



# Geological Landscapes of the Norfolk Coast

Introducing five areas of striking geodiversity in the Norfolk Coast Area of Outstanding Natural Beauty



Dersingham National Nature Reserve

PROTECTING AN AREA OF  
OUTSTANDING NATURAL BEAUTY

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## 1.0 Introduction

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 is fundamental to the character of the Norfolk Coast Area of Outstanding Natural Beauty (AONB). It contributes the elements of its landforms, the uplands, valleys and coast which form its physical character; its geology gives rise to the AONB's varied rock types and soils; its surface water and groundwater support the area's range of species and habitats, as well as human life.

Geodiversity provides the evidence to explain how the environment of the area has changed over millions of years. Although processes associated with glaciation, which were a very important influence, are no longer operating, the area continues actively to be shaped by the processes of erosion, deposition and weathering. The result is a beautiful, evolving physical landscape, the result of a dynamic blend of past and present processes.

Conserving the landscape of the Norfolk Coast AONB is about valuing and safeguarding those features which make it distinctive, and understanding the geological basis of the landscape is a vital part of this. This guide explains something of the contribution that geodiversity makes to the quality of this unique landscape. It focuses on some of the AONB's special features, and aims to inform its readers and inspire them to find out more.

This guide has been written and edited with the intention that it should be understood by readers who have an interest in landscape and geology, without necessarily having extensive understanding of geological terms. However, there may still be terms that are unfamiliar to some readers, or are difficult to express in a more accessible way. For further information about terminology see the Glossary, [Appendix 2](#).



Cley-Salthouse shingle bank. A highly distinctive feature of the Norfolk Coast AONB landscape – but why is it there?

## 2.0 An overview of the Geodiversity of the Norfolk Coast Area of Outstanding Natural Beauty

The Norfolk Coast AONB has a wealth of landscapes and geodiversity features. Compare the chalk downs of Ringstead Common with the coastal heathland of Winterton Dunes, or the sandstone bluffs of Sandringham Warren with the slumping cliffs at Sidestrand. Contrast the dry valleys of the Cromer Ridge with the mud flats of The Wash. There are springs and salt-marshes, active dunes and fossil dunes, mudslides and glacial moraines; there are no less than 20 different soil types.

Geology lies at the core of this diversity. The rocks are an archive of information about environmental change over millions of years as well as an economic resource for human life. See [Appendix 3](#) for a table summarising the underlying geological layers of the AONB.

### Elements of the physical landscape

The bedrock geology of the Norfolk Coast AONB is quite simple, with the oldest rocks exposed in the west, the layers dipping gently towards the North Sea basin in the east.

- The oldest rocks are Lower Cretaceous sandstones and clays, which form an eroded escarpment (ridge) between Heacham and Castle Rising, and underlie much sandy heathland locally. Rock types vary from sands and impermeable clays to tough, iron-cemented sandstones, giving rise to interesting contrasts in landforms.
- Overlying these rocks, the Upper Cretaceous Chalk forms a second eroded escarpment to the east; it provides an upland backdrop to the north-western part of the AONB, with its open, rolling, downland landscapes. The Chalk contains numerous flint nodules and contributes both chalk and flint to the soil; its influence is seen widely throughout the AONB, where it has been eroded by glacial action and redistributed as chalk-rich till and flint-rich gravel. It appears at the surface along the north coast plateau as far east as Weybourne, and also where river valleys have been cut into it, for example at Binham and Stiffkey. A spectacular view of the relationship between the Lower Cretaceous formations and the Upper Cretaceous Chalk can be seen at Hunstanton Cliffs, just outside the AONB, where a relatively thin Red Chalk layer and the white Lower Chalk can be seen above the Carstone.



Hunstanton cliffs © Countryside Agency – Photographer Andy Tryner

- Eastwards, the much younger Pliocene-Pleistocene marine sands and gravels (known as the Norwich Crag and Wroxham Crag formations) overlie the Chalk; all intervening deposits, representing some 63 million years, have been removed by erosion. Their principal role in

the landscape is as a readily-eroded source of sand and gravel taken up and deposited by coastal, fluvial and glacial processes.

The superficial geology of the AONB is more complex. Seas and ice sheets came and went over this part of Norfolk many times in the Pleistocene period, leaving a complex sequence of marine and terrestrial sediments which includes many gaps in the record. Geologists make an important distinction in time between the pre-glacial and glacial Pleistocene, with the onset of the Anglian glaciation about 450,000 years ago as a key marker event in local geological history.

- Terrestrial deposits of the pre-glacial period are represented by organic-rich freshwater sediments of the Cromer-Forest-bed Formation. They outcrop along the coast at Sidestrand, Trimmingham and Mundesley (the famous West Runton elephant was excavated from these deposits).
- The Anglian glacial period left an important legacy in the landscape of the AONB in the form of a variety of tills deposited directly by the ice sheets as well as sands, gravels and silts washed out as the ice sheets melted and retreated. The earliest ice sheet came from the north, depositing the sandy till known as the Happisburgh Formation across north-east Norfolk. Later, ice sheets from the west deposited two tills known as the Sheringham Cliffs Formation; they form the core of the Cromer Ridge, and can be seen dramatically displayed in the cliffs at Overstrand, Sidestrand and Trimmingham. To the west, a variety of chalk-rich tills known as the 'marly drift' is attributed to these ice sheets. As the glaciers retreated, they left huge quantities of outwash deposits known as the Briton's Lane Formation; these mantle much of the landscape of the AONB east of Morston, and notably form the summit of the Cromer Ridge and associated glacial and outwash features such as Kelling Heath and the Blakeney Esker.
- The history of the 400,000 years or so between the end of the Anglian glaciation and the most recent glaciation is not well understood. Deposits at Morston representing a former beach at a higher level than today's (known as a "raised beach") have been dated to about 185,000 years old, indicating higher relative sea levels then. A relict cliff line is present at Dersingham, but so far the time of its formation has not been precisely established.
- The last glaciation to affect the AONB was in the Devensian period. Between 25,000 and 14,000 years ago, an ice sheet from the north deposited till and outwash sediments known as the Holderness Formation between Heacham and Morston; a range of landforms is associated with this glaciation, including the Ringstead Downs meltwater channel. Other features associated with glaciation which developed in the landscape include patterned ground (a result of freeze-thaw processes) and 'head' deposits (where frozen soil has thawed to a slurry and slumped downhill).
- At the end of this most recent Ice Age Norfolk was part of the North Sea plain. Sea levels then rose until the present coastline was more or less established about 6,000 years ago. Land-based deposits gave way to marine deposits in coastal areas. Later fluctuations in relative sea level complicated this picture, and evidence of local marine advances and retreats can be seen in borehole samples taken from around the coastline of the AONB, from the The Wash to Broadland. Sediments are being laid down today, potentially forming the rocks of the future. Layers of peat and floodplain silts are being deposited in river valleys, and a range of sediments, including sands, muds, shingles and marine silts are being laid down in coastal areas such as Winterton Ness and Holkham Bay.

### **'Geological landscapes'**

All landscapes are influenced by geology; it is a fundamental building block of landscape. In this sense all landscapes are geological landscapes, with natural and cultural landscape elements developed on the geological base.

Rather than attempting a full geodiversity characterisation of the AONB (see [Appendix 3](#)) this document concentrates on landscapes in the area in which evidence of past or current geological events, processes and features are especially apparent, and often of national or international significance.

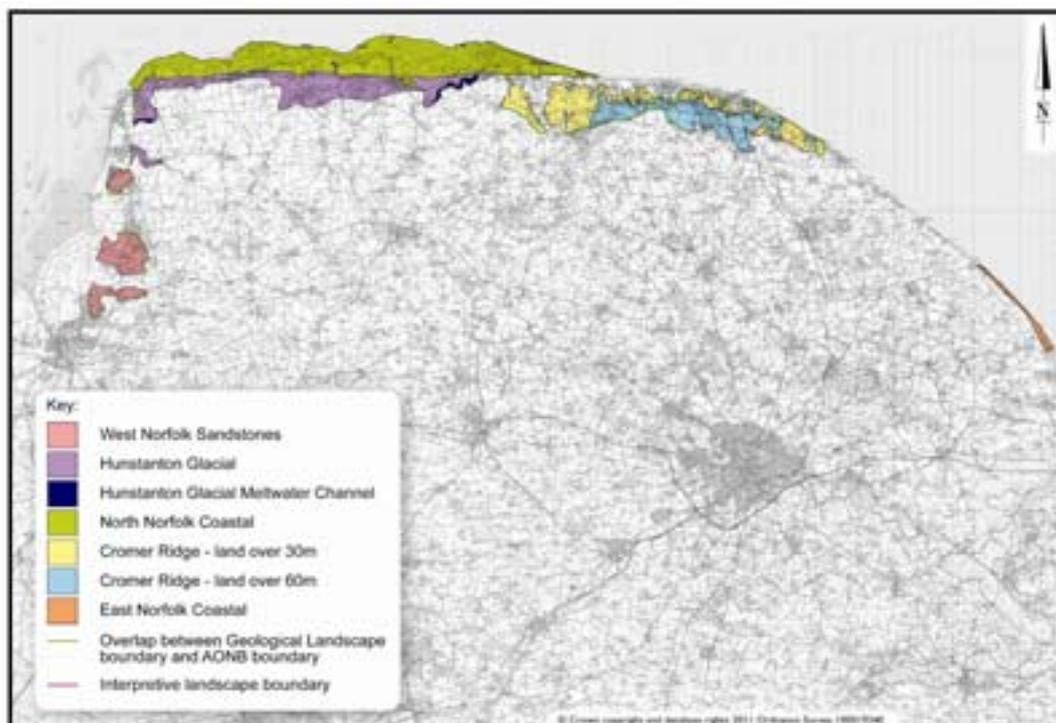
Using this approach, five key 'geological landscapes' - focal areas with high concentrations of interesting features, which make notable contributions to the physical character of the area – have been identified. These are:

- West Norfolk Sandstones
- Hunstanton Glacial
- North Norfolk Coastal
- Cromer Ridge
- East Norfolk Coastal

These 'geological landscapes' are presented here as explanatory text, pictures and maps, supported by information about conserving and enhancing their significant features. We hope this information will be useful and interesting for planners and land managers as well as for members of the public.



Hulver and Scrib Hills, near Salhouse. Distinctive landforms produced through glaciation.



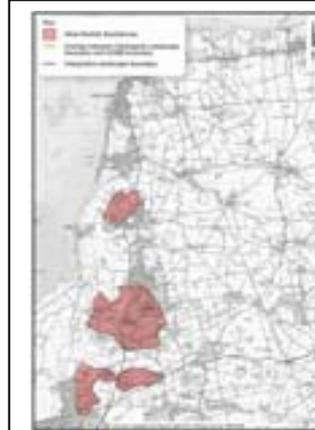
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## 3.0 Geological Landscapes

### 3.1 WEST NORFOLK SANDSTONES

A discontinuous line of low sandstone hills overlooking the eastern Wash in the western part of the AONB, running approximately north-south between Snettisham and Castle Rising, with associated superficial deposits.

Rising to a maximum height of 42 m (138 ft), it includes wooded knolls at Snettisham and Sandringham which provide fine views over The Wash as far as Lincolnshire. These sandstones were laid down in the Lower Cretaceous period between 144 and 110 million years ago; they have since been tilted by earth movements and sculpted by glacial erosion to leave upstanding remnants with the overlying layers of rock removed. Their acidic, sandy soils have given rise to tracts of heathland at Castle Rising, Sandringham, Dersingham and Snettisham. (As a backdrop, a few kilometres inland another glacially eroded escarpment of hills rises to over 70 m (230 ft); this is the rolling downland of west Norfolk developed on Upper Cretaceous Chalk.)



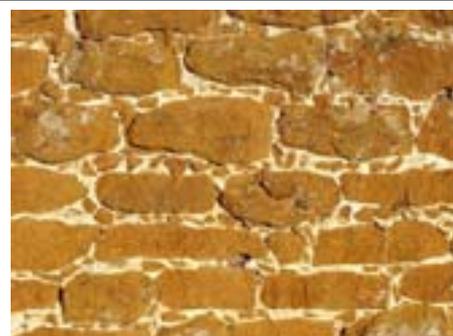
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Lodge Hill, Snettisham, with a capping of tough Lower Cretaceous Carstone. A glacially-eroded bench of Leziatite Beds and Dersingham Beds occupies the foreground.

The bedrock geological layers visible in this part of the AONB begin with the Sandringham Sands, followed by the Dersingham Beds overlain by the Carstone. They were laid down in shallow tropical seas, and contain different layers with variations in hardness and chemistry.

- The Sandringham Sands Formation includes the greenish grey sands and clays of the Mintlyn Beds, and the loose, running, quartz-rich sands of the Leziatite Beds; it includes layers cemented with iron.
- The overlying Dersingham Formation includes a lower layer of hard, iron-rich sandstones, with clay-rich layers further up the sequence, including the Snettisham Clay.
- The Carstone is a tough, grey-green, iron-rich sandstone which weathers to a rusty brown colour and hardens with age. This is the distinctive building stone seen in this part of the area.



A Carstone wall at Snettisham.



Subtle breaks in slope can mark changes in rock type. Seen here at Folly Hill, Sandringham, is the transition between the Dersingham Beds and overlying Carstone with intervening Snettisham Clay.

These variations in rock type are important from a landscape point of view. The harder sandstones form durable, terrace-like features; they may also act as impermeable layers, obstructing the flow of percolating groundwater and giving rise to spring-lines. Clay-rich layers also act in this way. By contrast, loose sands are freely draining, and are easily eroded by wind and water to form aprons of sandy material at the base of slopes, and locally may even form dunes. The result is a local landscape of great variety and charm, with slopes, scarps, plateaux and spring-lines formed at different levels.

Ken Hill and Lodge Hill form a prominent scarp feature at Snettisham. A walk through the woods will reveal stepped contours around the hill, which are founded on a sequence of Leziate Beds overlain by the Dersingham Beds and Snettisham Clay, with Carstone capping the plateau. A mantle of down-washed sands has masked the underlying geology, although weathered Carstone can be seen and appreciated in an old quarry near the footpath above Lodge Hill Farm. Damp patches may be seen where springs are active above impermeable layers, or where a thickness of poorly-draining 'head' material has been deposited at the foot of slopes by 'solifluction' (seasonal soil creep in a cold, 'periglacial' climate), as at Ken Hill Wood. At nearby Snettisham Common a sand pit near the old railway line was dug into the Leziate Beds in the 19<sup>th</sup> century for making glass. Carstone is a feature of many walls in Snettisham; it has been quarried for many years in the village, witness the series of quarries at Norton Hill; some are now grassed over but one is still active.

The best place to see landform features associated with this Lower Cretaceous geology is the Dersingham and Sandringham area. Selectively cleared of tree cover, an impressive escarpment may be seen overlooking the National Nature Reserve at Dersingham Bog. Here, sands of the Leziate Beds are capped by the harder, iron-rich layers of the basal Dersingham Beds, giving rise to the plateau feature of Sandringham Warren. A series of bold bluffs is separated by dry valleys, and the whole feature is thought to mark the line of a former cliff in the Pleistocene period with its base some 10 m (33 ft) above present sea level. The dry valleys are the product of a process known as 'spring-sapping' and erosion by stream action under 'periglacial' conditions (close to the edge of an ice sheet). The bog is developed on layers of poorly-draining, sandy 'head' washed down from the Leziate Beds, and is an example of an acid mire noted for its plant species such as sundew and cotton-grass.



The escarpment at Dersingham Bog National Nature Reserve, showing the iron-rich Dersingham Beds with white sands of the Leziate Beds washed out at the foot of the slope. © Robin Stevenson.

The Carstone forms the summit of the escarpment at Sandringham, and gives rise to scarp features in the woods and a spring-line in Sandringham Country Park. Heathland is developed extensively in this area on acidic, free-draining, sandy soils.

Southwards, the Lower Cretaceous rocks outcrop once again in the Castle Rising and North Wootton area. The Carstone is absent here, presumably eroded away by the Anglian ice sheet, so the landscape is gentler and more rounded, although it rises to an impressive 51 m (167 ft) near Knights Hill. The Dersingham Beds underlie this high ground, but they are mostly masked by a layer of glacial till. Lower down to the west, the Leziate Beds underlie local tracts of birch woodland and heather heath at Ling Common. Pits and hollows in the woods mark the site of quarries dug in the 19<sup>th</sup> century to extract pure sand for making glass. A layer of wind-blown



Wind-blown sands derived from the Leziate Beds in an old quarry at Ling Common.

sand was deposited here by wind action over 11,000 years ago at the end of the most recent (Devensian) glacial period, and also in Mediaeval times, when it was probably caused by a combination of deforestation and overgrazing on fragile, sandy soils. The Mintlyn Beds (greenish grey sands and clays) underlie the low ground around Wootton Carr.

[For conservation recommendations see Appendix 3.1](#)

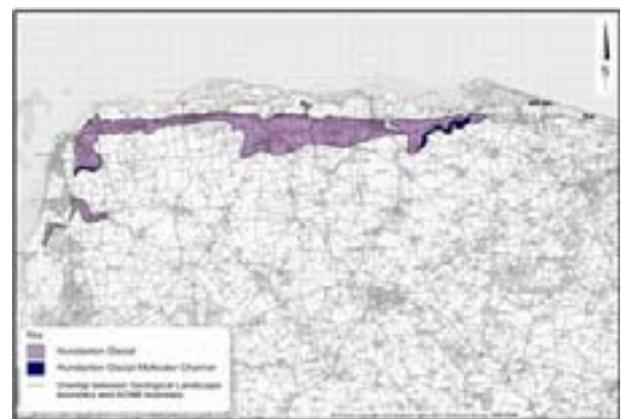
## 3.2 HUNSTANTON GLACIAL

Geology and landforms in a relatively narrow coastal band from Snettisham north and eastwards to Morston, associated with the 'Hunstanton glaciation' towards the end of the most recent (Devensian) Ice Age

North-west Norfolk has an important Ice Age heritage. 18,000 years ago it was in the grip of the coldest part of the Devensian period – the most recent glaciation. The North Sea basin was occupied by a vast ice sheet, and a lobe of ice penetrated as far south as the Fenland basin. Devensian glacial deposits and landforms shaped the landscape of the coastal hinterland between Snettisham and Morston, during what is sometimes termed the Hunstanton glaciation.

We know that a Devensian ice sheet reached Norfolk because of the geological evidence of the Holkham Till. Formerly known as the

Hunstanton Till, this reddish-brown or grey-brown sandy clay was laid down beneath the ice sheet, and contains a wide range of erratic stones (i.e. not derived from local bedrock) from as far away as southern Scotland; lumps of coal and dolerite from Northumberland mingle with locally-sourced chalk and carstone. The red-brown colour is thought to have been derived from rocks of the Triassic era (over 200 million years old) picked up by the ice sheet in the North Sea basin. The Holkham Till outcrops in stretches of ground between Snettisham and Morston, but it is rarely more than 3 m (10 ft) thick. It is found banked against Cretaceous bedrock which forms the higher ground in the area, but significantly it is not found above the 30 m (100 ft) contour; it may have been deposited by a late ice surge event which ground to a halt at this level, leaving the land over 30m untouched. Evidence of the Holkham Till on the ground is best seen in the red-brown, sandy soils of the Hunstanton Series seen along the coastal plateau, as at Holme, Titchwell and Burnham Deepdale; known, undisturbed exposures of the Till are currently few and far between. The outwash deposits of the Hunstanton ice sheet are known as the Ringstead Sands and Gravels; they form patches overlying the Holkham Till, for example at



Higher resolution version of the map for viewing or downloading



Characteristic reddish-brown soils developed on the Holkham Till at Warham

Warborough Hill, Stiffkey. There is also a series of gravel mounds in the coastal marshes east of Blakeney known as 'eyes', which are thought to be eroded remnants of outwash deposits.



Garrett Hill, Morston, a mound of outwash deposits from the Devensian glaciation.

The Hunstanton glaciation left a range of interesting features in the landscape. When the ice front advanced south-eastwards and met higher ground, lobes of ice pushed forwards into the mouths of pre-existing river valleys and blocked them. Meltwaters were ponded up there to form 'proglacial' lakes at the edge of the ice, and spillways were carved out as torrents of water sought outlet along the ice front. A good example of this can be seen near Warham, where the old northward course of the River Stiffkey became blocked at Northgate Hall Farm. Meltwater and river water created a lake which found outlet through a north-easterly overspill channel cut through Chalk bedrock, now forming the present valley at Stiffkey. The old Northgate valley now contains a 'wind gap', a section of old river valley abandoned because of river capture, and the present small watercourse in this valley, which drains into Warham Slade, is an example of what is known as a misfit stream.



The glacial meltwater channel at Ringstead Downs © British Geological Survey P210717.

At Holkham a lobe of ice is thought to have extended as far as Howe Hill, just west of where Holkham Hall now stands; the meltwaters found outlets north-eastwards through Dale Hole and the valley which now holds Holkham Lake. Another lobe of ice entered the valley at Hunstanton Park and blocked the Ringstead valley; deposits from the proglacial lake here have been found at Ringstead Common. The meltwaters carved out a spillway westwards through chalk bedrock, forming what is now a big dry valley at Ringstead Downs, thence draining into an enormous proglacial lake which filled the Fenland basin. It is quite possible that proglacial lakes occupied other local valleys, including that of the Burn. Other spillways may not be so visible in the landscape but boreholes have shown the existence of a buried channel running parallel to the coast between Brancaster and Cley; this may be evidence of a major meltwater channel draining the ice front eastwards.

Other interesting landforms from the Devensian period can be seen in this part of the AONB. The Hunstanton Park Esker is the most famous of these, an upstanding, winding ridge of sand and gravel about 2 km (1.2 miles) long, formed by a meltwater river running beneath the ice sheet as the Ringstead valley ice lobe retreated northwards. East of Heacham, the Sedgeford valley displays a range of gravel banks and mounds, thought to be 'kames' and 'kame terraces' – piles of sand and gravel formed in depressions in glaciers and dumped as they melted, and linear deposits left by a meltwater stream running alongside a glacier. Pits and depressions in Holkham Park may be the remains of kettle holes, where large blocks of stagnant ice melted out to form ponds.



Part of the Hunstanton Park Esker, photographed in 1991

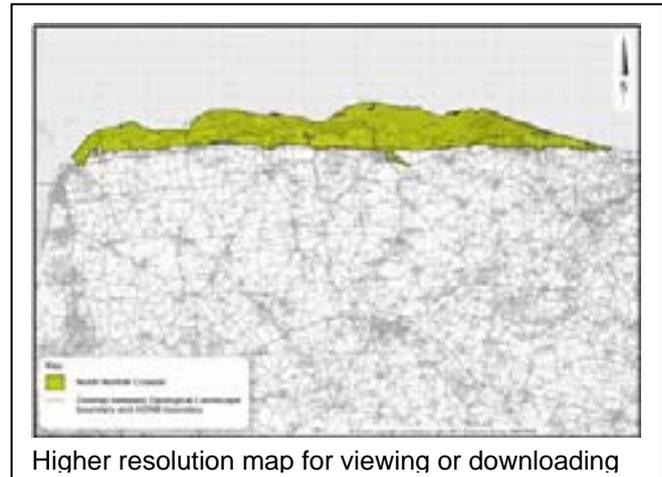
We can see plenty of evidence in this part of the AONB of 'periglacial' processes occurring close to the edge of the ice sheet in late Devensian times, as the Ice Age came to an end. The seasonal freeze-thaw regime modified slope profiles through 'solifluction', as thawed soil layers sludged slowly downhill, and many valley bottoms accumulated thick layers of what are known as 'head' deposits by this process. Patterned ground formed by freeze-thaw action developed in some areas where chalk bedrock reached the surface, for example at Burnham Deepdale. This shows up today in crop markings - on slopes one can see a beautiful series of stripes which appear to flow downhill; on plateau areas polygonal patterns can be seen.

[For conservation recommendations see Appendix 3.2](#)

### 3.3 NORTH NORFOLK COASTAL

Coastal landforms developed in the Holocene period (i.e. since the end of the last Ice Age) between Holme-next-the-Sea and Weybourne, including the processes that have given rise to the landforms (and continue to act upon them) and their geology; and also relict landforms and their geology and archaeology in the dynamic coastal zone.

The north Norfolk coast is famous for the wind-swept beauty of its landscape, where sea, land and sky combine in harmonies of muted colour and horizontal variations of sand, mud and shingle. This is a dynamic coastline, actively formed and reformed with every tide; storms and onshore gales may reshape its details literally overnight. But there remain at its core a suite of landforms which have attracted scientific attention as well as admiring visitors over many years. The north Norfolk coast between Holme-next-the-Sea and Weybourne is one of the best places in Britain to study coastal processes and landforms. It comprises a 40km stretch of intertidal sands and muds, salt-marshes, shingle banks and sand dunes, and its star features include the shingle spit at Blakeney Point and the offshore shingle bank at Scolt Head. Scientists have studied the coast at depth too, making boreholes and taking core samples to increase our understanding of the three-dimensional geometry of the buried layers of sediment, and hence understand how the area has evolved over the last 10,000 years. What we see today is a snapshot in time of a slowly-changing whole, with both durable and more ephemeral elements. A key factor is the availability of abundant soft sediments: sands, gravels and muds are derived from glacial deposits offshore and from the cliffs to the east, and are readily shaped by wind and water, erosion and deposition. The result is a true wilderness, a dynamic coastal zone where natural processes rule.



Active dunes at Wells-next-the-Sea.



'Seahenge', a Bronze Age ritual monument found embedded in eroded peat beds at Holme-next-the-Sea in 1999. © Norfolk Museums and Archaeology Service.

At the end of the last Ice Age around 10,000 years ago, the coastline was many miles away in what is now the North Sea basin, as sea levels were over 50 m / 165 ft lower than at present. A viewer standing on the edge of the north Norfolk plateau or the Cromer Ridge looking northwards would have seen a 'steppe' landscape similar to that seen today in northern Europe and Asia, with patchy trees, lakes and rivers stretching as far as the eye could see. This lost area has been called Doggerland. Rising sea levels caused by melting glacial ice progressively invaded the North Sea basin in the Holocene, reducing Doggerland to a series of islands and then finally submerging it. The shape of the present Norfolk coastline was more or less established by about 6,000 years ago. Since then relative sea levels have risen more slowly, with fluctuations leading to some local advances and retreats of the coastline, particularly in the stretch around Thornham.

The submerged landscapes of the north Norfolk coast can be appreciated at Holme-next-the-Sea and Titchwell. Displayed on old maps as 'Remains of Ancient Forest', a succession of prehistoric terrestrial and salt-marsh deposits is being eroded and exposed at low tide, including freshwater peats and the trunks of fallen pine trees. Flint tools of Late Glacial hunter-gatherers have been found at the base of the lower peat at Titchwell, dating back over 9,000 years ago. At Holme on the foreshore, timbers of the famous Seahenge ritual monument have been dated to the early Bronze Age, about 4000 years ago, when this site was woodland.

**NOTE:**

THE PEAT BEDS ARE FRAGILE AND EASILY DAMAGED, AS WELL AS BEING IMPORTANT FEEDING AREAS FOR BIRDS. PLEASE AVOID WALKING ON OR DAMAGING THE PEAT, AND HELP OTHERS TO UNDERSTAND ITS SENSITIVITY.



A log from the submerged forest at Thornham, 1936  
© British Geological Survey P253928.

Blakeney Spit and the barrier beach of Scolt Head Island are two of the best known coastal landforms in Britain. They are founded on ancient storm beach bars (ridges of inter-tidal gravel). The source of much of this gravel is likely to lie offshore, and the core of their structure is thought to be at least 4,000 years old. They have recurved tips shaped by long-shore currents, and relics of their gradual westward progression can be seen as a series of curving beach ridges partially buried in the tidal and salt-marsh sediments which have accumulated in their lee. Evidence from old maps shows they are moving westward at about 3 m (10 ft) per year and landward at about 1 m (3 ft) per year. Thus, the coastal zone is gradually narrowing, squeezed between the North Sea and higher ground to landward. In due course, the 'eyes', a series of relict mounds of gravel in the marshes deposited by the most recent (Devensian) glaciation, notably between Blakeney and Salthouse, will be eroded as the coast continues to retreat southwards.



Aerial view of Blakeney Point – a very dynamic coastal feature [© Mike Page](#)

Extensive salt-marshes have developed over thousands of years in the shelter of the Scolt and Blakeney barrier systems. Silts and muds are able to settle out in quiet backwaters, and are colonised in time by a succession of plants beginning with algae, followed by *Zostera* (eel grass) and *Spartina* (cord grass) which stabilise the sediment. A zone of salt-marsh now fringes the coast in many places, drained by large channels such as Blakeney Pit and a maze of small, winding creeks. Upper salt-marsh environments may become permanent features and may provide grazing over the centuries, as at Stiffkey. In recent centuries many areas of salt-marsh have been reclaimed by building sea walls and so converting tidal land to grazing marsh. A notable example is Wells, where the Beach Road embankment was built in 1859 and land to the west taken into agricultural use.



Salt-marshes are essentially vegetated tidal flats, as seen here at Warham.

The north Norfolk coast has abundant supplies of sand. Wide sand flats are formed in the lower part of the intertidal zone, washed by each tide and whipped by the wind. Bob's Hall Sand at Wells is over 5 km<sup>2</sup> (2 sq. miles) in extent. Dry sand is readily blown from these flats to form drifts and dunes where it is trapped along beach ridges and colonised by marram grass. This process can be seen well at Holkham Meals, where a dune system up to 6 m (20 ft) high and over 2,000 years old has developed west of Holkham Gap. By contrast, an old map shows that the dune system to the east of Holkham Gap is no older than the 18<sup>th</sup> century. Large areas of dune were stabilised in the 19<sup>th</sup> century by being planted with Corsican pines by the 3<sup>rd</sup> Earl of Leicester. Dunes are vulnerable to pressure from human activities, and blow-outs may occur where visitor footfall has eroded their stabilised surface.



Dunes stabilised by pine plantation in the 19<sup>th</sup> century at Wells-next-the-Sea.

The changing coastline has led to fluctuating fortunes for local harbours and landing places. The Mediaeval ports of Blakeney, Cley, Morston and Overy Staithe have declined due to silting. The harbour at Holkham Staithe was destroyed by the unintended effects of salt-marsh reclamation in the 19<sup>th</sup> century, and the port of Wiveton has also completely disappeared.

In this current era of global warming, local sea-level is predicted to rise by as much as 50cm (19") by 2050. As the coastal zone continues to become narrower, previously reclaimed salt-marshes may once again become tidal, opening up new areas of wildlife habitat and helping create buffer areas against the effects of flooding.



Shingle over-wash from a storm surge which over-topped the bank at Salthouse in 2008.



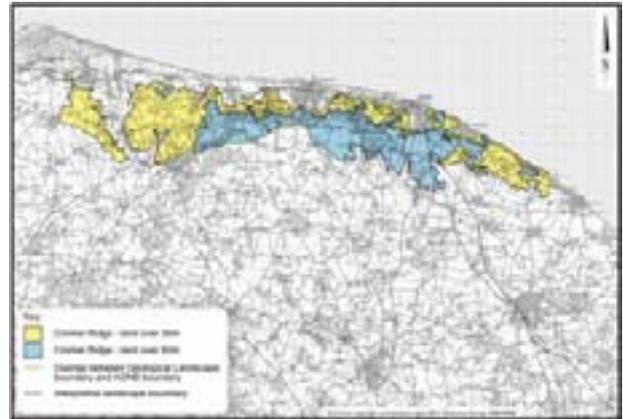
Patterns of erosion and deposition: current ripples in intertidal sands on Wells beach.

[For conservation recommendations see Appendix 3.3](#)

### 3.4 CROMER RIDGE

A large area of distinctive landforms and soils, forming a ridge about 30km long and up to about 5 or 6km wide from Langham in the west to Mundesley in the east, based on sands, gravels and clays deposited at the terminal edge of ice sheets in the Anglian glaciation over 400,000 years ago.

The Cromer Ridge landform is an important feature of the AONB. It forms a tract of high ground running east-west between Holt and Trimmingham, and includes the highest ground in Norfolk at Beacon Hill, Runton (103 m / 338 ft). Surprisingly for such a relatively lofty feature, it is composed of a range of sands, gravels and clays. The origins of the Ridge lie about 430,000 years ago during the Anglian glaciation. The heart of the Ridge is a stack of glacial moraines – material eroded, transported and piled up at the edge of ice sheets. Colossal ice sheets, possibly over a kilometre thick, from as far away as northern England and Scandinavia are thought to have terminated here on more than one occasion, leaving a succession of glacial tills so complex and contorted that geologists are still debating their origins and timing. Anyone wishing to see the interior make-up of the Cromer Ridge needs go no further than the cliffs between Cromer and Trimmingham, where marine erosion has cut a section through its eastern end.



Higher resolution version of the map for viewing or downloading



An undulating Cromer Ridge landscape, viewed from Incleborough Hill, Runton.

The moraine deposits of the Ridge were laid down on earlier marine sands and gravels, known as the Wroxham Crag, over 600,000 years old; they in turn rest on eroded Chalk bedrock, as seen on the foreshore at Overstrand. During the Anglian glaciation, a succession of three tills (the Happisburgh, Lowestoft and Walcot Tills) were deposited in three glacial phases, and also a range of water-lain silts, muds, sands and gravels, forming an elongated moraine feature over

20 km / 12 miles long. In one place, at Sidestrand, slabs of chalk bedrock were torn up by the glacier and thrust up into glacial deposits, where they can be seen displayed in the cliffs. The complexity of the glacial deposits has combined with the local ground water to produce a dramatic sequence of landslips and mud flows along the shore, as seen at Overstrand and



Folding in tills from the Anglian glaciation, displayed in the cliffs at Trimingham.  
© [Martin Warren](#)

Sidestrand. Water seeps through permeable sands and gravels until it reaches an impermeable clay layer. A large mass of material above this lubricated layer may then slip across it and down the cliff face, taking a chunk of cliff-top with it. This variable geology also gives rise to the variety of habitats found in the cliffs, including bare sand, grassland, scrub, and marshy areas, which in turn support a varied assemblage of plants and animals, including national rarities.



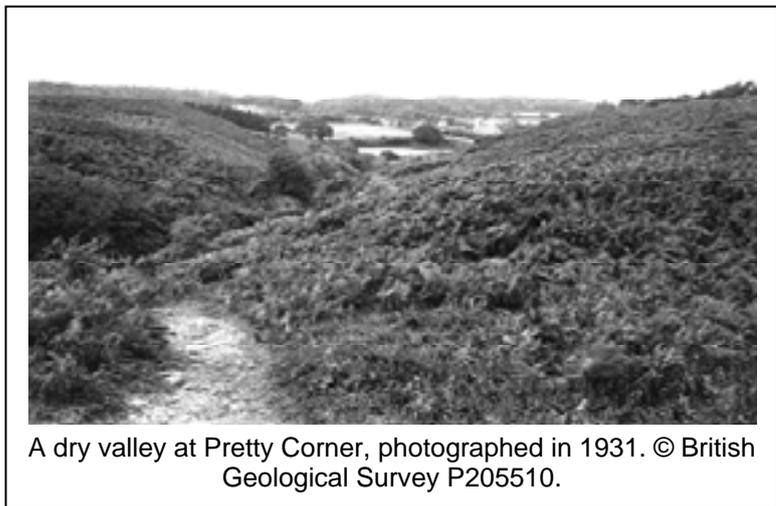
Slabs of Chalk thrust up by glacial action into Pleistocene till at Sidestrand © Martin Warren.

The surface of the Cromer Ridge is covered with sands and gravels of the Briton's Lane Formation, in some places up to 40 m / 130 ft thick, which give rise to acidic, sandy soils and heathy landscapes. They are thought to have been deposited by water gushing from the front of the last Anglian ice sheet which grounded along the line of the Ridge. In some places, such as Kelling Heath, Salthouse Heath, Roughton and Aylmerton areas of outwash gravel form important landscape features, gently sloping relict outwash plains with prominent scarp margins. In Mediaeval times the sands and gravels were exploited for a low-grade but valuable nodules of iron ore which they contain, and the traces of this industry are marked as 'Iron Workings' on Ordnance Survey maps, as at Weybourne. Today the only active local quarry (for sand and gravel) is at Briton's Lane, Beeston Regis, which has been designated a Site of Special Scientific Interest (SSSI) for its geological interest, and provides useful fresh exposures for geological investigation.



The steep northern edge of the Salthouse Heath outwash plain.

The Cromer Ridge has been strongly altered since the Anglian period. The agents of erosion have been at work over the last 400,000 years, and have modified the Ridge and formed the hills and valleys we know today. South of the Ridge, erosion has acted on local variations in the glacial deposits to produce a gently undulating landscape with smooth contours. The contours on the north side of the Ridge tell a different story. Its crest has been lowered and its scarp has retreated southwards, leaving a series of distinctive denuded gravelly knolls behind, for example Inceborough Hill and Oak Wood, and a broad, eroded bench upon which towns and villages such as Cromer and Sheringham are founded. At the same time, the face of the Ridge became sculpted by stream action and spring-sapping under 'periglacial' conditions to produce a fretwork pattern of steep-sided dry valleys



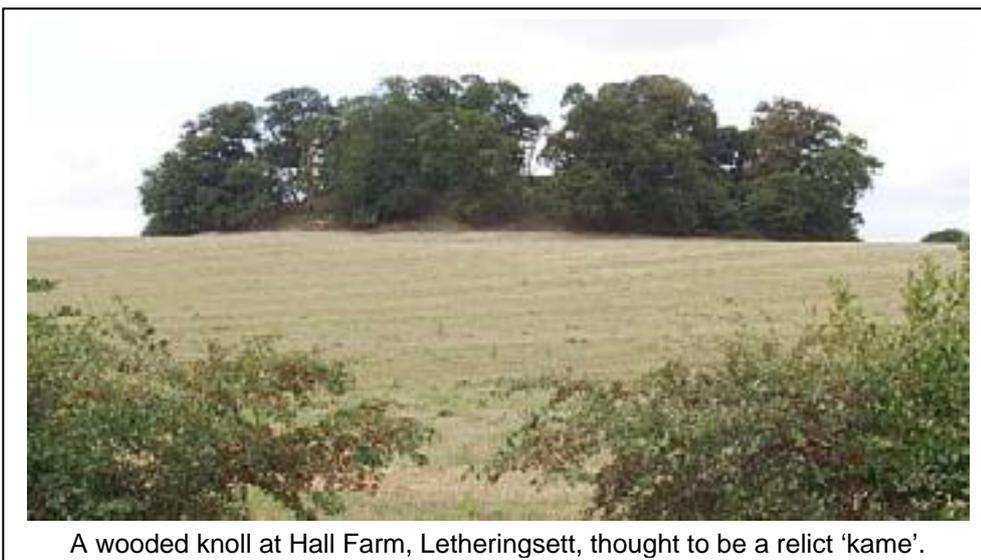
A dry valley at Pretty Corner, photographed in 1931. © British Geological Survey P205510.

and intervening spurs of high ground, as can be seen round Beeston Heath, Pretty Corner and south of Sheringham Park. The valleys are floored with 'head' deposits which accumulated by 'solifluction' (downhill sludging of seasonally-thawed material in a cold, 'periglacial' climate).

The area north-west of the Cromer Ridge between Holt and Morston has a lower relief and has a slightly different geological story to tell. Here, the River Glaven drains northwards and cuts through a thin sequence of Briton's Lane Sand and Gravels into underlying Anglian glacial deposits rich in chalk, the so-called 'marly drift'. The soils west of the Glaven are generally more chalky than those to the east. The last Anglian ice sheet is thought to have retreated north-westwards in this area, and masses of outwash gravel were flushed from the decaying ice front, leaving first the Kelling Heath and later the Salthouse Heath outwash plains, and also a long, winding ridge of gravel known as the Blakeney Esker. Some of this water would have drained away southwards down the Glaven valley towards Briston.



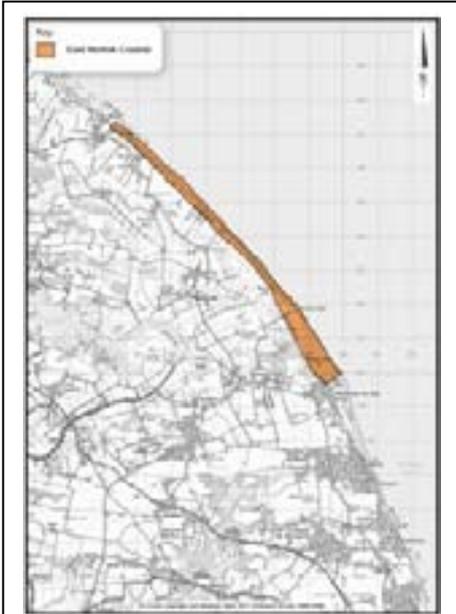
Interestingly, the landscape in the Glaven valley area is dotted with dozens of gravelly knolls and mounds. The freshness of these knoll features is a puzzle to geologists, who debate their origin, some seeing them as local, eroded remnants of a once extensive sheet of outwashed gravel from material deposited during the Anglian glaciation. Others see them as relict 'kames' and 'kame terraces' deposited individually by outwash processes as the glacier retreated. A third view is that they were developed in a post-Anglian glacial period, while others have emphasised the role of agriculture over the centuries in accentuating relief. Some valley-side benches, for example The Hangs near Salthouse, may be ice-contact slopes, marking the position of the edges of ice sheets.



[For conservation recommendations see Appendix 3.4](#)

### 3.5 EAST NORFOLK COASTAL

Coastal landforms developed in the Holocene period (i.e. since the end of the last Ice Age) between Sea Palling and Winterton-on-Sea by wind and water processes that remain active, influenced by human coastal defence interventions.



Higher resolution version of the map for viewing or downloading

The coastline between Sea Palling and Winterton-on-Sea is a North Sea frontier landscape. In some places a mere 100 m (328 ft) fringing zone of sandy beach and dunes is all that separates the fury of tides and waves from the low-lying acres of drained and settled marshland beyond. The shifting promontory of Winterton Ness swells out seawards, backed by a complex of old dunes, a site of national scientific importance. As past history and the flood events of 1938 and 1953 bear witness, this is potentially a much more dynamic coastal landscape; tidal surges could easily breach the fragile sand barrier and flood the land behind them with seawater, were it not for the sea defences. Rising sea levels due to global warming are likely to make this challenge more acute.

The dunes between Sea Palling and Winterton are important nature conservation areas, designated for their dune landforms and associated plant communities. Interestingly, unlike the sand and shingle beaches of the North Norfolk coast, the beaches here are predominantly sandy. This reflects a different geological setting: the local bedrock consists of glacial deposits of the Happisburgh

Formation from the early part of the Anglian glaciation overlying Norwich Crag (marine deposits from earlier in the Pleistocene period), and both rock types are rich in sand and readily eroded by the sea. The sands are blown into drifts and then fixed by marram grass to form mobile fore-dunes, which grade into a chain of semi-permanent dunes backing the beach. Currently their natural development is hampered by the concrete sea wall; in some places the dunes are isolated above beach level and are unable to interact with coastal processes and beach sediment and cannot roll back naturally. Over time, fresh 'yellow' dunes are stabilised and



Active fore dunes at Winterton Ness are able to replenish mature dunes developed along the sea wall behind.

colonised by lichens, grasses and sand sedge to become 'grey' dunes. To landward, there are extensive areas of such 'grey' dunes at Winterton and Horsey, totalling over 160 ha (395 acres); some dunes are over 10 m (32 ft) high, but are only about a hundred years old. Interestingly, the chemistry of these dunes is acidic, unlike those in north Norfolk; the calcareous matter has been leached out, so giving rise to notable areas of dune heath and acidic grassland which resemble the dunes of the Baltic coast. There are also 'slacks', wet hollows between the dunes which have a marked hydrological regime linked to fluctuating inputs from rainwater and the water-table; they are home to rare plants, dragonflies and the natterjack toad.



A slack among mature dunes at Winterton. In time such areas may become pockets of peat. © The Landscape Partnership.

Winterton Ness is an important example of a 'ness', a beach foreland or promontory created by tidal processes. It is an unusually dynamic landform, and has given rise to several hypotheses to explain its shifting shape over the years. Northerly and southerly longshore tidal streams are thought to converge on the Ness, tending to build it outwards, although the details of the balance between erosion and deposition either side of the promontory seem to vary over the decades. At present the Ness seems to be shifting northwards. Also, the role of offshore ebb-flow channels and sediment banks in this system is complex and not properly understood.



Sand and shingle at the constructional tip of Winterton Ness.

This stretch of coastline has for most of its history been a changing frontier between land and sea. To the south lie the relative uplands of the Isle of Flegg. In Saxon times Winterton was a fishing village on the northernmost tip of the Isle, surrounded by tidal waters which extended as far north as Waxham. The remnants of an old line of cliffs can be seen running south from Winterton. As its name suggests, Horsey was an 'eye' or island at this time. Relative movements of land and sea have since transformed estuarine muds into low-lying marshland, but the sea is now attempting to reclaim them. The Mediaeval village of Waxham Parva has been lost to the sea, and the long-term future of settlements such as Sea Palling is uncertain. The chain of hard rock reefs recently constructed offshore have led to unintended consequences in neighbouring parishes, as the natural flow of sediment to beaches is disrupted and depleted.



Sea defences at Sea Palling: offshore reefs and groynes backed by a sea wall.

Many people have heard of the devastation caused by the tidal surge of 1953, which breached the dune barrier at Horsey Gap and drowned seven people at Sea Palling. These sea floods are part of a story going back to at least the Middle Ages. The marshes behind the dunes are situated at very little above mean sea level, which makes them extremely vulnerable. Major events took place in 1250, 1287 and 1608; Faden's map of 1792 shows nine separate sea breaches between Horsey and Waxham, with mud and sand washed into the marshes behind. The dune barrier used to be rebuilt with faggots of wood. Today, sea breaches are much less likely, because sheet piling and a concrete sea-wall now back the length of the beach from Sea



The dunes at Sea Palling are isolated from coastal processes and sources of fresh beach sediment by a sea wall, and they are unable to develop naturally.

Palling to Winterton, groynes have been reinforced with boulders, and machinery can be used to artificially replenish beach material.

[For conservation recommendations see Appendix 3.5](#)

# APPENDIX 1 – Summary of Geological Stratigraphy in the Norfolk Coast Area of Outstanding Natural Beauty

## SUPERFICIAL GEOLOGY (Quaternary)

Age (000 years BP)	Stage	Formations (Fm)	Rock types, environment and landscape	Examples of localities in the AONB
Post 10,000	Flandrian	---	Recent coastal and river valley deposits in all parts of AONB	Brancaster Bay, Burn and Glaven valleys, Scolt Head, The Wash coast, Winterton Dunes
c.12,000	Late Devensian	---	Periglacial landforms such as dry valleys, solifluction sheets, coverloams and coversands, patterned ground, in many parts of AONB	Brancaster, Felbrigg, Ken Hill, Ling Common, Pretty Corner
c.18,000	Devensian	Holderness Fm	Ice sheet from north depositing reddish-brown till and outwash deposits along north-west coast (the 'Hunstanton glaciation'); proglacial lacustrine silts in valleys.	Heacham, Morston, Ringstead, Stiffkey
c.185,000 [c.430,000]	--- [Late Anglian]	--- Briton's Lane Fm	Raised beach deposits on the north coast Outwash sheets and outwash plains formed by successive ice retreats, forming summit areas of the Cromer Ridge	Morston Blakeney Esker, Kelling Heath, Roughton Heath, Salthouse Heath
c.450,000	Anglian	Sheringham Cliffs Fm	Contorted tills (3 <sup>rd</sup> Cromer Till) exposed in cliffs as part of the Cromer Ridge moraine, including: <ul style="list-style-type: none"> <li>▪ Weybourne Town Till - ice sheet lobe from the west depositing chalk-rich 'marly drift' till</li> <li>▪ Bacton Green Till - ice sheet from the west depositing sandy till visible in cliffs</li> </ul>	Brancaster, Cockthorpe, Wells, Weybourne Mundesley to Sheringham cliffs
c.450,000	Anglian--	Lowestoft Fm	Walcot Till (2 <sup>nd</sup> Cromer Till) – an ice sheet from the north-west depositing chalky till visible in cliffs, part of the Cromer Ridge moraine	Mundesley to Overstrand cliffs
[c.470,000]	Early Anglian	Happisburgh Fm	Happisburgh Till (1 <sup>st</sup> Cromer Till) – an ice sheet from the north depositing sandy till across north-east Norfolk visible in cliffs, part of the Cromer Ridge moraine	Mundesley to Overstrand cliffs
c.700,000	'Cromerian'	Cromer Forest-bed Fm *	River and estuarine deposits associated with a tributary of the Ancaster River draining the English Midlands, discontinuously visible near beach level	Mundesley, Sidestrand, Trimmingham

\* Note: The Cromer-Forest-bed Formation is here treated as a superficial deposit – see Moorlock, BSP et al. 'Geology of the Cromer District' (the British Geological Survey, 2002; p8).

## BEDROCK GEOLOGY (Cretaceous to Pleistocene)

- See the British Geological Survey Lexicon of Named Rock Units for more information about terminology: <http://www.bgs.ac.uk/lexicon/home.cfm>

Periods	Age (M years BP)	Geological Formations (Fm)	Members / Beds / bio-zones / lithology	Examples of localities in the AONB
Pleistocene	1.8	Wroxham Crag Fm +	Quartz and quartzite-rich marine gravels, sands and clays	Mundesley, Sidestrand, Weybourne
Pliocene	71	Norwich Crag Fm +	Marine sands, gravels and clays	[No outcrop]
Upper Cretaceous	83	Upper Chalk (White Chalk) *	Lanceolata Zone	Sidestrand
			Mucronata Zone	Weybourne
			Goniatites / Quadrata Zone	Stiffkey, Wells
	86		Marsupites Zone	
			Uitacrinus Zone	Titchwell, Burnham Overy
	88		Coranguinum Zone	Thornham
Lower Cretaceous	93	Middle Chalk (White Chalk) *	Lata Zone	Heacham, Ringstead
			Labiatus Zone	
	103	Lower Chalk (Grey Chalk) *	Plenus Zone	Heacham
		Hunstanton Fm	Red Chalk: pink and red limestone and clay	Heacham, Snettisham
	110	Carstone Fm	Carstone: iron-cemented, pebbly sandstone	Sandringham, Snettisham
	130	Dersingham Fm	Dersingham Beds: basal iron-cemented sandstones, overlain by sands, silts and clays, overlain by the Snettisham Clay.	Castle Rising, Sandringham, Snettisham
	135	Sandringham Sands Fm	Leziatite Beds: loose quartz-rich sands and iron-cemented sandstones Mintlyn Beds: greenish grey sands and clays, with beds of clay ironstone	Castle Rising, Sandringham, Snettisham Castle Rising, North Wootton

+ Note: the Norwich Crag and Wroxham Crag are here treated as bedrock deposits – see Moorlock, BSP et al. 'Geology of the Cromer District' (the British Geological Survey, 2002; p6). For the sake of interpretive convenience, the Norwich Crag is here placed wholly in the Pliocene Epoch.

\* Note: the Chalk is here subdivided by traditional biostratigraphical zonation – see Moorlock, BSP et al. 'Geology of the Wells-next-the-Sea District' (the British Geological Survey, 2008; p15)

## APPENDIX 2 – Glossary

Aeolian	Referring to the wind and its action.
Aggregate	Any loose material mixed with cement to form concrete, typically sand and gravel.
Anglian	A glacial stage in the middle Pleistocene (qv) from about 470,000 to 425,000 years ago, in which at least three ice sheets are thought variously to have been present in Norfolk.
Anthropogenic	Effects, processes or materials derived from human agency, as opposed to naturogenic (qv).
Aquiclude	A solid, impermeable layer of rock underlying or overlying an aquifer
Aquifer	A water-bearing geological formation.
Biodiversity	The variety / diversity of life forms; the totality of genes, species, and ecosystems of a region.
Bluff	A steep cliff, bank, or promontory
Coversand	Deposits of wind-blown sand and silt
Cretaceous	An epoch from 144 to 65 million years ago characterised globally by warmer temperatures, higher sea levels and higher carbon dioxide concentrations; in Norfolk, characterised by the deposition of a range of marine sediments, most notably the Chalk.
Denudation	the removal of overlying rock / material by erosion, and the consequent exposure of underlying formations
Devensian	A predominantly glacial (qv) stage in the late Pleistocene (qv) from c.110,000 to 10,000 years ago, which culminated in a glacial maximum c.16,000 years ago when which an ice sheet was present in parts of north Norfolk.
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).
Escarpment	A steep slope or long cliff formed by erosion or by vertical movement of the Earth's crust along a fault. Escarpments separate two relatively level areas of land. The term is often used interchangeably with <i>scarp</i> but is more accurately associated with cliffs produced by erosional processes rather than those produced by faulting.
Esker	A long, winding mound of glaciofluvial (qv) sand and gravel formed by a subglacial stream emerging from a retreating glacier and dumping its bedload.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding. See also River terrace.
Fluvial	Referring to rivers.
GCR	The Geological Conservation Review, which identifies over 3000 nationally important geodiversity sites in Britain. Administered by Natural England.
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.
Glacial	A period of time marked by colder temperatures and the advance of glaciers and ice sheets. Also referring to the physical processes associated with the activity and impact of glacier ice.

Glaciofluvial	Referring to meltwater streams associated with glaciers and ice sheets and the deposits and landforms they produce.
Glaciogenic	Sediments or landform features originating from the action of glacial ice or meltwater.
Head	Poorly sorted superficial material including gravel and silt moved downslope by solifluction (qv) in a periglacial (qv) climatic regime.
Holocene	An epoch spanning the 10,000 years ago since the end of the last ice age (qv), considered to be a warmer interglacial (qv) period in the Quaternary (qv) marked by the first significant human impacts on the environment.
Ice Age	An informal term for the Pleistocene (qv) period as a whole; as 'ice age' for any cold glacial period in the Pleistocene.
Interfluvial	The higher area between two valleys.
Interglacial	A warm period between two glacial periods.
Kame	A pile of sand, gravel and till that has accumulated in a depression on a retreating glacier, and is then deposited as a mound when the ice melts.
Kame terrace	A linear deposit of outwash sand and gravel formed along the side of glacial valley by a meltwater stream flowing between the ice and the valley side.
Kettle hole	The hole left in glacial outwash deposits by a melted block of ice.
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.
Local Site	A designated non-statutory nature conservation site of local importance, such as RIGS (qv), County Geodiversity Site 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.
Moraine	An accumulation of unconsolidated soil and rock formed by the eroding and transporting action of a glacier or ice sheet.
Naturogenic	Effects, processes or materials derived from natural, non-human agency, as opposed to anthropogenic (qv).
Ness	A promontory or headland; in Norfolk these are formed by longshore drift (qv) processes.
Norwich Crag	Marine deposits of late Pliocene / early Pleistocene age, typically fossiliferous sands and clays, outcropping in eastern Norfolk.
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.
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.
Pleistocene	An epoch in the Quaternary (qv) period lasting from c.2.5 million to 12,000 years ago, during which the world's climate markedly oscillated between colder glacial (qv) and warmer interglacial (qv) phases; sometimes loosely referred to as the Ice Age (qv); followed by the Holocene (qv).
Pliocene	An epoch lasting from c.5.3 to c.1.8 million years ago; a period of steadily cooling climate during which early humans first evolved.

Physical landscape	The geological and geomorphological components of landscape, including landforms, soils and water.
Proglacial	Features developed in front of a glacier or ice sheet margin.
Quaternary	A period spanning the Pleistocene (qv) and Holocene (qv) epochs, from c.2.5 million years to the present day.
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.
Scarp	(see escarpment)
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.
Spring-sapping	A set of geomorphological processes that erode a hillslope around the site where a spring emerges. The processes may include the collapse of saturated material, surface stream erosion, and chemical weathering. Its effect may have been enhanced by frost activity under former periglacial conditions.
SSSIs	Sites of Special Scientific Interest, comprising over 4000 nationally important sites designated for their wildlife and geological interest; administered by Natural England.
Stratigraphy	The study of the rock layers (strata) in the Earth.
Till	Unsorted, unstratified material deposited directly by glacial ice; sometimes called boulder clay.
Triassic	An epoch from about 250 to 200 million years ago, followed by the Jurassic.

## APPENDIX 3 Geodiversity Characterisation & Conservation

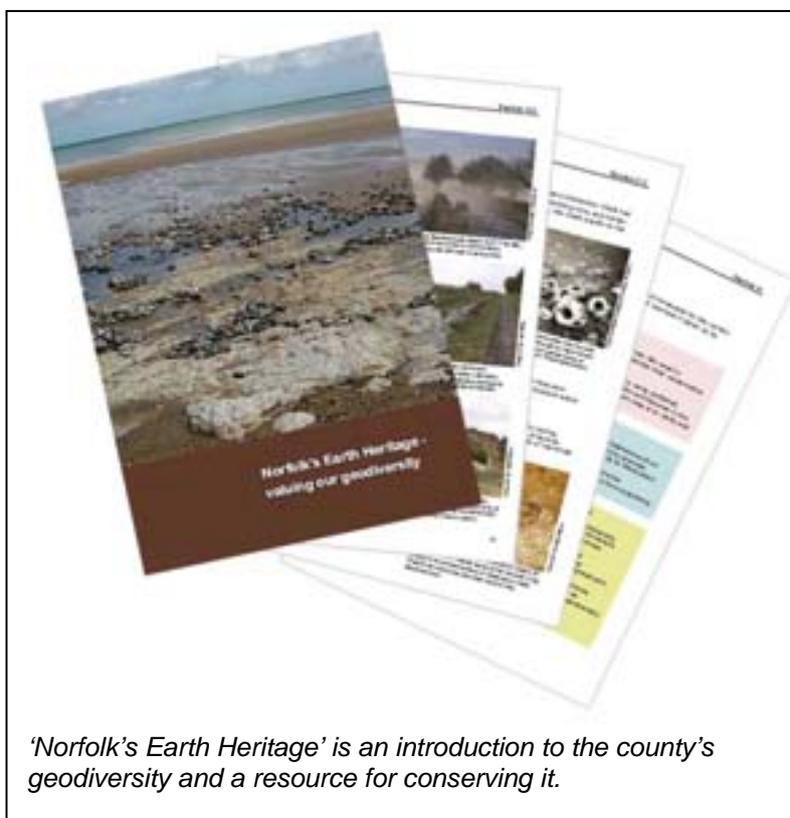
Conserving geodiversity is a key part of valuing the natural world. Nature conservation has been defined as ‘the protection, preservation, management or enhancement and the improvement of understanding and appreciation of flora, fauna and geological and geomorphological features’ (our emphasis)<sup>1</sup>. Conserving geodiversity is thus concerned with safeguarding and promoting the physical, abiotic part of nature: our Earth heritage.

While biodiversity conservation enjoys wide support today, until recently geodiversity conservation has lagged behind in terms of popular awareness and practical action. However, a number of official policies and initiatives are now helping to drive geoconservation forward, notably:  
The EU Water Framework Directive (2000/60/EC);  
The European Landscape Convention (Council of Europe Treaty 176, ratified 2004);  
Planning Policy Statement 9: Biodiversity and Geological Conservation (ODPM 2005);  
Local Sites: Guidance on their Identification, Selection and Management (DEFRA, 2006).

Statutory geoconservation in Britain is undertaken through the network of SSSIs, about a quarter of which are designated either wholly or in part for their geodiversity features. These sites were chosen through the Geological Conservation Review process<sup>2</sup>. There are 18 such SSSIs in the Norfolk Coast AONB – see Appendix 2. Policy guidance on the practical aspects of geoconservation is provided by the Earth Science Conservation Classification system<sup>3</sup>. This is a framework for deciding the conservation management needs of different types of site, based on their differing vulnerabilities.

Non-statutory conservation of geodiversity sites is principally carried out through the Local Sites designation scheme, which includes Regionally Important Geological / geomorphological Sites (RIGS). There are at present no Local Sites designated for their geodiversity in the AONB – an anomaly which does not reflect the large number of important candidate sites identified by the Norfolk Geodiversity Audit<sup>4</sup>.

Geoconservation is part of the remit of the Government agency Natural England. It is promoting a Geodiversity Action Plan (GAP) process, modelled on the successful Biodiversity Action Plan format for managing the conservation of species and habitats<sup>5</sup>. 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. The process has begun in Norfolk with the publication of ‘Norfolk’s Earth Heritage – valuing our geodiversity’ (Norfolk Geodiversity Partnership, 2010).



*‘Norfolk’s Earth Heritage’ is an introduction to the county’s geodiversity and a resource for conserving it.*

<sup>1</sup> Definition from Glossary of ‘Planning for Biodiversity and Geological Conservation - A Guide to Good Practice’ (ODPM 2006).

<sup>2</sup> See the Introduction to the GCR at <http://www.jncc.gov.uk/page-2947>.

<sup>3</sup> See: ‘Geological conservation, a guide to good practice’ (English Nature, Peterborough; 2006).

<sup>4</sup> See ‘Norfolk’s Earth Heritage – valuing our geodiversity’ (Norfolk Geodiversity Partnership, 2010)

<sup>5</sup> See Natural England web pages at

<http://www.naturalengland.org.uk/ourwork/conservation/geodiversity/protectandmanage/lgaps.aspx>

## Geodiversity and landscape character

Site-based geoconservation can deliver distinct benefits to chosen localities, but there is also a need to conserve geodiversity in the 'wider environment'<sup>6</sup>. One approach is landscape characterisation.

Protecting and enhancing landscape quality is central to the purpose of Areas of Outstanding Natural Beauty. Statements of Landscape Character provide a way of defining the distinctive character of an Area, highlighting the important qualities of the Area's component landscape types, and providing guidance on their appropriate management. An Integrated Landscape Character Guidance (ILCG) document has been prepared for the Norfolk Coast, and is a key resource for maintaining landscape quality in the AONB. Sixteen landscape character types have been identified, and descriptive Statements have been prepared for each which summarise their distinctive qualities of topography, biodiversity, landuse and historic features expressed in the landscape. Sensitivity to change is analysed and guidance is provided on their optimal management. Geodiversity is considered insofar as it contributes to perceived variations in landscape, for example major changes in soil type, topography and settlement patterns.

A similar process of characterisation may be undertaken specifically for geodiversity or for historic landscape<sup>7</sup>. Geodiversity characterisation can be applied to recognize and manage geodiversity at a landscape scale, beyond the boundaries of protected areas. For example, the Tendring Geodiversity Characterisation Report was developed '*as a tool for Tendring District to use in the creation of its Local Development Framework and to facilitate the development of positive approaches to the integration of geodiversity objectives into spatial planning...*'<sup>8</sup>. Large Geodiversity Character Areas may be identified from GIS-based mapping of geology, topography, soils, hydrology, the location and extent of past and present mineral working, and data from Historic Environment records. These may then be broken down into more specific and detailed Geodiversity Character Zones.

A different approach may involve identifying 'geological landscapes', focal areas of land with significant concentrations of geodiversity assets. These can be used to focus geoconservation initiatives, and promote greater public awareness of geodiversity.

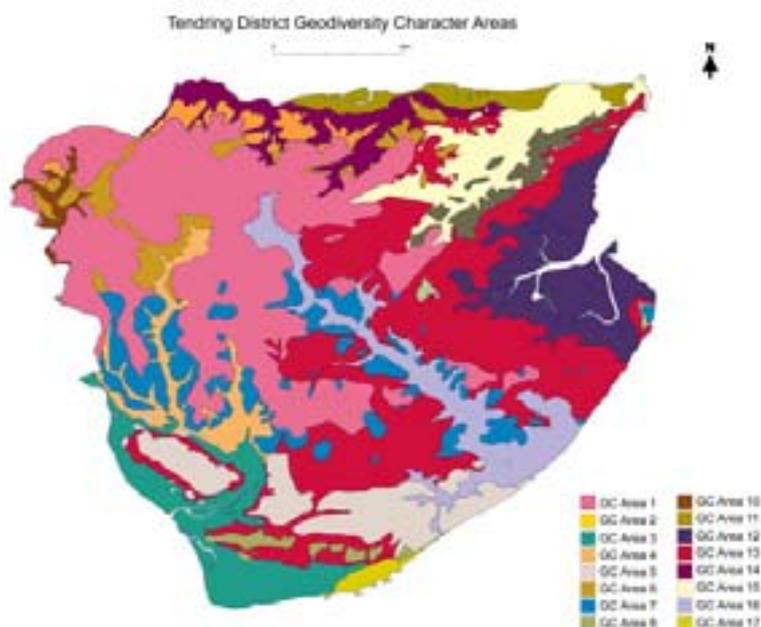


Fig. 19 Geodiversity Character Areas

*Tendring District in Essex has been divided into 16 Geodiversity Character Areas.*  
© Essex County Council, 2009.

<sup>6</sup> See Section 1(ii) of Planning Policy Statement 9: Biodiversity and Geological Conservation (ODPM 2005)

<sup>7</sup> See Norfolk's Historic Landscape Character (Norfolk County Council, 2009)

<sup>8</sup> Tendring Geodiversity Characterisation Report (Essex County Council, 2009)

# CONSERVATION RECOMMENDATIONS FOR NORFOLK COAST GEOLOGICAL LANDSCAPES

## A3.1 WEST NORFOLK SANDSTONES Conservation and enhancement

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>A. LANDFORMS</b>		<b>Generic issues are risk of damage to finite, relict geomorphological features, and lack of public understanding</b>	⇒ <b>Conserve integrity of landform as finite product of past processes through development planning constraints and positive conservation management</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Effect of lithological variation on relief	Folly Hill, Lodge Hill; Dersingham Bog; Sandringham Warren and Country Park	Earth moving and landscaping; afforestation	<ul style="list-style-type: none"> <li>• Avoid altering integrity of the landform elements, both shape and component geology</li> <li>• Avoid making artificial landform features such as banks and mounds</li> <li>• Avoid afforesting areas where landform elements can be clearly seen and appreciated</li> </ul>
Dry valleys	Sandringham Warren	Landscaping, earth moving; scrub overgrowth and afforestation	<ul style="list-style-type: none"> <li>• Avoid altering integrity of the landform elements</li> <li>• Avoid making artificial landform features such as banks, mounds and ditches</li> <li>• Reduce tree cover and avoid afforesting areas where landform elements can be clearly seen and appreciated</li> </ul>
Coversand sheet	Ling Common	Ditto	Ditto
Spring-line features	Dersingham Bog, Ken Hill; Sandringham Park	Hydrological changes; groundwater abstraction; pollution; culverting	<ul style="list-style-type: none"> <li>• Maintain natural groundwater flow regime</li> <li>• Maintain integrity of natural groundwater chemistry</li> <li>• Avoid channeling and culverting spring flows</li> </ul>

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>B. GEOLOGY</b>		<b>Generic issues are loss of access to geological information and lack of public understanding</b>	<p>⇒ <b>Conserve access to fresh geological exposures</b></p> <p>⇒ <b>Promote public education and geodiversity interpretation</b></p>
Access to geological exposures	Cat's Bottom Pits; Dersingham Common Pit and Sand Pit; Ken Hill Quarry; Ling Common Pits; Lodge Hill Pit; Snettisham Carstone Pit and Common Pit; Wolferton Railway Cutting; also minor extraction pits on farms	Backfilling, landscaping, vegetation growth, slumping of sediment; dumping and fly-tipping; recreation pressure; graffiti	<ul style="list-style-type: none"> <li>• Retain chosen geological exposures for future study in after-use planning for active extraction sites</li> <li>• Encourage ongoing mineral extraction to provide fresh exposures for study</li> <li>• Prevent tree and vegetation overgrowth from obscuring exposures</li> <li>• Prevent dumping and fly-tipping from obscuring exposures</li> <li>• Discourage inappropriate recreation such as motorbike scrambling from damaging exposures</li> <li>• Discourage graffiti from damaging exposures of the Leziate Beds</li> </ul>

## A3.2 HUNSTANTON GLACIAL Conservation and enhancement

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>A. LANDFORMS</b>			
		<b>Generic issues are risk of damage to finite, relict geomorphological features, and lack of public understanding</b>	⇒ <b>Conserve integrity of landforms as finite product of past processes through development planning constraints and positive conservation management</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Mounds of outwash gravel	Blakeney Eye, Cley Eye, Garrett Hill, Gramborough Hill, Little Eye, Warborough Hill	Quarrying, landscaping, earth moving	<ul style="list-style-type: none"> <li>• Avoid altering integrity of the landform elements, both natural shape and component geology</li> <li>• Avoid making artificial landform features such as banks and mounds</li> </ul>
Eskers	Hunstanton Park, Round O Wood	Ditto	Ditto
Kames and kame terraces	Heacham, Ringstead Common, Sedgford	Ditto	Ditto
Wind gap	Warham	Ditto	Ditto
Overflow channel	Dale Hole, Holkham Lake, Ringstead Downs, Stiffkey valley	Ditto	Ditto
Patterned ground	Brancaster, Burnham Deepdale	Earth moving and landscaping	<ul style="list-style-type: none"> <li>• Avoid altering integrity of the landform element by masking it with banks and mounds</li> </ul>
Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>B. GEOLOGY</b>			
		<b>Generic issues are loss of access to geological information and lack of public understanding</b>	⇒ <b>Conserve access to fresh geological exposures</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Access to geological exposures	Burnham Overy Parish Pit, Holkham Brick Pit, Red Lion Cutting, Round O Wood Pit, Warborough Hill Pit; also marl pits on farms	Backfilling, landscaping, vegetation growth, slumping of sediment; dumping and fly-tipping;	<ul style="list-style-type: none"> <li>• Retain chosen geological exposures for future study in site after-use planning</li> <li>• Encourage ongoing mineral extraction and farm quarries to provide fresh exposures for study</li> <li>• Prevent tree and vegetation overgrowth from obscuring exposures</li> <li>• Prevent dumping from obscuring exposures</li> </ul>

### A3.3 NORTH NORFOLK COASTAL Conservation and enhancement

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>A. LANDFORMS</b>		<b>Generic issues are risk of damage to the integrity of active and relict geomorphological features, and lack of public understanding</b>	<ul style="list-style-type: none"> <li>⇒ <b>Conserve integrity of active and relict landforms as products of present and past processes through development planning constraints and positive conservation management</b></li> <li>⇒ <b>Promote public education and geodiversity interpretation</b></li> </ul>
Salt-marshes	Brancaster, Burnham Norton, Cley, Holme, Morston, Stiffkey, Thornham	Disruption to estuarine processes, reclamation and other land-use changes, visitor pressure	<ul style="list-style-type: none"> <li>• Avoid altering dynamic processes in the natural coastal sediment transfer system</li> <li>• Avoid altering integrity of landform elements</li> <li>• Avoid visitor footfall in vulnerable areas</li> <li>• Avoid reclamation and land-take</li> </ul>
'Eyes'	Blakeney Eye, Little Eye, Gramborough Hill, Overy Marshes	Landscaping and earth moving	<ul style="list-style-type: none"> <li>• Avoid altering integrity of landform elements, for instance through quarrying shingle for beach recharge or re-embankment</li> </ul>
Shingle spits and offshore banks	Blakeney Point, Scolt Head Island	Coastal engineering and sea defences	<ul style="list-style-type: none"> <li>• Avoid altering dynamic processes in the natural coastal sediment transfer system</li> </ul>
Tidal flats	Bob's Hall Sand, East Sands, West Sands	Ditto	Ditto
Dunes, active	Holkham High Cape	Coastal engineering and sea defences, recreation	<ul style="list-style-type: none"> <li>▪ Maintain natural aeolian processes and coastal sediment transfer system</li> <li>▪ Avoid high human foot-fall which may lead to dune erosion, especially in fore-dunes</li> </ul>
Dunes, relict	Holkham Meals	Recreation	<ul style="list-style-type: none"> <li>▪ Avoid high human foot-fall which may lead to dune erosion</li> </ul>
Submerged landscape	Titchwell, Holme 'Forest Bed'	Coastal engineering and sea defences	<ul style="list-style-type: none"> <li>▪ Include submerged landscape in environmental impact assessment of any proposed coastal engineering within this coastal cell</li> </ul>

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>B. GEOLOGY</b>		<b>Generic issues are loss of access to geological information and lack of public understanding</b>	⇒ <b>Conserve access to fresh geological exposures</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Access to geological exposures	[Temporary exposures]	Loss of information	<ul style="list-style-type: none"> <li>• Promote recording and sampling of stratified Holocene sediments, for example in 'eyes' and dunes, exposed during coastal engineering work, including any palaeosols</li> </ul>
Terrestrial sediments offshore	Titchwell, Holme 'Forest Bed'	Recreation	<ul style="list-style-type: none"> <li>• Avoid high human foot-fall which may lead to destruction of finite peat beds and hence palaeo-environmental and archaeological archives</li> </ul>

## A3.4 CROMER RIDGE Conservation and enhancement

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>A. LANDFORMS</b>		<b>Generic issues are risk of damage to the integrity of relict geomorphological features, and lack of public understanding</b>	⇒ <b>Conserve integrity of relict landforms as finite products of past processes through development planning constraints and positive conservation management</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Outwash plains	Aylmerton, Kelling Heath, Roughton, Salthouse Heath	Landscaping and earth moving	<ul style="list-style-type: none"> <li>• Avoid altering integrity of plateau shape of outwash plain</li> <li>• Avoid altering bluffs and slopes associated with margins of plain</li> <li>• Avoid backfilling any pits and quarries developed in plateau or margins</li> </ul>
Mass movement features	Overstrand Cliffs, Sidestrand Cliffs,	Cliff stabilisation; hydrological changes	<ul style="list-style-type: none"> <li>• Avoid cliff engineering which damages natural mass movement processes</li> <li>• Maintain natural hydrology</li> </ul>
Eskers	Wiveton Downs	Quarrying, landscaping, earth moving	<ul style="list-style-type: none"> <li>• Avoid altering integrity of these landforms, both shape and component geology</li> <li>• Avoid making artificial landform features such as banks and mounds</li> </ul>
Kames / kame terraces	Oulton Wood, Bilsey Hill, Candlestick Hill, Hammer Hills	Ditto	Ditto
Ice-contact slope	The Hangs	Ditto	Ditto
Dry valleys and spurs	Pretty Corner, Roman Camp, Beeston Heath, Sheringham Park	Landscaping and earth moving; hydrological changes; vegetation growth; afforestation	<ul style="list-style-type: none"> <li>• Avoid altering topographic profiles of valleys and spurs</li> <li>• Maintain natural activity and landforms of any seasonal springs and streams</li> <li>• Reduce tree cover and avoid afforesting areas so landform elements can be clearly seen and appreciated</li> </ul>
Erosional knolls / outliers	Incleborough Hill, Town Hill, Stone Hill, Skelding Hill, Oak Wood, Round Hills, Muckleburgh Hill, Furze Hill, Scrib Hill	Landscaping and earth moving; hydrological changes; vegetation growth	<ul style="list-style-type: none"> <li>• Avoid altering topographic profiles of valleys and spurs</li> <li>• Maintain natural activity and landforms of any seasonal springs and streams</li> <li>• Reduce tree cover so landforms can be visually appreciated</li> </ul>

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>B. GEOLOGY</b>			
		<b>Generic issues are loss of access to geological information and lack of public understanding</b>	⇒ <b>Conserve access to fresh geological exposures</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Access to geological exposures	Gimingham Quarry, Briton's Lane Quarry, Wiveton Down Pit, Risng Hill Pit, Hurdle Lane Quarry, Bilsey Hill Pit  Mundesley Cliffs, Sidestrand Cliffs, Skelding Hill Cliffs	Backfilling, landscaping, vegetation growth, slumping of sediment; dumping and fly-tipping;  Coastal defences, cliff stabilisation;	<ul style="list-style-type: none"> <li>• Retain chosen geological exposures for future study in site after-use planning</li> <li>• Encourage ongoing mineral extraction to provide fresh exposures for study</li> <li>• Prevent tree and vegetation overgrowth from obscuring exposures</li> <li>• Prevent dumping from obscuring exposures</li> <li>• Avoid altering natural coastal processes of cliff and beach erosion which expose geological strata</li> </ul>

## A3.5 EAST NORFOLK COASTAL Conservation and enhancement

Features	Examples	Issues/sensitivities	Conservation and enhancement
<b>LANDFORMS</b>		<b>Generic issues are risk of damage to finite, relict geomorphological features, and lack of public understanding</b>	⇒ <b>Conserve integrity of landforms as product of active processes through development planning constraints and positive conservation management</b> ⇒ <b>Promote public education and geodiversity interpretation</b>
Beach	Sea Palling to Winterton	Coastal engineering and sea defences	<ul style="list-style-type: none"> <li>▪ Avoid altering dynamic processes in the natural coastal sediment transfer system, including offshore as well as processes</li> </ul>
Ness	Winterton Ness	Ditto	Ditto
Fore dunes	Winterton Dunes	Ditto	<ul style="list-style-type: none"> <li>▪ Maintain natural aeolian processes and coastal sediment transfer system</li> <li>▪ Maintain areas of shifting sand and dune dynamism</li> </ul>
Back dune complex	Delph Hills, Horsey Warren, Marram Hills, Waxham Sands, Winterton Dunes	Ditto	<ul style="list-style-type: none"> <li>▪ Maintain natural aeolian processes and coastal sediment transfer system</li> <li>▪ Reduce impact of hard sea defences on sediment supply</li> <li>▪ Maintain dune dynamism</li> </ul>
Dune slacks	Horsey Warren, Winterton dune complex	Hydrological changes, recreation, nutrient enrichment, vegetational succession	<ul style="list-style-type: none"> <li>▪ Maintain local groundwater and surface water regime</li> <li>▪ Avoid scrub overgrowth</li> <li>▪ Avoid ground-water pollution from agriculture</li> </ul>
Relict cliff	Winterton	Landscaping, earth moving	<ul style="list-style-type: none"> <li>• Avoid altering integrity of the landform element, both shape and component geology</li> <li>• Avoid making artificial landform features such as banks and mounds</li> </ul>

## APPENDIX 4 – ABOUT THE MAPS

Landscape boundaries have been mapped approximately using topographical features and information derived from scientific research and maps of the Soil Survey and British Geological Survey (see Appendix 2 for sources). The reasons behind the choice of these boundaries are explained below.

### West Norfolk Sandstones

Topographical landform elements in the AONB developed on variable Lower Cretaceous lithologies and associated superficial deposits between Snettisham and Castle Rising.	
Issues	<p>Definition of uppermost and lowermost boundaries.</p> <ul style="list-style-type: none"> <li>▪ Erosion by the Anglian glaciation [and later by the sea in places] has subdued the relative relief of the Lower Cretaceous lithologies, notable the Sandringham Sands, in many places, leading to indistinct topographical boundaries.</li> <li>▪ The lower slopes of Lower Cretaceous topographical features are masked by Anglian glacial deposits and sheets of Devensian head in many places; upper slopes are masked by Anglian glacial deposits in the Castle Rising area.</li> <li>▪ The Red Chalk forms the uppermost Lower Cretaceous unit, but does not have prominent topographical expression.</li> <li>▪ The Carstone outcrops discontinuously north of Snettisham.</li> </ul>
Mapping solution	<ul style="list-style-type: none"> <li>• Area overlain by Anglian glacial deposits at Castle Rising and between Cat's Bottom and Babingley included.</li> <li>• Head deposits at Ken Wood (Snettisham) and Dersingham and some at Wolferton selectively included.</li> <li>• Head deposits north of White Hills Wood (Roydon) and Keeper's Wood (Castle Rising) included.</li> <li>• Mintlyn Beds in vicinity of Wootton Carr only included.</li> <li>• Upper boundary defined as the top of the Carstone; Red Chalk excluded.</li> <li>• Carstone north of Gravelpit Belt (Snettisham) excluded.</li> </ul>

### Hunstanton Glacial

Late Devensian glacial geology and landforms in the AONB associated with the Hunstanton glaciation.	
Issues	<p>Reconciling mapping of evidence of Devensian glaciation and periglaciation from geology (outcrops of the Holderness Formation and head mapped by the BGS) with geomorphology (researched by Alan Straw and others). More research needs to be done on the Devensian geology and landforms of this part of the AONB.</p> <ul style="list-style-type: none"> <li>▪ Holderness Formation outcrops discontinuously.</li> <li>▪ Some glacial deposits attributed by the BGS to the Anglian glaciation may be Devensian.</li> <li>▪ Presence of ice in the Heacham River valley inferred from ice-contact features in the landscape, but not mapped by the BGS.</li> <li>▪ Presence of ice in the Stiffkey valley as far south as Warham inferred from evidence of Warham borehole but not mapped by the BGS.</li> <li>▪ Valley bottoms are occupied by periglacial head deposits and some may include proglacial lake deposits.</li> <li>▪ Meltwater channels present beyond the areas of deposition of Holderness Formation.</li> </ul>
Mapping solutions	<ul style="list-style-type: none"> <li>• Indicate all areas of outcrop of Holderness Formation, including patches overlying Chalk.</li> <li>• Map extension of ice lobe into the Heacham valley using the 30 m (100 ft) contour as far as Sedgeford.</li> <li>• Map extension of ice lobe into the Stiffkey valley at Warham using research publication by Brand <i>et al.</i> 2002.</li> <li>• Do not include head deposits or putative proglacial lakes.</li> <li>• Indicate boundaries of meltwater channels separately.</li> </ul>

## North Norfolk Coastal

Holocene coastal landforms in the AONB between Holme-next-the-Sea and Weybourne, including their generative geomorphological processes and component Holocene geology; also relict landforms and their component geology and archaeology in the active coastal zone.	
Issues	<p>Definition of component deposits in landscape area.</p> <p>Definition of landward and seaward boundaries of landscape area.</p> <ul style="list-style-type: none"> <li>▪ Holocene coastal deposits interdigitate with terrestrial deposits on landward side and grade into offshore marine deposits on seaward side.</li> <li>▪ Islands ('eyes') of Devensian gravels outcrop in several places in the marshes.</li> </ul>
Mapping solutions	<ul style="list-style-type: none"> <li>• Map landward boundary as limits of Holocene marine alluvium, including reclaimed saltmarshes; map seaward boundary as low water mark.</li> <li>• Outcrops of Devensian glacial sand and gravel are dealt with as outlying parts of the Hunstanton Glacial geological landscape.</li> </ul>

## Cromer Ridge

Anglian glacial geology and landforms of the Cromer Ridge in the AONB, including associated landform elements and geology between Langham and Trimmingham.	
Issues	<p>Definition of the Cromer Ridge as a distinct, mappable landform.</p> <p>Mapping of Anglian glaciogenic landforms associated with the emplacement of the Ridge but lying outside its core area.</p> <p>Uncertain mapping of geological deposits from different phases of the Anglian glaciation.</p> <ul style="list-style-type: none"> <li>▪ The summit areas of the Ridge naturally grade into slope areas, necessarily making boundary definition difficult from a geomorphological point of view.</li> <li>▪ The BGS has mapped Anglian deposits of the Lowestoft, Sheringham Cliffs and Briton's Lane Formations as underlying the Ridge and also adjacent areas of Norfolk. Their identification is incomplete in some areas. These extensive and varied deposits are unsuitable for defining 'geological landscape' boundaries.</li> <li>▪ A suite of glaciogenic landforms (e.g. kames, outwash plains) lies outside the summit areas of the Ridge. Recent research suggests these are of Anglian origin and may therefore be considered as part of the story of the Ridge.</li> </ul>
Mapping solutions	<ul style="list-style-type: none"> <li>• Map topographical boundaries but not geological ones. Following customary practice by geomorphologists, the summit areas of the Cromer Ridge are mapped as land over 60 m (197 ft).</li> <li>• Glaciogenic features beyond the boundaries of the summit areas of the Ridge lying west of Upper Sheringham as far as Langham are included by mapping land over 30 m (100 ft) as dotted lines; this defines an area in which such features are concentrated.</li> </ul>

## East Norfolk Coastal

Holocene coastal and aeolian landforms and active processes in the AONB between Sea Palling and Winterton-on-Sea, with associated story of human coastal defence interventions.	
Issues	<p>Definition of landward and seaward boundaries of landscape area.</p> <ul style="list-style-type: none"> <li>▪ Stabilised back dunes grade into areas of earlier Holocene marine alluvium of Broadland.</li> <li>▪ Holocene coastal deposits grades into offshore marine deposits.</li> </ul>
Mapping solutions	<ul style="list-style-type: none"> <li>• Mapping to include only Units 1, 3, 5, 9, 10, 13, 14, 15 and 16 of the Winterton-Horsey SSSI, and only shoreline and dune ridge components of County Wildlife Sites 1231 and 1247.</li> <li>• Map seaward boundary as low water mark.</li> </ul>

## APPENDIX 5 – FURTHER READING AND RESOURCES

Allison, H. and Morley, J.	Blakeney Point and Scolt Head Island	The National Trust, 1989
Brand, D., Booth, S.J. and Rose, J.	Late Devensian glaciation, ice-dammed lake and river diversion, Stiffkey, north Norfolk, England	Proceedings of the Yorkshire Geological Society 54, 2002
Bridges, E.M.	Classic Landforms of the North Norfolk Coast	The Geographical Association, 1998
England, A.C. and Lee, J.A.	Quaternary deposits of the eastern Wash margin	Bulletin of the Geological Society of Norfolk 40, 1991
Eyers, J.	Geology of northeast Norfolk: Hunstanton to Happisburgh	Rocks Afoot Field Guide Series, 1998
Funnell, B.M. and Pearson, I.	A guide to the Holocene geology of north Norfolk.	Bulletin of the Geological Society of Norfolk 34, 1989
Gallois, R.M.	Geology of the country around King's Lynn and The Wash	British Geological Survey, HMSO, 1994
Hodge, C.A.	Soils and their use in Eastern England	Soil Survey of England and Wales, Harpenden, 1984
Moorlock, B.S.P. et al.	Geology of the Cromer district	British Geological Survey, Keyworth, 2002
Moorlock, B.S.P. et al.	Geology of the Mundesley and North Walsham district	British Geological Survey, Keyworth, 2002
Moorlock, B.S.P. et al.	Geology of the Wells-next-the-Sea district	British Geological Survey, Keyworth, 2008
Norfolk Naturalists Trust	Nature in Norfolk. A Heritage in Trust	Jarrold & Sons, Norwich, 1976
Pawley, S.	Quaternary glaciations of north and west Norfolk	Ph.D. Thesis, University of London, 2006

### Maps

Geology 1:50,000	Cromer – Sheet 131	British Geological Survey, 2002
	Mundesley and North Walsham – Sheets 132 & 148	British Geological Survey, 1999
	King's Lynn and The Wash – Sheet 145 with part of 129	British Geological Survey, 1978
	Wells-next-the-Sea – Sheet 130	British Geological Survey, 2008
Soils 1: 100,000	Soils of Norfolk	Soil Survey of England and Wales

### Interesting websites

Landslides and coastal erosion at Sidestrand: <http://www.bgs.ac.uk/landslides/Sidestrand.html>  
North Norfolk Coastal Environment website: <http://www.northnorfolk.org/coastal/microsite/doc1.html>  
Field Guide to the Geology of North Norfolk: <http://www.northfolk.org.uk/geology/geoindex.html>  
The Geological Conservation Review : <http://www.incc.gov.uk/page-2947>  
River Glaven Conservation Group: [www.riverglaven.org.uk/home.html](http://www.riverglaven.org.uk/home.html)  
The Blakeney Esker Explored: [http://www.bgs.ac.uk/education/blakeney\\_esker.html](http://www.bgs.ac.uk/education/blakeney_esker.html)  
Cromer Museum: [http://www.museums.norfolk.gov.uk/Visit\\_Us/Cromer\\_Museum/index.htm](http://www.museums.norfolk.gov.uk/Visit_Us/Cromer_Museum/index.htm)  
Lynn Museum: [http://www.museums.norfolk.gov.uk/Visit\\_Us/Lynn\\_Museum/index.htm](http://www.museums.norfolk.gov.uk/Visit_Us/Lynn_Museum/index.htm)  
Geological Society of Norfolk: <http://www.norfolkgeology.co.uk/>

### Conserving geodiversity

Gray, M.; Geodiversity: Valuing and Conserving Abiotic Nature ; Wiley, 2004  
Holt-Wilson, T. ; Norfolk's Earth Heritage – valuing our geodiversity; Norfolk Geodiversity Partnership, 2010

Prosser, C., Murphy, M. & Larwood, J. ; Geological conservation: a Guide to Good Practice; English Nature, 2006

Stace, H. & Larwood, J.; Natural Foundations: Geodiversity for People, Places and Nature; English Nature, 2006

## **Designated areas**

National Nature Reserves

Blakeney  
Dersingham Bog  
Holkham  
Scolt Head Island  
Winterton Dunes

<http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/nnr/regions/east.aspx>

Sites of Special Scientific Interest

Briton's Lane Gravel Pit  
Bilsey Hill Pit  
Dersingham Bog  
Glandford Hurdle Lane  
Glandford Letheringsett Road  
Kelling Heath  
Holkham Brick Pits  
Hunstanton Park Esker  
Morston Cliff  
Mundesley Cliffs  
North Norfolk Coast  
Overstrand Cliffs  
Ringstead Downs  
Sidestrand and Trimmingham Cliffs  
Weybourne Cliffs  
Weybourne Town Pit  
Winterton Ness  
Wiveton Downs

[http://www.sssi.naturalengland.org.uk/Special/sssi/searchresults.cfm?sssi\\_name=&frmcounty=1028](http://www.sssi.naturalengland.org.uk/Special/sssi/searchresults.cfm?sssi_name=&frmcounty=1028)

Regionally Important Geological /  
Geomorphological Sites

Rising Hill Pit (Field Dalling)