CHAPTER 23
Environmental reconstruction: principles and practice

Introduction

The essential story of this book is of Earth’s dynamic environments here and now, and ~ with the rapidly developing concern for global climate change since the 1990s ~ of how they may change in the foreseeable future. It is often said that if human society wishes to know where it is going, it needs first to appreciate where it has come from ~ that respect for our history and heritage provides an important perspective on the future. The same can be said of the global environment. We grapple with the implications of climate change that may exceed rates and forms our species has never encountered before ~ driven, as some think, by sufficient human impact to rename the epoch we live in the *Anthropocene*. The only crystal ball we have to help us looks first to the past and starts with the principle our 19th century geological antecedents taught us. To their widely respected *Principle of Uniformity* ~ the present is the key to the past ~ we now add that both provide our only key to the future.

This chapter recognises that past processes left the signature of continuous and interlinked changes in the atmosphere, geosphere and biosphere in the character and content of Earth materials. We describe these as *proxies*, from which we now infer a range of environmental conditions at, and since, the time of their formation. Laws of stratigraphy, and correlation between different regions, enable us to construct a relative timescale and sequence of past events. Appreciating the age and rates of events and environmental processes is heavily dependent on sophisticated analytical techniques but the cost and effort involved is rewarding in creating the time-frame in which we can *reconstruct* past environments. This capability ~ which we outline, justify and demonstrate in this chapter ~ not only reveals the fascinating history of our planet but is fast becoming vital to help secure our own future in a world of increasing environmental change and uncertainty.

Chapter Summary

Principles of environmental reconstruction

- Early geologists held catastrophic events responsible for environmental processes and change. This *catastrophist* or *diluvialist* thinking was later replaced by widespread acceptance that geological processes operate continuously, over long timescales, largely by currently-observable processes and unconstrained by biblically short timescales.

- Although Earth scientists now recognise the role of sudden, high-energy, high-magnitude, low-frequency events ~ *neocatastrophism* ~ in environmental change, the paraphrase of the *Principle of Uniformity* as “*the present is the key to the past*” underpins environmental reconstruction.
We rely heavily on the *stratigraphic record* of past environments revealed by sediments, deposited by or through water, ice or air, as layers (*strata*) in sedimentary basins, often reflecting strong tectonic and/or climate influences.

The accuracy and completeness of subsequent environmental reconstruction depends on the extent and clarity with which these diagnostic properties survive subsequent burial, tectonic deformation, relocation, exhumation and subaerial geomorphic processes.

Sedimentological and stratigraphic principles governing their study focus on the stratigraphic “Law” of *Superposition* and differences between sediment packages. Superposition recognises that each *stratum* (single layer) must be younger than the base on which it is superimposed but older than the stratum above – establishing its *relative age* in the sequence or *succession*.

The predominance of *minerogenic* (inorganic) or *biogenic* (organic) material differentiates between *lithostratigraphy* and *biostratigraphy*, with both branches reunited in the field of *chronostratigraphy*, focusing on the age of rocks.

Stratigraphy embraces all rock types and not just sediments. Intrusive igneous rocks, dateable by their radioisotopes, also provide approximate or minimum ages for other rocks they were injected into, just as eruptive igneous or metamorphic rocks may be *age constrained* (identified by a particular time band) by underlying or overlying dateable organic sediments.

Environmental change prevents continuous rock successions from developing or surviving for long periods of geological time, placing reliance on the *correlation* of successions across space and time.

This entails recognising similarities in *indicator* fossils, distinctive mineral assemblages or structures in rocks from place to place, which reflect common environmental events.

These may be *time-equivalent* in age, or reflect the same event (glacier advance, sea level rise *etc*.), spreading gradually from one place to another and therefore *time-transgressive* in age.

**Lithostratigraphy**

Environmental reconstruction uses the principles of *sedimentology*, focusing on sediments themselves, and the *stratigraphy* of broader rock assemblages of all types, to unravel the nature, origins and sequence of past events. Processes take time to occur, creating direct or indirect measures of their age, rate and duration.
• Stratigraphy depends on the availability of surface exposures, preferably in vertical or near-vertical *stratigraphic sections*, or our ability to recover or *log* (record) subsurface rock profiles.

• The smallest individual layer or *stratum* of sediment is known as a *bed*, the boundary between each bed as a *bedding plane* and we can sometimes detect even finer layers or *laminae* within beds, especially in fine-grained materials.

• Thick accumulations and long sequences of rocks are divisible into manageable *packets or facies*. Each facies shares common internal characteristics (which may change laterally), formative processes and environmental origins.

• Each facies is distinguished from adjacent facies by recognisable boundaries indicative of *conformable* or continuous sequences, with negligible (typically seasonal) breaks; or *unconformity* representing longer, often erosional gaps.

• Facies represent discrete events or periods of accumulation and are therefore also basic units of chronostratigraphy and succession or *sequence*.

• Geology employs a hierarchy of progressively longer time from *ages, epochs, periods to eras* and *eons* for the age of rock *supergroups* (whole assemblages forming geological *terranes*) and their progressively smaller component *groups, formations* and *members*.

• Dynamic links between process, genetic facies and time at the largest geological scales underpin *sequence stratigraphy*, connecting tectonic, sea-level and climate change in the history of entire sedimentary basins. Sequence stratigraphy is a key diagnostic and predictive tool ~ best-developed in hydrocarbon exploration industries.

**Biostratigraphy**

• Biostratigraphy and lithostratigraphy share common principles but the biosphere adds unique features to the environmental record and reconstruction of the *palaeoecology* of organisms, communities, habitats and environmental interactions.

• Recognisable fossils provide potential evidence of habitat, evolution over geological timescales and opportunities for isotopic dating. The means by which organisms become preserved as fossils is known as *taphonomy* or their *preservation context*.

• Fossils are the preserved remains of body parts (*body fossils*) or evidence of former biological activity or *bioturbation* such as root channels, animal tracks and burrows (*trace fossils*). Durable, hard body parts (external or *exoskeletons* and internal or *endoskeletons*) are more common as fossils than rarely-preserved soft tissues.
• Most Quaternary organisms survive as original organic material and are known as subfossils, since relatively little time for replacement or total decomposition has occurred.

• Fossil forms survive best after replacement mineralization or contrasting sedimentation ~ the substitution of original organic material by inorganic minerals or infilling of trace fossil spaces respectively ~ but often only as moulds of inner or outer surfaces of the organism.

• Lone fossils are less useful than fossil assemblages which preserve recognisable communities of organisms. Some organisms are gregarious by nature and tolerant of a wide range of environmental conditions whereas others are extremely fussy about where they live!

• Organisms of widely-distributed occurrence combined with survival over a short-lived span of geologic time provide the best indicator or guide fossils.

• Biozone and assemblage zones identify packets of rock in which an individual taxon or assemblage of taxa occurs. They embrace the lifespan of a particular species or taxon, or a distinct community of many taxa sharing a common habitat, with stratigraphic boundaries marked by the appearance of new species.

• This also carries important chronostratigraphic implications, since community succession and species evolution take place over time.

Geomorphology

• Just as stratigraphy records palaeo-geomorphic environments, so individual landforms and their landsystem position today are relicts (rather than “fossils”) of past processes.

• Landforms and constituent materials provide diagnostic value, linked to modern analogues in active geomorphic environments, mapped with detailed accuracy and large-scale cover from airborne and satellite remote sensing.

• Their sub-surface character is assessed using radar, acoustic and seismic reflectance techniques allowing us to “see through” glacier ice to bedrock (thereby measuring ice thickness), weathering crusts to intact rock, and water to underlying lake- or sea-bed landforms.

• Area mapping locates individual landforms within their wider spatial context and is particularly useful in reconstructing relict fluvial, glacial and permafrost landsystems.
• Reconstruction of relict geomorphic environments extends by inference beyond general palaeo-climate to the modelling of related water or ice balances, thermal regimes etc.

• Altitudinal data, marking vertical distance above a datum or reference altitude such as sea-level, are essential for 3-D reconstructions of former sea and lake levels, snowlines (glacier mass balance equilibrium lines), upper limits of glaciation (trimlines) and river terraces.

• These are increasingly resolved using computerised geomorphometric techniques, linking high-resolution electronic distance measurement (EDM) and global positioning systems (GPS), to create digital elevation models (DEM).

Geoarchaeology

• The greater part of human evolution coincides with the Quaternary period of repeated, rapid large-scale global climate and landsurface change. The record of that evolution comprises not just human subfossils and our response to change but also our exponentially-increasing human “footprint”.

• Knowledge of the very earliest stages of human evolution rests on fragmentary, pre-Quaternary series of incomplete body fossils (mostly skulls) and trace fossils (mostly footprints) of hominins (early humans) between c. 8-6 Ma ago during the Miocene epoch, in eastern and southern Africa.

• What sets geoarchaeology it apart is the evidence of human use of artefacts (tools) to facilitate life and physically transform the landsurface, with built structures mimicking landforms. Most human prehistory is represented in this way, rather than as human remains, posing particular questions for interpretation and reconstruction.

• Archaeologists consider that artefacts represents actions or capacity to achieve a particular tasks. Successively larger collections of generically-similar artefacts parallel the bundles of sedimentary facies or communities of fossil taxa reinforcing environmental reconstruction. Several artefacts identify an assemblage, several assemblages an industry, several industries a culture or civilisation and so on.

• The oldest indisputable artefacts date from the early Quaternary, dominated by progressively more sophisticated lithic (stone) tools, and debitage (fragments) shed in their production, throughout the Palaeolithic or Old Stone Age until the early Holocene.

• Actions represented by stone hammers, axes, spear- and arrow-heads enabled our ancestors’ food strategies as hunter-fisher-gatherers and fabrication of primitive clothing, shelters and containers.
The final stages of predominantly-lithic cultures occurred in quick succession as the last global cold stage ended, after c. 12.5 ka BP. A brief Mesolithic stage reflected the largely-experimental transition from hunting-fishing-gathering to sedentary agriculture which particularly marks the Neolithic.

Lithic cultures also used bone and ivory which are robust but workable enough to be formed into artefacts such as harpoon points, needles and combs, with wood and animal sinews providing tool shafts and bindings. Neolithic use of “stone” extended to manufacture of clay pottery utensils and storage containers.

The Bronze Age ushered in the metal-using revolution c. 4.0 kr ago, smelting bronze as an alloy of copper and tin, followed by the first Iron Age from c. 1000 BC to AD 800; the Industrial Revolution is sometimes regarded as the second Iron Age.

Interpreting geoarchaeological records contends with problems of provenance, stratigraphic disturbance, taphonomy and preservation context like counterparts in bio-lithostratigraphy but with important differences.

The archaeo-equivalent of index fossils is provided by distinctive stone tool and pottery styles and, later, architecture. More recent “artificial” compounds vary in their biodegradability. Preservation of human and animal bones and soft tissues occurring as sub-fossils, and remains of human prey or artefacts, vary with acid↔base conditions of the burial site.

Preservation also requires that human materials enter the active geomorphic and sedimentary environment. For this reason, Palaeolithic evidence is concentrated in caves, lake-side, shore-line and flood-plain sites where humans found shelter, fresh water and prey concentrations and regular sediment influx provided burial.

Material becomes archaeo-sediment by chance, through accidental loss, or deliberate discard by its owner, as litter occurs on modern streets. Other material may be buried deliberately, in the case of kitchen middens, modern landfill sites and time capsules ~ or even preserved through mummification, pottery urn or coffin burials in the case of human corpses.

Our ancestors’ other principal legacy lies in what we call the “built environment” of functional buildings, earthworks and transport infrastructure.

Humans also modify landsurfaces inadvertently, primarily through alteration or removal of natural vegetation and resultant destabilisation of slopes and river channels, thereby acting as anthropo-geomorphic agents.

The coincidence of landslides and blanket bog formation in northern England with the early Bronze Age suggests that substantial human agency began in later prehistory.
Documentary records

- The emergence of written records defines the end of prehistory and beginning of the historic period, adding a potentially powerful resource to environmental reconstruction.

- Written form developed from pictorial symbols in early Middle Eastern civilisations c. 3.5 ka BP whilst our modern alphabet came from Greek and Roman civilisations c. 2 – 2.5 kyr ago. Early script survives primarily on clay tablets or stone monuments, rather than less-durable paper (developed in China c. AD 100), leather and skins.

- Meteorological data provide the most direct, purpose-made information we have on climate-related environmental change but are restricted to the past 350 years (as instrumentation was developed) and mostly to Europe, with sparse cover elsewhere, until the past century.

- We have since added hydrographic records and a wide range of individual geophysical, geological, geomorphological and biological data, often related to specific research and increasing use of environmental remote sensing, monitoring and impact assessment.

- These are held by private corporations, universities, museums and public agencies, including national and inter-governmental agencies and the United Nations which collate data from many sources for environmental management and forecasting purposes.

- Intermittent, informal and private records also exist in the form of diaries, etc. and open up a huge but indirect, potential source of environmental record contained in historical documents kept for other purposes ~ a form of “proxy documentary” record.

- Less-direct evidence comes from financial transactions, accounts, property inventories, chronicles, wills and other legal documents whose subject matter may have been influenced by climate and environmental events.

- The least-direct, most liberal definition of documentary records considers the value of artwork and literature in environmental reconstruction.

Chronostratigraphy

- Stratigraphic principles and correlation outlined above provide relative dating and event sequencing at single locations, and between sites sharing comparable evidence.

- Absolute dating depends on the availability of measurable chemical/physical properties and processes found in the stratigraphic record and/or the landscape.
and assumptions that rates of change in certain properties are constant over time.

- A distinction is made between precise and accurate dating — the difference between a watch showing time precisely in hours-minutes-seconds but not necessarily accurately in relation to a standard time-check — and both assume that samples have not been contaminated or moved from their original stratigraphic position.

- Available dating techniques span the entire range of Earth’s 4.6 Ba history although individual isotopes are useful for shorter time spans. Fortunately, they overlap each other in time but not necessarily in terms of target materials.

- Elements occurring in two or more chemically-identical forms, differentiated by atomic mass, are termed isotopes or nuclides. Most are stable isotopes but others with neutron imbalances are transformed by radioactive decay, shedding sub-atomic particles or energy, from unstable radioactive parent isotopes (radionuclides) to stable radiogenic daughter isotopes.

- Radiometric dating depends on two key requirements; that radioactive isotopes were sealed into the target environmental material as the latter formed and that residual amounts of radioactivity can be measured — by emissions counters or accelerator mass spectrometers.

- Four sets of radiometric elements are particularly useful to chronostratigraphy; carbon (C), potassium/argon (K/Ar), rubidium/strontium (Rb/Sr) and uranium series (uranium/thorium/lead ~ U/Th/Pb). Radiocarbon or $^{14}$C has the shortest range, but may be the best known through its value in dating Late Quaternary organic materials.

- Stable isotopes, by comparison, are not radiogenic products and therefore not capable of absolute dating. They include isotopes of hydrogen, boron, carbon and sulphur linked to temperature-dependent biotic and abiotic processes.

- By far the most significant, especially for Quaternary environmental change, is fractionation of $^{18}$O/$^{16}$O triggered by the evaporation of water. Substantial heat input and change of state from liquid to gas liberates more of the lighter isotope $^{16}$O into the atmosphere, increasing the proportion of heavier $^{18}$O remaining in the ocean.

- Tiny changes (recorded as $\delta^{18}$O) become measurable if stored and sustained over time, such as occurs during the growth of major ice sheets, when marine foraminifera (plankton) form $^{18}$O enriched sea-floor sediments, matched by ice layers enriched in $^{16}$O — reversed only when ice sheets melt during the following temperate stage.

- Many sediments and other environmental materials such as snow and ice accumulate to seasonal or annual rhythms, making the counting of years, and hence age, relatively straightforward.
• The biosphere is particularly attuned to seasonal and annual weather patterns, stimulating growth rings with absolute count-back dating opportunities or relative dating in older, fossil samples.

• They include tree-rings (studied by dendrochronology), lichens (lichenometry), marine molluscs, corals (sclerochronology) and reprecipitated carbonate (speleothem). Slow-growing, long-living species are most useful and, with annual growth rings varying in size according to favourable or stressful conditions, they produce a “bar code” unique to specific years.

• This can be correlated with similar species elsewhere within the same climate regime, or that part of the bar code shared with now-dead organisms overlapping in age with living specimens.

• Three other significant material clusters have time-dependent properties; rock weathering and diagenesis, soil formation or pedogenesis and the formation of loess deposits.

• A final cluster of techniques is derived initially from internal Earth processes. They include tephrochronology (specific geochemical signatures of ash from datable volcanic eruptions) and magnetostratigraphy (the record of Earth’s magnetic field imprinted on ferromagnetic minerals at the time and place of their formation or deposition).

• No single chronometer exists for establishing the real age of environmental events, or even testing whether major Earth events were time-synchronous or time-transgressive from place to place but many strands of potentially corroborative evidence, if organized and compared, increase the resolution of our reconstruction.

• The most important application of age-equivalent dating ~ providing a framework for all Quaternary events ~ is correlation of the Marine Oxygen Isotope (MOI) record with K/Ar dating of magnetic reversals, thence Antarctic and Greenland ice cores and Chinese loess sequences.

• The king-pin of multiple-correlation is the tuning of stratigraphic records with astronomic variations in Earth’s orbit providing an internationally-accepted “gold standard” of long-term global climate change which informs both environmental reconstruction and IPPC’s climate change forecasts.

CASE STUDY : Dinas Dinlle : Glaciers and the Iron Age

Aims and Objectives  Chapter 23 in the main text outlines a range of principles and methods in environmental reconstruction ~ linking the full range of global physical environments. It provides two extended case studies; one, an essentially physical environmental reconstruction from the immediately pre-Holocene Devensian cold stage and the other a landscape history centred around human landscape occupation and impacts. It is never entirely possible to isolate natural from human environments but it is far less common to see both interests focused on a single, small site ~ and,
what’s more, to observe both complementary and conflicting interests in its science and conservation. Such a site exists at Dinas Dinlle on the north-west Wales coast of Gwynedd, several kilometres south-west of Caernarfon. It is an eroding drumlin deposited by the last ice sheets and subsequently chosen as the site of an Iron Age Hillfort and we are about to explore what it can tell us about the past c. 20 kyr.

Glaciers

Seen from inland beyond the village of Llandwrog, Dinas Dinlle appears as a 1 km long, 0.5 km wide low coast-parallel ridge with an irregular central rise to 31 m OD (Plate 1).

![Plate 1](image1.png)

**Plate 1** The coastwise ridge of Dinas Dinlle seen looking west from the A499 road east of Llandwrog. The main drumlin lies beyond the church. Source: Ken Addison

The view is rather different from the beach, where active coastal erosion has cut a continuous, near-vertical cliff line, exposing its origins as a glacigenic sediment accumulation. From its constituent materials, overall size and oval shape, despite recent erosion, it has all the appearance of a glacial drumlin, deposited and then streamlined beneath actively-moving glacial ice on a north-south axis (Plate 2).

![Plate 2](image2.png)

**Plate 2** A second view of Dinas Dinlle, taken from a seaward perspective. This is taken from southwest of the main drumlin, which is seen to the far left, and therefore gives the secondary and drumlin form to the right more prominence. Source: Ken Addison
Storm-waves undercut the base of the cliff, generating frequent slumping of vegetated and more cohesive material from the crest, and less frequent but larger landslides and mudflows across the main face. These periodically obscure the exposures but toe-erosion is so active that almost all of the cliff face is exposed most of the time. The glacial stratigraphy is relatively simple in one sense but it possesses a more problematic internal structure in another (Figure 23.1).

Figure 23.1 An idealised section of glacigenic sediments and structures exposed by marine erosion at Dinas Dinlle, Gwynedd. Source: after Stewart Campbell in Addison, K., Edge, M.J. and Watkins, R. (1990)

Three main sedimentary units or members have been recognised but only two are commonly seen. The lowest, which passes under the modern beach, is a grey glacial till deposited beneath moving ice and containing recognisable erratics from Yyns Môn (Anglesey) and the Irish Sea basin to the north. These are overlain by sandy-gravels → massive gravels and they, in turn, by red-brown till with a mixture of northern Irish Sea basin and local Welsh erratics (Plate 3). The whole 1 km long section is folded into a broad but low anticline (gentle dome), with its core folded most steeply and also ruptured by several thrust faults (Plate 4).
Plate 3  The highest, central section of the exposed glacigenic sediments, with the degraded south rampart of the Hillfort visible on the crest. One of the large, period slumps triggered by marine erosion obscures the right hand portion of main exposure. Source: Ken Addison

Plate 4  Close-up of the principal thrust structures, rising from the bottom left two-thirds of the way to the top right. The main thrust – which displaces the sands and gravels and some upper till c. 8 metres from left (north) to right (south) – occurred during the later stages of ice sheet glaciation at this locality and appears to indicate a surge in flow. Source: Ken Addison
The stratigraphic sequence and internal structure has been subject to at least 3 quite different interpretations over the past few decades. Originally, sands and gravels sandwiched between two tills would have yielded a classic interpretation of two “ice ages” separated by an “interglacial”; this would probably imply a c. 250-450 ka history. More recently, it has been accepted that both tills probably represent two separate ice-streams ~ one from glacier source areas in the Lake District and south-west Scotland and the other in Snowdonia ~ competing for space in the southern dry-floored Irish Sea Basin, with their marginal glaciofluvial outwash depositing the sands and gravels. This would also explain the temperate-ocean marine shells (rather than cold-ocean species) found in the lower till, dredged up from the sea-bed abandoned as onset of the Late Devensian glaciation drew sea levels down. The time span for this single glacial event is considerably shorter, at ≤ 20 ka.

The third and most widely-accepted current interpretation is that the fold and thrust fault structures were caused by ice overriding earlier deposits and bulldozing them wholesale from north to south, without destroying their internal structure. The sequence is thus still attributed to Late Quaternary, Devensian glaciation within the past 20 ka ~ only the mechanism of overriding is now in question ! The fact that later ice overran earlier deposits is not in doubt but three interpretations have been proposed. The first suggests that ice retreated after depositing the lower till then re-advanced due to global or regional climate deterioration around 16 ka, before the cold stage ended. The second, and most “romantic”, is that the re-advance was in fact a major surge in an otherwise retreating ice sheet ~ triggered by rising sea levels under the base of the ice sheet, much as we expect to happen as climate change destabilises the Antarctic ice shelves ! The third, and possibly most likely, is that the location of the subglacial deformation zone shifted (see Chapter 15 in the main text), accelerating ice forward on a “raft” of water-saturated sediment at its base and ripping up some of its own sediment in the process.

We will continue to debate and re-interpret the evidence as technical innovation refines the science ~ but one thing is now for sure; that the marine erosion of the drumlin has not been gradual over the past 10-15 ka but extremely rapid very recently. Coastal erosion has exhumed “buried forests” at many places along the British coastline over the past century ~ and maybe for much longer. Within the past 15 years, large deciduous tree trunks in their growth positions have been exposed at low tides just 100 m west of the central portion of the Dinas Dinlle drumlin (Plates 5 and 6).
Plate 5  A broadleaved deciduous tree-trunk, more or less in its growth position, exhumed on the beach c. 100 m west of the southern. Source: Ken Addison

Plate 6  A second trunk, cut off just above its roots which are still arrayed in their growth position. Source: Ken Addison

Although no $^{14}$C dates have been obtained for this group, correlation with sites elsewhere in Wales suggests that they were probably growing c. 3500 - 4,000 BP. The
sea therefore could not have been this close to Dinas Dinlle at that time, despite mid-
later Holocene sea levels at amongst their highest. There is much evidence that the
Welsh coast may have been several kilometres west of its present line at that time.
Large-scale Ordnance Survey maps from the late 19th century indicate at least 35 m of
cliff retreat at Dinas Dinlle in just over 100 years ~ 30% of the distance to the trees.
This suggests that we are currently experiencing a very fast rate of coastal erosion ~
and one that is likely to accelerate as sea levels rise.

The Iron Age

On closer inspection, the irregular crest of the highest, northern portion of the drumlin
is anything but natural and is formed, instead by raised earth banks and intervening
ditches which mark out an Iron Age Hillfort (Plate 7).

![Aerial photograph of Dinas Dinlle Iron Age hillfort, Llandwrog, 1996](image)

It is a *multi-vallate* fort, that is with two ramparts rather than one (*vallum*), thrown up
from the excavation of an intervening ditch (*fossa*), protecting a slightly-elongate
internal enclosure 300 m x 200 m and some 2 ha in area (Figure 2).
The western ramparts are missing, presumed lost to the sea which, from their projected closure across the gap, has removed perhaps 40 m from the width of the original fort. Internal embankment structures can be seen at either end of the fort, where they are exposed but rapidly degraded in the cliff top. Their maximum height today is 6 m but c. 2000 yrs of exposure trimming their crests and infilling the ditch means they may have provided a defensive wall exceeding 10 m high, especially if they supported timber palisades.

The exact purpose, use and age of the Dinas Dinlle Hillfort are not known but it is one of a type and prominent location widespread in Britain, of characteristic Iron Age construction. It probably dates from several centuries BC but the oldest reasonably secure dates come from chance finds of 2nd and 3rd century AD coins and Roman pottery sherds (fragments), indicating that it was probably in use for several centuries. There is evidence of earlier Bronze Age occupation of the site from a possible burial mound in the north-east part of the fort.

The purpose of most individual forts is not certain but they provided at least a secured enclosure ~ probably for human settlement and animal pens during peaceful periods.
and no doubt as military defensive sites during civil unrest or invasion. It is quite possible that Dinas Dinlle was defended by the *Ordovices* against Roman incursions and occupation with a major Roman garrison eventually built only 7 km away at *Segontium* (modern Caernarfon).

**Conservation**

Dinas Dinlle is an important site for both its geological and historical heritage. The former is protected by UK Site of Special Scientific Interest (SSSI) status, the highest general category of conservation (exceeded only by National Nature Reserves) and is managed by the Countryside Council for Wales (CCW ~ *Cyngor Cefn Gwlad Cymru* ~ *CCGC*). The important historic interest earns the designation of Scheduled Ancient Monument and protection comes from the Royal Commission on Ancient & Historic Monuments in Wales. CADW, the Welsh Assembly Government’s heritage agency, has a general interest in the management of Dinas Dinlle.

Beyond these 2 designations, the site is also in a region with UK and European heritage coast status *inter alia* ~ and there lies the link between erosion and 3-way conflict in Dinas Dinlle’s conservation and management. The coastal segment is dynamic, with erosion of the soft glacigenic sediments and northwards longshore drift extending for 15 km from coastal cliffs of Yr Eifl to the south. Erosion of the glacigenic sediments is destroying the drumlin but continues to nourish the steep, barrier shingle beach which runs north immediately from below the base of the eroding cliffs and culminates in sand-dunes 2 km to the north (Plate 17.2 in the main text). This is ultimately bad for the geologists, disastrous for the archaeologists ~ but probably good for the residential tourist interest along the sea front and airfield and farmland of Morfa Dinlle which it protects.

The archaeologists would prefer to prevent erosion completely by hard sea defences but this would cause the steep cliffs to degrade, ultimately becoming overgrown and burying the geological exposures. The shingle beach, starved of local sediment supply, would also degrade as it continues to lose material northwards ~ posing an increased flood risk to the socio-economic activity inland. Indeed, all these processes will probably be enhanced as climate change drives sea level and storm surges higher. The three-way solution proposed by consultation with all interested parties, and implemented during the 1990s, was to slow ~ but not stop ~ the rate of longshore drift in front of Dinas Dinlle village (Plate 8), and periodically bulldoze shingle back up the beach front to simulate a storm berm. This has the back-up effect of retaining gravel and boulders, eroded out of the drumlin, for longer at its base. This, in turn, slows its rate of erosion without stopping it ~ thus maintaining geological exposure. Whilst archaeologists probably benefit least by reduced erosion of the Hillfort, they concede a lack of budget for major archaeological investigations. They monitor erosion, instead, and whilst this is a more random and occasionally rapid form of excavation than a controlled “dig”, it is better than potential catastrophic loss in a storm.
Plate 8 A “fish-tail” berm, seen from the north Hillfort rampart, constructed below the high tide mark in front of Dinas Dinlle village and designed to slow down left (south) → right (north) longshore drift to protect the beach. Material eroded from Dinas Dinlle has already overridden the inner section of the berm. Source: Ken Addison

Learning Objectives

- Understand the principles and purpose of environmental reconstruction and the important distinctions between proxy and documentary evidence of past environments.

- Explain the diagnostic properties of minerogenic and biogenic materials, the processes of their preservation, the incompleteness of the stratigraphic record and the importance of correlation in its interpretation.

- Appreciate how Earth Systems Processes write Earth Systems History and why our ability to reconstruct the latter has also become a vital tool for environmental management and forecasting.

- Acquire an understanding of the value of pollen analysis in reconstructing past vegetation

- Appreciate the value of documentary evidence in reconstructing past environments
Essay titles

1. Outline the broad succession of Late Quaternary events in northern hemisphere mid and high latitudes and their principal litho-, bio- and chrono-stratigraphic signatures.

2. Explain the value and limitations of isotope analysis in reconstructing environmental history.

3. Discuss the strengths and limitations of pollen analysis as a tool in reconstructing past vegetation and identify other biological techniques used to reconstruct past environments, in addition to pollen analysis, with examples of their use.

4. ‘Documentary evidence must be used cautiously to determine broad shifts in climate change.’ Discuss this statement, using examples from different countries.

Discussion Topics

1. Choose a sizeable geographical known to you personally and design a programme of investigation designed to reconstruct its environmental history.

2. Consider the view that an archaeologist is really a geologist dealing in people.

3. Choose an example of a pollen diagram from the literature. Discuss how the study of microscopic pollen and spores has provided a picture of the vegetation history.

4. Discuss how human activities can be recognised in pollen diagrams of Britain.

5. At what periods in the Quaternary have human influences been important?

6. Using the texts given in Further Reading, discuss the strengths and limitations of pollen analysis as a technique for reconstructing past environments.

7. Discuss the following attributes of historical documents and the human memory as aids to reconstructing past environments: their variety, reliability, strengths and weaknesses.

Further Reading


updated account of the past c. 25 kyr of interlinked climate, environmental and
human history crafted by an archaeologist (Bell) and geologist (Walker),
concluding with contemporary and future perspectives.

Ltd. Of many textbooks on stratigraphy, Brookfield’s provides a modern, well-
illustrated and very usable account for geography and environmental science
students.

Routledge. A key textbook linking historical records and the use of documents with
scientific evidence and records of climate and related environmental change and
human impacts, written by a leading pioneer of historical climate/environment
study.

second edition, Harlow: Longman. This text focuses on the nature of Quaternary
environmental evidence, with a shorter section on dating methodology, and
concludes with a review of the most recent, late Pleistocene interglacial-glacial
cycle.

archaeological interpretation*, Newhaven: Yale University Press. The
archaeological perspective on environmental reconstruction, illustrating how it complements but also adds substantially to geological perspectives.

Ltd. Walker provides an up-to-date focus on dating methodology which complements, rather than duplicates, his joint textbook with J.J. Lowe.

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Addison, K. and Edge, J.J. (1992) Early Devensian Interstadial and Glaciogenic

message of ancient trees, *Quaternary Science Reviews*, 19. 87-105

Atherden, M.A. (1976) The impact of late prehistoric cultures on the vegetation of
the North York Moors, *Transactions of the Institute of British Geographers*, 1, 284-
300.

God’s own county, *Naturalist*, 124, 137-156.


**Web resources**

http://www.ccw.gov.uk/ The website of the Countryside Council for Wales (CCW ~ Cyngor Cefn Gwlad Cymru ~ CCGC), accessible in Welsh or English, provides a wealth of knowledge, data, maps, images and policy statements covering all aspects of the protection and management of the Welsh landscape. Coastlines and coastal dune systems are entered under a number of headings worthy of exploration.

http://www.cadw.wales.gov.org The website of the Welsh Assembly Government’s historic environment agency, responsible for the conservation and of Wales’s natural and built heritage environment. It provides access to many useful sources of information, policy and imagery relevant to the case studies for Chapters 17 and 23 and has a particularly useful publication *Caring for Coastal Heritage*. 

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http://www.rcahmw.gov/uk
The website for the Royal Commission on Ancient & Historic Monuments in Wales (RCAHMW), providing a wealth of information and onward access to the huge archive of documents, reports and images of Wales’ ancient and historic culture.

http://www.nationaltrust.org/main/w-global/w-localtoyou/w-wales.htm The website of the National Trust in Wales covering a number of aspects of the 133 miles of Welsh coastline it manages, including coastal sand dunes.

http://www.gtj.org.uk/en/index The Gathering the Jewels website for Welsh cultural history, covering a wide range of topics including physical and historic environments and with useful information and imagery for this case study see below.

http://www.gtj.org.uk/item.php?lang=en&id=1234&t=1 The specific page on Dinas Dinlle Iron Age Hillfort in the Gathering the Jewels website, providing a fine aerial photograph of the Hillfort, a short description and the reference to Dr Frances Lynch’s concise published description of the site archaeology. An enlarged version of the aerial photograph is also available from the same website.