5 ENVIRONMENTAL ANALYSIS

5.1 Waterlogged wood, by Michael Cressey

5.1.1 Introduction

The brushwood assemblage was examined in the laboratory and all tooled wood extracted from the parent sample (see Section 3.2.1). A collection of non-tooled wood (105) was randomly sampled and added to the assemblage for analysis. The samples were frozen for 24 hours at –10°Celsius. Micro-thin sections were obtained from the frozen transverse sections and identified using a Nikon compound microscope at ×40–100. Where required, keys listed in Schweingruber (1990) were examined. Identification was carried out on transverse sections at ×10–40 magnification using a binocular microscope. Observations on the morphology of the material included age and diameter measurements, as well as side-shoot trimming and tool mark identification.

Twenty-one individual samples from the lattice work (context 108) were sub-sampled and identified according to the methods above. The preservation of much of this assemblage in comparison to the brushwood was poor, possibly due to the latter being more waterlogged.

5.1.2 Branchwood species composition

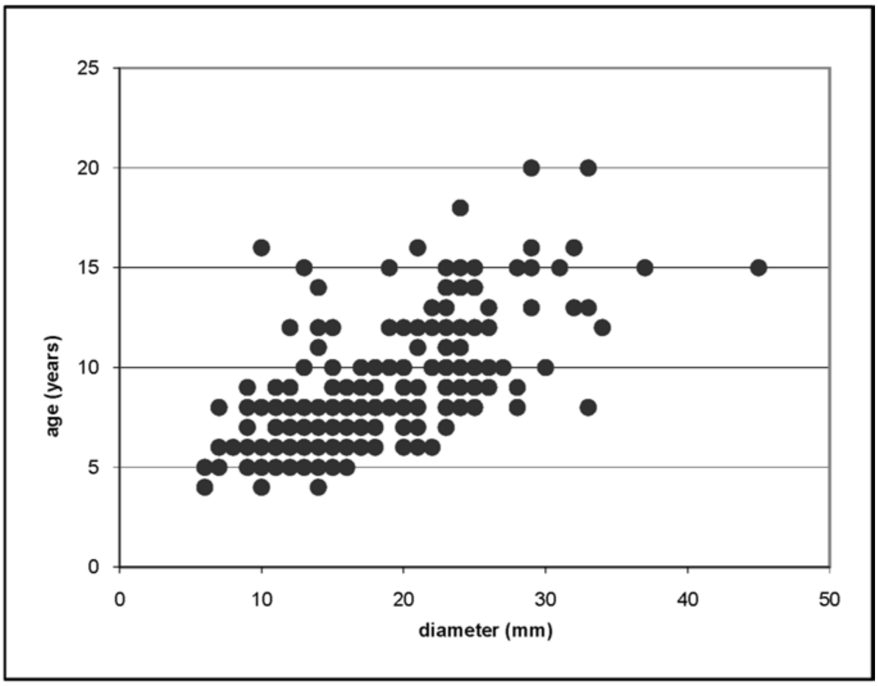
Three species of wood are represented in the total assemblage, which includes 296 individual identifications. *Corylus avellana* (Hazel) dominates the assemblage (291 identifications). *Betula pendula* (Silver Birch) and *Quercus* sp. (Oak) are represented by only three and two samples respectively.

5.1.3 Lattice structure species composition

Twenty-one samples obtained from the lattice structure were identifiable to species. The dimensions of the individual members making up the structure varied greatly. Fourteen samples from the lattice structure were exploited from Birch trees; two of the samples were of large enough stature to have originated from tree-trunks rather than smaller diameter branchwood. Two samples were identified as Alder, with one Hazel and one Ash. Most had been affected by compression owing to close contact with the road metalling. The species present (Table 1) in order of abundance are *Betula* (Birch n=14), *Alnus glutinosa* (Alder n=4), *Fraxinus* sp (Ash n=1)

Table1 Species composition of the lattice structure in illus 6

Sample No	Species	Dimensions (diameter mm)
108/1	*Betula*	150 × 125
108/2	*Corylus*	81 × 39
108/3	*Betula*	103 × 84
108/4	*Alnus*	117 × 114
108/5	*Betula*	105 × 95
108/6	*Betula*	91 × 46
108/7	*Betula*	113 × 50
108/8	*Betula*	50 × 48
108/9	*Betula*	86 × 59
108/10	*Betula?*	94 × 73
108/11	*Betula*	98 × 56
108/12	*Alnus*	76 × 68
108/13	*Alnus*	95 × 53
108/14	*Betula*	117 × 88
108/17	*Alnus*	61 × 68
108/18	*Betula*	144 × 128
108/19	*Fraxinus*	106 × 59
108/20	*Betula*	106 × 53
108/21	*Betula*	100 × 80
108/22	*Betula*	112 × 73



Illus 7 Age versus diameter plot for the brushwood mat (105)

and *Corylus* (Hazel n=1). The largest, in terms of diameter, were samples 108/1 and 108/18 which can be classified as trunk wood rather than the smaller diameter branchwood.

5.1.4 Tooled wood

One hundred and twenty-one samples obtained from the brushwood contained evidence of cut marks in the form of oblique facets that measured between 12mm and 74mm. There is no precise way of knowing exactly what tool was used to procure the branchwood but a bill-hook or axe seems probable.

5.1.5 Wood selection

The presence of holes from the death-watch beetle (*Xestobium rufovillosum*) within the wood samples confirms that dead wood was used in the construction of the lattice structure. The death-watch beetle is a common insect that inhabits dead wood or the branches or trunks of a number of hardwood trees where fungal decay has commenced. The beetle is most common in the south of England, but from the Midlands northwards it becomes progressively rarer, and is now absent from Scotland. It is known from only two localities in Ireland.

Several curving heels were identified within the assemblage and these are features usually associated with coppice woodland *sensu stricto*, however Hazel woodland in its natural unmodified state is a low-statured understorey shrub that will self-coppice and form curved heels from the base of its stool.

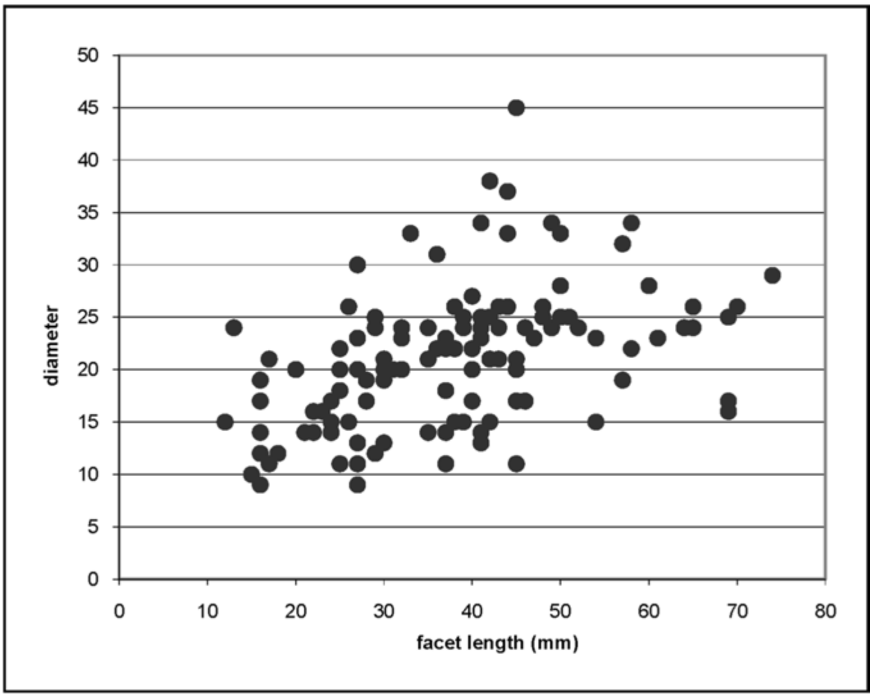
The degree of variability in the size of the wood from the lattice structure is indicative of an ad hoc collection method. Rather than just selective felling of trees of a similar size and maturity both dead branchwood, and in the case of the lattice material, felling of green wood was probably employed.

The age versus diameter plot (illus 7) shows that there is no correlation between these two parameters within the sample. This variability confirms that branchwood has been exploited by draw-felling; that is, there was no selective felling for size, but rather wood of any size was collected and/or felled for the construction of the lattice structure. Similarly there is no correlation between facet length of the cut mark and diameter of the wood (illus 8), diameter being used as a proxy for age. One may expect that if the wood came from a managed woodland then a process of selection and harvesting would be reflected in the method of harvesting. In this case it appears there is no uniformity in the way the wood was harvested.

5.2 Radiocarbon dating

The results of the radiocarbon dating from the lattice and brushwood elements of the road are shown in Table 2, and fit with the suspected date range for the construction of the road as interpreted from other lines of evidence.

The dates for the lattice framework were returned from samples of Birch wood and from branchwood



Illus 8 Diameter versus facet or cut-mark length for the brushwood (105) sample

Table 2 Calibrated radiocarbon dates for the lattice and brushwood mat

Context	Sample code	Age BP	Cal Age (1σ)	Cal Age (2σ)	$^{13}C/^{12}C$ Ratio
108/1 lattice framework	SUERC-20196	1895±30	65–135 AD	50–220 AD	–25.4
108/18 lattice framework	SUERC-20197	1930±30	25–125 AD	0–140 AD	–26.2
105 brushwood mat	SUERC-20198	1955±30	5–80 AD	40 BC–130 AD	–28.2
105 brushwood mat	SUERC-20199	1930±30	25–125 AD	0–140 AD	–27.6

samples of Hazel. The presence of holes within some of the (undated) wood samples made by the death watch beetle demonstrates that some dead wood was used in the construction of the lattice framework. How long the wood was dead before its use cannot be ascertained, but it can be assumed that the wood collected had not become too waterlogged or decayed to use in construction. It is likely then that the dated material reflects the construction timeframe of the lattice structure, and by extension the construction of the upper layers of the road, and that this falls within the period 40 Cal BC to 220 Cal AD.

5.3 Other organic material, by Jacqui Huntley and Michael Cressey

Concentrated around the north-east corner of the sample grid were discrete patches of black fibrous material. This material was found in small clumps trapped within the matrix of the brushwood.

The material has been identified as a monocot stem and the black fibrous bits as sclerenchymatous bundles. At ×400 there are some parenchymatous cells in between these bundles. The cells contain quite strong papillae, giving them a wavy appearance, and this is common in some sedges and rushes. The cells are square to slightly rectangular rather than distinctly rectangular. Several of the bundles have strongly ridged stems where the ridges are formed from sclerenchymatous bundles. The stems are flattened and there is no clear angle, possibly suggesting that they were round originally, rather than the triangular form typical of sedges. Also they are quite thin and 'clean' on the inside, possibly a result of internal pith having rotted away. Sedges have a much more robust stem throughout on the whole, so the most likely identification would appear to be cf Juncaceae (rushes).

Similar material, made of moss, is recorded at Buiston Crannog, Ayrshire (Crone 2000) and interpreted as cordage. Whether these rushes were used as cordage to tie up bundles of brushwood or were simply an intrusive material within the brushwood can only be speculated upon. However, given the advantage of handling and transporting bundles of wood rather than loose branches, it is likely that the brushwood was bundled and tied prior to use.

5.4 Soil micromorphology, by Clare Ellis

5.4.1 Aims

The aims of this analysis were to determine the nature of the deposits and their mode of formation and accumulation of the deposits.

5.4.2 Methodology

The samples were prepared for thin section analysis by G. McLeod at the Department of Environmental Science, University of Stirling using the methods of Murphy (1986). Water was removed and replaced by acetone exchange and then impregnated under vacuum using polyester crystic resin and a catalyst. The blocks were cured for up to four weeks, sliced and bonded to glass and precision lapped to 30μm with a cover slip. The samples were assessed using a MEIJI ML9200 polarising microscope following the principles of Bullock et al (1985), FitzPatrick (1993) and Stoops (2003). A range of magnifications (40×–400×) and constant light sources (plane polarised light – PPL; cross-polars – CPL; circular polarised light and oblique incident light – OIL) were used in the analysis.

5.4.3 Summary description

The samples were recovered from the lower portion of the north-west-facing section of the road (illus 5a, tin 5). Sample 5.1 largely comprised Unit 2 (114), a well humified peat with woody and fibrous plant remains and a minimal silt content; Sample 5.2 was unfortunately dominated by a large piece of wood (wood of Unit 3, contexts 105 and 107). Despite the peat having been re-worked by soil biota, which had resulted in a welded granular microstructure (Dawod & FitzPatrick 1992), there was a distinct slightly dipping preferred orientation to much of the fibrous organic material. The lower unit, Unit 1 (112), was only observed in Sample 5.1 and was dominated by a single large rock fragment. This was set within a moderately sorted sand with a silty organic matrix. This unit had also been affected by the post-depositional activities of soil biota. Units 1 and 2 contained very rare charcoal fragments.

5.4.4 Mode of formation and accumulation

Unfortunately because of the limited survival of Unit 1 (112) in Sample 5.1 it has not been possible to determine the mode of formation of this deposit. The juxtaposition of one large clast surrounded by sand-sized grains of different rock lithologies suggests a mixed source, either eroding bedrock such as a greywacke, or an eroding till. Given that Unit 1 (112) is capped by peat deposit 113, it is very unlikely that it is a product of the in situ physico-weathering of bedrock; rather it may have resulted from localised and relatively powerful fluvial deposition caused, perhaps, after a sudden or prolonged downpour; alternatively it is possible it may have been deliberately spread. The boundary between Unit 1 and Unit 2 was sharp and prominent, indicative of a rapid change in the depositional environment. The peat (Unit 2) has been extensively re-worked by soil biota, demonstrating that although damp the deposit cannot have been continuously waterlogged following its accumulation.

The gradual accumulation of this organic layer within a damp, probably periodically water-filled hollow, is clear from the slight preferred orientation exhibited by much of the elongated fibrous organic matter towards the base of the hollow. The presence of roots through the peat indicates in situ growth of plant matter, although some of the organic matter is detrital in origin.

5.5 Pollen analysis, by Robert McCulloch

5.5.1 Introduction

This report describes the detailed study of the gross stratigraphical and fossil pollen records for two profiles from Dun Law. On-site sampling methods are described above (Section 3.2.3).

The peat/organic-rich sediments were sampled for palaeoenvironmental analyses to reconstruct the past vegetation and land use changes at Dun Law and to provide an environmental context for Dere Street. The initial assessment of the potential palaeoenvironmental records at both sites suggested that Dun Law 3 (machine-cut trench) spanned the period *c* 4600 ^{14}C yrs BP to present and Dun Law 113 (section below the road) spanned the period *c* 5700 ^{14}C yrs BP to the construction of Dere Street at *c* 1950 ^{14}C yrs BP. The analysis of both sections would, therefore, depict the landscape changes and potential human agency from *c* 5700 ^{14}C yrs BP to present at Dun Law and especially for the period leading up to, during and after the construction of Dere Street.

The original aims of the study reported here are, therefore, straightforward. The assessment stage (McCulloch 2009) demonstrated the age-spans of the two profiles, and the aim of the analysis was to establish the continuity and rate of sediment accumulation at each site using further Accelerator Mass Spectrometry (AMS) radiocarbon dating and potential biostratigraphical horizons. Pollen samples were taken at closely spaced intervals throughout each profile to establish a high-resolution record of vegetation change. Pollen analysis remains the most powerful technique for reconstructing the vegetation history: 'No other technique provides the two key elements of being able to synthesise patterns of vegetation in space and time' (Tipping 1994, 2). The degree of organic humification was also analysed to construct a further proxy to establish the role of climatic change in driving vegetation changes and so help to separate the natural and human agencies in forming the landscape. The close proximity of the archaeology of Dere Street to the stratified organic deposits at Dun Law is an extremely rare situation that allows us to view human activity and landscape change at a high spatial resolution. Commonly, palaeoenvironmental records are either too distant from the archaeology and so can provide only a broad-scale backdrop of landscape change, or they are constructed from unstratified remains and so limit the reconstruction of a continuous sequence.

The results of these analyses are presented here, first in isolation and then secondly in an extended local context, and finally conclude with a summary of the key findings of this research.

5.5.2 Radiocarbon dating

Method

Twelve samples were selected for Accelerator Mass Spectrometry (AMS) dating, four of which derived from the brushwood matting (105) and lattice structure (108) of the road (see Section 5.2), the other eight from the sediment sequences (Dun Law 113 and 3). These samples were picked in order to establish the overall chronology of the sediment sequences and road construction event. The dates provide a maximum age constraint for the construction of the metalled road surface above Dun Law 113 and a minimum age constraint for the environmental record beneath.

Age–depth models constructed from the data in Table 3 using linear interpolation have been applied to the stratigraphical records and used to plot the secondary age axis for illus 9.

Two samples were from a large piece of trunk wood of *Betula* sp. (Birch) used as part of a lattice framework. Another two samples were from the brushwood matting of *Corylus avellana* (Hazel). The dated sample material (Dun Law 113 and 3) was bulk humified organic-rich sediments as they were considered to be more likely to reflect the age of their host horizon. Samples were analysed by Beta Radiocarbon Laboratories in Miami, Florida and at the Scottish Universities Environmental Research Centre (SUERC), East Kilbride, Scotland.

Results

All AMS ages increase with depth except for a stratigraphical reversal in ages in Dun Law 3 towards the base with the age of 5365±35 ^{14}C yrs BP being older than the basal sample age of 4610±40 ^{14}C yrs BP (cf Table 2). There are a number of reasons for age reversals in date sequences; it may be that younger material was carried downwards during the sampling of the open section in the field or erosion and reworking of sediments in the catchment surrounding the basin has introduced older carbon to the sample site. Several age–depth models were explored for Dun Law 3, first including the age of 5365 ^{14}C yrs BP at 164cm and excluding the basal age of 4610 ^{14}C yrs BP. This yielded an extrapolated basal age of *c* 7500 ^{14}C yrs BP. A second model excluded the *older* age from the sequence and retained the basal age of 4,610 ^{14}C yrs BP. Comparison of the organic content profiles (illus 9) suggests that the older age model distorted the biostratigraphical 'fit' and so the second age–depth model using the basal age of 4610 ^{14}C yrs BP is accepted and the older age of 5365±35 ^{14}C yrs BP is excluded from the age–depth model. The linear age–depth model suggests that the Dun Law 3 profile spans the period of *c* 4500 ^{14}C yrs BP to present.

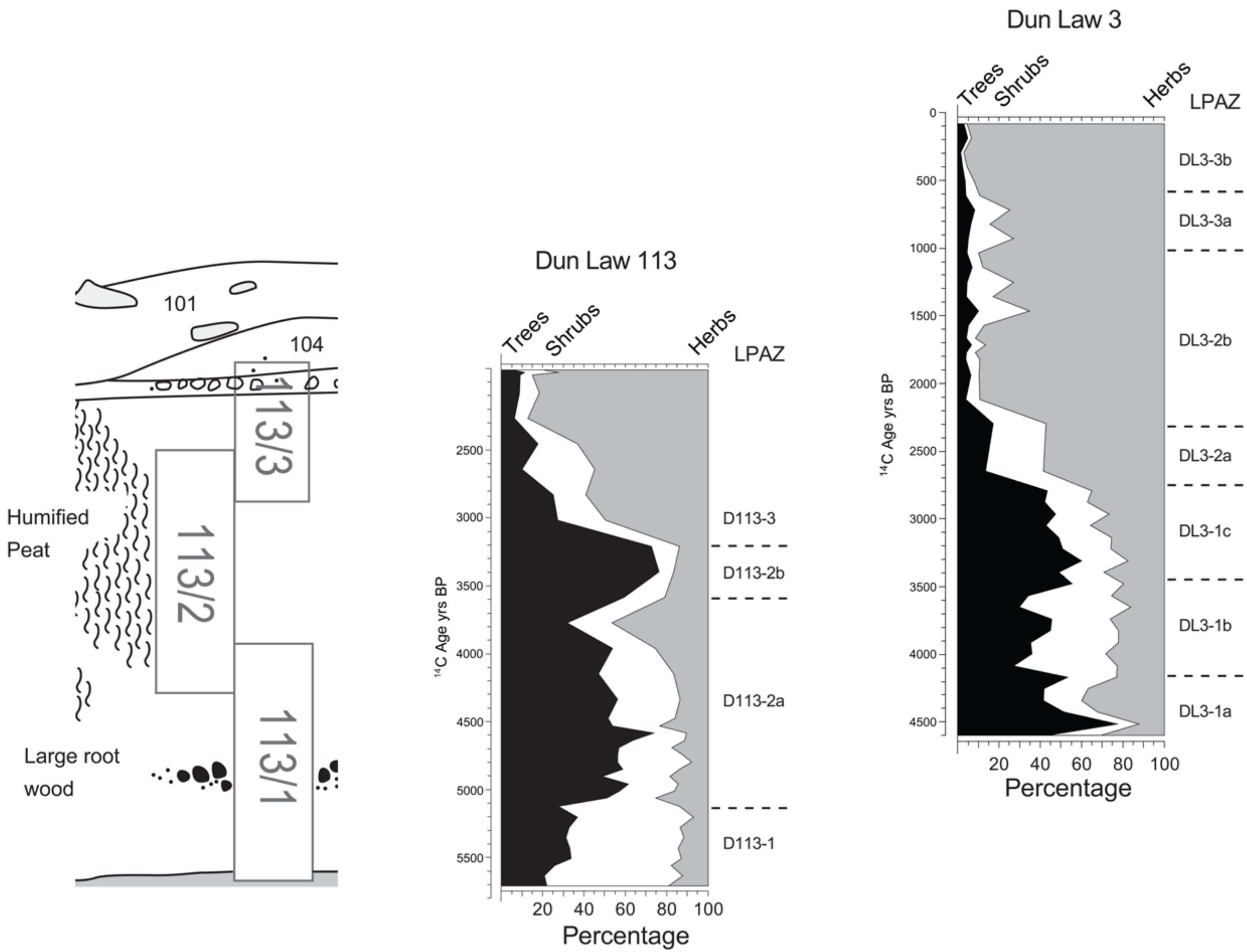
5.5.3 Organic content

Method

To reconstruct the bio-productivity of each site the percentage organic content of each profile was measured. The bio-productivity is a function of the

Table 3 Calibrated radiocarbon dates for the pollen sequences (* dates from wood)

Context	Sample code	Age BP	Cal Age (1σ)	Cal Age (2σ)	13C/12C Ratio
Dun Law 113					
0–1	SUERC-20196*	1895±30	65–135 AD	50–220 AD	–25.4 ‰
10–11	SUERC-20198*	1955±30	5–80 AD	40BC–130 AD	–28.2 ‰
49–50	Beta-256719	4460±40	3330–3020 BC	3350–2960 BC	–27.4 ‰
85–86	SUERC-24032	5100±35	3960–3800 BC	3970–3790 BC	–29.6 ‰
108.5–109.5	Beta-256718	5710±50	4620–4460 BC	4690–4450 BC	–27.0 ‰
Dun Law 3					
62–63	SUERC-24029	1650±35	340–430 AD	260–540 AD	–28.5 ‰
77–78	SUERC-24030	1850±35	125–225 AD	70–240 AD	–28.6 ‰
98–99	Beta-256721	2760±40	970–840 BC	1010–820 BC	–27.6 ‰
163–164	SUERC-24031	(5365±35)	(4330–4070 BC)	(4330–4050 BC)	–28.3 ‰
184–185	Beta-256720	4610±40	3500–3340 BC	3520–3120 BC	–28.3 ‰



Illus 9   Dun Law pollen summary

degree of plant growth, which in turn is related to the climate record (humidity, temperature), the degree of preservation of the plant material (related to surface wetness) and sediment supply (the erosion, transport and deposition of mineral matter, soil and organic material).

Contiguous samples of 1cm depth were combusted in a muffle furnace at 550°C for four hours. The Loss-On-Ignition (LOI) enabled the calculation of the percentage organic content for each sample. One hundred and eleven samples from Dun Law 113 and 185 samples from Dun Law 3 were measured.

Results

Changes in the percentage organic matter with depth through the profiles as measured by LOI show a highly variable pattern of sedimentation at each site. However, within this gross pattern there are more subtle changes. At the base of Dun Law 113 is a weathered substrate that grades into a 2–3cm thick band of mineral-rich soil with % LOI of less than 10%. Overlying this basal layer the sediments increase in organic content to approximately 60% with episodic inputs of fine- and medium-grained sands and silts. This continues to 52cm depth in the profile. Between 52cm and 7cm depth the organic content increases overall but also peaks to over 80% during three separate intervals (*c* 47cm, 30cm and 10cm). The organic sequence is truncated by the road armouring above 7cm.

The percentage organic profile of Dun Law 3 reflects the tri-part pattern of peaks in organic content at Dun Law 113. The Dun Law 3 peaks occur between 184–165cm, 110–96cm and 60cm upwards. The final peak is not truncated and so the organic-rich sediments/peats continued to accumulate up until the present. The matched phasing of the tri-part peaks in organic accumulation at both sites is broadly supported by the radiocarbon dating which suggests that the increase in organic content started at *c* 4500 ^{14}C yrs BP. The current age–depth constraints do not support the close correlation of each event. The episodes of increased organic production and/or preservation may have been asynchronous, though this is less persuasive. However, further AMS dating would be required to confirm the age–depth models for both sites.

5.5.4 Peat humification

Method

The degree of peat humification, as a proxy measure for mire surface wetness, was measured using a modified alkali extract method (Blackford 1993). Under drier conditions organic matter is more oxidised, the rate of accumulation is slower and there is an increase in humic material. Under wetter conditions the rate of organic growth increases, organic material is better preserved under anoxic conditions and less humic material is produced. Approximately 2cm^3 of sample material was dried at 60°C for 24 hours. To obtain a relatively homogeneous sample the dry sample was ground and 0.2g of the ground material was sub-sampled into a 50ml centrifuge tube. Each sample had 50ml of NaOH 8% w/v added to it and the tubes were placed in a boiling bath for one hour and intermittently stirred.

After one hour the tubes were removed from the boiling bath and the particulate material separated from the supernatant. A 0.5ml aliquot was pipetted into a 10mm quartz cuvette and 2.5ml distilled water added. The cuvette was analysed in a spectrophotometer and the % transmitted light measured at 540ηm. The greater the humic content the darker the extract solution and lower transmitted light values. Therefore, a low-percentage transmission value indicates drier conditions, whereas high transmission suggests wetter conditions. One hundred and nine samples from Dun Law 113 and 184 samples from Dun Law 3 were measured.

Results

The data show a high degree of variability in the amplitude of high-frequency oscillations in both Dun Law 113 and Dun Law 3. Comparison of the percentage transmission values suggests that the record of mire-surface-wetness has been affected by the episodic input of mineral material, which has had a dilutional effect. To counter this, the % transmission values have been corrected using the LOI data and then smoothed by calculating a 3-point moving average.

The smoothed data demonstrate that the % transmission values are consistently low, suggesting a relatively dry environment with very minor (less than 10% variation) fluctuations in values. Dun Law 3 shows a gradual increase in the percentage transmission values above approximately 30cm depth. This may suggest an increase in surface wetness, though the close proximity to the surface may also account for an increase in unhumified material.

5.5.5 Pollen separation and analysis

Method

Sub-samples of 1cc were taken at 4cm (approximately 80–100 yr) intervals from Dun Law 3 and at 3cm (approximately 65–80 yr) intervals from Dun Law 113 and prepared in the Palaeoecology Laboratory at the School of Biological & Environmental Science, University of Stirling, using standard pollen preparation procedures (Moore et al 1991). To enable the assessment of the total concentrations of pollen in each sample, tablets containing *Lycopodium clavatum* spores of known concentration were added to each sample and the spores counted alongside the fossil pollen (Stockmarr 1971). Pollen was identified using an Olympus BX40 light microscope at ×400 magnification with critical identifications made at ×800 and assisted by a pollen reference collection and photomicrographs (Moore et al 1991). For the pollen assessment a Total Land Pollen sum of ≥ 100 pollen grains was obtained for each sample.

To provide information about the depositional environment of the pollen each grain was assessed for its state of preservation using five categories: normal, broken, crumpled, corroded and degraded (Berglund & Ralska-Jasiewiczowa 1986; Tipping 1987). Grains that are broken and/or crumpled are likely to indicate damage due to mechanical processes such as through abrasion during transport. Pollen is best preserved in waterlogged (anaerobic) and acidic conditions and so corrosion and degradation suggest chemical processes whereby pollen is 'digested' by microbial activity under drier aerobic conditions.

Thirty-eight samples were analysed from Dun Law 113 and 46 from Dun Law 3 (illus 9). Local Pollen Assemblage Zones (LPAZ) were determined using the Constrained Sum and Squares (CONISS) multivariate statistical function based on all land pollen taxa greater than 2%. The LPAZs for each site are also applied to the profiles of organic content to enable comparison between each proxy dataset and between each site (full pollen diagrams are available in archive).

Results

Pollen preservation: The pollen profiles from the first half of the Dun Law 113 record and Dun Law 3 record suggest that the pollen preservation is generally poor, with normal grains consistently below 50%. However, supplementary data, such as the proportion of unidentified pollen grains, and the very low proportions of pollen grains resistant to deterioration which may become over-represented in a record (for example Lactuceae), suggests that there has not been significant taphonomic alteration of the records. This allows us to draw inferences about the rate and nature of environmental change from both profiles with a high degree of confidence.

Dun Law 113: Peat formed under the road (illus 9)

LPAZ D113–1 *Corylus avellana*-type (Hazel) – *Pinus* (Pine): This zone lies on the substrate of the palaeochannel and continues to have fluctuating amounts of mineral input resulting in low organic content. However, pollen preservation is consistently low for the whole profile, with normal grains constituting only 20% to 40% of the total. There does not appear to be over-representation of either mechanically deteriorated grains (broken and/or crumpled) or oxidised grains (corroded and/or degraded). The dominance of Hazel indicates a relatively dense shrub surrounding the site with tall herbs such as Meadowsweet (*Filipendula*) and Sedges (Cyperaceae) on or at the margins of the site. Lesser amounts of Pine, Oak (*Quercus*), Birch (*Betula*) and Elm (*Ulmus*) suggests that an open, though more mature, woodland may have been close by.

LPAZ D113–2a *Alnus* (Alder) – *Corylus avellana*-type (Hazel): There is a substantial increase in the proportions of Alder to ~40% to 50% and a corresponding decline in the levels of Hazel. Oak persists at similar proportions as in LPAZ D113–1 though Elm virtually disappears mid-way through the LPAZ and Pine declines towards the top of the LPAZ. The tall herbaceous cover of Meadowsweet and Umbelliferae is less than previously. This suggests an overall closing of an Alder canopy around the site at the expense of the cover of Hazel and herbaceous taxa. There are single cereal grains of *Hordeum*-type (Barley) but there is no sustained evidence for agriculture during this LPAZ.

LPAZ D113–2b *Alnus* (Alder): Alder reaches a sustained (for ~300 years) peak of ~70% and there is a corresponding reduction in Hazel and a near absence of all herbaceous taxa. This input of Alder is also concomitant with a similar peak in well-preserved pollen, perhaps through the greater direct input of pollen into the wetter basin sediments.

LPAZ D113–3 Poaceae (Grasses) – *Calluna vulgaris* (Ling): From approximately 30cm depth there is a gradual rise in grasses leading to a corresponding decline in the arboreal and shrub vegetation, with low proportions of Hazel, Willow (*Salix*) and Alder. Heathland taxa (*Calluna vulgaris*) also increase in step with grasses and there is a general expansion in the diversity of herbaceous taxa. This suggests a dramatic opening up of the landscape and possible agricultural influences. There are two occurrences of single *Hordeum*-type (Barley) pollen grains (Poaceae with annulus 8 to 10μm), which in themselves are inconclusive, but there is a significant increase in the rare taxa associated with ground disturbance (eg Ribwort Plantain – *Plantago lanceolata*; Buttercup – Ranunculaceae; Sheep's sorrel – *Rumex acetosella;* Bedstraws – *Galium*) suggesting pastoral as well as possible arable activity.

In the upper monolith tin the sediments at Dun Law 113 appear to persist above the brushwood matting (105) for approximately 7cm, though the high mineral content and the narrow age range between the brushwood and the lattice framework and the interstitial sediment would suggest that either the material was emplaced near instantaneously or at least reworked from beneath, as the brushwood and lattice were perhaps pushed down into the softer sediments before the cobbles and armouring were emplaced on top of the wooden framework.

Dun Law 3: Deep off-site section through palaeochannel (illus 9)

LPAZ DL3–1a *Alnus* (Alder) – *Corylus avellana*-type (Hazel) – Poaceae (Grasses): The pollen assemblage suggests a mix of Hazel and Alder growing on or around the site. There is a lesser but significant proportion of grass indicating that the tree/shrub cover is open. Organic content is approximately 80% during this LPAZ though pollen preservation at the site is poor, with normal grains constituting less than 40% of the total and oxidation (corroded and degraded grains) processes being dominant. The higher proportion of the more resistant pollen grains such as Polypodiaceae may suggest that there has been some taphonomic alteration of the pollen assemblages and an over-representation of the more durable pollen types. However, there is a near absence of unidentifiable pollen grains in LPAZ DL3–1a.

LPAZ DL3–1b *Corylus avellana*-type (Hazel) – *Alnus* (Alder) – Poaceae (Grasses): Organic content declines rapidly to <40% and there is a corresponding opening-up of the arboreal cover at the site. Alder is reduced and Hazel increases in proportion. Birch, Pine, Elm and Willow also appear in lesser amounts and there is an increase in Meadowsweet and Bracken (*Pteridium*). There is a small increase in the proportion of deteriorated pollen grains and overall this may suggest a shift to drier conditions at the site or a disturbance to disrupt the dominance of Alder and result in an opening-up of the vegetation cover. There does not appear to be a corresponding increase in indicators of pastoral or arable activity and so it is likely that this shift in the vegetation cover was natural in origin.

LPAZ DL3–1c *Alnus* (Alder) – *Corylus avellana*-type (Hazel) – Poaceae (Grasses): Alder returns to dominance at the expense of Hazel and some of the lesser taxa such as Pine, Willow and Meadowsweet. Elm also virtually disappears mid-way through the LPAZ. During this time Sedges appear more consistently, organic content increases back towards 80% and pollen preservation improves, suggesting a shift to more humid conditions. There are four occurrences of single *Hordeum*-type pollen grains during this LPAZ but with none of the taxa associated with ground disturbance common to the practice of agriculture.

LPAZ DL3–2a Poaceae (Grasses) – *Corylus avellana*-type (Hazel) – *Calluna vulgaris* (Ling): There is a gradual rise in grasses over the boundary of DL3–1c to DL3–2a and a corresponding decline in the proportions of arboreal taxa with a dramatic reduction in Alder, and the near disappearance of Pine and Oak. Of the shrub taxa, Hazel persists into LPAZ DL3–2a and Willow makes a sustained peak within this LPAZ. The increase in heath and bog taxa suggests that although grass cover is greater, the site is more humid. This is also reflected in the shift to better pollen preservation as normal grains consistently rise, reaching above 60% at the upper LPAZ boundary. Organic content continues to fluctuate, with lower levels between the tri-part peaks. The open grassland also contains a significant increase in the tall herb taxa of Meadowsweet and Sheep's sorrel (*Rumex acetosella*).

LPAZ DL3–2b Poaceae (Grasses) – *Corylus avellana*-type (Hazel) – *Calluna vulgaris* (Ling): Arboreal content diminishes to and remains less than ~10% for the rest of the profile. Grasses increase to more than 50% and there is a widespread increase in the proportion of herbaceous taxa. There are also three *Hordeum*-type (Barley) pollen grains (Poaceae with annulus 8 to 10μm) between 40 and 70cm depth and a significant increase in the diversity of those taxa associated with ground disturbance and possible agriculture (eg Ribwort Plantain – *Plantago lanceolata*; Buttercup – Ranunculaceae; Sheep's sorrel – *Rumex acetosella;* Bedstraws – *Galium;* Thistles – Lactuceae).

LPAZ DL3–3a *Calluna vulgaris* (Ling) – Poaceae (Grasses) – *Potentilla* (Cinquefoils): This pollen assemblage suggests a degree of continuity with the preceding LPAZ DL3–2b. However, there is a significant proportion of Willow and Cinquefoils and an overall reduction in grasses and the ground disturbance taxa. Heather reaches a brief peak of approximately 50% towards the upper LPAZ boundary. The proportion of well-preserved pollen grains reaches greater than 80%, which likely suggests an increase in relative moisture at the site. This is also reflected in the near continuous levels of peat accumulation during LPAZ DL3–3a, probably in response to increased surface wetness and greater preservation of organic matter.

LPAZ DL3–3b Poaceae (Grasses) – *Calluna vulgaris* (Ling) – *Potentilla* (Cinquefoils): Grasses return to proportions similar to LPAZ DL3–2b. Heather declines and Willow disappears. Cinquefoils persist and Sedges return along with *Sphagnum*. The continued high level of good pollen preservation, the small increase in Sedges and defined presence of *Sphagnum* within LPAZ DL3–3b suggests a shift to wetter conditions. This is further supported by the rise in % transmission values towards the top of DL3–3b, which suggests this signal is real rather than artefact.

5.5.6 Overall synthesis of the palaeoenvironmental records

It is apparent from the records of organic content and with the aid of the radiocarbon chronology that the 185cm record from Dun Law 3 correlates well with the pattern of change contained within the upper approximately 55cm of Dun Law 113. LPAZs DL3–1a–c and DL3–2a–b correlate from mid-way through LPAZ D113–2a to LPAZ D113–3. A summary of the main features of the changing landscape at Dun Law will be described in time-slices:

c 5700–5100 ^{14}C yrs BP (LPAZ D113–1): The initial dominance of Hazel and smaller, though significant, proportions of Pine, is only represented at Dun Law 113. The presence of Birch, Oak, Elm, Willow, Grasses and tall herbs suggests a relatively mature wooded landscape characteristic of the southern woodlands pre-Neolithic disturbance (Tipping 1996). The combination of poor pollen preservation, the pollen assemblages and organic content at Dun Law 113 suggests that conditions were relatively dry at this site during this period.

c 5100–4500 ^{14}C yrs BP (LPAZ D113–2a): The expansion of Alder at *c* 5100 ^{14}C yrs BP (*c* 5800 Cal yrs BP) appears to be later than its arrival elsewhere in southern Scotland and north-east England at *c* 7100 Cal yrs BP (Tipping 1996). This may reflect the upland nature of the site at Dun Law and the local differences of substrate moisture. The arrival of Alder is at the expense of Hazel and so appears to be part of a natural ecological succession at the site. The other lesser arboreal taxa (Pine, Birch, Oak and Elm) continue. There is no clear climatic signal that could account for this change as pollen preservation continues to be poor and the proportions of aquatic and cryptogammic spore taxa suggest the previous relatively dry conditions continued.

c 4500–2700 ^{14}C yrs BP: The starting age of this section is arbitrary beyond the correlative that it is at *c* 4500 ^{14}C yrs BP that the record from Dun Law 3 starts. Both profiles contain the large peak in Alder and the corresponding low proportions of Hazel. Ecologically the significance appears to be the same as during the previous period.

During this phase the arboreal cover at Dun Law is near its maximum extent with mixed Alder, Hazel and Oak. However, the signs of woodland disturbance and perhaps the precursors of wider woodland clearance appear in the record.

Firstly, Elm declines and this can be best seen in Dun Law 113 at *c* 4600 ^{14}C yrs BP (*c* 5300 Cal yrs BP). The primary Elm decline is believed to have occurred between *c* 5300 to 4850 ^{14}C yrs BP (Oldfield 1963; Tipping 1994) and so the disappearance of Elm at Dun Law appears to be a later event. However, the timing of this decline is similar to the Elm decline identified at Yetholm Loch, in the Cheviot Hills, to between 5550 and 5300 Cal yrs BP and also similar to Dun Law, in that there is no clear evidence for an anthropogenic cause (Tipping 1996). However, at Dun Law 3 there is a putative Elm decline (from albeit very low proportions) at *c* 3200 ^{14}C yrs BP (*c* 3400 Cal yrs BP). This local staggered Elm decline appears to be at odds with the regional pattern of Elm declines. However, spatial and temporal variability between Elm declines at sites in close proximity has been observed before and there is the suggestion that multiple attacks and regenerations within Elm woodland communities may have occurred (Turner et al 1993). The occurrence of single cereal pollen grains across this time period is intriguing. The lack of widespread indicators of ground disturbance may suggest that this represents simple small-scale clearances of wood, perhaps followed by periods of woodland regeneration. This is in sympathy with the staggered Elm decline at Dun Law.

Secondly, the Pine decline at *c* 4000 ^{14}C yrs BP (Dun Law 113) and later at *c* 3600 ^{14}C yrs BP is close to the region-wide pattern of the disappearance of Pine woodland from the landscape (Gear & Huntley 1991). It is likely that the event was near synchronous at both sites at Dun Law and that the age difference is an artefact of the age–depth models. There is no clear evidence for a climatic cause for the loss of Pine and so, similarly to the loss of Elm, the small-scale loss of woodland diversity may represent the gradual *chipping away* at the woodland by human activity.

c 2700–2000 ^{14}C yrs BP: There is a dramatic phase of woodland clearance represented by the expansion of grass and heathland. The woodland-loving Polypodiaceae (ferns) decline (most clearly at Dun Law 3) and there is an increase in the biodiversity of the herbaceous taxa, particularly those indicative of ground disturbance. There is no increase in the presence of cereal grains, though these are commonly under-represented at pollen sample sites due to their ecology. However, Sheep's sorrel, Bedstraws and Plantains all suggest an increase in agricultural activity against the backdrop of a climatic deterioration, suggested by the spread of heathland vegetation, which is consistent with the lowland evidence for increased wetness during the Iron Age and later Holocene (Tipping 1994).

c 2000 ^{14}C yrs BP – present: The final stage of the Dun Law 113 record is truncated by the construction of Dere Street and so is only represented at Dun Law 3. The landscape continues to be dominated by grasses and heath. The rich pattern of disturbed ground indicator taxa continues after the timing for the construction of Dere Street. Hazel persists beyond the initial phase of woodland clearance at *c* 2700 ^{14}C yrs BP but is finally cleared, likely for the brushwood and lattice constructs for the road. Woodland cover does not regenerate after *c* 2000 ^{14}C yrs BP though proportions of Willow do fluctuate and this may have been conserved and coppiced as a resource. However, after *c* 500 ^{14}C yrs BP all woodland and shrub taxa virtually disappear. Grasses dominate the landscape, *Hordeum*-type pollen, *Artemisia* (Mugworts) and the suppression of heathland, despite the indications of wetter conditions (increase in Cinquefoils, Sedges and Sphagnum), suggest management of the landscape up to the present time.

5.5.7 Conclusion

The two sediment sequences from Dun Law 3 and Dun Law 113 provide a rich record of landscape change for the period *c* 5700 ^{14}C yrs BP to present in an area where there is limited evidence at present. This study provides us with new data for:

1) The gradual and prolonged development through natural succession of the upland woodland cover at Dun Law during the mid-Holocene.
2) Potential evidence for the small-scale incursions into the upland woodland during the Neolithic.
3) Large-scale woodland clearance at *c* 2700 ^{14}C yrs BP which was sustained up to the construction of Dere Street and continued to be maintained after wards and evidence for the final removal of Hazel shrub, probably for the construction of the road.
4) A post Roman-Iron Age landscape that was open and represented by both agriculture and pasture.