Norfolk's Earth Heritage - valuing our geodiversity

Published by the Norfolk Geodiversity Partnership

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Norfolk's Earth Heritage
Valuing Our Geodiversity

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Foreword

"Norfolk doesn't have any geology" is the response I sometimes receive when I mention the work of the Geodiversity Partnership. As this new publication makes clear, nothing could be further from the truth. Norfolk possesses a remarkable range of geodiversity, from the dramatic shingle spit at Blakeney Point to the vertebrate fossils of Shropham Pit. Norfolk is also at the centre of some of the most lively and contentious geological debates of our time, particularly those surrounding the interpretation of the complex 'superficial geology' or 'drift' which overlies the county's bedrock.

Geodiversity is a critically important resource, but it remains misunderstood, under-valued and under-appreciated – in much the same way as biodiversity has been, until perhaps very recently. Yet geodiversity literally and figuratively underpins our society. It provides our minerals, fuels and soils; it influences our agricultural systems and our landscapes; and it has a profound impact on habitats and species. Fossils offer vital insights into evolution, adaptation and extinction – insights which can help guide our own actions as we grapple with challenges such as climate change.

For all these reasons, I am delighted by the publication of Norfolk's Earth Heritage. It represents the culmination of many months of dedicated effort and research by the Norfolk Geodiversity Partnership, and in particular Tim Holt-Wilson. It also addresses a longstanding gap in the county's natural history literature: for the first time, we have a readily accessible overview of the county's geodiversity, and I have no doubt that the booklet will be an invaluable reference.

Scott Perkin, PhD
Biodiversity Services Co-ordinator
Norfolk Biodiversity Partnership

Summary

'Norfolk's Earth Heritage' is a landmark publication on Norfolk's Earth heritage and the need to conserve it.

- It is a concise yet readable introduction to Norfolk's geodiversity and why it is an important resource for life today.
- It explains the business of geoconservation, and promotes a Geodiversity Action Plan for the county, calling for a partnership of like-minded organisations and individuals to take it forward.
- It includes a range of useful resources, including advice for planners and a list of geological SSSIs.

We hope that Norfolk's Earth Heritage will provide an interesting source of information and inspiration for years to come.

1 Introduction

What is geodiversity?

Geodiversity may be defined as the natural range (diversity) of geological features (rocks, minerals, fossils, structures), geomorphological features (landforms and processes), soil and water features that compose and shape the physical landscape.

Geodiversity influences every aspect of our lives. It provides our drinking water, our soils, our building stones, and the minerals we need to produce everything from tin cans to television sets and the fuels that drive our economy. It has determined many of our historical choices: the waterside locations of towns and villages, the types of agriculture we practice, our transport routes, for example. It determines our physical landscapes and wildlife habitats, and the climate and weather we experience.

Nature conservation has been defined as 'the protection, preservation, management or enhancement and the improvement of understanding and appreciation of flora, fauna and geological and geomorphological features'[*]. Geodiversity is thus the physical, abiotic part of nature; our Earth heritage. It is the setting, the stage for life itself.

Importantly, geodiversity includes the sediments and fossils associated with the archaeological evidence for human occupation. This palaeo-environmental material provides vital contextual information for archaeologists interpreting the evidence for human life in the past.

The time has come for geodiversity to be seen and valued more widely in Norfolk.

[*] Definition from Glossary of 'Planning for Biodiversity and Geological Conservation - A Guide to Good Practice' (ODPM 2006).

BACKGROUND

Action for geodiversity

Norfolk's Earth Heritage – Valuing our Geodiversity takes as its scope the county’s rich heritage of geology, landscape and landforms, soils and water. It includes the sedimentary context of the county’s archaeology.

Norfolk's Earth Heritage summarises the county's geodiversity and the threats it faces; it explains the business of geoconservation; it sets out a vision for conserving and promoting the county’s geodiversity. It is intended as a resource for explanation, planning and consultation.

Importantly, *Norfolk's Earth Heritage* also seeks to communicate the richness of the county’s geodiversity, and to inspire its readers to discover it for themselves.

The aim is to bring about a qualitative change in the way that Norfolk's Earth heritage is understood, communicated and conserved, for the benefit of present and future generations of people - and all living things.

Our vision is that

- the contribution of geodiversity to the landscape, biodiversity, economy and culture of Norfolk will be valued and understood;
- the geodiversity of Norfolk will be protected and enhanced for the sustainable use and enjoyment of all living things.

2 Geodiversity in Norfolk

2.1 Valuing our geodiversity

Norfolk's geodiversity is valuable for economic, scientific, educational and cultural reasons. It is also valuable in itself, as a key component of the natural world.

Outstanding features of the county's geodiversity include:

- the North Norfolk coast – an outstanding assemblage of dynamic coastal landforms, including the shingle spit at Blakeney Point, the offshore barrier island at Scolt Head and the dunes at Holkham and Wells-Next-The-Sea.
- Happisburgh Palaeolithic site – a handaxe and other flint tools from sediments of the Cromer Forest-bed Formation dated over 800,000 years ago are the earliest and northernmost evidence of human expansion into Eurasia.
- the Cromer Ridge – an outstanding assemblage of lowland glacial depositional landforms, including the Blakeney Esker and Kelling Heath outwash plain. The internal, geological structure of the Ridge is visible in the cliffs from Weybourne to Mundesley.
- Maastrichtian Chalk at Sidestrand - the youngest Cretaceous Chalk strata in Britain.
- the West Runton Elephant – the largest, most complete skeleton of the Steppe Mammoth ever found.
- the Lynford Neanderthal site – a rare example of an open-air Middle Palaeolithic site comprising river channel deposits with Mousterian flint tools and the bones of eleven Woolly Mammoths.
- The Broads – the UK's largest nationally protected wetland area.
- Hunstanton Cliffs – famous brown, red and white colour banded cliffs.
- Sheringham and West Runton beach - the only well-developed Chalk reefs found between North Yorkshire and Kent.
- the Happisburgh Formation – geological evidence of the earliest lowland glaciation in the UK.
- Norton Subcourse quarry – evidence for extinct hippopotamus and hyaena living in a tributary of the ancestral River Thames.
- Shropham Pit – the most prolific findspot in the UK for vertebrate fossils of the Ipswichian (last) interglacial.
- West Runton cliffs – the most prolific findspot for vertebrate fossils of the Cromerian interglacial.

The West Runton Elephant reconstructed

- lowland periglacial landforms – the best examples of patterned ground ('Breckland Stripes') and relict pingos / palsas in the UK are found in West Norfolk.
- Breckland meres – a group of natural lakes developed in Chalk solution hollows, with distinctively fluctuating water-levels linked with groundwater.
- Pliocene/Pleistocene stratigraphy – Norfolk has contributed many Stage names to the stratigraphy of the UK, including the Ludhamian, Thurnian, Antian, Bramertonian, Pastonian, Beestonian and Cromerian.

Despite all these special features, it is easy to overlook the importance of Norfolk's geodiversity, and it is very difficult to place a value on it. It is, and always has been, a vital resource for life.

Geodiversity provides varied habitats for living things (biodiversity) through soils and topography.

It has contributed many resources for economic life in Norfolk:

- soil for farming;
- water for domestic, agricultural and industrial consumption;
- building materials (freestone and flint, clunch, brickearth, aggregates, clay lump, etc.);
- flint for making gunflints and prehistoric tools;
- glass-making and foundry sand;
- agricultural lime and marl;
- ironstone for smelting, as in the Roman period;
- salt, in Mediaeval times;
- marl for making cement, in the 19th century;
- fuels (peat).

Photo © Tim Holt-Wilson

Mill Drove Quarry, Middleton. Lower Cretaceous Carstone is extracted here for use as hardcore and building material.

Photo © Sara Muldoon

Winfarthing is located in the prime arable landscape of the South Norfolk till plateau. Darker alluvial soils floor the shallow valley (right), a tributary of the Frenze Beck.

Geodiversity performs other useful functions, for example:

- freshwater storage in aquifers and surface waters;
- carbon storage in waterlogged peat;
- water filtration and purification via rock and soil;
- flood storage areas.

Geodiversity is the background for human culture and well-being in Norfolk, providing:

- open spaces, hills, rivers, beaches and other 'green infrastructure' resources;
- information for scientific research and education;
- material for folklore, artistic and spiritual inspiration and a 'sense of place'.

The following pages provide an introduction to the geology, geomorphology, landforms, soils and water of Norfolk.

Photo © Mike Page

In Mediaeval times Norfolk was densely populated and prosperous, with a high demand for peat as a fuel. The Broads originated as peat diggings, before being flooded by rising water levels in the 14th century. Seen here, the Trinity Broads (Ormesby, Rollesby, Ormesby Little, Lily and Filby). The straight edges of some Broads mark the edges of former peat diggings.

2.2 Introducing the geology of Norfolk

The geology of Norfolk is a unique record reaching back through some 160 million years of Earth history. The oldest exposed rocks date back to the Jurassic period, although much older rocks are present at depth, and fragments of rocks from different sources have been transported here during the Ice Age.

The structure of Norfolk's bedrock geology is relatively simple: it dips gently towards the North Sea basin, becoming younger eastwards. By contrast, the overlying superficial geology is notoriously complex, and continues to excite lively discussion among geologists.

Norfolk's geology is best exposed in cliffs, quarries and cuttings, but temporary exposures, wells and boreholes also provide much useful information. Sediments and fossils provide an archive of information about environmental change over time; they are particularly important for telling the story of the last two million years, with its extreme changes in climate and wildlife, and repeated phases of human occupation over the last 700,000 years.

The geology of Norfolk may be mapped as two layers: the bedrock deposits (otherwise known as the 'solid' geology) and superficial deposits (otherwise known as the 'drift'). The superficial deposits are those dating from the Pleistocene and Holocene periods which have been laid down over approximately the last 1.8 million years. Both layers are represented in the simplified geological maps and cross-section shown here. For information on the terminology please see Appendix 3.

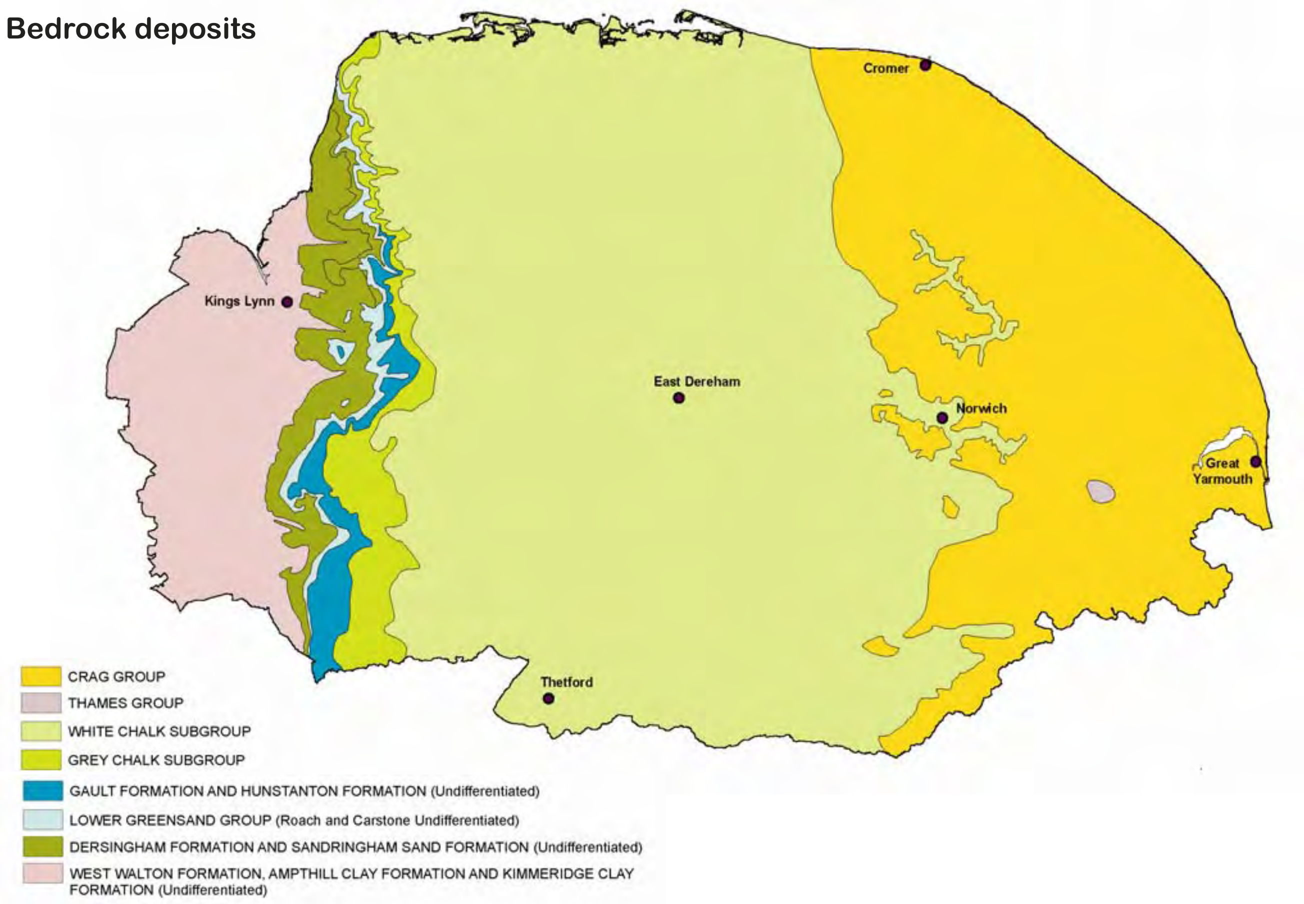
Photo © Tim Holt-Wilson

Marine erosion and deposition in action: intertidal sands at Wells-next-the Sea, showing asymmetrical current ripples with sinuous crests interrupted by tidal scour.

Photo © Phil Crabb (NHM) 2006

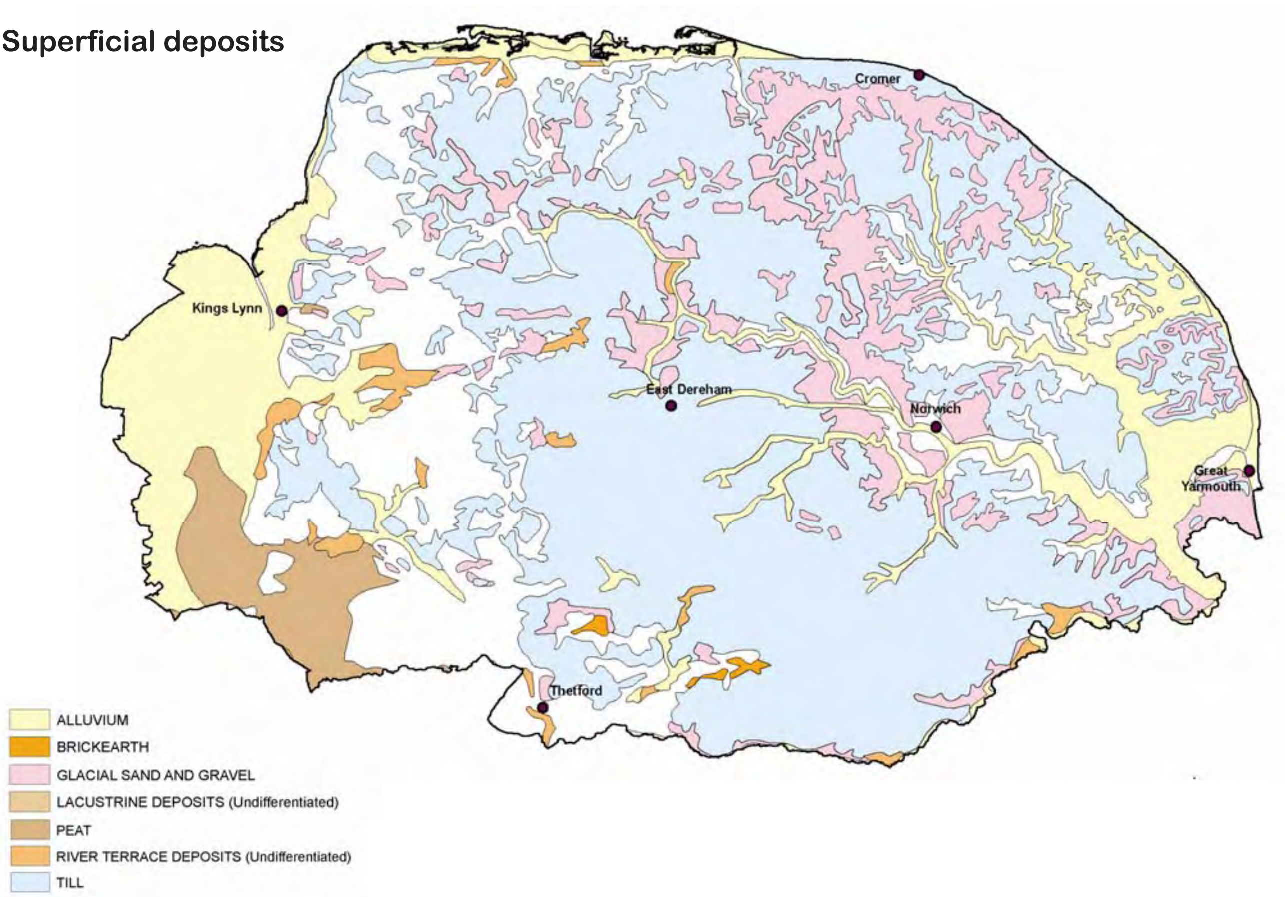
Excavations at Happisburgh, 2006, as part of the Ancient Human Occupation of Britain project. Early Pleistocene gravels have yielded evidence of the earliest and northernmost human occupation in Eurasia.

Bedrock deposits



Geological Mapping derived from DiGMapGB-50.
British Geological Survey © NERC 2009. IPR/118-46C.

Superficial deposits



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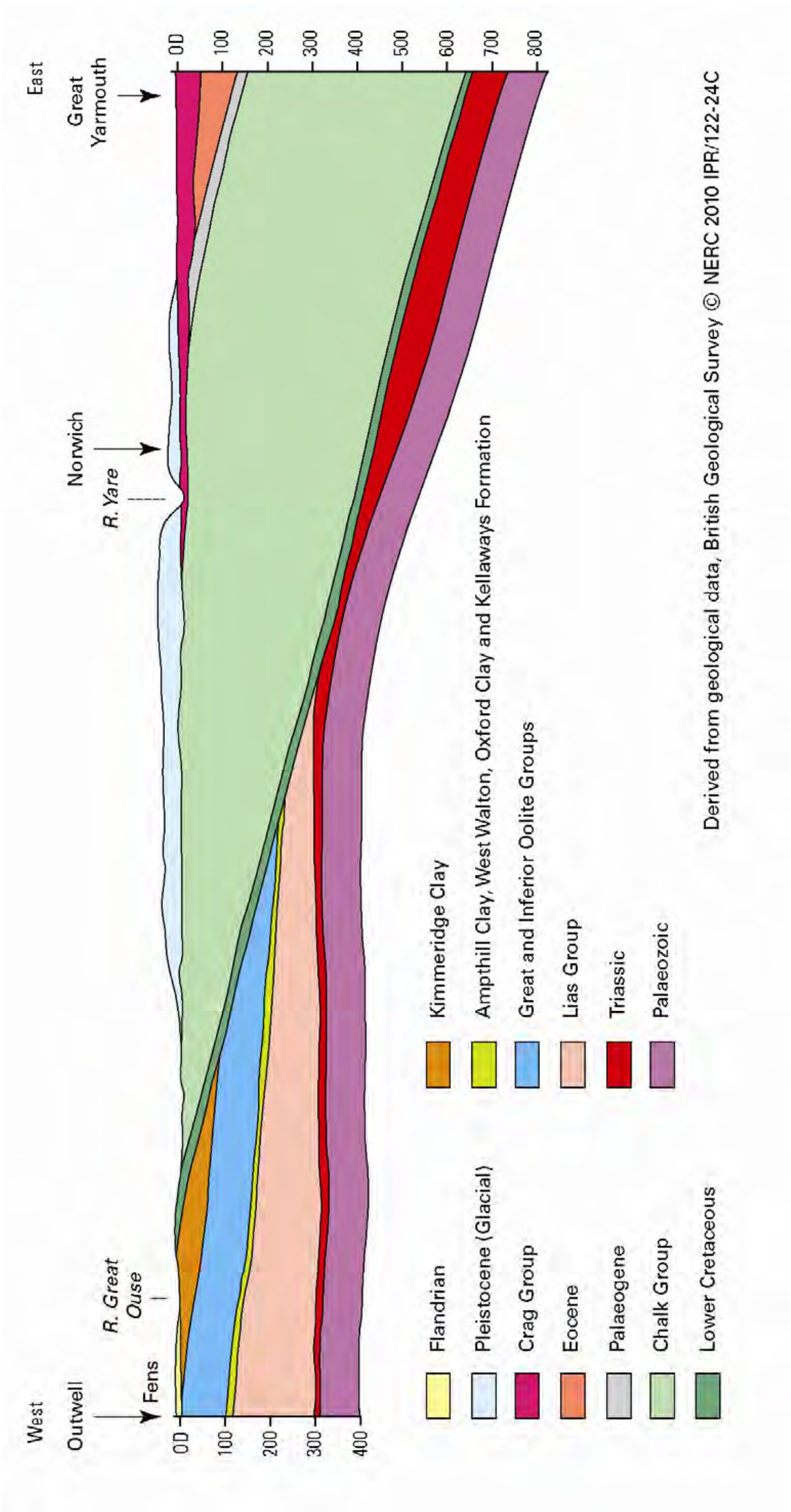


Simplified geological cross-section of Norfolk, showing bedrock and superficial deposits

Derived from digital geological data at 1:50,000 scale, British Geological Survey © NERC 2009. IPR/120-16C

The following pages present a simplified summary of the geology of Norfolk, and use informal names for the rock units.

a) Bedrock deposits

Periods	Age (million years ago)	Informal names of rock units
Pleistocene		Wroxham Crag
Pliocene	1.8 2.2	Norwich Crag
		[A gap in time from which no deposits are preserved]
Eocene	40	London Clay
	65	[A gap in time from which no deposits are preserved]
Upper Cretaceous		Chalk
	99	Red Chalk
	105	Gault
	110	Carstone
Lower Cretaceous	115	Roach
	130	Dersingham Beds
	135	Mintlyn and Leziate Beds (Sandringham Sands)
	144	Roxham and Runcton Beds (Sandringham Sands)
	153	Kimmeridge Clay
Jurassic	159	Ampthill Clay
	161	West Walton Beds

See Appendix 3 for information on the formal stratigraphic terminology used by the British Geological Survey.

b) Pleistocene superficial deposits

Age (yrs ago)	West and NW Norfolk	North and Central Norfolk	South and East Norfolk
20,000	Hunstanton Till		
125,000	Ipswichian interglacial deposits	Ipswichian interglacial deposits	Ipswichian interglacial deposits
380,000	Tottenhill Gravels		
400,000	Hoxnian interglacial deposits	Hoxnian interglacial deposits	
450,000	Lowestoft Till	Lowestoft Till	Lowestoft Till
630,000			Happisburgh Till & Corton Till
780,000		West Runton Freshwater Bed	Ingham Sand & Gravel

Basement rocks

Norfolk's bedrock geology is founded on a basement of much older Permo-Triassic and Silurian rocks, identified only from boreholes.

Jurassic

The oldest bedrock strata encountered in Norfolk are of Upper Jurassic age. They are found beneath superficial deposits in the Fenland basin and The Wash embayment, but are not exposed at the surface. The **West Walton Beds** are calcareous silty and shelly marine mudstones, with cementstone concretions. The **Ampthill Clay** has a similar lithology but the rock is softer and contains more clay; it was laid down in a shallow shelf sea not far from land. Both units contain fossil ammonites, bivalves, foraminifera and plant debris.

The **Kimmeridge Clay** is a blue-grey, marine mudstone rich in fossils and it contains cementstone concretions. It is the oldest rock exposed at the surface, principally in the eastern part of Fenland as far north as the Wash, where it forms low-lying land bordering and underlying the Fens. In places the Kimmeridge Clay has

Photo © Mike Hurn

A polished section of an ammonite from the Kimmeridge Clay at Crimplesham quarry.

Photo © Mike Hurn

Calcite crystals in a cavity from a Kimmeridge Clay mudstone concretion from Crimplesham quarry.

layers of bituminous oil shale, and attempts were made at Setchey c.1920 to exploit it as a source of fuel oil. The resource was judged to be commercially non-viable.

A sequence of greenish-coloured marine sandstones, the **Roxham and Runcton Beds** (part of the Sandringham Sands), span the boundary between the Upper Jurassic and Lower Cretaceous. They have been exposed from time to time in the King's Lynn area of West Norfolk.

Cretaceous

The Lower Cretaceous **Mintlyn and Leziate Beds** (part of the Sandringham Sands) and the **Dersingham Beds** are a succession of sands and sandstones interbedded with mudstones. They underlie tracts of heathland in West Norfolk, and are an important source of sand for glass making and foundry moulding, as at Leziate.

The **Roach** is a grey and brown pebbly mudstone containing nodules of ironstone. It has been found in excavations beneath Hunstanton beach, and in areas to the south beneath superficial deposits.

The **Carstone** is a brown, iron-rich sandstone which outcrops in west Norfolk and is quarried for building stone. It is a local equivalent of the Lower Greensand beds found elsewhere in England.

Photo © Robin Stevenson

A degraded former cliff-line at Dersingham Bog showing white sands of the Leziate Beds (Sandringham Sands) underlying iron-rich sands of the Dersingham Beds.

Photo © Tim Holt-Wilson

Wicken South pit at Leziate is developed in the Sandringham Sands Leziate Beds. The white, grey and yellow colours reflect variations in iron content and the effects of leaching.

Photo © Tim Holt-Wilson

A Carstone wall at Snettisham. Carstone is a useful building stone which tends to harden with age. It is also quarried to supply hardcore for roads.

Photo © Jenny Gladstone

Carstone outcrops at the base of Hunstanton cliffs and on the foreshore. It forms a strange pattern of 'tuffets', where the sea has preferentially eroded joints in the rock.

Photos © Val Vannet (left) and Jenny Gladstone

The Red Chalk forms a distinctive band in Hunstanton Cliffs, sandwiched between Chalk and Carstone. Both this rock and the overlying Grey Chalk show evidence of extensive disturbance by boring and burrowing organisms.

The **Red Chalk** is a red limestone rich in fossils which outcrops only in north-west Norfolk; it is spectacularly displayed in Hunstanton Cliffs. It is the same age as the **Gault**, fossil-rich mudstones which outcrop in other parts of West Norfolk. Parts of the Gault show interesting rhythmically deposited layers.

The **Chalk** is a white or grey limestone formed from the microscopic shells of planktonic organisms. The Chalk is over 460m thick in Norfolk, and the county has the greatest range of Chalk strata of anywhere in Britain, making it important for scientific research. It principally outcrops as a low, rolling plateau in West Norfolk, also along the north Norfolk coast as well as near Norwich where the rivers Yare and Wensum have cut down through overlying beds to expose it.

Flints originate in the Chalk, and have been widely used in Norfolk as a building stone; they were valued in prehistoric times for tool making and more recently for making gunflints.

Photo © Tim Holt-Wilson

Caistor St Edmund chalk pit. Chalk is extracted here, using disc harrows, to make agricultural lime. Norwich Crag sands overlie the Chalk.

Photo © Tim Holt-Wilson

The gallery of a Neolithic flint mine at Grimes Graves, Weeting. The miners extracted huge tabular nodules of black flint from the Brandon Flint Series of the Turonian Chalk.

Individual flint bands may often be followed across country for many kilometres. Chalk has been extensively quarried over the centuries for agricultural and building lime, and harder layers have been used as building stone known as 'clunch'. Today, the Chalk aquifer is the county's most important source of drinking water.

Photo © Tim Holt-Wilson

Cottage walls at Thorpe St Andrew, built from contrasting panels of knapped (broken) and nodular flint.

Photo © British Geological Survey P249701

Circular flints known as paramoudras may be seen at Runton beach. They are thought to have formed by precipitation of silica around vertical tubes or burrows in the Chalk sediment. These specimens were photographed in 1923.

Eocene

A small subcrop of London Clay has been identified from boreholes beneath Holocene deposits in the Yare valley near Cantley. The London Clay was deposited in brackish water on the margins of a tropical sea about 40 million years ago.

Pliocene

The Crags are a sequence of sandy, marine deposits laid down in the gradually cooling climatic conditions leading up the 'Ice Age'. They outcrop in the eastern parts of Norfolk. The **Norwich Crag**, dated about 2 million years old, contains the fossil remains of mammals such as mastodon, sabre-tooth and whale, and also molluscs.

Photo © Jenny Gladstone

A tooth of the Southern Elephant (*Mammuthus meridionalis*) originating from the Norwich Crag, found in Pleistocene sands and gravels at Aldeby.

Photo © Tim Holt-Wilson

A section of Pliocene seafloor exposed in Caistor St Edmund chalk pit: marine sands of the Norwich Crag resting on an eroded surface of Cretaceous Chalk. Fossil mammal bones are often found in this basement bed.

A section at Blake's Pit, Bramerton. This is the type-site of the Norwich Crag Formation and Bramertonian Stage of the Pliocene. Silty clays and cross-bedded sands were laid down in an inshore marine environment.

Photo © Peter Riches

Pleistocene

The Pleistocene 'Ice Age' is a complex series of cold glacial and warm interglacial climatic periods which began 1.8 million years ago[1]. It has left an important legacy of superficial deposits across Norfolk.

These have been the subject of intensive scientific research for over a century, and many of the classic geological sites and borehole sequences for understanding the environment and climatic changes of the Pleistocene are found in the county. This knowledge may help us to anticipate some of the changes which may occur as a result of global warming.

During early Pleistocene times two major rivers flowed through Norfolk into the North Sea basin: a large river from Lincolnshire (the 'Ancaster River'), and one from the Midlands (the 'Bytham River') which flowed north-eastwards across the south-eastern part of the county. We may track the course of the Bytham River using its distinctive suite of river terrace deposits known as the **Ingham Sands and Gravels**; these are dated between 1.0 and 0.5 million years ago. Meanwhile shallow marine deposits known as the **Wroxham Crag** were being laid down off the Norfolk coast, which reached as far west as Norwich at that time. Recent research suggests ice sheets may have reached Norfolk as early as 630,000 years ago and deposited the **Happisburgh Till** and **Corton Till**, though this date is disputed.

[1] The exact timing of the transition between the Pliocene and Pleistocene is subject to ongoing debate among geologists. For the purposes of this document it is taken to be marked by the end of the continental Tiglian C4c substage, the MIS 64/65 boundary and the end of the Olduvai magnetostratigraphic event. However, in 2009 the International Union of Geological Sciences revised the transition downwards to the base of the Gelasian Stage, being the MIS 103/104 boundary and the end of the Gauss event, at 2.58 million years - thus effectively placing the Norwich Crag in the Pleistocene.

Photo © Tim Holt-Wilson

Weybourne Cliffs SSSI, showing gravelly 'Weybourne Crag' (folded by glacial tectonic action) overlying Chalk bedrock. Anglian glacial deposits cap the cliffs.

Photo © Martin Warren

Happisburgh Cliffs show an important sequence of Anglian and pre-Anglian sediments spanning five stages in the Pleistocene period. This site has produced evidence of the earliest humans in north-west Europe.

The coldest glacial period, the Anglian, saw ice sheets spreading across Norfolk from the north and north-west around 450,000 years ago; they gouged out the broad depression that is now Fenland and swept over and eroded a former range of Chalk hills in the west of the county. They left behind thick layers of chalky 'boulder clay' known as the **Lowestoft Till** and associated sandy outwash deposits that underlie many parts of Norfolk, and which form much of its best corn-growing farmland. Much of the Cromer Ridge is thought to have formed at this time. Meltwater under pressure beneath the ice sheet eroded the bedrock and carved out tunnel valleys which later filled with sediment; one under the Thet valley at Snetterton is over 50m deep.

There is evidence that ice sheets also reached Norfolk in later cold periods: glacial outwash deposits at Tottenhill in the Nar Valley may be date from about 340,000 years ago, while the most recent glaciation took place 20,000 years ago, when a brown 'boulder clay' known as the **Hunstanton Till** was deposited along parts of the north coast.

Photo © Jeannie Harris

The Village Stone at Great Hockham, an erratic boulder brought to the area during the Anglian glaciation. It is ritually turned over to commemorate important events in the life of the village.

Photo © Martin Warren

Sidestrand Cliffs dramatically shows slices of Cretaceous chalk which have been sheared up by an Anglian ice sheet and rafted into glacial till.

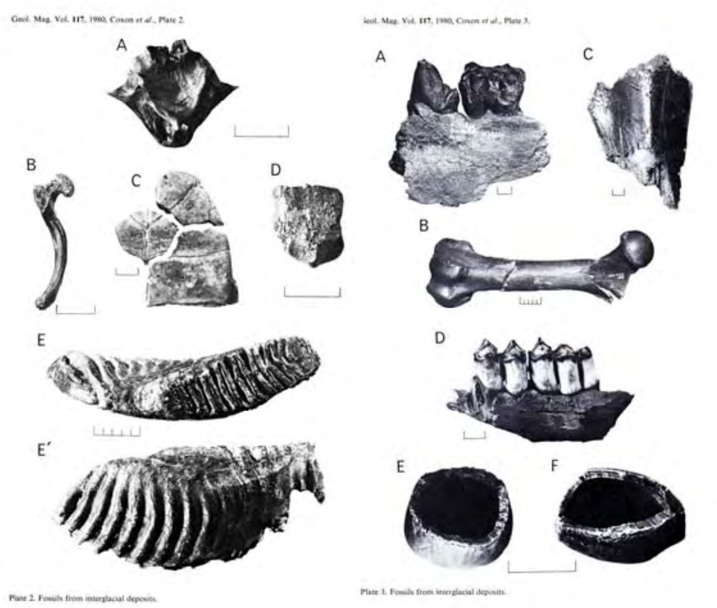
During cold periods when the landscape was not covered by an ice sheet, it was affected by permafrost and periglacial freeze-thaw action which mobilised soil and surface layers and modified slopes. Distinctive **patterned ground** developed in western Norfolk during the last cold period about 18,000 years ago, where frost action sorted chalky subsoil and sandy drift into polygonal or striped patterns. Superficial deposits known as **head** accumulated on slopes, valley flanks and floors by mass movement downhill. Meltwater rivers deposited thick **sand and gravel** sequences in valleys such as the Thet, Waveney and Wensum; these provide valuable resources for today's aggregates industry. Plants and animals, including humans, were able to colonise the region during warmer interglacial periods.

Photo © Tim Holt-Wilson

Slumping of glacial sands and clays of Anglian age in the cliffs at Overstrand SSSI. Three different ice advances are represented here. The unstable ground provides a notable range of wildlife habitats, with rare beetle species present.

Norfolk is rich in such warm phase deposits; the most famous being the **West Runton Freshwater Bed**, which has yielded the spectacular fossil remains of an elephant dating back perhaps 780,000 years. River-channel deposits at Happisburgh have yielded flint tools made by the earliest humans in northern Europe, dating back over 800,000 years. Norton Subcourse quarry is another important site from the early Pleistocene, with evidence of extinct hippopotamus. Interglacial deposits of Hoxnian and Ipswichian age (c.420,000 and 125,000 years ago respectively) have been found in Norfolk river valleys, and are typically rich in environmental evidence including vertebrate, beetle and plant remains.

Picture courtesy of Coxon et al. in Geological Magazine 117 (1980).



Fossils of Ipswichian interglacial age from Swanton Morley gravel pits, including pond turtle, straight-tusked elephant, hippopotamus and spotted hyaena. Gnawed hazelnut shells are pictured lower right.

Photo © Tim Holt-Wilson, courtesy John Lord

A handaxe found at Lynford gravel pit of a type used by Neanderthal humans. 47 handaxes have been found associated with bones of mammoth, horse and reindeer in sediments dated over 60,000 years old.

Photo © Tim Holt-Wilson

Grey, organic-rich deposits at Norton Subcourse quarry were laid down in a riverside environment, perhaps 680,000 years ago. They are underlain by shallow water marine sediments (yellow sands and gravels).

Photo © Martin Warren

Most of the fossil skeleton of a Steppe Mammoth (*Mammuthus trogontherii*) was excavated from West Runton cliffs in 1995. Seen here, the excavated right tusk and part of the skull are encased in a plaster jacket ready for removal.

Holocene

The last 10,000 years are part of the Holocene, which is the name for the present interglacial warm period which began at the end of the last Ice Age. Unlike previous periods, human influence has spread throughout the landscape and has modified and shaped it in new ways, through settlement, forest clearance, farming, drainage, earth moving and other activities.

In common with earlier periods, a range of marine, freshwater and terrestrial sediments have been, and continue to be, deposited by active geomorphological processes, notably in coastal areas and river valleys. Deposits include dune sands, shingle banks and sandbanks, estuarine saltmarshes and mudflats, river terraces and layers of floodplain peat and alluvium. Thus sediments continue to be laid down for the future.

Holocene wetland sites contain valuable palaeo-environmental archives in the form of stratified sediments and microfossils, including plants, beetles, molluscs and ostracods. Core samples may be analysed and the results used to provide evidence of environmental change over the last 10,000 years. Peat-rich wetland areas such as Broadland and Fenland may also be valuable for the ecosystem function they perform as natural sinks for storing carbon.

Photo © Tim Holt-Wilson

Alluvial silts underlie the Ouse Washes at Welney. This floodplain was created by drainage work in the Fens 400 years ago, and is now used as a winter floodwater storage area.

Photo © Norfolk Museums & Archaeology Service

Holocene peat beds are exposed along the North Norfolk coast. Seen here, a Bronze Age ceremonial structure ('Seahenge') at Holme-next-the-Sea was once situated in woodland. Sea levels have risen since then and the site is now intertidal.

2.3 Geomorphology – landforms and processes

Norfolk has diverse physical landscapes, ranging from the sandy hills of the Cromer Ridge to the peaty levels of the Fens, from the waterways of Broadland to the chalk uplands of West Norfolk, from the till (boulder clay) plateau of central Norfolk to the sand flats of the North Norfolk coast. These landscapes are the result of thousands of years of natural and human processes working on a varied inheritance of geology, soils and landforms.

Photo © Tim Holt-Wilson

Massingham Heath in North West Norfolk. This open, rolling landscape is developed on Chalk. Before the Ice Age it would have been as hilly as the Chilterns, but the contours were flattened by the advancing Anglian ice sheet c.450,000 years ago. Glacial deposits cap the wooded hill-tops in the distance.

Photo © Tim Holt-Wilson

A coastal landscape at Salthouse. A shingle barrier beach backed by reclaimed saltmarsh can be seen in the distance. The low hill on the right is a remnant of glacial moraine or esker, probably of Anglian age.

Photo © Tom Barrett

The flat, open landscape of the Potter Heigham marshes. Eight hundred years ago this was part of an estuary; an interdigitating sequence of marine clays and freshwater peats underlies the present floodplain.

Landforms

The physical landscapes of Norfolk are made up of many landform elements. Some are relict features, developed under a different climate during the Ice Age. Others are being shaped today by active, natural processes, and, in many instances, by human activity such as river management and coastal defence work. The result is a dynamic blend of ancient and modern features.

Relict landforms in Norfolk include:

- river terraces, the remnants of former floodplains isolated by later erosion, as in the Nar valley;
- dry valleys, formed during the Ice Age when permeable ground (e.g. chalk or sand) was frozen and could be eroded by water action, as at Tumbley Hill, West Acre;
- meanders, where rivers occupy meandering channels that were formed during periods of higher discharge in the past, as in the Tas valley at Swainsthorpe;
- floodplains, formed by rivers during periods of higher discharge, for example in a glacial meltwater regime, as in the Waveney valley at Earsham;
- floodplains, formed in the lower reaches of rivers where rises in sea level have forced them to deposit their sediment and aggrade, as at Geldeston;
- dolines, circular depressions caused by solution and collapse of chalk bedrock in cold climatic periods, as at the Devil's Punchbowl, Croxton;
- patterned ground, areas of contrasting sandy and chalky subsoil sorted by Ice Age frost action into a pattern of stripes and polygons, as at Brettenham Heath;
- palsas or pingos, hollows with earth ramparts left by collapsed blisters of ground ice, as at Thompson Common;

Photo © Tim Holt-Wilson

Salthouse Heath is a relict glacial outwash plain. A similar plain around Kelling Heath can be seen in the distance.

Photo © Tim Holt-Wilson

The Devil's Punchbowl, Croxton, is a spectacular example of a doline. Its water-level fluctuates according to the height of the local water table.

Photo © Robin Stevenson

A kame feature in the Glaven valley near Letheringsett. This area has many conical-shaped hills made of glaciofluvial sand and gravel thought to have been deposited by a wasting ice sheet.

Great Hulver Hill (left) and Scrib Hill (right) near Salthouse. The hills are outliers (erosional remnants) of the Salthouse Heath glacial outwash plain.

- glacial outwash plain, formed where many sub-glacial streams emerge from an ice sheet and deposit their bedload in a spreading apron of sand and gravel, as at Kelling Heath;
- glacial till plateaux, extensive areas of till (boulder clay) with interbedded glaciofluvial deposits laid down under an ice sheet, as at Tacolneston;
- terminal moraines, ridges of sand and gravel deposited at the limit of advance of an ice sheet, as at Garrett Hill, Stiffkey;
- kame terraces, irregular mounds of sand and gravel deposited by glacial meltwater along an ice-filled valley side, as in the Heacham River valley at Sedgeford;
- eskers, sinuous ridges of sands and gravels formed by the bed-load of streams flowing in tunnels under an ice sheet, as at Wiveton Downs;
- relict cliff-lines, formed along coasts and estuaries during periods of higher relatively sea level, as at Dersingham;
- raised beaches, where relative movements of land and sea have raised beach deposits above modern sea level, as at Morston;
- relict sand dunes now stabilised by vegetation, as the coastal dunes at Holkham.

Relict palsas or pingos at East Walton Common, dating from the last glacial period. Earth ramparts surround ponds in depressions where ice mounds once grew.

A raised beach at Morston, photographed in 1934. Recent analysis of the sediments suggests it was deposited about 185,000 years ago; relative movements of land and sea have since raised it above modern sea level.

Photo © Tim Holt-Wilson

River terraces along the River Whitewater at Hoe: the current floodplain (left) and rising ground (right) mark the eroded edge of Terrace 3, dated to about 40,000 years ago.

Active landforms in Norfolk include:

- sand-dunes, formed where wind-blown sand accumulates and may become bound by marram grass and other plants, as at Holkham;
- spring-lines, where downward percolating ground-water flushes out of a slope where it meets an underlying layer of impermeable rock, as at Dersingham Bog;
- estuarine mud-flats, where organic-rich silts and clays build up in sheltered areas of the coast, as at Wells;
- spits, curved promontories of beach material shaped by tidal currents and longshore drift, as at Scolt Head;
- saltmarshes, where sheltered areas of mud-flats become stabilised by a succession of plant species, as at Burnham Overy;
- floodplains, flat areas of alluvium deposited by rivers in their overbank phase, as at the Ouse Washes, Welney;
- land-slides, where unconsolidated sediment slumps on steep slopes or cliffs above a water-lubricated slide zone, as at Sidestrand cliffs;
- tufa mounds, where upwelling springs of chalk-rich water deposit their lime to produce mounds of calcareous tufa, notably at Badley Moor, East Dereham;
- cliffs, steep rock exposures created by processes or erosion and weathering, as at Happisburgh;
- wave-cut platforms, where waves erode a bench in resistant rocks, as at West Runton beach;

Photo © British Geological Survey P210717

Ringstead Downs, near Hunstanton, is a dry valley developed in Chalk bedrock. It is thought to have been carved by glacial meltwaters during the last glaciation, over 14,000 years ago.

Photo © The Landscape Partnership

Winterton Dunes displays a well developed system of stabilised dunes interspersed with ponds known as dune slacks; heathland has developed here on acidic sandy soils. The site is a National Nature Reserve.

- bournes or intermittent Chalk streams, as the River Burn at North and South Creake;
- terracettes, stepped micro-relief features caused by soil creep, as at Thetford Castle;
- valley-floor springs, where valleys have been incised and intercept current ground-water levels, as at St Helens Well, Santon;
- gullys, where runoff water collects and erodes channels, as at Roman Camp, West Runton.

Photo © Tim Holt-Wilson

A tidal creek in mature saltmarshes at Stiffkey. Such upper marsh environments on the North Norfolk coast are stable features, and may be at least 1000 years old.

Photo © Tim Holt-Wilson

Winter flooding by the River Waveney at Billingford. Clays and silts are deposited on the floodplain as thin layers of alluvium.

Photo © Tim Holt-Wilson

Holocene coversands at Ling Common, Castle Rising. Luminescence dating has shown that sand was actively deposited here in the first millennium AD, possibly as a result of a sand invasion event.

Photo © Tim Holt-Wilson

A view over intertidal sandflats and mudflats in The Wash, Snettisham. The land in the distance at Terrington St Clement was once saltmarsh, reclaimed from the sea in the 1950s and 1970s.

Geomorphological processes

Norfolk's physical landscape has been, and continues to be, shaped by natural as well as human processes.

The Norfolk coastline has been affected by changing sea-levels throughout the Holocene. After the end of the last glacial period, sea levels were over 50m lower than today and Norfolk was part of the land area known as Doggerland, now submerged by the North Sea. There was an initial fast rise in sea level caused by global ice melt, and the line of the present coastline was more or less established by 8,500BC. This was followed by a slower, steadier rise caused by isostatic adjustments[2]. The rate of sea-level rise has been episodic, with locally varied effects. The sediments in parts of the north Norfolk coast demonstrate subsidence of about 10cm per century over the last three millennia. Sediments at West Winch and Wiggenhall St Germans contain alternating marine and freshwater beds, and have been analysed to tell a story of successive sea level changes in Fenland, with marine advances into the basin about 4800, 2500 and 2000 years ago. The courses of former tidal creeks may be seen in Fenland as roddons, meandering deposits of silty soil surrounded by fen peat. A similar story of fluctuating sea levels can be told in eastern Norfolk, where borehole samples from Great Yarmouth and nearby marshland have been used to reconstruct varying details of coastal geography through the Roman, Saxon and Mediaeval periods. Climate change is likely to accelerate sea-level rise; estimates of future relative rise in eastern England vary between 22cm and 80cm according to different climatic scenarios for the year 2080[3].

Norfolk has a long history of coastal erosion. Estimates suggest that the coast has retreated landward by between 1 and 2km over the last 900 years, with several villages lost to the sea. Current losses at Happisburgh average over 8m per year[4].

[2]Norfolk is estimated to be sinking at a rate of about 0.5mm per year.
[3] Hulme et al. (2002): *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report* (Tyndall Centre for Climate Change Research, University of East Anglia)
[4]See http://www.bgs.ac.uk/landslides/Happisburgh.html

Photo © Tim Holt-Wilson

The lower reaches of Stiffkey River valley, once an estuary earlier in the Holocene. The present day floodplain is developed on marine silts and clays characteristic of a saltmarsh environment.

Photo © Tim Holt-Wilson

Active coastal processes at work at Salthouse: the sea has recently breached the beach barrier and spilled shingle over the reclaimed saltmarshes behind.

Photo © Tim Holt-Wilson

End of the road: the effects of marine erosion and cliff slumping at Loop Road, Trimingham. The cliffs are retreating here at a rate of over 1.5 m per year.

Coastal defences such as groynes, revetments and beach recharge have significantly slowed the rate, as at Overstrand and Mundesley. As the effects of global warming begin to bite, rises in relative sea level will extend active coastal processes into new parts of Norfolk, and increase rates of erosion in the most vulnerable areas. The lower parts of river valleys will become flooded as estuaries extend further inland, and low-lying areas such as the Fens and Broads may be lost to the sea.


Photo © British Geological Survey P235178

Evidence of coastal retreat at Eccles, near Lessingham, 1896. Other lost villages along this dynamic stretch of coast include Shipden, Waxham Parva and Wimpwell.

The geomorphology of Norfolk's rivers has significantly changed during the Holocene. Early Holocene rivers typically evolved from a late-glacial braided pattern to a branching and reconnecting (anastomosing) pattern; they later developed single-thread meandering channels within stable floodplains. River and floodplain systems have been greatly altered by human activities during the later Holocene; these include increased alluviation caused by sediment run-off from agriculture and deforestation, the cutting and deepening of artificial channels, peat removal, floodplain drainage, and built development such as weirs, sluices, bridges and buildings. It has been estimated that nearly 90% of the total length of the River Nar, for example, has been modified to some degree[5]. As a result of human activity, rivers have typically lost an active, formative relationship with their floodplains, wildlife habitat has been damaged, and peak river flow regimes have become much 'flashier', with an increased likelihood of flooding events.

In recent centuries, human activity has radically altered many of Norfolk's wetlands. Principal among these are the Fens and the Broads. Drainage of the Fens from the 17th century onwards has resulted in shrinkage of the peat and wind-blow of the soils, and many parts are now at, or below, mean sea level. The low-lying river valleys of the Broads were exploited for peat fuel in the early Middle Ages. Rising sea-levels in the 14th century flooded the peat diggings, leaving an extensive legacy of lakes and fens. The alluvial marshlands of Norfolk have also been drained for agriculture in places such as Halvergate and Terrington St Clement.


Photo © Tim Holt-Wilson

An electric pumping station at Fordham Fen, situated at mean sea level. Peat growth began about 4000 years ago in this part of the Fens, and continued uninterrupted until the drainage work of recent centuries.

[5] Sear et al. (2005): *Geomorphological Appraisal of the River Nar Site of Special Scientific Interest* (English Nature Research Report 684)

2.4 Water

Water is one of Norfolk's vital resources. It is a geological component as well as a geomorphological agent. Studies have shown that Norfolk has a diverse hydrology.

The Chalk is the county's principal aquifer, from which most of the county's water supply is extracted via boreholes. Water is also abstracted from rivers such as the Thet and Bure, and from lakes, as at Ormesby Broad. In eastern parts of the county the Chalk aquifer is confined by overlying deposits. Norfolk's Chalk groundwater has significant variations in hardness, chemistry and age of origin, related to the overlying deposits. For example, carbon-14 dating suggests that in interfluve areas capped by poorly permeable Lowestoft Till the Chalk groundwater may be up to 18,000 years old, and has high carbonate hardness; it is softer in Breckland where it is overlain by sandy drift.

Other aquifers include Cretaceous and Pleistocene sands and gravels and the Norwich Crag, and their water is often enriched with iron and manganese. Spring water from such 'chalybeate' sources was sometimes exploited in previous centuries for spa purposes, as at North Walsham and Shelfanger. Alongside surface water flows, subterranean groundwater plays a role in coastal areas by supporting a range of transitional habitats between fresh and salt water. However, groundwater near the coast, particularly in the east, is liable to be richer in chloride due to the influence of seawater.

Norfolk's surface waters are predominantly alkaline in character. Over 420km of the county's rivers are classified as chalk rivers[6] where they flow over the Chalk or chalk-rich superficial deposits. Away from the direct influence of the Chalk, surface waters may be alkaline due to the calcareous influence of the Lowestoft Till. Surface waters are liable to anthropogenic pollution. Pollutants include nitrates, phosphates, pesticide residues and metals such as copper, cadmium and lead from sewage. In 1982


Photo © Tim Holt-Wilson

Water lilies on Rockland Broad. Natural hydrological conditions in its catchment produce clear, chalk-rich water which supports a diverse flora. Many other broads suffer from pollution leading to eutrophication and loss of biodiversity.

Photo © Tim Holt-Wilson

Spa House, Shelfanger. A small spa was founded in the 19th century to exploit the supposed health-giving virtues of iron-rich 'chalybeate' springs emerging here from sandy glacial deposits.

[6] *The State of England's Chalk Rivers* (Environment Agency, 2004).

the River Yare became notably contaminated with mercury from an industrial source near Norwich. Such pollutants become incorporated and stored in river and lake sediments, as well as being transported into the sea.

Photo © Tim Holt-Wilson

The River Glaven at Wiveton. The Glaven is classed as a chalk river for 60% of its length, being directly supplied by springs and groundwater flow from the Chalk aquifer.

Photo © Tim Holt-Wilson

Diss Mere is fed by Chalk springs. Until the mid 19th century it was badly polluted by organic waste from the town, including sewage and effluent from the hemp processing industry.

2.5 Soils

Norfolk's varying landscapes are underlain by an intricate mosaic of different soils, supporting varied wildlife habitats and types of agriculture.

Soils are complex products of physical and biological processes, which include weathering of their underlying geological parent materials, and have reached their present form after at least 10,000 years of development since the last Ice Age. They are a vital economic resource for farmers, and their nature determines the types of agriculture which are feasible.


Photo © Tim Holt-Wilson

Heath Farm, Banham, Deep ditches are essential to drain the stagnogley soils of the till plateau of south and central Norfolk. Waterlogging means early harvesting of sugar beet in wet years and autumn sowing of winter cereals.


Photo © Robin Stevenson

Methwold Fen. Deep peat soils provide an easily-worked and fertile growing medium for root crops and vegetables. Problems include risk of wind erosion, and wastage of the peat, which is causing land sinkage and loss of carbon storage capacity.

Work by the Soil Survey of England and Wales has classified and mapped the soils of Norfolk into various soil associations and their constituent series, some of which are named after sites in the county, such as Methwold and Sustead, where they were first identified.

Examples of soil types in Norfolk include

Soil group	Parent material	Landscape element	Example of location
Calcareous Soils	Chalk and chalky superficial deposits	West Norfolk uplands	Massingham Heath
Brown Earths	Glacial, glaciofluvial and aeolian (wind-blown) deposits	North-east Norfolk plateau	North Walsham
Brown Sands	Sandy glaciofluvial deposits	Cromer Ridge	Upper Sheringham
Stagnogley Soils	Chalky glacial deposits	South Norfolk till plateau	Winfarthing
Earthy peat soils	Fen peat	The Broads	Barton Broad
Brown calcareous alluvial soils	Marine alluvium	Marshland	Terrington St John

Peat is an accumulation of partially decayed vegetation, and as such plays an important role in sequestrating carbon. Work is being carried out in the Broads area to evaluate the significance of the area's role in carbon capture. Here the total carbon stored in peaty material in deep and shallow peaty soils has been estimated to be 4.825 million tonnes[7].

Photo © Tim Holt-Wilson

Fine windblown silt (loess) of periglacial origin has made a major contribution to the soils of north-east Norfolk. It has combined with sandy glacial drift to make easily cultivated ploughsoil.

Photo © Tim Holt-Wilson

Leached, acidic sandy soils are common in many parts of Norfolk where glaciofluvial sands and gravels are close to the surface. Heathland is commonly developed in such areas, as seen here at Kelling Heath.

Photo © Robin Stevenson

The distribution of lime-loving and lime-hating plant species reflects variations in soil moisture and chemistry overlying periglacial patterned ground, consisting of alternating chalky and sandy subsoils. Grimes Graves SSSI.

[7]M Shepherd (2009): *Estimating Carbon Storage in Peatlands Within English National Parks* (Unpublished report, Natural England)

2.6 Cultural resources

Norfolk has a geocultural heritage of museum collections and information archives. The county's geology, landforms and archaeology have been the subject of active scientific research for over two centuries, during which many significant collections of specimens and associated photographs and documents have been compiled.

Notable local collectors include R Fitch (19th century), JE Sainty and N Peake (20th century); in many cases their material is archived by the Norfolk Museums and Archaeology Service or regional museums such as the Sedgwick Museum, Cambridge[8]. Such collections are important for scientific study: they may include type and figured material, and may hold specimens and samples from sites that are no longer accessible; sediment samples from the Ludham borehole (1959) are a case in point, as they have been preserved by the British Geological Survey and are still available for study 50 years later. Photographic archives, such as the Hallam Ashley, may provide useful evidence of now-vanished geological exposures and landforms.

Norfolk Landscape Archaeology holds important information relevant to geodiversity, including an archive of archaeological finds and the Norfolk Historic Environment Record, a database of all known archaeological sites and finds in the county, including Palaeolithic. It is backed up by an archive of aerial photographs which show landscape as well as archaeological features.

Photo © British Geological Survey P234674

Alfred Savin's collection of elephant and mammoth teeth from the Cromer Forest-bed, 1896. The collection is now curated by the Norfolk Museums and Archaeology Service.

Photo © Tim Holt-Wilson with kind permission of Colchester and Ipswich Museums

A Mosasaurus tooth from the Chalk of Norwich, preserved at Ipswich Museum. St James' Pit, Norwich, is designated as a SSSI for its fossils of the marine reptiles Mosasaurus and Leiodon.

[8]The Norfolk Museums and Archaeology Service alone curates over 40,000 geological and over 1000 Palaeolithic specimens from Norfolk

3 Conserving Norfolk's Geodiversity

Nature conservation has been defined as:

> ***'the protection, preservation, management or enhancement and the improvement of understanding and appreciation of flora and fauna and geological and geomorphological features'*** [9].

Nature conservation has great popular appeal. Big advances have been made in the official conservation of biodiversity (fauna and flora) since 1994[10], backed up by a range of national, regional and local Action Plans. However until recently, less attention has been paid to geodiversity; it has not enjoyed such wide understanding and support, even though it forms the physical context for all life on Earth, and the story of the development of our planet and its life forms, including humans, fascinates people of all ages. Norfolk's geodiversity has many special features worthy of conservation.

This section sets out the background to geoconservation in the county, explaining the policies and practices which facilitate this work, and giving a brief summary of the range of threats to the county's Earth heritage. It then goes on to list a set of conservation priorities for the county.

3.1 Geoconservation - the policy background

Statutory geoconservation

The statutory conservation of geodiversity features is part of the remit of National Parks, National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). These site and area designations are a precious geoconservation resource. The Norfolk and Suffolk Broads has the status of a National Park. There are 20 NNRS in Norfolk, and 39 SSSIs designated primarily for their Earth heritage interest (about 23% of the total). Geological SSSIs in Norfolk were selected as part of the Geological Conservation Review (GCR), a national review undertaken between 1977 and 1990[11]. SSSIs are administered by Natural England, and there is an ongoing programme of condition monitoring and management. See Appendix 4 for a list of geodiversity SSSIs in the county. The 123 remaining SSSIs are primarily designated for their biodiversity, while geodiversity plays a secondary role as a habitat factor. Seen from a regional perspective, Norfolk has a disproportionately large share of significant geodiversity sites, and is particularly important for its Quaternary and Lower Cretaceous heritage. See Appendix 4 for breakdown of GCR citations in Norfolk compared with regional totals.

[9] Definition from the Glossary of *Planning for Biodiversity and Geological Conservation - A Guide to Good Practice* (ODPM 2006)
[10] The UN Convention on Biodiversity, agreed at the Rio Earth Summit in 1992, and ratified in 1994.
[11] See the Introduction to the GCR at http://www.jncc.gov.uk/page-2947.

Water

Water is an important geodiversity resource which receives statutory protection through a range of laws and regulations[12]. It is managed by the Environment Agency through its Groundwater Protection Policy and the designation of Source Protection Zones, which are monitored for pollution and contamination. Water abstraction is managed by the Agency through Catchment Abstraction Management Strategies; both pollution and abstraction in Norfolk will be managed under the new Anglian River Basin Management Plan. The risk of flooding is managed through Catchment Flood Management Plans.

Soils

There is no legal framework for directly protecting and conserving soils in the UK. However action for soils is gathering momentum, backed by a Soil Action Plan[13], an Environment Agency report[14] and a DEFRA strategy document *Safeguarding our Soils – A Strategy for England*[15]. The latter addresses the role of peat deposits in storing and potentially capturing carbon. A Soil Framework Directive has been proposed by the European Commission[16] to address the range of threats to soils. The Water Framework Directive influences soil conservation by addressing the issue of pollution in surface water caused by farming activities, e.g. through designation of Nitrate Vulnerable Zones (over 90% of Norfolk is so designated).
Traditionally, soil has been valued in economic and functional terms; however its intrinsic conservation value, its geodiversity and associated archaeological and palaeo-environmental archives, is being increasingly recognised. Soil conservation is an important issue in Norfolk. Although the variety of the county's soils has been mapped, their diversity has not been evaluated and is not monitored for conservation purposes. However good soil management on farms may be included among the objectives of Environmental Stewardship and Catchment Sensitive Farming[17] schemes. Agricultural quality is conserved through Natural England's Agricultural Landscape Classification scheme.

Coastal processes

Norfolk has 98 km of coastline with conservation designations, more than any other county in eastern or southern England. *Planning Policy Guidance 20: Coastal Planning* (PPG20)[18] covers the coastal zone; it provides guidance on managing the impact of development on landscape and the natural environment (including coastal processes), and managing risk (flooding, erosion, landslips). The operation of coastal processes is managed by the Environment Agency through Shoreline Management Plans[19]. Flooding and coastal erosion are managed by a combination of planned defences and natural evolution. Coastal erosion is a live political issue in Norfolk, which has one of the fastest eroding coastlines in Britain. There is a need to communicate the scientific realities behind coastal processes, to promote greater public understanding of the long-term inevitability of loss to land and property faced with rising sea levels.

[12]Including the European Nitrates Directive 1991, the Groundwater Regulations 1998, the Water Framework Directive 2000, the Nitrate Pollution Prevention Regulations 2008.
[13]*The First Soil Action Plan for England*: 2004-2006 (DEFRA 2004)
[14]*The State of Soils in England and Wales*. Environment Agency (2004)
[15]See http://www.defra.gov.uk/environment/quality/land/soil/documents/soil-strategy.pdf.
[16]See http://ec.europa.eu/environment/soil/index_en.htm
[17]See http://www.defra.gov.uk/foodfarm/landmanage/water/csf/index.htm
[18]*Planning Policy guidance 20 - Coastal Planning*. Department of the Environment (1992)
[19]See http://www.environment-agency.gov.uk/research/planning/105014.aspx

Local sites

The non-statutory conservation of geodiversity sites is principally carried out under Local Sites designation procedures (DEFRA 2006)[20] , of which Regionally Important Geological / geomorphological Sites (RIGS) are the most widely designated category, although the network is not yet fully extended across the UK[21]. Despite its name, RIGS is a local rather than a regional designation. There are currently five RIGS in Norfolk, and they have the same status in planning as County Wildlife Sites. Local Sites designation is a voluntary agreement between the designating body and the site owner / manager to promote positive conservation management of features of interest, and does not imply any legal obligations nor confer any right of access. Over 280 potential Local Sites / RIGS have been identified in Norfolk through an audit commissioned by the Norfolk Geodiversity Partnership. Its purpose is to provide baseline information for planning purposes as well as suggesting candidate sites for possible designation. The term RIGS is being phased out, and Norfolk's RIGS may in future be renamed Local Geological Sites or County Geodiversity Sites.

Although Local Sites enjoy no legal protection local authorities give them a degree of protection from development through planning policies set out in the Local Development Framework (LDF) and Minerals & Waste Development Framework processes. *Planning Policy Statement 9: Biodiversity and Geological Conservation* (PPS9) was published in 2005 and sets out government policies on conserving geodiversity through the planning system in England[22]. It views the delivery of geoconservation as one of the objectives for sustainable development, nature conservation and social renewal, and lends important support for local efforts to conserve sites and features. For example, it states that local planning authority policies should attach 'appropriate weight' to designated sites and also 'geological interests in the wider environment[23]'. Significantly, PPS9 states that local authority plans and policies should be based on up-to-date information about the environmental characteristics of the areas. It also states that the aim of planning decisions should be to prevent harm to geological conservation interests, and it establishes the principle that where harm is unavoidable adequate mitigation measures should be put in place, or as a last resort planning permission should be refused; Section 106 agreements can be used to deliver such benefits for geodiversity. An opportunity exists to include baseline geodiversity indicators in the Sustainability Appraisal system in the LDF process. Furthermore, as is the case in Norfolk, the condition of RIGS may be adopted by local authorities as an indicator of natural environmental protection under the local authority performance framework target NI 197: Biodiversity[24]. Also, the planning application validation process (known as 1App) includes a requirement for the consideration of geodiversity interest, which might involve consideration of RIGS or other designated local geodiversity sites by applicants. This requirement tends to be compromised by a lack of awareness of geodiversity on the part of both planners and applicants, and the protection afforded by 1App could be strengthened through the issue of guidance notes for planners and developers in the same way as exists for biodiversity.

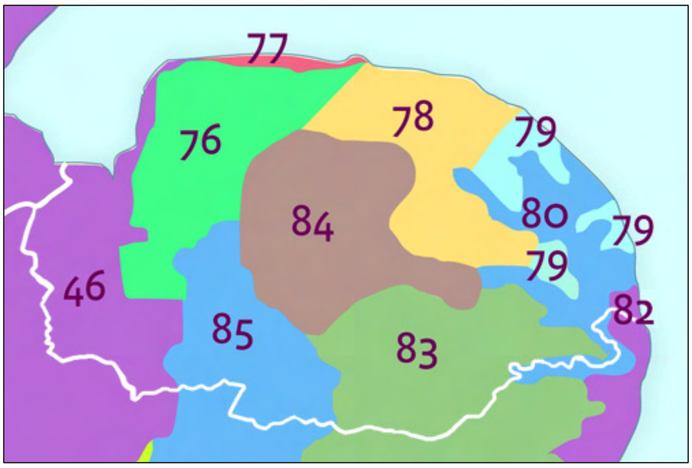
[20] *Local Sites. Guidance on their identification, selection and management*. Department for Food and Rural Affairs (2006)
[21] *UKRIGS Development Strategy 2006-2010*. The Association of UK RIGS Groups (2006)
[22] *Planning Policy Statement 9 - Biodiversity and geological conservation*. Office of the Deputy Prime Minister (2005)
[23] See PPS9, Key Principles, section 2.
[24] See http://www.defra.gov.uk/corporate/about/with/localgov/indicators/ni197.htm

Archaeology

Archaeological features of national importance may receive statutory protection by English Heritage as Scheduled Monuments, however this designation covers only deliberately created ones. Those that are not deliberately created cannot be scheduled, for example Palaeolithic sites or Holocene peat beds with associated archaeology, as at Titchwell and Holme-next-the-Sea; furthermore there may be difficulties in physically protecting such features, for example in a dynamic coastal environment. Such archaeological remains and associated palaeo-environmental material must be conserved through the local planning process. The conservation of heritage assets takes place under the policy direction of *Planning Policy Statement 5: Planning for the Historic Environment* (PPS5)[25]. Conditions may be placed on developments to preserve or mitigate damage to archaeological features. Maintenance of archaeological records for planning purposes in Norfolk is the responsibility of Norfolk Landscape Archaeology, and takes place within a strategic research framework which includes a Palaeolithic and Mesolithic agenda[26]. Buried resources from these periods are the least well known but are most impacted by aggregate extraction. Much important information has doubtless been lost from sand and gravel quarries (e.g. Keswick, Whitlingham) developed in river terrace deposits. Archaeological resource evaluation for these periods is at an early stage in Norfolk, and consequently is only patchily addressed by the development control process.

Landscape

Geodiversity contributes the fundamental elements of landscape directly through geology, geomorphology and soil type, and indirectly through the influence of geology on patterns of land use, settlement, etc. The foundations for landscape conservation were laid in the 1990s through the Natural Areas and Countryside Character Area programmes of English Nature and the Countryside Commission; these characterised variations in natural and cultural heritage at a national scale. In Norfolk, nine terrestrial and three marine Natural Areas were identified for their biodiversity and geodiversity. These schemes have now been replaced by Natural England's National Character Areas (NCA) programme[27]. NCA and Natural Area documents provide summaries of Norfolk's landscapes, and their varied geodiversity, biodiversity and landuse.



The National Character Area map for Norfolk

46. The Fens
76. North West Norfolk
77. North Norfolk Coast
78. Central North Norfolk
79. North East Norfolk & Flegg
80. The Broads
82. Suffolk Coast & Heaths
83. South Norfolk & High Suffolk Claylands
84. Mid Norfolk
85. Breckland

[25] See http://www.communities.gov.uk/publications/planningandbuilding/pps5
[26] Brown, N, and Glazebrook, J (eds) (2000): *Research and Archaeology: a Framework for the Eastern Counties* (East Anglian Archaeology Occasional Paper No.8). Revised 2008.
[27] Formerly known as Joint Character Areas.

At a more local scale, Norfolk's variety of landscapes has been mapped and described to varying degrees through procedures of Landscape Character Assessment (LCA) and Landscape Description[28]. The national policy driver for this is *Planning Policy Statement 7: Sustainable Development in Rural Areas* (PPS7)[29]. These procedures bring together information about topography, soils, landuse and 'sense of place' to generate qualitative information about the character and appearance of landscape in the county. The resulting datasets may be used to produce maps and policy guidance to inform planning decisions that respect local distinctiveness, including Earth heritage. However, unlike the historic landscape for example[30], Norfolk's geomorphological landscape, its natural topographic character and component landforms, has not been mapped and characterised. As a result the contribution of landforms and physical processes to landscape character has been systematically underestimated. Conserving physical landscape will require sympathetic development control policies and a commitment to describing explicitly geodiversity in statements of landscape character.

The European Landscape Convention (ELC) came into force in the UK in 2007, and promotes the protection, management, planning and the wider understanding and appreciation of landscapes. The lead implementing agency in Norfolk is Natural England, and it supports existing work in the county on landscape characterisation and interpretation for public benefit. The ELC defines landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'.

Non-statutory geoconservation may also be an important part of landscape designations such as the AONBs and Heritage Coasts in England, and parts of the north Norfolk coast are so designated[31]. Local planning authorities may designate Conservation Areas to include landscape features[32;]; North Norfolk District Council, for example, has designated the area of the Glaven Valley. Important landowning organisations such as the National Trust, the Norfolk Wildlife Trust and the Royal Society for the Protection of Birds are examples of conservation organisations which routinely protect geodiversity as part of their remit. Many countryside and green infrastructure partnerships and local conservation trusts also do the same. Landowners may conserve geodiversity on their land as part of enhancement of landscape, habitat and historic features. Natural England's Environmental Stewardship Scheme[33] contains measures which may support the conservation of local geodiversity features, for example maintaining and enhancing landscape quality and character, and protecting the historic environment and natural resources.

Links with biodiversity

The Norfolk Biodiversity Partnership is actively promoting the conservation of species and habitats in Norfolk through a range of species and habitat action plans[34]. The latter may

[28]Landscape Character Areas (LCAs) and Landscape Description Units (LDUs) have been defined. Historic Landscape Characterisation has also been carried out, to map the landscape in terms of its historic origin.
[29]*Planning Policy Statement 7: Sustainable Development in Rural Areas* Office of the Deputy Prime Minister (2004).; see sections 24 and 25.
[30]*Norfolk Historic Landscape Characterisation. Final Report April 2009* (Landscape Archaeology Unit, Norfolk County Council)
[31]See http://www.norfolkcoastaonb.org.uk/
[32]See Section 69 of the Planning (Listed Buildings and Conservation Areas) Act, 1990.
[33]See http://www.naturalengland.org.uk/ourwork/farming/funding/es/default.aspx
[34]See http://www.norfolkbiodiversity.org/

directly benefit geodiversity by conserving significant landform elements, for example coastal sand dunes, littoral and sublittoral chalk, maritime cliffs and slopes, and chalk rivers.

New approaches

The strength of a site-based approach is that it draws conservation attention to a designated feature of interest; the weakness is that it implicitly treats features outside the designated area as having lesser importance. Given the policy direction of PPS9 towards conserving 'geological interests in the wider environment', the need for a more holistic approach is indicated. Faced with ongoing, diffuse threats to geodiversity, such as development pressures at a landscape level, the site-based approach may be insufficient adequately to protect geodiversity in the wider landscape. Geographic Information Systems (GIS) and vulnerability mapping techniques offer new possibilities for geoconservation. For example, the Landmap programme in Wales combines geodiversity, biodiversity, historical/ archaeological, cultural, visual and sensory datasets to provide an integrated landscape planning tool[35]. A related approach may involve identification and designation of 'geological landscape assemblages', areas of land with significant concentrations of geodiversity assets, although current government policy favours a shift from landscape designation to 'criteria-based policies' in planning. In 2008 Norfolk County Council began work drafting a vulnerability mapping project for buried Palaeolithic and Mesolithic archaeological resources at risk from aggregate extraction and other processes in the Little Ouse, Waveney and Yare valleys[36].

See Appendix 5 for guidance on conserving and enhancing geodiversity through planning in Norfolk.

[35]See http://landmap.ccw.gov.uk/ .
[36]Ward, I (2009): *A Statistical Approach to Vulnerability Mapping of Archaeological Resources along the Waveney, Yare and Ouse River Corridors* (Project Design, Version 2; Norfolk Archaeological Unit)

3.2 Geoconservation – threats to Norfolk's geodiversity

Norfolk's geodiversity comprises a unique range of Earth heritage resources which have been exploited for human benefit for many thousands of years. However the integrity and accessibility of these resources is under constant threat.

The principal threats can be summarised as:

Loss of geological exposures and/or information through

- burial by coastal protection, landfill, landscaping or other planned development;
- burial by dumping and fly-tipping;
- vandalism and graffiti;
- natural processes, such as slumping of unconsolidated sediments and vegetation encroachment;
- non-recording and sampling of temporary exposures, including road cuttings and quarry sections;
- damage to palaeo-environmental archives in peat and alluvium through drainage and excavation.

Photo © Tim Holt-Wilson

A disused gravel pit at Hoe. Poorly consolidated Pleistocene sediments are very prone to slumping and scrub overgrowth, which may make access to geological information more difficult.

Photo © Tim Holt-Wilson

Castle Drain at Wormegay. Artificial channelisation of water courses destroys wildlife habitat and causes peat to dry out and oxidize, so reducing its carbon storage capacity and damaging palaeo-environmental fossil archives.

Photo © British Geological Survey P210193

The King's Lynn bypass cutting at Mintlyn Wood, 1965, showing new exposures of sandy clays and ironstones in the Sandringham Sands. Important local geological information may be lost if temporary excavations are not recorded and sampled.

Photo © Gilbert Addison

Graffiti damage at Dersingham Sand Pit, part of a SSSI and the type-site of the Lower Cretaceous Dersingham Formation.

Photo © Tim Holt-Wilson

A coastal protection reef at Sea Palling. Such hard sea defences are likely to alter the sediment supply to beaches and sandbanks further along the coast.

Damage to the physical landscape and its geomorphological features and processes through

- coastal protection schemes;
- inshore dredging;
- land drainage and river management schemes, including flood protection;
- anthropogenic landform developments, such as bunds, cuttings, quarries and embankments;
- built development, including infrastructure improvement.

Photo © Tim Holt-Wilson

The River Nar at Middleton. The river is artificially embanked and is perched over two metres above its floodplain. It is now prone to siltation and disconnected from a formative relationship with its floodplain.

Photo © ADAS

Catton Grove Chalk Pit is a designated SSSI and type-site of the Catton Sponge Bed. The site was partly landfilled in the 1970s, but access to a representative Chalk exposure was safeguarded by constructing a wall of stacked gabions (left).

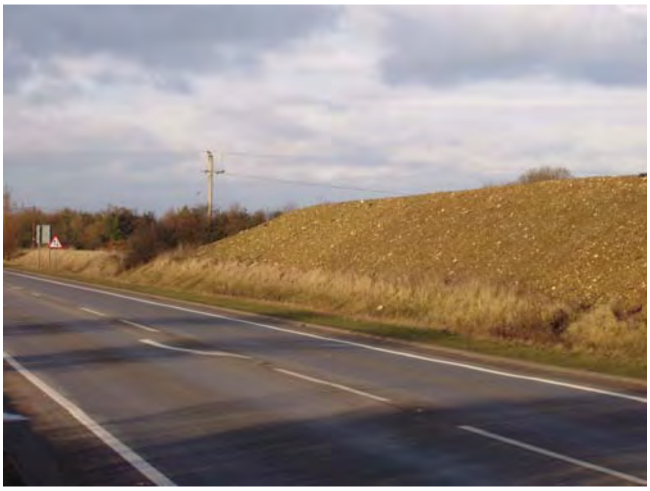


Photo © Tim Holt-Wilson

A high screening bund beside the Dickleburgh bypass. This artificial landform is at stark variance with the flat landscape of the surrounding South Norfolk glacial till plateau.

Damage to soil features and processes through

- destruction of soil profiles and structure, including compaction;
- drying out and shrinkage of peat;
- acidification and ochre accumulation;
- soil erosion;
- soil contamination;
- import of materials for filling and ground-raising

Damage to groundwater and surface water through

- pollution and contamination;
- soil acidification;
- over-abstraction.

And lastly, and perhaps most importantly:

Lack of public understanding about geodiversity, and why it is valuable to society for its contribution to economic life, science, wildlife, leisure and recreation.

Photo © Robin Stevenson

A dust storm at Beachamwell, March 2007. The silty soils of Breckland are prone to wind erosion, particularly if they are left bare in spring time.

Photo © Tim Schofield

De-stoning in a field in the Bure catchment. Removal of stones from fields makes cultivation easier. However it leads to progressive damage to soil structure and some archaeological features.

Photo © Tim Holt-Wilson

Mundesley Cliffs SSSI is designated for its exposures of Pleistocene sediments of the Cromer Forest-bed Formation and the Pastonian Stage. Sea defences here have stabilised the cliff, and the geological interest is now obscured by slumping and vegetation.

Photo © Tim Holt-Wilson

The Blakeney Esker is a glacial outwash feature almost unique in southern England, but about 40% of it has been quarried away. Part of its truncated body can be seen here at Blakeney Downs quarry.

3.3 Geoconservation – principles and priorities

Given the importance of Norfolk's geodiversity and the range of threats it faces, we propose a set of priorities to guide a programme of action.

This is based on geoconservation principles set out in the Earth Science Conservation Classification System (ESCC)[37], which has established a framework for deciding the conservation management requirements of geodiversity. It is based on the differing vulnerabilities of three kinds of site and feature (Exposure/Extensive, Integrity and Finite), and suggests different strategies for their conservation. See Appendix 6.

Geoconservation priorities

While all Norfolk's geodiversity has value and is worth conserving in its own right, the principles of the ESCC suggests the need to prioritise the conservation of certain features which are more significant or vulnerable. A schedule of geoconservation priorities for Norfolk is presented here.

A. GEOLOGICAL

Geological features from all stratigraphic horizons including

- representative occurrences of all stratigraphic units, including new ones when identified: sites designated as stratotypes are a priority for conservation, also lithostratigraphic type sites designated for their group / formation / member / bed status, also fossil type localities (Norfolk has national and international examples of such sites);
- stratigraphic boundaries and basement beds;
- unconformities;
- sites showing structural features such as faults and folds;
- fossiliferous beds, including those with microfossils which are important geo-archives;
- valuable examples of sedimentary structures, both primary and deformational;
- river terrace stratigraphy;
- occurrences of minerals (sensu stricto);
- palaeosols;
- hominid and associated palaeo-environmental evidence;
- interdigitating marine and terrestrial sequences;
- sites having a history of Earth science research.

B. GEOMORPHOLOGICAL

All kinds of relict and active landform and their generative processes are under-researched in Norfolk. Good examples of them all are priority features.

[37] Nature Conservancy Council: *Earth science conservation in Britain, a strategy*; Peterborough (1990); and amended: English Nature: *Geological conservation, a guide to good practice*; Peterborough (2006).

Aeolian	Erosional and depositional landforms and their processes (e.g. dunes (inland and coastal) and blow-outs)
Coastal	Erosional and depositional landforms and their processes (e.g. spits, nesses, bars, cliffs, saltmarshes; raised beaches and relict cliffs)
Fluvial	Erosional and depositional landforms and their processes (e.g. gullys, river terraces, meanders, examples of channel migration)
Glacial	Moraines; eskers; kames; erratic boulders; meltwater channels; outwash fans and plains
Groundwater	Springs and spring-lines; spring-sapping hollows; dune slacks;
Karst	Bournes; dolines and solution hollows; swallow-holes; seasonal meres
Lacustrine	Natural lakes
Mass movement	Active and relict landslides; terracettes; solifluction slopes
Tectonic	Fault scarps
Periglacial	Patterned ground; relict pingos, palsas and naleds; 'hummocky ground'; thermokarst hollows;
Impact	Meteorite impact features

The wider landscape

Many parts of the Norfolk landscape may be characterised as gently rolling or undulating plateau areas with intervening slopes and shallow valleys. Although it looks undramatic, this natural physical land form is essential to the county's landscape character, and is under threat from the cumulative, diffuse impact of artificial landforms such as embanking and bunding, infill and other 'landscaping' which alter the natural form of the land surface. What may be appropriate in one topographical context (e.g. a mound of landscaped landfill in a hummocky drumlin landscape) may be entirely inappropriate in flat Fenland or the South Norfolk till plain.

There is a general need to recognise the value of, and to protect, land form outside areas of designated landscape quality such as AONBs. This will mean improving the description of the physical landscape and its components in LCA and LDU work[38]. Natural, authentic land form is as much a priority for protection as the biological or cultural character of Norfolk's landscape[39].

C. SOILS

Soil sections exhibiting clear, undisturbed soil profiles of a particular soil type / association are priority features, as are soils which exhibit response to natural processes and demonstrate natural functions. Examples of palaeosols are a priority, particularly if they are vulnerable by being close to the present surface. Keeping peat soils in a waterlogged state is a priority to retain their carbon storage capacity.

D. WATER

Examples of naturally functioning hydrological systems with natural hydrochemical features are priority features in Norfolk.

[38] See page 3.1 (Landscape) above
[39] Gray, M. (2006): *Conserving geodiversity in the wider landscape – making it happen* (unpublished research report; English Nature)

E. LINKS WITH BIODIVERSITY

Examples of geodiversity features which contribute to the conservation of priority habitats identified in the UK Biodiversity Action Plan[40] .

F. ECONOMIC AND CULTURAL

Sites and features exhibiting clear associations with economic and cultural value are priorities. Such sites include those which exemplify

- brick-making and mineral working by retaining original buildings (e.g. lime kilns), equipment and worked faces;
- the unique contribution of Norfolk to the history of Earth science;
- use of geological materials for building purposes;
- the role of geodiversity in folk culture.

G. EDUCATION AND RESEARCH

Sites and features with a clear yield for educational and research purposes are a priority. Such sites may include those with potential for demonstrating geology and geomorphology in schools as part of the National Curriculum, and those with a history of published or unpublished scientific research or investigation (including stratotypes), or with likely potential for investigation.

Museum collections and archives relating to the geology of Norfolk, including specimens, photographs and geological records, may be a precious and irreplaceable resource for science and education. Their long-term preservation and the dissemination of the information contained in them is a priority.

[40] See http://www.ukbap.org.uk/PriorityHabitats.aspx for habitats list and descriptions.

3.4 Geoconservation practice

Some of the most important geodiversity sites and features in Norfolk enjoy a measure of statutory protection as SSSIs. Their designation documents include a list of operations likely to damage the site, and a statement about the management needs of the site. Listed operations cannot be carried out by the site owners or managers without the consent of Natural England.

In the case of sites and features outside the network of statutorily protected sites, their geodiversity interest may be conserved by voluntary agreement with the landowner. Non-statutory Local Site designation is one way forward; another is to provide information support at a local level.

Voluntary effort and partnership working are central to conserving Norfolk's geodiversity, through raising popular awareness and developing practical action.

For advice on identifying geodiversity features in your locality and practical guidance on their conservation management, please contact the Norfolk Geodiversity Partnership:

- Jenny Gladstone: tel.: 01603-619387; email: jennygladstone@aol.com
- John Hiskett : tel.: 01603-625540; email: johnh@norfolkwildlifetrust.org.uk
- Tim Holt-Wilson: tel.: 01379-870411; email: timholtwilson@onetel.com

To find out more about practical geoconservation, read the sources listed in Appendix 1.

4. Working in Partnership

Work to value and conserve geodiversity in Norfolk is being co-ordinated by the Norfolk Geodiversity Partnership (NGP). The NGP developed in 2007 from a geoconservation group, the Norfolk RIGS Committee. It is a voluntary association of organisations and individuals who are committed to conserving and enhancing Norfolk's special Earth heritage, and acts as an umbrella group to promote geoconservation in the county. It is developing relationships with a wide range of organisations and individuals, for example museums, land owners and managers, government agencies and quarry companies.

In 2008 Natural England offered the NGP funding to develop a Geodiversity Action Plan (GAP) for Norfolk. GAPs provide a new comprehensive approach to conserving Earth heritage, setting out a management framework for geology, geomorphology, soils and water resources for a defined area or an organisation. GAPs are modelled on the successful Biodiversity Action Plan format for managing the conservation of species and habitats in Britain. Since 2004 a range of Local GAPs have been prepared in the UK, covering various Areas of Outstanding Natural Beauty, counties, metropolitan areas and national parks. There are aggregate company GAPs, and a national UKGAP is currently at an advanced drafting stage.

A Norfolk Geodiversity Action Plan (NGAP) has been prepared to accompany this book. It aims to bring about a qualitative change in the way that Norfolk's Earth heritage is conserved and communicated. You are invited to contribute actively to the realisation of the Plan; maybe you are already doing so.

Photo © River Glaven Conservation Group

Removal of embanking along the river Glaven at Hunworth 2009, to help restore the river’s connection with its floodplain.

Action for geodiversity

A wide range of individuals and organisations are involved with conserving and promoting Norfolk’s geodiversity, either directly or indirectly. Action is happening in various ways across the county, as part of daily life and business. For example:

- river restoration work;
- maintaining museum displays relating to Earth heritage;
- conserving landform features as part of farm Environmental Stewardship;
- lectures, field trips and evening classes on the county’s Earth heritage;
- landowners permitting access to geological features for study and fossil collecting;
- monitoring condition of SSSIs, also Local Sites for NI197;
- maintaining historic environment records;

Photo © Jenny Gladstone

Aldeby gravel pit is now disused and landscaped. However a conservation section has been retained as part of site after-use planning by Norfolk County Council, 2008.

- developing the Norfolk Biodiversity Action Plan, particularly as it relates to habitats;
- conserving geodiversity features in wildlife reserves such as County Wildlife Sites;
- outdoor interpretive panels explaining the links between geodiversity and biodiversity;
- publishing information about landscape and environmental history;
- surveying and mapping geological and geomorphological features;
- incorporating geodiversity conservation into Local Development Framework documents;
- educational work at Field Centres;
- including geoconservation objectives into after-use plans at mineral extraction sites;
- amateur and academic research into Norfolk's geology, environment and archaeology including specimen collecting;
- local activities related to Geo-East's 'Chalk East' project;
- protecting soils and groundwater through the Catchment Sensitive Farming initiative.

These actions are links in a network of official and unofficial activity helping to promote the aims of the Norfolk Geodiversity Action Plan.

Photo © BGS©NERC.

An interpretation panel is being installed by the British Geological Survey at Wiveton Downs explaining the origins and significance of the Blakeney Esker.

Photo © Martin Warren

A Cromer Museum guided walk 2008 to see geological features at West Runton cliffs, including the Cromer Forest-bed.

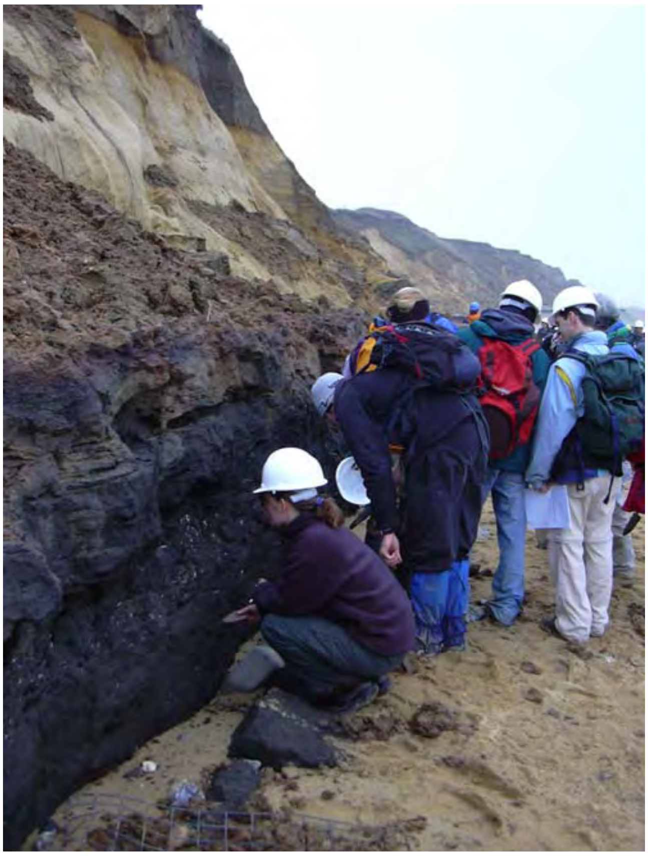


Photo © Dr Kim Cohen, Department of Geography, University of Cambridge

Communicating geology: university students studying the sediments of the West Runton Freshwater Bed.

The Norfolk Geodiversity Action Plan

The NGAP presents a set of objectives, actions, lead agents and timescales for the current period. Other actions may be introduced as resources allow, for example if taken up by partners. The NGAP has five work areas:

Work Area 1 – Understanding our geodiversity resources

Norfolk's geodiversity comprises cultural as well at natural resources. We need to understand these resources and their vulnerabilities in order to promote their conservation and enhancement.

This work involves carrying out an audit of the county’s geodiversity, using published sources and personal communications to build a list of significant sites and features in the field, and also cultural resources such as museum collections. The next step is to verify and assess this information by means of a ground-truthing programme.

Work Area 2 – Embedding geodiversity in plans and policies

The plans and policies of local and regional government and other organisations such as quarry companies have an impact on the geodiversity resource. We need to promote geodiversity conservation and enhancement by reviewing and contributing to these plans and policies.

This work involves responding in detail to public consultations, and may involve recommending policy formulations. Geodiversity information outreach may be a supporting aspect of this work.

Work Area 3 – Protecting and enhancing our geodiversity resources

Norfolk's geodiversity resources are subject to a range of threats, and even statutorily protected sites and features may be at risk. We need a conservation and enhancement programme both for designated sites and for geodiversity in the wider environment.

This work involves using the results of the geodiversity audit and a schedule of geoconservation priorities to identify candidate sites and features for Local Sites designation. These sites may then be designated and Site Management Plans agreed with their owners/managers to gain positive conservation management.
Other work includes monitoring the condition of designated sites, recording temporary geological sections, and developing practical resources for geoconservation such as volunteer labour. It may be necessary to explore new approaches to protecting geodiversity assets in the wider environment away from designated sites.

Work Area 4 - Promoting geodiversity awareness and understanding

One of the greatest threats to Norfolk's geodiversity is a lack of understanding of its importance as a fundamental resource. We need to promote public awareness of our Earth heritage as widely as possible.

This work involves publishing information about Norfolk's geodiversity, the Action Plan and other initiatives for geodiversity. It includes educational work and tourism focused on Norfolk's Earth heritage, and also contributes to regional action for geodiversity.

Work Area 5 – Managing the Norfolk Geodiversity Action Plan

The sustainability and success of the Norfolk GAP will depend on the strength and commitment of the Partnership. We will need to develop the Partnership as a key means of sustaining the GAP process.

This work involves managing and enhancing the Partnership and taking forward the NGAP, for which developing funding resources may be necessary. It will involves contributing to regional and national geoconservation initiatives.

An invitation

We invite you to join the Norfolk Geodiversity Partnership, and support the development and implementation of the Action Plan.

We also invite you to share information about your / your organisation's activities and achievements for Norfolk's geodiversity. This can be published through a Norfolk Geodiversity Partnership newsletter and website. Please contact:

Jenny Gladstone	01603-619387	jennygladstone@aol.com
John Hiskett	01603-625540	johnh@norfolkwildlifetrust.org.uk
Tim Holt-Wilson	01379-870411	timholtwilson@onetel.com

Appendix 1 - Information resources

1) Geodiversity in Norfolk

- Background
- Specialist sources
- Soils
- Water
- The Palaeolithic
- Landscape character
- Designated sites and areas

2) General geodiversity

3) Geoconservation

- General geoconservation
- Geoconservation in planning
- Geoconservation and biodiversity
- Geoconservation and the minerals industry

4) Geodiversity in education

5) Geodiversity in Museums

6) Geodiversity groups

Please notify the Norfolk Geodiversity Partnership if you know of any resources which you think should be included in this list. The hyperlinks were correct in August 2010.

1) Geodiversity in Norfolk

Background

From the early 19th century onwards, many hundreds of books and scientific papers have been written about the geology and landforms of Norfolk. Unfortunately, there is little introductory material on Norfolk geodiversity written for the general reader.

'Nature in Norfolk. A Heritage in Trust' (Jarrold & Sons, Norwich; 1976) has several excellent essays on Earth heritage and links between geodiversity and habitat.

'An Historical Atlas of Norfolk' by P Wade-Martins (ed) (Norfolk Museums Service; 1994) contains short chapters on the physical character of the county and early human settlement.

'British Regional Geology: East Anglia and Adjoining Areas' by CP Chatwin (HMSO 1961) - a useful short guide to the region, although the 'Superficial Deposits' and 'Early Man' sections need urgent revision.

The Norfolk Museums and Archaeology Service website has introductory pages on Norfolk geology, including the West Runton Elephant and information sheet downloads, and also a bibliography of N Norfolk geology and a Field Guide to NE Norfolk by Martin Warren. See http://museums.norfolk.gov.uk/default.asp?Document=400.500.

The Natural England website has an excellent summary of Norfolk geology. See http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/englands/counties/area_ID24.aspx.

'A Flora of Norfolk' by G Beckett and A Bull (Gillian Beckett; 1999) contains fine introductory chapters covering the influence of geology and soils on landscape, species, habitats and landuse history.

'The Land-use, Ecology and Conservation of Broadland' by M George (Packard, Chichester; 1992) provides unparalleled detail about the geology, physical and human geography of the Broads, including water, soils and natural history.

'Geology of northeast Norfolk: Hunstanton to Happisburgh' by J Eyers (Rocks Afoot Field Guide Series; 1998) (see http://www.rocksafoot.com/).

Introductory books on the evolution of the landscape include:

- 'England's Landscape: East Anglia' by T Williamson (Collins; 2006;)
- 'Southern England: The Geology and Scenery of Lowland England' by P Friend (Collins New Naturalist Library; 2009.)

Specialist sources

The British Geological Survey online publications catalogue, including Sheet Memoirs and maps for most parts of the region and some of Norfolk. See http://www.bgs.ac.uk/catalogue/home.html. See also the old 19th century Memoirs of the Geological Survey of Great Britain which cover most districts in the county. For online information about rock units and stratigraphic terminology, including a concordance of old and new terms, see the BGS Lexicon of Named Rock Units at http://www.bgs.ac.uk/lexicon/.

'The Geology of Norfolk' by GP Larwood and BM Funnell (eds) (Transactions of the Norfolk and Norwich Naturalists' Society Vol.19, pt.6; 1961) is a valuable collection of papers (re-edited in 1970), although the information about glacial deposits now needs substantial revision.

The Geological Society of Norfolk publishes an annual Bulletin of specialist articles on various aspects of East Anglia geology and geomorphology. See http://www.norfolkgeology.co.uk/.

The Quaternary Research Association regularly conducts specialist field trips in Norfolk, and publishes associated scientific papers in its annual Field Guides. Editions relevant to Norfolk include

- 'Pliocene-Middle Pleistocene of East Anglia' (1988)
- 'Central East Anglia and the Fen Basin' (1991)
- 'The Quaternary of Northern East Anglia' (2000)
- 'The Quaternary Mammals of Southern and Eastern England' (2004)
- 'The Quaternary of Norfolk and Suffolk' (2008)

See http://qra.org.uk/.

The complexities of the Pleistocene of Norfolk are subject to lively, ongoing debate. Readers looking for an introduction to this challenging period, for which Norfolk is famous, could do worse than begin with 'Pleistocene Environments of the British Isles' by RL Jones and DH Keen (Chapman and Hall 1993). This is a compendious summary of the changing environments of the Pleistocene, including biodiversity and human settlement, and 55 pages of references. Norfolk sites are well represented.

Recent thinking on stratigraphic terminology for Pliocene, Pleistocene and Holocene rock units is to be found in DQ Bowen (ed): 'A Revised Correlation of Quaternary Deposits in the British Isles' (Geological Society of London Special Report No.23; 1999).

The vertebrate fossils of the famous Cromer Forest-bed are dealt with in 'Fossil Vertebrates of the Cromer Forest Bed in Norwich Castle Museum' by B McWilliams (Norfolk Museums Service; 1975).

An account of the excavation of early Pleistocene vertebrate fossils at Norton Subcourse is presented at http://www.bohomedia.com/hippositenew/.

Details of the geology, landslides and coastal erosion at Happisburgh and Sidestrand can be found at http://www.bgs.ac.uk/landslides/caseStudies.html.

Details of the Lynford Neanderthal and mammoth site are at http://www.museums.norfolk.gov.uk and navigate to Research - Academic Articles - Archaeology - Neanderthals butcher mammoths.

'Subsidence in Norwich' by Humphreys, Howard and Partners (HMSO; 1993) is an interesting account of the effects of subsidence caused by historic chalk mining in Norwich.

A fascinating investigation into the evolution of the Waveney-Little Ouse corridor is found in 'From Brandon to Bungay. An exploration of the landscape history and geology of the Little Ouse and Waveney Rivers' by RG West (Suffolk Naturalists' Society, Ipswich; 2009).

For a classic account of the evolving geodiversity and ecology of the Fens see 'Fenland : Its Ancient Past and Uncertain Future' by H Godwin (Cambridge University Press; 1978).

Landscape and landforms

'Classic Landforms of the North Norfolk Coast' by E Bridges (The Geographical Association in conjunction with the British Geomorphological Research Group; 1998). A well-researched and illustrated guide book.

The geomorphology of Norfolk is dealt with in 'The Geomorphology of the British Isles (Eastern and Central England)' by K Clayton and A Straw (Methuen; 1979). It deals in detail with the glacial geomorphology of the Cromer Ridge and north-west Norfolk.

'Blakeney Point and Scolt Head Island' by H Allison and J Morley (eds) (The National Trust; 5th edtn, 1989) is an excellent introduction to the physiography, ecology and biodiversity of the North Norfolk coast.

Soils

Soils are one of the most fascinating and least appreciated aspects of Norfolk's geodiversity. The best reference guide is 'Soils and their Use in Eastern England' by CA Hodge, RG Burton, WM Corbett, R Evans and RS Seale (Soil Survey of England and Wales Bulletin No.13, Harpenden; 1984). It covers the soil associations and their component series, and their links with geology and land-use.
The accompanying map is 'Soils of England and Wales: Sheet 4 Eastern England' (Soil Survey of England and Wales), which displays Norfolk's variety of soils at 1:250,000 scale.
Overview information about Norfolk's soils may be obtained on-line through the National Soil Resources Institute's Soilscapes Viewer at http://www.landis.org.uk/soilscapes/.

Water

The story of Norfolk's water supply is patchily told. Individual geological sheet memoirs of the British Geological Survey contain useful details, although the otherwise excellent 'King's Lynn and The Wash' volume (Gallois, 1994) is inexplicably silent on the subject. The British Geological Survey publishes specialist maps on groundwater vulnerability to pollution, and hydrogeological maps detailing availability, exploitation and quality. See http://www.bgs.ac.uk/catalogue/home.html. Details of the hydrogeology of the North Norfolk Chalk aquifer are explained by Hiscock 1991 (Bulletin of the Geological Society of Norfolk no. 41).
'Taking the Waters' by M. Manning (Norfolk Industrial Archaeological Society; 1994) investigates the story of spas, spa wells and holy wells in the county.
General details of catchment hydrology and water resources in Norfolk may be obtained from the Catchment Abstraction Management documents published by the Environment Agency.

The Palaeolithic

The classic introduction to the Palaeolithic of Norfolk is 'Palaeolithic Sites of East Anglia' by JJ Wymer (Geobooks, Norwich; 1985). See also 'East Anglian Palaeolithic Sites and their Settings' by John Wymer in: 'Aspects of East Anglian Prehistory' by C Barringer (ed) (Geobooks, Norwich; 1984). This book has chapters on prehistoric environments & economies and archaeology, including Norfolk. Happisburgh has yielded evidence for the earliest and northernmost human expansion into Eurasia, over 800,000 years ago. See http://news.bbc.co.uk/1/hi/science_and_environment/10531419.stm
For online information about the Palaeolithic and Mesolithic of Norfolk see http://en.wikipedia.org/wiki/Prehistoric_Norfolk.

Landscape character

Norfolk's landscapes and coastal environments were characterised into Natural Areas by English Nature in the 1990s. The Natural Area Profile documents provide an excellent access point into the details of Norfolk's geodiversity and biodiversity. See http://www.naturalareas.naturalengland.org.uk/Science/natural/NA_search.asp.
In 2005 the Natural Areas concept was adapted to include human land use and settlement. See the National Character Area profiles at http://www.naturalengland.org.uk/ourwork/landscape/englands/character/areas/eastofengland.aspx.

Detailed local information about Landscape Character Assessment for Norfolk may be viewed at http://www.landscapecharacter.org.uk/results/list_new.php?res=LA45.

Designated sites and areas

Sites of Special Scientific Interest – see http://www.english-nature.org.uk/Special/sssi/search.cfm for details (maps and designation documents) for all SSSIs in Norfolk. See also the Geological Conservation Review (GCR) website http://www.jncc.gov.uk/page-4172 for further information about the geodiversity interest of SSSIs.

National Nature Reserves – see http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/nnr/regions/east.aspx for a list of Norfolk reserves, with associated maps and nature conservation information.

The Broads National Park – see http://www.broads-authority.gov.uk/index.html for more information.

The coastal environment

For excellent information on coastal processes, geological details and management issues of the coastline from Kelling to Happisburgh, see the North Norfolk Coastal Environment website - http://www.northnorfolk.org/coastal/microsite/doc1.html.

For scientific information on sediment movement along the Norfolk coast see the Southern North Sea Sediment Transport Study – http://www.sns2.org/.

For information about coastal management see the Environment Agency website for the Wash Estuary, North Norfolk and Kelling to Lowestoft Shoreline Management Plans - http://www.environment-agency.gov.uk/research/planning/105014.aspx.

2) General geodiversity

'Geodiversity: Valuing and Conserving Abiotic Nature' by Murray Gray (Wiley; 2004) - the seminal reference book.

'Natural Foundations: Geodiversity for People, Places and Nature' by H Stace and J Larwood (English Nature; 2006) – a useful and attractive overview of integrated thinking on geodiversity. Available as a PDF download or free from Natural England's publications dept. (code CORP.21)

3) Geoconservation

General geoconservation

'Earth Science Conservation in Great Britain. A Strategy' (Nature Conservancy Council; 1991) – a seminal policy document. Includes appendices comprising 'A Handbook of Earth Science Conservation Techniques' compiled by AP McKirdy.

'Geological conservation: a Guide to Good Practice' by C Prosser, M Murphy and J Larwood (English Nature; 2006) – essential reading. Available as a book or a PDF download from Natural England website.
Local Geodiversity Action Plans – see Natural England web pages explaining a national policy framework for conserving geodiversity:
http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/protectandmanage/lgaps.

'Local Geodiversity Action Plans - Setting the context for geological conservation' by C Burek and J Potter (Research Report 560; English Nature, Peterborough; 2006). Available as a PDF download from Natural England website.

Sites of Special Scientific Interest (SSSIs) – see Natural England's web pages about nationally important sites for nature conservation:
http://www.sssi.naturalengland.org.uk/Special/sssi/search.cfm.

The Earth Science Conservation Classification System – see Natural England's pages explaining the theoretical framework for conserving the different types of geodiversity sites:
http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/protectandmanage/conservation.aspx.

The Geological Conservation Review – an online guide to the JNCC's review of the most important geological and geomorphological sites in Britain.
http://www.jncc.gov.uk/page-2947.

'UK Geodiversity Action Plan (UKGAP): A Framework for Action' – see the draft document of our national Geodiversity Action Plan (available December 2010):
http://www.www.ukgap.org.uk.

GeoConservation UK—see the home-page for the Regionally Important Geological and Geomorphological Sites conservation scheme: http://wiki.geoconservationuk.org.uk/index.php5?title=Main_Page.

'Safeguarding our Soils: A Strategy for England' (DEFRA 2009 and 'The First Soil Action Plan for England: 2004-2006' (DEFRA 2006) – see
http://www.defra.gov.uk/environment/quality/land/soil/sap/index.htm.

Geoconservation in planning

'Local Sites. Guidance on their Identification, Selection and Management' (DEFRA; 2006) – information about conserving geodiversity and biodiversity through non-statutory designated sites. Available as a PDF download:
http://www.defra.gov.uk/rural/documents/protected/localsites.pdf

'Planning Policy Statement 9: Biodiversity and Geological Conservation' (ODPM, 2005) – aka PPS9, how geoconservation is embedded in government planning policy. Essential reading. Available as a PDF download:
http://www.communities.gov.uk/publications/planningandbuilding/pps9.

'Planning for Biodiversity and Geological Conservation: A Guide to Good Practice' (Defra; 2006) – the guide associated with PPS9. Available as a PDF download:

http://www.communities.gov.uk/publications/planningandbuilding/planningbiodiversity.

The Biodiversity Planning Toolkit (Association of Local Government Ecologists) - an interactive on-line resource for planners which includes geodiversity: see http://www.biodiversityplanningtoolkit.com/ (in development 2010).

The European Landscape Convention – an international treaty for the protection, management and planning of Europe's landscapes. See http://www.coe.int/t/dg4/cultureheritage/heritage/landscape/default_en.asp.

EU Water Framework Directive 2000 – a legal framework for the protection of rivers and lakes, estuaries, coastal waters and groundwater. See http://ec.europa.eu/environment/water/water-framework/index_en.html.

Planning and Policy Guidance 20: Coastal Planning (DoE; 1992) - conserving the coastal environment through planning. Available as a PDF download: http://www.communities.gov.uk/documents/planningandbuilding/pdf/147498.pdf

Geoconservation and biodiversity

'Geological conservation benefits for biodiversity ENRR 561' by R N Humphries and L Donnelly (English Nature Research Report No. 561; 2004). Available as a PDF download from Natural England website.

'Geology and biodiversity - making the links' (English Nature; 2004) – an 8-page booklet available as a PDF download from Natural England website.

'Habitat Creation Handbook for the Minerals Industry' by GJ White and JC Gilbert (eds) (The RSPB, Sandy; 2003) - discusses restoration planning, site management during mineral extraction, habitat creation techniques, case studies.

'Linking Geology and Biodiversity' by R Cottle (English Nature Research Report No. 562; 2004) – investigates the strong ties between geology and biodiversity. Available as a PDF download from Natural England website.

'The State of England's Chalk Rivers: A report by the UK Biodiversity Action Plan Steering Group for Chalk Rivers' (Environment Agency; 2004) – Norfolk has 421km of chalk rivers; information on management. Contact enquiries@environment-agency.gov.uk or tel. 08709-506 506 for a copy.

Geoconservation and the minerals industry

'Geodiversity and the Minerals Industry' (English Nature, Quarry Products Association, Silica and Moulding Sands Association; 2003). Available as a PDF download from Natural England website.

'Good Quarry' – this is a joint project of the University of Leeds and the Mineral Industry Research Organisation, aimed at all who have an interest in the environment and quarrying. See http://www.goodquarry.com/.

Research Framework for the Archaeology of the Extractive Industries in England (Mining and Quarrying) - a joint English Heritage and NAMHO project: http://www.vmine.net/namho-2010/research.asp.

4) Geodiversity in education

On-line educational material that relates to Norfolk's geodiversity is in short supply.

Norfolk Heritage Explorer includes Resource Packs for the National Curriculum, one of which is Prehistoric Flints. See http://www.heritage.norfolk.gov.uk/.
The British Geological Survey's website 'The Blakeney Esker Explored' provides educational resources and information about this important Pleistocene landform.
See http://www.bgs.ac.uk/education/blakeney_esker.html.

There are many Field Studies Centres in North Norfolk which provide physical geography courses, for example:

- Holt Hall (Norfolk County Council): http://www.holthall.norfolkedunet.gov.uk/courses.html (coastal processes in North Norfolk; fluviatile processes on the River Glaven; introduction to rocks and soils; habitat ecology)

The Norfolk Coast AONB team publishes information about field studies in North Norfolk at http://www.norfolkcoastaonb.org.uk/mediaps/pdfuploads/pd000135.pdf.

Soil-Net is an educational resource on soil for Key Stages 1-4 developed by Cranfield University in association with Norwich School of Art and Design. See http://www.soil-net.com.

General Earth heritage-related teaching websites include:

- The Earth Science Teachers' Association http://www.esta-uk.net/.
- Earth Learning Idea http://www.earthlearningidea.com/.
- Earth Science On-site http://www.esos.ukrigs.org.uk.

5) Geodiversity in Museums

The Norfolk Museums and Archaeology Service makes information about its geological collections available online through 'Collections Online for All'. See http://museums.norfolk.gov.uk/ and navigate to: Research - Collections - Search our collections.

Norfolk Heritage Explorer is Norfolk's Historic Environment Records database online. See http://www.heritage.norfolk.gov.uk/.

Cromer Museum (East Cottages, Tucker Street, Cromer Norfolk NR27 9HB; 01263 513543). Has a new Geology Gallery, with an interpretation programme involving local geology, including guided walks on West Runton beach. See http://museums.norfolk.gov.uk/ and navigate to: Visit Us - Cromer Museum.

Lynn Museum (Market Street, King's Lynn, Norfolk PE30 1NL; 01553 775001). Has geological specimens in the collection. See http://museums.norfolk.gov.uk/ and navigate to: Visit Us - Lynn Museum.

Norwich Castle Museum (Castle Meadow Norwich Norfolk NR1 3JU; 01603 493625). Has a display of geological specimens and the skeleton of the West Runton elephant; has large collections in storage; employs a geological curator. See http://museums.norfolk.gov.uk/ and navigate to: Visit Us - Norwich Castle Museum and Art Gallery.
Ancient House Museum of Thetford Life (White Hart Street Thetford Norfolk IP24 1AA; 01842 752599). Has a small case of geological specimens on display, and more in storage. See http://museums.norfolk.gov.uk/ and navigate to: Visit Us - Ancient House Museum of Thetford Life.

Other museums in Norfolk have small collections of local geological specimens and records, particularly Diss and Swaffham.

6) Geodiversity groups

The East of England Geodiversity Partnership – see http://www.geo-east.org.uk/. Includes interactive map showing places to visit of geodiversity interest in Norfolk.

The Geological Society of Norfolk – see http://www.norfolkgeology.co.uk/.

Norfolk Mineral & Lapidary Society – see http://norfolkminandlapsoc.homestead.com/.

Open University Geological Society. East Anglia Branch - http://www.ougs.org/branches/.

Appendix 2 - Glossary

Aeolian	Referring to the wind and its action.
Aggrade; Aggradation	The accumulation of unconsolidated sediment by fluvial (qv), marine or aeolian (qv) action; the shift in a river's dynamic erosional and depositional equilibrium towards net deposition.
Aggregate	Any loose material mixed with cement to form concrete, typically sand and gravel.
Anastomosing	A network of multiple river channels that both branch out and reconnect.
Anthropogenic	Effects, processes or materials derived from human activities.
Aquifer	A water-bearing geological formation.
Biodiversity	The variety / diversity of life forms; the totality of genes, species, and ecosystems of a region.
Bituminous	Resembling or containing bitumen (tar-like hydrocarbons).
Boulder clay	See entry for Till.
Bourne	A seasonal or intermittent stream.
Braided river	A river composed of a network of small channels separated by small, often temporary islets called bars. Braided streams occur in rivers with a large sediment load.
Bund; bunding	Embankment.
Cementstone	Muddy limestone that may form fractured concretions with calcite infill, known as septaria.
Chalybeate	Containing iron salts.
Clunch	Local name for hard building material, usually chalk or stiff clay.
Coversand	Deposits of wind-blown sand.
Doggerland	The name given to the former land area in northwest Europe lying between England, Holland and Denmark, now submerged by the North Sea.
Earth heritage	The inherited assembly of geodiversity features.
Erratic	A glacially-transported rock now resting on country rock of a different lithology (qv).
Eutrophication	An increase in the concentration of chemical nutrients in an ecosystem to an extent that it increases the primary productivity of that ecosystem. Eutrophication is often a result of pollution such as sewage effluent and nitrate run-off from farmland.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.
Fluvial	Pertaining to rivers.
GCR	The Geological Conservation Review, which identifies over 3000 nationally important geodiversity sites in Britain. Administered by Natural England.
Geoarchaeology	A multi-disciplinary approach which uses the techniques and subject matter of geography, geology and other Earth sciences to examine archaeological evidence.
Geoconservation	Action taken with the intent of conserving and enhancing geological and geomorphological features, processes, sites and specimens.

Geodiversity	Geodiversity may be defined as the natural range (diversity) of geological features (rocks, minerals, fossils, structures), geomorphological features (landforms and processes), soil and natural water features that compose and shape the physical landscape.
Geomorphology	The physical features and natural processes operating on the surface of the Earth which enable us to understand landforms and their origin.
Glaciofluvial	Referring to meltwater streams associated with ice sheets and glaciers, and the deposits and landforms they produce.
Head	Mixed superficial deposits of periglacial (qv) origin on slopes, mobilised by solifluction (qv).
Hummocky ground	A periglacial (qv) landform characterised by undulating ridge/mound and hollow topography developed in chalky head (qv).
Interfluve	The higher area between two valleys.
Interglacial	A warm period between two glacial periods.
Isostatic	Referring to the equilibrium in the Earth's crust such that the forces tending to elevate landmasses are balanced by forces tending to depress them.
Landscape	An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.
Landscape character	A distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, and hence unique.
Lithology	The character of a rock, its composition, structure, texture and hardness; the study or description of rock.
Little Ice Age	A period of cooler climate in the northern hemisphere lasting from c. 16th century to the 19th century, characterised by colder winters.
Local Site	A designated non-statutory nature conservation site of local importance, such as RIGS (qv) or County Wildlife Site; as defined by DEFRA.
Loess	A windblown deposit of silt or clay.
Longshore drift	The transport of sand and shingle along a beach or coast by means of waves and currents.
Mass movement	The downslope movement of loose rock, soil and surface debris by processes such as slumping, sliding, solifluction (qv), soil creep and hillwash. It also includes landslides.
Mineral; minerals	A mineral is a naturally occurring solid formed through geological processes that has distinctive chemical composition, internal crystal structure and physical properties. Minerals combine with each other to form rocks. In economic and planning terms, 'minerals' refers to excavated geological resources such as sand, gravel, chalk or sandstone.
Moraine	An accumulation of sediment and rock debris formed by the eroding and transporting action of a glacier or ice sheet.
Naled	A sheet-like mass of layered ice formed from successive flows of groundwater in a valley bottom during freezing temperatures; otherwise known as an aufeis or icing.
Ness	A promontory or headland; in Norfolk these are formed by longshore drift (qv) processes.
OD	Abbreviation for Ordnance Datum, the sea level datum point established by the Ordnance Survey at Newlyn, Cornwall.

Outwash fan	An apron or fan of sediment deposited by glacial meltwater in front of a glacier or ice sheet.
Palaeosol	A former or fossil soil preserved by burial beneath later sediments. Analysis of such deposits may have great value in reconstructing past environments.
Palsa	Low mounds developed from groundwater over permafrost (qv) in boggy environments; like pingos (qv), palsas consist of a core of ice with overlying peat, but they are smaller than pingos and often occur in groups.
Patterned ground	The arrangement of superficial deposits into structures such as circles, stripes and polygons due to freeze-thaw action in a periglacial (qv) environment.
Periglacial	In the vicinity of a glacial environment, with conditions dominated by freeze-thaw processes.
Permafrost	Permanently frozen ground.
Pingo	A mound of earth-covered ice formed in regions of permafrost (qv); they typically form over artesian springs or in former lake beds; in the Arctic they can reach up to 70m in height and up to 600m in diameter. See also entry for palsa.
Physical landscape	The geological and geomorphological components of landscape, including landforms, soils and water.
Raised beach	A former beach raised above the current shore line by a relative fall in sea level.
RIGS	A non-statutory Local Site (qv) designation, meaning Regionally Important Geological / geomorphological Site.
River terrace	The remains of a river's former floodplain (qv) sited above current floodplain level, formed when a river shifts its dynamic equilibrium towards net erosion and incises to a lower level.
Roddon	Deposits of marine alluvium in Fenland formed in former tidal creeks, seen now as meandering channels of silty soil in reversed relief surrounded by wasted fen peat.
Sedimentary structure	A structure in sedimentary rocks, such as cross-bedding and ripple marks, produced either contemporaneously with deposition or shortly afterwards.
Solifluction	The slow movement of an active layer of waterlogged sediment downslope, over impermeable material such as permanently frozen ground (permafrost (qv)). It occurs in periglacial environments where surface layers melt in summer.
Stratotype	A type section of a geological stratigraphic unit; used for scientific reference purposes.
SSSIs	Sites of Special Scientific Interest, comprising over 4000 nationally important sites designated for their wildlife and geological interest; administered by Natural England.
Swallow hole	A natural hole into which a stream flows, formed by solution of the underlying bedrock such as chalk or limestone.
Stratigraphy	The study of the rock layers (strata) in the Earth.
Terracette	Small-scale, step-like landforms developed by soil creep on steep, grassy slopes.
Till	Unsorted, unstratified material deposited directly by glacial ice; in the past called 'boulder clay'.
Tufa	Soft, white, porous formation of calcium carbonate deposited from solution in spring water or percolating groundwater.

Appendix 3 - Stratigraphic Chart

The following chart gives a concordance between informal names of rock units used in this document and their formal stratigraphic equivalents defined by the British Geological Survey. For more information consult the BGS Lexicon of Named Rock Units at http://www.bgs.ac.uk/lexicon/.

a) Bedrock deposits

Periods	Age (m yrs ago)	Informal names of rock units	Stratigraphic names of rock units
Pleistocene		Wroxham Crag	Crag Group (part)
	1.8		
Pliocene		Norwich Crag	
	2.2		
		[A gap in time in which deposits were eroded away]	
Eocene	c.40	London Clay	Thames Group (part)
		[A gap in time in which deposits were eroded away]	
	65		
Upper Cretaceous		Upper and Middle Chalk	White Chalk Subgroup
		Lower Chalk	Grey Chalk Subgroup
	99		
Lower Cretaceous		Red Chalk	Hunstanton Formation
	105	Gault	Gault Formation
	110	Carstone	Carstone Formation
	115	Roach	Roach Formation
	130	Dersingham Beds	Dersingham Formation
	135	Mintlyn and Leziate Beds (Sandringham Sands)	Sandringham Sand Formation
	144	Roxham and Runcton Beds (Sandringham Sands)	
Jurassic	153	Kimmeridge Clay	Kimmeridge Clay Formation
	159	Ampthill Clay	Ampthill Clay Formation
	161	West Walton Beds	West Walton Formation

b) Pleistocene superficial deposits

For information on formal stratigraphic terminology for Pleistocene superficial deposits consult DQ Bowen (ed): 'A Revised Correlation of Quaternary Deposits in the British Isles' (Geological Society of London Special Report No.23, 1999). Note that the Hunstanton Till is given here as part of the Hunstanton Formation, while the BGS Lexicon of Named Rock Units gives it as part of the Holderness Formation; we understand this discrepancy is currently being resolved by the BGS.

Appendix 4 - Sites of geodiversity importance in Norfolk

The Norfolk Geodiversity Audit

In 2007/08 the Norfolk Geodiversity Partnership commissioned a geodiversity audit. It was carried out through a survey of published literature and consultation with geological specialists. Some 328 entries were made in what will be an ongoing process. At present, it represents an initial digest of significant geological and geomorphological sites and features in the county, including SSSIs.

Preliminary work has also begun on identifying areas with significant concentrations of features. These 'landscape assemblages' are arranged on a geomorphological basis, and represent an attempt to think holistically about associations of geological and geomorphological features in the landscape; they may be used to inform statements of Landscape Character. Geomorphological themes identified include Coastal, Fluvial, Glacial, Ground-ice, Karst and Topographic.

Much work remains to be done. The results of the audit will be subject to a programme of verification, including identifying and contacting land owners / managers, and hopefully checking details of visible features and site condition. The results will help inform the Partnership's Local Sites designation process, and represent baseline information about designated sites and 'geological interests within the wider environment'[1] for use by local planning authorities. The listing of a site does not imply any official conservation status or designation, nor right of public access.

Results to date have been prepared in a spreadsheet database organised on a Local Authority basis. The number of audited sites and features (including SSSIs) broken down by local authority is shown right (as at July 2009).

Breckland District	77
Broadland District	38
Gt Yarmouth Borough	5
Kings Lynn & West Norfolk Borough	77
Norwich City	15
North Norfolk District	56
South Norfolk District	61

The results of the audit are available on request from the following sources:

- Norfolk Geodiversity Partnership - contact Jenny Gladstone: tel.: 01603-619387; email: jennygladstone@aol.com or Tim Holt-Wilson: tel.: 01379-870411; email: timholtwilson@onetel.com.
- Norfolk Biodiversity Information Service - http://www.nbis.org.uk/.

An online version is available through the Geo-East website -

- http://www.geo-east.org.uk/spages/norfolk.htm.

The results of the audit present publicly available information. If there are any queries about its contents or purpose please contact Jenny Gladstone or Tim Holt-Wilson, as above.

The following pages present a summary of information about designated sites of geodiversity importance.

[1] Planning Policy Statement 9: Biodiversity and Geological Conservation' (ODPM, 2005), section1.ii.

Designated sites of international, national, regional and local importance for geodiversity

1) Statutory sites

EARTH HERITAGE SSSIs in Norfolk, based on the GCR

The GCR categories given below are termed 'Blocks'; for more information see http://www.jncc.gov.uk/page-4171.

Site name	OS grid ref	GCR categories	Summary of interest
Bawsey	TF680194	QEA	Bawsey Calcareous Till and Woodland Farm Till (Anglian)
Beeston Cliffs	TG167434 to TG171433	QEA	Type site of Beestonian Stage
Bilsey Hill	TG023416	QEA	Deep sections in the north Norfolk till plain adjacent to Wiveton Downs and Glaven Valley
Blackborough End Pit	TF670145	BER	Carstone resting on Leziate Beds. Dersingham Beds absent
Bramerton Pits	TG295060 to 298061	PLV + QEA	Type site for the Norwich Crag and Bramertonian temperate stage. Vertebrate fauna present.
Briton's Lane Gravel Pit	TG169145	QEA	Briton's Lane Gravels of the Cromer Ridge
Broome Heath Pit	TM345913	QEA	Broome Terrace of Waveney valley
Caistor St Edmund Chalk Pit	TG239048	CEN + QEA	Late Campanian Beeston Chalk and mid Pleistocene sequence with palaeosols
Catton Grove Chalk Pit	TG229109	CEN	Type site for late Campanian Catton Sponge Bed
Dersingham Bog	TF675289	BER	Type site for Dersingham Formation
East Runton Cliffs	TG340280	PLV + QEA	Pre-Cromerian vertebrate fauna (Pastonian)
East Walton & Adcock's Commons	TF734164	QEA	Ground-ice depressions (late Devensian)
Glandford Hurdle Lane	TG054416	QEA	Pleistocene glaciogenic deposits
Glandford Letheringsett Road	TG043411	QEA	North Norfolk Pleistocene till plain
Grimes Graves	TL810902	QEA	Periglacial patterned ground
Grimston Warren Pit	TF673223	BER	Dersingham Formation

Happisburgh Cliffs	TG379314 to TG38331	QEA	Anglian Cromer Tills and Cromer Forest Bed Formation
Heacham Brick Pit	TF679364	QEA	Barremian Snettisham Clay
Holkham Brick Pit	TF862428	QEA	Late Devensian Hunstanton Till
Hunstanton Cliffs	TF672413 to TF679424	ALB	Ferriby Chalk Formation and Carstone
Hunstanton Park Esker	TF695409	QEA	Devensian glacial esker landform
Kelling Heath	TG100420	No GCR citation	Pleistocene glacial outwash plain
Leet Hill, Kirby Cane	TM381929	QEA	Middle Pleistocene fluvial and glaciogenic sediments
Morston Cliff	TF990441	QEA	Ipswichian interglacial raised beach
Mundesley Cliffs	TG317365 to TG331352	QEA	Cromer Forest-bed Formation
North Norfolk Coast	TF690443 to TG095440	COG	Salt marshes and modern coastal processes
Overstrand Cliffs	TG248411	QEA	Deformed Anglian glaciogenic sequence
Setchey	TF633132	QEA	Flandrian sea level change
Sidestrand and Trimingham Cliffs	TG252408 to TG305375	QEA + PLV + CEN	Pre-Pastonian, Pastonian and Cromerian sediments and associated vertebrate fauna; glaciotectonic Chalk rafts; active rotational slumping.
St James' Pit	TG242094	JCR	Upper Chalk Mosasaurus
Stanford Training Area	TL870940	KAR	Breckland Meres including the Devil's Punchbowl doline
Wells Chalk Pit	TF929429	QEA	Marly Drift
West Runton Cliffs	TG183432 to TG192430	QEA + PLV	West Runton Freshwater Bed with rich fossil fauna; pre-Pastonian to Anglian sequence.
Weybourne Cliffs	TG111437 to TG152435	QEA + PLV	Cromer Forest-bed and Weybourne Crag
Weybourne Town Pit	TG1 l 4431	QEA	Type locality for Marly Drift
Wiggenhall St Germans	TF588139	QEA	Holocene sea level changes (pollen and foram data)
Winterton-Horsey Dunes	TG489216 to 506181	COG	Active dune system
Wiveton Downs	TG023433	QEA	Blakeney Esker glacial landform
Wretton	TG685992	QEA + PLV	Ipswichian and Devensian terrace with abundant fossil mammals

GCR SITES not designated as SSSIs for their geological interest

Site name	OS grid ref	GCR categories	Summary of interest
Hockham Mere	TL933937	QEA	Holocene pollen sequence
Welney	TL535942	QEA	Holocene sediment and pollen sequence

SSSIs cited in GCR but not designated for their geological interest

Site name	OS grid ref	GCR categories	Summary of interest
Wells Chalk Pit	TF929429	QEA	Chalk grassland biodiversity

GCR CITATIONS in Norfolk compared with regional totals

GCR 'blocks' of interest	Norfolk total	Regional total	% regional total
Quaternary East Anglia	31	64	48
Quaternary of the Thames		17	
Neogene		12	
Pleistocene Vertebrates	6	11	54
Cenomanian, Turonian, Senonian, Maastrichtian	4	6	67
Coastal Geomorphology	2	6	33
Berriasian, Valanginian, Hauterivian, Barremian	4	4	100
Aptian, Albian	1	3	33
Karst	1	3	33
Mesozoic-Tertiary Fish/Amphibia		3	
Aves		2	
Fluvial Geomorphology		2	
Jurassic-Cretaceous Reptilia	1	2	50
Tertiary Palaeobotany		2	
Caves		1	
Mass Movement	1	1	100
Oxfordian		1	
Tertiary Mammalia		1	
Total 'blocks' of interest	51	141	36%

Note: the discrepancy between number of geological SSSIs (39) and GCR citations (51) may be explained because some sites are cited for more than one category of interest.

NATIONAL PARKS

Name	Summary of geodiversity interest	Area (ha)
The Broads	Holocene peatland and marine alluvium giving rise to open water, fen and carr habitats; broads developed in former early Mediaeval peat diggings; rivers including lower reaches of Bure, Waveney and Yare and their tributaries including Ant, Chet and Thurne.	30,300

NATIONAL NATURE RESERVES

Name	Summary of geodiversity interest	Area (ha)
Ant Broads & Marshes	Holocene peatland including open water and associated fens and carrs.	178
Blakeney	Active coastal landforms, including the shingle spit and ridges of Blakeney Point and associated saltmarshes.	1097
Brettenham Heath	Contrasting chalky and acidic soil types give rise to classic Breckland heath, including periglacial patterned ground producing vegetation stripes	233
Bure Marshes	Holocene peatland including open water and associated fens and carrs.	412
Calthorpe Broad	Holocene peatland including broad and associated fens and carrs.	44
Dersingham Bog	Lower Cretaceous lithologies give rise to peatland and lowland heath habitats; Pleistocene degraded cliff line forms escarpment.	159
Foxley Wood	Lowestoft till lithologies of Central Norfolk plateau give rise to woodland and meadowland habitats.	125
Hickling Broad	Holocene peatland including open water and associated fens and carrs.	586
Holkham	Active coastal landforms, including intertidal sands and muds, saltmarshes and sand dunes.	3851
Holme Dunes	Active coastal landforms including sand dunes, mudflats and saltmarsh.	192
Ludham - Potter Heigham	Holocene marine alluvium gives rise to lowland grassland habitat.	86
Martham Broad	Holocene peatland including open water and associated fens and carrs.	59
Mid-Yare	Holocene peatland including open water and associated fens and carrs.	779
Redgrave and Lopham Fen	Holocene peatland and calcareous springs including associated fens and carrs.	125
Roydon Common	Lower Cretaceous lithologies give rise to lowland heath, mire and wood habitats.	183
Scolt Head Island	Active coastal landforms, including offshore shingle bank, sand dunes, mud flats and saltmarsh.	737
Swanton Novers	Lowestoft till lithologies of North Norfolk plateau give rise to ancient woodland habitat.	84
The Wash	Active coastal landforms, including intertidal sands and mudflats, saltmarsh and open water.	8881
Weeting Heath	Pleistocene coversands over chalky till lithologies give rise to Breckland heath habitat with contrasting vegetation types.	137
Winterton Dunes	Active coastal landforms including beach and sand dunes, with associated dune heath and dune slack habitats.	109
	Total	18,057

2) Non-statutory

Designated sites of local importance for nature conservation in Norfolk include RIGS and County Wildlife Sites, and are generically termed Local Sites (see Section 4 Policy Background).

Local Sites of geodiversity importance are designated by the Norfolk RIGS Group, a sub-committee of the Geological Society of Norfolk. Designation involves surveying features of interest, and gaining voluntary agreement with the land owners / managers on beneficially managing those features to retain or enhance their interest. Its principles follow those outlined in the DEFRA advisory booklet 'Local Sites. Guidance on their Identification, Selection and Management' (2006). Designation does not confer any right of public access to the site. Norfolk has five designated RIGS, as follows:

<u>Breckland District</u>
Newton by Castle Acre Chalk Pit; also known as Needham Chalks Quarry
Grid reference: TF837149
Area (ha): not available
An active quarry displaying Cretaceous Chalk of the Coniacian Stage (transitional M.cortestudinarium / M.coranguinum Zones) and Santonian Stage. Fossils include Inoceramus, Micraster, ammonites, fish and bryozoans. Large, fresh exposures available.
Date of designation: 12.11.1999

Great Hockham Erratic; also known as Village Stone
Grid reference: TL95309257
Area (ha): not available
Large erratic boulder of Cretaceous Spilsby Sandstone Formation. Discovered on farmland east of the village and resited on the Village Green c.1880; ritually turned over to mark notable events in the life of the parish.
Date of designation: 23.11.2009

<u>Broadland District</u>
Thorpe St Andrew, Pinebanks Pit
Grid reference: TG261089
Area (ha): not available
A disused gravel pit exposing sands of Pleistocene Anglian outwash and/or Pliocene Norwich Crag displaying sedimentary structures. Site has educational potential, being close to Norwich and part of a recreational area.
Date of designation: 30.08.2000

North Norfolk District
Letheringsett With Glandford, Rising Hill Pit
Grid reference: TG033404
Area (ha): not available
Disused quarry with good exposures of Pleistocene Anglian fluvio-glacial sand, gravel and chalky mud overlain by a thin sheet of chalk-rich glacial diamicton. Interpreted as a deglacial sequence dominated by ice-contact meltwater deposits and meltout tills. Complements the nearby Bilsey Hill geological SSSI.
Date of designation: 22.01.1999

Hempton Quarry
TF904284
Area (ha): not available
Partly landfilled former quarry, exposing Pleistocene Anglian sediments, comprising a glacio-tectonised sequence of bedded silty sands overlain by fine, sandy, well-bedded gravels, all with high chalk content. Adjacent to Hempton Green County Wildlife Site.
Date of designation: 04.04.2000

Appendix 5 - Geodiversity in Planning

Guidance on conserving and enhancing geodiversity through planning in Norfolk

Development is carried out by a range of agencies, including national and local government departments, utility companies and private sector developers (housing, commercial, agricultural, industrial), but all development will impact in one way or another on geology, landscape, landforms, soil and water resources. Depending on the nature of its activity, development may enhance or may damage geodiversity. On the positive side, it may:

- create access to new geological information for research and education, via creation of temporary or permanent exposures;

On the negative side it may:

- destroy the integrity of landforms that have taken millennia to develop;
- destroy finite geological deposits and the palaeo-environmental information they contain, including associated archaeological evidence of early human settlement;
- contaminate and deplete soils and water resources.

This document is a short statement by the Norfolk Geodiversity Partnership (NGP) on how planners may successfully conserve and enhance geodiversity as part of their LDF work, and so may contribute towards sustainable development.

Policy background

Planning Policy Statement No.9: Biodiversity and Geological Conservation (PPS9)

PPS9 covers the conservation of designated geological and geomorphological sites, which include statutory SSSIs and non-statutory Local Sites e.g. RIGS and County Geodiversity Sites[1]. PPS9 states that

- local planning authority policies should attach 'appropriate weight' to designated sites and also 'geological interests in the wider environment';
- plans and policies should be based on up-to-date information about the environmental characteristics of their areas, including its geodiversity;
- the aim of planning decisions should be to prevent harm to geological conservation interests; where harm to such interests is unavoidable mitigation or compensation measures should be put in place; mitigation may include modification of the design, methods and timing of development, or adjustments in its nature, scale or location; compensation includes measures to offset or make up for losses caused by the development, including residual effects which cannot be mitigated;
- criteria-based policies should be established in Local Development Framework documents against which proposals for any development on, or affecting, Local Sites will be judged.

Minerals Planning Guidance 7: Reclamation of Mineral Workings (MPG7)

MPG7 sets out policy guidance on how reclamation can be used to enhance the

[1] Local Sites, as defined in *'Local Sites. Guidance on their Identification, Selection and Management'* (DEFRA; 2006)

quality of land and landscapes taken for mineral extraction. It provides for enhancement for amenity use including nature conservation, and recommends permanent retention of features of geological importance revealed by quarrying or predicted to be revealed (section B52).

Planning Policy Statement 5: Planning for the Historic Environment (PPS5)

We note that buried archaeological assets are intimately linked with the sediments and soils which form their palaeo-environmental context and which are an essential part of evaluating their significance. PPS5 defines the historic environment in terms of heritage assets to be conserved in proportion to their significance. It recognizes that these are a non-renewable resource. There are many heritage assets which are not currently designated as Scheduled Monuments; however the absence of designation does not mean they have lower significance.

Recommendations for Norfolk planners

1) Planners should have access to baseline information about geodiversity features in their areas. This is available through British Geological Survey maps and publications, and the Norfolk Geodiversity Audit carried out by the NGP, and which is available as a GIS layer through the Norfolk Biological Information Service. Advice on geodiversity features 'in the wider environment' is also available from these sources. The audit also includes information about the overlap between palaeo-environmental and Palaeolithic archaeological evidence.
2) Planners need to understand how development may impact on and threaten geodiversity, particularly certain finite types of landforms and geological resources. They are recommended to familiarise themselves with the basic principles of geological conservation as set out in *Geological conservation: a Guide to Good Practice* by C Prosser, M Murphy and J Larwood (English Nature; 2006). The NGP can advise on the relative importance and vulnerability of geodiversity resources at national, county and local levels, and Norfolk Landscape Archaeology can give specialist advice on potential impact of development on archaeological heritage assets.
3) Planners should set up procedures to integrate geodiversity in the planning process. Such procedures should include:
   (a) Establishing a requirement for developers to carry out early consultation on the likely impact of their proposed development on geodiversity. This is best achieved through including geodiversity in the 1App planning application validation checklist as has been done in Suffolk[2].
   (b) Establishing effective mitigation measures via Section 106 agreements as part of gaining planning permission. Such measures may include
      - Agreeing access to site before and during works for recording and sampling by representatives of the NGP;
      - Designing development to avoid damage to or obstruction of geodiversity features, and to allow access for future study and recording; if damage is unavoidable then creating replacement geological exposures of equivalent value, or otherwise enhancing local geodiversity features, e.g. through conservation of features or interpretation;

- Provision for long-term maintenance and management of geodiversity features such as geological sections;
- Agreement on access for future scientific and educational study;
- Provision of interpretation appropriate to the scale of the development;
- Agreeing geodiversity objectives in after-use plans for mineral extraction sites, as per MPG7.

(c) Including baseline geodiversity indicators in the LDF Sustainability Appraisal system. Please consult the NGP for further information.

(d) Establishing the Condition of Local Sites as a local government performance framework target for NI 197 (Local Sites). Please consult the NGP for further information.

(e) Developing internal policy documents (e.g. SPDs) to cover geodiversity as well as biodiversity.

(f) Including geodiversity features (e.g. geological exposures, natural landforms, river restoration) in Green Infrastructure initiatives.

4) Planning authorities are invited to join the Norfolk Geodiversity Partnership and to subscribe to the objectives of the Norfolk Geodiversity Action Plan.

FURTHER INFORMATION

Norfolk Biological Information Service
See http://www.nbis.org.uk/; tel.: 01603 224458; email: nbis@norfolk.gov.uk.

Norfolk Geodiversity Partnership
Contact Jenny Gladstone: tel.: 01603-619387; email: jennygladstone@aol.com or
Tim Holt-Wilson: tel.: 01379-870411; email: timholtwilson@onetel.com.

British Geological Survey
Contact Keith Ambrose: tel.: 0115-936 3203; email: kam@bgs.ac.uk or
Jonathan Lee: tel.: 0115-936 3517; email: jrlee@bgs.ac.uk.

Natural England
See http://www.naturalengland.org.uk/; tel.: 01603 674920; email:
enquiries.east@naturalengland.org.uk.

GLOSSARY

Geodiversity
Geodiversity is the variety of rocks, fossils, minerals, landforms and soils along with the natural processes that shape the landscape.

Nature conservation
The protection, preservation, management or enhancement, and the improvement of understanding and appreciation of, flora, fauna and geological and geomorphological features.

[Definitions taken from 'Planning for Biodiversity and Geological Conservation - A Guide to Good Practice' (ODPM 2006)]

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Geoconservation

Geological conservation: a Guide to Good Practice by C Prosser, M Murphy and J Larwood (English Nature; 2006). Available from Natural England website: http://naturalengland.etraderstores.com/NaturalEnglandShop/product.aspx?ProductID=712db525-75de-4079-862e-5b654546ea56.

Local Geodiversity Action Plans – see Natural England web pages explaining a national policy framework for conserving geodiversity: http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/protectandmanage/lgaps.aspx.

Local Geodiversity Action Plans - Setting the context for geological conservation by C Burek and J Potter (Research Report 560; English Nature, Peterborough; 2006). Available as a PDF download: http://www.mineralsandnature.org.uk/downloads/localgeodiversity.pdf.

Sites of Special Scientific Interest (SSSIs) – search Natural England's web pages about nationally important sites for nature conservation, including geodiversity: http://www.sssi.naturalengland.org.uk/Special/sssi/search.cfm.

The Earth Science Conservation Classification System – see Natural England's pages explaining the theoretical framework for conserving the different types of geodiversity sites: http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/protectandmanage/conservation.aspx.

The Geological Conservation Review – an online guide to the JNCC's review of the most important geological and geomorphological sites in Britain. http://www.jncc.gov.uk/page-2947.

UK Geodiversity Action Plan (UKGAP): A Framework for Action – see the draft document of our national Geodiversity Action Plan (available December 2010): http://www.ukgap.org.uk.

GeoConservation UK—see the home-page for the Regionally Important Geological and Geomorphological Sites conservation scheme: http://wiki.geoconservationuk.org.uk/index.php5?title=Main_Page.

Geoconservation in planning

The Biodiversity Planning Toolkit—an interactive, on-line resource for planners which includes geodiversity: http://www.biodiversityplanningtoolkit.com/ (in development 2010).

Draft Supplementary Planning Guidance for Nature Conservation – Geodiversity and Development in the United Kingdom (UKRIGS Geoconservation Association; undated) – A code of practice for early consultation. Available as a PDF download: www.ukrigs.org.uk/public/ncguidance.pdf.

Local Sites. Guidance on their Identification, Selection and Management (DEFRA; 2006) – information about conserving geodiversity and biodiversity through non-statutory designated sites. Available as a PDF download: http://www.defra.gov.uk/rural/documents/protected/localsites.pdf.

Minerals Planning Guidance 7: Reclamation of Mineral Workings (ODPM; 1996) - Available as a PDF download: http://www.communities.gov.uk/publications/planningandbuilding/mineralsplanningguidance5.

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Planning Policy Statement 9: Biodiversity and Geological Conservation (ODPM, 2005). Available as a PDF download: http://www.communities.gov.uk/planningandbuilding/planning/planningpolicyguidance/historicenvironment/pps9/.

Planning for Biodiversity and Geological Conservation: A Guide to Good Practice (DEFRA; 2006) – the guide associated with PPS9. Available as a PDF download: http://www.communities.gov.uk/publications/planningandbuilding/planningbiodiversity.

Planning and Policy Guidance 20: Coastal Planning (PPG20) (DoE; 1992). Available as a PDF download: http://www.communities.gov.uk/documents/planningandbuilding/pdf/147498.pdf.

Norfolk Geodiversity Partnership
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Appendix 6 - Principles of geodiversity conservation

The Earth Science Conservation Classification System (ESCC)[1] has established a framework for deciding the conservation management requirements of geodiversity. It divides sites/ features into three categories:

ESCC category	**Exposure / Extensive Sites & Features**
Site types	Geology, with features extensive beneath surface
Relevant to Norfolk	• Active quarries and pits • Coastal cliffs and foreshore • River and stream sections • Extensive buried interest • Road, rail, canal cuttings
Conservation principle	Removal of material does not damage integrity of the resource
Conservation strategy	Manage to maintain acceptable exposure of resource

ESCC category	**Integrity Sites & Features**
Site types	Geomorphology, soils and water
Relevant to Norfolk	• Static (fossil) geomorphological • Active process geomorphological • Karst
Conservation principle	Damage to one part may affect whole resource
Conservation strategy	Holistic management to maintain integrity of resource

ESCC category	**Finite Sites & Features**
Site types	Geological features limited in extent
Relevant to Norfolk	• Finite mineral, fossil or other geological • Finite buried interest
Conservation principle	Features may be unique and irreplaceable
Conservation strategy	Permit scientific use but conserve long-term

Strategies

As the above explains, different geodiversity resources have differing vulnerabilities, which suggests different strategies for their conservation.

- Geological strata may be thought of as physical archives of sediment and fossil information. Some are more vulnerable than others. In the case of laterally extensive deposits such as the Chalk or boulder clay we need to conserve access to them rather

[1]Nature Conservancy Council: *Earth science conservation in Britain, a strategy*; Peterborough (1990); and amended: English Nature: *Geological conservation, a guide to good practice*; Peterborough (2006).

than preserve them outright. This is because their resources are relatively infinite. The conservation priority in this case is to maintain access points (exposures) for scientific study. However, in cases of finite deposits, such as an ancient lake deposit or a lens of interglacial sediment with animal bones and evidence of associated human flint knapping, we need to preserve the resource in situ or, if physical preservation is not a practical option, record it fully prior to destruction (i.e. preservation by record).

- Geomorphological features are particularly vulnerable to damage. They are either one-off features created in past environments, or are currently active features being created by natural processes, and so can be damaged if the formative processes on which they depend are stopped or interrupted. We need to preserve the integrity of landforms and their relationship with their formative processes, with reference to the most natural examples. It is not about preserving the outward form or appearance of landforms, rather their wholeness as structured outcomes of natural processes, past and present.

- Soils have a complex history of development often over many millennia. Here, the conservation priority is to preserve their integrity (quality and diversity), protecting the resource from depletion, erosion and contamination.

- Groundwater, and river, lake and spring water are vital components of geodiversity, but they are vulnerable to depletion and contamination, with consequent impacts on biodiversity, landscape and the economy. The priority is to conserve the integrity of the natural hydrology and chemistry of groundwater and surface waters through systemic management.

- Landscapes are ever-evolving products of interacting cultural, biological and geological factors. However they are vulnerable to a steady erosion of their distinctive qualities and the integrity of their landform assemblages, particularly outside designated areas such as AONBs. We need to conserve their local distinctiveness and integrity through descriptions of local character which include geodiversity, particularly landforms.

- Features associated with economic geology such as quarries, tramways and brick kilns are part of the history of human activity. They are vulnerable to economic and industrial change, and preservation by record may be the best way to conserve their geodiversity interest where physical preservation as the first resort is not practical.

Norfolk Geodiversity Partnership

NBIS Norfolk Biodiversity Information Service

Norfolk County Council

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Norfolk's Earth Heritage

Members of the Norfolk Geodiversity Partnership:

Breckland Council

Broads Authority – The Broads - a member of the National Park family

British Geological Survey – Natural Environment Research Council

GeoConservationUK

The Geological Society of Norfolk

the landscape partnership – landscape architecture, urban design, environmental planning

NBIS Norfolk Biodiversity Information Service

Natural England

nbp Norfolk Biodiversity Partnership

Norfolk Museums & Archaeology Service

Norfolk Wildlife Trust

RSPB

UEA University of East Anglia