School of Archaeology, Geography and Environmental Science

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SHIFTING SAND: THE PALAEOENVIRONMENT AND ARCHAEOLOGY OF BLOWN SAND IN CORNWALL

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Declaration

I confirm that this is my own work, and the use of all material from other sources has been properly and fully acknowledged.

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ABSTRACT

Coastal sand dunes are common in Britain, especially along western Atlantic coasts, and archaeological sites are well preserved under blown sand. One of the questions is how Holocene palaeoclimate variation influences patterns of settlement establishment and abandonment. Few studies of coastal sites have included palaeoenvironmental evidence, and even fewer include securely dated stratigraphy. This study uses a multiproxy approach to investigate two main and five minor coastal sites in Cornwall, with molluscs analyses being the principal analytical method. Chronology is established by radiocarbon dating and optically stimulated luminescence so that episodic human activity can be related to periods of sand blow and instability. Evidence is sought concerning the history of mineral mining in the Red River catchment area.

Twenty three cores and a test pit were examined along a transect at the multiperiod site at Gwithian on the north Cornish coast. Mollusc columns were obtained at Strap Rocks near the main Gwithian site, and from five trenches excavated at the early medieval site of Gunwalloe on the Lizard peninsula.

The study establishes that initial sand deposition was about 3000 BC, with further marked periods of sand blow in the early and late Bronze Age, the Iron Age and the mid-medieval period. Some, but not all, sand blow correlates with periods of settlement occupation and abandonment, and with known palaeoclimate episodes such as the Little Ice Age. Difficulty in establishing periods of sand conflation and deflation and how this may lead to errors in chronology are discussed. There is weak evidence for mining activity in the Bronze Age, but strong evidence from *c* 1050 AD. The chronology of mollusc extinctions and introductions is refined, e.g. *Xerocrassa geyeri* did not become extinct until the end of the early Bronze Age and *Cochlicella acuta* was present from the late Neolithic, about 2400 BC.

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Note concerning mollusc names used in this thesis

Latin names of molluscs have been used in this thesis, given in the latest printed publication giving a list of extant British Mollusca (Anderson 2005); a later electronic modification of this printed list was published (Anderson 2008) which contains some variations but it was decided that, due to the ephemeral nature of web pages, these later modifications would not be adopted.

The only exceptions to the names in Anderson (2005) are *Cochlicopa* cf. *lubrica*, *Cochlicopa* cf. *lubricella* and *Vallonia* cf. *excentrica* where, for ease of reading, the 'cf.' has been omitted.

Authority names/dates of shells have not been included in the text, but are included in Appendix 1 which outlines the habit preferences of all molluscs found during the present study.

The binomial names of many molluscs have been revised since publication in earlier sources. To provide consistency modern names has been used whenever they differ from those in previous publications.

Note concerning dates used in this thesis

Radiocarbon and optically stimulated luminescence dating was obtained on samples from Gwithian as part of this thesis. The former are expressed as 'cal BC' or 'cal AD' whereas the latter are absolute dates that do not require calibration. In the discussions concerning chronology there is therefore a mixture of calibrated and absolute dates. Where quoted dates refer solely to one or the other dating technique the appropriate terminology is used, but when discussion involves dates obtained by both methods then 'cal' is omitted. The OSL dates should be regarded as provisional until full publication.

The author begs forgiveness if this approach at times leads to confusion.

Photographs and maps

Acknowledgment for photographs is given when necessary. All unacknowledged photographs are by the author. The aerial photographs not otherwise credited were taken by the author on 4 November 2013 during a flight round Cornwall, courtesy of Prof. and Mrs J. Whicher.

The maps (apart from historical ones) are all traced from Ordnance Survey maps obtained from the web pages of digimap.edina.ac.uk.

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1. Introduction

> The coastal sand dune sequences that line the exposed, gale-prone Atlantic shorelines of north-west Europe are the result of poorly-known histories of storminess and quiescence, geomorphic and pedological processes, and past human activities.
>
> (Gilbertson *et al.* 1999)

Coastal sand dunes are common around the coasts of Britain and northern Europe and are likely to have been visited regularly by humans during the Holocene. Sandy bays permit access routes for sea transport and to food resources both on land and from in-shore waters. Many archaeological sites may have been lost over time as a result of coastal erosion or sea level rise, while others were buried by blown sand and remain remarkably well preserved.

Dune formation is thought to have commenced during the Late Glacial Maximum about 18,000 years ago (Goode and Taylor 1988, 29), although many Pleistocene dunes are below modern sea level. In some areas of Britain Pleistocene dunes exist onshore, usually overlying a raised beach, as at Brean Down in Somerset (ApSimon *et al.* 1961; Bell 1990) and at Newquay and Godrevy in Cornwall (James 1994). These glacial dunes are generally only exposed in cliff sections and are not apparent on the land surface. The majority of Holocene dunes around the British coast did not appear until sea levels became relatively stable at slightly below present levels during the early Neolithic (Shennan and Horton 2002, 518).

1.1 Archaeological importance of coastal dune sites

The archaeological sites that survive in or under coastal dunes are an important resource for understanding human presence and activity in prehistoric periods during the Holocene. The blown sand which buries the sites may accumulate slowly or rapidly but stratigraphy is well preserved and less likely to be disturbed by later ploughing or other human activity than on sites further inland. Repeated episodes of sand blow may cover sequential phases of activity or occupation, the latter representing phases of stability. Bell and Brown (2008) have outlined the key contexts in which archaeological and palaeoenvironmental evidence is preserved on dunes, and this will be discussed below. In brief, human presence may be represented by the remains of buildings, field walls and trackways, for example, while their activities may be seen by preserved plough marks or animal footprints, charcoal from burning, midden material and artefacts.

Major sand blow episodes in different parts of Britain are likely to be broadly coeval, especially at times of rapid climate change, but less severe episodes will more probably impact only in local areas. Comparison of blown sand sites can aid in establishing chronologies of coastal environmental change, but only when there has been a robust programme of context dating in association with material culture and/or palaeoenvironmental evidence.

One of the most important sites where these sequences have been studied is at Gwithian in Cornwall, where excavations from the late 1940s to the mid 1960s showed three distinct phases of occupation during the Bronze Age (*c* 1800 cal BC, *c* 1500-1200 cal BC and *c* 1300-900 cal BC) followed by abandonment for around 1300 years before establishment of a post-Roman settlement on a nearby dune in the fifth century AD (Thomas 1958; Megaw 1976; Nowakowski *et al.* 2007). There was a Roman homestead on the adjacent headland (Fowler 1962) but no known settlement on the dunes at Gwithian during the Iron Age or Roman period. Elsewhere significant studies of prehistoric settlements built on blown stand have been undertaken especially in Scotland in the Outer Hebrides and Orkney Islands (e.g. Murphy and Simpson 2003; Wessex Archaeology 2008).

1.1.1 Coastal seaways

Coastal sites on the western British shores have received increasing attention in recent years as the importance of maritime communication routes has become widely recognised, arguably from the Mesolithic but with strong evidence from the Neolithic (Sheridan 2004), during the Bronze Age and later (e.g. Mercer 2003). It has been accepted for many years that the sea route round the Atlantic coast of Armorica and either through the Irish Sea or to the west of Ireland was important during the Iron Age, entering written history with the travels of Pytheas round Britain about 320 BC, recorded by Strabo in his *Geographica*. Evidence for sea movement comes, not only from comparison of material culture found along the Atlantic zone (e.g. Henderson 2007, 1; Cunliffe 2013, 131), but is also emerging from genetic analysis (e.g. Oppenheimer 2007, 156, 197).

There is debate about whether boats made sea crossings in one long trip or by multiple shorter journeys with repeated coastal stops. The motive power during the Mesolithic and Neolithic was likely to be limited to paddles, with oars and sails not being developed in Atlantic Europe until the Bronze Age (McGrail 2001, 171). Access to safe intermediate landing places would have been essential during these long journeys, especially in view of the often adverse weather conditions in the Atlantic Ocean. St. Ives Bay, on the north coast of western Cornwall, is the first bay encountered by boats after rounding Lands End and entering the Bristol Channel and would have provided a safe haven. There are beaches in the bay where boats could land easily, obtain fresh water and re-provision prior to setting off further north or east up the Bristol Channel to the Severn Estuary. Gwithian, lying on the east side of St. Ives Bay, is at the north end of a long beach with the Red River flowing into the bay and would have been an ideal location for such activities.

1.1.2 North Atlantic climate change during the Holocene

The climate of Britain has fluctuated during the Holocene, with overall warming following the Last Glacial Maximum (*c* 22000 BP) and the cold episode of the Younger Dryas (12800-11000 BP) (Bell and Walker 2005, 87). By the commencement of the Holocene at around 12000-11500 BP warming had increased considerably, as revealed by both deep (Austin and Kroon 1996) and surface (Koç *et al.* 1993) Atlantic water temperatures, which had risen approximately to those equivalent to the present day (Atkinson *et al.* 1987; Ponel and Russell Coope 1990).

Climate reconstructions in the North Atlantic have mainly been derived from high-resolution studies of deep ice cores in Greenland: the American Greenland Ice Sheet Projects (GISP/Dye 3, 1971-1981; GISP2, 1986-1993) and the European Greenland Ice Core Projects (GRIP, 1989-1992; NorthGRIP/NGRIP), 1999-2003). Measurement of oxygen stable isotopes, $\delta^{18}O$, has allowed temperature fluctuations to be calculated and both regular and irregular variations analysed (e.g. Alley *et al.* 1997; Bond *et al.* 1997; Bianchi and McCave 1999; Bond *et al.* 2001; Fleitmann *et al.* 2008; Wanner *et al.* 2008). Several other methodologies have contributed to the compilation of climate fluctuations during the Holocene, for example dendrochronology (Briffa 2000; McCarroll *et al.* 2013), pollen studies (Davis *et al.* 2003; Salonen *et al.* 2012), molluscs (Rousseau *et al.* 1993; Rousseau *et al.* 1994; Wang *et al.* 2012), speleothems (Lauritzen and Lundberg 1999) and mires (Barber *et al.* 1994; Hughes *et al.* 2000).

After the end of the last ice age temperatures rose steadily to a plateau of 'climatic optimum' which lasted from *c.*9000-4000 BP following which there was slow cooling until around 2000 BP (Figure 1.1) (Dahl-Jensen *et al.* 1998; Johnsen *et al.* 2001). The climate then again warmed, reaching a maximum about 1000 BP – the Medieval Warm Period, followed by a further progressive decline leading to the Little Ice Age during the sixteenth to nineteenth centuries, although with some alleviation of the cold in the eighteenth century (Bell and Walker 2005, 94). Within this overall sequence, periods of extreme climatic instability have been demonstrated by Mayewski *et al.* (2004) and in peat bog sequences by van Geel *et al.* (1996), such as the 8.2ka event clearly seen in Figure 1.1.

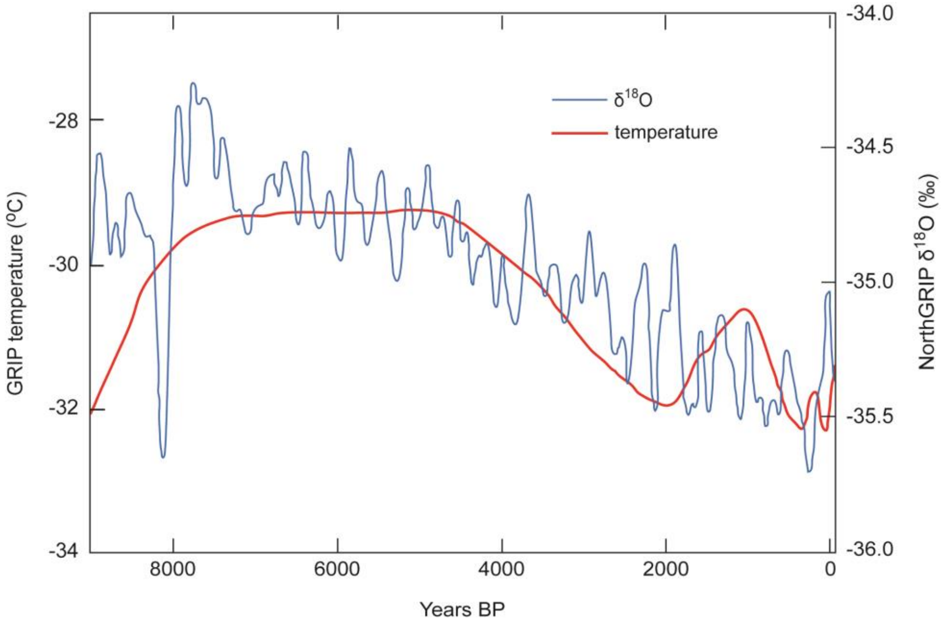


Figure 1.1. The NorthGRIP $\delta^{18}O$ record and GRIP long-term temperature profile for the mainland of Greenland during the Holocene (modified from Johnsen *et al.* 2001, Figure 8)

Climatic variations during the Holocene are discussed in detail by Bell and Walker (2005, 85 and references therein), and will only be summarised here:

Historic period

c 600-100 BP	The Little Ice Age, with cooler summers and cooler, wetter, winters, temperatures reaching their lowest in the early seventeenth century (Barber *et al.* 2000; Fagan 2000; Mann *et al.* 2009; PAGES 2k Consortium 2013).
c 1150-750 BP	Medieval Warm Period (Mann *et al.* 2009).
1450-1350 BP	Deterioration (Briffa 2000).
2200-1550 BP	The Roman Warm Period (Wang *et al.* 2012).

Prehistoric period

c 2650 BP	Climate deterioration and coastal inundations during the Bronze Age/Iron Age transition (Van Geel *et al.* 1996).
2800-2500 BP	Cooler, wetter conditions (Van Geel *et al.* 1996).
3500-2500 BP	Instability (Bond *et al.* 1997; Bond *et al.* 2001) with wet shifts in climate.
4410 BP	Wet shifts in climate (Hughes *et al.* 2000; Barber *et al.* 2003).
c 4500-4000 BP	The '4200 event' with colder, wetter conditions in Europe, but drier elsewhere (Barber *et al.* 1994; Barber *et al.* 2003).
c 7500-4400 BP	The period of 'thermal maximum' with warmer, dryer conditions (Johnsen *et al.* 2001), although with both spatial and temporal variations (Bell and Walker 2005, 89).
c 8400-8000 BP	The '8200 event' when there was rapid climate change leading to a short-lived period of cool, dry or windy conditions (Alley *et al.* 1997).

Numerous major lowland riverine flooding episodes have been identified in Britain during the Holocene (Johnstone *et al.* 2006; Macklin *et al.* 2006) and it would seem probable that some at least would have affected the rivers of Cornwall. These are listed in Table 1.1.

Table 1.1. Major Holocene flooding events in lowland unglaciated rivers (cal BP dates) (after Johnstone *et al.* 2006)

Mesolithic Neolithic	**Bronze Age**	**Iron Age**	**Romano-British Medieval**	**Post-medieval**
11190	4160	2320	1650	290
10600	3830	2150	1160	
10170	3150		650	
9300	2800		570	
7540			390	
6780				
5920				
5690				

It is likely that human activity was strongly influenced by the climate during the Holocene, changes in the environment impacting both locally and on a wider scale. While climate changes affect wide areas of the globe, weather events often have a much more local impact. There can be little doubt that isolated winter storms, for example, may have a major impact on discrete areas of a coastline, and which were usually not documented until recent times. For example, contemporary reports describe the Lisbon tsunami affecting the west of England on 1 November 1755 with seas retreating and then rising up to eight feet in Penzance and eight to nine feet in St. Ives Bay (Borlase 1755).

1.2 Sea level change and coastal erosion

The coastline of Britain has undergone marked change since the onset of the Holocene (Shennan and Horton 2002). Compared to the present, sea level was around 120m lower during the Late Glacial Maximum, and about 30m lower at the onset of the Holocene. At the commencement of the Holocene Britain was connected to the rest of Europe by dry land, and did not become separated until the beginning of the later Mesolithic (Cunliffe 2013, 50). Sea level curves show that there was rapid rise in sea level in the early post-glacial millennia, with much slower rate of rise in the later Holocene (e.g. Shennan *et al.* 2012). Some curves have been produced for the west of England (Figure 1.2) (Heyworth and Kidson 1982), which have been reproduced by other authors (Healy 1995, 1999; Shennan *et al.* 2006; Shennan *et al.* 2012); in the Bristol Channel the furthest west location on which the curves were based was at Westward Ho! in Devon, while in the English Channel there were several data points from Penzance in the west to Portland in the east. To date no sea level curves have been proposed for the north Cornish coast.

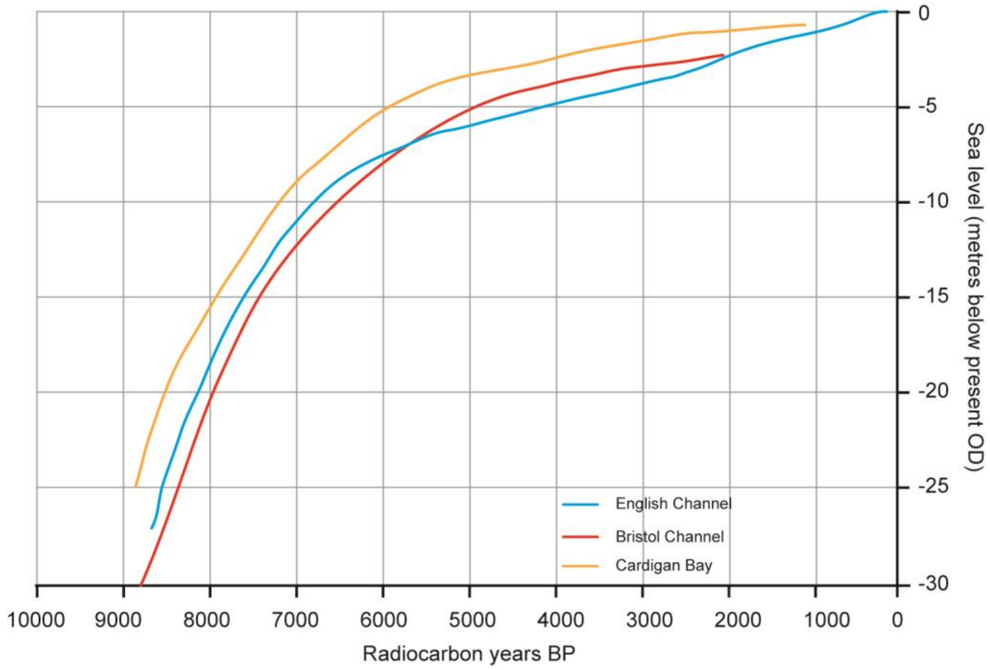


Figure 1.2. Sea level curves for south west England and Wales (after Heyworth and Kidson 1982)

Coastal resources were important during the early Holocene when, in the Mesolithic, marine food such as fish and molluscs are thought to be the main dietary components (e.g. Richards and Hedges 1999; Schulting and Richards 2002). This necessitated settlement close to the coast, at least on a seasonal basis (e.g. Mellars 2004; Bell 2007). Many of the sites occupied prior to sea level rise are now beneath sea level and therefore lost to archaeological excavation, although recent work in the Solent has revealed a Mesolithic landscape at a depth of 12m below the surface (Momber *et al.* 2011). There are numerous archaeological sites on dry land which are located close to the present coastline (e.g. Bell 1987, 6; Ayala *et al.* 2007, 9; Bell and Brown 2008), and which are often well preserved under blown sand derived from local beaches.

Rising sea level is not the only cause of coastal change. Also important is the effect of erosion of beaches and cliffs from storm and wave action often causing rapid and catastrophic damage to land close to the sea. Every year in Britain there are reports of cliff falls with buildings collapsing onto beaches and unknown archaeological sites are often revealed following coastal erosion. Examples include the discovery in 2013 of human footprints at Happisburgh, Norfolk which were revealed in eroding laminated sediments and were made between *c* 1 million and 0.78 million years ago (Ashton *et al.* 2014) and Palaeolithic hand axes at Pakefield, Suffolk, from about 700,000 years ago (Parfitt *et al.* 2005). Holocene examples include the Neolithic settlement at Skara Brae on the Orkney Islands, first exposed by a storm during the winter of 1850 (Childe 1931) and at present preserved from further erosion only by protective concrete walls. The Skara Brae village at the time of occupation was probably some way inland from the coast.

1.3 Burial of archaeological sites

Those sites which today are on dry land did not escape change. Sand dunes by their very nature are potentially unstable and mobile features. There may be dramatic movement of blown sand during storms which can rapidly bury occupation and agricultural sites, perhaps leading to their abandonment. Examples in relatively recent times on the north Cornish coast are the fifteenth century St. Enodoc church at Trebetherick which was buried to roof level by sand during the sixteenth century and not restored until 1863–64 (Cornwall Historic Environment Record, no. 26442) and St Gothian's Chapel at Gwithian, which was buried by sand sometime during the medieval period and not rediscovered until 1827 (Thomas 1964a).

Aeolian sands are important from an archaeological perspective, as they preserve occupation horizons *in situ*, often in remarkable detail. Blown sands, being derived from beach deposits, are normally highly calcareous due the presence of fragmented marine molluscs and calcareous algae, permitting preservation of materials which would be lost on more acidic sites. This especially applies to environmental evidence such as molluscs which can be found in large numbers in many dune and blown sand deposits. Conversely, pollen and other materials which survive in more acidic environments are normally absent or poorly preserved in coastal sand deposits.

The sites where humans established their settlements were influenced by the environment and in turn the environment was altered by the presence of humans and their activities in the area around settlements (Gilbertson *et al.* 1999). Study of this changing environment permits greater knowledge of the nature of human habitations, perhaps allowing understanding of why particular sites were selected and later abandoned. Sites that were occupied over a long period of time are likely to reveal changes in the environment caused by human intervention and/or natural events such as climate change, storminess, tsunamis, etc.

1.4 Waste and pollution

Humans leave their footprint wherever they have established settlements and produced waste products. Middens are one of the prime sources of information about the activity of settlement occupants, providing information not only on the dietary habits of those who produced the waste, but often leaving the material culture that were part of their everyday life, such as ceramics, bone and metal artefacts. Manufacturing processes also leave waste, which increased considerably during and after the Industrial Revolution of the eighteenth century, when exploitation of mineral resources resulted in dramatic changes to the landscape of Britain and other countries. Evidence of industry can often be found for much earlier times, such as the Bronze Age copper mines at the Great Orme, North Wales, (Lewis 1994) and the Roman lead mines in the Mendip Hills of Somerset (Todd 2007). Even where the sites of primary activity cannot be located there may be remote evidence when waste products are dispersed by rivers. Tin extraction in Devon and Cornwall is thought to have commenced during the Early Bronze Age as artefacts have been found dating from that period (Buckley 2005, 13), but it is possible that the ores were recovered from streaming and open surface exposures rather than quarrying into the underlying rock. During these processes some ore and waste products enter the river systems and will be deposited into river sediments on the way to the sea. Analysis of these sediments may provide evidence of mining activity in prehistoric times as well as during medieval and later periods.

1.5 Aims and objectives

The principal hypothesis to be tested is that the main driver of sand blow and instability is palaeoclimatic in origin, thus influencing the episodic site occupation of coastal sites.

This study will explore the palaeoenvironment in areas of human habitation on blown sand in Cornwall, and relate this to other sites in Britain. Refinement of the chronology of the stratigraphy will permit correlation with known Holocene climatic episodes in the North Atlantic, and assessment of how this has influenced human activity at the study sites. Although many archaeological sites on dunes have been excavated in the past, relatively few have incorporated environmental data, and reliably dated chronological sequences are frequently lacking. This new investigation aims to address some of these issues, and provide a precisely dated and archaeologically correlated record of dune blow and stability in south western Britain.

Within the framework of the main hypothesis the answers to several questions will be sought:

- Is the episodic history of sand blow driven by secular climatic episodes, storm events, sea level changes or land use factors?

- Are the sand blow and stability episodes coeval in the study areas and how do they relate to known climatic episodes elsewhere in Britain?

- How do sediments and molluscs contribute to understanding spatial variation in the landscape?

Study of molluscs will allow hypotheses concerning the introduction and extinction of certain molluscan species during the Holocene to be tested in relation to south west Britain.

The main case study is at Gwithian on the north Cornish coast, a multiperiod settlement from the early Bronze Age to the late medieval period, in an area which, during and since the Industrial Age, had been altered as a consequence of mining in and around Camborne. A secondary case study is at Gunwalloe on the Lizard peninsula, an early medieval settlement but with some evidence of Bronze and Iron Age activity in an area subject to major coastal erosion. Evidence will also be included from other blown sand sites in Cornwall. A multiproxy approach to analysis of environmental data will be employed, with study of molluscs providing core data. This will enable new insight into how humans lived on the shifting and unstable sands of Cornwall.

Answers will be sought for particular questions at each of the principal study sites:

Gwithian

- Did human activity influence the environment, or *vice versa*, in different regions of the study area?
- Is there evidence for agriculture, either grazing or arable, more widely than previously established?
- Is there evidence that the lower Red River valley was ever a tidal estuary?
- Is there evidence in the lower Red River valley for mining in the river catchment area during prehistory or the historic period?

Gunwalloe

- Why was the early medieval settlement abandoned around the ninth to tenth centuries?
- Has the area of the settlement always been sand dunes or was it ever wooded?
- How has the environment in the vicinity altered during the time before, during, and after human occupation?

1.6 Thesis outline

Chapter 1. Introduction, with discussion leading to the project hypotheses and questions to be answered concerning the individual study sites.

Chapter 2. Discussion of dune formation processes, molluscs and archaeology, and of the methods used to date sediments containing molluscs.

Chapter 3. Discussion of coastal dune sites on the north coast of Cornwall where mollusc samples have previously been obtained, and the selection of sites for detailed case study.

Chapter 4. The methods employed for sample collection in the field and the analytical methods used in the laboratory.

Case study 1 – Gwithian

Chapter 5. Discussion of the archaeological site and the history of mining in the catchment area of the Red River.

Chapter 6. The coring transect at Gwithian, with description of the field methods and laboratory analyses, with detailed discussion of the findings in the cores.

Chapter 7. The results of dating, stable isotope and geochemistry analyses of the cores.

Chapter 8. Description of the trench excavation at Gwithian, and of the laboratory analyses of the mollusc column obtained from the trench.

Chapter 9. Description of the Strap Rocks site and analysis of the mollusc column.

<u>Case study 2 – Gunwalloe</u>

Chapter 10. Discussion of the archaeological site; description of the mollusc columns obtained and the results of laboratory analyses. Discussion of the findings and of the specific questions asked about this site.

Chapter 11. Discussion of the overall findings in connection to the landscape and change over the time of settlement occupation and relationships to Holocene climate events, both at the study sites and elsewhere in Britain. Discussion of the history of mining revealed by the study. New findings concerning the extinction and introduction of mollusc species to Cornwall.

Chapter 12. Conclusions drawn from the overall study, addressing the specific questions raised concerning the Gwithian site, and the hypotheses proposed for the project as a whole.

2. Sand, molluscs and archaeology

2.1 Dune formation processes

Coastal sand dunes are common in Britain (Figure 2.1), especially on Atlantic-facing coasts, but also around the North Sea coasts of Scotland and northern England (Doody 2008, 2009). In total these cover about 70,000ha, of which 71% by area are in Scotland (May 2003, 332).

The development of modern sand dunes in Britain is often considered to have commenced no earlier than around 4000 BC (Carter 1988, 303), once sea levels were sufficiently close to present day levels for sand to be driven onshore by wind and wave action. However, some more recent reports suggest older dates for blown sand deposition. Gilbertson *et al.* (1999) found that carbonate sands on the machair of the Benbecula in the Outer Hebrides commenced development from *c* 7000 to 6300 BC and on Vatersay from *c* 4800 BC while on the Bay of Skail on the Orkney Islands blown sand is dated to 5040–4855 cal BC (de la Vega-Leinert *et al.* 2000). At Sefton on the Lancashire coast the first dune complexes are thought to have developed around 3800 BC (Pye and Neal 1993). Evans (1972, 296) proposed that sand deposition at Northton in Harris, Outer Hebrides, could not be earlier than about 3000 BC, while a somewhat later date of *c* 2000 BC has been suggested for Cornwall (Caseldine 1980, 7; Turk 1984, 271; Lewis 1992). On Sanday in the Orkney Islands the first blown sands accumulated around 3000 BC but with established dunes not developing until 1000 BC (Sommerville *et al.* 2007). Some British dunes are argued to be of much more recent origin, commencing in medieval or later times (Saye 2003, 42)

Primary coastal dunes often contain carbonate-rich aeolian deposits with high levels of shell-derived material from marine sources. The predominance of dunes along the Atlantic seaboard of the British Isles is the consequence of the strength and direction of prevailing winds which in Britain are from the west.

The processes by which sand is moved from a beach to form dunes or is deposited over a wide area to form aeolian sand flats are complex, involving many factors which vary both from site to site and within different areas of any one site (e.g. Ritchie 1972; Pye and Tsoar 1990). Sand grains are those mineral particles which are light enough to be moved by the wind but too heavy to remain in suspension. Different authors have specified various grain sizes for sand but the currently accepted size range is 63µm–2mm (e.g. Blott and Pye 2001). Sand derives from the breakdown of rocks, particularly by physical weathering or freeze/thaw processes, especially originating during glaciations. Remobilization by wind and rain action results in movement from inland sources, with sediment redistributed towards the coast by rivers, particularly during flood episodes. Onshore drift from the sea floor contributes to coastal sand (Bird *et al.* 2003, 204) but beach sand also originates from local cliffs undergoing erosion (Lyell 1830-1837, 300).

Figure 2.1. Coastal sand dunes in the British Isles, shown in red.
The sites which include molluscs in palaeoenvironmental analysis
are indicated (modified from Doody 2008, 2009)

In order for coastal dunes to develop it is necessary for adequate supplies of well-sorted beach sand to be available, and for onshore winds of sufficient strength and frequency to move the sand grains (Packham and Willis 1987, 153). These aeolian deposits may be spread over a wide area as blown sand flats or accumulate into mounds as dunes. In Britain the prevailing wind is from the west, which accounts for the predominance of dunes along the Atlantic seaboard of the British Isles. North east winds have more influence on the dunes of the east Scottish and Northumberland coasts.

Sand grains are moved by a variety of processes (Figure 2.2) which depend on wind strength (Masselink *et al.* 2011, 274). In sand creep the grains roll or slide downwind but remain in contact with the sediment bed, while with reptation (grains >500µm), saltation (grains 70−1000µm) and suspension (grains <20−70µm) wind strength is sufficient to lift grains off the ground.

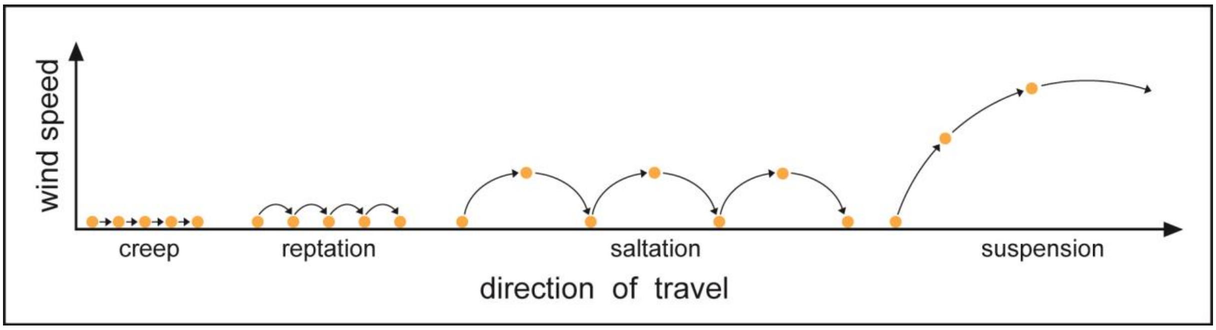


Figure 2.2. Methods of movement of sand grains by wind

The presence or absence of vegetation also affects sand movement. Sand grains become trapped around plants which reduces mobility allowing pioneer species to become stabilized (Masselink *et al.* 2011, 290). Trapping of sand, in combination with supply and erosion rates, is the initial stage in the stabilization of a dune within an area of blown sand. In Britain marram grass (*Ammophila arenaria*) and sand couch (*Elytrigia juncea*) are succeeded by red fescue (*Festuca ruba*), common bent grass (*Agrostis capillaris*), smooth meadow grass (*Poa pratensis*) and bird's foot trefoil (*Lotus corniculatis*). As the dunes become older shrubs and trees are able to gain a foothold. As plants decay organic matter is added to the underlying sediments and in time these alter the sediment composition and chemistry, eventually forming soils – the process of pedogenesis (Masselink *et al.* 2011, 291). Soil formation may continue until interrupted by new deposition of blown sand, resulting in a palaeosol. Repeated episodes of stabilization with soil formation interspersed with deposition of blown sand produces multiple buried soil horizons.

Dune sands, being mainly of beach origin, frequently contain debris from marine molluscs which may contribute a significant portion of the sand. This is especially so on the coasts of south west England; the beaches of north Cornwall from Godrevy to Padstow contain 25−37% calcium carbonate, the highest proportion found on any beach in England and Wales (Saye 2003). This shell debris consists largely of carbonate and the soils that develop are therefore alkaline, providing optimal environments for non-marine Mollusca to live, and for their preservation after death of the animal. Palaeosol horizons in dune sands are frequently rich in terrestrial molluscs, an important resource in the study of the palaeoenvironment, especially in determining whether the dunes remained open or became covered with scrub or woodland.

Coastal dunes are not static features of the landscape. Sand may be carried far inland by wind action especially during stormy weather, burying pre-existing land surfaces. Equally, wind may remove sand by deflation, altering the composition of sediments that remain. Lighter debris, including that from shells, may be blown a considerable distance from their original site of deposition, while larger fragments will remain in-situ (Bell 1987, 6). This concept is important, as it can result in assemblages differing significantly from the original death assemblages. Soils which have formed may become buried and preserve the structure of that soil, enveloping both archaeological and natural material; the recognition of palaeosols is a vital element in reconstruction of ancient landscapes and occupation patterns. Study of the fauna and flora associated with archaeology may shed light on the environment at the time, and help understand the uses to which land was put. Coastal erosion and dune stability is also affected by human action, particularly agricultural and recreational use, and the value of dunes as flood defence of inland areas can be compromised if erosion of excessive. A comprehensive review of dunes throughout England and Wales in the light of potential threats from erosion has recently been completed (Pye *et al.* 2007b).

Dunes may be classified in different ways. Geomorphology describes both the underlying geology and marine current movements which lead to the formation of dunes on the varying types of coast. Physical appearances describe their shape and position in the landscape, both of which have a major influence on the vegetation able to colonize the initially bare sand surface.

Various classifications have been proposed to describe the geomorphology of dunes (Doody 2001, 113; Saye 2003; Pye *et al.* 2007a). The main types which are found in Britain are (Figure 2.3):

- Bay dunes: develop in coastal bays, often between rocky headlands.
- Spit dunes: sand is deposited at the mouth of an estuary, the pattern depending on combinations of wave action and the river flow.
- Hindshore dunes: develop when sand is blown inland, especially in exposed coastal areas. These may become very extensive, both in area and sand depth.
- Ness dunes: occur when the prevailing and dominant winds blow from opposite directions.
- Offshore island dunes.
- Climbing dunes: sand is blown over rising ground, often sea cliffs.

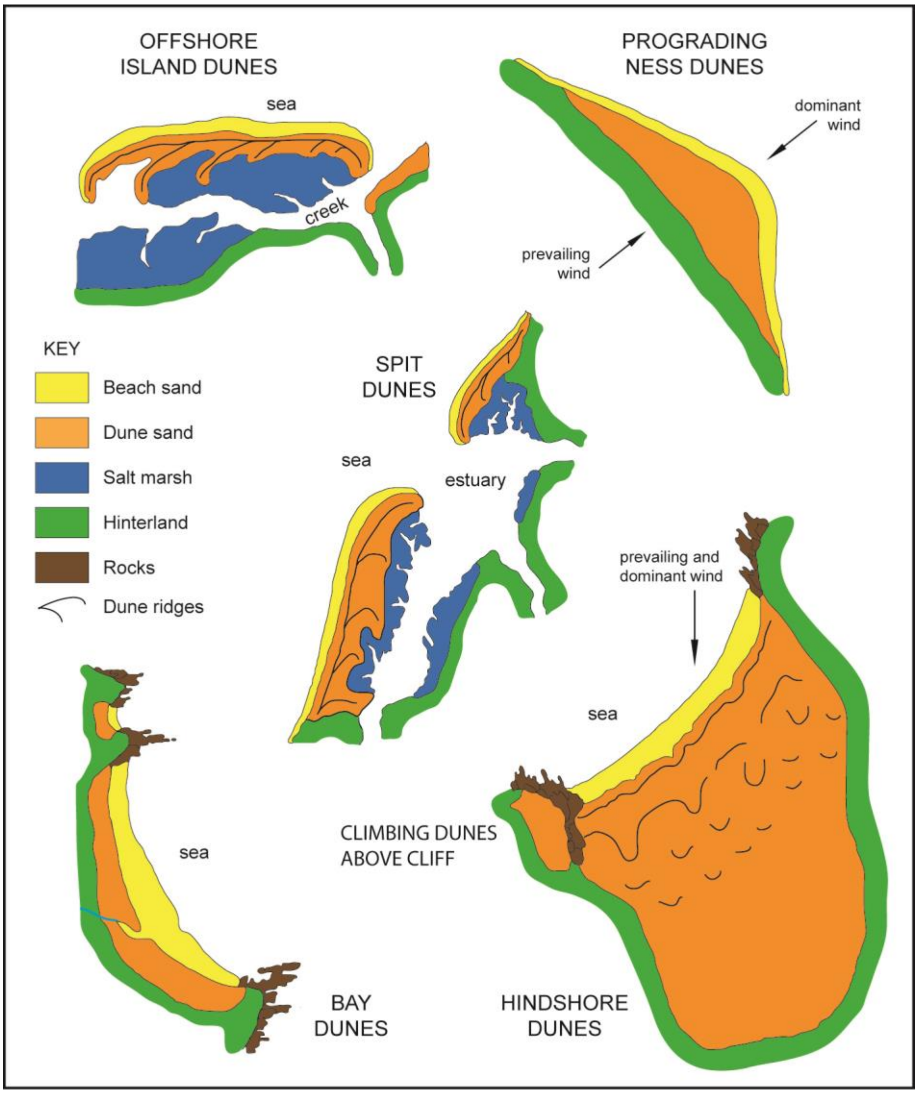


Figure 2.3. The principal geomorphological types of dune systems occurring in Britain (after Ranwell and Boar 1986, 21)

The structure and vegetation of dunes (Figure 2.4) generally varies depending on the distance from the foreshore. The greater the distance the greater the likelihood of stability and therefore of increasing vegetation (Barratt 1962; Packham and Willis 1987; Doody 2001, 120):

- Foredunes (yellow dunes): young dunes, with *Ammophila arenaria* (marram grass) and *Elytrigia juncea* (sand couch grass) being the dominant vegetation species.
- Dune heath (grey dunes): more mature dunes but often unstable; if acid then grassland is dominated by *Deschampsia flexuosa* (wavy hair grass) and *Festuca ovina* (sheep's fescue). Where calcium carbonate levels are low (brown dunes) or absent *Empetrum nigrum* (black crowberry) and *Calluna vulgaris* (common heather) appear.
- Dune flats, pasture, machair: inland areas where sand if often spread thinly over a wide area. In the western Scottish islands machair is a specific type of extensive dune flat used as pasture and has a rich flora.
- Dune slacks: depressions in the dunes where the water table is at or near the surface, often rich in vegetation, particularly on calcareous sand.
- Mature dune: scrub and woodland can develop on very stable dunes, especially if grazing is at low levels.

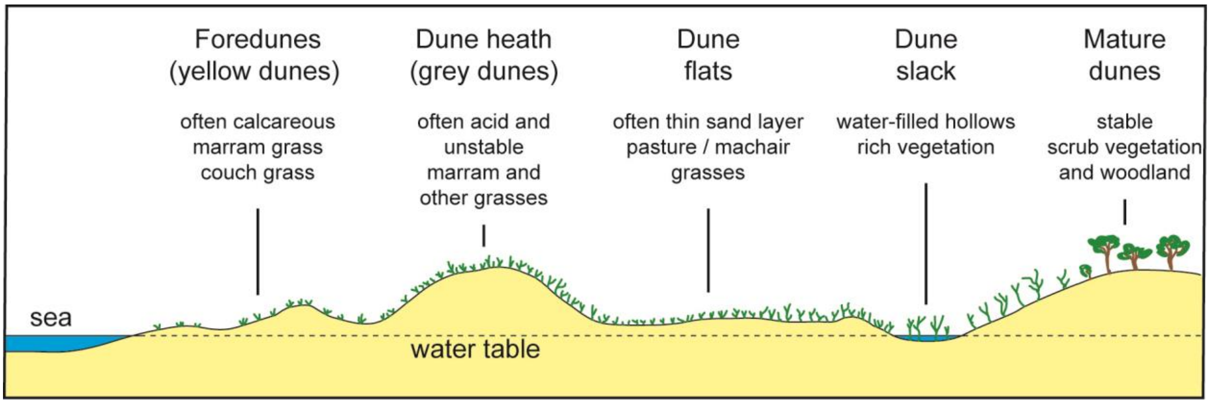


Figure 2.4. Coastal dune structure
(modified from Greenfield 2013)

Sand dunes may be shallow or deep, small in area or extensive. In Scotland there are extensive dunes, particularly in the Outer Hebrides. Large areas remain unstable but much of the blown sand has become stabilized and developed into grassy and very fertile machair plains (Gilbertson *et al.* 1999). In Cornwall the largest expanse of dune is at Penhale Sands near Newquay, being approximately 8.5 x 2km in extent (542ha) and over 60m in height; these dunes are unstable, with shifting sand and little surface vegetation. Gwithian Towans on the east side of St. Ives Bay in Cornwall is 3.5 x 1.5km in extent, but is now stable with vegetation covering almost the entire area. In contrast at Holywell Bay, just north of Penhale Sands, the dunes are contained within a steep sided estuary and cover only about 0.5 x 0.5km.

The value of dunes and areas of blown sand in the preservation of archaeological sites has already been stressed. Coastal sand is normally alkaline with a pH of around 7−9, conditions in which both structures and many artefacts survive. Bell and Brown (2008, 21) have identified the various contexts in which environmental and archaeological evidence may be found (Figure 2.5).

Coastal resources were important during the early Holocene; many archaeological sites are located close to present coastline (Bell 1987, 6; Ayala *et al.* 2007, 9) and are often well preserved under the blown sand. This may be related to the diet during the Mesolithic which consisted largely of marine sources (e.g. Tauber 1981; Richards and Hedges 1999; Schulting and Richards 2002), fish and molluscs being a major component of the diet. This necessitated habitation close to the coast, at least on a seasonal basis (e.g. Richards and Mellars 1998; Schulting and Richards 2000). Some of the sites occupied prior to sea level rise are now beneath water level and lost to most archaeological excavation, although recent work in the Solent has revealed a Mesolithic landscape 12m below the surface (Momber *et al.* 2011).

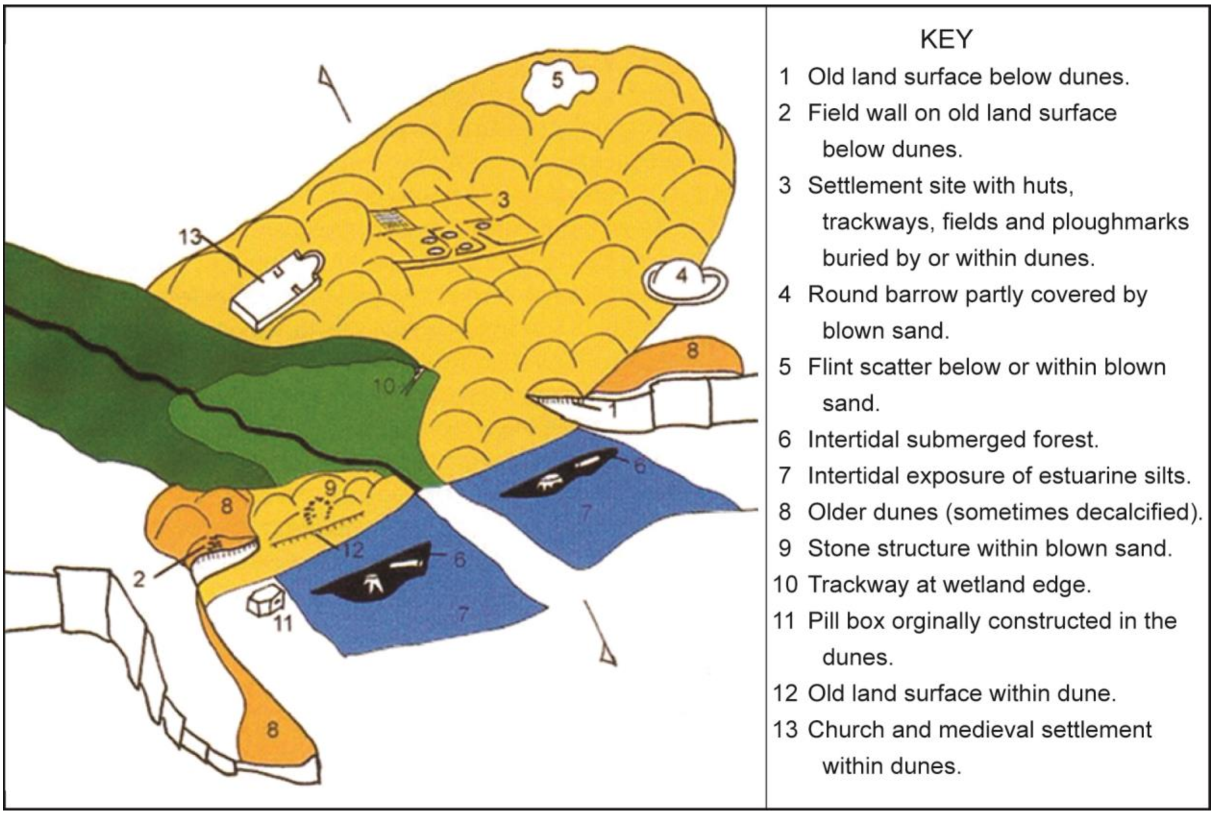


Figure 2.5. Schematic diagram to illustrate some of the key contexts in which archaeological and palaeoenvironmental evidence is found in relation to coastal dunes
(Bell and Brown 2008, 22)

Although diet altered to a more terrestrial basis during the Neolithic and Bronze Age (Richards *et al.* 2003), occupation close to the sea remained common. Water transport would have been considerably easier than travel across country, particularly prior to deforestation during the Neolithic. No remains of Neolithic water transport have yet been found in Britain, but the discovery of remains of early Bronze Age boats at Dover (Clark 2004) and at Kilnsea (Van de Noort *et al.* 1999) and Ferriby (Wright 1990) on the Humber provides evidence that coastal shipping did occur at that period.

2.2 Molluscs and archaeology

2.2.1 Non-marine molluscs as ecological indicators

Terrestrial molluscs living in Britain at present are generally small in size, the majority being less then 10mm in maximum length/width, and many less than 5mm. Their small size and rate of movement means that they are restricted to relatively small areas of ground during life, and that the site where they die is likely to be good indicator of the habitat in which they were living. This does not necessarily hold for an assemblage found some time after death, as the dead shells may have moved large distances, especially as a result of wind and/or water action. When interpreting any death assemblage it is important to consider whether that assemblage is autochthonous, *in situ*, and representative of the habitat during life or allochthonous, not *in situ*, and displaced from the site occupied while alive.

Despite these restrictions, knowledge of the varying ecological preferences can provide useful information concerning the local habitat at the time when those molluscs were living. The value of mollusc analysis in this context depends on the assumption that the habitats preferred by subfossil species are the same, or similar, to those of modern species – the principal of uniformitarianism – but this may not always be the case.

It has long been recognised that different taxa of non-marine Mollusca may be found in different habitats (e.g. Boycott 1934; Evans 1972). Some species live in open country exposed to the sun while others require varying degrees of shade, either continual shade, or that afforded by the base of vegetation. There are many taxa which are more catholic in their requirements, with the ability to live in widely differing environments. Most molluscs also require access to a source of calcium, an essential element necessary to build their shells.

The first detailed reports of the ecological preferences of British non-marine molluscs appeared in the early years of the twentieth century when Arthur Boycott reported on the habitats of freshwater Mollusca (Boycott 1918); he followed this with several brief reports but his seminal papers in the 1930s on both land and freshwater molluscs provided a solid base which other investigators later developed (Boycott 1934, 1936). Boycott recognized terrestrial species as preferring wet places (hygrophiles), dry places (xerophiles) or woodland, while freshwater species were divided into those living in rivers, canals or lakes. Boycott's work was furthered by Bruce Sparks (1961, 1964) who explored the environmental requirements of fossil molluscs and then expanded this to include archaeological deposits (Sparks 1969). Meanwhile Michael Kerney was also using molluscan analysis in relation to archaeological sites to investigate the environments in which prehistoric man lived (Kerney 1963; Kerney 1966; Kerney 1968). But it was not until John Evans published his seminal work *Land snails in archaeology* (1972) that the value of molluscs in palaeoenvironmental reconstruction entered the archaeological mainstream; while Evans's work concentrated on the chalk downlands of southern England, he also discussed the value of molluscs in dune environments. Many more recent studies have been reviewed by Paul Davies (2008).

It is now generally accepted that terrestrial molluscs can be divided into three broad categories**: shade preferring**, **catholic** and **open country** (e.g. Boycott 1934; Sparks 1961; Evans 1972, 194), although it is often useful to include **marsh** as an additional category for those species preferring wetter conditions. Freshwater molluscs are categorised into four groups: **slum**, **ditch**, **moving water** and **catholic** (e.g. Boycott 1936; Sparks 1961). A **brackish water** group in coastal habitats can tolerate a degree of salinity.

Analysis of molluscan assemblages can take the **autecological** or **synecological** approach (e.g. Cameron 1978; Davies 2008, 55). Autecology takes into account the habitat ranges of individual species, from which the average environmental requirements for multiples species can be assessed; in the context of palaeoecology, this approach is reliant on the principle of uniformitarianism. In contrast, synecology studies the inter-relationships between communities of species and has the ability to reveal groupings that cross the habitat boundaries described above.

There are many different ways in which the molluscs found either in living or subfossil context may be analysed, and these were summarised by Evans *et al.* (1992) and discussed by Davies (2008, 62):

1. Total number of individuals

This provides an overall picture of the suitability of the habitat for molluscs, for instance the availability of calcium for shell building and vegetation for food and shade. In the context of wind blown sand this can be very helpful in understanding rates of sand deposition, as a large number of shells implies stability with adequate dietary requirements, whereas a small number suggests rapidly accumulating dunes with insufficient time or lack of calcium/vegetation for high numbers of individuals to collect.

2. Total number of species

This gives some indication of the number and variety of microhabitats and diversity and, as with the number of individuals, to some extent reflects the stability of the ground, as time is necessary for a large number of species to colonize an area. In Scottish dune sequences increasing stability and shade was indicated when 'non-wet ground' species numbers increased above 12 or 13, with numbers above 15 'non-wet taxa' often coinciding with true shade species, perhaps indicating rich, long, very stable grassland or open woodland (Thew 2003, 165).

3. Distribution of numbers of individuals among species

This is measured by various diversity indices giving an indication of the structure of the environment. When used in archaeological contexts they are useful to compare assemblages from different sediments to assess how the environment changed either over time or space. Diversity indices will be discussed in more detail below.

4. Age structure

Unstable environments are likely to have a high proportion of juveniles which were unable to live long enough to mature whereas in stable environments there will be a greater proportion of adults surviving to reach reproductive age. In subfossil assemblages there is often difficulty in differentiating juvenile and fragmented shells which reduces usefulness.

5. Intra-specific variation

The morphology of some molluscs varies either over time or in different environments. For example *Pupilla muscorum* tended to be larger during the last glacial period than in the Holocene, especially when found in wet habitats (Kerney 1963, 236; Kerney *et al.* 1964, 160). Calow (1981) demonstrated that *Radix balthica* is often smaller in exposed environments than in more sheltered places, while Tattersfield (1981) suggested that shell size for some helicid species related more to population density than environment.

6. Stenotopy

Stenotopy reflects the environmental tolerances of a species and is useful when 'indicator species' can be identified. This implies that the particular species is capable of inhabiting only a narrow habitat range and if present in an assemblage it is reasonable to assume that the local habitat met those requirements. Unfortunately, there are few British non-marine species that can be considered as indicator species. An example is *Pomatias elegans*, a species associated with ground showing some form of soil disturbance such as forest clearance, slope processes, tree throws, etc. (Evans 1972, 134; Thomas 1977, 138).

7. Ecological groups

These reflect the groupings described above, being the preferred habitats for different species of land or freshwater shells. While very useful for many assemblages they do not take into account interactions between species but can usually provide a broad classification of the likely environment. A further problem was highlighted by Cameron (1978), who demonstrated that buried assemblages may not reflect living assemblages, especially if there has been bioturbation by earthworms in a changing habitat, such as the progression from short grazed grass to longer non-grazed grass to scrub to woodland.

8. The behaviour of pairs of species

There may be consistent relationships between two species of mollusc. The proportion of one species may increase as another decreases, or both increase or decrease in unison. On grassland *Pupilla muscorum* is an early pioneer of bare earth and readily colonizes newly created grassland (Evans 1972, 146) while *Vallonia excentrica* is more common on grazed grassland, although it may live in taller, damper grassland (Evans 1972, 162); a shift in proportions from *Pupilla* to *Vallonia* is a pointer to the commencement of grazing.

9. Taxocenes

The use of synecological concepts has led to the development of taxocenes: the identification of groups of species, often from different groups of the broad ecological classifications, that have a tendency to occur in association and may therefore indicate a habitat which would not be suggested from study of individual species. Such groupings may be identified subjectively or by various multivariate methods such as detrended correspondence analysis or principal components analysis. Several taxocenes for both wet and dry ground have been proposed (e.g. Ložek 1990; Evans 1991; Evans *et al.* 1992; Davies 2008, 24, 64). Although taxocenes may be very useful as an analytical tool in some circumstances they cannot be applied to all assemblages as there are insufficient numbers of shells or species to determine groups of taxa. Also, it is clear that taxocenes may not necessarily apply across different sites where microhabitats may vary over often short distances.

2.2.2 Problems using molluscs as environmental indicators

The interpretation of molluscan assemblages is not without problems (Cameron 1978; Thomas 1985). There are many processes involved in the progression from the living assemblage to the specimens being analysed in a laboratory. The various steps are summarised in Figure 2.6.

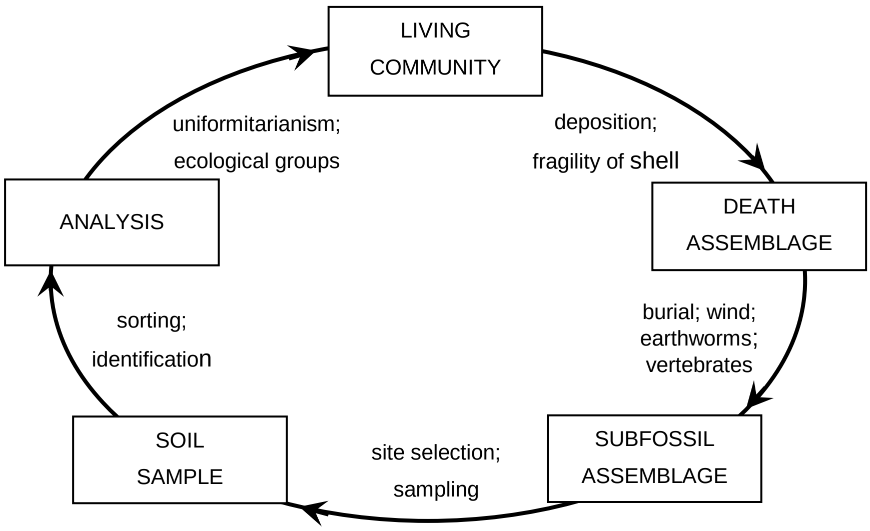


Figure 2.6. Stages in the formation and analysis of subfossil mollusc assemblages

Taphonomic and diagenetic factors must be considered; these may significantly alter the assemblage after death of the shells (Bobrowsky 1984; Preece 2005). Different shells will be deposited at different rates, and their preservation in buried soils or sands depends on many factors, not least of which is the robustness of the shell. Carter (1990) studied fragmentation processes and showed that larger, more robust, shells persist for longer than more fragile shells. Thus, the appearance in an archaeological context not only reflects the assemblages present at the time of deposition, but also whether the shells survive sufficiently intact to appear in the archaeological record. For example, *Helicella itala* remains intact for over ten times the length of time of *Vallonia excentrica*, and thus, if similar numbers are found in the excavated sediment, it is probable that vastly greater numbers of *Vallonia* were present in the living state. Very fragile shells are susceptible to total destruction; *Zenobiella subrufescens* has never been recorded subfossil although it is a not infrequent shell in old woodland at the present time (Evans 1972, 176).

A further problem is the movement of shells after deposition, both vertically and horizontally. Charles Darwin (1882), in his experiments on earthworms, showed that worms move soil particles and plant material downwards within the upper layers of a sediment, and particle sorting of ground surfaces is a common finding in buried soils (Atkinson 1957). Although Darwin and Atkinson did not specifically mention shells in their works, it is accepted that similar diagenetic processes apply to shells as well as to stones (Bell 1981b, 377). Larger animals may also disturb assemblages following deposition; rabbit burrows and other small animals regularly lead to redistribution of shells long after deposition (Claassen 1998, 79). Colluvial and alluvial movement of sediments containing molluscs may deposit the shells at a long distance from their death site. The winnowing effect of wind has been discussed above, altering the composition of lighter and heavier fragments of sediment, including mollusc shells (Bell 1987, 6). Shell size will influence all of these factors, smaller shells (or shell fragments) being more likely to be moved than larger shells.

The method of collecting the sample is also clearly important. There should be sufficient shells in each sample which can be identified at least to genus level in order to obtain meaningful results; a minimum of 150 identifiable shells has been recommended (Evans 1972; Davies 2008, 5). This will normally be achieved with bulk samples, where between 500g and 2kg is usually adequate. If samples are obtained by coring, then the quantity of sediment for each subsample will generally be considerably smaller, with consequent reduction in the likelihood of obtaining sufficient mollusc numbers to achieve a species spread representative of the local environment. The use of diversity indices may provide an indication of adequacy of sampling; the closer together the Shannon and Brillouin indices are then the more representative is the sample likely to be of the true assemblage (diversity indices are discussed in Section 2.2.5).

Once collected and sorted reliable identification is essential. While many mollusc species are easily recognised, others are more difficult, especially for the inexperienced. Use of good reference books is necessary (e.g. Evans 1972; Macan 1977; Cameron 2008) and it is greatly advantageous to have reliable reference collections. In subfossil assemblages many shells are fragmented and it may not be possible to identify to species level, only to genus. Scanning electron microscopy has been useful for some groups of molluscs (Paul 1975; Preece 1981, 1991b) but this is not practical on a routine basis.

Following identification and analysis of an assemblage thought must be given to whether this is, or is not, representative of the living population from which it derived. Many of the problems discussed above must be considered as well as the question of uniformitarianism: are the accepted ecological requirements of modern species the same as those in earlier times? One example of where this may not hold has been demonstrated by Evans (2004) who showed that in prehistory *Lauria cylindracea* tended to favour shaded or diverse habitats but that in historic times has spread to more open grassland and sand dune habitats in the north and west of Britain, while often retaining its woodland preferences in the south and east. Unfortunately, the detailed ecology for many species is little understood and uniformitarianism often has to be assumed even when it may be inappropriate.

A further potential problem is the rate of build-up of the sediment from which the mollusc assemblage is derived. When the rate of accumulation is rapid then it is likely that the shells within thin layers are coeval, whereas if build-up is slow then a thin deposit may represent accumulation over a long period of time and therefore may contain species which were not contemporary but cover many decades or even centuries. Plotting shell numbers against age rather than depth can help to overcome this.

Spatial variation of mollusc species can lead to difficulties in interpretation. Cameron and Morgan-Huws (1975) demonstrated variation in a chalk grassland environment while Gardner (1991) showed that woodland species may persist for a considerable time in deforested areas of grassland. At Maiden Castle, Dorset, Rouse and Evans (1994) investigated variability on the ramparts and showed variation in assemblage composition over short distances, dependant on subtle differences in habitat factors, especially light, moisture and lime content.

2.2.3 Non-marine molluscs and archaeology

The description of molluscs found in association with archaeological excavations has a long history, and includes discussion of Pleistocene as well as Holocene deposits. As early as 1869 Pitt-Rivers commented on the presence of *Pomatias elegans* and other molluscs in the pits and ditches of Cissbury Rings, Sussex (Lane Fox 1869, 1876), although he did not draw any environmental conclusions. Later in the nineteenth century and in the first quarter of the twentieth century the number of archaeological reports mentioning non-marine molluscs increased. In Britain among the first in this field were Bernard Woodward (1889, 1891, 1908), R. Ashington Bullen (1899; 1902b, 1909) and Arthur Kennard and colleagues (e.g. Kennard and Woodward 1902; Kennard and Warren 1903; Kennard 1923; Kennard 1924). These early reports usually just listed the molluscs found, marine and non-marine, with no attempt to relate the findings to the palaeoenvironment. In America there were some early reports of molluscs in relation to archaeology, some of which attempted to draw environmental conclusions from the assemblages (e.g. Morse 1867; Wyman 1868).

The works of Sparks and Kerney have been mentioned above, but the relevance of molluscs to archaeological interpretation reached prominence with the publication in 1972 of *Land snails in archaeology* by John Evans. This work established the value of mollusc analysis in the interpretation of the palaeoenvironment, providing many examples from Evans's own work. In the last four decades shells have regularly been studied on archaeological sites, especially in locations where, in alkaline deposits, they can survive in good numbers. There are many reports of the molluscan fauna of archaeological sites on chalk downlands, especially in southern Britain (Evans 1972). Examples include the Neolithic long barrow at South Street, Avebury, Wiltshire, where study of the molluscs helped to establish that the turf levels below the barrow reflected a dry grassland environment probably kept open by grazing animals (Evans 1972, 331); the long sequence of environmental change at Holywell Combe in Kent, stretching from the Late glacial period to the present (Preece and Bridgland 1999); the changing land use in relation to human ecology in Malling-Caburn on the South Downs in Sussex (Allen 1995) and the establishment of prehistoric land use on dry valleys in south east England (Bell 1981b).

The method employed to recover shells from samples is important. It is easy to pick out by eye the larger shells found during an excavation, but this will miss a very large proportion of the smaller shells and the broken shell apices which are vital to a true interpretation of mollusc assemblages (Sparks 1960, 1961, 1964). Sieving of bulk samples has become the accepted method of sample acquisition, when small and fragmented shells will not be lost.

2.2.4 Molluscs and the archaeology of blown sand sites in the British Isles

The majority of reports which discuss the role of molluscs in environmental reconstruction on archaeological sites have been concerned with chalk downlands. Many of these have been summarised in *Land and people; papers in memory of John G. Evans* (Allen *et al.* 2009) and will not be discussed here.

Studies examining molluscs in coastal dunes are less frequent, and are mainly on the Scottish Islands (Outer Hebrides and Orkney) and in the south west of Britain (Somerset and Cornwall). A gazetteer showing all the blown sand sites which have included molluscs in environmental analysis is included in Appendix 2.

Prior to 1960 reports of molluscs on blown sand sites associated with archaeology were mostly limited to the north coast of Cornwall, some merely listing the shells present in different horizons, as at Perranporth (Bullen 1902b), Harlyn Bay (Bullen 1902a) and Daymer Bay (Bullen 1909), although others attempted to match the assemblages to palaeoenvironment. At Towan Head, Newquay, woodland was present in the lowest Holocene levels, and is one of the few Cornish sites where the shade species *Pomatias elegans* has been found (Kennard and Warren 1903; Woodward 1908). At Daymer Bay a mollusc sequence showed blown sand only, with no evidence of any early woodland, despite there being a submerged forest in the bay (Arkell 1943). Accurate chronology of these sequences was necessarily limited as they pre-date the advent of scientific dating methods.

In south west England radiocarbon dates were first associated with molluscan analysis in 1986 at Bantham, Devon, when a hearth-like feature containing *Cochlicella acuta* was dated to the post-Roman/early medieval period (Bell 1986). An extensive program of radiocarbon dating correlated with mollusc analysis was used to provide chronology at Brean Down, Somerset, showing open country with some shade/woodland in the Neolithic, the latter disappearing by the late Bronze Age, and with the landscape becoming progressively more open up to the sixteenth/seventeenth centuries (Bell 1990). To date this is probably the best dated dune sequence in Britain.

In Cornwall dating of dune excavations became standard during the 1990s although there are few reports of this being associated with molluscan palaeoenvironmental data. Multiple radiocarbon dates were obtained from the middle Bronze Age settlement at Trethellan Farm, Newquay (Nowakowski 1991) but the mollusc analyses from the site were all probably from later colluvial sand (Milles 1991a) and were not associated with the dated material. At Gwithian palaeoenvironmental data was not part of excavations in the mid twentieth century, but several studies since then have examined molluscan fauna both later trenches (Spencer 1974, 1975; Milles 1991b; Davies 2007); a single Bronze Age radiocarbon date was obtained during excavations in the 1961, and a further 19, together with two OSL dates, in 2005 (Hamilton *et al.* 2008). The Gwithian environment shows alternating horizons of stabilization (with plough soils) and rapid sand accumulation. Further investigations at Gwithian are reported in this thesis. Another Cornish site, the Romano-British settlement at Atlantic Road, Newquay, has incorporated shell studies (Davies 2008) with radiocarbon dating (Marshall forthcoming) showing a dune succession from bare to well-vegetated open country conditions.

Holocene mollusc analysis in Wales associated with archaeology is limited to Pembrokeshire. A Beaker to Roman period settlement at Stackpole Warren revealed Bronze Age woodland clearance with progression to open country (Evans and Hyde 1990). Dune grassland, often unstable, was present at Brownslade, a possible Bronze Age barrow with an overlying early medieval cemetery (Bell and Brown 2011) and a similar landscape was found at Freshwater East (Walker 2011). All these sites included radiocarbon dating (Stackpole Warren: Benson *et al.* 1990; Freshwater East: Schlee 2009; Brownslade: Groom *et al.* 2011), although only at Stackpole and Freshwater East were any directly related to mollusc analysis.

Excavations, mainly in the Scottish islands, have used mollusc analysis much more widely in the establishment of the palaeoenvironmental history, and permitted a chronological successional appearance of several mollusc species on sand dunes to be established by Evans (1979):

1 On the old land surface or initial blown sand xerophile species (*Vallonia*, *Helicella*, *Pupilla*) are often absent, but species indicative of woodland (*Carychium*, *Discus*) may be present, and can indicate the presence of woodland prior to sand deposition.
2 In some sites open country species, mainly *Vallonia* and *Pupilla*, are present in basal contexts and suggest a degree of open country, but still with some tree and/or scrub cover.
3 A zone of open country species but with *Pomatias elegans*, as found in Cornwall, implies deforestation with disturbed ground; *P. elegans* is not present on Scottish or Irish sites and has never been found in these areas (apart from one twentieth century record in Galway, Ireland (National Biodiversity Network)).
4 The introduction of open country species in early blown sand, normally with a regular sequence of appearance:
    a) *Vallonia costata*, *Pupilla muscorum* and *Vertigo pygmaea*, followed later by *Vallonia excentrica*.
    b) *Helicella itala*, followed by *Cochlicella acuta*.
    c) ‘Recent’ introduced helicids, such as *Cernuella* and *Candidula*.

The Neolithic to Iron Age settlement at Northton, on the isle of Harris in the Outer Hebrides, first enabled Evans to propose this succession (1971b, 1972), where the Neolithic woodland environment was initially cleared, before briefly recurring in the Bronze Age; sand accumulation was rapid in the Iron Age and has become stable in more recent times. Radiocarbon dating was directly linked to molluscan data (Burleigh *et al.* 1973). The succession was confirmed at the Beaker to Bronze Age settlement at Sligeanach, South Uist (Evans 2004; Evans *et al.* 2012).

Recent well dated studies on several islands in the Outer Hebrides (Hornish Point, South Uist; Baleshare and Newtonferry, North Uist) (Barber 2003) used molluscs to help establish environmental succession in settlements dating from the early Bronze Age to the medieval period (Thew 2003). On the machair close to the coast of the islands open country conditions generally prevailed but with intermittent marsh formation and with numerous blown sand deposits. Evidence of early woodland was lacking. Many middens contained marine molluscs which informed about the diet at the time of settlement and helped to establish that seaweed was used as a fertilizer.

Excavations of Mesolithic middens on Oronsay, Inner Hebrides, (Mellars 1987) included analysis of land snails (Paul 1976) which demonstrated several soil horizons with intervening blown sand; early woodland reverted to open dunes after abandonment of the middens. Radiocarbon dating was related directly to mollusc analyses in two middens.

The Orkney Islands contain several sites where molluscs aided environmental interpretation. Original woodland with ponding and open marshy areas was present at the Neolithic village of Skara Brae (Spencer 1974, 1975) and in the surrounding area of the Bay of Skail (de la Vega-Leinert *et al.* 2000) as well as at nearby Bronze Age to Viking sites at Buckquoy and Birsay Bay (Spencer 1974; Evans and Spencer 1976–7; Rackham *et al.* 1989); deforestation during the Bronze Age resulted in open country with significant blown sand accumulations. Mollusc studies at the Knap of Howar, Papa Westray, (Spencer 1974, 1975; Vaughan 1976; Evans and Vaughan 1983) showed a woodland landscape during the Neolithic while both there and at Tofts Ness on Sanday (Milles 1991b, 1994, 2007) blown sand prevailed during later periods. Mollusc studies at other Scottish sites have shown a similar pattern, and are detailed in the gazetteer in Appendix 2.

In Ireland molluscs were reported from old land surfaces or middens showing some areas to have early woodland, but few contain further details, and none are linked to archaeological investigations or with scientific dating (Kennard and Woodward 1917; Vaughan 1976).

2.2.5 Sample size and diversity

Diversity is a measure of the range of species found within a community. The more species there are in an assemblage then the greater the diversity of the community. However, diversity is also a measure of the heterogeneity of an assemblage – how the proportions of each species vary within an assemblage. For example, a community with an equal number of specimens of all species has a higher diversity than one where 95% of the specimens belong to a single species. Thus an assemblage has a high diversity if it contains many species with fairly even abundances, and a low diversity if there are few species with uneven abundances (Pielou 1977, 292; Krebs 1999, 410).

Studies have indicated that molluscan communities with high diversity tend to be associated with complex habitats such as woodland, whereas those with lower diversity are more related to less complex habitats such as short grazed grassland (Davies 2008, 10). Many different indices have been proposed to assess these factors ranging from the relatively straight forward, e.g. number of taxa or rank order curves, to more complex indices, mostly derived from information theory (Walsh and Webber 1977).

One of the problems with assessing diversity in archaeological faunal assemblages is that the samples, being limited in size, are not necessarily representative of the population as a whole (Chiarucci *et al.* 2011; Maurer and McGill 2011). While common species will normally be present it is not unusual for rare species to be absent from small samples. It is self-evident that the larger the sample then the more likely it is to approach the true assemblage of the whole population. The question is, how large does the sample need to be to give an acceptable level of accuracy? As far as molluscs are concerned, Evans (1972, 83) demonstrated that 150–200 shells 'is a sufficient number to establish the broad composition of a fauna.'

Coring, the technique used in much of the present study, creates a particular problem in that sample sizes are usually very small, and do not approach the 500–2000g normally recommended. Consequently, mollusc numbers within samples are often small, frequently in single figures, and it is therefore questionable whether useful information can be obtained. Comparison of two indices, Shannon and Brillouin, can give some indication of completeness of a sample. Both indices are, to some extent, influenced by the presence of rare species (Krebs 1999, 146).

The Shannon index (Shannon and Weaver 1949) assumes that individuals are sampled from an infinitely large community, and that all species are represented in the sample. It takes no account of the total number of specimens within the sample, only the proportions of each species within that sample. It therefore represents the ideal if sampling has not missed any species, but this is very rarely the case in archaeological work.

$$Shannon\ index = -\sum_{i=1}^{n}(p_i \ln_e p_i)$$

where: n = the number of individuals within in a sample.
p_i = the proportion of individuals in the ith species in the sample.

The Brillouin index (Brillouin 1956), assumes that individuals are from a finite community and randomness is not assured. It takes into account the total number of specimens in the sample and so is sensitive to sample size and accepts that there may be missing species in the sample.

$$\text{Brillouin index} = \frac{\ln_e(N!) - \sum_{i=1}^{n} \ln_e(n_i!)}{N}$$

where: N = the total number of individuals of all species in the sample.

n_i = the number of individuals in the ith species in the sample.

For an infinite sample size the Brillouin index approaches the Shannon index (Peet 1975). It follows that the difference between the two indices provides an indication of completeness of a sample (Allen 2009). The mollusc diagrams in the following chapters usually show graphs of both indices so that sample adequacy can be assessed for each assemblage. Figures are included in the mollusc tables either in the following text or on the CD.

As a test of this approach a graph is shown plotting the difference between the Shannon and Brillouin indices against number of shells for every sample analysed in the present study (Figure 2.7). 163 mollusc column samples and 106 core samples were assessed but samples with less than twenty five shells are not shown on the graph. It is clear the greater the number of shells then the nearer the two indices approach each other.

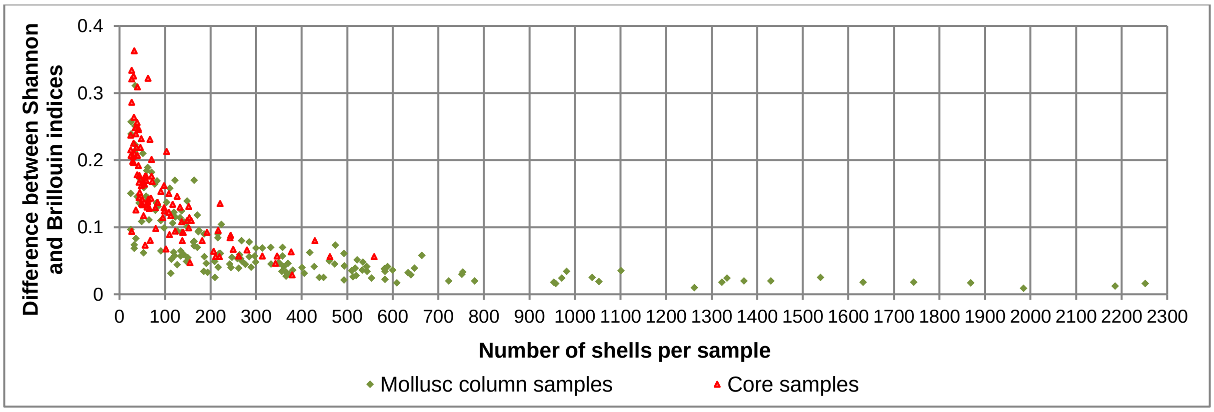


Figure 2.7. Comparison of shells per sample with difference between Shannon and Brillouin diversity indices

A Shannon-Brillouin difference of 0.1 seems to be a 'break' point, and if this were taken as an acceptable level then only two samples with more than 180 shells would fall above this figure, entirely in accord with Evans's experiment. It is evident that most of the core samples fall outside this criterion, and even if a Shannon-Brillouin difference of 0.2 was accepted, then many would still be inadequate. In the following work it is clear that the majority of the core samples and many of the mollusc column samples may not represent the complete assemblages from which they are derived. Despite these limitations (which apply to many mollusc studies) it is felt that analyses of samples with fewer than 180 shells can validly be used as a guide to habitat types.

2.3 Establishing a chronology

It is usually necessary in palaeoenvironmental studies to determine the chronology of deposits which contain the molluscs under study. Also important is careful recording of the stratigraphy both in the field and in the laboratory. An indirect chronology can often be established by examination of any material culture that is present within appropriate contexts, particularly including ceramic material, metal objects, coins, etc. However, these are frequently not present and alternative methods must be considered.

2.3.1 Direct dating of shells

2.3.1.1 Radiocarbon dating

The principles of radiocarbon dating are well established (e.g. Aitken 1990; Taylor 2004) and do not need repeating. There are, however, problems which have to be considered if the method is used on non-marine molluscs. Dating of mollusc samples from archaeological deposits will only be reliable if the carbon being measured accurately reflects the conditions present at the time the carbon atoms were incorporated into the shell. This may not always be the case. Some of the carbon deposited in the shell matrix is derived from the groundwater which itself contains carbonates – the 'dead carbon content'. These carbonates may come from older environmental sources such as chalk, limestone or tufa, which contain carbon atoms that have already undergone some decay (Yates 1986, 22). The effect will be to give dates which are artificially old. Goodfriend and Stipp (1983) showed that Jamaican shells collected in a non-limestone area gave accurate ages, while those from limestone areas produced variable ages up to 3120 years too old. Rubin *et al.* (1963) found that living shells took in about 10–12 per cent of inorganic carbon and concluded this could give dates approximately 1000 years too old. An additional problem arises if there has been any post-depositional alteration of the shell leading to exchange of ^{14}C with the environment; chemical alteration in the shell matrix or incorporation into the shell of material of younger date (such as soil particles) may lead to reduction of the apparent age of the shell (Yates 1986, 22).

The converse is true if there has been some exchange of shell matrix carbon with atmospheric carbon dioxide in the period since death of the shell. Newer ^{14}C will then be absorbed into the shell and an artificially young date obtained. The 'marine effect', when shells absorb old carbon from deep ocean reservoirs which have circulated to surface waters, is unlikely to be of importance for terrestrial shells, although could have a minor effect if they are subjected to regular sea spray.

Despite these limitations the technique has occasionally been used by researchers. Early and mid Holocene molluscs from archaeological sites in the French Pyrenees gave consistently early dates, about 1000 years older than corresponding ^{14}C charcoal dates (Evin *et al.* 1980). At Brook, Kent, radiocarbon dates of specimens of *Pomatias elegans* and *Cepaea nemoralis* were compared with with charcoal from the same context and gave an age of 400–500 years older than the charcoal date of 2590 cal BC, suggesting some ingestion of old carbon (Burleigh and Kerney 1982). Counter to this, Preece (1991a) showed that AMS dating on *Arianta arbustorum* shells at Holywell Coombe, Folkestone, gave consistent results when compared to charcoal dates from the same Late Glacial alluvial horizons.

Fossil freshwater and land shells from China were dated by Zhou *et al.* (1999). They used the ^{14}C levels of modern shells to provide a correction factor for the fossil shells, on the assumption that the ecological habits of both sets of shells are similar. The radiocarbon dates of freshwater shells were compared with those obtained from wood and land shells to pollen. There was good correlation for the freshwater shells, which consist purely of aragonite, but was less good for the land shells which contained more calcite. The presence of calcite indicates recrystallization from aragonite with consequent alteration in ^{14}C levels in the shells.

2.3.1.2 Uranium series disequilibrium

The nuclide ^{238}U is unstable and decays through a complex series of intermediate nuclides to a stable lead isotope, ^{206}Pb. This process will proceed naturally, if undisturbed, until all the intermediates have reached equilibrium. If, however, a quantity of an intermediate nuclide is added or removed from the decay chain then the chain is interrupted and a state of imbalance, or disequilibrium, develops (Lowe and Walker 1984, 225; Latham 2001, 63). Measurement of the amount of excess or deficient nuclide is the basis for determining age by the ‘uranium-series disequilibrium’ method. Use in mollusc dating relies on the fact that uranium is soluble in water and readily passes into and out of living organisms, while thorium, one of the intermediate isotopes, is insoluble and will not be incorporated into the shell. Thus, the in-growth of the daughter isotope (^{230}Th) with its nearest long-lived parent isotope (^{234}U) is the basis of this technique.

The accuracy of the procedure relies on there being a ‘closed’ system – i.e. there is no addition or loss of uranium after the death of the shell. In practice this is rarely the case and there is usually an ‘open’ system with some isotopic exchange with ingress/egress of water into/out of the dead shell after death and a portion of the uranium is considered to be diagenetic in origin (Edwards *et al.* 2003: 398). This leads to inaccurate dates, and mollusc ages may vary by up to 50% when compared with ages proven by other methods (Blanchard *et al.* 1967; Schwarcz and Blackwell 1992, 523; McLaren and Rowe 1996). Kaufman *et al*. (1971) reviewed 400 analyses, all of marine shells, and showed that correct ages were recorded on only about half of the samples.

An additional problem is the necessity to obtain pure sub-samples of the shells being dated. Any contamination of the shell surface may well contain older nuclide, known as detrital thorium, which will result in erroneous dates (Geyh 2001). In practice the level of ^{232}Th should be below 40µg/kg; if this criterion is not met then in many cases a date with reasonable reliability can be obtained by using isochrons from different subsamples (Bischoff and Fitzpatrick 1991; Ludwig and Titterton 1994). With large shells it is possible to clean the shell surface with acid and then use a micro-drill to obtain a small quantity of powdered shell. When the shells are small, as is often the case with terrestrial molluscs, then removal of all visible foreign material is essential, followed by cleaning in an ultrasonic waterbath.

The great majority of research using uranium series disequilibrium to date molluscs has concentrated on marine deposits (e.g. Kaufman *et al.* 1971; Semghouli *et al.* 2001; Staubwasser *et al.* 2004), with very few reports of use of the technique on non-marine shells. Goodfriend (1992b, 666) stated that dating with this technique has generally proved unreliable due to systems which are not closed, but mentioned that dating of snails from the Negev Desert may be reliable under some circumstances. Holyoak and Preece (1985, 221) looked at Pleistocene *Cepaea nemoralis* from Lincolnshire, commenting that the results of 75–115 ka might be unreliable due to detrital contamination. Hillaire-Marcel *et al*. (1995) compared radiocarbon and U-series dating of terrestrial shells from the Canary Islands and found good agreement in the 25–40 ka year old age range, possibly due to the relatively closed system achieved in the arid conditions of the location. Semghouli *et al*. (2001) used U-series to date land shells from Morocco, all from 113–266 ka, but without any other method for comparison.

2.3.1.3 Amino acid racemization

Proteins in living tissue are made up of amino acids. These amino acids may each be found in two mirror-image forms, called enantiomers: L-amino acids and D-amino acids (*laevo* or *dextro* depending on their effect on polarized light) (Aitken 1990; Hare *et al.* 1997; Johnson and Miller 1997; Penkman 2010). During life all amino acids are in the L-form. After death proteins undergo diagenesis and hydrolyse to release polypeptides and amino acids, and these acids commence racemization – the conversion from the L-form to the D-form – until equal proportions of each enantiomer is reached. Racemization occurs at a steady rate, different for each amino acid. If the proportion of L- to D-enantiomers can be measured then the age since commencement of racemization, and hence death of the organism, can be calculated. The amino acid isoleucine transforms by a slightly different process called epimerization (Renfrew and Bahn 2000, 157) and comparison of racemization/epimerization rates is an alternative method of age measurement.

Up to 20 different amino acids may be found in calcified tissues (Hare *et al.* 1997, 263), and many have been used to determine age. Several factors influence the rate of racemization: temperature, genus of organism, contamination or other physical-chemical diagenetic effects (Wehmiller 1982, 85), and these need to be taken into consideration when assessing age. Following death of an organism the tissues become part of an ‘open’ system with the surrounding sediment, permitting exchange of proteins and amino acids, thus reducing the accuracy of age measurement. However, in some mollusc species a portion of the original protein is trapped within the mineral structure of the shell and protected in a ‘closed’ system; the racemization process for these closed system amino acids is therefore dependent purely on age and temperature (Demarchi *et al.* 2011) and if they can be isolated then accuracy of dating may be considerably improved. Penkman and colleagues (Penkman *et al.* 2007; Penkman *et al.* 2008; Penkman 2010) have recently investigated methods of evaluating closed system amino acids in the opercula of the freshwater gastropod *Bithynia* and shown that improved geochronology can be achieved (Penkman *et al.* 2013).

Research into mollusc dating with AAR has concentrated mainly on marine shells, with relatively few studies of non-marine shells. Goodfriend (1987) compared dating obtained with both AAR with ^{14}C (the latter corrected for old carbonate anomalies) and found good correlation with Holocene shells in fluvial sediments from the Negev Desert, Israel. Correlation from colluvial sediments was weaker, perhaps due to delayed burial in the desert. A later study involved shells from Jamaica and Madeira (Goodfriend 1992a) as well as those from Israel and showed good correlation with radiocarbon dating in recent centuries.

Recent studies on both land and freshwater shells (Penkman *et al.* 2007; Penkman *et al.* 2008) have used newer methods using intracrystalline fractions. There is interspecific variability in resolution, with *Corbicula* from the Thames Valley giving unreliable results, while *Bithynia* opercula give better resolution than their shells.

2.3.2 Indirect dating ― dating of material that contains shells

2.3.2.1 Optically stimulated luminescence

Optically stimulated luminescence (OSL) cannot date the molluscs themselves, unlike the methods described above, but can date some of the sediments in which molluscs are found. When minerals are formed, all the electrons are in their base energy states. Cosmic radiation acting on the atoms within the mineral causes some of the negatively charged electrons to be ejected into higher orbits where they may become trapped, leaving a positively charged ‘hole’ in the original valence band. Most electrons return to their basal position, but some may be trapped in defects within the mineral: e.g. lattice defects, interstitial atoms, impurities, etc. The number of trapped electrons increases with time. However, should the mineral be exposed to heat or light (bleaching) the trapped electrons are released back to their basal state. If the sediment is then buried, the radiation effect recommences with new electron trapping, a state which increases until the next exposure to heat or light. When the mineral is stimulated in the laboratory either by heat (thermoluminescence, TL), visible light (optically stimulated luminescence, OSL) or infra-red light (IRSL) the trapped electrons are evicted and emit luminescence which can be detected by appropriate instruments, and the quantity of luminescence measured. This is proportional to the number of trapped electrons which have accumulated since burial, which in turn is proportional to the amount of radiation to which the mineral has been exposed. If the background radiation rate is known it is therefore possible to calculate the time since last exposure to heat or light (Aitken 1990, 140; Grün 2005; Duller 2008). It is clear that one of the requirements for luminescence dating is that samples must be collected under totally light-free conditions, usually achieved by using opaque tubes to acquire the sediments.

OSL can be applied to minerals that contain sand or silt-sized particles of quartz or feldspar. It is therefore an excellent technique for sand-based deposits such as dunes. The sediments in which the mollusc assemblage is found is dated, thus inferring a date for the molluscs themselves, assuming that the stratigraphy is secure and that the molluscs are not intrusive.

A review of approximately 200 publications from all areas of the world which used luminescence for dating coastal and marine sediments was provided by Jacobs (2008); she emphasizes that more research is needed to refine the technique and increase precision in comparison with other dating methods. The danger of ascribing dates to material that has been incompletely bleached, and the value of using modern analogues to assess completeness of bleaching, is stressed. An earlier review (Prescott and Robertson 1997) also emphasized the importance of complete bleaching, pointing out that this may be difficult to establish in alluvial deposits. Similarly, incomplete zeroing at deposition was found in some coversand deposits in Norfolk (Clarke *et al.* 2001). Bailey *et al.* (2001) investigated sand deposition over the last millennium in Anglesey, Wales, using a combination of ground penetrating radar (GPR) and OSL dating. Samples were obtained using hand augers in cased boreholes; but no details of the procedure are given. A tsunami in 1755 was shown, using OSL dating, to account for marine and aeolian deposits in the Scilly Isles (Banerjee *et al.* 2001).

In Denmark, OSL was used with amino acid racemization to establish the chronology of an extensive dune system at Vejers (Clemmensen *et al.* 2001) but some contamination within the core may have influenced the results. OSL successfully dated another series of Danish dunes (Murray and Clemmensen 2001), showing four individual phases of deposition ranging from 2200 BC to the nineteenth century.

Wilson *et al.* (2001) used coring with 6cm lined cores to obtain samples in Northumberland for OSL dating of the dunes at multiple sites, and compared these with radiocarbon dates from organic material in the same cores. Phases of marine transgression and regression were established, showing that most dune formation occurred during the Little Ice Age. Roberts and Plater (2007) explored the progression of dune formation at Dungeness in Kent by obtaining OSL dates from multiple bore hole samples across the dunes. The technique was found to be stratigraphically reliable in both vertical and lateral planes. Also in Britain the dune sands of the Orkney Islands were investigated by Sommerville (2001; 2003; 2007), who demonstrated six periods of increased sand movement between the Neolithic and Little Ice Age which were also identified elsewhere in Scotland and north west Europe.

2.3.2.2 Palaeoclimate – Stable isotopes: $\delta^{13}C$ and $\delta^{18}O$

Carbon and oxygen each exist in several stable isotopic forms. The less abundant isotopes are all slightly heavier than the dominant isotopes. Isotopic fractionation results from the way the heavier or lighter isotopes react to different physical and/or chemical processes. Lighter isotopes evaporate from water (e.g. sea, rivers, lakes) or vegetation more quickly than heavier isotopes, but the heavier isotopes will fall by precipitation (rain, snow) more quickly than the lighter ones. Thus an imbalance develops which, if measured, gives an insight to the conditions under which the various elements were taken into the living tissues. It is important to emphasize that these techniques do not provide an absolute chronology, but establish palaeoenvironmental changes over time which can be correlated with known climatic change in, for example, ice cores.

Among the first to study stable isotopes in land shells, as opposed to marine or freshwater shells, was Yapp (1979). He found that there was some enrichment of $\delta^{18}O$ due to evaporation and that the degree of enrichment could be correlated with the local relative humidity. The analysis showed that the climate at Sudden Shelter, Ivie Creek, Utah, was warmer and/or drier around 7100−7800 BP than at present.

$\delta^{13}C$ had been used as a check on the validity of radiocarbon dating of shells. If the $\delta^{13}C$ in modern live-collected and ancient shells is the same, then it is likely that there has been little recrystallization within the ancient shell whereas if there is a difference, then there has been some diagenetic change in the shell since animal death (Burleigh and Kerney 1982). Yates *et al*. (2002) showed that measurement of $\delta^{13}C$ and $\delta^{18}O$ in modern shells of several species of British land shells gave a fair indication of the reliability of radiocarbon dating in sub fossil shells from the same location.

There are very few studies which used $\delta^{18}O$ of non-marine shells to investigate climate change during the Holocene. Bonadona and Leone (1995) studied stable isotopes in molluscs, mainly freshwater, from a palaeolake in Italy and found that changes in $\delta^{18}O$ proved a reliable indicator for the reconstruction of climatic evolution over the Holocene. Colonese and colleagues (Colonese *et al.* 2010b; Colonese *et al.* 2013a; Colonese *et al.* 2013b) have used stable isotopes in a variety of land shells to study climatic change from the Pleistocene to Holocene in several caves in southern Europe. They also demonstrated that there was little intraspecific variability for most mollusc species studied, although species which hibernate do not reflect rainfall during winter periods (Colonese *et al.* 2010a). They found that low $\delta^{18}O$

values in the archaeological specimens correlated well with other palaeoenvironmental records. There was considerable interspecific $\delta^{13}C$ variability, but intraspecific measurement was useful in determining change of diet in *Pomatias elegans* between the early and middle Holocene, possibly due to climate induced vegetation change.

Zanchetti *et al.* (2005) studied living land shells from across Italy to establish a relationship between $\delta^{18}O$ and local rainfall and were able to establish formulae to determine temperature which could be applied to sub-fossil assemblages.

2.3.3 Extinctions and introductions of mollusc species

The fauna of Britain is not constant. Some species become extinct either through natural causes or the action of man, while other are introduced, often inadvertently but sometimes deliberately. The aurochs, lynx and brown bear are examples of mammals that no longer inhabit Britain, while fallow deer, rabbits and rats are introductions during the Holocene (Kerney 1966; O'Connor and Sykes 2010). Molluscs are no exception. Many species survived from the last Ice Age and are still found in Britain, although some with very restricted distributions. A few species did not survive the warming during the early Holocene and are now extinct in Britain. Others have been introduced. Introductions may be accidental, arriving, for example, on garden produce, although a few species were almost certainly brought to Britain intentionally; an example is the Roman snail, *Helix pomatia*, which is thought to have been a food resource during Roman times (Davies 2010).

If the timing of extinctions and introduction can be established with a high degree of certainty, then this can be useful from the chronological point of view in archaeological deposits. It is, however, very important to consider how secure is the stratification, as the presence of molluscs in unexpected strata is frequently due to intrusion, often by worms or rodent activity. Dating correlation should, whenever possible, be obtained by independent testing rather than relying on the presence or absence of molluscs, although the latter may be helpful in some circumstances. For example, if *Xerocrassa geyeri* is present in a sediment, then that sediment almost certainly dates to the Bronze Age or earlier, and only in Cornwall has it been found later than the very early post-Glacial period (Kerney 1999, 184).

The introduction of particular species is perhaps more useful from the chronological point of view, although the problems of bioturbation are easily overlooked and shells found in inappropriately deep levels can be ascribed to older sediments than they should be. For example, the various species introduced into Britain in medieval or later periods should not be present in deposits considered to date from earlier centuries or millennia, and if present at inappropriate early dates probably indicate bioturbation or other forms of contamination. However, the *caveat* is that not all is yet known about introductions and extinctions of many species, and detailed work may change present understanding of the time scales, as this thesis shows.

The discussion which follows concerns only those taxa which have been recorded in Cornwall (National Biodiversity Network; Turk *et al.* 2001). Elsewhere in the British Isles there are an additional eight relict Glacial species which are now extinct, being unable to survive climatic warming and/or associated vegetation changes during the Mesolithic (*Cochlicopa nitens*, *Columella columella*, *Discus ruderatus*, *Helicopsis striata*, *Nesovitrea petronella*) but have never – yet – been found in any Cornish location. As far as introductions are concerned, there are a few additional species not yet recorded from Cornwall: *Monacha cartusiana* (Neolithic), *Balea biplicata* (Roman), *Candidula gigaxii* (probably Romano-British), *Helix pomatia* (Roman/Romano-British), *Lucilla singleyanus* (recent), *Semilimax pyrenaicus* (uncertain, but probably introduced), *Bradybaena fruticum* (probably recent, now not known living in Britain), *Trochoidea elegans* (twentieth century) and *Hygromia limbata* (recent) (Kerney 1999).

Freshwater species seem to have been relatively constant during the Holocene, although distributions may have varied. *Margaritifera auricularia* and *Pisidium vincentianum* are now extinct (neither recorded in Cornwall), while the introductions not discussed below include *Physella gyrina*, *Menetus dilatatus*, *Dreissena polymorpha*, *Mytilopsis leucophaeta*, *Corbicula fluminea* and *Musculium transversum* (all recent).

The presence or absence of any of these species in a subfossil assemblage may be helpful in dating that assemblage. For example, if *Cornu aspersum*, a species thought to be introduced in Roman times, is present in a sample then it is probable that the context containing it dates from the Romano-British period or later. If found in older sediments then either it is intrusive or current concepts concerning its introduction to Britain need reconsidering.

2.3.3.1 Extinctions

Xerocrassa geyeri (Soós, 1926) (until recently named *Trochoidea geyeri*)

The only extinct non-marine mollusc from Cornwall is *Xerocrassa geyeri*, which was found at Gwithian (Spencer 1974, 1975; Milles 1991b) and where it managed to survive into Bronze Age levels. It was identified by Spencer at Gwithian as '*Candidula* cf. *intersecta*' but the correct identification was subsequently confirmed by Milles (1991b) and also by Dr Edmund Gittenberger (pers comm). This Pleistocene relict has been documented in the very early post-Glacial period at Upper Halling, Holborough, Kent and Oxted, Surrey (Kerney 1963, 237), at Aylesford, Maidstone, Kent (Burchell and Davis 1957), at Durrington Walls, Wiltshire (Evans 1971a, 334; Evans 1972, 182). It is considered to be a cold climate indicator with a restricted European distribution at present (Magnin 1993), although capable of surviving in cryptic refugia during major climatic changes (Pfenninger *et al.* 2003).

2.3.3.2 Introductions – in chronological order

Cochlicella acuta (Müller, 1774)

This species is unknown in Britain with certainty before the Bronze Age (Lewis 1968, 315). It was well established in Cornwall by the beginning of the first millennium BC at Gwithian (Davis 1956; Lewis 1975, 159; Spencer 1975) but did not reach the outer Hebrides until the Iron Age, along with *Helicella itala* (Evans 1971b, 59; Evans 2004). A burnt specimen in a hearth at Bantham, Devon, dated 1690±80 BP (HAR-5775) and 1440±80 BP (HAR-5776), definitely established it present in Romano-British times (Bell 1987). Its present day range is almost entirely restricted to Ireland and the western and southern coasts of Britain, there being very scarce records on the east coast (National Biodiversity Network; Kerney 1999, 186). Although a xerophile shell found widely on sand dunes it has also been reported from a few inland sites across southern England.

Ponentina subvirescens (Bellamy, 1839)

There is considerable uncertainty about the introduction of this species during the Holocene. While it may have arrived in Britain during the early post-Glacial period before loss of the land bridge (Kerney 1966) it is more likely that it was not present in this country until the Bronze age (Davis 1956) and possibly not until the Iron Age (Evans 1972, 178). Today it is found only around the coasts of Devon and Cornwall, with a small population in west Pembrokeshire (Kerney 1999, 198).

Oxychilus draparnaudi (Beck, 1837)
Oxychilus navarricus helveticus (Blum, 1881)

These may both be introductions during the Roman or post-Roman period, but the timing is questionable. Evans (1972, 187) claims that any pre-Roman records are dubious and probably refer to large forms of *O. cellarius*. Turk (1984) states that the only British subfossil record of *O. draparnaudi* is at Towan Head, Newquay. Ellis (1926a, 245) recorded *O. navarricus helveticus* from 'the English Holocene', but Evans (1972, 189) says that is 'unknown with certainty from archaeological deposits.' Both these species are now widespread throughout England and Wales, being considerably less frequent in Scotland and Ireland (Kerney 1999, 143, 146).

Cornu aspersum (Müller, 1774)

The earliest appearance in Britain of the common garden snail is accepted to be in the Romano-British period; reports claiming earlier dates are now considered unreliable. Kennard (1923, 248) claimed that it 'occurs in the early Holocene in Cornwall and Devon, and in a Bronze Age tumulus in Somerset, but is unknown from any pre-Roman deposit over the greater part of England' while Evans (1972, 175) states that 'all pre-Roman subfossil records are either erroneous or doubtful'. It was found in Bronze Age levels at Brean Down, but the authors accept that is probably intrusive, having been brought in by rabbits or other fauna (Bell and Johnson 1990, 248). There are several early reports of this snail in pre-

Roman levels in Cornwall (Bullen 1899; Bullen 1902b; Kennard and Warren 1903; Woodward 1908; Bullen 1909) but all are likely to be intrusive shells. *C. aspersum* was found in late Bronze Age and Iron Age colluvium at Malling Hill, Sussex (Allen 1995, 33) but it is unclear how these relate to the true chronology. It was present at Lullingstone, Kent, by 250−300 AD (Kerney *et al.* 1964). This mollusc is abundant throughout most of the British Isles, although relatively scarce in Scotland and Ireland (Kerney 1999, 205).

Monacha cantiana (Montagu, 1803)

This species was introduced to Britain towards the end of the Roman period, the earliest secure date for its presence being the third century AD at Lullingstone, Kent (Kerney 1970). It seems to have had a very restricted distribution until the medieval period. George Montagu, who first named the shell in 1803, stated that it had never been found outside Kent (Montagu 1803, 422). It is now widespread and very common throughout southern and eastern England, but remains scarce elsewhere. It is very rare in Cornwall, there being only sporadic finds of this shell in the last 50 years (Turk *et al.* 2001, 101).

Cernuella virgata (da Costa, 1778)

Another shell which is almost certainly a post-Roman introduction. Reports by early workers of its presence in prehistoric levels in Cornwall (Bullen 1902b; Kennard and Warren 1903; Woodward 1908; Bullen 1909; Arkell 1943) are all considered unsatisfactory until proven by more detailed environmental and archaeological examination (Kerney 1966, 10; Evans 1972, 179). A Bronze Age occurrence at Brean Down is similarly considered to be intrusive (Bell and Johnson 1990, 248). The earliest substantiated report in Britain seems to be in an area of Romney Marsh, Kent, which is thought to have been reclaimed from the sea between AD 1240 and 1270 (Kerney 1966, 10) and it was found in a medieval pit at Southeram in Sussex (Allen 1995, 26). It is currently widespread in southern and eastern England, being rather more scattered elsewhere (Kerney 1999, 181).

Candidula intersecta (Poiret, 1801)

A shell widespread in modern Britain, this is likely to be a medieval introduction, there being no certain earlier records (Kerney 1999, 179). Of interest is that Martin Lister, the earliest author to illustrate any British shells, did not include this as a British shell in his *Historiae Conchyliorum* (Lister 1685, Book 1, plate 85), implying that it was not known in this country at that time. Bullen's (1902b) report of finding it in Cornwall is likely to be unsatisfactory (Evans 1972, 179). It was present in sixteenth/seventeenth century levels at Brean Down (Bell and Johnson 1990, 248). It made a late appearance at Gwithian, Cornwall, being found in superficial levels only (Spencer 1975; Walker 2010).

Theba pisana (Müller, 1774)

Although Pennant (1777, 137 (octavo), 119 (quarto)) was the first to report this as a British shell, the earliest reliable observation was at St. Ives, Cornwall, in 1797, following which it was 'lost' and only rediscovered there in 1966 (Turk 1966). There are no reliable fossil records and it has not been recorded in an archaeological blown sand deposit (Evans 1979) although it now is a very common shell on the coastal dunes in parts of Cornwall, sometimes reaching several thousand in a square metre. It has spread rapidly, now being present along much of the Devon, Cornish and South Wales coasts with some in eastern Ireland (National Biodiversity Network).

Paralaoma servilis (Shuttleworth, 1852)
Hygromia cinctella (Draparnaud, 1801)
Cochlicella barbara (Linnaeus, 1758)

These are all twentieth century introductions to Britain. *P. servilis* was first recorded in Bedfordshire in 1985 (Guntrip 1986), *H. cinctella* in 1950 in Devon (Comfort 1950) and *C. barbara* also in Devon in 1975 (Kerney 1976). The distributions of *P. servilis* and *C. barbara* remain very restricted although *H.*

cinctella has spread rapidly and is now a common shell throughout southern Britain except in the extreme south east (National Biodiversity Network).

Cecilioides acicula (Müller, 1774)

This is a subterranean shell, and living specimens can be found up to 2m below the ground surface. It is common in areas that have been recently cultivated or disturbed. It is therefore very difficult to establish when it was first introduced to Britain, as stratigraphy is often confounded, but there are no reliable Holocene subfossil records (Evans 1972, 168). The first British record was in 1784 in Faversham, Kent (Boys and Walker 1784, 16). It is rare in Cornwall, only being recorded at two sites by 2013 (National Biodiversity Network).

Testacella haliotidea Draparnaud, 1801
Testacella maugei Férussac, 1819
Testacella scutulum Sowerby, 1820

These are all synanthropic subterranean molluscs, and are probably very recent introductions to Britain. The first observation of any of the family (*T. maugei*) was in a market garden in Bristol in 1812 (Férussac 1819, 94; Norman 1860), and all three species remain scarce throughout Britain, although probably under-recorded (Kerney 1999, 175-177). Evans (1972, 169) considered that there are no reliable Holocene subfossil records but it has subsequently been reported in a sub-Roman context at a depth of 130−140cm at Brean Down, Somerset (Bell and Johnson 1990, 248), although it could have been intrusive due to its burrowing nature. Although subterranean they live only a few centimetres below the ground surface (which would imply that the Brean Down record is reliable), coming to the surface at night to feed (Taylor 1900–1907, 5) and their presence may be valid in analyses when found in archaeological contexts.

Potamopyrgus antipodarum (Gray, 1843)
Physella acuta (Draparnaud, 1805)
Ferrissia wautieri (Mirolli, 1960)
Dreissena polymorpha (Pallas, 1771)

These four freshwater molluscs are all recent introductions to Britain. *Potamopyrgus antipodarum* arrived from New Zealand in the mid-nineteenth century (Forbes and Hanley 1853, 266) and is now ubiquitous throughout Britain, being known in Cornwall since 1943 (Turk *et al.* 2001, 8). *Physella acuta* was first found in a water tank in Kew Botanical Gardens in 1860 (Choules 1860); it is native to North America and is now widespread throughout lowland England. The small limpet, *Ferrissia wautieri*, was first described in Italy as recently as 1960 (Mirolli 1960), and was first recorded in Britain in 1977 (Brown 1977); it is currently known only from two locations in Cornwall: near Bude on the north coast and on the Lizard peninsula. The bivalve *Dreissena polymorpha* was first observed in Britain in the London Docks in 1824 (Sowerby 1824); it is native to eastern Europe and probably arrived on timber imports. It is now very widespread in the canal basin of central Britain and in the Norfolk Broads, but has only been found in Cornwall in the Bude Canal, in 2006.

3. Study sites

The county of Cornwall is rich in Holocene archaeological sites, covering all periods from the Mesolithic to modern times (Webster 2007). While many are situated inland on the igneous and metamorphic rocky areas such as West Penwith and Bodmin Moor there are numerous sites related to the sand dunes around the coast, some of which extend several kilometres inland (Figure 3.1). Penhale Sands covers over 542 hectares and is the largest dune complex in England (Radley 1994), exceeded in size only by some in Scotland. Other dunes are very small, only a few hectares in area.

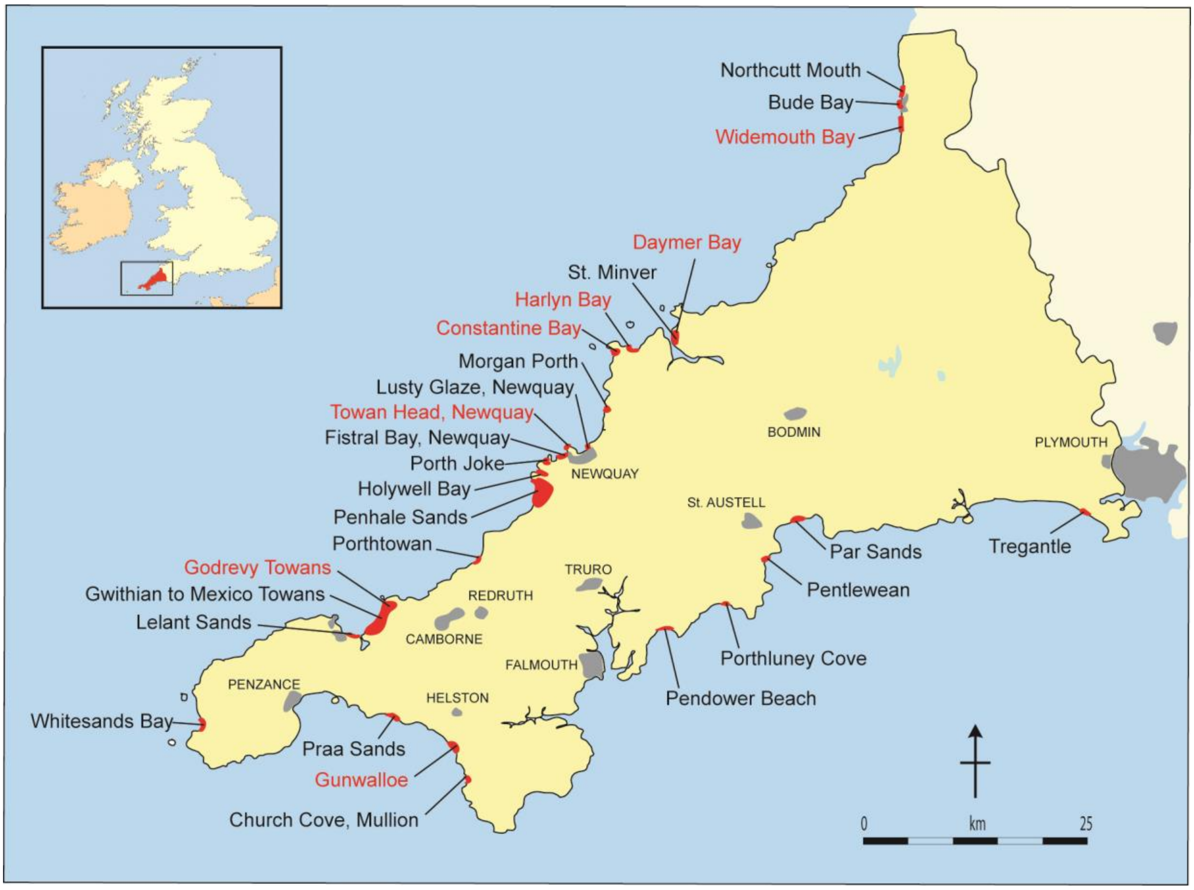


Figure 3.1. Coastal dunes in Cornwall, with the sites discussed in this chapter highlighted in red (Sites from Bell and Brown 2008)

During July/August 2007 a visit was made to Cornwall under the leadership of Professor Martin Bell of the University of Reading Department of Archaeology. The prime purpose of the visit was to review coastal dunes in a survey of windblown deposits funded by English Heritage as part of the Southern Regional Review of Geoarchaeology (Bell and Brown 2008), and the majority of the dunes marked on the map were visited. The author was part of the team on this survey and during this visit obtained mollusc samples from blown sand exposures at Widemouth Bay, Daymer Bay, Harlyn Bay, Constantine Bay, Towan Head (Newquay) and Godrevy Towans. The purpose of sample acquisition was to select potential sites suitable for more detailed studies for BSc dissertations, both for the author and for a fellow student. Although only mollusc analyses were performed on these samples, with no sedimentological or loss on ignition analyses, they are reported here as all are in areas of archaeological interest and add to the corpus of knowledge on coastal blown sand sites. All samples were prepared by standard methods with wet sieving (Evans 1972). The weight of each sample analysed varied from site to site and is indicated in the tables.

The findings are presented below, with the exception of that on Constantine Bay mainland which were analysed by Boardman (2008). However, a report is included of a column obtained on Constantine Island in October 2007.

3.1 Widemouth Bay

3.1.1 Background

Widemouth Bay is in north east Cornwall, facing west, and is about 2km in length (Figure 3.2). However, the blown sands cover only about 700m in the central portion of the bay and extend to a maximum of 700m inland. Some land shells, *Cernuella virgata*, *Candidula intersecta* and *Cochlicella acuta*, were previously reported 'at a depth of from one to two feet [30–60cm] from the surface with Neolithic flakes' (Kennard and Woodward 1901, 235), but no further details were given, and the identification of *C. intersecta* is likely to be unsound. Other than this vague report the only known archaeology in the region of Widemouth Bay is a few pieces of Roman period burnt pottery and bone found eroding from a buried soil on the cliff (Wood 1965). *Cepaea nemoralis*, *Cochlicella acuta*, *Cernuella virgata* and *Cornu aspersum* were also reported on a 1.07m deep raised beach at the north end of the bay (Freshney *et al.* 1972, 70).

3.1.2 Mollusc study

The samples for mollusc analysis were obtained from an exposed face of blown sand containing a buried soil horizon, approximately in the centre of the area covered by blown sand (Figure 3.3; grid ref: SS19832.02046), about 400m south of the finds described in the previous paragraph. Four samples of the sand layers from the base of the turf down to the underlying solid bedrock were taken, the depths below the surface being 40–100cm.

Figure 3.2. View looking south across Widemouth Bay, showing erosion of the blown sands

Figure 3.3. The location of the mollusc samples

The basal layer (85−100cm) suggested an old land surface which was covered with clean blown sand (77−85cm). This was overlain with darker sand consistent with a buried soil horizon (40−77cm). The shells obtained from each layer are shown in Table 3.1 and graphically in Figure 3.4. Diversity is high for the top and bottom samples, fair at 70−77cm and poor at 77−85 where there was fewer than 50 shells.

Table 3.1. Mollusc numbers from the Widemouth Bay mollusc column (1kg samples)

Depth (cm)	40–70	70–77	77–85	85–100
Sample ID	**W1**	**W2**	**W3**	**W4**
Carychium tridentatum	-	-	-	2
Galba truncatula	-	-	-	80
Cochlicopa lubrica	9	8	-	31
Cochlicopa lubricella	1	-	-	-
Cochlicopa sp.	15	5	-	-
Vertigo pygmaea	8	3	1	97
Pupilla muscorum	45	10	3	26
Vallonia excentrica	60	4	-	99
Punctum pygmaeum	5	-	-	3
Cochlicella acuta	190	135	39	114
Cernuella virgata	47	9	2	21
Helicella itala	92	48	4	70
Cornu aspersum	1	-	-	-
TOTAL SHELLS	**473**	**222**	**49**	**543**
Shannon index	1.73	1.24	0.77	1.98
Brillouin index	1.68	1.18	0.66	1.94

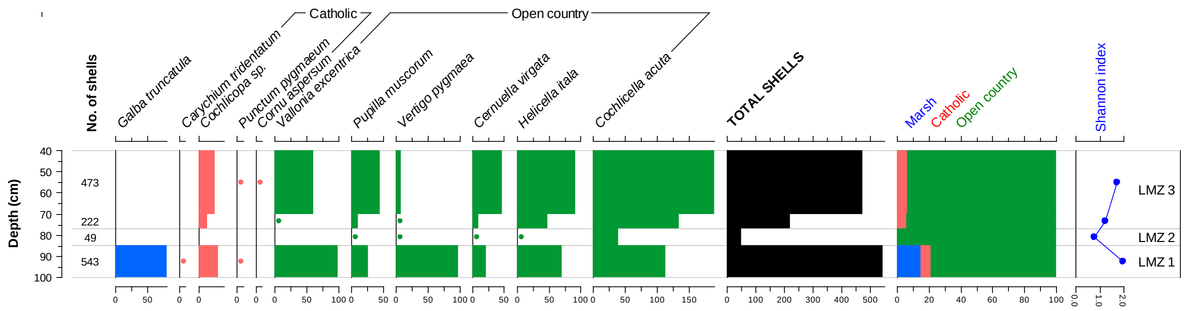


Figure 3.4. Mollusc diagram for the Widemouth Bay samples
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

The molluscan fauna consists mainly of open country species although it is of interest that there are significant numbers of *Galba truncatula* (15% of the total) in the basal old land surface (LMZ 1); this is an amphibious species which requires wetland but can survive periods of desiccation. Its presence strongly suggests that at the time this horizon was formed there was swampy ground or marshland in the near vicinity. The sea margin may have been many hundreds of metres distant but the blown sands at this time were open grassland, possibly grazed as suggested by the higher proportion of *Vallonia* relative to *Pupilla*. However, the presence of *Cernuella virgata*, thought to be a post-Roman introduction to Britain, implies that this surface may not be prehistoric. The basal layer became covered by a thin blown sand deposit (LMZ 2) which, judging by the relatively fewer molluscs than elsewhere, was unstable or accumulated rapidly. Stability then became established (LMZ 3) with sand accumulating slowly over a long period of time, allowing large numbers of molluscs to colonize the area with an increasing and reasonable diversity of species. At no level are there any species which require shade, implying a total absence of woodland or scrub environments, and probably not even rank grassland where species such as *Aegopinella nitidula* might be expected.

The modern turf was not sampled but, as indicated by the photographs, is relatively short grassland, with no shade vegetation in the vicinity. There is considerable rabbit activity on these blown sands.

3.2 Daymer Bay

3.2.1 Background

Daymer Bay (Figure 3.5) lies on the east side of River Camel estuary close to its opening into Padstow Bay, immediately south of Trebetherick Point. Inland from the bay there are dunes extending 900m inland which, although now stable, progressively buried the church of St Enodoc, which dates back to the twelfth century, up to roof level, and which was only cleared of sand in 1864 (Maclean 1876, 34). There is a submerged forest in the bay which was widely exposed by a gale in 1857 and rapidly reburied (Anon. 1955). A Mesolithic flint is recorded from the headland to the north of the bay (Wymer 1977). A prehistoric shell midden is documented in the hind dunes (Cornwall & Scilly HER no. MCO56253); a Bronze Age barrow is recorded on Brea Hill to the south of the bay and there are buried remains of a Romano-British settlement in the sands near the church (Cornwall & Scilly HER nos. 28385 and 26348).

Figure 3.5. Daymer Bay viewed from the north west. Brea Hill is to the right of the picture, with St Enodoc church in the small enclosure inland from the hill. The location of the mollusc sample is marked by the red dot

Although no excavations are reported, some environmental studies have been conducted on the blown sand on the low cliffs around Trebetherick Point, immediately to the north of the bay. Arkell (1943) examined the geology of six sections, showing Holocene blown sand above a raised beach; he identified some non-marine shells, all of which were open country species. A column obtained by Spencer (1974) also showed an entirely open country sequence, thought to be medieval in date. Milles (1991b) looked at two mollusc columns from the blown sand on the rocks at the north end of the bay and demonstrated a basal level with shell midden material and molluscan species suggesting the presence of woodland which in time became more open with unstable shifting blown sand; it is therefore likely that these latter columns predate those of Arkell and Spencer.

3.2.2 Mollusc study

One sample for mollusc analysis was taken in 2007 from sand overlying the raised beach (grid ref.: SW92662.77742; Figure 3.6). In this pilot study to assess whether molluscs were present in any quantity a single bulk sample was obtained from 30–80cm below the present ground surface. 664 shells were obtained (Table 3.2), shown graphically in Figure 3.7. There is high diversity of species (Shannon and Brillouin indices both >2).

Figure 3.6. The Daymer Bay mollusc sample, indicated by the cut above the raised beach

Table 3.2. Mollusc numbers from the Daymer Bay sample
(2kg samples)

Depth (cm)	30–80
Sample ID	**D**
Pomatias elegans	87
Carychium minimum	158
Carychium tridentatum	93
Carychium sp.	47
Cochlicopa lubrica	3
Cochlicopa lubricella	2
Cochlicopa sp.	1
Vertigo pygmaea	3
Pupilla muscorum	6
Vallonia excentrica	6
Punctum pygmaeum	1
Discus rotundatus	100
Vitrea contracta	9
Aegopinella nitidula	78
Clausilia bidentata	25
Cochlicella acuta	9
Cernuella virgata	3
Helicella itala	1
Cepaea sp.	25
Cornu aspersum	7
TOTAL SHELLS	664
Shannon index	2.22
Brillouin index	2.17

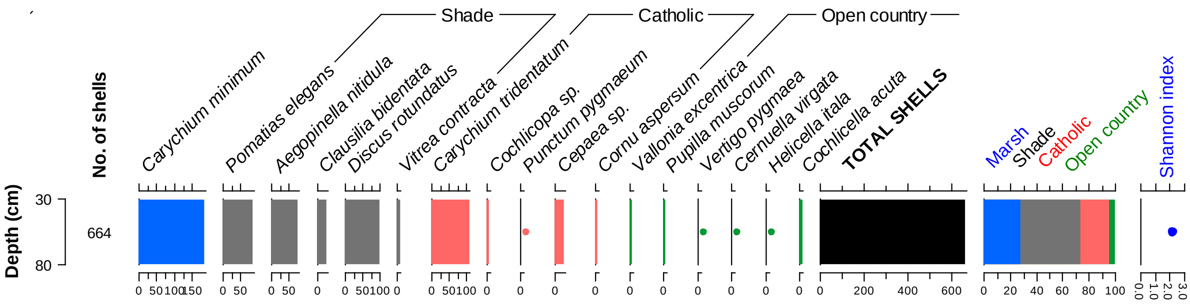


Figure 3.7. Mollusc diagram for the Daymer Bay sample
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

This sample was taken from immediately above the raised beach although does extend upwards into cleaner blown sand; it contains an interesting range of species. Of note is that 45% of all shells are those normally associated with shade; in particular *Pomatias elegans* is a species which burrows into loose soil and its presence often suggests some form of disturbance, either natural or anthropogenic (Evans 1972, 133). *Clausilia bidentata* and *Discus rotundatus* (19% of total) are species associated with leaf litter, implying woodland or scrub. In contrast there are virtually no xerophilic shells (4% of total).

Carychium minimum, the most numerous shell present (24%), is normally regarded as a wet ground species, although is very occasionally found in drier habitats (Evans 1972, 136). The findings indicate that some at least of this sediment was laid down before major accumulations of blown sand, and is consistent with the time when woodland clearance was being undertaken, perhaps in the Neolithic, and there may have been wet swampy ground in the area. However, it is recognized that this single sample is an amalgamation of sand over 50cm thick and therefore may represent changes over a long period of time. What is clear is that this area merits further study with a more detailed examination of the molluscs in a stratified column of samples.

3.3 Harlyn Bay

3.3.1 Background

Harlyn Bay lies on the east side of Trevose Headland in north Cornwall. A large area of blown sand extends from Harlyn Bay west to Constantine Bay (Figure 3.8), and there is evidence of multiperiod human activity over a wide area (Figure 3.9).

Harlyn Bay first reached archaeological attention in the mid-nineteenth century when two gold lunulae and a flat axe were discovered eroding from the cliff (Hencken 1932), now considered to date from the early Bronze Age (Mattingly *et al.* 2009). Four early Bronze Age urns have also been recovered from the cliffs (Crawford 1921; Preston-Jones and Rose 1987) and there is a Bronze Age barrow group on the headland west of the bay (Preston-Jones and Rose 1987). Several cists/pits are known eroding from the cliff edge, the most recently excavated being dated to 2040−1880 cal BC (3610±35 BP; SUERC-15536) (Jones *et al.* 2011, this paper reviews all the cists found along this cliff). In 1900 an Bronze/Iron Age burial ground was excavated under blown sand about 200m inland in which there were numerous human and animal bones, spindle-whirls, pottery and flint implements on an old land surface (Bullen 1902a). Further excavations in 1976 revealed a circular stone building beneath the cemetery, with charcoal dated to 2139−1664 cal BC (1600±90 bc; HAR 1922) (Whimster 1977).

Figure 3.8. Harlyn Bay viewed from the west. The locations of the study mollusc columns are marked with red dots and the site of the Iron Age cemetery with a yellow dot

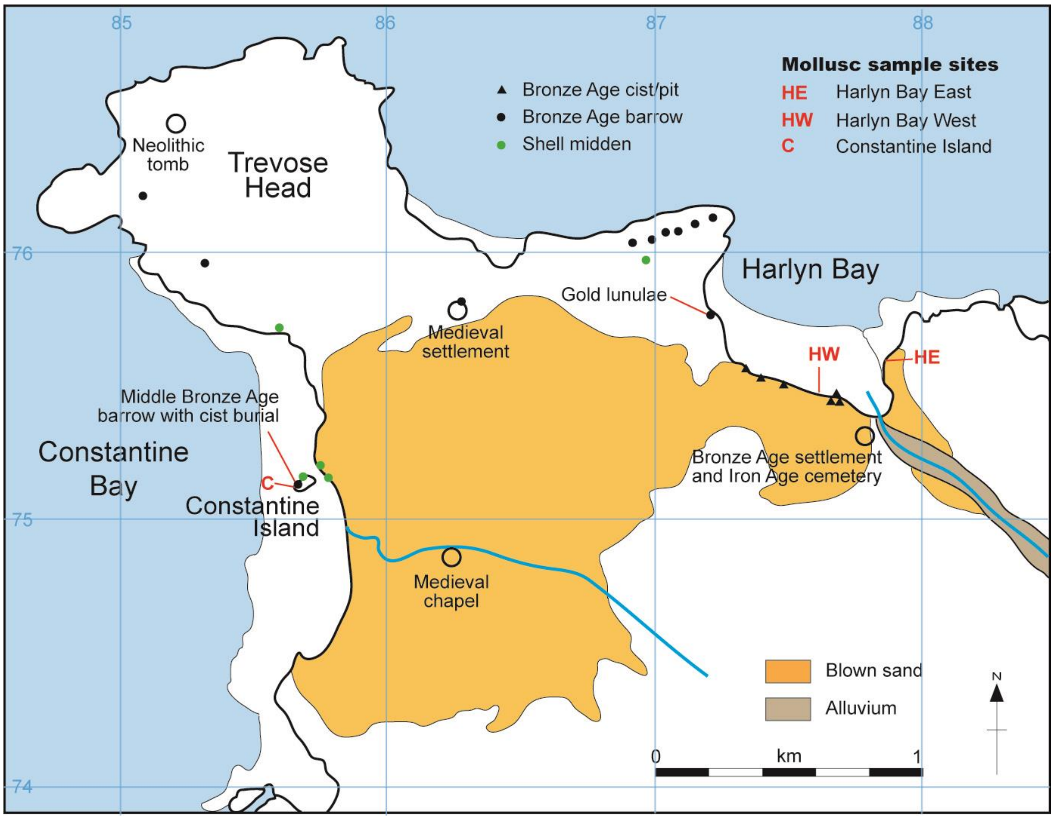


Figure 3.9. The area of blown sand between Constantine and Harlyn Bays showing the archaeological sites. The sites from which mollusc samples were acquired are indicated
(Sites from Cornwall & Scilly HER and Jones *et al.* 2011)

Non-marine molluscs have been reported from Harlyn Bay on several occasions, both from the cemetery site (Bullen 1902b; Bullen 1902a, 1912; Spencer 1974; Whimster 1977; Evans 1979) and the eroding cliff face on the shore (Spencer 1974). The presence of *Pomatias elegans* and other shade species (*Discus rotundatus* and *Clausilia bidentata*) in the Bronze and Iron Age levels from the cemetery site implies that the area contained woodland or scrub providing good leaf litter, but the higher levels consist almost entirely of open country species. This shady horizon was not found in the cliff section. These studies have allowed the sequence of sand deposition to be clarified by Bell and Brown (2008, 28): the first sand blow was between the middle Bronze Age and the time of the Iron Age burials and this was followed by the main episode of sand deposition.

3.3.2 Mollusc study

The present study obtained material for mollusc analysis from two sites at Harlyn Bay. A single sample was taken from a buried soil beneath compacted blown sand on top of a 20m cliff on the east side of the bay ('Harlyn Bay East'; grid ref.: SW87887.75567 – Figure 3.10 and Figure 3.11) and a column of four samples from the central area of the bay on a 1.5m rock face, close to the area where the urns had earlier been found eroding from the sand ('Harlyn West'; grid ref.: SW87703.7542 – Figure 3.12 & Figure 3.13); both sites are marked on Figure 3.9.

Figure 3.10. The cliff on the eastern side of Harlyn Bay, covered with a layer of blown sand

Figure 3.11. The Harlyn Bay East sample was obtained from the base of this blown sand

Figure 3.12. Buried soil above a low rock face at the Harlyn Bay West site

Figure 3.13. The Harlyn Bay West mollusc column location after sampling

The Harlyn East sample from the buried soil of the old land surface produced 971 molluscs from a 2kg sample (Table 3.3 and Figure 3.14) while the Harlyn West mollusc column produced a total of 595 shells from 1kg samples (Table 3.4 and Figure 3.15). Diversity at Harlyn East was good, but at Harlyn West was lower in all but the turf sample, despite the good number of shells.

Table 3.3. Mollusc numbers from the Harlyn Bay East sample (2kg sample)

	buried soil
Sample ID	**HE**
Cochlicopa lubrica	11
Vertigo pygmaea	14
Pupilla muscorum	192
Vallonia excentrica	209
Aegopinella nitidula	1
Cochlicella acuta	229
Ashfordia granulata	2
Candidula intersecta	3
Cernuella virgata	200
Helicella itala	106
Trochulus hispidus	4
TOTAL SHELLS	**971**
Shannon index	1.73
Brillouin index	1.71

Table 3.4. Mollusc numbers from the Harlyn Bay West mollusc column (1kg samples)

Depth (cm)	**0–30**	**30–40**	**40–70**	**70–80**
Sample ID	**HW1**	**HW2**	**HW3**	**HW4**
Carychium minimum	-	1	-	-
Galba truncatula	1	-	-	-
Cochlicopa lubrica	-	3	1	-
Cochlicopa lubricella	1	1	-	-
Vertigo pygmaea	2	7	7	2
Vertigo sp.	-	-	-	-
Pupilla muscorum	19	37	40	15
Vallonia excentrica	7	116	85	32
Discus rotundatus	2	-	-	-
Vitrina pellucida	2	-	-	-
Aegopinella nitidula	2	-	-	-
Oxychilus cellarius	4	-	-	-
Cecilioides acicula	1	-	-	-
Clausilia bidentata	1	-	-	-
Cochlicella acuta	63	78	-	1
Ashfordia granulata	-	27	1	1
Cernuella virgata	11	-	-	-
Helicella itala	1	-	-	3
Ponentina subvirescens	-	-	7	8
Trochulus striolatus	3	-	-	-
Cepaea sp.	2	-	-	-
TOTAL SHELLS	**122**	**270**	**141**	**62**
Shannon index	1.75	1.41	1.03	1.34
Brillouin index	1.58	1.36	0.97	1.20

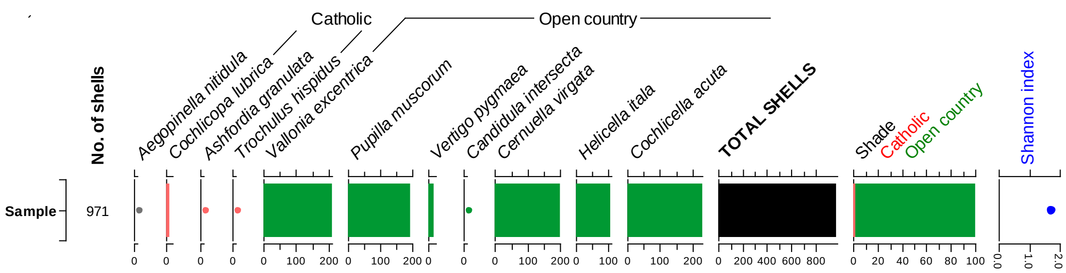


Figure 3.14. Mollusc diagram for the Harlyn Bay East sample
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

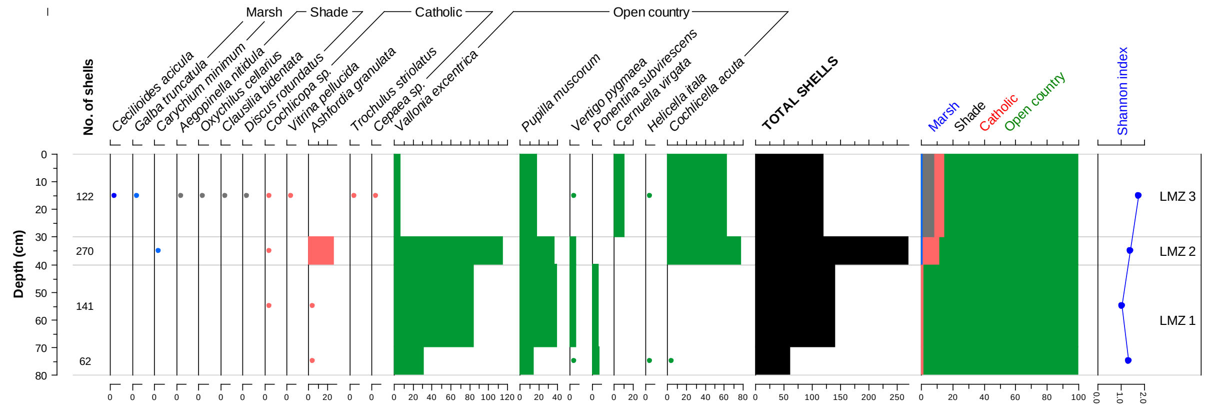


Figure 3.15. Mollusc diagram for the Harlyn Bay West samples
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

None of the samples from either location produced the woodland/scrub species that had previously been identified by previous studies in the deep samples at Harlyn Bay, but those were from the Bronze and Iron Age sites inland from the sea cliff (Bullen 1902a; Whimster 1977). The current samples show almost entirely open country species, although with a few shade taxa able to live in the rank grass of the modern turf (LMZ 3), where there is a higher diversity than in the lower levels. It is interesting that a specimen of *Galba truncatula* is included, an amphibious species resistant to drying. There is no wet ground in the close vicinity at the present time, and the most likely explanation is this was carried to this site by birds from nearby marshes.

The absence of *Cochlicella acuta* in the lower two levels (LMZ 1) (apart from a single shell which may be displaced from higher up) does, however, raise the possibility that these deposits date from prehistoric times, as this mollusc it not thought to have been introduced into Britain until the Bronze Age, and does not seem to have become established in Cornwall until the late 1st millennium BC. If this is the case, then it may be that the coast during the Bronze/Iron Ages was open country, with the more shaded and wooded area only commencing further inland. This is, perhaps, supported by the dominance of *Vallonia excentrica* in the lower three levels at Harlyn West, a species often associated with grazed grassland. It seems likely that in earlier times there was relatively level ground at the base of the present cliffs extending seawards sufficient for animal grazing, and which has now been eroded away. There is one horizon of relative stability (LMZ 2), indicated by the much greater number of molluscs, although with fewer taxa than in the overlying sand.

Little can be learned from the sample from the top of the Harlyn East cliff, which contains almost entirely open country species with no evidence of shade other than that provided by low vegetation. This sample was taken from the old land surface at the base of the blown sand and it would seem that this was open country from the commencement of sand deposition.

3.4 Constantine Island

3.4.1 Background

Constantine Bay is a long sandy beach south of Trevose Head (Figure 3.9). The area is rich in archaeology, both on Trevose Head, and on the blown sand between Constantine Bay and Harlyn Bay. Mesolithic flint scatters have been found over a wide area (Wymer 1977, 44; Johnson and David 1982). A small promontory in the middle of the bay is an island at high tide, but linked to the mainland by rocks at mid and low tide (Figure 3.16). Although only about 100 x 40m in size the island contains abundant archaeology with flint scatters, mainly Mesolithic, (Whitehead 1973; Norman 1977; Wymer 1977, 44; Johnson and David 1982; Bell and Brown 2008, 29) and a 'Neolithic hut' (Bullen 1902b; Bullen 1912, 83) which is no longer visible and probably lost to erosion. A cist was discovered eroding from the blown sand near the west of the island in 2007 and a rescue excavation (Figure 3.17) revealed an early Bronze Age burial within a barrow, dated to 1380–1110 cal BC (2985±35; SUERC-16818) (Jones 2009–10). Several shell middens, mostly with mussels and limpets, can be seen eroding from the blown sand both on the north side of the island (Figure 3.18) and on the adjacent mainland.

Figure 3.16. Constantine Bay showing the Island in the centre of the photograph. The position of the cist and mollusc column is marked with a red dot

Figure 3.17. Constantine Island. The barrow excavation showing the sand into which the cist is cut.

Figure 3.18. Shell middens eroding from the sand on the north side of Constantine Island.

Mollusc studies have been conducted on the island (Bullen 1902b; Bullen 1902a, 1912; Walker 2009–10) and the mainland immediately opposite the island (Spencer 1974; Boardman 2008). All show predominantly open country species. The sand in the lower half of the barrow on the island was decalcified but the upper half, into which the cist was cut, contained mostly *Vallonia excentrica* and *Pupilla muscorum*, in numbers suggesting grazed grassland. Of interest is that there were no examples of *Cochlicella acuta* or *Helicella itala*, implying that this sand was deposited prior to their appearance in this part of Cornwall (Walker 2009–10).

3.4.2 Mollusc study

While the samples were being collected during the barrow excavation the opportunity was taken to obtain a column for mollusc analysis from the blown sand on the island in an area close to, but separate from, the barrow (grid ref.: SW85772.75184), and this column is described here (Figure 3.19).

Figure 3.19. The blown sand exposure on Constantine Island from which the mollusc column was obtained. The barrow is to the left of this exposure

The column was obtained from the turf line on the summit of the island to the base of the exposure, but does not reach down to the old ground surface which is probably 20−30cm deeper. The column was divided into eight samples and all produced good numbers of molluscs, with a total of 2795 shells (Table 3.5). Figure 3.20 shows the findings graphically. Diversity of species is good in the turf and lower four samples, but less so in the horizons from 10−42cm.

Table 3.5. Mollusc numbers from the Constantine Island mollusc column (3kg samples)

Depth (cm)	0–10	10–20	20–32	32–42	42–50	50–63	62–65	65–75

Sample ID	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8
Cochlicopa lubrica	1	-	1	2	7	5	11	36
Cochlicopa sp.	-	-	-	-	1	-	3	15
Vertigo pygmaea	2	7	-	2	1	1	-	2
Pupilla muscorum	30	30	37	48	56	40	108	222
Vallonia excentrica	25	71	40	60	51	42	65	166
Punctum pygmaeum	-	-	-	-	-	-	-	4
Vitrina pellucida	-	-	-	-	-	-	-	1
Cochlicella acuta	295	230	158	235	100	90	56	16
Ashfordia granulata	2	-	-	-	-	3	5	46
Candidula intersecta	32	-	-	-	-	-	-	-
Cernuella virgata	34	-	-	-	-	-	-	-
Helicella itala	23	26	23	56	48	36	12	-
Ponentina subvirescens	-	-	-	-	1	-	3	8
Trochulus hispidus	5	1	3	-	-	-	-	-
Cepaea sp.	-	1	-	3	1	2	1	2
Theba pisana	45	-	-	-	-	-	-	-
TOTAL SHELLS	494	366	262	406	266	219	264	518
Shannon index	1.46	1.11	1.15	1.21	1.50	1.50	1.51	1.50
Brillouin index	1.41	1.08	1.12	1.18	1.45	1.44	1.45	1.46

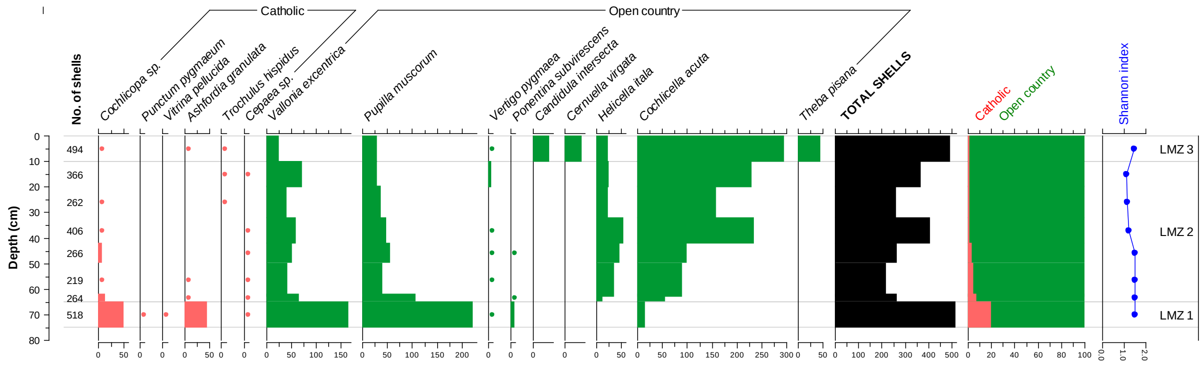


Figure 3.20. Mollusc diagram for the Constantine Island samples
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

No species requiring shade were found at any level, the assemblages containing almost entirely open country taxa, although with a few catholic species. Of note is the basal level (LMZ 1) with very few *Cochlicella acuta*, although there is progressive increase in numbers above this. As already mentioned, this taxon is considered to be a late prehistoric introduction to Britain, which suggests that this sediment may date prior to the Iron Age. The species was not present in the barrow sands, implying that the barrow was constructed prior to the arrival of the bulk of the blown sand now covering the island, and that *C. acuta* did not arrive in this area until after the early Bronze Age. The barrow is very visible from inland, a feature well recognized in the siting of Bronze Age barrows (e.g. Renfrew and Bahn 2000, 200). The presence of *Vallonia excentrica* and *Pupilla muscorum* in high numbers indicates grazed grassland in the lowest level examined. *Ponentina subvirescens* in the same horizon is also of note; subfossil specimens of this mollusc have rarely been reported from Cornish sites (Davis 1956) and is thought to have arrived in Britain in the Bronze or Iron Age and if correct corresponds well to the dating suggested.

Above this basal level the island vegetation probably becomes longer and less closely grazed (LMZ 2), indicated by the reduction of *Vallonia* and *Pupilla*. *Cochlicella* rapidly becomes the dominant species, and continues so until modern times. The appearance of *Candidula intersecta* and *Cernuella virgata* in the uppermost level (LMZ 3) implies sand accumulation during medieval times or later, but the finding of *Theba pisana*, a species first observed in Britain in the late 18th century (at St Ives in Cornwall) places deposition probably as late as the 19th century. This shell is today present in huge abundance on Constantine Island.

3.5 Towan Head, Newquay

3.5.1 Background

Towan Head (Figure 3.21) is at the north end of a dune complex that extends across Fistral Bay at the north end of an extensive area of blown sand to the west of the town of Newquay. Mesolithic scatters have been found on the headland but not in the area of blown sand (Wymer 1977, 40). Apart from shell middens the only pre-medieval archaeology reported within the area of blown sand (Figure 3.22) is the Iron Age and Romano-British settlement of Atlantic Road on the south margin of the sand (Reynolds 2000–01; Light 2001) and an Iron Age/Romano-British round 200m to the west of the settlement (Cornwall & Scilly HER 55452). Five Bronze Age barrows are recorded on the Pentire East Headland (Cornwall & Scilly HER). South of the sand there is a major Bronze Age settlement with an Iron Age cemetery at Trethellan Farm which was buried initially by a possible mud flow and later by a colluvial sediment containing sand from cultivated land higher up the River Gannel hillside (Nowakowski 1991).

Figure 3.21. Towan Head, Newquay, viewed from the south. The location of the present mollusc column is marked with a red dot

There are several reports of mollusc studies from sands exposed above a rocky cliff on either side of a narrow isthmus at the south end of the rocky Towan Head and further south towards Fistral Bay (Figure 3.22). The earliest (Kennard and Woodward 1901, 247) merely comments on a few open country species from an undefined location, but several later reports describe mollusc columns obtained along 600m of the headland (Figure 3.22) (Kennard and Warren 1903; Woodward 1908; Spencer 1974, 1975; Milles

1991b). A basal soil overlying the head included molluscs indicating a shaded environment prior to the appearance of C*ochlicella acuta* and *Helicella itala*, probably representing a landscape before woodland clearance. Blown sand then accumulates with increase in *Vallonia excentrica*, *Pupilla muscorum* and other open country species consistent with short dry grassland. *Cernuella virgata* only appears in higher levels in agreement with its post-Roman introduction to Britain.

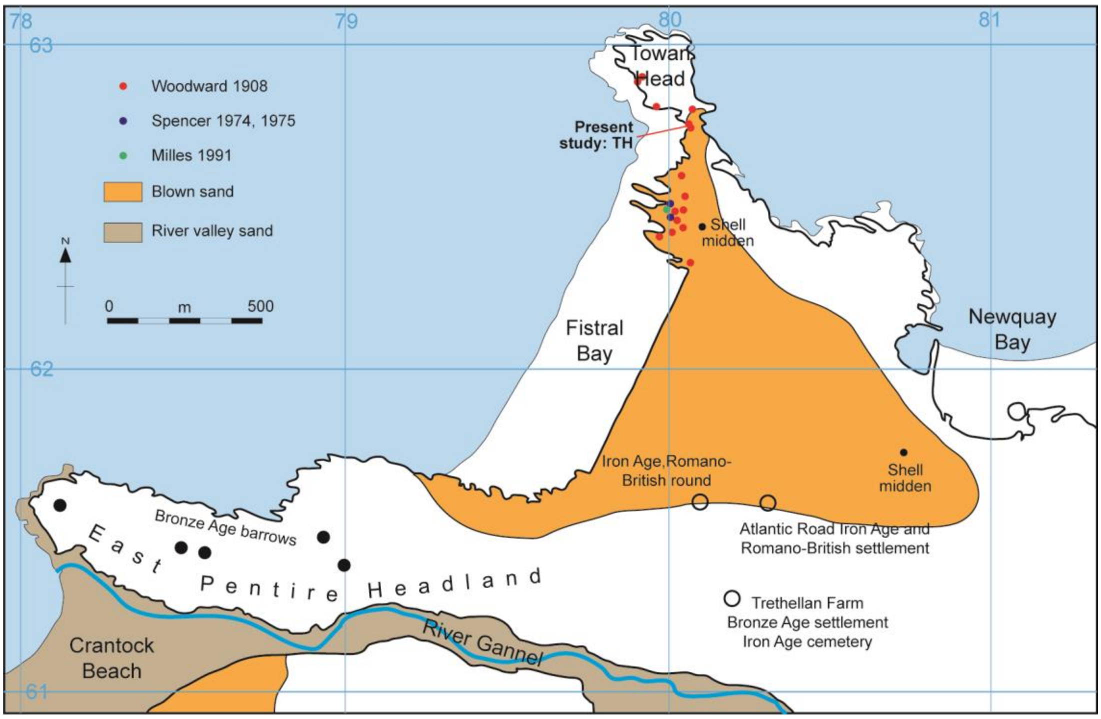


Figure 3.22. Map showing the area of blown sand to the west of Newquay, with the archaeological sites. The locations of the present mollusc column (TH) and those reported by Woodward (1908), Spencer (1975) and Milles (1991) are indicated (Sites from Cornwall & Scilly HER)

3.5.2 Mollusc study

For the current study a single mollusc column was obtained from an exposure immediately north of the headland isthmus, on its west side (Figure 3.23 & Figure 3.24; grid ref: SW80077.62768). It should be noted that this location is about 300m north of the sites described by Spencer and Milles.

Figure 3.23. The west side of Towan Head, looking north. The mollusc column site is just to the right of the red life buoy station

Figure 3.24. The mollusc column obtained at Towan Head

The column was divided stratigraphically into eight samples and did not include the uppermost 30cm of sediment as this was clearly disturbed ground associated with the building of a car park and steps leading to the beach. A total of 890 shells were obtained (Table 3.6 and Figure 3.25). Diversity was fair in the upper two levels but poor below 39cm.

Table 3.6. Mollusc numbers from the Towan Head mollusc column (1.5kg samples).

Depth (cm)	**20–30**	**30–39**	**39–42**	**42–47**	**47–60**	**60–67**	**67–78**	**78–85**
Sample ID	**TH1**	**TH2**	**TH3**	**TH4**	**TH5**	**TH6**	**TH7**	**TH8**
Cochlicopa lubrica	-	1	-	-	-	-	1	-
Cochlicopa lubricella	-	1	-	-	-	-	-	-
Vertigo pygmaea	2	1	-	1	-	-	-	-
Pupilla muscorum	5	9	1	1	-	-	1	-
Lauria cylindracea	-	1	-	-	-	-	-	-
Vallonia excentrica	8	23	-	-	1	-	-	-
Cochlicella acuta	45	56	186	100	148	95	-	-
Cernuella virgata	6	7	13	7	29	16	1	-
Helicella itala	24	65	10	11	6	2	-	-
Ponentina subvirescens	-	-	-	1	-	-	-	-
Cepaea sp.	-	-	-	-	1	-	2	1
Cornu aspersum	1	-	-	-	-	-	-	-
TOTAL SHELLS	**91**	**164**	**210**	**121**	**185**	**113**	**5**	**1**
Shannon index	1.39	1.43	0.45	0.66	0.64	0.49		
Brillouin index	1.28	1.35	0.43	0.60	0.60	0.46		

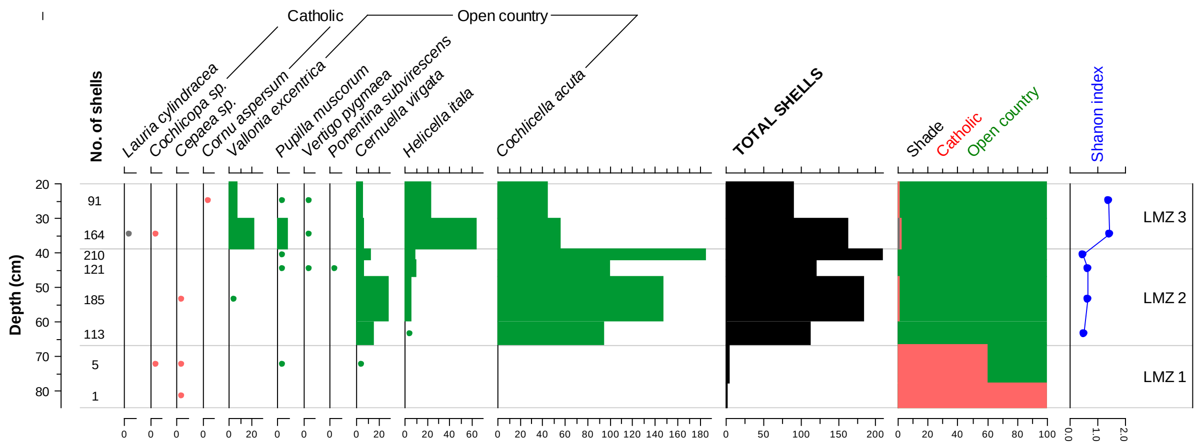


Figure 3.25. Mollusc diagram for the Towan Head samples
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

The basal two levels (LMZ 1), of what appeared to be the old ground surface, contained virtually no shells, and those that are present are non-specific. Above this (LMZ 2) the blown sand has open country taxa which include *Cernuella virgata*; if the post-Roman introduction of this species is accepted, then there is no molluscan evidence of any prehistoric sand accumulation. The absence of *Vallonia* in the lower blown sands (LMZ 1, 2) suggests that grazing was not occurring. Of particular relevance is the fact that there is no evidence of shade species at any level; *Lauria cylindracea* in the uppermost level (LMZ 3) is a species that can live in rock rubble habitats and does not require shade from vegetation.

The findings at this site are at variance with those found elsewhere around Towan Head, and it may be that this entire deposit above the old ground surface is unnatural and a recent deposition. Indeed, Woodward (1908) states that there was a bridge 'just where the slope leads down into the gully'. No bridge is now present and the gully only extends part way across the isthmus from the west, the remainder of the neck of the headland having been filled in at some time during the last century when a road was built. Numerous mussel fragments were present in the 39–42cm sample which was thought at the time of collection to be part of a shell midden but this now seems unlikely, with the sand containing the mussels having been obtained from another location which contained the shells. A short distance away on the east side of this neck of land a lifeboat slipway has been cut and there are clear mussel deposits in the face of the cut and it is suggested that material from this cutting was used to fill in the 'gully' described by Woodward.

3.6 Godrevy Towans

3.6.1 Background

Godrevy Towans cover a ridge of land to the north of the Red River to the east of St Ives Bay. The river valley is very rich in archaeology, with evidence of human activity from the Mesolithic to post-Roman times, and with a medieval site on the Towans summit. This archaeology will be discussed in detail in Chapter 5. Previous environmental studies involving molluscs have been conducted on or close to the main archaeological sites in the river valley at Gwithian (Spencer 1974, 1975; Lewis 1977; Milles 1991b; Davies 2007), but none on the towans themselves.

3.6.2 Mollusc study

An exposure of sand at the extreme west end of Godrevy Towans, close to the coast road from Gwithian village to Godrevy lighthouse, included two stabilization horizons with numerous shells exposed on the surface. Samples were obtained from each of these horizons together with one from the intervening cleaner sand (Figure 3.26).

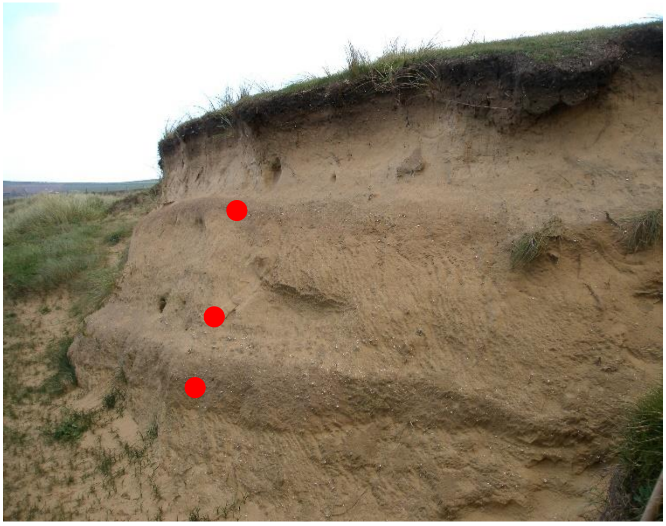


Figure 3.26. The sand scarp at Godrevy Towans. The stabilization horizons are visible as darker layers. The sample positions are indicated

The number of molluscs found in both of the stabilization horizons was very high (Table 3.7 and Figure 3.27), with fewer in the interposed sand. Open country species greatly predominate, although with some catholic and shade taxa at the lower level. The high number of *Vallonia excentrica* at 170–180cm (20% of shells) suggests that the land was grazed at the time it was accumulating.

Table 3.7. Mollusc numbers from the Godrevy Scarp pilot samples (1.0kg samples)

Depth (cm)	70–80	130–140	170–180
Sample ID	**GS1**	**GS2**	**GS3**
Cochlicopa lubrica	**-**	**2**	**14**
Cochlicopa lubricella	-	2	6
Cochlicopa sp.	-	-	6
Vertigo pygmaea	-	2	31

Pupilla muscorum	76	2	126
Lauria cylindracea	-	-	5
Vallonia excentrica	4	8	172
Punctum pygmaeum	-	-	4
Vitrina pellucida	1	-	-
Aegopinella pura	-	-	2
Cochlicella acuta	221	23	319
Cernuella virgata	143	9	7
Helicella itala	178	34	169
Cepaea sp.	-	1	-
TOTAL SHELLS	**623**	**83**	**861**
Shannon index	1.36	1.60	1.65
Brillouin index	1.34	1.45	1.63

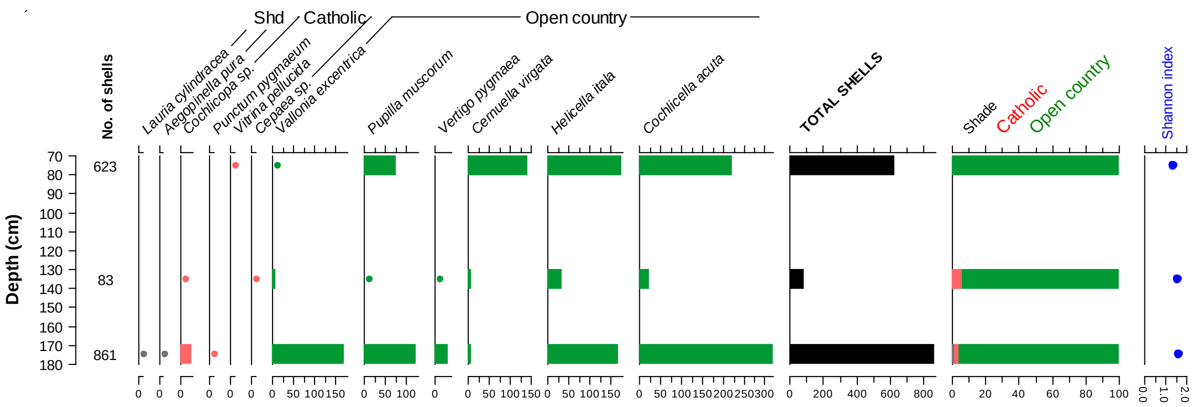


Figure 3.27. Mollusc diagram for the Godrevy Towans samples
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)

Table 3.8); the mollusc diagram is shown in Figure 3.28. Uranium-series dating on the shells was only partially successful (there were discrepancies due to detrital thorium at several levels). AMS radiocarbon dates have subsequently been obtained from *Cochlicella acuta* shells from four horizons and *Prunus* sp. charcoal from the old ground surface (Table 3.1). The study showed that old ground surface dated to the late Neolithic with five stabilization layers dating to the middle Bronze Age, late Bronze Age, Romano-British period, with one undated more superficial horizon. All these stabilization deposits are separated by blown sand.

Table 3.8. Mollusc numbers from the Godrevy Scarp mollusc column (1.0kg samples)

Depth (cm)	0–5	5–12	12–19	19–25	25–31	31–40	40–50	50–59	59–68	68–75	75–83	83–96	96–110	110–123	123–137	137–150	150–160	160–170	170–180	180–191	191–210	210–228	228–245	245–255	255–265	265–275	275–288	288–300	300–310	310–332	OLS
Sample ID	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Carychium minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	1	-	-	-	-	-
Carychium tridentatum	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carychium spp.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Peringia ulvae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-
Galba truncatula	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochlicopa lubrica	-	-	-	1	-	-	-	-	-	-	-	-	6	19	7	-	3	71	48	14	9	3	2	2	4	5	5	90	-	30	2
Cochlicopa lubricella	-	1	-	-	-	-	2	-	-	-	-	1	2	5	6	-	-	30	11	-	-	1	-	-	-	-	-	5	-	-	-
Cochlicopa spp.	-	4	-	-	2	-	-	-	-	-	1	-	6	10	-	2	-	62	42	19	-	1	3	-	-	-	-	29	1	7	-
Vertigo pygmaea	42	208	22	3	2	1	-	-	1	4	2	1	9	22	1	-	2	118	149	26	1	1	1	3	-	2	2	30	1	8	5
Pupilla muscorum	46	106	71	-	17	13	13	6	12	114	59	8	96	501	11	5	35	279	237	220	88	124	58	155	71	58	34	249	13	94	15
Lauria cylindracea	-	68	14	19	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-
Vallonia excentrica	105	178	22	5	6	7	13	8	3	4	21	8	31	156	28	6	10	348	498	220	31	33	38	47	37	33	29	412	5	38	18
Punctum pygmaeum	1	55	9	-	-	-	-	-	1	-	3	2	2	2	-	-	5	4	33	7	1	1	1	-	-	-	-	8	-	3	2
Discus rotundatus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Vitrina pellucida	4	3	3	6	2	-	-	-	-	2	6	1	1	1	-	-	4	6	3	1	-	2	3	-	-	-	-	-	-	-	1
Vitrea crystallina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-
Aegopinella nitidula	-	13	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	11
Oxychilus alliarius	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	-	-	-	-	-	-	-	-	-	-	-	-
Limacidae	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochlicella acuta	320	601	668	247	304	196	122	73	80	308	157	24	235	1064	59	17	147	600	776	564	253	174	153	391	95	145	181	336	127	132	13
Ashfordia granulata	-	3	2	-	-	-	-	-	-	-	-	-	2	2	1	-	-	-	5	-	-	3	2	-	-	3	2	11	-	-	-
Candidula intersecta	41	178	4	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cernuella virgata	1	62	77	22	15	12	6	2	4	182	19	1	2	-	8	-	10	7	-	-	-	-	-	-	-	-	-	-	-	-	-
cf. *Xerocrassa geyeri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-	-	-	1	6	2	42	4
Helicella itala	79	46	142	37	45	44	53	46	68	343	84	14	189	401	63	30	80	339	428	249	200	199	108	664	159	85	44	194	1	1	-
Trochulus hispidus	-	7	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cepaea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-
Cornu aspersum	1	4	1	9	7	3	-	-	-	-	-	-	-	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL SHELLS	**640**	**1539**	**1038**	**350**	**401**	**277**	**209**	**135**	**171**	**958**	**352**	**60**	**582**	**2186**	**186**	**61**	**297**	**1869**	**2252**	**1323**	**583**	**544**	**370**	**1262**	**366**	**333**	**299**	**1371**	**150**	**358**	**71**
Shannon index	1.51	1.95	1.21	1.11	0.94	1.00	1.15	1.07	1.19	1.37	1.48	1.63	1.44	1.34	1.67	1.32	1.41	1.82	1.76	1.51	1.26	1.38	1.43	1.11	1.31	1.42	1.23	1.76	0.62	1.68	1.89
Brillouin index	1.48	1.92	1.24	1.07	0.90	0.95	1.11	1.01	1.12	1.35	1.44	1.45	1.41	1.33	1.58	1.19	1.35	1.80	1.74	1.49	1.24	1.35	1.39	1.10	1.28	1.87	1.19	1.74	0.57	1.63	1.70

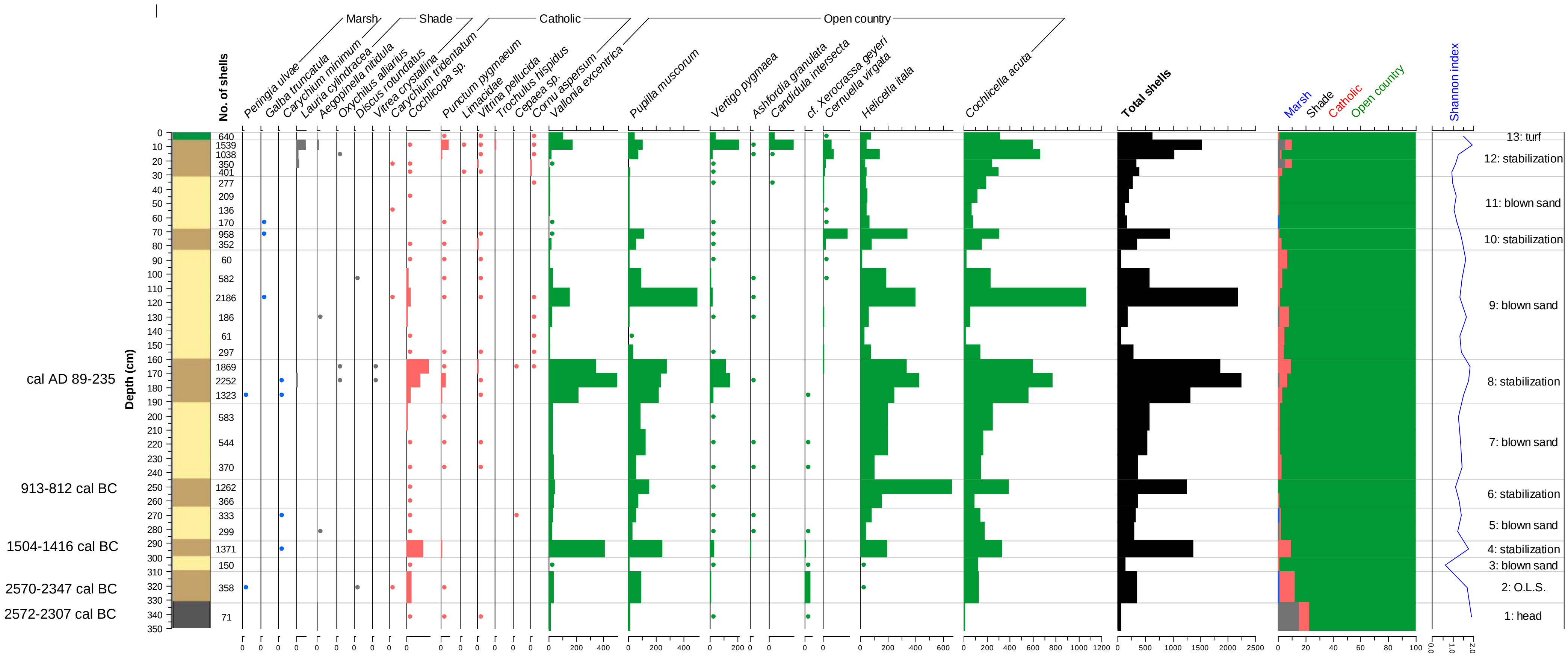


Figure 3.28. Mollusc diagram for the mollusc column from Godrevy Towans
Absolute numbers of shells (dots represent ≤ 5 specimens; summary table shows %)
Stabilization horizons are shown as brown on the stratigraphic diagram, intervening blown sand in yellow

Table 3.9. Radiocarbon dates on the Godrevy Towans mollusc column samples

Lab number	Material	Corrected depth (cm)	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)	Mid-date
OxA-28969	*Cochlicella acuta*	170–180	-5.81	1833±26	cal AD 89–-235	AD 171
OxA-28968	*Cochlicella acuta*	255–265	-6.53	2718±27	913–812 cal BC	862.5 BC
OxA-28967	*Cochlicella acuta*	288–300	-6.45	3187±27	1504–1416 cal BC	1460 BC
OxA-28966	*Cochlicella acuta*	310–332	-3.52	3957±29	2570–2347 cal BC	2458.5 BC
Beta-280906	*Prunus* sp. charcoal	332–340	-23.80	3950 ±40	2572–2307 cal BC	2439.5 BC

This area of towans has always been open country with very little evidence of shade or even long rank vegetation. The varying proportions of *Vallonia excentrica* and *Pupilla muscorum* suggest that grazing took place during two of the stabilization episodes in the middle Bronze Age and post-Roman period, as well as at the present time. It was possible to correlate many of the deposition sequences to those on the main archaeological site.

It is important to state that the radiocarbon date for the shells in the old ground surface (310–332cm) is the same as that from the charcoal which almost certainly derived from the same sediment. This makes any old carbon effect of the shell estimation unlikely, and gives a very early date of the late Neolithic for the presence of *Cochlicella acuta* in Cornwall. This will be discussed further in Chapter 11.

3.7 Discussion of the sites

The mollusc columns described in this chapter give a palimpsest of the make-up of dunes and blown sand accumulations along the north Cornish coast, despite the lack of scientific dating at most sites to establish a firm chronology. At Widemouth Bay, Harlyn Bay (both East and West) and Constantine Island there is no evidence of any woodland cover at the lowest levels, and the surrounding country was open grassland at all times, although with some marshy ground in the vicinity at Widemouth. It is known from previous studies that there was woodland/scrub cover somewhat further inland at Harlyn Bay in the area of the prehistoric cemetery, but it seems this did not extend seawards.

The absence of *Cochlicella acuta* in the basal deposit at Harlyn Bay West and lowest sampled level at Constantine Island suggests that these layers may have accumulated prior to the arrival in Britain of this taxon. In contrast, at Widemouth and Harlyn Bay East the lowest sampled layers are likely to be post-Roman as both *C. acuta* and *Cernuella virgata* are present. One conclusion is that at the former sites the ground was sufficiently stable to resist deflation by winter storms, while at the latter sites prehistoric sand accumulations have been removed, probably by storm action.

The full mollusc column from Godrevy Towans proved very rich in molluscs and apparently represents an undisturbed sequence of sand accumulation for over 4,000 years.

At the Towan Head sample site the basal sediment may be an undisturbed prehistoric deposit and a true old ground surface but the very small number of shells found make interpretation hazardous. Above this the sands were deposited in recent times and no conclusions can be made about the palaeoenvironment of this location, especially as it is at variance with previous studies in the vicinity.

Daymer Bay is clearly different from the other sites. Its position is somewhat protected within the River Camel estuary, unlike the exposed coast of the other sites studied. Although only one sample was obtained on this occasion, and that from 50cm depth of sand, the environment at the time was shaded and wet, conditions which are likely to have lasted throughout the duration of sand accumulation, as evidenced by the paucity of open country species in the whole sample. As can be seen in Figure 3.5 the area above the cliff is, at the present time, open short grassland and the woodland/scrub is about 100m to the east of the sample site. When the woodland was cleared is not known (the earliest large scale Ordnance Survey map (1881) shows that the whole peninsular was pasture apart from a small area of open dune at the south end). These sediments would greatly benefit from further study with a properly stratified column.

3.8 Selection of sites for present study

3.8.1 Case study 1 ─ Gwithian

The results of the mollusc column at Godrevy Towans and the earlier environmental studies on and around the main archaeological sites (Spencer 1974, 1975; Milles 1991b; Davies 2007) indicated that there was more to learn concerning the palaeoenvironment of the Gwithian area. It was considered that study of additional material from the area would provide further insight into human activity and how the evolution of blown sand deposits may have been influenced by climatic events, both locally and in the North Atlantic as a whole. The resulting study forms the major part of this thesis (Chapters 5–9).

In addition to the environmental investigations it was decided to explore the influence that mining may have had in the local area. The region of Camborne and Redruth in west Cornwall was one of the most intensively mined areas for tin in the county. Many of the mines discharged waste into the Red River which flows immediately to the south of the Gwithian archaeological sites shortly before its discharge into St. Ives Bay. More details of mining are given in Section 5.2.

3.8.2 Case study 2 – Gunwalloe

A second study site on the south coast of Cornwall provides a contrast to the main study site at Gwithian on the north coast. During the summer of 2010 a team from the University of Exeter led by Imogen

Wood conducted rescue excavations in a field at Winnianton, south of Gunwalloe on the west side of the Lizard peninsula. An early medieval settlement had been revealed by erosion early in the twentieth century and further erosion from farm machinery was in danger of adding to the loss of archaeological material already threatened by inclement weather conditions on this very exposed coastline. A mollusc column obtained by the author close to the cliff edge revealed a small section of wall of an early medieval building. Several trenches were opened during 2011 providing the opportunity for more extensive molluscan analysis, contributing to the understanding of the palaeoenvironment of the area (Chapter 10).

4. Methods

4.1 Field methods

The field work for this study consisted of a variety of techniques. These will be discussed in detail in the relevant chapters under each study site, with a general introduction included in the present chapter.

4.1.1 Surveying

The surface topography along a transect line at Gwithian was mapped using a Leica real time kinematic (RTK) differential global positioning satellite (GPS) system providing an accuracy of ±1cm in both horizontal and vertical axes (Figure 4.1).

Figure 4.1. Using the differential GPS system on the summit of Godrevy Towans. Godrevy Lighthouse is seen on the island in the distance

4.1.2 Ground penetrating radar (GPR)

Subsurface topography along the Gwithian transect line was examined using ground penetrating radar. It was considered that this might allow mapping of the stratigraphy between core locations, and help in correlation of the cores to the stratigraphy. GPR uses instruments which emit a radar signal into the ground which is reflected off structural interfaces in the sediments. The returning signals are recorded and stored in an on-site computer. The time between signal transmission and detection of the returning pulse is related to depth of the reflecting interface. When there are multiple interfaces, then the differences in transmission/receipt time allow a 'map' of the sub-surface stratigraphy to be plotted.

The velocity of the radar pulse varies with the nature of the material through which the pulse is passing. Dry sediments such as sand or silt generally transmit radar waves at high velocity, but the presence of even a small amount of water, especially saline water, or clay considerably attenuate the velocity (Conyers 2004, 47). It can therefore be very difficult to determine reliable depth conversions when the sediments being studied contain a mixture of dry and wet materials, and the geological material comprising the sediments is variable. The water table at Gwithian varied between visits by from 15cm below the surface close to the river to 50cm indicating that much of the valley is permanently waterlogged. No attempts were therefore made to convert the time-based computer trace to an accurate depth-correlated trace using dialectric constants. However, a good estimation of depth could be obtained by direct comparison of the scans with the known depth of bedrock found on coring.

The depth to which radar waves penetrate depends on many other factors, one of which is the frequency of the transmitted pulse. Depth penetration is greater with lower radar frequencies, but the resolution of the resulting image is substantially reduced. If higher frequencies are used the resolution improves, but the depth achievable is correspondingly reduced. At Gwithian it was found appropriate to use probes of different frequency in different sections of the transect, described in Chapter 6.

After establishing the line of the proposed transect the radar transmitter was dragged along the ground, the length of each traverse being limited by the length of the high-tension cable connecting the computer to the transmitter/receiver (Figure 4.2).

Figure 4.2. Ground penetrating radar.
Left: dragging the 200MHz probe through the vegetation immediately north of the Red River
Right: the 100MHz probe in use in the field south of the river

4.1.3 Coring

Two methods of coring were used at Gwithian: percussion coring with a Eijkelkamp system driven by a Cobra percussor and hand coring with gouge augers. Percussion coring was used for the deeper sediments across the valley and hand coring for the shallower sediments in the upper part of the meadow and the Towans. Details of the method for each location are given in Chapter 6.

Percussion coring

The Eijkelkamp system uses a petrol driven percussion hammer (Cobra) to drive a metal tube vertically into the ground (Figure 4.3) (Canti and Meddens 1998). A 5cm diameter plastic lining tube is placed inside the metal casing; the lining tubes were opaque – an important consideration if OSL dating is required, as it is essential to prevent exposure of the sediment to light. At the nose end of the tubing a core catcher is inserted to prevent loss of sample on withdrawal of the tubes, which is held in place by a cutting head (Figure 4.4). The sample tubes are 1m in length with addition of 1m extension rods as necessary until the lowest desired depth is reached or until the nature of the sediment prevents any further insertion; at Gwithian it was found that the organic silt levels were very difficult to penetrate, probably because the silt, being spongy, reverberated so much with vibration that the corer moved up and down with each percussive action rather than penetrating deeper into the sediment. When this happens the sampling tube was replaced with gouge corers of diameters 3–6cm, the largest size being used when possible, reducing to smaller gauges when it proved impossible to insert the larger gauge gouge.

Figure 4.3. The percussion corer in use.
Left: the core sample tube being inserted into the ground. Right: the extraction process.

Figure 4.4. The lower end of the sampling tube.
From left: the cutting head; the core catcher; the lining tube which will contain the sediment sample; the outer metal casing (www.eijkelkamp.com)

After one tube is fully inserted it is withdrawn and the inner lining tube containing the sample extracted and carefully labelled with the location code and core depth and the top and bottom clearly indicated. The open ends of the tubes are sealed with cling film held in place with adhesive tape.

When the gouge corer was used the samples were examined in the gouge before removal. Boundaries between deposits were defined by eye and recorded. The depth of each deposit and Munsell numbers were recorded. The deposits were then removed from the gouge into pre-labelled plastic bags for subsequent analysis in the laboratory. If the deposit was up to 10cm in length it was removed in its entirety but if longer then it was divided into equal portions of no more than 10cm each.

Problems with percussion cores

There are difficulties with percussion coring, both as regards obtaining the samples and the quality of the samples obtained. Insertion of the sampler may be difficult if the vibration of the percussion unit is unable to advance the cutting edge, as mentioned above. At Gwithian the sediments are mainly sand or organic silt and while advancement through sand was generally steady the silt proved more difficult. Withdrawal of the sample chamber may also be extremely difficult with the manual extraction apparatus, illustrated in Figure 4.3 (a hydraulic withdrawal device was not available for this work). The pressure of sand binds on the sides of the chamber and considerable effort is sometimes required to retrieve the sampler, especially from greater depth. A further problem is that sand grains may be forced between the outer metal tube of the sampler and the inner plastic sample chamber. These are a tight fit and if grains become lodged between the two then it can be very difficult to extract the liner from the outer sheath.

The quality of the samples is affected in two major ways. This coring system does not use any form of sheath which remains in place after withdrawal of each 1m length, which means that after each extraction the core hole may become partially filled with sediment from the sides of the cavity. When the sampler is next introduced this extraneous sediment enters the sample chamber; although some will leave the chamber through an opening at its upper end much material may remain within the chamber. If the ‘new’ sediment is very compressible then more ‘contaminated’ sediment will remain in the upper portion of the chamber. While this may be clearly evident on opening the tubes if there is obvious mixed or inappropriate sediment in the upper part of the core it can sometimes be very difficult to determine the junction between the 'new' and 'contamination' sediments. Methods for calculating the true thickness of different sediments, allowing for compression and contamination, will be discussed in Section 4.2.1.1.

A serious problem arises with percussion coring in the compression of samples. While this may be of minor concern with biological material that is flat or relatively incompressible, such as many plant stems, seeds and pollen, it can have major consequences for fragile items such as molluscs. The repeated actions of the compressor progressively fracture the shells and it is likely that some may be so fragmented that they become unrecognisable during the sorting process, which may lead to underestimation of both species and specimen numbers. Figure 4.5 shows examples of shells which have clearly been broken round their whorls into numerous fragments and are only held together by soil. These were extracted from unsieved sediments and the apices may well have been lost if subjected to wet sieving as is the norm in mollusc sample preparation.

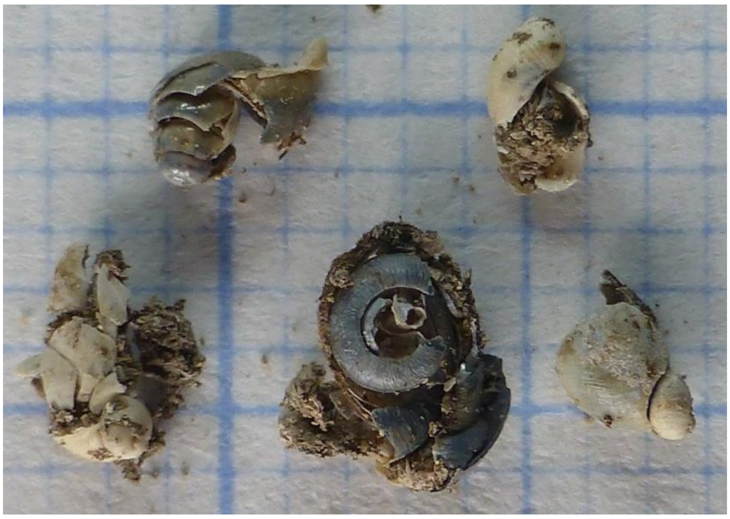


Figure 4.5. Shells showing concentric fracturing caused by percussion coring.
The graph paper has 2mm divisions

4.1.3.1 Hand auger coring

Coring using a gouge auger was performed at Gwithian on the shallower parts of the transect where it was anticipated that the underlying natural could be reached without too much difficulty. A 2.5cm diameter gouge corer (1m length) was used at the initial visit. The quantity of material obtained using this gauge of core is limited and all the hand cores except those at 287m and 400m were later repeated using a 5cm diameter corer (50cm length). Unlike percussion coring there was no obvious damage to mollusc shells caused by the hammering action required to drive the augers.

The stratigraphy and Munsell number of each core was recorded on a pro-forma on withdrawal from the ground. The sediments were then placed in labelled plastic bags, either as complete stratigraphic samples or with long sediments divided into portions, usually no more than 10cm in length.

4.1.4 Excavation

A single trench was excavated at Gwithian and five trenches at Gunwalloe. These will be discussed in detail in the relevant chapters.

4.1.5 Mollusc samples

4.1.5.1 Bulk samples from mollusc columns

Samples for mollusc analysis were obtained wherever possible using mollusc columns taken in a standard way (Evans 1972, 41). In the present study these were obtained from the trench at Gwithian, and from each of the five trenches at Gunwalloe. At Strap Rocks a coastal cliff exposure was cleaned to obtain as vertical a surface as possible, and a small pit was dug at the base of the exposure to extend the column as deeply as possible. Stratigraphic boundaries were respected in deciding where to divide samples. It is normal when taking samples from a mollusc column to commence at the lowest level to reduce the risk of contamination from falling material from higher levels. This was not possible on these sand dune sites due to the instability of the sand and all samples were taken from the ground surface downwards; care was taken to ensure that after one sample was taken the upper surface of the next sample was cleaned of any extraneous matter as much as possible to avoid contamination.

Munsell colours were recorded on site while the sediments were still damp.

4.1.5.2 Core samples

Samples obtained from the hand auger cores along the Gwithian transect, as well as those obtained with the percussion gouge, were separated and bagged on site, again respecting stratigraphic boundaries and dividing thicker contexts. Munsell colours were recorded.

4.1.5.3 Modern molluscs

Samples of turf were taken from each of the Gwithian core sites to assess molluscs which were present in very recent times, although the number of living animals was found to be few. At each site a square approximately 20 x 20cm in size and 4–5cm deep was cut using an archaeological trowel and placed in labelled plastic bags. Photographs of each location were taken so that the mollusc assemblages could be matched as far as possible to current microhabitat preferences.

One sample was obtained from the Red River leet by dipping with a scoop with a 0.5mm mesh into the sediment at the base of the leet. Approximately 500ml of sediment was retrieved from which the molluscs were extracted, but it is emphasised that mollusc numbers for this sample are not quantitative in regard to weight or volume of sediment; the sample is, nevertheless, valuable in assessing the current freshwater molluscs likely to be found in the area.

4.2 Laboratory methods

4.2.1 Core samples

4.2.1.1 Percussion core samples

The cores containing the percussion samples consist of a plastic tube which must first be divided lengthwise into two halves. This was done using a circular saw set to a depth which just penetrates the thickness of the plastic without damaging the contained sediment. The tubes are then wrapped in cling film to keep them together and prevent dehydration.

When required the tube is unwrapped and the sediment divided into two halves by cutting lengthwise with a sharp knife and the two halves spread side by side. Once displayed it is necessary to decide how much contamination there is in the upper part of the core from material which has fallen into the bore hole between removing one length of core and inserting the next. This is usually fairly clear, as contaminating material frequently has an uneven mix of sediments of varying texture and colour and is different from new material in the lower part of the core. On occasions, especially in the sand cores at Gwithian, it was very difficult to determine the change from contamination to new sediment and a 'best guess' was made. In practice it was found that if the core was purely sand then 5−15cm was contaminant, whereas if there were thick silt layers then up to 65−70cm may be contaminant with subsequent marked compression of the silt (Figure 4.6).

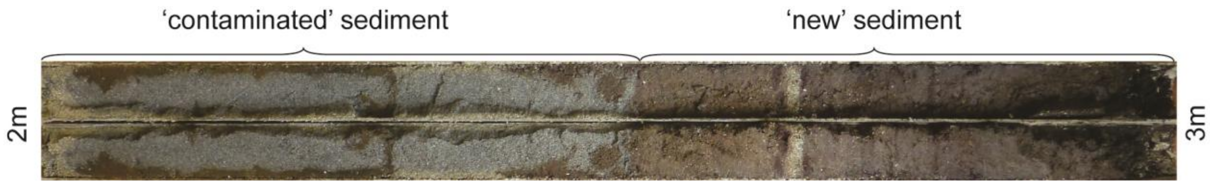


Figure 4.6. An example of contamination of a percussion core.
The 2–3m core from the 0.5m location, demonstrating the contamination of the upper 54cm of the core

The stratigraphic levels in a newly opened length of core were determined by inspection and recorded on a pro-forma, together with the nature and texture of the sediments, the abruptness of the interfaces, the presence of stones or other inclusions and the Munsell colours. One half of the core was then re-wrapped in cling film and stored as a potential archive for tests at a later date; however, it soon became clear that both halves of the core were necessary to maximise the number of molluscs in each sub-sample and all the results that follow include the whole core content. The sediments were removed into small labelled open containers in lengths determined by the stratigraphy, with thick contexts being divided into portions. The sandy sediments were air dried and weighed. In the case of organic silt the material was kept moist and the whole examined microscopically for molluscs; in practice it was easy to tease silty nodules in a Petri dish using forceps into sufficiently small units so that the molluscs could be extracted.

Correction method for compression caused by percussion coring

The problems with compression caused by the vibrations of the percussion corer have been mentioned above, and it was necessary to find a method to provide corrected depths for each stratum within the core. If the core consists of similar sediment throughout its length, such as all sand or all organic silt/peat, then conversion is easy, as, once the length of contamination in the upper part of the core tube is deducted, then the remaining length can be extrapolated to cover the full tube length (Canti and Meddens 1998). However, if there is a mixture of organic sediments in the core there will be different degrees of compression, and a straightforward conversion cannot be applied. Sand compresses relatively little whereas organic silt was subject to marked compression, with up to 70cm of contamination in some core lengths.

A method has been calculated which to a large degree compensates for this. In several of the 1m core lengths in the present study the contained sediments were entirely sand, as at the 76m core location. Compression was found to be fairly consistent, with 5−15cm of contamination in each tube, with an average of 10cm per 1m length. Therefore, to obtain the correct thickness of each sand layer in the tube the measured thickness should be multiplied by a factor of 1.1 (there is, of course, no contamination in the 0−1m core, as this starts at the ground surface).

In a sequence of cores with differing sediments the following method was applied:

1. Add the measured total of all the sand deposits (but excluding 0–1m, after deducting the contamination lengths.
2. Multiply that total by 1.1 to give a corrected total for sand; this is also done for each individual sand layer within the cores.
3. If bedrock has been reached, then the difference between the corrected sand depth and the depth of the bedrock is the thickness which must be accounted for by organic silt.
4. Calculate the factor by which the silt/peat must be multiplied to convert the measured thickness to the difference found in (3) and apply this to each organic silt layer.
5. The total of the corrected thickness for sand and organic silt should equate to the depth of the bedrock.

This method will not be applicable if the bedrock has not been reached as the depth to which the lowest levels of silt have been pushed by the percussion process is not known. In practice when the bedrock has been reached the average compression ratio has been found to be 1.9−2.1 (i.e. the silt has been compressed to around half its 'true' thickness). A factor of 2 can therefore be applied in these circumstances and will provide corrected depths of acceptable accuracy.

4.2.1.2 Hand auger samples

As with the percussion samples the quantity of material of each subsample in the auger cores was small and wet sieving was not used. The same method as that given above was employed, with air drying of each whole sample and extraction of molluscs. There was, however, no need to make any compression corrections, as none of the hand auger cores passed through organic silt, all being entirely sandy.

4.2.2 Mollusc analysis

Mollusc extraction by naked eye from sediments is inadequate for palaeoenvironmental purposes as the majority of very small shells and shell apices are easily overlooked (Sparks 1960, 1961). Wet sieving is therefore normally used with the finest mesh size being 500µm; this size has been found to give acceptable results, although it is probable that some very small shell apices (e.g. *Vertigo* spp.) may still be lost.

4.2.2.1 Core samples – percussion and hand

None of the samples from any of the cores was wet sieved. For many of the samples the total quantity of sediment in each sample was required for other tests (in particular particle size analysis and loss on ignition) and all material <500µm is lost in the process of wet sieving. All the sand samples were air dried and weighed. The sand was then passed through a sieve with a 500µm mesh and shells extracted under low power magnification using a stereo zoom microscope (GT Vision XTL-103BT with x0.7–4.0 zoom). All complete shells and all shell apices were removed and placed in a Petri dish, together with other relevant material such as charcoal, seeds, wood fragments. Non-apical shell fragments were only removed if there were few or no apices of the relevant shell so that the presence of that species could be recorded. Apices were the prime method of recording to ensure the ‘minimum number of individuals’, thus obviating duplicate counting (Evans 1972, 44). Almost all the shells were in remarkably good condition and further cleaning was not considered necessary.

The samples consisting of organic silt were partially dried and weighed. The whole sample was examined microscopically to extract the shells; it was found that with gentle teasing of the sediment while still moist, using fine forceps, it was possible to see and remove all the shells.

4.2.2.2 Mollusc column samples

Wet sieving was used for the samples obtained from the mollusc columns from the Gwithian trench, the modern Gwithian turf samples, the Strap Rock samples and all the samples from Gunwalloe as well as all those from the sites visited in 2007 (Chapter 3). The method employed is similar to that described by Evans (1972, 44). The samples were initially air dried. A suitable portion for mollusc analysis was weighed on domestic scales accurate to 1g. The weight used was determined by the likelihood of obtaining sufficient molluscs for reliable analysis and varied from 500g to 2kg. The appropriate weight to be sieved should yield at least 150–200 shells per sample if possible as this number has been shown to provide reasonable comparison of species (Evans 1972, 83 and see Section 2.2.5).

4.2.2.3 Extraction of shells from bulk samples

The weighed samples were placed in a plastic container which was filled with water, and the sand gently stirred to ensure mixing. The supernatant was poured through a 500μm sieve to recover any shells and other material that floated (the ‘flot’). This procedure was repeated several times until no more shells were released from the sediment.

The remaining sediment was then wet sieved through a stack of graded sieves of 2mm, 1mm and 500μm (it was not necessary to use a 4mm sieve due to the fine nature of the sands). The material passing through the 500μm sieve was discarded. Each sieve was then air dried, and, when dry, the molluscs and other material were carefully tipped onto paper, and then placed in plastic bags. At each stage meticulous attention was paid to the labelling of sieves and bags. Extraction of shells from the dried sieved samples followed the same procedure as described in Section 4.2.2.1.

4.2.2.4 Identification of shells

Shells were sorted into individual species whenever possible, but to genus where this was not possible. The number of specimens of each species present in each sample was recorded and they were placed in a labelled glass tube or hard gelatine capsule. Identifications were made using standard texts (Evans 1972; Macan 1977; Kerney and Cameron 1979; Killeen *et al.* 2004; Cameron 2008) and a reference collection.

For one particular species, *Xerocrassa geyeri*, now extinct in Britain, outside assistance was obtained. The shells were shown to Dr. Richard Preece (University Museum of Zoology, University of Cambridge) who considered identification probable, but positive confirmation was received from Dr Edmund Gittenberger (Professor of Systematic Zoology, Leiden University, Netherlands), an international expert on the Helicidae, the family to which this species belongs. Dr Gittenberger's opinion was that 'The shells are very well preserved and **very typical *geyeri* indeed**, i.e. in sculpture, shape (globularity), roundish 'very open' umbilicus and size' (E. Gittenberger, *in litt.* 29 January 2013).

4.2.2.5 Mollusc diagrams and diversity/dominance

Once identified the species were divided into different groups depending in their accepted habitat preferences, these being taken from published sources (Boycott 1934, 1936; Sparks 1961; Evans 1972; Davies 2008). Problems with using modern preferences as analogues for subfossil assemblages have been discussed above and it must be borne in mind that there will inevitably be some inaccuracies in allocation to particular groups. This is to some degree ameliorated by reference to the assemblages obtained from the modern turf at Gwithian, although this too assumes uniformitarianism with ancient assemblages.

The ecological groupings used are: a) marsh/wet ground, b) shade, c) catholic, able to tolerate a wide variety of habitats, d) open country. There are difficulties in using these ecological groups too rigidly, as some species are able to vary their requirements depending on the environment. Chapter 2 includes discussion of this problem. A summary of the preferences for each species of mollusc encountered in this study is given in Appendix 1; these generally accepted preferences are useful in the analysis of particular assemblages, but do not imply exclusive habitats for any particular taxon.

Mollusc diagrams were constructed using the software C2, version 1.7.2 (Juggins 2011). Diagrams for absolute numbers of shells have been used throughout as for many samples the number of shells was too small to be meaningful on a percentage basis. However, diagrams showing the relative numbers of shells have been constructed when appropriate. For all the mollusc column samples the number of shells found in each weighed sample was used. However, for the core samples the sample weights varied markedly, and diagrams have been constructed with mollusc numbers normalized to 500g samples in each case; the sample weights and actual numbers of shells in each sample are indicated numerically in the diagrams and in the tables included in the Appendices 3 and 4 on the CD.

Species diversity was calculated using the Shannon and Brillouin indices, calculated using PAST software (Hammer *et al.* 2001). These indices have been discussed in Section 2.2.5. Both indices are shown on the core sample mollusc diagrams to provide an indication of whether that sample is adequately representative of the overall assemblage.

4.2.3 Particle size analysis

Particle size analysis was performed using the Coulter™ LS 230 laser granulometer (Pye and Blott 2004) in the School of Human and Environmental Science, University of Reading. Particles in the size range 0.4µm to 2mm are measured using a laser system and from 0.04µm to 0.4µm with polarisation intensity differential scattering (PIDS). Sand samples from the cores for particle size analysis were taken from the subsamples after mollusc extraction. For the bulk samples from other sites material which had been passed through a sieve with 2mm mesh was used as the granulometer cannot accommodate particles larger than 2mm. Approximately 40g of each sample was repeatedly passed through a riffler until a sample of 1−3g. remained; this was disaggregated with Calgon (sodium hexametaphosphate) at a dilution of 3.3%. For the silt samples a quantity of sediment was smeared on a palette with water to make a paste and small subsamples taken from different areas to give a representative sample prior to disaggregation with Calgon. It was not considered necessary to remove organic particles prior to analysis (Allen and Thornley 2004). The sample was then poured into the granulometer chamber and measurements performed.

Analysis of the raw data was performed using the Gradistat software programme (Blott and Pye 2001). Sediment statistics and graphs of class volume *vs* particle size were used to compare the composition of the various samples in relation to depth below the present ground surface.

4.2.4 pH estimation

The pH of samples was measured using a Hanna Instruments pH209 pH meter which was calibrated with pH 4.00 and pH 7.00 buffers for acid sediments and pH 7.00 and pH 9.22 for alkaline sediments.

The method outlined by Rowell (1994, 160) was used. 10g of air dried sediment was weighed into a 50ml centrifuge tube and 25ml of ultra pure water added; for a few samples there was little material and 5g was used with corresponding reduction in the quantity of water. The tubes were then placed in a rotating shaker unit for 15 minutes. The pH was measured using the meter probe which was rinsed with ultra pure water between each measurement. Two measurements were made for every sample with a third measurement if the first two differed by more than 0.2 units. The mean of the two/three measurements was then calculated.

4.2.5 Loss on ignition

The organic matter content and carbonate content of samples was determined by loss on ignition (e.g. Ball 1964; Dean 1974; Howard and Howard 1990; Heiri *et al.* 2001; Santisteban *et al.* 2004). Recommended times and temperatures vary between authors but the principles are the same. A sample is first completely dried by placing it an oven at 105^{O}C and then all organic matter is burned off at 450−500^{O}C; this is followed by heating to 850−1000^{O}C when carbonates are oxidized. The times and temperatures used in this project are those which are standard in the Department of Soil Science, University of Reading; dehydration was achieved by 24 hours at 105^{O}C, followed by 24 hours at 500^{O}C to determine organic matter content and finally two hours at 950^{O}C for carbonate content. At each stage weights were measured to four decimal places. The carbonate content was multiplied by a factor of 1.36 to allow for the loss of some carbonate during the heating at 500^{O}C. Using this factor shows good correlation with other methods of determining carbonate content (Heiri *et al.* 2001).

4.2.6 X-ray fluorescence (XRF) geochemistry

When materials are exposed to X-rays the component elements undergo ionisation, and in the process radiation is emitted which is characteristic of individual atoms; i.e. the atoms 'fluoresce'. This fluorescence can be detected and measured quantitatively, either as differing photon energies or by separating the emerging wavelengths.

4.2.6.1 Pressed pellet XRF

The traditional method of using XRF in the chemical analysis of soil sediments is by using pellets of finely ground sediment. Approximately 5g of sediment is ground to powder in an agate pestle and mortar placed in a rotating grinder for 15 minutes. The powder is formed into a pellet with a boron surround using a 13 ton press. The analysis was performed on a Philips PW 1480 XRF spectrometer with parameters of 100kV, 30mA and 3 kW, using X40 analytical software.

The lower detection limits using this technique vary between 1 and 5 ppm depending on the element.

4.2.6.2 Itrax fluorescence of cores

An automated XRF method of obtaining geochemical information from core samples has recently been introduced (Croudace *et al.* 2006). In the Itrax (Cox Analytical Systems, Gothenburg, Sweden) system the half-section of the split core is placed in a cradle which then passes incrementally beneath the detector housing (Figure 4.7). It gathers optical and radiographic images as well as XRF elemental and magnetic susceptibility profiles. The surface of the core to be scanned must be fairly smooth with no stones of other material protruding above the surface more than about 2−3mm. XRF scanning resolution is practicable at intervals of $\geq$100µm. The X-ray tube anode can be either molybdenum (for elements with a higher range of atomic number) or copper (for a lower range of atomic number). Unlike pellet XRF which measures quantities of elements present, Itrax scanning measures the counts emitted by each element over a pre-determined length of time.

A molybdenum anode was used at 30kV and 35mA with a data acquisition time of 10 seconds and with scanning increments of 1mm for the XRF and 5mm for magnetic susceptibility. For analysis of the geochemistry running averages of 2cm were used to provide some smoothing of the curves. Itrax scanning for this study was performed by the author in the Department of Geography and Earth Sciences in Aberystwyth University under the guidance of Dr Sarah Davies.

Figure 4.7. The Itrax core scanner. The core passes from the cradle holder on the left, beneath the detector array in the centre, to the receiving cradle on the right

4.2.7 Stable isotope analysis

Carbonate $\delta^{18}O$ and $\delta^{14}C$ were measured on shells from Gwithian 30m core samples and the Gunwalloe trench 1 mollusc column samples. The shells were cleaned both visually under a low power stereo-microscope and by immersion for 30 minutes in a 35 watt ultrasound cleaner. For the mollusc samples three individual shells of *Cochlicella acuta* were used to provide replicates whenever there were shells of adequate size, but for several samples from the Gwithian core there were insufficient shells and replicates were obtained from a single shell; for one level a shell of *Helicella itala* was used. The Gunwalloe replicates were from sub-samples of the same shell/s, mainly *C. acuta* but *Cernuella virgata* in five cases where there were insufficient *C. acuta* shells. Each subsample was ground to fine powder using an agate pestle and mortar and 0.25–0.35µg weighed on a microbalance to provide the material for analysis.

Analyses were performed on a Thermo Delta V Advantage IRMS with GasBench II. The raw $\delta^{18}O$ values were converted to VPBD scale after normalizing against NBS18 and NBS19 carbonate standards.

Conversion of the $\delta^{18}O$ values from SMOW to VPBD standards was performed using the formula from Lachniet (2009), and temperature derived from the formulae in Zanchetta *et al*. (2005). The latter used standards obtained from a variety of molluscs from Italy, there being no equivalent studies on British molluscs. It is therefore probable that there will be discrepancies in the derived temperatures as a result of any differences in molluscan diet in Italy and Britain, and the differences in temperature in the two countries.

4.2.8 Micromorphology

Micromorphology on two samples from the trench in the Gwithian meadow was performed by Dr Rowena Banerjea (University of Reading). Full details of the technique used are given in her report which is included on the CD.

4.2.9 Pollen analysis

Ten samples from the organic silt layers in the 0.5m core at Gwithian were initially examined to see if pollen was preserved in sufficient quantities for analysis. These proved rich in pollen and a further 55 samples taken from the core to cover the entire length of silty sediment throughout the core. An additional ten of these were prepared for analysis for the current study, with the remaining 45 samples place in cold store for potential study at a later date.

The slides for analysis were prepared by Kevin Williams (University of Reading), using the method outlined in Branch *et al*. (2005, 126), with deflocculation in sodium pyrophosphate, acetolysis and separation of the minerogenic fraction with sodium polytungstate and with Erdtman's mixture; the slides were stained with safranin. The prepared slides were examined and pollen counted by Dr Rob Bachelor (University of Reading), whose fill report is included in Appendix 17 on the CD.

4.2.10 Diatom analysis

Slides for diatom analysis from six samples from the 15m core at Gwithian were prepared by Kevin Williams (University of Reading), using the method outlined in Branch *et al*.(2005, 126). Preparation involved disaggregation with 30% hydrogen peroxide, digestion in 10% hydrochloric acid, centrifuging to concentrate the diatoms and then removal of clay particles with dilute ammonia before mounting on microscope slides. The prepared slides were sent to Dr Nigel Cameron (University College London), who kindly examined them and reported on the species present using x400 and x1000 magnification. The aim of diatom analysis was to determine whether any marine species were present, and identifications only were performed. Counting of numbers present was not done.

4.2.11 Optically stimulated luminescence (OSL) dating

The basic principles of OSL dating and its value in providing chronology of sand sediments have been outlined in Chapter 2.4.4.1, and the procedure is discussed in detail in the report on the CD. Two OSL dates have previously been obtained at Gwithian from sands in a trench opened in 2005 (Hamilton *et al.* 2008), and it was considered appropriate to obtain further OSL dates on the new material from the present study. The Luminescence Research Laboratory at Aberystwyth University was chosen as the 2005 samples had been dated in this laboratory. The analyses were performed under the direction of Dr Helen Roberts and her full report is included on the CD (Appendix 15).

Five OSL samples were taken during excavation of the trench opened at Gwithian and a further five from the 30m core, subsampled at Aberystwyth. This core was selected for various reasons: it was the deepest core (10m), it had a good range of stratification of both sand and organic sediments, and one half of the split core was available to take the OSL sub-samples before it was exposed to white light.

4.2.12 Radiocarbon dating

Application for radiocarbon dating was made to the National Environmental Research Council (NERC), and a grant approved (NF/2103/14) for 19 samples to be dated. The dating was performed at the NERC Radiocarbon Facility (Archaeology) at the Oxford Radiocarbon Accelerator Unit. Organic matter was generally only present in the organic silt layers in the deeper core samples and many of the dates were obtained on land shells. The merits and limitations of radiocarbon dating of shell material have been discussed in Section 2.3.1.1.

Eight of the samples were taken from the core obtained at 30m from the Red River; this core was considered best to use as five samples had already been selected for OSL dating. A sequence of 13 dates was thereby obtained from a single core sequence. Six radiocarbon dates from these samples were on alder wood (*Alnus glutinosa*), one on bog-bean seeds (*Menyanthus trifoliata*) and two on *Cochlicella acuta* shells.

Four samples for radiocarbon dating came from the trench in the Gwithian meadow, all from the two buried soil horizons and all on the shell *Xerocrassa geyeri*. These dates provide correlation with the OSL dates from the same trench.

Four samples came from shells (*Cochlicella acuta*) from stabilization layers from the Godrevy Towans samples obtained in 2007, and provide dating of the deposition history at a site remote from the main occupation areas at Gwithian. The results on these samples have been discussed in Section 3.6.2.

Finally, three shell samples were dated from the exposure at Strap Rocks, all on shells (the uppermost *Cochlicella acuta*, the lower two *Xerocrassa geyeri*). These can help date this newly discovered feature eroding from the cliffs, and also provide additional dating evidence concerning the extinction of *X. geyeri* and the introduction of *C. acuta*.

Standard methods were used for the radiocarbon dating. Isotopic fractionation was corrected for using the measures $\delta^{13}C$ values measured on the AMS. The quoted $\delta^{13}C$ values were measured independently on a stable isotope mass spectrometer (to ~0:3 per mil relative to VPDB). Details of the chemical pre-treatment, target preparation and AMS measurement are given in Bronk Ramsey *et al.* (2002; 2004). Calibrations were performed with OxCal 4.2 software using the IntCal 13 curves (Reimer *et al.* 2013).

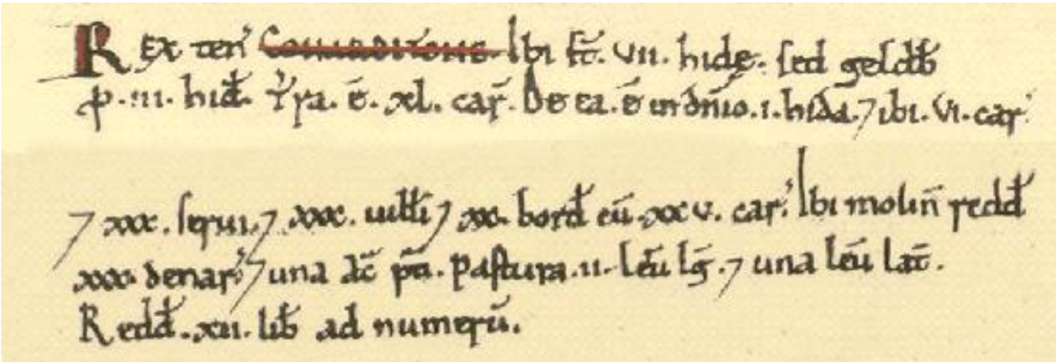
Other dating techniques

Amino acid racemization and uranium series dating, both of which may be used to date molluscs, were not used in this study.

5. Case study 1 – Gwithian

5.1 Godrevy Towans and the Gwithian archaeological site

A settlement in the area of what is now known as Gwithian was recorded in 1086 in the Domesday Book (Figure 5.1), when it was called 'Conarditone'.



The King holds Conarditone. There are 7 hides, but it paid geld for 3 hides. There is land for 40 ploughs. Of this, 1 hide is held in demesne, and there are 6 ploughs and 30 slaves: and 30 villains and 20 bordars with 25 ploughs. There is a mill rendering 30d, and 1 acre of meadow, pasture 2 leagues long and 1 league broad. It renders 12 pounds by tale.

Figure 5.1. Entry for Gwithian in The Domesday Book
(original text: htttp://archive.org; translation: Williams 2003: 342)

In medieval times it had various names, Conerton, Conarditon or Nikenor, all with spelling variations, although these names may refer to an older settlement a short distance away from the modern village (Thomas 1964a). In his perambulations around Cornwall in about 1538, John Leyland mentions that the settlement was 'now gone' – presumably buried in sand:

> Nikenor a 2. miles from Ryvier sumtyme a great Toun now gone. 2 Paroche Chirchis yet seene a good deale several on from the other, sumtyme in the Toune, but it is now communely taken to be in S. Guivian's Paroch, and there commith a Broket to the Sea.
>
> (Hearne 1769, vol. 3: 18)

There is now no trace of this 'great town' except for some remains of St. Gothian's chapel on a slight rise of ground about 700m north of the present church (Thomas 1964a).

The modern village of Gwithian lies on the north coast of Cornwall on the east side of St Ives Bay, 5km north east of Hayle, and 7km north west of Camborne (Figure 5.2), which was, until recently, the centre of the densest area of tin mining in Britain. To the north of the modern village the lower valley of the Red River contains dunes and areas of blown sand close to its outflow into the bay. Extensive sand dunes line the coast from Hayle to the Red River valley and were exploited for sand extraction for many years

(Nowakowski *et al.* 2007, 15). North of the river is Godrevy Headland, with precipitous cliffs up to 65m in height. Godrevy Towans is an area of high ground in the southern part of the headland (Figure 5.3) and is covered by a surface layer of blown sand. The term 'Towans' derives from the Cornish *towyn*, a 'turfy down' (Edmonds 1846, 301), perhaps simply with change of the 'd' of 'down' to the 't' of 'towyn'.

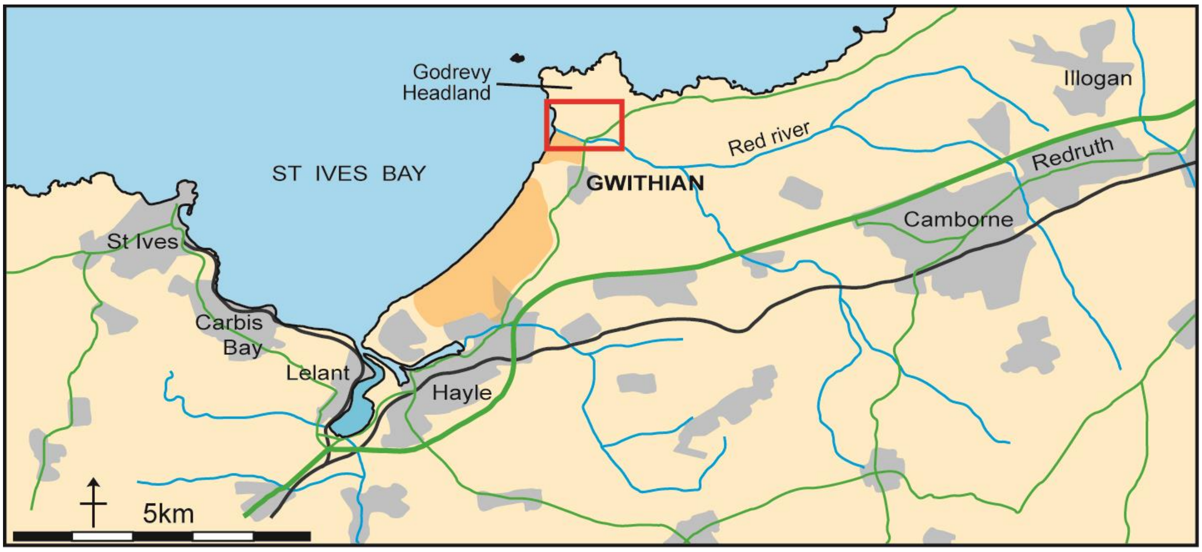


Figure 5.2. The location of Gwithian and the study site (red box) in west Cornwall.
Modern sand dunes between Hayle and Gwithian are highlighted in orange

Figure 5.3**.** Aerial view of the Godrevy headland, looking north east.
The Towans are the area of high ground in the centre of the photograph.
The Bronze Age and post-Roman settlements are at the east end of the meadow in the lea of the Towans.

5.1.1 Geology and geography

The underlying solid geology (Figure 5.4) is Devonian, with the Porthtowan Formation derived from the Gramscatho Group of interbedded sandstone, slate and siltstone and with areas of exposed Mylor Slates (British Geological Survey 1984; Goode and Taylor 1988; Shail 1989), known locally as killas, an old Cornish miners' term. Quaternary head lies over some of the slates and this is topped by the blown sand of the Towans. The sand in the Red River valley extends to a depth of about 10m and there are alluvial deposits along the line of the river.

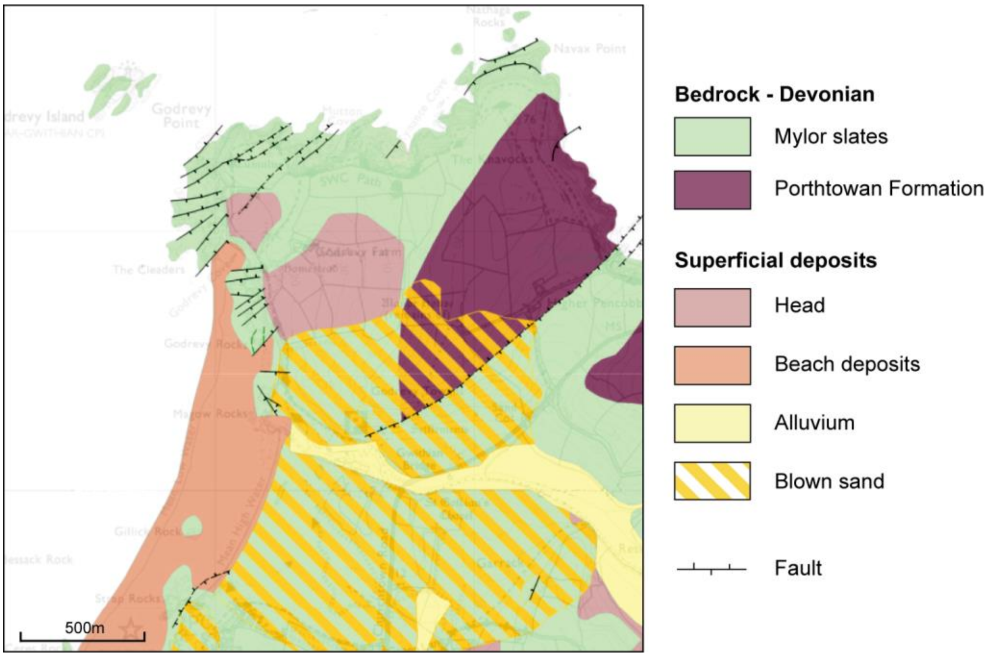


Figure 5.4. The solid and superficial geology of the Gwithian/Godrevy area

Sections of the cliff at Godrevy (the exact points were not specified) have been reported by Robson (1943–44, 147) and Thomas (1957–58, 7) and show the presence of a raised beach on the slates with head and blown sand above it. This Pleistocene raised beach is visible in many cliff sections both south and north of Godrevy beach (Figure 5.5), consisting of well-rounded pebbles up to about 20cm in diameter, 4–5m above modern sea level. In places this beach may be about 1m in thickness. Above these raised beaches along a 100m length of Godrevy Headland are outcrops of calcite-cemented shell sand known as sandrock (Campbell *et al.* 1999) (Figure 5.6), found only on the north Cornish coast at Godrevy, Fistral (Newquay) and Trebetherick (Howie and Ealey 2010). This hard compacted stone has been used for many centuries as building material (e.g. Borlase 1758, 95).

Figure 5.5. The raised beach at Strap Rocks.

Figure 5.6. Sandrock boulders fallen from the cliff on Godrevy Headland.

The Red River runs to the sea in a flat valley with Gwithian village to the south and Godrevy Towans to the north. This river, approximately 13km in length, arises near Bolenowe west of the granite mass of Carnmenellis and, with several tributaries, drains into the east side of St Ives Bay (Figure 5.7).

Figure 5.7. The lower Red River valley viewed from near the summit of Godrevy Towans, looking south. St. Ives Bay is on the right, with Gwithian/Phillack Towans between the sea and the road. The Red River runs from left to right across the centre of the photograph.

For much of its inland course the river runs through the Camborne/Redruth tin mining area and it is likely that its current name originates from the colour of its water which became stained a rich red from the ochre released during tin extraction (Figure 5.8). The original name of this river was Conar Dour (with many spelling variations), meaning 'river of fury'. Borlase (1758, 262) states 'in the river Conar, which divides the parish of Camborne from Gwinear and Gwythien … the many mines which have been of late years wrought in the neighbourhood, have destroyed the fish.' By the 1790s it had become known as the Red River (Hamilton Jenkin 1965, 24), so presumably the river was renamed between these two dates. After cessation of mining in the Camborne area in the 1990s the river was restored to its natural clean state.

Figure 5.8. The outflow of the Red River into St Ives Bay during the active mining era
(Historic England Archive; ref. AFL03/Aerofilms/363441)

The lower reaches of the river were considerably modified in the nineteenth century. In 1806 the outlet to the sea was at the south end of Godrevy beach (Figure 5.9) and was unchanged on the Ordnance Survey First Series map of 1830. By 1839 (Figure 5.10) its outflow had been diverted adjacent to Godrevy Towans at the north end of the beach and by 1850 the length immediately upstream and downstream from Gwithian Bridge altered at least twice, evidenced by 'New cut' and 'Former cut' on an 1850–51 estate map (Figure 5.11). A drain or leet was cut north and parallel to the river from just below Gwithian Bridge upstream for 1.5km sometime between 1839 and 1850. The reason for its creation is not recorded although it may serve to reduce flooding (Kirkham 2005, 14). Another possibility is that it was capable of providing clean, clear, water for human and animal consumption, as opposed to the mine-polluted water of the main Red River.

Figure 5.9. Part of Tehidy estate map of 1806 by James Mills. The course of the Red River is shown prior to its diversion (Cornwall Record Office AD894/7/8)

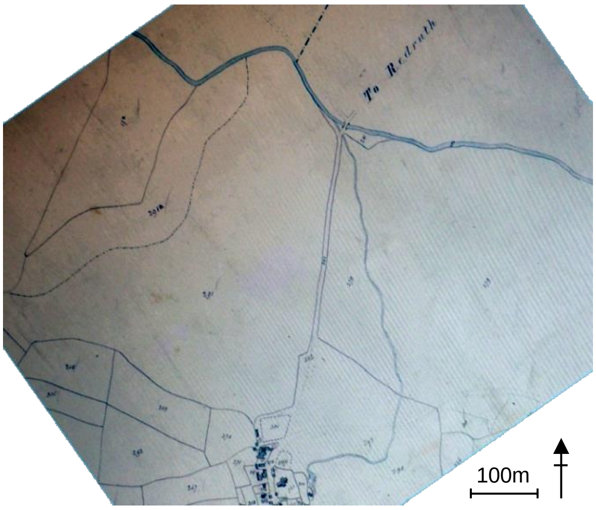


Figure 5.10. Part of Tehidy tithe map, 1839. The Red River now opens more directly into St Ives Bay on the extreme left of the image although the original river course is still drawn (Cornwall Record Office)

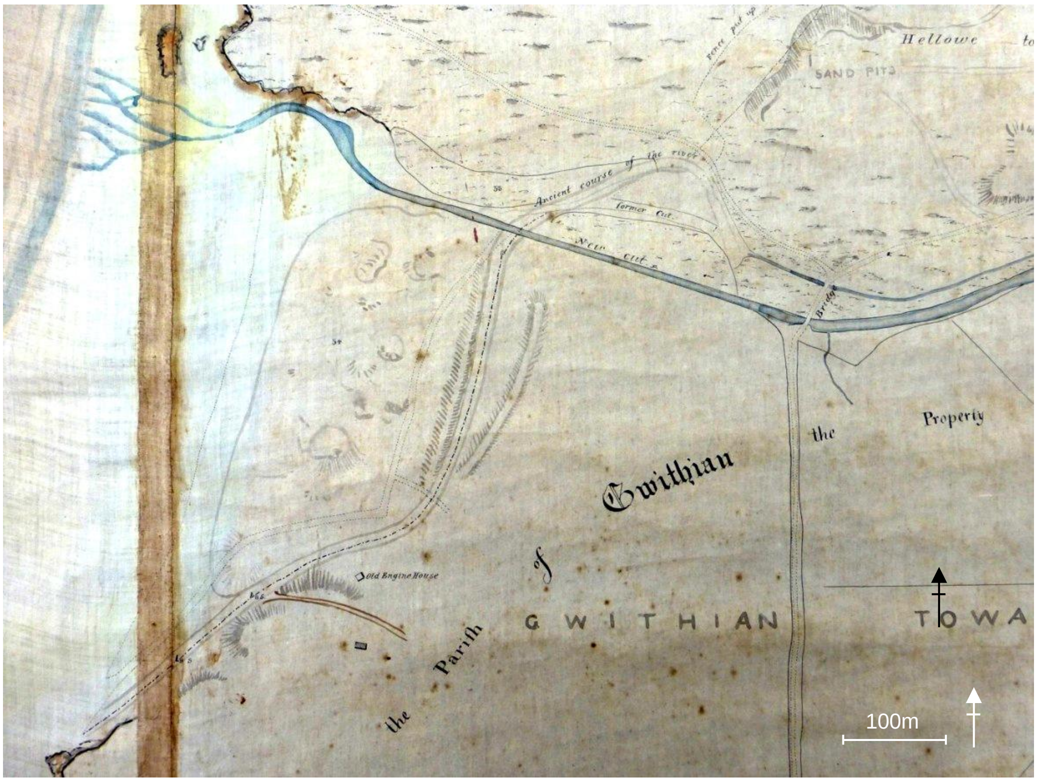


Figure 5.11. Part of 1850–51 Tehidy estate map by Nicholas Whitley.
The 'New cut', 'Former cut' and 'Ancient course of the river' are shown (Charles Thomas collection)

The 1850–51 estate map (Figure 5.11) marks 'Sand Pits' north of Gwithian Bridge, evidence that sand extraction has taken place in the past, which may have altered the modern landscape more than is easily recognized. Fowler and Thomas (1962) state that sand extraction was practiced perhaps as early as the seventeenth century, the sand being used for liming the fields in the area. The Spring Assizes of 1834 recorded that farmers had been using towan sand for manure, and had been doing so from 'times beyond memory of man' (Rowe 1953, 219).

There is good place name evidence that the lower Red River valley has been marshland for up to 3km from the sea, at least back until the late Middle Ages. The Cornish word for marsh is 'Hal' or 'Hel' and the place names Halglasen, Hellow, Halenvelyn and Halvernocks are recorded back to the mid-fifteenth century (Nowakowski and Thomas 2007, 56). It has been suggested that this was estuarine marsh rather than a purely freshwater valley (Stephens 1899, 1899–1900; Thomas 1958; Nowakowski and Thomas 2007, 57).

The deposits along the valley were investigated at the end of the nineteenth century when about 200 bore holes were put down along and across the valley to assess their potential for mineral rich deposits (Stephens 1899, 1899–1900). Unfortunately, detailed reports of these cores do not seem to have survived, although some drawings are extant (Figure 5.12). F. J. Stephens, who conducted this coring exercise, concluded that 'the sum of the borings went to prove the former existence of a shallow tidal estuary with no deep channel or old river bed in the centre as was expected' (Stephens 1899). He based this assumption on the finding of stiff clay or consolidated mud deposits without any shells, bluish-gray in colour, which he concluded were 'evidently estuarine, and mark at least two periods in what was then a creek' which extended at least 1½ miles (2.4km) up the valley. Stephens' extant drawings show a line of six boreholes extending over a distance of 2954 ft (900m) (Figure 5.13); the nearest to the sea being 12m east of Gwithian Bridge, where he found a thick band of clay, with the bedrock 6.1m below the surface. However, Hosking and Ong (1963–64) reported a borehole 'just east of the main coast road and near the present course of the river' (i.e. clearly very close to Stephens core); they only found a thin (0.3m) band of clay at 8.5m depth, with the killas at 10.7m. The difference between the two findings is not explained.

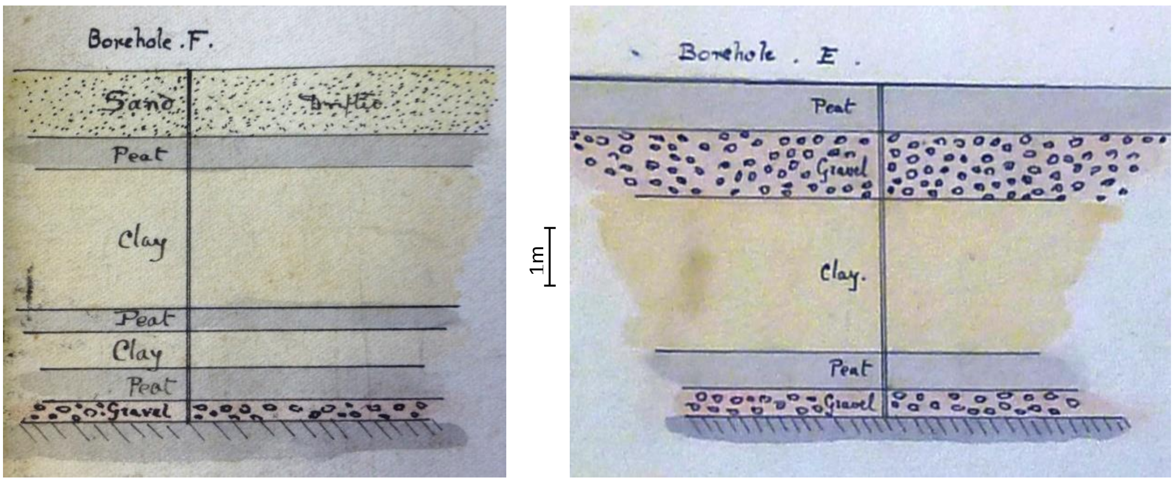


Figure 5.12. Profiles of two of the cores obtained by F.J. Stephens in the region of Gwithian Bridge. Borehole F is 12m east of Gwithian Bridge and borehole E 235m east.

The transect line of the present study is between these two cores (180m east of the bridge).
The depth from surface to base of the gravel is 6.1m (Cornwall Record Office, ref. M\RO/A48)

During the 1980s commercial boring for the Central Electricity Generating Board and for a regional sewerage scheme was undertaken at several locations between the Red River and Gwithian village, (British Geological Survey 2013). Clay was found in most of these bores, at depths ranging from 1.2m to 8.4m (Figure 5.13) and at 7.35cm and 7.40cm in the region of the cores in the present study. In 2002 a survey of 30 auger holes was undertaken in the area south of the river, between the road and the beach, prior to the establishment of a nature reserve in an area of old sand pits (Wessex Archaeology 2002). Most of the cores only reached 3m in depth, showing thick layers of windblown sand; the deepest, at the site of the original river course, reached 5m and was the only one to show estuarine clay at 4.45m. In only two cores were there any silty layers consistent with old ground surfaces, at 3.78m and 3.80m respectively.

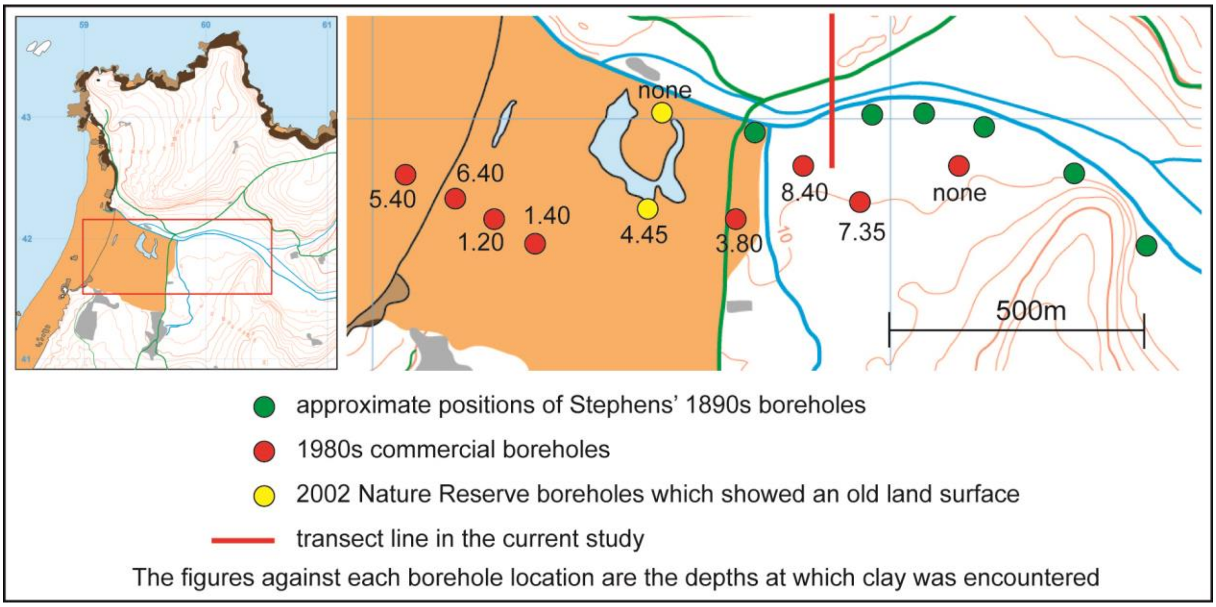


Figure 5.13. The locations of the boreholes in the lower Red River valley

Windblown sand covers large areas of ground along the course of the lower Red River and the adjacent countryside (Figure 5.4), extending inland for at least for 1km, beyond which the valley becomes marshy. To the north sand covers Godrevy Towans, with only a thin layer over higher elevations, but in some areas with dunes up to about 8–10m in depth. Between the river and the estuary of the Hayle River the contiguous Gwithian, Upton and Phillack Towans form an extensive dune system covering about 160ha. The dunes are at present largely vegetated with few areas of bare sand. Much of the lower Red River valley is used for grazing, mainly cattle but also sheep, and there is a flourishing rabbit and fox population.

5.1.2 Archaeology

The area around Gwithian and Godrevy is remarkably rich in archaeology, ranging from the Mesolithic to the medieval period, being concentrated on the flatter land either side of the Red River. However, little was recognized before the middle of the 20th century. The medieval settlement of Conerton lay between the river and the present village of Gwithian, but is now buried by sand (Thomas 1964a). Some remains were still visible when Leyland visited around 1738 (see above), but when William Borlase arrived in the mid-18th century nothing remained visible apart from a few 'cotts' and 'dead bodies':

> It was formerly a considerable town … had two churches, reach'd to the river; this town is now buried in the Sand, all but a few cotts near the Southernmost church but as the sands are not high from the banks of the River to the present church, either the Land (where the Northern church [St Gothian's Chapel] appears by the dead bodies and other remains to have been) is sunk and the houses cover'd, or the blasts of sand render'd that part of the town uninhabitable, and the ruines must be removed into the hedges, and cotts, of the neighbourhood.
>
> (Borlase, quoted in Thomas 1964a, 6)

The archaeology began to be explored in detail by Charles Thomas, who conducted excavations both in the Red River valley and on Godrevy Towans and Headland (Figure 5.14) from the late 1940s into the 1960s. The locations of the main archaeological sites are shown on Figure 5.15. Thomas also collated numerous finds collected by field walking or shown to him by many other people. There were regular interim and summary reports of the excavations (e.g.Thomas 1958; Megaw *et al.* 1960–61; Fowler and Thomas 1962; Thomas 1969; Megaw 1976), and a summary published in 2007 brings together much of the work, including 20 radiocarbon dates (Nowakowski *et al.* 2007), but the excavations have never been fully published. As part of the recent post-excavation programme a small trench (4.6m x 2.0m) was opened in 2005 to obtain palaeoenvironmental samples. These were assessed for potential and two samples were dated by OSL, but in the event it was not possible for funding reasons to proceed to full analyses (Nowakowski *et al.* 2006). The entire Gwithian archive was examined and indexed between 2003 and 2007 following the award of a grant to the Cornwall Historic Environment Service by the Aggregates Levy Sustainability Fund, administered by English Heritage. The results have been collated into a series of narratives covering the Bronze Age, post-Roman and later medieval excavations (Sturgess and Lawson Jones 2006b, 2006a, 2006c; Nowakowski 2007b, 2007a).

Figure 5.14. View looking north across the Red River valley with Godrevy Towans filling the background.
The main Gwithian archaeological site is in the exact centre of the photograph at the base of the Towans

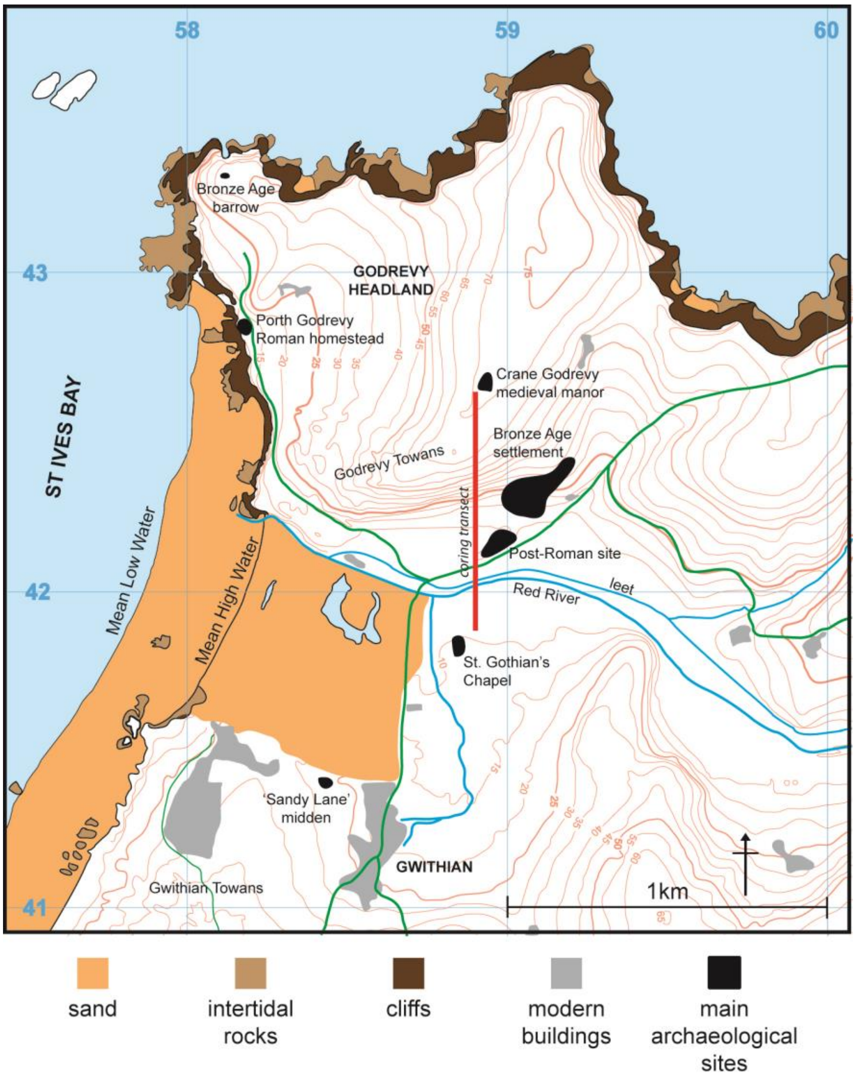


Figure 5.15. The main archaeological sites in the Gwithian area.
The coring transect line in this study is shown to indicate its relationship to the archaeological sites

5.1.2.1 Mesolithic

Many Mesolithic flints have been found in over 20 recorded sites in the Gwithian area (Thomas 1957–58; Roberts 1987; Nowakowski 2004, Figure 5; Thomas 2007, 21). No native flint is available in the vicinity but flint pebbles are found either in the Pleistocene raised beaches or in the shingle of the Holocene beaches.

5.1.2.2 Neolithic

There is very little evidence of Neolithic presence in the Gwithian area. Some early Neolithic gabbroic sherds, a few lithic pieces and two fragments of greenstone axes were found in early Bronze Age contexts indicating that there was some Neolithic activity in the vicinity (Megaw 1976; Quinnell 2007c, 23).

5.1.2.3 Bronze Age

A Bronze Age barrow mound on the north west tip of Godrevy Headland was excavated by Charles Thomas and T. J. Scantlebury in the 1950s (Jacky Nowakowski, pers com) and re-excavated during 2012 (James Gossip, pers com). The findings of these excavations have not been published.

The major Bronze Age presence is a settlement site at the foot of Godrevy Towans towards the eastern end of the meadow north of the Red River (Figure 5.15). Excavations between 1954 and 1961 revealed three phases of occupation: *c* 1800 cal BC, *c* 1500–1200 cal BC and *c* 1300–900 cal BC (Megaw *et al.* 1960–61; Sturgess 2007a; Nowakowski 2009). The following is a summary of the chronology, taken from Sturgess (2007a):

Phase 7		Modern turf and topsoil.
Phase 6		**Sand dune formation**: a multi-phase blown sand horizon containing sparse evidence for later activity.
Phase 5	*c* 1300–900 cal BC	**Middle to late Bronze Age**. A major settlement with farming, fishing and craft industries (Figure 5.16).
Subphase 5d		Settlement demise. Phased dumps of midden material overlying and in the vicinity of the post-built and stone-built structures.
Subphase 5c		A group of stone-built enclosures and structures associated with field boundaries and ploughing.
Subphase 5b		A new farmstead. A group of post-built structures set within fields, with associated boundaries and terraces and phases of ploughing.
Subphase 5a		A series of roughly dug hollows, possibly the result of vegetation clearance.
Phase 4		**Middle Bronze Age**. Farming and minor neglect of an isolated area; a blown sand horizon which contained midden material, suggesting soil improvement.
Phase 3	*c* 1500–1200 cal BC	**Middle Bronze Age**. Settlement and farming; a probable stone and post-built structure associated with terraces and field boundaries and several phases of ploughed fields (Figure 5.17).
Phase 2		Possible minor neglect: a blown sand horizon.
Phase 1	*c* 1800 cal BC	**Early Bronze Age**. A homestead and farming; a single post-built structure within a fenced enclosure associated with terraces and ploughed fields (Figure 5.18).

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Figure 5.16. Close-up view of spade marks in the phase 5 Bronze Age sequence
(© J.V.S.Megaw, Gwithian archive)

Figure 5.17. Bronze Age plough marks from phase 3 (site GMX).
(© J.V.S.Megaw, Gwithian archive).

Figure 5.18. View of a phase 1 early Bronze Age building (site GMXV).
Wooden stakes have been placed along the line of the enclosure and at the entrance of the structure
(© J.V.S.Megaw, Gwithian archive)

An early Bronze Age gold lunula was found in Penwith in 1783; its discovery site is unclear, but Trevarnon Round, 1km south of Gwithian, is a likely location (Mattingly *et al.* 2009). As recently as 2011 an unfinished gold torc from the middle Bronze Age was found 'on Gwithian meadow land', but the discovery site has not been made public (Figure 5.19).

Figure 5.19. The gold lunula (left) found in 1783 and the torc (right) in 2011.
(photographs: lunula – www.britishmusuem.org; torc – www.thisiscornwall.co.uk)

5.1.2.4 Iron Age and Roman period

Activity in the Gwithian area was considerably reduced compared to the earlier Bronze Age (Quinnell 2007b). An Iron Age/Romano-British univallate earthwork is present on the summit of Godrevy Towans, beneath the medieval structures of Crane Godrevy (see below). A Roman period homestead at Porth Godrevy, close to the cliff edge on the west side of the headland, was excavated in 1956−58 (Fowler 1962). This was a single dwelling within an enclosure; dating of the settlement is unclear, but there was probably occupation from the late first/early second century into the fourth century AD, before abandonment for unknown reasons. If the abandonment date is correct there is a period prior to the post-Roman settlement in the valley when there is no evidence of occupation in the Gwithian/Godrevy area. There is a Roman villa dating from the late second to fourth century AD about 5km to the east of Gwithian at Magor (O'Neill 1934). Scatters of gabbroic pottery from the Roman period have been found south of the Red River, but in such low frequency that deposition of waste on agricultural land has been suggested (Quinnell 2007b, 38).

5.1.2.5 Post-Roman

The major post-Roman activity in the Gwithian area is on an elevated dune slightly to the south west of the Bronze Age site (Figure 5.15). This was excavated throughout the 1950s and showed buildings and associated industrial activity ranging from about the fifth to eighth centuries AD (Sturgess 2007b), but the contemporary domestic settlement has not yet been located.

Phase 4		Abandonment.
Phase 3	7th–8th centuries AD	**Buildings and a workshop complex** with at least nine buildings (Figure 5.20).
Phase 2	5th–7th centuries AD	**Industrial features and pits**.
Phase 1		Blown sand deposits of the dune with occasional turf lines.

Figure 5.20. Buildings from phase 3 of the post-Roman activity.
The walls were partly rebuilt by the excavators (© J.V.S.Megaw, Gwithian archive)

Two field systems were excavated in 1961 and 1963 (Fowler and Thomas 1962; Sturgess 2004, 172). One was in the depression between the dune and the Bronze Age settlement; the other lay in in an area of gently sloping ground close the base of the steep scarp of Godrevy Towans, about 100m north west of the dune. Both of these excavations concentrated on post-Roman levels, although the existence of Bronze Age activity was mentioned.

5.1.2.6 Early medieval

St. Gothian's Chapel, south of the Red River, has already been mentioned in the opening of this section, being one of the few 'old' sites known prior to the commencement of Charles Thomas's excavation in the mid-twentieth century. There seems to be no record of when it is was constructed but is presumed to be early medieval. It became overrun by blown sand some time prior to the thirteenth century when the present Parish Church, 500m to the south, was founded (Edmonds 1863; Thomas 1964a). Some remains were seen by Leland during his perambulations round Cornwall in about 1538 (Hearne 1769, vol. 3: 18). It was then lost for around 300 years before rediscovery in 1827 by a farmer who converted it into a cowshed (Haslam 1846; Edmonds 1863; Thomas 1964a). At the present time only isolated stones are visible in the turf mound covering the ruins.

5.1.2.7 Later medieval

The valley north of the Red River seems to have been permanently abandoned after the eighth century with no later evidence of any activity close the sites of earlier occupation.

5.1.2.8 Crane Godrevy

There is evidence of multi-period occupation at the site of Crane Godrevy, on the level summit of Godrevy Towans at an elevation of about 70m OD. The site commands extensive views both of the coastline and inland. Excavations under the direction of Charles Thomas took place intermittently from 1952–1969. The earliest archaeology is a round dating from the Romano-British period, although possibly commenced in the late Iron Age (Quinnell 2007b), but which was later abandoned. Re-occupation for reasonably long periods spanned the mid to late medieval periods. A sunken-walled structure was on this site by the late tenth or early eleventh century which was expanded and modified into a 'manorial complex' by the fourteenth century (Figure 5.21). The site was abandoned around the end of the sixteenth century and was a ruin by about 1750 (Thomas 1954–55, 1969; Sturgess and Lawson Jones 2006b; Nowakowski and Thomas 2007).

Figure 5.21. Crane Godrevy medieval manor at completion of excavations (Nowakowski 2004, Figure 23)

5.1.3 Previous environmental work at Gwithian

Palaeoenvironmental studies were not part of the original excavations at Gwithian. Spencer (1974, 13; 1975, 98) and Milles (1991b, 18.6, 19.5) obtained material for mollusc analyses from small re-opened trenches in the Bronze Age and post-Roman settlements and field systems (Figure 5.22). Lewis (1968) used material from boreholes and small trenches to investigate banding on the mollusc *Cochlicella acuta*. In 2005 a small trench was opened in the Bronze Age site at Gwithian to revisit the stratigraphic sequence and obtain samples for a wide variety of palaeoenvironmental studies and samples for OSL dating. Preliminary assessments have been reported on the soils, land snails (Milles 1991b, 19.5; Davies 2006; Davies 2007, 64), pollen, charcoal, vertebrate bones, marine shells, lithics, pottery and stonework (Nowakowski *et al.* 2006), but full reporting of these studies has not been possible due to funding restrictions. These studies all show that the area was open grazed grassland from earliest represented levels, although shady areas may have been present in the late Bronze Age horizons (Davies 2008, 137). Spencer (1975) suggested the absence of shade molluscs may have resulted from forest clearance during the Mesolithic, prior to initial sand deposition.

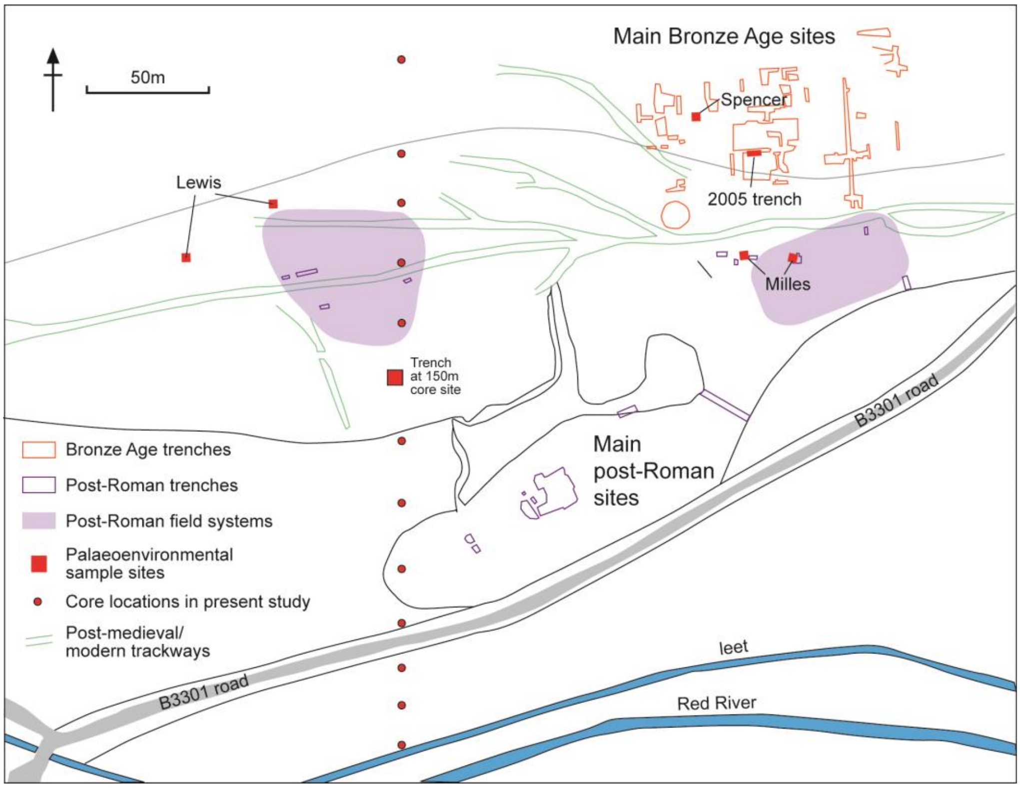


Figure 5.22. The excavations at Gwithian showing the locations of palaeoenvironmental studies. The exact positions of the Spencer, Milles and Lewis studies are difficult to determine accurately. The locations of the core and trench locations in the present study are marked (redrawn, with additions, from Nowakowski 2007b, Fig. 2)

5.2 Mining for tin and other metals

Mining for tin and other minerals has been carried out in Cornwall for many centuries, although, with the closing of the South Crofty mine at Camborne, this ceased in 1998. The importance of the mining industry to the history of Cornwall was recognised when the Cornish Mining World Heritage Site was established in 2006 incorporating mining areas in many parts of the county (Cornish Mining World Heritage Site.). The rapidly increasing price of tin during the twenty first century has led to consideration about reopening several mines.

The earliest written records of specific mines within the Red River catchment area date from the 1580s (Hamilton Jenkin 1965, 5) but it is likely that knowledge of Cornish tin extends well into prehistoric times. 'Tin Islands' were mentioned by Hecataeus of Miletus (*c.* 549–476 BC) on his map of the world (unfortunately no longer surviving; a reconstruction is shown in Figure 5.23) who depicted them lying off the coast of north west Europe. Pytheas of Massilia (Marseilles) circumnavigated Britain in the fourth century BC and implied a tin trade between Cornwall and western France (Cunliffe 2008, 347).

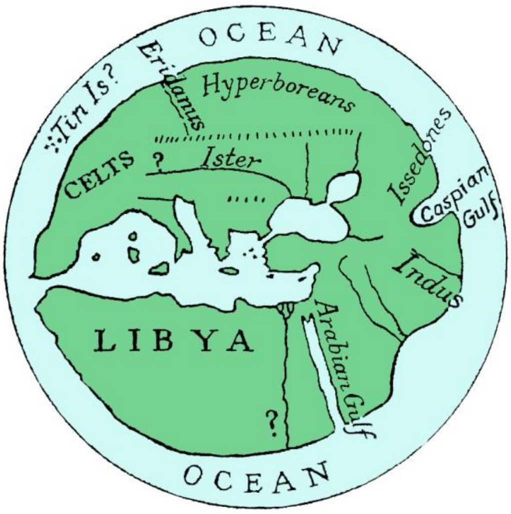


Figure 5.23. Reconstruction of the Map of the World, by Hecataeus of Miletus (after Thomson 1965, Fig. 11).

Texts by Strabo, who lived from 63/62 BC to about AD 24, are among the earliest surviving written references to Britain as a source of tin:

> The westerly parts of Britain lie opposite these headlands towards the north; and in like manner the islands called Cassiterides, situated in the open sea approximately in the latitude of Britain, lie opposite to, and north of, the Artabrians.
>
> (Strabo *Geographica*, 2.5.15; translation: Jones 1917) .

> [Tin] is produced both in the country of the barbarians who live beyond Lusitania, and in the Cassiterides Islands; and tin is brought to Massilia from the British Islands also.
>
> (Strabo *Geographica*, 3.2.9; translation: Jones 1923) .

> The Cassiterides are ten in number, and they lie near each other in the high sea to the north of the port of the Atrabrians. One of them is desert, but the rest are inhabited by people who wear black cloaks, go clad in tunics that reach to their feet, wear belts around their breasts, walk around with canes, and resemble the goddesses of vengeance in tragedies. They live off their herds, leading for the most part a nomadic life. As they have mines of tin and lead, they give these metals and the hides from their cattle to the sea-traders in exchange for pottery, salt and copper utensils. … After Publius Crassus crossed over to these people and saw that the metals were being dug from only a slight depth, and that the men there were peaceable, he forthwith laid abundant information

before all who wished to traffic over this sea, albeit a wider sea than that which separates Britain from the continent.

(Strabo *Geographica*, 3.5.11; translation: Jones 1923) .

Strabo's original maps no longer survive but a reconstruction from his texts indicate where he thought the Casseritides may lie (Figure 5.24).

Figure 5.24. Europe according to Strabo, showing the Cassiterides Islands north of Iberia (adapted from Jones 1917, frontispiece)

The ore from which tin is extracted is cassiterite (SnO_2), and the location of the 'Cassiterides' or 'Tin Islands' is unclear, with many islands or groups of islands being debated, although *The Oxford Classical Dictionary* (Hornblower and Spawforth 2005) states:

The unambiguous evidence about the location of the Cassiterides in the classical sources suggests that it was a partly mythologized generic name for the sources of tin beyond the Mediterranean world and not a single place. The absence of archaeological evidence for any pre-Roman iron age trade with the tin-producing areas of SW England supports this.

Diodorus Siculus, a Greek from Sicily, writing around the end of the first century BC, described the tin trade on the mainland of Britain. His 'Belerium' is considered to be the Land's End peninsula; the identity of Ictis is a matter of much debate, although either St. Michael's mount or Mount Batten near Plymouth are likely (Cunliffe 2005, 472).

Now we shall speak something of the tin that is dug and gotten there. They that inhabit the British promontory of Belerium, by reason of their converse with merchants, are more civilized and courteous to strangers than the rest are. These are the people that make the tin, which with a great deal of care and labour they dig out of the ground; and that being rocky, the metal is mixed with some veins of earth, out of which they melt the metal, and then refine it; then they beat it into four-square pieces like to a dye, and carry it to a British isle near at hand, called Ictis. For at low tide, all being dry between them and the island, they convey over in carts abundance of tin in the mean time. But there is one thing peculiar to these islands which lie between Britain and Europe: for at full sea, they appear to be islands, but at low water for a long way, they look like so many peninsulas. Hence the merchants transport the tin they buy to the inhabitants to France; and for thirty day's

> journey, they carry it in packs upon horses' backs through France, to the mouth of the river Rhone.
>
> (Sicurus *The historical library of Diodorus the Sicilian* 5.2; translation Booth 1814: 310) .

When tin was first obtained in the west country is unknown, although it is probable that ore was originally available in alluvial gravels on Dartmoor during the middle /late Bronze Age (Gerrard 2000, 17; Thorndycraft *et al.* 2004). Slag and artefacts associated with archaeological sites of a similar period have been recorded (Penhallurick 1986, 151; Penhallurick 1997). Trace element studies have suggested prehistoric metal mining (or perhaps widespread burning) in the early Bronze Age (*c* 2500 BC) and middle Bronze Age (*c* 1600 BC) (Webster 2007, 87). There is less evidence in the late Bronze Age (Buckley 2005, 14) but tin smelting was found in the Iron Age villages of Chysauster, Goldherring and the Roundago of Castallack (Gerrard 2000, 19).

There is good archaeological evidence for tin mining in the Roman-British period (Buckley 2005, 18), but no written records survive. The first documentary evidence dates from 1156 (Lewes 1906, 524) when Pipe Rolls of Henry II refer to mining in Devon and Cornwall. During later medieval times the tin trade was of sufficient importance in Devon and Cornwall that Stannary Courts were established to administer the law independently to the normal process of law (Penhallurick 1986, 148). It was not until the Industrial Revolution and the development of pumping engines that the exploitation of deep tin mining expanded dramatically, with large areas of Cornwall being given over to mine complexes.

Other metals are also available in Cornwall, principally copper, lead, zinc, tungsten and arsenic. There is, however, no evidence of prehistoric copper mining in Cornwall (Sharpe 1997; Timberlake 2009, 100). Whether minerals containing the other metals were obtained during the Bronze Age has not been determined.

5.2.1 The mining process

Minerals may be extracted either by lode mining, when ores are obtained directly from the rocks in which they are formed, or from tin streaming, the process of recovery of tin from mine tailings or natural washing into rivers downstream from the original ore sites.

Convincing evidence for prehistoric lode mining in Cornwall is hard to come by, as the region has been so exploited over the last 4000 years that signs of early quarrying may have been lost. However, substantial centres of early Bronze Age lode mining have been found in Wales, especially at The Great Orme (Dutton and Fasham 1994) and Cwmystwyth (Timberlake 2003). Penhallurick (1997) considers a middle Bronze Age palstave illustrated by Borlase (1872, 41) to come from lode mining. Further evidence comes from the fact that there is no alluvial copper in Cornwall, so any copper mined must have come from lode working (Penhallurick 1997). Underground lode mining became the principle method of extraction by the end of the fifteenth century (Buckley 2009, 125). The development of pumping machines in the nineteenth century to remove water and to transport miners from the ground to the working areas enabled ever deeper seams to become accessible (Richardson 1974, 64). Great depths were reached, the deepest being at Dolcoath mine (Figure 5.25) at Tuckingmill, Camborne where 925m was achieved in 1910 (Buckley 2010, 362).

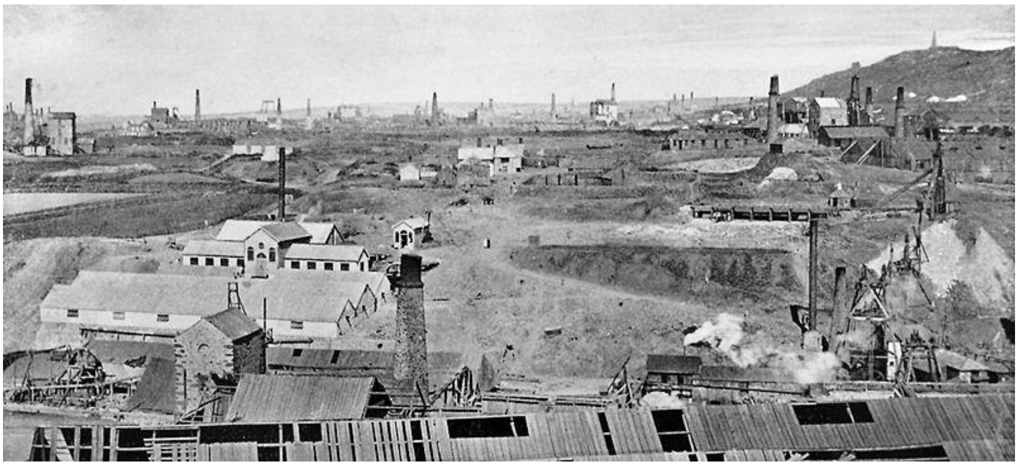


Figure 5.25. Dolcoath mine in the foreground, looking east towards Redruth, 1892/93.
Each chimney represents a separate mine working (The Cornwall Centre, Redruth: ref. corn00352)

Tin streaming refers to the process of washing cassiterite ore once it has been extracted from the ground, and was originally synonymous with opencast mining (Penhallurick 1997); it is only later that the term became more associated with the recovery of tin lost into the river system from upstream mines. Prehistoric artefacts have been recovered from many tin streamworks in Cornwall, but none from the Red River catchment (Penhallurick 1997, Fig. 16). Streaming probably became established around the late fifteenth century when lode mining began to produce large quantities of tailings, and continued into the nineteenth and twentieth centuries along many Cornish rivers.

Tin streaming in the current sense consists of using gravity to separate the heavy tin ores from lighter clays and sand found in alluvial deposits. This is in contrast to lode mining when the rock has to be crushed and ground to concentrate the ore and extract the minerals. There is no native alluvial tin in the Red River catchment area (Penhallurick 1997), but large quantities of waste material were discharged into local river systems. Quantification of the mineral losses from mines is difficult, but it is clear that substantial amounts of tin and other minerals failed to be extracted at the mines. In 1890, for example, 66 Cornish mines sold 12,944 tons of black tin for £700,962, while 1,730 tons worth £69,206 were recovered from Red River streaming – 10% of the total value (Thomas 1913); Thomas estimated that 'the average loss in dressing tin in Cornish mines at present must certainly exceed 33%.' It is important to appreciate that the process of load mining results in the build up of sediment which leads to the formation of dams or lakes unless it is flushed, when a proportion settles out as sediment in steams and river. In contrast, tin streaming is the process of removal of sediment from river beds.

5.2.2 The Red River and its catchment area

One of the most developed mining regions in Cornwall was around the towns of Redruth and Camborne, an area which at one time was the richest tin mining district in southwest England (Dines 1956, 276; Yim 1981). This is the catchment area of the Red River, which arises south east of the modern town of Camborne and flows north between Camborne and Redruth before turning west towards Gwithian and which drains into the east side of St. Ives Bay (Figure 5.26). Many of the mines in the Camborne area were immensely profitable; an area north of the Carn Brea range of hills, covering only about 650ha, had yielded an aggregate amount of £2 million by 1871 (Thomas 1871), an enormous sum for those times.

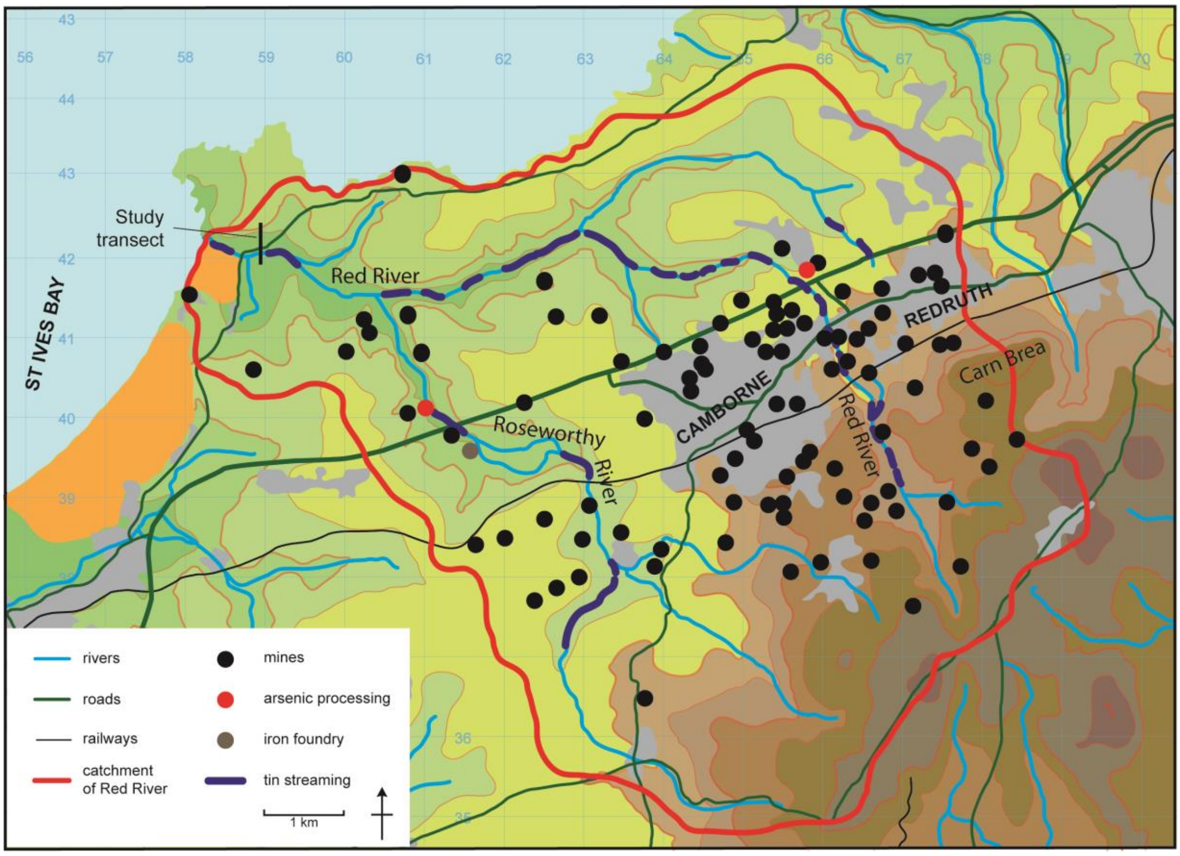


Figure 5.26. The catchment area of the Red River, with the mines and tin streaming locations marked. The map also shows the position of two arsenic processing plants and an iron foundry. The present study site is marked near the outlet of the Red River into St Ives Bay

With its tributaries it was the main tin streaming river in Cornwall, with over 40 separate activities in the nineteenth century (Barton 1969, 152, 182). Although originally named the Conor Dour it earned its new name from the colouring caused by mine effluent, mainly soluble ferrous (Fe^{2+}) and ferric (Fe^{3+}) compounds and insoluble ferric hydroxide ($Fe(OH)_3$) which forms red/orange 'ochre' at low pH

(Younger 2002) and which increased following the expansion of lode mining. Since the closure of the last mine in the catchment area in 1998 (South Crofty) there has been a programme to clean the waters, and the river currently flows clear. However, in the past its name was clearly justified. Figure 5.27 shows its colour close to one of the mine adits, while Figure 5.28 shows its exit to the sea at Gwithian, giving a very good indication of the spread of colouration into St. Ives Bay.

Figure 5.27. The adit of Dolcoath mine into the Red River (www.plymouth.ac.uk/science/cornwall/images/RedRiver1_sml.jpg)

Figure 5.28. The Red River outflow in July 1978 (photo: Ian Stebhens)

The numerous mines in the catchment area of the Red River in Cornwall produced waste which was discharged into the river system. It is difficult to determine exactly how many mines were active in this area at any one time due to regular name changes and amalgamation of pits. Figure 5.26 shows nearly 100 mines but doubtless many more have left little or no trace and there were often several shafts for an individual mine. In the majority of these tin, in the form of cassiterite, was the main mineral sought, but copper was another major mineral extracted from this area of Cornwall. Arsenic was important and obtained from mines in the Redruth/Camborne area (Earl 1996) and there were two arsenic calcining (refining) plants in the catchment area (marked in red on Figure 5.26), each depositing tailings into the streams. Arsenic is a toxic element, and its deposition on the sediments beside the river during periods of flooding may have affected the wellbeing of both animal and plant life, especially in the lower reaches of the river where it passes through the Reskajeage marshes below the confluence of the Red and Roseworthy Rivers, and on the flood plain north of Gwithian village. However, arsenical compounds are poorly taken up by plants during growth and quantities found in modern foods grown on alluvial silts are unlikely to be seriously harmful to humans or livestock (Xu and Thornton 1985; Mitchell and Barr 1995). Other elements mined commercially included tungsten and zinc, with small quantities of lead, silver, cobalt, nickel and bismuth.

The first documented lode mine in the Red River catchment dates from 1584 when John Norden mentioned tinworks at Tolcarne (Hamilton Jenkin 1965, 5). It would seem probable that quarrying for copper and tin predates this and tin streaming almost certainly existed along the Conor Dour, as the Red

River was then known, during medieval times. Geochemical analysis of the sediments accumulating in the river valley may provide some clues as to the timing. Some of the minerals sink to the river bottom during their passage to the sea and become attached to particulate matter. Yim (1981) studied fluvial bottom sediments at eleven sites along the Red River and two in its tributary, the Roseworthy River, and found high concentrations of multiple metals along the rivers. He found that there was high positive correlation of levels of tin with those of iron, tungsten and arsenic in these bottom sediments and demonstrated that residues of tin, copper, zinc, iron, arsenic and lead in the river were the result of mining activity and not natural erosion processes. Hosking and Ong (1963–64) looked at tin and other heavy metals deposited on the Gwithian/Hayle beach on the west side of St Ives Bay and concluded that most of the heavy elements derived from mine tailings in the Red River catchment, although some zinc and lead came from local cliff lodes. Similar findings are described from the Camel and Gannel estuaries in the north Cornish coast (Pirrie *et al.* 2000) and in Fal estuary in south Cornwall (Pirrie *et al.* 2002; Pirrie *et al.* 2003).

Tin streaming has already been noted as being prolific in the Red River catchment. As refining processes became more efficient the importance of streaming declined. However, sufficient quantities of tin reached St Ives Bay that a new streamworks was constructed between the Gwithian road bridge and the sea in the mid-nineteenth century to recover tin from beach shingle in Godrevy Bay. The Gwithian Streamworks continued in operation until the beginning of World War II (Kirkham 2005, 19). However, that may not be the end of the story, as new consideration is being given to recover tin from the sea bed in St Ives Bay (BBC Cornwall News Report, 7 February 2013).

5.3 The current study at Gwithian

The principal area of study relates to the archaeological areas described above, and comprise a coring transect line from the fields south of the Red River to the summit of Godrevy Towans at Crane Godrevy and a small trench excavation in the meadow between the river and the base of the towans scarp (Figure 5.29). There are no records of stream working in this part of the river; the 1877 Ordnance Survey 1st edition map does mark disused stream works 250m upstream from the present study transect line, although Stephens (1899) could find no evidence of working in this area. A mollusc column was also obtained from an area of cliff at the south end of Godrevy beach opposite Stack Rocks.

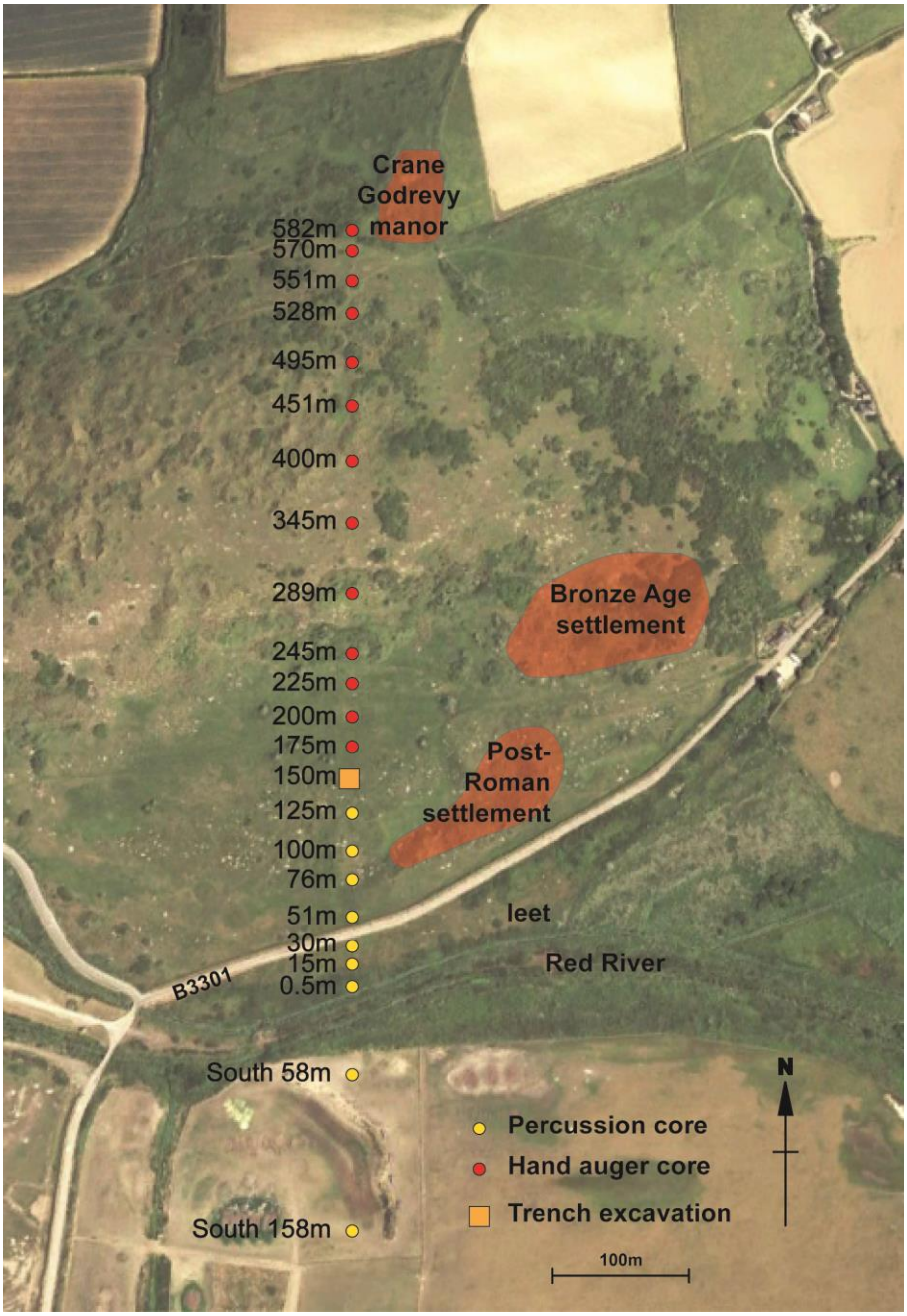


Figure 5.29. The transect line at Gwithian, showing the positions of each core and the excavation trench. The major archaeological areas excavated in the mid-twentieth century are also marked

5.3.1 Consents for study

The Gwithian land north of the B3301 road is owned by Professor Charles Thomas, who readily gave permission for the fieldwork to be carried out. The site is also a Scheduled Monument (CO 771) and an SSSI, and appropriate consents were obtained from English Heritage and Natural England. The land between of the B3301 road and the Red River and the cliffs opposite Stack Rocks are owned by Cornwall County Council, and the fields south of the Red River by Mr and Mrs A. James, all of whom kindly granted access to their land and agreed to the study being conducted.

5.3.2 Field methods

Multiple methods of investigation were used in the field, and several visits were made to the site over a period of 15 months:

2–6 June 2011	Layout of transect line using ranging rods and hand-held GPS.
	Percussion coring north of Red River.
	Hand augering using 2.5cm gouge.
27–28 June 2011	Differential GPS survey of transect line north of the river.
	GPR survey of transect line north of the river with 200MHz and 400MHz units.
25–29 June 2012	Percussion coring north and south of the Red River.
12–17 July 2012	Excavation of trench at 150m location.
	Hand augering using 5cm gouge.
13 September 2012	GPR survey north and south of the river using 100MHz unit.
	Differential GPS survey of transect line south of the river.
	Mollusc column obtained at Stack Rocks.

5.3.2.1 Global positioning satellite (GPS) survey

The principal field technique used on the Gwithian archaeological site was coring. This method was selected as a long transect line would cause minimal damage to underlying deposits. From the outset it was assumed that the depth of sediments in the valley bed would be too deep to permit excavation of a trench with the intention of reaching the basal natural geology and this was confirmed when details of previous coring in the area were known.

The transect line was selected to avoid any settlement areas known from the previous excavations and still allow a straight line from the valley to the towans summit close to the Crane Godrevy medieval manor (Figure 5.29). A line running north-south was plotted initially using ranging rods and a hand-held (GPS) unit (Garmin Etrex) which gave a claimed accuracy of 4–5m in both horizontal axes. At a later date the transect line was replotted using differential GPS (Leica), with a claimed accuracy of 1cm in both horizontal and vertical axes, at 1m intervals along the entire transect except where vegetation or the river precluded access.

It was decided that the cores north of the Red River would be spaced at 15m intervals near the river widening to 25m intervals in the meadow. Spacing on the scarp of the towans would be much wider, the exact positions being determined to some extent by access through scrub. Across the top of the towans the intervals were 50m reducing to 25m close to Crane Godrevy. The fence on the north side of the Red

River leet was designated as the '0' point of the transect line. When the line was later extended south of the Red River the points at wide intervals were recorded with 'South' distances (Figure 5.30).

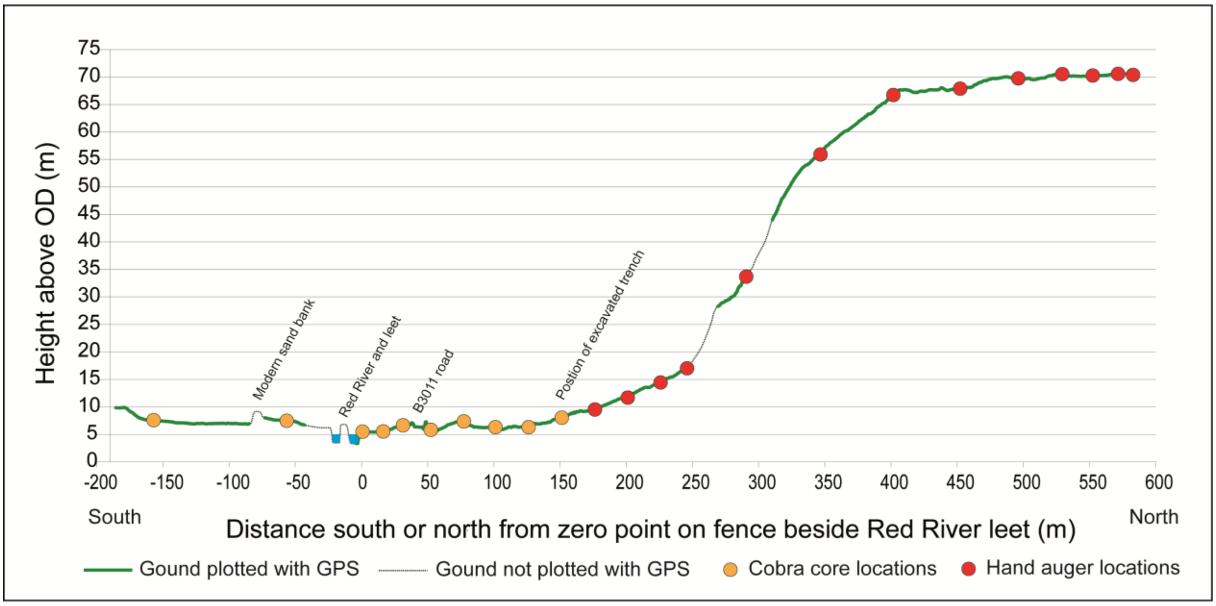


Figure 5.30. Graph showing the elevations of the transect line and the locations of the cores

5.3.2.2 Ground penetrating radar (GPR) survey

The GPR survey (Figure 4.2) was conducted along the entire length of the transect except where vegetation or the river precluded access; the road running across the site was also not surveyed due to dangers from road traffic. Equipment used was Geophysical Survey Systems Inc. (GSSI) units. At the first radar visit in June 2011 scanning was performed with a 400MHz unit along the whole length of the transect from the Red River to Crane Godrevy and with a 200MHz unit from the river to the base of the scarp (245m) to obtain deeper penetration of the sediments. However, this frequency did not reach the base of the river valley and a return visit was made in September 2012 with a 100MHz probe. On this occasion GPR was performed north of the river for a distance of 150m and south of the river for 185m to cover the south side of the Red River valley.

5.3.2.3 Coring

Percussion coring was used at those locations along the transect which were too deep to core satisfactorily with the hand auger as well as those in the lower part of the meadow. All the positions across the Red River valley and in the lower part of the meadow were cored in this way, while those in the upper part of the meadow, on the towans scarp and over the summit of the towans were cored using hand augers. The findings of the coring are described in Chapter 6.

Percussion coring

At the 0.5m, 15m, 30m, 100m, 125m and 150m it was possible to reach the killas underlying blown sand or organic silt, while at South 158m, South 58m, 51m and 76m the solid base was not reached despite the use of gouges as well as core tubes. At the two locations south of the river and at 51m the percussion action was unable to penetrate the deep organic silts where reverberation prevented downward movement of the core tubes. At 76m very waterlogged sand was encountered which was not retained either in the core tube or gouges.

Hand auger coring

Coring using a gouge auger was performed on the shallower parts of the transect line where it was anticipated that the underlying natural could be reached without too much difficulty. A 2.5cm diameter gouge was used at the site visit in June 2011 when cores from 13 locations were obtained. The base geology was reached at all locations except 289m. The quantity of material for mollusc analysis that can be obtained in a gauge of this size is limited, and it was decided to repeat augering using a 5cm gouge on the visit of June 2012; this was performed at all hand auger locations except those at 289m and 400m which were omitted as the depths meant that augering with this gauge would not have been successful (the auger binds tightly in deep sand and withdrawal becomes extremely difficult).

5.3.2.4 Modern molluscs

Samples of turf were taken from each of the 23 core sites for assessment of modern molluscs. 500g of dried sediment from each location was used for the analyses. A sample of material was also obtained from the bed of the leet at the 0.5m location to assess recent freshwater molluscs.

5.3.2.5 Trench excavation

After the cores were obtained and initial analyses performed it became evident that additional palaeoenvironmental information would be obtained if a small trench was excavated at one site along the transect line. This would not be possible in the bottom of the valley due to the depth of the deposits and it was decided that a site close to the known post-Roman field system in the meadow would be most suitable. The 150m location was selected as this lay between the southern limit of the field system excavated in 1960−62 and the margin of the presumed tidal estuary. The cores obtained previously had indicated that the underlying killas lay at a depth of about 100cm below ground level and that there was at least one layer of buried soil at a depth of about 60−70cm. The excavation is described in Chapter 7.

5.3.2.6 Mollusc columns

Mollusc columns from the Gwithian Trench and from Strap Rocks (Chapter 8) were obtained using standard techniques (Evans 1972, 41), except that the samples were taken from ground surface downwards as the sands were insufficiently stable to sample from the base upwards. Care was taken to identify and respect stratigraphic boundaries wherever possible. 2–4kg of sediment was obtained for each sample.

5.3.3 Laboratory analyses

The laboratory methods used to investigate the samples have been described in the previous chapter and comments will only be made here concerning the specific tests on certain samples. Mollusc analysis, particle size analysis, pH estimation and loss on ignition were performed on all samples from the cores and on the mollusc columns from the Gwithian Trench and Strap Rocks.

Other analyses performed are summarised:

Geochemistry

Compressed pellet XRF: samples from the 15m core.

Itrax core scanning XRF: samples from the 0.5m core.

Stable isotope analysis for δ^{18}O and δ^{13}C

Mollusc samples from the 30m core.

Dating

Radiocarbon dating: mollusc and organic samples from the 30m core; mollusc samples from Gwithian Trench, Godrevy Scarp and Strap Rocks (NERC Oxford Radiocarbon Unit).

OSL dating: sand samples from the 30m core and Gwithian Trench (Dr Helen Roberts, Aberystwyth).

Micromorphology (performed by Dr Rowena Bannerjea, Reading).

Two samples from the upper buried soil in Gwithian Trench.

Pollen analysis (performed by Dr Rob Batchelor, Reading).

Organic samples from the 0.5m core.

Diatom analysis (performed by Dr Nigel Cameron, University College London).

Samples from the 15m core.

The selection of which core to use for specific tests was determined by availability at the time of testing and the appropriateness of the sediments within the cores

6. Gwithian – coring transect

6.1 The transect

This chapter opens with a general discussion of the modern molluscs, both from the turf blocks taken along the transect line and from the Red River leet. Analyses of the assemblages found will establish modern analogues for the varying habitats which may have been found in earlier times, and can be a useful guide to the interpretation of sub-fossil assemblages. This is followed by descriptions of each core obtained along the coring transect; the locations of the cores are shown on Figure 5.29. As well as the findings of the various analyses the modern vegetation is described and reference made to the modern molluscs of each location.

6.2 Modern molluscs

6.2.1 Turf blocks

The numbers of each species identified from the samples is shown Table 6.1 and graphically in Figure 6.1. A total of 3679 shells was identified in the 23 samples comprising 27 taxa. Only a very few of the molluscs (approximately 3%) were live at the time of collection, although more retained an intact periostracum or were translucent indicating recent death. The assemblages therefore do not accurately represent a modern living population, but will be indicative of the population in the recent past when the very superficial sands were accumulating and will be a guide on how to interpret palaeoassemblages.

There were no shells in the two turf blocks taken south of the river and very few in the 0.5m and 15m samples; possible reasons for this will be discussed below. At all other locations there was a good number of shells, but with considerable variation at different sites along the transect; understanding these variations will aid the interpretation of subfossil assemblages. Figure 6.2 shows how the number of shells and taxa varies from site to site; generally each rose and fell in accord, but there are discrepancies at locations 245m, 289m and 497m which will be discussed under each core. Only some general comments will follow here.

Table 6.1. Number of molluscs in the modern turf samples
500g samples

Distance from Red River (m)	South 158	South 58	0.5	15	30	51	76	100	125	150	175	200	225	245	289	345	400	451	495	528	551	570	582
Habitat	bare field	bare field	lush, dense, vegetation	shorter vegetation	grass tussocks	In shadow of Cornish hedge	short grazed grass	short grazed grass	short grazed grass	short grazed grass	short grazed grass	short grazed grass	short grazed grass	at edge of scrub	in area of dense scrub	very bare open hillside	marram grass	short grazed grass	at edge of scrub	in shadow of scrub	short grazed grass	short grazed grass	at edge of tall scrub
Carychium minimum	-	-	-	-	1	83	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galba truncatula	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochlicopa lubrica	-	-	-	-	17	1	-	-	-	-	-	5	5	4	4	3	5	1	28	-	-	-	1
Cochlicopa lubricella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-
Vertigo pygmaea	-	-	-	-	65	-	18	6	7	15	32	40	52	11	1	14	7	25	4	6	24	18	1
Pupilla muscorum	-	-	-	-	-	-	5	-	-	1	-	-	-	-	-	-	-	-	-	-	20	38	3
Lauria cylindracea	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	9	72	2	16	-	2	-	-
Vallonia excentrica	-	-	-	-	36	51	52	27	117	62	157	78	216	144	2	36	9	151	25	28	133	22	65
Punctum pygmaeum	-	-	-	-	21	-	2	-	-	8	5	8	5	5	-	1	15	34	1	1	32	9	4
Vitrina pellucida	-	-	-	-	3	1	1	-	-	-	1	-	-	-	-	-	-	-	-	9	-	-	-
Vitrea crystallina	-	-	-	-	24	-	3	-	-	-	-	-	-	-	-	-	4	-	1	-	-	-	-
Aegopinella nitidula	-	-	-	1	2	-	-	-	-	-	-	-	-	-	5	-	39	-	7	-	-	-	3
Aegopinella pura	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nesovitrea hammonis	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Oxychilus alliarius	-	-	-	-	8	-	-	-	-	-	-	9	-	-	-	-	-	-	22	28	-	-	-
Milacidae	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limacidae	-	-	-	-	-	-	-	-	4	-	2	2	3	1	-	-	-	-	1	-	1	-	-
Cecilioides acicula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-	-	-
Clausilia bidentata	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Cochlicella acuta	-	-	-	1	50	4	26	26	90	27	23	12	66	95	14	125	22	27	6	-	8	11	1
Ashfordia granulata	-	-	-	-	19	-	-	-	1	-	1	-	1	-	-	-	3	-	1	-	-	-	-
Candidula intersecta	-	-	-	-	10	-	6	4	1	1	-	-	1	-	2	23	12	8	3	-	4	26	-
Cernuella virgata	-	-	1	-	18	-	4	4	8	3	5	-	6	17	1	34	-	-	-	-	2	1	-
Helicella itala	-	-	-	1	8	-	15	30	54	10	8	4	17	22	4	47	7	23	9	-	3	21	5
Trochulus hispidus	-	-	-	-	-	17	1	-	15	1	3	-	1	-	3	5	2	1	3	1	-	-	1
Cepaea nemoralis	-	-	2	-	3	1	-	-	-	-	-	2	-	-	-	1	3	1	4	-	-	-	-
Cornu aspersum	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
TOTAL SHELLS	**0**	**0**	**4**	**3**	**289**	**169**	**133**	**97**	**299**	**128**	**237**	**160**	**373**	**299**	**42**	**299**	**201**	**273**	**135**	**74**	**229**	**146**	**90**
TOTAL TAXA	**0**	**0**	**3**	**3**	**17**	**11**	**11**	**6**	**11**	**9**	**10**	**9**	**11**	**8**	**12**	**12**	**14**	**10**	**16**	**7**	**10**	**8**	**10**
Shannon index					2.35	1.36	1.79	1.51	1.51	1.51	1.19	1.51	1.31	1.34	2.13	1.78	2.03	1.44	2.29	1.37	1.39	1.88	1.14
Brillouin index					2.34	1.27	1.67	1.41	1.45	1.40	1.12	1.42	1.26	1.29	1.79	1.71	1.91	1.39	2.11	1.25	1.32	1.78	1.01

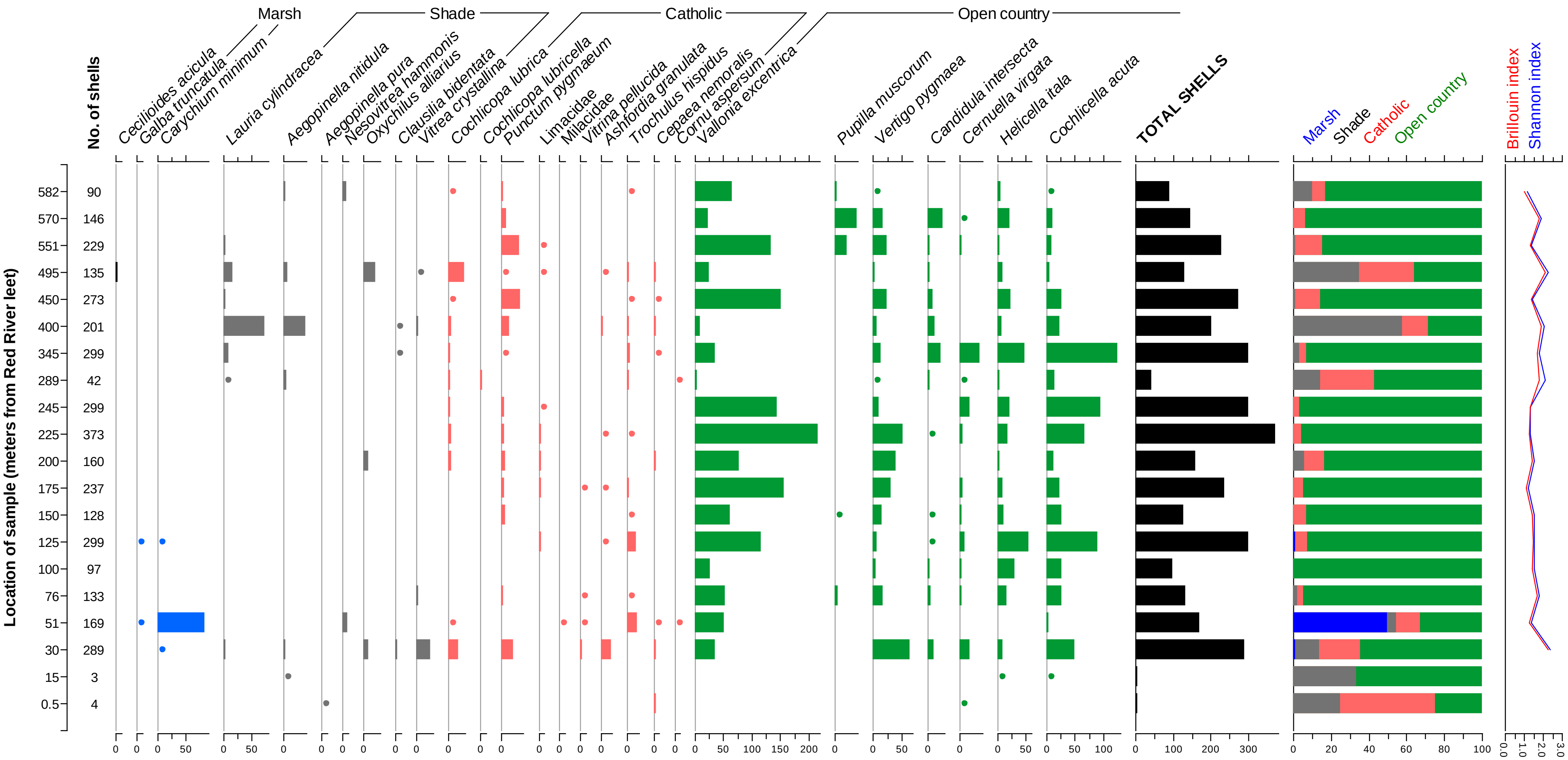


Figure 6.1. Mollusc diagram for the modern turf samples, arranged from south (base) to north (top).
Absolute numbers of molluscs (cumulative graph is percentage). Dots indicate single specimen only present in sample
The two locations south of the river are not shown as neither contained any molluscs

The molluscs found in the modern turf samples at Gwithian contain species from all ecological groupings, sometimes in locations where they might not normally be expected. The most obvious example is at 30m, an area of rank grass but with no scrub or woodland within about 200m; the only shade is among stems of grass so it is perhaps surprising to find two specimens of *Clausilia bidentata*. Other species normally associated with shade are *Vitrea crystallina*, *Aegopinella nitidula* and *Oxychilus alliarius* were also present, but all of these may live in tall damp grassland, and *O. alliarius* may be one of the first colonizers of grassland left to become rank (Davies 2008, 177). If any of these species are found in sub-fossil assemblages then the presence of a good degree of shade is to be expected, although not necessarily woodland or scrub.

Figure 6.2. Numbers of shells and taxa in the modern turf samples, from south (left) to north (right)

The shady and damp habitat provided by the Cornish hedge (the construction of this type of 'hedge' is described in Section 6.4.1.6) at the 51m position is also instructive. This low-lying area is very damp or under water for much of the year, and the perpetual moisture is consistent with the presence of large numbers of *Carychium minimum* and a single *Galba truncatula*. *Nesovitrea hammonis* is also capable of living in wet meadows. However, the presence of many *Vallonia excentrica* is, perhaps, unexpected, although this species may occasionally live in marshy habitats (Evans 1972, 162).

The open country species found on the meadow and towans summit and can be used as an analogy when present in subfossil assemblages, indicating short grassland which may be grazed. When in association with species which require some shade, such as *Aegopinella nitidula*, then it is likely that there was at least long rank vegetation, as at 400m, or scrub in the close vicinity, as at 289m and 495m. There is no true woodland at any site along the transect line (the nearest trees are about 700m to the east where there is a line bordering a track), so there are no modern analogues in this immediate area for woodland. If subfossil assemblages differ significantly from those found above and contain a higher proportion of shade species, then the presence of woodland should be considered but is not proven. Also of relevance is the finding of a few ‘unexpected’ shells such as the wet ground species *Galba truncatula* and *Carychium minimum* on the hillside at 289m or the woodland species *Clausilia bidentata* on bare ground at 345m, strongly implying transport from a good distance away either by wind or animals.

6.2.2 Molluscs from the Red River leet

Approximately 500ml of sediment was obtained from the bed of the leet and wet sieved down to 500µm. The pH of the water was 7.65. Very few molluscs were live at the time of collecting, and the great majority of those that were live were *Potamopyrgus antipodarum*. The shells recovered are listed in Table 6.2.

Table 6.2. The molluscs found in the sample from the Red River leet

FRESHWATER 565 shells	
MOVING WATER	
Ancylus fluviatilis	2
CATHOLIC	
Radix balthica	23
Gyraulus albus	71
Gyraulus laevis	102
Pisidium spp. (including *P. milium* *P. nitidum, P. subtruncatum*)	282
DITCH/SLUM	
Potamopyrgus antipodarum	71
Physella acuta	14

WET GROUND 12 shells	
AMPHIBIOUS	
Galba truncatula	3
Carychium minimum	7
Anisus leucostoma	2

TERRESTRIAL 38 shells	
SHADE	
Lauria cylindracea	
Punctum pygmaeum	1
Discus rotundatus	1
Vitrea crystallina	1
Zonitoides nitidus	6
Euconulus alderi	2
Balea heydeni	2
CATHOLIC	
Cochlicopa lubrica	4
Cochlicopa lubricella	1
Cochlicopa sp.	4
Ashfordia granulata	4
Trochulus sp.	1
Cornu aspersum	4
OPEN COUNTRY	
Pupilla muscorum	1
Cernuella virgata	2
Cochlicella acuta	4

The majority of shells are catholic freshwater species, those which require continuous wet conditions without periods of drying, unlike the amphibious group which tolerate drying. The leet is generally slow flowing, which is, perhaps, why there is only one moving water mollusc. Of note is the presence of large numbers of *Potamopyrgus antipodarum*, a nineteenth century introduction to Britain which is ubiquitous in all types of flowing and brackish water and tolerant of mildly polluted waters. There is a wide range of terrestrial molluscs which have clearly been deposited here from further upstream where there are woods down to the water’s edge.

It is important to observe that in the cores, the discussions of which follow, almost no true freshwater molluscs have been found. If there had been regular deposition of overbank alluvium then some at least of these would have been expected, and their absence considerably reduces the likelihood that overbank flooding occurred more than very infrequently.

6.3 Ground penetrating radar

The radar survey was conducted in several sections:

south of the Red River;

between the river and the base of the Godrevy Towans scarp;

the upper scarp and Towans summit, as vegetation allowed.

In no part of the main valley did the radar reach the bedrock, although this was visible on the slopes north of the river. The depths indicated on the 0.5m to 150m traces are extrapolated from the known depths of interfaces and bedrock observed in the cores. No attempt has been made to determine depths from the radar signals, as explained in Section 4.1.2.

6.3.1 South of the Red River

This section was scanned only with the 100MHz probe (Figure 6.3) but despite this low frequency no clear interfaces were seen. While some of the subsurface lines may represent subtle changes in stratigraphy these were not evident in the cores and no interpretations have been attached to this section of the GPR scan. Of particular note is that the scan did not show any evidence of the valley slope to the south.

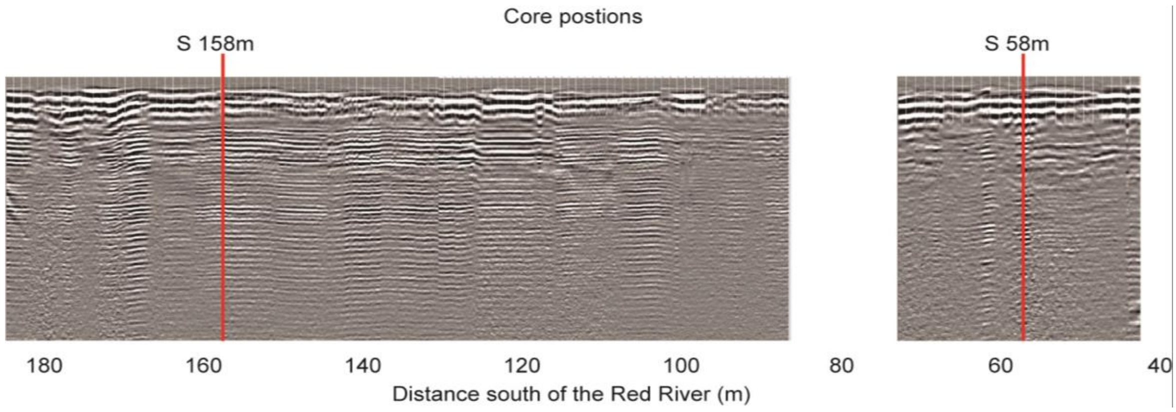


Figure 6.3. GPR scan (100MHz) of the field south of the Red River, with the core locations marked

6.3.2 Between the Red River and the Towans scarp

Scans were done between the river and the 150m core location with the 200MHz and 100MHz probes, while those between the road and the scarp also included scans with the 400MHz probe. Multiple oblique interfaces are revealed between the river and 150m (Figure 6.4) which are outlined in Figure 6.5. Those from 50m to 150m are interpreted as the northern bank of the river valley gradually infilling with sand over time, while those from 0m to 50m are changes in the sediment layers sufficient to produce radar reflections. The 400MHz scans over this distance are not illustrated as they did not provide additional information. Good detail was obtained in some areas with the 200MHz probe to an extrapolated depth of about 3–4m, while the 100MHz revealed some interfaces to a depth of about 8m.

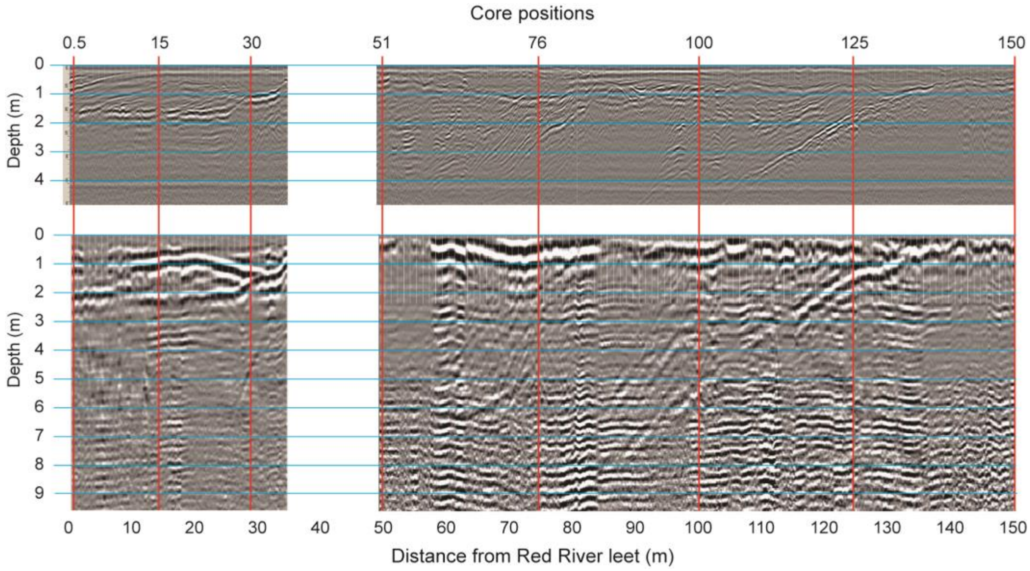


Figure 6.4. GPR between the Red River and the 150m core position, with the core locations marked. 200MHz scan above, 100MHz scan below. Depths extrapolated from known bedrock depths at 100m and 125m. The gap in the sequence is the B3301 road

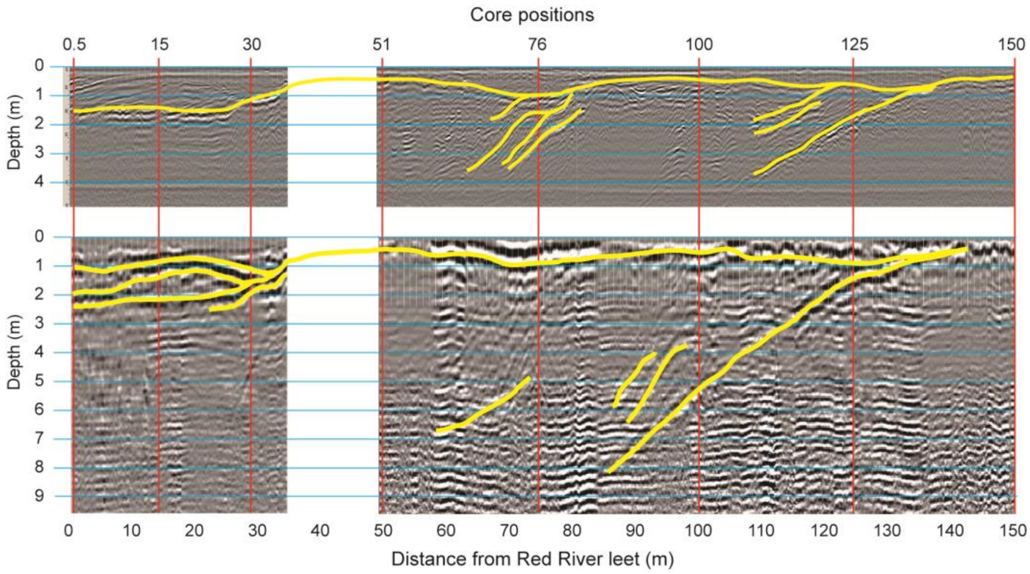


Figure 6.5. The strong radar interfaces drawn onto the GPR scans

It is difficult to correlate many of these potential interfaces with the stratigraphy found in the cores, and described in more detail below. The 0.5m and 15m cores both show clear stratigraphic changes from sand to organic silt at 120–145cm, corresponding very well with the radar, but deeper boundaries at 600–700cm are not revealed in any area. The 30m core shows stratigraphic changes at 172cm and 207cm in accordance with the GPR. No horizons below 50cm are seen at the 51m location with the scan being very noisy, largely due to difficulty encountered in maintaining contact of the radar probe with the ground due to grass tussocks. Several boundaries are suggested at 76m but none seen in the core, so these appearances are equivocal.

A sloping bank is clearly demonstrated between 85m and 135m on the GPR, and this corresponds with the bedrock levels found in the 100m and 125cm cores, and has allowed depth models to be applied to the GPR. Possible higher interfaces are shown but are difficult to correlate with the core stratigraphy.

The GPR between 150m and 245m, shown with the 400MHz probe (Figure 6.6), reveals little detail which is perhaps only to be expected as the cores reached bedrock at depths between 22cm and 100cm, with no significant stratigraphic horizons except at 150m (see below), and no attempt has been made to attach depth scales. There is some undulation on the possible bedrock interface but this is equivocal. Of interest is that there are no features at all between 170m and 205m, exactly the position of the post-Roman field system; the disturbance of the ground seems to have resulted in radar noise only with loss of all interfaces.

6.3.3 The Towans

It was not possible to perform any GPR on the steep slope of the Towans in the region of the 289m core due to the irregularity of the ground and the scrub vegetation. Scanning with the 400MHz probe between 333m and 582m was possible over much of the transect but there are gaps due to dense or tall vegetation (Figure 6.7). The bedrock is shown for most of the scanned transect, but, as in the cores, there are no clear interfaces between the surface and the bedrock. There is irregularity in the solid surface indicating some hollows along the Towans summit. In particular there is a depression at around 530m which is discussed further below.

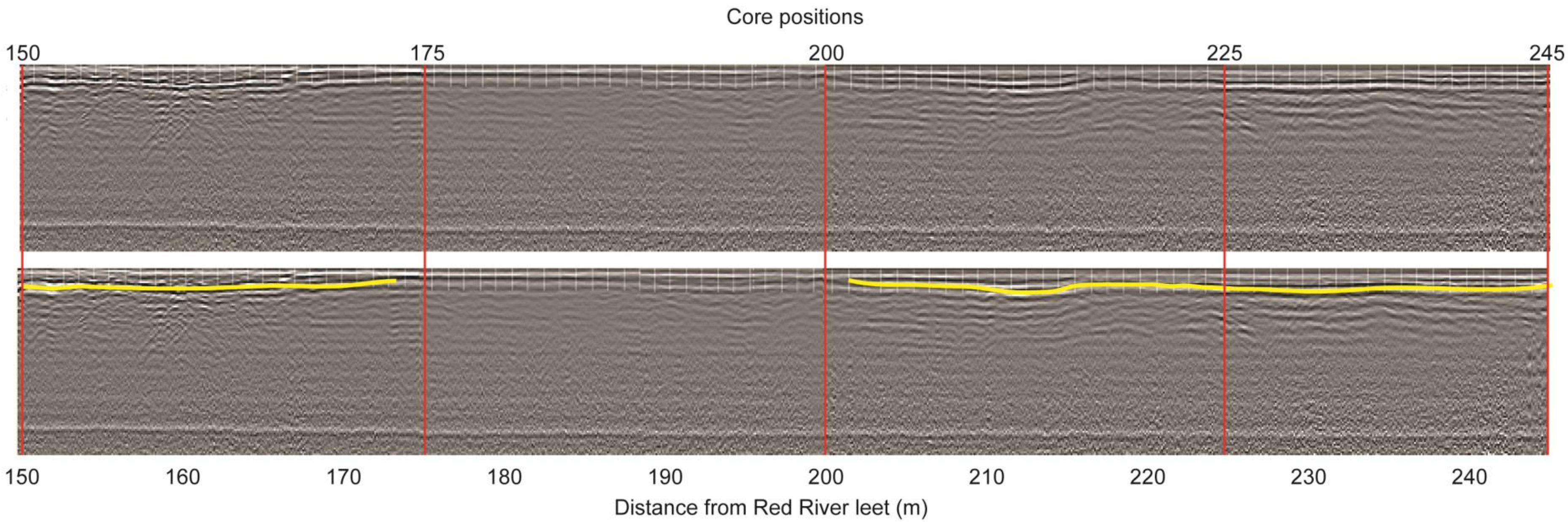


Figure 6.6. GPR between 150m and 245m (400MHz).
The lower image shows the interface between the bedrock and overlying sandy sediments drawn onto the same scans

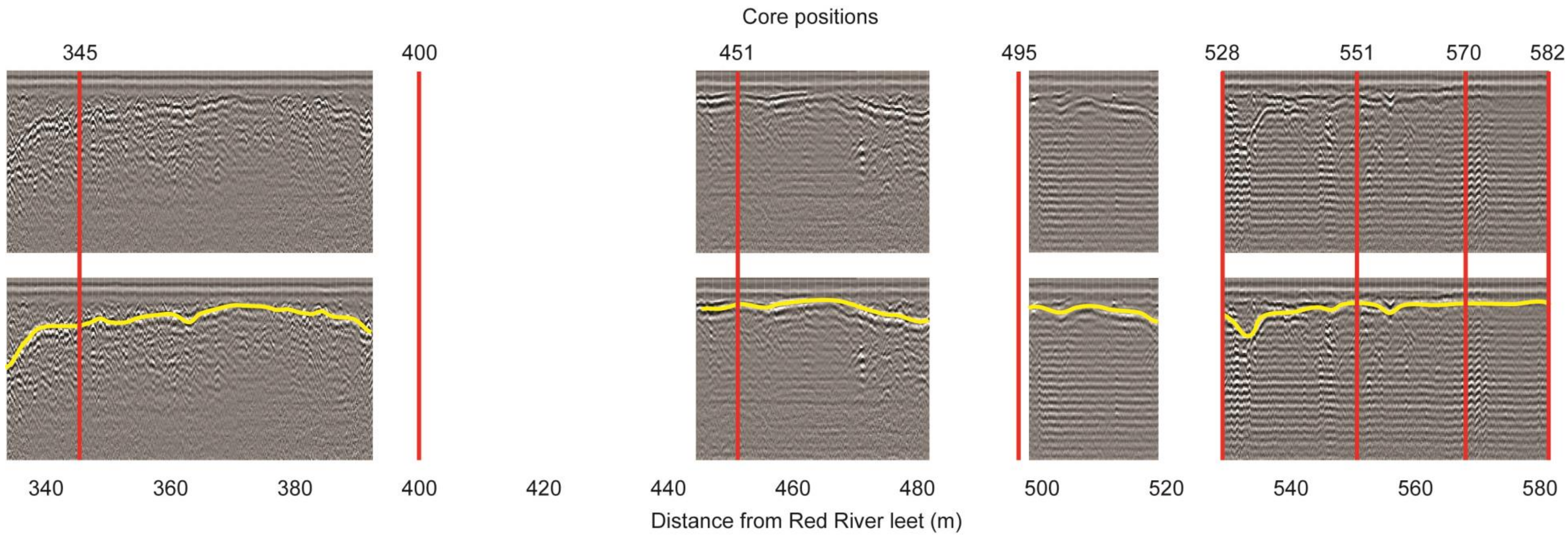


Figure 6.7. GPR between 333 and 582m (400MHz).
The lower image shows the interface between the bedrock and overlying sandy sediments drawn onto the same scans

6.4 The cores

Each core will be discussed individually with summary tables of laboratory investigations and mollusc diagrams. A zoning interpretation is given to the right of each summary and mollusc diagram which represents an analysis of all the analytical modalities used to provide a best fit to the stratigraphy. Figures in the text in square brackets [ ] refer to these zones. For those cores which did not reach bedrock the lowest level reached has been designated zone [2]. The depths shown in all figures and tables pertaining to percussion cores relate to the depths corrected for compression and contaminating material, as described in section 4.2.1.1.

Radiocarbon and OSL dating was performed on the 30m core and geochemistry and pollen analysis on the 0.5m core. These findings are not included in this Chapter, but are fully discussed in Chapter 7.

Flowering plants are mentioned at the core locations. Specimens were collected within approximately a 2m radius of each core site in August 2011 and kindly identified by Steve Hebdige and Precilla Oates.

Some comments are needed concerning the tables and figures:

<u>Summary diagrams</u>

The first figure for each core shows a combination photograph of the core to demonstrate the stratigraphy, followed by bar charts of particle size and loss on ignition (LOI) and line graphs of pH and the total number of molluscs at each level within the core, normalized to 500g samples. Tables of the figures for all these analyses are included on the CD (Appendix 5 and 6). The depths are those below modern ground surface.

In the interests of clarity the keys for the summary diagrams are not reproduced for each core but are shown in Figure 6.8.

particle size						
clay	silt	very fine sand	fine sand	medium sand	coarse sand	gravel
0–2µm	2–63µm	63–125µm	125–250µm	250–500µm	500µm–2mm	>2mm

loss on ignition	
organic matter content	carbonate content

Figure 6.8. Keys for the particle size and loss on ignition charts

Tables of mollusc numbers

Many of these tables are very long and therefore not shown within the text. They are included in full on the accompanying CD (Appendices 3 and 4).

Mollusc diagrams

Mollusc diagrams showing the absolute numbers of molluscs for each sample are presented in the second figure for each core. For every sample the actual number of shells found and the sample weight is given for reference. Since the volume and weight of sediment in each sample varied considerably, some sediments being very thin (especially some of the organic silt levels) while others were thick, all the graphs show mollusc numbers normalized to 500g per sample. Dots on the diagrams indicate samples with ≤5 shells (normalized numbers). In many of the cores there were no molluscs in the deeper levels, so the diagrams only include samples down to the lowest level in which shells were found. The stratigraphic diagram included in each mollusc diagram uses the same colouring as in Figure 6.9. The Shannon and Brillouin diversity indices are shown graphically only when there are more than 10 shells in the relevant sample. Many of the samples contain only small numbers of shells and the difference between the two indices is an indication of how representative the sample is of the true assemblage – the closer the indices then the more representative is the sample. Diversity indices are discussed more fully in Section 2.2.5.

The habitat requirements on the diagrams are consistent in all the diagrams but are not intended to be prescriptive. It is accepted that the ecological niches of many molluscs are variable, and some of these variations are discussed in the accompanying text. References to specific habitats are only included in this Chapter when there are particular points to be made. Full details of mollusc habitat preferences for all species found in this study are given in Appendix 1.

6.4.1 Percussion cores

Percussion cores were obtained in two positions south of the Red River and in eight positions north of the river. All depths, both in the diagrams and the text, are those after correction for differential compaction of sand and organic silt (see Section 4.2.1.1 for discussion of the correction method).

Figure 6.9 shows the stratigraphy of the percussion cores. It can be seen that of the ten cores, the bedrock was only reached in six. Lines have been placed which link suggested equivalent sediment horizons.

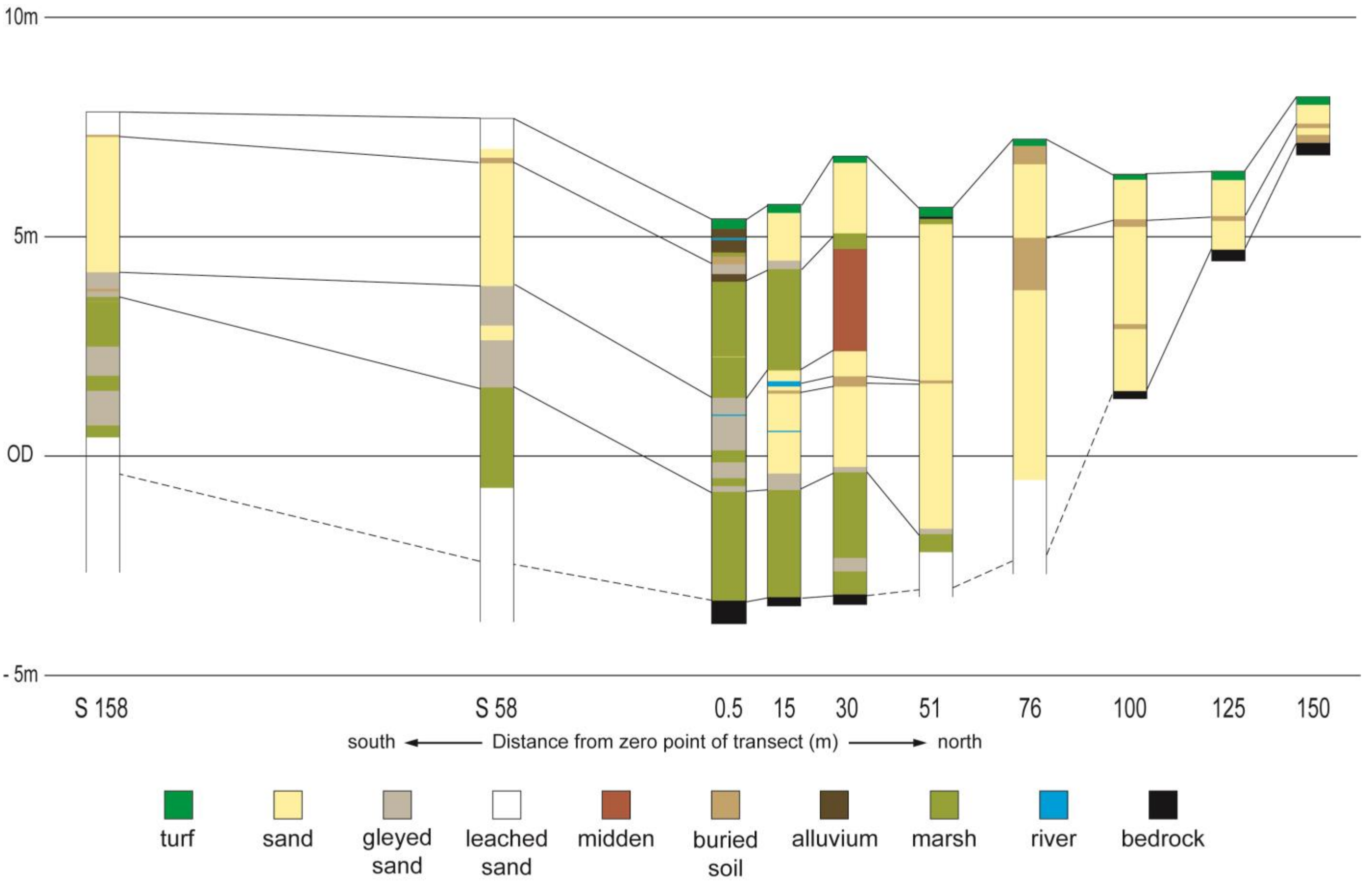


Figure 6.9. Stratigraphy of the percussion cores from Gwithian

6.4.1.1 South 158m core

Grid ref.: SW 58886.41876; modern ground level: 7.57m OD.

Mollusc figures: CD; summary diagram: Figure 6.10; mollusc diagram: Figure 6.11.

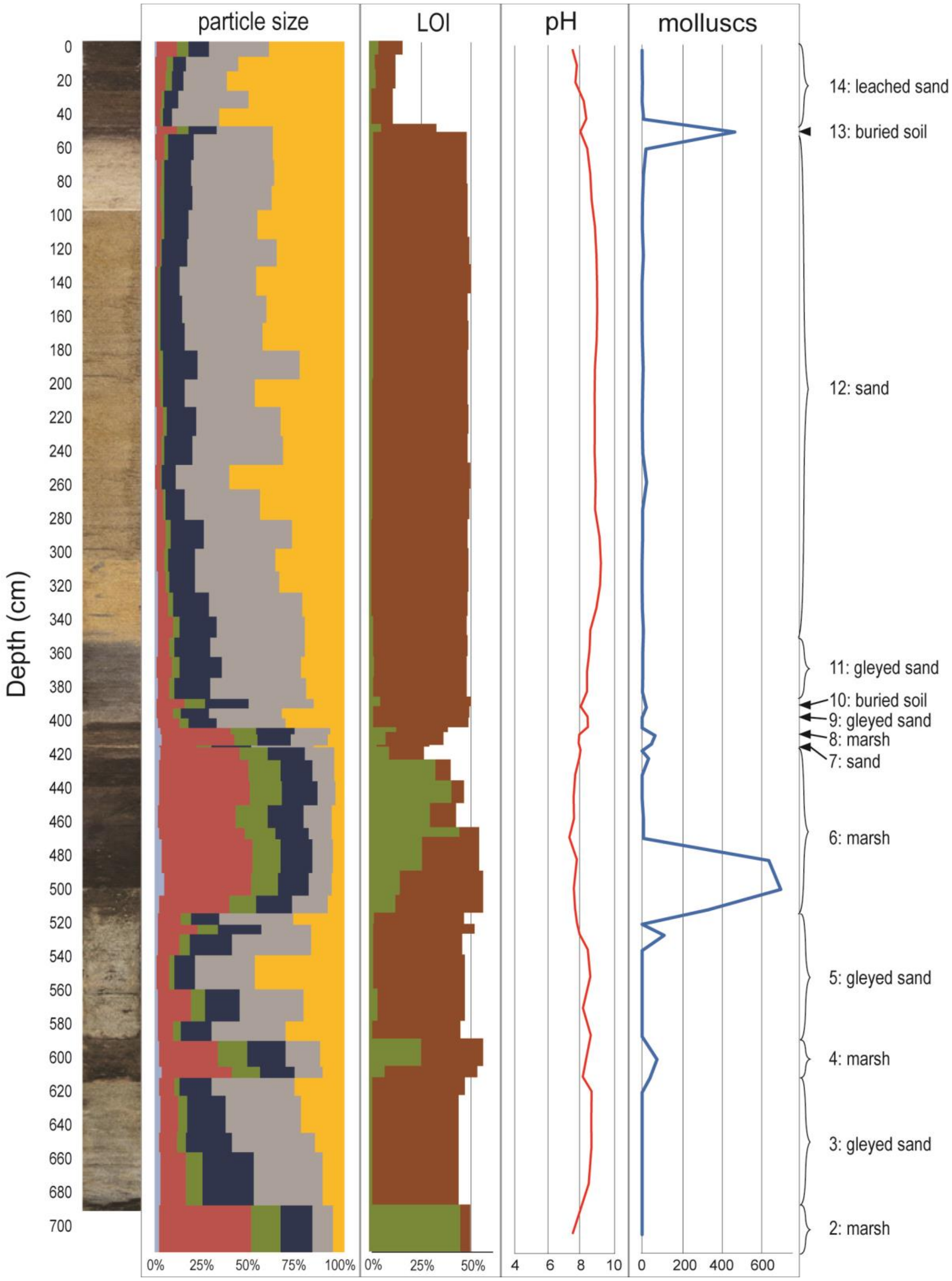


Figure 6.10. Summary diagrams for the South 158m core

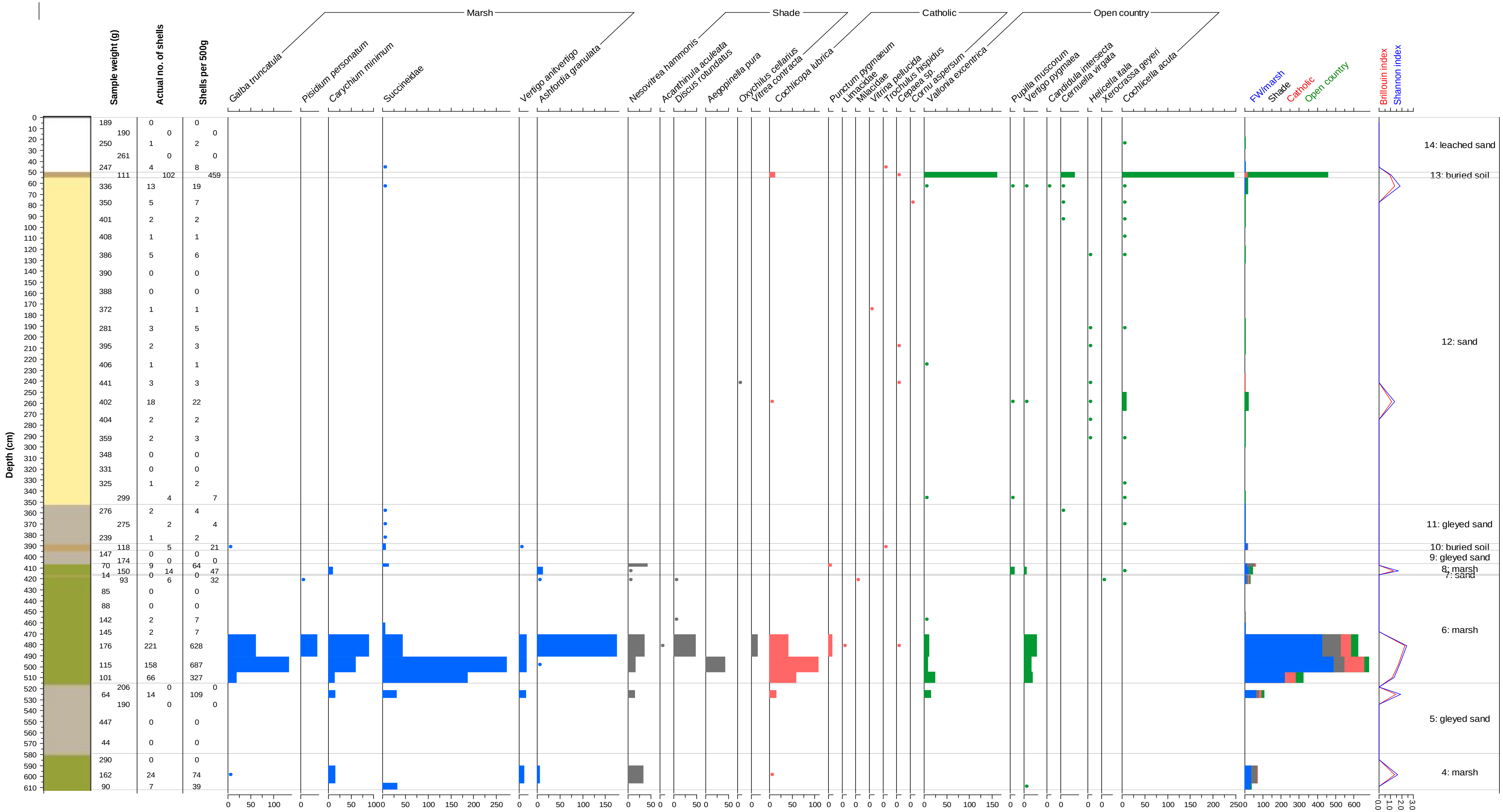


Figure 6.11. Mollusc diagram for the South 158m core
No molluscs were found below 612cm

The most southerly core was obtained on the slope of the south side of the Red River valley (Figure 6.12) in a large field, now part of Churchfield Farm, and at the time of visiting grazed by cattle although with some root vegetable dumps. The field is generally level but slopes up to the south at the margin of the valley. Across the field is a bank of piled sand, about 100m in length although only 10m in width. This sand was bulldozed off the flat field surface in about 2000 by the farmer to create a windbreak for cattle on the field (A. James, pers com). There were no shells in the turf sample; there is no clear reason for this total absence of molluscan life, but may be consequent to agricultural fertilization, weed control and/or flooding with possible contamination from mining pollution. Extensive flooding was present on this field during early 2014 due to a very high water table after several weeks of severe rain (personal observation) and if this was a regular occurrence then conditions would be adverse for molluscs to live.

Figure 6.12. Coring at the South 158m location in the field south of the Red River.
The sand bank can be seen in the middle distance. The South 58m location is just beyond the sand bank

Coring was extremely difficult deeper than about 500cm and abandoned at 714cm without reaching bedrock. Organic silt caused the sample tubes to vibrate sufficiently to prevent the percussion action of the Cobra unit from advancing the tube deeper than 485cm. The core tubes were replaced with decreasing diameters of gouges (5cm, 4cm) but even with these it proved impossible to core through the deeper silt levels and difficulty in extracting the corer precluded further attempts. The zone numbering therefore commences at [2] for the lowest level achieved, but it is not known whether sediment [2] lies directly on the bedrock or there are intervening deposits.

The lowest depth reached was 714cm. The basal layer was organic silt [2] with 45% organic matter. This is overlain by gleyed sand [3] and then another horizon of organic silt [4]. These silt layers are interpreted as marsh/alder fen, the lowest level [2] containing large fragments of alder wood. Wood fragments were also present in layer [4], together with bog bean (*Menyanthus trifoliata*) seeds and it is in this layer that molluscs are first found, nearly all species associated with wet ground (*Carychium* *minimum*, *Galba truncatula*, Succineidae, *Vertigo antivertigo* and *Ashfordia granulata*), although a few dry ground species do occur (*Cochlicopa lubrica*, *Nesovitrea hammonis* and *Vertigo pygmaea*).

There is then a further deposit of gleyed sand [5], almost devoid of shells, before a thick marsh layer [6], the mid-portion of which contains large numbers of shells with wet ground taxa strongly predominating. The presence of large numbers of Succineidae and *Ashfordia* suggests that the vegetation in this area was tall and rank and that it was not regularly under water. Reeds and sedge are plentiful, and there is alder growing in the close vicinity, fragments of alder wood being present in many samples. Of interest here is the presence of *Pisidium personatum*, a bivalve mollusc associated with very poor habitats such as stagnant ponds, ditches and other wet ground habitats subject to regular drying. There are moderate numbers of catholic species but few open country shells in marsh horizon [6] and it may well be that these are allochthonous. Layer [7] is a very thin (1cm) sand horizon which may represent a storm event with blown sand covering the marsh; it is devoid of shells. The marsh, however, persists [8] for a short time before it is covered with a 12 cm layer of gleyed sand [9] indicating that it was regularly under water, and also without molluscs. This gives way to more stable conditions with a thin buried soil [10] at 388−394cm containing a few wet ground molluscs (*Galba truncatula*, Succineidae, *Vertigo antivertigo*), but further flooding returns with more gleyed sand [11].

Dryer conditions then become established, with a thick (302cm) layer of yellow sand [12] containing very few molluscs consistent with instability during accumulation. Another thin buried soil [13] at a depth of 50−55cm indicates a period of greater stability; it contains open country molluscs, mainly *Vallonia excentrica* and *Cochlicella acuta*, the high numbers *Vallonia* suggesting grazed grassland. The topmost 50cm [14] of sand is almost devoid of molluscs and has a very low carbonate content; it is very similar to the 4–5cm thick turf block.

The overall interpretation of this location is that there are deep layers of marshland and alder fen [2, 4, 6] which were subject to periods of drying. There is no indication that the river course ever reached this far south, and regular overbank alluvium is unlikely due to the lack of true freshwater species. There were episodes of blown sand deposition which, at times, were subject to flooding resulting in gleying [5, 9, 11], but with at least one sufficiently stable episode for a shallow buried soil to accumulate [10]. This was followed by massive sand accumulation [12] without standing water and the relative lack of shells indicates that there were no significant periods of stabilization until more recent times with a phase of stability with grazed grassland [13] and the land may have been used as pasture for farm animals. Finally, modern practices have created a largely sterile leached sediment [14] with little faunal activity.

6.4.1.2 South 58m core

Grid ref.: SW 58885.41976; modern ground level: 7.50m OD.

Mollusc figures: CD; summary diagram: Figure 6.13; mollusc diagram: Figure 6.14.

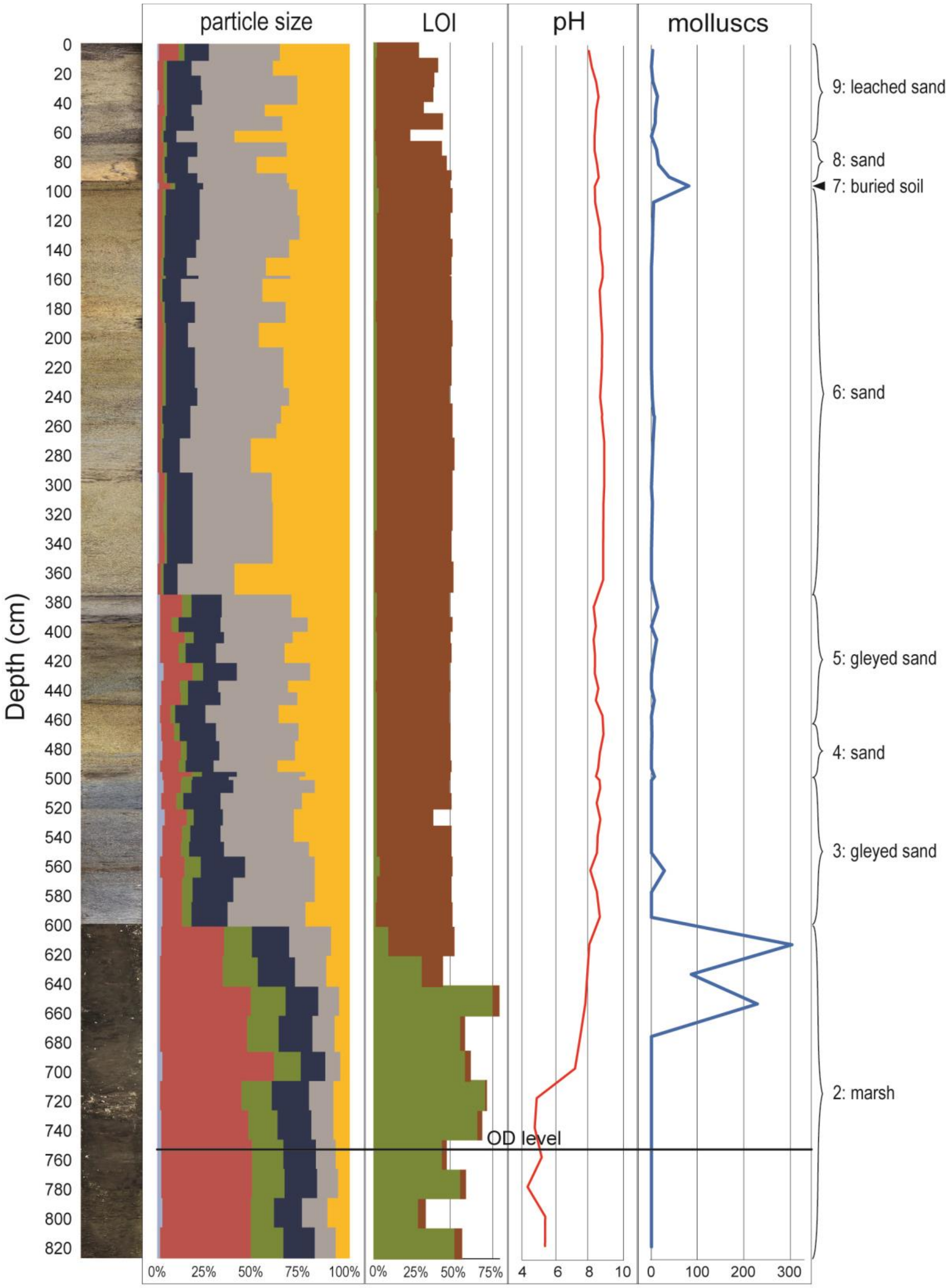


Figure 6.13. Summary diagrams for the South 58m core

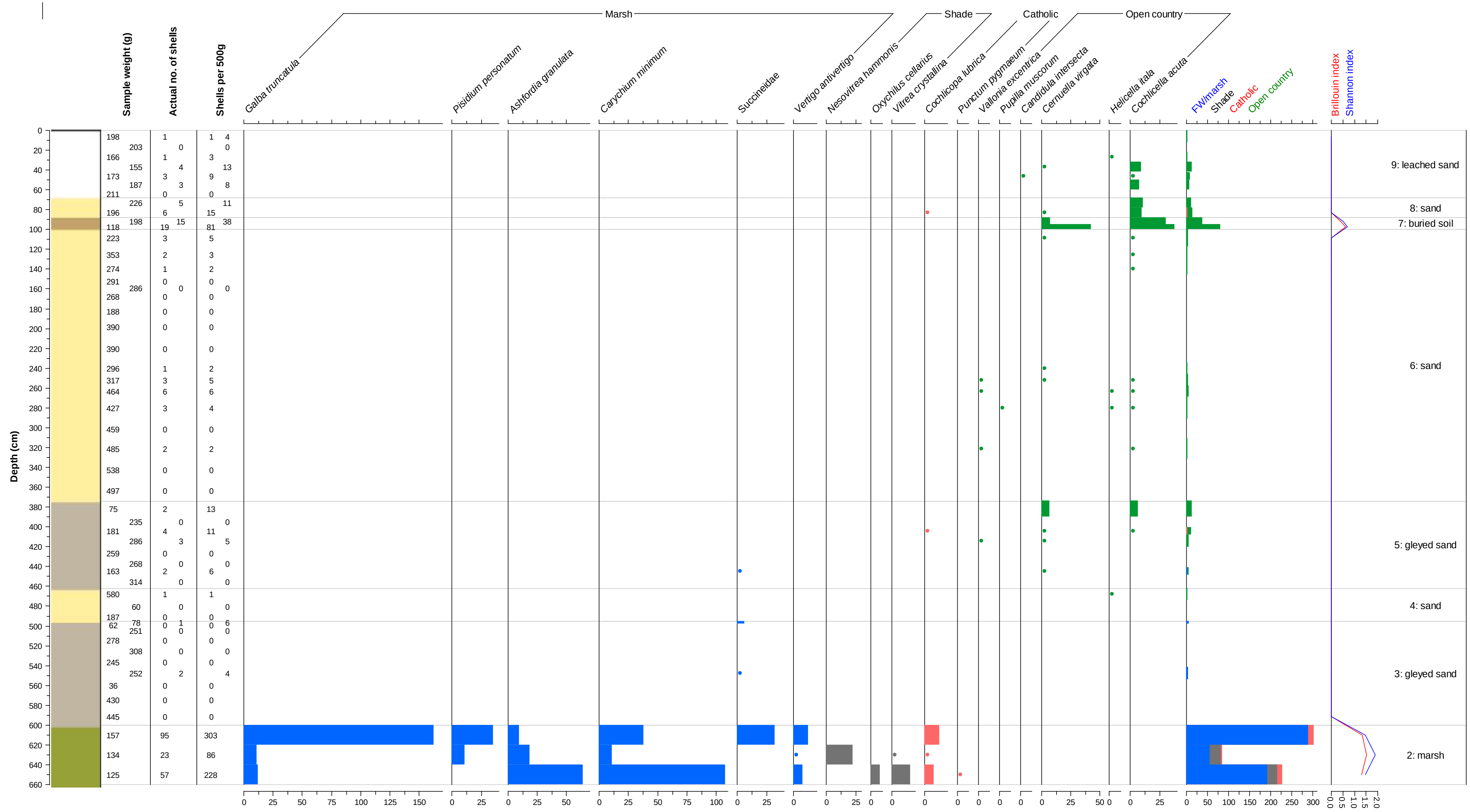


Figure 6.14. Mollusc diagram for the South 58m core.
No molluscs were found below 660cm

This core was obtained from an area of level meadow between the Red River and the bank of sand mentioned above. As at the South 158m location molluscs were absent from the turf sample. Coring again failed to reach bedrock despite the use of gouges below 600cm, the corer being unable to penetrate deeper than 824cm.

The lowest recovered sediment [2] is organic silt, the lower half being acidic (down to pH 4.3) but becoming alkaline in its upper half (pH 8). Molluscs are only present in the upper 60cm of this lowest unit, all being wet ground or catholic species with no taxa associated with open country. *Galba truncatula*, an amphibious mollusc of wet grasslands and poor freshwater habitats, is strongly dominant in the uppermost 20cm, with *Carychium minimum* and *Ashfordia granulata* a little deeper, perhaps indicating a slightly dryer habitat, although still with regular flooding. Reeds and sedge are present throughout this deposit with fragments of alder wood at 724–744cm.

Unlike the South 158m location there is no evidence of any marsh above 600cm depth. However, a thick layer of gleyed sand [3] overlying the marsh implies regular flooding, and is covered by a non-gleyed horizon [4] indicating a dryer interval when flooding ceased, but flooding later recurred as shown by another gleyed sand accumulation [5]. Above this there is a thick layer (254cm) of non-gleyed blown sand [6], corresponding to the equivalent accumulation at the South 158m position. None of these sands [3–6] contain more than very occasional molluscs, implying unstable ground, with rapid accumulation of sand. A thin buried soil [7] is indicated by slight increase in silt levels with open country molluscs (*Cochlicella acuta*, *Cernuella virgata*), although the absence of *Vallonia excentrica* makes grazing unlikely. Finally there is a blown sand horizon [8] covered by the leached sand [9] similar to that found further south.

As at South 158m there is no suggestion of flowing river at this location. None of the sediments at either site contain coarse grained material which is found at other positions north of the present river, and at no level is there any mollusc associated with moving water. In addition, there is no suggestion that this area of the valley was ever estuarine; there are no clay layers similar to those described by Stephens (1899). It is possible that some clay could be found beneath the lowest levels reached by these new cores.

6.4.1.3 0.5m core

Grid ref.: SW 58886.42035); modern ground level: 5.42m OD.

Mollusc figures: CD; summary diagram: Figure 6.15; mollusc diagram: Figure 6.16.

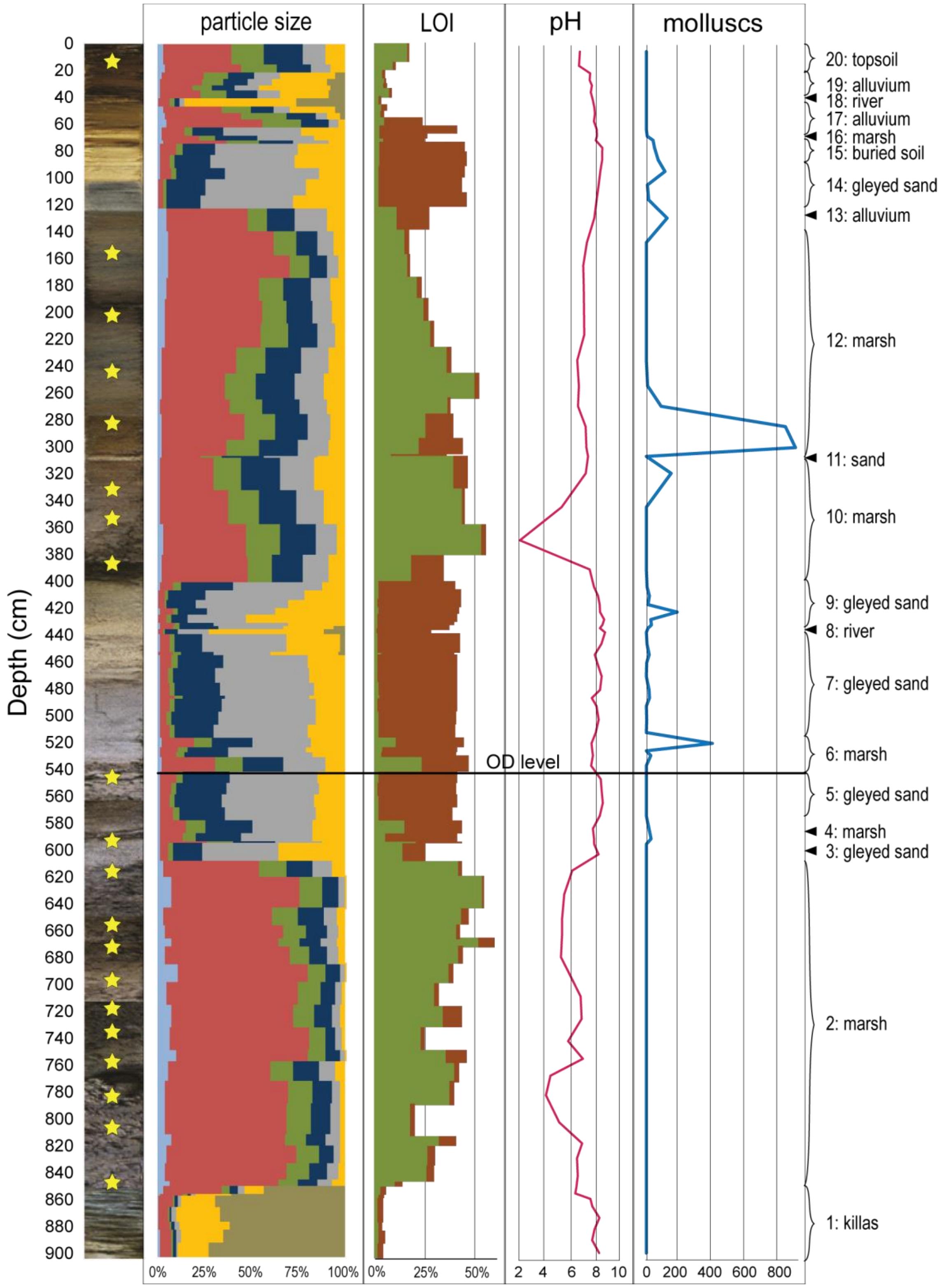


Figure 6.15. Summary diagrams for the 0.5m core

☆ = pollen samples

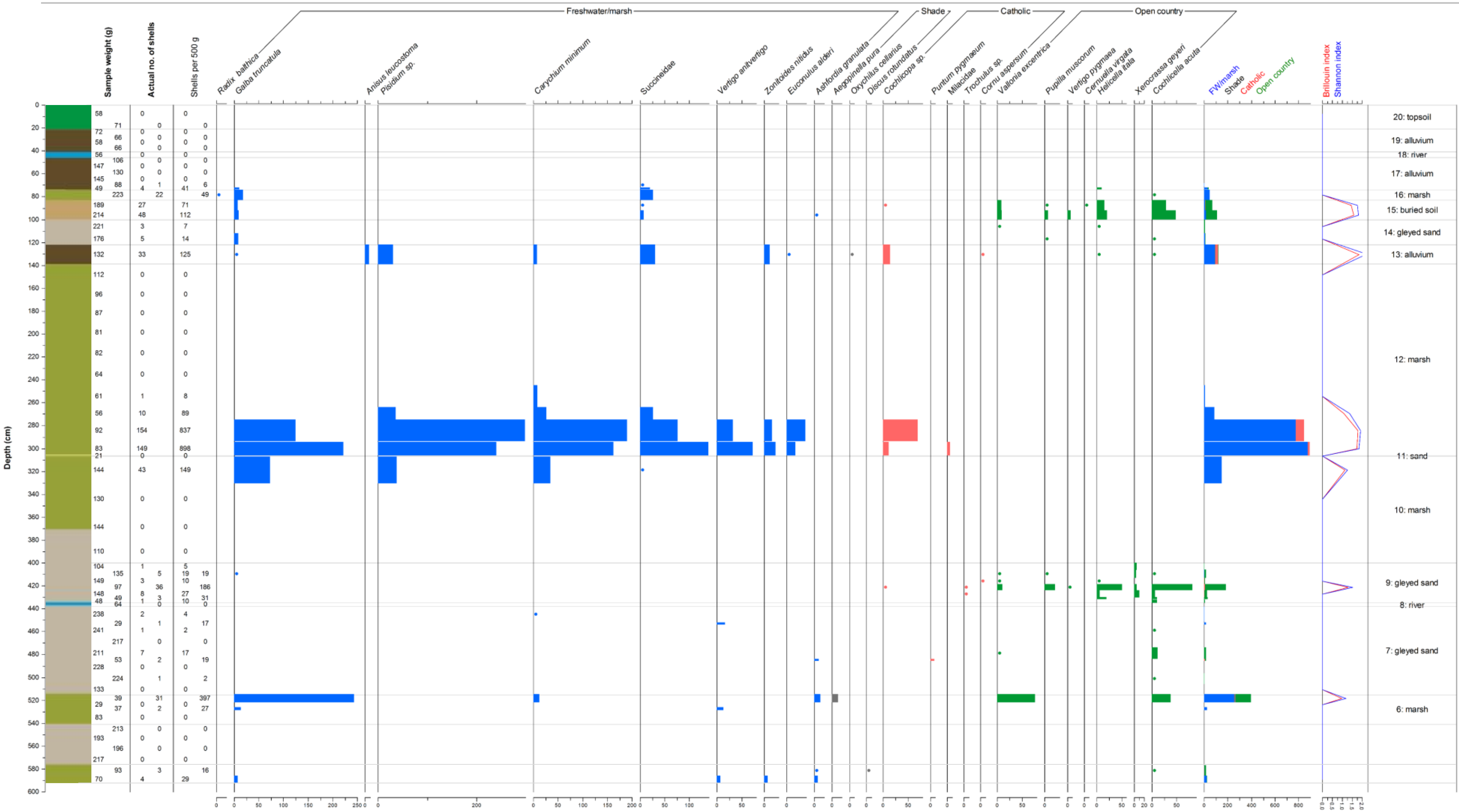


Figure 6.16. Mollusc diagram for the 0.5m core
No molluscs were found below 584cm (the diagram does not show the molluscs below 540cm)

This core was obtained as close as possible to the nineteenth century leet cut parallel to and north of the Red River channel. The ground between the leet and the river has been built up in modern times and no attempt was made to core close to the position of the present river. A wire fence is present on the north bank of the leet which was designated the '0m' position for the coring transect. At the present time there is tall lush vegetation in the meadow bordering the leet (Figure 6.17) including hemp agrimony (*Eupatorium cannabinum*), bird's foot trefoil (*Lotus corniculatus*), hemlock water-dropwort (*Oenanthe crocata*), common fleabane (*Pulicaria dysenterica*), sea bindweed (*Calystegia soldanella*), dead nettle (*Lamium* sp.), sea club-rush (*Scirpus maritimus*), creeping cinquefoil (*Potentilla reptans*) and silverweed (*Potentilla anserina*). There were only four molluscs in the turf block (*Aegopinella pura*, *Cernuella virgata* and *Cepaea nemoralis*) which is difficult to explain as the sediments are not acidic. Overbank flooding after heavy rain is known to occur (as happened in Spring 2013) but that alone should not account for the molluscan sterility.

Figure 6.17. Lush, dense, vegetation surrounding the 0.5m core position

Pollen analysis was performed on 20 samples from this core by Dr C. R. Batchelor (University of Reading) and interpreted on a time/depth scale. The findings will be not be included in this section but discussed in detail in Chapter 7 when dating of the cores is covered.

The core was driven 0.5m north of the fence, a distance which allowed working space for the coring equipment, and was successful to the bedrock at a depth of 849cm. This is a very complex core, with numerous stratigraphic levels. The bedrock [1] consists of the local killas; it is largely slate and represents post-glacial head. The lowest layer of deposited sediment [2], from 607–849cm, is organic silt. No molluscs have survived, which is not surprising as the pH is acidic throughout, dropping to pH 4.0 at one point. This sediment contains reeds and sedge, with tree fragments in several samples, with a tree branch/root filling the core tube at 745–754cm, identified as alder (*Alnus glutinosa*). As in the cores south of the river this is entirely consistent with marsh and alder fen.

A thin layer [3] (594–607cm) has slightly different sedimentary characteristics to adjacent deposits, with a higher mean particle size (Figure 6.18), and a higher proportion of coarse sand grains. The difference is not great and is considered to be the initial deposit of sand at this location.

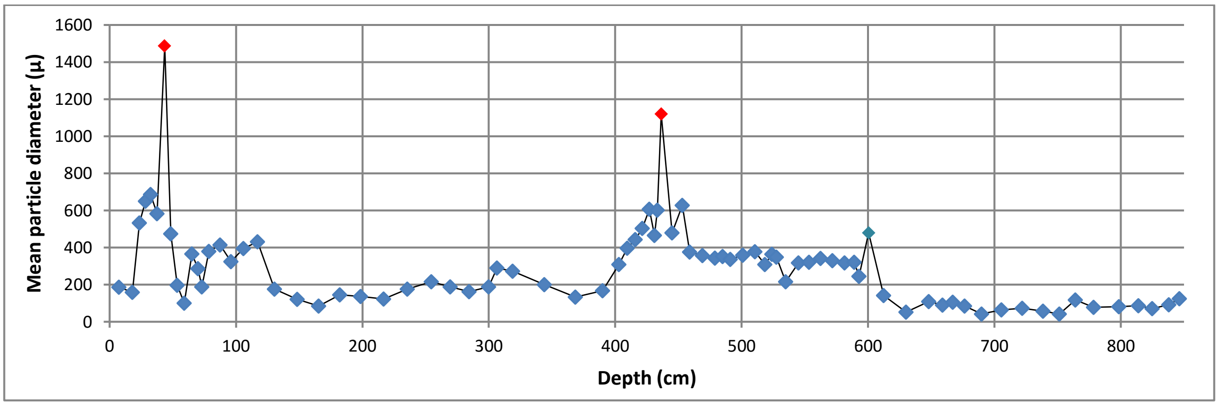


Figure 6.18. The mean particle size for each sample in the 0.5m core.
The points marked in red correspond to the assumed river sediments at 41–46cm and 435–438cm

This is covered by another thin marsh layer [4] containing wood fragments. A very few molluscs (seven shells) are present in this horizon, mainly of marsh species. Sand [5] again accumulates at this location with alder fragments in its lower part; gleying indicates that it was regularly flooded with standing water. The sand is overlain by a further probable marsh layer [6] with molluscs, mainly *Galba truncatula*, but with some *Vallonia excentrica* and *Cochlicella acuta*. The former implies continuing flooding but with dry periods allowing open country species to survive, although the latter may be allochthonous. Pollen concentrations were very low in the two samples (from [4] and [6]), most likely due to destruction in the dominantly sandy sediments.

Further gleyed sand [7] with few shells covers the marsh. There is then another thin deposit [8] (435–438cm) with markedly coarser sand and gravel particles (Figure 6.18) which is likely to be riverine in origin. After a period of time the river changes course and there is a layer of gleyed sand [9], the mid-portion of which contains open country molluscs (mainly *Pupilla muscorum*, *Cochlicella acuta* and *Helicella itala*) implying a period of stability.

Wet conditions recur [10] with organic silt which is highly acidic in its lower part (pH as low as 1.9; the measurement was repeated on two samples to check this unexpectedly low reading) and it is not surprising that no shells have survived in this acidic environment. No explanation for the acidity is evident although it could be related to stagnant water; it did not last long as the upper part of this organic silt contains wet ground molluscs, mainly *Galba truncatula*, *Carychium minimum* and *Pisidium* sp. The absence of dry land species suggests that these shells are autochthonous.

A very thin (1cm) layer of sand without any molluscs [11] interrupts the marsh deposits, perhaps representing a brief episode of blown sand deposition. It is covered by 170cm of organic silt [12] with abundant reeds and sedge throughout. Large numbers of molluscs are present in the lowest 30cm, mainly wet ground species (*Carychium minimum*, *Galba truncatula*, Succineidae, *Vertigo antivertigo*, *Zonitoides nitidus* and *Euconulus alderi*) and with a few dry ground shells (*Cochlicopa* sp., Milacidae), the whole assemblage indicating standing water for much of the time, but with areas of land out of water where riverside species could thrive. The molluscs then disappear, although marshy conditions persist, implying that water levels have risen sufficiently that these amphibious molluscs can no longer survive. Conditions were unstable as no freshwater molluscs appear. Only in the uppermost 17cm of the silt [13] do wet ground molluscs return, but the reduced organic matter content suggests that this may be overbank alluvium rather than continuing marsh.

Gleyed sand [14] with few molluscs covers the alluvium but there is then a period of greater stability [15] with open country molluscs appearing (*Cochlicella acuta*, *Helicella itala*, *Vallonia excentrica*, *Vertigo pygmaea*) indicating that this is an interlude of drier ground although still with moderate wetness. Marshy conditions return [16] with *Galba truncatula* and Succineidae, but above this molluscs disappear and there are no shells at all in the top 68cm of the sediments. It is likely that some of these superficial silty deposits are alluvial [17, 19] but a river deposit [18] at 41−46cm (Figure 6.18) indicates that for a period the river course moved to this site and was sufficiently close for regular overbank alluvium to cover the surrounding valley both earlier and later in time. The top 15cm [20] has a higher organic matter content than deeper levels and with very low carbonate content. No pollen has survived in a sample at 10−11cm depth, which together with the lack of molluscs further supports some local alteration to the conditions in these superficial deposits, and it is conjectured that this may be related to mining activity or regular variation in water table level.

In summary, this core, very close to the modern river course, shows that this north side of the valley was very marshy for much of the Holocene, but with intermittent periods of drying with layers of blown sand. The river itself has been at this location at least twice. The short period when the sediments are highly acidic [10] is difficult to explain although may be connected with late medieval mining activity.

6.4.1.4 15m core

Grid ref.: SW 55886.42049; modern ground level: 5.55m OD.

Mollusc figures: CD; summary diagram: Figure 6.19; mollusc diagram: Figure 6.20.

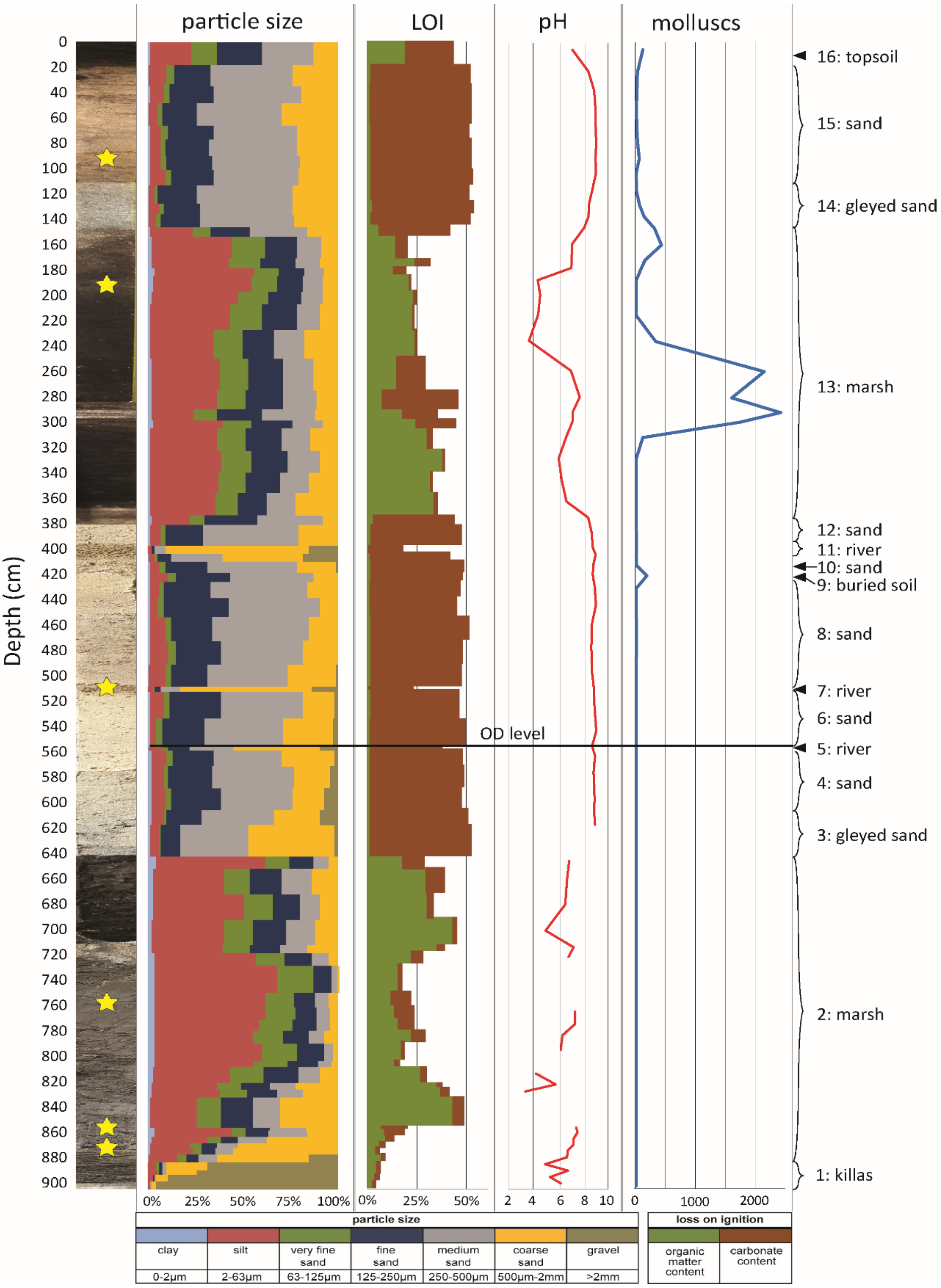


Figure 6.19. Summary diagrams for the 15m core.

☆ = diatom analysis. The gaps in the pH graph are where there was insufficient material for analysis

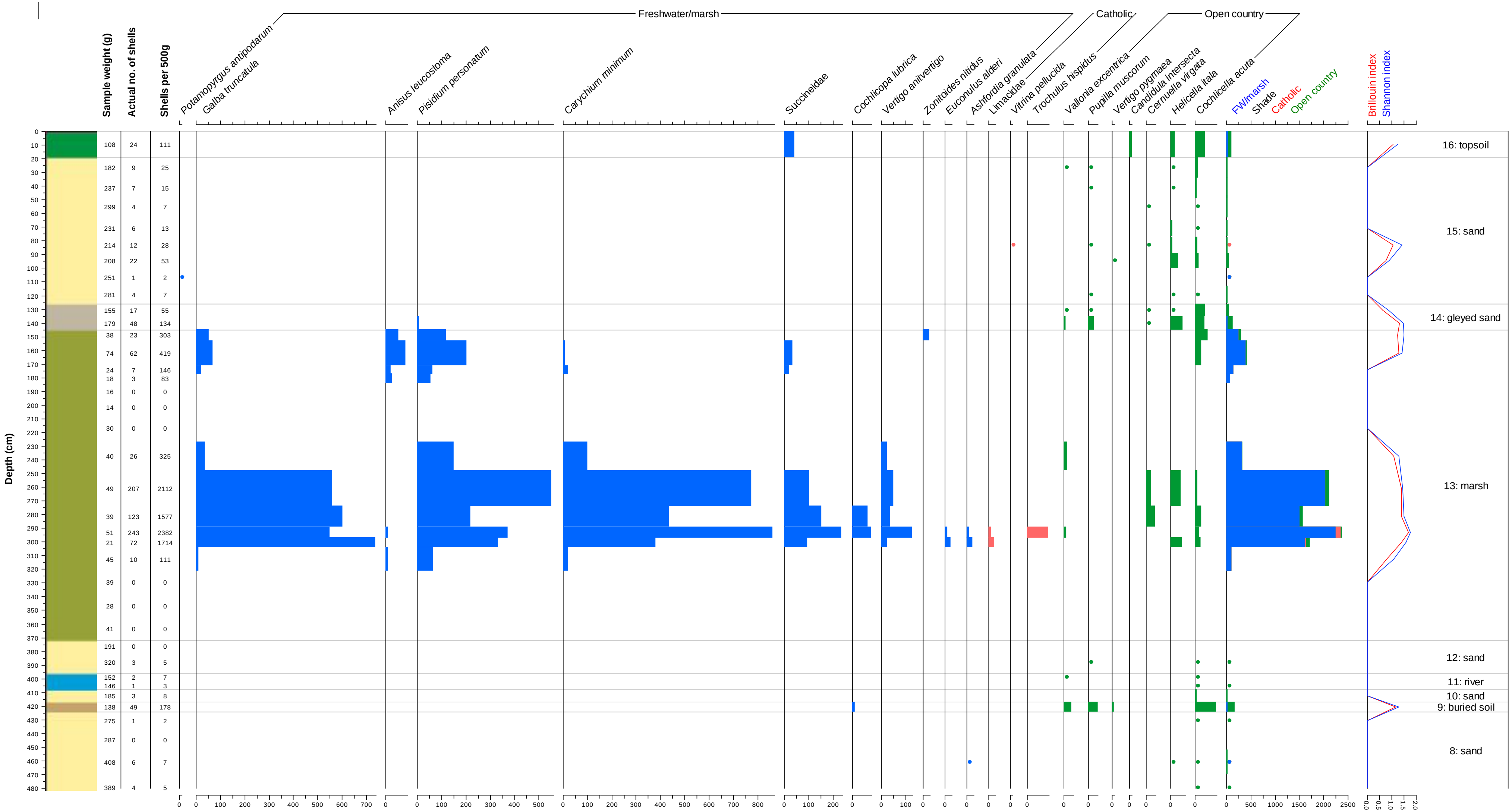


Figure 6.20. Mollusc diagram for the 15m core
No molluscs were found below 483cm

The core location is at the margin of the tall riverbank vegetation and the shorter but rank grass of the meadow between the Red River and the B3301 road (Figure 6.21). Flowering plants include hemp agrimony (*Eupatorium cannabrinum*), creeping cinquefoil (*Potentilla reptans*) and silverweed (*Potentilla anserina*).

Figure 6.21. The 15m core is marked by a white peg in the centre of the photograph.
The long grass at the margin of the taller vegetation is clearly seen

The core reached the killas at a depth of 880cm. Coring with the 5cm tube equipment was only possible down to 600cm and gouges were used for deeper sediments: 6cm to 700cm, 5cm to 740cm and 4cm to 895cm.

The bedrock [1] is killas, as found elsewhere. The basal deposit on the bedrock is a thick layer (346cm) of organic silt [2], although the proportion of organic matter varies considerably at different levels, being low (<10%) in the deeper layers and increasing abruptly to nearly 40% at 852cm depth. At this level the pH drops to 3.4 before rising to around 7.0 and falling again to 5.0 at 689−710cm depth. No molluscs have survived in these silts. There are wood fragments at many levels, as well as reeds/sedges, and a hazelnut was noted at 869−874cm. The findings are entirely consistent with marsh/alder fen. The differing proportions of silt and organic matter indicate that there was regular change in the landscape, with periods when water may have been deeper than at other times, with variable amounts of relatively dry land.

There is abrupt change at 640cm when sand begins to be deposited. The lowest sands [3] are gleyed indicating the persistence of regular flooding or standing water but above this yellow sand [4] shows that the land has dried out. Organic matter almost disappears and carbonate content increases to 40%, although there are still no surviving molluscs, despite the pH being around 9 throughout.

The river channel [5] moves to this location, suggested, as at 0.5m, by increase in grain particle size at 554−556cm (Figure 6.22). The river then moves elsewhere and there is further lens of sand [6] before the river returns to this location [7] (507−510cm). Shells of open country species begin to appear in the next layer of sand [8], although numbers are small and they may be the result of bioturbation from a more stable sand horizon [9] which contains a moderate number of molluscs consistent with a buried soil, with increasing silt but no appreciable change in sediment colour. These shells are of open country species, mainly *Cochlicella acuta*, *Vertigo pygmaea*, *Pupilla muscorum* and *Vallonia excentrica* consistent with newly stable short grassland.

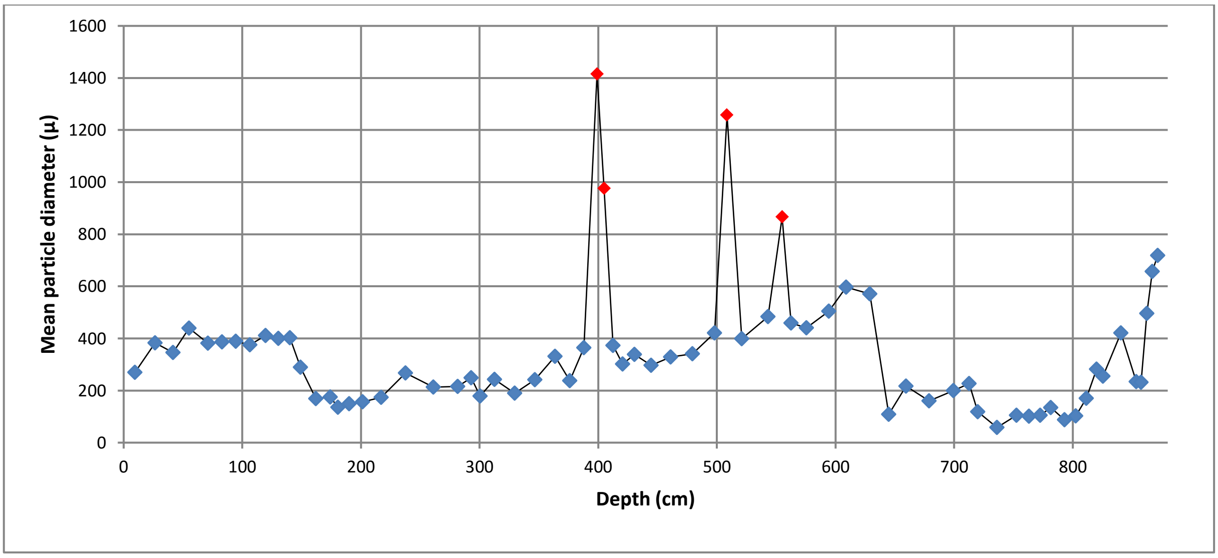


Figure 6.22. The mean particle size for each sample in the 15m core.
The points marked in red correspond to the assumed river sediments at 396–408cm (2 dots), 507–510cm and 554–556cm

There is a further thin horizon of sand [10] before the river moves to this site [11] for the third time (396–408cm), again with high mean particle size (Figure 6.22). Sand [12] covers the river horizon but marsh conditions return [13], with another thick organic silt layer, 227cm in depth. There are no molluscs in the lowest 50cm of this marsh where the pH falls to 6.1, although reeds/sedge are present. In time, conditions change sufficiently for molluscs to thrive in very large numbers, up to 2382 per 500g. These are nearly all wet ground species (mainly *Carychium minimum*, *Galba truncatula*, Succineidae, *Vertigo antivertigo*, *Euconulus alderi*, *Ashfordia granulata* and *Pisidium personatum*) with only very few dry ground shells. The marshy areas with both standing water and some dryer areas found nearer the river clearly extend this far. The pH, having risen to 7.7 in the shell-rich sediments, falls to 4.4 in the higher marsh levels with corresponding absence of shells. The pH then rises again, with return of wet ground molluscs, although in smaller numbers than in the deeper levels. The presence of *Anisus leucostoma* is interesting, as this amphibious mollusc prefers sites with summer drying, strongly implying that the marsh conditions are variable at different times of the year.

Sand covers the organic silt but the lower levels are gleyed [14] although containing xerophilic molluscs, especially *Cochlicella acuta* and *Helicella itala*, indicating some degree of stabilization. The overlying yellow sand [15] generally contains few molluscs despite having a carbonate content of over 40%. Of relevance is the finding of a single specimen of *Potamopyrgus antipodarum*, a freshwater snail introduced into Britain in the mid-nineteenth century and probably washed here from the nearby river. It is noted that this is one of the common species in the modern leet water sample.

The top 19cm of this core [16] contains a few molluscs including Succineidae, *Cochlicella acuta*, and *Helicella itala* consistent with the habitat of long grassland adjacent to tall mixed vegetation. Two shells of *Candidula intersecta* are also present, a species absent from the older, deeper, levels.

This core north of the present river course shows a similar profile to the adjacent 0.5m core, with an initial marshy environment subject to regular flooding from the river. This early marsh is followed by somewhat dryer conditions, only to be succeeded by more marsh. The course of the river is variable, moving here on three occasions, but this seems to be its most northern limit. At no time has there been really stable dry land this close to the river which would have allowed terrestrial molluscs to thrive, and even in modern times there is a very marked absence of molluscs, only four specimens being present in the modern topsoil at 0.5m and three at 15m. Why this should be is unclear, as conditions seem suitable and are currently not acid. However, fluctuation in water table levels or pollution from mining contamination are possible explanations. The very marked acidity of some of the marsh horizons may also be the result of contamination, and will be discussed in Chapter 7 when reviewing the geochemistry of the sediments.

Diatom analysis

This was the only location at which samples were analysed for diatoms. The aim was to see if there was evidence of marine or freshwater diatoms which may have indicated that this area of the valley was estuarine at some time. Six slides prepared in Reading were kindly assessed and interpreted by Dr Nigel Cameron (University College London).

Three samples from the deep marsh layer [2], at 869–874cm, 855–860cm and 758–768cm, all contained similar diatom assemblages with freshwater (mostly acid water) taxa:

Eunotia (e.g. *E. pectinalis* v. *minor*, *E. pectinalis* v. *ventralis*, *E. incisa* and others)
Pinnularia spp.
Cymbella (*Reimeria*) *sinuata*
Frustulia sp.
Tabellaria quadiseptata (possibly *T. fenestra*)
Fragilaria exigua
Fragilaria virescens
Gomphonema parvulum
Achnanthes lanceolata
Cocconeis placentula
Meridion circulare
Diatoma sp.
Navicula perpusilla

At the river level [5], 507−510cm, there were very few valves or fragments but those present included:

Tabellaria flocculosa
Hantzschia amphioxys
Pinnularia cf. *irrotata*
other indeterminate fragments

Diatoms were absent in two more superficial samples: marsh [11], 248−274cm and sand [13], 89−100cm.

Dr Cameron states ‘There is no evidence for marine incursion from these diatom assemblages, with no marine or marine-brackish taxa present. Freshwater taxa with higher salinity optima, e.g. *Rhopalodia gibberula*, *Synedra tabulata*, *Synedra pulchella* are present but rare and do not necessarily indicate any significant increase in salinity.’

The conclusions to be drawn from this limited diatom study support those found in the sediments and the mollusc findings – that the locations studied have never been subject to marine incursion, and that this lower length of the Red River valley was riverine throughout the Holocene, with no evidence that it has ever been a tidal estuary of St Ives Bay.

6.4.1.5 30m core

Grid ref.: SW 58886.42064; modern ground level: 6.71m OD.

Mollusc figures: CD; summary diagram: Figure 6.23; mollusc diagram Figure 6.24.

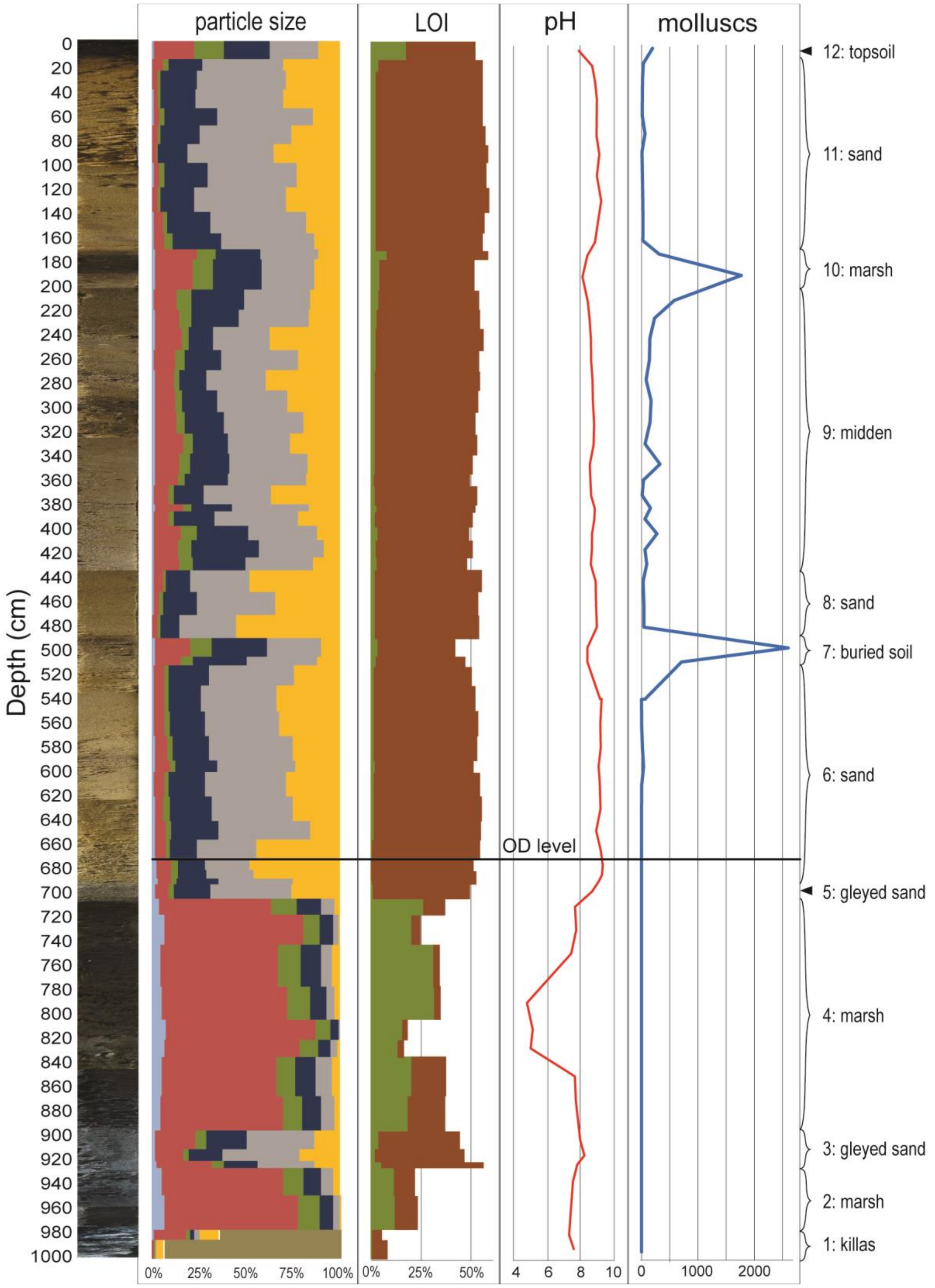


Figure 6.23. Summary diagrams for the 30m core

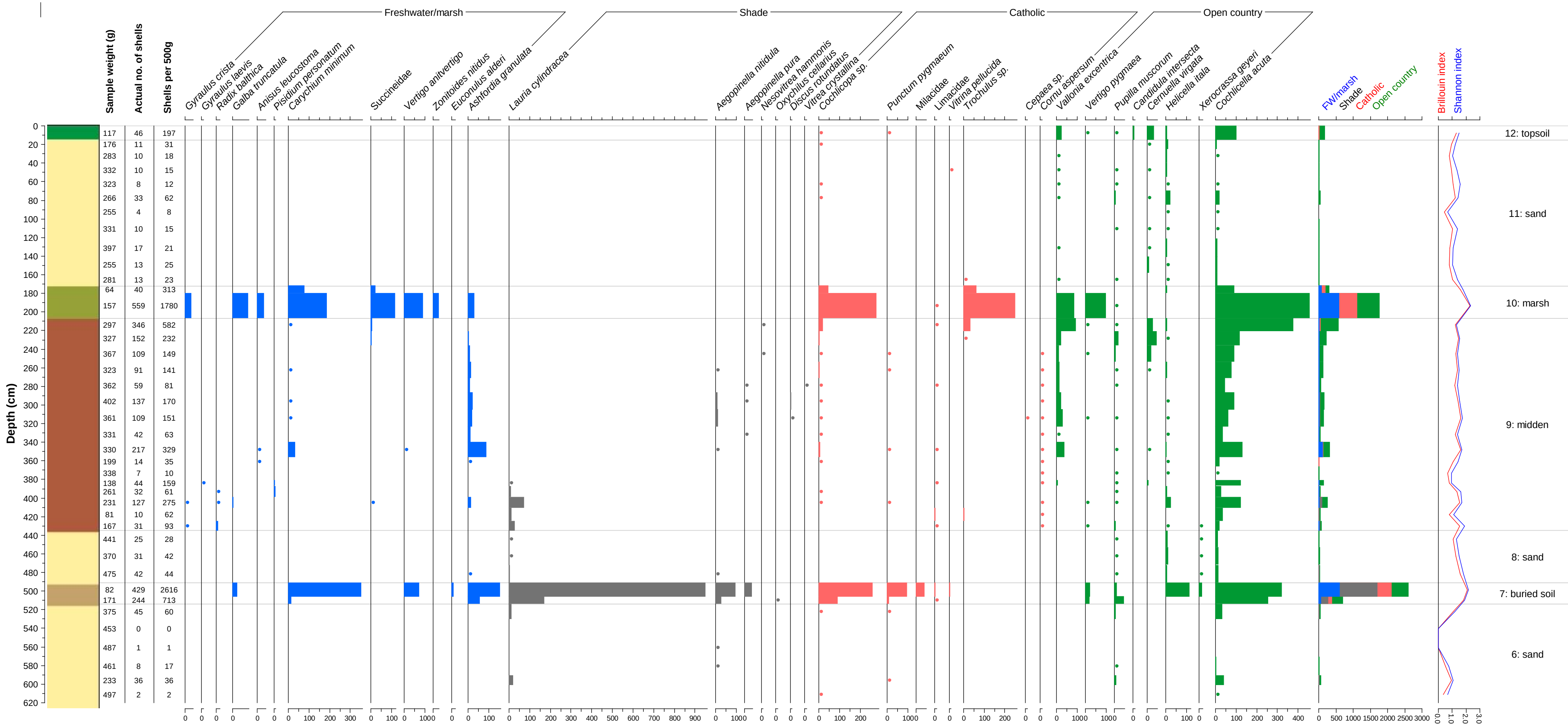


Figure 6.24. Mollusc diagram for the 30m core
There were no molluscs below 621cm

The 30m core is the one on which OSL and radiocarbon dates have been obtained. These will be discussed in Chapter 7, and are not included in the current section in order to maintain consistency in format of presentation for each of the cores.

The core, taken from the meadow just south of the B3301 road, was from an area of tussocky grass growing to a height of about 30cm, and therefore providing moderate shade (Figure 6.25). Lady's bedstraw (*Galium verum*) and common knapweed (*Centaurea nigra*) were found flowering in the immediate vicinity. The turf contained a high number of individual shells (289 per 500g) and the highest number of taxa (17) of any site, as well as the highest species diversity (Shannon index 2.35); there is a good range of taxa with differing ecological preferences. The meadow here has not, in recent years, been regularly grazed or cultivated and it may be that the lack of disturbance has allowed the very rich fauna to develop. This assemblage is in distinct contrast to the absence of molluscs at the 15m location; the 30m site is on a slight elevation, with the ground level 1.16m higher than the 15m position, and therefore less liable to flooding. This elevation may have allowed the immediate surroundings to be spared the effects of regular inundation from the Red River.

Figure 6.25. The 30m core site showing rank tussocky grass but no taller vegetation

The percussion core reached killas [1] at a depth of 977cm. The basal sediment is 51cm of organic silt [2], likely to be marsh, and is overlain by 30cm of gleyed sand [3]. There is no equivalent sandy layer in the 0.5m or 15m cores and it is therefore likely that this position represents the margin of dryer land adjacent to the earliest river bank. The sand is overlain with a thick layer of organic silt [4] containing wood and reeds, more abundant in the upper than the lower portion and is interpreted as marsh. The pH at the top and bottom is between 7 and 8, but falls to 4.8 centrally.

The marsh is covered with a 191cm deposit of blown sand, a thin basal 12cm of which is gleyed [5] indicating continued flooding, while the majority is yellow sand [6]. Molluscs have survived in the upper half of the sand, although few in number indicating instability. Mollusc numbers increase at the top of this sand which is overlain by a buried soil [7], with an increase in proportion of silt. This deposit is very rich in molluscs, both in terms of numbers (up to 2616 per 500g) and of taxa (19 species) and with high diversity (Shannon index 2.17 in the upper half). The assemblage includes taxa from all habitat groups. *Carychium minimum*, *Galba truncatula* and *Vertigo antivertigo* imply wet ground, but this is probably intermittent. There are large numbers of open country and catholic species with a few, such as *Aegopinella nitidula*, requiring some shade, such as that found at the base of rank vegetation. *Pupilla muscorum*, an early colonizer of rough ground, is present but *Vallonia excentrica* is absent, implying that the ground was not grazed. The remarkable mollusc in this deposit is *Lauria cylindracea*, which accounts for over a third of all shells present, in contrast to adjacent cores where this species was not found. Although classified in Figure 6.24 as a shade species, *Laura* is a mollusc characteristically associated with stone walls (Evans 1972, 151). The presence of field walls close to the river which, at the time *Lauria* is abundant, was probably at the 0.5m location, seems probable. They may have been constructed along the line of the river, perhaps for stock control.

This stabilization horizon is overlain by a blown sand layer [8] with relatively few molluscs, although still with a *Lauria* presence. Small numbers of the mollusc *Xerocrassa geyeri* are present in this sand, but in insufficient numbers to draw conclusions about whether they are autochthonous to this layer or intrusive from a lower deposit.

Above this is a thick (228cm) deposit of sand [9] but with different characteristics. There is slightly more silt than in the lower sand. *Lauria cylindracea* disappears and is replaced by *Vallonia excentrica* which is absent at all deeper levels, and with only a few *Pupilla muscorum* suggesting that there may have been short grassland at this time. Totally different from the deposits above or below is the presence of numerous marine molluscs and other marine faunal fragments. Mussels (*Mytilus* sp.), limpets (*Patella* sp.) and dog whelks (*Nucella lapillus*) are present throughout. At one level (381–387cm) mussels comprise nearly 9% by weight of the whole sample. There are barnacle plates and fish bones and scales in some samples. The consideration of marine incursion over this period to account for the marine molluscs can be discounted as there are virtually no small marine shells; non-marine molluscs could not survive in a saline environment and it is very unlikely that they are all allochthonous. Animal bone fragments, not identifiable to species but of a size consistent with pig or sheep, are present at most levels with wood charcoal in two samples. Overall, the faunal assemblage indicates the deposition of midden material. There is no evidence of similar material in the 15m or 51m cores, so this midden was presumably limited in extent. There is evidence of further middens on the dune containing the post-Roman industrial structures, only 50m away, where mussel shells are regularly brought to the surface by rabbit activity (Figure 6.26).

Figure 6.26. Mussel shells brought to the surface by rabbits burrowing into the post-Roman site

The midden was covered by marsh [10], with a very large number of molluscs (1780 shells per 500g, 15 taxa) and high diversity (Shannon index 2.34), evenly split between wet ground, catholic and open country taxa, but with no shade species. The wet ground molluscs include *Carychium minimum*, *Galba truncatula*, *Anisus leucostoma*, Succineidae, *Vertigo antivertigo*, *Zonitoides nitidus* and *Ashfordia granulata* as well as one true freshwater mollusc, *Gyraulus crista*, which does not tolerate drying. There are good numbers of catholic (*Cochlicopa* spp., *Trochulus* sp.) and open country (*Vertigo pygmaea*, *Vallonia excentrica*, *Cochlicella acuta*, *Cernuella virgata*, *Helicella itala*) species. This very varied assemblage shows that the local habitat was likely to be swampy with pools of open water and areas of marsh, but with some permanently dry ground. The core position was probably at the margin of wet and dry ground, with grazed land uphill leading to the meadows below the scarp of the towans and marsh with some standing water extending downhill in the river valley. The GPR scan (Figure 6.5) reflects both the upper and lower limits of this horizon.

A further deposit of windblown sand [11] covers the marsh. Molluscs are scarce implying instability, those present all being open country species indicating that the ground is now dry with no evidence of marshland. The topsoil [12] is more stable, with open country molluscan species. The likely medieval introduction, *Candidula intersecta*, is present in this horizon but at no lower level. The topsoil sample, at 15cm thick, contains fewer molluscs than the modern 4–5cm turf sample, both in numbers and species, indicating that true stability was only established in the very recent past.

6.4.1.6 51m core

Grid ref.: SW 58886.42085; modern ground level: 5.61m OD.

Mollusc figures: CD; summary diagram: Figure 6.27; mollusc diagram: Figure 6.28.

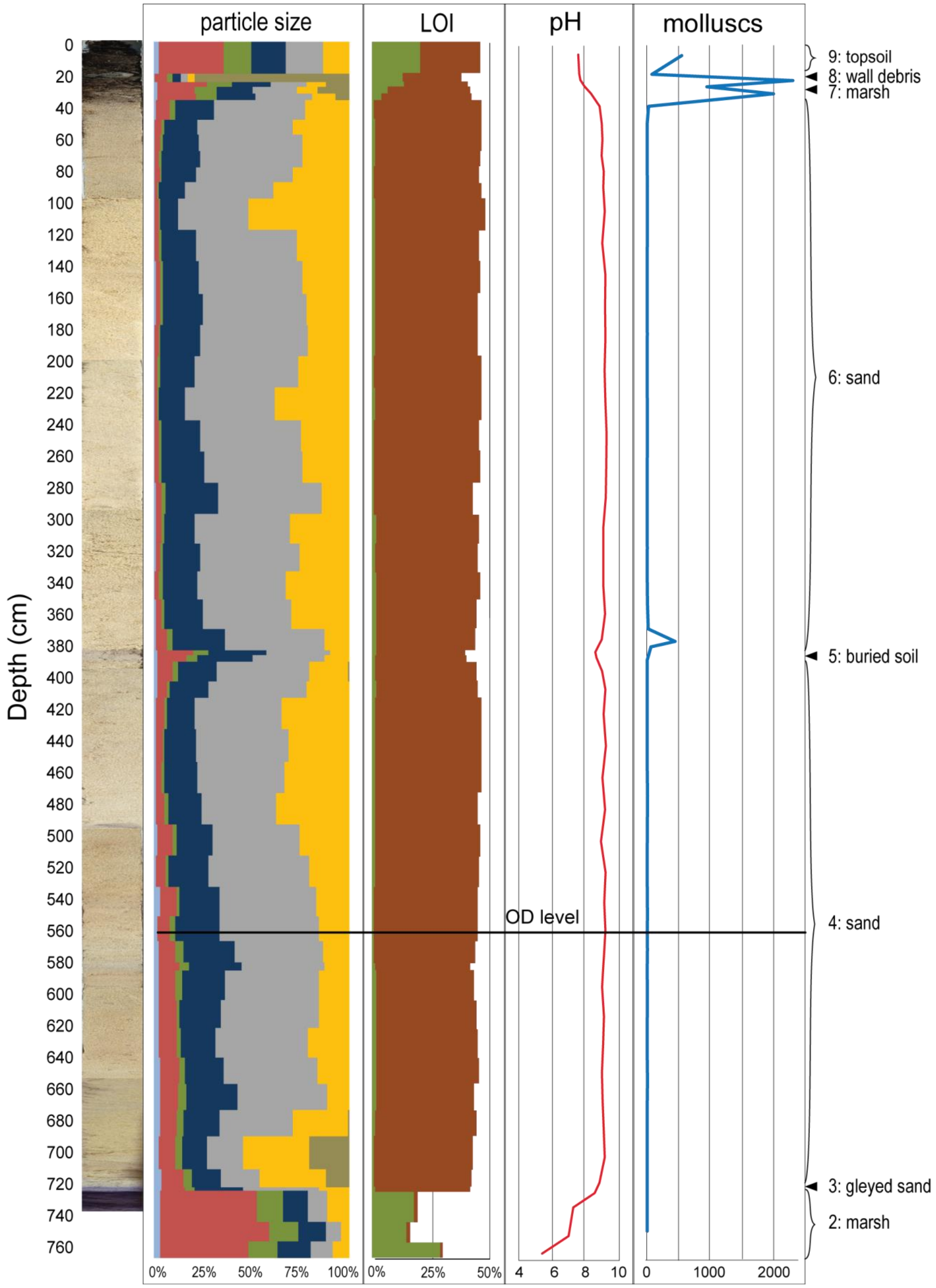


Figure 6.27. Summary diagrams for the 51m core

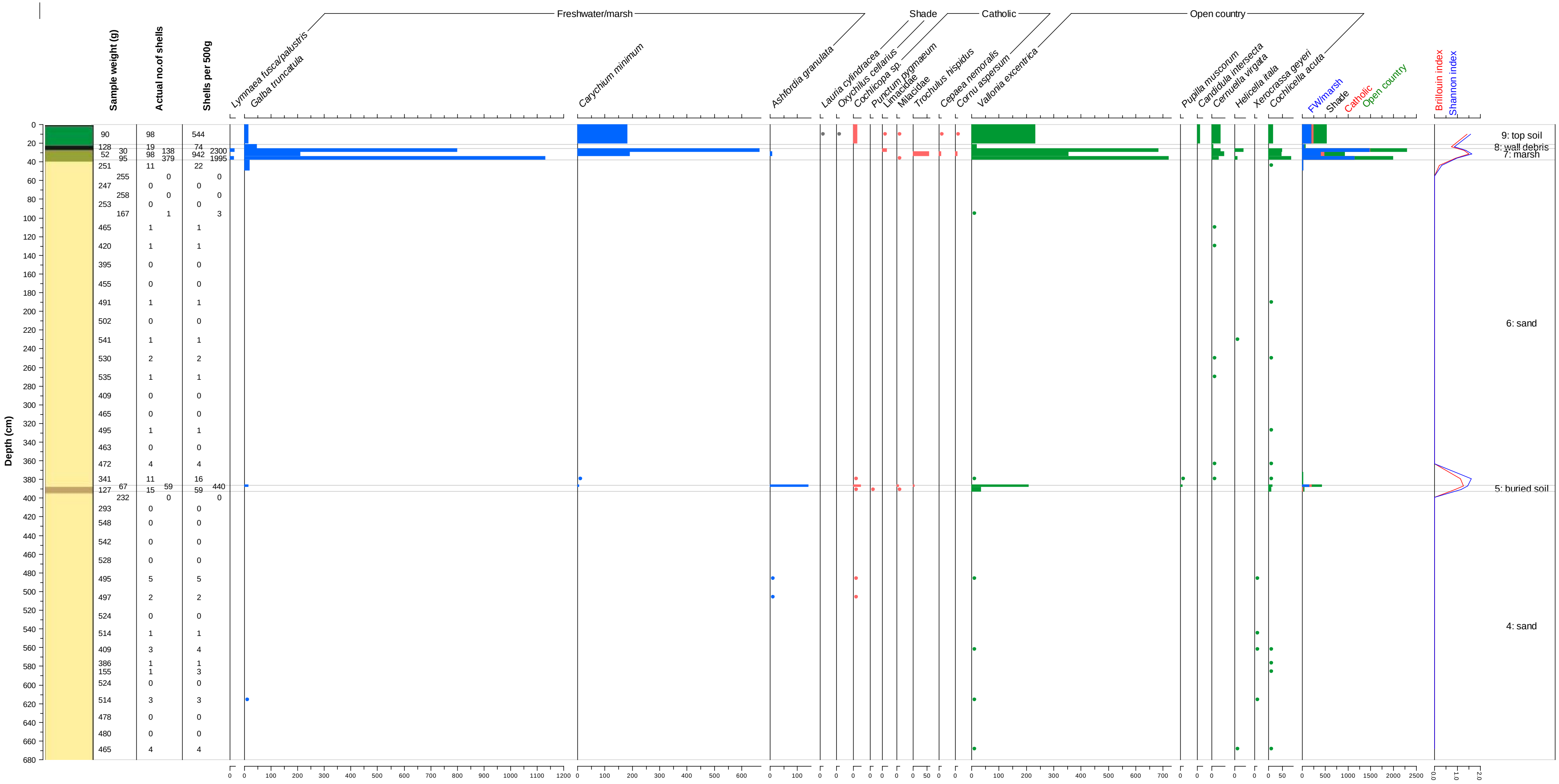


Figure 6.28. Mollusc diagram for the 51m core
There were no molluscs below 677cm

The position of the 51m core is close to the north side of the 'Cornish hedge' running along the northern side of the B3301 road (Figure 6.29). Cornish hedges consist of stone walls on either side with infilling of earth. Its height (140cm) is such that the ground close to its north face is continually in shade with very little direct sunlight. Tall vegetation between it and the core site consists largely of tall grasses, rose bay willowherb (*Chamerion angustifolium*), rough chervil (*Chaerophyllum temulum*), mare's tail (*Hippuris vulgaris*) and dock (*Rumex* sp.). There is a slight depression in the ground surface at this point, such that it remains waterlogged with standing water for much of the winter (Charles Thomas, pers com), allowing the mare's tail to thrive. This wetness is reflected in the molluscan fauna, where *Carychium minimum* accounts for 49% of all shells present in the turf, and there is a single shell of *Galba truncatula*, a marsh species tolerant of regular moderate desiccation. There are good numbers of *Vallonia excentrica*, normally a short grassland species although occasionally found in wetter situations (Evans 1972, 162), and *Trochulus hispidus* (a catholic species), but only small numbers of other taxa and it is possible that some or all of these dry ground shells are allochthonous, having been blown or washed into this low-lying area from elsewhere.

Figure 6.29. The 51m location (white peg) showing the Cornish hedge and tall vegetation

Bedrock was not reached in this core. The lowest sediment obtained was organic silt [2] at 769cm, with an acidic pH (down to 5.3) which almost certainly corresponds to the region of low pH found in the 30m core. The silt is overlain by a thick (336cm) sand layer, the lowest 4cm of which is gleyed [3] while the remainder [4] is yellow sand. This sand contains only very sporadic molluscs of all habitat types. This sparse assemblage suggests that the sands were unstable most of the time during accumulation and these few shells may be allochthonous.

A probable 7cm buried soil is present at 386−393cm [5] with higher silt levels, corresponding to zone [7] in the 30m core and representing a phase of stabilization. A moderate number of molluscs is present, with a mixture of wet ground, catholic and open country species, although notably there are no *Lauria cylindracea* present and the absence of this species only 20m from the location where they were the dominant taxon may be due to the hypothetical structures on which they were living being very localized.

The buried soil is covered by another thick (348cm) layer of blown sand [6] which is almost devoid of molluscs implying continual instability. This sand is capped by a more silty sediment [7] containing very large numbers of wet ground molluscs (up to 2300 per 500g), notably *Galba truncatula* and *Carychium minimum*, as well as grassland species, mainly *Vallonia excentrica*. The assemblage suggests that this land was swampy but subject to drying and is very similar to the modern turf, implying that there has been little change in the local conditions in the recent past. The surrounding slightly higher ground was more continuously dry and probably grazed, which may well account for the open country species.

The 21−26cm horizon in this core [8] is different from any other near-surface horizon in that it contains a large proportion of stones, some of which are fragments of slate cut by the core tube (Figure 6.30). Molluscs are few and it seems almost certain that the stones are debris from the building of the adjacent Cornish hedge when the road was stabilized, probably in the mid/late nineteenth century.

Figure 6.30. The upper 44cm of the 51m core showing the slate fragments from the Cornish hedge

The topsoil [9] contains a moderate number of molluscs of both wet ground (mainly *Carychium minimum*) and open country (mainly *Vallonia excentrica*) taxa consistent with the present regular waterlogging, but adjacent to grazed grassland.

In summary, this core, with marsh only in its lowest levels, indicates that this location was close to the northern limit of the wet river basin. It is almost entirely sand, containing virtually no molluscs implying continual instability over a long period of time, with only one brief episode of greater stability. Sufficient silt to permit a rich molluscan fauna to develop only accumulated in very recent times, and with a significant wet ground component consistent with localized regular ponding.

6.4.1.7 76m core

Grid ref.: SW 58886.42110; modern ground level: 7.12m OD.

Mollusc figures: CD; summary diagram: Figure 6.31; mollusc diagram: Figure 6.32.

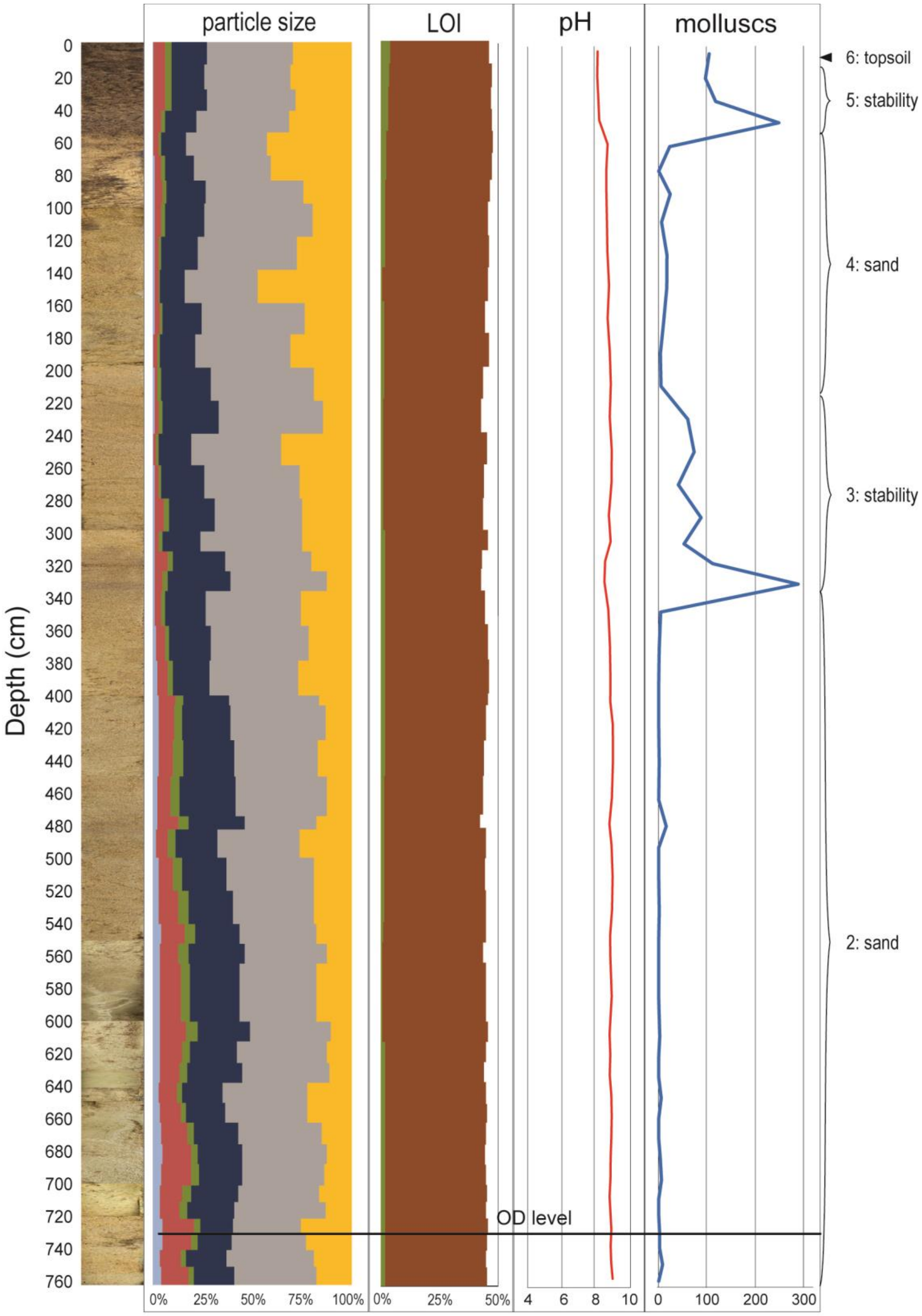


Figure 6.31. Summary diagrams for the 76m core

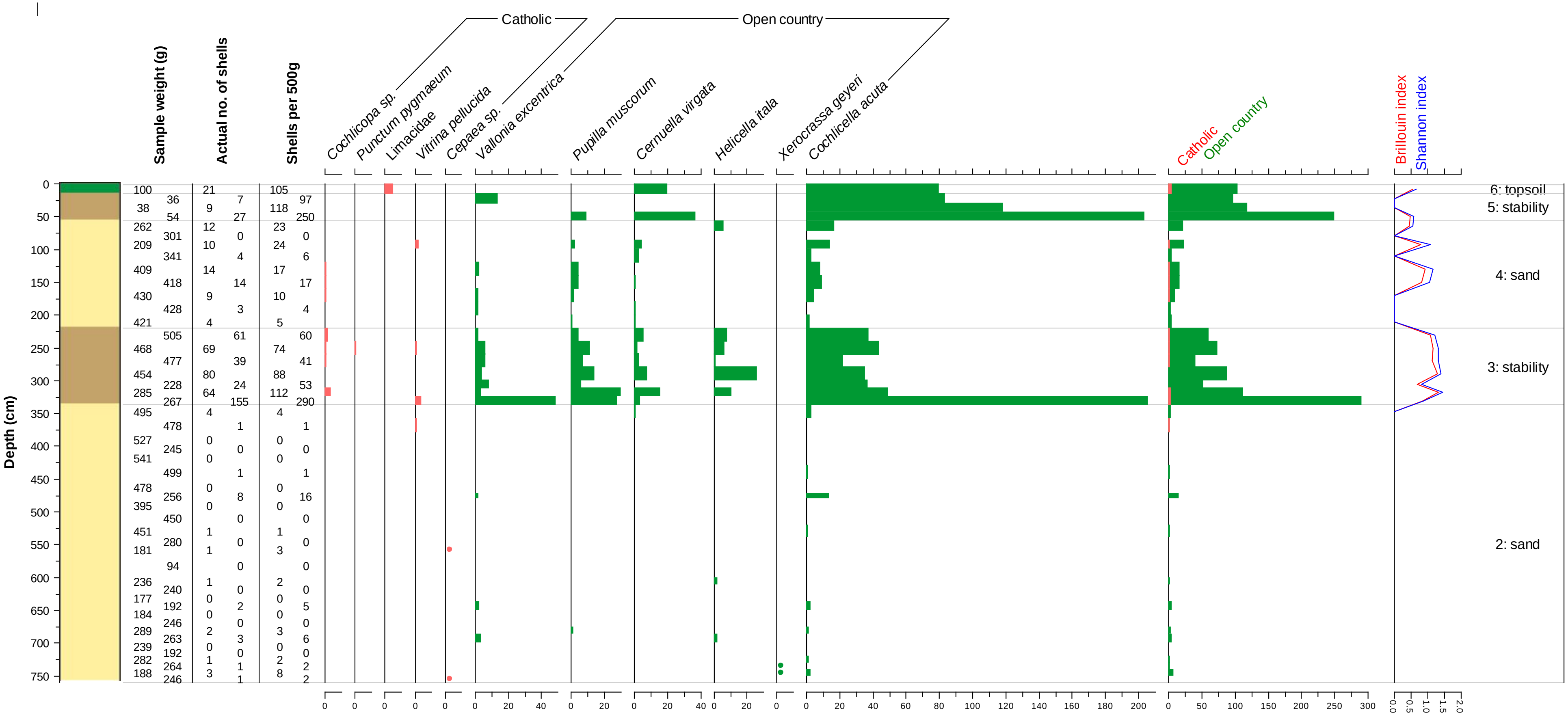


Figure 6.32. Mollusc diagram for the 76m core
There were no molluscs below 750cm

The 76m core was obtained part-way up the slope of the west end of the large sand dune on which are the post-Roman buildings excavated by Charles Thomas in the 1960s (Figure 6.33). The core location was on the rise of ground near the terminus of the dune at an elevation of around 1m above the surrounding pasture, and is currently vegetated with short grasses as well as some lady's bedstraw (*Galium verum*), wild thyme (*Thymus polytrichus*), sheep's fescue (*Festuca ovina*) and moss. The turf molluscs are almost entirely open country species as might be expected. Coring was only successful to 760cm as the sand at this depth was so wet that it was not retained in either core tubes or gouges, the latter being used below 540cm. Depths containing organic silt, if they ever extended this far from the river, were not reached. Of importance is that, at least in the area investigated at the westernmost end of the dune, this very prominent mound in the landscape appears to be sand throughout, with no evidence that it has accumulated on a rocky spur.

Figure 6.33. The sand dune with the post-Roman settlement viewed from the north west. The location of the 76m core is marked by a red dot

The lower half of this core (337–760cm) is blown sand [2] with only scattered open country shells. There are slightly more molluscs at 474–482cm than elsewhere which may indicate a brief episode of relative stability. The sand from 220–337cm has been called a buried soil [3] on the basis of the much greater number of shells present at each level indicating stabilization, rather than on any change in the physical characteristics of the sand, which are no different from the sands above and below. The molluscs are almost entirely xerophilic species with *Cochlicella acuta* strongly predominant, with *Pupilla muscorum*, *Vallonia excentrica*, *Cernuella virgata* and *Helicella itala* also present as well as a few with more catholic tolerances, but no taxa requiring shade. This is clearly a period of stability, although a soil has not developed. If the late medieval date for the introduction of *Cernuella* is accepted then its presence down to a depth of 330cm indicates that much of the sand at this end of the dune has accumulated in recent centuries, and the extend of the dune may have been much smaller during the post-Roman activity.

Instability returns with further blown sand [4] containing few molluscs; this is overlain by another period of stability [5], although with far fewer molluscs – entirely open country – than in the lower mollusc-rich level. The topsoil [6] also contains open country species as well as a single Limacidae plate. These upper layers are consistent with the bare grassland now present, but the absence of *Vallonia* in the topmost 15cm, although present in the turf sample, implies that only recently has this dune been covered in short grazed grass.

6.4.1.8 The meadow – 100m to 245m

The cores from 100m to 245m were obtained across the gently sloping meadow below the scarp of Godrevy Towans (Figure 6.34). The ground is much disturbed by rabbit burrows, and the meadow is regularly grazed by cattle and sheep. A wide variety of meadow plants are present:

Dock (*Rumex* sp.)
Creeping cinquefoil type (*Potentilla reptans*)
Yellow vetchling (*Lathyrus aphaca*)
Rest harrow (*Ononis spinosa*)
Bird's foot trefoil (*Lotus corniculatus*)
Clover (*Trifolium* sp.)
Lady's bedstraw (*Galium verum*)
Wild thyme (*Thymus polytrichus*)
Ribwort plantain (*Plantago lanceolata*)
Creeping thistle (*Cirsium arvense*)
Smooth sow-thistle (*Sonchus oleraceus*)
Few-leafed hawkweed (*Hieracium umbellatum* agg.)
Sea couch grass (*Elytrigia juncea*)
Sheep's fescue (*Festuca ovina*)
Sphagnum moss (*Sphagnum* sp.)

Figure 6.34. View across the meadow with the slope of Godrevy Towans in the background

The modern turf molluscs across the meadow show a fairly consistent pattern with a good number of shells, nearly all of which are those associated with this type of pasture. *Vallonia excentrica* is dominant at almost all locations, but with *Vertigo pygmaea*, *Cochlicella acuta* and *Helicella itala* strongly represented. These assemblages are entirely consistent with the grazed grassland of the meadow which abounds with rabbit burrows and is regularly browsed by sheep and cattle.

6.4.1.9 100m core

Grid ref.: SW 58886.42140; modern ground level: 6.35m OD.

Mollusc figures: CD; summary diagram: Figure 6.35; mollusc diagram: Figure 6.36.

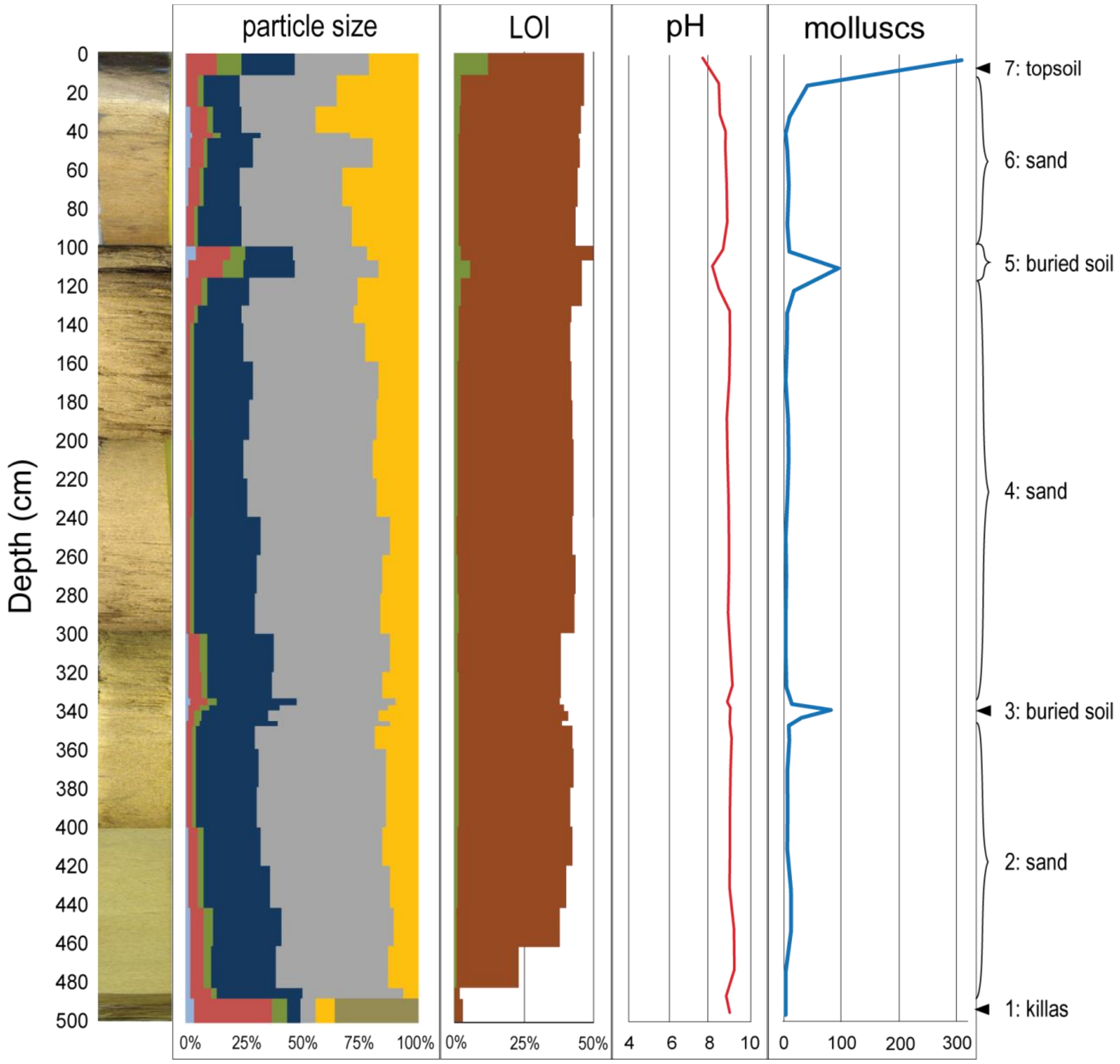


Figure 6.35. Summary diagram for the 100m core

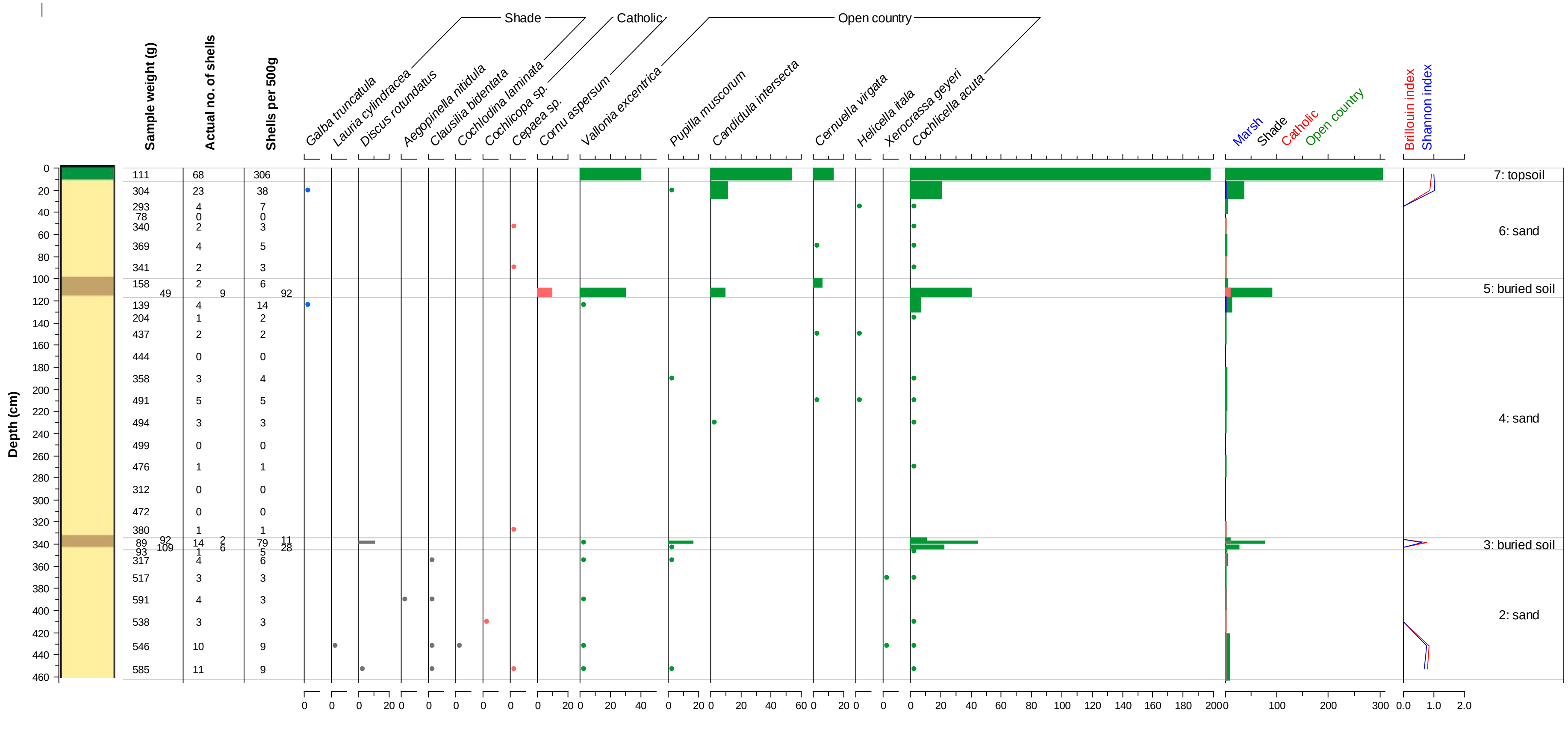


Figure 6.36. Mollusc diagram for the 100m core
There were no molluscs below 462cm

The 100m core reached bedrock [1] at a depth of 489cm, well seen on the GPR (Figure 6.4), and overlain with sand [2] containing an assemblage of mollusc species of varying habitat requirements. Of interest is the presence of *Discus rotundatus*, *Clausilia bidentata* and *Cochlodina laminata*, all species associated with leaf litter and shade, perhaps suggesting woodland or scrub in the near vicinity during the time that this sediment was deposited. While the shade-loving molluscs may be intrusive due to bird or animal movement their association and the lack of any wet ground species makes an autochthonous explanation more likely. *Clausilia* was found in the modern turf samples at 30m (long grass), at 345m (bare ground) and at 400m (marram grass) but *Discus* and *Cochlodina* were not present in any turves. Open country species are also present here indicating that this was probably open scrub or woodland.

A stabilization horizon with buried soil [3] is indicated by the slight increase in silt proportions and of molluscs, the latter being mostly open country taxa, but again with two specimens of *Discus rotundatus* suggesting that the wood/scrub persisted in the area. A possible interface on the GPR corresponds to this horizon (Figure 6.5). Deep sand [4] covers the soil which contains very few open country shells and single *Galba truncatula*, a wet ground mollusc probably deposited here by wind or birds. This sand is overlain by another buried soil [5], with increase in clay, silt and organic matter. Shells remain scarce, again open country, but with a single catholic shell, *Cornu aspersum*.

Further blown sand [6] represents another period of instability with few shells except in its uppermost portion where there is an increase in xerophilic species, especially *Cochlicella acuta* and *Candidula intersecta*. Another *Galba truncatula* is almost certainly allochthonous. The topsoil [7] contains solely open country taxa, with *Vallonia excentrica* reappearing consistent with the current grazed grassland on the site.

6.4.1.10 125m core

Grid ref.: SW 58886.42159; modern ground level: 6.34m OD.

Mollusc figures: CD; summary diagram: Figure 6.37; mollusc diagram: Figure 6.38.

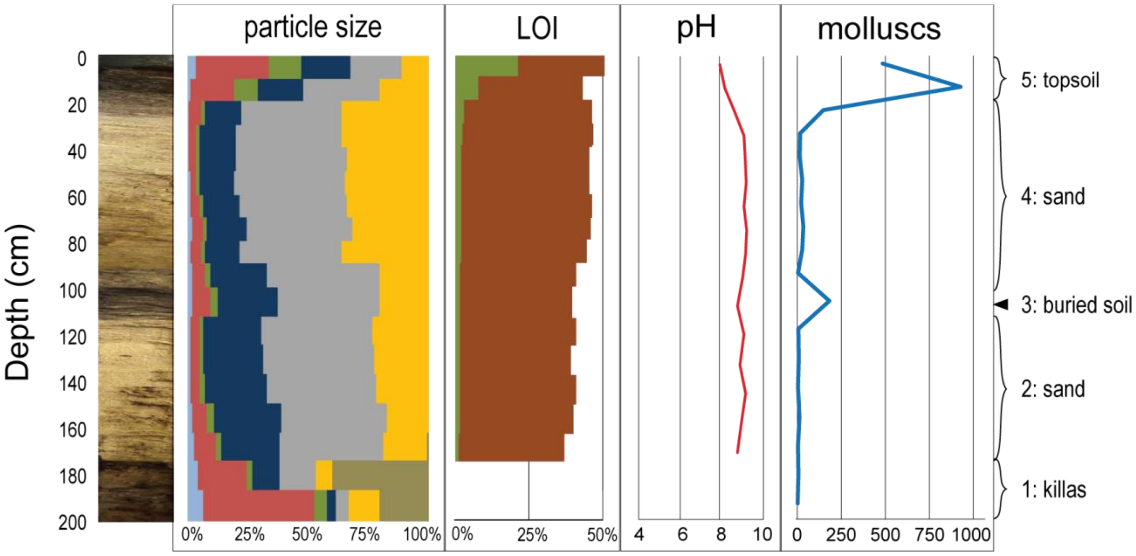


Figure 6.37. Summary diagram for the 125m core

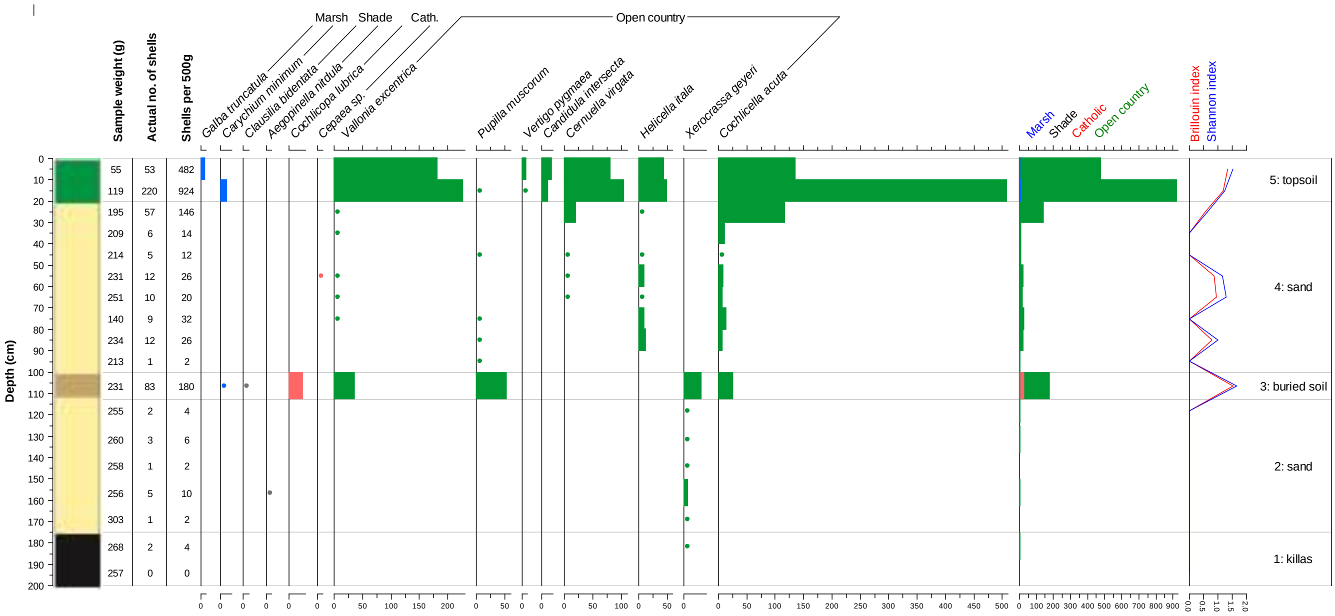


Figure 6.38. Mollusc diagram for the 125m core

Bedrock [1] was found at a depth of 175cm. Blown sand [2] covers the killas for a depth of 62cm with no trace of any buried soil. A few shells are present in this sand, entirely *Xerocrassa geyeri* apart from a single *Aegopinella nitidula*, indicating open ground. This sand is overlain by horizon [3] which has a slight increase in silt at 100–113cm, implying a stabilization zone with a buried soil. It contains a high number of shells, nearly all open country taxa, and is the highest level containing *X. geyeri*. The catholic

Cochlicopa lubrica is well represented and there are single specimens of *Clausilia bidentata* and *Galba truncatula*, the likely presence of which in this meadow habitat has been discussed under the 100m core.

The sand overlying this buried soil [4] contains a few more molluscs than at 100m, all open country species, with high numbers of *Cochlicella acuta* in the uppermost level. The topsoil [5] is rich in shells, again all open country except for three *Carychium minimum* and one *Galba truncatula* which are probably allochthonous. *Vallonia excentrica* is abundant while there is only a single specimen of *Pupilla muscorum*, entirely consistent with grazed grassland.

A broken Mesolithic flint blade was found in the basal sediment of this core (Figure 6.39). Blades and microliths have previously been described from Gwithian (Thomas 1958; Roberts 1987; Thomas 2007), although none are recorded from the area of the later Bronze Age settlement or in the meadow in the region of the coring transect (Sturgess 2004, Fig. 5) .

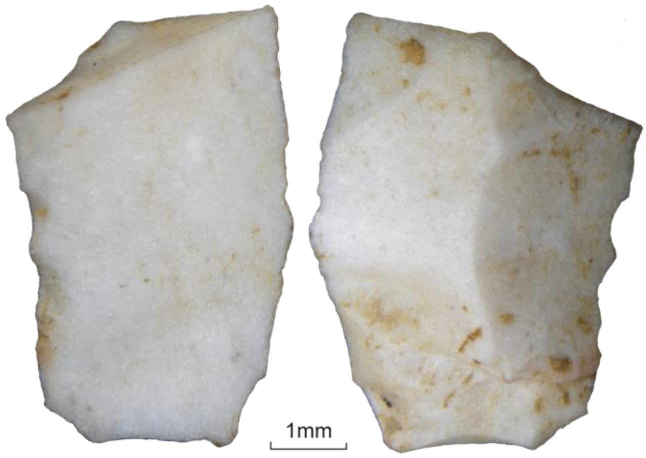


Figure 6.39. The flint blade found at the base of the 125m core

6.4.1.11 150m core

Grid ref.: SW 15889.42184; modern ground level: 8.03m OD.
Mollusc numbers: CD; summary diagram: Figure 6.40.

This core will only be mentioned briefly, as it is the location of the trench which was excavated in 2012 which is fully discussed in the Chapter 7.

The percussion core, obtained in 2011, reached a depth of 175cm, with bedrock at approximately 110cm; the exact level was difficult to determine as there was gradual increase in the proportion of gravel below 91cm, unlike other cores where there was a clear-cut change in appearance and sedimentology. What was clear is an increase in silt and in the number of molluscs at 69–82cm, consistent with a buried soil.

A further slight increase in molluscs at 91–100cm may indicate a further buried soil. Many fragments of mussel shell and some charcoal were found in the 69-–82cm sample.

When the decision was made to excavate a small trench this location was selected partly on the basis of the above findings but also because this position is just outside the area of the post-Roman field system excavated in the 1960s. The core findings will not be discussed further, as considerably more detail was obtained from the trench excavation.

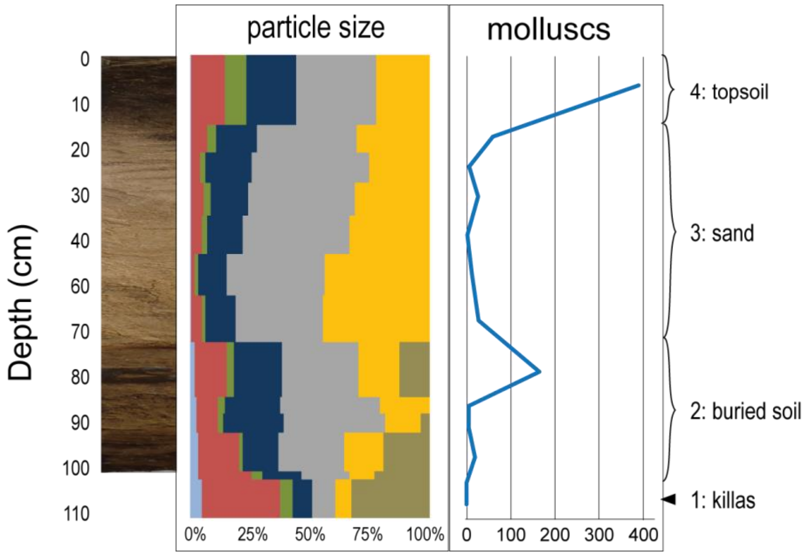


Figure 6.40. The particle size diagram and mollusc graph for the 150m core

6.4.2 Hand auger cores

Thirteen hand auger cores were obtained from the meadow between 175m and the summit of Godrevy Towans at 582m. Initially cores were taken with a 2.5cm gouge and the particle size and loss on ignition measurements were made on those; the cores were later repeated using a 5cm gouge to obtain additional material for mollusc analysis and the mollusc graphs and diagrams use the numbers from those larger cores.

pH graphs have not been included in the summary diagrams for the hand auger cores; the pH for every sample ranged between 7.1 and 8.8, with very little variation within each core. In no sample did pH fall into the acidic range, unlike many of the deeper samples in the percussion cores. The pH figures are, however, included on the CD (Appendix 6).

6.4.2.1 175m core

Grid ref.: SW 58886.42209; modern ground level: 9.51m OD.

Mollusc figures: CD; summary diagram: Figure 6.41; mollusc diagram: Figure 6.42.

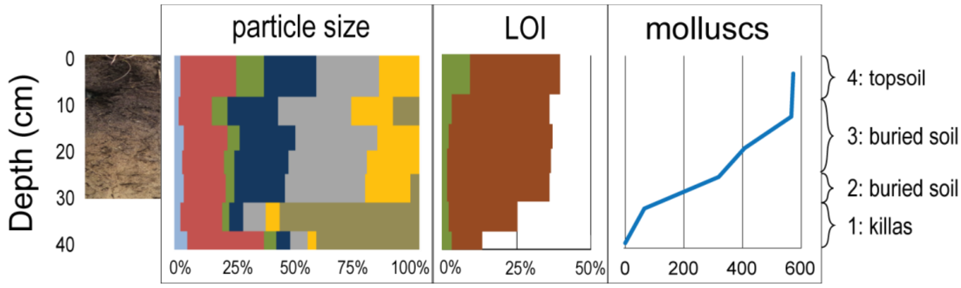


Figure 6.41. Summary diagram for the 175m core

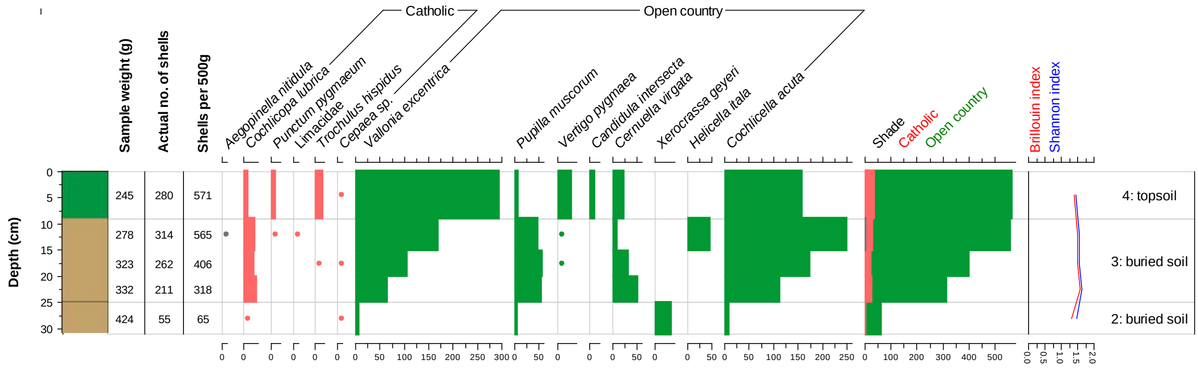


Figure 6.42. Mollusc diagram for the 175m core

This core is located within the area of the field system in the meadow to the west of the Bronze Age and post-Roman settlements at Gwithian (Figure 5.22), excavated in the early 1960s (Fowler and Thomas 1962). The core reached the underlying killas [1] at a depth of 31cm with the sediments above this [2, 3] being very consistent in particle size. There were numerous fragments of mussel shells (*Mytilus* sp.) in all levels below 9cm, especially at 25–31cm, together with scallop fragments (*Pecten* sp.) below 20cm and with dog whelk (*Nucella lapillus*) and limpet (*Patella* sp.) shells below 25cm. These findings, together with some charcoal in the lower levels, are consistent with manuring of the fields, probably with seaweed from the beach and some midden material, as proposed by Fowler and Thomas (1962). Mollusc numbers are poor in the lowest sediment [2] but increase considerably above 25cm [3]. *Vallonia excentrica* in particular becomes more and more evident as the sediments accumulate, while there is a corresponding decrease in *Pupilla muscorum*, consistent with change from arable to grazing over time. However considerable caution is needed with this interpretation as ploughing will have resulted in marked bioturbation aided and abetted by rabbit activity. The presence of high numbers of *Xerocrassa geyeri* in level [2] with none higher up indicates that this lowest deposit is relatively undisturbed and reflects Bronze Age activity. *Cernuella virgata* then replaces *Xerocrassa* [3], entirely consistent with these upper levels of the field system being post-Roman in age. *Candidula intersecta*, considered to be a medieval introduction, is only found in the topsoil sample.

Vallonia excentrica is markedly dominant in the topsoil [4], as in the modern turf sample, while *Pupilla muscorum* is hardly represented, and was not found in the turf sample, all consistent with the present grazed grassland.

6.4.2.2 200m core

Grid ref.: SW 58887.42234); modern ground level: 11.71m OD.

Mollusc figures: CD; summary diagram: Figure 6.43; mollusc diagram: Figure 6.44.

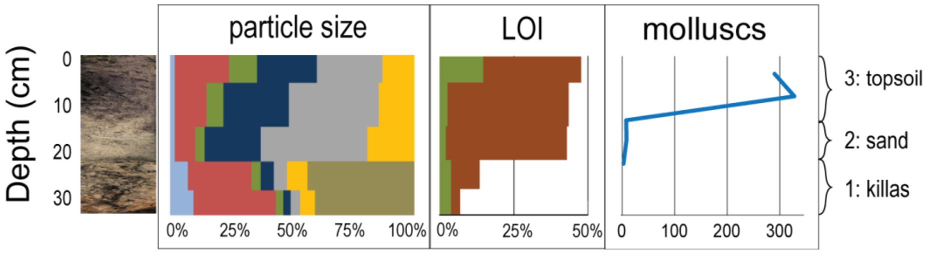


Figure 6.43. Summary diagram for the 200m core

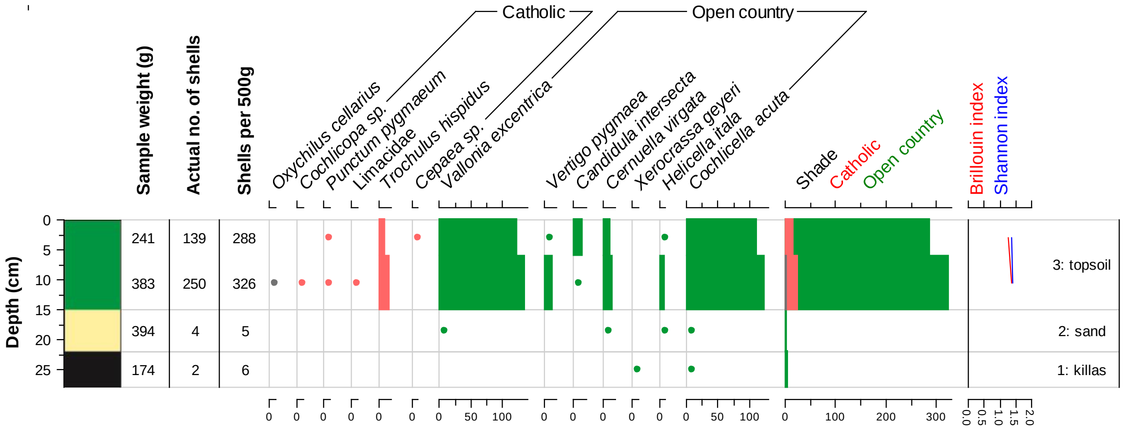


Figure 6.44. Mollusc diagram for the 200m core

This core is also within the post-Roman field system, and is on the northern edge of a modern grassy trackway running east-west across the meadow. The sand is very shallow, with the killas [1] being reached at 22cm.

The sand [2] contains very few shells but the topsoil [3] is rich in molluscs, mainly xerophilic species, and entirely consistent with the medium height grazed grass now present. Of interest is that no *Pupilla muscorum* were found in these samples, despite the large number of shells. *Oxychilus cellarius*, a shade species, can live at the base of vegetation, or could have been deposited at this site by aeolian action or by animals.

Although within the confines of the field system described by Fowler and Thomas (1962) the findings differ from those at 175m, also within the field. Molluscs are only present in any number much nearer to the surface in the topsoil. Whether this area was more unstable than that further from the scarp of the towans or was less intensively used for agricultural purposes so that soils were less able to form, cannot be determined.

6.4.2.3 225m core

Grid ref.: SW 58886.42259; modern ground level: 14.46m OD.

Mollusc figures: CD; summary diagram: Figure 6.45; mollusc diagram: Figure 6.46.

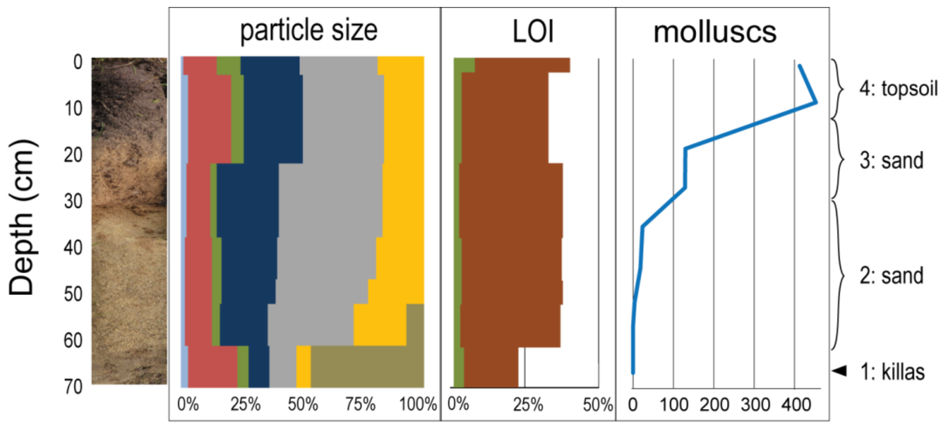


Figure 6.45. Summary diagram for the 225m core

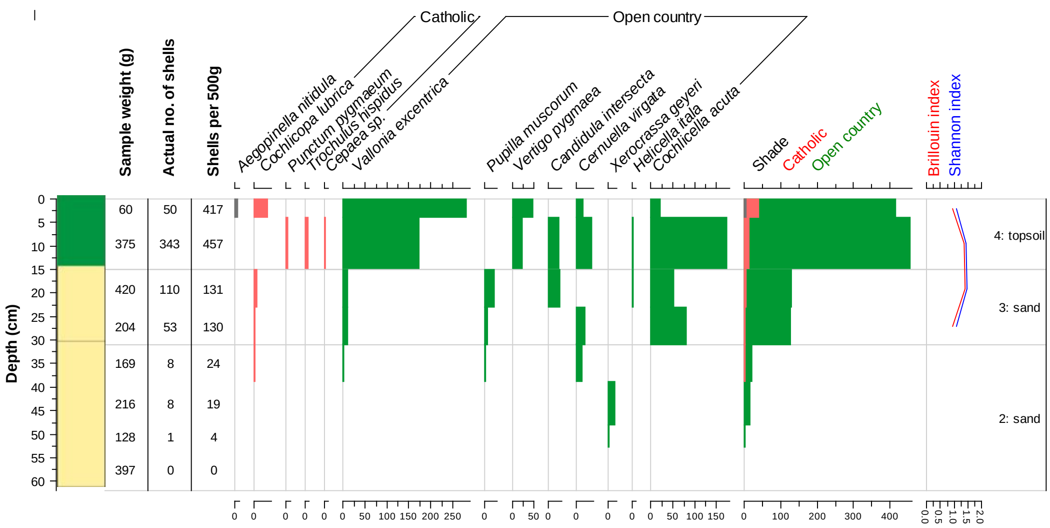


Figure 6.46. Mollusc diagram for the 225m core

This core was obtained from an area of sloping meadow close to the base of the scarp rising to the summit of the towans. Killas [1] was reached at 62cm, considerably deeper than at 200m and perhaps where some of the colluvial run-off from the scarp has accumulated. The lower layer of sand [2] is almost devoid of shells but does include *Xerocrassa geyeri*, implying that this layer has been little disturbed. Mollusc numbers increase considerably in the sand from 31cm upwards [3]. *Pupilla muscorum*, a shell almost absent from other meadow cores, is found, particularly at 15–23cm, showing that this area was probably less grazed than further down the meadow, perhaps due to continual disturbance from run-off. In the topsoil [4] it is replaced by *Vallonia excentrica* – also present in high numbers in the modern turf block – showing more stability of the ground with grazing. Other topsoil shells are nearly all open country species but with some more catholic taxa including a single *Aegopinella nitidula* which can live in the damp shade at the base of meadow grasses.

6.4.2.4 245m core

Grid ref.: SW 58887.42279; modern ground level: 17.02m OD.

Mollusc figures: CD ; summary diagram: Figure 6.47; mollusc diagram: Figure 6.48.

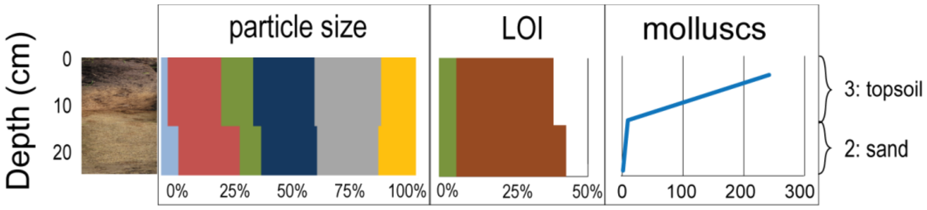


Figure 6.47. Summary diagram for the 245m core

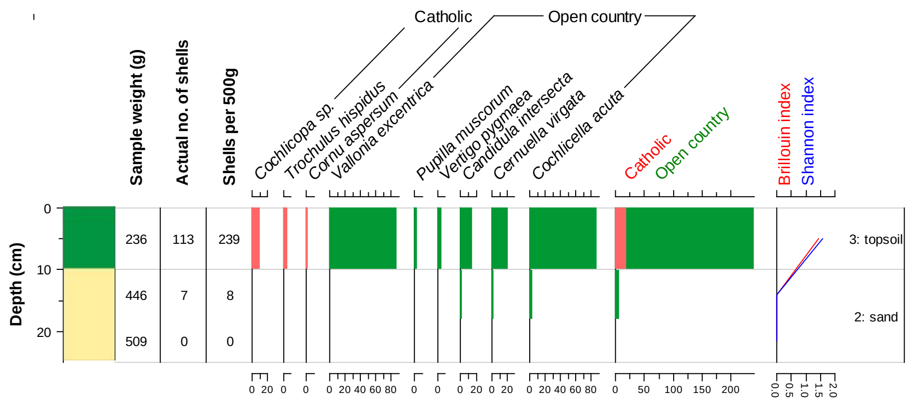


Figure 6.48. Mollusc diagram for the 245m core

The 245m core was taken as close as possible to the base of the steep scarp rising to the summit of Godrevy Towans (Figure 6.49). Blackthorn (*Prunus avium*) scrub covers the lower slopes of the scarp and although there is some shade this aspect is directly south facing. The sand overlying the killas is very thin, the latter being reached at only 25cm. The sand [2] contains a moderate quantity of silt, as might be expected from run-off from the scarp, but there are virtually no molluscs, implying it is unstable, being regularly removed and replaced by wind/water action. The topsoil [3], in contrast, contains a good number of shells indicating relative stability of the sediments in more modern times.

Figure 6.49. The 245m core position (white peg) at the edge of the scrub at the base of the Towans scarp

6.4.2.5 289m core

Grid ref.: SW 58887.42324; modern ground level: 33.71m OD.

Mollusc figures: CD; summary diagram: Figure 6.50; mollusc diagram: Figure 6.51.

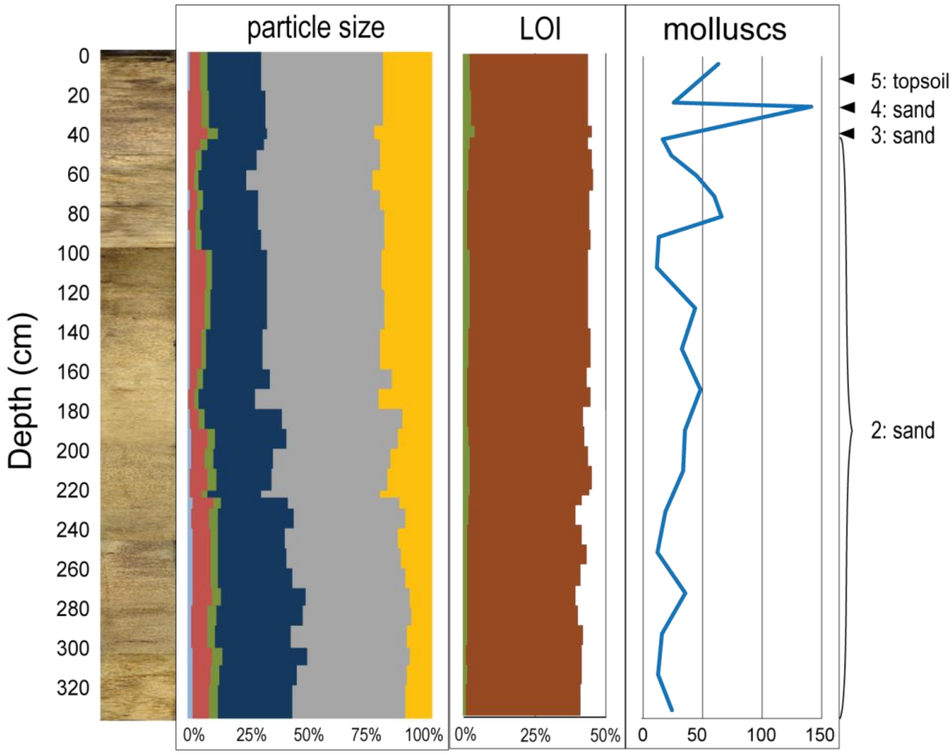


Figure 6.50. Summary diagram for the 289m core

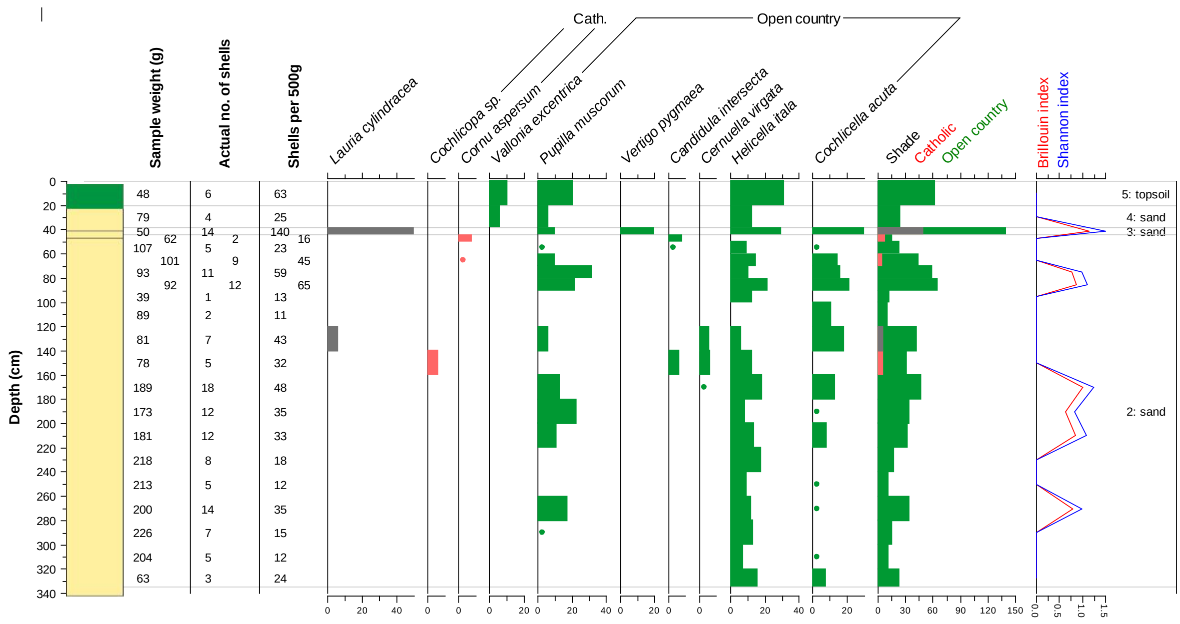


Figure 6.51. Mollusc diagram for the 289m core

The vegetation on the lower part of the steep slope of the towans changes markedly from that of the meadow, with blackthorn (*Prunus avium*), elder (*Sambucus nigra*) and bramble (*Rubus fruticosus*) (Figure 6.52) and it was difficult to find an adequate sampling location. A position at the upper end of a relatively bare area was selected, just above a more level section of the scarp. This levelled area has been ascribed to sand extraction, referred to in a parish map of 1603 (Fowler and Thomas 1962), and marked on a 1850–51 parish map (Figure 5.11). The turf sample was poor in molluscs, mostly open country, especially *Cochlicella acuta*, but with some catholic species.

Figure 6.52. The steep slope of Godrevy Towans showing blackthorn, elder and bramble scrub.
The 289m position is in the centre of the photograph

The sand was surprisingly deep in this position; the auger could not be driven and extracted below 335cm and it is not known whether this is the level of the bedrock or the sand extends still deeper. The scarp is steep above this location (a gradient of 35% measured from the differential GPS readings between 285m and 320m), and it seems probable that there is a localized hollow in the underlying killas which has allowed this depth of sand to accumulate.

The sand [2] below 44cm shows little variation in particle size or organic/carbonate content although there is slightly less silt above 100cm. Mollusc numbers are low with almost entirely open country taxa although occasional shade/catholic species are found. A thin layer of sand at 38–44cm [3] contains a few more shells, particularly with *Lauria cylindracea*, although there are only 5 specimens of this species. Numbers of molluscs are too few to draw any firm conclusions, but it is possible that this was the earliest time when scrub became established on these lower slopes, providing some shade in an otherwise very open and unstable landscape. This layer is overlain by more sand [4] and then topsoil [5], both very sparse in molluscs despite the stabilizing effect of the modern scrub growing in the immediate vicinity.

6.4.2.6 345m core

Grid ref.: SW 58887.42380; modern ground level: 55.90m OD.

Mollusc figures: CD; summary diagram: Figure 6.53; mollusc diagram: Figure 6.54.

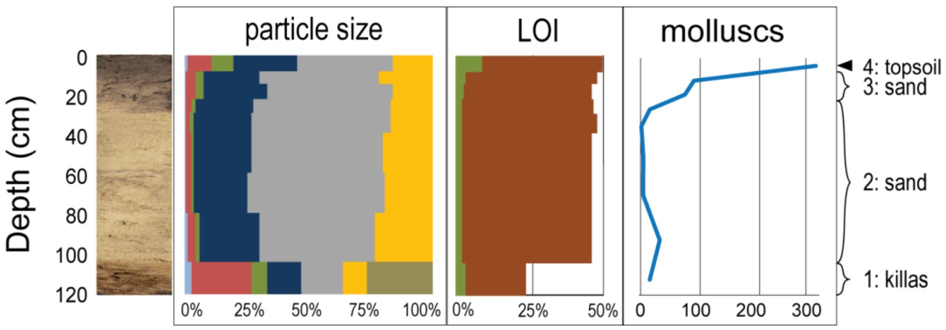


Figure 6.53. Summary diagram for the 345m core

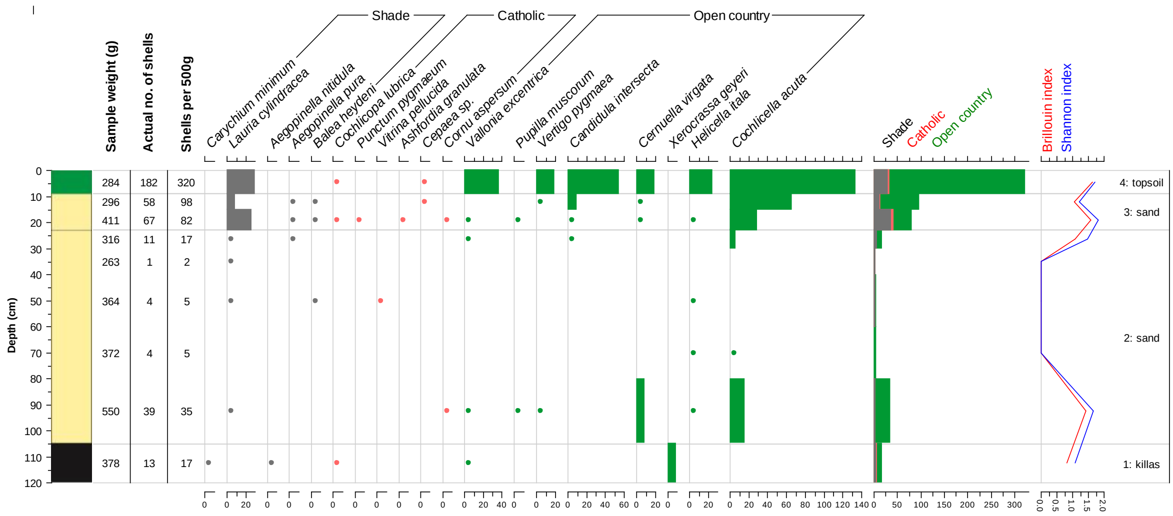


Figure 6.54. Mollusc diagram for the 345m core

The scrub now growing on the lower part of the scarp fades out about half way up the slope and gives way to very short grazed mixed vegetation (Figure 6.55) which at 345m includes ragwort (*Senecio jacobaea*), bird's foot trefoil (*Lotus corniculatus*), unidentified moss, heath dog–violet (*Viola canina*) and wild thyme (*Thymus polytrichus*), with very little grass. The modern turf is surprisingly rich in molluscs with moderate diversity (Shannon index 1.78). Nearly all shells are xerophilic taxa (93%) as would be expected from this very exposed area of ground. The presence of a single *Clausilia bidentata* here is anomalous, and it may have been blown in, or brought to the area by birds or other animals.

Figure 6.55. The hillside around the 345m location, showing very short vegetation on the bare slope

The killas [1] was reached at a depth of 105cm and contains a few shells, including *Xerocrassa geyeri*, which are presumably derived from the overlying sand. The bedrock is overlain by a thick sand deposit [2] with a moderate number of shells in its lowest level, but few more superficially implying instability for much of the deposition history. The sand from 9–23cm [3] has similar sedimentology to that below but contains much larger numbers of shells with a mixture of shade, catholic and open country species. The presence of *Balea heydeni* (four shells) is very unexpected as this a geophobic species normally living in woodland and rarely found on the ground, although is able to live in walls; as with the specimen of *Clausilia* found in the modern turf it is presumably allochthonous. *Lauria cylindracea* is present in good numbers, a taxon well able to live in rock rubble habitats, although perhaps surprising in such numbers on so bare a hillside. The possibility that there were, in the past, areas of woodland or stone walls in this immediate area to account for the *Balea* and *Lauria*, should be considered, but there is no evidence for either at the present time.

The shallow topsoil [4] has large numbers of open country shells indicating that the modern sediment at this location is stable and is not currently subject to major wind deflation or hillwash.

6.4.2.7 400m core

Grid ref: SW 58886.42435; modern ground level: 66.72m OD.

Mollusc figures: CD; summary diagram: Figure 6.56; mollusc diagram: Figure 6.57.

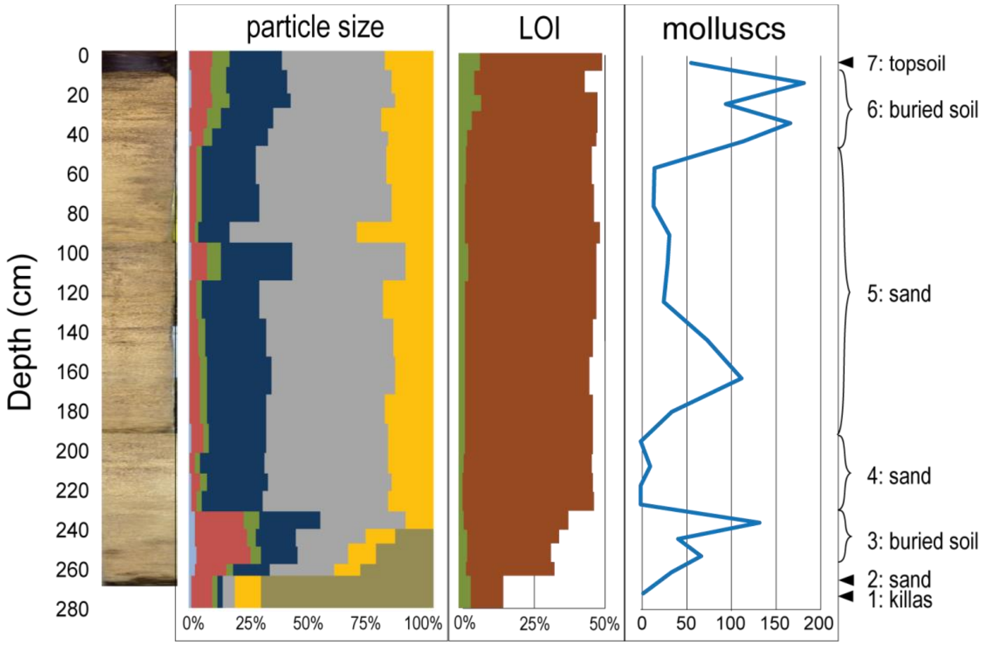


Figure 6.56. Summary diagram for the 400m core

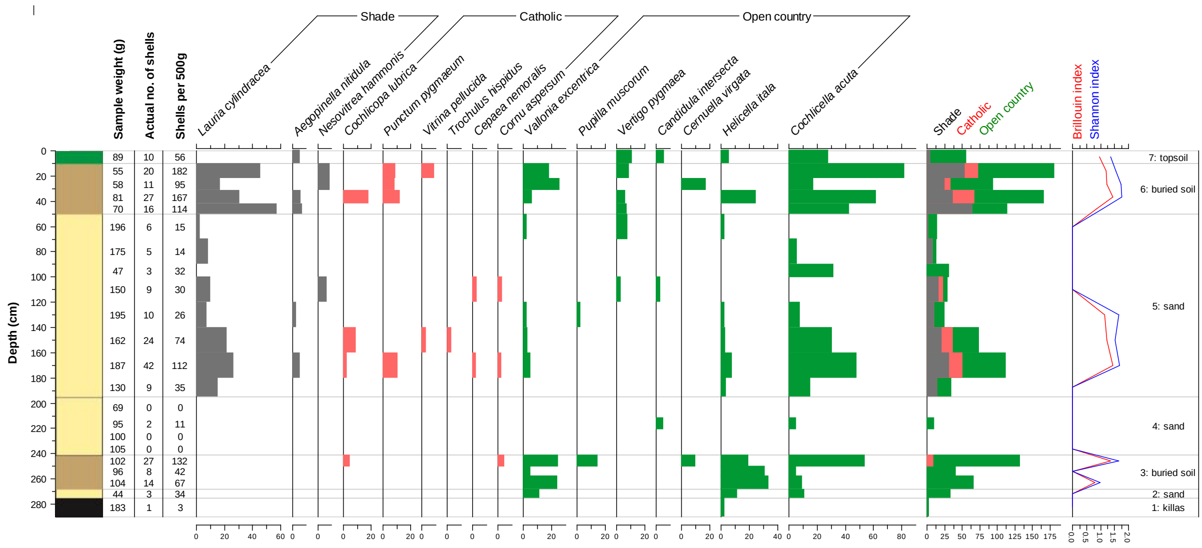


Figure 6.57. Mollusc diagram for the 400m core

The 400m location is within an area of tall marram grass (*Ammophila arenaria*) (Figure 6.58) close to the break of slope at the top of the steepest part of the scarp, although still sloping gently uphill. The density of this grass is reflected in the high proportion of shade species in the turf (65%), notably with *Lauria cylindracea* accounting for over one third of all shells. Xerophile species requiring dry exposed habitats are few in number at this site. In particular *Vallonia excentrica* is very scarce, consistent with the greater degree of shade.

Figure 6.58. The 400m post is shown within an area of marram grass

The sand here is deep, the killas [1] being at a depth of 275cm. A thin sand layer [2] is overlain by a horizon with 25% silt [3] containing a moderate number of molluscs and is interpreted as a buried soil. It would seem likely that there is a hollow in the bedrock into which sediment has accumulated sufficiently slowly for pedogenesis to take place. Unfortunately, the marram grass was too tall to permit a GPR scan of this section of the transect. The presence of *Cernuella virgata* rather than *Xerocrassa geyeri* suggests that this deposit is post-Roman and not prehistoric, although its presence at this level due to bioturbation cannot be excluded.

This soil is overlain by a 50cm horizon of sterile sand [4] which is covered by 145cm of sand [5] containing varying numbers of molluscs at different depths with *Lauria cylindracea* being prominent, suggesting that there was some shade. Above 50cm silt and organic matter proportions slightly increase and there is also increase in mollusc numbers with a broad spread of habitat requirements, again consistent with buried soil [6] with good vegetation cover, similar to the modern local environment. However, there are few shells in the current topsoil [7] with no *Lauria* although the modern turf sample from very close to the core position did contain numerous *Lauria*. The relative lack of molluscs in the core topsoil can be partially explained by its being 10cm thick while the modern turf block was 4‒5cm thick.

6.4.2.8 451m core

Grid ref.: SW 58884.42485; modern ground level: 67.89m OD.

Mollusc figures: CD; summary diagram: Figure 6.59; mollusc diagram: Figure 6.60.

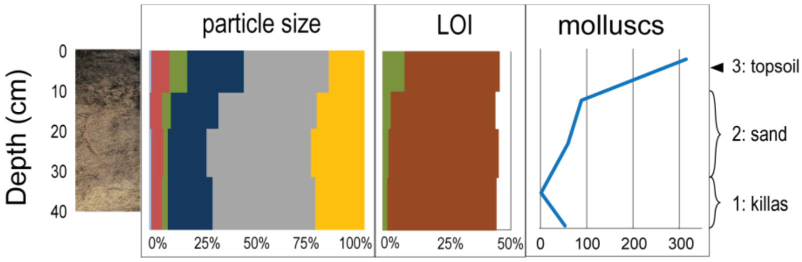


Figure 6.59. Summary diagram for the 451m core

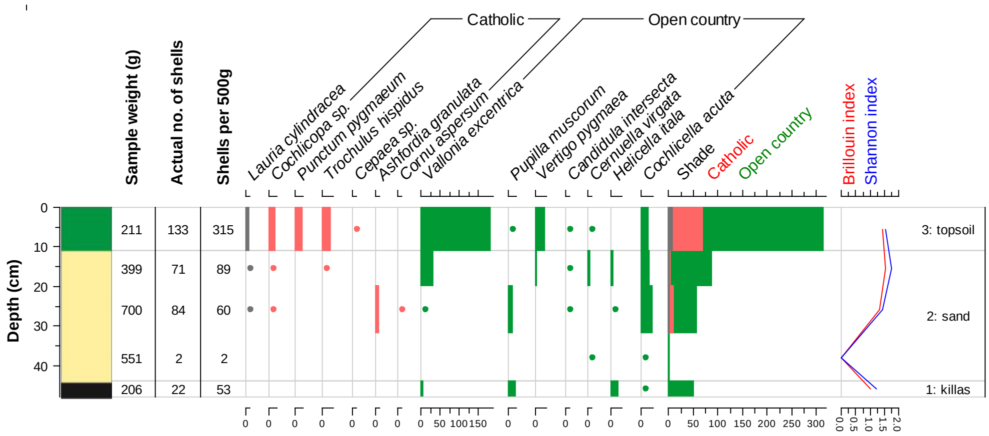


Figure 6.60. Mollusc diagram for the 451m core

The 451m core is from an area of short grazed grassland about 20m in diameter surrounded by low gorse/bramble scrub and marram grass (Figure 6.61). There is minimal shade, although hemp-agrimony (*Eupatorium cannabinum*), dandelion (*Taraxacum officinale* agg.) and traveller's joy (*Clematis vitalba*) were found flowering here and provide some shade at their bases. The turf molluscs are variable, with a mixture of species across the habitat range, with *Vallonia excentrica* dominating.

Figure 6.61. The open short grassland of the 451m position

The sand is relatively shallow, the killas [1] being at 44cm and containing a few open country molluscs. Above this is a sand layer [2] with a mixed mollusc assemblage of no specific characteristics. The topsoil [3], in contrast, contains a large number of shells, 60% of which are *Vallonia excentrica*, entirely consistent with the short grass grazed by the modern abundant rabbit population. Some shade and catholic species are able to live in the little shade provided by the vegetation.

6.4.2.9 495m core

Grid ref.: SW 58887.42529; modern ground level: 69.75m OD.

Mollusc figures: CD; summary diagram: Figure 6.62; mollusc diagram: Figure 6.63.

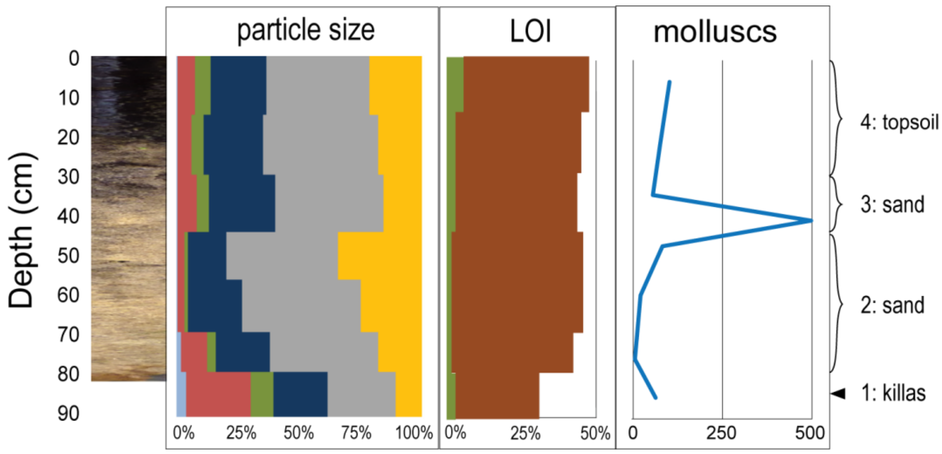


Figure 6.62. Summary diagram for the 495m core

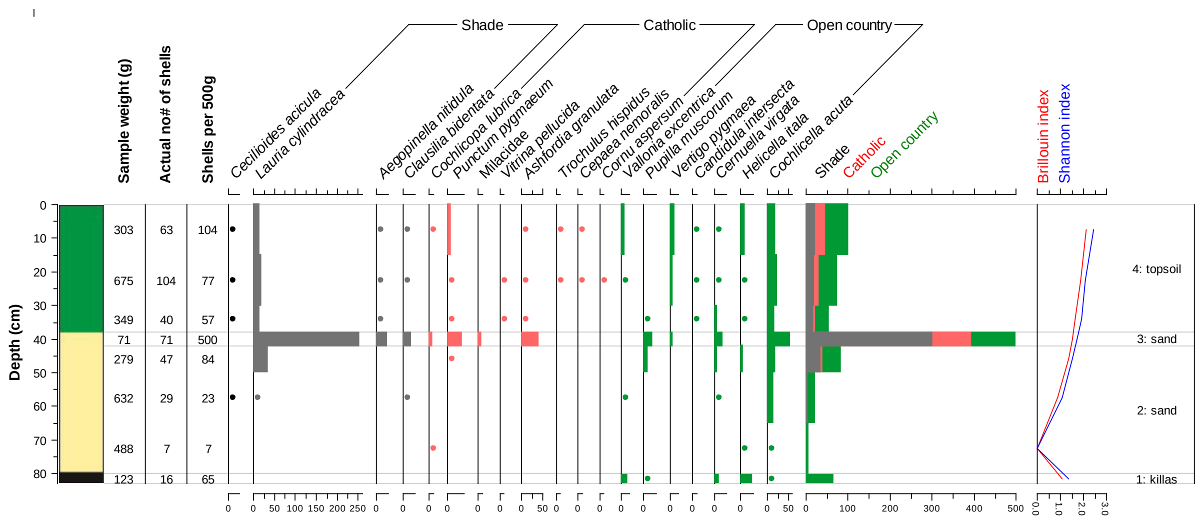


Figure 6.63. Mollusc diagram for the 495m core

The core position is immediately on the south side of an area of gorse and bramble scrub about 150cm high and is in partial shade but with tall grass (Figure 6.64). The turf molluscan population shows a large number of taxa (16) with high diversity (Shannon index 2.29). The molluscs include species across the habitat spectrum entirely consistent with its mixed shade/open situation, providing micro-habitats suitable for species requiring both shade and more exposed areas.

Figure 6.64. Gorse bushes and brambles at the 495m location

Killas [1] was reached at 80cm, overlain by sand [2] with few molluscs. At 38–42cm there is a thin horizon [3] with numerous *Lauria cylindracea*, as well as *Clausilia bidentata* and *Aegopinella nitidula*, the latter two consistent with the extent of shade provided by the scrub, and therefore not necessarily intrusive. The thick topsoil above this [4] contains shells with mixed environmental requirements but high diversity, very similar to the modern turf block.

Of great interest is the presence of *Cecilioides acicula*, which was also found in the modern turf block This mollusc is usually ignored in palaeoenvironmental studies as it may burrow to depths of up to 2m, and therefore has little biostratigraphic value. The timing of its introduction to Britain has not been established as there are no reliable prehistoric records (Evans 1972, 168). Its value at the present site is that it is frequently associated with cultivated or disturbed ground (Evans 1972, 168). The location of this core is close to the medieval manor of Crane Godrevy, and about 85m south west of the closest known extent of the field system to the south of the building (Thomas 1969; Sturgess and Lawson Jones 2006b). The presence of *C. acicula* in this core may, together with the possible finding of a ditch in the 528m core (see below), suggest more extensive agricultural activity than previously thought; the high number of *Lauria cylindracea* supports this conjecture, with the possibility that field walls were, at one time, present in this location to give adequate shade for the *Lauria*.

6.4.2.10 528m core

Grid ref.: SW 58887.42562; modern ground level: 70.54m OD.

Mollusc figures: CD; summary diagram: Figure 6.65; mollusc diagram: Figure 6.66.

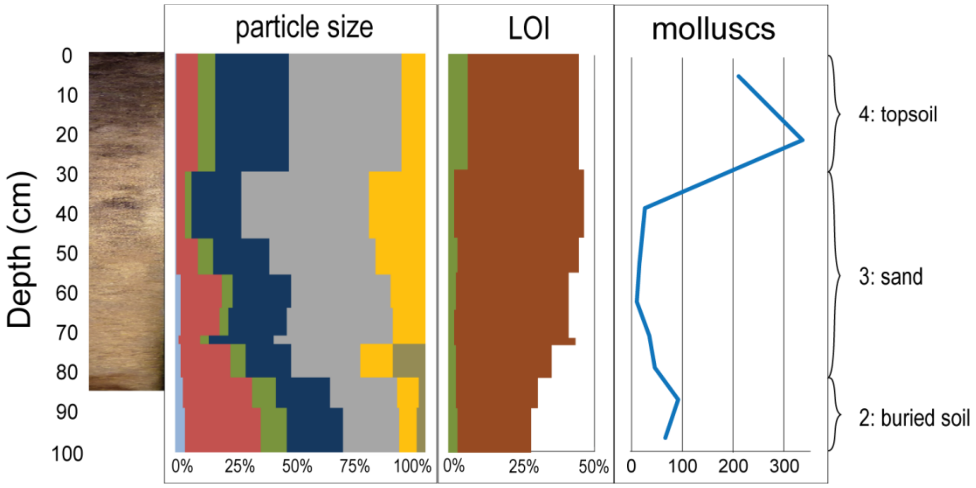


Figure 6.65. Summary diagram for the 528m core

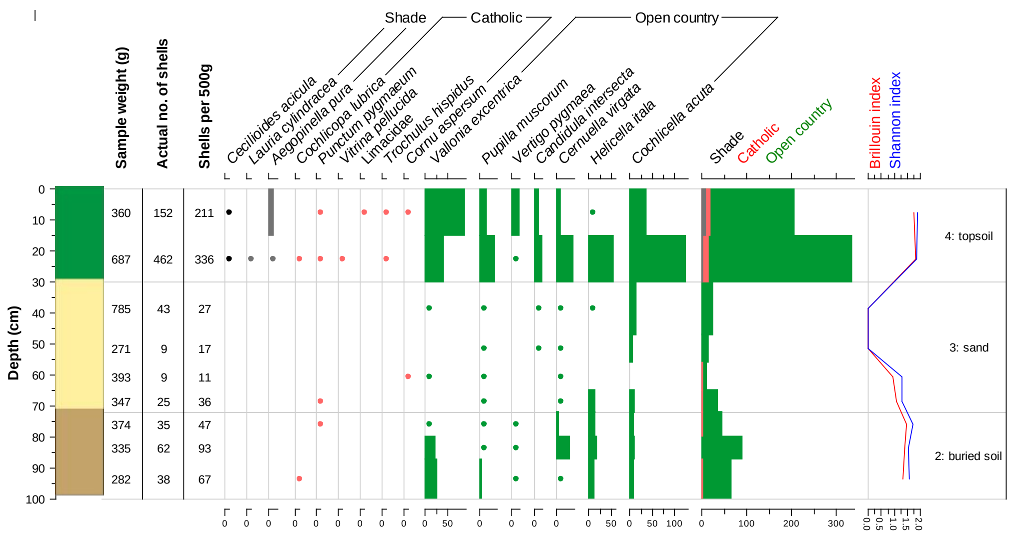


Figure 6.66. Mollusc diagram for the 528m core

This core was obtained in an area of rank grass at the southern margin of the bare grass of the summit plateau, close to gorse/bramble scrub, and so is largely in shade (Figure 6.67). This is reflected in the turf molluscs which, although with good numbers of *Vallonia excentrica*, include shade species *Vitrina pellucida* and *Oxychilus alliarius*.

Figure 6.67. Scrub and rank grass at the 528m core position

It was only possible to drive the corer to 100cm and it is probable that the bedrock is at this level, but not certain. The lowest sediments [2] contain a high proportion of clay/silt (up to 30%) with a moderate number of molluscs, nearly all open country taxa, and is consistent with a buried soil. This is overlain by sand [3] with fewer shells, again mostly open country species. The topsoil [4] is rich in molluscs, some of which are shade and catholic species consistent with its shady location.

The finding of *Cernuella virgata* and *Candidula intersecta* in the base levels with *Cornu aspersum* in the intermediate sand and *Cecilioides acicula* in the topsoil implies that this is disturbed sand throughout its depth. The ground penetrating radar (Figure 6.68) shows a dip in the bedrock profile at 530−535m, very close to the position of this core. The combination of the radar and mollusc findings suggest that there may have been a ditch in this area of the towans, perhaps defining a field system, and with disturbance of the sands during medieval times associated with the nearby Godrevy manor house. This is approximately 50m south west of the nearest ditch revealed in previous excavations (Thomas 1969; Sturgess and Lawson Jones 2006b, Figure 2) and, together with the findings described in the 495m core, may indicate a previously unknown area of activity.

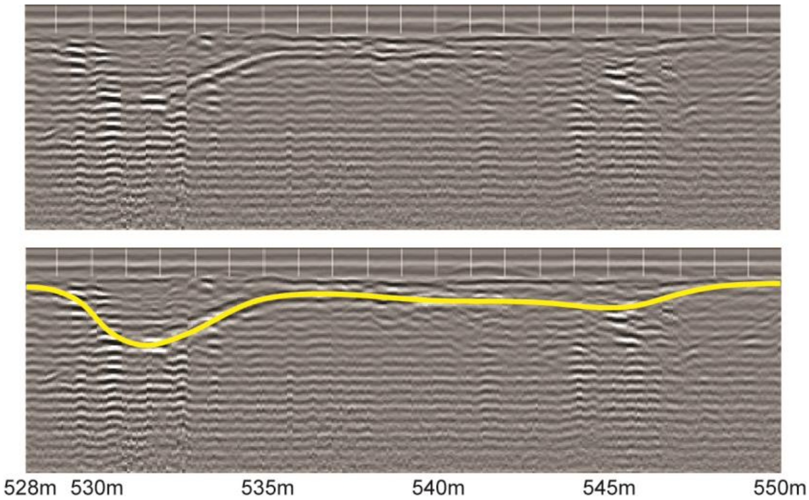


Figure 6.68. Ground penetrating radar (400MHz) from 528m to 550m.
The depression in the line of the bedrock from 530–535m is drawn on the lower trace

6.4.2.11 551m core

Grid ref.: SW 58887.42585; modern ground level: 70.26m OD.

Mollusc figures: CD; summary diagram: Figure 6.69; mollusc diagram: Figure 6.70.

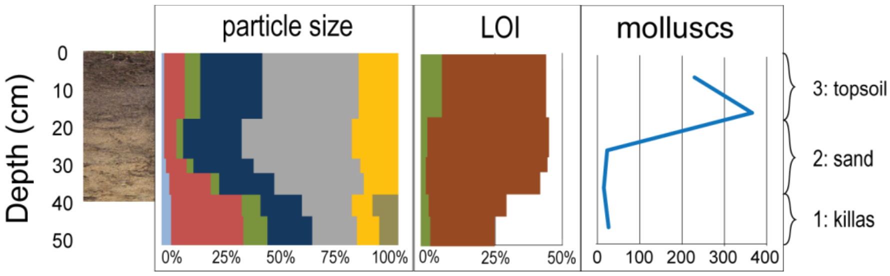


Figure 6.69. Summary diagram for the 551m core

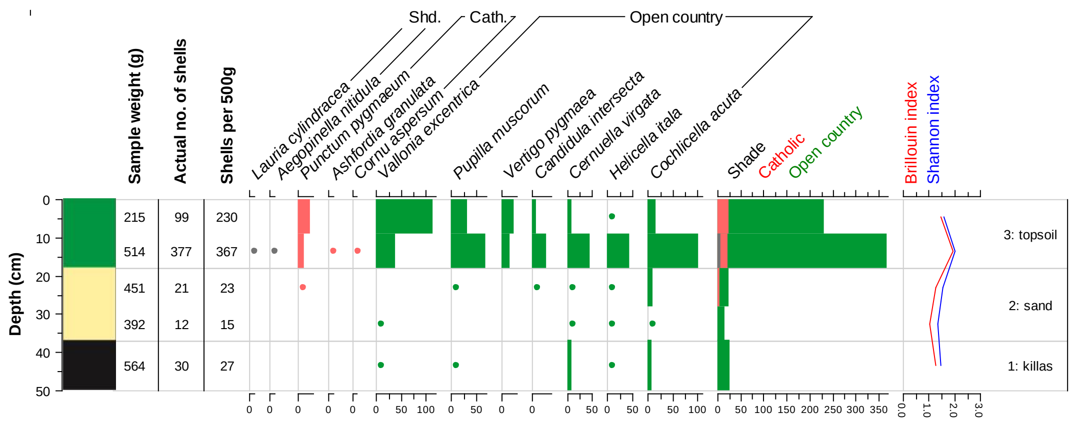


Figure 6.70. Mollusc diagram for the 551m core

The summit of Godrevy Towans is a level plateau with large areas of short grazed grass and with gorse/bramble patches of scrub to the north and south (Figure 6.71), but open to the east and west, and very exposed to storms blowing in from the Atlantic Ocean to the west, there being no higher ground or vegetation between this location and the coast. Wild thyme (*Thymus polytrichus*), columbine (*Aquilegia vulgaris*) and sheep's fescue (*Festuca ovina*) were all growing in the area.

Figure 6.71. The flat grazed summit of Godrevy Towans.
The fence at the west edge of the Crane Godrevy manor house site is on the right of the photograph

The core is from the centre of this bare grassland. The sand is shallow, with the bedrock [1] at 39cm and containing a few open country molluscs. The blown sand [2] over this is relatively sterile as far as molluscs are concerned but there are good numbers of shells in the topsoil [3], mostly open country in keeping with the local environment, but with some *Punctum pygmaeum*, a species capable of living in a very wide variety of habitats, including open, dry grassland. Post-Roman mollusc introductions are present at all levels, either due to bioturbation or regular removal and replacement of the sands by storms blowing over the summit of the towans.

6.4.2.12 570m core

Grid ref.: SW 58887.42604; modern ground level: 70.56m OD.

Mollusc figures: CD; summary diagram: Figure 6.72; mollusc diagram: Figure 6.73.

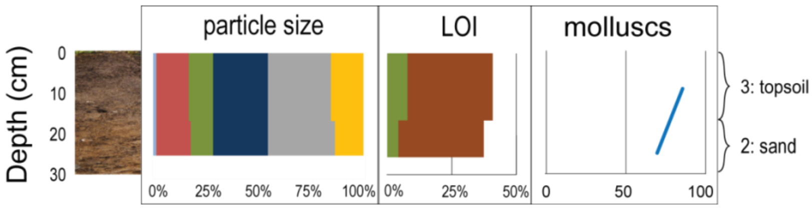


Figure 6.72. Summary diagram for the 570m core

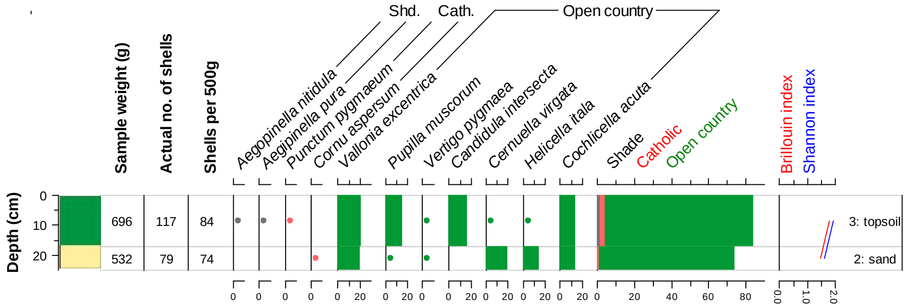


Figure 6.73. Mollusc diagram for the 570m core

This sand in this core, also from the open grazed grassland exposed to the weather from the west, is very shallow, with bedrock at only 25cm. There is an overlying thin layer of sand [2] with a covering of topsoil [3]. Molluscs, mainly open country species, are present in moderate numbers with the variety consistent with the habitat, and are similar to the modern turf molluscs although with fewer *Vertigo pygmaea* and *Helicella itala*. The shade species *Aegopinella nitidula* and *A. pura* are surprising; they may well have blown here from the surrounding scrub but may be able to live at the base of the short vegetation.

6.4.2.13 582m core

Grid ref.: SW 58887.42616; modern ground level: 70.39m OD.

Mollusc figures: CD; summary diagram: Figure 6.74; mollusc diagram: Figure 6.75.

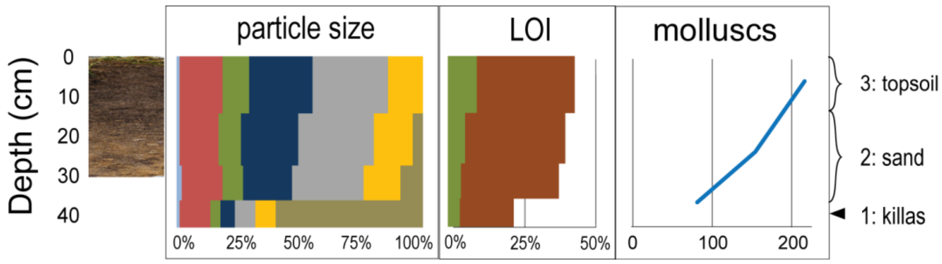


Figure 6.74. Summary diagram for the 582m core

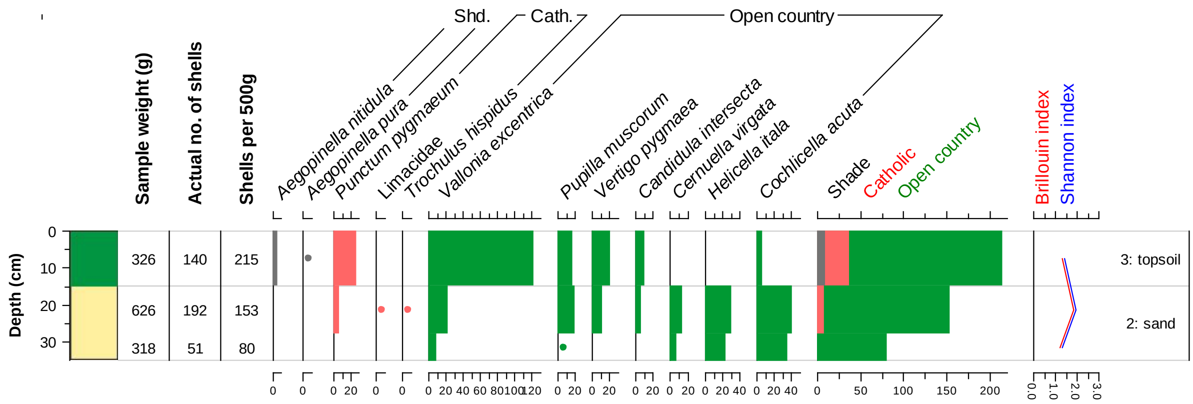


Figure 6.75. Mollusc diagram for the 582m core

The final core in the transect is from the north edge of the open summit grassland, in an area surrounded on three sides with 2m high gorse (Figure 6.76), with turf molluscs strongly dominated by *Vallonia excentrica* which accounts for over 70% of shells present. As in the 570m core the sediments are shallow with the bedrock [1] at 35cm. The sand above this [2] contains open country and a few catholic molluscs while the topsoil [3] has a high number of shells, again mostly open country species, but more catholic shells, including *Aegopinella nitidula* and *A. pura* which are more likely to be autochthonous here than at the 570m site.

Figure 6.76. The 582m site with gorse encircling on three sides

6.5 Summary of the coring transect

The cores well demonstrate much of the stratigraphy of the Red River valley and the land north to the summit of Godrevy Towans. Although bedrock in the river basin was only reached in three of the cores they show that for at least 30m north of the present river position the bedrock is level, at a depth of just over 3m below present OD level. How far this level bottom extends to the south was not determined. The earliest sediments laid down were organic silts containing alder wood, reeds and sedges, entirely consistent with marsh and alder fen. No molluscs have survived at this depth, so whether or not there was any flowing water at the study sites is not known.

Whether there is sand beneath the organic silt layers south of the river has not been established. There was no evidence of any clays which might have indicated estuarine deposits and the supposition is that most of this valley was always freshwater at a time when sea level was below the level of the river outflow, 3m below modern OD level (this will be discussed further in Chapter 11). The broad extent of the valley remained marshy, with deposits currently being 220−260cm thick. No account has been taken of compaction of these silts over time as a result of autocompaction and the weight of overlying sand. Allen (2000) has demonstrated that this may have a significant influence on the interpretation of stratigraphy in coastal lowlands, with differential autocompaction across valleys and over hillocks and depressions varying by several metres, although no such hillocks are likely in the river basin. Caution is therefore needed when modelling sea level curves (Edwards 2006; Brain *et al.* 2012).

There were phases when the silts became markedly acidic, as low as pH 2 at one time. No cause for this is firmly established, but it is probable that there were extensive areas of anoxic stagnant waters with decaying vegetable matter from the marsh plants. Whether there was any contribution from mining effluent is discussed in Chapter 7. Where the flowing waters of the Red River were at this time in not known; its position may have been very variable as its course moved through the extensive marshes and wet ground.

Thick layers of sand began to accumulate in the valley on top of the marsh, at times sufficiently slowly to allow some stabilization and pedogenesis. Molluscs have survived in the sediments for the first time during this period, initially in some persisting marsh in the centre and south of the valley and later in the sands on the northern side. The location of the river channel wandered during this period, being found at different times and depths in the 0.5m and 15m cores, but it was never as far south as the South 58 or South 158 positions, nor as far north as far as 30m.

The presumably drier conditions with sand accumulation did not last indefinitely. Marsh returned to the centre of the valley, and was again highly acidic at times consistent with stagnant ponding; at other times the quality of the water was adequate for a rich molluscan fauna to flourish above the standing water level in wet ground areas which were liable to drying. To the south there was less marsh, but the sands are gleyed indicating anoxic conditions over a wide area, although there is never the acidity found more centrally in the valley. To the north the edge of the marsh was between the 15m and 30m locations, where at the latter site a deep midden accumulated, probably during the post-Roman period and is almost certainly associated with the buildings on the nearby dune.

The marsh, which had persisted in the valley for the whole time the midden was accumulating, eventually spread to cover the midden, although only in the region of the present river site, implying that the river channel was restricted to a fairly narrow part of the valley. Conditions in the marsh were such that wet ground molluscs were able live in above-water locations and in some areas overbank alluvium may have spread over the valley. Finally blown sand again took over, when conditions were probably very unstable, implied by the marked lack of molluscs in any of the sands across the valley at this time. Sand accumulation continued up to the present day, becoming stabilized in recent times, molluscs only being found in the uppermost few centimetres of deposit. In the meadows to the south of the river conditions have developed which are averse to mollusc life, the topmost 50–60cm being totally devoid of shells. Molluscs are also unable to live close to the surface at the northern margin of the valley, and it is suggested that this may be associated with the fluctuating water table or to chemical toxicity in the flood waters associated with upstream mining activity.

Turning now to the north of the valley and the meadow below the scarp of Godrevy Towans it is clear that the west end of the dune on which the post-Roman buildings are situated is sand down for several metres below present ground surface, there being no indication of a solid spur of bedrock on which the sand has accumulated. The sands become thinner further up the meadow, being nearly 500cm deep just north of the dune (100m core), reducing to only 25cm near the scarp (245m core). Thin stabilization layers are found in the sands up to the position of the field system about two-thirds of the way up the meadow, but generally the sands are unstable, with very few molluscs. Above the field system there are no stabilization layers.

There is a suggestion of woodland or scrub at the 100m location in the earliest deposits above the bedrock, likely to correspond to the early Bronze Age horizons in the nearby field systems. Interestingly Davies (2006) found, in the 2005 trench, shade species in layers above the basal sand corresponding to the middle Bronze Age. The two analyses, about 200m apart, do suggest that there were shaded areas capable of supporting a variety of shade-loving species (e.g. *Discus rotundatus, Clausilia bidentata*) but that its extent and location may have varied over time. It is possible that they relate to periods of abandonment when upkeep of the field systems in the area had lapsed. Spencer (1974, 1975) did not find species suggestive of woodland, but speculated that there may have been woodland clearance prior to the establishment of the Bronze Age settlement, although she did not find any evidence of this.

Further details of the findings at 150m will be given in the Chapter 8, but it appears that agricultural practices were established here during the Bronze Age. The core within the field system (175m) has sediment throughout entirely consistent with the plough soils revealed in the 1960s excavations. Over the meadow as a whole there is good evidence that there has been grazing but this was intermittent and associated with periods of sediment stability represented by buried soils.

Little needs to be said about the sand deposition on the scarp of the towans. On the steep slope there is, somewhat surprisingly, moderate stability at least for part of the deposition period, although the sand here is likely to be continuously lost and replaced by wind/water action, but with quantities of sand extracted during the seventeenth to nineteenth centuries. Over the gently rising upper slopes there are hollows in which sediments can stabilize and vegetation grow sufficiently to allow molluscs requiring some shade to thrive. The appearance of marram grass and scrub in more recent times also permits good mollusc populations to develop in areas of resulting stability.

On the flat summit of the towans molluscs thrive on the open ground, with catholic and shade species appearing where sufficient shade is provided by rank vegetation, but with no evidence of woodland. The study suggests that the field systems associated with Crane Godrevy may be more extensive than previously thought, with the radar showing one probable ditch, and the molluscs suggesting disturbed ground during, or since, medieval times.

7. Gwithian cores – dates, isotopes and chemistry

7.1 Chronology, with discussion of the pollen analysis

Dates have been obtained at several locations at Gwithian, but only those from the 30m core will be discussed in this chapter, with extrapolation to the 0.5m and 15m cores to permit correlation with stable isotope and geochemistry studies. The dates obtained from the trench samples and at Strap Rocks will be covered in the relevant chapters. All dates are given as calendar years BC/AD; this overcomes the differences of 'BP' dating: 1950 for the radiocarbon and 2010 for OSL, and that OSL dates are absolute and not calibrated. Periods have been defined as Mesolithic: to 4000 cal BC; Neolithic: 4000−2200 cal BC; early Bronze Age: 2200−1500 cal BC; middle Bronze Age: 1500−1150 cal BC; late Bronze Age: 1150−750 cal BC; Iron Age: 750 cal BC−cal AD 50; Romano-British and medieval: AD 50−1500; recent: AD 1500−present (Needham 1996; Needham *et al.* 1997; Needham 2012).

The 30m core was selected for scientific dating as the sediments within the core tubes had not been disturbed other than splitting at the time of the visit to Aberystwyth in August 2011 and were therefore suitable for OSL dating. The sediments contained several sand deposits necessary for OSL as well as organic sediments for radiocarbon dating. Selection of sample levels for OSL was determined by the presence of sandy deposits to provide a spread of dates along the length of the core. Selection of material for radiocarbon dating depended on the presence of organic material from the marsh levels, with molluscs being used for intermediate levels. Funding for the radiocarbon dating was obtained from a NERC award and performed by the Oxford Radiocarbon Accelerator Unit. OSL dating was performed at Aberystwyth University. Identification of wood and charcoal samples was performed by Phil Austin (University College London); Dan Young (University of Reading) identified the seeds.

The dates obtained are shown in Table 7.1 (OSL dates) and Table 7.2 (radiocarbon dates). Figure 7.1 is an age/depth plot, with trend lines linking all except the 384cm shell radiocarbon date which is anomalous. With that exception, all of the dates fall in chronological sequence (allowing for 2σ variation). The graph shows alternating phases of slow and rapid deposition of sediments – slow to the early Bronze Age, rapid through the Bronze Age, slow to the mid post-Roman/medieval period, and then rapid again to the present time.

The organic silts of the early marsh formed over at least 2000 years, from *c* 4000−*c* 2000 BC, but after an episode of sand blow there was much more rapid accumulation of silt up to the middle of the mid Bronze Age. A thick deposit of sand built up on the marsh at the same overall rate from the middle of the mid Bronze Age to about the middle of the late Bronze Age, but it cannot be determined whether this was constant or if there were varying episodes of rapid and slow sand deposition, with or without periods of deflation. The dating of the midden will be discussed below, but it is unlikely that the graph accurately reflects the time when it was deposited.

Table 7.1. OSL dates on the 30m core samples

Lab number	Uncorrected depth (cm)	Corrected depth (cm)	OSL date (1σ) (years before 2010)	Calendar date (2σ)	Mid-date
Aber-203/GT12-B30-1	148±3	150±3	250±25	AD 1735–1785	AD 1760
Aber-203/GT12-B30-2	360±3	384±3	1280±80	AD 640–800	AD 730
Aber-203/GT12-B30-3	435±3	463±3	3040±240	1290–710 BC	1030 BC
Aber-203/GT12-B30-4	648±1	665±1	3340±210	1550–1130 BC	1330 BC
Aber-203/GT12-B30-5	873±2	903±2	3870±210	2080–1660 BC	1860 BC

(the uncorrected depths are included, as they are shown in the full report in the Appendix).

Table 7.2. Radiocarbon dates on the 30m core samples

Lab number	Material	Corrected depth (cm)	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)	Mid-date
OxA-29165	*Menyanthus trifoliata* seeds	180–207	-25.97	313±29	cal AD 1485–1648	AD 1567.5
OxA-28960	*Cochlicella acuta*	381–387	-5.98	1975±26	41 cal BC–AD cal 75	AD 17
OxA-28959	*Cochlicella acuta*	491–506	-7.50	2837±28	1086–914 cal BC	1000 BC
OxA-28958	cf. *Alnus glutinosa* wood	705–718	-28.75	3081±27	1416–1268 cal BC	1342 BC
OxA-28957	*Alnus glutinosa* wood	718–740	-27.15	3093±29	1427–1281 cal BC	1354 BC
OxA-29164	cf. *Alnus glutinosa* charcoal	835–867	-28.06	3455±34	1881–1689 cal BC	1785 BC
OxA-28956	*Alnus glutinosa* wood	949–977	-27.90	5016±32	3943–3708 cal BC	3838.5 BC

(an additional sample, at 777–804cm, was submitted but failed to produce a date due to excessively low yields)

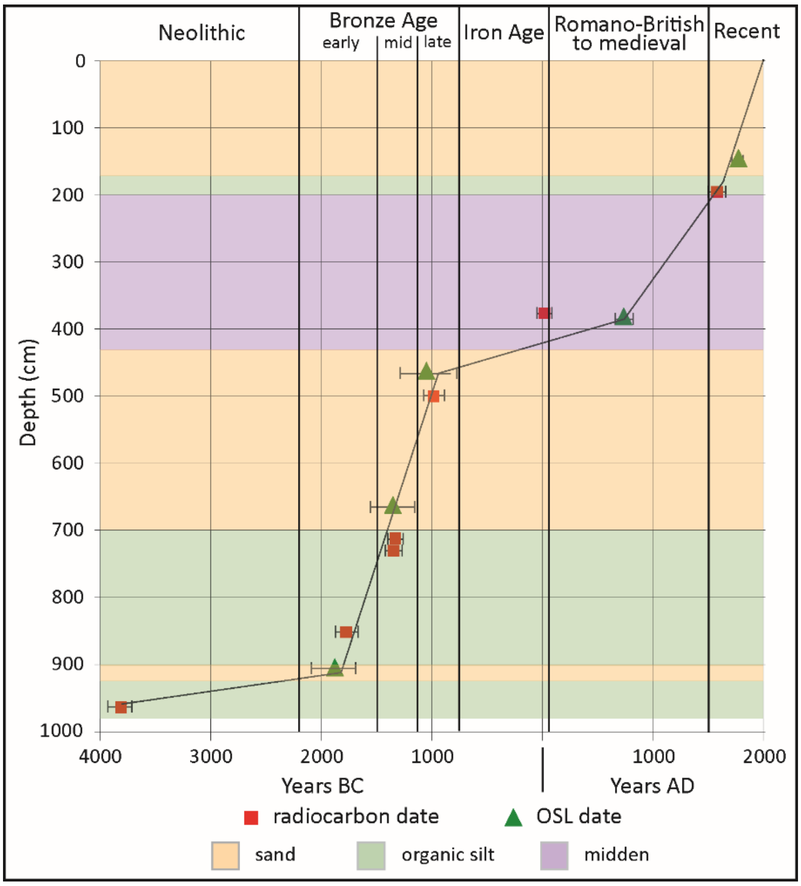


Figure 7.1. Time/depth plot for the 30m core

The above dates can used to construct a time/depth model. The mid-date for each estimation has been used, with the intervening dates calculated on an Excel spreadsheet, based on the summary diagram shown in Figure 6.23. An even spread of dates has been assumed between each dated level, although there will definitely be resulting inaccuracies caused by lack of measured dates, especially in the deep sand levels. There is reasonable likelihood that the organic silt deposits will have accumulated at a relatively steady rate over the duration of deposition, but this is unlikely to apply to the sand horizons. There will inevitably have been periods when large quantities of sand were deposited in a short period of time, especially during adverse weather conditions, and also that significant depths of sand may have been removed at other times as a result of the action of wind and/or water.

Given these limitations, Figure 7.2 shows the modified 30m summary diagram, with the data arranged on an even time basis, as opposed to the even depths on the original diagram. Similar diagrams can be constructed for the 15m (Figure 7.3) and 0.5m (Figure 7.4) cores, with extrapolation of the dated levels by comparison of the stratigraphy. It is accepted that there will be some error as a result of this extrapolation, but this is likely to be minor, owing the similarity of stratigraphy between the cores (see Figure 6.9). In the discussion evidence will be drawn from all these cores as well as information gained from the pollen analysis (Figure 7.5: summary diagram; Figure 7.6: tree and shrub pollen; Figure 7.7: herb, aquatic and spore pollen) on the 0.5m core; although not itself dated the stratigraphy is sufficiently similar to the dated core that valid conclusions can be drawn. The zone numbers [ ] shown refer to the 30m core, being the one which was dated.

The earliest date, obtained from alder wood in the marsh deposit [2] immediately above the underlying killas, is 3943−3708 cal BC, which represents the commencement of marsh formation at this location. The pollen analysis is consistent with these findings, showing a wetland environment of fen/carr woodland, with alder (*Alnus glutinosa*) and willow (*Salix*) and a range of herbaceous and aquatic taxa consistent with a damp floodplain surface with areas of still, or slowly moving, water. Oak (*Quercus*), hazel (*Corylus*) and birch (*Betula*) indicate a deciduous woodland/scrubland which was relatively open and perhaps limited in extent. Elm pollen is absent, suggesting either that it did not grow in the area, or that the earliest sediments post-date the early Neolithic elm decline (Parker *et al.* 2002). It is likely that this fen/carr habitat extended across the valley during these early stages of deposition, but the site of the main river channel at this time is not known. The pollen does not include any taxa which might indicate saline conditions, supporting the hypothesis that this was not a marine estuary.

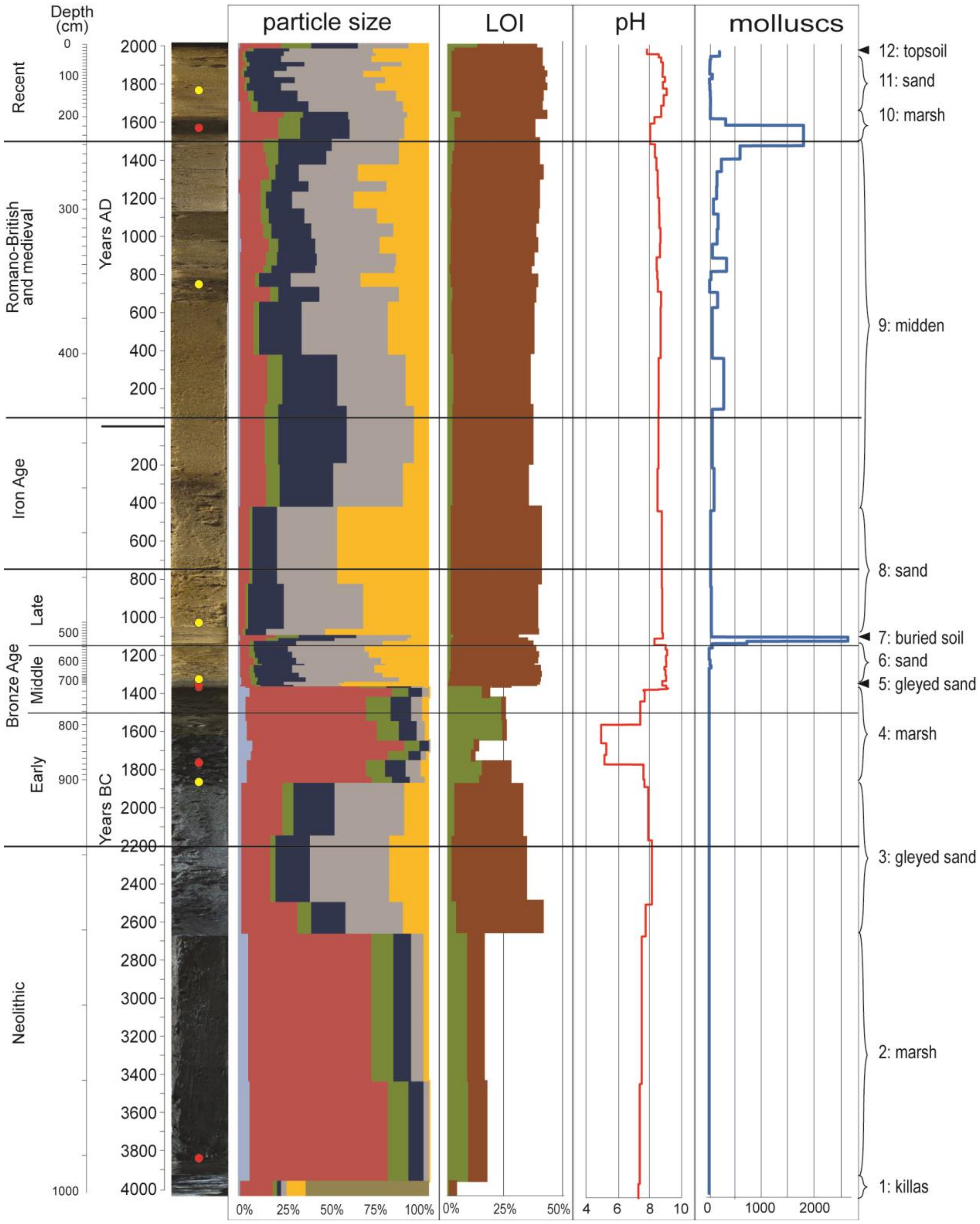


Figure 7.2. The 30m core summary diagrams plotted against age.
The dots indicate the levels at which material was dated; red dot = radiocarbon, yellow dot = OSL

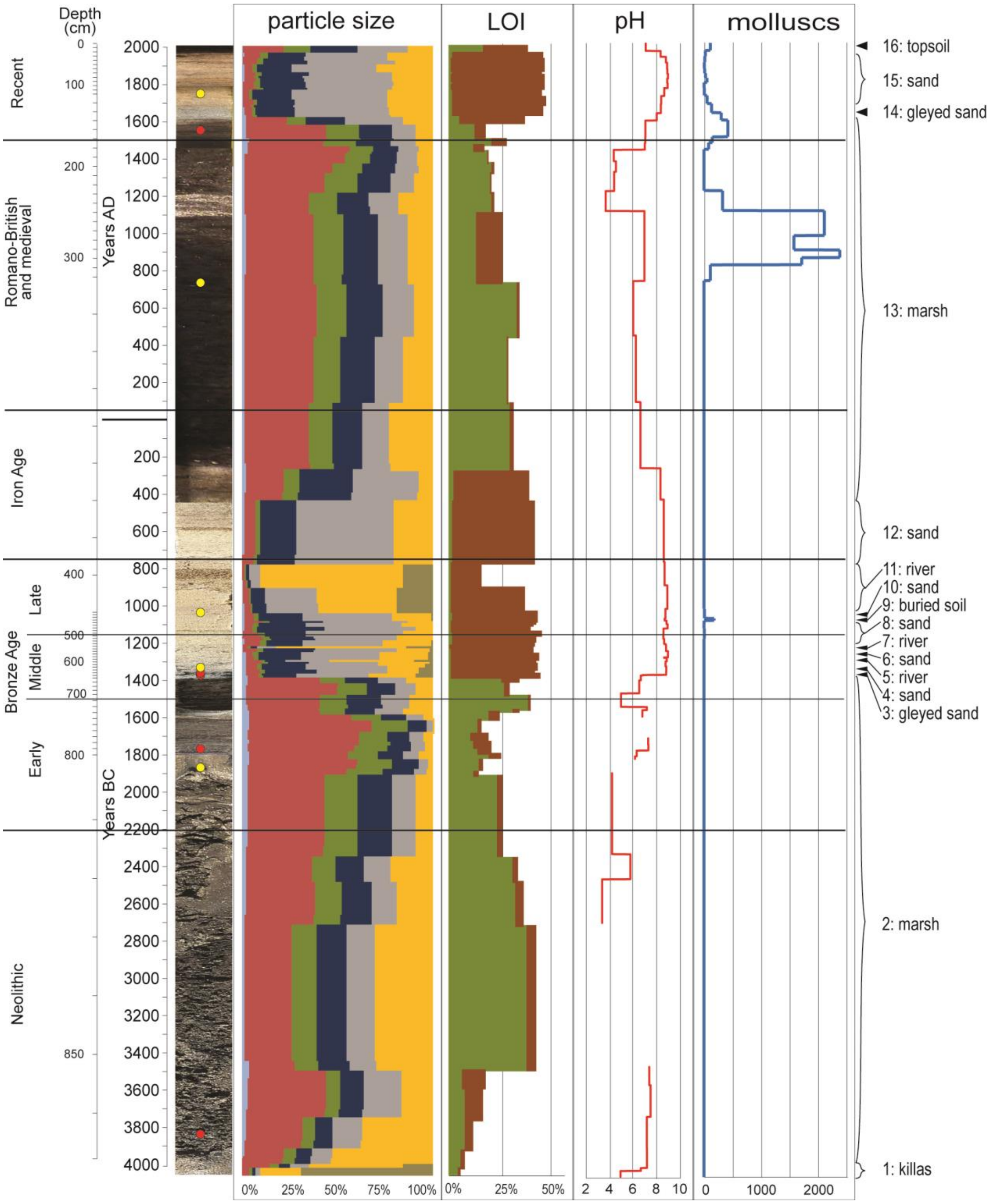


Figure 7.3. The 15m core summary diagrams plotted against age.
The dots indicate the levels at which material was dated; red = radiocarbon, yellow = OSL.
The gaps in the pH curve are where there was insufficient material for analysis

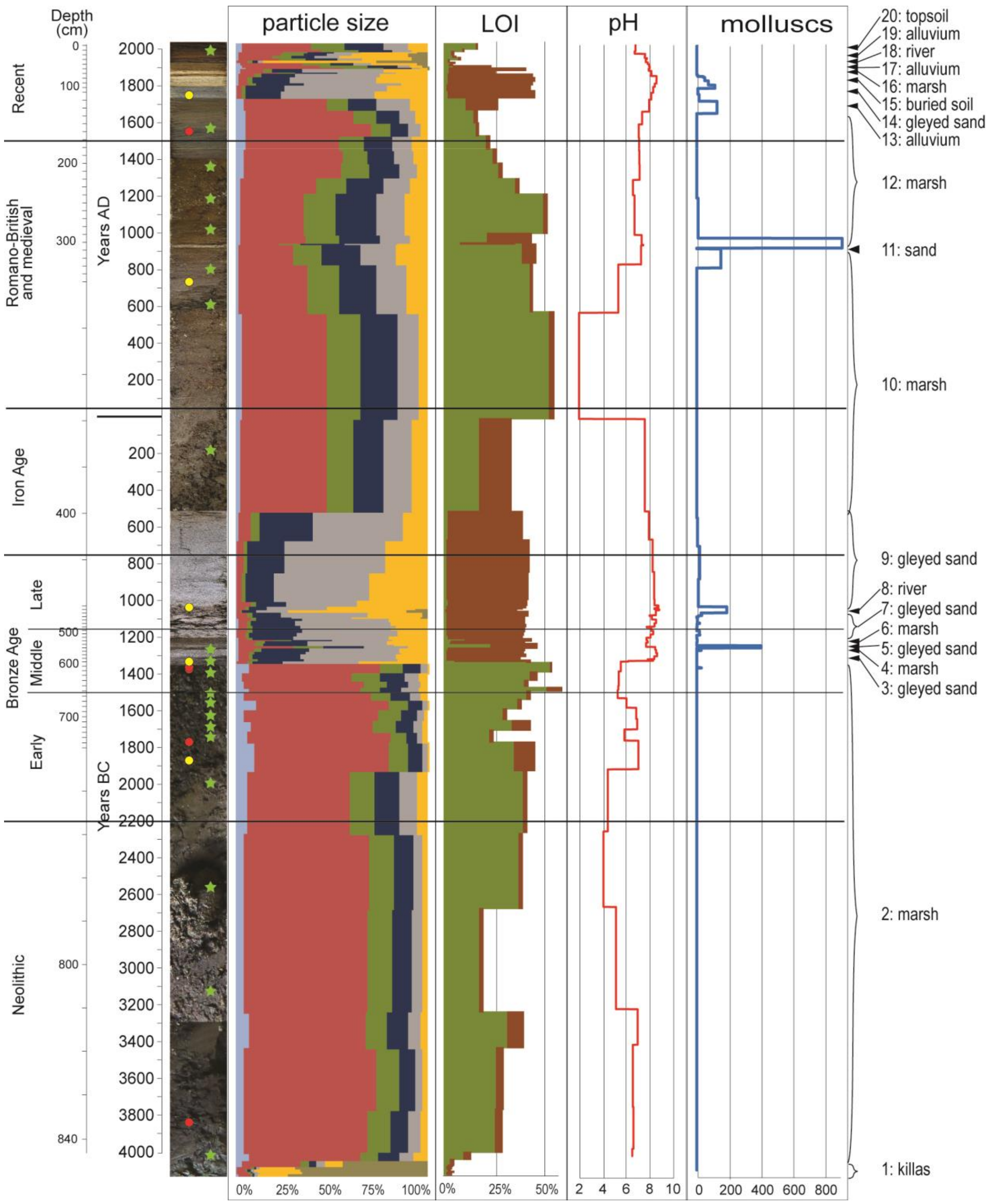


Figure 7.4. The 0.5m core summary diagrams plotted against age.
The dots indicate the levels at which material was dated; red dot = radiocarbon, yellow dot = OSL.
The stars indicate the levels from which pollen samples were obtained

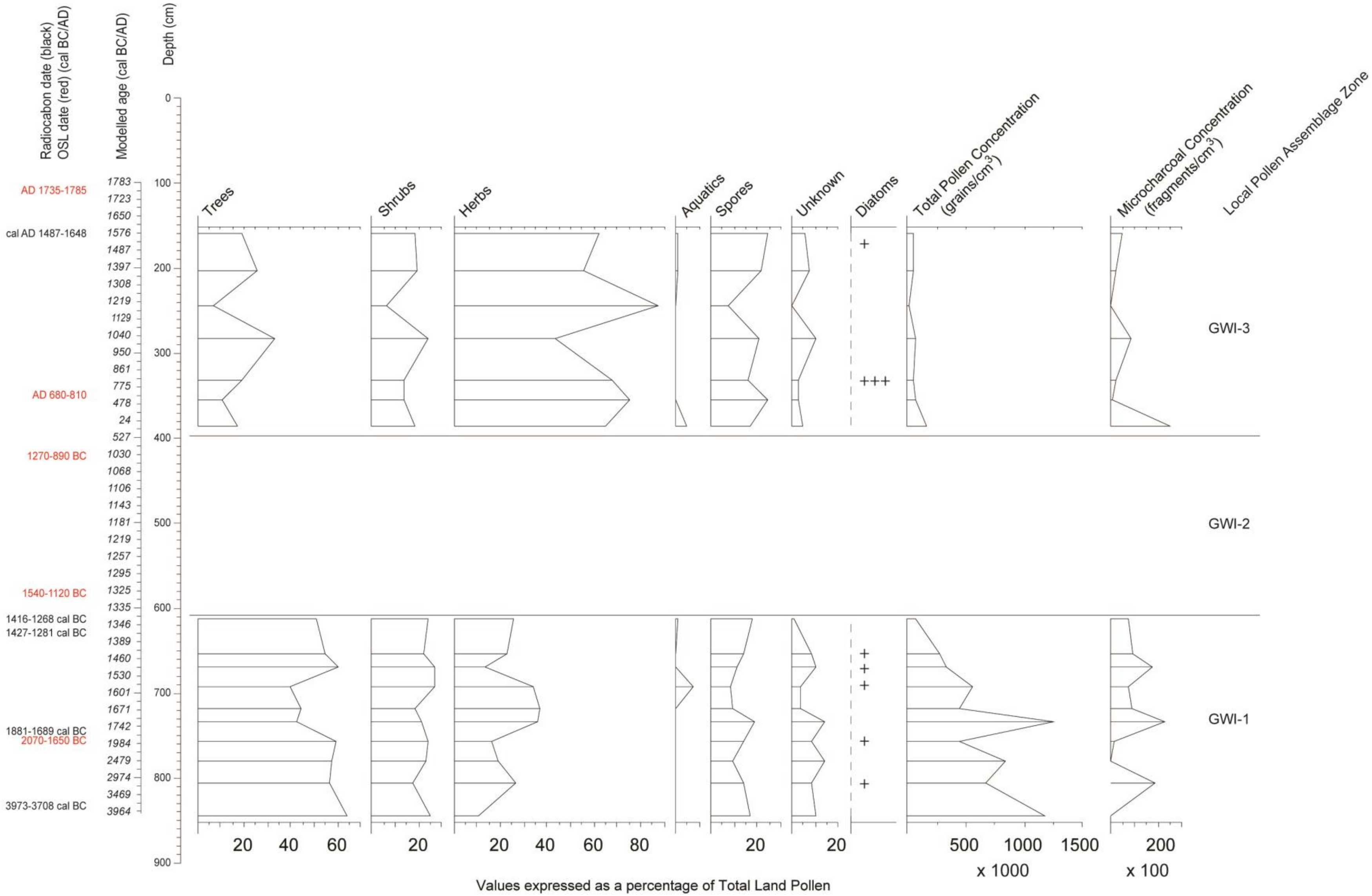


Figure 7.5. Summary pollen diagram for the 0.5m core. Radiocarbon and OSL dates are extrapolated from the dated 30m core (pollen analysis and diagram: Dr R. Batchelor)

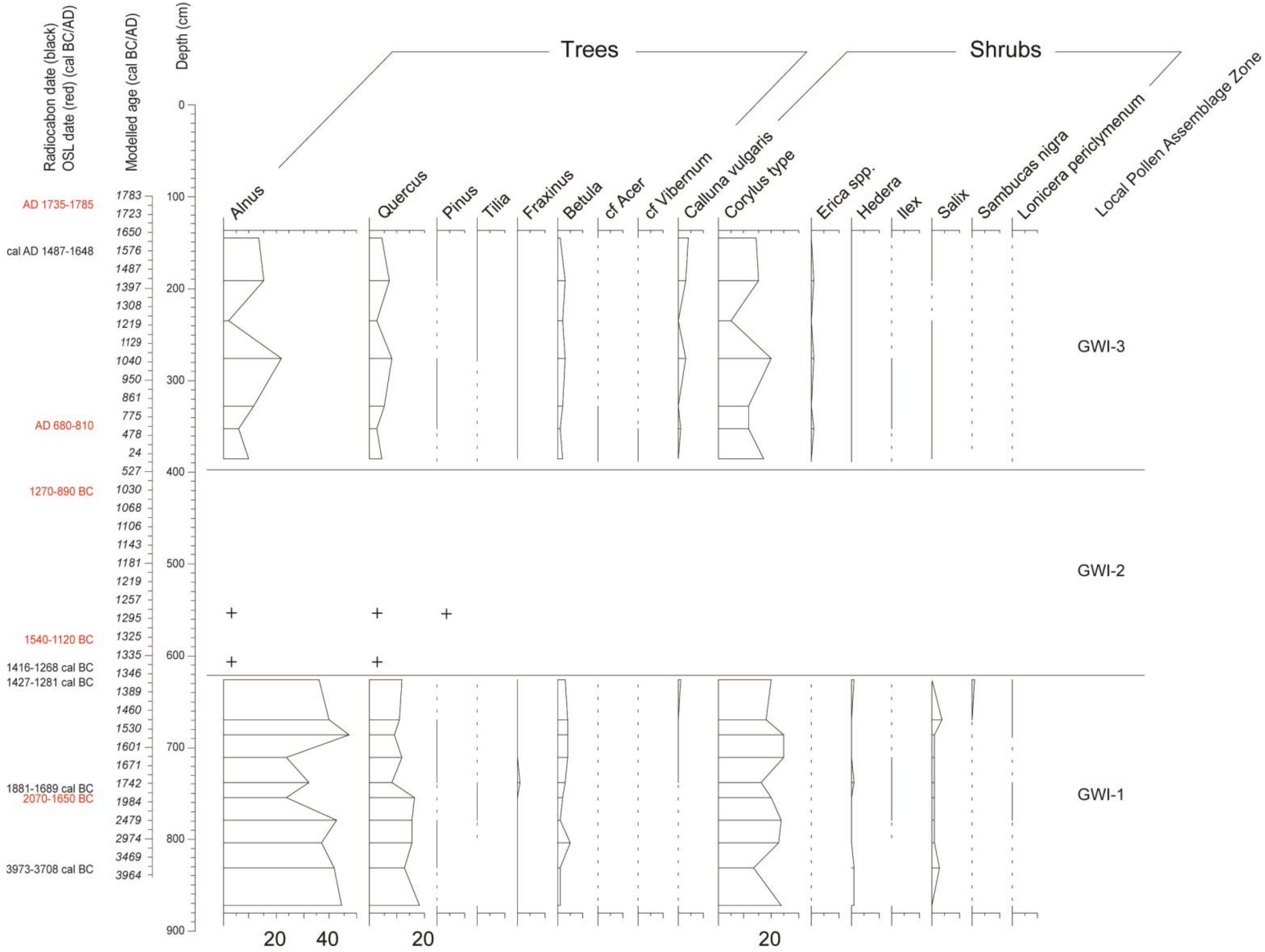


Figure 7.6. Diagram for tree and shrub pollen in the 0.5m core. Radiocarbon and OSL dates are extrapolated from the dated 30m core (pollen analysis and diagram: Dr R. Batchelor)

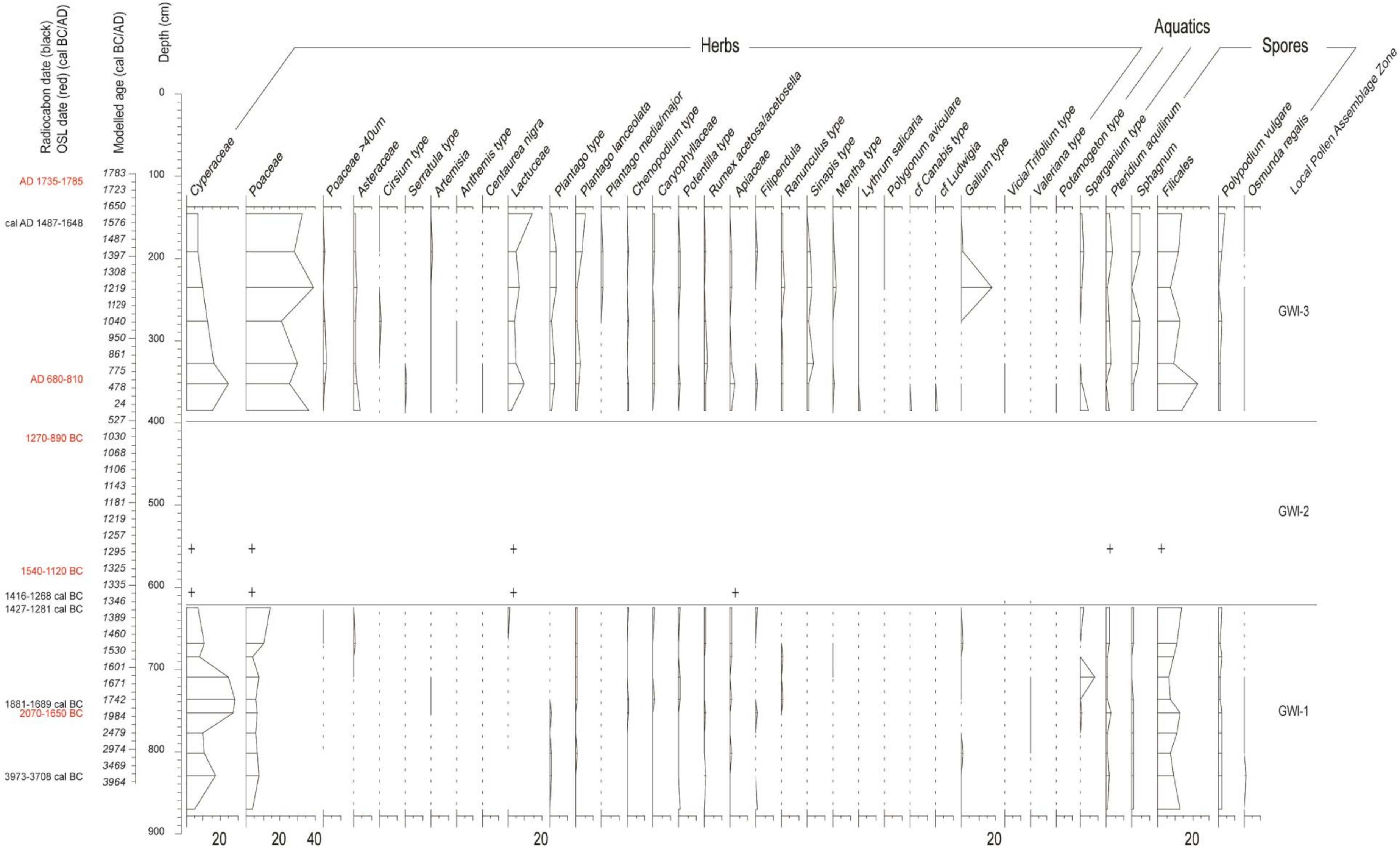


Figure 7.7. Diagram for herb, aquatic and spore pollen in the 0.5m core. Radiocarbon and OSL dates are extrapolated from the dated 30m core (pollen analysis and diagram: Dr R. Batchelor)

When sand [3] first accumulated is not clear, as individual samples cover long time sequences, and the graphs have assumed an even rate of deposition between date estimations. Using this assumption sand was certainly present by about 2600 BC but may have been earlier. This sand horizon is not evident in the 15m or 0.5m cores, implying that it did not cover the whole valley. However, its spatial extent is unclear because the two cores in the south of the valley did not reach bedrock.

At 30m the sand was replaced by further marsh [4] at about 1800 BC, securely dated by OSL in the sand (2080–1660 BC) below marsh dated by radiocarbon (1881–1689 cal BC). The pollen indicates a return to wetter conditions about 1750 BC, indicated by decline in alder/willow and increase in sedges/bur reed. Oak pollen values decline about this time, suggestive of a reduction in dry woodland. The marsh was acidic at this time and the occurrence of heather pollen (*Calluna vulgaris*) may indicate a coastal heath community with plantain and cinquefoil (*Potentilla* type).

The chronology of the transition to wetter conditions across the valley and from sand to marsh at 30m corresponds closely to the commencement of the first known settlement at Gwithian, around 1850 cal BC, during the early Bronze Age (Phase 1) (Sturgess 2007a). Although definitive evidence is lacking, Dr Batchelor, in his pollen report, considers anthropogenic interference may be the cause of vegetation change due to the timing of the event in the early Bronze Age, the increase in herbaceous taxa, some of which may indicate disturbed ground (e.g. fat hen (*Chenopodium* type) and ribwort plantain (*Plantago lanceolata*), and relatively high values of microcharcoal. However, the date of this change from sand to marsh closely correlates to the 1880 cal BC major riverine flooding event elsewhere in Britain identified by Johnstone *et al*. (2006) and, if that also affected Cornwall, may have been a contributing factor in the return to marsh conditions.

There is an abrupt change in the sedimentology from marsh [4] to sand [5, 6] during the middle Bronze Age, reflected in all the cores. The time at which the marsh retreated and was replaced by sand is securely dated, there being marsh at 1416–1268 cal BC (radiocarbon date), but sand at 1550–1130 BC (OSL date). Despite the wide range in the OSL date it is clear that the latest time that the marsh persisted was 1268 BC and that sand was definitely there by 1120 BC. This corresponds to the later part of the middle Bronze Age levels in the settlement (Phase 3), following which the fields on the west side of the site were partly abandoned (Phase 4), shown in the 2005 trench excavations as catholic and shade mollusc with few open country shells (Davies 2006; Sturgess 2007a, 29). Unfortunately, no shells have survived in the core samples from this depth, so no comparison can be made regarding the molluscs at the two sites. The pollen, also, has not been preserved sufficiently for any conclusions to be drawn concerning the vegetation.

Phase 5 of the Bronze Age settlement, from *c* 1300–900 cal BC (Sturgess 2007a, 30), was a period during which the settlement prospered, with new buildings and a flourishing field system. The sediments in the core indicate a period of stability, being maximal at 1100 BC, during which a buried soil [7] accumulated, sufficient for a very rich and diverse molluscan fauna to develop (18 species, Shannon index: 2.17). There is a mixture of taxa indicating that the ground was still wet (principally *Carychium minimum*, *Vertigo antivertigo* and *Ashfordia granulata*), but with a good spread of species associated with more varied habitats (mainly *Cochlicopa* sp., *Aegopinella nitidula*, *Cochlicella acuta*, *Helicella itala*). The dominant shell is *Lauria cylindracea*, a species requiring some shade, but commonly associated with stone walls, suggesting that there may have been walls in this vicinity, perhaps with adjacent ponding to provide habitat suitable for the wet ground species, similar to modern day conditions behind the road wall (see discussion for 51m core in Section 6.3.1.6). The river channel was mobile during this period, being at the 15m location at *c* 1350 BC and *c* 1220 BC, at 0.5m at *c* 1060 BC and then back to 15m again at *c* 1050–800 BC.

Sand [8] covers this buried soil, with an OSL date range 28cm above its base of 1290–810 BC. The thickness of the sand makes it difficult to be precise about the timing of accumulation, but it is certainly about this time, and correlates very well with final abandonment of the Bronze Age settlement around 900 cal BC. It has long been proposed (Thomas 1958) that inundation with sand was the precipitating factor for abandonment, and the present study supports this hypothesis.

The sediments in the 30m core from 207–435cm have all been identified as midden material [9], on the basis of the presence of numerous animal bone fragments and of the mollusc assemblages, both marine and non-marine (see section 6.3.1.5), and were considered to derive from the post-Roman settlement on the adjacent sand dune, occupied from the fifth to eighth centuries AD (Sturgess 2007b). However, the age/depth plot implies that midden formation commenced around 400 BC. This seems unlikely as there is no known occupation in this part of the valley between the end of the Bronze Age and the post-Roman period, the earliest dated pottery from this area being cal AD 420–600 (1534±29; OxA-14529) (Hamilton *et al.* 2008). A likely hypothesis is that the initial deposition of sand was rapid and thick, and this deposit remained until commencement of midden use in the post-Roman period. In the diagram the dates have been distributed evenly between 1060 BC and 730 AD, as there are no intervening dated levels; if the above interpretation is correct, and sand beneath the midden was deposited in a very short period of time, then the sand/midden interface could coincide with the commencement of post-Roman occupation on the adjacent dune. Further dating of samples from the interface would help resolve this question.

The 15m and 0.5m cores, although liable to the same dating problems at this time discussed above, show that these areas were marsh during the time that the midden accumulated, reflected in both the sedimentology and the very high numbers of wet ground molluscs around 800−1100 AD. This marshland did not extend right across the valley, as there is no evidence of any wet ground in either core south of the present river site.

The pollen in the marsh sediments from *c* 500 BC to *c* AD 1700 show a reduced woodland cover of both wetland and dryland areas, indicated by a reduction in alder and willow, but increase in herbaceous and aquatic flora, including grasses and sedges. Anthropogenic modification of disturbed land, grassland, crops and associated weeds is suggested by the presence of ribwort plantain (*Plantago*), dandelion (Lactuceae), dock/sorrel (*Rumex acetosa*/*acetosella*), daises (Asteraceae), Brassica family plants (*Sinapis* type) and possible cereal (Poaceae >40µm). Higher values of heather (*Calluna vulgaris*) pollen, *Sphagnum* moss spores and heath (*Erica*) suggests expanding acidic soils and heathland, again perhaps that of a coastal heath community. There is no indication of a shaded environment in the molluscan record, nor even significant dry ground, so presumably there was considerable variation in the environment in different parts of the valley over this long period of time.

The 30m diagram suggests that midden use continued into the late medieval period, despite the abandonment of the post-Roman industrial site on the nearby dune in the eighth century. The OSL date of AD 640−800 concurs very well with the known settlement occupation, and it is likely that the even distribution of dates between this time and the next dated level (cal AD 1487−1648) is misleading.

Marsh [10] covers the midden site following its abandonment and was presumably contiguous with wet conditions closer to the river, but which never extended to the south of the valley. It was not until the seventeenth century that sand again accumulated [11]; the ground remained unstable, reflected in the low number of molluscs, until very recent times with stabilization and formation of the turf and topsoil now present [12]. The mollusc assemblage in the modern turf at 30m is very rich and diverse, but closer to the river molluscs are virtually absent, and no pollen was preserved in the sample taken at 11cm depth. The leet, a short distance north of the present river course, was cut sometime between 1839 and 1850 (see Section 5.1.1). Figure 7.4 suggests that there was flowing water at 0.5m in the early twentieth century, and whether this indicates slight variation in the line of the leet over time, or, more likely that the date is slightly late due to inaccuracies in the dating of sediment deposition over the last three hundred years, is unclear. The modern vegetation beside the leet is lush and varied and it is curious that neither pollen nor molluscs are found in the topsoil, despite the neutral pH. Intermittent flooding and/or contamination from mine pollution could explain both the lack of molluscs and pollen.

7.2 Isotopes

Carbon and oxygen stable isotopes were measured on molluscs from the 30m percussion core. Wherever possible, specimens of *Cochlicella acuta* were used, but at one level, 40–55cm, *Helicella itala* was measured as there were no *Cochlicella* in the sample. When sufficient specimens were available three different shells were used as replicates, but, when limited, three replicates were obtained from a single shell. There were no suitable shells at some levels, and no shells were present in any of the samples below 600cm. The methods for conversion to temperature are described in Section 4.2.7 and figures for the measurements and analyses are included on the CD (Appendix 7).

Figure 7.8 shows the $\delta^{18}O$ and $\delta^{13}C$ age/depth graphs, together with the derived temperature curve. The estimations from living molluscs (dots at the top of each graph) correlate well with the recent sub-fossil shells, providing confidence in the measurements. Modern temperature records from Camborne (five miles south east of the study site) show that the mean annual April-October temperature (the growing period of molluscs when shell is laid down) from 1979 to 2012 was 11.10^{O}C, with a mean maximum temperature of 15.90^{O}C (www.metoffice.gov.uk). This compares very favourably with the measurement of living shells in the 30m core of 14.96^{O}C, again supporting the reliability of these results.

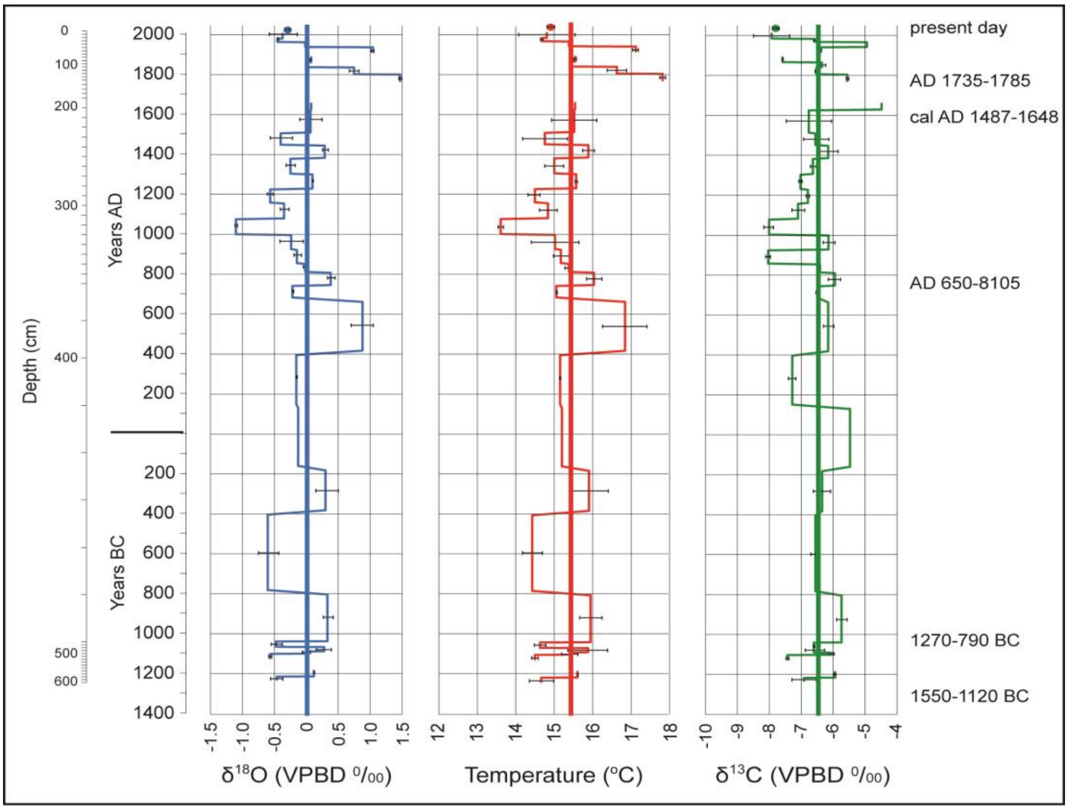


Figure 7.8. Age/depth graphs for the stable isotopes and temperature in the 30m core.
The dot at the top of each graph indicates measurements on shells from living specimens.
Error bars are 2σ. The average measurement for each graph is indicated by heavy lines

Overall the oxygen stable isotope measurements give an approximate indication of climate variation at Gwithian for over 3000 years. There are three periods when the temperature falls below average – about 1250−1050 BC, 800−400 BC and AD 900-1250. The earliest broadly corresponds to the period of instability proposed by Bond *et al*. (1997; 2001) at 1540−550 BC, while the 800-400 BC episode (albeit from a single measurement) correlates with the period of cooler, wetter, conditions proposed by Van Geel *et al*. (1996) at 850−550 BC. The colder episode at 800−400 BC corresponds to a period of major sand blow, at the time when the Bronze Age settlement was abandoned, supporting the supposition that abandonment was connected to sand inundation.

The graphs from 400 BC–AD 1550 cover the period when there was midden material in the core, and almost certainly does not represent regular deposition of sediment, as discussed above. The isotope variations over this time are therefore unlikely to be a reliable to temperature alterations over this period. The warm episode suggested at AD 400−650 is too late for the Roman warm period and the deterioration in temperature indicated at AD 900−1250 is the opposite of that expected during the medieval warm period. These anomalies can be accounted for by the midden deposits, which are likely to contain sediments of mixed age and irregular stratigraphy. The slight reduction in temperature around AD 1500 could correspond to the early part of the Little Ice Age but is inconclusive. Unfortunately there are no measurements relating to the later part of the Little Ice Age, but a steep rise in temperature before AD 1800 is consistent with the warmer episode in the eighteenth century (Bell and Walker 2005, 94). There is then fluctuation to the present day.

The carbon stable isotopes show variation reflecting minor differences in diet of the molluscs over time, but the range of $\delta^{13}C$, from -8‰ to -5‰ (with a single measurement of -4.5‰), and the scarcity of studies concerning the diet of *Cochlicella acuta*, makes further analysis difficult. This is a vegetarian mollusc normally living in short grassland, and its food is likely to consist of grasses and other low growing plants. The variation in $\delta^{13}C$ presumably indicates minor changes in the relative proportions of the different plants on which it feeds.

7.3 Chemistry

The history of mining, particularly for tin, in the catchment area of the Red River suggested that analysis of cores taken from the valley might provide insight into the chronology of mining in the area. Although much of the river bed has been disturbed by stream mining (see Section 5.2) there is no historical evidence that such disturbance has ever taken place at the location where the cores in the present study were obtained. The sequences and chronologies obtained for this project show that they are not disturbed by mining activity.

The chemical composition of sediments was studied in two cores; the 0.5m core by fine resolution Itrax XRF scanning (measurements at 1mm intervals) and the 15m core by pressed pellet XRF (one measurement on each sample used for mollusc analysis). Further details of the techniques are given in Section 4.2.6. It is emphasised that the Itrax method measures radiation counts per unit time and not element concentration, whereas the pressed pellet XRF measures concentrations of elements or minerals. The magnetic susceptibility of the 0.5m core was also measured at 5mm intervals with the Itrax analyser.

One of the problems with Itrax analyses is that the emitted signals from calcium and tin are very similar, and it is not possible to separate the two elements. This is unfortunate in that tin, in the form of cassiterite, was the principle ore sought in the mining process. A wide range of other metals can, however, act as proxies for mining activity. The main tin ore, cassiterite, is closely associated with wolframite and arsenopyrite (Dines 1956, 20; Bishop *et al.* 1999, 50), so tungsten and arsenic levels may provide a guide to tin extraction; both of these metals were mined commercially in the nineteenth and twentieth centuries (Dines 1956, 23, 25). Sphalerite, the main mineral containing zinc (Dines 1956, 26; Bishop *et al.* 1999, 24), was also mined in the Camborne area and is found in association with lead and sometimes copper, all of which may provide a guide to mining activity. Other metals ascribed to mine tailings contaminating the Red River are iron, manganese and yttrium (Yim 1981; Morris *et al.* 1985).

A further problem is the degree to which elements and minerals are retained in the sediments deposited in the valley floor. When the sediment consists mainly of sand-sized grains then there is little retention of minerals giving misleading results. In the figures that follow the periods when sand was the dominant deposit have been highlighted.

The Itrax XRF graphs for the 0.5m core are shown in Figure 7.9 and the pressed pellet XRF for the 15m core in Figure 7.10. All the graphs show +ve or –ve variation from the average measurement before the commencement of the Bronze Age (2200 BC), prior to any likely mining activity in the area. No readings for tungsten or tin are available for the 15m core as levels were below the detection limits for the spectrometer. It is important to point out that the dates on these figures are extrapolated as carefully as possible from the 30m core, but there will inevitability be some discrepancies with true dates.

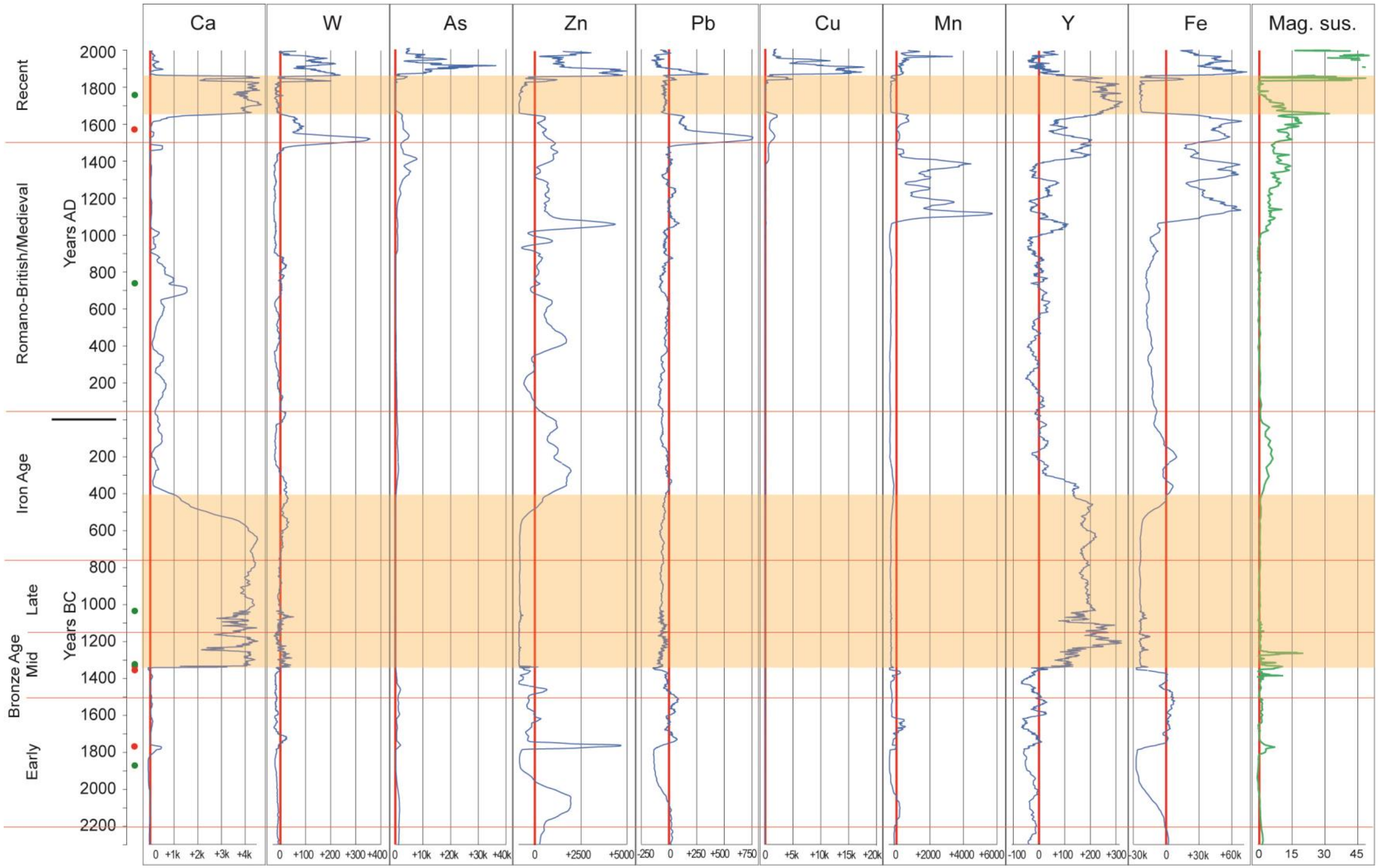


Figure 7.9. Itrax XRF geochemistry and magnetic susceptibility on the 0.5m core.
Values are differences (- or +) from the average background counts/10 seconds prior to the Bronze Age (2200 BC) with the baseline indicated by the red line on each graph. The highlighted areas are those where the sediment is sandy with high calcium levels.
The dots indicate dated levels: ● = radiocarbon; ● = OSL

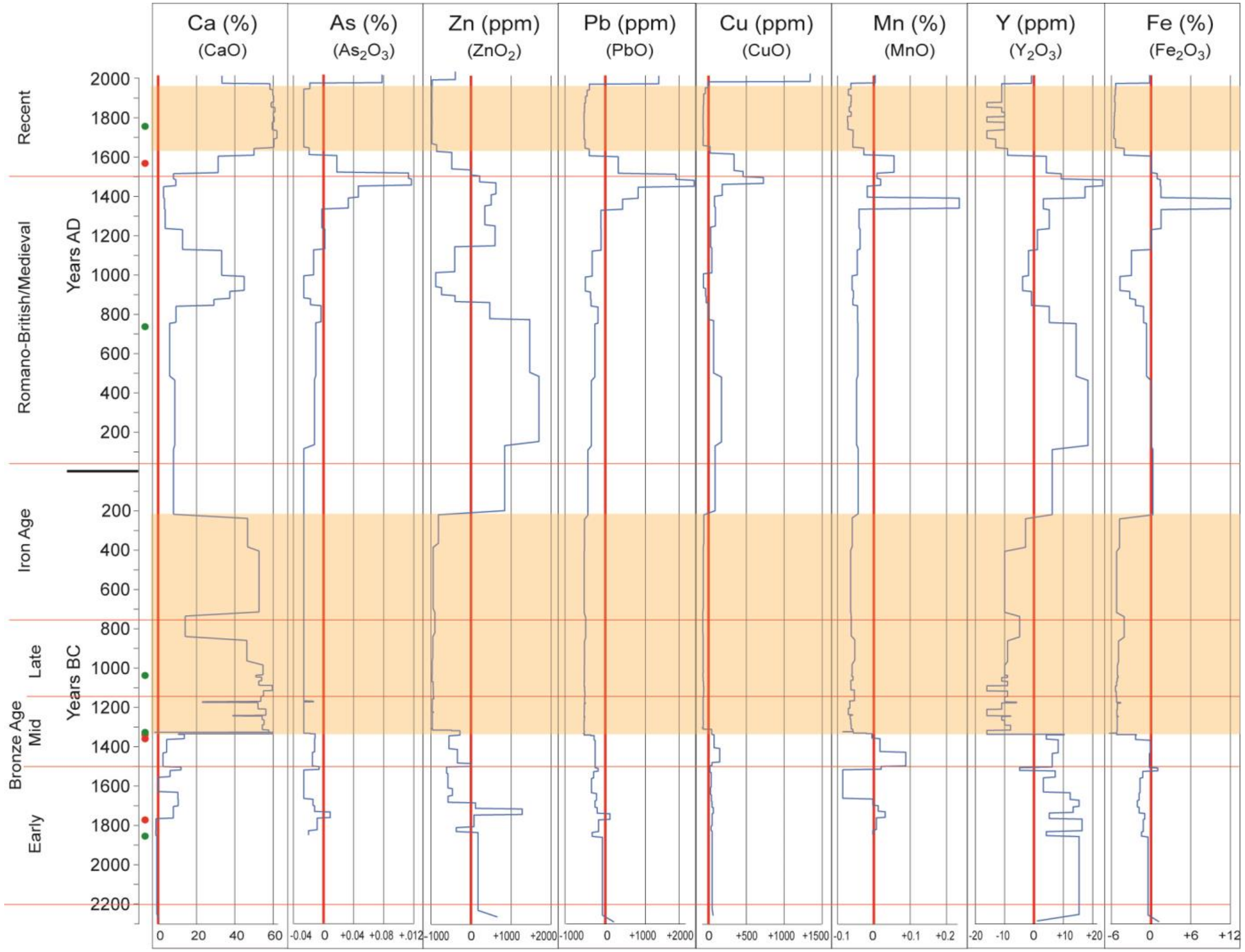


Figure 7.10. Pressed pellet XRF geochemistry on the 15m core.
Values are differences (- or +) from the average background concentration prior to the Bronze Age (2200 BC) with the baseline indicated by the red line on each graph. The highlighted areas are those where the sediment is sandy with high calcium levels.
The dots indicate dated levels: ● = radiocarbon;.● = OSL

The periods of 1310−400 BC and AD 1690−1850 in the 30m core and of 1310−220 BC and AD 1310−1970 in the 0.5m core are those where measurements are affected by the presence of significant quantities of sand, and do not give a true reflection of the chemical composition of sediment; these periods will not be discussed further.

Peaks of different metals/minerals are evident at different times, and there is generally good correlation between the two cores. The first detected rise is about 1750 BC, when there is slight increase in tungsten, arsenic and lead, marked increase in zinc and some elevation of magnetic susceptibility. These increases are short-lived, reducing to background levels after only a few years. The OSL date range of 2080−1660 BC is within the early Bronze Age, but is this sufficient evidence to suggest that there was mineral extraction activity during this period? If mining did take place, then it is probable that cassiterite, the main tin ore, was the mineral being sought, but that metal cannot be detected by the analytical methods used. The small increase in tungsten and arsenic levels is consistent with the presence of wolframite and arsenopyrite, ores associated with cassiterite. The high level of zinc, from sphalerite, is another pointer to mining at this time. The lead signal is likely to be incidental. These metal levels are not strong enough to provide solid evidence of mineral extraction during the early Bronze Age, although there are tentative indications that this did occur.

During the middle Bronze Age none of the measurements show any variations from background level apart from manganese which is elevated in the 15m core, hardly evidence of activity. Unfortunately, sand levels after 1320 BC preclude any interpretation of mining during the later Bronze Age. This is regrettable, as fragments of two stone axe moulds were found at Gwithian during the twentieth century excavations and have been dated to the century or so before 1150 cal BC (Burgess 1976).

Some increase in zinc is present in the Romano-British period, but the dating at this time is not secure and no conclusions can be drawn. More convincing is elevation of several metal signals around AD 1050−1100, reflected in zinc, lead, manganese, yttrium and iron levels, but not of tungsten or arsenic. This implies that tin, in the form of cassiterite, was not being mined at this time, but that zinc minerals as sphalerite were obtained, with manganese and yttrium being incidental contaminants. While zinc may not have been utilized during this period it may be that lead-containing galena was sought, the two minerals resembling each other – sphalerite is also known as 'false galena' and 'mock lead ore'. The very marked increase in iron at this time probably caused the waters of the Conor Dour to turn red, and the name 'Red River' could well have been adopted for the first time.

It is not until AD 1400 that arsenic levels rise, with marked increase in yttrium, and with tungsten and lead following about AD 1500. The earliest elevation of a copper signal is at this time, there having been no earlier rise. Manganese levels, however, fall. These findings strongly indicate mining activity during the late medieval period and early Industrial Age, and are consistent with documented mining in the Red River catchment area at this time (Hamilton Jenkin 1965, 5).

No information is gained for the period from 1650 to about 1870 due to lack of metal signals associated with the presence of sand. In the later nineteenth and the twentieth centuries there is very clear increase in all the measured metals in the 0.5m core. Resolution of the 15m pressed pellet samples is too poor for fine dating, but all the metals are increased in the most superficial sample, which was 19cm thick. These findings are in accord with the widespread introduction of new technology, especially pumping machines (manufactured on a very large scale at nearby Hayle), during the nineteenth century, making the Camborne/Redruth area one of the most productive mining areas in the country.

8. Gwithian – trench excavation

The transect core samples, because of their small size, only permitted a limited analysis of the sediments through which they pass. There is no opportunity to see stratigraphy *in situ*, either in plan or in profile. The excavation of a small trench permitted the stratigraphy at one location to be examined in detail and gave the opportunity for larger samples for palaeoenvironmental analysis to be obtained. The location at 150m along the transect line was selected as the core had previously suggested that buried soils were present at this site, close to the field system excavated in the 1960s (Fowler and Thomas 1962). There was therefore a high likelihood that there had been human activity in the vicinity both during the Bronze Age and in the post-Roman period. Consent to conduct the excavation was obtained from English Heritage (Scheduled Monument CO 771), Natural England (SSSI) and the landowner, Professor Charles Thomas.

8.1 Excavation methods

The excavation was conducted over five days in July 2012 by a team from the University of Reading. It was considered that a 2 x 2m trench would provide adequate working space to enable the bedrock to be reached. The east margin of the trench was located on the transect line, with an area of ground to the west reasonably level and free from obvious recent rabbit activity. The exact co-ordinates of the corners of the trench were plotted using differential GPS:

	Grid references		
	Easting	**Northing**	**Elevation**
Northwest corner	SW 58883.97	SW 41285.23	8.12m
Northeast corner	SW 58885.91	SW 42185.24	8.04m
Southeast corner	SW 58885.90	SW 42183.27	8.02m
Southwest corner	SW 58883.93	SW 42183.28	7.92m

The upper portion of turf was removed by spade and placed aside. All sediments below this were sieved using sieves with a mesh of 10mm or ½in; sieving with a smaller mesh size was attempted but the sands were too wet to permit this. Spoil was placed on groundsheets in separate piles for each context.

The excavation was conducted by context. All artefacts, stones, shells, charcoal, etc., detected during excavation were given a small find number before removal and their position recorded by GPS; they were then lifted and placed in labelled bags. All material retained in the sieves was recorded as bulk finds. Animal footprints found on the buried soil horizons were photographed and traced on plastic sheeting at life size.

The underlying natural geology was reached at an average depth of 100cm. A small (20 x 20cm) pit was dug in the north west corner of the trench to obtain samples of the natural and to provide working space to insert the sample tube for OSL dating. On completion of the excavation section drawings at 1:10 scale were prepared from all four trench sections.

Samples for palaeoenvironmental analysis were obtained from several locations within the trench (Figure 8.1). Five samples for OSL dating were taken by Dr Helen Roberts (Aberystwyth University) from the south facing section to date the old ground surface and the sands within, above and below two buried soil levels. Samples for mollusc and other geophysical analyses were taken from a column at the west end of the south facing section and a 50cm monobloc sample covering the buried soils obtained between the mollusc column and the OSL sample positions (the monobloc column has not been analysed, but has been retained as an archive). Finally, two small samples for micromorphology were taken from possible ard marks in the west facing section.

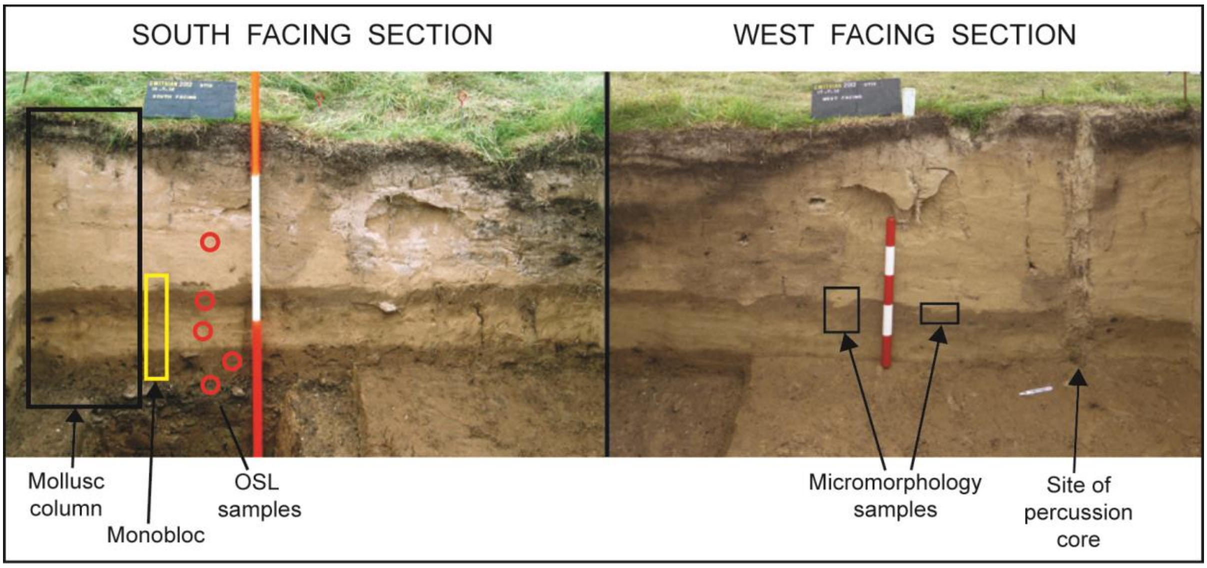


Figure 8.1. The positions of the dating and environmental samples obtained from the trench.
Scales — left: 50cm divisions; right: 10cm divisions

After completion of the recording and sampling the trench was backfilled by hand with the spoil being returned as far as possible in context sequence and the turf replaced.

8.2 Excavation findings

The drawing of the south-facing section of the trench is shown in Figure 8.2; numbers in square brackets [ ] in the following text refer to the contexts shown on the section drawing. Munsell numbers of the sediment colours were recorded in the field and shown in the following text.

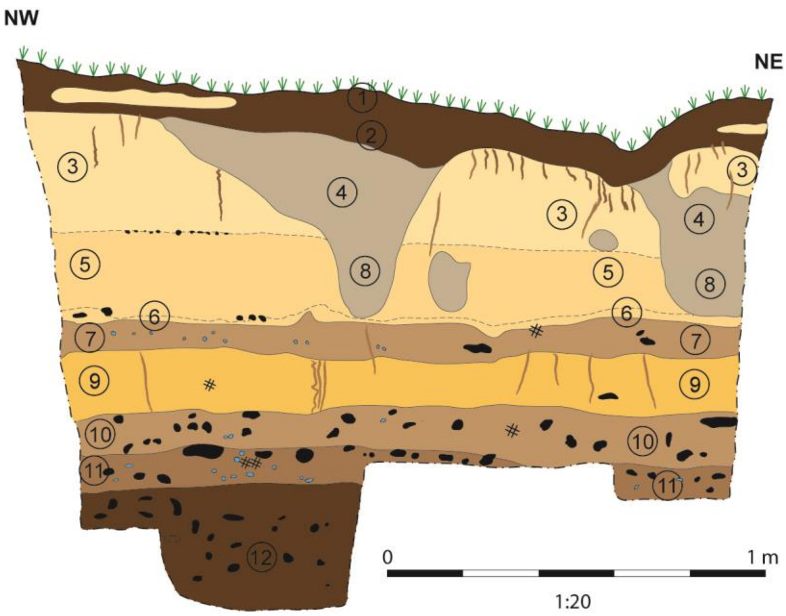


Figure 8.2. Drawing of the south-facing section of the trench excavation.

The turf [1] and sub-soil [2] (7.5YR 3/3) was 10–20cm thick and the only artefacts within it were some clay pipe fragments. Beneath the turf rabbit burrows became evident [4, 8], but limited to part of the trench only. Within the disturbed sand of the rabbit burrow [4] there were several rabbit bones, some sandrock and one decaying golf ball. None of these are considered of importance, although there is no record there has ever been a golf course in the vicinity.

The turf overlay a 35cm thick sand layer [3] (10YR 7/6) above 20cm of slightly darker sand [5] (10YR 7/5), with a horizon of small stones at the interface. No finds were present in either of these sands apart from a few mussel shell fragments in the lower part. The lowest 4cm [6] was indistinguishable in colour, but clearly different in that it contained numerous fragments of sandrock (1.44kg) up to about 6cm in diameter. Only four fragments of sandrock were found in any other context (apart from the rabbit burrows), two fragments each in contexts [5] and [9]; it is clearly a feature principally of context [6]. *Mytilus* sp. fragments (9g) were also found in this horizon, as well as several small stones up to 6cm diameter, weighing in total 0.5kg. Other marine molluscs within context [6] were two *Nucella lapillus* (dog whelk) shells and one *Patella pellucida* (blue-rayed limpet) shell; this latter is important as it is a small limpet which grows in the holdfast of Laminarian fronds, and is likely to have been brought to the site with seaweed.

A horizon of sand with silt consistent with a buried soil [7] was clearly visible, being darker in colour (10YR 5/4); it contained numerous stones (28.1kg), mostly less than 6cm in diameter, but with one fragment 15cm in length. The stones were mainly the local Cornish killas of slate and quartz. The marine molluscs found in this layer were *Mytilus* sp. fragments (344g) and *Patella* sp. (two shells). Several small charcoal fragments were found, the largest being 16mm in length. This buried soil horizon will be discussed in more detail below.

There is then another pale sand layer [9] (10YR 6/4) containing stones (16.8kg) of similar size and shape to those in the layer above, again mostly slate with some quartz. The marine shells were *Mytilus* sp. (116g), *Patella* sp. (five shells), *Nucella lapillus* (one fragment) and *Littorina obtusata* (one shell), together with one barnacle plate. Some charcoal fragments were present, but considerably fewer than in the overlying buried soil.

A second buried soil horizon [10] (10YR 5/4), similar to the one above, again contained numerous stones (19.7kg), a few of which were fire-cracked. Only one stone was clearly beach-worn. The stones included eight flint fragments, of which four had evidence of working (Figure 8.3). The marine molluscs were *Mytilus* sp. (85g), *Patella* sp. (31 apices) and *Pecten* sp. (one fragment). Only very few charcoal fragments were found in this sediment.

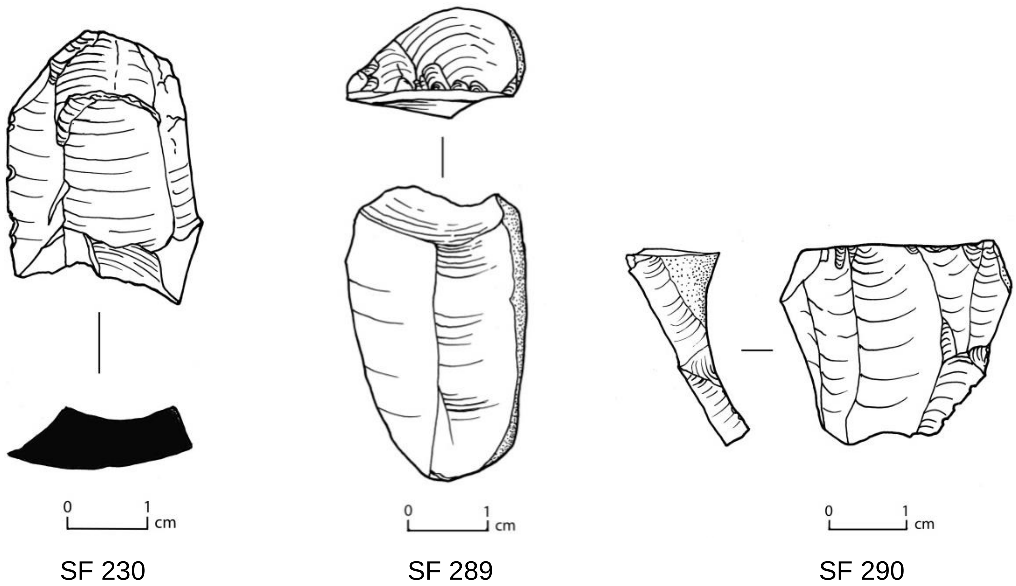


Figure 8.3. Three of the worked flints from the lower buried soil [10] in the Trench (graphic: Dr J. Foster)

The lowest deposit, the old ground surface [11] (10YR 4/3) is a silty sand with several charcoal fragments, some stones (7.1kg) including two worked flint fragments. There were some marine molluscs: *Mytilus* sp. (27g), *Patella* sp. (26 apices) and *Nucella lapillus* (one fragment). The flint fragments from this and the overlying context are considered to be of Mesolithic origin (Charles Thomas, *in litt.* 15 August 2013).

The bedrock of killas [12] was only excavated in the north west corner of the trench to allow working space for the OSL sample collection and mollusc sampling at the base of the trench.

8.2.1 Buried soils

The upper buried soil horizon [7] was dark in colour but with numerous marks of lighter coloured overlying sand impressed into its upper surface (Figure 8.4), shown in close-up in Figure 8.5, and diagrammatically in Figure 8.6. These are mainly semicircular in shape, ranging in size up to 10cm in diameter, and are interpreted as animal hoof prints. The large prints, over 7cm, are likely to be bovid, while those less than 5cm are probably ovi-caprid (Bell 2013b, Plate 7.2). All these species have cloven hooves but only a few of the prints in the trench were clearly cloven, the majority being semicircular. However, when footprints are impressed into soft sediment the cleft posteriorly is often lost, clearly demonstrated in the prints at Redwick (Bell 2013b, 146). Laboratory examination for the presence of spherulites was undertaken to assess whether animal dung was present, but none were found in samples from any of the buried soil sediments.

Figure 8.4. The upper surface of context [7] showing the animal footprints and ard marks (marked with asterisks) (scale: 10cm divisions)

Figure 8.5. Close up of the footprints (scale: 1cm divisions)

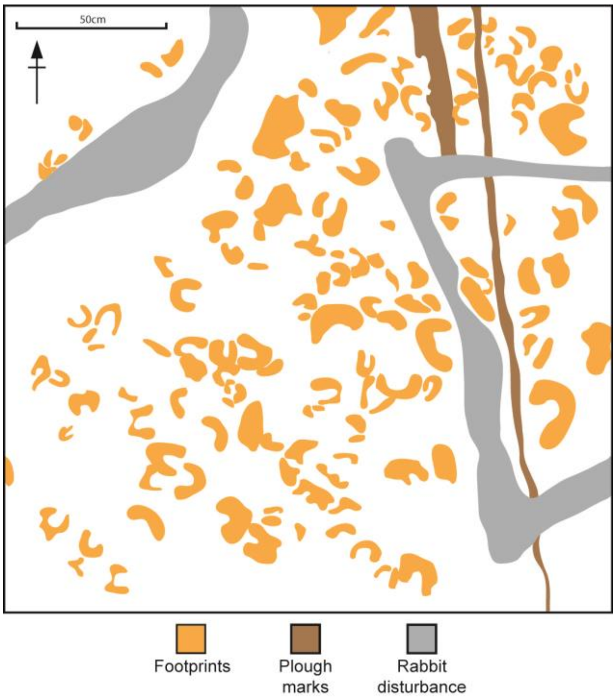


Figure 8.6. Drawing of the footprints and ard marks in context [7]

Two linear pale stripes, running north-south, were also present and are interpreted as ard marks. In the cleaned west facing section there were several ‘U-shaped’ indentations in the upper surface of the buried soil (Figure 8.7), and micromorphology (Figure 8.8) supported these being ard/plough marks, although no east-west marks were seen during the excavation. (The full micromorphology report by Dr Rowena Banerjea is included on the CD in Appendix 16). No spherulites were seen in the micromorphology sections. The slides confirmed the presence of a thin buried soil overlying blown sand. However, other features such as the colour and mollusc assemblages suggest that this entire context is likely to be a buried soil, albeit not so well developed throughout, implying that true stability was perhaps only achieved in its upper portion.

Figure 8.7. The west facing section showing indentations consistent with marks on the upper buried soil (scale: 10cm divisions)

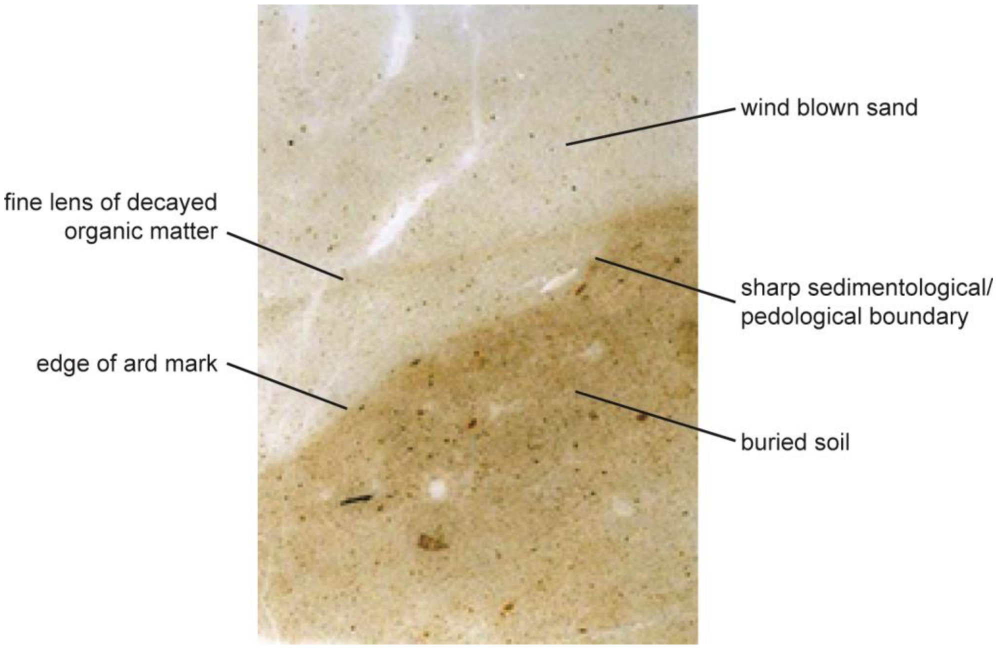


Figure 8.8. Micromorphology slide showing the ard mark (photo: Dr R. Banerjea)

A very thin (<500µm) lens of decayed organic matter overlay the ard mark which Dr Banerjea considered could represent a possible brief phase of stabilization over the plough marks, but which did not develop into a soil. Of relevance is that one of the micromorphology slides demonstrated a thin calcrete/sandrock crust on the surface of the buried soil, entirely consistent with the finding of the numerous sandrock clasts in the overlying sand [6].

The lower buried soil [10], in contrast to the upper soil, showed only a very few footprints (Figure 8.9). These were 10cm in diameter and are consistent with bovid prints. No ard marks were detected in this horizon.

Figure 8.9. The hoof prints in the lower buried soil [10].
The ard marks cut into the upper buried soil [7] are visible at the top of the image (scale: 10cm divisions)

8.3 Dating of the trench samples

Five samples for OSL dating were obtained during the excavation (Figure 8.1) to determine the chronology of the buried soil horizons. In addition, four molluscs from the buried soils, all *Xerocrassa geyeri*, were submitted for radiocarbon dating, one of which (68cm) was duplicated by the radiocarbon laboratory. The aim of using both dating techniques was to obtain comparison between the methods, and to establish the times at which this particular mollusc was living at Gwithian. The results are shown in Table 8.1 (OSL dates) and Table 8.2 (radiocarbon dates) and graphically in Figure 8.10.

Table 8.1. OSL dates on the mollusc column sand samples

Lab number	Depth (cm)	OSL date (2σ) (years before 2010)	Calendar date (1σ)	Mid-date	Context
Aber-203/GWT-12-1	45±3	310±30	AD 1670–1730	AD 1700	[5] overlying sand
Aber-203/GWT-12-2	64±3	2800±150	940–640 BC	790 BC	[7] upper buried soil
Aber-203/GWT-12-3	77±3	3060±170	1220–880 BC	1050 BC	[9] intervening sand
Aber-203/GWT-12-4	87±3	3110±190	1290–910 BC	1100 BC	[10] lower buried soil
Aber-203/GWT-12-5	97±3	5120±240	3350–2870 BC	3110 BC	[11] old land surface

Table 8.2. Radiocarbon dates on the mollusc column *Xerocrassa geyeri* shells

Lab number	Depth (cm)	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)	Mid-date	Context
OxA-28965	60-64	-6.46	3599±28	2026–1891 cal BC	1958.5 BC	[7] top of upper buried soil
OxA-28964	67-70	-6.23	3537±28	1946–1771 cal BC	1858.5 BC	[7] bottom of upper buried soil
OxA-28963	67-70	-6.53	3515±29	1921–1751 cal BC	1836 BC	
OxA-28962	85-88	-6.38	3576±29	2025–1785 cal BC	1905 BC	[10] top of lower buried soil
OxA-28961	91-94	-7.22	3558±29	2013–1776 cal BC	1894.5 BC	[10] bottom of lower buried soil

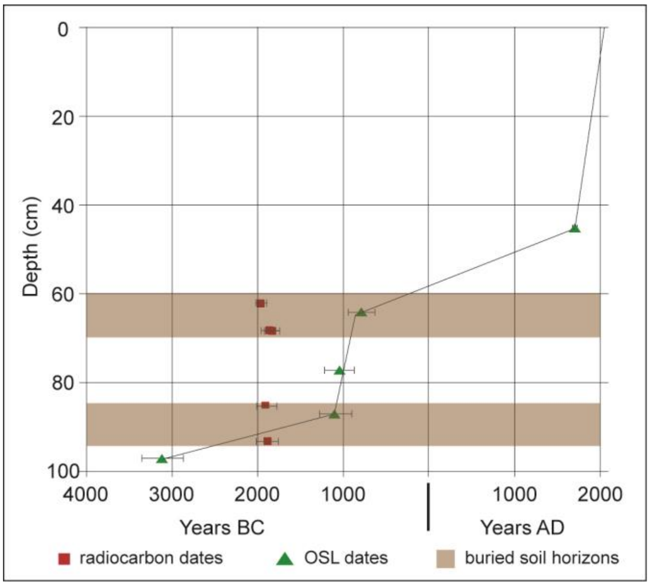


Figure 8.10. Age/depth plot for the OSL and radiocarbon dates in the trench. The trend lines join only the OSL dates

It is evident from the age/depth plot that there is discrepancy between the OSL and radiocarbon dates. The OSL dates give a good chronological sequence for the old ground surface, the two buried soil horizons with intervening sand and the overlying sand, and are likely to be a more accurate representation of the chronology than the radiocarbon dates, the latter giving almost identical dates for both of the buried soils. The $\delta^{13}C$ values for the molluscs, except for the lowest one, are very similar which implies that the shells in these three upper samples may actually derive from a closely similar deposit. It is likely that the shells have been moved, most probably as a result of deflation leading to reworking of shells, although animal disturbance cannot be excluded (earthworm burrows were evident in the section, but upward movement of the shells by worms would not be expected). The lowest radiocarbon date, which has a $\delta^{13}C$ value lower than the other shells, is more in accord with the OSL dating and another possibility is that the radiocarbon dates could be older than the true date of the shells as a result of ingestion of some old carbon from shell debris in the sand.

8.4 Mollusc column

The column was taken from the north west corner of the trench in an area that was clear of rabbit disturbance (Figure 8.1). 25 samples were obtained, one of which was the killas underlying the old ground surface. The laboratory analyses are summarised in Figure 8.11. The figures on which these graphs are based are included on the CD. The dates shown on the left are the OSL dates, the radiocarbon dates not being shown for reasons explained above.

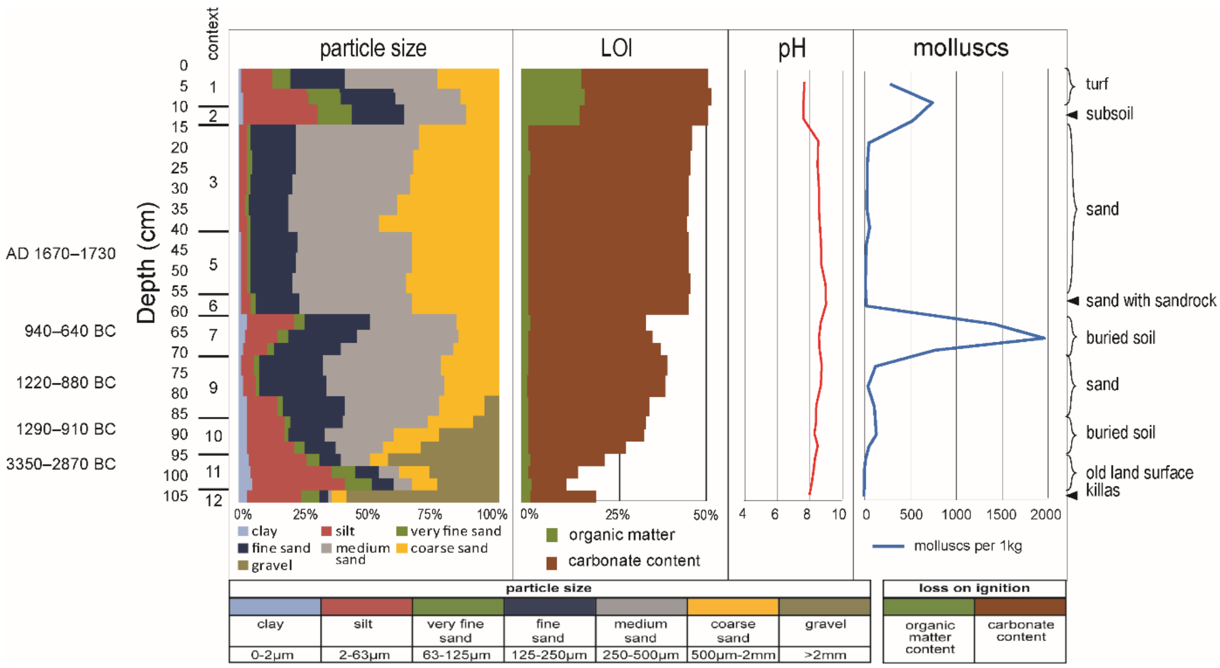


Figure 8.11. Summary diagram for analyses on the trench mollusc column. The OSL dates are shown

The killas bedrock [12] contains a moderate proportion of clay/silt (24%) and carbonate (18%), but no molluscs were found in this sediment. The old ground surface [11] did contain a few molluscs, although the carbonate content decreased to 9%, while there was increase in clay/silt to 40%. The proportions of silt and clay steadily decrease during accumulation in the lower buried soil [10], while sand and carbonate content increase, as do the numbers of shells present, although still relatively few in number. The sandy layer [9] between the two buried soils is identified in the particle size analysis and contains only a small number of molluscs, consistent with rapid accumulation.

There is marked change in the upper buried soil [7], with a greater proportion of silt and a very dramatic rise in the numbers of shells present. The progressive increase in silt at shallower depths in this soil indicates a steady build up of finer grain size over time and is a mark of the increasing stability of this horizon, in accord with the micromorphology findings. The silt in the buried soils may be derived from colluvial downwash from the adjacent towans, although input by wind action from the nearby valley has to be considered. The sand above the buried soil [6, 5, 3] has almost no silt and very few shells. There is no clear distinction on these graphs of context [6], no sandrock nodules being present in the sample from the mollusc column. There is some differentiation between the sand layers [5] and [3], with a higher proportion of coarse sand marking the base of [3], the proportion decreasing upwards. The top- and subsoil [2, 1] is clearly identified both on the particle size and loss on ignition graphs, being more silty and containing a higher proportion of organic matter than the underlying sand, and with a moderate number of molluscs.

Prepa

8.4.1 The molluscs

Table 8.3,, and graphically in Figure 8.12. A small number of species indicating open ground dominate the sequence, with a larger range of taxa, some more catholic in their ecological preferences, found in the upper buried soil [7] and the topsoil [1 and 2].

No shells were found in the sample of killas [12]. Very few were present in the old ground surface [11] probably due to relative decalcification; the taxa that do remain indicate open conditions with no evidence of shade in the vicinity. Some small flint flakes were present as well as charcoal. Marine shells in this deposit were *Mytilus* sp., *Patella* sp. and *Nucella lapillus*. The OSL date of this layer is mid-Neolithic. These findings are sufficient to indicate human presence at this time, perhaps with middening or manuring to account for the marine shells.

Table 8.3. The mollusc from the Trench column
1kg samples. No shells were found in the bedrock (>103cm)

Depth (cm)	**0–5**	**5–9**	**9–14**	**14–20**	**20–26**	**26–31**	**31–36**	**36–40**	**40–45**	**45–50**	**50–55**	**55–60**	**60–64**	**64–67**	**67–70**	**70–75**	**75–80**	**80–85**	**85–88**	**88–91**	**91–94**	**94–97**	**97–100**	**100–103**
Context	**1**		**2**	**3**					**5**			**6**	**7**			**9**			**10**			**11**		
Sediment	turf		sub-soil	sand					sand				buried soil			sand			buried soil			old land surface		
Munsell number	7.5YR 3/3		10YR 5/2	10YR 7/6				10YR 6/4	10YR 7/4				10YR 5/4	10YR 4/4		10YR 6/4			10YR 5/4			10YR 4/3		
Carychium minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-
Cochlicella lubrica	-	-	-	-	-	-	-	-	-	-	-	-	40	26	25	7	-	3	2	3	-	1	-	-
Cochlicella lubricella	-	-	1	-	-	-	-	-	-	-	-	-	3	3		-	-	-	-	-	-	-	-	-
Cochlicopa spp.	-	3	-	-	-	-	-	1	-	-	-	-	31	42	10	1	-	-	1	3	2	-	-	-
Vertigo pygmaea	41	63	18	-	-	-	-	-	-	-	-	-	28	-	1	-	-	-	-	-	-	1	-	-
Pupilla muscorum	2	2	22	1	6	3	5	-	1	4	-	2	309	230	148	28	6	4	1	3	-	-	-	-
Lauria cylindracea	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	1	-	-	-
Vallonia excentrica	163	378	180	6	2	4	-	1	1	1	1	1	316	331	228	38	8	7	2	1	-	1	1	1
Punctum pygmaeum	23	28	8	-	-	1	-	-	-	-	-	-	14	2	-	-	-	-	-	-	-	-	-	-
Vitrina pellucida	2	-	19	-	-	1	4	-	-	-	-	-		-	-	-	1	-	-	2	-	-	-	-
Vitrea contracta	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Aegopinella nitidula	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	1	-	-	-
Limacidae	1	1	6	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Clausilia bidentata	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Cochlicella acuta	34	214	224	26	15	12	12	9	11	6	7	10	632	1228	230	25	2	-	-	1	-	2	-	2
Ashfordia granulata	1		15	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1
Candidula intersecta	4	8	14	1	2	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Cernuella virgata	9	19	9	10	6	1	2	27	-	2	4	1		-	-	-	-	-	-	-	-	-	-	-
Helicella itala	3	4	2	9	4	13	10	18	12	7	5	10		-	-	-	-	-	-	-	-	-	-	-
Xerocrassa geyeri	-	-	-	-	-	-	1	3	-	-	-	2	43	123	138	27	26	99	120	121	49	14	2	1
Trochulus hispidus	16	31	17	1	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Cepaea nemoralis	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-
Cepaea sp.	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	1	-	-	-	-	-
Cornu aspersum	1	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL SHELLS	**300**	**752**	**535**	**54**	**35**	**35**	**34**	**62**	**25**	**20**	**17**	**26**	**1430**	**1985**	**780**	**128**	**43**	**114**	**127**	**135**	**53**	**19**	**3**	**5**
TOTAL TAXA	**13**	**12**	**13**	**7**	**6**	**7**	**6**	**7**	**4**	**5**	**4**	**6**	**13**	**7**	**6**	**7**	**5**	**5**	**4**	**7**	**4**	**5**	**2**	**4**
Shannon index	1.54	1.39	1.62	1.43	1.54	1.50	1.53	1.43	0.97	1.43	1.23	1.38	1.51	1.17	1.52	1.61	1.12	0.55	0.30	.052	0.35	0.93		
Brillouin index	1.47	1.36	1.57	1.27	1.33	1.28	1.53	1.28	0.82	1.17	1.00	1.14	1.49	1.16	1.50	1.52	0.99	0.50	0.25	0.46	0.28	0.71		
Mytilus sp. (umbos)									frag			1	frags	1	frag	frags	1	1	6	4	9	11	6	4
Patella sp.										frag				frag					frags		frags	2	frags	frag
Nucella lapillus																frag							frags	1
Charcoal														(+)	+		(+)	+	++	+++	++	+++	+++	++
Flint flakes																					1		1	3

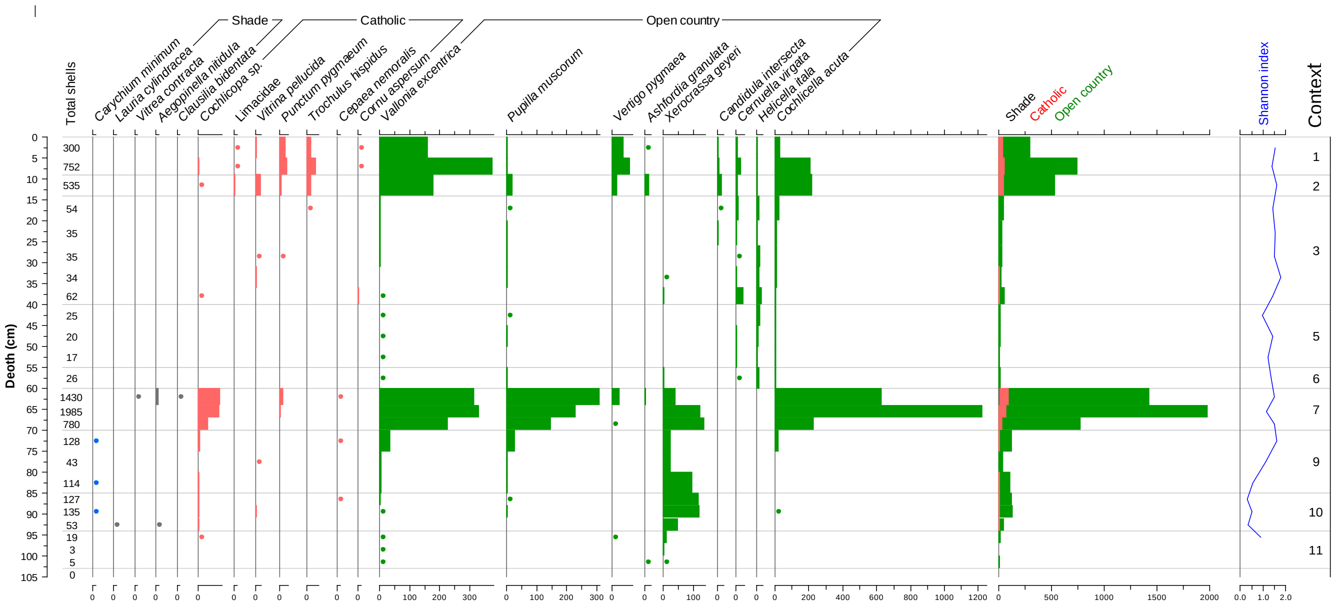


Figure 8.12. Mollusc diagram for the Trench samples
(absolute numbers of molluscs; dots represent single specimens)

The lower buried soil [10] contains a mollusc assemblage of low diversity, with a single species, *Xerocrassa geyeri*, accounting for 92% of all shells. This is a species associated with open, dry, calcareous environments and its abundance in the soil to the exclusion of almost all other taxa indicates that it is one of the first colonizers of newly stable ground. The few other molluscs indicate that there were some areas containing a mixed environment. *Mytilus* fragments are present in moderate numbers, as well as a few *Patella* fragments.

The molluscs in sand horizon [9], between the buried soils, is also dominated by *Xerocrassa geyeri*, with few other shells, although *Pupilla muscorum*, *Vallonia excentrica* and *Cochlicella acuta* become more prominent in the upper third of this layer. These are likely to represent the early stages of stabilization, but may all be derived from the overlying buried soil, moved downwards by worm or rain/wind action.

The upper layer of buried soil [7], dated to the late Bronze Age/early Iron Age, is very rich in shells, with 780, 1985 and 1430 per kg from bottom to top, and has high mollusc diversity. *Cochlicella acuta* is now the dominant species, with corresponding decline in *Xerocrassa geyeri*; as discussed above, comparison of OSL and radiocarbon dates suggest that *Xerocrassa* may be reworked to this soil, which may also apply to other elements of the fauna. *Pupilla muscorum* and *Vallonia excentrica* are strongly present, the former being an early colonizer of newly cleared ground, the latter at these levels of abundance being indicative of dry open grassland (Evans 1972, 266), probably grazed (Cameron and Morgan-Huws 1975; Evans and Evans 1995). *Vertigo pygmaea*, another species of short grassland, appears in the upper part of this sand. A moderate number of more catholic molluscs, mainly *Cochlicopa* *lubrica*, although with some *Punctum pygmaeum*, are also found in these soils. *Aegopinella nitidula* is able to live in the shade found at the base of long grass, as shown in the modern turf blocks at several locations (see section 6.2.1). The single *Clausilia bidentata* is an anomaly, and is probably intrusive from woodland/scrub in the vicinity, brought here by animal or wind action.

The sands overlying this buried soil [6, 5] contain very few molluscs indicating an unfavourable habitat with rapid accumulation and/or regular deflation. *Helicella itala* is first encountered; it is perhaps surprising that this species is not found in lower levels, as it is considered to be a native species and not a late Holocene introduction. *Cernuella virgata* first appears, albeit in small numbers; if current opinion suggesting this is a probable post-Roman introduction is correct then its presence gives support to much sand in this horizon having been lost to deflation. The upper part of the thick layer of sand [3] does contain a few more shells, mostly open country. *Candidula intersecta*, considered a likely medieval introduction, is found in the upper part of this sand only. The question of the periods of introduction of these species to Britain will be reviewed in Section 11.5.

Mollusc numbers increase markedly as the more stable subsoil and modern turf is reached. The mainly open country assemblage is entirely consistent with the modern habitat of grazed grass and tussocks of taller vegetation. Several catholic species are present (Limacidae, *Vitrina pellucida*, *Punctum pygmaeum, Trochulus hispidus*, *Cornu aspersum*), but no shade species and it is probable that grazing by the abundant rabbit population and intermittent cattle and sheep has kept much of the meadow vegetation sufficiently cropped so that shade species cannot easily survive. The decline in *Vallonia* and *Cochlicella* in the most superficial layer may, however, be associated with the gradual increase in tussocky grass with patches of scrub that is currently developing, as revealed by comparison with photographs of the 1960s excavations (Nowakowski *et al.* 2007, Colour plate 1) with those of the present landscape.

8.5 Discussion

The finding of flints dated to the Mesolithic is entirely consistent with flint scatters from this period previously found over a wide area of the Gwithian/Godrevy landscape (Thomas 1958; Roberts 1987; Sturgess 2004; Thomas 2007), although none from the area of this trench.

The OSL date for the old ground surface (3350−2870 BC) suggests that sand first accumulated on the killas hillside during the middle Neolithic. Neolithic Gabbroic pottery sherds were found in the original Bronze Age settlement excavations (Quinnell 2007a), but none were discovered during the present excavation. The strong dominance of the mollusc *Xerocrassa geyeri* in this horizon implies that this was bare open ground during the mid-Neolithic; if the area had been wooded during the Mesolithic then this had all been cleared prior to sand deposition.

The OSL dates for the trench horizons suggest that the lower buried soil formed during the middle to late Bronze Age (1290-910 BC), while the upper buried soil is dated to the late Bronze Age/early Iron Age (940-640 BC). The question then arises of whether this chronology compares to that in the trench opened in 2005 in the Bronze Age settlement site? Figure 8.13 shows a section of the 2005 trench with the OSL dates marked, to compare with the equivalent section in the new trench, shown in Figure 8.14. Both sections show two dark buried soil horizons separated by a layer of paler sand. It is easy to assume that these are equivalent coeval deposits in the two sections. There is, however, discrepancy in the OSL dates (Table 8.4). It is noted that the dates for the 2005 trench are chronologically inverted, although there is overlap in date range and they were accepted as valid (Hamilton *et al.* 2008).

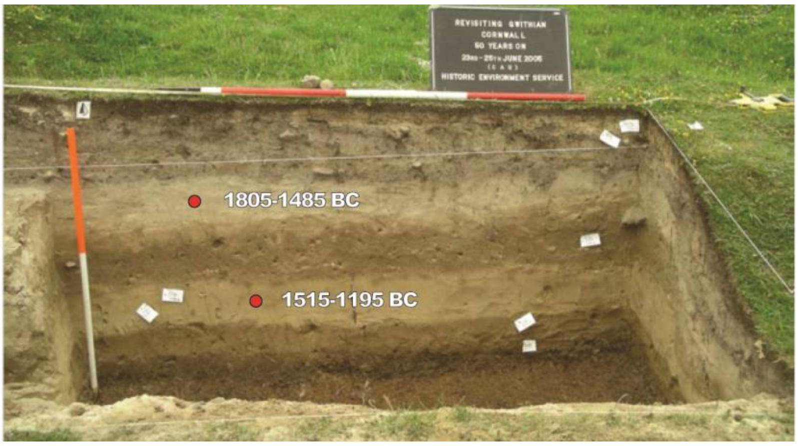


Figure 8.13. Section of the 2005 trench with OSL dates (modified from Roberts 2006, Figure 12)

Figure 8.14. Section of the 2012 trench with OSL dates (photo: M. Bell)

Table 8.4. Correlation of the chronology of the 2005 and 2015 trenches. The phases are those established during the original Bronze Age site excavations (Sturgess and Lawson Jones 2006a).

2005 trench		**Period**	**Phase**	**2012 trench**	
		Medieval		Overlying sand	AD 1670–1730
		Late BA/early IA	**5**	Upper buried soil	940–640 BC
		Late BA	**5**	Intervening sand	1220–880 BC
		Middle/late BA	**5**	Lower buried soil	1290–910 BC
Overlying sand	1805–1485 BC		**4**		
Upper buried soil		**Middle BA**	**3**		
Intervening sand	1515–1195 BC		**2**		
Lower buried soil		**Early BA**	**1**	Molluscs	2026–1751 cal BC
		Neolithic		Old ground surface	3350–2870 BC

The lower buried soil layer in the 2005 trench was considered to equate to the Phase 1 early Bronze Age level of the original excavations (*c.*1800 cal BC) and this is consistent with the new dates obtained on molluscs in the old ground surface. The upper soil in the 2005 trench was considered to equate to original Phase 3 middle Bronze Age level (*c.*1500−1200 cal BC) (Nowakowski *et al.* 2006), for which there is no equivalent in the new trench.

The soils in the 2012 trench show two phases, the lower dated to the earlier part of the late Bronze Age (1290−910 BC), and the upper to the later part of the late Bronze Age (940-640 BC), with an intervening episode of sand blow (1220−880 BC). All of these horizons fit chronologically with Phase 5 of the original excavations which were dated to *c* 1300−900 cal BC (Sturgess 2007a, 30). These periods correlated well with the evidence of agriculture found previously, although it was suggested that arable cultivation was less intensive during this phase (Sturgess 2007a, 32). It is now proposed that the focus of agriculture moved west to the area of the field system excavated in the early 1960s (Fowler and Thomas 1962), although that excavation did not explore the prehistoric horizons.

The late Bronze Age ard marks and evidence of animal hoof prints indicate that this area of land was both in arable and pasture use. Ard marks were found at the base of the middle Bronze Age layers during the original excavations (Thomas 1970; Sturgess 2007a, 30), identified as impressions cut into the underlying sand, so that the marks showed as darker buried soil cut into the lighter coloured underlying sand (Nowakowski *et al.* 2007, Colour plate 6). This is in contrast to the ard marks and hoof prints in the present study which are shown as lighter coloured sand impressed into the darker underlying buried soil, similar to the spade marks found in the settlement excavations (Nowakowski *et al.* 2007, Colour plate 7).

Prehistoric ard marks are not infrequently found in appropriate locations (e.g. Shepherd and Tuckwell 1976–77; Everton and Fowler 1978; Stevenson 1984; Groom *et al.* 2011), but the presence of animal footprints is less common (Evans 1984; Huddart *et al.* 1999; Bell 2013b). These new findings indicate that animal husbandry was practiced certainly during the later Bronze Age occupation phase at Gwithian (on the upper buried soil), when footprints are abundant, and perhaps during the middle Bronze Age (on the lower buried soil). Animal movement may have been transient, as there was no evidence of spherulites to indicate the presence of dung.

The mollusc assemblages can assist in understanding land use during the phases in which the buried soils accumulated. The lower soil, likely middle to late Bronze Age, contained very few shells other than the open country species *Xerocrassa geyeri*, which it has been suggested derive from an earlier, deflated, horizon. This xerophilic species is found today on dry, open, calcareous ground with short vegetation, rocks or rock rubble, in natural or undisturbed habitats. The virtual absence of *Vallonia excentrica* implies that short grazed turf was not a feature at this time. This is in marked contrast to the upper soil, which is likely late Bronze/early Iron Age. Although there are still substantial numbers of *X. geyeri* (which may be intrusive from lower levels), *Cochlicella acuta* is now the dominant species, and there are large numbers of *Pupilla muscorum* and *V. excentrica*. The ground is now much more stable, and the strong presence of *Vallonia* implies that this was short grazed grassland, entirely consistent with the finding of animal hoof prints in this horizon.

There is no evidence of any soil horizon or agricultural activity relating to the post-Roman phase of occupation of the site, despite this being found in the excavations within the nearby ridge-and-furrow field system only 20m uphill from the 2012 trench (Fowler and Thomas 1962). No scientific dating was undertaken during those 1960s excavations, but the lower layers produced pottery sherds typical of the early and middle Bronze Age as well as numerous sherds from more superficial layers with a typology suggesting ninth to late tenth century AD. No pottery of any type was found during the 2012 excavation, with the conclusion that the post-Roman activity did not extend this far down the meadow.

Fowler (1962) postulates that manuring took place on the post-Roman field systems, indicated by the inclusion of shells, animal bones and teeth, pebbles and sherds within the plough-soil. He considered that tiny mussel and periwinkle shells, too small for foodstuff, and various little beach pebbles, pointed to the use of seaweed as manure, in addition to midden material. Although beach pebbles were not a feature of the present excavation (apart from the single stone in context [10]), the large quantities of mussel shells, together with the *Patella pellucida* in the layer just over the upper buried soil, all point to seaweed being used as manure on the site of this trench during the late Bronze Age. The limpet *P. pellucida* lives in seaweed holdfasts and is small with no cultural use, indicating that it was almost certainly deposited here with seaweed. The use of seaweed as manure is well attested in Cornwall (Carew 1766, 27) and elsewhere (Smith 1994; Bakels 1997; Guttmann *et al.* 2005; Smith 2012, 390). Bell (1981a; Milles 1994, 2007), however, cautions against assuming that such materials derive from seaweed specifically brought in as manure, as all may have come from other sources such as domestic middens or farmyard manure.

Sometime during the late Bronze Age or early Iron Age blown sand covered the buried soil, and the very small number of shells found in the overlying sand implies continual instability. The thin sand horizon immediately covering the soil contains large quantities of sandrock and stone and it is probable that one or more episodes of winnowing removed higher layers of sand leaving heavier grains. Where the sandrock originated is uncertain, as this is found mainly in the cliffs about 1km to the northwest, although there is one surface outcrop in the meadow about 200m west of the trench. Sandrock has for long been used as building material in this area of Cornwall (Bristow 2011; King 2011) and it may be that there were sandrock field walls which became decayed due to stormy weather or neglect. Sand continued to accumulate and remained unstable until the modern top- and subsoil became established. An OSL date at 45cm depth (about 1/3 up these sands) is AD 1670−1730, meaning that there is only 15cm of sand representing over 2000 years of deposition, and it must be supposed that there have been regular episodes of winnowing over this period, probably leaving bare dune for much of the time. Only in much more recent times has stability returned to the area, with establishment of good vegetation cover and recolonization by molluscs, reflected by the numbers of both shells and of taxa, albeit with some reduction in the uppermost layer, perhaps related to the gradual return of the meadow to taller vegetation and scrub.

9. Strap Rocks

9.1 The site

Atlantic gales regularly impact on the coasts of Cornwall and erosion of the cliffs and dunes is a constant threat. New features may be observed eroding out of newly exposed cliff sections, and one such feature was recently noted 700m south of the Red River at Gwithian. During 2011 Prof. Martin Bell noticed a line of large stones high in the cliffs under a covering of blown sand (Figure 9.1), towards the northern limit of Strap Rocks, between Gwithian Towans and the Red River estuary. He considered that these stones did not look natural and could be a man-made wall. He suggested that further investigation would be appropriate, particularly to determine whether this may be a prehistoric wall or associated with Industrial Age mine workings. The location (grid ref.: SW 5802.4163) is at the south end of Godrevy beach near the northern limits of a line of low cliffs which extend southwards along the coastline of Gwithian Towans (Figure 9.2) and rising to a height of 10m.

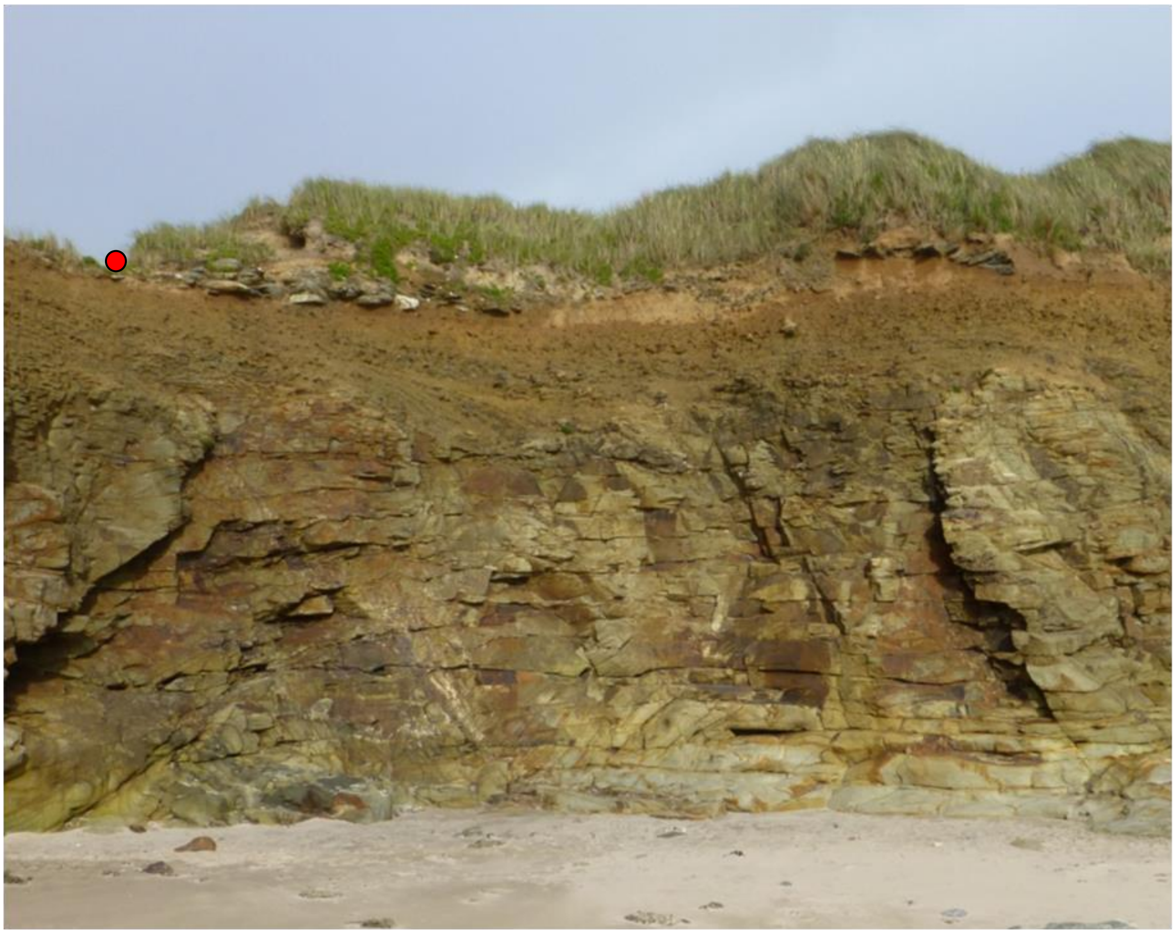


Figure 9.1. The cliffs adjacent to Strap Rocks, showing the blown sand and lines of stones.
The red dot indicates the location of the mollusc column

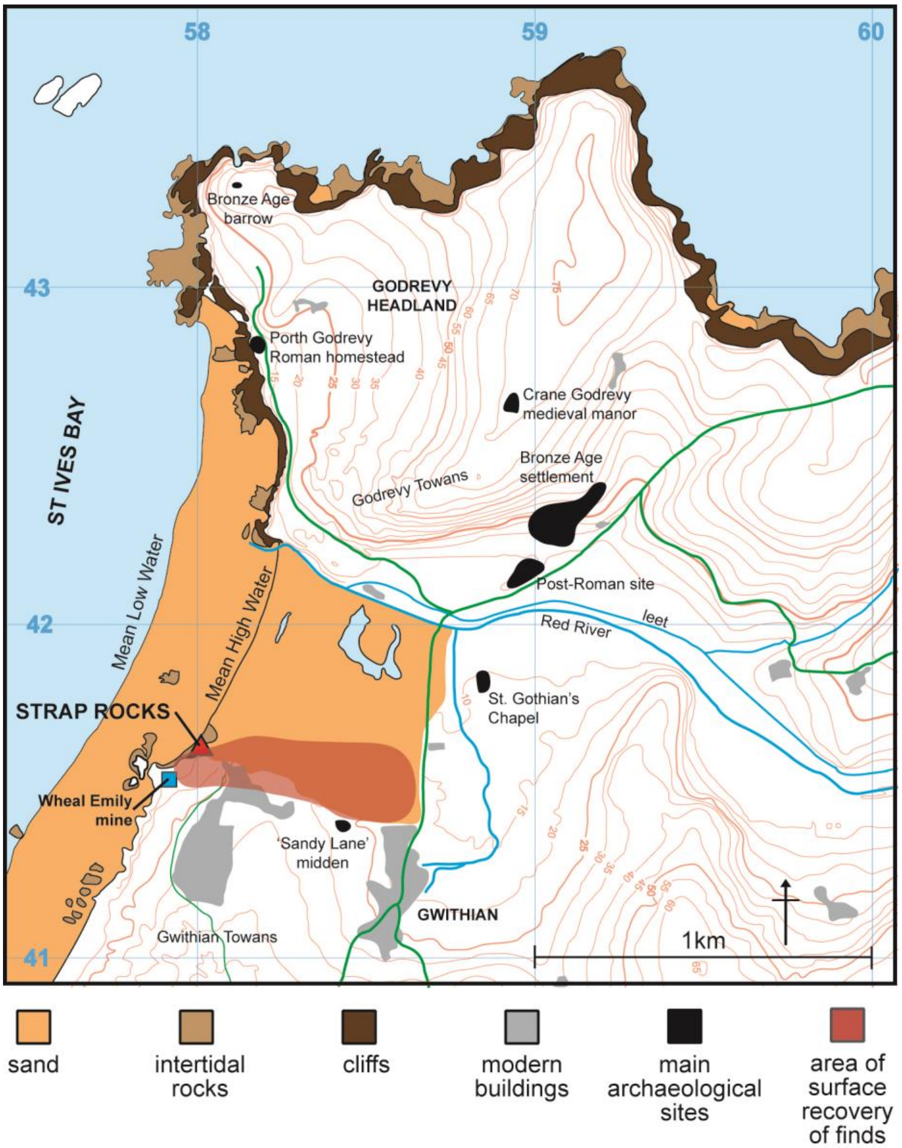


Figure 9.2. Map to show the Strap Rocks site

A visit to the site in July 2012 showed that there was a solid platform high on the cliff very close to the stone layers approximately at the level of the presumed wall (Figure 9.3). This provided a sound and safe base from which to obtain a mollusc column. The land is owned by Cornwall County Council and permission to do the required work was obtained from Alison Clough, Countryside Officer for the Council. The location is just outside the SSSI of Godrevy and Hayle Towans so consent from Natural England was not necessary.

Figure 9.3. The stone layers in the cliff face at Strap Rocks seen from the platform at the sampling site

9.2 Archaeology

There have been no excavations in the immediate vicinity but a cist and walling have previously been observed eroding from the cliff at the base of the dunes (Jones 1998); the walls were considered to be parts of medieval or prehistoric field systems, and the cist may be that found in 1741 containing an urn and bones (Polsue 1868, 162). Their position in relation to the wall investigated in the present study is shown in Figure 9.4. There is evidence of previous human activity revealed by a mussel midden, of unknown age, seen eroding out of the sand 2m inland from the new stone line (Figure 9.5), only observed during a site visit in February 2014 following the exceptionally severe winter storms which battered southern England during the previous weeks.

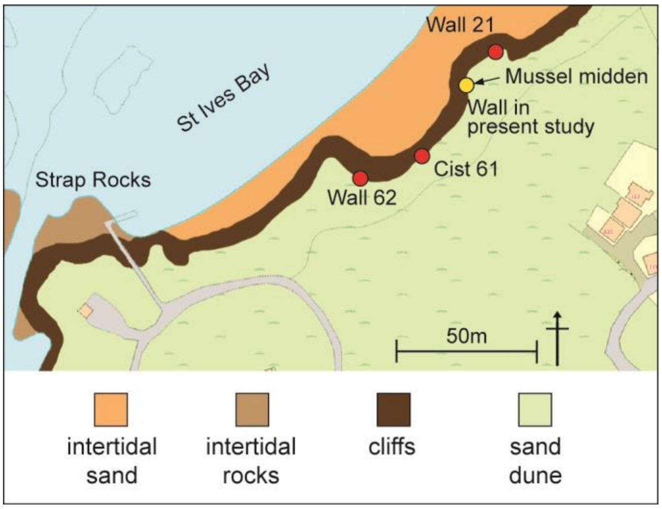


Figure 9.4. The Strap Rocks area showing the sites of the walls and cist eroding from the cliff.
Previously observed walls and cists from Jones (1998).
The location of the mussel midden illustrated in Figure 9.5 is marked

Figure 9.5. The mussel midden eroding from the sand at Strap Rocks

Surface collection of artefacts has taken place since the late 1950s over an area of about 700 x 200m (Figure 9.2), and has produced material dating to the Mesolithic, Bronze Age, Romano-British, post-Roman and medieval periods (Sturgess 2004, 119, 180). A small excavation, in 1963, of a midden at 'Sandy Lane' (500m east of the present site – Figure 9.2) which had been exposed by winter gales, produced quantities of medieval and post medieval pottery, but also a few sherds of Bronze Age and Iron Age/Romano-British pottery (Thomas 1964b; Sturgess 2004, 203). Thomas considered Sandy Lane to be a medieval site, perhaps the location of the settlement of Conarton mentioned in Domesday.

The abandoned mine shaft of Wheal Emily is 160m to the south west. Details of this mine are unclear, but it produced copper, zinc and lead until it closed sometime between 1860 and 1887 (Dines 1956, 149; Hamilton Jenkin 1963, 44).

9.3 Fieldwork

The mollusc column was obtained on 14 September 2012, with suitable precautions being taken to cordon off the area of beach below the site to preclude injury to people on the beach from falling debris. An exposed dune section was cleaned to a vertical face (Figure 9.6). The uppermost layer, 0–20cm, consisted largely of a dense matt of marram grass roots. Disturbance from rabbit burrowing was evident at 30–40cm, but the stratigraphy above and below this seemed undisturbed. There was yellow blown sand from the surface down to 94cm where there was an abrupt change to a pinker more silty sediment. At 105cm large stones were encountered which had a level upper surface and appeared to have been laid with abutting edges (Figure 9.7). They were on the same level as the stones in the cliff and are consistent with a line of walling. It was only possible to obtain samples for a further 15cm inside the stone line as it was not considered justified at this time to extend the exposure.

Figure 9.6. The exposure prior to removal of the mollusc column

Figure 9.7. The layer of stones corresponding to the top of the probable wall seen in the cliff face

A column of samples was acquired, each of about 3kg, commencing from the surface downwards. Instability of the sands precluded sampling from the base upwards, but care was taken to ensure that there was no contamination of samples with debris from higher levels.

After completion of sample acquisition the small pit was backfilled and the cut into the sand face and smoothed to leave as little evidence of disturbance as possible.

9.4 Laboratory analyses

9.4.1 Mollusc analysis

1kg samples from the mollusc column were wet sieved and the molluscs extracted and identified using standard procedures (see section 5.2.2). The shells found in the samples are shown in Table 9.1. There was a total of 5807 non-marine shells identified from 24 taxa. A few mussel fragments were present in the 94–105cm sediments, and charcoal fragments in each of the 94–130cm samples, although very scarce in the 94–105cm deposit. Some rabbit fur was present in the 30–40cm sample entirely consistent with this level being part of a rabbit burrow.

Table 9.1. The molluscs found in the Strap Rock samples
1kg samples

Depth (cm)	0–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–94	94–100	100–105	105–110	110–120	120–130
Munsell number	10YR 6/4		10YR 4/3	10YR 6/3						10YR 5/4				
Carychium minimum		1										3	1	2
Cochlicopa lubrica	2		2	11	2	10	7	3	4	31	42	5	2	
Cochlicopa lubricella		1				3	3	1	1	16	13	5		
Cochlicopa spp.	3	2	1	14	13	19	15	8	11	59	69	39	14	2
Vertigo pygmaea	10	3	2	11	1	6	11	4	14	86	64	23	5	6
Pupilla muscorum	28	4	12	45	34	49	39	32	11	34	49	16	4	13
Lauria cylindracea	1		2	9	8	15	3	4	7	34	54	32	11	7
Acanthinula aculeata														2
Vallonia excentrica	80	23	19	152	65	137	96	44	56	335	286	142	30	25
Punctum pygmaeum	2			16	4	4	8	2	4	10	7	4		1
Discus rotundatus										2	1	14	34	34
Vitrina pellucida	3			4	2	6	5	6	3	2	1	1	1	3
Vitrea contracta														7
Vitrea crystallina				1		1		2		10	8	11	11	2
Aegopinella nitidula		1								17	23	28	24	30
Aegopinella pura														5
Limacidae						2					3	2		
Clausilia bidentata	5													
Cochlicella acuta	161	81	63	278	160	157	150	154	100	298	399	95	1	14
Ashfordia granulata	2	1	4	6	6	4	3	5	4	45	50	26		1
Cernuella virgata	44	23	4		17	2	7	1	1					
Helicella itala	120	34	11	42	18	3	10	2			3			
Xerocrassa geyeri										3	25	27	11	9
Cepaea sp.					1		1				4	1		1
Cornu aspersum		1			1									
TOTAL SHELLS	**461**	**175**	**120**	**589**	**332**	**418**	**358**	**268**	**216**	**982**	**1101**	**474**	**149**	**164**
TOTAL SPECIES	**12**	**11**	**9**	**11**	**13**	**14**	**13**	**13**	**11**	**14**	**17**	**17**	**12**	**18**
Shannon index	1.70	1.56	1.55	1.58	1.67	1.68	1.73	1.46	1.63	1.87	1.96	2.23	2.12	2.37
Brillouin index	1.65	1.47	1.43	1.54	1.60	1.62	1.66	1.38	1.54	1.83	1.93	2.16	1.98	2.20
mussels										y	y			
wood charcoal										(y)	(y)	y	y	y
rabbit fur			y											

These mollusc numbers are shown graphically in Figure 9.8 (absolute numbers of shells) and Figure 9.9 (relative numbers of shells).

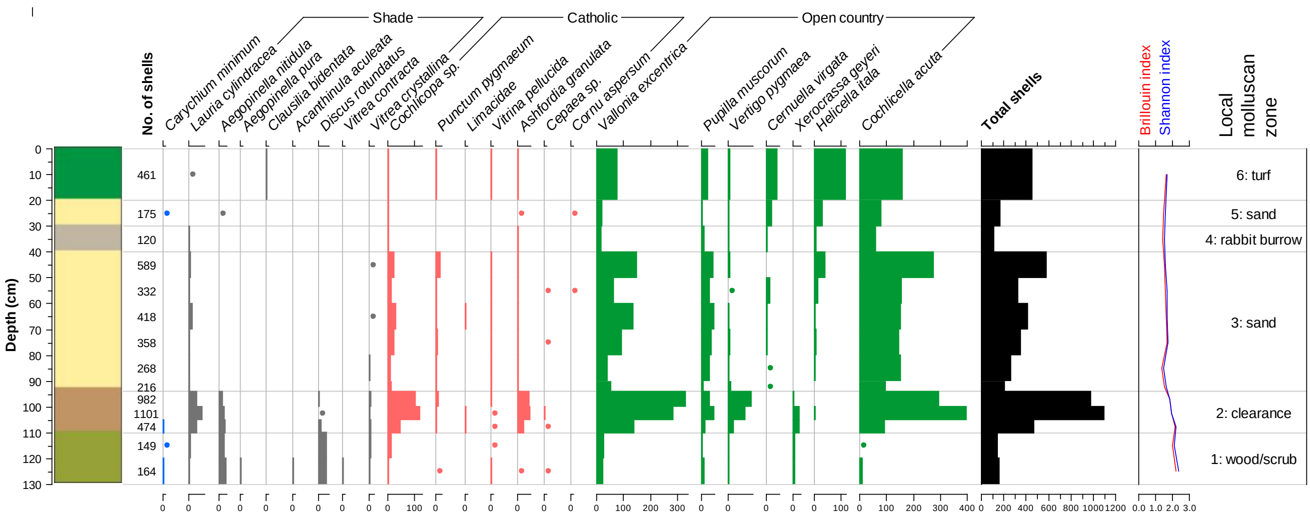


Figure 9.8. Mollusc diagram for Strap Rocks
Absolute numbers of molluscs. Dots indicate single specimen in that sample

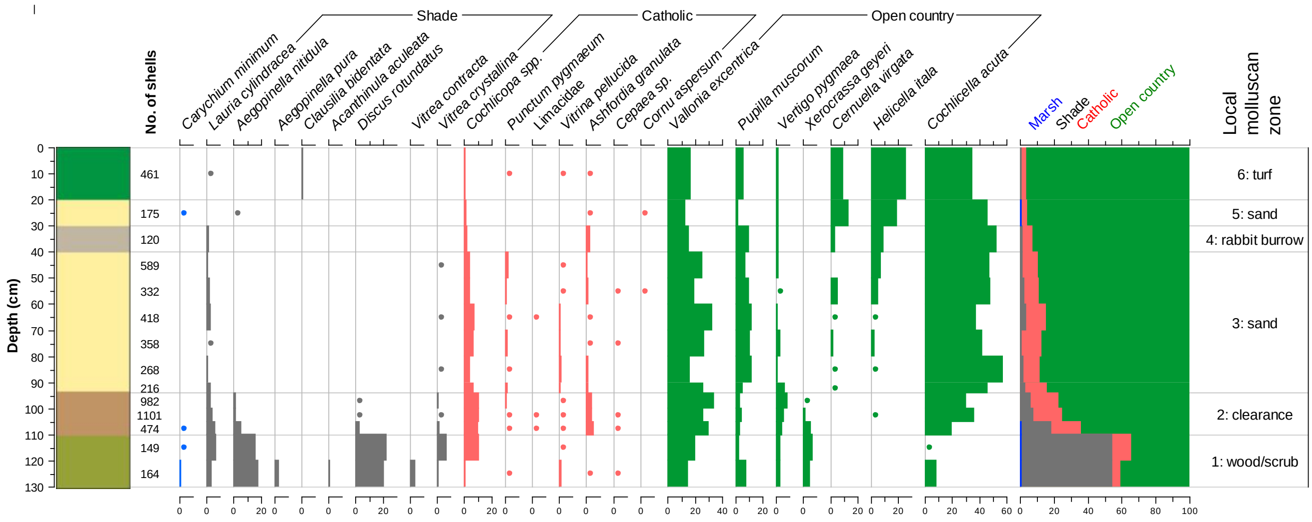


Figure 9.9. Mollusc diagram for Strap Rocks
Relative numbers of molluscs. Dots indicate <1% of that species in the sample

9.4.2 Other analyses

Particle size, loss on ignition analyses and mollusc numbers are summarised in Figure 9.10. pH was also measured but is not shown as every reading was between 8.6 and 9.2, the highest measurements being at 60–80cm. The numbers on which these graphs are based are included on the CD (Appendix 11). Radiocarbon dating was performed on molluscs from three samples from the lower part of the column, shown in Table 9.2. The selected samples were at the lowest level of blown sand (*Cochlicella acuta*), immediately above the top of the stone line (*Xerocrassa geyeri*) and the lowest level reached in the mollusc column (*Xerocrassa geyeri*).

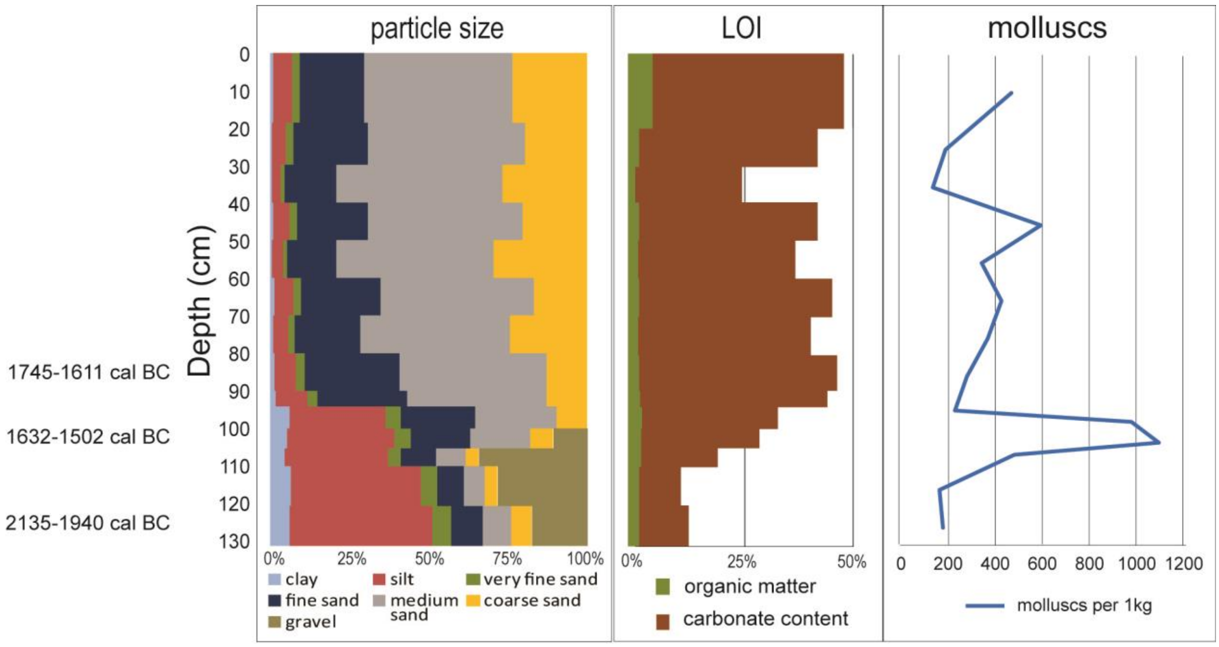


Figure 9.10. Summary diagram for Strap Rocks

Table 9.2. Radiocarbon dates for the Strap Rocks molluscs

Lab number	Material	Depth	δ^{13}C	Radiocarbon date (BP)	Calibrated date	Mid-date
OxA-28972	*Cochlicella acuta*	80–90	-6.40	3370±29	1745–1611 cal BC	1678 BC
OxA-28971	*Xerocrassa geyeri*	100–105	-7.59	3290±29	1632–1502 cal BC	1567 BC
OxA-28970	*Xerocrassa geyeri*	120–130	-7.55	3650±29	2135–1940 cal BC	2037.5 BC

9.5 Discussion

There is a distinct difference between the sediments above and below 94cm. Above this level there is wind blown sand with typical rounded grains, whereas below this level the grains were much more angular, strongly implying that they are not of blown sand origin (Figure 9.11). There is also abrupt change in particle size distribution, with the lower sediments containing 38–67% clay/silt while those above contain only 4–12% clay/silt. There is no significant alteration in the organic matter content, although the carbonate content is lower in the deeper samples. The high proportion of clay/silt and the appearances of the sand grains below 94cm suggest that these lower sands derive from an old ground surface with reworked Pleistocene Head. Differences in the sand at this site have previously been noted by Rogers (1909),who stated: ‘At Gwithian, on the south side of the Red River near Strap Rocks, old and modern sand may be seen close together, separated only by a thin layer of stony Head.’ That layer of Head was not seen in the present section.

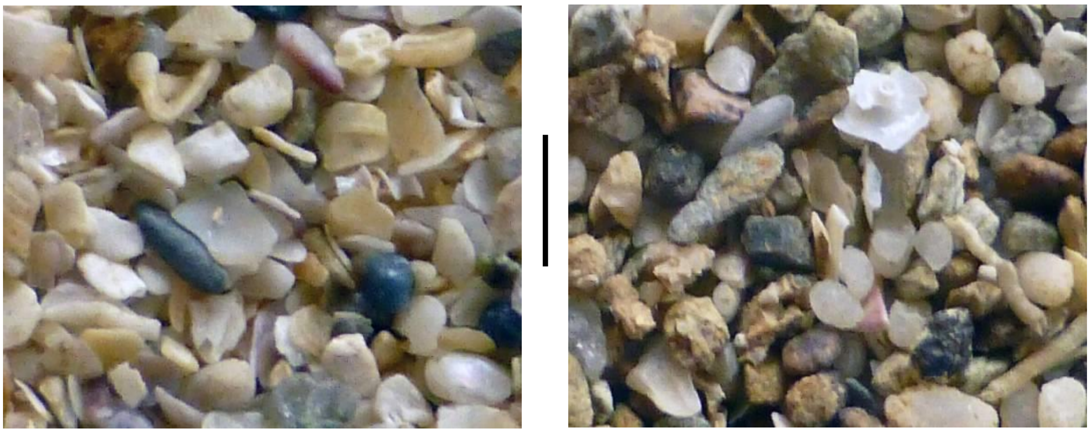


Figure 9.11. Residues in the 500μm sieve after wet sieving.
Left: sediment at 80–90cm with rounded sand grains.
Right: sediment from 105–110cm with angular sand grains.
Scale bar = 1mm

The lowest two samples [LMZ 1] contain a molluscan fauna that has a large proportion of species which require shade (over 50%), some needing more than is provided at the base of grass tussocks or similar vegetation. *Discus rotundatus*, *Acanthinula aculeata*, *Vitrea contracta*, *V. crystallina* and *Aegopinella pura* are all associated with woodland, being found in leaf litter, some requiring higher degrees of moisture than others, but all capable of surviving in more open environments. *Aegopinella nitidula* also requires shade, but is regularly found at the base of rank vegetation, and wood/scrub is not necessary. However, the open country species *Vallonia excentrica* and *Xerocrassa geyeri* are also well represented, the latter being a xerophile shell of very dry open areas. This, then, is a very mixed assemblage, with both shade and open country taxa. The mollusc assemblage indicates that there was open woodland/scrub in the vicinity of the wall. The sands of this zone are from the Pleistocene Head, either deposited against the wall as a revetment or blown/washed to this site from further inland. The date (2135‒1940 cal BC) places it firmly in the early Bronze Age. The charcoal fragments support there being human presence at this time and the presence of the midden in the immediate vicinity suggests the possibility of a settlement at this site.

The sediments from 94‒110cm [LMZ 2] contain very high numbers of shells, over 1000kg^{-1}. The proportion of shade species is markedly reduced, to around 7%, being replaced by those found in open country, especially *Vallonia excentrica* and *Cochlicella acuta*, the latter being very scarce in LMZ 1. *Xerocrassa geyeri* is frequent in the lower part of LMZ 2 but is less common in its topmost level. *Vertigo pygmaea*, a shell especially of dry short turved grassland, increases in number, while *Lauria cylindracea*, a species of dry shady places commonly found under rocks or stone walls, is also present. This is a mixed assemblage, although the diversity indices show it to be somewhat less diverse than that lower down, despite the much greater shell numbers; nevertheless, it clearly represents a stable landscape. Much of this sand covers the remaining structure of the wall and is likely to have derived from sediments that are becoming increasingly stable over the wall, probably with some grazing to keep the vegetation low, but still tall enough to provide shade for *Aegopinella nitidula*. These levels should, perhaps, be seen as a transition zone between the lower sediments and the more open country above, and is likely to represent a period of woodland/scrub clearance. The date of this horizon (1632‒1502 cal BC) overlaps that of the overlying blown sand (1745‒1611 cal BC), indicating that at this particular site blown sand did not start to accumulate until close to the end of the early Bronze Age. Eleven centimetres of Pleistocene sand cover the upper surface of the stones, suggesting that this field wall went out of use prior to the deposition of blown beach sand. However, the dates show that this deposit is contemporary with the base of the blown sand, and it may be that some of the stones were lost soon after burial. The wall in this study appears to be only about 50cm in height (not measured accurately as the exposure in the cliff face is not accessible), but wall no. 62 further south observed by Jones (1998, 92) was 'under 1 metre in height', so loss of wall height would seem indicated. Mussel shells with a few charcoal fragments were present in this sediment, and may link chronologically with the eroding midden illustrated in Figure 9.5.

Although conjectural, sand blow could have been the precipitating factor for abandonment of these coastal fields. Certainly major sand blow is known in this immediate area in more recent times. Writing in 1868, Polsue states that:

> The barton of Upton, one of the principal farms in the parish, was overwhelmed and now lies buried in the sands. This was so suddenly done during one tempestuous night that the members of the family were obliged to make their escape through the chamber windows; shortly after the house disappeared.

The upper sediments, from the ground surface down to 94cm [3, 1] contain almost entirely open country molluscan taxa, although there is a slightly higher proportion of catholic taxa in the lower half of this sand. These assemblages are those expected on open sand dunes and areas of blown sand providing adequate shade at the base of vegetation for some of the catholic and few shade requiring species to live. Of note is the presence of five specimens of *Clausilia bidentata* in the turf sample. At present there is no woodland or scrub in the immediate area, although marram grass is growing and provides shade. Three of the five shells in the sample are juveniles with translucent upper whorls only, while the other two are more mature apical fragments. Whether they are autochthonous or have been deposited here by wind or animal action is open to question, but there is probably sufficient shade for them to have lived at this site. It is also important to note that there are specimens of *Cernuella virgata* in the majority of the samples above 94cm, but no *Xerocrassa geyeri*. *Helicella itala*, an obligatory heliophile typical of dry grassland, becomes increasingly common towards the surface and is common only in the turf sample.

The rabbit burrow level, 30–40cm [2], contains similar molluscs to the sands above and below it, although with somewhat reduced numbers of both shells and taxa. It is clear that the burrow has become infilled with sand from the vicinity.

9.6 Conclusions

There is sufficient evidence to conclude that this structure is a field wall of early Bronze Age date, and it is therefore likely that the other walls along this stretch of coast are of a similar date. This is an important result because it indicates the presence of Bronze Age walls in the towans south of the Red River in addition to these previously investigated on the main Gwithian site north of the river. The lower portion of the deposits, below 94cm, are likely to be a buried land surface with a colluvial top which built up against the wall. Bronze Age lynchets marking field boundaries were previously shown at the main Gwithian site (Megaw 1976) and the present investigation at Strap Rocks suggests a similar landscape. The walls were constructed at a time when the environment had evidence of woodland or scrub, prior to the deposition of the first blown sand, and the clearance of the wood/scrub predated the initial sand blow episodes. Evidence of former woodland conditions on Cornish coastal blown sand sites are few. While Spencer (1975) implied their presence at Gwithian, it is only at Newquay that there is strong evidence of woodland prior to clearance or burial by sand (Kennard and Warren 1903; Woodward 1908; Spencer 1975; Milles 1991b); away from the coast there is more evidence, for example at Daymer

Bay (Arkell 1943; Milles 1991b, and this study: Section 3.2) and Harlyn Bay (Bullen 1902b; Bullen 1912; Whimster 1977).

The date of wall construction has not been established, but it continued in use until around 1600 cal BC before being overwhelmed by sand blow which seems likely to be the cause of its abandonment.

10. Case study 2 – Gunwalloe

10.1 Background

Gunwalloe is on the west side of the Lizard Peninsula in south Cornwall (Figure 10.1). The modern village is 2km north of an area of dunes, and there is currently only a farmhouse with outbuildings and the medieval church of St Winwaloe in the immediate area of the dunes (Figure 10.2).

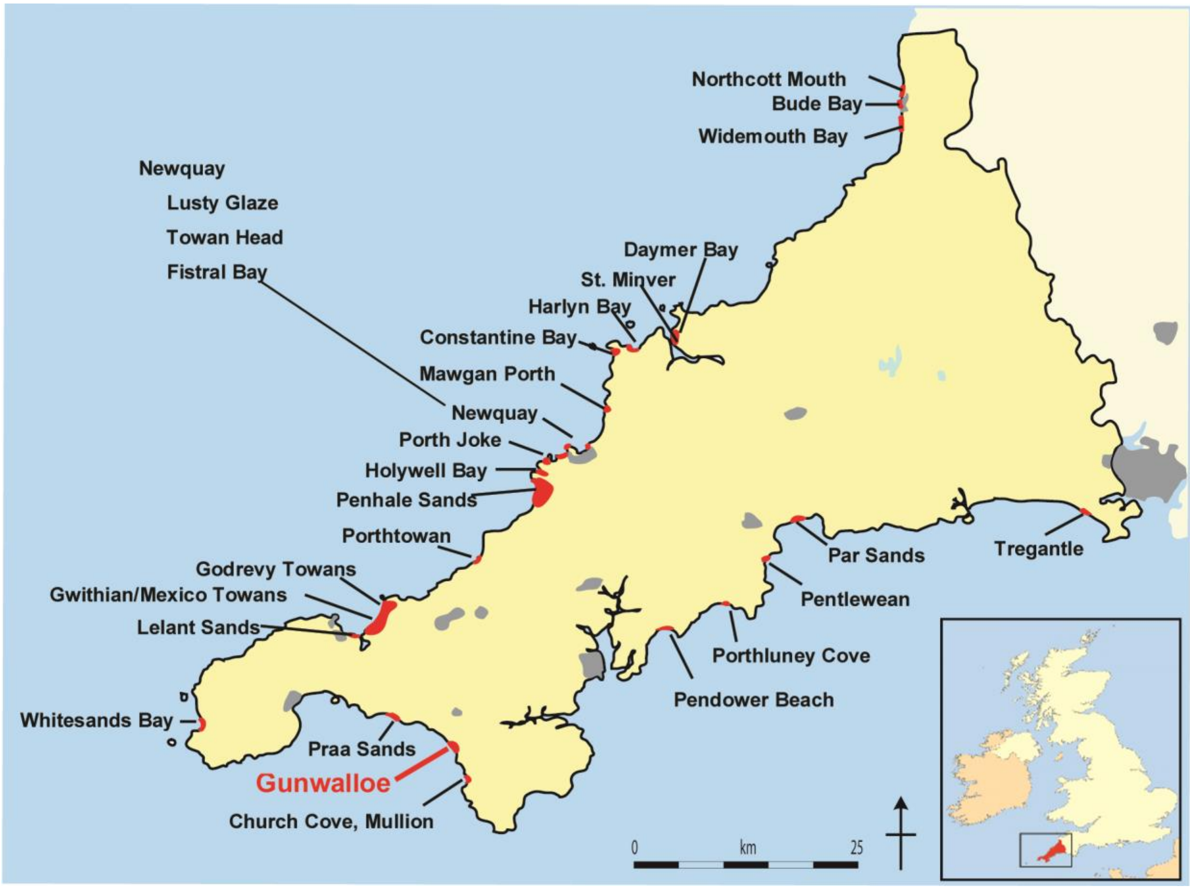


Figure 10.1. Coastal dunes in Cornwall, showing the location of Gunwalloe (dune sites from Bell and Brown 2008)

At the present time the name Winnianton refers to a farm which is set back from the shingle beach of Jangye-ryn (Figure 10.3). In the early Norman period Winnianton was clearly more important as it is the first settlement in Cornwall to be listed in the Domesday Book of 1086 and was of considerable size, the largest holding in the county (Figure 10.4). The 'Ecclesia Sancti Winwalli' (church of St. Winwalli) is mentioned in 1294 by the Bishops of Lincoln and Winchester and in 1521 in Wolsey's Inquisition (Gilbert 1838, 126).

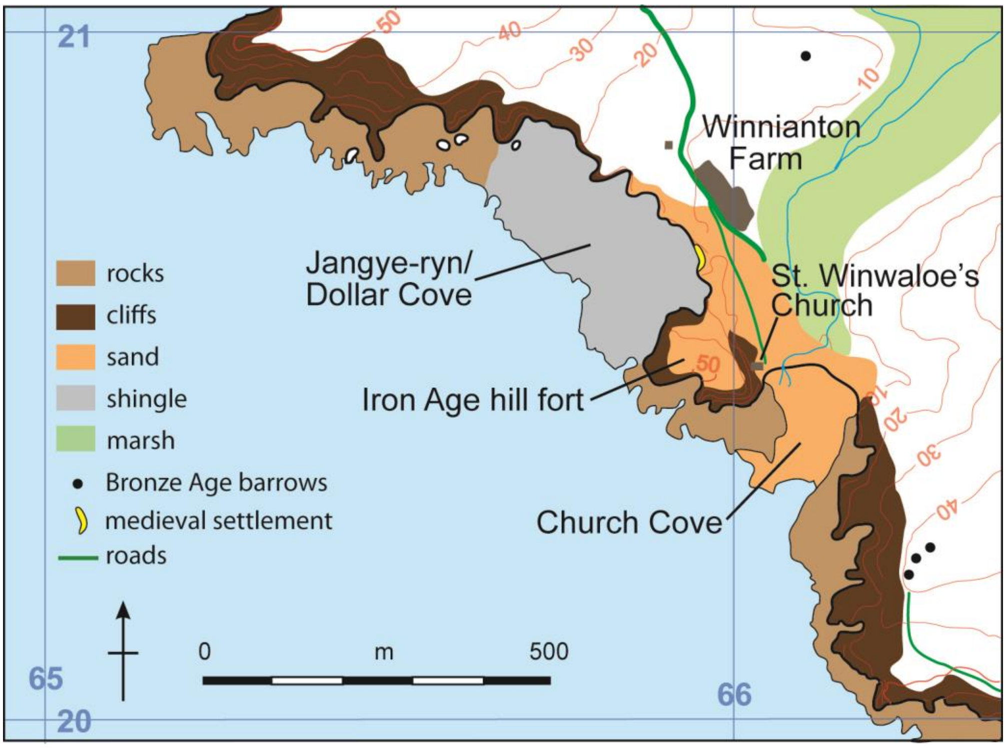
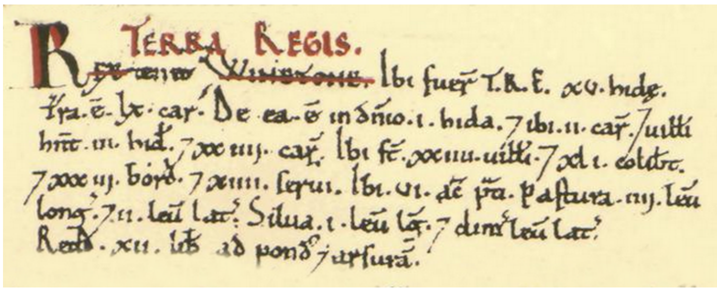


Figure 10.2. Map of the area round Winnianton Farm showing the locations and features discussed (barrow locations from Cornwall & Scilly HER)

Figure 10.3. Jangye-ryn and Church Cove bays at Gunwalloe.
The investigation site is on the sloping ground in front of the Winnianton farm buildings in the centre foreground.
The promontory hill fort is in the right foreground. A shallow valley is seen leading inland



The KING holds WINETONE. There are 15 hides before 1066. There is land for 60 ploughs. Of this, 1 hide is in demesne, and there are 2 ploughs: and the villans [villagers] have 3 hides and 24 ploughs. There are 24 villans and 41 coliberts [freedmen] and 33 boarders [smallholders] and 14 slaves. There are 6 acres of meadow, pasture 4 leagues long and 2 leagues broad; woodland 1 league long and 2 leagues broad. It renders 12 pounds weighed and assayed.

Figure 10.4. Entry for Winnianton in The Domesday Book
(original text from http://archive.org/stream/DomesdayBookCornwall; translation: Williams and Martin 2003, 341)

The church at Church Cove is dedicated to Saint Winwaloe, and may have been the manor chapel of Winnianton. Winwaloe (*c* AD 460–532) was the founder and later patron saint of a monastery in Landévennec in Brittany which was allied to Landewednack in Cornwall; an alternative name for Landewednack is 'Gonwallo in Lizard' which gives a link between the saint and the modern village name (Doble 1962, 59). The present church is mainly fifteenth century, although there is manuscript evidence that a church existed in the thirteenth century (Long 1998). It is probable that there was an earlier place of worship on the site associated with St Winwaloe, although there is no evidence for this. The church tower, separate from the church, is built into the side of a rocky headland.

10.2 Geography and geology

Gunwalloe lies a short distance north of the complex geology of the southern part of the Lizard peninsula. A fault passing through Mullion separates the pre-Cambrian metamorphic rocks, mainly serpentine, horneblende-schist and gabro, of the southern Lizard from the Devonian Portscatho Formation running across the whole peninsula from Gunwalloe in the west to the Helford River in the east. The immediate area surrounding Winnianton (Figure 10.5) consists of these Portscatho Beds with the alluvial valley of an unnamed stream running north east to south west which drains into Church Cove. Blown sand covers an area about 1.2 x 0.8km with a narrow band reaching the coast between the farmhouse at Winnianton and a rocky promontory adjacent to the church of St Winwaloe (Flett 1946). In contrast to Gwithian there is no Pleistocene Head underlying the sand at Gunwalloe, the nearest Head being about 2km to the north (Flett 1946, 170). A short stretch of raised beach is visible at Gunwalloe Fishing Cove, 1.5km to the north of Jangye-ryn bay, but none in the immediate vicinity of the blown sand. The origin of the name ‘Jangye-ryn’ is obscure, claimed by some to derive from the Cornish *rynn yeynjy*, perhaps meaning 'ice-house promontory' (Wetherill 2005). The bay is also known as Dollar Cove, so named after a vessel (probably a 1770s Spanish ship, although several other vessels have been suggested), was wrecked in the bay; silver dollars from the cargo are occasionally washed ashore (English Heritage Pastscape: Dollar wreck).

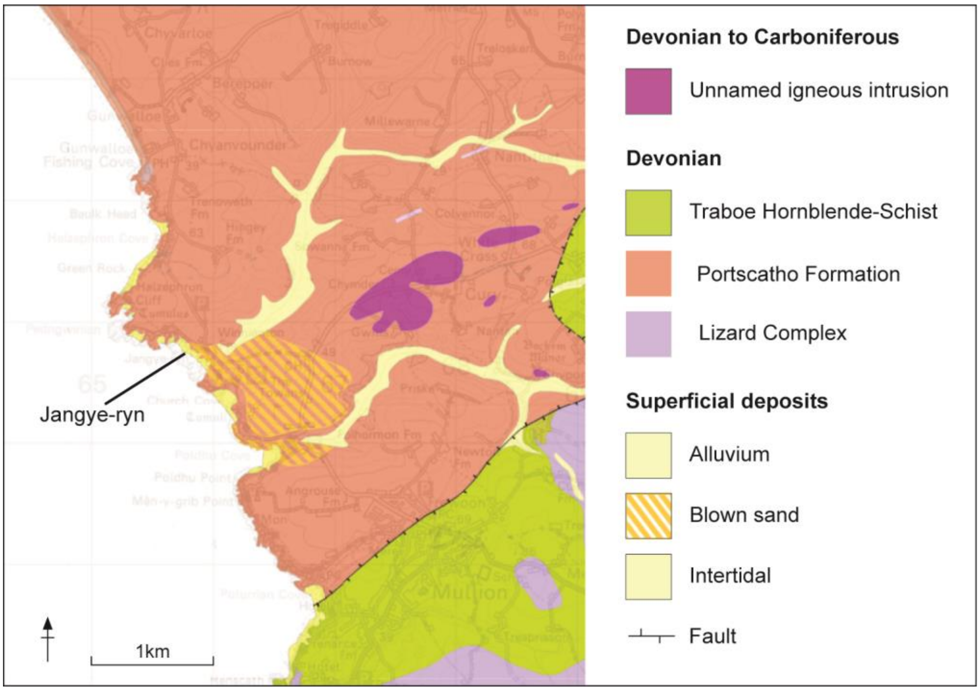


Figure 10.5. Geology of the area around the study area (British Geological Survey 1975)

Hindshore dunes extend inland across a shallow valley (Figure 10.5). The coastline here is subject to considerable erosion from westerly winter gales, with new cliff rock falls occurring on a regular basis. Historic maps show that since *c* 1780 the cliff has receded by between 30m and 60m, an average rate of 1m every 4–8 years (Figure 10.6). In one area about 3m of cliff has fallen in the three winters since the 2011 excavations described below (personal observation). This implies that in prehistoric times the shoreline may well have been many hundreds of metres seaward from its present site, and the cliffs could have run directly across what is now the bay. However, the presence of the dunes suggests that there was always some relatively low ground reaching the sea in order to permit sand to be driven inland in large quantities.

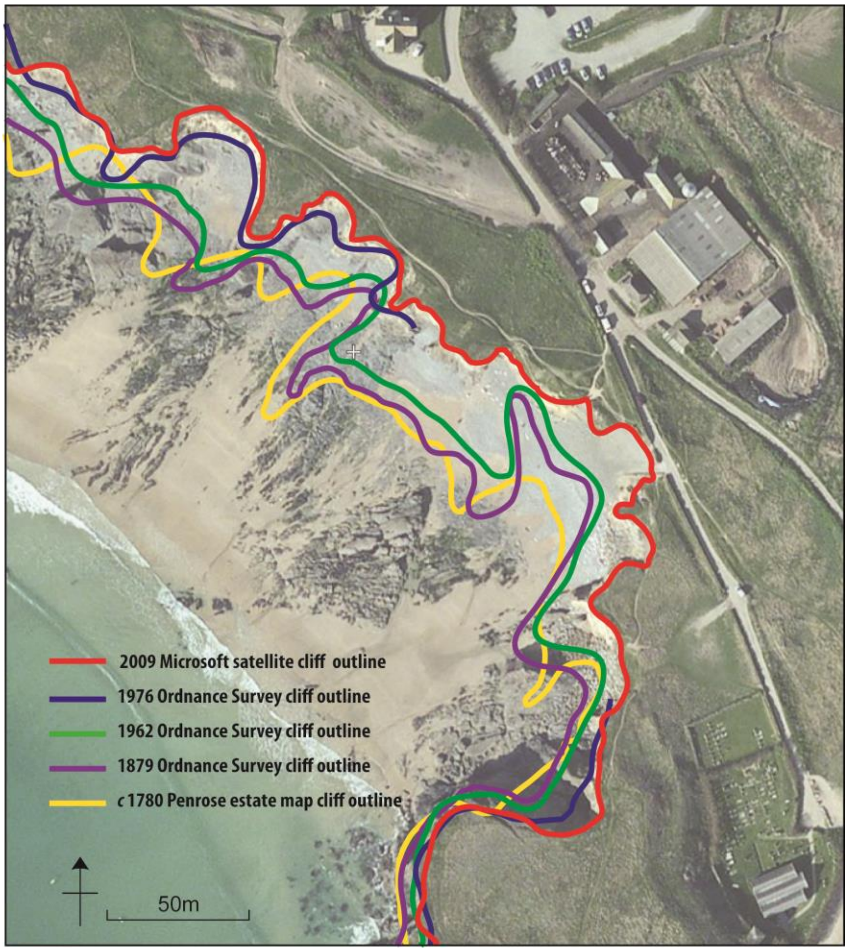


Figure 10.6. The erosion of the coast at Jangye-ryn over the last 240 years

10.3 Archaeology

10.3.1 Prehistoric

There is some documented evidence of prehistoric activity in the area surrounding Jangye-ryn. A broken Mesolithic or Neolithic flint blade was found in 1986 after it had eroded from the cliff face in the cove (Cornwall & Scilly HER SCO7199) and there are a number of Bronze Age barrows on the coastal margin (Figure 10.2), none of which have been excavated.

The Iron Age is somewhat better represented. On the summit of the promontory at the south end of the bay there is a univallate structure recorded on the Tithe Map of 1840 as 'The Castle'. The Ordnance Survey, on a visit the site in 1973, recorded a lynchet up to 7m in height; they suggested that although this could be a man-made structure it was probably of geological origin with windblown sand and slip. No archaeological excavation was undertaken until 2012 when a team led by Dr Imogen Wood, University of Exeter, excavated a trench on the north side of the structure and proved conclusively that this was of Iron Age origin (Wood 2013).

10.3.2 Medieval

An early medieval settlement eroding out of the cliff at Jangye-ryn was first noted by W. Rogers in 1909, although no details are given (Rogers 1910–11). A section of the cliff was cleaned in 1929 and revealed some stone walls and clay floor surfaces with pottery and other midden material (Hogg 1930). There were three or four occupation horizons separated by blown sand (Jope and Threfall 1955–56). Pottery, mainly of grass-marked bar lug type dating to the seventh to twelfth centuries (Thomas 1963) as well as animal bones, mainly sheep, continued to be found over the following twenty years and is still regularly recovered from the cliffs (Johnson 1978).

The church of St Winwaloe, mentioned above, is situated at Church Cove. It was rebuilt in the fifteenth century, but retains a fragment of a Norman font (Doble 1962, 105) and there is a fourteenth/fifteenth century circular enclosure wall. The detached bell tower probably dates from the thirteenth century (Long 1998). A holy well, at one time close to the church porch, has been lost to coastal erosion (Cummings 1875, 182; Doble 1962, 105). An early medieval stone cross, once a waymark, remains in the churchyard.

10.3.3 Post-medieval

The manor of Winnianton was owned by the Arundell family from the late sixteenth to the early nineteenth century but nothing remains of buildings dating to this period. The modern farmhouse and associated farm buildings were constructed in the mid-nineteenth century.

10.4 Previous environmental studies at Gunwalloe

Environmental studies were undertaken in the 1980s by Caradoc Peters as part of BA (University of Wales) and MA (Bradford University) dissertations (1986, 1987). This involved coring and two small pit excavations, with molluscs being the main analytical method. These suggested that sand deposition commenced after 3000 BC with some early stability which gave way to more sand build up before further stability in the medieval period, conditions then deteriorating with further sand blow. He proposed that some of this instability could have been a result of farming practices with over-grazing and excessive ploughing. Of interest is that he found *Candidula intersecta* in large numbers in the basal levels; the presence of this shell, supposedly introduced to Britain in the medieval period, raises questions about the stratigraphy, suggesting either bioturbation, or that the initial prehistoric sand deposit was no longer present at this location, having been replaced, presumably through storm action, by much later sands. However, the *caveat* made by Peters is that the shells of this species were ‘atypical and showed some resemblance to *Helicella itala*’ (Peters 1987, 61), so his identifications may be inaccurate. Coring in the valley margin showed marsh/swamp/carr conditions from earliest times, although with two phases when there was drying.

Peters' environmental studies included some midden material obtained from a pit in the vicinity of some building remains found during the 1970s; this showed that cattle, sheep/goats, pigs, horse, dogs, deer and domestic fowl were all present at the site, as well as several species of fish (including a whale, presumably washed up on the shore), together with numerous limpets (Peters 1986, 27). In a second pit very near the site of the house discussed below (Trench 1) he found cultivated cereals (barley and possibly wheat) as well as wild fruits including hazel nuts and blackberries (Peters 1987, 77).

10.5 Excavations during 2011

A rescue project conducted by Imogen Wood in 2010 on an eroding farmer's track at Winnianton Farm had shown several areas of archaeological importance, including a midden, early medieval hearths, pits filled with charcoal and clay floor surfaces (Wood 2010, 2011, 2013). The present author obtained a mollusc column from an exposed face of blown sand very close to the cliff edge and, in the course of doing this, revealed part of a building wall with several courses of clay-bonded stones in a 1 x 1m pit at the base of the exposure (Figure 10.7). The mollusc column taken on this occasion was 1.60m in height and included blown sands with some stabilization layers down to, and including, the level of the wall.

Figure 10.7. The wall discovered in 2010

During August 2011 five trenches were opened for further evaluation, to include the wall found in 2011 as well as other areas possibly associated with human activity (Figure 10.8). The siting of these trenches was determined to explore a variety of scenarios, from likely settlement to middens, and to investigate the area before further coastal erosion destroyed any remains surviving on the cliff top. The 2011 trenches were excavated under the direction of Dr Wood by a team of staff and students based at the University of Exeter and including this writer from the University of Reading. This was followed in 2012 by excavation of a trench on the north side of the presumed promontory hill fort.

The excavations were planned to include a range of palaeoenvironmental analyses which are reported elsewhere (Wood 2013), with only the analyses performed on the mollusc column samples being described here. After completion of each trench excavation and prior to backfilling sample columns for mollusc analysis were taken from the ground surface to the base of each trench excavated in 2011. For all the mollusc columns discussed below approximately 4kg of material was obtained for each sample. Stratigraphic boundaries were respected when taking the samples, with larger contexts being subdivided. Munsell colours were recorded on the fresh sediments during sampling.

Brief excavation details and findings of each trench will be presented and discussed together with the result of mollusc column analyses. Details of the archaeological findings are extracted from on-site field notes and from the excavation report (Wood 2013). The radiocarbon dates quoted below were all obtained by Dr Wood and are given with 2σ calibration.

Figure 10.8. The locations of the numbered trenches during the 2011 excavations
The position of each mollusc column is indicated by yellow dots (based on Google Earth image)

Mollusc and particle size analyses and loss on ignition for organic matter and carbonate content were undertaken on the Gunwalloe samples as part of this study, using the methods described previously; figures for these analysis are included in Appendices 12 and 13 on the CD. With regard to the molluscs no attempt was made to separate *Cernuella virgata* or *Candidula intersecta* apices <2mm in diameter due to the large numbers encountered and the difficulty in differentiating these small fragments; in the mollusc diagrams these are apportioned according the numbers of identified shells of the relevant species larger than 2mm. Limpets were counted only when apices were present.

All the molluscs were extracted from 1kg samples. In the mollusc diagrams the "Number of shells" and "Total shells" columns refer to non-marine shells only; limpet shells are plotted separately. All graphs are absolute numbers of molluscs, except for the cumulative percentage graphs. Dots (•) on the diagrams indicate that five or fewer shells were present in that sample (except for Trench 3, where the dots indicate single shells).

10.5.1 Trench 1

A 6 x 3m trench excavated close to the cliff edge and including at its western end the wall discovered during 2010. Following turf removal the thick blown sand layers were rapidly removed down to a depth of about 1.50m, and then more carefully when likely archaeological levels were reached. The wall was exposed at the west end of the trench, revealing several courses of clay-bonded stones forming part of the exterior walls on two sides of a structure with a rounded corner (Figure 10.9) and very smooth interior surfaces although with a rougher exterior face. Another section of rough wall was found in the eastern corner of the trench, but its structural relationship to the first wall is unclear. The base of the building featured two successive thin clay floor surfaces, each containing a hearth. Below this structure was another metre of blown sand with the natural nearly 3.0m below the modern surface. A ditch cut into the natural was shown to have been cut shortly prior to the laying of the lowermost floor. Several darker sand horizons both above and below the building indicated multiple stabilization layers within the blown sand (Figure 10.10).

Figure 10.9. Trench 1 at the excavation level of the main floor surface of the building. The wall found in 2010 is on the left with the second wall in the top right corner; the stones in the centre foreground are wall tumble (photo: Bryn Morris).

During 2010 a column for mollusc analysis (Figure 10.11: left) had been obtained from the west-facing exposed face of what became Trench 1, down to the upper level of the wall at the west end of the building. In 2011 further samples were collected from the exposed south-facing section outside the wall down to the old ground surface (Figure 10.11: right). This meant that the samples, while not in physical continuity, were in stratigraphic continuity, providing a complete sequence from the ground surface to the natural at a depth of 2.84m. A total of 29 samples were taken, 16 in 2010 and 13 in 2011.

Figure 10.10. Trench 1. The completed excavation. The ditch cut into the natural is shown

Figure 10.11. Trench 1 showing the positions of the mollusc columns.
Left: section above wall excavated in 2010; right: section at and below level of wall excavated in 2011

The mollusc diagram for this trench is shown in Figure 10.12 and the particle size and loss on ignition analyses in Figure 10.13. All samples for radiocarbon dating in Trench 1 were obtained within the outline of the stone building, and not in the immediate area of the mollusc samples. Correlation of sediments between the two is therefore not exact but is as close as possible.

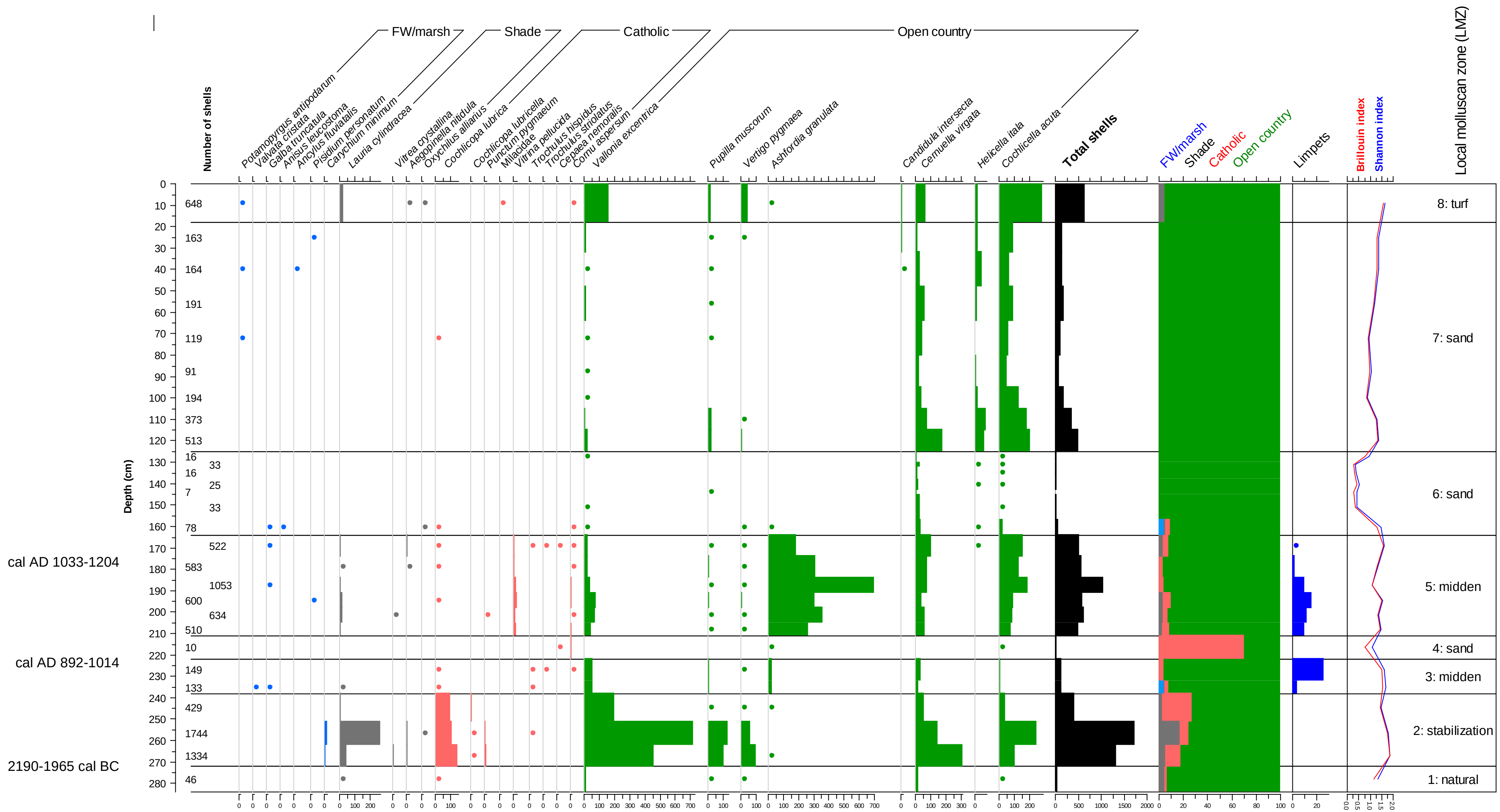


Figure 10.12. Trench 1 mollusc diagram

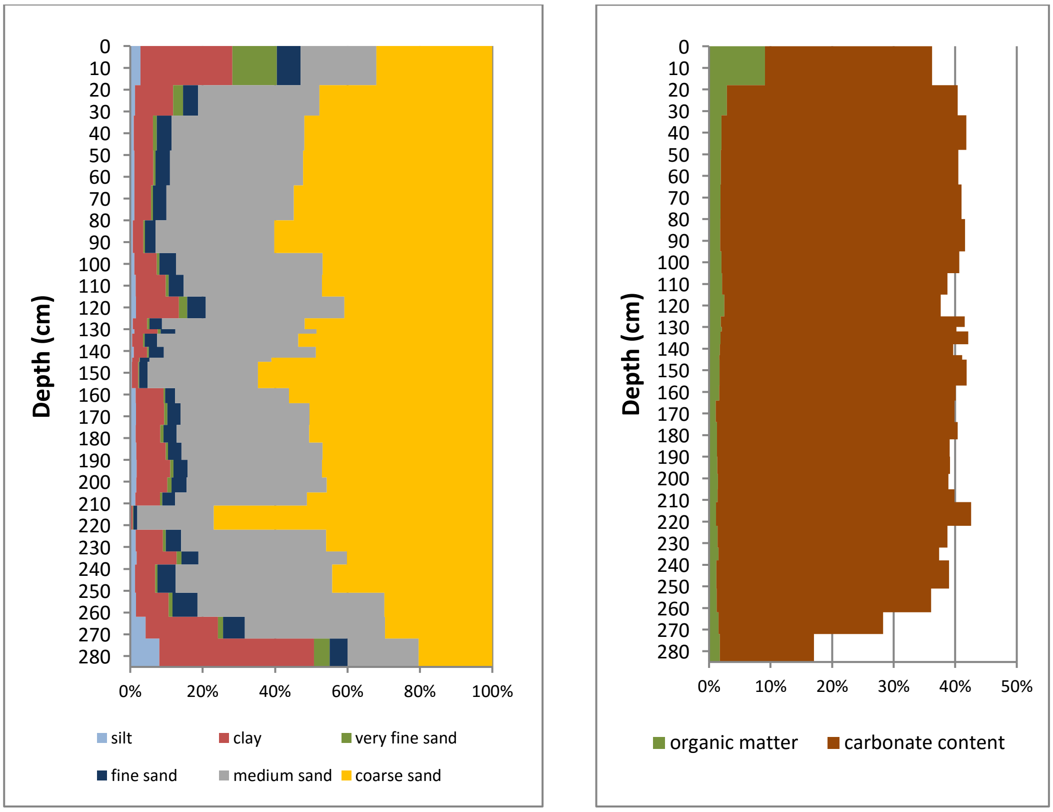


Figure 10.13. Particle size (left) and loss on ignition (right) analyses for Trench 1

A total of 10,410 non-marine shells was found in the columns from this trench, of which 2,664 were in the deposits above the upper level of the wall at 164cm, and 7,746 below. 81 limpet shells were also found in midden deposits adjacent to the wall.

The basal layer of sediment lying on the natural at 272−284cm is very poor in molluscs [LMZ 1]. This deposit represents the initial accumulation of blown sand, and has a high proportion of clay/silt (50%) and low carbonate content (13%) consistent with the clay-rich underlying geology. Of importance is the finding of 12 specimens of *Cernuella virgata* in this lowest level, in which charcoal (*Quercus*) has been dated to 2190−1965 cal BC (3680±30 BP; Beta-322803). This mollusc is believed to have been in introduced into Britain during the Romano-British period (Kerney 1999, 181). There are reports of it in earlier Cornish Iron Age deposits (Bullen 1902b) and possibly in Neolithic levels (Woodward 1908; Kennard 1923), although Evans (1972, 179) considers these ages unsatisfactory.

The earliest blown sand is a stabilization layer rich in molluscs [LMZ 2; 238−277cm]. *Cernuella virgata* and *Cochlicella acuta* indicate open ground, and the dominance of *Vallonia excentrica* implies that this area was grazed grassland. *Lauria cylindracea*, *Vitrea crystallina* and *Oxychilus alliarius* suggest that there are areas of shade, at least rank vegetation, although woodland or scrub is not excluded. *Lauria* often inhabits rock rubble, and the crevices in the rubble of the underlying natural would well suffice.

There is then more sand accumulation [LMZ 3; 222−238cm] with charcoal and animal bone fragments in the upper part as well as limpets (26 limpet apices were present in the sample), all indicating this is either a midden deposit, or that midden material has been used to enrich the ground for agriculture (note that this deposit predates the construction of the building on this site). A date from *Ulex*/*Cytisus* charcoal obtained approximately at the level of LMZ 3 is cal AD 890−1020 (1090±30 BP; Beta-322802) and is therefore consistent with the mollusc species present. Shade shells almost disappear. Another likely Romano-British introduction, *Cornu aspersum*, makes its first appearance, albeit with a single shell, and its presence is consistent with the early medieval date mentioned above. The layer is contiguous with a dark coloured pit visible on the inside of the building, pre-dating the construction of the wall. What is perhaps surprising is that there is no increase in organic matter content in the midden sediments. Above this there is a lens of very clean sand, well shown in Figure 10.11, with very few shells [LMZ 4; 211−222cm] although there are several *Cornu aspersum*, again supporting a Romano-British or early medieval date. This sand may have been deliberately placed as revetment against the wall foundation or could derive from naturally blown sand; it is not extensive and therefore unlikely to be associated with a major storm event.

The sand deposits against the wall (LMZ5; 164−211cm) have a high number of molluscs with moderate diversity. The assemblage is dominated by *Ashfordia granulata*, which accounts for 60% of all non-marine shells, but with smaller numbers of open country species and a few with more catholic or shade requirements. Numerous limpets were present as well as charcoal, animal bone fragments and fish bones and scales. This is a midden assemblage, and as such is unlikely to reflect the wider landscape. A radiocarbon date (*Ulex*/*Cytisus* charcoal) from a hearth within the house at approximately the level of the base of the wall is cal AD 1033−1204 (900±30 BP; Beta-322801). *Ashfordia* has here been classified on the graph as an open country shell although it is normally included with wet-ground species; it does favour moist environments, entirely consistent with it being in a midden, although in Cornwall it is frequently an open country species (Turk *et al.* 2001, 102). What is remarkable is that many of the shells are hatchlings which died very young. The adult shell measures about 7−8mm in diameter and has 5½−6 whorls. A very large proportion (50−70%) of the shells in these layers are only about 0.5mm in width and with less than one full whorl (Figure 10.14). Why they died young is unclear; perhaps the population exceeded available food resources or, being within midden material, were buried by new deposits. The eggs of *Ashfordia* are laid in the late autumn with hatching in early spring (Taylor 1916–1921, 73) and one possible explanation is that the hatchlings were unable to survive winter storms impacting on the west side of the Lizard peninsula.

Figure 10.14. *Ashfordia granulata* from Trench 1.
Left: adult shells; right: shows the small size and immaturity of many of the shells found in the midden deposits between 164 and 211cm (scale bar: 1cm)

The molluscan fauna in the deposits above the level of the top of the wall (LMZ 6; 125−164cm] is completely different from those below, although there is no change in organic matter or carbonate content. The lowest portion of this zone (157−164cm) has a moderate number of shells and particle size analysis shows nearly 10% of clay/silt, but above this, up to 125cm, the clay/silt proportion falls markedly, and there are very few shells, all of which are open country taxa, and there is low diversity. This is likely to be a period of environmental instability, with stormy weather depositing and removing sand on a regular basis.

Some stability then returns, with the deposits above 125cm showing intermittent stabilization layers with higher numbers of molluscs [LMZ 7; 18−125cm] and a greater proportion of clay/silt, reflected in colour changes in the different layers. There are several thin stabilization horizons, well seen as darker bands in Figure 10.9, interspersed with layers of lighter blown sand. *Pupilla muscorum*, an early colonizer of newly stable ground, temporarily increases in number in the lowest part of this zone. Almost all the molluscs are open country species suggesting that there was little shade cover, the vegetation consisting of low plants.

The turf layer [LMZ 8; 0−18cm] seems to be the most stable with a much greater number and higher diversity of molluscs, with longer grass providing sufficient shade for species such as *Lauria cylindracea*, *Aegopinella nitidula* and *Oxychilus alliarius* to survive; there are no trees or shrubs within 50m of this trench at the present time. The particle size and organic matter analyses for this uppermost layer are entirely consistent with a stable turf structure able to support the longer vegetation required by these molluscs.

10.5.2 Trench 2

This trench was situated in the field where areas of burning had been found eroding from the farm track in 2010. The upper layers had previously been removed when this field was used as a car park. The trench measured 6 x 2m and reached bedrock at a depth of 1.70m. Three post-holes, sealed by sand layers, were cut into the natural. Possible plough marks were observed in the layer of sand above the post holes (Figure 10.15). Higher levels revealed a midden and a hearth immediately below modern car park hard standing,

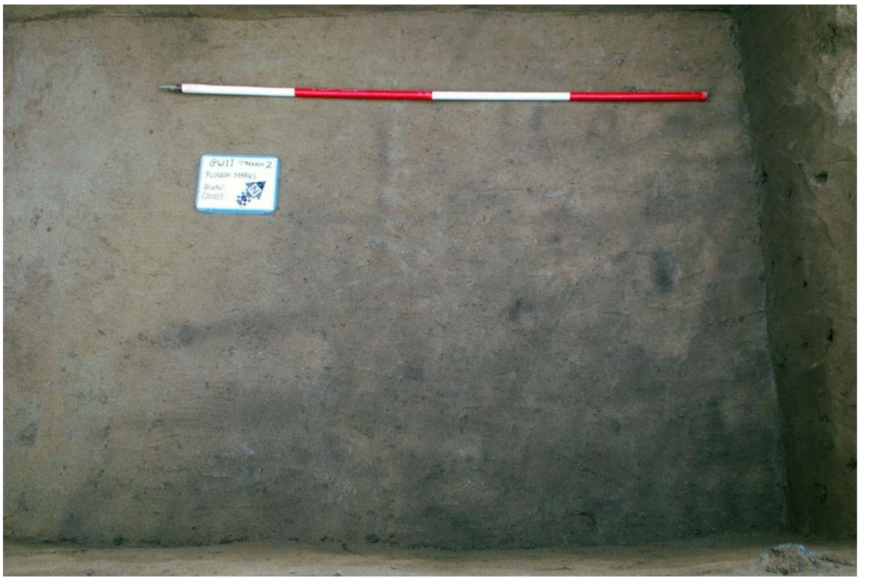


Figure 10.15. Trench 2 showing the possible plough marks as dark lines cut into the lighter underlying sand (photo: Bryn Morris)

The mollusc column consisted of 13 samples from the east-facing section of the trench from the modern ground surface to the base at a depth of 1.68m (Figure 10.16).

Figure 10.16. Trench 2. The south east facing section. The position of the mollusc column is marked with a black rectangle (photo: Bryn Morris)

The mollusc diagram for this trench is shown in Figure 10.12 and particle size and loss on ignition analyses in Figure 10.18.

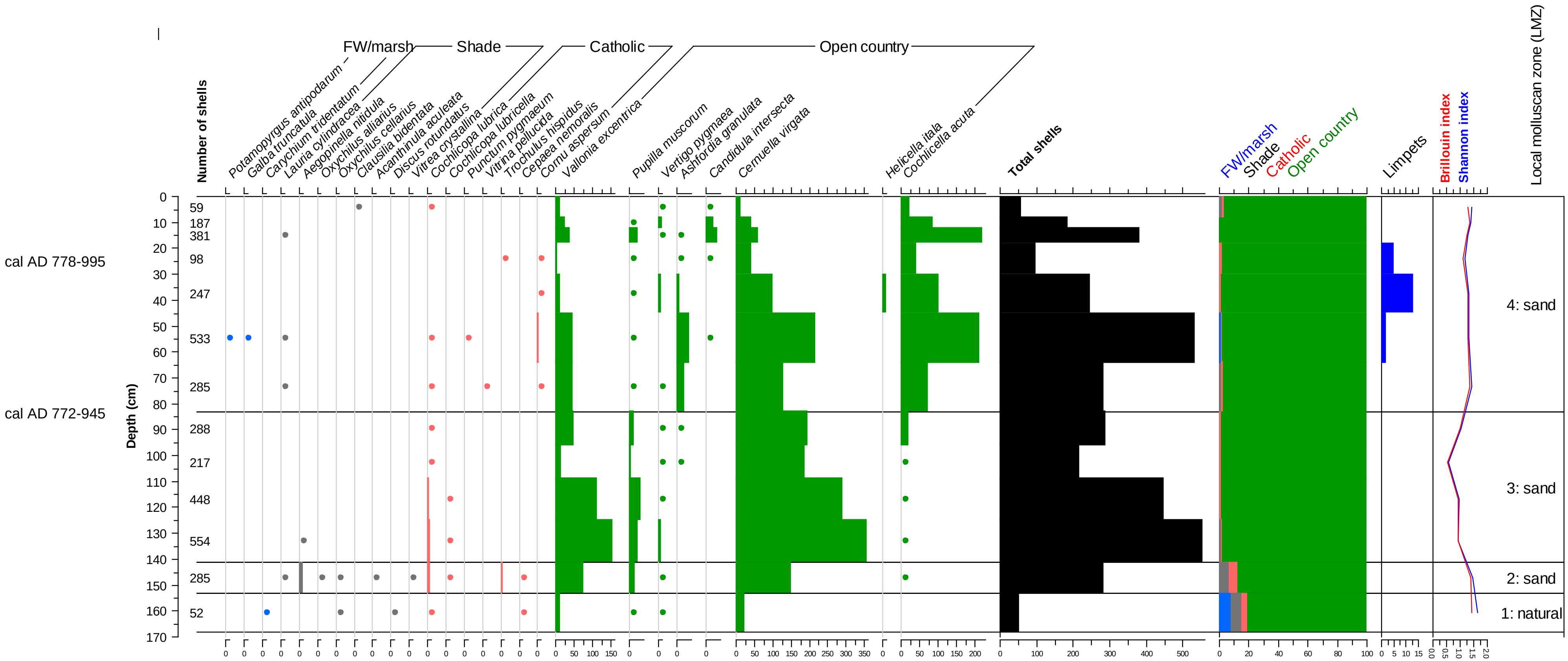
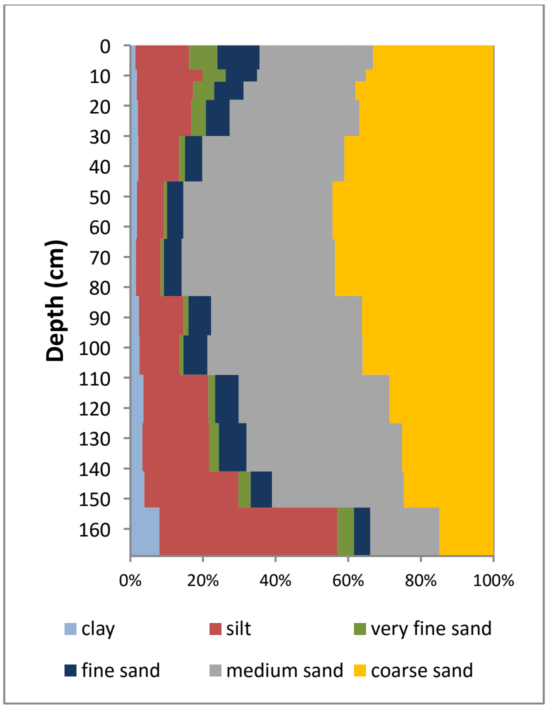


Figure 10.17. Trench 2 mollusc diagram.



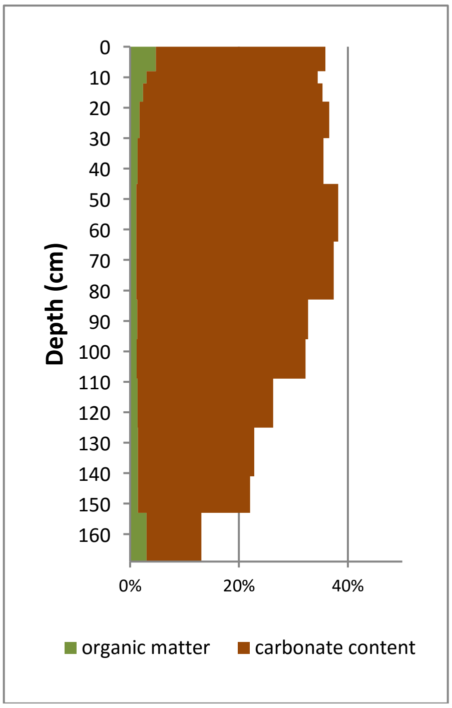


Figure 10.18. Particle size (left) and loss on ignition (right) analyses for Trench 2

3,634 non-marine shells were present in the column, with open country species predominating, although there are a few shade and catholic species at most levels. This trench is further from the cliff than Trenches 1, 4 and 5, and this is reflected in the mollusc assemblages.

The base level [LMZ 1; 153–168cm] is the natural with clayey sediment, similar to that in Trench 1, and it also contains *Cernuella virgata*. The molluscs in LMZ 2 (141–153cm), although mainly open country, contain an assemblage of species which indicate that some shade is present (*Lauria cylindracea*, *Aegopinella nitidula*, *Oxychilus alliarius*, *O. cellarius*, *Acanthinula aculeata*), probably more than that provided by just rank vegetation and suggesting woodland or scrub in the close vicinity during this early period.

Shade species disappear as sand accumulates in LMZ 3 (83–141cm), but the rate of deposition is slow, reflected in the higher numbers of shells, principally *Vallonia excentrica* and *Cernuella virgata*, with very few *Cochlicella acuta* showing that the area was more open than previously. The slight dip in numbers at 95–109cm may be equivalent to the much thicker shell-poor deposits in Trench 1 above the wall. A radiocarbon date (*Quercus* charcoal) from a post-hole correlated to the junction between LMZ 3 and LMZ 4 is cal AD 722–1190 (1200±30 BP; Beta-322805).

The main differences between LMZ 3 and LMZ 4 (10–83cm) is that *Cochlicella acuta* increases at the expense of *Cernuella virgata*, although the reason for this change is unclear as their habitat requirements of exposed dry grasslands are similar (Boycott 1934; Davies 2008, 178). It is difficult to correlate these zones with those in Trench 1. There is clearly no zone which is largely devoid of shells equivalent to LMZ 5 in Trench 1, and it may be that large deposits of blown sand did not reach this far inland. The sediments from 18cm to 64cm contain limpet shells and several layers contain charcoal, animal bone fragments and fish bones/scales suggesting midden deposition over a moderate period of time. Dating from charcoal (*Quercus*) obtained from a pit cut into the 18–30cm sediment is cal AD 778–995 (1160±30 BP; Beta-322804). The similarity of this date to that obtained from the deeper post holes suggests that the pit fill contains older material than the horizon into which it was dug.

The turf layer seen in other trenches is absent from Trench 2, consistent with this field having been used as a car park in recent times, so precluding a wide variety of mollusc life, despite there being adequate proportions of clay/silt (up to 20%).

10.5.3 Trench 3

An area containing large quantities of limpet shells was clearly visible on the eroded ground surface to the west of the other trenches and which seemed likely to be an eroding shell midden. A trench was therefore dug to explore this midden further. The 4 x 4m trench reached natural at a depth of 1.10m. There were vast quantities of limpets in the upper half of the trench in two distinct layers, but very few shells in the lower half. Many fish bones were present within the midden deposits. The mollusc column in this trench was from the south-facing section close to the north west corner of the excavation (Figure 10.19). This position was selected as it passed through the largest section of midden shown in the sections of the completed excavation. Nine samples were taken from the exposure.

Figure 10.19. Trench 3. Part of south facing section. The position of the mollusc column is marked with a black rectangle. The pock-marks in the upper half of the section are all imprints left after removal of limpets

The mollusc diagram for this trench is shown in Figure 10.20 and particle size and loss on ignition analyses in Figure 10.21.

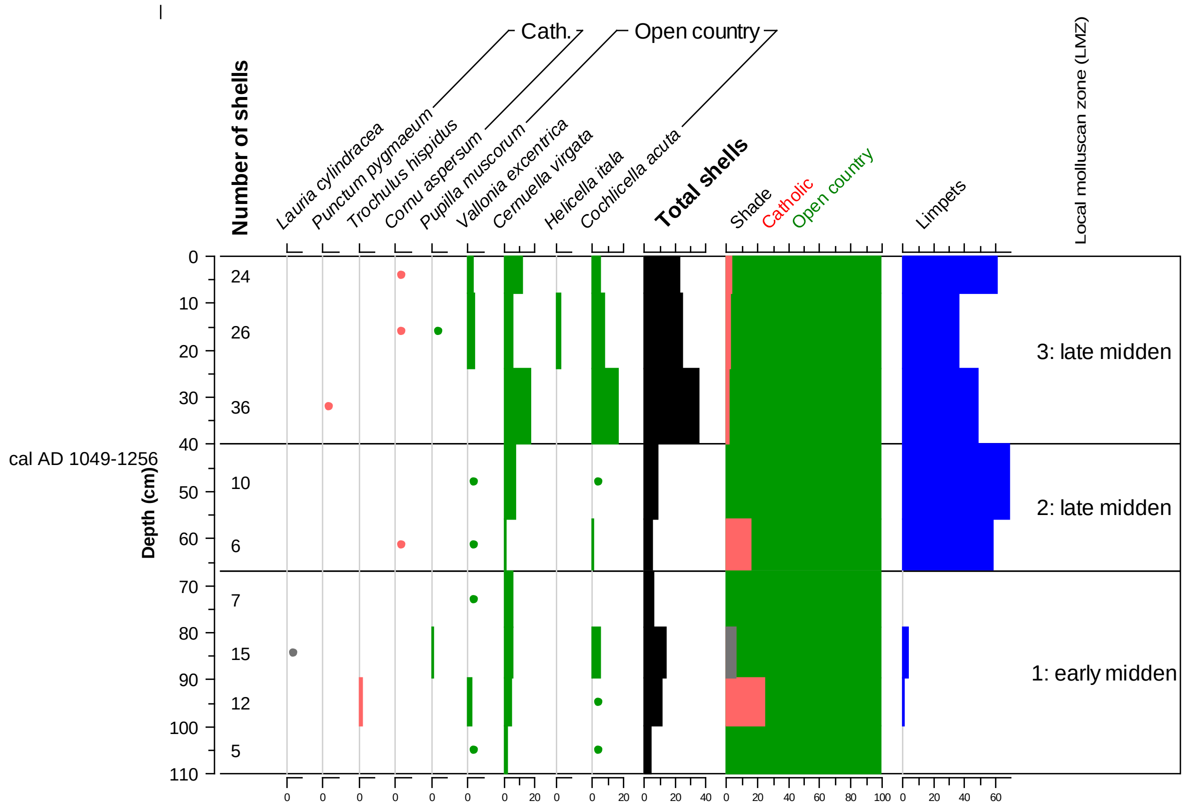


Figure 10.20. Trench 3 mollusc diagram

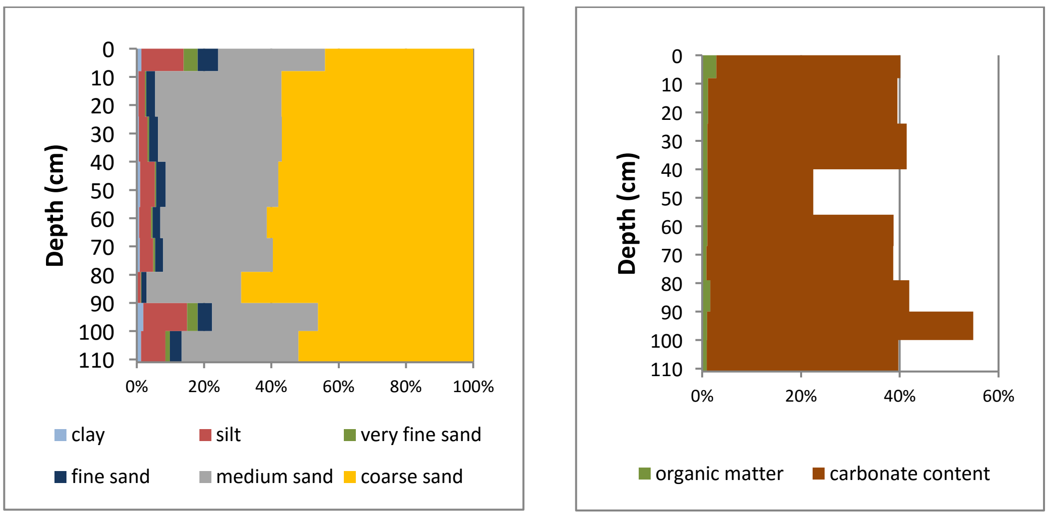


Figure 10.21. Particle size (left) and loss on ignition (right) analyses for Trench 3

The mollusc assemblage as a whole in this trench is entirely consistent with a midden, especially in the upper part of the trench. There are very few land shells at any level (141 in total); those that are present are mainly those associated with open country, although whether authochthonous or allochthonous cannot be determined. Limpets are very scarce in the lower half of the column [LMZ 1; 67–110cm], although they were plentiful elsewhere in the trench, together with numerous fish bones (mainly wrasse, hake and one unidentified species). Perhaps the main accumulations of midden material moved over time, with the exact site of the mollusc column not being much in use during early deposition. Particle size analysis shows that the lower half of LMZ 1 has a greater proportion of clay/silt (12%) than the upper half (3%), consistent with a darker layer visible in the trench section, but there is no molluscan evidence that this is a stabilization layer.

There is an abrupt increase in limpets above 67cm [LMZ 2; 40−67cm], clearly seen in the visual appearance of the section (Figure 10.19). A radiocarbon date from *Ulex*/*Cytisus* charcoal in this context (exact depth unclear) is cal AD 1049−1256 (850±30 BP; Beta-322806), implying continued use of the shell midden at least until the abandonment of the building in Trench 1.

The marine shells in the mollusc column are nearly all limpets, with only very occasional fragments of mussels and cockles. This was also evident during the excavation of the whole trench, when very few marine shells other than limpets were found. Limpets are abundant on the intertidal rocks of the modern beach of Jangye-ryn below the excavation site, while mussels are very scarce and no dead cockles were seen on the sands during a visit in 2011. It would seem likely that there was an absence of larger marine shells other than limpets in earlier times, as at present, although whether the limpets were collected for human consumption or for fish bait is unclear.

The upper part of the trench [LMZ 3; 0−40cm] also contains good numbers of limpets with higher numbers of land shells, implying slower build up of the blown sands, but with the area still being used as a limpet midden. There is no molluscan evidence of any proper turf development at this site, probably because farming practice has regularly stripped some of the topsoil. At the time of excavation this area of the field was used as a manure dump which would markedly inhibit mollusc colonization.

The quantity of sand present in the midden mound implies the continual deposition of sand during midden use, and this could well contribute to the scarcity of land shells at this location.

10.5.4 Trench 4

The siting of the trench was on a small levelled area of turf close to the cliff edge; an explanation for the levelling was sought. The area of Trench 1 was similarly levelled, and subsequent information revealed that these were two tees of the Mullion golf course which were in use from 1906−1956 (Wood 2013, 18).

This 3 x 2m trench did not reach the old ground surface, excavation stopping when it was clear that the sides of the trench had become unstable. The lowest level was blown sand with occasional charcoal flecks. Above this was a thick sand layer into which a ditch was cut, filled with midden material. This was covered by a sequence of four clay surfaces of uncertain purpose, but perhaps to seal the midden.

Above them was further blown sand and modern turf. The mollusc column of 15 samples was taken from the south-facing wall from the turf to the base of the excavation at 1.76m (Figure 10.22).

Figure 10.22. Trench 4. Part of south facing section. The position of the mollusc column is marked with a black rectangle (photo: Bryn Morris)

The mollusc diagram for this trench is shown in Figure 10.23 and particle size and loss on ignition analyses in Figure 10.24.

There was a total of 3,804 non-marine shells in this column. Shade and catholic species are present at all levels with open country taxa again predominating. The lowest layers of this trench [LMZ 1; 149–190cm] have relatively few shells, almost all open country. *Cernuella virgata* is present in good numbers. A radiocarbon date from *Ulex*/*Cytisus* charcoal in this deposit is cal AD 773–968 (1160±30 BP; Beta-322807).

LMZ 2/3 (30–140cm) probably corresponds to LMZ 6/7 in Trench 1, although the reduction in number of shells in the lower half is not as marked as the equivalent zone in Trench 1. The deposit from 114–140cm is from the fill of a pit, but its molluscan fauna is little different from the levels above it. The sediments become much more silty above 80cm, although there is no increase in mollusc numbers. Minimal numbers of *Pupilla muscorum* indicates that this ground was still unstable. A single shell of *Clausilia bidentata*, a species normally found in woodland, was probably dropped here by wind or birds. Dating of a clay surface (*Ulex*/*Cytisus* charcoal) cut into the sampled horizon at 73cm is cal AD 993–1155 (980±30 BP; Beta-322808).

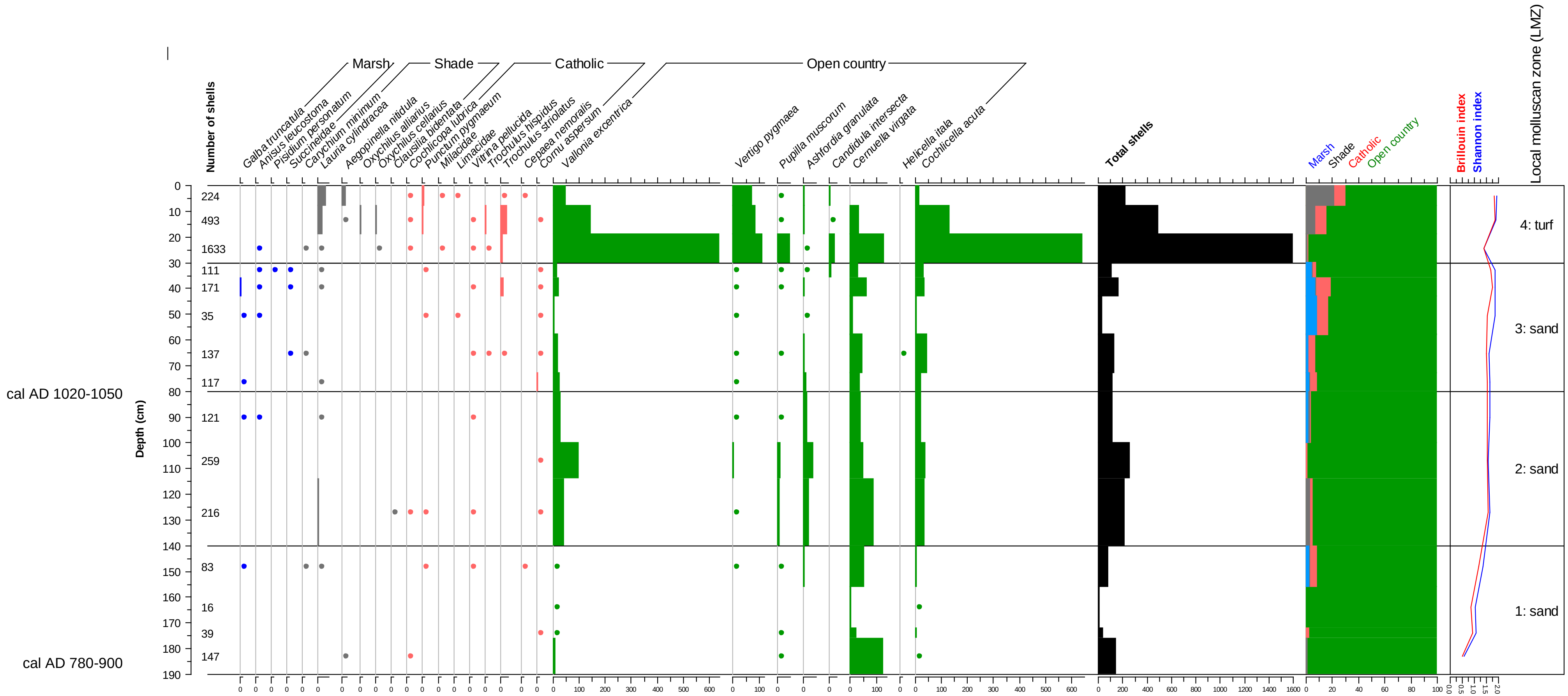


Figure 10.23. Trench 4 mollusc diagram

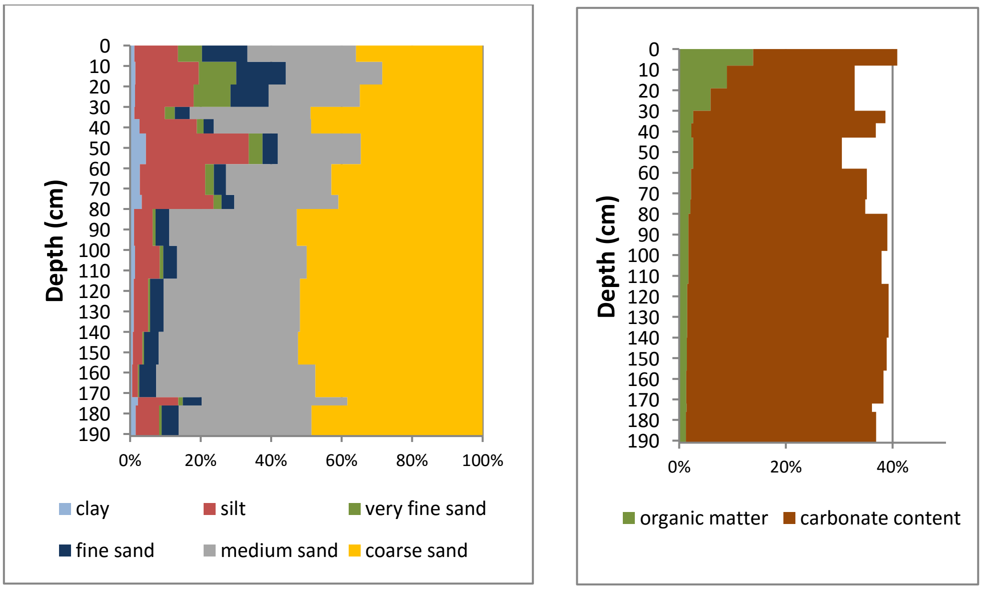


Figure 10.24. Particle size (left) and loss on ignition (right) analyses for Trench 4

The uppermost layers in this trench contain high numbers of molluscs [LMZ 4; 0–30cm], especially at 19–30cm where *Vallonia excentrica* and *Cochlicella acuta* each account for 40% of the total assemblage. The very high numbers of *V. excentrica* strongly suggests that this is now short grazed grassland. It may be that this layer corresponds to the time when the golf course became established, accounting for the increasing levels of organic matter in the sediments.

Of interest is the presence of wet ground species at several levels; these taxa (*Galba truncatula*, *Anisus leucostoma* and *Pisidium personatum*) are all amphibious and able to withstand some degree of drying such as found at the edges of marsh where standing water is intermittent. This trench is the closest of those excavated to the valley where there is extensive marshland, and it is probable that these shells were either wind blown from the marsh, or were carried to the area of the trench by birds or other animals.

10.5.5 Trench 5

This 4 x 2m trench was located on a promontory of land close to the cliff and which was in danger of loss to erosion, and close to a shell midden eroding out of the cliff edge. The bedrock was reached at a depth of 2.37m and was covered by blown sand. This was overlain by a deposit of brown sand containing small pieces of slag, pottery, large bone fragments, charcoal, burnt clay and patches of heat-affected sand, suggesting a domestic midden deposit. Sand above this was sealed by a series of clay surfaces in horizontal sheets, the uppermost of which contained grass-marked pottery and animal bones. The top 1m of the trench was blown sand, disturbed in areas by rabbit burrowing. The mollusc column consisted of 21 samples from the south east-facing section (Figure 10.25).

Figure 10.25. Trench 5. Left: north east facing section; right: south east facing section. Several rabbit holes are visible. The position of the mollusc column is marked with a black rectangle. The midden deposit is visible to the left of the lower part of the mollusc column outline

The mollusc diagram for this trench is shown in Figure 10.26 and particle size and loss on ignition analyses in Figure 10.27.

6938 shells were obtained from 15 contexts. As in the other trenches the assemblages contain predominantly open country taxa. *Cernuella virgata* is present in the lowest layers [LMZ 1; 198−237cm] as in Trenches 1 and 2, but unlike the nearby Trench 1 there is minimal evidence of shade or catholic species in this basal level; perhaps it was more exposed with shorter vegetation.

There is a slight reduction in diversity at 160−198cm [LMZ 2] which is a thick layer of darker sediment containing charcoal, slag, pottery, large bone fragments from many different species, ages and body parts, burnt clay and patches of heat-reddened sand. The appearances are those of a domestic midden and is dated from *Alnus*/*Corylus* charcoal to cal AD 887−1013 (1100±30 BP; Beta-322809). Of relevance is that there are no limpets in this level, raising the possibility that marine shells were not used in this immediate area. *Cornu aspersum* was found in the upper part of this zone and in the next higher level, entirely consistent with the dating.

The sediments above these occupation layers have slightly higher numbers of shells with high diversity [LMZ 3; 112−160cm] indicating some degree of stabilization with slowing of the rate of accumulation of sand, thus providing sufficient time for the fauna to adapt between deposition episodes. This is reflected in the greater proportion of clay/silt shown in the particle size. Four limpet shells were present in the upper part of this sediment (not plotted on the graph) – insufficient numbers to draw any conclusions about their origin.

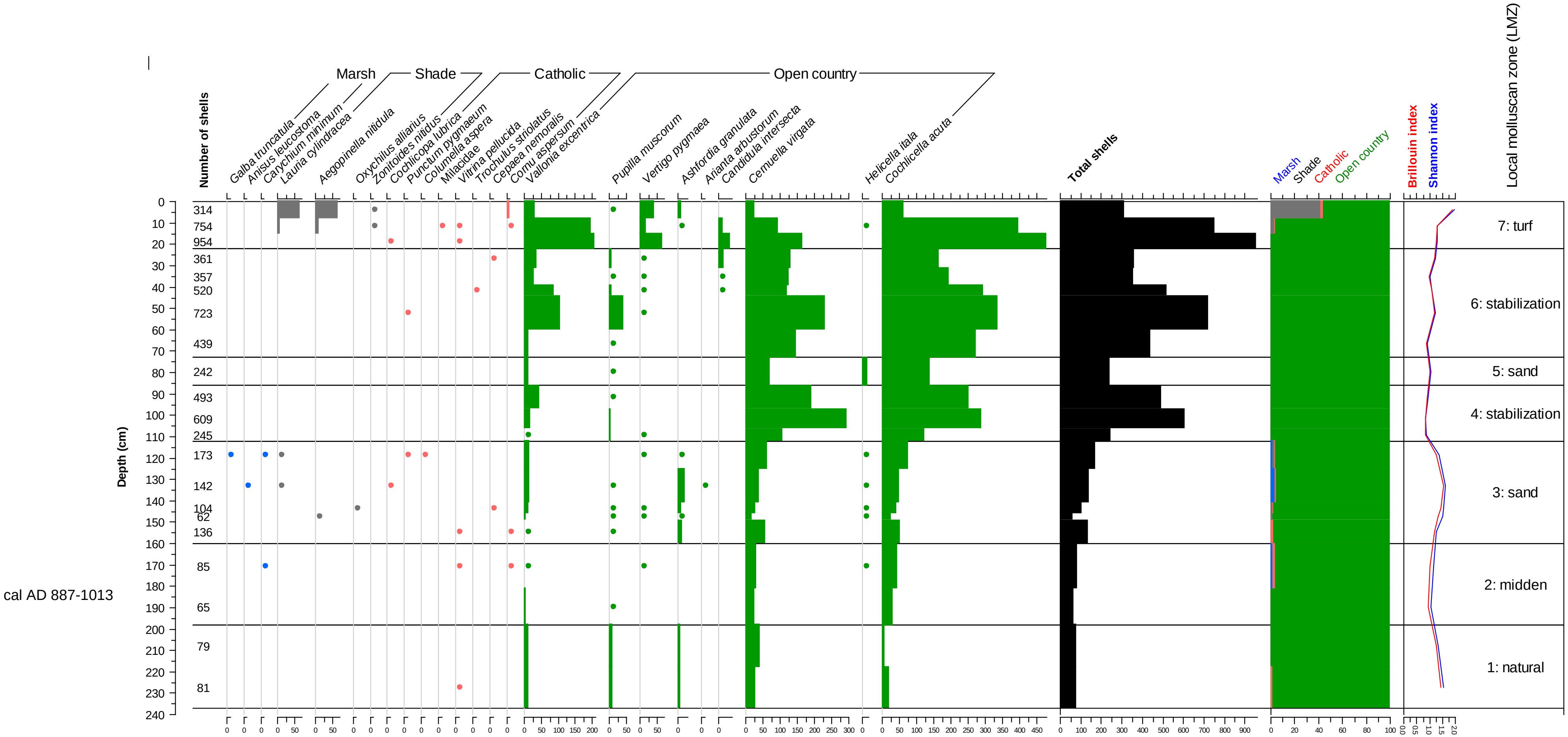


Figure 10.26. Trench 5 mollusc diagram

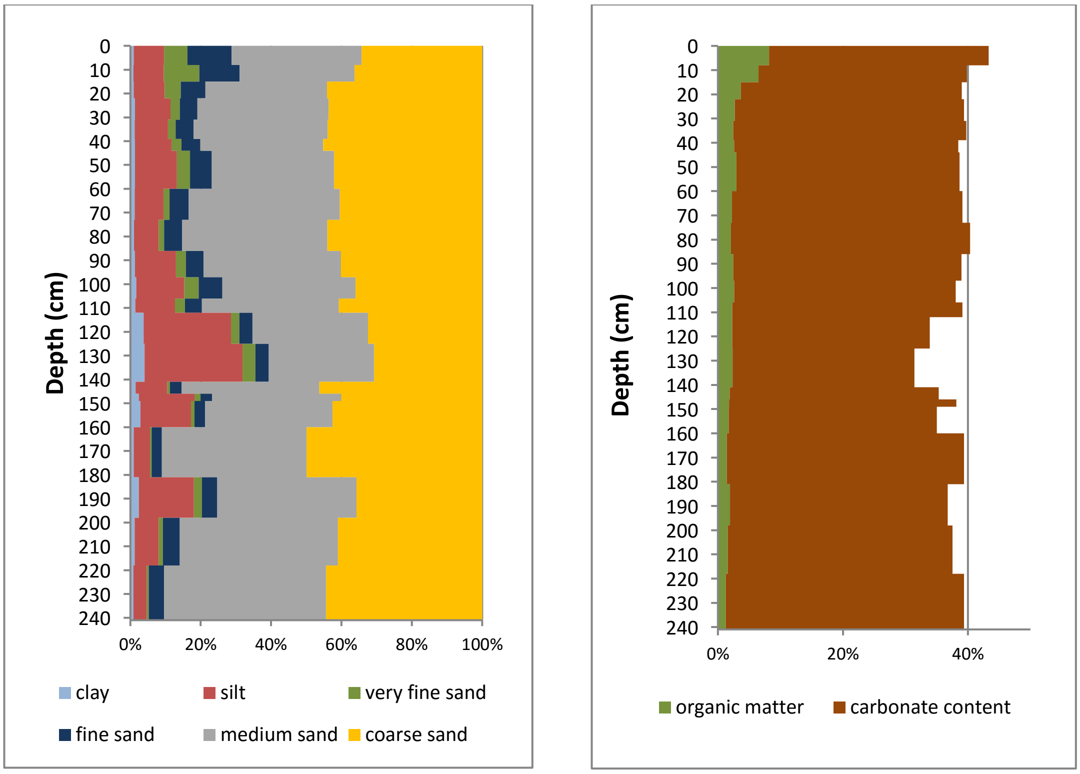


Figure 10.27. Particle size (left) and loss on ignition (right) analyses for Trench 5

This is followed by increasingly stable conditions [LMZ 4; 86−112cm] with many more molluscs and almost certainly corresponding to the deposits at the level of the building in Trench 1. It is relevant that the 106−112cm level contained considerable quantities of slag suggesting some industrial use in the area, contemporary with the occupation of the Trench 1 building.

A thin less stable horizon [LMZ 5; 73−86cm] probably corresponds to the very shell-poor sand in Trench 1, although at this site adequate conditions prevailed for some shells to survive. There is a return to more stable conditions above this [LMZ 6; 22−73cm], with continuing accumulation of sand, but at a slow enough rate to permit a good molluscan fauna throughout. Throughout this time the habitat was open country, with intermittent grazing, reflected in the varying numbers of *Vallonia excentrica*.

The turf [LMZ 7; 0−22cm] contains an assemblage very similar to Trenches 1 and 4, with mainly open country species. The high numbers of *Vallonia excentrica* in the lower part of the turf implies that it was originally grazed grassland. This part of the coast is now no longer grazed and numbers of *Vallonia* are much reduced in the uppermost portion, being replaced by species well able to live in the shade of the tussock grass now present (*Lauria cylindracea*, *Aegopinella nitidula*).

10.5.6 Stable isotopes

Stable isotopes (^{18}O and ^{13}C) estimations were made on molluscs from all samples in Trench 1. Wherever possible *Cochlicella acuta* was used, but for four samples (130–132cm, 138–143cm, 143–145cm, 272–284cm) *Cernuella virgata* shells were used as there were insufficient *Cochlicella* for analysis. In many samples the number of shells was small (frequently only small apical fragments were found in the deposits) and therefore fragments of several shells were combined and ground to powder to provide material for testing. Three replicate measurements for each sample were made in every case except at 211–222cm where there was only enough material for two replicates. It is stressed that these replicates are from the same powder batches, not from different shells. The $\delta^{18}O$ measurements were converted to temperature using the methods outlined in Chapter 4. Figures for the analyses are included on the CD (Appendix 14).

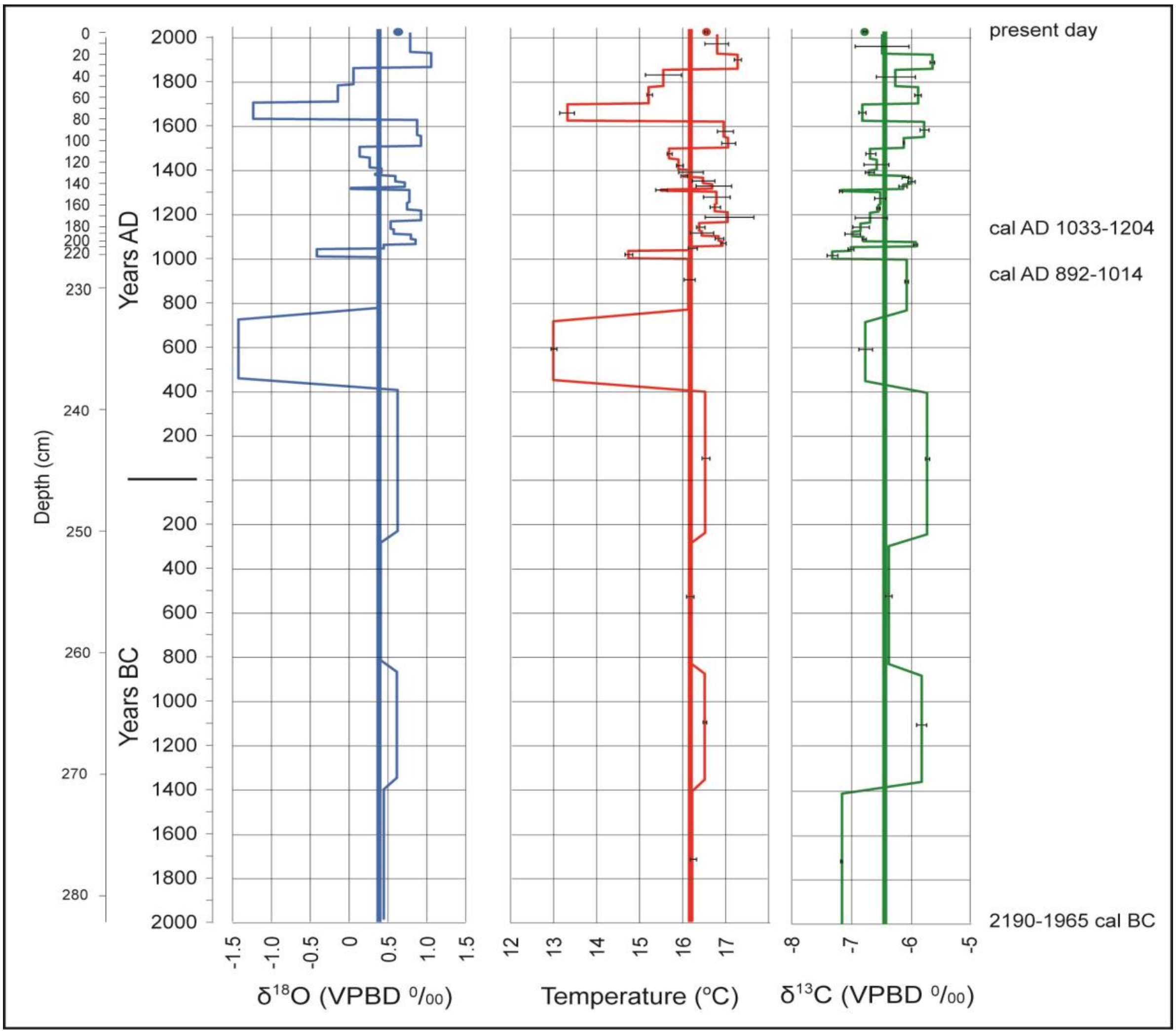


Figure 10.28. Age/depth graphs for the stable isotopes in Gunwalloe Trench 1.
The dots at the top of each curve are measurements on living shells from Gunwalloe.
The average measurement for each graph is shown

The graphs demonstrate that in this area of Cornwall the temperature was relatively stable until early post-Roman times, but that there was then a period with a marked fall in temperature, although only one sample demonstrates this, and it is not possible from this single reading to be certain about the duration of this phase; however, the timing correlates well with a deterioration in climatic conditions around 500–600 AD (Briffa 2000; Bell and Walker 2005, 93). After another period of average temperature there was a further brief episode of reduction in the early eleventh century, but not as marked as the earlier one; this was followed by warming from 1100–1300 AD, consistent with the medieval warm period (e.g. Mann *et al.* 2009). After further fluctuation there is a considerably colder episode from 1600–1850 AD, corresponding to the later part of the Little Ice Age (Barber *et al.* 2000; Fagan 2000; Mann *et al.* 2009). Warmer conditions are then shown to the present time, when the temperature derived from subfossil shells equates closely to those from living specimens obtained from the same site. This temperature curve will be discussed in more detail below, in relation to the sedimentary and climate changes at Gwithian (page 267).

The $\delta^{13}C$ curve shows almost exactly the same variation at that of the $\delta^{18}O$ curve, indicating that the molluscs ingested a range of vegetation which presumably altered with the climatic variation. As mentioned previously little seems to be known about the diet of *Cochlicella acuta*, and no further conclusions can be drawn.

10.6 Discussion

Mollusc analysis indicates that the environment in the area of the Gunwalloe settlement was predominantly open country since the initial accumulations of blown sand. The lowest levels in each trench contain few shells and virtually no shade species (except in the more inland Trench 2), entirely consistent with early accumulation of sand. Particle size analysis shows high proportions of silt/clay derived from the underlying clayey bedrock.

The earliest dated horizon, from the early Bronze Age (2190–1965 cal BC), is the old ground surface in Trench 1. The molluscs do not accord with this as they include specimens of *Cernuella virgata*, which is also present in the basal levels of Trenches 2 and 5, and its presence needs explaining. Disturbance from ploughing during the early medieval period causing downward movement of the shells from higher sediments is possible, especially in view of the evidence of ploughing in Trench 2. Another explanation is that shells from more superficial horizons were retained by the effect of winnowing when the lower sediments were removed by deflation. There is insufficient evidence to overturn the current concepts that this mollusc was first introduced to Britain during the Romano-British period, although direct dating of the *Cernuella* shells would be interesting.

Peters, in his investigation of the molluscs at Gunwalloe (1986, 1987), reported *Candidula intersecta* in the lowest levels of trenches obtained very close to the present Trench 1 and slightly south east of the present Trench 4. This shell, considered to be a medieval, possible late medieval, introduction to Britain was not found in the present study in the lower levels of any trench. *Cernuella virgata*, found now in all the deepest levels, was not reported by Peters in any deep levels and the question therefore arises concerning the correct identification of these two similar species in Peters' work, and he does note that he considered his specimens of *C. intersecta* were atypical. Other than this discrepancy his results are reasonably in accord with those of the present study.

Prehistoric activity is well documented in the area of Gunwalloe (see Section 11.3.1), but evidence for this at the site of the later medieval settlement is virtually lacking, despite Bronze and Iron Age finds on the nearby promontory hill fort. A slate 'fish de-scaler' found in Trench 2 may date from the Bronze Age (Wood 2013, 81). The landscape at this time was partly wooded or with areas of scrub, probably limited to the areas further from the coastal margin and nearer to the marshy area of the valley to the east.

It is not until the early medieval period that evidence of human presence becomes clear, from the eighth to eleventh centuries AD, with some activity in the thirteenth century. Dr Wood (2013) has proposed three phases of medieval activity at Gunwalloe. In Phase 1 a settlement became established in the first half of the eighth century AD, with a field system adequate for ploughing, but as yet there is no evidence of buildings dating to this phase. The molluscan taxa in the early sands of Trenches 1 and 2 indicate that there was woodland, scrub or tall rank vegetation in the immediate vicinity. Shade species are absent in the lowest levels in Trench 5, making it probable that the well-vegetated area was to the east of the site, towards the valley north of Church Cove, and it did not extend as far west as Trench 5. By the time of the earliest dated level in Trench 2 (cal AD 727−945) around 30cm of sand had accumulated below probable plough marks. The areas of shade soon disappeared, whether through the action of man or natural factors such as sand deposition cannot be determined, although the evidence of agriculture would suggest human activity did have an influence on landscape changes. The predominance of *Vallonia excentrica* over *Pupilla muscorum* in the lower levels above the old ground surface of Trenches 1 and 2 suggests short grazed grassland, although this was limited in extent, as only small numbers of *Vallonia* are found at corresponding levels in the other trenches.

Phase 2 is represented by the building in Trench 1, dating to the ninth to tenth centuries, with a house foundation from cal AD 889−1013 and a hearth dated to cal AD 1033−1204, implying continuous occupation for up to 300 years. The sediments immediately outside the west wall of the building exposed in Trench 1 consist of blown sand and midden material containing considerable quantities of charcoal and bone. There is a single lens of very clean sand almost devoid of molluscs just below the base of the wall, perhaps placed as packing against the wall footings. The presence of *Cornu aspersum* in this layer is consistent with a Romano-British or early medieval date for this deposit. The deposits abutting the wall itself contain large numbers of molluscs, with limpet shells, charcoal and mammal and fish bones, all likely midden material. The equivalent deposit in Trench 5 is probably at 106−112cm where numerous fragments of slag were found, but no limpets, also implying a midden but perhaps from an industrial site rather than one which was purely domestic.

Phase 3 is suggested to correspond with the development of the Royal Manor at Winnianton, clearly established by the time of the Domesday Book. The mollusc and sediment evidence implies that there was rapid accumulation of unstable sand in the locations of the trenches (apart from Trench 2 where much of the superficial deposits have been removed), and it seems likely that this instability led to the abandonment of the Trench 1 building, and perhaps any other buildings in the immediate vicinity. Midden activity during the tenth/eleventh centuries AD is evident in Trench 3, with limpets being very prominent in the upper levels of the midden deposit. Whether these limpets were used for food or fish bait cannot be determined, but certainly vast quantities were deposited. Quite when the area was again abandoned after several centuries of occupation is unclear; may be the encroaching sands became too much to compete with, or, as Wood speculates (2013, 98), the developing urban centres such as Helston became too attractive.

During the periods when sand was accumulating there were some short episodes of relative stability with the formation of thin buried soils, but these are fairly insubstantial and are unlikely to have been of sufficient duration for return of activity. In more recent times greater stability returned, revealed by increasing mollusc populations near the modern ground surfaces in Trenches 4 and 5, and to a lesser extent in Trench 1, reflected in numbers of both individual shells and of taxa. The topsoil of Trench 1 may have been partly removed when the golf tee was constructed in the mid-twentieth century, and it is known that the upper levels of Trench 2 are truncated by recent farming activity and the use of this field as a temporary car park. In Trench 3 there is also no modern topsoil, the limpets from the midden being readily visible on the surface; this area has recently been used for manure storage, and it is probable that the surface is regularly removed by agricultural practices.

Some specific questions were asked concerning Gunwalloe in the introduction to this thesis, and these can now be addressed.

Why was the early medieval settlement abandoned around the tenth to eleventh centuries?

It is clear that there was a major sand blow episode which covered the settlement around the tenth/eleventh centuries and which was presumably a contributing factor leading to abandonment of this site. However, the stable isotope record does not show more than a brief episode of cooler temperature in the early eleventh century. Whether there was a single episode of massive sand blow during one particular inclement winter or a more sustained period of sand blow is not clear, but the chronology of the isotope record concurs with the timing of abandonment. The area as a whole was not deserted during the eleventh century as the Domesday Book entry for Winnianton makes clear that there was still a major holding somewhere in the vicinity.

Has the area of the settlement always been sand dunes or was it ever wooded?

There is no convincing evidence of woodland at any site within the confines of the area investigated. Trench 2, being further inland that the other trenches, does contains some mollusc species normally associated with shade and leaf litter (*Oxychilus alliarius, O. cellarius, Acanthinula aculeata*), but all are capable in living in more open habitats, although *Discus rotundatus* is only very rarely found outside woodland, and it is probable that there was wood or scrub close to this site in the Bronze Age.

Elsewhere shade species are sparse, being found only intermittently in most of the trenches, where the small numbers present may be allochthonous, being brought by wind or birds. Similarly, the presence of several marsh and freshwater species in all the trenches at different times does not suggest that these areas were ever marshy, but that the shells are intrusive. *Clausilia bidentata*, another species usually found in wooded areas, is present in several assemblages, including some modern ones when it is known that that the nearest trees (a hedge line) were never more than about 30m distant, strongly implicating intrusion, and not the existence of significant shade.

How has the environment altered during the periods before, during, and after human occupation?

The old ground surface at Gunwalloe, dating to the early Bronze Age, is overlain by sands which are almost certainly Romano-British in chronology with no intervening sand deposits. It is probable that earlier prehistoric sands, if ever present, have been removed by deflation. At this time the coastal margin was probably a good distance from the present site and the settlement would have been relatively ‘inland’, but still near enough to the cliff margin to be affected by winter storms. Erosion is still progressing at a rapid rate, as shown in Figure 10.6, and Figure 10.29.

Figure 10.29. Coastal erosion close to Trench 5 at Gunwalloe over twenty months.
The left photograph, taken on 24 June 2012, shows the coast path about 2m from the cliff face;
the right photograph, taken on 19 February 2014, shows it reduced to about 0.5m.
There were exceptionally severe storms in south west England during the winter of 2013/14

There has been little overall change in the environment since post-Roman times; episodes of sand blow have occurred, probably on a regular basis, but there have been many periods of stabilization, some of longer duration than others. The country round the settlement remained open throughout, with no evidence of vegetation larger than that able to provide some degree of shelter.

11. Discussion

This chapter will focus mainly on the Gwithian studies, but expand to include the findings at Gunwalloe, and attempt to place these Cornish results into the wider context of British blown sand environments. This will be followed by a brief discussion of how mining activities in the Red River catchment are reflected in the Gwithian sediments. The hypotheses concerning mollusc extinctions and introductions will be discussed in the light of the findings at Gwithian.

11.1 Tidal estuary and sea level

Data obtained from the sedimentology, pollen and diatom analyses show that the northern side of the lower Red River valley was never a tidal estuary, contrary to previous opinion (Thomas 1958; Nowakowski *et al.* 2007). The cores on the south side of the valley failed to reach solid geology and marine incursion in that area is therefore not excluded. By combining the present findings with the depth of marine clay found in the boreholes from the 1980s and 2002, when clay was found at depths varying from 1.20m to 8.40m, it is possible to reconstruct approximate outlines of the extent of the marine estuary which probably extended a short distance inland from the present shore line (Figure 11.1). The earliest 'prehistoric' estuary penetrated on the south side of the valley no more than 1km inland from the modern shoreline. The extent of tidal influence then retreated, and two phases can be determined: 'intermediate' and 'late'. Although no dates can be ascribed to these phases they are probably related to rising sea levels. The suggested position of the 'late' inlet corresponds to the course of the Red River prior to nineteenth century rerouting of the river (see Figure 5.9). There is no evidence at any of the locations sampled in the present study of the gravel and clay horizons described by Stephens (1899, 1899–1900) (see Figure 5.12); either he misinterpreted his findings (unfortunately his detailed reports do not seem to have survived), or there was a narrow, winding, river channel which has not been discovered.

The earliest dated sediments at Gwithian are the organic silts laid down on the underlying killas on the north side of the valley at 3942–3705 cal BC, when there is no evidence of blown sand nor of any marine sediments. This, together with the other measured dates shown in Tables 7.1 and 7.2 can be plotted against earlier sea level curves (Figure 11.2). It is stressed that these are the maximum possible heights for sea level, and the actual level could have been lower. These points from the Gwithian study fit very well with the previous curves, being very close to those from elsewhere in the Bristol Channel rather than that from the English Channel. There are no previous studies with data from the north Cornish coast for comparison.

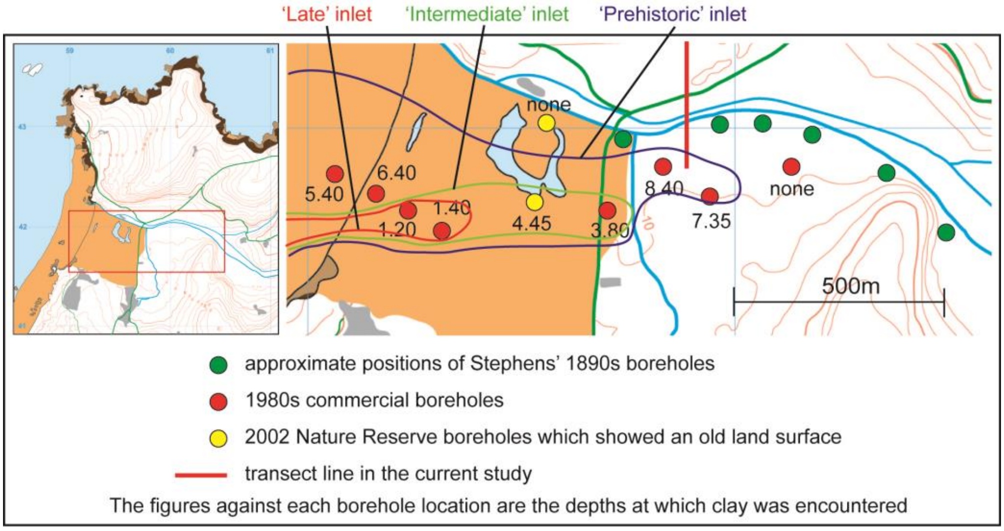


Figure 11.1. Suggested tidal extent at different times in the lower Red River valley

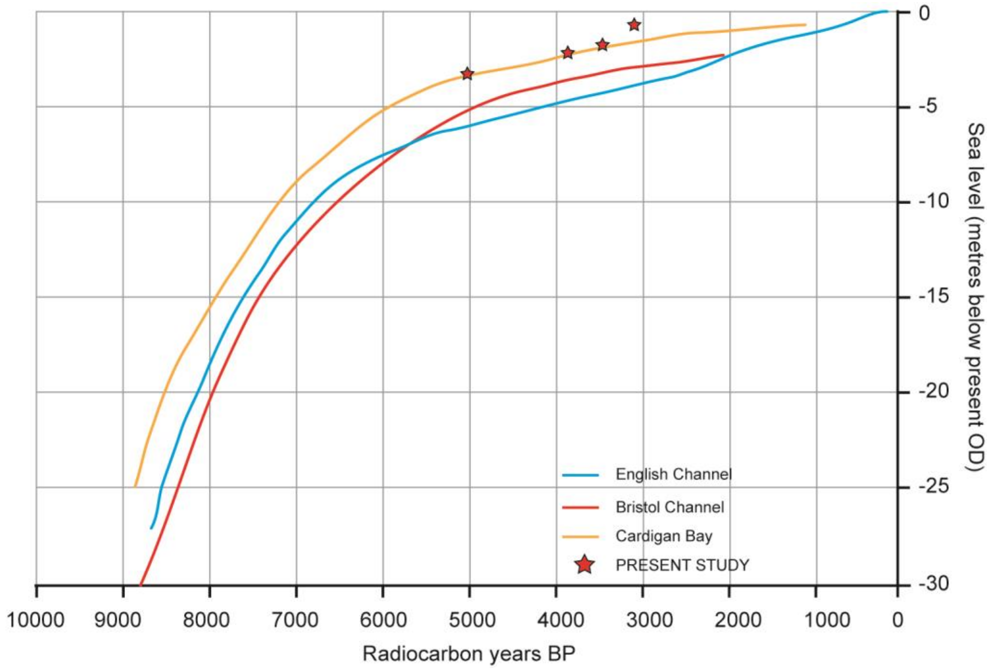


Figure 11.2. Sea level curves for south west England and Wales to include the results from the present study. Note that the time scale is in radiocarbon years BP, so uncalibrated radiocarbon dates as well as the OSL dates have been used for this graph, which shows the highest possible sea levels (after Heyworth and Kidson 1982)

11.2 Landscape reconstruction and archaeological occupation

The Gwithian coring study and trench excavation, together with the mollusc column at Strap Rocks and the dates from the mollusc column at the western end of Godrevy Towans, add to knowledge concerning the landscape of the lower Red River valley during the Holocene. The new dates, together with those obtained from the 1950s to 1960s excavations and the 2005 trench, allow a sediment sequence at Gwithian to be proposed (Table 11.1).

Table 11.1. Chronology of the Gwithian palaeoenvironment. The settlement activities did not necessary span the full length of the time periods shown in column 1. The colours indicate differing sedimentary deposits

Date	Valley basin	Valley sides	Godrevy Towans (west end)	Strap Rocks	Settlement activity
AD 1950–present	stabilization	stabilization		stabilization	
AD 1650–1950	blown sand	blown sand		blown sand	
c AD 800–1650	marsh	blown sand		blown sand	Crane Godrevy
c AD 400–*c* 800	marsh	stabilization	blown sand	blown sand	Post-Roman site
c 800 BC–*c* AD 400	marsh	blown sand	stabilization	blown sand	Porth Godrevy
900–*c* 800 BC	stabilization	stabilization	stabilization	blown sand	Phase 5 settlement
1100-–900 BC	blown sand	blown sand	blown sand	blown sand	Phase 5 settlement
1150–1100 BC	stabilization	stabilization	blown sand	blown sand	Phase 5 settlement
1350–1150 BC	blown sand	stabilization	blown sand	blown sand	Phase 3 settlement
c 1700–1350 BC	fen/carr woodland	stabilization	stabilization	buried land surface	
c 1800–*c* 1700 BC	fen/carr woodland	blown sand	blown sand	buried land surface	Phase 1 settlement
3000–*c* 1800 BC	fen/carr woodland	blown sand	stabilization	buried land surface	
4000–3000 BC	fen/carr woodland	initial sand blow			
pre–4000 BC					Mesolithic activity

Within this chronology the specific episodes of aeolian activity can be placed in a somewhat tighter time frame, and include the few dates obtained at Gunwalloe (Table 11.2).

Table 11.2. Summary of sand blow events at the study sites

Date	Location	Event
Medieval		
end 16th century AD	Crane Godrevy	abandonment, perhaps related to sand blow
12th century AD	Gunwalloe	sand blow
Romano-British		
4th century AD	Porth Godrevy farmstead	abandoned due to sand blow
after AD 89–235	Godrevy Towans (west)	sand blow
Late Bronze Age		
after 913–812 BC	Godrevy Towans (west)	sand blow
after 900 BC	Gwithian Trench	sand blow
after 900 BC	Gwithian settlement	abandonment, probably related to sand blow
1220–880 BC	Gwithian Trench	blown sand
Middle Bronze Age		
1540–1120 BC	Gwithian valley	buried by sand
Early Bronze Age		
1745–1611 BC	Strap Rocks	blown sand
1800–1500 BC	Gwithian settlement	blown sand horizon
2070–1650 BC	Gwithian 30m core	sand blow
before 2190–1965 BC	Gunwalloe	initial sand blow
3350–2870 BC	Gwithian Trench	initial sand blow
Late Neolithic		
2572–2307 BC	Godrevy Towans (west)	initial sand blow

Figure 11.3 is a summary diagram of the changes at Gwithian since 3000 BC, including correlation between settlement activity with climate events. The Gwithian stable isotope temperature curve has not been used as it has been shown to be unreliable for the period 400 BC–AD 1550 due to presence of midden material in the core (see page 198). The Gunwalloe temperature curve has therefore been included as this closely follows established climatic events. Although Gunwalloe is on the south coast of Cornwall and Gwithian on the north, the two sites are only about 25km apart and the overall temperature curve is likely to be valid.

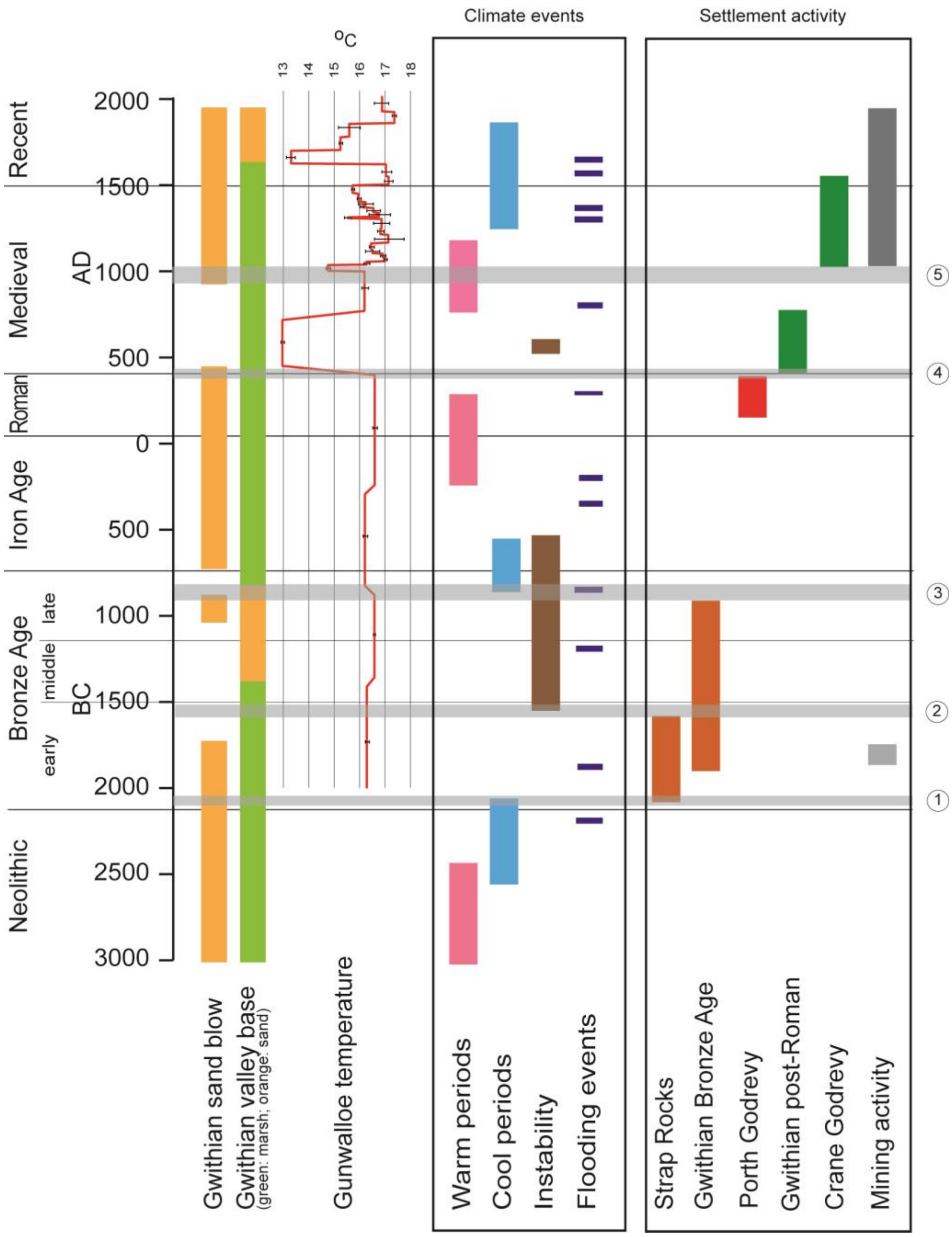


Figure 11.3. Summary diagram of sand blow, temperature, climate events and settlement activity at Gwithian. The numbers on the right refer to correlations discussed in the text
(Warm periods: Johnsen *et al.* 2001; Mann *et al.* 2009; Wang *et al.* 2012) (Instability: Bond *et al.* 1997; Bond *et al.* 2001) (Cool periods: Barber *et al.* 1994; Van Geel *et al.* 1996; Barber *et al.* 2000; Fagan 2000; Barber *et al.* 2003; Mann *et al.* 2009; PAGES 2k Consortium 2013) (Flooding events: Johnstone *et al.* 2006; Macklin *et al.* 2006)

11.2.1 Mesolithic and Neolithic

The base of the Red River valley was wet ground during the entire Mesolithic and Neolithic periods. Alder wood in the lowest level of sediment (949–977cm) in the 30m core is radiocarbon dated to 3943–3708 cal BC. Molluscs have not survived at these depths, but pollen analysis indicates a fen/carr woodland with relatively open areas. Mesolithic flints have previously been found on many sites in the Gwithian/Godrevy area but for the first time they have now been discovered close to the later Bronze Age settlement.

The earliest evidence of sand deposition away from the valley basin is the old ground surface in the 2012 trench, which was dated by OSL to 3350–2870 BC. Molluscs were few, mainly *Xerocrassa geyeri*, but sufficient to suggest that by this time the landscape was open. At the west end of Godrevy Towans there is a slightly later date of 2572–2307 cal BC from both charcoal and molluscs (Section 3.6). These dates are in broad agreement for the first blown sand with that of 3000–4000 BC proposed by Carter (1988, 303) for the earliest dunes in Britain and with that of 3000 BC for St Ives Bay in Cornwall suggested by Lewis (1992). The open landscape supports the findings by Spencer (1975) of the loss of woodland during the Neolithic; she additionally showed that the base layers at Towan Head, Newquay, contained shade species of molluscs indicating scrub or light woodland prior to sand deposition but does consider that sand may have contributed to clearance rather than ascribing a purely anthropogenic cause, a suggestion that would also be applicable to Gwithian.

At Strap Rocks the landscape was open woodland/scrub at least until the end of the Neolithic and probably into the early Bronze Age, when field walls were constructed. Blown sand did not arrive at this site until later, after clearance, making anthropogenic cause for loss of woodland likely.

11.2.2 Bronze Age

11.2.2.1 Early Bronze Age

The earliest (Phase 1) settlement at Gwithian, excavated in the 1950s and 1960s, dates to the early Bronze Age: 1890–1610 cal BC (3430±50 BP; OxA-14568) (Hamilton *et al.* 2008). The molluscs in the lowest sand above the old ground surface in the 2012 trench were dated to 2013–1776 cal BC, in agreement with the settlement evidence, but there is a 'hiatus' in the trench of around 600–800 years, with the sand above the old ground surface dated by OSL to 1290–810 BC. Any sand that did accumulate previously in this location may have been deflated by wind.

Closer to the river the first dated sand deposition occurred about 1800 cal BC, but this only affected the valley sides, evident in the 30m core where there is a 30cm thick sand horizon between two organic silt layers, dated by OSL to 2080−1660 BC, i.e. during the early Bronze Age, at the time that the sand comprising the old ground surface in the trench was deposited. At the present river location the stratigraphy indicates continuity of marsh throughout this period. The molluscan evidence shows that the area of the meadow was still very open, but pollen indicates that the lower parts of the valley remained little changed since earlier times, being wet ground although some areas of woodland are still present. The initial building in the settlement was constructed of wood, and charcoal included oak, hazel, hawthorn, gorse and broom consistent with woodland and scrub (Nowakowski 2009, 119). It is significant that, contrary to deterministic expectation, this first settlement phase is associated not with stabilization but with a period of sand deposition, at least in part of the landscape.

At Strap Rocks, 1.2km south west of the main Gwithian Bronze Age site, the stones eroding out of the cliff are shown to be a wall line, presumably a field boundary. The sand against the wall, reworked Pleistocene Head, is dated to the early Bronze Age (2135−1940 cal BC at the base and 1632−1502 cal BC at the top), slightly earlier than Phase 1 of the main Gwithian settlement. This basal date correlates with amelioration of the colder climate (Figure 11.3: ①). It is likely to be associated with other sections of wall which have previously been observed in the cliff face. Whether a midden close to the wall is coeval has not been established but it could suggest the presence of a nearby settlement, and a watch should be maintained in this area as erosion proceeds. The presence of the cist observed in the eighteenth century in the cliff face is another pointer to a second settlement in the Gwithian area. It must also be remembered that the margin of the sea would probably have been many hundreds of metres further into St Ives Bay during the Bronze Age, and that an associated settlement may have been seawards of the wall and now lost to coastal erosion. A further pointer to some settlement in the area is the finding of 21 sherds of pottery, considered to date to the Bronze Age, found in a primarily early medieval midden at the ‘Sandy Lane’ site, east of Strap Rocks, towards Gwithian village (Sturgess 2004, 203). Sand commenced accumulating over the field system during the later part of the early Bronze Age (*c* 1600 cal BC) and probably led to the abandonment of the fields, certainly in this area. This is approximately at the time when there was a long period of climatic instability (Figure 11.3: ②) and the two may well be related.

It is possible to suggest reasons why these settlements were established close to the outflow of the Red River. St Ives Bay is the most westerly sandy bay on the south side of the Bristol Channel and the first easily accessible beach for sea craft that rounded Cape Cornwall on the Land’s End peninsula. Plentiful supplies of fresh water could be obtained and there was presumably access to food supplies. This site close to the bay enabled inhabitants to combine maritime and terrestrial resources. Its benefits for crop growing (frost free, higher temperatures and earlier growth), as well as the availability of sea weed and shell sand to improve the soils, would have made the area attractive.

The excavations on the main Gwithian site indicated that there was a period of neglect (Phase 2) with a blown sand horizon sometime between *c* 1800 and *c* 1500 cal BC (Sturgess 2007a), although cultivation continued (Nowakowski 2009, 120). The fields at Strap Rocks were buried by sand during the later part of the early Bronze Age and may be coeval with this neglect. The timing could relate to a possible climatic downturn marked by a major flooding event recorded in Britain by Johnstone *et al*. (2006) in 1880 cal BC but is too early for the period of climatic instability outlined by Bond *et al*. (1997; 2001) of 1550–550 BC.

At Gunwalloe on the west side of the Lizard peninsula charcoal in the old ground surface is dated to the early Bronze Age (2190–1965 cal BC), and the deposit, although silty, does contain 50% sand-size particles and represents the first surviving blown sand at this site. There are no specific climatic events to which this can be related. The mollusc assemblages in the sand above the old ground surface suggest that there was probably continual deposition and winnowing during the Bronze Age, resulting in there being no remaining sand which can be ascribed to the remainder of the Bronze Age, or to the Iron Age. This aeolian activity is not unexpected due to the very exposed landscape on the west side of the Lizard peninsula.

11.2.3 Middle/late Bronze Age

Conditions at Gwithian were sufficiently stable for the settlement to become re-established (Phase 3) during the middle Bronze Age (1500 and 1200 cal BC) with evidence for field systems and ploughing covering about 1.5ha (Sturgess 2007a; Nowakowski 2009, 120). A stabilization horizon with open country molluscs is identified at the western end of the Towans dated to 1504–1416 cal BC (Section 3.6). But the local landscape changed abruptly in the middle of the mid Bronze Age. The marsh across the valley was covered by blown sand. Radiocarbon dating at the surface of the marsh is 1416–1281 cal BC, while OSL dating of the base of the overlying sand is 1550–1130 BC. If the mid-point date of the various measurements is taken, then this change in the landscape occurred around 1350 BC. Whether or not there was a major climatic event leading to massive sand blow is not resolved, but the deposit, at the 30m core site, of 200cm of sand over 250 years which contains very few molluscs suggests rapid accumulation. Significantly it is now evident that the deposition of these large quantities of sand over the valley basin did not lead to abandonment of the settlement and is probably coeval with the blown sand deposit west of the main north-south field wall of the settlement described as Phase 4 (Sturgess 2007a, 29).

A thin stabilization horizon containing very high numbers of molluscs (2616 shells per 500g) is present at the 30m core position, dated to about 1100 BC. The presence of abundant *Lauria cylindracea*, given its frequent association with stone walls (e.g. at Strap Rocks) and the known presence of walls elsewhere at Gwithian suggests that there may have been field walls close to the river, which is shown in the 15m core to be close by. Abundant wet ground molluscs show that the area was still very damp and the walls may have been constructed to demarcate the margin of the earlier marsh.

Conditions remained relatively stable into the late Bronze Age, with short periods when soils had sufficient time to accumulate along the river banks, although still with intermittent flooding, shown by the presence of wet ground molluscs and horizons of gleyed sand. This is Phase 5 of the settlement, when ground was cleared and a new farmstead constructed with major field boundaries, and with ard marks indicating agricultural activity including ploughing.

In the 2012 trench the lower buried soil horizon on the old ground surface dates to this period, with an OSL date of 1290−910 BC. Some bovid hoof prints are present on the surface of this sand indicating that animal husbandry did extend at least this far from the settlement, not surprising due to the nature of the ground. The mollusc assemblage in this sand comprises almost entirely of *Xerocrassa geyeri*, consistent with very open ground, probably with sparse vegetation. Some marine shells, mussels and limpets probably derive from midden spread. This horizon correlates well with the farming activities associated with Phase 5 of Bronze Age settlement.

11.2.4 Late Bronze Age/early Iron Age

The 2012 trench at Gwithian shows an episode of sand blow dated by OSL to 1220−880 BC; moderate numbers of molluscs indicate that it accumulated relatively slowly. This is overlain by a buried soil horizon dated to 940−640 BC and containing large numbers of open country molluscs with no evidence of shade. A stabilization horizon at the western end of the towans is coeval, dated to 913−812 cal BC (Section 3.6), implying that this was a time of stability across the landscape, despite it being a period of North Atlantic instability (Bond *et al.* 1997; Bond *et al.* 2001). This period at the settlement site (Phase 5) was very active, being a 'farmstead' with several buildings, and evidence of both arable and pasture land. Nowakowski (2011, 122) comments that the 'settlement at Gwithian, by this phase, appears to have reached a level of comfortable maturity and we may imagine that life in the sands was, on the whole, pretty good.'

This upper buried soil horizon in the trench contained a rich open country mollusc assemblage with little evidence of shade. High numbers of *Vallonia excentrica* indicate grazed grassland, a conclusion strongly supported by the presence of large numbers of bovid hoof prints, with some of ovi-caprids, impressed into the upper surface of this sand, together with some ard marks. The use of seaweed as fertilizer is suggested by the finding of a specimen of *Patella pellucida* on the surface of the soil, a shell which is only found in seaweed holdfasts. The dates of the trench sediments (940−640 BC) overlap with those of final years of the settlement which was abandoned about 900 BC (Sturgess 2007a; Nowakowski 2011, 123) and it seems probable that the two are coeval.

The demise of the settlement seems to have been planned rather than an abrupt abandonment (Sturgess 2007a; Nowakowski 2011, 123). Some of the buildings were destroyed and the ruins sealed by spreads of settlement waste (Nowakowski 2011, 123). The trench, however, does indicate that blown sand at some time covered the stabilization horizon; the stable isotope graph from the core (Figure 7.8) shows an episode of lowered temperature corresponding to the phase of cooler, wetter, conditions from 800–400 BC proposed by Van Geel *et al*. (1996) and a flooding episode demonstrated by Johnstone *et al.* (2006) (Figure 11.3: ③). A thin layer containing sand rock fragments covers this horizon; their origin is unclear. They may have come from field walls or other structures up-slope of the trench location and that wind and/or water has deflated any sand deposits associated with them, leaving the heavier sandrock fragments in this 5cm thick layer. The timing of this event has not been resolved but may be related to the abandonment of the area for several hundred years.

11.2.5 Iron Age to post-Roman/early medieval

There is scant evidence of Iron Age presence at Gwithian. A few pottery sherds found on the Godrevy hillside and in the area of Gwithian village cover a period from the late Bronze Age to the Roman period, but no settlement or agricultural activity is known in the valley (Quinnell 2007b). The earliest evidence of occupation at Crane Godrevy on the towans summit is a round dating to the Roman, or possibly late Iron Age, and could indicate that agricultural activity moved from the Bronze Age site in the valley to the higher ground of the towans.

Dating in the valley after the Bronze Age is insecure as it is not possible to determine whether the later sands accumulated steadily or intermittently, and whether quantities of sand were lost to deflation, either by wind or by water from the river. Conditions in the valley certainly changed during this period, with return of marsh on the north side of the valley, but not on the south which remained sandy, although intermittent gleying of the sand suggests that flooding for extended periods of time did occur. No specific cause for this is revealed in the study, but there are several major flood episodes recorded in lowland Britain (Johnstone *et al.* 2006) during this period – 320 cal BC, 200 cal BC, cal AD 300 – implying stormy conditions and these could have affected Cornwall, although the overall temperature remained stable. One flood event does fit chronologically with the loss of sand and flooding of the valley leading to a prolonged period of marsh, an environment that persists to the present day at Reskajeage Marshes, which commence only 200m upstream from the study site. Access to St Ives Bay may have been difficult which is why the Roman homestead on Godrevy Headland is situated on high ground well above the Bay, although it would still have been liable to adverse storms from the west. A stabilization horizon is present in the Godrevy Towans scarp section, dated to cal AD 89–235 (Section 3.6), fitting well with the proposed date of the homestead occupation situated 500m to the north.

The homestead was abandoned probably in the fifth century AD, approximately at the time when the post-Roman industrial site on the dune in Gwithian meadow was first established, and when there was a period of relative stability from sand blow (Figure 11.3: ④), although the Gunwalloe temperature curve does suggest a period of marked cooling. The only evidence in the present study of human activity during this period is the 260cm deep midden deposits at the 30m core location; these are almost certainly connected to the post-Roman industrial site on the sand dune to the north east. An OSL date in the middle of this deposit is AD 640–800, agreeing closely with the period of occupation determined from previous studies (Sturgess 2007b; Hamilton *et al.* 2008). This midden was very localized in extent, not being found in the cores on either side.

The marsh conditions varied considerably at different times and places. At 0.5m the pH dropped as low as 2 during the early accumulation of sediment, but then rose sufficiently to permit a flourishing assemblage of wet ground molluscs to survive; nearby, at 15m, there is an even richer wet ground mollusc community at the equivalent level to that at 0.5m. Pollen confirms the increase in herbaceous wetland, but some open woodland/scrub remains, with suggestion of an anthropogenically modified landscape. This points to a spatially varied environment.

There was no indication in the trench of any buried soil or agricultural activity during the post-Roman period which correlates with that found in the adjacent field system to the north of the trench (Fowler and Thomas 1962). Whether this area was never part of the post-Roman system, or whether evidence of activity has been lost to deflation, cannot be determined.

There is no evidence yet found of human activity at Gunwalloe on the Lizard Peninsula from this period. Any sand deposits are no longer present implying that conditions here, as on the north coast, were adverse for much of the time, although a single very stormy episode could have accounted for the loss of substantial quantities of sand. The stable isotope results show a period of reduced temperature *c* 600 AD which may be associated with these events.

11.2.6 Medieval and recent

The settlement investigated at Gunwalloe was first established during the eighth century AD, about the time when the post-Roman site at Gwithian was abandoned (these sites are 25km apart, and no connection is suggested). No buildings have been found associated with this first community at Gunwalloe. The landscape was a mosaic of open ground with areas of woodland/scrub with field systems and evidence of ploughing and grazing. It is unclear whether there were ever deposits of blown sand beneath the medieval horizons which have since been deflated. An alternative is that this area was sufficiently inland prior to coastal erosion that significant quantities of sand were never deposited in the area of the trenches.

The earliest identified building at Gunwalloe is dated to cal AD 889‒1013. It was continuously occupied for up to 300 years and the settlement was important in the early post-Conquest period when it featured prominently in the Domesday Book. Midden material was used as a revetment against the wall of the house, and further midden deposits are present in Trench 5, while in Trench 3 there was a major limpet midden. The abandonment of this settlement was almost certainly precipitated by rapid deposition of sand covering the house building in Trench 1 and the midden horizon in Trench 5. There is no obvious climatic episode to account for this but a single violent storm could have mobilized sufficient sand from the adjacent beach or dunes. This abandonment is approximately coeval with the commencement of a period of sand blow observed at Gwithian, and my reflect overall conditions in western Cornwall.

At Gwithian, the northern side of the valley remained marsh at least until the end of the medieval period, following which sand again covered the whole valley floor, corresponding to a period of reduced temperature during the Little Ice Age consistent with climatic instability. At the trench site there was continual accumulation of sand, with an OSL date of AD 1670‒1730 at 15cm above the buried soil horizon. Whether this 15cm represents the total depth of sand deposited over several hundred years or there was intermittent deposition with or without deflation is not known. The timing could be coeval to later sand blow episodes at Gunwalloe on the Lizard Peninsula.

The study reveals evidence of more extensive human activity than previously recognized high on Godrevy Towans during the medieval period. The medieval manor house of Crane Godrevy, dating from the late tenth or early eleventh century, is located on the summit of the towans, and the present study, while away from the site of earlier excavations, has expanded the area of probable activity on the surrounding hillside. This date approximates to further sand blow episodes in the Gwithian valley, although not sufficient to cover the valley base with sand (Figure 11.3: ⑤). This also correlates with the commencement of mining activity in the Red River catchment area, but whether the two events are connected is not known.

At the southern limit of the flat Towans plateau, at 495m, very high numbers of *Lauria cylindracea* suggested that there were field walls close to the core location. This supposition is supported by the finding of *Cecilioides acicula*, given the frequent association of this species with former agricultural land. This burrowing shell was found to a depth of 55cm and could derive from higher levels, but its association with the *Lauria* increases the likelihood of field systems extending this far from the manor. A probable ditch was revealed by ground penetrating radar at 530m, some 50m south west of the closest ditches excavated previously (Thomas 1969; Sturgess and Lawson Jones 2006b). The site was abandoned around the end of the sixteenth century. No dates have been obtained from the sand that covers the buildings, but it is not unreasonable to suggest that sand blow may have played its part, possibly by deflating what little fertile sandy soils there may have been on the towans summit. Also, the extensive and thick sand layers downslope of Crane Godrevy and at the west end of the towans are likely to have inundated some of the fields associated with the medieval manor house.

The steep scarp of Godrevy Towans has, until recently, been a continuously open environment with little molluscan evidence of more than short vegetation. Although much of this slope is in modern times covered in scrub, there is nothing to suggest that a similar habitat existed earlier. At 289m, about one-third of the way up the scarp, deep sand (in excess of 340cm) accumulated on a hillside devoid of tall vegetation throughout its time of deposition and provided sufficient sand for quarrying, as shown on a map of 1850–1851 (Figure 5.11).

11.3 Coastal sand in the wider landscape

The studies in Cornwall have demonstrated distinct episodes of sand blow, which are summarised in Table 11.2. An attempt will be made to correlate these with similar episodes described elsewhere in Britain which have included mollusc studies, and link them to established palaeoclimatic climate events. Analysis is complicated by the lack of reliable dating at the majority of sites and the resulting difficulty of defining the chronology of settlement activity in relation to aeolian action.

A further difficulty is in determining whether sand blow episodes occurred as single violent events of storm action causing rapid conflation of sand, or to a more gradual process of sand accumulation. Similarly, storms may deflate large areas rapidly or slowly, thus creating potential hiatuses within sequences and removing environmental evidence, such as found in the Gwithian trench.

The earliest sand dunes in Britain were deposited during the period of 'thermal maximum' defined by Johnsen *et al*. (2001, c 5500–2500 BC), when reduced storminess might be expected, although spatial and temporal variations are likely (Bell and Walker 2005, 89). Rising sea levels provided adequate quantities of sand to be available close to modern coastlines for it to be blown on shore. At Gwithian the first sand dates to around 3000 BC in the Trench and 2500 BC on the Towans. Both of these are somewhat earlier than at Brean Down in Somerset where the earliest sand deposit, albeit limited in extent, was in the Beaker period, around 2000 cal BC (Bell 1990, 24; Bell 2013a, 309). Several Neolithic/Beaker sites in Scotland seem to have been covered by sand at about this time, some with storm events being postulated as the cause (Evans 1972, 296). Northton (Evans 1971b, 52) and Sligeanach (Evans *et al.* 2012) in the Outer Hebrides, Knap of Howar, (Traill and Kirkness 1937; Spencer 1975) and Tofts Ness in Orkney (Simpson *et al.* 2007, 240), all show one or more sand blow horizons during the Beaker/early Bronze Age period. Anthropogenic causes are often ascribed to reduction in woodland cover during the Neolithic but burial by blown sand may be a major contributing factor, as suggested at Towan Head, Newquay, (Spencer 1975) and at Northton (Burleigh *et al.* 1973); this may also be applicable at Gwithian.

There was a period of colder, wetter, conditions in Europe between *c* 2550 and 2050 BC (Barber *et al.* 1994; Barber *et al.* 2003). Movement of large quantities of sand requires the sand to be relatively dry and mobile, but there is likely to have been increased storminess associated with this climatic shift. It is doubtful, however, whether the Bronze Age sand deposition observed at Gwithian can be ascribed to these climatic events, as the date is later (2070−1650 BC). Relative climatic stability following the period of cooling may be associated with the commencement of settlement at Gwithian and Strap Rocks, although some aeolian activity did deposit sand on the Gwithian valley sides. The first sand at Gunwalloe dates to this time, although there may have been many episodes of conflation and deflation. At Tofts Ness, Orkney, sand blow did occur towards the end of the early Bronze Age, (Dockrill 2007) but the lack of dated coeval sand blows elsewhere suggests that this may have been a local event. Similarly, at Ardnave on Islay, there was sand blow which buried an early Bronze Age settlement, which was not re-established until the late Iron Age (Ritchie and Welfare 1983).

Climatic instability is recorded between 1550 and 550 BC (Bond *et al.* 1997; Bond *et al.* 2001) becoming cooler and wetter from 850−550 BC (Van Geel *et al.* 1996; Barber *et al.* 2003). The major sand blow which buried the marsh in the Red River valley at Gwithian is dated to the middle Bronze Age and is likely to be associated with the instability. The settlement at Baleshare, Outer Hebrides, was abandoned for about 200 years during the middle Bronze Age with conflation of blown sand (Barber 2003, 222), although climatic events are not discussed.

Correlation of the abandonment of Gwithian in the late Bronze Age with climatic activity is difficult. Abandonment seems to have been a planned process (Sturgess 2007a, 31). There is good evidence of widespread sand blow in the first part of the late Bronze Age but the area seems to have been more stable when abandoned although adverse conditions did recur about 800 BC when the valley floor returned to marsh and blown sand accumulated on the valley sides. Elsewhere in Britain aeolian activity is dated to the late Bronze Age at Stackpole Warren in Pembrokeshire (Benson *et al.* 1990), within the timeframe of climatic instability, and could be related.

Sand blow episodes can, perhaps, be associated to climate during the Roman Warm period (Wang *et al.* 2012). As mentioned above sand needs to be dry to enable aeolian activity, and thus may have been more mobile during these warmer centuries. Whether there were some stormy episodes sufficient to move quantities of sand is not recorded cannot be excluded. Sand blow during the later Iron Age is recorded at Stackpole Warren, Pembrokeshire (Benson *et al.* 1990), and at Atlantic Road, Newquay, Cornwall (Reynolds 2000–01; Davies forthcoming). There was also sand blow at Brownslade, Pembrokeshire, at some time between the late Iron Age and end of the Roman period (Groom *et al.* 2011). There are, however, no clear climatic correlates with the episode of presumed sand blow which led to the abandonment of the Porth Godrevy farmstead on the Godrevy Headland close to Gwithian.

The medieval warm period, from *c* AD 800–1200 (Mann *et al.* 2009), may have been linked to sand blow episodes as a result of drying of the sand, but it is difficult to link this to individual coastal sites. The Gunwalloe settlement was abandoned towards the end of this phase with good evidence of rapid sand accumulation, but it is not possible to establish a direct climatic connection. The colluvial sand which covered Trethellan Farm in Newquay, Cornwall, contained molluscs introduced to Britain during the medieval period (Milles 1991a) but there is no close dating. In the Outer Hebrides in Scotland at the Viking Age settlement at Udal blown sand was increasingly deposited during the thirteenth century AD or later and climatic deterioration was considered, although increasing exploitation of the land by the Norse economy was also postulated (Crawford and Switsur 1977). Also in the Outer Hebrides deposits of blown sand covered medieval occupation horizons at Newtonferry (James and Ridout 2003) and South Glendale (James and Forbes 2003) during the thirteenth/fourteenth centuries but these events were not linked to climate events.

11.4 Mining in the Red River catchment

Geochemical analyses have allowed some insight into the chronology of mining activity in the Camborne area, the tailings of which flow with the Red River into St Ives Bay at Gwithian. Although it was not possible, with the XRF methods used, to evaluate levels of tin due to its similarity to calcium signals, other metals and minerals can act as proxies.

During the early Bronze Age there is a short period around 1750 BC when there is a marked increase in zinc levels and small increases in tungsten, arsenic and lead and with some rise in magnetic susceptibility. These changes are possible indications of mining activity upstream, but are not sufficiently strong for certainty. The lack of any copper signal is not surprising, there being no evidence elsewhere of copper being extracted in Cornwall during the Bronze Age (Sharpe 1997; Timberlake 2009, 100). It is unfortunate that this study cannot provide evidence of any mining activity during the second half of the Bronze Age as minerals only adhere readily to fine grained silt or clay particles and not coarse sand grains. The sediments at the sample site were sandy from *c* 1350 BC to *c* 400 BC.

There is no evidence of mining residues during the post-Roman period. This might seem unexpected in view of the industrial nature of the buildings on the nearby dune (Sturgess 2007b), where metal residues suggest that smithing was undertaken (Hatton 2004). However, it is considered (Thorpe and Thomas 2008) that the source of iron may have been from concretions obtained from the local cliffs at Gwithian (Thomas 1957–58).

It is not until about AD 1050−1100 that there is good evidence of mine contaminants in the Red River sediments. Initially there is a marked rise in zinc consistent with sphalerite extraction, and of manganese and iron, with small rises in lead and yttrium. The strong increase in iron concentrations and in magnetic susceptibility is also good evidence that mine tailings were entering the river system; the river waters must have turned red at this time, and the river name subsequently became known as the 'Red River'. It is not until AD 1300 that a slow rise in arsenic levels is detected followed by large increases in lead and tungsten at AD 1500, almost certainly indicating extraction of cassiterite for tin; copper only shows a small increased signal at this latter date, having been only minimally evident for the previous 300 years. These findings clearly indicate that mining was active in the catchment area during the late medieval and early Industrial Age.

How do these results correlate with the sedimentology of the cores? At 0.5m there was fall in the pH to 2 probably during the post-Roman period, but the XRF does not reveal any evidence of mining activity at this time. It is therefore more likely that the period of extreme acidity was due to stagnant ponding of water in the area of this core rather than mine contamination. However, at 15m, a period of acidity (to pH 3.8) occurred around AD 1100−1450 which correlates very well with the evidence given in the previous paragraph, when there was considerable elevation of the signals of several metals. It is therefore suggested that mining contributed to these changes in the local environment.

Sand precludes analysis from AD 1650−1850, but after this there is dramatic increase in most metal signals, entirely consistent with the expansion of mining activity during the nineteenth century. It is only very recently, towards the end of the twentieth century, that tungsten, arsenic, copper and iron signals show reduction towards baseline levels contemporary with the cessation of mining. South Crofty, Europe's last tin mine, finally closed in 1998 (www.westernunitedmines.com), and all mining activity around Camborne ceased.

It has been shown earlier (Sections 6.4.1/2) that the upper 50‒60cm of the sands in the fields south of the Red River and those close to the north side of the river were virtually devoid of molluscs. Some of the uppermost layers have been removed to construct a windbreak but the remaining sand seems unexpectedly sterile. It is known that flooding from high water levels occurs during periods of adverse weather such as the winters of 2013 and 2014 (Figure 11.4), although overbank flooding is not a regular occurrence (A. Thomas, pers com). It seems reasonable to suspect that some of the mining contaminants are affecting the fields during these periods of high water leading to the relative sterility of the present findings.

Figure 11.4. Flooding in the lower Red River valley, February 2014.
View looking north across the valley from Godrevy Towans

11.5 Mollusc extinctions and introductions

One of the aims of this thesis was to test accepted hypotheses concerning the chronology of extinctions and introduction dates of certain mollusc species into Britain and particularly to Cornwall.

Xerocrassa geyeri

The only species now extinct throughout Britain, but present in the samples obtained in this study, is the xerophile *Xerocrassa geyeri*. Although it probably disappeared from the remainder of southern Britain early in the Holocene it persisted at Gwithian, probably in a very local refugium, until the Bronze Age. The radiocarbon dating of several specimens of this species in the present study establishes that it was present on the main Gwithian site at least until 2026‒1751 cal BC and at Strap Rocks until 1632‒1502 cal BC. It therefore appears to have survived until towards the end of the early Bronze Age. This was a period of instability (Table 11.2) sufficient to deflate the sand in the trench, and may well have contributed to the final demise of a species that had managed to survive in this small area for several thousand years after it became extinct elsewhere.

Cochlicella acuta

The first appearance of *Cochlicella acuta* in Cornwall is considered to be in the late Bronze Age, although it did not reach Scotland until the Iron Age (Section 2.3.3.2). Several specimens have been radiocarbon dated in the present study. Those from the old ground surface at Godrevy Towans scarp, where shells were numerous, are dated to 2570–2347 cal BC; even if some allowance is made for old carbon effect, this places the species in Cornwall during the late Neolithic. Shells from Strap Rocks dated to 1745–1611 cal BC, the early Bronze Age. Specimens from a buried soil above the old ground surface at the Towans scarp are dated to 1504–1416 cal BC. The evidence seems conclusive that this species was in Cornwall considerably earlier than thought, probably as early as late Neolithic. It could well have been introduced to this area by traders from the Continent, of which there is increasing evidence from at least the early Bronze Age (Van de Noort *et al.* 1999). It could have survived in a local microclimate for at least a thousand years before spreading elsewhere in Britain. Further research might reveal its presence elsewhere in southern England earlier than the traditionally accepted date.

Helicella itala

Helicella itala is considered native, i.e. it was established before separation of Britain from the Continent. This species in known on the chalk of southern England from the end of the glacial period (Kerney 1999, 182) but the successional appearance of *Helicella* before *Cochlicella* observed by Evans (1979) does not seem to apply in west Cornwall. In every site where bedrock was reached (Gwithian trench, Godrevy Towans, Gunwalloe trenches 1, 2, 3, 5), as well as at Strap Rocks, *Cochlicella* is found in deeper levels than *Helicella*. This succession was also found at Gwithian by Spencer (1975) and Milles (1991b), but not at Atlantic Road, Newquay, Cornwall (Davies 2008, 140) or Brean Down, Somerset, (Bell and Johnson 1990, fig. 156) where *Helicella* preceded *Cochlicella*. It would seem likely that the environment on the open dunes in west Cornwall was not favourable for *Helicella*, and the conclusion is that this species was a late colonizer of some Cornish dunes, not becoming established until the middle or even late Bronze Age. This is contrary to the succession found at Scottish dune sites (see Section 2.2.4).

Cornu aspersum

This was an infrequent finding during the present study at both Gwithian (all sites) and Gunwalloe although at no location was it found in prehistoric sediments. Its occurrence is consistent with the generally accepted view of its Romano-British introduction (Kerney 1999, 205).

Cernuella virgata

The introduction of this mollusc has been difficult to date as many early records are considered unsatisfactory (Section 2.3.3.2). In the present study it was found in the deepest sand in all the Gunwalloe trenches but, as discussed in Section 11.6, the shells were probably winnowed from more superficial sediments. In the Godrevy Towans section it did not appear until the early medieval period and in the Gwithian trench probably not until early medieval or later times, although deflation has made this timing unreliable. In some of the other Cornish sites it was only found in superficial levels (Constantine Island, Harlyn Bay West). Overall the accepted view of a post-Roman introduction remains valid, although the appearance time varies considerably at different sites, perhaps due to differing microclimates. Radiocarbon dating of the Gunwalloe shells could, however, provide evidence for a prehistoric introduction of *Cernuella*.

Candidula intersecta

This makes its appearance only in very recent times in all the study sites, except for two specimens in early medieval levels in Gunwalloe Trench 2. There is therefore no need to revise the accepted opinion that this a medieval introduction, although it may not have reached many parts of Cornwall until at least the end of the medieval period, and probably even later. It was not present at all at Strap Rocks, even in the most superficial sediments.

Cecilioides acicula

This mollusc lives a subterranean life, burrowing up to 2m below ground surface, and its introduction is therefore very difficult to date. It was found at Crane Godrevy in levels probably associated with late medieval agricultural activity. It has never previously been recorded on Godrevy Towans (National Biodiversity Network www.nbn.org.uk). One of the turf specimens was live when collected proving that the species is extant in the area. It is therefore not possible to determine whether the subfossil specimens are contemporary with the medieval activity or modern.

Potamopyrgus antipodarum

No other introduced species were found at any site in this study apart from *Potamopyrgus antipodarum* in the Red River leet sample; its finding here is consistent with its recorded mid-twentieth century appearance in Cornwall (Forbes and Hanley 1853, 266; Kerney 1999, 36).

12. Conclusions

12.1 Gwithian summary

It is appropriate before referring to the main hypothesis proposed at the outset of this thesis to draw some conclusions from the main study site at Gwithian, and answer the specific questions posed concerning that site.

Did human activity influence the environment, or *vice versa*, in different regions of the study area?

The various analyses clearly demonstrate that there is interaction between the environment and human activity. There is evidence that woodland clearance did take place in the lower Red River valley prior to the initial settlement at Gwithian during the early Bronze Age, although whether due to human action or burial by sand cannot be determined; a combination of both is probable.

Sand blow episodes provide the clearest evidence of environmental forces altering settlement patterns, both during the Bronze Age and later. Blown sand covered the early Bronze Age settlement and this horizon is also seen close to the marsh of the valley floor; whether the valley was totally abandoned for a period around 1800−1500 cal BC is unclear, but no evidence of activity has been found. The earlier part of the middle Bronze Age seems to have been stable, but another major sand blow around the fourteenth century BC led to sand, for the first time, covering the full width of the Red River valley. How this involved the humans living in the area is not resolved, but there was a period of neglect in the settlement field systems. It was not until stability returned that full activity resumed, perhaps with the construction of field walls along the river bank. A further episode of blown sand deposition occurred in the late Bronze Age/early Iron Age leading to final abandonment both of the settlement and the field systems. Whether or not agricultural activity in the field system played a part in destabilizing the sand of the meadow is not established, but the evidence in the trench that cattle and sheep/goats were present on this valley side adds to the likelihood of an anthropogenic factor in destabilization. It is probable that there would have been some effect on the thin sands on the gently sloping hillside, and the lynchets previously observed by Fowler and Evans (1967) support this proposition; the formation of the lynchets indicates some down-slope movement of soil and/or sand which would have been abetted by the trampling effect of animals and the loss of stabilizing vegetation resulting from grazing.

No definite evidence has been found in the present study to substantiate major sand blow as the cause of abandonment of the post-Roman industrial site on the sand dune around the eighth century AD. The valley basin at this time was marsh and there are no stabilization horizons in any of the cores on the valley sides. The implication is that conditions were generally unstable, probably with repeated episodes of sand deposition and deflation. In the trench there is a hiatus for at least 800 years from the end of the Bronze Age when sand is absent, a period of instability which may well have lasted into the early medieval period.

It is not until the middle medieval period that evidence of interaction is again seen, with the construction of field systems on the summit of the towans in the area of Crane Godrevy manor in the tenth/eleventh centuries. The chronology of sand accumulation and loss cannot be assessed on the upper towans due to the lack of sediment variation, but there is little doubt that the local landscape was altered by agricultural practices.

Mining activity upstream in the catchment area of the Red River probably had little influence on the environment during prehistoric times, but the accumulation of contaminants from the second half of the eleventh century onwards is likely to have impacted on the habitat in later times. The continual rise and fall in the water table, with spread of toxic minerals from the river, probably altered the fauna and flora in adjacent fields.

Is there evidence for agriculture, either grazing or arable, more widely than previously established?

There is clear evidence that grazing took place during the middle and late Bronze Age on the meadow to the north of the Red River and outside the field systems investigated in the 1960s. The presence of a few animal hoof prints in sediments dated to 1290–910 BC and abundant prints in those of 940–640 BC demonstrates this, together with the ard marks in the latter sediment. The molluscan assemblages are consistent with grazing during the later period but not during the earlier phase. Arable farming during the later phase is evident from the ard marks, supported by the probability of manuring with seaweed.

There is new evidence of field systems at Strap Rocks with the supposition of agriculture. There is no clear indication of the location of the settlement to which these fields were associated but the adjacent midden exposed in 2014 and the Bronze Age pottery previously found near Gwithian village may point to the areas of likely settlement location.

Is there evidence that the lower Red River valley was ever a tidal estuary?

The data obtained from the sedimentology, pollen and diatom analyses show no evidence that the valley was ever estuarine at the study locations. However, the *caveat* is that neither core south of the present river course reached solid geology, and it is likely that there was a tidal estuary for a short distance inland from the sea. If this is so then it gradually diminished in extent, probably related to progressive riverine sedimentation and sand deposition. Contrary to previous opinion (Thomas 1958; Nowakowski *et al.* 2007), the north side of the valley in the region of the prehistoric and post-Roman settlements has never had a tidal inlet extending up to and round the post-Roman dune.

Is there evidence in the lower Red River valley for mining in the river catchment area during prehistory or the historic period?

There is possible evidence that small scale mineral extraction took place during the early Bronze Age, with a marked increase in zinc signal about 1750 BC suggesting that sphalerite was acquired for its lead content, this metal also showing a small rise. Evidence for tin extraction at this time is weak as tin concentrations were not assessed by the techniques used, but the small rise in tungsten at this time, a constituent of the tin ore cassiterite, is a possible pointer to tin acquisition in the early Bronze Age. Unfortunately, no information is gained concerning activity in the later Bronze Age due to lack of appropriate fine grained sediments in the river valley to retain the relevant elements.

Strong evidence of mining activity commences in the late medieval period, from 1050−1100 AD, with zinc-containing minerals first being obtained followed cassiterite for tin, possibly by 1300 AD and certainly by 1500 AD. During the nineteenth century contamination of the river waters reached its peak before diminishing during the later twentieth century with the cessation of mining in the Camborne area.

12.2 Study questions

Is the episodic history of sand blow driven by secular climatic episodes, storm events, sea level changes or land use factors?

The study has identified sand blow events at both Gwithian and Gunwalloe which may be related to secular climatic episodes but the chronologies of those episodes are too broad to correlate directly with aeolian activity. Storm events sufficient to move large quantities of sand may be violent and short-lived, perhaps only a single day. These events may either remove existing sand from a site, or deposit new sand. The chronologies obtained do not provide adequate resolution to identify individual storms. It is probable that, on these exposed coasts of Cornwall, storms played a significant role in altering the landscape and that their frequency and strength will have varied within the broad periods of palaeoclimatic change.

Are the sand blow and stability episodes coeval in the study areas and how do they relate to known climatic episodes elsewhere in Britain?

The preceding paragraphs have summarised the evidence that several of the sand blow events are broadly coeval across the different locations at Gwithian, but some are specific to individual locations and significant spatial variability has been identified (Table 11.1). It is not possible to provide a chronology of most of the aeolian activity at Gunwalloe due to the lack of appropriate dates, but sand blow is likely to be the prime factor leading to its abandonment around the twelfth century AD, long after the final settlement in the river valley at Gwithian had been subsumed by sand. As far as other

British sites are concerned, correlation is more difficult due to the lack of robust chronologies, but there is good evidence for climatic influence at some sites, e.g. Brean Down in Somerset, where significant sand deposition occurred during the Bronze Age (Bell 1990), at Stackpole Warren in Pembrokeshire, at sites in the Outer Hebrides and at Tofts Ness, Orkney. During the Little Ice Age, at a time when renewed sand blow is evident at Gwithian and about when Crane Godrevy was abandoned and sand buried the marsh across the Red River valley at Gwithian, sand inundation sufficient to bury several churches is recorded. These include St Gothian's Chapel at Gwithian (Section 5.1.2.6), St Piran's (Cornwall & Scilly HER 19720) and St Enodoc (Cornwall & Scilly HER 26442) on the north Cornish coast and Berrow in Somerset (Rippon 2000).

<u>How do sediments and molluscs contribute to understanding spatial variation in the landscape?</u>

The study as a whole, not solely of the molluscs, clearly demonstrates different activities both at Gwithian and Gunwalloe, and the importance of a multiproxy approach to analyses is clear. The transition at Gwithian between the Red River valley basin and the valley sides is clearly demonstrated, despite no molluscs having survived in the deepest basin sediments. The changing nature of the valley floor, from initial fen/carr open woodland to blown sand, then marsh with less evidence of woodland/scrub and finally back to blown sand is revealed, both by the sediments and by the molluscs. These changes will certainly have had an influence on human activity, altering access to settlements on different sides of the valley and routes to the sea, and probably availability of different food resources in the valley and river. The tidal inlet was considerably smaller than that originally proposed but, while present, would have provided easy access from St Ives Bay to the Bronze Age settlement and was probably still accessible during the post-Roman phase.

On the northern valley side and towans molluscs have demonstrated the probable presence of field walls in areas where they were not previously known, broadening the area of cultivated land, mainly given over to grazed grassland. In the area of the trench at Gwithian molluscs demonstrate that at the time when the lower buried soil was accumulating the vegetation was not grazed (although some cattle were present), but at a later date the upper soil was grazed by both bovids and ovi-caprids.

The sediments and the molluscs at Strap Rocks both show that, during the early Bronze Age, there was woodland/scrub which was cleared before the middle Bronze Age. This is the first evidence of such a habitat on the Cornish coastal dunes which has been securely dated. Elsewhere shade molluscs were present in an undated sediment at Daymer Bay – an area that warrants further study.

At Gunwalloe the study has shown spatial variation of different activities, particularly concerning the middens, one of which was solely a limpet midden, one was a domestic midden within a possible industrial site and one was used as revetment against building walls.

Extinction and introduction of mollusc species

It has previously been established that *Xerocrassa geyeri*, extinct since the early Holocene in most of southern Britain, survived in a refugium in Gwithian area until the Bronze Age. Dating of shells has shown that it was present until the later part of the early Bronze Age but probably did not survive into the middle Bronze Age.

Cochlicella acuta was present in large numbers in late Neolithic levels at Godrevy Scarp. This species, previously thought to be a first millennium BC introduction to Britain, was almost certainly present in Cornwall at least 1000 years earlier. Whether more reliable chronologies elsewhere in Britain will substantiate this outside Cornwall remains to be seen. Its appearance earlier than *Helicella itala* at all the study sites suggests that the successional order of these species established elsewhere in Britain does not hold for west Cornwall.

Little can be added concerning other species. The introduction dates previously suggested for *Cernuella virgata* (Romano-British) and *Candidula intersecta* (medieval) are supported by this study, although dating of molluscs at Gunwalloe lead to a revision of the *Cernuella* introduction date.

The main driver of sand blow and instability is palaeoclimatic in origin, thus influencing the episodic occupation of coastal sites*.*

The primary hypothesis proposed in the introduction to this project has not been convincingly proven. There is good evidence that human settlement activity both at Gwithian and at Gunwalloe was influenced by episodes of sand blow but it is not possible to relate most such episodes closely to palaeoclimatic variations, largely due to chronological constraints. Some occur during established periods of instability or with colder, wetter, conditions while others take place during warm climatic phases (Figure 11.3). It has been shown that whilst sand was deposited in some parts of the landscape, occupation of fields was flourishing in other areas. This demonstrates the value of the spatial approach adopted here. A number of distinct sand deposition episodes have been identified, some just a single specific episode, other being more widespread. It has been shown that the main sand blow events were during the Bronze Age and Little Ice Age, although some instability is demonstrated between the late Bronze Age and early medieval period.

Further dating of deposits may provide tighter chronologies at individual settlement sites and permit closer correlation with the much broader timescales of palaeoclimate variation. The problems of identifying specific periods when deflation has removed evidence of blown sand deposition will always remain. Nowakowski (2007, 59) summarises this dilemma:

> The long history of settlement and arable cultivation documented [at Gwithian] ... suggests that while sand blows may have been a daily hazard they did not deter settlement or indeed prohibit cultivation. Indeed the archaeological evidence points strongly to successive generations flourishing and actively exploiting the range of resources offered by the coastal zone.

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APPENDICES

Appendices 1 and 2 are included within the main text. Other appendices are placed on the accompanying CD. These include tables of figures of the laboratory analyses and three specialist reports.

Appendix 1

Habitat preferences of molluscs found in this study

The habitats in which the molluscs found in the present study at Gwithian and Gunwalloe are described, together with the broad categories of preferences with which they are typically associated. It should be remembered that the categories quoted for the terrestrial (open country, shade, catholic, marsh) and freshwater (slum, ditch, moving water, catholic) shells are generalizations which are useful in the analysis of mollusc assemblages. They by no means indicate that the particular mollusc is restricted to that particular habitat, as many species are capable of living in varying habitats, often depending on very local ecological differences.

The main sources which have been consulted to compile the information given are:
Habitat preferences: Boycott (1934, 1936), Cameron (2003), Davies (2008), Ellis (1926b), Evans (1972), Kerney (1979), Taylor (1894–1921).
Occurrence in Holocene in Britain: Evans (1972), Kennard and Woodward (1926), Turk (1984), Turk *et al.* (2001).
Recent occurrence in Cornwall*:* National Biodiversity Network (www.nbn.org.uk) , Turk (1984; 2001). This defines the modern distribution in Cornwall, with records mainly since the middle of the 20th century.

References are only included in the following text when specific points need to be emphasized.

The sizes given for each shell are of the actual specimen photographed by the author. Size is variable in most species, but those used for the illustrations are typical adult shells, generally around the middle of quoted size ranges.

TERRESTRIAL MOLLUSCS

POMATIIDAE

Pomatias elegans (Müller, 1774) – length 14.2mm

Shade
An operculate mollusc living in scrub, woods, sand hills, etc, always on highly calcareous soil (Ellis 1951). A strongly calicphile shell, not found in marshes. It prefers loose, broken, ground into which it can burrow, although also found in arable land. Archaeologically it is a useful marker for disturbed ground such as forest clearance, showing marked increase in clearance horizons when other woodland species decrease (Evans 1972, 134).
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: very restricted, being found only in a few dunes west of Newquay on the north coast.

CARYCHIIDAE

Carychium minimum Müller, 1774 – length 2.1mm

Shade
Mainly a species occurring in leaf litter or at the roots of grass in damp habitats such as marshes or damp woods, but occasionally found on drier ground. In archaeological literature it was only adequately segregated from *C. tridentatum* in 1925, so early records may refer to both species.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: scattered occurrence, but often overlooked due to its small size, and easily confused with *C. tridentatum*.

Carychium tridentatum (Risso, 1826) – length 2.1mm

Shade (but may be found in open country)
Prefers drier, shadier, areas than *C. minimum*, being found mainly in leaf litter; however, its very small size may allow it to live in more open ground where there is a microhabitat of shade at the base of open country vegetation.

Recent occurrence in Cornwall: rather more frequently documented in Cornwall than *C. minimum*, but still with only scattered records.

SUCCINEIDAE

Oxyloma elegans (Risso 1826) – length 14mm

Succinea putris (Linnaeus, 1758) – length 16mm

Marsh

A family of molluscs that live on wet ground vegetation. The two species named above are very difficult to distinguish from fragments and are recorded in this study as 'Succineidae'. Both live on wet, rank, grassland such as marshes or fens, or on the banks of streams and ditches. *O. elegans* tends to prefer damper habitats than *S. putris*.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: O. elegans is widespread in Cornwall, mainly in coastal locations and along river valleys; *S. putris* is recorded in very few sites but may be under-recorded as the genitalia need dissection for reliable identification.

COCHLICOPIDAE

Cochlicopa lubrica (Müller, 1774) – length 6.0mm

Catholic

A species tolerant of a wide variety of habitats, from grassland to woods, but rarely found in very dry areas such as dunes. Generally in slightly damper areas than the very similar *C. lubricella*, with which it may be confused. It is a very common shell in flood debris.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

Cochlicopa lubricella (Rossmässler, 1834) – length 2.1mm

Catholic

On somewhat drier and more exposed ground than *C. lubrica*, but also found in shaded or damp woodland.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: limited to coastal areas, especially around the Newquay area.

VERTIGINIDAE

Vertigo antivertigo (Draparnaud, 1801) – length 2.1mm

Marsh

A wet ground species, common in well-vegetated fens and in the marshy ground beside rivers, canals, ditches and lakes, mainly on the stems of sedges, grasses, flags and other marsh plants, as well as under stones and logs. It may be found in flood debris or on dead sedge leaves.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: sparsely distributed, although probably under-recorded.

Vertigo pygmaea (Draparnaud, 1801) – length 2.1mm

Open country

Very common in open country calcareous habitats, preferring dry ground, thriving in short-turved grazed grassland, although occasionally found in wetter open areas such as marshes. It is a good marker for more stable habitats with complete vegetation cover (Evans 1972, 143), but is also on barer blown sand. It is extremely rare in woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: recorded at only a very few sites, but it certainly under-recorded.

PUPILLIDAE

Pupilla muscorum (Linnaeus, 1758) – 3.0mm

Open country

A widespread species characteristic of dry grassland, walls and dunes. It is very rare in woodland. It generally avoids areas of intensive cultivation, but is often found in patches of broken ground such as areas grazed by sheep or round rabbit burrows. It is often one of the first molluscs to colonize newly stable ground. It is especially common in sand dunes, being a calcicole and xerophile.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: it is currently recorded only in a very few sites in Cornwall, limited to the north coast; as with other species it may be under-recorded.

LAURIIDAE

Lauria cylindracea (da Costa, 1778) – length 3.5mm

Shade

Lives in dry, shady, places such as under rocks and logs, and in crevices in stone walls where it may be extraordinarily abundant (Boycott 1934, 24) and may therefore be a pointer to the presence of walls in the vicinity. It may also be found on grassland or unstable sand dunes (Evans 2004). It is susceptible to winter cold.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: abundant and widespread.

VALLONIIDAE

Acanthinula aculeata ((Müller, 1774) – width 2.1mm

Shade

A woodland species, mainly rupestral, found on the underside of logs and in leaf litter, although occasionally in more open habitats.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread but not common.

Vallonia excentrica Sterki, 1893 – width 2.4mm

Open country

A species characteristic of open grassland of all types, especially dunes, but with a more stable non-arable habitat than often seen with *Pupilla muscorum* and therefore less common on newly created open habitats. It is particularly associated with short grazed grassland (Chappel *et al.* 1971; Evans and Evans 1995) and a shift in dominance from *P. muscorum* to *V. excentrica* can suggest a move to more intensive grazing. It prefers slightly wetter habitats than *V. costata*, but not as wet as *V. pulchella*. It is virtually unknown in woods, but can rarely be found in marshy ground (Evans 1972, 162).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: in scattered coastal areas, especially dunes in the north coast. Old literature recording subfossil *V. pulchella* probably all refer to this species (Turk 1984: 268).

PUNCTIDAE

Punctum pygmaeum (Draparnaud, 1801) – width 1.7mm

<u>Usually shade</u>
Lives in a wide range of habitats, including woods and hedgerows, marshes and in dryer situations. It is generally classed as a shade species, although it may be found with more catholic species on open dry ground, including chalk grassland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread but sparse, and probably under-recorded, perhaps due to its minute size.

DISCIDAE

Discus rotundatus (Müller, 1774) – width 6.3mm

<u>Shade</u>
A woodland species, living in leaf litter and on the underside of dead logs and stones. It has a narrower habitat range than *Punctum pygmaeum*, but is rare in marshes or open, dry, downland (Evans 1972, 185).
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: very widespread and common.

VITRINIDAE

Vitrina pellucida (Müller, 1774) – width 5.0mm

<u>Catholic</u>
A species found in a wide variety of conditions, from woods, marshes and other damp places to drier habitats such as sand dunes, scree slopes and short-turved grassland. Although a facultative xerophile it is not found in the driest of habitats (Evans 1972, 295). Its fragility means that it is easily broken and may be under-represented in archaeological material.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: common and widespread.

PRISTILOMATIDAE

Vitrea contracta (Westerlund, 1871) – width 2.0mm

Shade

This shell lives in a wide variety of habitats, but generally in drier, more eutrophic conditions than *V. crystallina*, although the two species are often found together. It is characteristic in limstone scree or on collapsed walls (Evans 1972, 187).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

Vitrea crystallina (Müller, 1774) – width 3.0mm

Shade

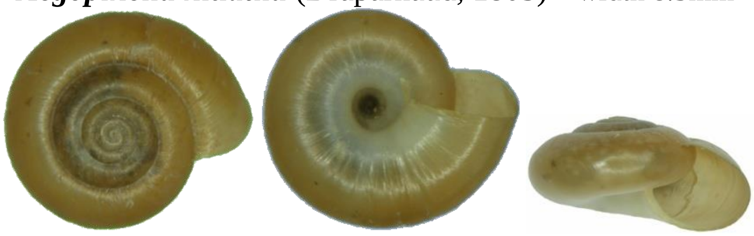
In a wide variety of habitats, but generally in moister conditions such as damp grassland, hedgerows, marshes and woods. It is typical of moist sheltered places, but can be more catholic in its requirements.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

OXYCHILIDAE

Aegopinella nitidula (Draparnaud, 1805) – width 8.3mm



Shade

Found in a variety of habitats wherever there is shade and shelter. It does not require full shade, being often found in the limited shade found at the bases tall unkempt grassland vegetation (Evans 1972, 190).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common, both coastal and inland.

Aegopinella pura (Alder, 1830) – width 4.1mm

Shade
A woodland species but also found in well-vegetated damp places such as fens and rank grassland. It is common amongst moss and in leaf litter.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread although not common.

Nesovitrea hammonis (Ström, 1765) width 3.8mm

Catholic
A mollusc able to live in a wide variety of habitats ranging from wet grassland and meadows to hedgerows and dry grassland, but is not common. It is one of the few British species able to tolerate more acidic conditions such as pine woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence Cornwall: widespread but not common.

Oxychilus alliarius ((Miller, 1822) width 7.3mm

Shade
A woodland species which readily colonizes grassland that has become rank; it is also found in shady cliff areas and is known on sand dunes. It is tolerant of acid conditions.
Occurence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common, both coastal and inland.

Oxychilus cellarius ((Müller, 1774) width 8.5mm

Shade
A very common woodland species found in leaf litter and under logs, but also in tall grassland, in stone wall debris, scree, cave deposits, tombs, etc. It may occasionally be found on bare open grassland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: common and widespread.

GASTRODONTIDAE

Zonitoides nitidus (Müller, 1774) – width 6.8mm

Marsh

A wet-ground species living in marshes, fens, wet woodland and similar habitats, especially among aquatic grasses. It is moderately amphibious, tolerating complete submersion for long periods and therefore able to survive flooding.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and fairly common.

LIMACIDAE

length 7.6mm

Catholic

These slugs have a small internal shell plate, and it is usually very difficult to differentiate species. The species with larger plates (which are more frequently found in archaeological material) generally live in woodland, while those with smaller plates have much more varied ecological preferences. They are of little value in environmental interpretation.

Recent occurrence in Cornwall: widespread.

MILACIDAE

length 2.1mm

Catholic

As with the Limacidae, it is not easy to determine species from the slug plate alone. The Milacidae are more synanthropic, being common in gardens and cultivated land.

Recent occurrence in Cornwall: widespread.

EUCONULIDAE

Euconulus alderi (Gray, 1840) – width 2.5mm

Marsh

A wet-ground species typical of marshes and boggy woodland.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very rarely recorded, with only three authentic records; differentiation from the very similar *E. fulvus* is difficult, although the latter is also rare in Cornwall; there has undoubtedly been some confusion between species in the past.

FERUSSACIIDAE

Cecilioides acicula (Müller, 1774) – length 4.9mm

Burrowing

A subterranean species which can burrow up to 2m beneath ground surface among plant roots or in rock crevices, mostly on calcareous soils (Boycott 1934, 31). It is therefore of little use in palaeoenvironmental interpretation as it is not possible to determine its stratigraphic horizons with any reliability; it is therefore normally excluded from habitat analyses. It is common in recently cultivated land and often absent from longstanding grassland (Evans 1972, 168), so can be an indicator of cultivation.

Occurrence in Holocene in Britain: uncertain, but probably a recent introduction.

Recent occurrence in Cornwall: very rare, there only being three records, one of which is on Godrevy Towans.

CLAUSILIIDAE

Balea heydeni von Maltzen, 1881 – length 4.0mm

Shade

A mollusc only recently recognized in Britain as separate from *Balea perversa* (Cameron 2007). A species of well-shaded moist woodland; in leaf litter, among nettles and may be found in walls. This is a synanthropic species and is geophobic, rarely being found on the ground.

Occurrence in Holocene in Britain: unknown, due to the confusion with *B. perversa*, which is a native species.

Recent occurrence in Cornwall: widespread.

Clausilia bidentata (Ström, 1765) – length 10mm

<u>Shade</u>
A very common species found in woodland, in hedges, on rocks and walls. In wet conditions it often climbs vertical surfaces such as tree trunks or walls.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: very common and widespread.

COCHLICELLIDAE

Cochlicella acuta (Müller, 1774) – length 12mm

<u>Open country</u>
A very common xerophilic species in bare and vegetated sand dunes and other dry habitats, and mainly restricted to coastal areas. It is a calcicole shell and is frost sensitive, so is less common in areas subject to cold winter episodes.
Occurrence in Holocene in Britain: probably a late prehistoric introduction.
Recent occurrence in Cornwall: very abundant in sand dune areas all round the county.

HYGROMIIDAE

Ashfordia granulata (Alder, 1830) – width 6.8mm

<u>Catholic</u>
A common species in damp shady areas, in woods and river banks, but may also occur in dryer hedgerows and similar habitats. In western Britain it may also be found on sand dunes and in cliffs, being more of a xerophile than elsewhere in southern or eastern England. Although generally classified as a shade species, in Cornwall it is often regarded as a catholic species.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common, especially at the base of dune vegetation.

Candidula intersecta (Poiret, 1801) – width 9.2mm

<u>Open country</u>
A xerophile and calcicole species common on dry, open sites, especially dunes and grassland.
Occurrence in Holocene in Britain: probably a medieval introduction; archaeological records suggesting an earlier date are considered unreliable.
Recent occurrence in Cornwall: abundant in dune areas all round the county, with some inland records.

Cernuella virgata (da Costa, 1778) – width 11.8mm

<u>Open country</u>
An obligatory calcicole. Another xerophilic species of vegetated dunes, grassland, hedges, quarries, sea cliffs and cultivated fields. Although tolerant of heat, in prolonged dry, hot weather it shelters by burying itself among the roots of plants.
Occurrence in Holocene in Britain: probably introduced during the Romano-British period.
Recent occurrence in Cornwall: abundant and widespread in coastal areas, especially in dunes.

Helicella itala (Linnaeus, 1758) – width 18mm

<u>Open country</u>
A dry grassland species, especially where the grass has been kept short by grazing. Although occurrences in ploughed fields are reported it tends to avoid pasture and arable habitats, preferring wilder habitats away from the man's influence. It is never found in shade, being an obligatory heliophile. The young are more resistant to drought than adults.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: restricted almost entirely to areas of blown sand and dunes along the north coast.

Ponentina subvirescens (Bellamy, 1839 – width 6.3mm

Open country

A xerophile mollusc living on coastal calcareous grassy slopes, often by cliffs, but occasionally found inland on well-drained non-calcareous soils (Turk *et al*. 2001, 107).
Occurrence in Holocene in Britain: uncertain appearance in Britain, and may not have been introduced until the Iron Age.
Recent occurrence in Cornwall: widespread around the coast of Cornwall, with a few inland reports from Bodmin Moor.

Xerocrassa geyeri (Soós, 1926) – width 9.0mm

Open country

A xerophile shell of very open dry areas (Kerney 1963).
Occurrence in Holocene in Britain: a late glacial relict, now extinct throughout Britain but common in the Pleistocene on the chalk of southern England. In most of Britain it became extinct in the early Holocene but survived locally at Gwithian, Cornwall, until the early Bronze Age.
Recent occurrence in Cornwall: extinct, recorded only from Gwithian.

Trochulus hispidus (C. Pfeiffer, 1828) – wdith 9.0mm

Catholic

A calcicole species with a wide variety of habitat preferences, but different subspecies or varieties may have different tolerances. It is found in both shaded and open environments, in moist or dry areas as well as in marshes, but tending to avoid the very driest places, although it has been recorded on sand dunes.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common.

Trochulus striolatus (Linnaeus, 1758) – wdith 13.8mm

<u>Catholic</u>
A synanthropic mollusc of cultivated habitats and waste ground, often in damp, shady places. It is common in arable land and semi-natural woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread, but scarce on the granite uplands.

HELICIDAE

Cepaea nemoralis (Linnaeus, 1758) – width 21mm

<u>Catholic</u>
Found in a wide variety of habitats, from open dunes to damp woodland, but normally in drier and warmer environments than *C. hortensis*, although the two species are often found in the same locality. It is often not possible to separate the species if only small apical fragments are present.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: very widespread and common.

Cornu aspersum (Müller, 1774) – width 35mm

<u>Catholic</u>
A synanthropic species occurring in gardens, hedgerows and waste ground, but also in more open places.
Occurrence in Holocene in Britain: probably a Roman introduction.
Recent occurrence in Cornwall: very widespread and abundant. In Cornwall it is a common dune species, often in association with *Cochlicella acuta* and *Cernuella virgata*.

Theba pisana (Müller, 1774) – width 21mm

<u>Open country</u>
A xerophile living in dry exposed places frequently on coastal dunes. It is a capable of colonizing suitable new areas very rapidly. The shell may be found in vast numbers from suitable habitats but be absent in apparently similar habitats nearby
Occurrence in Holocene in Britain: a probable eighteenth century introduction, with no reliable sub-fossil records.

Recent occurrence in Cornwall: recent rapid spread from its possible introduction area at St Ives, it is now common in many coastal areas of Cornwall, although mainly on the north coast.

FRESHWATER MOLLUSCS

VALVATIDAE

Valvata cristata (Müller, 1774) – width 2.8mm

Ditch

A mollusc living in well-oxygenated still or flowing water. It is found in places with a muddy substrate, often on emergent vegetation at the margins of ponds, lakes and drainage ditches, as well as clean backwaters.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: extremely rare, being only recorded from the Bude Canal on two occasions.

HYDROBIIDAE

Peringia ulvae (Pennant, 1777) – length 6.8mm

Brackish water

A species found on estuarine mudflats and salt marshes, ofen in vast numbers. The animal is very resistant to dehydration and to variations in salinity.

Occurence in Holocene in Britain: native.

Recent occurance in Cornwall: retricted mainly to south coast estuaries, although also found in isolated brackish water areas on the north coast.

Potamopyrgus antipodarum (Gray, 1843) – length 4.4mm

Ditch

A ubiquitous species found in all types of flowing water and rare in still water; it is tolerant of mild pollution. Although originally a brackish water species it has adapted to freshwater and colonized rivers and streams throughout the British Isles.

Occurrence in Holocene in Britain: introduced into Britain probably in the mid 19th century.

Recent occurrence in Cornwall: very common throughout the county, despite being first found in Cornwall as recently as 1943.

LYMNAEIDAE

Galba truncatula (Müller, 1774) – length 4.3mm

Marsh

An amphibious species living out of water, but near the edges of water rather than immersed. It is found in poor freshwater habitats as well as wet grassland areas such as marshes, streams, ditches, dune slacks and in deep grass of fields.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread in appropriate habitats.

Lymnaea fuscsa (C. Pfeiffer, 1821) – length 20mm
Lymnaea palustris (Müller, 1774) – length 18mm

Catholic

It is not possible to distinguish these two species reliably from the shells alone, dissection of the reproductive organs being necessary. Both live in stagnant or slowly flowing water with plentiful vegetation such as swamps and blocked ditches. They are resistant to moderate degrees of drying in summer.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: difficulties in species differentiation makes records unreliable, but neither is common in Cornwall.

Radix balthica (Linnaeus, 1758) – length 16mm

Catholic

A ubiquitous species found in all freshwater habitats, in both hard and soft water areas. It may crawl out onto dry land. In the event of drying it will bury itself in mud or hide under stones, weeds or debris until wetter conditions return.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common.

PHYSIDAE

Physella acuta (Draparnaud, 1805) – length 9.4mm

Slum

A sinistral shell capable of living in almost all freshwater habitats: rivers, streams, lakes, ponds and swamps.

Occurrence in Holocene in Britain: a recent introduction, being first observed in Kew Gardens in 1830.

Recent occurrence in Cornwall: a few scattered records only.

PLANORBIDAE

Anisus leucostoma (Millet, 1813) – width 7.4mm

Catholic

An amphibious species found in all types of habitat, but especially in swampy pools and ditches. It prefers sites susceptible to summer drying and is therefore typical of marshes and ditches which hold water in winter but become dry in summer.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common.

Gyraulus albus (Müller, 1774) – width 5.4mm

Catholic

Able to live in all habitats from stagnant to flowing water, but not tolerant of summer drying.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: a few records only scattered throughout the county.

Gyraulus crista (Linnaeus, 1758) – width 3.1mm

Catholic
Found in most types of freshwater habitats on leaves of water plants. It cannot live in areas prone to drying.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread.

Gyraulus laevis (Alder, 1838) – width 4.8mm

Catholic
A mollusc of clean, quiet waters such as lakes and ponds, gravel pits, quarries, reservoirs, ornamental lakes. It is rare in canalized rivers or drainage dykes.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: rare, being reliably recorded only from only five sites in the county.

Ancylus fluviatilis Müller, 1774 – length 7.4mm

Moving water
A freshwater limpet living in clean, flowing, water, avoiding muddy substrates. It cannot withstand drying. It is attaches itself to stones where it feeds on algae.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread throughout the county.

SPHAERIDAE

Pisidium milium Held, 1836 – length 3.4mm

Catholic

Associated with quiet waters not prone to drying; in rivers, lakes and marsh drains, but tends to avoid swamps.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: uncommon, with a few scattered records.

Pisidium nitidum Jenyns, 1832 – length 3.2mm

Catholic

A bivalve living in clean unpolluted bottom sediments in still or flowing water, but which are not prone to drying or low oxygen levels; it avoids swampy areas.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: scattered records only.

Pisidium personatum Malm, 1855 – length 3.0mm

Slum

A species of very poor habitats such as stagnant and temporary ponds, drying ditches and other poor quality wet-ground habitats and capable of surviving in areas subject to summer drying.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common.

Pisidium subtruncatum Malm, 1855 – length 2.8mm

Catholic

Ubiquitous in streams, lakes and ponds, especially those with still clean water; it is rare in larger rivers but is able to live in flowing marsh drains.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: scattered records only, but locally abundant in some pools.

<u>Appendix 2</u>

Gazetteer of coastal dunes sites in the British Isles with mollusc analyses

The majority of reports which discuss the role of molluscs in environmental reconstruction on archaeological sites have been concerned with chalk downlands. Many of these have been summarised in *Land and people; papers in memory of John G. Evans* (Allen *et al.* 2009) and will not be detailed here.

Studies examining molluscs in coastal dunes are less frequent, and concentrate mainly on the Scottish Islands (Outer Hebrides and Orkney) and the south west of England (principally Cornwall). The sites are shown on a map of the British Isles in Figure Ax 2.1 and in tabular form in Table Ax 2.1. These include all those associated with known archaeology, as well as several where there is no archaeology but analyses have included buried soils.

A review of coastal blown sand deposits which included mollusc analyses up to 1979 was provided by Evans (1979) and included comments on several surveys unpublished up that date. The sites in his list are only included in the following table and descriptions when there are no other earlier or later published or grey literature reports, and his brief comments are all that is available concerning the relevant site.

The following gazetteer only discusses those dune sites where mollusc studies have been undertaken. The order of sites commences in south Devon and follows the coast of Britain in a clockwise direction to Fife in Scotland, followed by Ireland.

Figure Ax 2.1. Map showing coastal sand dunes in the British Isles.
Sites where mollusc analyses have been performed are named

Table Ax 2.1. Sand dunes sites with mollusc analyses and the publications detailing those analyses.

	ENGLAND														WALES				SCOTLAND																					IRELAND			
	Bantham, Devon	Gunwalloe, Cornwall	Samson, Scilly Isles	Gwithian, Cornwall	Perranporth, Cornwall	Trethellan Farm, Newquay, Cornwall	Atlantic Road, Newquay, Cornwall	Towan Head, Newquay, Cornwall	Constantine Bay, Cornwall	Harlyn Bay, Cornwall	Daymer Bay, Cornwall	Widemouth Bay, Cornwall	Braunton Burrows, Devon	Brean Down, Somerset	Freshwater East, Pembrokeshire	Stackpole Warren, Pembrokeshire	Brownslade, Castlemartin, Pembs	Freshwater West, Pembrokeshire	Ardnave, Islay	Oronsay, Argyll	Allasdale, Barra	South Glendale, South Uist	Sligeanach, South Uist	Hornish Point, South Uist	Borve, Benbecula	Rosinish, Benbecula	Udal, North Uist	Baleshare, North Uist	Baleone, North Uist	Newtonferry, North Uist	Ensay, off Harris	Northton, Harris	Horgabost, Harris	Bay of Skaill & Skara Brae, Orkney	Buckquoy & Birsay, Orkney	Knap of Howar, Orkney	Tofts Ness, Orkney	Freswick Links, Caithness	Morton, Fife	Doughmore, Co. Clare	Lehinch, Co. Mayo	Leach Air Iorrais, Co. Clare	Gorteen Bay, Co. Galway
Kennard & Woodward (1901)												x																															
Bullen (1902a)										x																																	
Bullen (1902b)									x	x																																	
Kennard & Warren (1903)								x																																			
Woodward (1908)								x																																			
Bullen (1909)					x																																						
Bullen(1912)									x	x																																	
Arkell (1943)											x																																
Lewis (1968)				x																																							
Evans (1971b)																										x						x											
Evans (1972)																																x											
Spencer (1974)				x	x			x	x	x	x			x													x				x			x	x	x							
Spencer (1975)				x	x			x																										x		x							
Vaughan (1976)														x				x								x										x				x	x	x	x
Evans & Spencer (1976–7)																																			x								
Whimster (1977)										x																																	
Evans (1979)			x																						x																		
Evans (1983a)																																							x				
Evans (1983b)																				x																							
Evans & Vaughan (1983)																																				x							
Smith *et al.* (1983)													x																														
Bell (1986)	x																																										
Peters (1986)		x																																									
Paul (1987)																				x																							
Peters (1987)		x																																									

Table Ax 2.1 continued.

	ENGLAND														WALES				SCOTLAND																					IRELAND			
	Bantham, Devon	Gunwalloe, Cornwall	Samson, Scilly Isles`	Gwithian, Cornwall	Perranporth, Cornwall	Trethellan Farm, Newquay, Cornwall	Atlantic Road, Newquay, Cornwall	Towan Head, Newquay, Cornwall	Constantine Bay, Cornwall	Harlyn Bay, Cornwall	Daymer Bay, Cornwall	Widemouth Bay, Cornwall	Braunton Burrows, Devon	Brean Down, Somerset	Freshwater East, Pembrokeshire	Stackpole Warren, Pembrokeshire	Brownslade, Castlemartin, Pembs	Freshwater West, Pembrokeshire	Ardnave, Islay	Oronsay, Argyll	Allasdale, Barra	South Glendale, South Uist	Sligeanach, South Uist	Hornish Point, South Uist	Borve, Benbecula	Rosinish, Benbecula	Udal, North Uist	Baleshare, North Uist	Baleone, North Uist	Newtonferry, North Uist	Ensay, off Harris	Northton, Harris	Horgabost, Harris	Bay of Skaill & Skara Brae, Orkney	Buckquoy & Birsay, Orkney	Knap of Howar, Orkney	Tofts Ness, Orkney	Freswick Links, Caithness	Morton, Fife	Doughmore, Co. Clare	Lehinch, Co. Mayo	Leach Air Iorrais, Co. Mayo	Gorteen Bay, Co. Galway
Rackham *et al*. (1989)																																			x								
Bell & Johnson (1990)														x																													
Evans & Hyde (1990)																x																											
Milles (1991a)					x																																						
Milles (1991b)				x				x			x																										x						
O’Connor (1992)																																						x					
Milles (1994)																																					x						
Davies (1998)	x																																										
Leinert *et al*. (2000)																																		x									
Thew (2003)																						x		x				x	x	x													
Evans (2004)																							x								x												
Davies (2007)				x																																							
Milles (2007)																																					x						
Boardman (2008)									x																																		
Davies (2008)							x																																				
Walker (2008)														x																													
Wessex Archaeology (2008)																					x																						
Walker (2009–10)									x																																		
Walker (2010)				x																																							
Bell & Brown (2011)																	x																										
Walker (2011)															x																												
Evans *et al*. (2012)																							x																				
Law & Thew (2012)																																	x										
Davies (forthcoming)							x																																				

England

The use of molluscs in palaeoenvironmental investigation of sand dunes in England has been limited to the south west, with several sites in Cornwall, two in Devon and one in Somerset being reported.

Bantham, Devon

A late prehistoric and Romano-British occupation site on the west coast of south Devon. A few shells were recovered during a rescue excavation close to the coast from a hearth-type feature on the surface of a pit, with two radiocarbon dates from its base. Burnt shells were recovered from the fill and included *Helicella itala* (1), *Vallonia excentrica* (1) and *Cochlicella acuta* (5) (Bell 1986). One *C. acuta* apex was burnt, with its hearth context providing clear evidence of the presence of this species in Britain by about AD 350.

Excavation about 200m inland from the above work revealed a second century AD enclosure (Griffith and Reed 1998). Mollusc analysis of a sample from a shell midden showed mainly open country molluscs with some species associated with shade from a nearby stone revetted rampart (Davies 1998).

Gunwalloe, Cornwall

An early medieval settlement with evidence of Bronze Age activity, described more fully with new investigations in Chapter 10. Molluscs were obtained from cores and two small test pits in 1986 and 1987, but additional excavation was performed (Peters 1986, 1987). Well vegetated dunes were present during the Bronze Age with evidence of ploughing, with accumulation of sand later leading to abandonment of the medieval site. Marsh in the adjacent valley is shown to be longstanding. There was no scientific dating.

Samson, Scilly Isles (Evans 1979)

A buried soil in blown sand of unknown age (probably recent) with some *Cornu aspersum* but mainly *Cernuella virgata* and *Cochlicella acuta*. It is not stated whether this assemblage relates to any archaeology.

Gwithian, Cornwall

A multiperiod site with archaeology from the Mesolithic to the late medieval period. Extensive excavations have been conducted on Bronze Age and post-Roman settlements as well as a medieval manor house. Mollusc studies have been described from both of the settlements (Spencer 1974, 1975; Milles 1991b; Davies 2007), the valley meadow (Lewis 1968) and Godrevy Towans to the west of the settlement area (see Section 3.6 and Walker 2010). The molluscs show alternating horizons of stabilization (with plough soils) and rapid sand accumulation. Shaded areas were probably present in the valley floor before the Bronze Age. Twenty radiocarbon and two OSL dates are reported from the excavation site (Hamilton *et al.* 2008). Further work from this location forms the major part of this thesis, and is discussed in Chapters 5 to 9.

Perranporth, Cornwall

Bullen (1909) found marsh and open country species in the area of the medieval church of St. Piran. Spencer (1974, 1975) reported on the molluscs in a cliff section 1km west of the church, but not related to known archaeology; she found open country fauna in a basal buried soil with overlying blown sand, with a phase of damper conditions shown by the presence of *Discus rotundatus*, *Ashfordia granulata* and several Zonitidae. The open country species were mainly *Vallonia excentrica* and *Pupilla muscorum*; *Helicella itala* and *Cochlicella acuta* were totally absent. The known presence of human activity from the Mesolithic (Harding 1950) led Spencer to speculate that man may have been responsible for early deforestation. There is no scientific dating associated with the mollusc analyses.

Trethellan Farm, Newquay, Cornwall

A middle Bronze Age settlement on sloping ground above the River Gannel. Although this settlement is not itself on blown sand, it is included here as it was buried largely by recent colluvial sand from dunes above Fistral Bay. Mollusc analyses were mainly from the overlying colluvium with some from the hut floors (Milles 1991a). A limited numbers of shells were found, almost entirely open country taxa; *Cernuella virgata* and *Candidula intersecta* were present, probably from more recent blown sands, suggesting that all the molluscs are more recent than the settlement. Fifteen radiocarbon dates are reported from the settlement (Nowakowski 1991) but none are related to the mollusc analyses.

Atlantic Road, Newquay, Cornwall

A Romano-British settlement, excavated in 1998, with a mollusc column incorporating two occupation horizons separated and covered by blown sand (Davies 2008). There was progression from bare to well-vegetated to open country conditions with dune erosion. The succession sequence of *Helicella* followed by *Cochlicella* then *Cernuella* supports accepted theories of the introduction of these species to Britain. Eleven radiocarbon dates from bone and charcoal (Marshall, forthcoming).

Towan Head, Newquay, Cornwall

Several mollusc analyses from buried soils and overlying blown sand within a Holocene sand cliff have been reported (Kennard and Warren 1903; Woodward 1908; Spencer 1974, 1975; Milles 1991b) but none are related to archaeology in the immediate area. The basal layers show a shaded environment with light wood or scrub containing *Pomatias elegans*, but which gives way to an open country molluscan fauna as blown sand accumulates. *Helicella itala* and *Cochlicella acuta* were absent from the basal buried soil, but then appear in succession. The base soil may predate woodland clearance. No radiocarbon dates are associated with these analyses. A new mollusc column is reported in Section 3.5.

Constantine Bay, Cornwall

Constantine Island is a small rocky outcrop and an island only at high tide. A prehistoric hut base, of uncertain date, was originally thought to be Neolithic (Bullen 1902a). There is a burial mound radiocarbon dated to the middle Bronze Age (Jones 2009–10). The molluscs from a column in the burial mound show a non-calcareous base and blown sand above, the latter with restricted fauna (six species) of open country and catholic species in the upper sand; *Ponentina subvirescens* was present but no *Cochlicella acuta* and *Helicella itala*, consistent with the dating (Walker 2009–10). A new mollusc column from the island is reported in Section 3.4.

On the adjacent mainland mollusc columns show almost entirely open country species in blown sand with some stabilization horizons (Spencer 1974; Boardman 2008).

Harlyn Bay, Cornwall

Bronze Age artefacts have been found eroding from the cliffs (Jones *et al.* 2011) at Harlyn Bay, and there is an Iron Age cemetery site a short distance inland. Mollusc studies during excavations of the Iron Age site early in the twentieth century (Bullen 1902a; Bullen 1902b; Bullen 1912) and in 1976 (Whimster 1977) found large numbers of *Pomatias elegans*, a shade species associated with disturbed woodland, as well as other shade species such as *Discus rotundatus*, but also with a mixture of open country and catholic taxa. Bullen reported *Cornu aspersum* which was almost certainly intrusive into the prehistoric levels. A mollusc column from the cliff, remote from the archaeological site (Spencer 1974) showed open country fauna throughout. Two new mollusc studies from the cliffs are reported in Section 3.3.

Daymer Bay, Cornwall

Extensive Mesolithic flint scatters have been found in the area (Johnson and David 1982) but no other archaeology has been reported from the low cliffs and raised beach north of the main bay. Several mollusc columns (Arkell 1943; Spencer 1974; Milles 1991b), show that there was early woodland on the shores of the estuary, with large numbers of *Pomatias elegans*, *Discus rotundatus* and *Clausilia bidentata*, although this gave way to an open country fauna with some episodes of stabilization. A new bulk sample report is given in Section 3.2.

Widemouth Bay, Cornwall

A few open country shells have been reported near a 'surface with Neolithic flakes' (Kennard and Woodward 1901), but there is no further information. A new mollusc column is reported in Section 3.1.

Braunton Burrows, Devon

A series of auger samples from a medieval shell midden in the dunes of Braunton Burrows included open country molluscs from two organic rich horizons, but in insufficient quantities to assess any environmental difference from the open dunes in the area at the present time (Smith *et al.* 1983).

Brean Down, Somerset

A Bronze Age settlement in the dunes has been extensively excavated, with evidence of earlier Neolithic presence (flints) and with early medieval graves and a post-medieval building (Bell 1990). Five mollusc columns forming continuous stratigraphic sequences were obtained from the settlement and from a test pit (Spencer 1974; Vaughan 1976; Bell and Johnson 1990; Walker 2008). During the Neolithic there was mainly open country with some shade/woodland which had disappeared by the late Bronze Age, the landscape becoming progressively more open up to the sixteenth/seventeenth centuries AD. The presence of brackish water species during the middle Bronze Age indicates the presence of estuarine mud flats. The succession of introductions of *Helicella itala*, *Cochlicella acuta*, *Cernuella virgata* and *Candidula intersecta* is generally supported, although the finding of *C. virgata* and *Cornu aspersum* in Bronze Age levels makes some degree of bioturbation likely. Twenty one radiocarbon dates from bone, peat and charcoal (Bell 1990, 107) were obtained and were correlated with the mollusc columns. To date this is probably the best dated dune sequence in Britain but the need to redate this site using improved techniques has recently been highlighted (Bell 2013a).

Wales

There have been very few reports involving molluscs at archaeological sites associated with Welsh sand dunes, with Pembrokeshire being the only county represented.

Freshwater East, Pembrokeshire

An early medieval chapel and cemetery. Samples from a mollusc column in one of the trenches showed that the basal layers were devoid of shells; during the early medieval period the area was open country with grazed grassland, with no evidence of woodland or rank vegetation (Walker 2011). Twelve radiocarbon dates (Schlee 2009), including two from the trench with the mollusc analysis, one from the burial, and one from the shell-free basal layer of sand

Stackpole Warren, Pembrokeshire

A settlement with probable continuous occupation from the Beaker to early Roman periods, with many buildings and a field system. Multiple mollusc analyses were from field systems at several sites (Evans and Hyde 1990). There was a high diversity of species in lower more stable sands with lower diversity assemblages in higher unstable sands. Woodland clearance in the Bronze Age evolved to open country by the Roman period. Some cultivation was evident, but the land reverted to grassland after cultivation. Eleven radiocarbon dates, only one of which was in the area of one of the mollusc analyses (Benson *et al.* 1990). These show three episodes of sand blow in the late Bronze Age, mid/late Iron Age and medieval period.

Brownslade, Castlemartin, Pembrokeshire

An early medieval cemetery associated with a possible Bronze Age barrow. Mollusc analysis from two columns showed a basal non-calcareous cultivated soil overlain by a probably mobile dune system containing the medieval burials. The dunes later became stabilized with dry grazed grassland (Bell and Brown 2011). Twelve radiocarbon dates (Groom *et al.* 2011), close to, but not directly associated with, the mollusc columns.

Freshwater West, Pembrokeshire

A 1.30m cliff section not containing archaeology but in an area where flint scatters have been found. There was slow but constant sand accumulation with two stabilization layers. Molluscs were almost entirely open country species, with *Helicella itala* being found in the lowest levels, followed in sequence by *Cochlicella acuta* and *Cernuella virgata*, with *Candidula intersecta* only in the modern turf (Vaughan 1976). No dating.

Scotland

Dunes in Scotland are found principally on the western and northern islands, and molluscs have featured regularly in environmental studies, particularly in the Outer Hebrides and in the Orkney Islands. Only two mainland sites with mollusc analyses are reported.

Ardnave, Islay

An early Bronze Age house and a late Iron Age hearth with intervening blown sand. The mollusc analysis (Evans 1983b) was incomplete as a 2mm sieve was used, but the land shells do show an initial totally vegetated land surface during the early period of occupation with tall plants and grasses. Ten radiocarbon dates on charcoal and bone, one from same house as the mollusc study (Ritchie and Welfare 1983).

Oronsay, Argyll, Inner Hebrides

Three Mesolithic shell middens from the mid-fourth millennium BC have been excavated (Mellars 1987) with land shell analyses performed from two middens: Caisteal Nan Gillean II and Cnoc Coig (Paul 1987). There were several soil horizons with intervening blown sand layers. Open country with woodland was present in the vicinity during the earlier periods, later reverting to open dunes after abandonment of the middens. 25 radiocarbon dates (Switsur and Mellars 1987), several of which are related to the mollusc analyses. It is of interest that fine shell sand was present prior to accumulation of midden deposits at both sites during the later Mesolithic, somewhat earlier than the postulated initial formation of dunes during the early Neolithic (Evans 1972, 296; Shennan and Horton 2002, 518); this discrepancy has not been explained. *Cochlicella acuta* and *Helicella itala* were only found at one site (Caistel nan Gillean II) and both appeared in the same sand horizon, not showing the normal succession of appearance.

Allasdale, Barra, Outer Hebrides

A settlement site with a possible Neolithic building, early Bronze Age burials and Iron Age roundhouses (Wessex Archaeology 2008). Three radiocarbon dates, one associated with the mollusc analysis. Molluscs were assessed from cist and pit fills, from middens and from the roundhouse floors and generally showed open country species with some shade molluscs associated with the cist fills.

South Gendale, South Uist; Newtonferry, North Uist, Outer Hebrides

A thirteenth/fourteenth century AD byre at South Glendale and a midden at Newtonferry with molluscan faunas showing continuous fixed-dune pasture (Thew 2003). Five radiocarbon dates (Barber 2003).

Sligenach, South Uist, Outer Hebrides

A Beaker period and early Bronze Age settlement. Two mollusc columns showed open country species in interspersed layers of stabilization and blown sand (Evans 2004; Evans *et al.* 2012). *Helicella itala* and *Cochlicella acuta* appear together late in the sequence. Eighteen radiocarbon dates, four of which were directly related to the mollusc columns (Evans *et al.* 2012).

Hornish Point, South Uist; Baleshare and Baleone, North Uist, Outer Hebrides

Late Bronze Age and Iron Age settlements and middens were investigated mainly with coring although with some excavation. Land molluscs and marine shells from middens were analysed from numerous samples (Thew 2003). The terrestrial molluscs were mainly open country species, although marsh taxa were present in some areas, especially in deep contexts (but not the lowest levels), possibly due to human interaction, but probably indicative of intermittent flooding. This is followed by generally stable dune-machair pasture. The appearance of, and interactions between, *Helicella itala* and *Cochlicella acuta* provided relative chronologies consistent with other sites. A total of 46 radiocarbon dates from the three sites, nearly all associated with non-marine mollusc assemblages from middens (Barber 2011).

Borve, Benbecula, Outer Hebrides

An intertidal deposit of peat and wood with interspersed blown sand. One layer contained almost entirely freshwater molluscs (Evans 1979). One early Bronze Age radiocarbon date from the organic layers. No mention of any archaeology.

Rosinish, Benbecula, Outer Hebrides

Molluscs in Beaker and Iron Age middens continuing to early medieval occupation. Molluscs from four sections revealed open country conditions throughout, with several episodes of sand blow interspersed with periods of stabilization, although with rapid accumulation between the Iron Age and early medieval period (Evans 1971b; Vaughan 1976). Two radiocarbon dates, neither associated with the molluscs (Shepherd and Tuckwell 1976–77).

Udal, North Uist, Outer Hebrides

Two mollusc sections from fifteenth century AD and later shell middens with interspersed layers of blown sand, showing a typical open country molluscan fauna and a few shade species (Spencer 1974). Ten radiocarbon dates (Crawford and Switsur 1977), but not related to the mollusc study.

Ensay, off South Harris, Outer Hebrides

A section from a series of Beaker and Bronze Age middens showed a non-calcareous basal soil (Spencer 1974; Evans 2004). Above this early grassland gave way to denser vegetation with some hygrophiles suggesting ponding. A high number of *Lauria cylindracea* associated with large stones in the upper part of the sequence may indicate collapsed buildings or walls. *Cochlicella acuta* and *Helicella itala* are only present in surface layers dating from the Iron Age or later. No scientific dating.

Northton, South Harris, Outer Hebrides

A Neolithic to Iron Age settlement site with multiple occupation horizons interspersed with blown sand. Interpretation of a mollusc section through the deposits was complicated by the effects of deflation and rapid deposition of sand by wind action, with subsequent loss of shells and incorporation of molluscs from a variety of habitats (Evans 1971b; Evans 1972, 293). Shells were absent from the basal layers but, by the later Neolithic, molluscs indicate a woodland environment which is later cleared. Following a period of open country there was a brief period of woodland regeneration during the Bronze Age. This was again cleared with open country conditions persisting through the Iron Age when there was rapid accumulation of sand. *Helicella itala* and *Cochlicella acuta* successively appear only in the later Iron Age. There is relative dune stability in historic times, with little increase in sand depth. Three radiocarbon dates (Simpson 1966; Burleigh *et al.* 1973) confirmed the Neolithic to Beaker chronology, and were linked to the mollusc data.

Horgabost, South Harris, Outer Hebrides

Shells were analysed from two bulk samples from a first century AD settlement within a landscape containing later Iron Age archaeology. Mollusc analysis showed stable grassland with colonization by tall herbs following abandonment of the site (Law and Thew 2012).

Skara Brae and Bay of Skaill, Mainland, Orkney

The Neolithic village of Skara Brae on Mainland in The Orkney Islands showed clear molluscan evidence of original woodland but with a strong open country element (Spencer 1974, 1975; de la Vega-Leinert *et al.* 2000); deforestation occurred prior to significant sand accumulation. On the north side of the Bay of Skaill environmental studies of bore hole sediments showed freshwater ponds in the mid-sixth millennium BC which were then infilled with blown sand with recurrent sand deposition episodes interspersed with ponding. Nine radiocarbon dates from two of the Bay of Skaill cores.

Buckquoy and Birsay Bay, Mainland, Orkney (Spencer 1974; Evans and Spencer 1976–7; Rackham *et al.* 1989)

Bronze Age to Viking settlements, with the molluscs from cliff sections (200m north of the archaeological site) showing initial woodland with subsequent deforestation due to windblown sand and/or human activity. The basal Bonze Age buried soils contain almost entirely woodland/scrub species; this is followed by deforestation and deposition of blown sand. No dating from the area of the mollusc columns.

Knap of Howar, Papa Westray, Orkney

A Neolithic house site with middens. Mollusc analyses were obtained from coastal cliff sections (Spencer 1974, 1975; Vaughan 1976; Evans and Vaughan 1983). The basal buried soil, sealed by the Neolithic site, indicated a woodland environment. This was covered by massive sand accumulation but with periods when small ponds and marsh formed in the area. No helicid shells were found in any of the mollusc columns. Ten radiocarbon dates from animal bones in the house floor deposits and middens and one from organic soil in a test pit (Ritchie 1983).

Tofts Ness, Sanday, Orkney

A Neolithic and Iron Age settlement and landscape. Molluscan analysis of three columns (Milles 1991b, 1994, 2007) provided some evidence for manuring during the Neolithic with areas of damp grassland and some taller vegetation; this landscape was then buried during the Bronze Age by windblown sand before stabilizing during the Iron Age where midden tips showed soil build-up. It is probable that many of the molluscs were allochthonous, brought in with turf as fertilizer or fuel. Twenty six radiocarbon dates (Ambers 2007), but none from the mollusc columns themselves.

Freswick Links, Caithness

A Viking Age settlement with molluscs from nine excavation columns (but many specimens were probably lost as only sieve fractions larger than 1.7mm were examined) (Jones *et al.* 1983; O'Connor 1992). Few shells were recovered, but sufficient to indicate a grassy environment, lush in the lower areas, with dune instability, with only one layer suggesting a stable buried soil. No dating (Morris *et al.* 1992).

Morton, Fife

A Mesolithic shell midden, with molluscs indicating an environment of deep shade, extreme dryness, and a certain amount of fallen timber (Evans 1983a). Eleven radiocarbon dates, but it is unclear how these relate to the mollusc samples.

Ireland

The non-marine Mollusca of numerous Atlantic Coast Irish sites were reported by Kennard and Woodward (1917); these included two crannogs, four middens and 27 old land surfaces. There was little mention of stratigraphy or chronology, and the individual sites are not listed here. Generally the basal layers were devoid of shells, probably due to acidic boulder clay; above this there were clay layers with woodland fauna which were then covered by blown sand.

Doughmore, nr. Doonbeg, Co. Clare; *Lehinich, Co. Clare*; *Leacht Air Iorrais, nr. An Gheata Mor, Co. Mayo*; *Gorteen Bay, Conemara, Co. Galway*

Dune sections were analysed at four sites on the west coast of Ireland (Vaughan 1976). They were not related to archaeology except for Leacht Air Iorrais, where sand overlies a possible Neolithic structure. The molluscs are almost entirely open country taxa in blown sand, although there are some stabilization horizons. At all sites the appearance of *Helicella itala* preceded that of *Cochlicella acuta*; no other introduced helicids were found. No dating.

Appendix 1

Habitat preferences of molluscs found in this study

The habitats in which the molluscs found in the present study at Gwithian and Gunwalloe are described, together with the broad categories of preferences with which they are typically associated. It should be remembered that the categories quoted for the terrestrial (open country, shade, catholic, marsh) and freshwater (slum, ditch, moving water, catholic) shells are generalizations which are useful in the analysis of mollusc assemblages. They by no means indicate that the particular mollusc is restricted to that particular habitat, as many species are capable of living in varying habitats, often depending on very local ecological differences.

The main sources which have been consulted to compile the information given are:
Habitat preferences: Boycott (1934, 1936), Cameron (2003), Davies (2008), Ellis (1926b), Evans (1972), Kerney (1979), Taylor (1894–1921).
Occurrence in Holocene in Britain: Evans (1972), Kennard and Woodward (1926), Turk (1984), Turk *et al.* (2001).
Recent occurrence in Cornwall: National Biodiversity Network (www.nbn.org.uk) , Turk (1984; 2001). This defines the modern distribution in Cornwall, with records mainly since the middle of the 20th century.

References are only included in the following text when specific points need to be emphasized.

The sizes given for each shell are of the actual specimen photographed by the author. Size is variable in most species, but those used for the illustrations are typical adult shells, generally around the middle of quoted size ranges.

TERRESTRIAL MOLLUSCS

POMATIIDAE

Pomatias elegans (Müller, 1774) – length 14.2mm

Shade

An operculate mollusc living in scrub, woods, sand hills, etc, always on highly calcareous soil (Ellis 1951). A strongly calicphile shell, not found in marshes. It prefers loose, broken, ground into which it can burrow, although also found in arable land. Archaeologically it is a useful marker for disturbed ground such as forest clearance, showing marked increase in clearance horizons when other woodland species decrease (Evans 1972, 134).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very restricted, being found only in a few dunes west of Newquay on the north coast.

CARYCHIIDAE

Carychium minimum Müller, 1774 – length 2.1mm

Shade

Mainly a species occurring in leaf litter or at the roots of grass in damp habitats such as marshes or damp woods, but occasionally found on drier ground. In archaeological literature it was only adequately segregated from *C. tridentatum* in 1925, so early records may refer to both species.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: scattered occurrence, but often overlooked due to its small size, and easily confused with *C. tridentatum*.

Carychium tridentatum (Risso, 1826) – length 2.1mm

Shade (but may be found in open country)

Prefers drier, shadier, areas than *C. minimum*, being found mainly in leaf litter; however, its very small size may allow it to live in more open ground where there is a microhabitat of shade at the base of open country vegetation.

Recent occurrence in Cornwall: rather more frequently documented in Cornwall than *C. minimum*, but still with only scattered records.

SUCCINEIDAE

Oxyloma elegans (Risso 1826) – length 14mm
Succinea putris (Linnaeus, 1758) – length 16mm

Marsh
A family of molluscs that live on wet ground vegetation. The two species named above are very difficult to distinguish from fragments and are recorded in this study as 'Succineidae'. Both live on wet, rank, grassland such as marshes or fens, or on the banks of streams and ditches. *O. elegans* tends to prefer damper habitats than *S. putris*.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: O. elegans is widespread in Cornwall, mainly in coastal locations and along river valleys; *S. putris* is recorded in very few sites but may be under-recorded as the genitalia need dissection for reliable identification.

COCHLICOPIDAE

Cochlicopa lubrica (Müller, 1774) – length 6.0mm

Catholic
A species tolerant of a wide variety of habitats, from grassland to woods, but rarely found in very dry areas such as dunes. Generally in slightly damper areas than the very similar *C. lubricella*, with which it may be confused. It is a very common shell in flood debris.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread.

Cochlicopa lubricella (Rossmässler, 1834) – length 2.1mm

Catholic
On somewhat drier and more exposed ground than *C. lubrica*, but also found in shaded or damp woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: limited to coastal areas, especially around the Newquay area.

VERTIGINIDAE

Vertigo antivertigo (Draparnaud, 1801) – length 2.1mm

Marsh

A wet ground species, common in well-vegetated fens and in the marshy ground beside rivers, canals, ditches and lakes, mainly on the stems of sedges, grasses, flags and other marsh plants, as well as under stones and logs. It may be found in flood debris or on dead sedge leaves.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: sparsely distributed, although probably under-recorded.

Vertigo pygmaea (Draparnaud, 1801) – length 2.1mm

Open country

Very common in open country calcareous habitats, preferring dry ground, thriving in short-turved grazed grassland, although occasionally found in wetter open areas such as marshes. It is a good marker for more stable habitats with complete vegetation cover (Evans 1972, 143), but is also on barer blown sand. It is extremely rare in woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: recorded at only a very few sites, but it certainly under-recorded.

PUPILLIDAE

Pupilla muscorum (Linnaeus, 1758) – 3.0mm

Open country

A widespread species characteristic of dry grassland, walls and dunes. It is very rare in woodland. It generally avoids areas of intensive cultivation, but is often found in patches of broken ground such as areas grazed by sheep or round rabbit burrows. It is often one of the first molluscs to colonize newly stable ground. It is especially common in sand dunes, being a calcicole and xerophile.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: it is currently recorded only in a very few sites in Cornwall, limited to the north coast; as with other species it may be under-recorded.

LAURIIDAE

Lauria cylindracea (da Costa, 1778) – length 3.5mm

Shade

Lives in dry, shady, places such as under rocks and logs, and in crevices in stone walls where it may be extraordinarily abundant (Boycott 1934, 24) and may therefore be a pointer to the presence of walls in the vicinity. It may also be found on grassland or unstable sand dunes (Evans 2004). It is susceptible to winter cold.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: abundant and widespread.

VALLONIIDAE

Acanthinula aculeata ((Müller, 1774) – width 2.1mm

Shade

A woodland species, mainly rupestral, found on the underside of logs and in leaf litter, although occasionally in more open habitats.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread but not common.

Vallonia excentrica Sterki, 1893 – width 2.4mm

Open country

A species characteristic of open grassland of all types, especially dunes, but with a more stable non-arable habitat than often seen with *Pupilla muscorum* and therefore less common on newly created open habitats. It is particularly associated with short grazed grassland (Chappel *et al.* 1971; Evans and Evans 1995) and a shift in dominance from *P. muscorum* to *V. excentrica* can suggest a move to more intensive grazing. It prefers slightly wetter habitats than *V. costata*, but not as wet as *V. pulchella*. It is virtually unknown in woods, but can rarely be found in marshy ground (Evans 1972, 162).
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: in scattered coastal areas, especially dunes in the north coast. Old literature recording subfossil *V. pulchella* probably all refer to this species (Turk 1984: 268).

PUNCTIDAE

Punctum pygmaeum (Draparnaud, 1801) – width 1.7mm

Usually shade

Lives in a wide range of habitats, including woods and hedgerows, marshes and in dryer situations. It is generally classed as a shade species, although it may be found with more catholic species on open dry ground, including chalk grassland.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread but sparse, and probably under-recorded, perhaps due to its minute size.

DISCIDAE

Discus rotundatus (Müller, 1774) – width 6.3mm

Shade

A woodland species, living in leaf litter and on the underside of dead logs and stones. It has a narrower habitat range than *Punctum pygmaeum*, but is rare in marshes or open, dry, downland (Evans 1972, 185).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very widespread and common.

VITRINIDAE

Vitrina pellucida (Müller, 1774) – width 5.0mm

Catholic

A species found in a wide variety of conditions, from woods, marshes and other damp places to drier habitats such as sand dunes, scree slopes and short-turved grassland. Although a facultative xerophile it is not found in the driest of habitats (Evans 1972, 295). Its fragility means that it is easily broken and may be under-represented in archaeological material.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: common and widespread.

PRISTILOMATIDAE

Vitrea contracta (Westerlund, 1871) – width 2.0mm

Shade

This shell lives in a wide variety of habitats, but generally in drier, more eutrophic conditions than *V. crystallina*, although the two species are often found together. It is characteristic in limstone scree or on collapsed walls (Evans 1972, 187).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

Vitrea crystallina (Müller, 1774) – width 3.0mm

Shade

In a wide variety of habitats, but generally in moister conditions such as damp grassland, hedgerows, marshes and woods. It is typical of moist sheltered places, but can be more catholic in its requirements.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

OXYCHILIDAE

Aegopinella nitidula (Draparnaud, 1805) – width 8.3mm

Shade

Found in a variety of habitats wherever there is shade and shelter. It does not require full shade, being often found in the limited shade found at the bases tall unkempt grassland vegetation (Evans 1972, 190).

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common, both coastal and inland.

Aegopinella pura (Alder, 1830) – width 4.1mm

Shade
A woodland species but also found in well-vegetated damp places such as fens and rank grassland. It is common amongst moss and in leaf litter.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread although not common.

Nesovitrea hammonis (Ström, 1765) width 3.8mm

Catholic
A mollusc able to live in a wide variety of habitats ranging from wet grassland and meadows to hedgerows and dry grassland, but is not common. It is one of the few British species able to tolerate more acidic conditions such as pine woodland.
Occurrence in Holocene in Britain: native.
Recent occurrence Cornwall: widespread but not common.

Oxychilus alliarius ((Miller, 1822) width 7.3mm

Shade
A woodland species which readily colonizes grassland that has become rank; it is also found in shady cliff areas and is known on sand dunes. It is tolerant of acid conditions.
Occurence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common, both coastal and inland.

Oxychilus cellarius ((Müller, 1774) width 8.5mm

Shade
A very common woodland species found in leaf litter and under logs, but also in tall grassland, in stone wall debris, scree, cave deposits, tombs, etc. It may occasionally be found on bare open grassland.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: common and widespread.

GASTRODONTIDAE

Zonitoides nitidus (Müller, 1774) – width 6.8mm

Marsh

A wet-ground species living in marshes, fens, wet woodland and similar habitats, especially among aquatic grasses. It is moderately amphibious, tolerating complete submersion for long periods and therefore able to survive flooding.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and fairly common.

LIMACIDAE

length 7.6mm

Catholic

These slugs have a small internal shell plate, and it is usually very difficult to differentiate species. The species with larger plates (which are more frequently found in archaeological material) generally live in woodland, while those with smaller plates have much more varied ecological preferences. They are of little value in environmental interpretation.

Recent occurrence in Cornwall: widespread.

MILACIDAE

length 2.1mm

Catholic

As with the Limacidae, it is not easy to determine species from the slug plate alone. The Milacidae are more synanthropic, being common in gardens and cultivated land.

Recent occurrence in Cornwall: widespread.

EUCONULIDAE

Euconulus alderi (Gray, 1840) – width 2.5mm

Marsh

A wet-ground species typical of marshes and boggy woodland.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very rarely recorded, with only three authentic records; differentiation from the very similar *E. fulvus* is difficult, although the latter is also rare in Cornwall; there has undoubtedly been some confusion between species in the past.

FERUSSACIIDAE

Cecilioides acicula (Müller, 1774) – length 4.9mm

Burrowing

A subterranean species which can burrow up to 2m beneath ground surface among plant roots or in rock crevices, mostly on calcareous soils (Boycott 1934, 31). It is therefore of little use in palaeoenvironmental interpretation as it is not possible to determine its stratigraphic horizons with any reliability; it is therefore normally excluded from habitat analyses. It is common in recently cultivated land and often absent from longstanding grassland (Evans 1972, 168), so can be an indicator of cultivation.

Occurrence in Holocene in Britain: uncertain, but probably a recent introduction.

Recent occurrence in Cornwall: very rare, there only being three records, one of which is on Godrevy Towans.

CLAUSILIIDAE

Balea heydeni von Maltzen, 1881 – length 4.0mm

Shade

A mollusc only recently recognized in Britain as separate from *Balea perversa* (Cameron 2007). A species of well-shaded moist woodland; in leaf litter, among nettles and may be found in walls. This is a synanthropic species and is geophobic, rarely being found on the ground.

Occurrence in Holocene in Britain: unknown, due to the confusion with *B. perversa*, which is a native species.

Recent occurrence in Cornwall: widespread.

Clausilia bidentata (Ström, 1765) – length 10mm

Shade

A very common species found in woodland, in hedges, on rocks and walls. In wet conditions it often climbs vertical surfaces such as tree trunks or walls.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very common and widespread.

COCHLICELLIDAE

Cochlicella acuta (Müller, 1774) – length 12mm

Open country

A very common xerophilic species in bare and vegetated sand dunes and other dry habitats, and mainly restricted to coastal areas. It is a calcicole shell and is frost sensitive, so is less common in areas subject to cold winter episodes.

Occurrence in Holocene in Britain: probably a late prehistoric introduction.

Recent occurrence in Cornwall: very abundant in sand dune areas all round the county.

HYGROMIIDAE

Ashfordia granulata (Alder, 1830) – width 6.8mm

Catholic

A common species in damp shady areas, in woods and river banks, but may also occur in dryer hedgerows and similar habitats. In western Britain it may also be found on sand dunes and in cliffs, being more of a xerophile than elsewhere in southern or eastern England. Although generally classified as a shade species, in Cornwall it is often regarded as a catholic species.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common, especially at the base of dune vegetation.

Candidula intersecta (Poiret, 1801) – width 9.2mm

Open country

A xerophile and calcicole species common on dry, open sites, especially dunes and grassland.

Occurrence in Holocene in Britain: probably a medieval introduction; archaeological records suggesting an earlier date are considered unreliable.

Recent occurrence in Cornwall: abundant in dune areas all round the county, with some inland records.

Cernuella virgata (da Costa, 1778) – width 11.8mm

Open country

An obligatory calcicole. Another xerophilic species of vegetated dunes, grassland, hedges, quarries, sea cliffs and cultivated fields. Although tolerant of heat, in prolonged dry, hot weather it shelters by burying itself among the roots of plants.

Occurrence in Holocene in Britain: probably introduced during the Romano-British period.

Recent occurrence in Cornwall: abundant and widespread in coastal areas, especially in dunes.

Helicella itala (Linnaeus, 1758) – width 18mm

Open country

A dry grassland species, especially where the grass has been kept short by grazing. Although occurrences in ploughed fields are reported it tends to avoid pasture and arable habitats, preferring wilder habitats away from the man's influence. It is never found in shade, being an obligatory heliophile. The young are more resistant to drought than adults.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: restricted almost entirely to areas of blown sand and dunes along the north coast.

Ponentina subvirescens (Bellamy, 1839 – width 6.3mm

<u>Open country</u>
A xerophile mollusc living on coastal calcareous grassy slopes, often by cliffs, but occasionally found inland on well-drained non-calcareous soils (Turk *et al.* 2001, 107).
Occurrence in Holocene in Britain: uncertain appearance in Britain, and may not have been introduced until the Iron Age.
Recent occurrence in Cornwall: widespread around the coast of Cornwall, with a few inland reports from Bodmin Moor.

Xerocrassa geyeri (Soós, 1926) – width 9.0mm

<u>Open country</u>
A xerophile shell of very open dry areas (Kerney 1963).
Occurrence in Holocene in Britain: a late glacial relict, now extinct throughout Britain but common in the Pleistocene on the chalk of southern England. In most of Britain it became extinct in the early Holocene but survived locally at Gwithian, Cornwall, until the early Bronze Age.
Recent occurrence in Cornwall: extinct, recorded only from Gwithian.

Trochulus hispidus (C. Pfeiffer, 1828) – wdith 9.0mm

<u>Catholic</u>
A calcicole species with a wide variety of habitat preferences, but different subspecies or varieties may have different tolerances. It is found in both shaded and open environments, in moist or dry areas as well as in marshes, but tending to avoid the very driest places, although it has been recorded on sand dunes.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common.

Trochulus striolatus (Linnaeus, 1758) – wdith 13.8mm

Catholic

A synanthropic mollusc of cultivated habitats and waste ground, often in damp, shady places. It is common in arable land and semi-natural woodland.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread, but scarce on the granite uplands.

HELICIDAE

Cepaea nemoralis (Linnaeus, 1758) – width 21mm

Catholic

Found in a wide variety of habitats, from open dunes to damp woodland, but normally in drier and warmer environments than *C. hortensis*, although the two species are often found in the same locality. It is often not possible to separate the species if only small apical fragments are present.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: very widespread and common.

Cornu aspersum (Müller, 1774) – width 35mm

Catholic

A synanthropic species occurring in gardens, hedgerows and waste ground, but also in more open places.

Occurrence in Holocene in Britain: probably a Roman introduction.

Recent occurrence in Cornwall: very widespread and abundant. In Cornwall it is a common dune species, often in association with *Cochlicella acuta* and *Cernuella virgata*.

Theba pisana (Müller, 1774) – width 21mm

Open country

A xerophile living in dry exposed places frequently on coastal dunes. It is a capable of colonizing suitable new areas very rapidly. The shell may be found in vast numbers from suitable habitats but be absent in apparently similar habitats nearby

Occurrence in Holocene in Britain: a probable eighteenth century introduction, with no reliable sub-fossil records.
Recent occurrence in Cornwall: recent rapid spread from its possible introduction area at St Ives, it is now common in many coastal areas of Cornwall, although mainly on the north coast.

FRESHWATER MOLLUSCS

VALVATIDAE

Valvata cristata (Müller, 1774) – width 2.8mm

Ditch
A mollusc living in well-oxygenated still or flowing water. It is found in places with a muddy substrate, often on emergent vegetation at the margins of ponds, lakes and drainage ditches, as well as clean backwaters.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: extremely rare, being only recorded from the Bude Canal on two occasions.

HYDROBIIDAE

Peringia ulvae (Pennant, 1777) – length 6.8mm

Brackish water
A species found on estuarine mudflats and salt marshes, ofen in vast numbers. The animal is very resistant to dehydration and to variations in salinity.
Occurence in Holocene in Britain: native.
Recent occurance in Cornwall: retricted mainly to south coast estuaries, although also found in isolated brackish water areas on the north coast.

Potamopyrgus antipodarum (Gray, 1843) – length 4.4mm

Ditch
A ubiquitous species found in all types of flowing water and rare in still water; it is tolerant of mild pollution. Although originally a brackish water species it has adapted to freshwater and colonized rivers and streams throughout the British Isles.

Occurrence in Holocene in Britain: introduced into Britain probably in the mid 19th century.
Recent occurrence in Cornwall: very common throughout the county, despite being first found in Cornwall as recently as 1943.

LYMNAEIDAE

Galba truncatula (Müller, 1774) – length 4.3mm

Marsh
An amphibious species living out of water, but near the edges of water rather than immersed. It is found in poor freshwater habitats as well as wet grassland areas such as marshes, streams, ditches, dune slacks and in deep grass of fields.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread in appropriate habitats.

Lymnaea fuscsa (C. Pfeiffer, 1821) – length 20mm
Lymnaea palustris (Müller, 1774) – length 18mm

Catholic
It is not possible to distinguish these two species reliably from the shells alone, dissection of the reproductive organs being necessary. Both live in stagnant or slowly flowing water with plentiful vegetation such as swamps and blocked ditches. They are resistant to moderate degrees of drying in summer.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: difficulties in species differentiation makes records unreliable, but neither is common in Cornwall.

Radix balthica (Linnaeus, 1758) – length 16mm

Catholic
A ubiquitous species found in all freshwater habitats, in both hard and soft water areas. It may crawl out onto dry land. In the event of drying it will bury itself in mud or hide under stones, weeds or debris until wetter conditions return.
Occurrence in Holocene in Britain: native.
Recent occurrence in Cornwall: widespread and common.

PHYSIDAE

Physella acuta (Draparnaud, 1805) – length 9.4mm

Slum

A sinistral shell capable of living in almost all freshwater habitats: rivers, streams, lakes, ponds and swamps.

Occurrence in Holocene in Britain: a recent introduction, being first observed in Kew Gardens in 1830.

Recent occurrence in Cornwall: a few scattered records only.

PLANORBIDAE

Anisus leucostoma (Millet, 1813) – width 7.4mm

Catholic

An amphibious species found in all types of habitat, but especially in swampy pools and ditches. It prefers sites susceptible to summer drying and is therefore typical of marshes and ditches which hold water in winter but become dry in summer.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common.

Gyraulus albus (Müller, 1774) – width 5.4mm

Catholic

Able to live in all habitats from stagnant to flowing water, but not tolerant of summer drying.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: a few records only scattered throughout the county.

Gyraulus crista (Linnaeus, 1758) – width 3.1mm

Catholic

Found in most types of freshwater habitats on leaves of water plants. It cannot live in areas prone to drying.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread.

Gyraulus laevis (Alder, 1838) – width 4.8mm

Catholic

A mollusc of clean, quiet waters such as lakes and ponds, gravel pits, quarries, reservoirs, ornamental lakes. It is rare in canalized rivers or drainage dykes.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: rare, being reliably recorded only from only five sites in the county.

Ancylus fluviatilis Müller, 1774 – length 7.4mm

Moving water

A freshwater limpet living in clean, flowing, water, avoiding muddy substrates. It cannot withstand drying. It is attaches itself to stones where it feeds on algae.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread throughout the county.

SPHAERIDAE

Pisidium milium Held, 1836 – length 3.4mm

Catholic

Associated with quiet waters not prone to drying; in rivers, lakes and marsh drains, but tends to avoid swamps.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: uncommon, with a few scattered records.

Pisidium nitidum Jenyns, 1832 – length 3.2mm

Catholic

A bivalve living in clean unpolluted bottom sediments in still or flowing water, but which are not prone to drying or low oxygen levels; it avoids swampy areas.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: scattered records only.

Pisidium personatum Malm, 1855 – length 3.0mm

Slum

A species of very poor habitats such as stagnant and temporary ponds, drying ditches and other poor quality wet-ground habitats and capable of surviving in areas subject to summer drying.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: widespread and common.

Pisidium subtruncatum Malm, 1855 – length 2.8mm

Catholic

Ubiquitous in streams, lakes and ponds, especially those with still clean water; it is rare in larger rivers but is able to live in flowing marsh drains.

Occurrence in Holocene in Britain: native.

Recent occurrence in Cornwall: scattered records only, but locally abundant in some pools.

Appendix 2

Gazetteer of coastal dunes sites in the British Isles with mollusc analyses

The majority of reports which discuss the role of molluscs in environmental reconstruction on archaeological sites have been concerned with chalk downlands. Many of these have been summarised in *Land and people; papers in memory of John G. Evans* (Allen *et al.* 2009) and will not be detailed here.

Studies examining molluscs in coastal dunes are less frequent, and concentrate mainly on the Scottish Islands (Outer Hebrides and Orkney) and the south west of England (principally Cornwall). The sites are shown on a map of the British Isles in Figure Ax 2.1 and in tabular form in Table Ax 2.1. These include all those associated with known archaeology, as well as several where there is no archaeology but analyses have included buried soils.

A review of coastal blown sand deposits which included mollusc analyses up to 1979 was provided by Evans (1979) and included comments on several surveys unpublished up that date. The sites in his list are only included in the following table and descriptions when there are no other earlier or later published or grey literature reports, and his brief comments are all that is available concerning the relevant site.

The following gazetteer only discusses those dune sites where mollusc studies have been undertaken. The order of sites commences in south Devon and follows the coast of Britain in a clockwise direction to Fife in Scotland, followed by Ireland.

Figure Ax 2.1. Map showing coastal sand dunes in the British Isles.
Sites where mollusc analyses have been performed are named

Table Ax 2.1. Sand dunes sites with mollusc analyses and the publications detailing those analyses.

	ENGLAND														WALES				SCOTLAND																					IRELAND			
	Bantham, Devon	Gunwalloe, Cornwall	Samson, Scilly Isles	Gwithian, Cornwall	Perranporth, Cornwall	Trethellan Farm, Newquay, Cornwall	Atlantic Road, Newquay, Cornwall	Towan Head, Newquay, Cornwall	Constantine Bay, Cornwall	Harlyn Bay, Cornwall	Daymer Bay, Cornwall	Widemouth Bay, Cornwall	Braunton Burrows, Devon	Brean Down, Somerset	Freshwater East, Pembrokeshire	Stackpole Warren, Pembrokeshire	Brownslade, Castlemartin, Pembs	Freshwater West, Pembrokeshire	Ardnave, Islay	Oronsay, Argyll	Allasdale, Barra	South Glendale, South Uist	Sligeanach, South Uist	Hornish Point, South Uist	Borve, Benbecula	Rosinish, Benbecula	Udal, North Uist	Baleshare, North Uist	Baleone, North Uist	Newtonferry, North Uist	Ensay, off Harris	Northton, Harris	Horgabost, Harris	Bay of Skiall & Skara Brae, Orkney	Buckquoy & Birsay, Orkney	Knap of Howar, Orkney	Tofts Ness, Orkney	Freswick Links, Caithness	Morton, Fife	Doughmore, Co. Clare	Lehinch, Co. Mayo	Leach Air Iorrais, Co. Mayo	Gorteen Bay, Co. Galway
Kennard & Woodward (1901)												x																															
Bullen (1902a)										x																																	
Bullen (1902b)									x	x																																	
Kennard & Warren (1903)								x																																			
Woodward (1908)								x																																			
Bullen (1909)					x																																						
Bullen(1912)									x	x																																	
Arkell (1943)											x																																
Lewis (1968)				x																																							
Evans (1971b)																										x						x											
Evans (1972)																																x											
Spencer (1974)				x	x			x	x	x	x			x													x				x			x	x	x							
Spencer (1975)				x	x			x																										x		x							
Vaughan (1976)														x				x								x										x				x	x	x	x
Evans & Spencer (1976–7)																																			x								
Whimster (1977)										x																																	
Evans (1979)			x																						x																		
Evans (1983a)																																							x				
Evans (1983b)																				x																							
Evans & Vaughan (1983)																																				x							
Smith *et al.* (1983)													x																														
Bell (1986)	x																																										
Peters (1986)		x																																									
Paul (1987)																				x																							
Peters (1987)		x																																									

Table Ax 2.1 continued.

ENGLAND

	Bantham, Devon	Gunwalloe, Cornwall	Samson, Scilly Isles`	Gwithian, Cornwall	Perranporth, Cornwall	Trethellan Farm, Newquay, Cornwall	Atlantic Road, Newquay, Cornwall	Towan Head, Newquay, Cornwall	Constantine Bay, Cornwall	Harlyn Bay, Cornwall	Daymer Bay, Cornwall	Widemouth Bay, Cornwall	Braunton Burrows, Devon	Brean Down, Somerset
Rackham *et al*. (1989)														
Bell & Johnson (1990)														x
Evans & Hyde (1990)														
Milles (1991a)					x									
Milles (1991b)				x				x			x			
O'Connor (1992)														
Milles (1994)														
Davies (1998)	x													
Leinert *et al*. (2000)														
Thew (2003)														
Evans (2004)														
Davies (2007)				x										
Milles (2007)														
Boardman (2008)									x					
Davies (2008)							x							
Walker (2008)														x
Wessex Archaeology (2008)														
Walker (2009–10)									x					
Walker (2010)				x										
Bell & Brown (2011)														
Walker (2011)														
Evans *et al*. (2012)														
Law & Thew (2012)														
Davies (forthcoming)							x							

WALES

	Freshwater East, Pembrokeshire	Stackpole Warren, Pembrokeshire	Brownslade, Castlemartin, Pembs	Freshwater West, Pembrokeshire
Rackham *et al*. (1989)				
Bell & Johnson (1990)				
Evans & Hyde (1990)		x		
Milles (1991a)				
Milles (1991b)				
O'Connor (1992)				
Milles (1994)				
Davies (1998)				
Leinert *et al*. (2000)				
Thew (2003)				
Evans (2004)				
Davies (2007)				
Milles (2007)				
Boardman (2008)				
Davies (2008)				
Walker (2008)				
Wessex Archaeology (2008)				
Walker (2009–10)				
Walker (2010)				
Bell & Brown (2011)			x	
Walker (2011)	x			
Evans *et al*. (2012)				
Law & Thew (2012)				
Davies (forthcoming)				

SCOTLAND

	Ardnave, Islay	Oronsay, Argyll	Allasdale, Barra	South Glendale, South Uist	Sligeanach, South Uist	Hornish Point, South Uist	Borve, Benbecula	Rosinish, Benbecula	Udal, North Uist	Baleshare, North Uist	Baleone, North Uist	Newtonferry, North Uist	Ensay, off Harris	Northton, Harris	Horgabost, Harris	Bay of Skiall & Skara Brae, Orkney	Buckquoy & Birsay, Orkney	Knap of Howar, Orkney	Tofts Ness, Orkney	Freswick Links, Caithness	Morton, Fife
Rackham *et al*. (1989)																	x				
Bell & Johnson (1990)																					
Evans & Hyde (1990)																					
Milles (1991a)																					
Milles (1991b)																			x		
O'Connor (1992)																				x	
Milles (1994)																			x		
Davies (1998)																					
Leinert *et al*. (2000)																x					
Thew (2003)				x		x				x	x	x									
Evans (2004)					x								x								
Davies (2007)																					
Milles (2007)																			x		
Boardman (2008)																					
Davies (2008)																					
Walker (2008)																					
Wessex Archaeology (2008)			x																		
Walker (2009–10)																					
Walker (2010)																					
Bell & Brown (2011)																					
Walker (2011)																					
Evans *et al*. (2012)					x																
Law & Thew (2012)															x						
Davies (forthcoming)																					

IRELAND

	Doughmore, Co. Clare	Lehinch, Co. Mayo	Leach Air Iorrais, Co. Mayo	Gorteen Bay, Co. Galway
Rackham *et al*. (1989)				
Bell & Johnson (1990)				
Evans & Hyde (1990)				
Milles (1991a)				
Milles (1991b)				
O'Connor (1992)				
Milles (1994)				
Davies (1998)				
Leinert *et al*. (2000)				
Thew (2003)				
Evans (2004)				
Davies (2007)				
Milles (2007)				
Boardman (2008)				
Davies (2008)				
Walker (2008)				
Wessex Archaeology (2008)				
Walker (2009–10)				
Walker (2010)				
Bell & Brown (2011)				
Walker (2011)				
Evans *et al*. (2012)				
Law & Thew (2012)				
Davies (forthcoming)				

England

The use of molluscs in palaeoenvironmental investigation of sand dunes in England has been limited to the south west, with several sites in Cornwall, two in Devon and one in Somerset being reported.

Bantham, Devon

A late prehistoric and Romano-British occupation site on the west coast of south Devon. A few shells were recovered during a rescue excavation close to the coast from a hearth-type feature on the surface of a pit, with two radiocarbon dates from its base. Burnt shells were recovered from the fill and included *Helicella itala* (1), *Vallonia excentrica* (1) and *Cochlicella acuta* (5) (Bell 1986). One *C. acuta* apex was burnt, with its hearth context providing clear evidence of the presence of this species in Britain by about AD 350.

Excavation about 200m inland from the above work revealed a second century AD enclosure (Griffith and Reed 1998). Mollusc analysis of a sample from a shell midden showed mainly open country molluscs with some species associated with shade from a nearby stone revetted rampart (Davies 1998).

Gunwalloe, Cornwall

An early medieval settlement with evidence of Bronze Age activity, described more fully with new investigations in Chapter 10. Molluscs were obtained from cores and two small test pits in 1986 and 1987, but additional excavation was performed (Peters 1986, 1987). Well vegetated dunes were present during the Bronze Age with evidence of ploughing, with accumulation of sand later leading to abandonment of the medieval site. Marsh in the adjacent valley is shown to be longstanding. There was no scientific dating.

Samson, Scilly Isles (Evans 1979)

A buried soil in blown sand of unknown age (probably recent) with some *Cornu aspersum* but mainly *Cernuella virgata* and *Cochlicella acuta*. It is not stated whether this assemblage relates to any archaeology.

Gwithian, Cornwall

A multiperiod site with archaeology from the Mesolithic to the late medieval period. Extensive excavations have been conducted on Bronze Age and post-Roman settlements as well as a medieval manor house. Mollusc studies have been described from both of the settlements (Spencer 1974, 1975; Milles 1991b; Davies 2007), the valley meadow (Lewis 1968) and Godrevy Towans to the west of the settlement area (see Section 3.6 and Walker 2010). The molluscs show alternating horizons of stabilization (with plough soils) and rapid sand accumulation. Shaded areas were probably present in the valley floor before the Bronze Age. Twenty radiocarbon and two OSL dates are reported from the excavation site (Hamilton *et al.* 2008). Further work from this location forms the major part of this thesis, and is discussed in Chapters 5 to 9.

<u>*Perranporth, Cornwall*</u>

Bullen (1909) found marsh and open country species in the area of the medieval church of St. Piran. Spencer (1974, 1975) reported on the molluscs in a cliff section 1km west of the church, but not related to known archaeology; she found open country fauna in a basal buried soil with overlying blown sand, with a phase of damper conditions shown by the presence of *Discus rotundatus*, *Ashfordia granulata* and several Zonitidae. The open country species were mainly *Vallonia excentrica* and *Pupilla muscorum*; *Helicella itala* and *Cochlicella acuta* were totally absent. The known presence of human activity from the Mesolithic (Harding 1950) led Spencer to speculate that man may have been responsible for early deforestation. There is no scientific dating associated with the mollusc analyses.

<u>*Trethellan Farm, Newquay, Cornwall*</u>

A middle Bronze Age settlement on sloping ground above the River Gannel. Although this settlement is not itself on blown sand, it is included here as it was buried largely by recent colluvial sand from dunes above Fistral Bay. Mollusc analyses were mainly from the overlying colluvium with some from the hut floors (Milles 1991a). A limited numbers of shells were found, almost entirely open country taxa; *Cernuella virgata* and *Candidula intersecta* were present, probably from more recent blown sands, suggesting that all the molluscs are more recent than the settlement. Fifteen radiocarbon dates are reported from the settlement (Nowakowski 1991) but none are related to the mollusc analyses.

<u>*Atlantic Road, Newquay, Cornwall*</u>

A Romano-British settlement, excavated in 1998, with a mollusc column incorporating two occupation horizons separated and covered by blown sand (Davies 2008). There was progression from bare to well-vegetated to open country conditions with dune erosion. The succession sequence of *Helicella* followed by *Cochlicella* then *Cernuella* supports accepted theories of the introduction of these species to Britain. Eleven radiocarbon dates from bone and charcoal (Marshall, forthcoming).

<u>*Towan Head, Newquay, Cornwall*</u>

Several mollusc analyses from buried soils and overlying blown sand within a Holocene sand cliff have been reported (Kennard and Warren 1903; Woodward 1908; Spencer 1974, 1975; Milles 1991b) but none are related to archaeology in the immediate area. The basal layers show a shaded environment with light wood or scrub containing *Pomatias elegans*, but which gives way to an open country molluscan fauna as blown sand accumulates. *Helicella itala* and *Cochlicella acuta* were absent from the basal buried soil, but then appear in succession. The base soil may predate woodland clearance. No radiocarbon dates are associated with these analyses. A new mollusc column is reported in Section 3.5.

Constantine Bay, Cornwall

Constantine Island is a small rocky outcrop and an island only at high tide. A prehistoric hut base, of uncertain date, was originally thought to be Neolithic (Bullen 1902a). There is a burial mound radiocarbon dated to the middle Bronze Age (Jones 2009–10). The molluscs from a column in the burial mound show a non-calcareous base and blown sand above, the latter with restricted fauna (six species) of open country and catholic species in the upper sand; *Ponentina subvirescens* was present but no *Cochlicella acuta* and *Helicella itala*, consistent with the dating (Walker 2009–10). A new mollusc column from the island is reported in Section 3.4.

On the adjacent mainland mollusc columns show almost entirely open country species in blown sand with some stabilization horizons (Spencer 1974; Boardman 2008).

Harlyn Bay, Cornwall

Bronze Age artefacts have been found eroding from the cliffs (Jones *et al.* 2011) at Harlyn Bay, and there is an Iron Age cemetery site a short distance inland. Mollusc studies during excavations of the Iron Age site early in the twentieth century (Bullen 1902a; Bullen 1902b; Bullen 1912) and in 1976 (Whimster 1977) found large numbers of *Pomatias elegans*, a shade species associated with disturbed woodland, as well as other shade species such as *Discus rotundatus*, but also with a mixture of open country and catholic taxa. Bullen reported *Cornu aspersum* which was almost certainly intrusive into the prehistoric levels. A mollusc column from the cliff, remote from the archaeological site (Spencer 1974) showed open country fauna throughout. Two new mollusc studies from the cliffs are reported in Section 3.3.

Daymer Bay, Cornwall

Extensive Mesolithic flint scatters have been found in the area (Johnson and David 1982) but no other archaeology has been reported from the low cliffs and raised beach north of the main bay. Several mollusc columns (Arkell 1943; Spencer 1974; Milles 1991b), show that there was early woodland on the shores of the estuary, with large numbers of *Pomatias elegans*, *Discus rotundatus* and *Clausilia bidentata*, although this gave way to an open country fauna with some episodes of stabilization. A new bulk sample report is given in Section 3.2.

Widemouth Bay, Cornwall

A few open country shells have been reported near a 'surface with Neolithic flakes' (Kennard and Woodward 1901), but there is no further information. A new mollusc column is reported in Section 3.1.

Braunton Burrows, Devon

A series of auger samples from a medieval shell midden in the dunes of Braunton Burrows included open country molluscs from two organic rich horizons, but in insufficient quantities to assess any environmental difference from the open dunes in the area at the present time (Smith *et al.* 1983).

Brean Down, Somerset

A Bronze Age settlement in the dunes has been extensively excavated, with evidence of earlier Neolithic presence (flints) and with early medieval graves and a post-medieval building (Bell 1990). Five mollusc columns forming continuous stratigraphic sequences were obtained from the settlement and from a test pit (Spencer 1974; Vaughan 1976; Bell and Johnson 1990; Walker 2008). During the Neolithic there was mainly open country with some shade/woodland which had disappeared by the late Bronze Age, the landscape becoming progressively more open up to the sixteenth/seventeenth centuries AD. The presence of brackish water species during the middle Bronze Age indicates the presence of estuarine mud flats. The succession of introductions of *Helicella itala*, *Cochlicella acuta*, *Cernuella virgata* and *Candidula intersecta* is generally supported, although the finding of *C. virgata* and *Cornu aspersum* in Bronze Age levels makes some degree of bioturbation likely. Twenty one radiocarbon dates from bone, peat and charcoal (Bell 1990, 107) were obtained and were correlated with the mollusc columns. To date this is probably the best dated dune sequence in Britain but the need to redate this site using improved techniques has recently been highlighted (Bell 2013a).

Wales

There have been very few reports involving molluscs at archaeological sites associated with Welsh sand dunes, with Pembrokeshire being the only county represented.

Freshwater East, Pembrokeshire

An early medieval chapel and cemetery. Samples from a mollusc column in one of the trenches showed that the basal layers were devoid of shells; during the early medieval period the area was open country with grazed grassland, with no evidence of woodland or rank vegetation (Walker 2011). Twelve radiocarbon dates (Schlee 2009), including two from the trench with the mollusc analysis, one from the burial, and one from the shell-free basal layer of sand

Stackpole Warren, Pembrokeshire

A settlement with probable continuous occupation from the Beaker to early Roman periods, with many buildings and a field system. Multiple mollusc analyses were from field systems at several sites (Evans and Hyde 1990). There was a high diversity of species in lower more stable sands with lower diversity assemblages in higher unstable sands. Woodland clearance in the Bronze Age evolved to open country by the Roman period. Some cultivation was evident, but the land reverted to grassland after cultivation. Eleven radiocarbon dates, only one of which was in the area of one of the mollusc analyses (Benson *et al.* 1990). These show three episodes of sand blow in the late Bronze Age, mid/late Iron Age and medieval period.

Brownslade, Castlemartin, Pembrokeshire

An early medieval cemetery associated with a possible Bronze Age barrow. Mollusc analysis from two columns showed a basal non-calcareous cultivated soil overlain by a probably mobile dune system containing the medieval burials. The dunes later became stabilized with dry grazed grassland (Bell and Brown 2011). Twelve radiocarbon dates (Groom *et al.* 2011), close to, but not directly associated with, the mollusc columns.

Freshwater West, Pembrokeshire

A 1.30m cliff section not containing archaeology but in an area where flint scatters have been found. There was slow but constant sand accumulation with two stabilization layers. Molluscs were almost entirely open country species, with *Helicella itala* being found in the lowest levels, followed in sequence by *Cochlicella acuta* and *Cernuella virgata*, with *Candidula intersecta* only in the modern turf (Vaughan 1976). No dating.

Scotland

Dunes in Scotland are found principally on the western and northern islands, and molluscs have featured regularly in environmental studies, particularly in the Outer Hebrides and in the Orkney Islands. Only two mainland sites with mollusc analyses are reported.

Ardnave, Islay

An early Bronze Age house and a late Iron Age hearth with intervening blown sand. The mollusc analysis (Evans 1983b) was incomplete as a 2mm sieve was used, but the land shells do show an initial totally vegetated land surface during the early period of occupation with tall plants and grasses. Ten radiocarbon dates on charcoal and bone, one from same house as the mollusc study (Ritchie and Welfare 1983).

Oronsay, Argyll, Inner Hebrides

Three Mesolithic shell middens from the mid-fourth millennium BC have been excavated (Mellars 1987) with land shell analyses performed from two middens: Caisteal Nan Gillean II and Cnoc Coig (Paul 1987). There were several soil horizons with intervening blown sand layers. Open country with woodland was present in the vicinity during the earlier periods, later reverting to open dunes after abandonment of the middens. 25 radiocarbon dates (Switsur and Mellars 1987), several of which are related to the mollusc analyses. It is of interest that fine shell sand was present prior to accumulation of midden deposits at both sites during the later Mesolithic, somewhat earlier than the postulated initial formation of dunes during the early Neolithic (Evans 1972, 296; Shennan and Horton 2002, 518); this discrepancy has not been explained. *Cochlicella acuta* and *Helicella itala* were only found at one site (Caistel nan Gillean II) and both appeared in the same sand horizon, not showing the normal succession of appearance.

Allasdale, Barra, Outer Hebrides

A settlement site with a possible Neolithic building, early Bronze Age burials and Iron Age roundhouses (Wessex Archaeology 2008). Three radiocarbon dates, one associated with the mollusc analysis. Molluscs were assessed from cist and pit fills, from middens and from the roundhouse floors and generally showed open country species with some shade molluscs associated with the cist fills.

South Gendale, South Uist; Newtonferry, North Uist, Outer Hebrides

A thirteenth/fourteenth century AD byre at South Glendale and a midden at Newtonferry with molluscan faunas showing continuous fixed-dune pasture (Thew 2003). Five radiocarbon dates (Barber 2003).

Sligenach, South Uist, Outer Hebrides

A Beaker period and early Bronze Age settlement. Two mollusc columns showed open country species in interspersed layers of stabilization and blown sand (Evans 2004; Evans *et al.* 2012). *Helicella itala* and *Cochlicella acuta* appear together late in the sequence. Eighteen radiocarbon dates, four of which were directly related to the mollusc columns (Evans *et al.* 2012).

Hornish Point, South Uist; Baleshare and Baleone, North Uist, Outer Hebrides

Late Bronze Age and Iron Age settlements and middens were investigated mainly with coring although with some excavation. Land molluscs and marine shells from middens were analysed from numerous samples (Thew 2003). The terrestrial molluscs were mainly open country species, although marsh taxa were present in some areas, especially in deep contexts (but not the lowest levels), possibly due to human interaction, but probably indicative of intermittent flooding. This is followed by generally stable dune-machair pasture. The appearance of, and interactions between, *Helicella itala* and *Cochlicella acuta* provided relative chronologies consistent with other sites. A total of 46 radiocarbon dates from the three sites, nearly all associated with non-marine mollusc assemblages from middens (Barber 2011).

Borve, Benbecula, Outer Hebrides

An intertidal deposit of peat and wood with interspersed blown sand. One layer contained almost entirely freshwater molluscs (Evans 1979). One early Bronze Age radiocarbon date from the organic layers. No mention of any archaeology.

Rosinish, Benbecula, Outer Hebrides

Molluscs in Beaker and Iron Age middens continuing to early medieval occupation. Molluscs from four sections revealed open country conditions throughout, with several episodes of sand blow interspersed with periods of stabilization, although with rapid accumulation between the Iron Age and early medieval period (Evans 1971b; Vaughan 1976). Two radiocarbon dates, neither associated with the molluscs (Shepherd and Tuckwell 1976–77).

Udal, North Uist, Outer Hebrides

Two mollusc sections from fifteenth century AD and later shell middens with interspersed layers of blown sand, showing a typical open country molluscan fauna and a few shade species (Spencer 1974). Ten radiocarbon dates (Crawford and Switsur 1977), but not related to the mollusc study.

Ensay, off South Harris, Outer Hebrides

A section from a series of Beaker and Bronze Age middens showed a non-calcareous basal soil (Spencer 1974; Evans 2004). Above this early grassland gave way to denser vegetation with some hygrophiles suggesting ponding. A high number of *Lauria cylindracea* associated with large stones in the upper part of the sequence may indicate collapsed buildings or walls. *Cochlicella acuta* and *Helicella itala* are only present in surface layers dating from the Iron Age or later. No scientific dating.

Northton, South Harris, Outer Hebrides

A Neolithic to Iron Age settlement site with multiple occupation horizons interspersed with blown sand. Interpretation of a mollusc section through the deposits was complicated by the effects of deflation and rapid deposition of sand by wind action, with subsequent loss of shells and incorporation of molluscs from a variety of habitats (Evans 1971b; 1972, 293). Shells were absent from the basal layers but, by the later Neolithic, molluscs indicate a woodland environment which is later cleared.

Following a period of open country there was a brief period of woodland regeneration during the Bronze Age. This was again cleared with open country conditions persisting through the Iron Age when there was rapid accumulation of sand. *Helicella itala* and *Cochlicella acuta* successively appear only in the later Iron Age. There is relative dune stability in historic times, with little increase in sand depth. Three radiocarbon dates (Simpson 1966; Burleigh *et al.* 1973) confirmed the Neolithic to Beaker chronology, and were linked to the mollusc data.

Horgabost, South Harris, Outer Hebrides

Shells were analysed from two bulk samples from a first century AD settlement within a landscape containing later Iron Age archaeology. Mollusc analysis showed stable grassland with colonization by tall herbs following abandonment of the site (Law and Thew 2012).

Skara Brae and Bay of Skaill, Mainland, Orkney

The Neolithic village of Skara Brae on Mainland in The Orkney Islands showed clear molluscan evidence of original woodland but with a strong open country element (Spencer 1974, 1975; Leinert *et al.* 2000); deforestation occurred prior to significant sand accumulation. On the north side of the Bay of Skaill environmental studies of bore hole sediments showed freshwater ponds in the mid-sixth millennium BC which were then infilled with blown sand with recurrent sand deposition episodes interspersed with ponding. Nine radiocarbon dates from two of the Bay of Skaill cores.

Buckquoy and Birsay Bay, Mainland, Orkney (Spencer 1974; Evans and Spencer 1976–7; Rackham *et al.* 1989)

Bronze Age to Viking settlements, with the molluscs from cliff sections (200m north of the archaeological site) showing initial woodland with subsequent deforestation due to windblown sand and/or human activity. The basal Bonze Age buried soils contain almost entirely woodland/scrub species; this is followed by deforestation and deposition of blown sand. No dating from the area of the mollusc columns.

Knap of Howar, Papa Westray, Orkney

A Neolithic house site with middens. Mollusc analyses were obtained from coastal cliff sections (Spencer 1974, 1975; Vaughan 1976; Evans and Vaughan 1983). The basal buried soil, sealed by the Neolithic site, indicated a woodland environment. This was covered by massive sand accumulation but with periods when small ponds and marsh formed in the area. No helicid shells were found in any of the mollusc columns. Ten radiocarbon dates from animal bones in the house floor deposits and middens and one from organic soil in a test pit (Ritchie 1983).

Tofts Ness, Sanday, Orkney

A Neolithic and Iron Age settlement and landscape. Molluscan analysis of three columns (Milles 1991b, 1994, 2007) provided some evidence for manuring during the Neolithic with areas of damp grassland and some taller vegetation; this landscape was then buried during the Bronze Age by windblown sand before stabilizing during the Iron Age where midden tips showed soil build-up. It is probable that many of the molluscs were allochthonous, brought in with turf as fertilizer or fuel. Twenty six radiocarbon dates (Ambers 2007), but none from the mollusc columns themselves.

Freswick Links, Caithness

A Viking Age settlement with molluscs from nine excavation columns (but many specimens were probably lost as only sieve fractions larger than 1.7mm were examined) (Jones *et al.* 1983; O'Connor 1992). Few shells were recovered, but sufficient to indicate a grassy environment, lush in the lower areas, with dune instability, with only one layer suggesting a stable buried soil. No dating (Morris *et al.* 1992).

Morton, Fife

A Mesolithic shell midden, with molluscs indicating an environment of deep shade, extreme dryness, and a certain amount of fallen timber (Evans 1983a). Eleven radiocarbon dates, but it is unclear how these relate to the mollusc samples.

Ireland

The non-marine Mollusca of numerous Atlantic Coast Irish sites were reported by Kennard and Woodward (1917); these included two crannogs, four middens and 27 old land surfaces. There was little mention of stratigraphy or chronology, and the individual sites are not listed here. Generally the basal layers were devoid of shells, probably due to acidic boulder clay; above this there were clay layers with woodland fauna which were then covered by blown sand.

Doughmore, nr. Doonbeg, Co. Clare; *Lehinich, Co. Mayo*; *Leacht Air Iorrais, nr. An Gheata Mor, Co. Mayo*; *Gorteen Bay, Conemara, Co. Galway*

Dune sections were analysed at four sites on the west coast of Ireland (Vaughan 1976). They were not related to archaeology except for Leacht Air Iorrais, where sand overlies a possible Neolithic structure. The molluscs are almost entirely open country taxa in blown sand, although there are some stabilization horizons. At all sites the appearance of *Helicella itala* preceded that of *Cochlicella acuta*; no other introduced helicids were found. No dating.