The Environmental Context and Function of Burnt-Mounds: Palaeoenvironmental Studies of Irish *Fulacht Fiadh*

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Burnt mounds or fulachta fiadh as they are known in Ireland are probably the most common prehistoric site type in Ireland and Britain. Typically Middle to late Bronze in age (although both earlier and later examples are known), they are artefact-poor and rarely associated with settlements. They generally consist of a low mound of stones often showing signs of fire-exposure arranged by, or around, a pit or trough which may be unlined or lined by wood or stone. 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 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 remarkably well preserved. This afforded an opportunity to investigate these sites as landscape features using environmental techniques - specifically plant macrofossils, pollen, beetles and multi-element analyses. This paper presents the results from nine sites from Ireland and compares them with burnt mound sites in Britain. The fulachta 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 and have predominantly 'natural' beetle assemblages found in wet woodlands. At 7 out of the 9 sites evidence of nearby agricultural (arable) activity was revealed and all sites revealed, some but not high, levels of grazing. At one site (Cahiracon) both pollen and coleoptera suggested that oak galls or leaves were brought onto site, at another (Coonagh West) both pollen and macrofossils suggested that alder was being used on site and at a third (Jigginstown) the pollen of two dye plants (purging flax and knapweed) was recovered. Multi-element analysis at two sites (Inchagreenoge and Coonagh West) revealed elevated heavy metal concentrations suggesting that non-local soil or ash had been used in the trough. This evidence, taken together with the shallow depth of all the sites, their self-filling nature, attempts to filter incoming water, the occasional occurrence of flat stones and flimsy stake structures at one site (Inchagreenoge), suggests that the most likely function for these sites is textile processing involving both cleaning and/or dying of wool and/or natural plant fibres. This can be regarded as a functionally related activity to hide cleaning and tanning for which there is evidence from one site (Ballygawley) as well as from other Irish burnt mound sites. Whilst further research is clearly needed to confirm if fulachta 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 Bronze Age.flax

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INTRODUCTION

Burnt mounds and associated pits or troughs are one of the most ubiquitous of all monument types throughout the British Isles and yet remain enigmatic in terms of function and cultural significance (O'Sullivan and Downey 2004; Ó Néill 2009). In Ireland alone they 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 remarkably high densities are recorded (1 per 1.5 km stream length) prompting the strong suspicion that the distribution is almost entirely a product of the differential intensity of fieldwork (Barfield and Hodder 1987; Buckley 1990). They also spread the entire length of the British Isles from Tangwick in Shetland (Moore and 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 and Pallister 1967). Although examples are recorded from as early as the Neolithic they generally date both in Ireland and the Britain to the Middle-Late Bronze Age (Brindley and 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. Such troughs or pits may be lined with a variety of substances, including wattle, stone, clay or planks; sometimes a moss lining or 'corking' is also recovered. 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 a 'hot-stone technology' (Barfield 1991). For many years probably the most favoured interpretation has that they are the remains of cooking places. This is at least in part due to the use in Ireland of the term *fulht fiadh* or *fulachta fiadh* which has a literal meaning of cooking place in Irish Gaelic but was only coined in the 17th century by Geoffrey Keating in his history of Ireland (Bradshaw 1993). Experimental reconstructions by M. J. O'Kelly in 1952 demonstrated that meat could be satisfactorily cooked by this method, and this practice is known from the ethnographic record (O'Kelly 1954; Fahy 1960; Hurl 1990). However, a number of other functions have been proposed including; the rendering of animal fats (Monk 2006), bathing - either conventional bathing places or the remains of 'sweat lodges' or 'saunas' (Barfield and Hodder 1987; O'Drisceoil 1988), the tanning of hides and brewing (Quinn and Moore 2007). Fabric processing (including cleaning and dying) has also been proposed (Denvir 2002; Reilly and Brown in press). 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 importance in Bronze Age society. We approached this with the hypothesis that each postulated function could have characteristic environmental evidence 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 both insects and geochemistry indicative of carrion and foul or toxic conditions (*cf.* Hall and Kenward 2003). Bathing might be expected to leave traces of human ectoparasites (i.e. fleas and lice). Brewing could potentially leave traces of grain pollen and insect grain-related taxa or taxa associated with flavouring plants and textile processing could potentially result in traces of mordants, dye-plants and dependant taxa e.g. concentrations of *Apion difficile* postulated to indicate the use of Dyer's Greenweed, (*Genista tinctoria*) at Coppergate in York (Kenward and Hall 1995).

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

THE IRISH BURNT MOUND DATABASE

As part of this project a database was constructed of Irish sites reported as 'burnt mounds' or *fulacht fiadh* (Fig. 1). The database was compiled from the Irish Excavations Database (http://www.excavations.ie) as it was at the end of 2008, using the search terms 'burnt mound', 'fulachta 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. As opposed to excavated samples, 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.

SITES AND METHODS

Sites

The nine sites discussed here comprise four from the Bord Gáis pipeline to the West (Cahiracon, Cragbrien, Inchagreenoge, Leahys), and four from various road excavations between 2002 and 2007 (Killescragh and Caraun More, Coonagh West, Jigginstown and Ballygawley, Fig. 1). The aim was to use pollen and spore analyses, plant macrofossils, fossil insect remains and multi-element analysis to interpret the environmental context of the burnt mounds and if possible shed light on their function. Although most of the sampling was from columns and monoliths shipped to the laboratory (Exeter, Southampton and Edinburgh). In order to allow sampling between, and adjacent to, timbers one trough was quartered and one entire quarter crated and shipped (Inchagreenoge). All the samples were stored in cold rooms at 4^{o}C prior to sampling. All samples were described using the modified Troels-Smith system (Aaby and Berglund 1986) prior to sampling. Where they are appropriate the context numbers of sedimentary units are included in parentheses.

Pollen, Spores and Entomological Analysis

Standard preparation procedures were used on 0.5 ml of sediment from either close (1cm) spacing from a column or monolith or in some cases from an intact block of sediment. Standard processing methods were used (Barber 1976; Moore *et al.* 1991) although double HF and double acetolysis was employed. The samples were sieved (180 microns and 8 microns) and mounted in silicone oil. Identification was at 400 magnification and 1000 magnification for critical features. The University of Exeter's pollen reference collection and subsequently the Palaeoenvironmental Laboratory University of Southampton (PLUS) collection supplemented by the analysts' personal reference slides were used for critical identifications. The pollen types recognised generally follow Bennett (1994) and plant taxonomy follows Stace (1997), however, critical types were taken as far as taxonomically possible in order to identify any rare types brought onto site. A pollen sum of 500 land pollen grains excluding aquatic types and spores was initially used but in several cases this was increased to over 500 TLP due to a) high alder (*Alnus*) or occasionally pine (*Pinus*) values, and b) a desire to encounter rare pollen types with a low frequency which might be of importance in site interpretation. In order to compensate for this the other counts were also increased. The high variation in the counts that necessitated this has also caused problems for display of the data. A conventional pollen diagram has not been produced as it is highly misleading to plot levels with a different pollen sum and the plotting of all the levels together with either TLP or TLP-A would have either exaggerated or diminished non-*Alnus* types.

The monoliths used for sampling were taken from the excavations of the mound, trough or sediments adjacent to the mound or trough. All the sites are unusually small (<10m) and within woodland and therefore would only be expected to provide a strong representation (>80%) of the local vegetation in a patchy largely wooded landscape (Jacobsen and Bradshaw 1980; Sugita 1994). A recent modeling approach has supported a 'relevant source area of pollen' (RSAP *sensu* Sugita 1994) for small sites (25-250m in diameter) of between 1000-3000m and for sites at the smaller end of this range the RSAP is likely to be under 2000m (Hellman *et al.* 2009). The sites can be regarded as comparable with forest hollows or wind-gaps (Calcote 1998) rather than raised mires or lakes with the implication that 40%-50% of the pollen comes from plants within 50-100m of the site.

The procedure used for the isolation of invertebrate remains followed a standard paraffin flotation technique as described by Kenward *et al.* (1980). Samples for insects were washed over a 300µ sieve and the residues mixed well with paraffin. Following addition of cold water, the resultant mixture was decanted and washed with hot water and detergent. The flots were sorted for insect remains. which were stored in denatured ethanol, and identified with the aid of the collections housed in the Royal Albert Museum, Exeter with reference to the work of Joy (1932)) and standard entomological keys. Taxonomy largely follows that of Kloet and Hincks (1977). Dipterous (fly) remains have proved relatively sparse within the samples but have included occasional puparia of the family Calliphoridae (blow flies) and Heleomyzidae, and head capsules of the family Bibionidae (fever flies). Calliphoridae are characteristic carrion taxa whilst the other two families are characteristic of more general decaying organic matter, often of plant origin. The Ballygawley the samples were prepared using the same procedures and where possible, the insect remains were identified by comparison with specimens in the Gorham and Girling collections housed at the University of Birmingham by kind permission of Dr. David Smith. The taxonomy used for the Coleoptera (beetles) follows that of Lucht (1987). To aid interpretation, where applicable, the taxa have been assigned ecological groups modified by the author based after those of Whitehouse (1999, 2006) and Olsson and Lemdahl (2008) which modified and enhanced categories first proposed by Kenward (1978) and Robinson (1981, 1983). The paradigm applied to the species from Ballygawley draws upon the most pertinent environments described in the existing schemes. The 'decomposer' groups used, where appropriate was proposed by Kenward (1978), and those of the natural and aquatic environment were devised by Whitehouse (1999, 2006) and Olsson and Lemdahl (2008).

Plant Macrofossil, Macroscopic charcoal, Multi-element Analysis and Radiocarbon Dating

For plant macrofossil analysis samples of 125 ml were disaggregated in warm water and washed through a nest of sieves ranging from 150-500 µm size. The residues were scanned using a Leica MZ6 stereomicroscope and identification was aided by modern reference collections and the seed atlas of Beijerinck (1947), Katz *et al*. (1965) and Cappers *et al*. (2006). Plant taxonomic nomenclature follow Stace (1997). Charcoal and wood identification involved the examination of the transverse, radial and tangential sections, at up to X600 magnification using a Leica DMLM microscope. Identification was assisted by the descriptions of Hather (2000) and a modern reference collection held at Durham. Moss identifications were made by examining branch and stem leaves at up to X600 magnification and identification was assisted using the descriptions of Smith (1978) and Watson (1981). At Ballygawley bulk samples were sub-sampled at volumes of 1 litre, measure using the displacement method. Samples were then washed through a stack of sieves with 1mm and 250µm meshes. The remains were sorted and identified using a binocular microscope at magnification of x10, and x40 where greater magnification was needed for identification. Identifications were confirmed using modern reference material and seed atlases including Berggren (1969), Cappers *et al*. (2006) and Schoch *et al.* (1988).

At Ballygawley and the pipeline excavations, a maximum of fifty charcoal fragments were randomly selected from each sample based on their size and therefore suitability for identification. The charcoal was broken or fractured to view three sectional surfaces (transverse (TS), tangential (TLS) and radial (RLS) necessary for microscopic wood identification. The charcoal fragments were then mounted onto a slide and examined using an incident light microscope at magnifications of 100x, 200x and 400x, where applicable. The procedure for wood analysis involved taking samples one cell thick was taken with a razor blade from the transverse, radial and tangential planes of the wood. Thin section analysis was completed using a compound Nikon microscope of magnifications of 100x, 200x and 400x. Charcoal and wood identifications were made using wood keys by Schweingruber (1978, 1990) and IAWA (1989).

Samples of approximately l25g were analysed both at Exeter and at Southampton both using a Thermo Elemental Xseries ICP-MS. The sediment was subjected to a HF/HNO_3 digest. However, with some samples (e.g. Coonagh West) problems were encountered due to the highly organic nature of the sediments and in order to overcome any non-digestion the results are also expressed as a ratio to Ti as it has a constant and relatively high concentration in all the samples. All the sites have been radiocarbon dated by the excavating team and the reader is referred to the original reports for details of the methodologies employed although where relevant details are given in the analysis and discussion. Dates quoted in the text are given as quoted by the excavators in their site reports.

BGE GAS PIPELINE RESULTS

These samples were all provided by Margaret Gowen & Co. between 26/06/02 and 13/1202 come from multi-phase *fulachta fiadh* sites excavated in Section 3 of the BGE Gas Pipeline from Co Clare to Co. Limerick.

Cahiracon

The site at Cahiracon Co. Clare (02E0952 BGE 3/37/7) was located in a bowl-shaped valley near the Shannon Estuary and was one of four identified within Section 37 of the pipeline (Grogan *et al* 2007, 188). The spread of the burnt mound averaged 5.2m x 3.8m lying on peat. A larger site was located beneath the peat. This was a large *fulachta fiadh* with a horse-shoe shaped mound centred on a rectangular timber trough (C56, Fig. 2a). The trough which was cut into clay was constructed of oak (*Quercus*) planks with alder (*Alnus*) pegs. A small wooden platform was constructed to the south of the trough and several large stepping-stones lead to the trough from the north (Dennehy 2003a). The site was located in a shallow bowl-shaped depression overlooking the Shannon estuary and was supplied by water from shallow groundwater flow. Charcoal identifications from the site are composed of mainly oak, with some birch (*Betula*) hazel (*Corylus avellana*), ash (*Fraxinus*), alder (*Alnus*), Maloideae sp., blackthorn (*Prunus spinosa*), holly (*Ilex aquifolium*) and willow (*Salix*). Radiocarbon dating of charcoal from the burnt mound dates the site to the late Bronze Age. Two monoliths (M7 and M5) were taken from the site for environmental analysis; one (M7) from the west facing edge of the baulk directly above the trough which is was assumed would relate to post-trough use activities and M5 from the north end of the same excavation which included a section through a lower peat below the edge of the burnt mound, burnt material and peat above the burnt material.

The pollen diagram from M7 has been divided into five zones and is unusually complex for 0.5m of sediment (Fig. 3). The diagram is characterised by mixed deciduous woodland of alder (*Alnus*), hazel (*Corylus*) and oak (*Quercus*). However, there are dramatic changes in the dominant species with the lower zones dominated by oak which is replaced after a partial clearance by the alder and hazel. The basal zone (CC7P1) indicates a large clearing within oak woodland 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. This suggests it is the wetter areas of the site around the stream and troughs that is affected. The fall of oak values early in zone CC7P4 represents a second clearance phase again with an increase in heathland or bog. Late in zone CC7P4 a second regeneration of woodland occurs over the site or area but on this occasion dominated by oak rather than hazel and alder. Indeed the remarkably high oak values (80% TLP) strongly suggest its presence on site. Lastly in zone CC7P5 there is another phase of woodland clearance, however, with some expansion of heathland. Cereal cultivation is also restricted to this last clearance phase. On stratigraphic grounds the base of the column must post-date both the construction and backfilling of the trough and this is supported by the highest quantities of charcoal at the base. It is tempting to correlate the pollen and spore zone CC7P1 with the abandonment of the trough and the later zones with 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.

Quantities of Coleoptera fragments high enough for meaningful analysis were present throughout the monolith (Appendix A). The basal sample (30cm-50cm) was the most diverse of the three samples with the assemblage comprising 102 individuals from 45 taxa. A number of taxa characteristic of swampy or waterside environments are present, comprising 15% of all taxa present. 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 are 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 and Key 1991), so has may arrived as a result of the proximity of the site to the Shannon estuary. *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 rub*i is characteristic of woody members of the Rosaceae, probably *Rubus fruticosus* agg. of which a number of seeds were evident in sorting.

The sample above (20cm -30cm) 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 (e.g. Joy 1932; Tottenham 1954). However, a number of continental European studies suggest it is often also present at the edges of lakes, ponds, bogs, and streams with luxuriant vegetation (e.g. 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 present 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 *Plantago* spp. as a host plant.

The uppermost sample (0cm-10 cm) also contained a moderate to highly diverse fauna (97 individuals from 42 taxa). The assemblage is strongly dominated by taxa of swampy or stream-side localities (e.g. the pselaphids *Bryaxis bulbifer*, *Brachygluta haematica*, *Reichenbachia juncorum* and the carabids *Pterostichus anthracinus*, *P. gracilis* and *P. vernalis*), which comprise 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, 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 (Koch 1989) 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 (e.g. 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 *Hordeum* type and *Avena/Triticum* 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. 4). More specifically the upper two samples both include some taxa of open cultivated ground which in conjunction with the pollen evidence strongly suggest 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 dying 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.

On stratigraphic grounds M5 provide a sequence from pre to post-fulacht activity as it spanned two natural units, a lower peat (19) and an upper peat (22) with in between sediment from the edge of the burnt mound. The pollen diagram has been allocated a single zone described (Fig. 5) due to the lack of major changes in the main pollen types. Given the high levels of oak and alder it suggests that the site was is from very close to, or more likely within an oak woodland, with some alder trees nearby. During the period covered by the diagram there is a partial clearance of the 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. The rise in pine during the deforestation event is almost certainly due to increased input of long-distance pollen but the presence of heather and bracken suggests that some heathland was nearby. The decline in Cyperaceae after the sites use phase suggests that the site became drier. This maybe due to local factors (including oak regeneration) and the construction of the mound. The coleoptera analyses (Table 1) suggest the conditions prior to deposition of the burnt mound were mixed open and wooded ground but more shaded than the sample from after deposition of the burnt mound which also had evidence of grazing. However, the poor condition of the remains and the low concentration limits inference from this monolith.

Inchagreenoge

The Inchagreenoge site (02E0899 BGE 3/45/1) in Co. Limerick consisted of two burnt mounds with troughs (C28 & C69) constructed in an a small area of bog at the base of a hill and 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. Close to the site, at the spring that fed one of the troughs (C22) was found a human skull (young male adult) suggesting ritual associations. The early Bronze Age trough (C28,

Fig. 2b, Fig. 6) was sub-rectangular and lined by planks (alder, ash and 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). The later trough (C69) lay under two overlapping stone spreads (C20 & C21) was also lined by timber planks (alder) was truncated by a later drain and not fully excavated. Charcoal identifications are dominated by alder (*Alnus*), with lesser amounts of ash (*Fraxinus*), hazel, birch, blackthorn, wild/bird cherry, Maloideae, elm (*Ulmus*), yew (*Taxus*) and willow. An animal bone assemblage was recovered from the fill of this trough which included large domestic ungulates (cattle). The monolith section (0.58m x 0.10m) was taken through the stratigraphy of the southern baulk of the site. The stratigraphy reported was a base of natural boulders, a peat unit (71), the edge of the burnt mound (21), another peat unit (5), a thinner clay (4) and finally a soil A horizon (1). In addition a large section of the trough (C28, fill C35) was cut *in situ* and shipped to the laboratory.

The pollen diagram from the core profile has been divided into two local pollen assemblage zones as described in Fig. 7. The pollen diagram is particularly interesting as in zone ISCP1 the trees are dominated by 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 extra-local origin. The high common polypody (*Polypodium*) and other ferns (*Pteropsida*) but low bracken also indicate that the site was at the edge of or close to a pine woodland. In zone ISC2 the spectra is dominated by grass, herbs and sedges indicative of grazed pasture or meadow. A second unusual feature of the diagram is the high peak of large grass pollen at the lowest level of zone ISCP2. This maybe cereal type pollen as both barley type and oats or wheat occur in the diagram. Oats or wheat also appear at 32cm 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 decline in pine is extremely diachronous in Ireland being earlier (c. 7000-5000 BC) in the Northern and Central Ireland, but significantly later in Western Ireland where it can be as late as 4,400 BP (Mitchell *et al.* 1996). In some western peat profiles pine remains above levels that would normally be regarded as long-distance transport (eg. Lough Namackanbeg, Co. Galway, O'Connell *et al.* 1988). Pine is 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). The site is believed to be of early Bronze Age 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 *fulacht fiadh* were constructed.

The Coleoptera from the same core was sparse but the sample from 57-42 cm 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 present. In the sample from 0-20cm 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 further inference is limited.

The bulk sample of the Inchagreenoge trough (C28) was dissected and 6 samples of wood and three of sediment were taken, washed if wood and then digested in nitric acid before dilution and analysisby 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. 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; Zn (zinc), Sr (strontium, Mo (molybdenum), Cd (cadmium), Sb (antimony), Ba (barium), Pb (lead) and U (uranium) (Fig. 8). 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 Na (sodium), Ti (titanium), Cr (chromium) and As (arsenic). With the exception of Na which could be of meteoric and/or groundwater origin these elements are associated with either tanning or the dying of textiles. Naturally they occur in zones of mineralization (titano-magnetites and arsenic) and associated serpentinites (chromium). 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). Chromium particularly 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. Particularly suitable for the dying of wool is, after as thorough washing as possible, the use of a mordant and an acid dye such as that derived from oak galls or leaves which contain tannic acid (Liese 2004).

Cragbrien

The Cragbrien (02E1352 BGE 3/23/2) burnt mound in Co. Clare was located on flattish boggy ground 25m 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 takes from above a section adjacent to the mound (Fig. 2c). The mound was made up of laminated deposits of burnt limestone and this is reflected in the stratigraphy of the column (Table 2). No evidence for a trough was recorded during the excavation although it is possible it lies nearby but outside the area of excavation. Seven phases of deposition/activity were identified with contexts 12, 14, 15, 20 & 21 being the deposition of the burnt stone. Charcoal data from C21 indicates that hazel, alder, blackthorn, oak and wild/bird cherry were growing in the vicinity. From the stratigraphy of the column and from photographs and section drawings it is clear that units 4 and 5 correspond to context 12 in the burnt mound. We can therefore take a monolith depth of 84 dm to correspond to the initiation deposition of mound assuming no truncation. The full core (1.45 m) was subject to high-resolution pollen and spore analysis (Fig. 9).

In interpreting the sequence the following relative chronology has been assumed: zone CB1 (pre-mound environment), zone CB2a (immediately pre-mound environment), zone CB2b (mound deposition/use?), zone CB3 (immediately post-mound environment) and zone CB4 (post-mound environment). The sequence clearly represents the clearance of the alder woodland on the site and oak and hazel woodland around the site of the burnt mound. There is a period of cereal cultivation nearby and eventually a reversion of the area to rough grazing. Interestingly the boundary between context 12 and the burnt mound material does not appear as a pollen zone boundary. Indeed the nearest full boundary is below in the peat and is marked by a relatively subtle change in stratigraphy. This suggests that there is not a hiatus at 84 cm and so the pollen sequence is continuous from before burnt mound construction, through its use, and after its abandonment. The basal zone CBP1 clearly indicates wet alder dominated woodland with both pine and mixed oak/hazel woodland in the area. That the woodland was not completely closed and had gaps or clearings as is indicated by the high ivy (*Hedera*) and the wide range of herb types present many of which are light demanding. This is also supported by the increase in these types as alder declines and more pollen from these woodlands can reach the site. The deforestation of alder pre-dates construction of the burnt mound, but by how much is unknown. The deforestation of the pine (*Pinus*) and oak are later and immediately pre-date the burnt mound level. Immediately prior to mound construction there is an increase in the rate of deforestation (assuming linear accumulation rates) and an interesting increase or spike in willows (*Salix*) (zone CBP2a). This could be due to these trees having been left by the streamside (25m 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 charcoal curve clearly highlights the period of deposition of mound material. The *Hordeum* type record is difficult to interpret as it could be reed grass (*Glyceria*) which is typical of such wet locations, however, the correspondence with oat/wheat type (*Avena*/*Triticum* type) and to and rye (*Secale*) 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 slight rise in bracken (*Pteridium*), high grass to sedge ratio and a peak in ribwort plantain (*Plantago lanceolata*). This would suggest the area was characterised by rough grazing with scattered trees, at least initially. Zone CBP3 largely post-dates the burnt mound levels and covers a reversal in the grass/sedge (Poaceae/Cyperaceae) ratio which suggests either/or a reduction in grazing pressure or an increase in local surface wetness. As noted above cereal cultivation is occurring in the vicinity and heathland is better represented than at any other point in the sequence. The final zone CB4 shows a peak in bracken (*Pteridium*) again suggesting a reduction in grazing pressure.

The most obvious interpretation of the vegetation sequence is: clearance of an area of alder car and oak woodland close to the river at a time when there was still a largely wooded landscape. Deforestation of the dry-land woodland along with continued removal of alder may indicate that the site was at the boundary of the wet and dry woodland. The burnt mound is then created in an open environment characterised by rough pasture and some heath of bracken and heather. After the mound has gone out of use and is being buried by sediment grazing pressure decreases and cereal cultivation increases only to be abandoned and bracken infestation to occur at the end of the sequence. This suggests that the construction of the burnt mound is not unreasonably associated with a pastoral economy.

Leahys

The fulacht fiadh at Leahys, Co. Limerick (02E0859 BGE 3/42/5) consisted of a large semi-circular spread of burnt material overlying three troughs hearths and a number of cut features (Dennehy 2003b). The cut features included a 'potboiler/roasting pit' (C9) constructed after the construction of the first large and rectangular trough (C5) and prior to the construction of the latest oval trough (C23). The short monolith (25cm x 15cm) from the peat formation at the base of trough (C23) contained a peat fill with a moderate amount of charcoal and moss. Given that the thin peat unit was only thick enough for a single sample the pollen and spore diagram is limited to a snap-shot of the vegetation at the time of deposition (Table 3). This is an unusual spectrum and can only have come from a small gap or clearing in an alder woodland. The local environment was adjacent to (or in) a woodland dominated by alder which was probably quite dense and shaded due to the lack of ground flora except for ferns. The unusually high ivy and lonicera (*Lonicera*) are most probably due to a partially fallen tree within the woodland gap upon which ivy and lonicera will flower prolifically. Charcoal is high suggesting some local burning was taking place. The *Hordeum* type cannot be taken as evidence of arable agriculture due to the distinct possibility it could be from the wetland reed grass (*Glyceria*) and there are no other indications of arable cultivation. The site was multi phase and an AMS dates on charcoal gives an early Bronze Age range (799-538 BC (UB-6024), 827-544 BC (UB-6022), 888-559 BC (UB-6023)).

Three bulk samples were assessed for coleoptera, one from inside, one from below and one from the outside of the timbers forming the trough (Table 4). All the samples are dominated by slow water with abundant waterside vegetation and reeds. There are differences between the samples beneath and the outside the trough both assumed to predate the trough and those from inside the trough which are presumed to postdate the use of the trough. However, the trough itself (as a microhabitat) may be responsible for some of the differences.

Killescragh and Caraun More

Two burnt mounds were excavated at Killescraigh Townlands (sites A024/22 and A024/23) in 2006 by Cultural Resource Development Services (CRDS) Ltd. in advance of the N6 Galway to East Ballinasloe Road Scheme. The burnt stone mounds lay at the foot of an esker ridge with a small river to the south. The deposits at A024/222 consisted of the burnt mound, a spread of burnt stone and a series of associated wooden features including trackways and deposits of worked wood all dated to the Bronze Age. A susbstantial minerogenic layer separated phases of the human activity on the site suggested to be due to flooding which may have caused temporary abandonment. The site A024/23 consisted of a burnt mound and associated wooden features, including 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 same inundation of the site. Bulk samples from this site were analysed for plant macrofossils and coleoptera. The site is dated to the late Bronze Age (1131-926 BC (UB-7241), 1394-1192 BC (UB-7242)).

The results from the 7 samples from A024/22 and 3 from A024/23 are tabulated in Appendix B. The earliest peats analysed from site A024/22 (F22 & F8) formed before the flooding event indicate a local landscape dominated by open fen woodland with a diverse wetland understory. The woodland comprised a range of trees including *Alnus glutinosa* (alder), *Betula* spp. (birch), *Corylus avellana* (hazel), *Fraxinus excelsior* (ash) *Prunus padus* (bird cherry) and *Taxus baccata* (yew). *Pinus* (pine) and *Ulmus* sp. (elm) were also growing in the vicinity and may have occupied areas of blanket peat and the well drained slopes of the esker ridges respectively. The expansion of *Taxus* is thought to be associated with reductions in intensive woodland clearance in the Neolithic (O'Connell and Molloy 2001) and Iron Age (Molloy 2002). The presence of a charred barley grain in sample (F8) suggests some cereal cultivation in the area. Sample F3 from after the flooding horizon suggest an open fen vegetation with little woodland cover, however, this was temporary as samples F4 & F38 show wet woodland re-establishment. Charcoal from these samples suggest that Corylus and Fraxinus were used foe fuel and may relate to fires associated with the burnt mound. Sample F52 from site A024/23 indicates the occurrence of wet woodland during the first phase of burnt mound activity. Betula and Corylus charcoal suggests these species were being used as fuel and local wet woodland is indicated by samples F18 and F19.

The coleoptera from the earliest peats from site A024/22 are suggestive of a predominantly wet, but open environment with occasional trees (Fig. 10a). 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 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 floodplain landscape, the phytophages indicating plant taxa capable of rapid regeneration (e.g. rosebay willowherb) and disturbed conditions (e.g. *Plantago lanceolata*). 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, this single sample included five woodland taxa no longer found in Ireland, including the first record in Ireland 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 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 floodplain 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 *P. lanceolata* suggest a disturbed and grazed environment, typical of many later period lowland floodplains. Two assemblages recovered from this phase include a high proportion of fast water taxa and possible allochthonous taxa (i.e. dryland species within a predominantly wetland assemblage) and may represent increased severity of floods.

Bulk samples from the nearby wattle-lined trough site number A024/20 (Caraunmore) were analysed for plant macrofossils and coleoptera. The plant macrofossil assemblage from sample A024/17 indicates the local presence of a carr woodland (Appendix C). This comprised a diverse range of species including *Alnus glutinosa* (alder), *Betula pendula/pubescens* (Silver/downy birch), *Corylus avellana* (hazel), *Fraxinus excelsior* (Ash), *Prunus* sp(p) (cherry) and Salicaceae sp (willow/poplar). *Quercus* sp (oak) wood and *Ulmus* sp (elm) charcoal suggest that these taxa were also growing locally. *Ilex aquifolium* (holly) and *Rubus* spp (Brambles) made up the shrub understorey, and *Ajuga reptans* (bugle), *Filipendula ulmaria* (meadowsweet), *Carex* spp (sedges) and *Juncus* spp (rushes) were growing on the damp woodland floor. Charcoal is abundant in the sample suggesting that there was anthropogenic activity in the area at the time that the organic deposit formed. *Corylus avellana* is the most common taxon, with *Alnus glutinosa*, *Prunus domestica/spinosa* (plum/sloe), Salicaceae sp and *Ulmus* sp also recorded. Macrofossils of *Sonchus asper* (prickly sow-thistle), Asteraceae sp (daisy family), Poaceae sp (grass family), *Ranunculus* subgenus *Ranunculus* sp (buttercups), *Stachys* sp(p) (woundwort) and *Viola* sp (violet) were also recorded and these taxa may have grown in areas of grassland or scrub near the site. The sample comprises a large amount of sand and gravel which may indicate deposition as a result of flooding.

Only one sample (Feature 27; Sample 43) from the entire site 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 woodland 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 relates to the decomposing wood 'shavings' which were home to *T. dermestoides*. It is conceivable that this debris was created during working of wood for trough construction.

Coonagh West 6

Two burnt mounds were excavated (site E2093 (was A005/2021)) by TVAS Ireland Ltd. as part of the Limerick Southern Ring Road Phase II in 2005 (Fig. 2e, Bermingham 2013). The samples described here included three monoliths (columns 1-3) which were used for macrofossil and coleopteran analyses and 60 samples from the excavation of the trough feature in 5 levels (A, B, C, G, H and F). Levels A, B, G and H were sampled using a grid and F level included 4 samples from below timbers (V-VIII). The monoliths were entirely used for the macrofossil and coleopteran analysis and for pollen analysis it was decided to samples all 6 levels in the same area of the trough. The grid chosen was the eastern-most corner 1a, B1, C1, G2, H1 along with FV. These were all counted to an unusually high count (see below) in order to improve statistical inferences. The concentration of pollen and spores was high (20,00-100,000 grains ml) and very few showed signs of degradation or corrosion. The record has therefore almost certainly not suffered from differential preservation and the counts can be taken as an accurate reflection of the pollen and spore rain into the site. As part of this non-column based approach (using samples taken during excavation by level) and due to high concentrations of some pollen types (see methods) the counts were all over 600 grains and thus provide greater statistical reliability than most pollen analyses (Table 5). All six samples are dominated by trees, but this is where the similarity ends. The samples from levels A, B and C are all similar but different from levels G, H and F.

It is also apparent that the three lower levels 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. As *Alnus* and *Quercus* remain high even with 29-39% of *Pinus* 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. In the interpretation below these three samples will be discussed together as samples from the landscape that pre-existed the trough construction by an unknown period of time. The other samples have significant differences and so will be discussed individually. Sample CW1A is dominated by *Alnus* and *Quercus* with high *Pinus*, *Corylus*, *Ulmus* and *Fraxinus*. As with all the samples *Ulmus* is surprisingly high (>4% TLP) and suggests that it was a significant component of the regional woodland (see later discussion). *Betula* although present is not a major component of the woodland as is *Salix* although due to its dioecious biology Salicaceae are generally under and rather erratically represented in pollen diagrams even from hazel-willow cars. The pollen also indicates that there is a nearby clearing, gap or opening, most likely at the site itself. This is indicated by high *Hedera* (ivy) (which only flowers in sunlight and most prolifically at the edges of woodland) and the presence of a restricted range of herbaceous pollen types and the spores of *Pteridium* (bracken). This includes grasses and sedges but also Lactuceae (dandelions family) Chenopodiaceae (goosefoot family), *Plantago lanceolata* (ribwort plantain) and *Rumex acetosa* (common sorrel). A single grain of cereal type pollen (*Avena/Triticum* type) was also recorded. The closed nature and close proximity of the surrounding woodland is also indicated by the high levels of *Polypodium* (common polypody) and *Helleborus* (helebores). Sample CWB1 is also dominated by *Alnus* and *Quercus* with high *Corylus*, *Pinus* and *Ulmus*. The extremely high *Alnus* value (1910 grains counted) and the presence of clusters of *Alnus* grains clearly indicates that anthers had blown into the trough from either overhanging or adjacent alder trees. An unusual occurrence is *Malus sylvestris* (crab apple) at 1.1% TLP-A along with even higher *Hedera* 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 *Rumex acetosa* (common sorrel) at 10.4 %TLP-A, *Filipendula* (meadowsweet) at 5.1 %TLP-A and Ranunculaceae at 2.5% TLP-A. Cereals (*Avena/Triticum* type) are also high at 1.2 &TLP-A and one grain of *Linum bienne* (pale flax) type was recorded. Sample CWC1 is also dominated by *Alnus* and *Quercus* with high *Corylus*, *Pinus* and *Ulmus*. *Alnus* is still very high (865 grains counted) but no clusters were observed and both the herbaceous total at 19% TLP-A and unusually high Hedera (nearly 6% TLP-A) indicate a clearing or forest gap. The high herbs are again Ranunculaceae *Plantago lanceolata*, *Rumex acetosa* and *Filipendula*. Cereals are present, *Cannabis* type (1 grain), *Linum bienne* t. and *Stellaria holostea* (greater stitchwort). Samples CWG2, CWH1 & CWF5 are all dominated by *Pinus*, *Alnus*, *Corylus*, *Quercus* and *Ulmus*. The range of herbaceous types is greatly reduced but and with lower *Hedera* and low non-tree total (5.6% TLP) there is little evidence of a significant clearing on-site. This is supported by the spores as *Pteridium* is low (under 1% TLP) but both *Polypodium* and Filicales und. are high. Given the alluvial and stream-side location of the trough it is most likely that this represents the surrounding alder-hazel-oak woodland with some small gaps and surrounded by pine dominated mixed woodland containing *Quercus*, *Ulmus* and *Betula*. No cereals are present in any of the three counts, or any other cultivars. The only unusual element is the occurrence in CWG2 of three grains of

Acer campestre (field maple). Given that this is a low-pollen producer (being insect pollinated) it is most likely that the tree was close to the site.

Plant macrofossil analysis conducted on columns 1 and 3 all produced a similar plant assemblage (Durham Archaeological Services 2007) and this can be compared with the pollen data from samples CWA1, CWB1 and CWC1 (Table 6). This is meaningful in this case because of the undoubtedly very localised source area for most of the pollen and spores. This is a strong correspondence amongst both the common elements (e.g. *Alnus*, *Quercus* etc.) but also some rarities such as *Stellaria holostea*. It reinforces the inference of a small damp grass-dominated clearing within wet/damp alder-hazel-oak woodland within the regional woodland with pine, oak, 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%), pomaceous (8%), ash (5%) and willow (3%). In particular it is rare to be able to match less common species, in this case *Malus sylvestris*, which of course is also a potentially important prehistoric 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, supporting the contention that they were growing in the area but not on the floodplain or in the immediate vicinity of the site.

<u>Coleoptera</u>

Two pre-mound samples from a palaeochannel fill below a trough 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. 10b). 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 includes 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 present 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 (*Urtica* sp.) and hence increased nitrogen input, the Chrysomelid *Hydrothassa marginella*, found on a range of plants by fresh water (including *Caltha palustris* and *Ranunculus* spp.) 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 floodplain assemblages, indicating an area of mixed oak woodland, possibly secondary in nature (suggested by the presence of ash), adjacent to a largely cleared floodplain environment. This may have been agricultural pasture (implied by the presence of *Urtica* and some dung taxa), possibly with the presence of some cattle.

A single assemblage was investigated from a trough fill, again, 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 of these is a common taxon, which feeds 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 docks (*Rumex* spp.). 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 (i.e. the dead wood component), the fauna probably derives in part from post-use infilling resulting from overbank sedimentation.

Two assemblages from the post-mound phase of the 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 dryer depositional environment. However, several waterside taxa are present. A number of woodland taxa are also still present within the assemblage, 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 the 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 floodplain environment. 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. 10b). 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 the pollen 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.

Multi-element analysis

Multi-element analysis was undertaken on 23 samples from the trough at Coonagh West using a 3D grid of samples. As can be seen from the values for five of the more common metals lie in general within the normal range found in UK soils, however, the higher values of Pb and Zn lie well above this range (Table 7). 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 (and Appendix 1) 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 values found which are not associated with anthropogenic enhancement. However, both at Inchagreenoge and Coonagh West the higher values of Pb and Zn lie well above this range. They 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 there are anomalously high values of Pb and Zn which is most easily explained by the importation of soil from an area or areas with intrusive igneous rocks which have undergone mineralisation.

An initial analysis of high outlier concentrations suggests that some samples are enriched relative to others (Table 4). The atypical samples appear to be CW6C, 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 (Molybdenum) and in one case Cu. This suggests that there is some depth-related structure to the data, particularly in Co, Zn and Mo. The mean concentrations of Zn, Mo and Cu are respectively higher than the concentrations 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 is probably that this reflects modern pollution and iron mobility.

Although more research is needed on multi-element analysis of troughs and associated sediments the preliminary indications are of anomalously high levels of certain heavy metals. The Shannon catchment is the largest catchment in Ireland draining over 12,000 km2 and Coonagh West is located on the floodplain 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 the Tertiary igneous provinces which are high in Cu, Ni, Zn and other metals and in for most heavy metals the area has relatively low values by in comparison with the rest of Ireland (Fay *et al.* 2007). The regions nearest to the lower Shannon with higher values include the Galway/Burren area to the north and the Galtee Mountains to the south (Fay *et al.* 2007). Given this size, and its mixed sedimentary lithology outlet sediments would expected to be relatively low background levels in trace elements and heavy metals. This maybe 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 most obvious use would be for either tanning and cleaning animal skins or for the washing and processing of wool with the soil being used as a mordant. The possibility that the troughs were used for a combination of mordant and vat dyeing as is known to have occurred in Europe (Joosten *et al.* 2006) is possible and would be consistent with the low-level of vegetation disturbance, the accumulation of some organic materials, some agriculture and the multi-element analyses to date.

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It is clear from these case studies that synanthropic taxa are conspicuous by their absence. 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 floodplain 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.

Jigginstown

Archaeological monitoring in advance of the Millenium Park Western Ring Road, Co. Kildare in 2005 by Margaret Gowen & Co. Ltd. located a *fulachta fiadh* on the southern side of a peat basin (05E0524) (Bolger 2005). A second *fulachta fiadh* is known to the west (monuments record KD19:028) probably on the edge of the same peat basin. A profile 0.7m deep was sampled by monolith and used in the analyses described here. The pollen sequence is unusually complex given its limited depth (Fig. 11). 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-mid Mesolithic is established as is confirmed by the radiocarbon dates (S2, Fig. 11). 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. 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 and subsequently arable cultivation occurs within the close vicinity of the site. The definite presence of purging flax (*Linum catharticum*) at the base of the zone JG6 strongly suggests that is being grown or processed near the site and 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. Purging flax 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 and Hall 1996). The unusually high representation of black knapweed (*Centaurea nigra*) could be due to the very close proximity of a rough relatively damp knapweed infested meadow and its local abundance or alternatively it may have been being encouraged/cultivated or brought onto site due to its well-known use in fabric dying (it produces a yellow dye). This is a very unusual pollen and spore diagram as it appears that oak dominated temperate woodland never developed around this site or did but the period is entirely missing from the record. Either way it is clear that the activities associated with the *fulacht 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 *fulacht fiadh* may have been in some way related to the manufacture and dying of textiles.

Ballygawley

Archaeological works were carried out in advance of the A4/5 road corridor improvement scheme at Ballygawley, Co. Tyrone, where a complex of twenty-six burnt mounds and spreads were excavated. The burnt 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. 12). The results of 65 radiocarbon dates taken from features and sediment profiles suggest continuous activity took place on the site from the

Neolithic period at 3340-3020 cal BC (4470±30) to the late Iron Age c. 384-203 cal BC (2225+-30 BP) A 900-year hiatus occurs in the dates between the late Iron Age and cal AD 664-856 (1270+-30 BP) when activity recommences in the early medieval period at cal AD 1050-1270 (840+-30 BP). Sixteen of the mounds had troughs, which were circular, oval or rectangular in design. Ten of these were lined and eight styles of construction using wood, wicker or a combination of both were used with no direct (radiocarbon dating) evidence of chronological preferences in style. There was some evidence of elaboration in the trough design of medieval trough (9667), where a channel connecting the trough to the stream was dug, in order to bring water directly into the trough.

Pollen

Monolith 2 contained a stratigraphic sequence of alluvium truncated by burnt mound (9031) deposits consisting of macroscopic charcoal and fire-cracked stone, the use of which has been dated from 2470-2270 cal BC (SUERC-16035; 3865+-35 BP) to 2460-2200 cal BC (SUERC-16033; 3850+-35 BP). The pollen sequence has been divided into four local pollen assemblage zones (LPAZ S1II1-4) (Fig. 13). The pollen assemblage from the site 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, milk parsley (*Peucedanum palustre*) and nettles (*Urtica* sp.). Within LPAZ S1ii1and 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 (e.g. coppicing cycles) of the local woodland in association with the sampled burnt mound and one 40m 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 burnt mound material has been deposited (upper LPAZ S1II3 and LPAZ S1II4); this is likely an effect of poor preservation through the burnt 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 to >50 um) 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.

Macroscopic charcoal, plant remains and Entomology

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 e.g. oak was utilised mainly in the Neolithic period, while holly was resourced in the Late Bronze Age to Early Iron Age period. Other tree and shrub types used for fuel include: wild cherry, apple-type (Maloideae sp.), willow, blackthorn and ash. Ring curvature shows fragments mainly had strong and moderately curved growth rings suggesting that branch wood was the main timber sized used as wood fuel (Scott 2009). Fragments with weakly curved growth rings were present in low numbers, which together with the worked (waterlogged) wood from the trough linings show that large-sized timbers (e.g. trunk wood) were also used on occasion (Bamforth *et al*, 2009).

A total of thirty-seven 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: marsh violet (*Viola palustris*), marsh cinequefoil (*Potentilla palustris*), pond weed (*Potamogeton* sp.) and water pepper (*Persicaria hydropiper*), together with a range of sedge species (*Carex* sp.). Evidence of the local treescape is limited within the samples with only elder (*Sambucus nigra*) 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 meadow land plants in the assemblage, such as redshank (*Persicaria maculosa*), buttercups (*Ranunculus* sp.), hemp-nettle (*Galeopsis tetrahit*), goosefoots (*Chenopodium* sp.) and chick weed (*Stellaria* sp.) (Tetlow, 2009). 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).

Thirty-seven samples were analysed for insect remains, again taken from archaeological features such as wicker trough lining and palaeochannel deposits. The overall assemblage from the insects 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 and 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, in the assemblage is of interest and suggests that animals were present around the site (Tetlow and Davis, 2009). The potential presence of domesticates is also shown in the faunal bone assemblage from the Bronze Age with cattle, some pig and occasional sheep/goat recovered. The bones were largely recovered from the palaeochannel fills, with over 200 faunal bones recovered and eight showing evidence of butchery. Together with the bone fragments tools related to butchery were also recovered from the palaeochannel fills including: two bone points for hanging skins, twelve lithic scrapers and two stone knives.

DISCUSSION

There have been few environmental studies of burnt mounds and they have produced disappointing results. This is despite the significant numbers that have been excavated over the last ten years in England as a result of aggregate quarrying (Brown 2009) and the large number excavated in Ireland. Several comparable studies of burnt mounds have been published in the past few years including excavations at the N9/N10 Carlow Bypass (Tourunen 2008), West Row, Mildenhall in Suffolk England (Murphy 1986), Feltwell Anchor in Norfolk (Bates and Wiltshire (2001), Watermeade Way (Ripper 2004), Burlescombe in Devon (Best and Gent 2007) and Clifton in Worcestershire (Jackson *et al*., in press). One of the most comparable analyses to the this Irish dataset is from the Feltwell burnt mound. The pollen diagram shows a largely cleared landscape with evidence for both pastoral and arable agriculture nearby. The diagram does not show the local deforestation event or post-mound regeneration except possibly for regeneration of lime. The reason for this is probably the uncertain temporal relationship between the monolith column and the trough and burnt mound. The monolith from pit 44 would appear to contain two units the lower of which may have accumulated after the trough went out of use the upper of which is a silty clay inwashed from the edge of the pit. Excavations at Watermeade Country Park in Leicestershire of an early Late Neolithic burnt mound have involved substantial environmental analyses (Ripper 2004). This site included a groundwater fed trough on the bank of a palaeochannel which was first lined with a withy basket and later alder planks. An important aspect of the site was the preservation of contemporary faunal remains which included wild cattle or aurochs (*Bos primegenius*) and domesticated cattle (*Bos taurus*). These animals 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 local woodland with mixed lime, oak and elm of drier land and oak and alder car on the valley floor. The local woodland was relatively undisturbed and pine was also still present in the region. 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 and Grieg in Ripper 2004). No cereal remains were recovered and no insect remains were 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 bones and the deer bones suggested on-site slaughter, tanning and antler working rather than consumption. A burnt mound was most recently excavated as part of the multi-period spring head site at Burlescombe in Devon (Gent et al. 2010). The pit provided a full pollen sequence and abundant insect material. The pollen evidence from Burlescombe suggests that the burnt mound and pit were in oak-dominated wet woodland interspersed with rough pasture and clearings and a small amount of oat or wheat cultivation. The coleoptera analyses from the plank lined pit (C654) agree with the pollen that the pit was constructed adjacent to woodland and received debris from the woodland either naturally or as part of fodder production. Both the beetles and the pollen indicate that both open land and woodland was present and that grazing was being undertaken in the vicinity. Also found was a rare weevil *Hylobius transversovittatus*, which is monophagous on Purple Loosestrife, which is a well known dye plant. At Burlescombe there is 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 holly (*Ilex*), which had been apparently sealed in the manner observed in ethnographic silage-making methods (Best and Gent 2007). At Clifton (Worcestershire) a burnt was excavated adjacent to a palaeochannel of the River Severn. The burnt mound is dated to the early Bronze Age and analysis of the coleoptera little if any indication of human activity associated with the burnt mound (Brown *et al.* 2008) although pollen analysis from the palaeochannel revealed arable cultivation on the floodplain island (Head 2007). 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. com.).

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). 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 (e.g. type 18). Additionally the shallow depth and thermal inefficiency of these troughs (Table 8) would appear to make cooking meat unlikely. Conversely this shallow depth, 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 of between planks (as at Cahiracon) is ideal for the washing and dying of fleeces as illustrated by Denvir’s (2002) textile experiments. Artefacts often consist of a few stray animal bones, quernstones, occasional flints and personal ornaments but at some sites spindle-whorls weights have been found (e.g. 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 *fulacht fiadh* appear to have closing deposits including the skull inserted into the spring at Inchagreenoge. 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 com.). Whilst this may attest their importance to the builders users of the sites it only reinforces the multi-functional nature of such sites and the anachrony of separating functional from ritualistic aspects of such sites (Ó Néill 2009). Despite the clear advance that this research has made in relation to our knowledge of the specific environmental context of burnt mounds and probably functions there remain many questions. The major weakness is that this approach builds up a database of circumstantial, largely negative, evidence. It is unlikely that all burnt-mounds/troughs have the same function, as is suggested by the variation in their design and dimensions, or indeed had only one function, and therefore there is unlikely to be a magic bullet that conclusively verifies a unique function for these enigmatic sites. The research described here suggests that there should be a more targeted approach to future environmental investigations and in particular troughs/pits of different designs and dimensions should be analysed to establish if there are systematic variations in the environmental data that may be related to site function.

CONCLUSIONS

The plant macrofossils, the pollen and insect analyses all indicate that all the *fulacht 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 *fulacht fiadh* construction is part of the process of opening-up the landscape and clearing the wetter areas of woodland on floodplains and around springs. All the sites also show limited livestock presence with dung beetles present, but at or only marginally above background levels (Fig. 14). No site investigated shows evidence of the levels of dung taxa associated with even moderate-scale pastoral activity (Dinnin and Sadler 1999). No animal ectoparasites have been recovered. There are also few carrion taxa with only occasional carrion-dwelling flies and beetles recovered, providing no support for large-scale carcass processing activity. However, 6 out of the 8 sites show arable cultivation nearby, so presumably within the cleared area, and at one site (Killescragh) some charred barley was found. The insect analysis, however, revealed no pests of stored grain and no chaff was recorded of significant quantities of cereals as might be expected if brewing activity was being undertaken. There is some evidence of plants associated with dying including the weevil *Curculio pyrrhocerras*, which lives in oak galls (much used in prehistoric dying) and alder anthers and fruit 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 input or the burning of peat both of which could have been used as a mordant. Archaeological support for a textile-related function for these sites comes from their 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 *fulacht fiadh* or indeed 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 role in the transition from animal skins to textiles that accompanied deforestation and population increase in the Middle to Late Bronze Age of Europe.

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Figure and Table Captions

Figure 1. Map of Ireland, burnt mound sites from the Irish burnt Mound database and sites used in this study.

Figure 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)

Figure 3 Cahiracon monolith 7 pollen diagram

Figure 4. Sample by sample ecological comparison for site Cahiracon 3/37/7(M7). Groupings after Robinson (1991) are: WS= slow water, T = woodland, REF = refuse. PD = pasture/dung, M = meadow, GR = grassland, AM = aquatic/marsh and AD = arable/disturbed. Unclassified taxa are not included.

Figure 5 Cahiracon monolith 5 pollen diagram

Figure 6. Inchagreenoge trough C28 plan showing stake holes and location of the large *in situ* bulk sample.

Figure 7. Inchagreenoge short core (3/45/1) pollen diagram

Figure 8. ICP-MS multi-element analysis of Inchagreenoge (3/45/1) trough (C28). E1-E6 Trough fill, E9W & E12 Wood and other samples control/sediment.

Figure 9. Craigbrien pollen diagram

Figure 10. Ecological summary diagram for insect-yielding samples from (a) Killesragh and (b) Coonagh West site A005 2021. 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).

Figure 11. Jigginstown pollen diagram

Figure 12. Plan of the Ballygawley burnt mounds, palaeochannels and selected troughs.

Figure 13. Pollen and spore diagram from Monolith 2 at Ballygawley.

Figure 14 (a) DCA analysis sub-dividing the woodland component, (b) Minimum Variance Cluster Analysis : Burnt Mounds and Other Sites (incl. modern sites).

Appendices

Appendix A List of coleoptera from Cahiracon monolith 7
Appendix B. Pollen results from Killescragh A024/22 and A024/23.
Appendix C. The plant macrofossil list from Caraun More and Killescragh

BM PPS Paper Tables

Depth (cm)	**Vol. processed (litre)**	**Material Assessment**	**Environmental Assessment**
0-10	1	Sparse, v. poor condition	Water dominated fauna (*Hydraena riparia*, *Agabus* sp., *Limnebius truncatellus*) indicates mixed stagnant/flowing regime. One *Aphodius* dung beetle present, some Carabidae of open ground, some Elateridae (*Athous* sp., *Agriotes* sp.) may indicate nearby woodland, supported by a fragment of elytra from the weevil *Polydrusus* sp..
40-50	1	Sparse, poor condition	Fewer water taxa (only *Hydraena riparia*). Weevils (*Polydrusus* sp., *Strophosoma melanogrammum*) indicate woodland proximity with a carabid fauna characteristic of both open (*Pterostichus* sp.) and shaded ground (*Bembidion harpaloides*).

Table 1. Coleoptera assessment of Cahiracon, Co. Clare (BGE 3/37/7 No. 5).
assemblage zones as described in Table 5.1.

Unit	**Depth below top of monolith (cm)**	**Sediment description**
1	0-10	Dark soil horizons & herb. Remains; Th4, Nig4, Strat0
2	10-19	Bioturbated clay rich soil & herb. Remains; Th2, As2, Ag+, Nig3/4, Strat0
3	19-54	Grey/brown clay & herb. Remains; As4, Ag+, Dh+, Nig2, Strat0
4	54-76	Dark silty organic clay & large (5cm) angular sandstone clasts; Th+, As1, Ag3, Nig3, Strat0
5	76-84	Calcareous mud: Lc4, Nig3, Strat0
6	84-103	Moderately humified woody peat & pellets of silt; Tl4, Ag+, Nig4, Strat0
7	103-145+	Moderately humified woody peat & silt and clay (wood throughout but concentration in basal 5 cm) also twig (1.2 cm diameter); Tl4, Ag+, As+, Nig4, Strat 0

Table 2. The stratigraphic description of the Cragbrien Monolith (BGE 3/32/2)

Lpaz	**Depth (cm)**	**Description**
LCP	12.0-12.5	Trees at % with the major type being *Alnus* with low values of other trees, next highest type is *Hedera*, then *Polypodium*, *Pteropsida* and *Ilex*. Poaceae low, *Hordeum* type present but no other cereal types. High charcoal.

Table 3. Local pollen assemblage zone description for Leahs, Co. Limerick (BGE 3/42/5)

Sample location	**Vol. (litres)**	**Material assessment**	**Environmental assessment**
Inside trough	1.5	Sparse, poor preservation	Almost all slow water taxa (*Agabus* sp., *Hydroporus* sp., *Anacaena* sp.). *Coelostoma orbiculare* indicates wet refuse and *Cyphon* sp. waterside vegetation.
Outside trough	1.5	Moderately sparse, poor condition	Taxa more indicative or running water (*Limnebius truncatellus*, *Ochthebius* sp.) with slow water component (*Hydroporus* sp., *Agabus bipustulatus*) with emergent vegetation (*Donacia* sp.). More substantial refuse/dung component including *Megasternum obscurum*, *Anotylus rugosus*, *Tachinus laticollis*, *Tachyporus hypnorum* and *Aphodius* sp.). Presence of a scolytid (*Leperisinus varius*) indicates *Fraxinus* sp. and a large elaterid (*Athous* sp.) suggests possible woodland margin conditions.
Below trough	1.5	Moderately sparse, poor condition	Mostly slow water taxa. *Helophorus flavipes*, *Agabus sturmii*. Single *Limnebius truncatellus*, indicating running water. Donacia sp. indicating reeds present as are some weevils (*Caenopsis waltoni*, one *Ceutorhynchus* sp.). Staphylinids of shady locations (*Anthobium* sp., *Olophrum* sp.) possibly indicative of a woodland edge environment.

Table 4. Coleoptera assessment of BGE 37/45/1 Trough.

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	+		
Helleborus	+							
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.		+	+					
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**

Table 5. Pollen counts expressed as % of total land pollen sum (%TLP) and % of total land pollen sum-*Alnus* (%TLP-A) in cases where Alnus was very high. For further elaboration see text.

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

Table 6. Plants found both as macrofossils in columns 1 and 3 and as pollen in samples CWA1, CWB1 or CWC1.

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	65.1-80	1-100
Co (Cobalt)	2.8-22.1	3.8-24.6	5.01-7.5[1]	-	10.05-12.5	1-40
Cu Copper)	8.0-57.5	25.4-110.5	18.6	7.4	25.1-30	0-30
Pb Lead)	13.3-79.8	3.1-45.0	24.8	17.9	50.1-60	10-30
Zn (Zinc)	17.7-124.5	102.9-226.7	72.7	65.4	100.1-120	10-300 (50 av.)

Table 7. Heavy metal concentration ranges from burnt mound sites and typical soil values from Irish soils. [1] values from the lower Shannon area, [2*] from Alloway (1990) and Salomans and Forstner (1984). Note that the conversion from mg/kg to ppm is density dependant for soils but not liquids.

Site	Length (m)	Width (m)	Depth (m)	Vol. (m^3)	Construction	Additional features	Hydro-environmental context
Cahiracon	2.3	1.27	0.56	1.63	oak planks, alder pegs cut into clay	several large stepping stones to the site, small wooden platform by trough	shallow groundwater spring
Inchagreenoge (C28)	2.2	1.28	0.4	1.12	alder, ash & hazel planks with pegs cut into peaty clay	adjacent spring with human skull, stake holes under mound	
Inchagreenoge (C69)	1.45	1.2*	0.4	0.69	alder planks with pegs	stone-lined spring	
Leahs (C5)	3.3	1.5	0.5		unburnt flat sandstones		
Leahs (C42)	1.6	1.3	0.43				higher & dry
Leahs (C23)	2.5	2.43	0.6		basal large flat limestone		fed by underlying spring
Killescragh							
Caraun More							
Jigginstown							
Ballygawley							

Table 8. Burnt mound trough data.. * is where it is a (minimum) estimate due to damage or truncation


N
Killescragh
Enniscoffey
Jigginstown
Cragbrien
Coonagh West
Cahiracon
Carlow
Leahys
Inchagreenoge
0
25
50
100 Kilometers
Fig. 1

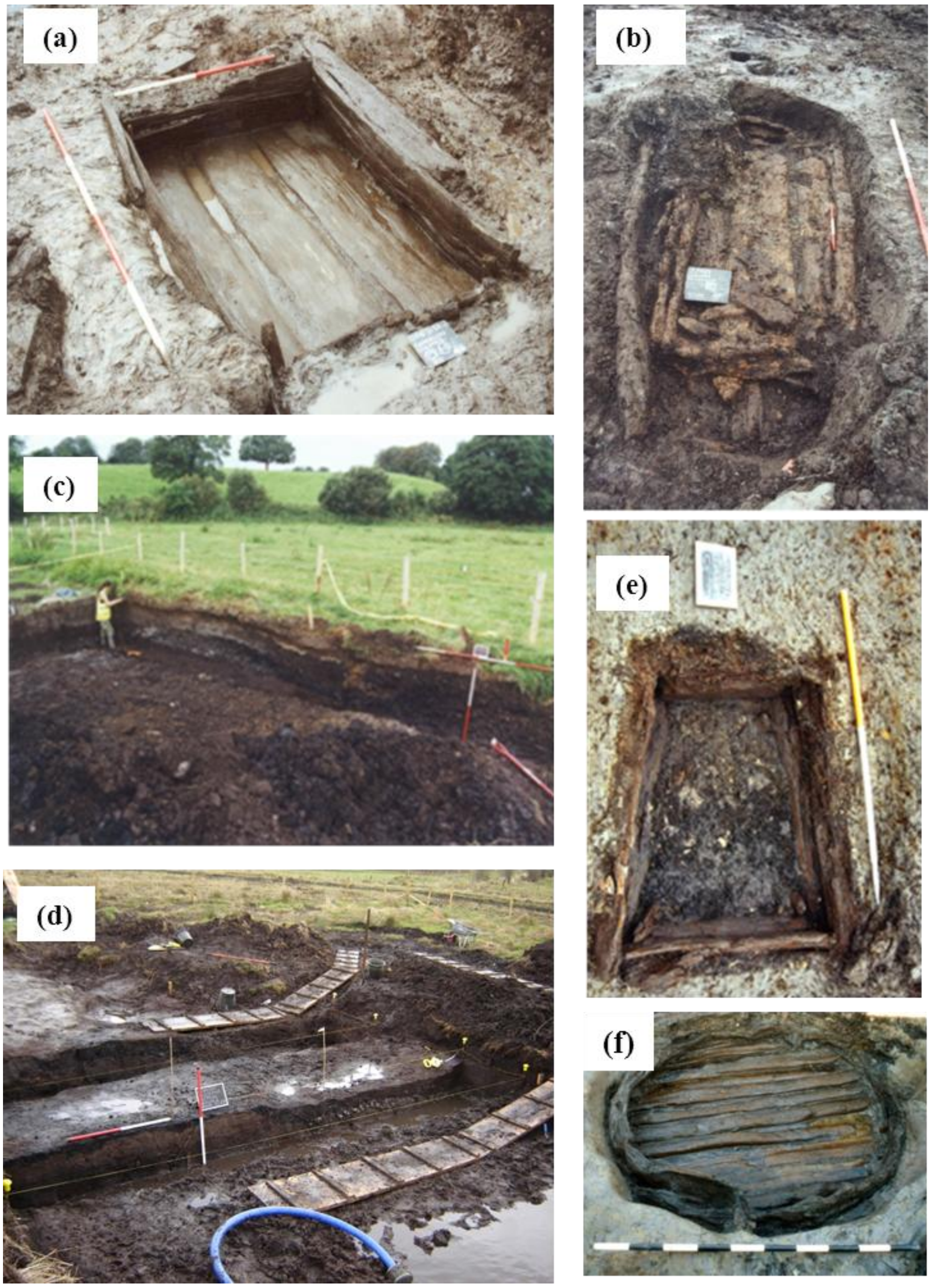


Fig. 2

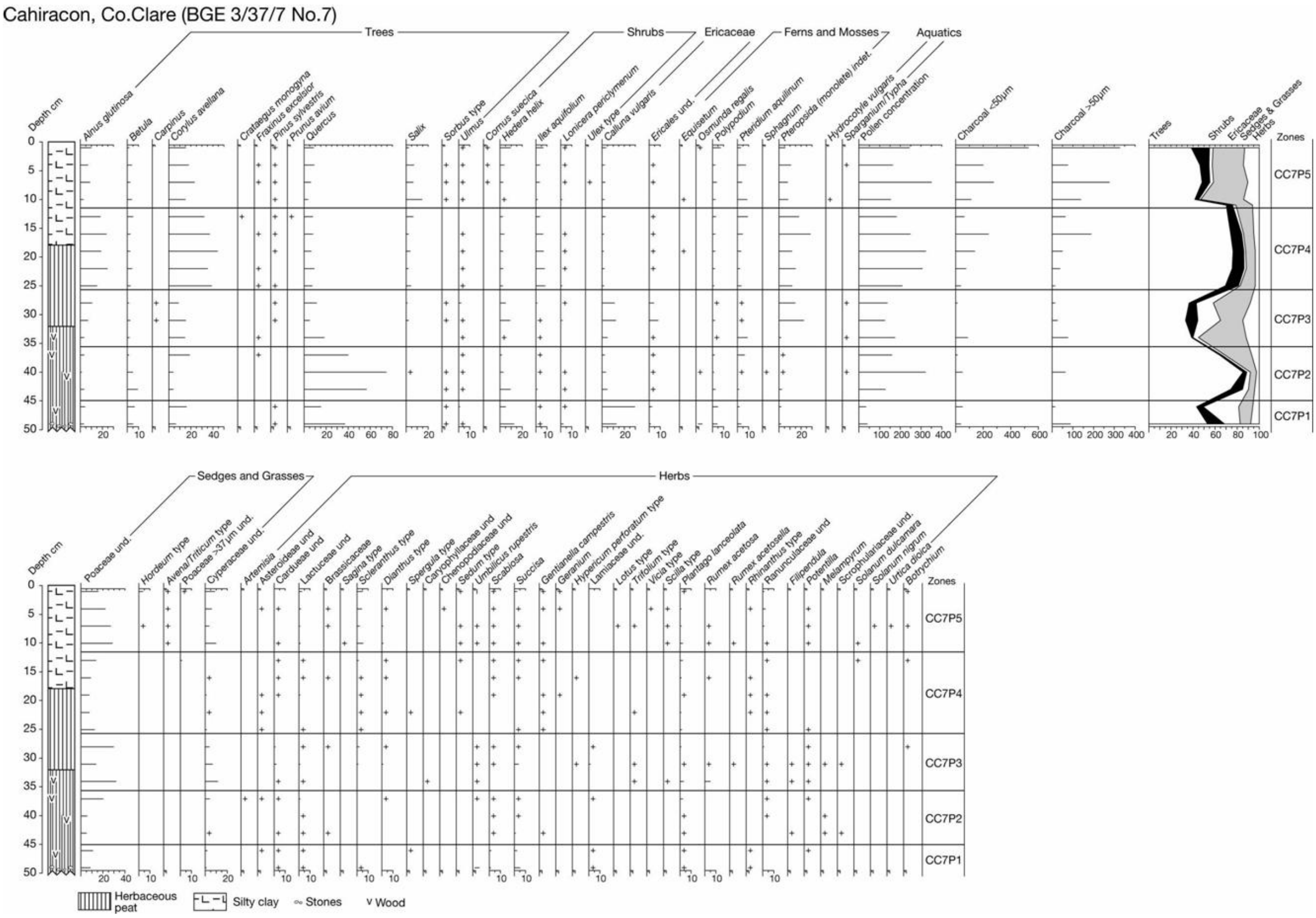

Cahiracon, Co.Clare (BGE 3/37/7 No.7)
Trees
Shrubs
Ericaceae
Ferns and Mosses
Aquatics
Depth cm
Alnus glutinosa
Betula
Carpinus
Corylus avellana
Crataegus monogyna
Fraxinus excelsior
Pinus sylvestris
Prunus avium
Quercus
Salix
Sorbus type
Ulmus
Cornus suecica
Hedera helix
Ilex aquifolium
Lonicera periclymenum
Ulex type
Calluna vulgaris
Ericales und.
Equisetum
Osmunda regalis
Polypodium
Pteridium aquilinum
Sphagnum
Pteropsida (monolete) indet.
Hydrocotyle vulgaris
Sparganium/Typha
Pollen concentration
Charcoal <50µm
Charcoal >50µm
Trees
Shrubs
Ericaceae
Sedges & Grasses
Herbs
Zones
CC7P5
CC7P4
CC7P3
CC7P2
CC7P1
Sedges and Grasses
Herbs
Poaceae und.
Hordeum type
Avena/Triticum type
Poaceae >37µm und.
Cyperaceae und.
Artemisia
Asteroideae und
Carduceae und
Lactuceae und
Brassicaceae
Sagina type
Scleranthus type
Dianthus type
Spergula type
Caryophyllaceae und
Chenopodiaceae und
Sedum type
Umbilicus rupestris
Scabiosa
Succisa
Gentianella campestris
Geranium
Hypericum perforatum type
Lamiaceae und.
Lotus type
Trifolium type
Vicia type
Scilla type
Plantago lanceolata
Rumex acetosa
Rumex acetosella
Rhinanthus type
Ranunculaceae und
Filipendula
Potentilla
Melampyrum
Scrophulariaceae und.
Solanum dulcamara
Solanum nigrum
Urtica dioica
Botrychium
Herbaceous peat
Silty clay
Stones
Wood

Fig. 3

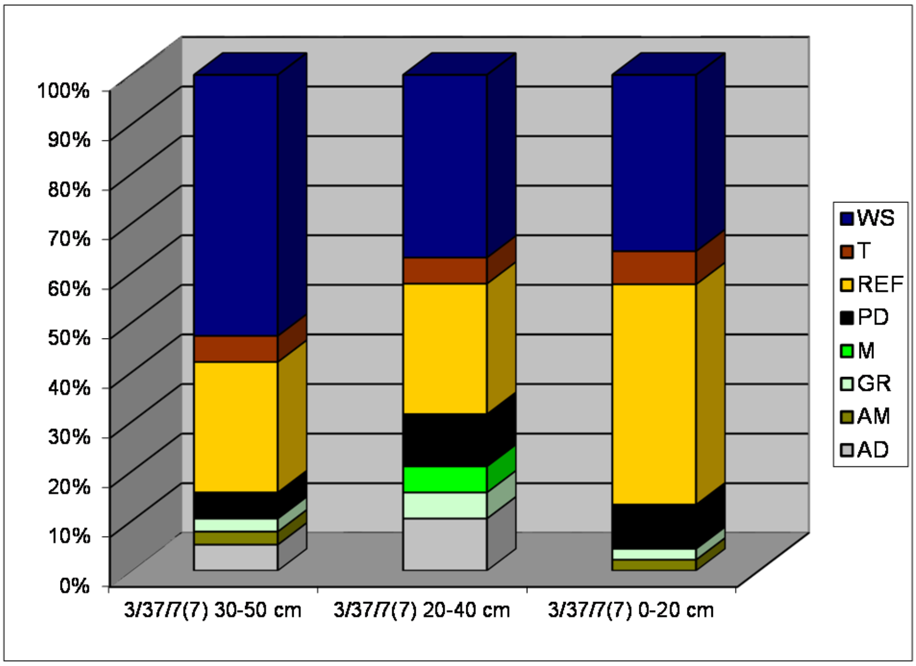

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3/37/7(7) 30-50 cm
3/37/7(7) 20-40 cm
3/37/7(7) 0-20 cm
WS
T
REF
PD
M
GR
AM
AD

Fig. 4

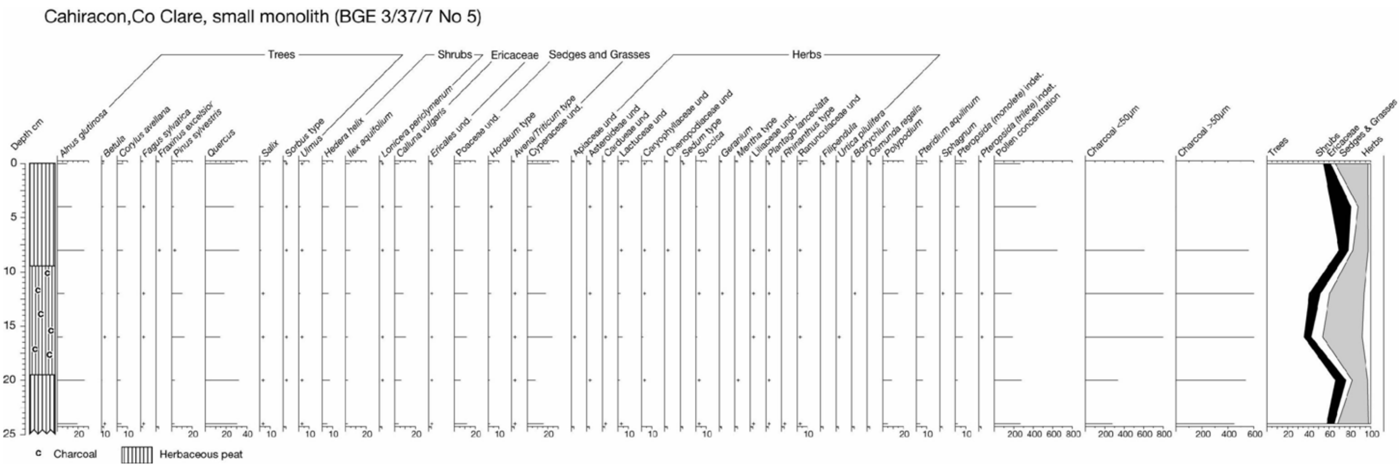

Cahiracon,Co Clare, small monolith (BGE 3/37/7 No 5)
Trees
Shrubs
Ericaceae
Sedges and Grasses
Herbs
Depth cm
Alnus glutinosa
Betula
Corylus avellana
Fagus sylvatica
Fraxinus excelsior
Pinus sylvestris
Quercus
Salix
Sorbus type
Ulmus
Hedera helix
Ilex aquifolium
Lonicera periclymenum
Calluna vulgaris
Ericales und.
Poaceae und.
Hordeum type
Avena/Triticum type
Cyperaceae und.
Apiaceae und
Asteroideae und
Carduae und
Lactuceae und
Caryophyllaceae und
Chenopodiaceae und
Sedum type
Succisa
Geranium
Mentha type
Liliaceae und.
Plantago lanceolata
Rhinanthus type
Ranunculaceae und
Filipendula
Urtica pilulifera
Botrychium
Osmunda regalis
Polypodium
Pteridium aquilinum
Sphagnum
Pteropsida (monolete) indet.
Pteropsida (trilete) indet.
Pollen concentration
Charcoal <50µm
Charcoal >50µm
Trees
Shrubs
Ericaceae
Sedges & Grasses
Herbs
c Charcoal
Herbaceous peat

Fig. 5

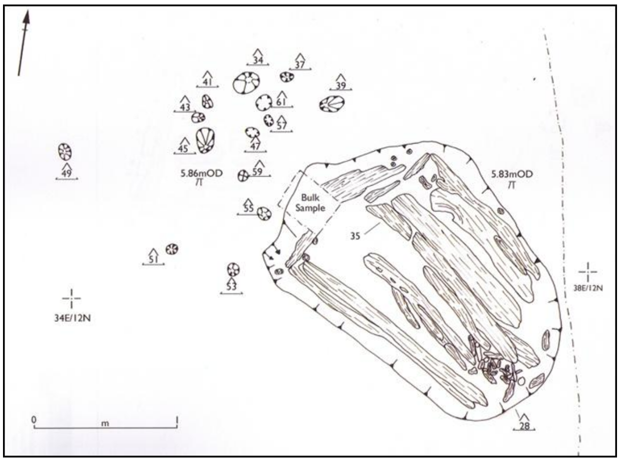

34
37
41
39
43
61
57
45
47
49
5.86mOD
59
5.83mOD
Bulk Sample
55
35
51
53
38E/12N
34E/12N
0
m
28

Fig. 6

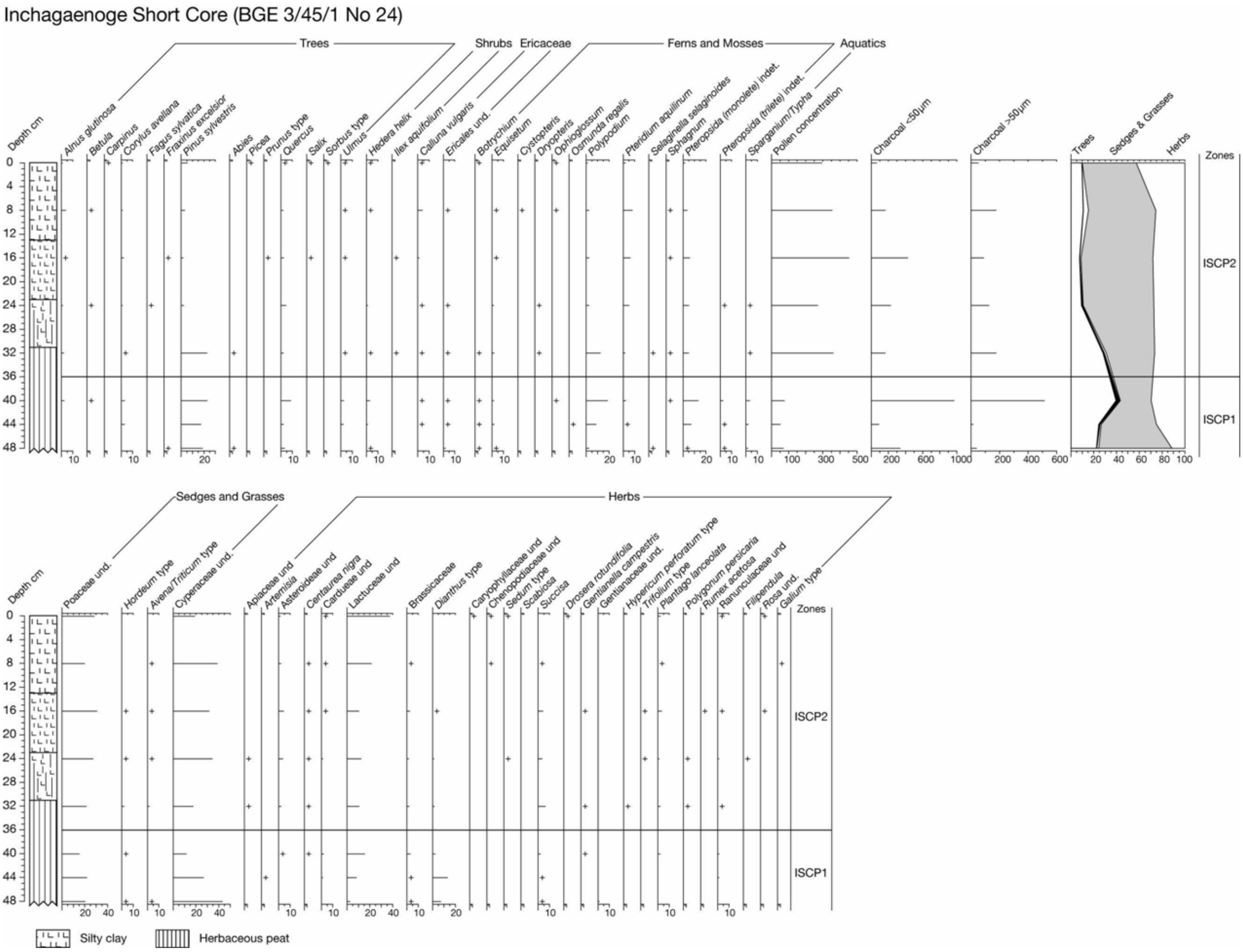

Inchagaenoge Short Core (BGE 3/45/1 No 24)
Trees
Shrubs
Ericaceae
Ferns and Mosses
Aquatics
Sedges and Grasses
Herbs
Depth cm
Zones
ISCP2
ISCP1
Silty clay
Herbaceous peat

Fig. 7

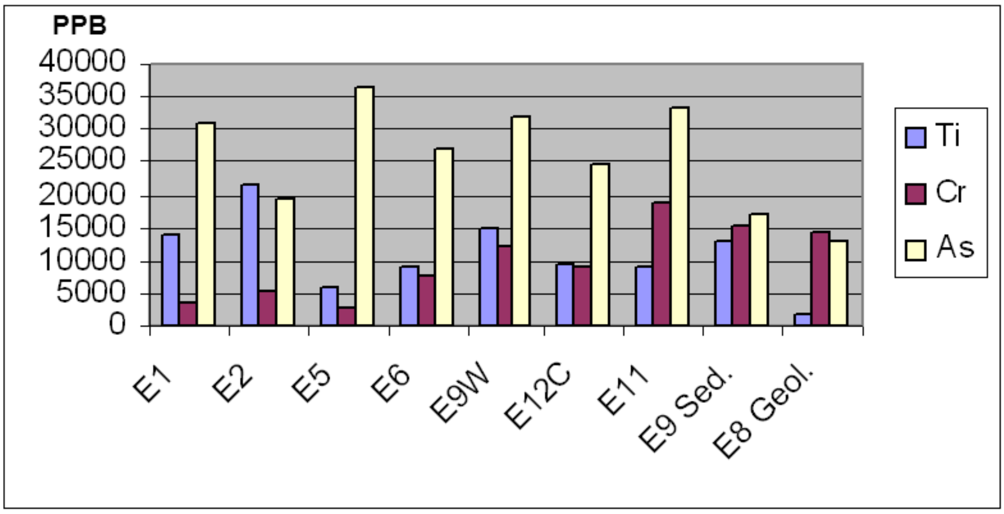
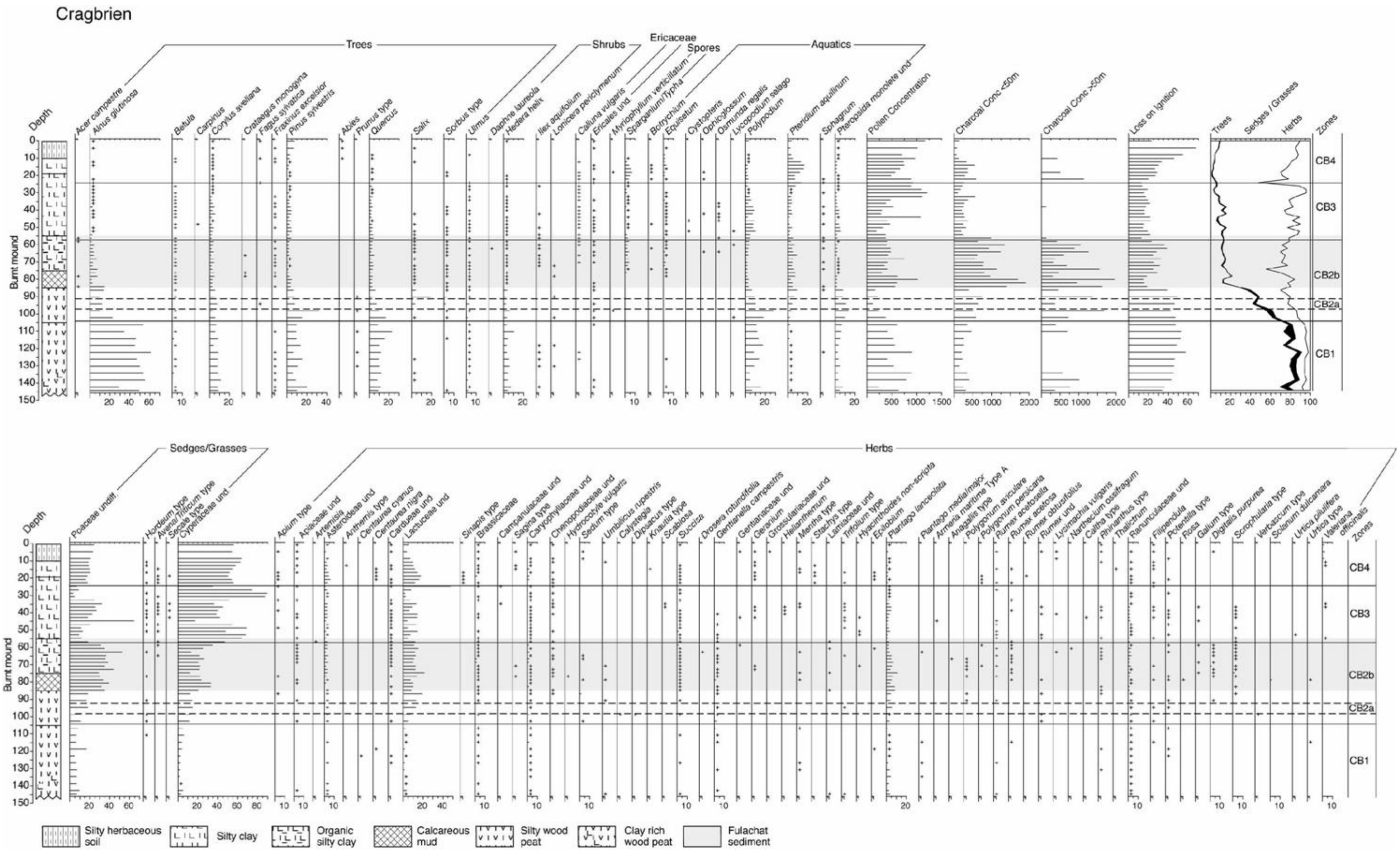

PPB
Ti
Cr
As
E1
E2
E5
E6
E9W
E12C
E11
E9 Sed.
E8 Geol.

Fig. 8



Cragbrien
Trees
Shrubs
Ericaceae
Spores
Aquatics
Sedges/Grasses
Herbs
Depth
Burnt mound
Zones
CB4
CB3
CB2b
CB2a
CB1
Pollen Concentration
Charcoal Conc <50m
Charcoal Conc >50m
Loss on ignition
Silty herbaceous soil
Silty clay
Organic silty clay
Calcareous mud
Silty wood peat
Clay rich wood peat
Fulachat sediment

Fig. 9

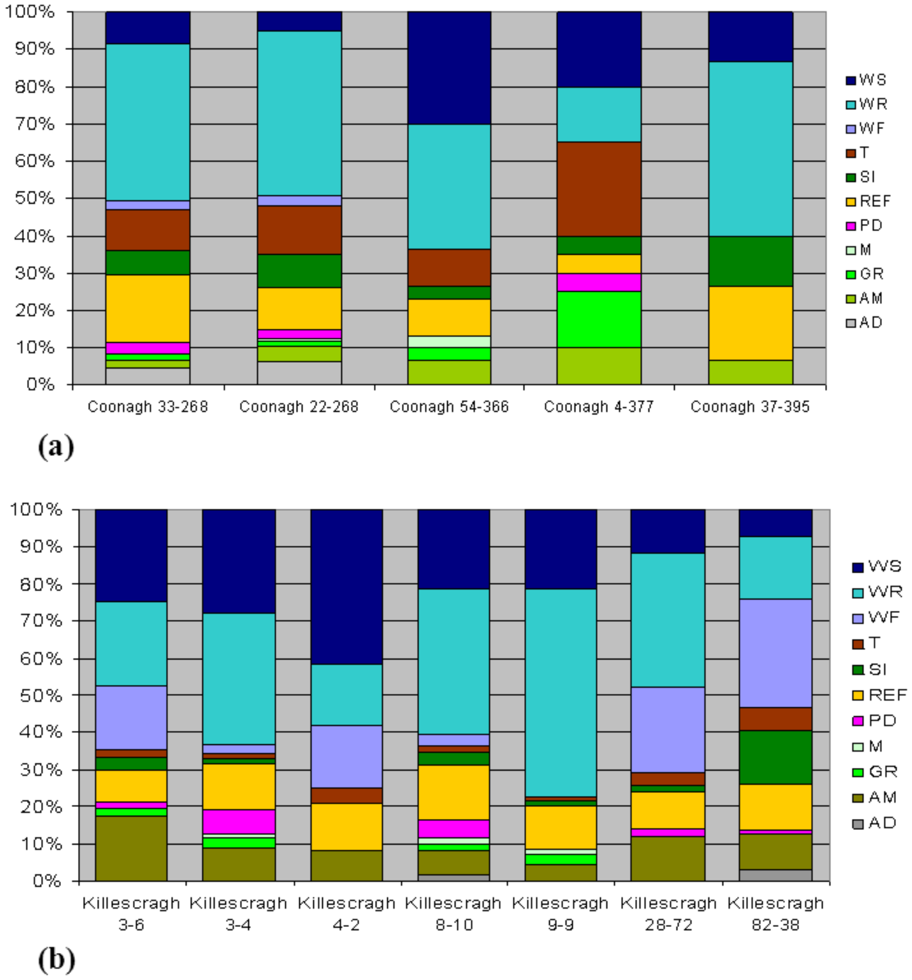
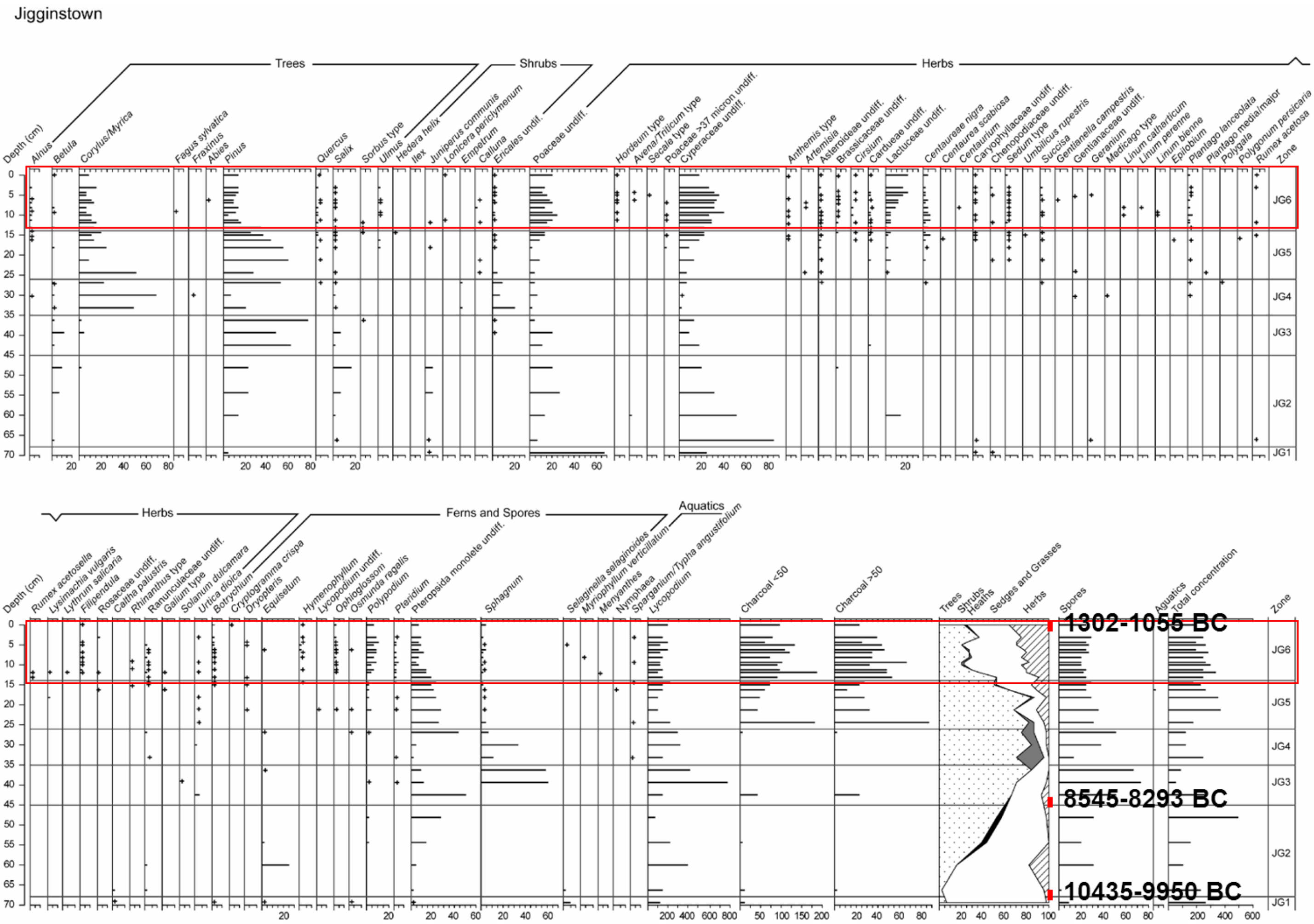

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coonagh 33-268
Coonagh 22-268
Coonagh 54-366
Coonagh 4-377
Coonagh 37-395
WS
WR
WF
T
SI
REF
PD
M
GR
AM
AD
(a)
Killescragh 3-6
Killescragh 3-4
Killescragh 4-2
Killescragh 8-10
Killescragh 9-9
Killescragh 28-72
Killescragh 82-38
(b)

Fig. 10



Jigginstown
Trees
Shrubs
Herbs
Ferns and Spores
Aquatics
1302-1055 BC
8545-8293 BC
10435-9950 BC
JG6
JG5
JG4
JG3
JG2
JG1

Fig. 11

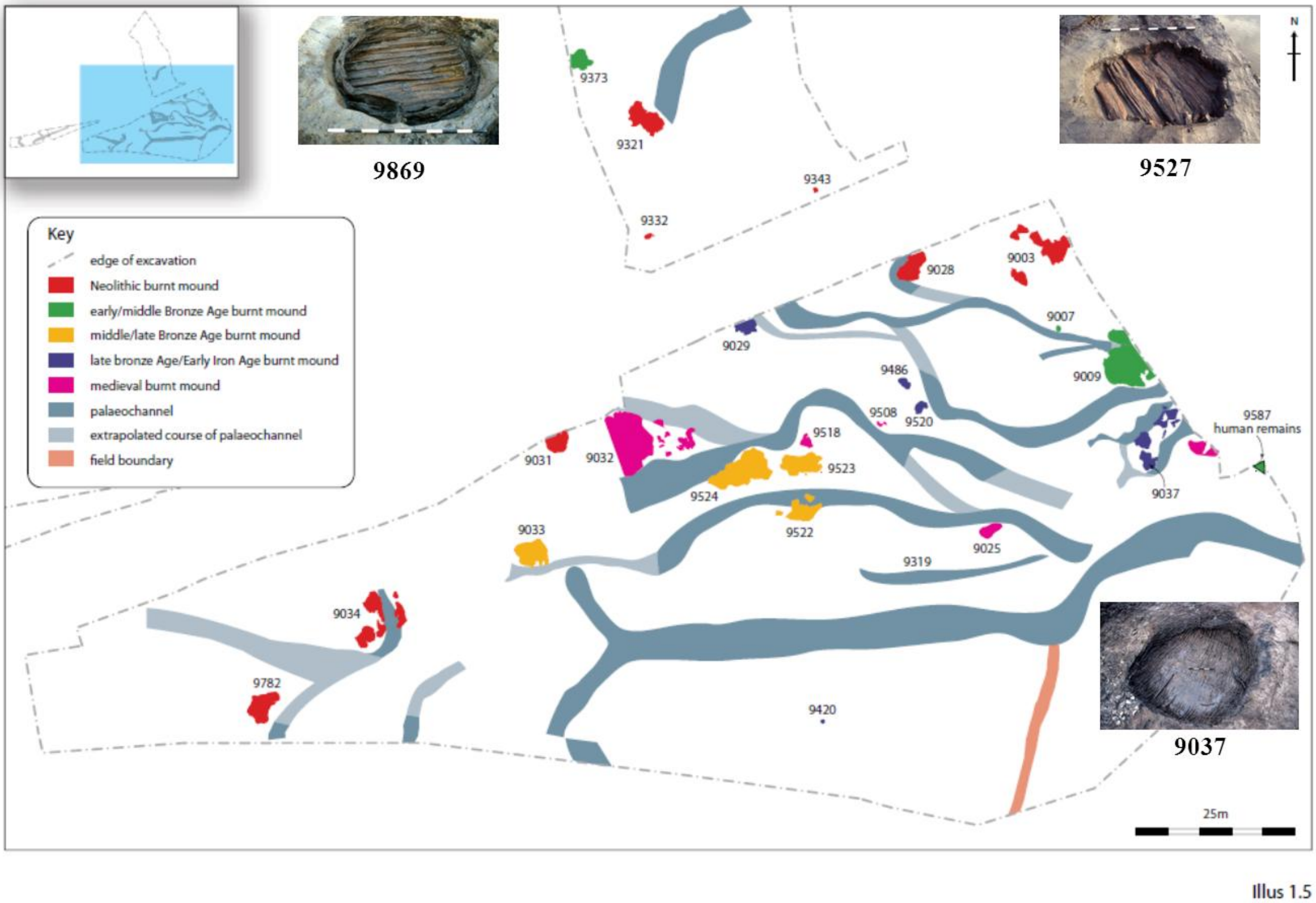

9869
9527
9037
N
Key
edge of excavation
Neolithic burnt mound
early/middle Bronze Age burnt mound
middle/late Bronze Age burnt mound
late bronze Age/Early Iron Age burnt mound
medieval burnt mound
palaeochannel
extrapolated course of palaeochannel
field boundary
9587 human remains
25m
Illus 1.5

Fig. 12

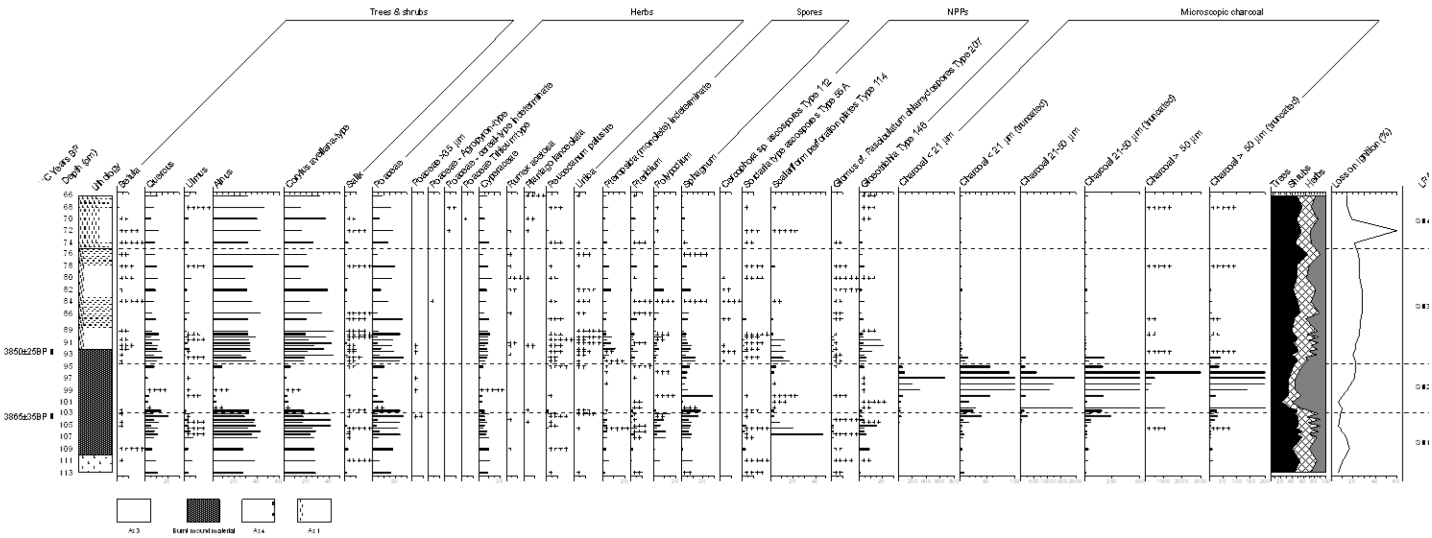
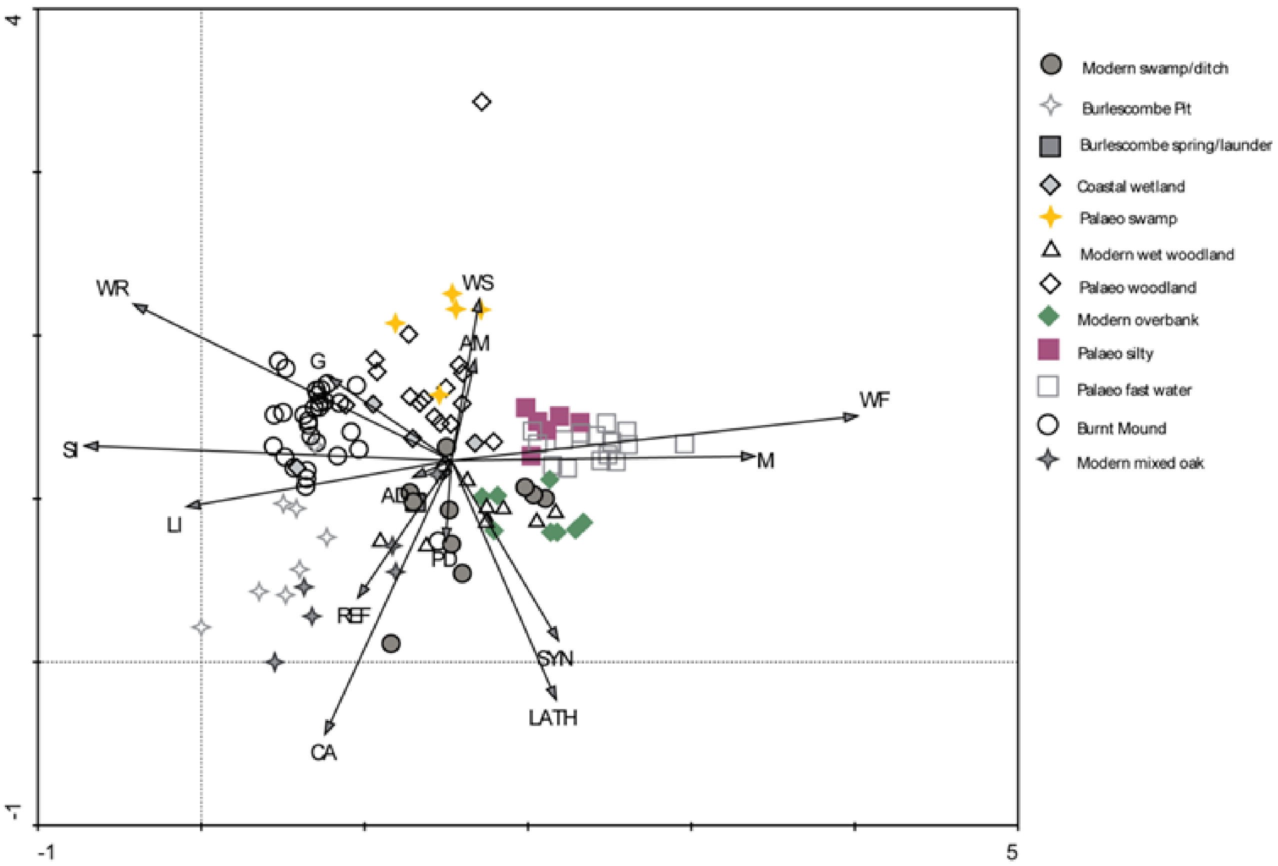
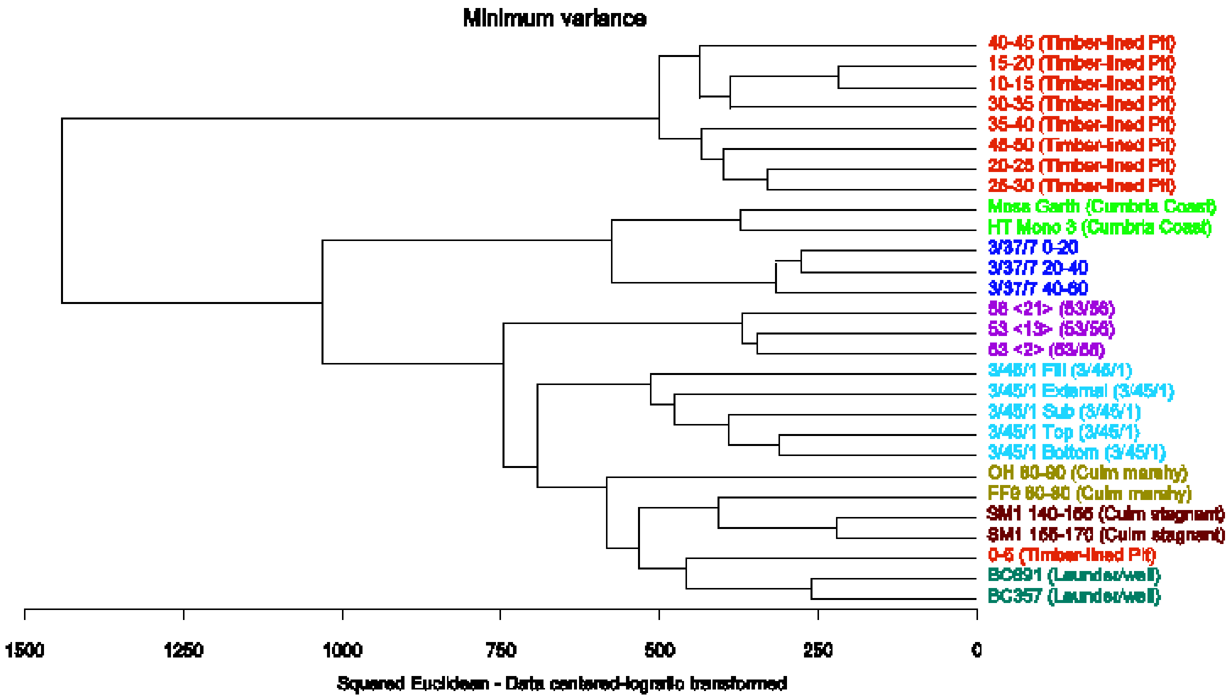

Trees & shrubs
Herbs
Spores
NPPs
Microscopic charcoal
3850±25BP
3865±35BP

Fig. 13



4
-1
-1
5
WR
WS
AM
G
WF
SI
M
LI
AD
PD
REF
SYN
LATH
CA
Modern swamp/ditch
Burlescombe Pit
Burlescombe spring/launder
Coastal wetland
Palaeo swamp
Modern wet woodland
Palaeo woodland
Modern overbank
Palaeo silty
Palaeo fast water
Burnt Mound
Modern mixed oak



Minimum variance
40-45 (Timber-lined Pit)
15-20 (Timber-lined Pit)
10-15 (Timber-lined Pit)
30-35 (Timber-lined Pit)
35-40 (Timber-lined Pit)
45-50 (Timber-lined Pit)
20-25 (Timber-lined Pit)
25-30 (Timber-lined Pit)
Moss Garth (Cumbria Coast)
HT Mono 3 (Cumbria Coast)
3/37/7 0-20
3/37/7 20-40
3/37/7 40-60
56 <21> (53/56)
53 <13> (53/56)
53 <2> (53/56)
3/45/1 Fill (3/45/1)
3/45/1 External (3/45/1)
3/45/1 Sub (3/45/1)
3/45/1 Top (3/45/1)
3/45/1 Bottom (3/45/1)
OH 60-80 (Culm marshy)
FF9 60-80 (Culm marshy)
SM1 140-155 (Culm stagnant)
SM1 155-170 (Culm stagnant)
0-5 (Timber-lined Pit)
BC691 (Launder/well)
BC357 (Launder/well)
1500
1250
1000
750
500
250
0
Squared Euclidean - Data centered-logratio transformed

Fig. 14