Natural Area: 91. West Cumbrian Coastal Plain	Geological Significance: Notable (provisional)

General geological character: The rocks of the West Cumbrian Coastal Plain Natural Area are of late Palaeozoic and earliest Mesozoic age (345 to 230 Ma). At this time, this area was first a tropical sea then, filled by river sediments, and finally part of a red desert. The oldest rocks are exposed in the south, these Carboniferous Limstones formed as muds and coral reefs in a warm sea. With time, tropical swamps and rivers advanced over the sea, laying down sandstones and Coal Measures. As Britain moved north out of the tropics, the area became a desert, but was for a time covered by an inland salt sea, rather like the modern Dead Sea. This evaporated, leaving salt pans of gypsum and other minerals. By Triassic times (about 230 Ma), the area was still a desert, probably similar to parts of northern Africa today, with seasonal rivers depositing conglomerates and sands, with muds in the flood plains. The iron in the red sands was washed down into older rocks, staining them and in places forming iron ore deposits (Florence Mine). The area was glaciated in the 'Ice Ages', leaving extensive glacial clays and other deposits. Modern day coastal processes have formed a wide range of coastal landforms.

Key geological features:

- Quarry exposures of Palaeozoic sediments
- Iron and coal mines and links with mining heritage
- Coastal landforms and exposures of sediments
- Glacial deposits and landforms.

Number of GCR sites:

Dinantian of North England and North Wales: 2 Westphalian: 1 Permian-Triassic: 1
Pleistocene-Quaternary of Cumbria: 1 Mineralogy of the Lake District: 1
Coastal Geomorphology of England: 1

Geological/geomorphological SSSI coverage: There are 6 (P)SSSIs in the Natural Area covering 7 GCR SILs and representing 6 different GCR networks. The geological sites cover different aspects of Late Palaeozoic times in the area, after the Caledonian Orogeny which formed the Lake District rocks. The changing environments in which the rocks were formed are captured in the Carboniferous and Permian age sites (eg. Clints Quarry). The minerals which formed in the rocks during these and later times are represented in Florence Mine. Geomorphological sites represent the effects of the Ice Age on the area (St. Bees) and Holocene coastal processes (Walney Island). The site coverage includes quarries and mines (eg. Elliscales Quarry), natural exposures in coastal crags (eg. St. Bees Head), and shores (Walney Island).

Key geological management issues:

- Good relations with land managers to optimise management of existing sites, and where possible, the enhancement and promotion of geological exposures (where appropriate) in the Natural Area
- Maintaining clean and stable rock faces in quarry and cutting sites free from vegetation or obscuring developments
- Support promotion of the links between geological heritage and archaeological / mining heritage.

Key geological objectives:

1. Maintain and where possible enhance the existing geological exposures and natural processes, including use of shoreline management plans for the coastal zone.

2. Encourage initiatives aimed at the joint management of the geological and biological resources.

3. Promote heritage value of sites, by signboards and in educational and tourist literature, particularly through links between the iron and coal mining industries and the geological reasons for their existence.

Useful guides/references:

DAVIS, R.V. 1988: Geology of Lakeland. Dalesman Books, Clapham.

MITCHELL, G.H. 1970: Geologists Association Field Guide No. 2: The Lake District. Geologists' Association

MOSELEY, F. 1978: The Geology of the Lake District. Yorkshire Geological Society Occasional Publication No. 3.

Earth science SSSIs in the Natural Area:

- Clints Quarry
- Duddon Estuary
- Elliscales Quarry
- Florence Mine
- South Walney and Piel Channel Flats
- St. Bees Head

Natural Area: 92. Solway Basin	**Geological Significance:** Some **(provisional)**

General geological character: The solid geology of the Solway Basin Natural Area is of Late Palaeozoic and early Mesozoic age (230 to 195 Ma). The soft red sandstones and clays weather easily, and are therefore mostly hidden below the rolling low farmland of the area. The red marls and sandstones which give the soil its characteristic colour formed when this area was a desert in Triassic times (around 215 Ma), probably similar to parts of northern Africa today, with seasonal rivers depositing sands and muds. By around 195 Ma, at the beginning of the Jurassic period, the sea had risen and flooded the area, depositing bluish, fossil - rich clays which are known as the Lias. The area was glaciated in the 'Ice Ages' leaving extensive glacial deposits (clays, sands). Since the end of the 'Ice Age', the modern climate has evolved, a record of which has been captured by the changing plants whose pollen has been deposited in the peat bogs in some areas. The north of the area is part of the Solway Firth, where a major estuary has developed since the 'Ice Ages'. The creeks and banks of the estuary are important for the development of major saltmarshs.

Key geological features:

- Estuarine saltmarsh formations and the processes which form them
- Peat bog pollen records of climate change in last few tens of thousands of years
- Quarry exposures of Triassic and Liassic sediments
- Glacial till deposits and landforms

Number of GCR sites:

Saltmarsh Morphology: 1 Pollen Stratigraphy of England: 1

Geological/geomorphological SSSI coverage: There are 2 geomorphological (P)SSSIs in the Natural Area covering 2 GCR SILs and 2 different GCR networks. The saltmarsh morphology site (Upper Solway) covers the features of one of the best developed Holocene estuarine marshes in Britain. The site lies on both sides of the Solway, and management is shared with Scotland. The Pollen Stratigraphy site (Scaleby Moss) is a peat moor which provides a record of the changes in climate over the last 10 to 30 thousand years.

Key geological management issues:

- Use of Estuary management plans to support the conservation of continued natural processes in the area
- Maintenance of hydrological conditions at Scaleby Moss to ensure preservation of pollen record
- Promotion of the links between geomorphological sites and biological plus environmental aspects.

Key geological objectives:

1. **Maintain and where possible enhance the existing geomorphological features and natural processes**, including use of estuarine and shoreline management plans for the coastal zone.

2. **Encourage initiatives aimed at the joint management of the geological and biological resources.**

Useful guides/references:

ALLEN, J. R. L. 1992: Saltmarshes - Morphodynamics, conservation and engineering significance. Cambridge University Press.

JONES, R. L. & KEEN, D.H. 1993: Pleistocene Environments in the British Isles. Chapman & Hall, London.

MOSELEY, F. 1978: The Geology of the Lake District. Yorkshire Geological Society Occasional Publication No. 3.

Earth science (P)SSSIs in the Natural Area:

- Upper Solway Flats and Marshes
- Scaleby Moss

Maritime Natural Area: M1 Eastern Scottish Border to north bank of the River Tyne	**Geological Significance:** Notable **(provisional)**

General geological/geomorphological character: The Eastern Scottish Border to north bank of the River Tyne is generally low-lying coast is dominated by limestones, sandstones and shales with igneous cliffs rising at Dunstanburgh and sandstone cliffs at Tynemouth. Throughout, the sequence is capped by glacial clays, sands and gravels.

Geological History: The coastline exposes the most complete Carboniferous sequence in England dominated by sandstones and limestones. From the Scottish Border to Alnmouth Lower Carboniferous Dinantian (362-333 Ma) limestones dominate, from here to Tynemouth Upper Carboniferous Namurian (333-318 Ma) to Westphalian (318-303 Ma) sandstones, shales and coals are exposed. Marine conditions dominated the Dinantian eventually giving way to Namurian fluvial environments (Millstone Grit), rivers flowing southward into the Northumbrian Basin. Fluvial conditions persisted into the Westphalian which was dominated by a humid, tropical climate. Associated swamp development and build up of plant debris produced the extensive coal seams of the Durham-Northumberland Coalfield. Towards the end of the Carboniferous arid, Saharan-like conditions dominated, Permian desert sands (Permian Yellow Sands) covering much of the area at this time, today seen capping the cliffs at Tynemouth Priory. Offshore the Carboniferous sequence dips gently beneath younger Permian rocks the whole sequence thickening basinwards. Carboniferous strata are particularly important as a source rock for North Sea oil and gas.

Late Carboniferous igneous activity, associated with the Hercynian mountain building phase, led to the intrusion of the Whin Sill which today forms the castle rocks of Bamburgh, Lindisfarne and Dunstanburgh as well as the Farne Islands. Further igneous activity during the Tertiary (approximately 60 Ma) lead to the intrusion of a number of W-E orientated dykes in the south of the area. During the Pleistocene the area was covered by ice sheets which, on retreat, left a thick covering of glacial clays, sand and gravels (approximately 100,000 BP) today seen capping the coastal cliffs and filling former valleys.

Geomorphological Evolution and Processes: Differential erosion of deposits laid down during the last ice age has resulted in the formation of a headland and bay coastline: low rugged cliffs and reefs alternate with wide sandy bays backed by dunes. At St.Abbs Head near the Scottish border, cliffs rise up to 100m high, they are precipitous, deeply fissured and dissected by ravines. There are also numerous stacks and reefs offshore. Resistant sandstone outcrops form Holy Island, which is infact a group of islands covered by glacial drift and linked by shingle beaches. The sand and shingle banks enclose an extensive area of active accumulation of marine silts, mud and fine sand, which when exposed at low water, allows wind to blow the sands into sizeable dune systems 10 or more metres high. Dunes are also extensive on the mainland as far south as Seahouses. At Ross Links, south of Holy Island, the dunes reach a height of 18m and protect the low lying land behind which is susceptible to flooding. To the south of Budle Bay, the coastline is relatively drammatic with headlands, and embayments created through more rapid erosion of the carboniferous limestone. South of Alnmouth, the cliffs generally become lower with wide sandy bays eg. Alnmouth Bay and Druridge Bay, fringed with wind blown dunes up to 15m high. The dune systems , characteristic of the Northumberland coast, have been forming for the last 10,000 years. Between Blyth and Seaton Sluice the dunes reach ¼km in width. Local outcrops of more resistant strata within the coal measures form promontories and reefs. The economic exploitation of the local geology with open-cast and shaft mining, and spoil tips directly onto the beach in the inter-tidal zone in some areas e.g. Lynemouth. The mouths of the rivers Aln, Coquet, Lyne, Wansbeck and Blyth are all deflected to the south by sandy spits, indicating the net movement of beach material southwards.

The north-east is exposed to a very high energy wave climate dominated by north and north-easterly gales, and promoting a net transport of beach sediment southwards assisted by tidal currents. The littoral drift is not large due to the natural groyning effect of the headlands and the near-shore rock platforms. (Man-made defences are predominantly restricted to south of Lynemouth). Major coastal recession occurred during the post-glacial sea-level rise, and much of the available beach material is thought to have been accumulated in the near-shore zone during this time. Fresh supplies of beach material are currently limited to localised cliff erosion along the open coast. The marked indentation of Holy Island acts as a major sink for sand and finer sediment fractions. St. Abbs Head by contrast is a point of divergence for both beach and seabed sediments, such that material is transported away from the promontory, both north-westwards and southwards.

Key geological features:

- Lower Carboniferous (Dinantian) stratigraphy and palaeogeography
- Upper Carboniferous (Namurian/Westphalian) stratigraphy and palaeogeography
- Late Carboniferous igneous activity (Whin Sill)
- Pleistocene glacial deposition features and coastal evolution
- Economic resource - Durham-Northumberland Coalfield
- Lindisfarne is a group of islands where extensive accumulation of silts and fine sediments occurs with sizeable dune systems

Number of GCR sites:

Permian-Carboniferous Igneous: 3 Westphalian: 2 Pleistocene/Quaternary of NE England: 2 Dinantian of Northern England and Wales: 1 Namurian of England and Wales: 1 Holocene Sea Level: 1 Coastal Geomorphology of England: 1

Geological/geomorphological SSSI coverage: There are 7 coastal (P)SSSIs in this Maritime Natural Area containing 11 GCR SILs representing 7 different GCR networks. Lindisfarne SSSI exposes one of the finest Dinantian sections in England, critical for understanding the changing environments of the Northumberland Basin, while Howick to Seaton Point SSSI provides the best exposure of Namurian rocks in Northumberland. Tynemouth to Seaton Sluice and Creswell and Newbiggin Shores expose the completest sequence of Westphalian rocks in the Durham-Northumberland coalfield and include numerous coal seams, mudstones and sandstones. These sections are among the most important in the country for interpreting the complex environmental and palaeogeographical evolution of the Upper Carboniferous.

The compositional variation of the Whin Sill, and its relationship with over and underlying rocks, is visible at Bamburgh and Lindisfarne SSSIs. As the first described 'sill' this is the world type (reference) area for all sills. Goswick-Holy Island-Budle Bay is a 25km stretch of dunes, sandy bays and barrier beaches, and is a key site for coastal geomorphology. The significance of the site lies in (i) the progradation of sandy beaches, (ii) illustrating the role of wave-energy distributions on beach form and process, and also (iii) for its assemblage and variety of past and present coastal features.

The overlying glacial clay, sand and gravel is particularly well exposed at Sandy Bay (Creswell and Newbiggin Shores). This represents the most extensive Devensian (late Pleistocene) till on the Northumberland Coast while a raised beach on Lindisfarne is important for understanding coastal evolution over the last 5000 years.

Key geological/geomorphological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Agree conservation sections in working quarries
- Assess new sites
- Promote the educational value of the resource

Key geological objectives:

1. Maintenance and enhancement of the geological/geomorphological resource through a) development of Shoreline Management Plans ensuring continued maintenance of natural coastal processes, b) continued assessment of the educational/research value of coastal sections.

2. Promotion of the geological resource through a) assessment and promotion of site educational value (eg. coastal Whin Sill exposures), b) on site interpretation (eg. sign boarding, trail guides, leaflets), c) promotion of the link between geology, local habitats and scenery (eg. Whin Sill and location of Dunstanburgh/Bamburgh castles) and development of the link between geology and the former coal industry of the area.

3. Effective management of Dune systems is required through a) restriction on public access points to avoid trampling, b) opposing sand extraction from either the beaches dunes or intertidal areas, c) reseeding areas that have been subject to severe erosion and allow a recovery period.

4. Any coastal defence scheme should be considered carefully within a Shoreline Management Plan to ensure the maintenance and enhancement of natural coastal processes.

Useful guides/references:

CARRUTHERS, R.G., DINHAM, B.A., BURNETT, G.A. & MADEN, J., 1927. The geology of Belford, Holy Island and the Farne Islands, Memoir of the Geological Survey of England and Wales, HMSO, London.

FOWLER, A., 1936. The geology of the country around Rothbury, Amble and Ashington. Memoirs of the Geological Survey, U.K.

LAND, D.H., 1974. Geology of the Tynemouth District. Memoirs of the Geological Survey, U.K.

TAYLOR *et al.*, 1971. British Regional Geology, Northern England, publ. British Geological Survey. HMSO, London

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Bamburgh Coast and Hills
- Lindisfarne
- Castle Point to Cullernose Point
- Howick to Seaton Point
- Low Hauxley Shore
- Creswell and Newbiggin Shores
- Tynemouth to Seaton Sluice

Maritime Natural Area: M2 North bank of River Tyne to Saltburn	**Geological Significance:** Notable **(provisional)**

General geological/geomorphological character: The North bank of the River Tyne to Saltburn Maritime Natural Area is a cliffed section of coastline with several natural embayments and harbours. From Tynemouth through to Hartlepool the coast is dominated by Permian Magnesian Limestone. South of Hartlepool the overlying Triassic sequence is largely concealed though isolated sandstones crop out in Hartlepool Bay. In the south of the area Jurassic shales, mudstones and limestones crop out on the foreshore, most notably at Redcar. The Magnesian Limestone produces a rocky coastline generally capped by Pleistocene glacial clays, sands and gravels which increasingly dominate the coastline towards and south of Hartlepool.

Geological History: The oldest rocks in this area are exposed on the banks of the River Wear, uppermost Carboniferous Westphalian Beds being unconformably overlain by lowermost Permian Yellow Sands. The Permian Period (290-245 Ma) was dominated by an arid Saharan-like climate, desert sands sweeping across much of the area. Local rise in sea level swamped the then shallow North Sea Basin creating a shallow sea known as the Zechstein. Fringing reef developments lead to the deposition of the Magnesian Limestone which today dominates much of this unique coastline. Repeated evaporation and flooding of the Zechstein Sea produced a repeated sequence of limestones and evaporites - the Zechstein Cycles - progressively younger cycles being exposed southwards along the coast. The Triassic sequence south of Hartlepool (largely proved by borehole investigation and limited exposure in Hartlepool Bay) includes the Sherwood Sandstone and Mercia Mudstone Groups deposited by a river system flowing into the North Sea Basin (245-208 Ma). Lowermost Jurassic (Lias) rocks (c. 195 Ma) are dominantly marine in origin and are exposed on the coast at Redcar. Pleistocene deposits (boulder clay, gravel and sand) of the last (late Devensian - 100, 000 years BP) ice age cover much of the area. Pre-Devensian Pleistocene deposits area have also been noted. The most recent (Flandrian) sediments, most notably submerged forests along the coast, document the vegetational change over the last 10,000 years; a period of climatic amelioration with the environment becoming increasingly influenced by agricultural development.

Geomorphological Evolution and Processes: This is a cliffed section of coastline with several natural embayments and harbours. The north-east coast is exposed to a high energy wave environment, giving a high potential for sediment transport,however actual volumes of material moved in a longshore southerly direction are small, verified by the relatively small recent accumulations of sand on the beaches north of the harbour entrances at Tynemouth, Wearmouth and Seaham. The beaches in these areas are substantial, but appear not to be accreting. Longshore drift is thus mainly confined to individual embayments, where extensive rock platforms at headlands providing a partial barrier to the transfer of material from one bay to another. For example there is little exchange of material between the bays of South Shields and Marsden Sands, separated by the headland called Trow Point. While there is only low intermittent southward drift, wave action produces strong seasonal onshore/offshore sand movement.Between Seaham and Blackhall Rocks colliery works are situated on both the cliffs and the beaches. The beach surface now consists of a mixture of pebbles, grit and sand, as a result of large scale tipping of colliery waste. The net rate of littoral drift is modest and most of the colliery waste dumped on these beaches is ground down by wave action and carried offshore. There is a significant transfer of beach material between Hartlepool and Tees Bays, both are part of one large embayment stretching from Hartlepool to Redcar. The southward movement of sand is increasing the problems of coastal erosion in Hartlepool Bay.

Key geological features:

- Permian Magnesian Limestone
- Lower Jurassic stratigraphy
- Lower Jurassic palaeontology
- Pleistocene clays, sands and gravels
- Flandrian sediments and recent habitat change
- Suite of coastal cliffs and shore platforms cut into Magnesium Limestone

Number of GCR sites:

Marine Permian: 3 Pleistocene/Quaternary of NE England: 2 Hettangian-Pliensbachian: 1
Westphalian: 1 Coastal Geomorphology of England: 1 Holocene Sea Level: 1

Geological/geomorphological SSSI coverage: There are 6 coastal (P)SSSIs within this Maritime Natural Area containing 9 GCR SIL's representing 6 different GCR networks. Inland, the tidally influenced River Wear exposes uppermost Westphalian beds (Wear River Bank SSSI) unconformably overlain by the lowermost Permian Yellow Sands. Trow Point to Whitburn Steel, Seaham Harbour and the Durham Coast expose an unparalleled sequence through the Permian Magnesian Limestone. Trow Point to Whitburn Steel SSSI, includes Marsden Bay which is an important site for its geomorphology. The suite of coastal cliffs and shore platforms are cut into Magnesium Limestone. Unlike many other sites, there is a lack of major fault and joint controls so that an intricate assemblage of coastal forms has developed as local individual weaknesses have been exploited by marine erosion processes. The Durham Coast is capped by an important sequence of Pleistocene boulder clays the oldest of which are Pre-Devensian in age and are overlain by the typically tripartite Devensian boulder clay, an Ipswichian (125,000 years BP) raised beach is also present. Redcar Rocks provides the most complete sequence of Lower Jurassic rocks (spanning the Hettangian/Sinemurian Stage boundary - 204 Ma) in the country. The Hartlepool Submerged Forest (exposed in Hartlepool Bay and at Redcar) has yielded important plant and mammal faunas reflecting climate and habitat changes over the last 5,000 years.

Key geological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Asses the value of new coastal sites
- Promote the educational value of the geological resource.
- Assess the effect of a declining coal mining industry on the sediment budget and beach decline.

Key geological objectives:

1. **Maintenance and enhancement of the geological resource** through a) development of Shoreline Management Plans ensuring continued maintenance of natural coastal processes, b) continued assessment of educational/research value of coastal sites, e) encourage joint conservation initiatives on sites with dual biological/geological interests (eg. Magnesian Limestone sites).

2. **Promotion of geological resource** through a) assessment and promotion of site educational value, b) on site interpretation (eg. sign boarding/ geological trails), c) promotion of the link between geology, local habitats and scenery (eg. Hartlepool Submerged Forest - recent vegetational history and man's arrival on the scene).

3. **Maintenance of natural coastal processes** by a) restricting dredging operations offshore and extraction onshore and, b) any coastal defence scheme must be considered within a shoreline management plan and, c) monitor the effect of declining inputs of colliery waste into the local beach systems.

Useful guides/references:

SMITH, D.B., 1994. Marine Permian of England. JNCC, Chapman & Hall.

KENT, P., 1980. British Regional Geology, Eastern England from the Tees to the Wash. HMSO, London.

RAYNER, D.H., & Hemmingway, J.E., 1974. The geology and mineral resources of Yorkshire. Yorkshire Geological Society.

SMITH, D.B. & FRANCIS, D.B., 1967. Geology of the country between Durham and West Hartlepool. Memoirs of the Geological Survey of G.B.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Wear River Bank
- Hartlepool Submerged Forest
- Redcar Rocks
- Durham Coast
- Trow Point to Whitburn Steel
- Seaham Harbour

Maritime Natural Area: M3 Saltburn to Bridlington	**Geological Significance:** Outstanding **(provisional)**

General geological/geomorphological character: The Saltburn to Bridlington Maritime Natural Area is predominantly a cliffed coastline. South of Saltburn high irregular cliffs characterise the coast to Flamborough Head. At Saltburn, Lower Jurassic Liassic shales and sandstones form dark, unstable cliffs, southeastwards harder Middle Jurassic rocks appear, Boulby Head, which attains a height of 203 m, is one of the highest cliffs on the English Coast. Towards Scarborough the Middle Jurassic coast is indented by small 'wykes' and bays while between Scarborough and Speeton Upper Jurassic and Lower Cretaceous Clays form a more subdued cliff line. Cretaceous chalk gives rise to the massive Flamborough Headland and associated sea caves and isolated stacks. Towards Bridlington cliffs become dominated by thick glacial deposits forming low, rapidly eroding cliffs.

Geological History: The Lower Jurassic Lias Group (268-178 Ma) includes fossiliferous mudstones, sandstones and shales deposited in a shallow sea that inundated the Cleveland Basin. Middle Lias ironstones are economically important while the Upper Lias shales were formerly exploited for Alum production and are also world famous for their fossils (even commemorated as ammonites on the Whitby coat of arms). The Middle Jurassic (178-157 Ma) is dominated by sandstones with some shales; dominantly deposits of a large deltaic river system and include important fossil floras. Towards the end of the Middle Jurassic a marine transgression had once more inundated the area depositing fossil rich sandstones and limestones followed by the Oxfordian and Kimmeridgian Clays of the Upper Jurassic (157-145 Ma).

Continued rise in sea level into the Cretaceous lead to the deposition of the Lower Cretaceous (145-97 Ma) Speeton Clay and Hunstanton Formations followed by the Upper Cretaceous (97-75 Ma) Chalk (Ferriby, Welton, Burnham and Flamborough Chalk Formations) which completes the most extensive marine Cretaceous sequence in the UK. Much of the area is capped by Pleistocene clays, sands and gravels (the area being glaciated at least twice) and coastal sections in the south expose a Pleistocene cliff line and raised beach which can be traced inland to the Humber.

Geomorphological Evolution and Processes: South of Saltburn high irregular cliffs characterise the coast down to the massive Flamborough Headland. The whole length of this coastal section has shale/clay cliffs with an overburden of boulder clay but towards Flamborough Head, chalk cliffs become steeper and more resistant to wave attack. Sandy Bays have formed generally where the boulder clay outcrops at sea-level and more rapid erosion has occured to form embayments such as Runswick Bay. Otherwise the foreshore at the foot of the cliffs is rocky with little beach material. The boulder clay overburden is easily erodible by aerial weathering and is the most likely source of material in the pocket beaches.

Littoral drift is low and intermittent. Wave action produces seasonal onshore/offshore movement but material is generally retained within bays which are strongly indented with little interaction between embayments. There is very little accretion of beach material against any of the promontories verifying that the drift of material is weak.

Cliff erosion occurs along most of the coastline with cliff instability, weathering, toe scour occuring in most of the bays eg. Whitby, Scarborough and Robin Hood Bay. The Jurassic rock in Filey Bay is subject to a rapid rate of erosion accounting for the marked embayment before the chalk promontory of Flamborough Head. Flamborough Head comprises approximately 20km of coastal, chalk cliffs overlain with Devensian till and forms the largest promontory of the English North Sea coast. Around Flamborough Head itself the cliffs display excellent examples of caves, arches and stacks associated with faulting and jointing, and a number of blowholes have developed where the overlying till has collapsed into underlying caves. Shore platforms are also well developed both at Flamborough Head and along the southern shoreline, where the beach is mainly sandy and lacks flints which are not present in the Flamborough chalk formation. Marine processes vary from north to south and the southern cliffs are less active than those to the north.

Key geological features:

- Jurassic stratigraphy and palaeontology
- Lower Cretaceous marine sequence/stratigraphy
- Upper Cretaceous stratigraphy
- Pleistocene deposits especially fossil cliff line and raised beach
- Economically important ironstones and Alum shales of the Lias
- Flamborough Head - a complex chalk headland

Number of GCR sites:

Mesozoic Palaeobotany: 7 Toarcian: 4 Callovian: 4 Aalenian-Bajocian: 3 Bathonian: 2 Oxfordian: 2 Pleistocene/Quaternary. of E. England: 2 Jurassic-Cretaceous Reptilia: 1 Hettangian-Pliensbachian: 1 Cenomanian-Maastrichtian: 1 Kimmeridgian: 1 Berriasian-Barremian: 1 Aptian-Albian: 1 Coastal Geomorphology of England: 1 Pleistocene Vertebrata: 1

Geological/geomorphological SSSI coverage: There are 12 coastal (P)SSSIs within this Maritime Natural Area of which 3 are considered of international importance: Whitby-Saltwick, Maw Wyke-Miller's Nab and Flamborough Head. The 12 (P)SSSI's contain 32 GCR SIL's representing 15 different GCR networks. Whitby-Saltwick and Maw Wyke-Miller's Nab expose world famous sections in the Lower Jurassic Lias Group, noted not only for their stratigraphy but also for a unique fossil marine reptile fauna and, at Saltwick, the preservation of fossil plants. Iron Scar and Hundale Point-Scalby Ness exposes some of the most important Middle Jurassic rocks in the country, notably a marine band in an otherwise deltaic sequence, and again important fossil plant horizons. The Upper Jurassic coastal stretch includes a number of type (reference) sections including Gristhorpe Bay SSSI, the type locality for the Cayton Bay Formation and the Gristhorpe Plant Bed which has yielded 90 described plant species. Flamborough Head SSSI includes Speeton Cliffs which expose the regionally rare Upper Jurassic Kimmeridge Clay Formation and the type section of the Lower Cretaceous Speeton Clay Formation while from Buckton Cliffs to Sewerby an unsurpassed Upper Cretaceous chalk sequence is exposed. At Sewerby a buried cliff, oblique to the modern cliff, was formed during the Ipswichian Interglacial (128,000 years BP), the associated raised beach sediments containing important vertebrate remains of this age

Flamborough Head SSSI is an important site geomorphologically representing the most complex chalk cliffline in Britain, which is uniquely affected by the North Sea wave climate. It displays examples of cave formation, stacks and arches.

Key geological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Fossil collecting on Jurassic sections
- Promotion of the educational value of the geological resource

Key geological objectives:

1. Maintenance and enhancement of the geological resource through a) continued maintenance of natural coastal processes (Shoreline Management Plans), b) development of local conservation strategies (e.g. joint initiatives on the Flamborough Heritage Coast) that include geology, c) development and promotion of responsible fossil collecting policies, d) continued assessment of educational/research value of the coast.

2. Promotion of geological resource through a) assessment and promotion of site educational value (eg. Flamborough Head), b) on site interpretation (eg. sign boarding, trail guides, leaflets [see Scarborough Castle interpretation panel]), c) promotion of the influence of geology on local habitats and scenery (eg. topography of the Yorkshire Wolds).

3. Ensure Natural Processes continue to shape the coastline through a) ensuring development planning policies aim to keep cliff tops free from development that might require future damaging coast protection works, b) Shoreline management plans should define a setback line for the coast (in say 100 years) i.e. where the coast should be left to natural erosion processes and, c) proposals for aggregate extraction should be reviewed with care.

Useful guides/references:

KENT, P. 1980. British Regional Geology, Eastern England from the Tees to the Wash. HMSO, London.

RAWSON, P.J. & WRIGHT, J.K. 1992. The Yorkshire Coast, Geologists' Association Guide, No. 34, 117pp.

RAYNER, D.H., & HEMMINGWAY, J.E. 1974. The geology and mineral resources of Yorkshire. Yorkshire Geological Society.

Earth science coastal (P)SSSIs in the Maritime Natural Area:

- Flamborough Head
- Filey Brigg
- Gristhorpe Bay and Red Cliff
- Cayton, Cornelian and South Bays
- North Bay to South Toll House Cliff
- Staithes to Port Mulgrave
- Runswick Bay
- Whitby to Saltwick
- Maw Wyke to Miller's Nab
- Beast Cliff to Miller's Nab
- Hayburn Wyke
- Iron Scar and Hundale Point to Scalby Ness