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Coring in glacial sequences: comparison of cable percussion and window sampler techniques

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Front cover

Window sampler rig at Woodford, Northants

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Foreword

This internal report results from a study by the Eastern England Integrated Surveys project of the British Geological Survey (BGS) into the glacial sequence in Northamptonshire. Shallow drilling and sampling was partially funded by the Quaternary Methods and Training project and this report compares two techniques for acquiring continuous samples in relatively thin (up to 10 m) glacial (predominantly till) sequences and gives an account of the sub-sampling strategy undertaken.

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Summary

The glacial sequence of Northamptonshire in the English Midlands is relatively poorly studied, but for over 60 years has been known to include a thin and laterally impersistent chalk-free diamicton beneath a thick and persistent chalky till blanket. During early preparation of new BGS publications in this region, it was deemed necessary to improve knowledge of these deposits by obtaining high quality samples for further testing. This report compares the merits of U100 sampling, using ‘traditional’ cable percussion (aka shell and auger) drilling techniques, and use of a ‘window/windowless sampler’, to acquire near-continuous cored samples through till-dominated (i.e. clay-rich) superficial deposits less than 10 metres thick.

In the event, the cable percussion operation was subcontracted at short notice, and this may have compiled the problems of supervising two sites simultaneously (see 4). With hindsight, it seems desirable to forbid subcontracting and to maintain constant supervision on a cable percussion operation.

The acquisition of U100 samples by the cable percussion method offers the following advantages: large diameter (100mm) samples, potential for near continuous coring, typically capable of 30 to 40m depth, widely available, simple technology, not easily obstructed, able to operate below water table in sand and gravel. The disadvantages include access restrictions, safety issues, requirement for careful operator/close supervision for good sampling, problems posed by use of water for drilling, costly and time consuming mobilisation, noise, water supply, hole and site restoration.

The window/windowless sampler offers the following advantages: ease of access and positioning, speed, fewer safety issues, continuous sampling from surface to terminal depth, no water supply, little restoration necessary, relatively quiet, likely to be cheaper. Its disadvantages include safety issues of solo operation, small diameter samples, limited depth capability, easily obstructed, less robust, limited availability.

The sub-sampling and testing strategy undertaken on the samples obtained is also set out.

1 Introduction

The glacial (pre-Devensian) sequence of Northamptonshire in the English Midlands is relatively poorly studied, and much of the knowledge stems from BGS mapping of the region in the 1940's as part of the strategic ironstone survey, including the first report of a chalk-free diamicton ('Lower Boulder Clay') found locally beneath a thicker and more extensive chalk-clast-rich ('chalky') till blanket ('Chalky Boulder Clay') (Hollingworth and Taylor, 1946). This was widely and consistently recorded on field and MS maps mainly in the Wellingborough district, but was not distinguished from the chalky till on the published BGS maps. Additionally, their relationship and absolute ages remained uncertain. However, during investigations at Biggin Grange near Oundle for sand and gravel resources by the Industrial Minerals Assessment Unit (IMAU) of the BGS in 1974 (Harrisson, 1981) (Merritt, 1982), possible organic-material-bearing 'lacustrine' deposits were encountered in a borehole, lying beneath the chalky till and above a chalk-free diamicton, possibly representing the 'Lower Boulder Clay' (although it had not been mapped hereabouts). These intervening deposits promised the opportunity to improve knowledge of the age of the sequence here (Merritt, 1982).

During preparation of new editions of the BGS 1:50 000 scale sheets 171 (Kettering), 186 (Wellingborough) and 203 (Bedford), and accompanying descriptions, it was deemed necessary to improve knowledge of these deposits by obtaining high quality samples for examination and further testing and determinations. It was intended to examine the reputed organic material for microflora and fauna, and coleopterans (beetles), for age and palaeoclimate indications. It was also intended to apply sedimentological and engineering tests, and spectral analysis, to characterise and compare these deposits, for comparison with other sequences, and to provide data for provenance studies and calibration for further studies.

It was decided to try to replicate the 1974 IMAU borehole (which was 10 m deep) and gain samples from the critical interval, which lay at 7 to 8 m depth, and the underlying and overlying deposits. In addition, it was decided to obtain samples at a site where the Lower Boulder Clay had been distinguished from the Chalky Boulder Clay on field maps, with no recorded intervening deposits, to gain knowledge of what had been mapped in the 1940's. It was hoped to find a suitable site where any excavation should be less than 6 m deep, to restrict costs, and increase choice of methods, and where the formation thought to be at rockhead should be easily identifiable.

2 Site selection

The borehole site at Biggin Grange was chosen as close as possible to the original borehole site (as far as known). However, allowing for practical and other factors, including the space required to site a cable percussion rig, this reduced the choice. It was hoped to start at a similar elevation above OD, to assist prognosis. The immediate area is slightly sloping, and the ground level of the eventual site is probably about 0.5 m below the original, in the corner of a ploughed field. The formation at rockhead was mapped as Oxford Clay Formation (although there was a possibility that the Kellaways Formation might be encountered), and it was thought that this should pose no difficulties in identification in samples.

The 'Lower Boulder Clay' as mapped across the Wellingborough sheet is up to about 3 m thick, and is generally directly overlain by 'Chalky Boulder Clay'. A site was chosen at Woodford House, near Kettering where both were shown as present, and the limestone-dominated Cornbrash Formation was mapped at rockhead. Hand augering appeared to confirm the map, and indicated a prognosis of 2.5 to 4 m depth to rockhead. The site lay at the top of a grass paddock, on flat ground. Owing to an exceptionally dry summer, soil conditions at both sites were very dry.

3 Drilling and sampling method selection

3.1 BIGGIN GRANGE SITE

An accurate borehole prognosis was drawn from the existing log of the IMAU borehole (TL08NW/179) as set out by Merritt (1982), indicating that rockhead should lie at about 9 m depth, although allowance was made for it to be several metres deeper (10 to 16 m). This precludes pitting, and it was thought that this depth and the possibilities of running sand and boulders in the till put it beyond the capabilities of a window sampler. This depth is well within the reach of a standard cable percussion rig (e.g. a Pilcon or Dando type, as used in the original borehole), and a specification was drawn up to include 40 cm-long U100 samples taken at 1.5-m intervals to 6 m depth, continuous U100 sampling between 6.0 and 10.0, and one at the terminal depth if below this.

3.2 WOODFORD HOUSE SITE

With a prognosis of less than 6 m depth, several methods were available. Trenching/pitting was rejected as a sampling method due to depth limitations, restoration requirements and health and safety restrictions. Cable percussion drilling with continuous U100 sampling was considered and invitations to tender included this option. However, the relatively new technique of window sampling was also thought to offer considerable benefits and tenders were sought for this method. In the event, the price quoted by the same company for a single 6 m cable percussion hole was slightly less (£565 against £647) than for two 6m window sampler holes. However, one window sampler hole would have cost £441.

Window sampler rigs available vary in size and therefore in capacity. However, for this size of task they are typically mounted on a mini-crawler body (see front cover), and are sufficiently light (less than 700 kg) and compact to be carried in a large van or a trailer drawn by a LandRover-type vehicle (see http://www.archway-engineering.com/products/rig_features.html). Thus they can be transported into quite restricted locations (compared with a truck-towed Pilcon or Dando rig) and can easily be independently manoeuvred some metres to the final site, and repositioned. They are one-man operated and with a low ground pressure cause less ground damage than a lorry-mounted rig. The mast is about 2.3 m high. The method of progression involves driving a hollow steel tube up to 150 mm in diameter using a caged hammer, rising and falling through half a metre. The hole diameter is reduced as necessary to enable progression, and a capacity of up to 15 m depth is claimed, depending on ground conditions. Strictly, in a window sampler the steel tube has a broad slot down the side for extraction of disturbed material. However, where continuous, less disturbed samples in liners are required, the driven tube may lack the slot and contain a disposable plastic tube enabling the sample to be extracted intact, marked up and sealed for easy transport and preservation. This type is strictly known as a 'windowless sampler', but the family are known collectively as window samplers (see http://www.archway-engineering.com/products/windowless_sampler.html). No water needs to be added.

Allowing for the possible presence of large stones in the till, and the aim to at least partially penetrate the Cornbrash limestone, an initial sample tube internal diameter of not less than 83/85 mm was specified for window sampling, reducing as necessary, to perhaps less than 50 mm. This generates 1.0-m-long samples (see link above), which in tubes are sufficiently strong and light to be easily handled by one man. However, this diameter range produces significantly less volume than the same length of U100, so two holes side-by-side were specified, as opposed to one cable percussion hole.

4 Account of operations

The two sites lie about 10 miles apart, and the contractor estimated that both operations could be completed within a single day. It was decided for cost reasons to drill the holes on the same day (1st September 2003), with an experienced BGS supervisor (RTM) shuttling between the sites as necessary. With hindsight (see 4.1), it seems desirable to maintain constant supervision on a cable percussion operation.

4.1 BIGGIN GRANGE SITE

In the event, at very short notice, with our (reluctant) agreement, the successful tenderer, Ground Engineering of Peterborough, subcontracted the cable percussion drilling. A Pilcon Wayfarer percussion rig was utilised and was erected at the site with no problems reported. Continuous U100 sampling was sought as specified, but across the target interval (6.0 to TD at 9.1 m) only about 66% recovery in U100s was achieved, despite the driller's claimed experience of working to IMAU standards. Much water was employed in the hole, sandy and silty horizons were reduced to a slurry and some U100 samples had consequently been lost. On arrival from the Woodford site, RTM had the first hole terminated at 9.1 m, having already run into Oxford Clay at 8.1 m (which the driller had failed to recognise). After consultation with AJMB at the office and discussion of the inadequate sampling, the rig was manhandled two metres backwards and a second attempt was made at recovering the target sequence, with the intention that the second set of samples would straddle the gaps in the first set. Again the driller insisted on using large amounts of water, with similar results, and only a slight improvement was achieved.

Between them, the two boreholes generated eleven 0.4-m-long U100 tubes, 32 disturbed (cutting-shoe) samples in bags and eight bagged bulk samples, the largest weighing 9 kg. One man easily handles each, and all samples were transported from the site in the BGS vehicle the same day.

Both holes were filled with bentonite to 1.5 m below GL, and plugged with spoil. The site was restored to an acceptable standard.

4.2 WOODFORD HOUSE SITE

Ground Engineering of Peterborough were also the successful tenderer for this task. Access to the site with the rig in a Transit-type van and rapid one-man set-up of the self-contained unit were achieved without any problems (see Plates 1 and 2). Several diameters (approximate internal diameters between 83 and 53 mm) of windowless sampler tubes were employed, the holes were reamed out to facilitate continued drilling, and both boreholes were cased to 1.0 metres depth. No water was used. The first borehole passed through moderately stony clay (till) without difficulty, and struck limestone in clay (presumed weathered Cornbrash Formation) at about 4.4 m depth, and penetrated it to continue through mottled clay (Blisworth Clay Formation) to terminal depth at 5.65 m. Extraction of the drill string was by an integral hydraulic jack. Repositioning of the rig between holes (about 1 m apart) was easily done, and the second borehole progressed without reported problems. It was terminated in limestone (Cornbrash) at 4.55 m, the driller considering that no further penetration was possible or necessary. In both cases, near-continuous coring was achieved, with recovery below the (compressible) topsoil of over 95%. The transparent plastic sample tubes were extracted on site, and sealed and marked up. One man easily carries them, and all eleven were removed in the BGS vehicle the same day. The holes were plugged, and the limited site restoration necessary was carried out.

Plate 1. Window sampler rig being manoeuvred to site at Woodford.

Plate 2. Window sampler rig in operation at Woodford.

5 Comparison of methods

5.1 CABLE PERCUSSION, PROS AND CONS

Advantages:

- Large diameter (100mm) samples, relatively undisturbed
- Potential for near continuous coring with care
- Typically capable of 30 to 40m depth, exceptionally up to 60
- Widely available
- Simple and familiar technology
- Not easily obstructed in superficial deposits and most Mesozoic formations
- Able to operate below water table in sand and gravel

Disadvantages:

- Size and manoeuvrability limitations limit site choices and pose access and recovery problems
- Close adherence to procedures required for safe operation
- May require close supervision to achieve quality sampling
- Tendency to use water in drilling process, jeopardising sampling and increasing restoration work and potential for environmental damage
- Costly and time consuming mobilisation, set up and repositioning
- Noise
- Water supply may be required
- Large hole needing backfilling
- Inherently messy process may require considerable site restoration

5.2 WINDOW/WINDOWLESS SAMPLER, PROS AND CONS

Advantages:

- Ease of access to sites
- Lightweight rig and transporter limit ground damage
- Ease of positioning, including on sloping ground and close to walls etc.
- Very quick set-up (minutes) and repositioning
- Rapid: approximately 5 minutes per sample/metre in diamicton. Whole operation at Woodford took about 2 hours
- Fewer safety risks for operator and attendees
- Sampling process is integral to borehole progression
- No necessity for water reduces reliance on local services and potential for extra restoration
- Narrow hole diameter reduces restoration

- Relatively quiet
- Likely to be cheaper per hole-metre
- Plastic liners are moderately transparent

Disadvantages:

- Unsupervised solo operation has safety implications
- Small diameter samples (may be less than 50 mm)
- May have difficulties operating below water table in sand and gravel
- Limited depth capability (15 m claimed – may be less)
- Easily obstructed by harder layers or boulders
- Less robust than cable percussion
- Less widely available (in 2003)

6 Logging and sub-sampling

The samples acquired during the drilling processes ('the samples') were checked on arrival at BGS. Some of the samples from the cable percussion boreholes were not clearly marked and had to be re-marked or noted for rechecking (i.e. for way up) once opened. The samples are accounted for below.

The four boreholes were each assigned BGS registered numbers.

The core tubes were cut in half lengthwise (by electric saw) prior to logging. The cores and samples were lithologically logged (by AJMB) in November 2003, and photographs taken (by RTM). Generally, one half of the split tube samples (U100s and window sample tubes) were retained intact, and representative and other lithology, and macrofauna specimens were also collected for the BGS Materials Collections (not detailed below). Material collected during logging and curated for determinations and testing ('sub-samples') is accounted for below. Following advice, unless conspicuous black carbonaceous ('lignitic') material was present, the biostratigraphical sub-samples (AMB series) were taken from the material with the darkest and most clay-rich appearance. In addition, the Portable Infra-red Mineral Analyser (PIMA) was run at 0.1 m intervals along the scraped core surfaces of the entire length of cores from Biggin Grange No 1 and Woodford House No 1. A limited number of measurements were taken of Woodford House No 2. Measurements of reflectance have been found to be useful in sediment classification and provenance studies. Different rocks and soils tend to possess unique spectral signatures which can be used to identify soil species or to, with more in depth analysis to identify soil properties including clay mineralogy, organic matter, carbonate content or moisture. Representative sub-samples of the lithologies were collected (FZ series) for analysing particle-size distribution (PSD), heavy minerals and clast lithology. For PSD, samples were required to weigh around 200 grams in order to provide representative results.

Due to the requirement of a sub-sample of ~200 g, a wider core is advantageous as it leads to a thinner sampling band. This also provides the potential to sample at a higher resolution and precision. Thus, if variations, such as laminations, occur within a unit, samples can be taken to investigate this. For Biggin No.1 borehole, to collect ~200g samples, samples spanned ~5cm vertical thickness of core.

The sub-samples are then sieved relative to the 63µm interval; the above 63µm fraction is analysed using sieves at each phi size (63µm to 8mm, +4 to –3phi), and the below 63µm is analysed using the Micromeritics Sedigraph 5100. For Sedigraph analysis, a sample size of ~5g is required, however analysis can be carried out on smaller samples, but may not be as accurate. In this case, 200g samples for the diamictons were sufficient to provide more than 100g of below 63µm, so the fraction was subsampled again. The Sedigraph can be set up to record the percentages at any particle size between 0 to 63µm. However, as the accuracy at below 1µm is so poor, samples are rarely analysed below 1µm. The Sedigraph measured the cumulative mass finer at the grain sizes 60, 50, 40, 30, 25, 20, 15, 10, 8, 6, 5, 4, 3, 2 and 1µm.

Heavy mineral analysis is to be performed on the 63-125µm (+3to +4phi) fraction of all the sub-samples, with the separation performed by the NERC Isotope Geosciences Laboratory (NIGL). The clast lithology of the 8mm to 16mm (–3 to –4phi) and 16mm to 32mm (–4 to –5phi) fractions of all the samples is to be examined.

Particle size distributions were also determined on a second set of samples to enable the calibration of the reflectance measurements taken using the PIMA. It was necessary to carry out sampling at a higher resolution so that any anomalous measurements of reflectance could be accounted for against detailed data. It was not known at the time of testing what degree of reflectance variation would be apparent within individual facies. Ideally a detailed description would have been carried out at each measurement point but this would have been very time consuming and may not have yielded significant benefit if there was no reflectance variation.

Particle size was determined using the hydrometer method described in the British Standard for Soil Testing BS1377 (British Standards Institute, 1990). Although this method is not as rapid as those described above, it allowed the opportunity to observe any variations in clay ‘colour’ and the presence of stratification within the sub-63 µm fraction as this is retained at the base of the hydrometer tube after settling. Again it was not known whether this would provide useful information in assessment of samples at the time of testing. Carrying out the particle size distribution test in this way also allowed easier sub-sampling for other tests. Samples sizes were not strictly comparable to those described previously, for the purpose of wet/dry sieving and hydrometer testing the initial sample had to be sufficient to yield a <63 µm volume of 30 g for clay soils and 50-100g for coarse soils. In the case of one sand sample this required an initial sample of 1.2 kg, all other initial PSD samples required initial volumes of between 35-100 g dry weight.

In addition, consistency limit tests were also carried out on those samples that demonstrated cohesive behaviour. This test was thought potentially useful as it provides an indication of the bulk mineralogy of the clay fraction and can also be related to other soil classification tests and properties

In addition to providing ‘calibration’ data for reflectance measurements, these tests provide further useful information which can be input into provenance analysis.

It was initially intended to carry out testing to determine the consolidation ratio of each till type and relate this to possible overburden and loading conditions that each material had gone through. These were not carried out – such tests require the extraction of ‘plug’ samples which ideally possess as wide a diameter as possible. Although the sample is not destroyed during testing and can be split afterwards, it is greatly disturbed and this would have conflicted with the other tests described.

6.1 BIGGIN GRANGE BOREHOLES

6.1.1 Biggin Grange No.1

6.1.1.1 SAMPLES

Sample recovery in the chalky till (0-3.79 m) was as specified, with additional disturbed (cutting-shoe) samples collected at c 0.5 m intervals (fit only for gross lithological description). In the underlying sand (3.79-5.9 m), and into the interbedded sand and clay (to 6.1 m), only bagged (bulk and cutting-shoe) samples were obtained due to use of added water (groundwater was struck at 5.5 m). Below this, 'continuous' sampling by U100 (alternating with cutting shoe samples) was achieved through interbedded sand and clay, diamicton and mudstone (Oxford Clay Formation), apart from between 6.5 and 6.8 and between 7.3 and 7.7 where disturbed bulk (bagged) samples were obtained (also fit only for gross lithological description, with some suspicion of contamination by cavings). Generally the U100 samples showed little disturbance apart from slight dragging in softer clay layers at the margins (Plate 3).

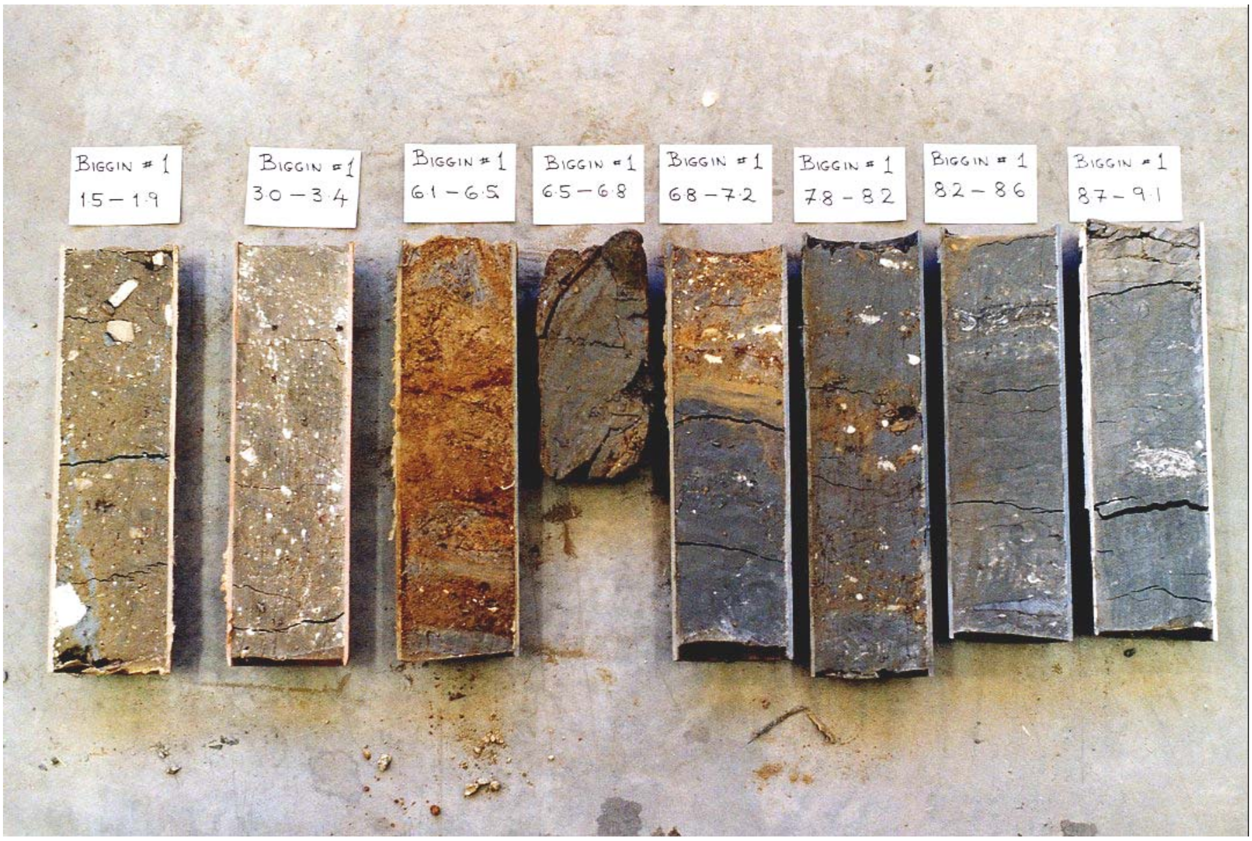

Plate 3. Split U100 samples, Biggin Grange No.1.

6.1.1.2 SUB-SAMPLING

Ten sub-samples (AMB715-726) were collected for biostratigraphical studies; one each from the 'tills', two from the Oxford Clay Formation, and six from the interbedded sand and clay, of which four appear to include dark organic traces. Seven sub-samples were collected for sedimentological analysis, of which two (FZ1, 2) were from the chalky till, two (FZ3, 4) were entire bulk samples (B2 and B4) from the pebbly sand unit, one (FZ5) from the underlying bedded clay, and two (FZ6, 7) from the lower diamicton. The above 63µm PSD for all FZ samples was analysed, and the below 63µm fraction of the sub-samples FZ1-2, 4-7 were analysed using the Sedigraph.

The complete PSD of FZ4 was analysed and because FZ3 represents the same unit, FZ3 was not analysed using the Sedigraph. The above 63µm fractions of FZ3 were separated to provide the relevant fractions for clast lithology and heavy mineral analysis.

Using this multi-proxy approach and combining the results from PSD, heavy mineral analysis and clast lithology can improve our understanding of the environment in which the material was laid down, aid positive identification and therefore assist stratigraphic correlation.

Five samples for engineering characterization were taken (Table 6.1). Samples were chosen to represent each lithology and to increase the sample taken where there was considerable lithological variation or where it was felt that spectral response might vary from 'background' reflectance.

Table 6.1 Characterization tests carried out on samples from Biggin Grange No 1.

Depth	Characterization Test		
	Particle Size Distribution	Consistency Limits	Particle Density
1.7-1.9	X	X	X
3.0-3.25	X	X	X
3.8-4.4	X		X
5.0-5.5	X		X
7.4-7.7	X	X	X

6.1.2 Biggin Grange No.2

6.1.2.1 Samples

As instructed on site, only cutting-shoe samples were obtained, at approximately 1 m intervals, between GL and 6 m depth. Below this, in the interbedded sand and clay, and into the diamicton (at TD), near-continuous sampling was achieved. However, as well as the four U100s and cutting-shoe samples, this included two smaller bagged bulk samples close to the same levels as in Biggin Grange No.1. Similar comments apply to the condition and fitness of the samples as in 6.1.1.1 above.

6.1.2.2 Sub-sampling

Two sub-samples (AMB725, 726) were collected for biostratigraphical studies from the clay interbedded with the sand between the two diamictons. One (AMB726) appears to contain carbonaceous material.

6.2 WOODFORD BOREHOLES

6.2.1 Woodford No.1

6.2.1.1 SAMPLES

Recovery in the first 1.0 m run was about 60%, probably due to compression of the topsoil. However, as stated above, below this recovery through the diamicton, weathered Cornbrash limestone and Blisworth Clay Formation was in excess of 95%. Internal diameter was reduced progressively from approximately 83 mm (0-1.0 m) to 53 mm (3.0-4.0 m). However, reaming out permitted ID to be 63 mm between 4.0 and 5.0 m, reducing to 53 mm to TD at 5.65. Slight marginal distortion due to the sample driving process was present in the diamicton, and there was more extensive distortion in the plastic and laminated clay of the Blisworth Clay Formation (see Plate 4). It seems likely that this hole penetrated a softer part or joint in the Cornbrash, resulting in recovery of limestone fragments in clay.

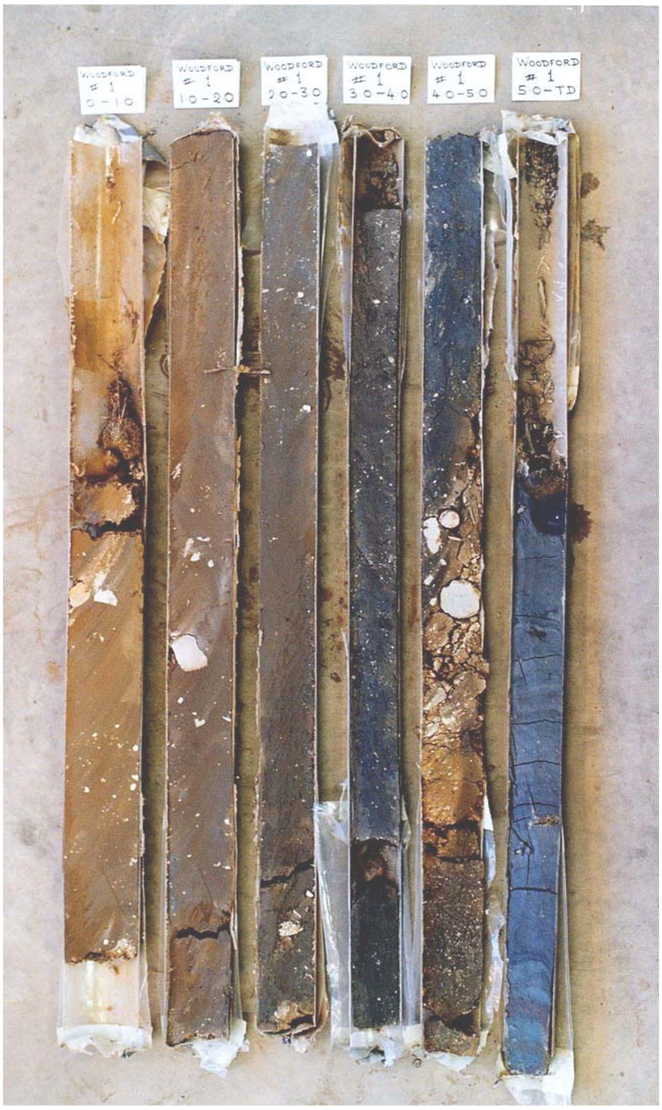

Plate 4. Split window samples from Woodford No.1.

6.2.1.2 Sub-sampling

Three biostratigraphical sub-samples (AMB727-729) were collected in the diamicton(s). Six samples for engineering characterization were taken (Table 6.2).

Table 6.2 Characterization tests carried out on samples from Woodford No 1.

Depth	Characterization Test		
	Particle Size Distribution	Consistency Limits	Particle Density
0.6-0.9	X	X	X
1.1-1.4	X	X	X
2.4-2.7	X	X	X
3.2-3.55	X	X	X
4.1-4.3	X	X	X
5.2-5.5	X	X	X

6.2.2 Woodford No.2

6.2.2.1 Samples

Recovery in the first 1.0 m run was over 80%, probably due to compression of the topsoil, in the next run about 85%, and in the remainder virtually full (Plate 5) to TD at 4.55. A similar pattern of progressive reduction in internal diameter was carried out; from 83 mm to 53 mm at TD.

6.2.2.2 Sub-sampling

Five samples for engineering characterization were taken (Table 6.3).

Table 6.3 Characterization tests carried out on samples from Woodford No 2.

Depth	Characterization Test		
	Particle Size Distribution	Consistency Limits	Particle Density
0.5-1	X	X	X
1.5-1.8	X	X	X
2.5-2.8	X	X	X
3.5-3.7	X	X	X
4-4.25	X	X	X

Plate 5. Split window samples from Woodford No.2.

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