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Chapter 7

Establishing a lithostratigraphic and palaeoenvironmental framework for the investigation of vibracores from the southern North Sea

Martin Bates, Ben Gearey, Tom Hill, David Smith,
John Whittaker and Erin Kavanagh

Introduction

Pivotal to the aims and associated objectives of the Lost Frontiers project, two phases of fieldwork in the southern North Sea resulted in the recovery of 78 cores varying in length from less than 1m to greater than 5m. These cores span a wide geographic space and many topographic locations from the top of the Doggerbank to a submerged palaeovalley system off the Norfolk coast (Figure 7.1). Additionally, some cores targeted geomorphological saddles between drowned valleys and the interfluves between palaeovalley systems, while others were taken on the margins of assumed submerged lakes or estuaries. This paper sets out our methodology and rationale for the development of a lithostratigraphic and subsequent multiproxy palaeoenvironmental analytical workflow, for the assessment and analysis of cores deemed to be of greatest potential to reconstruct the landscape evolution of Doggerland. Such investigations assisted in the initial provision of first order geological and geomorphological settings for the recovered cores,

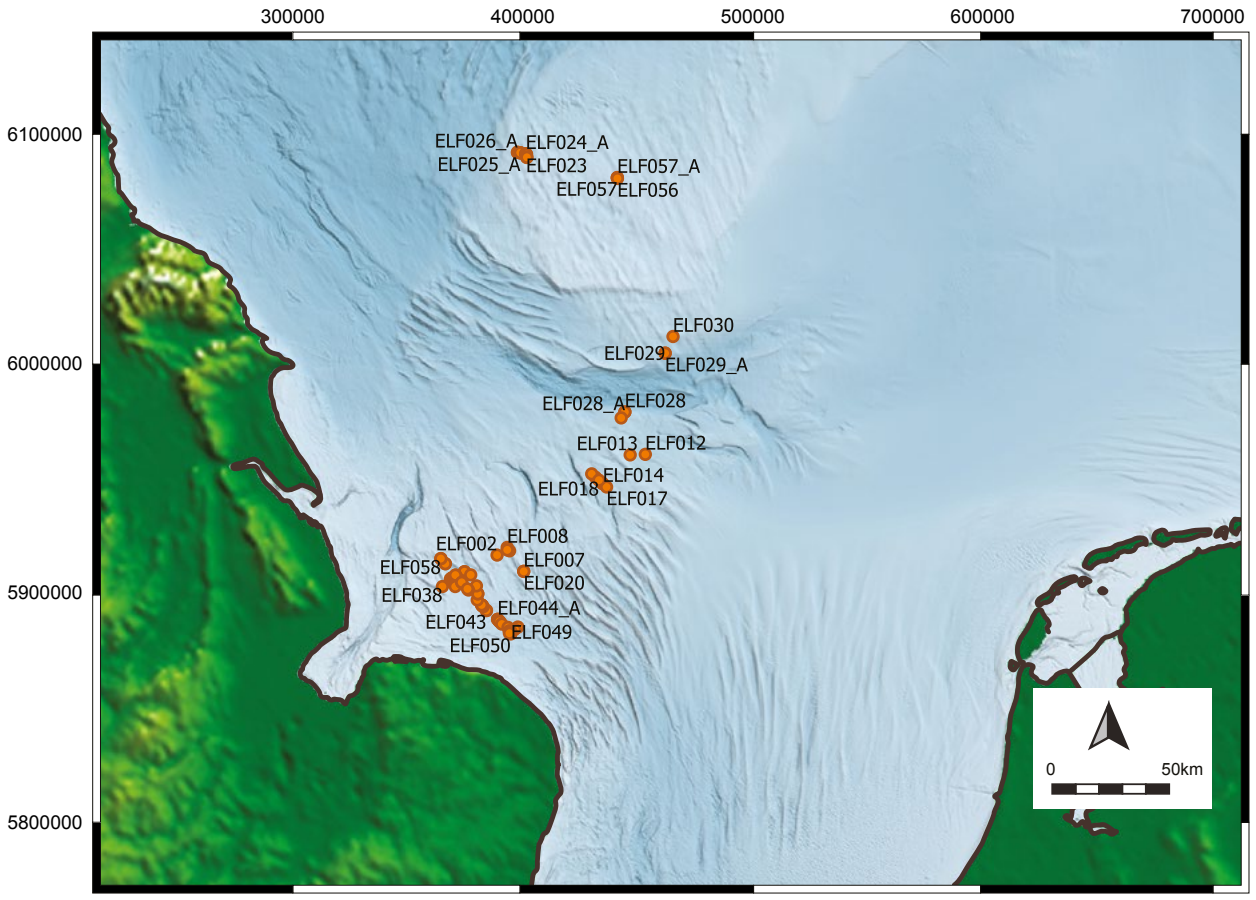


Figure 7.1 Distribution of cores taken during Europe's Lost Frontiers

to guide the subsequent identification of the most appropriate proxy assessments to be applied.

Core recording and sampling

Core processing was undertaken in order to deliver material to a range of specialists working on diverse materials in the project (Figure 7.2). In order to satisfy the needs of individual specialists the following workflow was adopted from the outset of the project:

1. Core cutting was carried out under controlled conditions at the University of Warwick laboratories. Cutting of cores and initial sampling for preserved sedimentary DNA (Allaby *et al.* this volume) was undertaken within environmentally controlled laboratories in order to minimise chances of sample contamination by modern DNA. In addition, cutting was undertaken under red light so as to minimise likely light contamination of sediments designated for Optically Stimulated Luminescence (OSL) profiling and dating (Kinnaird *et al.* this volume). After cutting, one half of the core was immediately sealed in black plastic for OSL dating. The other half of the core was rapidly scanned and locations for the recovery of sedaDNA samples identified and samples taken (Figure 7.2). The sampled cores were sealed in plastic and both halves of the core were returned to cold storage at the University of Wales Trinity Saint David (UWTSD) laboratories in Lampeter, Ceredigion.
2. Core recording was undertaken at UWTSD laboratories in Lampeter where cores were photographed (Figure 7.3 and 7.4), recorded and sub-sampled for rapid calcareous microfossil (foraminifera and ostracoda) assessments and initial 'rangefinder' radiocarbon dating. Samples were taken from key lithological units (Figure 7.3B).
3. Profiling and sub-sampling of cores for OSL dating was also undertaken in the laboratories at UWTSD.
4. Upon completion of the preliminary rapid assessments, sampling for palaeoenvironmental assessments (pollen, diatoms, mollusca) could be initiated (Figure 7.3), and was also undertaken at UWTSD. Phase 1 was a low resolution, preliminary assessment, focussing on stratigraphy deemed to be of the greatest interpretative value for each analytical technique (such as organic horizons, fine grained minerogenic horizons, or where mollusca were visible).
5. Upon completion of Phase 1, further high-resolution sampling was undertaken (Phase 2) within the stratigraphic units where proxies were found to be present in sufficient abundance and diversity for full analyses to be achieved. This included the high-resolution radiocarbon dating sampling to improve the chronological control provided from preliminary range-finder dates.
6. Once all dating and proxy sampling was completed to achieve full analysis investigations, the remaining organic units (predominantly peats or organic-rich silts and clays) were subdivided into bulk samples (Phase 3). These were for macrofossil palaeoenvironmental investigations (beetles and waterlogged plant remains) requiring large sample volumes to return suitable counts.

Stratigraphic and associated environmental methodologies of core sampling

As outlined in the workflow above, due to the large number of cores and associated samples, combined with the need to produce a basic lithological model of the recovered material, it was decided that during lithostratigraphic logging, key units would be sampled and subject to a rapid assessment for the preservation of foraminifera and ostracods. This would provide a basic characterisation of the key environments of deposition. In conjunction with this, sampling for range-finder 14C dates were also undertaken, to provide a crude chronological framework for the data being developed. Upon completion of the initial rapid assessments and preliminary dating, Phases 1-3 of the palaeoenvironmental workflow was undertaken. A summary of the relevant methodologies is now provided

Lithostratigraphic assessments of core profiles

Core recording procedures follow the guidelines of Jones *et al.* (1999) (Table 7.1). Full details of all cores and recording are presented in Table 7.2. The basic lithostratigraphic profiles produced from the core logging have been drawn into sections to facilitate interpretation (Figure 7.5). The lithology recorded exhibits the range of commonly occurring facies types typically associated with tide dominated estuaries (*sensu* Dalrymple *et al.* 1992).

Foraminifera and ostracod rapid assessments

Of the samples selected for rapid palaeoenvironmental assessments, each was broken into smaller pieces by hand, placed in ceramic bowls and dried in an oven. After drying, a small quantity of sodium carbonate was added (to facilitate the removal of the clay fraction). The sediment mix was immersed in hot water and because of the high organic content of many of the samples, was left to soak overnight; for some this process had to be

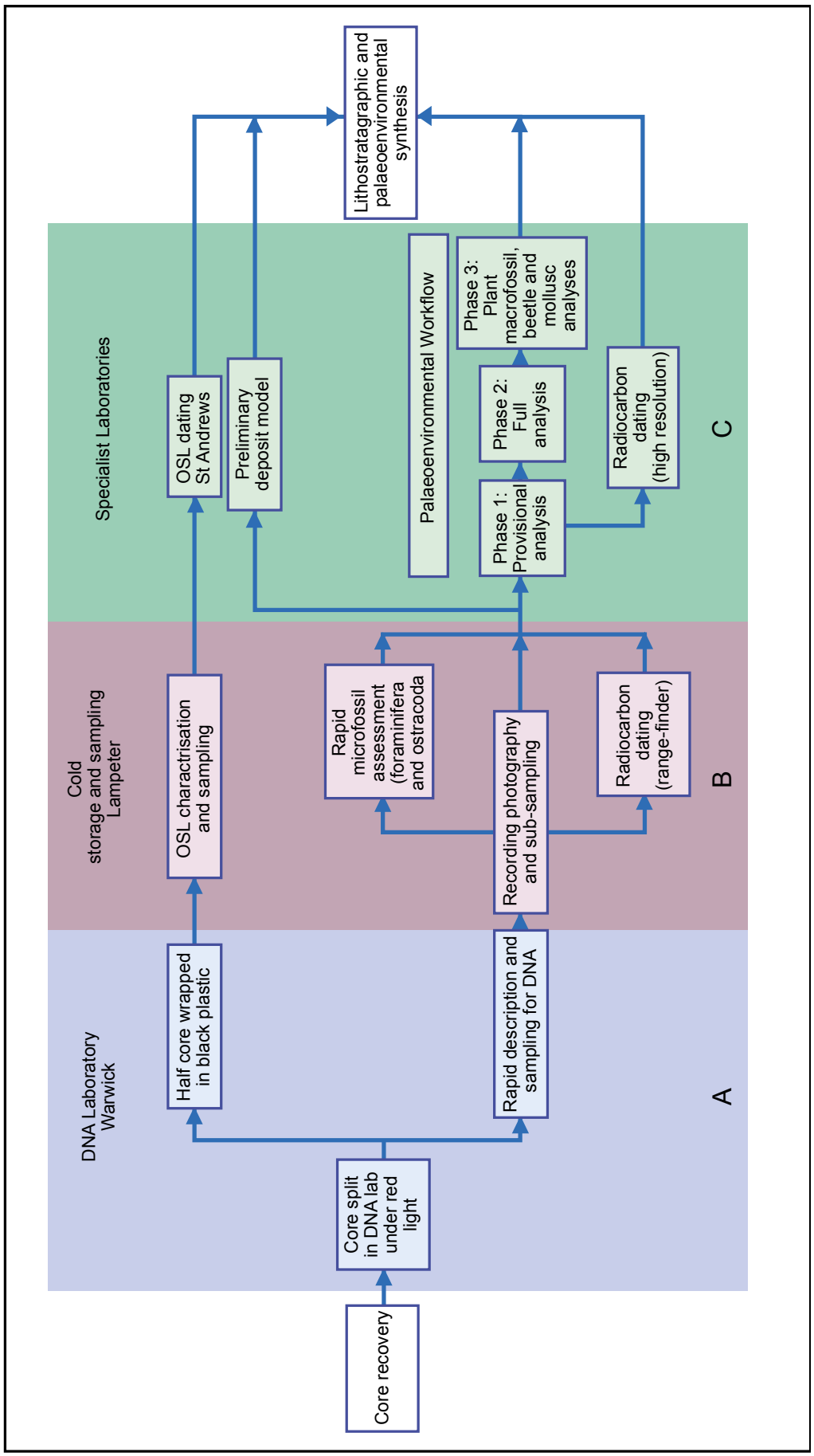


Figure 7.2 Flow diagram illustrating pathways of samples in the laboratory.



Figure 7.3 Cold storage facility for the Lost Frontiers Project at Lampeter (Left). Core recording (Right).

repeated to achieve a full breakdown. Sediment was then washed through a 75-micron sieve with hand-hot water, the resulting residue being returned to the bowl for drying. Once thoroughly dry, the residue was transferred to plastic labelled bags for storage and picking. For examination, the residue was first sieved through a nest of >500μ, >250μ and >150μ sieves. Sediment from each grade was then picked by sprinkling a small amount of residue onto a tray and examining it under a binocular microscope. A representative selection of material from each sample (foraminifera, ostracods and other sub-fossil material) of potential environmental value was picked out into 3x1 inch plastic faunal slides and recorded on a presence/absence basis (see Tables 7.3 and 7.4). Only foraminifera and ostracods were identified to species level.

The ecological preferences of the microfaunas are based on one of the authors own observations (JEW), and on the work of Murray (2006) for the foraminifera, and Athersuch *et al.* (1989) and Meisch (2000) for the brackish/marine and freshwater ostracods, respectively. All foraminiferal and ostracods are grouped and colour-coding in order to document the main ecological groups

Dating

There were two stages to the radiocarbon dating programme: an initial selection of samples for 'rangefinder' dating, followed by a more focussed programme of sample selection, based on the results of these 'rangefinder' dates and the various proxy assessments (see below). A full description of the radiocarbon dating programme including Bayesian modelling of the chronologies is presented in Hamilton and Kinnaird (this volume). Optically Stimulated Luminescence dating was also undertaken on selected cores (see Kinnaird *et al.* this volume).

Pollen assessment and analyses

Sub-samples for assessment (Table 7.5) were selected from vibrocores on the basis of sediments most likely to preserve pollen; hence predominantly organic units such as peats and silts. On the basis of the assessment stage and the rangefinder radiocarbon dating (see above), seven sequences were selected for full analyses.

Sub-samples were taken at regular intervals, dependent on the thickness of the stratigraphic unit under question. Pollen preparation for all samples followed standard techniques including KOH digestion, HF treatment and acetylation (Moore *et al.* 1991). Pollen concentrations were established by adding a known concentration of *Lycopodium clavatum* spore (batch number 161018201) to the samples before treatment (Stockmarr 1971). Pollen counts were made using a Leica DM 1000 LED microscope at x400, x800 and x1000 magnification under oil immersion for critical examination of pollen sculpture and measurement of pollen grains. A minimum terrestrial pollen sum

Project	Europe's Lost Frontiers	**Borehole**	ELF 045
Easting	393559.6	**Northing**	5885524
Elevation	-27m O.D.	**Date drilled**	
Date to laboratory		**Date recorded**	4/4/18
Date sampled	4/4/18	**Location of samples**	Lampeter Cold Store
Depth below ground surface (m)	**Depth O.D.**	**Lithological description**	
0.00-0.20	-27.00 - -27.20	Greyish brown, medium, sand with common shell fragments, some articulated. Structureless.	
		--- Diffuse Contact---	
0.20-0.41	-27.20 - -27.41	Greyish brown, becoming grey with depth, slightly silty medium sand with shell fragments <1cm. Structureless. Moderately compact.	
		--- Sharp Undulating Contact---	
0.41-0.75	-27.41 - -27.75	Grey silt with grey, medium, silty sand patches. Finely laminated in places. Extensive burrowing filled with sand as above.	
		--- Sharp Contact ---	
0.75-1.40	-27.75 - -28.40	Dark grey, laminated, slightly sandy silt with thin laminations of fine sand, typically 0.5cm-1cm in thickness. Occasional dark brown organic laminations, Occasional shell fragments. Burrowing continues to about 1.10.	
		--- Abrupt Contact ---	
1.40-2.94	-28.40 - -29.94	Mid grey clay silt with occasional darker grey, slightly organic, horizon, Occasional thin sand beds 1cm in thickness. Occasional thin dark brown organic laminations, quite soft.	
		--- Abrupt Contact ---	
2.94-3.02	-29.94 - -30.02	Dark greyish brown silty fine sand with common organic fragments.	
		--- Diffuse Contact ---	
3.02-5.21	-20.02 - -32.21	Grey to dark grey laminated sandy silt with thin fine sand laminations. Occasional dark brown silty fine sand.	
		--- Sharp Dipping Contact ---	
5.21-5.46	-32.21 - -32.46	Dark grey shelly silty sand, becoming coarser sand with depth. Small stones towards base. Possibly bedded.	
		--- Base 5.46 ---	

Table 7.1. ELF 045, lithology table.

of 500 pollen grains, excluding spores and aquatics, was employed. Indeterminate grains include broken, degraded and obscured grains. Pollen grains were identified mainly using the key of Moore *et al.* (1991), Beug (2004) and the pollen reference collection at the University College Cork, with reference to Fægri *et al.* (1989). The nomenclature employed followed Stace (1997) with suggestions from Bennett *et al.* (1994).

The designation '*cf* ' indicates that this was the closest identification possible but not an exact match, or that type material was not available to confirm the identification. *Cerealia*-type pollen (cereal) was distinguished from other Poaceae (grass) pollen based on size of grain pore and annulus and were presented in a separate curve (cf. Beug 2004). Monoporate pollen grains of less than 39µm were placed in the Poaceae (non-cultivated grass) curve. The difficulty in the separation of *Myrica gale* (sweet-gale) and *Corylus avellana* (hazel) pollen resulted in these grains being classified as *Corylus avellana*-type (Edwards 1981). For the saccate grains of *Pinus* (pine) the individual air sacs were counted and subsequently divided by two, in order to estimate the number of grains. The programmes TILIA and TILIA-GRAPH (Grimm 2013) were used to construct spreadsheets and pollen diagrams. The pollen sum consists of total land pollen grains (TLP), excluding aquatics and spores.

Diatom assessments

Sub-samples for assessment were selected from vibrocores on the basis of sediments most likely to preserve diatoms; hence predominantly minerogenic units and organic-rich silts (Table 7.5). On the basis of the assessment stage and the rangefinder radiocarbon dating (see above), seven sequences were selected for full analyses.

0.5g of sediment was required for diatom assessment preparation. All samples were first tested with dilute HCl to assess for carbonate content prior to the



Figure 7.4 Cores ELF 47 and ELF 51.

initiation of sample preparation. In the majority of cases, HCl reactions were minimal and hence the need for subsequent carbonate removal pre-treatments was unnecessary. Due to the high silt and clay content of most samples, samples were then treated with sodium hexametaphosphate and left overnight, to assist in minerogenic deflocculation. Samples were then treated with hydrogen peroxide (30% solution) depending on organic carbonate content. Samples were finally sieved using a 10µm mesh to remove fine minerogenic sediments. The residue was transferred to a plastic vial, from which a slide was prepared for subsequent assessment.

For samples undergoing an initial assessment of potential, if present, a minimum of 100 diatom valves were identified. If preservation was found to be poor, ten slide traverses were undertaken in an attempt to extract the diatom data available from the sample under assessment. For samples proceeding to full analysis, a minimum of 300 diatoms were identified for each sample depth. Diatom species were identified with reference to van der Werff and Huls (1958-74), Hendy (1964) and Krammer & Lange-Bertalot (1986-1991). Ecological classifications for the observed taxa were then achieved with reference to Vos and de Wolf (1988; 1993), Van Dam *et al.*, (1994), Denys (1991-92; 1994) and Round *et al.* (2007).

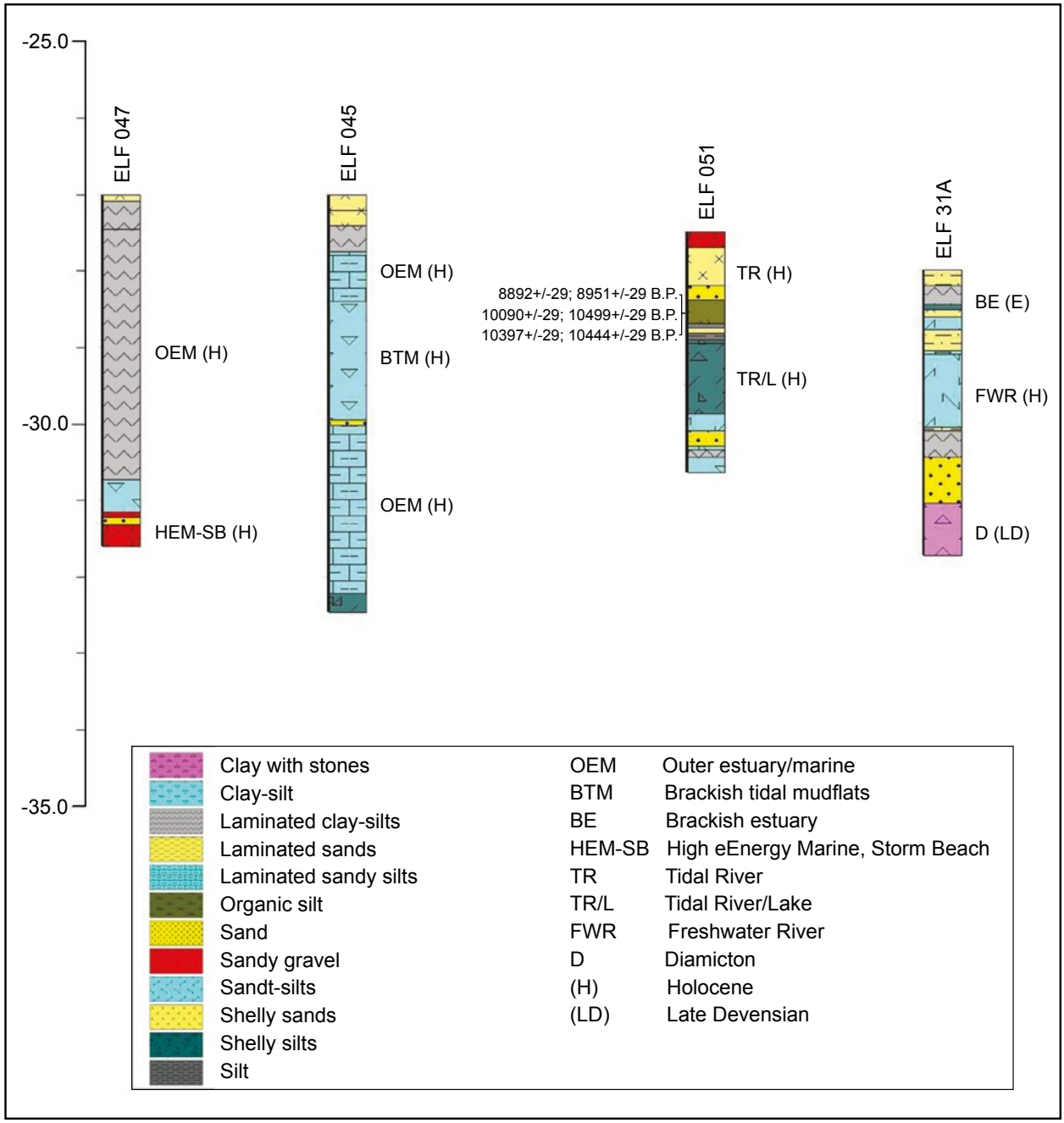


Figure 7.5 Basic lithological profiles drawn up in the Southern Valley.

Assessment and sampling of macrofossils from the cores

During the assessment for Foramifera and Ostracods the presence and quality of a number of other macrofossils was also recorded. This included molluscs, plant and insect remains. Based on this assessment, and the description and lithography of the cores themselves, a number of locations in the cores were selected for further sampling for macrofossils.

The sampling for macrofossils (Table 7.6) followed late in the project since there was a need to ensure that all other samples that need to be taken for dating and other forms of analysis had occurred first. This is down to the relatively large volume of material needed for such work (normally >1l). This resulted in the 'emptying' of selected cores, or parts of cores, for which plant macrofossil/insect/mollusc works was to be undertaken on.

Core	Description	Photograph	Samples	Core scan	Fossil material	14C	OSL (P1, P2, D)
ELF 001A	Y	Y	17	Y	Y	Y	Y (P1, P2, D)
ELF 002	Y	Y	9	N	Y	Y	Y (P1)
ELF 003	Y	Y	12	N	Y	Y	Y (P1)
ELF 004	Y	Y	9	N	Y	N	N
ELF 005	Y	Y	12	N	Y	Y	N
ELF 005A	Y	Y	10	N	Y	Y	N
ELF 005B	Y	Y	8	N	Y	Y	Y (P1, P2)
ELF 006	Y	Y	6	N	Y	N	Y (P1, P2)
ELF 007	Y	Y	10	N	Y	Y	N
ELF 008	Y	Y	4	N	Y	N	N
ELF 009	Y	Y	11	N	Y	Y	N
ELF 010	Y	Y	7	N	Y	N	N
ELF 011	Y	Y	4	N	Y	N	N
ELF 011A	Y	Y	7	N	Y	N	N
ELF 012	Y	Y	4	N	Y	N	Y (P1, P2)
ELF 013	Y	Y	6	N	Y	N	N
ELF 014	Y	Y	3	N	Y	N	N
ELF 015	Y	Y	1	N	N	N	N
ELF 016	Y	Y	2	N	N	N	N
ELF 017	Y	Y	1	N	N	N	N
ELF 018	Y	Y	5	N	Y	Y	N
ELF 019	Y	Y	14	Y	Y	N	Y (P1, P2, D)
ELF 020	Y	Y	9	N	Y	Y	N
ELF 021	Y	Y	-	N	-	N	N
ELF 021A	Y	Y	2	N	Y	N	N
ELF 022	Y	Y	16	N	Y	N	Y (P1)
ELF 023	Y	Y	3	N	N	N	N
ELF 023A	Y	Y	3	N	Y	N	N
ELF 024A	Y	Y	3	N	N	N	N
ELF 025A	Y	Y	-	N	-	N	N
ELF 025B	Y	Y	3	N	Y	N	N
ELF 026	Y	Y	2	N	Y	N	N
ELF 026A	Y	Y	3	N	Y	N	N
ELF 027	Y	Y	10	N	Y	N	Y (P1)
ELF 028	Y	Y	1	N	Y	N	N
ELF 028A	Y	Y	-	N	-	N	N
ELF 029	Y	Y	4	N	Y	N	N
ELF 029A	Y	Y	6	N	Y	N	N
ELF 030	Y	Y	14	N	Y	N	N
ELF 031	Y	Y	7	N	Y	N	N
ELF 031A	Y	Y	14	N	Y	N	Y (P1)
ELF 032A	Y	Y	6	N	Y	N	N
ELF 033	Y	Y	12	N	Y	N	N
ELF 033A	Y	Y	6	N	Y	Y	N
ELF 034	Y	Y	11	N	Y	Y	Y (P1)
ELF 034A	Y	Y	4	N	Y	Y	N
ELF 035	Y	Y	2	N	Y	N	N

Core	Description	Photograph	Samples	Core scan	Fossil material	14C	OSL (P1, P2, D)
ELF 036	Y	Y	2	N	Y	N	N
ELF 037A	Y	Y	5	N	Y	N	N
ELF 038	Y	Y	2	N	Y	N	N
ELF 039	Y	Y	14	N	Y	N	Y (P1)
ELF 040A	Y	Y	13	N	Y	N	Y (P1)
ELF 041	Y	Y	4	N	Y	N	N
ELF 042	Y	Y	11	N	Y	N	Y (P1)
ELF 043	Y	Y	-	N	-	N	N
ELF 044	Y	Y	7	N	Y	N	N
ELF 044A	Y	Y	8	N	Y	N	N
ELF 045	Y	Y	11	N	Y	N	Y (P1)
ELF 046A	Y	Y	11	N	Y	N	N
ELF 047	Y	Y	12	N	Y	N	Y (P1)
ELF 047A	Y	Y	5	N	Y	N	N
ELF 048	Y	Y	2	N	Y	N	N
ELF 049	Y	Y	15	N	Y	N	Y (P1)
ELF 050	Y	Y	2	N	Y	N	N
ELF 051	Y	Y	14	N	Y	N	Y (P1)
ELF 052	Y	Y	3	N	Y	Y	N
ELF 053	Y	Y	12	N	Y	N	Y (P1)
ELF 054	Y	Y	11	N	Y	Y	Y (P1)
ELF 055	Y	Y	2	N	N	N	N
ELF 056	Y	Y	-	N	-	N	N
ELF 056A	Y	Y	-	N	-	N	N
ELF 057	Y	Y	1	N	Y	N	N
ELF 057A	Y	Y	3	N	Y	N	N
ELF 058	Y	Y	-	N	-	N	N
ELF 058A	Y	Y	-	N	-	N	N
ELF 059	Y	Y	11	N	Y	N	N
ELF 059A	Y	Y	8	N	Y	N	N
ELF 060	Y	Y	10	N	Y	N	Y (P1)
Total	**78 cores**		**502 samples**				

Table 7.2. Cores sampled in project. Abbreviations as follows: P1, profile 1, uncalibrated OSL; P2, profile 2, calibrated OSL; D, OSL sediment ages.

The areas of the cores identified as being of interest were normally sampled in 10cm lengths (which has the potential to produce enough material for a suitable sample from this size of core) unless there are any obvious stratigraphic divisions that had to be taken into account.

Sample processing for macrofossils from the cores

The samples obtained from the cores for macrofossil analysis were prepared as a 'chained' sample. Normally 'general biological samples' such as these weigh around 10 kg and can be subdivided for each specialism. Due to the small volume of material per sample available from the cores it was decided that the same sample would be processed for each type of macrofossil in a distinct sequence or 'chain'.

The sample was sieved over a 300-micro mesh sieve following the process for plant macrofossils outlined in Kenward *et al* (1980). Plant remains were then extracted from the material. The remaining material is then available for mollusc/vertebrate material extraction. Finally, the same material was paraffin floated (see Kenward *et al.* 1980) to recover any insect remains present. A X7-40 stereo-microscope was used throughout this process.

DEPTH IN CORE	0.60-0.62m	0.98-1.00m	1.20-1.22m	1.60-1.62m	2.20-2.22m	2.60-2.62m	3.20-3.22m	3.60-3.62m	3.98-4.00m	4.10-4.12m	4.24-4.26m	4.50-4.52m
DEPTH (LAT)	27.60-27.62m	27.98-28.00m	28.20-28.22m	28.60-28.62m	29.20-29.22m	29.60-29.62m	30.20-30.22m	30.70-30.62m	30.98-31.00m	31.10-31.12m	31.24-31.26m	31.50-31.52m
CONTAINED MATERIAL												
plant debris	x	x	x	x	x	x	x	x	x	x	x	
molluscs	f + j	j	f + j	f + j		j	j	f + j	f + j	x	x	
diatoms (>75µ)	x	x	x	x	x	x	x					
brackish foraminifera	x	x	x	x	x	x	x	x	x	x	x	x
outer estuarine/marine foraminifera	x	x	x	x	x	x	x	x	x	x	x	x
outer estuarine/marine ostracods	x	x	x	x	x	x	x	x	x	x	x	x
brackish ostracods	x	x			x	x	x	x	x	x	x	
freshwater ostracods									x	x	x	
stones											x	x

Contained material is recorded on a presence (x) / absence basis; f – fragments; j – juveniles only

Table 7.3. Example of data from rapid assessment of cores samples.

DEPTH IN CORE	0.60-0.62m	0.98-1.00m	1.20-1.22m	1.60-1.62m	2.20-2.22m	2.60-2.62m	3.20-3.22m	3.60-3.62m	3.98-4.00m	4.10-4.12m	4.24-4.26m	4.50-4.52m
DEPTH (LAT)	27.60-27.62m	27.98-28.00m	28.20-28.22m	28.60-28.62m	29.20-29.22m	29.60-29.62m	30.20-30.22m	30.70-30.62m	30.98-31.00m	31.10-31.12m	31.24-31.26m	31.50-31.52m
Ecology	*Outer estuary, initially forming in Early Holocene at seaward end of valley feature (on till landscape). Latterly with less marine influence, perhaps due to changing position of estuary mouth.*											
BRACKISH FORAMINIFERA												
Ammoniasp. (brackish)	x	xx	x	xx	xx	xxx	xxx	xxx	xxx	xx	xxx	x
Haynesina germanica	x	x		x	x	x	x	x	xx	x	x	
Elphidium williamsoni	x	x	xx	x	xx	xx	xx	xx	xx	x	x	
Trochammina inflata									o			
OUTER ESTUARINE/MARINE FORAMINIFERA												
Nonion depressulus	x	x	x	x	o	x	x	x				
miliolids	x	x	x	x	x	x	x	x	xx	xx	xxx	x
lagenids		o										
Elphidium macellum			x						x			
Ammonia batavus					xx			x		xx	x	
Elphidium margaritaceum						x	o	x	x	x	x	
Elphidium excavatum						x	x	x	x	x	x	
Nonion orbicularis											o	
OUTER ESTUARINE/MARINE OSTRACODS												
Palmoconcha guttata	x	xx	x	x		x	x	x	x	x	x	o
Hirschmannia viridis	x	x	x	x	x	x	x	x	x	x	x	o
Bonnyannella robertsoni		o					x					
Hemicythere villosa			o		o	x	o	x	x	x	x	
Heterocythereis albomaculata					x	x	x	o	x	o	x	
Hemicyherura clathrata					o							
Semicytherura nigrescens						x	x	o			o	
Leptocythere pellucida								o	o			
Pontocythere elongata								o		o		
Robertsonites tuberculatus									o		o	
Palmoconcha laevata											x	
BRACKISH OSTRACODS												
Leptocythere castanea	o									o	o	
Leptocythere lacertosa	o	x				o	x					
Xestoleberis nitida					o	o	x	x		x	o	
Cyprideis torosa							x		x	x	o	
Cytherois fischeri								x				
Loxoconcha elliptica									o		o	
FRESHWATER OSTRACODS												
Cytherissa lacustris									o	o	o	

Foraminifera and ostracods are recorded: o – one specimen; x – several specimens; xx – common; xxx – abundant

cold/cool indicator, extinct in Britain since Early Holocene | cold/cool indicator | cold/cool freshwater indicator

Table 7.4 Detailed assessment of microfossils from ELF 047.

Cores selected for assessment	Cores selected for analysis
001A, 002, 003, 005, 007, 009, 019, 020, 031A, 034, 039, 045, 051, 054	001A, 002, 007, 020, 034, 051, 054

Table 7.5. Cores selected for pollen and diatom investigation.

Core number	Number of samples
ELF 002	3
ELF 007	3
ELF 020	6
ELF 034	19
ELF 39	2
ELF 51	22
ELF 54	12

Table 7.6. Cores samples for macrofossil analysis.

Any plant remains recovered were identified under a low power binocular microscope. Species identification were made through plant reference collections and the Digital seed Atlas of economic plants (Cappers *et al.* 2010). Material that could not be identified using these sources were compared to the more extensive collection housed at Historic England, Fort Cumberland. Ecological interpretation used a number of plant flora.

Molluscs were identified to species level where possible under a low-power binocular microscope in consultation with a reference collection. Ecological interpretation was carried out with reference to standard sources for marine and non-marine Mollusca (Graham 1971; Evans 1972; Macan 1977; Kerney and Cameron 1979; Kerney 1999; Killeen *et al.* 2004; Davies 2008; Allcock *et al.* 2017). Nomenclature followed WoRMS Editorial Team (2020) for marine fauna, and Anderson and Rowson (2020) for non-marine Mollusca. The assemblage is discussed in relation to its ecological, biogeographical and climatological implications, and consideration made of the taphonomy of the assemblage. Where appropriate, standard statistical analyses will be undertaken, as outlined in Claassen (1998) and Law (2017).

Insect identification occured using a 7-40x binocular microscope and by direct comparison to the Girling and Gorham collections of British Coleoptera housed at the University of Birmingham. Ecological interpretation are drawn mainly from Buckland and Buckland (2006). Where appropriate basic statistical analysis will be based on Kenward (1978) and Kenward and Hall (1995).