemblage with cattle, some pig, and occasional sheep/goat recovered. Bones (200+) were largely recovered from the palaeochannel fills, eight showing evidence of butchery. Tools related to butchery were also recovered from the palaeochannel fills including two bone points for hanging skins, 12 lithic scrapers, and two stone knives.

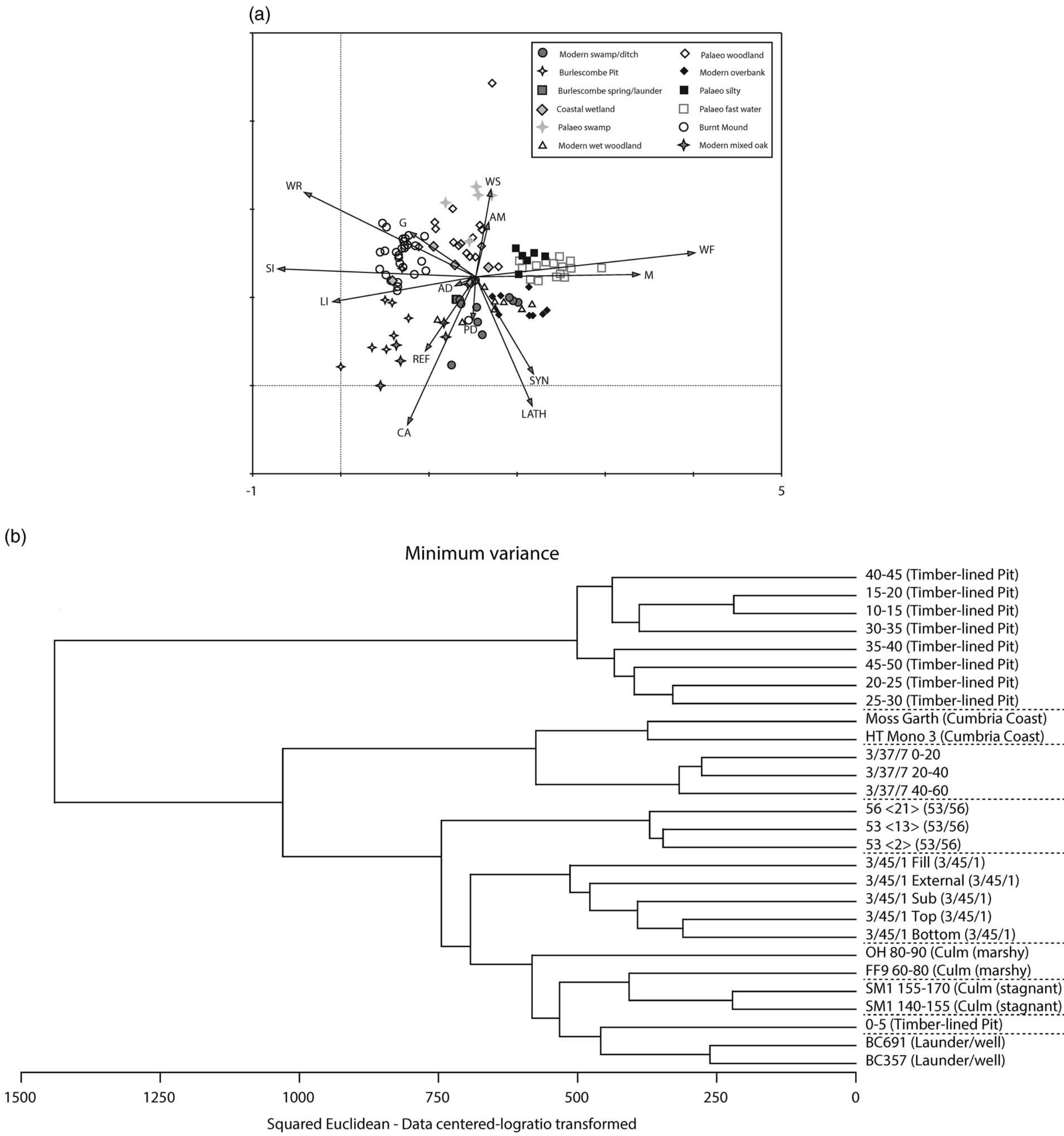

Fig. 10.
a. DCA analysis sub-dividing the woodland component; b. Minimum Variance Cluster Analysis: burnt mounds and other sites (including modern sites)

Multi-element analyses

The aim of multi-element analysis was to detect any anomalous enhancement of trace elements that might indicate any human activity such as tanning, food processing, or preserving, or any industrial activities, all of which can be reflected by trace element accumulations. The bulk sample of the Inchagreenoge trough (C28) was dissected and six samples of wood and three

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of sediment taken, washed (if wood) and then digested in nitric acid before dilution and analysis by ICP-MS. This use of ICP-MS is based upon the comparison of the sediment as control samples with wood from various parts of the inside of the trough (Fig. 11). The control samples come from below, inside, and outside the trough and should represent the geological background of the site. The principle is that wood values less than the control represent dilution, as would be expected, whilst values above the control samples represent accumulation or enhancement due to an external addition at some point in the past. As might be expected many elements are higher in the control samples, especially the underlying sediment. These include; strontium (Sr), molybdenum (Mo), cadmium (Cd), antimony (Sb), barium (Ba) and uranium (U). These are mostly elements that are derived from the geology, probably from the Carboniferous Limestone which underlies the site. However, there are a small number of elements with higher concentrations in the wood than in the control samples. These include sodium (Na), titanium (Ti), chromium (Cr) and arsenic (As). With the exception of sodium, which could be of meteoric (rainfall) and/or groundwater origin, these elements are typically associated with either tanning or the dyeing of textiles. Multi-element analysis was also undertaken on 21 samples from the trough at Coonagh West using a 3D grid of samples (Supplementary Data Fig. S4). Five of the more common metals lie in general within the normal range found in UK soils, however, the higher values of lead (Pb) and zinc (Zn) lie well above this range (Table S4). Started in 2000 the Irish Soil Database (Fay *et al.* 2007) now provides comparative values of heavy metal concentration from across Ireland. As can be seen from Table 3 the values for five of the more common metals lie at the upper end, or above in general within the normal range found in UK soils exceeding the median values for Irish soils and for some (Cr, Cu, Pb) exceeding the highest natural values found. However, both at Inchagreenoge and Coonagh West the values of Pb and Zn also lie well above the range of values from ancient agricultural field systems in Scotland (Wilson *et al.* 2008) and Zn and Cu lie above the levels found in sewage effluent sludge within the Shannon catchment (Reid *et al.* 2009). A full analysis of all the 44 elements analysed will only be possible when more background soil and geological data becomes available for this region of Ireland, but at Coonagh West and Inchagreenoge the anomalously high values of Pb and Zn are most easily explained by the importation of soil from an area or areas with intrusive igneous rocks which have undergone mineralisation, or some form of bio-accumulation related to human activities.

An initial analysis of high outlier concentrations from the 3D sampling suggests that some samples are enriched relative to others. The atypical samples appear to be CWA6, CW1C, and CW2C which are low. What is noticeable about these is that they are all derived from the basal levels of the trough fill (level C) and could be expected to be susceptible to groundwater leaching. These are all significantly lower in Cr, than all the other samples. However, the samples above (H, G, D, & B) have higher concentrations of Co, Zn, Pb, Mo, and in one case Cu. This suggests that there is some depth-related structure to the data, particularly in Co, Zn, and Mo, mean concentrations of which are respectively higher than at level F (below the timbers). The atypical sample here is CW6 A and, given that this is a near-surface (top of trough fill) sample, it probably reflects modern pollution and iron mobility.

Heavy metals occur naturally in zones of mineralisation (Zn, Mo, Cu, Pb) and Ti, As, and Cr occur in titano-magnetites, arseno-pyrites, and serpentinites. Serpentine bearing rocks are relatively common in Ireland, occurring in the Dalradian Southern Highlands Group in Tyrone, north-west Mayo and in north Connemara, and in the Appin Group in the Connemara green marble (Daly 2001) as well as in association with Tertiary igneous activity in north-west and Northern Ireland (Preston 2001). Cr is known to be a particularly effective mordant which has been used inadvertently as part of the use of soil as a mordant with natural dyes. Heavy metals are particularly suitable for the dyeing of wool, after thorough washing as possible, and with acid dyes such as that derived from oak galls or leaves which contain tannic acid (Liese 2004). The Shannon catchment is the largest catchment in Ireland draining over 12,000 km^2 and both Inchagreenoge and Coonagh West are located on the flood plain at its outlet. The geology of the catchment is dominated by Carboniferous (Dinantian) limestone with small areas of Ordovician rocks and, at its downstream end, Devonian and Silurian sandstones and siltsones (Holland 2001). The whole basin is covered by glacial deposits varying from till to glacial sands and gravels. The catchment includes very little of the highly mineralised areas of Ireland such as the south-west peninsula or

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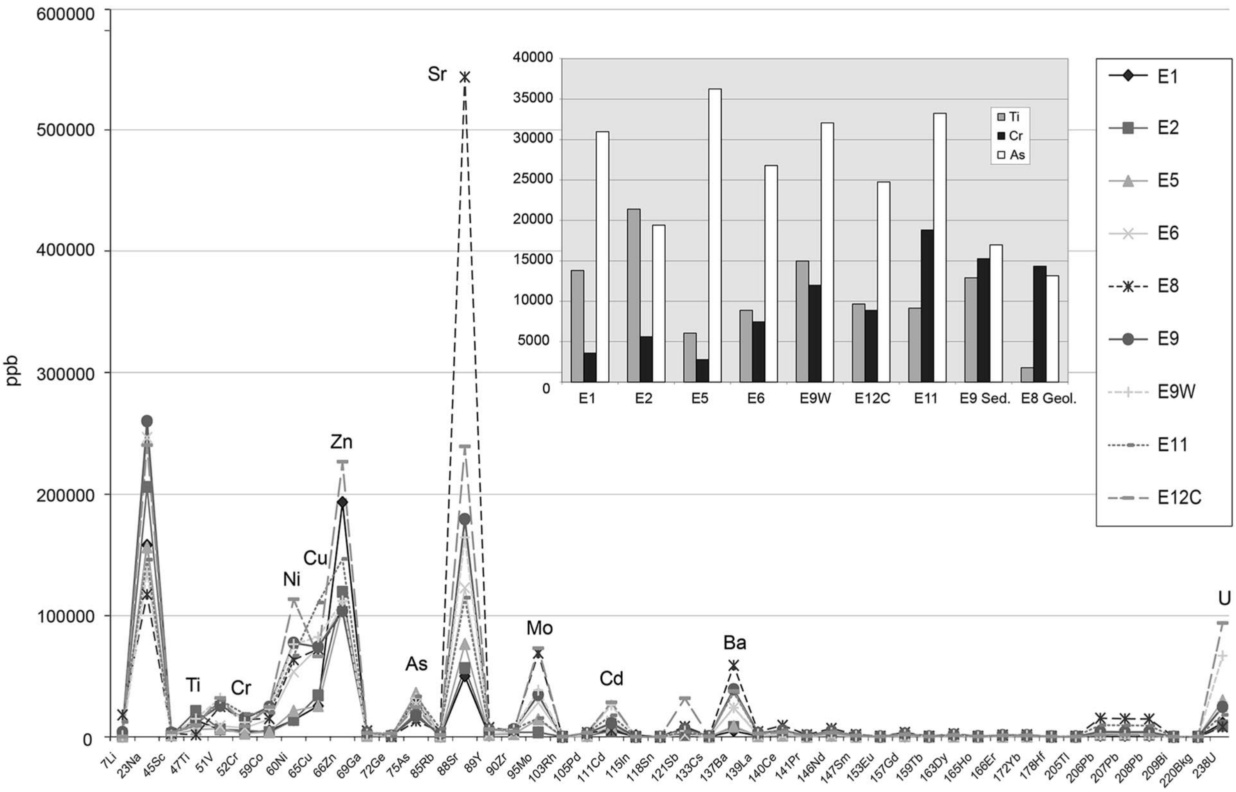

Fig. 11.
ICP-MS multi-element analysis of Inchagreenoge (3/45/1) trough (C28). E1–E6 Trough fill, E9W & E12 Wood and other samples control/sediment

TABLE 3: HEAVY METAL CONCENTRATION RANGES FROM BURNT MOUND SITES & TYPICAL SOIL VALUES FROM IRISH SOILS

Element	*Coonagh West ppm*	*Inchagreenoge ppm*	*Irish soils mineral median mg/kg*	*N Ireland soils median mg/kg*	*Maximum bounded range class for Irish Soils mg/kg*	*Typical range of soil values[2] mg/kg*
Cr (Chromium)	29.0–114.6	3.5–113.4	48.9	46.5	65–80	1–100
Co (Cobalt)	2.8–22.1	3.8–24.6	5.0–7.5[1]	–	10–12.5	1–40
Cu Copper)	8.0–57.5	25.4–110.5	18.6	7.4	25–30	0–30
Pb Lead)	13.3–79.8	3.1–45.0	24.8	17.9	50–60	10–30
Zn (Zinc)	17.7–124.5	102.9–226.7	72.7	65.4	100–120	10–200 (50 av.), 267 (97 av.)[3], 967(58 av.)[4]

[1]values from the lower Shannon area, [2]from Alloway (1990) and Salomons and Forstner (1984), [3]upper-outlier cutoff and mean from McGrath and Zhao (2006), [4]from Scottish soils in Peterson *et al.* (nd). Note that the conversion from mg/kg to ppm is density dependant for soils but not liquids

the Tertiary igneous provinces which are high in Cu, nickel (Ni), Zn, and other metals and for most heavy metals the area has relatively low values by comparison with the rest of Ireland (Fay *et al.* 2007). The regions nearest to the lower Shannon with higher heavy metal values include the Galway/Burren area to the north and the Galtee Mountains to the south (*ibid.*). Given this size, and its mixed sedimentary lithology, outlet sediments would be expected to be relatively low background levels in trace elements and

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TABLE 4: BURNT MOUND TROUGH DATA

Site	*Length (m)*	*Width (m)*	*Depth (m)*	*Vol. (m^3)*	*Construction*	*Additional features*	*Hydro-environmental context*
Cahiracon	2.3	1.27	0.56	1.6	oak planks, alder pegs cut into clay	several large stepping stones to site, small wooden platform by trough	shallow groundwater spring
Inchagreenoge (C28)	2.2	1.28	0.4	1.1	alder, ash & hazel planks with pegs cut into peaty clay	adjacent spring with human skull, stake holes under mound	floodplain
Inchagreenoge (C69)	1.45	1.2*	0.4	0.6	alder planks with pegs	stone-lined spring	floodplain
Leahys (C5)	3.3	1.5	0.5	2.4	unburnt flat sandstones	3 intercut troughs, small pit & 4 hearths	hillside spring
Leahys (C42)	1.6	1.3	0.43	0.8	Unlined	with burnt sandstone	higher & dry
Leahys (C23)	2.5	2.43	0.6	3.6	basal large flat limestone	peat formation in abandoned trough	fed by underlying spring
Killescragh	–	–	–	–	Wattle-lined	burnt mound & stone spread, wooden trackways, platform worked wood, evidence of flooding possibly leading to abandonment of 1st phase	Located between esker ridge & fen-mire
Jigginstown	–	–	–	–	–	–	Peat basin
Ballygawley	26 burnt mounds spanning Neolithic–periods				16 mounds had troughs – circular, oval or rectangular; 10 of these lined with 8 styles of construction using wood, wicker or combination of both	human remains of Early/Middle Bronze Age date	All on floodplain of small river associated with numerous palaeochannels

*Minimum estimate due to damage or truncation heavy metals. This may be a coincidence, caused by the concentration of these elements in fine alluvial sediments washed into the troughs or it could represent some importation of a foreign soil which had particular properties valued by Bronze Age people. The alternative, which may be more plausible, is the concentration of these elements in peat ash or urine which was collected in urine pots as a mordant in the medieval period particularly used for dyeing using weld (Priest-Dorman 2002). The most obvious use would be for either tanning and cleaning animal skins or for the washing and processing of wool with the soil, ash and/or urine being used as a mordant. Use of troughs for a combination of mordant and vat dyeing (as is known from Europe; Joosten *et al.* 2006) is consistent with the low-level of vegetation disturbance, the accumulation of some organic materials, some agriculture, and the multi-element analyses to date.

ARTEFACTS AND DISCUSSION

One of the reasons for the relative neglect of burnt mounds in research excavations has been their common lack of associated structures and artefacts. The principal structures are the troughs which are often poorly preserved or truncated although a variety of stone structures are also known (Ó Néill 2009). Artefacts often consist of a few stray animal bones, quernstones, occasional flints, and personal ornaments but at some sites spindle-whorls have been found (eg, Coarhamore and Ballyvourney: Cherry 1990; Ó Néill 2009) and other sites often have enigmatic round stones or stone discs such as in Ballyvourney, Drombeg, and Catstown in Ireland (Cherry 1990) and Bos Swallet in Somerest (ApSimon 1997). Several *fulachtaí fiadh* appear to have closing deposits including the skull inserted into the spring at Inchagreenoge (Taylor 2004). Other examples include the superb set of musical pipes preserved in a trough at Charlesland, Co. Wicklow (Molloy 2004) and cow heads deposited after abandonment in the trough at Fordham, Cambridgeshire (Mortimer pers comm.). Whilst this may attest their importance to the builders or users of the sites it only reinforces their multi-functional nature and the anachrony of separating functional from ritualistic aspects (Ó Néill 2009). The troughs described here all belong to Ó Néill's (2009) pit types 1–9 and are not associated with high faunal remains unlike circular pits (eg, type 18). Additionally the shallow depth and thermal inefficiency of these troughs (Table 3) appears to make cooking meat unlikely but not impossible. However, the shallow depth (Table 4), the self-filling nature of the troughs (from the groundwater table), and the frequent attempts to filter incoming water by using sand and moss under or between planks (as at Cahiracon) is ideal for the washing and dyeing of fleeces as illustrated by Denvir's (2002) textile experiments. In this respect the frequent observation that burnt mounds are virtually never found within settlements but are typically in the vicinity though at least 200 m distant (Grogan *et al.* 2007) suggests a common practice but one which was not desirable within the close proximity of dwellings. These observations, along with the common association of troughs with common dye plants such as alder, oak galls, meadow sweet, and common sorrel, all suggest a link with the cleaning of wool and the dyeing of fibres. However, it is unlikely that all burnt-mounds/troughs have the same function, as is suggested by the variation in their design and dimensions, or had only one function, and therefore there is unlikely to be a magic bullet that conclusively verifies a unique function for these sites.

CONCLUSIONS

The plant macrofossils, pollen, and insect analyses all indicate that all the *fulachtaí fiadh* were constructed within partially cleared areas or clearings within light woodland with evidence of timber/woody debris. At Killescragh there is also evidence of woodworking, with abundant wood-chips and taxa characteristic of rotting wood debris. Whilst this is not unexpected due to the fuel-intensive nature of hot-stone activity and the use of wood for troughs and associated structures, it does illustrate how *fulachtaí fiadh* construction is part of the process of opening-up the landscape and clearing the wetter areas of woodland on flood plains and around springs. All the sites also show limited livestock presence with dung beetles present, but at or only marginally above, background levels (Fig. 10). No site investigated shows evidence of the levels of dung taxa associated with even moderate-scale pastoral activity (Dinnin & Sadler 1999). No animal ectoparasites were recovered and only occasional carrion-dwelling beetles, providing no support for large-scale carcass processing activity. However, six out of the eight sites have pollen evidence of arable cultivation. The insect analysis, however, revealed no

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pests of stored grain and no chaff was recorded as might be expected if brewing activity was being undertaken. There is some evidence of plants associated with dyeing including the weevil *Curculio pyrrhocerras*, which lives in oak galls (used in prehistoric dyeing) and alder catkins (green dye) and fruit (red dye) in one trough. It is however, difficult to prove such activity due to the large number of common plants that have been used as natural dyes, and because dye plants could have been brought some distance to the site and used almost immediately. The elevated heavy metals revealed at two sites suggests off-site soil, ash, or possibly urine, all of which could have been used as a mordant. Archaeological support for a possible textile-related function for these sites comes from their locations *vis-á-vis* settlements, dimensions, their self-filling nature, evidence of water filtration, the occurrence of flat stones in and around several sites, and the evidence at one site (Inchagreenoge) of a structure made up of small stakes identified as a possible drying structure. It is not suggested here that all *fulachtaí fiadh* or burnt mounds have the same function, but this study will it is hoped, prompt more investigation of suitably well preserved sites with the aim of testing a possible connection with the transition from animal skins to textiles that accompanied deforestation and population increase in the Middle–Late Bronze Age of Europe.

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SUPPLEMENTARY DATA

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/ppr.2016.7

BIBLIOGRAPHY

Alexander, K.N.A. 1994. *An Annotated Checklist of British Lignicolous & Saproxylic Invertebrates*. Cirencester: National Trust Estates Advisors' Office (Draft)

ApSimon, A.M. 1997. Bos swallet, Burrington, Somerset: Boiling site and beaker occupation site. *Proceedings of the Bristol Spelaeological Society* 21, 43–82

Barfield, L.H. 1991. Hot stones: hot food or hot baths? In M.A. Hodder & L.H. Barfield (eds), *Burnt Mounds and Hot Stones Technology*. Sandwell: Sandwell Metropolitan Council

Barfield, L.H. & Hodder, M.A. 1987. Burnt mounds as saunas and the prehistory of bathing? *Antiquity* 61, 370–9

Bates, S. & Wiltshire, P. 2001. Excavation of a burnt mound at Feltwell Anchor, Norfolk 1992. *Norfolk Archaeology* 153, 389–414

Bermingham, N. 2013. *Coonagh West Report*. Dublin: National Roads Authority, Ireland

Best, J. & Gent, T. 2007. Bronze Age burnt mounds and early medieval timber structures at Town Farm Quarry, Burlescome, Devon. *Archaeological Journal* 164, 1–79

Böcher, J. 1995. Insect remains from Asummiut. In J. Arneborg & H.C. Gulløv (eds), *Man, Culture and Environment in Ancient Greenland*, 133–4. Copenhagen: Danish National Museum & Danish Polar Centre

Bolger, T. 2005. *Final Report Archaeological Excavation Millenium Park Ring Road Jigginstown County Kildare*. Licence No. 05E0524 & 05E0442 Unpublished report for Margaret Gowen & Co

Boismier, W. 1995. *Zionshill Farm, Chandlers Ford, Hampshire*. Salisbury: Wessex Archaeological Field Evaluation Report, unpublished

Bradley, R. 2007. *The Prehistory of Britain and Ireland*. Cambridge: Cambridge University Press

Bradshaw, B., Hadfield, A. & Maley, W. (eds). 1993. *Representing Ireland: literature and the origins of conflict*. Cambridge: Cambridge University Press

Brindley, A.L. & Lanting, J.N. 1990. The dating of *fulachtaia fiadh*. In Buckley (ed.) 1990, 55–6

Brown, A.G. 1988. The palaeoecology of *Alnus* (alder) and the postglacial history of floodplain vegetation: pollen percentage and influx data from the West Midlands, U.K. *New Phytologist* 110, 425–36

Brown, A.G., Hatton, J. & Davis, S. 2004. *Environmental Analyses of Samples the BGE Gas Pipeline Excavations, Ireland. A Report Prepared for Margaret Gowen & Co Ltd*. Exeter: School of Geography and Archaeology, University of Exeter, unpublished

Buckley, V. (ed.). 1990. *Burnt Offerings*. Dublin: Wordwell

Cherry, S. 1990. The finds from *fulachtaia fiadh*. In Buckley (ed.) 1990, 49–58

Daly, J.S. 2001. Precambrian. In C.H. Holland (ed.), *The Geology of Ireland*, 7–46. Edinburgh: Dunedin Academic Press

Davis, S.R., Wynne, S. & Brown, A.G. 2008. *An Analysis of the Coleoptera Remains From an Excavation at Clifton Quarry, Severn Stoke, Worcestershire.* Report from the Palaeoenvironmental Laboratory University of Southampton (PLUS) for Worcestershire County Council, unpublished

Dennehy, E. 2003. *Archaeological Stratigraphic Report Cahiracon, Co. Clare License No. 02E952* Margaret

Gowen & Co. on behalf of M. C. O'Sullivan & Co. Ltd. for Bord Gáis Eireann, unpublished

Denvir, A. 2002. *Fulachtaia Fiadh – An Irish Mystery*. www.angelfire.com/fl/burntmounds, consulted 1/10/2012

Dinnin, M.H. & Sadler, J.P. 1999. 10,000 years of change: the Holocene Entomofauna of the British Isles. *Journal of Quaternary Science* 14, 545–62

Durham Archaeological Services. 2007. *Report on Plant Macrofossil Analysis from Coonagh West, Ireland*. Durham: University of Durham, unpublished

Fahy, E.M. 1960. A hut and cooking place at Drombeg, Co. Cork. *Journal of the Cork Historical & Archaeological Society* 65, 1–17

Fay, D., McGrath, D., Zhang, C., Carrigg, C., O'Flaherty, V., Kramers, G., Carton, O. T. & Grennan, E. 2007. *Towards A National Soil Database Synthesis Report. (2001-CD/S2-M2)*. Wexford: Environment Protection Agency, An Ghníomhaireacht um Chaomhnú Comhshaoil

Gosling, P., Manning, C. & Waddell, J. 2007. *New Survey of Clare Island Volume 5: Archaeology*. Dublin: Royal Irish Academy

Grogan, E., O'Donnell, L. & Johnston, P. 2007. *The Bronze Age Landscapes of the Pipeline to the West: an integrated archaeological and environmental assessment*. Dublin: Wordwell

Hall, A.R. & Kenward, H.K. 2003. *Assessment of Plant and Invertebrate Remains from Deposit Associated with a Roman Road at Adel near Leeds West Yorkshire* (*site code ARR/02*). York: Reports from the Centre for Human Palaeoecology, University of York 2003/02

Hall, V., Pilcher, J.R. & McCormac, F.G. 1994. Iceland volcanic ash and the mid-Holocene Scots pine (*Pinus sylvestris*) decline in the north of Ireland: no correlation. *Holocene* 4, 79–83

Harde, K.W. 1984. *A Field Guide in Colour to Beetles*. London: Octopus

Hather, J.G. 2000. *The Identification of the Northern European Woods: a guide for archaeologists and conservators*. London: Architype

Head, K. 2007. *Environmental Remains from a Palaeochannel Investigated at Clifton Quarry, Severn Stoke, Worcestershire*. Historic Environment and Archaeology Service, Worcestershire County Council, unpublished

Holland, C.H. 2001. *The Geology of Ireland*. Edinburgh: Dunedin Academic Press

Hoffmann, A. 1954. *Coleoptérès Curculionides* 2, 487–1208. Faune de France 59. Paris: Lechevalier

Hurl, D. 1990. An anthropologists tale. In Buckley (ed.) 1990, 154–6

Joosten, I., Maarten, R., van Bommel, R., Hofmann-de Keijzer, R. & Hans Reschreiter, H. 2006. Micro analysis on Hallstatt textiles: colour and condition. *Microchim Acta* 155, 169–74

Joy, N.H. 1932. *A Practical Handbook of British Beetles*. London: Witherby

Kenward, H.K. & Hall, A.R. 1995. *Biological Evidence from Anglo-Scandinavian Deposits at 16–22 Coppergate*. Archaeology of York 14, 435–797. York: Council for British Archaeology

Koch, K. 1989. *Die Käfer Mitteleuropas*, *Ökologie* 2. Krefeld: Goecke & Evers

Koch, K. 1992. *Die Käfer Mitteleuropas*, *Ökologie* 3. Krefeld: Goecke & Evers

Laibner, S. 2000. *Elateridae of the Czech and Slovak Republics*. Zlin: Kabourek

Liese, A. 2004. http://www.geocities.com/anne_liese_w/Dyeing/dyemordants.htm

Luff, M.L. 1998. *Provisional Atlas of the Ground Beetles (Coleoptera, Carabidae) of Britain*. Abbots Ripton: Centre for Ecology & Hydrology, Biological Records Centre

McGrath, S.P. & Zhao, F.J. 2006. *Ambient Background Metal Concentrations for Soils in England and Wales*. Bristol: Environment Agency Science Report: SC050054/SR SCHO1106BLPV

Molloy, K. 2004. *Final stratigraphical report from Charlesland, Co. Wicklow Licence no 03E0592 Site CA1*. who, unpublished

Molloy, K. & O'Connell, M. 2007. Fresh insights into long-term environmental change on the Aran Islands based on palaeoecological investigations of Lake sediments from Inis Oírr. *Journal of the Galway Archaeological & Historical Society* 59, 1–17

Monk, M. 2007. A greasy subject. *Archaeology Ireland* 21, 22–4

Moore, H. & Wilson, G. 1999. Food for thought: a survey of burnt mounds of Shetland and excavations at Tangwick. *Proceedings of the Society of Antiquities Scotland* 129, 203–37

Murphy, P. 1986. *Palaeoecological Studies of Three Bronze Age `Burnt Flint' Sites Near West Row, Mildenhall*. London: Ancient Monuments Laboratory Report 165/8, English Heritage

Newman, C., O'Connell, M., Dillon, M. & Molloy, K. 2007. Interpretation of charcoal and pollen data relating to a late Iron Age ritual site in eastern Ireland: a holistic approach. *Vegetation History & Archaeobotany* 16, 349–65

O'Connell, M. & Molloy, K. 2001. Farming and woodland dynamics in Ireland during the Neolithic. *Biology & Environment: Proceedings of the Royal Irish Academy* Series B 101, 99–128

Ó Drisceoil, D.A. 1988. Burnt mounds: cooking or bathing? *Antiquity* 62, 671–80

O'Kelly, M.J. 1954. Excavations and experiments in ancient Irish cooking places. *Journal of the Royal Society of Antiquities of Ireland* 84, 105–55

Ó Néill, J. 2009. *Burnt Mounds in Northern and Western Europe: a study in prehistoric technology and society*. Saarbrücken: Dr Müller

O'Sullivan, M. & Downey, L. 2004. *Fulachtaia Fiadh*. *Archaeology Ireland* Spring Issue, 35–7

Pasmore, A.H. & Pallister, J. 1967. Boiling mounds in the New Forest. *Proceedings of the Hampshire Field Club* 24, 14–19

Priest-Dorman, C. 2002. *"A Grass that Grows in Bologna": Dyeing with Weld in the Middle Ages*. Paper prepared for presentation at the Colour Congress 2002, Iowa State University, Ames, Iowa 19 May 2002, unpublished

Preston, J. 2001. Tertiary igneous activity. In Holland (ed.) 2001, 353–74
Quinn, B. & Moore, D. 2007. Brewing and fulachtaia fiadh. *Archaeology Ireland* 21, 46–7
Reid, A.M., Brougham, C.A., Fogarty, A M. & Roche, J.J. 2009. Analysis of bio-obtainable endocrine disrupting metals in river water and sediment, sewage influent/ effluent, sludge, leachate, and concentrated leachate, in the Irish Midlands Shannon Catchment. *International Journal of Analytical Chemistry* 2009, 1–12
Reilly, F. 2010. *Limerick Southern Ring Road Phase II, Site E2092, Coonagh West, Co. Limerick*. Final archaeological excavation report. Unpublished report for TVAS (Ireland) Ltd
Reilly, F. & Brown, A.G. 2013. Possible evidence of textile processing at a burnt stone mound at Coonagh West, Co. Limerick. *Journal of Irish Archaeology* 21, 57–84
Ripper, S. 2004. *Bodies, Burnt Mounds and Bridges: a riverine landscape at Watermead Country Park, Birstall, Leicestershire*. University of Leicestershire Archaeological Services Report, unpublished
Stork, N.E., Hammond, P.M., Russell, B.L. & Hadwen, W.L. 2001. The spatial distribution of beetles within the canopies of oak trees in Richmond Park, U.K. *Ecological Entomology* 26, 302–11
Taylor, K. 2004. Inchagreenoge *fulachta fiadh*, ritual deposit of a human skull, wooden artifacts, post-medieval trackway. In I. Bennett I (ed.), *Excavations 2002*, 322–24. Dublin: Bray
Tetlow, E. & Davis, S.R. 2009. *The Insect Remains from RNI05 the A4/A5 the Ballygawley Tullyvar Roundabout, Co. Tyrone*. Report to Northern Ireland Roads Authority, Northern Ireland, UK, unpublished
Tomlinson, P. & Hall, A.R. 1996. A review of the archaeological evidence for food plants from the British Isles: an example of the use of the Archaeobotanical Computer Database (ABCD). *Internet Archaeology* 1. Council for British Archaeology. doi:10.11141/ia.1.5
Tottenham, C.E. 1954. *Coleoptera. Staphylinidae, Section (a) Piestinae to Euaesthetinae. Handbooks for the identification of British Insects* IV, 8(a). London: Royal Entomological Society of London
Tourunen, A. 2008. *Fauna and Fulachtaia Fiadh: Animal Bones From the Burnt Mounds on the N9/N10 Carlow Bypass*. Dublin: National Roads Authority
Warren, M.S. & Key, R.S. 1991. Woodlands: past, present and potential for insects. In N.M. Collins & J.A. Thomas (eds), *The Conservation of Insects and their Habitats*, 155–212. London: Academic Press
Wheeler, E., Baas, P. & Gasson, P.E. (eds). 1989. IAWA List of Microscopic Features for Hardwood Identification. *IAWA Bulletin* 10(3), 219–332
Wheeler, J., Timpany, S., Mighall, T.M. & Scott, L. (in press). A palaeoenvironmental investigation of two prehistoric burnt mound sites in Northern Ireland. *Geoarchaeology*, 1–24.
Whitehouse, N.J. 2006. The Holocene British and Irish ancient forest beetle fauna: implications for forest history, biodiversity and faunal colonisation. *Quaternary Science Reviews* 25, 1755–89
Wilson, C., Davidson, D.A. & Cresser, M.S. 2008. Multi-element soil analysis: an assessment of its potential as an aid to archaeological interpretation. *Journal of Archaeological Science* 35, 412–24

RÉSUMÉ

Contexte environnemental et fonction des tertres calcinés. Nouvelles études des fulachtaí fiadh irlandais, d'Antony G. Brown, Steven R. Davis, Jackie Hatton, Charlotte O'Brien, Fiona Reilly, Kate Taylor, K., Emer Dennehy, Lorna O'Donnell, Nora Bermingham, Tim Mighall, Scott Timpany, Emma Tetlow, Jane Wheeler, et Shirley Wynne

Les tertres calcinés, ou fulachtaí fiadh, nom sous lequel ils sont connus en Irlande, sont probablement le type de site préhistorique le plus courant en Irlande et en Grande-Bretagne. Typiquement d'une date de l'âge du bronze moyen ou final (bien que nous en connaissions à la fois des exemples plus récents et des plus anciens), ils sont pauvres en objets façonnés et rarement associés à des occupations. Il a été longuement débattu de la fonction de ces sites, les usages les plus souvent cités étant la cuisson, les bains de vapeur ou saunas, la brasserie, la tannerie ou le traitement de tissus. Un certain nombre d'importants projets d'aménagement des infrastructures en Irlande dans les années 2002–2007 ont révélé un nombre remarquable de ces tertres, souvent associés à des cuves garnies de bois dont beaucoup étaient extrèmement bien préservées. Ceci nous a offert l'occasion de les examiner en tant qu'éléments du paysage en utilisant des techniques environnementales, plus précisément les macrofossiles de plantes, le charbon de bois, le pollen, les scarabées, et les analyses de multiples éléments. Cet article résume les résultats provenant de huit sites irlandais et les compare à des sites de tertres calcinés en Grande-Bretagne. Les fulachtaí fiadh, qui se trouvent généralement en groupes, sont tous alimentés en eau souterraine par des sources, le long des plaines inondables et au bas de pente. Ils sont associés au défrichement de forêts humides à la recherche de combustible. La plupart avait à proximité des témoignages d'agriculture (arable et tous ont révélé de faibles niveaux de pâturage. Des analyses multi éléments sur deux sites révélèrent des concentrations élevées de métaux lourds donnant à penser que des sols venus d'ailleurs, de l'orme ou de l'urine avaient été utilisés dans

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la cuve. Dans l'ensemble, ces témoignages indiquent que la fonction la plus probable de ces sites était la production de textile incluant à la fois nettoyage et/ou teinture de laine et/ou fibres de plantes naturelles, et comme activité liée à une fonctionalité, cacher nettoyage et tannage. Tandis qu'il est évident que de nouvelles recherches sont nécessaires pour confirmer si les fulachtaí fiadh font bien partie de la 'révolution textile', nous devrions aussi reconnaître l'importance de leur rôle dans la rapide déforestation des parties les plus humides de la forêt primaire et l'expansion de l'agriculture dans des zones marginales au cours de l'âge du bronze irlandais.

ZUSSAMENFASSUNG

Der landschaftliche Kontext und die Funktion von Burnt Mounds: Neue Untersuchungen irischer Fulachtaí Fiadh, von Antony G. Brown, Steven R. Davis, Jackie Hatton, Charlotte O'Brien, Fiona Reilly, Kate Taylor, K., Emer Dennehy, Lorna O'Donnell, Nora Bermingham, Tim Mighall, Scott Timpany, Emma Tetlow, Jane Wheeler, und Shirley Wynne

Burnt Mounds oder Fulachtaí Fiadh, wie sie in Irland genannt werden, sind wahrscheinlich der häufigste Fundplatz-Typ in Irland und Großbritannien. Diese fundarmen Befunde datieren meist in die mittlere und späte Bronzezeit (auch wenn sowohl ältere als auch jüngere Beispiele bekannt sind) und stehen nur selten mit Siedlungen in Verbindung. Die Funktion dieser Befunde wird seit langem diskutiert, wobei als häufigste Nutzungen Kochstellen, Dampfbäder oder Saunen, Einrichtungen zum Brauen oder Gerben oder Anlagen zur Textilverarbeitung genannt werden. Eine Reihe von größeren Infrastrukturmaßnahmen in Irland in den Jahren 2002 bis 2007 führte zur Entdeckung einer bemerkenswerten Anzahl dieser Hügel, oft in Verbindung mit holzeingefassten Trögen, von denen viele auffallend gut erhalten waren. Dies bot die Gelegenheit sie als Bestandteil der Landschaft mit Hilfe von naturwissenschaftlichen Methoden zu untersuchen, insbesondere pflanzliche Makroreste und Holzkohle, Pollen, Käfer und multielementare Analysen. Dieser Beitrag fasst die Ergebnisse der Untersuchung von acht irischen Fundplätzen zusammen und vergleicht sie mit Burnt Mounds in Großbritannien. Die Fulachtaí Fiadh, die üblicherweise in Gruppen auftreten, weisen alle Feuchtbodenerhaltung auf durch Quellen oder in Überschwemmungsgebieten oder am Fuß von Hängen. Ihre Auffindung steht im Zusammenhang mit der Abholzung von feuchten Wäldern zur Gewinnung von Brennmaterial. Die meisten Fundplätze lieferten Hinweise auf nahegelegen Ackerbau und alle wiesen Beweidung in geringem Maßstab auf. Multielement-Analysen an zwei Fundplätzen zeigen erhöhte Schwermetallkonzentrationen, was vermuten lässt, dass herbeigebrachte Erde oder Asche oder Urin innerhalb der Wanne genutzt wurde. Insgesamt legen die archäologischen und naturwissenschaftlichen Daten nahe, dass die wahrscheinlichste Funktion dieser Fundplätze die Verarbeitung von Textil ist, einschließlich der Reinigung und/oder dem Färben von Wolle und/oder von natürlichen Pflanzenfasern, sowie die Reinigung von Fellen und das Gerben. Zwar sind weitere Forschungen notwendig um zu bestätigen, ob die Fulachtaí Fiadh Teil der „Textilrevolution" waren, doch sollte ihre Bedeutung auch in Bezug auf die schnelle Entwaldung der feuchteren Bestandteile von Primärwald und die Expansion von Ackerbau in marginale Gebiete während der irischen Bronzezeit gesehen werden.

RESUMEN

El contexto medioambiental y la función de los túmulos quemados: nuevos estudios en los Fulachtaí Fiadh irlandeses, por Antony G. Brown, Steven R. Davis, Jackie Hatton, Charlotte O'Brien, Fiona Reilly, Kate Taylor, K., Emer Dennehy, Lorna O'Donnell, Nora Bermingham, Tim Mighall, Scott Timpany, Emma Tetlow, Jane Wheeler, y Shirley Wynne

Los túmulos quemados, o los *fulachtaí fiadh* como se conocen en Irlanda, son probablemente los yacimientos arqueológicos más comunes en Irlanda y Bretaña. Generalmente se datan en el Bronce Medio-Final (aunque se conocen ejemplos más antiguos y posteriores), son pobres en material arqueológico y pocas veces están asociados con asentamientos. La función de estos sitios ha sido ampliamente debatida siendo los usos más citados los relacionados con el procesado de alimentos, con baños o saunas, con el destilado, o con el curtido o procesado de textiles. El desarrollo de las infraestructuras en Irlanda durante los años 2002 y 2007 reveló un

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elevado número de este tipo de estructuras asociadas a depresiones delimitadas con maderas, muchas de las cuales están excepcionalmente conservadas. Esto ofreció una oportunidad para investigar estos sitios como elementos del paisaje empleando técnicas medioambientales -específicamente macrorrestos vegetales y carbón, polen, escarabajos y análisis multielemental. Este artículo presenta los resultados de ocho sitios documentados en Irlanda y los compara con los conocidos en Gran Bretaña. Los *fulachtaí fiadh* que aparecen generalmente agrupados están alimentados subterráneamente por manantiales, en las llanuras de inundación o al pie de laderas. Están asociados con el desbroce de bosques húmedos para la obtención de combustible reflejando evidencias de una actividad agrícola cercana y niveles bajos de pastoreo. El análisis multielemental en dos yacimientos reveló un elevada concentración de metales pesados sugiriendo el empleo de tierra, de ceniza o de orina de fuera del yacimiento en la fosa. En general, esta evidencia sugiere que la función más probable es la relacionada con la producción textil incluyendo la limpieza y/o el tinte de lana y/o fibras vegetales y, por tanto, una actividad funcionalmente relacionada con actividades de limpieza y teñido de pieles. A pesar de que se requiere un mayor número de investigaciones para confirmar si los *fulachtaí fiadh* tuvieron un importante papel en la "revolución textil" debemos reconocer su importancia en el rápido proceso de deforestado de las zonas húmedas de los principales bosques y en la expansión de la agricultura en las áreas marginales durante la Edad del Bronce en Irlanda.