Environmental reconstruction and formation processes in a large Mesolithic lithic scatter at Nethermills of Crathes, Aberdeenshire, Scotland

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Abstract

The rich resources of river valleys provided a focus for much Mesolithic hunter-gatherer-fisher activities across Europe. In Scotland there is one notable concentration of lithic evidence for this, at several locations along the River Dee in Aberdeenshire, but the environmental context of these sites has, to date, been poorly understood. Here we present evidence from excavation, repeated field-walking, flint typology, geomorphological mapping, sedimentology, pollen analysis, AMS ^{14}C dating, OSL profiling and dating to understand the postglacial evolution of the terrace surface at the largest concentration of lithics along the River Dee, at Nethermills of Crathes. The aim was to understand in detail the environment and landscape dynamics of the site, to define whether occupation was on the active valley floor or on a terrace above the river, and whether fluvial processes had a role in site formation processes. We conclude that occupation was on a dry wooded surface, the active channel having incised below this, though to an unknown depth, and that although major floods have swept the terrace surface, the present distribution of lithics is probably largely the original distribution.

Keywords

Mesolithic, north west Europe, fluvial geomorphology, palaeoecology, luminescence profiling

Introduction

Many syntheses of Mesolithic settlement throughout Europe have established a relation to river valleys, whether it be a simple association with proximity to water (Masojć 2007) or through detailed multi-proxy environmental reconstruction to more specific micro-environments (Berger et al., 2016; Bos and Urz, 2003; Bos et al., 2006; Donahue and Lovis, 2006; Jochim, 2011; Passmore and Waddington, 2012, 128, 130; Ramsden et al., 1995; Vandenberghe et al. 2010; Weerts et al., 2012; Wickham-Jones et al., 2020). In northern Britain, the large and long river systems like that of the Tweed (Mulholland, 1970; Passmore and Waddington, 2012) are seen to have been routeways to the interior as well as resource-rich and favourable to settlement.

In Scotland, work to date has been invested in coastal locations (Finlayson and Edwards, 2003; Fojut, 2006; Hardy and Wickham-Jones, 2002; Mellars, 1987; Mithen, 2000; Saville and Wickham-Jones, 2012; Warren, 2000, 2005; Wickham-Jones, 1990). In eastern Scotland, however, amateur collections and early excavations (Paterson and Lacaille, 1936) drew attention to the exceptionally frequent and dense assemblages of Mesolithic flints along low terraces of the River Dee (Wickham-Jones et al., 2017). At 140 km long and with a catchment >2000 km^2, the Dee is one of Scotland's largest rivers (Figure 1a). The assemblages from the Dee have now also yielded Late Upper Palaeolithic (LUP) finds (Ballin, 2019; Ballin and Wickham-Jones, 2017). Excavation in the 1970s of part of a small part of the largest lithic assemblage, at Nethermills, near Crathes in lower Deeside, amounting to nearly 4000 lithics from excavation and field-walking, was until recently unpublished (Wickham-Jones, *et al* 2017) but had encouraged some environmental reconstructions from analyses of pollen (Ewan, 1981) and charred plant macrofossils (Boyd and Kenworthy, 1982). Ecological and edaphic reconstructions were limited, though, to suggestions that the river terrace surface was dry at the time the lithic scatters were created, without considering what this meant for fluvial change or the detailed landscape context of the lithic scatters.

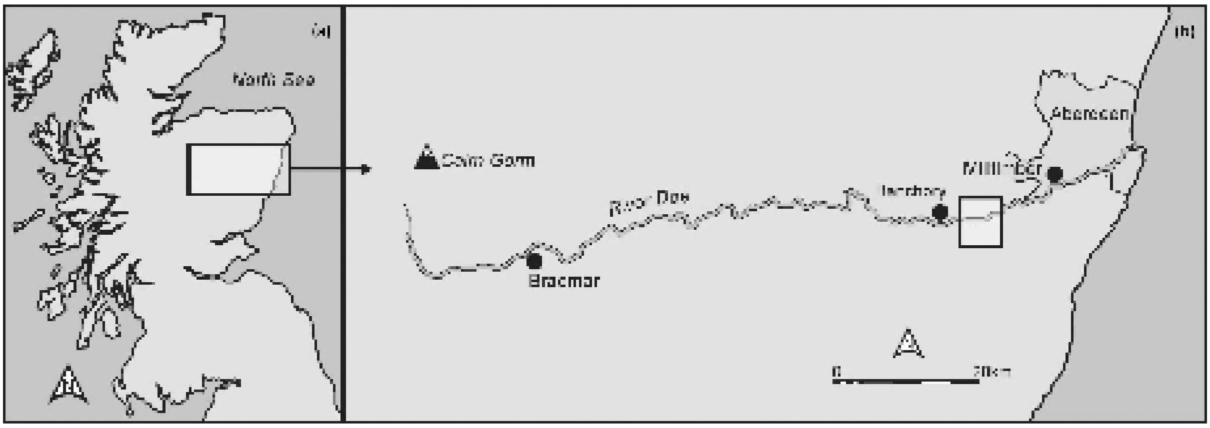

Figure 1. (a) The Dee Valley in eastern Scotland and (b) the River Dee from its source in the Cairngorm Mountains to the North Sea at Aberdeen. The box in (b) outlines the area in Figure 2.

Correlation of terrace fragments has now established that almost all the known Mesolithic lithic assemblages in lower Deeside, east of Banchory (Figure 1) lie on a single terrace surface, called the Camphill Terrace (Tipping, 2019; Tipping and Ross, in Wickham-Jones et al., 2021): an absolute chronology for some terrace fills has been constructed at one locality, Milltimber, 10 km downstream of Nethermills (Figure 1; Tipping, 2019). The Camphill Terrace surface at Nethermills (Figure 2) is underlain by very coarse sandy gravel >10 m thick, formed before the LUP lithics found on its surface accumulated (Ballin, 2019; Ballin and Wickham-Jones, 2017), the gravel probably glaciofluvial in origin. Thin sand sheets cover the glaciofluvial sediments. The terrace surface is around 4–5 m above the present surface of the River Dee in the Nethermils reach with a gradient parallel to the river. Three glaciofluvial terraces in the Lochton Sand & Gravel Formation (Merritt et al., 2003), the Lochton, Maryfield and Toll House Terrace surfaces lie around 12, 6 and 2 m respectively above the Camphill Terrace. The Maryculter Terrace lies around 0.5 m below the Camphill Terrace surface. Its fill at Nethermills comprises some 1.5 m of stoneless sand. Tipping (2019) suggested from the presence of later prehistoric archaeological evidence on the Camphill Terrace at Milltimber that incision from the Camphill Terrace surface occurred around 4000 cal BC, and that Mesolithic occupation was on the active valley floor, although the earliest OSL dated sediments in the Maryculter Terrace fill at Milltimber formed from circa 2500 cal BC (Tipping and Kinnaird 2019). A complicating factor on the River Dee is that major floods along its length frequently overtop and deposit sand on parts of the Camphill Terrace surface (Fieman et al. 2020; McEwen, 2000; Warren, 1985).

This complexity has meant that the precise environmental settings of these important lithic assemblages, and so the relation between occupation of the Camphill Terrace surface to the range of valley floor resources, and to fluvial change over this long period, has not been understood. It was not known, critically, whether occupation was on the active floodplain, a micro-environment markedly different to higher and drier terrace surfaces (Bos and Urz, 2003; Bos et al., 2006; Fyfe et al. 2003; Vandenberghe et al., 2010; Weerts et al., 2012) or was on a dry terrace surface. The role of later Holocene floods shaping the distribution of the lithic assemblage was also unclear. Continued fieldwalking (e.g. Mesolithic Deeside 2019-2021; Sabnis, 2019) and preparation for publication of the Nethermills excavation (Wickham-Jones et al., 2017) drove a new tranche of investigations along lower Deeside (Wickham-Jones et al., 2021) and allowed the opportunity to explore these issues.

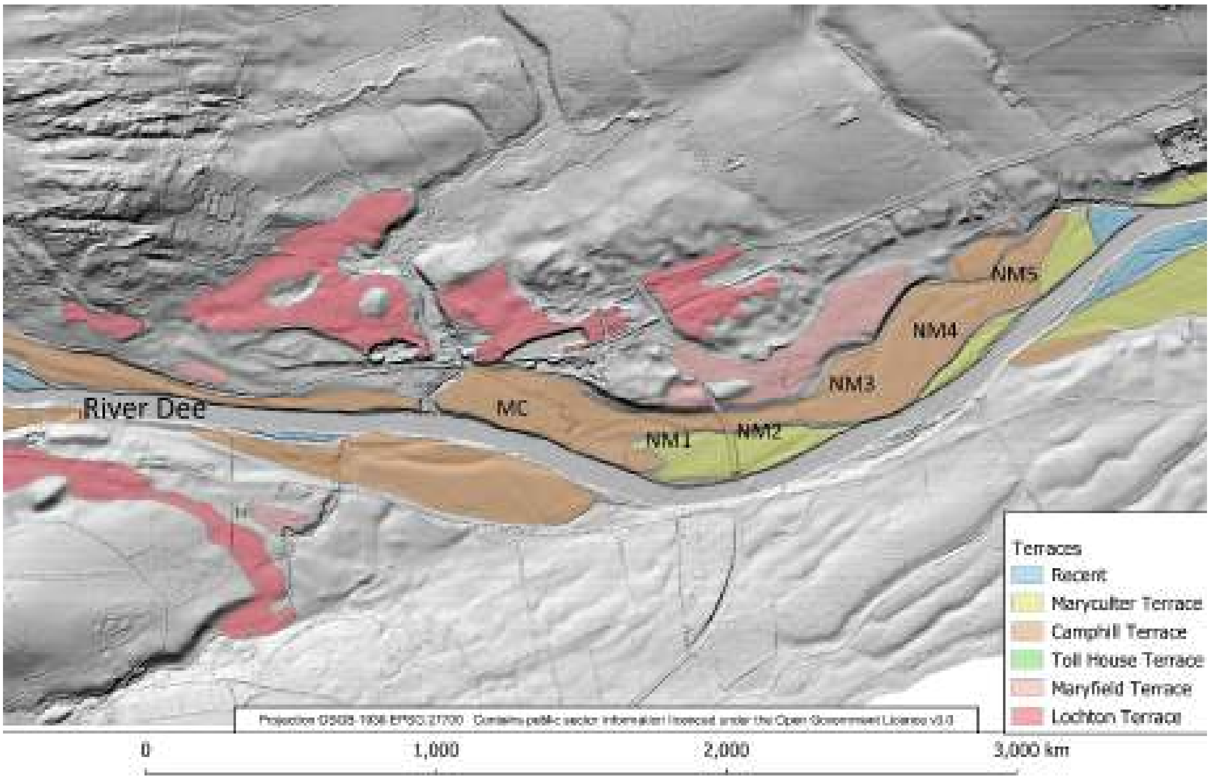

Figure 2: a LiDAR image at 1.0 m resolution (Scotland Lidar Phase 1: DTM https://remotesensingdata.gov.scot/data#/map) of the River Dee and river terrace surfaces on the reach of the river east of Banchory (see Figure 1), showing the terrace surfaces and fields where lithics have been collected (orange: MC to NM5) on the left bank of the river. (COLOUR)

Materials and Methods

The Nethermills lithic assemblage stretches some 1.75 km along the Camphill Terrace surface on the left bank of the Dee: this report is concerned with the landforms and archaeology in two fields, NM3 and NM4 (Figure 3). Methods included geomorphological mapping, analysis of aerial photographs and LiDAR flights, high-resolution topographic and geophysical (conductivity; magnetic susceptibility) mapping, auger survey, archaeological fieldwalking of weathered ploughed soils across entire fields and recording of finds with hand-held GPS (spatially resolved to circa 3 m), typological analyses of lithics, test-pitting of 120 pits (2 x 2 m) dug across Field NM4 to the base of the soil profile (35-50 cm depth), machine excavation of 10 deeper trenches into natural sediment, sampling down-profile in these for luminescence profiling (Munyikwa et al. 2021; Sanderson and Murphy, 2010) at 10 cm intervals, AMS ^{14}C dating of plant macrofossils and OSL dating of sediment, with re-evaluation of Ewan's (1981) pollen data and Boyd and Kenworthy's (1982) plant macrofossil data. Pollen analyses were prepared by standard chemical procedures (Moore, Webb and Collinson 1991, 42-46), pollen concentrations calculated from addition of *Lycopodium* spores (Stockmarr 1971) and slides counted until 100 *Lycopodium* spores were recorded. 'Damaged' grains were recorded: they do not affect interpretation (cf. Bunting and Tipping 2000).

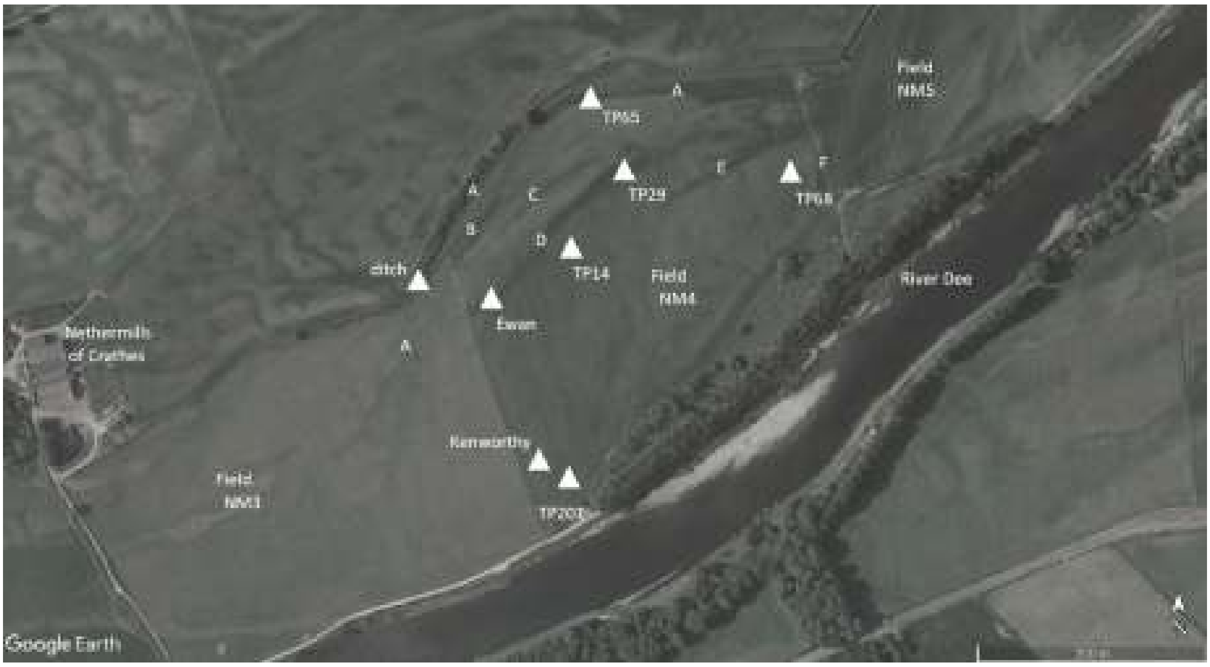

Figure 3: Google Earth image (flown 6/28/2018) of Fields NM3, 4 and 5 showing the dark peat-filled channels A-F and locations where the absolute chronology of sediments has been sought from ^{14}C, OSL or pollen stratigraphy (see text): ©Google.

Results

Topography and surficial sediments of the Camphill Terrace at Field NM4

The terrace surfaces in Fields NM3 and NM4 (Figure 2) are largely featureless because they have been heavily disturbed by farming. They are covered in minerogenic ploughed soil. A few narrow channels run parallel to the Dee, much narrower than the present river at 70 m, identified on aerial photographs due to their being peat-filled beneath the ploughed soil (Figure 3). In Field NM3, channel A is around 10 m wide, leading north from the present river, eroding Maryfield Terrace gravel above as it widened the Camphill Terrace, forming a 2 m high cliff. The same channel forms the northern edge of the Camphill Terrace in Field NM4, its peat surface a metre below the Camphill Terrace surface. Crossing the northern part of Field NM4 are four sub-parallel, slightly arcuate channels barely incised below the terrace surface (B to E: Figure 3). Their parallel development is suggestive of the development of channels formed by avulsion on a meander scroll bar (Nanson, 1980) that was prograding northward over time, a characteristic planform of meandering rivers. In this interpretation, channel (E) formed first, and channel (A) formed last: channel A might have truncated the western end of channel D (Figure 3). A sixth channel, channel F, leads north from the present river, incised circa 75 cm below the terrace surface, for around 80 m where it intersects channel E: this channel is truncated in the south by Maryculter Terrace sediment.

Photographs of Kenworthy's excavation (e.g. Figure 4) and illustrations 2, 5 and 8 in Wickham-Jones et al. (2017) show an organic-rich surface soil above a thin, almost stoneless sand, which overlies pebble-rich coarse gravel. Figure 5 is a map of sediments in Field NM4 at the bases of test-pits. The sand in Kenworthy's excavation is underlain by gravel, part of a continuous surface of clean sand, several tens of centimetres thick, rising to circa 36m above sea level (asl: UK Ordnance Datum) next to the river. A second band of sand, also underlain by gravel, occurs in the north of the field, below 34.5 masl, and is also several tens of centimetres thick where excavated. Separating these southern and northern sand sheets is a broad band of sandy gravel along the wide spine of a barely perceptible ridge rising to circa 35masl. Gravel outcrops also in the northern edge of the field, on the north side of channel A. The gravel ridge may represent the final glaciofluvial deposit in a braided river, or a gravel bar deposited later in a fluvial environment. The top metre of gravel is much richer in sand than deeper gravel (NO79NE5: BGS Geoindex) probably resulting from sand filtering into the gravel. Channel E cuts into the gravel and may be a chute. The scroll bars of channels D-A develop northward from the gravel ridge into the wide channel of a meandering river.

Figure 4: photograph of pit complex C being excavated in 1980 showing the pit cutting sand and cutting into underlying pebbly gravel. The overlying soil at bottom left has been removed over most of the surface.

Sediment stratigraphies and absolute dating of surficial sediments

Organic matter from the fills of some channels (Figure 3) have been dated by AMS ^{14}C, OSL or by pollen analysis. Table 1 gives the most complex sediment stratigraphies.

Channel D		**Channel A**		**TP65**	
Depth (cm)	*Description*	*Depth (cm)*	*Description*	*Depth (cm)*	*Description*
0-30	ploughsoil; gradual boundary to	0-2	grass surface in pale yellow structureless coarse sand; sharp boundary to	0-25	ploughsoil; gradual boundary to
30-80	highly humified, becoming less so, amorphous peat with many wood fragments; sharp boundary to	2-33	very dark brown compact amorphous, structureless peat with rare disseminated sand, rare large rounded stones 2-20cm depth, occasional pea-grit 28-33cm depth, rare compressed round-wood and wood fragments, occasional coarse fibrous vertical roots penetrating to the base; sharp broadly horizontal boundary to	25-65	dark reddish-brown highly humified amorphous peat with occasional wood fragments; abrupt boundary to
80-89	grey clay with organic matter; sharp boundary to	33-50	series of 0.5 to 2.5 cm thick interbedded orange-brown peat, maybe with disseminated fine mineral grains, and very dark brown, more humified, amorphous peat; peat below 42 cm depth has common disseminated sand; sharp horizontal boundary to	65-120	white clean structureless sand
89-95+	fine-medium clast-supported gravel; base not seen	50-71	strongly bedded cream-pale grey well-sorted medium sand; sharp wavy boundary to	120-130+	fine-medium clast-supported gravel
		71-79	strongly bedded 1-3 cm thick bands of pale-mid grey well-sorted medium and coarse sand; sharp boundary to		
		79-90+	clast-supported, structureless sub-rounded to rounded coarse gravel of granite and Dalradian lithologies, fining up to clast-supported, strongly imbricated (west to east) medium-fine gravel; base not seen		

Table 1. Sediment stratigraphies in Channel D (Ewan 1981), Channel A and TP65.

Ewan (1981) found in channel D, above impenetrable gravel, 9 cm of grey clay with organic matter overlain by 40 cm of peat, increasingly well humified up-profile and with many wood fragments, beneath some 30 cm of soil. Pollen analyses at NO 758 963 (Figure 7) record a vegetation succession from the earliest Holocene circa 9700 cal BC to the mid-Holocene (Edwards, 1979a, b; Tipping, 1991, 1994, 2007; Vasari and Vasari, 1968; Walker et al., 1994) though with low representation of *Betula* prior to the appearance of *Corylus avellana*-type. An absolute chronology from Birks' (1989) synthesis of tree migration would have *Corylus* colonising around 8000 cal BC, *Ulmus* around 7500 cal BC, *Quercus* around 6500 cal BC and *Pinus* pushing east from the Cairngorm around 5800-5550 cal BC (Tipping, 2007, 38). The *Alnus* rise is locally variable in timing but dates to around 6050 cal BC at nearby Loch of Park (Vasari and Vasari, 1968). How long peat accumulated at Nethermills of Crathes after colonisation of *Alnus* is unclear: an *Ulmus* decline is not seen because *Ulmus* pollen is rare.

Within channel D some 200 m north-east of Ewan's site, in test-pit (TP) 29 (Figure 3), ^{14}C assay SUERC-39098 dated *Betula* charcoal in the upper part of the peat to 3954-3731 cal BC (Table 2). At the northern edge of Field NM3 (ditch: Figure 3), in a section in a drainage ditch cut in channel A, *Betula pendula* bark at 3 cm depth in a 47 cm thick peat is ^{14}C dated to 3786-3657 cal BC. At TP65 in channel A, the top of around 40 cm of structureless sand, beneath peat and above clast-supported coarse gravel, is OSL dated to 4.7 ± 0.3 (0.21) ka BP (2500-2920 cal BC): an unusual Th:U ratio in the sample, however, implies post depositional mobility of soluble radionuclides (Olley et al. 1996) and the assay is regarded as a *terminus ante quem*. The OSL assay contrasts with the stratigraphically younger ^{14}C assay SUERC-39098 in the same channel. The peat in TP65 contained a large fragment of *Quercus* trunk, indicating an age younger than circa 6500 cal BC for the peat surrounding it.

Feature	*Location*	*Material*	*Lab No.*	*^{14}C bp*	*δ^{13}C ‰*	*Calibrated age*
Channel D	TP29	*Betula* charcoal	SUERC-39098	5055 ± 31	-29.6	3954–3731 BC (95.4 %)
Channel A	ditch	*Betula* bark	SUERC-79257	4950 ± 30	-29.4	3786–3657 BC (95.4 %)
gravel	TP68	*Betula* charcoal	SUERC-39093	7868 ± 31	-24.8	6825–6635 BC (95.4 %)
gravel	TP68	*Salix* charcoal	SUERC-39097	7887 ± 31	-24.7	7001–6643 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50957	4999 ± 27	-25.9	3993–3705 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50958	4932 ± 27	-25.9	3769–3653 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50959	4914 ± 29	-25.6	3763–3724 BC (95.4 %)
*	Kenworthy	*Quercus* charcoal	Poz-69106	6350 ± 35	–	5355–5217 BC (95.4 %)
*	Kenworthy	*Quercus* charcoal	SUERC-55380	6644 ± 28	-24.9	5628–5527 BC (95.4 %)
Pit W*	Kenworthy	*Betula* charcoal	SUERC-50960	5021 ± 29	-25.6	3943–3711 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50957	4999 ± 27	-25.9	3993–3705 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50958	4932 ± 27	-25.9	3769–3653 BC (95.4 %)
Pit C*	Kenworthy	*Betula* charcoal	SUERC-50959	4914 ± 29	-25.6	3763–3724 BC (95.4 %)

Table 2. AMS ^{14}C assays from Kenworthy's excavation published by Wickham-Jones *et al* 2017 (marked *) and from test-pitting in 2019.

Other ^{14}C assays are from archaeological features. *Betula* charcoal in a cut feature in the surface of gravel in TP68 is ^{14}C dated to 6825-6635 cal BC while *Salix* charcoal in the same feature is ^{14}C dated to 7001-6643 cal BC. The most securely dated feature in Kenworthy's excavation (Wickham-Jones et al., 2017) is pit complex C, dated by three *Betula* charcoal fragments to between 3993 and 3653 cal BC. Pit complex C lay just below the soil, cut into sand as well as underlying gravel. Sand deposition was, then, in part a pre-Neolithic event but may have continued after the early Neolithic.

Pre-Mesolithic age-diagnostic lithics are all from ploughed soil. A possible Havelte Phase tanged point excavated by Kenworthy (Ballin and Wickham-Jones, 2017) from within the Windermere Interstadial circa 12100 cal BC (Mortensen, *et al* 2014) originated in the southern sand sheet. A possible Hamburgian-age shouldered point (13500–11100 cal BC) was recovered in TP14 from test-pitting in 2019 at the centre of the gravel ridge as it is preserved today. In addition, a possible LUP end-scraper was recovered in 2019 from TP201 at the southern edge of Field NM4 in the southern sand sheet circa 20 m south of Kenworthy's excavation.

Luminescence characteristics and relative dating of surficial minerogenic sediments

Luminescence profiling was made using a SUERC portable OSL reader (Sanderson and Murphy 2010) in continuous wave mode on sediment in three test-pits in the northern sand sheet (TPs 42, 43 and 65), three on the gravel ridge (TPs 11, 28 and 39) and five in the southern sand sheet (TPs 35, 37, 38, 39 and 201) (Figure 5).

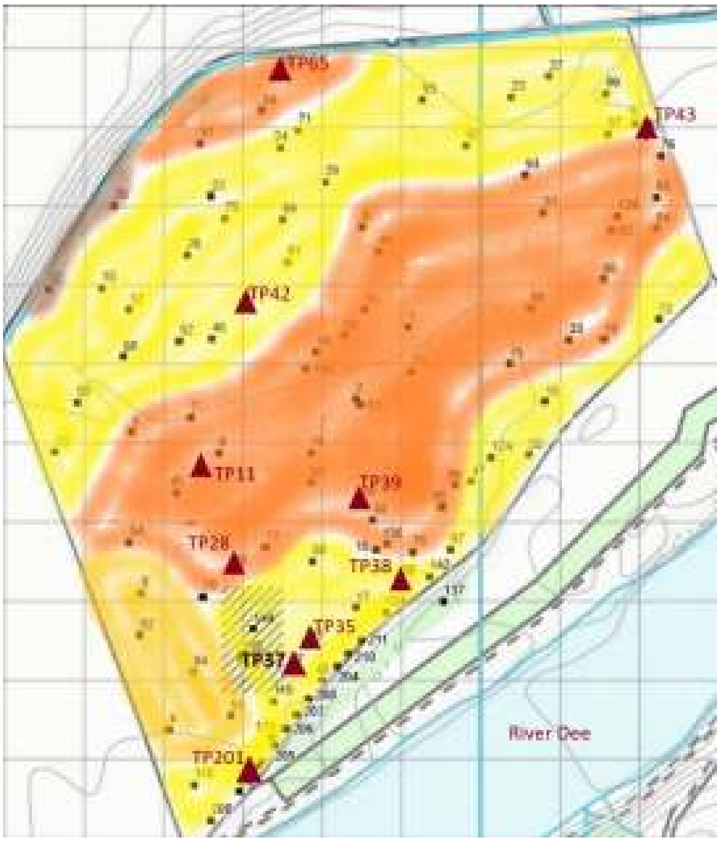

Figure 5: map of surficial sediments in Field NM4 beneath ploughed soil in archaeological test-pits (numbered) with the locations of deeper test-pits (TP: triangles) sampled for OSL profiling. The area excavated by Kenworthy is hachured. Each grid is 40.0 m on a side. Gravel at the surface is in orange; sand at the surface is in yellow; pebbly sand is in darker yellow; gravel over sand is in brown.

Figure 6 presents OSL net signal intensities by depth for each profile, arranged with increasing distance from the present River Dee channel. Optically stimulated luminescence (OSL) net signal intensities (photon counts released in 60 seconds, minus background) are discussed because intensities are 3.35 ± 1.21 (n 102) times ‘brighter’ than the equivalent infra-red stimulated luminescence (IRSL) obtained in the same measurement sequence. Net signal intensity can also vary with sediment provenance, sedimentological and geochemical characteristics, background radiation and radiation history. However, assuming a fluvial source for the sand provides well-mixed and uniform luminescence characteristics, net signal intensities can suggest a relative order of deposition. A test of mineralogical uniformity is the ratio of IRSL:OSL, a proxy for relative concentrations of infra-red sensitive minerals (feldspar) and blue-sensitive quartz (Sanderson and Murphy, 2010): this is a mean of 0.34 with a small SD of 0.09. Samples vary in particle size, from sand to sand in gravel, but there is no significant difference in the IRSL:OSL ratios of the two sediment types (0.32 ± 0.08; 0.34 ± 0.09 respectively). The lack of correspondence in luminescence characteristics between adjacent TPs 37 and 35 (Figure 4) indicates that some channels cut into sand sheets. Interpretation of each profile in Figure 6 draws on the scheme for fluvial sediments of Muñoz-Salinas et al. (2011): (a) declining net signal intensities up-profile characterise sediments fully bleached during transport and exposed to radiation during re-deposition, younger sediment being exposed for shorter times; (b) unchanging net signal intensities typify the same process though greatly accelerated so that the time-difference between deposition of older and younger sediment is negligible; (c) increasing net signal intensities up-profile reflect deposition of partially or unbleached grains; (d) fluctuating profiles of net signal intensity have complex depositional histories or bioturbation; (e) abrupt changes in net signal intensity represent hiatuses in deposition.

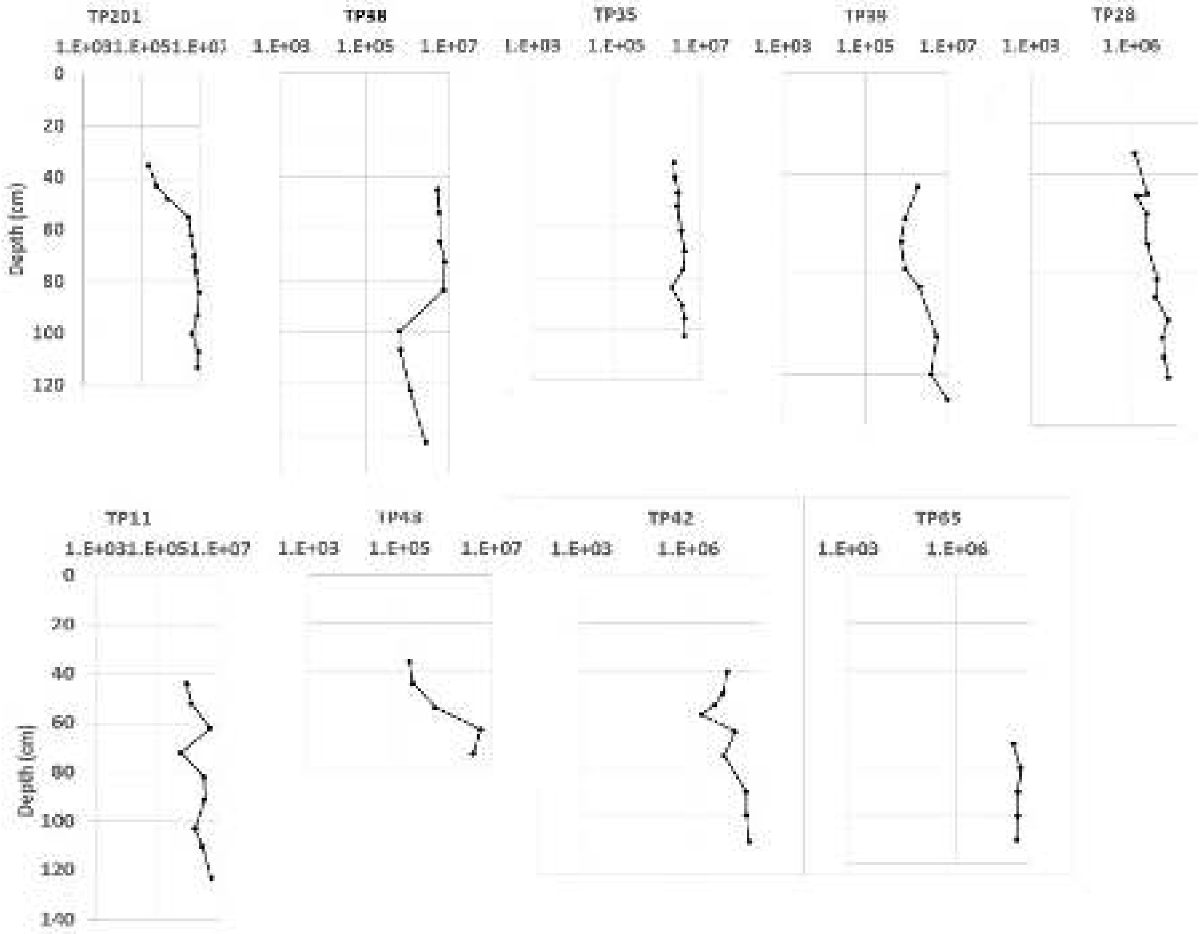

Figure 6: OSL net signal intensities (photon counts) plotted against depth for the 10 deeply excavated test-pits (TP) in Figure 4 [5], arranged (top-bottom; left-right) with increasing distance from the River Dee. Note the different horizontal scale for TP35.

40 samples are interpreted to have received radiation only after deposition on the terrace surface. Their net signal intensities should therefore be a measure of the relative time they have lain on the Camphill Terrace. Table 3 shows the relative age and order that each profile received sediment, listing these 40 samples in each profile with increasing distance from the present Dee channel, distinguishing sediment types and ordering samples in relative chronological order, as percentage values relative to the highest OSL net signal intensity in the set, 4.9 x 10^7 photon counts at 111 cm depth in TP42 (Figure 6). Gravel in this stratigraphic position, beneath earliest Holocene peat in channel D (above; Ewan, 1981), is assumed to have an age within the Younger Dryas circa 10350 cal BC (Rasmussen et al., 2008). Table 3 is synthesised with all other data in the Discussion.

201	37	38	35	39	28	11	43	42	65
							0.3		
0.4							0.4		
0.6									
							1.2		
				1.5					
1.6									

				🟧 1.8					
					🟧 2.7				
					🟧 3.0				
						🟧 3.2			
				🟧 4.0					
								🟨 4.7	
		🟧 5.4							
		🟧 5.4							
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🟨 9.9									
						🟧 10.6			
					🟧 10.9				
							🟨 11.9		
🟨 16.8									
					🟨 18.0				
				🟧 19.1					
								🟧 19.5	
					🟨 19.9				
					🟨 26.4				
								🟧 82.6	
								🟧 82.8	
									🟨 91.9
								🟧 100.0	
🟨 sand	🟧 gravel								

Table 3: sequences of conformable pOSL samples in the 10 geological test-pits in Field NM4, ordered with decreasing distance from the present Dee channel, showing the sediment type analysed and proportions of net signal intensities relative to the oldest sediment (100%) in TP42.

Early-mid Holocene ecological change

Organic matter accumulation in channel D began in the earliest Holocene (above): this is likely to be the time it commenced in channel A (Figure 3) because it has a similar sediment stratigraphy and is located close to Channel D. Peat seems to have been confined to narrow channels: it was not encountered in test-pits away from these though it may have been lost during modern ploughing. The northern sand sheet, though lower-lying than the gravel bar and the southern sand sheet, was probably not a back-swamp environment. Basal peat in channel D was less decomposed than later peat (Ewan, 1981). Peat at channel A visibly alternated in colour and humification as the water table fluctuated, until circa 7500 cal BC. After this the channels were probably drier, the peat more humified, and introduced sand was far less common. Holocene floods depositing sand seem only rarely to have reached channels A or B. The peat in channel D was wet with standing water supporting *Equisetum* (horsetails) spores, below 76 cm depth (circa 9000 cal BC) (Figure 7), but percentages of wetland Cyperaceae pollen (sedges and rushes) are very low and spores and pollen of aquatic plants almost absent after circa 9000 cal BC. The very slow estimated mean peat accumulation rate, of around 150 yrs/cm, is hard to reconcile with peat growth in a constantly wet environment. There may have been hiatuses in peat growth (pollen samples in Figure 7 too few to detect these) but the peat-filled channels were probably not active conduits for water after circa 9000 cal BC.

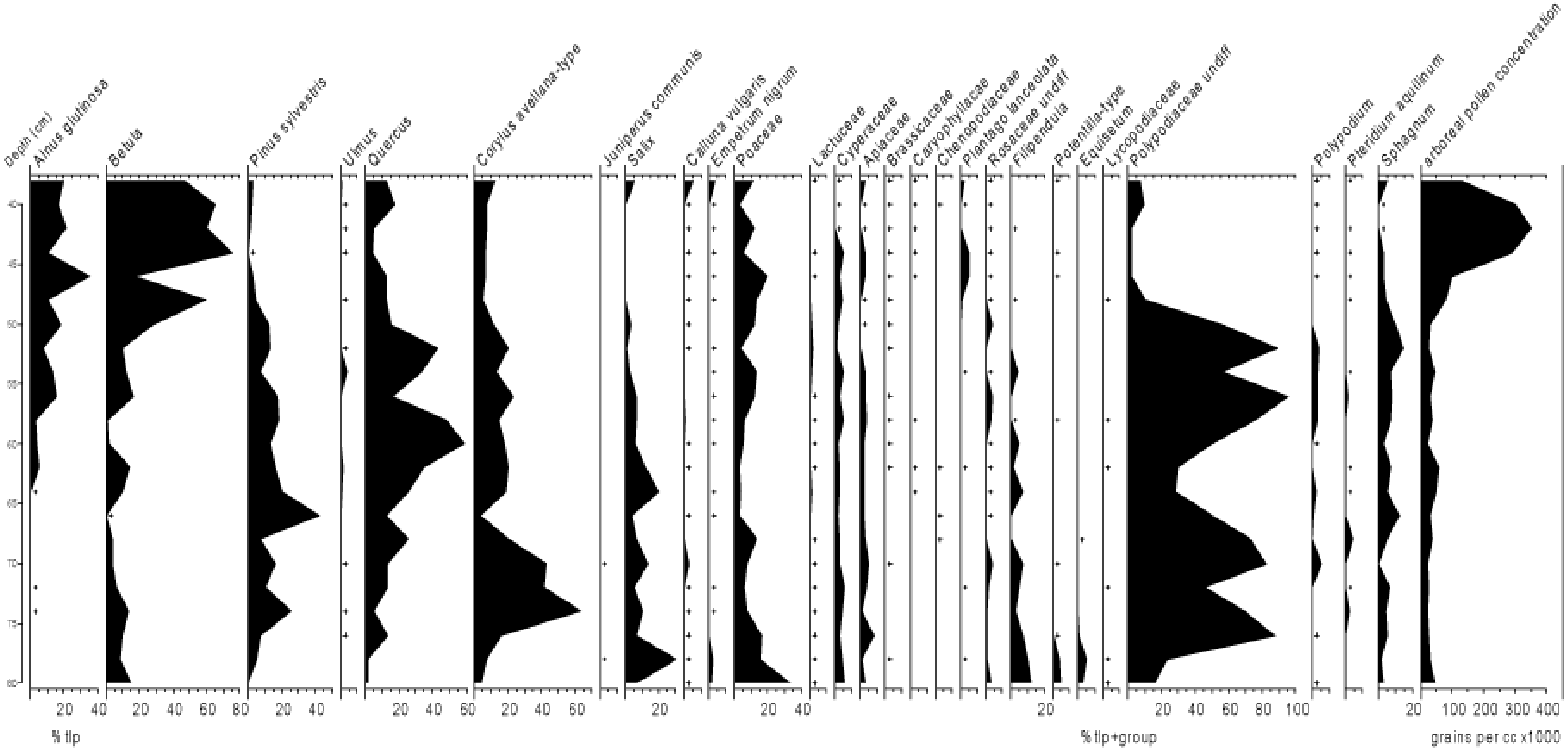
Depth (cm)
Alnus glutinosa
Betula
Pinus sylvestris
Ulmus
Quercus
Corylus avellana-type
Juniperus communis
Salix
Calluna vulgaris
Empetrum nigrum
Poaceae
Lactuceae
Cyperaceae
Apiaceae
Brassicaceae
Caryophyllaceae
Chenopodiaceae
Plantago lanceolata
Rosaceae undiff
Filipendula
Potentilla-type
Equisetum
Lycopodiaceae
Polypodiaceae undiff
Polypodium
Pteridium aquilinum
Sphagnum
arboreal pollen concentration
40
45
50
55
60
65
70
75
80
20 40
20 40 60 80
20 40
20 40 60
20 40 60
20
20 40
20
20 40 60 80 100
20
100 200 300 400
% tlp
% tlp+group
grains per cc x1000

Figure 7: percentage-based pollen diagram of taxa presented by Ewan (1981) plotted against depth (cm) from peat in channel D in Field NM4 (see Figure 3), as % total land pollen (% tlp), those plants considered to derive from soils away from the channel. Proportions of pollen of aquatic plants and spores (*Equisetum* to *Sphagnum*) are calculated as % tlp+ aquatics and spores. Arboreal pollen concentrations are grains per cm^3 x 10^3. Taxonomic nomenclature follows Bennett (1994).

Channel D is around two metres wide, closely comparable to Channel J at Torbhlaren, Argyll where simulation modelling defined a pollen source area, from where most pollen grains derive, of around 500m radius (Verrill et al. in Jones et al. 2011, 171-175). Most pollen deposited on Channel D at Nethermills would have predominantly come from the Camphill Terrace surface, particularly in a wooded environment, though would include the gravelly sand of the valley sides.

Figure 7 is a pollen diagram from the peat in channel D. There were large changes in tree and shrub populations but herb communities, most likely to have grown on the terrace surface, seem to have been more stable. Below 75 cm depth (before circa 9000 cal BC), tree and shrub taxa are <70% total land pollen (tlp). *Salix* (willow) probably grew in some abundance on and by peat-filled channels: pollen records under-estimate its abundance. *Betula* (birch), a tree that thrived on all soils in the early Holocene, was seemingly rare: Ewan (1981, 30) argued that dense *Salix* stands limited transport of *Betula* pollen. *Betula* and *Salix* charcoal ^{14}C dated to circa 6700-6300 cal BC from TP68 (above) may have been derived from Camphill Terrace surface plant communities. *Corylus avellana*-type, probably representing *Corylus* (hazel), reaches circa 50% tlp around 8000 cal BC, not high given the apparent scarcity of competing trees like *Betula*, and it may not have colonised the terrace surface. Grasses (Poaceae) persisted throughout, though were most abundant before trees colonised, with damp grassland herbs like meadowsweet (*Filipendula*) and tormentil (*Potentilla*-type). *Pteridium* (bracken) became common, its abundance also under-estimated from the pollen record (Rymer, 1976). Ferns (Polypodiaceae undiff.) were extraordinarily abundant. Herb taxa indicative of some disturbance, like the Apiaceae (umbellifers), Brassicaceae (crucifers) and Compositae (dandelions) are almost constant though in low numbers, with Chenopodiaceae (goosefoots) better represented circa 8000 to circa 6000 cal BC. *Calluna vulgaris* (ling) was rare though nearly constant, growing on acid soils and dry peat. *Empetrum nigrum* (crowberry) can indicate drier substrates (Bell and Tallis, 1973).

Corylus avellana-type values declined, probably as more competitive deciduous trees like *Quercus* (oak) became established. *Quercus* values expand thereafter, consistently >25% tlp after circa 7200 cal BC and circa 60% tlp around 6500 cal BC. Boyd and Kenworthy (1982) and Ramsay (in Wickham-Jones et al., 2017) record *Quercus* charcoal in abundance, Boyd and Kenworthy arguing for its growth close to the archaeological features, on the Camphill Terrace. At least one oak tree grew on the terrace surface, at TP65 (above), unless it floated in on a flood. Tinsley and Smith (1974) and Birks (1980) report from present-day woodland the proportions of *Quercus* seen at Nethermills. The earliest ^{14}C dated charred *Quercus* fragments at Nethermills have closely comparable ages, of 5355-5217 cal BC (Poz-69106) and 5628-5527 cal BC (SUERC-55380) (Table 2; Wickham-Jones et al., 2017, table 9). *Quercus* can tolerate damp soils but not waterlogged ground. *Pteridium* and ferns like *Dryopteris* and *Blechnum*, both of which produce spores that can become undifferentiated Polypodiaceae spores, would be at home in such a wood (Tittensor and Steele, 1971; Rodwell, 1991), as would *Polypodium* cf. *P. vulgare*, epiphytic on *Quercus* (Turner, 1987).

Pinus sylvestris (Scots pine) may also have grown locally, related to a brief expansion east from the Cairngorm (Figure 1a) between 5800 and 5550 cal BC (Tipping, 2007, 38). Boyd and Kenworthy

(1982) reported occasional pieces of *Pinus* charcoal, which they thought had been driftwood from further west: Ramsay (in Wickham-Jones et al., 2017, 34) reported one fragment. A dry terrace surface may explain the low pollen percentages and inferred limited establishment of *Alnus* (alder).

Above 52 cm depth the local woodland was transformed, with the probable loss of *Salix*, the demise of the local *Quercus* population, and *Pinus*, locally or in the vicinity, and the expansion to dominance of *Betula* woodland: proportions of *Betula* pollen at Nethermills are comparable with those inside present-day *Betula* woods in western Scotland (Birks, 1973, 1980). It is likely that *Betula* replaced *Quercus* on the terrace, which then continued to dominate without the successional re-establishment of more competitive trees. This was site-specific: it is not a widely observed feature of mid-Holocene Scottish pollen records (Tipping, 1994). *Betula* and *Quercus* commonly grow together In the Scottish Highlands. Something like McVean's (1964, 151) herb-rich birch and oakwood association or *Quercus petraea*–*Betula pubescens*–*Oxalis acetosella* woodland (Humphrey and Swaine, 1997a) grew locally, quite densely, on acid mineral soils derived from base-poor sand. Increasing soil acidification may explain the vegetation change. Humphrey and Swaine (1997a, b) explored, in the woods of mid-Deeside, grazing-independent biological stresses on *Quercus* regeneration, including seedling suppression by bracken (*Pteridium*) and insect defoliation, but neither can be demonstrated palaeoecologically. The terrace surface may have become drier since *Sphagnum* and *Salix* declined, which would not have favoured *Betula*. This may have affected peat accumulation rates and chronological estimates, however: a very large increase in arboreal pollen concentrations above 50 cm depth may reflect much slower peat accumulation. This, and because palynological dating controls cannot be applied to the peat after circa 6500 cal BC (above), make uncertain the timing of this change. It is not known whether the closely comparable, earliest Neolithic ^{14}C age estimates for *Betula* wood in channels A and B (Table 2), and four assays from *Betula* wood in pit complexes C and W and yielding a combined age-range at 95.4% probability of 3933-3653 cal BC (Table 2; Wickham-Jones et al., 2017, table 9), provide a better estimate of local *Betula* expansion but this is a reasonable inference. The assays from pit complexes C and W also date early Neolithic anthropogenic activity. Poaceae pollen percentages did not significantly increase when *Betula* began to dominate. Disturbance to the ground flora above 48 cm depth, not necessarily purposeful, probably allowed open-ground herbs such as taxa within the Apiaceae (parsley family), the Caryophyllaceae (pinks) and the grazing indicator, ribwort plantain (*Plantago lanceolata*), to become more common.

Lithic distribution

Around 30 000 lithics, almost all flint, have been retrieved during repeated fieldwalking (Figures 8, 9). Almost all age-diagnostic lithics are Mesolithic: Wickham-Jones et al. (2017) noted how few were post-Mesolithic. The lithic distribution closely accords with the Camphill Terrace surface. In Field NM2 (Figure 8), where the Maryfield, Camphill and Maryculter terrace surfaces were walked equally, the older Maryfield Terrace had far fewer lithics than the Camphill Terrace: the Maryculter Terrace surface is much younger than the Mesolithic. In Fields NM3 and 4, the lithic distribution is across the full width of the Camphill Terrace but is not uniform (Figure 9). The north-south alignment of lithics is a bias introduced in field-walking, but there are patterns related to what today are quite subtle topographic features: concentration (1) is on a low ridge, emphasised by the Late Devensian channel A immediately to the west; concentration (2) is on the levee to the River Dee, which attracted Kenworthy; at (3) lithics appear to lie either side of channel D. Lithics are scarce across the summit of the gravel ridge (4). Field NM5 has been walked less because recent flood sediments bury underlying sediment.

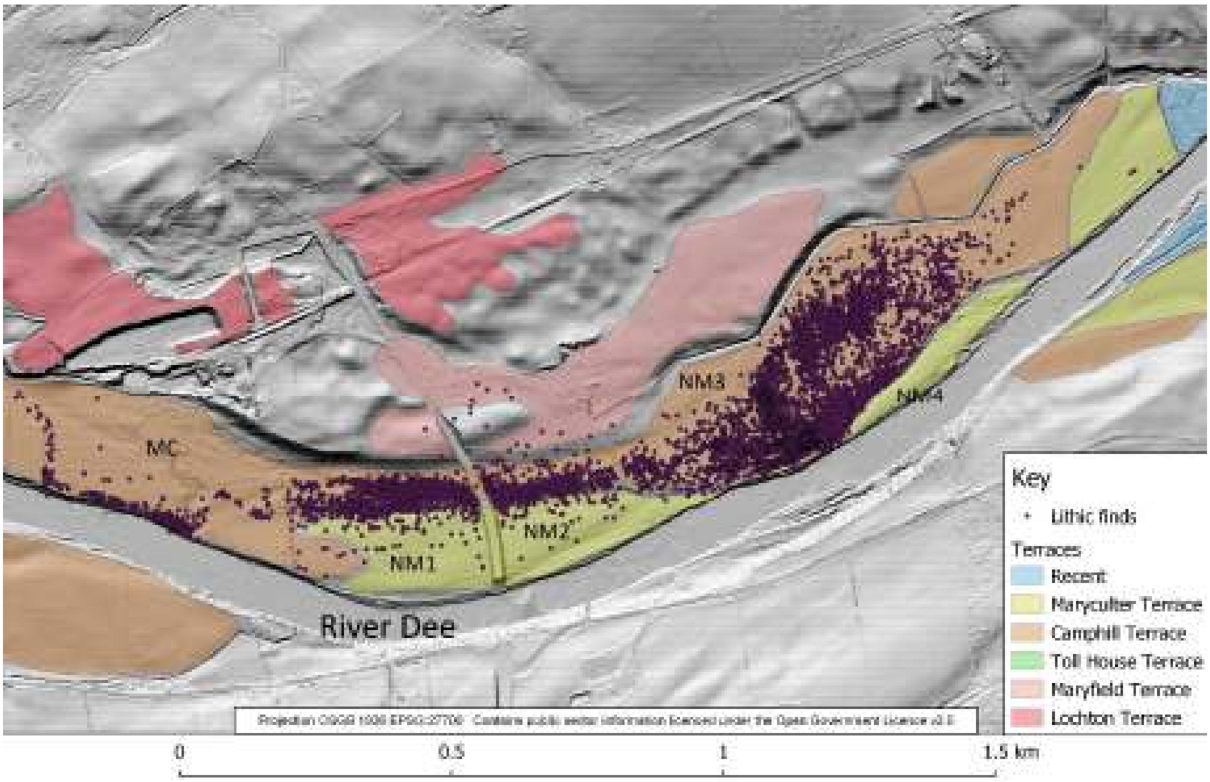

Figure 8: Distribution of lithics recovered by field-walking in Fields MC to NM4 in relation to the river terrace stratigraphy. (COLOUR)

Discussion

This section attempts a narrative of environmental change for the Camphill Terrace in Field NM4. The coarse gravel underlying the Camphill Terrace surface is likely to represent the bedload of a sediment-charged braided river (Vandenberghe, 2015) deposited in a late stage in deglaciation. The upper metre or so of sand-rich gravel may have been constructed later, when sand was more abundant. The small but important assemblage of probable LUP flints is from ploughed soil, but unless they were derived from elsewhere, a surface existed before or in the Windermere Interstadial circa 13500-11500 cal BC onto which they were dropped. These lithics have been displaced, however, because in TP201, a possible LUP end-scraper lay in the soil above sands which OSL profiling suggest are younger (Table 3; below). This is true also to an extent for the thousands of Mesolithic flints. Age-diagnostic lithics in the ploughed soil have no precise relation to underlying stratified sediment but it is likely that the LUP lithics were dropped onto the gravel bar.

Deposition of the gravel bar may, at least in part, have continued into the Younger Dryas. A series of parallel, narrow channels (D-A) transporting sand was formed in gravel-lined swales at this time on a northward-prograding lateral bar of a meandering river that flowed east in the 75 m wide, shallow valley between the gravel ridge and older, Maryfield Terrace gravels. It is not known how large this river was, whether it was the sole channel or whether there were other channels south of the gravel ridge.

The oldest gravel from OSL profiling (Table 3) is in this broad channel, at TP65, either within channel A or on a floodplain. OSL net signal intensities >80% are very likely to date to the Greenlandian Stage of the Holocene before circa 6300 cal BC (Walker et al., 2018). Around 40 cm of sand then accumulated at TP65, very rapidly from the evidence of the OSL profiling (Figure 7) before peat grew above it. Deposition of sand at TP65 was probably contemporary with peat formation in channel D. Peat formed in channels A and D for any number of reasons: increasing biomass and productivity of aquatic and marsh plants to rapid thermal amelioration (Brooks et al., 2012), reduced discharge driven by evapo-transpiration increases (Pastre et al., 2003), paludification through groundwater rise in response to increased effective precipitation (Bohncke, 1993; Bohncke et al. 1988), channel abandonment (Gibbard and Lewin, 2002; Turner et al., 2013) or incision below the Camphill Terrace surface, a common fluvial response at the Younger Dryas-Holocene boundary (Vandenberghe, 2015).

With peat formation, significant transport of sand to the northern sand sheet ceased. Peat in channels A and B may have become drier after circa 7500 cal BC. There is evidence for a very long hiatus in sand deposition. In TP28 the deepest profiled sand has an OSL net signal intensity only 26% that of the oldest sand in TP42 (Table 3): this sand probably dates to the later Northgrippian or Meghalayan Stages, in later prehistory. Older fluvial sediment may lie beneath those sampled, but sand is not common in the early-mid Holocene peats of channels A and D. The fill of the anthropogenic cut close to the apex of the gravel bar at TP68 has not been eroded since it was made in the 7th millennium cal BC, although gravel on parts of the bar have formed at TPs 38, 39, 28 and 11 in the last few thousand years (Table 3 [4]). The *Quercus* charcoal ^{14}C dated to 5355-5217 cal BC (Poz-69106: Table 2) is associated with probable anthropogenic features, and pit complexes C and W, of early Neolithic age have also survived just below the ploughed soil (Wickham-Jones *et al* 2017). Fluvial sediment of Mesolithic age is generally rare in the British Isles (Macklin et al. 2010) although it is also less likely to be discovered because of its age (Lewin and Macklin, 2003). Paterson and Lacaille (1936) recorded flood-generated sand contemporary with Mesolithic anthropogenic activity at Birkwood, 5 km upstream, but the location of this excavation is frustratingly vague. From the evidence at Nethermills, it is very likely that the Camphill Terrace was not the active floodplain of the Dee throughout the Mesolithic, and that incision below the terrace surface had occurred, probably in the early Holocene, contrasting with interpretation downstream at Milltimber in which abandonment of the Camphill Terrace, though poorly temporally constrained, was seen as a later prehistoric event (Tipping, 2019). The active channel/s in the Mesolithic are likely to have lain where the present channel is, confined (cf. Lewin and Brindle, 1977) to the south bank, an unknown depth below the Camphill Terrace surface.

Soils formed, since destroyed by ploughing. These supported plant communities with dryland herbs, although trees and shrubs on the terrace surface before circa 8000 cal BC, *Betula* and *Salix*, are commonly seen as growing on wetland soils. These plant communities, or these conditions, seem to have excluded *Corylus* from the terrace surface. *Quercus* probably colonised the terrace surface after circa 7000 cal BC. The low percentages of *Alnus* pollen suggests this wetland tree could not compete with other trees on what had become a quite dry terrace surface (Boyd and Kenworthy, 1982).

It was this dry terrace surface, its morphology almost fully formed before the 7th millennium cal BC, that Mesolithic communities visited, probably frequently over a long time (Wickham-Jones et al., 2017). Incision from the Camphill Terrace, though poorly defined, probably protected the archaeology from erosion (cf. Jochim 2011). A dry Camphill Terrace in the Mesolithic might imply that people could work lithics anywhere on its surface, but the lithic distribution is not uniform (above; Figure 9). Processes controlling this pattern are not well understood. Being from ploughed soil, no flint at Nethermills is precisely *in situ* and there has been vertical displacement (cf. Barrowman, 2003), and most probably lateral displacement, easiest to envisage for the few LUP lithics clustered on the southern edge of the gravel bar and pushed across the southern sand sheet (above), harder but probably necessary to visualise for the entire assemblage. Another process is flooding of the terrace surface. The impact of Storm Frank (winter 2015) on the floodplain was seemingly limited despite peak discharge being 28 times normal and a water depth of several metres (Fieman et al., 2020) but this cannot be assumed for all past floods: since AD1900 there have been 20 floods that had water depths along the Nethermills reach greater than three metres higher than the normal water surface (McEwen, 2000). Thin spreads of gravel and sand across the Camphill Terrace surface (Table 3) probably represent flood sediment. Erosion of sediment and lithics during floods might explain some features of the lithic distribution, such as the scarcity of lithics in channel D, which would channel floodwater, and on the higher ground of the gravel bar (Figure 9). However, the Mesolithic peat in channel D survives, the gravel bar at TP68 has not been truncated, and concentrations of lithics survive on equally exposed sand levees and ridges (concentrations 1 and 2). Something of the original lithic distribution is still present, shaped by small-scale variations in topography and sediment. People seem not to have worked lithics in peat-filled channels but on their edges. Mesolithic artefacts will have been buried in these channels by later-forming peat, which might affect the lithic distribution but all lithics are from ploughed soil, having the same probability of being collected. People at Nethermills were drawn to the Dee: Kenney (1993) noted that most lithic scatters throughout lower Deeside are within 100 m of the river. What specifically drew them is unknown; acid soils have not preserved bone. And although reconstruction of the Camphill Terrace surface is now much more detailed, we do not know where the River Dee was in the Mesolithic. We can surmise it was where it is now but how far it incised below the Camphill Terrace surface is unknown. We also do not know what the valley floor looked like and what resources it offered, beyond the very general (Tipping 2019, 32-37). It is likely that the increased evidence for flood sediment in the last few thousand years (Table 3) was a product of the Maryculter Terrace fill aggrading (rising) to approach the Camphill Terrace, but from what depth?

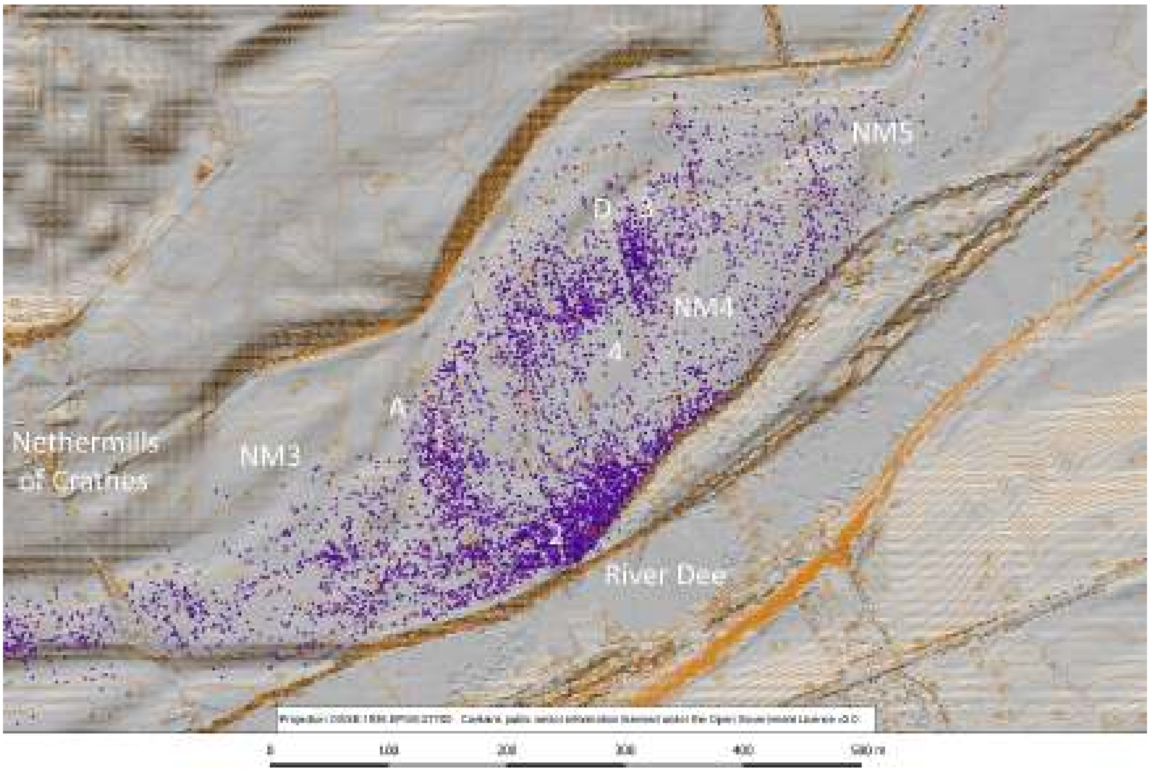

Figure 9: LiDAR image plotting the distribution of individual lithics recovered from field-walking in Fields NM3 and NM4. Channels A and D are marked as are scatters at 1, 2, 3 and 4 discussed in the text. Contours are plotted at 0.5m intervals. (COLOUR)

There is little evidence other than digging pits (e.g. pit complex C) for Neolithic human activity (Wickham-Jones et al., 2017) although archaeological evidence for early Neolithic settlement and land use close to Nethermills of Crathes along the River Dee, on dryer soils, is exceptional in the British Isles (Dingwall et al., 2019; Fairweather and Ralston 1993; Murray and Murray 2014; Murray et al. 2009; Tipping et al., 2009). At Nethermills of Crathes, birch (*Betula*) trees probably replaced oak (*Quercus*) trees on the terrace surface at a date that is poorly constrained but argued to have been early in the Neolithic. The replacement of one tree genus by another is not readily interpreted as anthropogenic and is thought to have been pedological in cause (above). Grazing within the *Betula* woodland did not reduce the tree cover. The resources that attracted hunter-gatherer-fishers in the Mesolithic seem not to have drawn early farmers to Nethermills.

Conclusions

Mesolithic hunter-gatherer-fisher communities were strongly attracted to the banks of one of Scotland's largest rivers, the River Dee, draining to the North Sea. Several very large lithic assemblages have been found along the lower course of the river. Nearly all lie on one river terrace close to the water surface, the Camphill Terrace. An understanding of the chronology and depositional environments of the Dee terraces has until now been inadequate to explain how difficult occupation of this surface was. In this paper we have drawn on the results of archaeological excavation and repeated field-walking for lithics, the accumulation in space and over time of a thin veneer of postglacial fluvial sediments by OSL profiling, interpretation of pollen analyses and charred plant macrofossils, and AMS ^{14}C dating. The terrace, glaciofluvial in origin, continued to be the active valley floor into the Devensian Lateglacial. Accumulation of gravel bars and sand sheets is probably a product of meandering channels at that time. It is likely that the deposition of Late Upper Palaeolithic flints, very rare in Scotland, was on or close to an aggrading gravel bar. From the earliest Holocene, the environment changed sharply. Peat grew in narrow channels no longer hydrologically active and deposition of sand across the terrace all but ceased. Quite dense woodland was established on the terrace surface which eventually had the character of dry, terrestrial soils. We interpret the early-mid Holocene environment of the terrace surface as dry, as the Camphill Terrace was incised by the river. As a measure of Mesolithic resources, proximity to water alone is insufficient to understand the subtlety of the relation: geoarchaeological work of the kind presented here is necessary. Even so, we have not yet established the timing of this change, only its effects. Mesolithic communities, over several thousand years, re-visited this dry wooded terrace surface, making it a 'persistent place' (Barton et al., 1995), without significantly altering it, their main interest being in what the river had to offer in resources and communication. Those resources are yet to be documented for the River Dee in the Mesolithic, as elsewhere. This level of environmental reconstruction has yet to be applied to comparable river terrace environments in Scotland.

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