Natural Area: 5. Durham Magnesian Limestone	**Geological Significance:** Considerable (provisional)

General geological character: The Durham Magnesian Limestone Natural Area exposes a geological sequence from the Upper Carboniferous through to the uppermost Permian, capped throughout by more recent Pleistocene Boulder Clay. The Upper Carboniferous rocks (295 Ma) are gently folded sandstones, shales and coal seams deposited by a complex river floodplain interrupted by occasional rises in sea level. These rocks are overlain by Permian rocks (255 Ma), dominated by the Magnesian Limestone which was deposited in a shallow sea (the Zechstein Sea). In addition to the Magnesian Limestone (dolomites and limestones), the Zechstein sediments comprise evaporites, marls and siltstones. These overlie basal yellow sands and breccias. The interbedded carbonates-evaporites have been grouped into a number of distinct cycles which relate to large scale palaeoenvironmental changes often culminating in the evaporation of marine water in arid climates and the resultant formation of evaporite (salt) deposits. The lower and middle Zechstein limestones frequently contain fossils of marine brachiopods, gastropods and bryozoans; some of these organisms formed reef communities. Marine conditions became progressively more saline in late Zechstein times and the fossil faunas were typically impoverished and of low-diversity indicating the unfavourable environmental conditions which were present. The Permian deposits are capped by sediments of Pleistocene age (the last 1.8 Ma) consisting mainly of glacial boulder clays, sands and gravels.

Key geological features:

- Magnesian Limestone escarpment and associated exposures
- Thick Boulder Clay cap in valley areas, thinning on escarpment
- Upper Carboniferous coal resource and links with mining heritage

Number of GCR sites:

Marine Permian: 13 Pleistocene/Quaternary of North East England: 2 Permian-Triassic: 1
Palaeozoic Palaeobotany: 1 Coastal Geomorphology of England:1 Permian-Triassic Reptilia: 1

Geological/geomorphological SSSI coverage: There are 16 (P)SSSIs in the Natural Area containing 19 GCR SILs representing 6 different GCR networks (predominantly the Marine Permian GCR block). The majority of these sites are either coastal exposures or inland quarries and cuttings. The remains of the Zechstein reef, which fringed the Zechstein Sea, provide a prolific source of Upper Permian marine fossils. Notable localities include Tunstall Hills SSSI and Humbledon Hill SSSI. In addition, Middridge Quarry SSSI is the most important locality in Britain for Permian fossil reptiles and plants. Many of the SSSIs in the Natural Area are type localities, and lend their name to established stratigraphical nomenclature for the Upper Permian. These include: Raisby Hill Quarry (Raisby Formation), Ford Quarry (Ford Formation) and Seaham Harbour (Seaham Formation).

Key geological 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 geological resource.

Key geological objectives:

1. Maintenance and enhancement of geological resource through a) site clearance (removal of concealing vegetation, debris etc.), b) agreed conservation (present and future) in working quarries (eg. Raisby Hill Quarries), c) continued assessment of the research/educational potential of new sites, d) continued maintenance of natural coastal processes (eg. Trow Point - Whitburn Steel), e) encouraging joint conservation initiatives on sites with dual biological/geological interest (Eg. Fulwell and Carley Hill Quarries).

2. Promotion of geological resource through a) assessment and promotion of site educational value (eg. urban sites), b) on-site interpretation (eg. sign boarding/geological trails), c) promotion of the link between geology, local habitats and scenery and the cultural/industrial development of the Natural Area.

Useful guides/references:

HOLLINGWORTH, N. & PETTIGREW, T. (1988): Zechstein Reef Fossils and their Palaeoecology. Palaeontological Association Field Guides to Fossils No. 3.

Earth science (P)SSSIs in the Natural Area:

- Trow Point to Whitburn Steel
- Fulwell and Carley Hill Quarries
- Claxheugh Rock and Ford Limestone Quarry
- Tunstall Hills and Rhyhope Cutting
- Gilleylaw Quarry
- Humbledon Hill Quarry
- Hylton Castle Cutting
- High Moorsley
- Seaham Harbour
- Durham Coast
- Hawthorn Quarry
- Yoden Village Quarry
- Trimdon Limestone Quarry
- Raisby Hill Quarry
- Crime Rigg and Sherburn Hill Quarry
- Middridge Quarry

Natural Area: 6. Lower Tees	**Geological Significance:** Notable **(provisional)**

General geological character: The Lower Tees Natural Area comprises a sequence of Triassic and lowermost Jurassic rocks, bounded to the north by the Permian Magnesian Limestone escarpment and to the south by the Jurassic North Yorkshire Moors. The Triassic sequence (largely proved by borehole investigation and limited exposure in Hartlepool Bay) includes the Sherwood Sandstone and Mercia Mudstone Groups which were deposited by a river system flowing into the North Sea Basin (245-208 Ma). Lowermost Jurassic (Lias) rocks (dominantly marine in origin and approximately 208-180 Ma) are exposed on the coast at Redcar and form the prominent feature of Roseberry Topping on the edge of the Yorkshire Moors. The remnants of the Cleveland Dyke (intruded approximately 58 Ma) forms a ridge to the west of Roseberry Topping. Pleistocene deposits (boulder clay, gravel and sand) cover much of the area being deposited during the last (late Devensian - approximately 100, 000 years BP) 'Ice Age'. The most recent (Flandrian) sediments (most notably exposed as submerged forests along the coast) document the vegetational change over the last 10,000 years; a climatic amelioration and an environment coming under the influence of changing land use.

Key geological features:

- Lower Jurassic stratigraphy and palaeontology
- Cleveland Dyke, Tertiary igneous activity
- Flandrian sediments and recent habitat change

Number of GCR sites:

Tertiary Igneous: 2 Pollen Stratigraphy of England: 1 Pleistocene/Quaternary of Northeast England: 1
Mesozoic Palaeobotany: 1 Holocene sea level rise: 1 Hettangian to Pliensbachian: 1

Geological/geomorphological SSSI coverage: There are 7 (P)SSSIs in the Natural Area containing 7 GCR SILs representing 6 different GCR networks. These sites reflect the range of geological interest in an area where inland exposures are relatively rare. Redcar Rocks provides the most complete sequence of Lower Jurassic rocks (spanning the Hettangian/Sinemurian stage boundary - 204 Ma) in the country while Roseberry Topping yields similarly aged plant faunas of superb preservational quality. Cliff Ridge and Lanburgh expose the Cleveland Dyke which is traceable over some 400 km to the Mull igneous complex. Hollows in the thick drift cover at Hart Bog and Neasham Fen contain important pollen records documenting the vegetational history of the area over the last 10,000 years. The Hartlepool Submerged Forest (dated at 5,000 BP) has also yielded important plant and mammal faunas.

Key geological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Asses new sites - both temporary and permanent (Note - inland Triassic exposures are rare)
- Promote the educational value of the geological resource

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 new sites (e.g. inland quarries and cuttings, temporary or permanent).

2. **Promotion of geological resource** through a) assessment and promotion of site educational value, b) on-site interpretation (e.g. Roseberry Topping - link between stratigraphy, palaeontology, Tertiary igneous activity and landscape), c) promotion of the link between geology, local habitats and scenery (e.g. Hart Bog and Hartlepool Submerged Forest - recent vegetational history and man's arrival on the scene).

Useful guides/references:

KENT, P. 1980: British Regional Geology, Eastern England. British Geological Survey. 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 Great Britain, HMSO, London

Earth science (P)SSSIs in the Natural Area:

- Cliff Ridge
- Hart Bog
- Hartlepool Submerged Forest
- Lanburgh Ridge
- Neasham Fen
- Roseberry Topping
- Redcar Rocks

Natural Area: 7. Yorkshire Dales	**Geological Significance:** Outstanding **(provisional)**

General geological character: The Yorkshire Dales Natural Area is dominated by vast tracts of Carboniferous Limestone forming an open and rugged upland separated from the surrounding north Pennines by Palaeozoic faulting associated with the Alston and Askrigg Blocks. The Carboniferous rocks are divided into the following ascending sequence: Carboniferous Limestone (Dinantian, 350-333 Ma), Millstone Grit and Shale (Namurian, 333-318 Ma) and Coal Measures (Westphalian, 318-303 Ma). The boundary between the limestones and grits is known as the Yoredale Succession, and is made up of a rhythmic sequence of limestones, shales, sandstones, grits and coals. This sequence indicates the changes in the Carboniferous seas from clear water oceans (limestones), through increasingly muddy seas (shales) to estuaries and deltas (current-bedded sandstones and grits). Today, the impervious sandstones and grits support surface streams which descend steeply into the porous limestones through potholes and dolines to form a classic karst landscape. Beneath the present day land surface the Carboniferous Limestone is cut into extensive and mature cave systems fed by these surface waters. Where the limestone outcrops on the surface, it has been extensively modified by the Quaternary glaciations (over the last 2 million years). Valleyside cliffs and scars have been carved out, and in areas where the limestone has been scoured clean by the glaciers extensive areas of limestone pavement have developed.

Key geological features:

- Exposures of Carboniferous rocks and their stratigraphical relationship
- Karst landforms including dolines, potholes, scars and areas of limestone pavement
- Underground cave systems and their associated surface and subsurface streams
- Geological influence on the character of the Dales landscape and National Park

Number of GCR sites:

Caves: 18 Dinantian of Northern England and Wales: 10 Karst: 8
Pleistocene/Quaternary of the Pennines: 5 Fluvial Geomorphology: 2 Pleistocene Vertebrata: 2
Mineralogy of the Pennines: 1 Mineralogy of the Lake District: 1
Precambrian of England: 1 Namurian of England and Wales: 1 Caledonian Structures: 1
Caradoc-Ashgill: 1 Pleistocene/Quaternary of Cumbria: 1

Geological/geomorphological SSSI coverage: There are 42 (P)SSSIs in the Natural Area containing 52 GCR SILs. This represents 13 different GCR networks which indicates the amount of geological variety within the area. The site coverage is dominated by exposures of the Carboniferous Limestone and the landforms created on and within it. Of particular note are the extensive areas of limestone pavement at Malham-Arncliffe SSSI and Ingleborough SSSI, the cave systems at Stump Cross Caves SSSI and Black Keld Catchment SSSI, and the exposures of Carboniferous Limestone at Clints Rock Quarry SSSI and Cracoe Reef Knolls SSSI. School Share Section SSSI shows the nature of the Dinantian - Namurian junction and its association with the Craven Fault. Langcliffe Scars and Jubilee, Albert and Victoria Caves SSSI contains good examples of karst landforms, including scars and potholes, and also is the site of important Pleistocene mammal remains.

Key geological management issues:

- Maintaining and enhancing the exposures of Carboniferous rocks in the Natural Area
- Maintaining the operation of natural fluvial processes in the Natural Area
- Protecting and enhancing the areas of limestone pavement within the Natural Area
- Potential for damage to the underground cave systems through both internal and external activities

Key geological objectives:

1. Protect areas of limestone pavement through Limestone Pavement Orders, and through encouraging initiatives aimed at joint geological/biological management of these areas.

2. Encourage local caving organisations to take responsibility for cave conservation by undertaking cave conservation plans for cave systems.

3. Encourage initiatives aimed at interpretation of the geological and landscape character of the Yorkshire Dales National Park and this prime recreational area.

Useful guides/references:

LEEDER, M.R. 1992: Dinantian *in* Duff, P.McL.D. & Smith, A.J. (eds). Geology of England and Wales. The Geological Society, London.

WALTHAM, A.J. & DAVIES, M. 1987: Caves and Karst of the Yorkshire Dales. British Cave Research Association, Cave Studies Series 1. BCRA, London.

WHITLOW, J.B. 1992: Geology and Scenery in Britain. Chapman and Hall, London.

Earth science (P)SSSIs in the Natural Area:

- Aysgarth
- Birks Fell Cave
- Black Keld Catchment
- Boreham Cave
- Brimham Rocks
- Conistone Old Pasture
- Dow Cave System
- Great Almscliff Crag
- Greenhow Quarry
- Hambleton Quarry
- Haw Crag Quarry
- Brants Gill Catchment
- Birkwith Caves and Fell
- Cautley Thwaite Meadows and Ecker Secker Beck
- Cliff Force Cave
- Clints Rock Quarry
- Cracoe Reef Knolls
- Cumpston Hill
- Foredale
- Giggleswick Scar and Caves
- Hell Gill
- Shaw Beck Gill
- Upper Nidderdale
- Holywell Bridge
- Strans Gill
- Pen Y Ghent Gill
- Ingleborough
- Leck Beck Head Catchment Area
- Meal Bank Quarry
- Pen Y Ghent
- Scandal Beck, Brunt Hill
- Short Gill Cave System
- The Clouds
- Thornton and Twistleton Glens
- Upper Dentdale Cave System
- Whernside
- Whitfield Gill

- Langcliffe Scars and Jubilee, Albert and Victoria Caves
- Malham-Arncliffe
- Pikedaw Calamine Caverns
- School Share Section
- Stump Cross Caves

Natural Area: 8. The Vales of Yorkshire	**Geological Significance:** Considerable **(provisional)**

General geological character: The Vales of Mowbray and York form the main N-S tract underlain by the Triassic Sherwood Sandstone and Mercia Mudstone Groups (approximately 240-210 Ma). Two cross-cutting terminal glacial moraines form the only positive features in the Vale of York. The E-W running Vale of Pickering is underlain by Upper Jurassic Kimmeridgian clays with Callovian and Oxfordian limestones forming a distinct ridge along its northern edge. The best exposures in the Natural Area are coastal, between Scarborough and Filey Brigg, where a near-complete Upper Jurassic sequence is exposed (Callovian, Oxfordian and Kimmeridgian Stages; 161-152 Ma). The Triassic rocks are dominantly fluvial in origin with an increasing marine influence towards the Jurassic. Marine conditions were established by the Jurassic which was dominated by a sub-tropical humid climate. During Pleistocene times (1.6 Ma and younger) the area was covered by ice on several occasions, much of the original Vale topography now being concealed by glacially eroded till (clay, gravel and sand) belonging to the last glaciation.

Key geological features:

- Upper Jurassic stratigraphy and palaeontology
- Pleistocene stratigraphy and palaeontology

Number of GCR sites:

Callovian: 5 Oxfordian: 4 Aalenian-Bajocian: 3 Kimmeridgian: 2 Mineralogy of the Pennines: 1 Pleistocene/Quaternary of North East England: 1 Bathonian: 1 Mesozoic Palaeobotany: 1

Geological/geomorphological SSSI coverage: There are 13 (P)SSSI in the Natural Area containing 18 GCR SILs representing 8 different GCR Networks. Most of the sites are located in the Vale of Pickering. The Natural Area provides the best exposures of Upper Jurassic rocks in northern England. The 4 coastal SSSIs expose comprehensive sections through the Callovian, Oxfordian and Kimmeridgian Stages including a number of type (reference) sections (eg. Gristhorpe Bay SSSI - type locality for the Cayton Bay Formation and the Gristhorpe Plant Bed which has yielded 90 described plant species). Inland exposures provide additional sections through many of the key stratigraphical units (eg. Drewton Lane Pits - Callovian ammonite zone type locality). Black Scar Quarry SSSI, on the western edge of the Vale of Mowbray, contains evidence of copper mineralisation (approximately 390 Ma) associated with the Pennine Orefield. The pollen record from Tadcaster SSSI places the York-Escrick moraine complex in the last Pleistocene glaciation (Devensian - 100,000 years BP). Kirkdale Cave, however, contains earlier Pleistocene sediments (Anglian - 300,000 years BP) which have yielded a rich vertebrate fauna (including the most northerly hippopotamus remains), the subject of pioneering work by Dean Buckland in 1822.

Key geological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Agree conservation sections in working quarries
- Assess new sites (temporary or permanent)
- Promote 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 that include geology, c) continued assessment of educational/research value of new sites (eg. inland quarries and cuttings, temporary or permanent).

2. **Promotion of geological resource** through a) assessment and promotion of site educational value (e.g. coastal sections), b) on-site interpretation (e.g. sign boarding, trail guides, leaflets), c) promotion of the influence of geology on local habitats and scenery (e.g. York-Escrick moraine complex).

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.

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

Earth science (P)SSSIs in the Natural Area:

- Filey Brigg
- Gristhorpe Bay and Red Cliff
- Cayton, Cornelian and South Bays
- North Bay to South Toll House Cliff
- Drewton Lane Pits
- Everthorpe Quarry
- Betton Farm Quarries
- Golden Hill Pit
- Green Lane Pit
- Spikers Hill Quarry
- Kirkdale Cave
- Mount Pleasant Quarry
- Tadcaster Mere

Natural Area: 9. North York Moors	**Geological Significance**: Outstanding **(provisional)**

General geological character: The solid geology of the North York Moors Natural Area is dominated by rocks of Jurassic age, especially Middle Jurassic. At Saltburn Lower Jurassic shales and sandstones form dark, unstable cliffs. Southeastwards, harder Middle Jurassic rocks appear and dominate the coastline to Scarborough. Boulby Head (203m AOD) is one of the highest cliffs on the English coast.

The earliest deposits belong to the dominantly marine Lias Group (268-178 Ma) and include fossiliferous mudstones, shales and sandstones that are best exposed in coastal areas. Of particular note is the development of economically important ironstones in the Middle Lias, which have been extensively mined. The overlying Upper Lias shales were formerly exploited for Alum production but are also world famous for their fossils (even being commemorated, as the ammonites on the town coat of arms of Whitby testify). The overlying Middle Jurassic strata (178-157 Ma) is dominated by sandstones with some shales, which underlie much of the northern moors area. These are dominantly deposits of large river systems and include sites of international importance for their fossil flora. The late Middle Jurassic saw a marine transgression and fossil-rich sandstones and limestones of the Abbotsbury Cornbrash and Osgodby formations were deposited. The Hackness Rock Member in particular has long been famous for its fossils and the district around that village was one of the earliest in the world to be geologically mapped in detail by the 'Father of English Geology', William Smith. The overlying Oxford Clay forms lush green slopes and is inturn overlain by Upper Jurassic (157-145 Ma) Corallian Group limestones and sandstones, which are locally rich in fossils including coral-reefs.

Ice advances in the Quaternary Period (during the last 2 Ma) deposited glacial clays, sands and gravels (till), over some areas and glacial melt-water eroded spectacular channels especially around Newtondale. Typical forms of the till, with a wealth of diverse and far-travelled erratics, is well exposed in many coastal areas and was deposited around 200,000 years BP. Other Quaternary features include tors (the result of periglacial erosion) and peat deposits recording climatic and vegetational changes since the end of the Pleistocene.

Key geological features:

- Coastal and inland exposures of Jurassic rocks of international importance for stratigraphy (especially faunas)
- Coastal and inland exposures of Jurassic rocks internationally important for palaeontology (including plants, reptiles and fish)
- Ironstone and Alum shale mines (Boulby) of great historical importance
- The northern-most Jurassic limestone platform area in Europe
- Exceptional ice-age meltwater erosion features and important glacial tills with diverse content of erratics
- Periglacial erosional features eg. tors

Number of GCR sites:

Oxfordian: 6 Mesozoic Palaeobotany: 5 Pleistocene/Quaternary of North East England: 5
Toarcian: 5 Callovian: 4 Mass Movement: 2 Jurassic-Cretaceous Reptilia: 2
Aalenian-Bajocian: 2 Bathonian: 1 Fluvial Geomorphology of England: 1
Hettangian-Pliensbachian: 1

Geological/geomorphological SSSI coverage: There are 28 (P)SSSIs in the Natural Area covering 34 GCR SILs which represent 11 different GCR networks. At least 2 sites are currently considered to be of international importance (Whitby-Saltwick and Maw Wyke-Millers Nab). The Natural Area is dominated by rocks of Jurassic age with the best exposures located on the coast. Whitby-Saltwick and Maw Wyke-Millers 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 expose some of the most important Middle Jurassic rocks in the country, notably a marine band in an otherwise deltaic sequence and again, fossil plant horizons. Inland sections include Fairy Call Beck, Hackness Quarry and Wath Quarry. Another group of sites illustrate the 'Ice-Age' development of the area and include the glacial melt water channels of Newtondale, the pollen stratigraphy of Gormire Moor and the tors of the Bride Stones and the ancient soils of Harwood Dale Moor.

Key geological management issues:

- Insufficient interpretative material to aid use of geological resources
- Poor quality of some exposures (overgrowth, etc)
- Coastal defence works
- Irresponsible fossil collecting including commercial exploitation
- Low profile of sites' international stratigraphical importance

Key geological objectives:

1. **Ensure protection of palaeontological resource** and safeguard threatened sites.

2. **Ensure appropriate management of stratigraphical sites** (eg. scrub clearance, interpretation).

3. **Promote the geological resource through interpretation** including signboards, leaflets and trail guides

4. **Adopt geological objectives within Shoreline Management Plans**

Useful guides/references:

KENT, P. 1980: British Regional Geology, Eastern England, from the Tees to the Wash. Institute of Geological Sciences, HMSO. London

RAWSON, P.F. & WRIGHT, J.K. 1992: A guide to the geology of the Yorkshire coast. Geologists Association Guide No. 34.

RAYNER, D.H. & HEMMINGWAY, J.E. 1974: The Geology and Mineral Resources of Yorkshire. Yorkshire Geological Society.

Earth science (P)SSSIs in the Natural Area:

- Bille Howe Dale
- Botton Head
- Bride Stones
- Fairy Call Beck
- Hackness Head Quarry
- Hackness Rock Pit
- Harwood Dale Moor
- Hill House Nab
- Hole of Horcum
- Newbridge Quarry
- Newtondale
- Broughton Bank
- Gormire
- Gowerdale Windy Pits/Peak Scar
- Kildale Hall
- Nunnington Cutting and Quarries
- Ryedale Windy Pits
- Shaws Gate Quarry
- Snape Hill Quarry
- Wath Quarry
- Boulby Quarries
- 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

Natural Area: 10. Yorkshire Wolds	**Geological Significance:** Considerable **(provisional)**

General geological character: The Yorkshire Wolds Natural Area exposes a sequence of uppermost Jurassic (Kimmeridge Clay Formation) rocks along the northern margin of the Natural Area, the most complete Lower Cretaceous (Speeton Clay and Hunstanton Formations) marine section in the UK and the best sequence of Upper Cretaceous Chalk (Ferriby, Welton, Burnham and Flamborough Chalk Formations) in northern England. The sequence of Jurassic and Cretaceous rocks reflect widespread changes in sea level between 155 and 70 Ma; initial marine deposition of the Kimmeridge Clay across the Cleveland Basin followed by continued sea level rise in the Cretaceous culminating in the ubiquitous deposition of chalk throughout the UK. The Wolds are characterised by the SE tilted chalk sequence cut throughout by a series of dry valleys. This chalk also forms the spectacular coastline north and south of Flamborough Head displaying excellent examples of caves , arches and stacks. 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, this topographic feature delineates the southern boundary of the Natural Area.

Key geological features:

- Upper Jurassic stratigraphy
- Lower Cretaceous marine sequence/stratigraphy
- Upper Cretaceous stratigraphy
- Pleistocene deposits esp. fossil cliff line and raised beach
- Coastal geomorphology
- Wolds drainage pattern

Number of GCR sites:

Cenomanian - Maastrichtian: 3 Pleistocene/Quaternary of North East England: 3 Aptian-Albian: 2 Coastal Geomorphology of England: 1 Kimmeridgian: 1 Pleistocene Vertebrates: 1 Karst: 1 Berriasian - Barremian: 1

Geological/geomorphological SSSI coverage: There are 6 (P)SSSIs in the Natural Area containing 13 GCR SILs representing 8 GCR networks. Flamborough Head SSSI provides the best exposures in the Natural Area and is considered to be of international importance: Speeton Cliffs expose the regionally rare Kimmeridge Clay Formation and the type section of the Speeton Clay Formation, from Buckton Cliffs to Sewerby an unsurpassed Upper Cretaceous chalk sequence is exposed and at Sewerby a buried cliff, oblique to the modern cliff, was formed during the Ipswichian Interglacial (128,000 years BP), the raised beach sediments containing important vertebrate remains of this age. Inland sections compliment the Flamborough Head SSSI, notably, Rifle Butts Quarry which exposes an attenuated sequence spanning the Jurassic/Cretaceous boundary and Melton Bottom Quarry, the type locality for the Welton Chalk Formation. Millington Wood and Pasture exposes classic examples of the characteristic dry valleys of the Yorkshire Wolds.

Key geological management issues:

- Maintain and enhance existing exposures
- Maintain natural coastal processes
- Agree conservation sections in working quarries
- Assess new sites (temporary or permanent)
- Promote 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 (eg. joint initiatives on the Heritage Coast) that include geology, c) continued assessment of educational/research value of new sites (eg. inland quarries and cuttings, temporary or permanent).

2. Promotion of geological resource through a) assessment and promotion of site educational value (e.g. Flamborough Head), b) on-site interpretation (eg. sign boarding, trail guides, leaflets (see Rifle Butts)), c) promotion of the influence of geology on local habitats and scenery (eg. topography of the Yorkshire Wolds).

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.

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

Earth science (P)SSSIs in the Natural Area:

- Flamborough Head
- Enthorpe Railway Cutting
- Melton Bottom Chalk Pit
- Millington Wood and Pasture
- Rifle Butts Quarry
- Boynton Willow Garth

Natural Area: 11. Plain of Holderness	**Geological Significance:** Notable **(provisional)**

General geological character: Although the Plain of Holderness Natural Area is underlain by Cretaceous Chalk, in most places it is so deeply buried beneath later glacial deposits that the Chalk plays little or no part in fashioning the landscape. Instead the landscape is dominated by a series of glacial deposits consisting of tills, boulder clays and glacial lake clays. These were deposited during the Devensian glaciation, during a period of glacial advance known as the Dimlington Stadial which took place between 26,000 and 13,000 years BP. The glacial deposits form a more or less continuous lowland plain, characterised by poorly sorted and poorly consolidated stony material. In places, the boulder clay plain is capped by peat filled depressions (known as meres) which mark the existence of former lake beds. Some of these are kettle holes formed due to the differential melting of glacial ice and their peat and pollen remains provide important information about Quaternary environmental change and archaeological settlement patterns in the area over the last 13,000 years. The coastal section of the Natural Area is dominated by rapid marine erosion, with rates of cliff recession measured at up to 2 metres per year in places.

Key geological features:

- Glacial clays forming low-lying plain
- Sites of former meres and links to palaeobotany and archaeology
- Coastal sections characterised by rapid marine erosion

Number of GCR sites:

Quaternary of Eastern England: 4 Pollen Stratigraphy of England: 2

Geological/geomorphological SSSI coverage: There are 6 (P)SSSI in the Natural Area containing 6 GCR SILs representing 2 different GCR networks. The coverage is dominated by the four sites which demonstrate the effects of the Quaternary glaciation on the area. Of these, Kelsey Hill Gravel Pits SSSI shows the composition of fluvioglacial outwash gravels on top of the glacial clay plain while Withow Gap Skipsea SSSI is the type locality for the Skipsea Till. The pollen contained in the peat deposits at sites such as Skipsea Bail Mere SSSI and Roos Bog SSSI provide information about the plant succession and re-establishment of vegetation communities following deglaciation. Skipsea Bail Mere SSSI is also an important archaeological site, showing evidence of Bronze Age settlement of the Holderness area. Dimlington Cliffs SSSI is important as the type site for the Dimlington Stadial, a glacial advance between 26,000 and 13,000 years ago.

Key geological management issues:

- Threats to coastal geological exposures from coastal defences and coast protection schemes
- Threats to inland geological exposures from mineral extraction and inappropriate site restoration schemes

Key geological objectives:

1. **Maintain and enhance the geological exposures** in the Natural Area
2. **Maintain the operation of natural coastal processes** in the Natural Area
3. **Encourage links** between Quaternary geology, archaeology, palaeobotany and history in the Natural Area

Earth science (P)SSSIs in the Natural Area:

- Old Mere, Hornsea
- Kelsey Hill Gravel Pits
- Roos Bog
- Skipsea Bail Mere
- Withow Gap, Skipsea
- Dimlington Cliffs

Natural Area: 12. Southern Pennines	**Geological Significance:** Notable **(provisional)**

General geological character: The Southern Pennines Natural Area is dominated by Carboniferous rocks forming a gently-sloping upland plateau. The Carboniferous rocks present in the Natural Area were laid down in tropical sea conditions and are divided by geologists into the following sequence: Millstone Grit and shale (Namurian, formed 333-318 Ma) and Coal Measures (Westphalian, formed 318-303 Ma). The lower part of the rock sequence in the Natural Area is known as the Yoredale succession, and is made up of a rhythmic sequence of limestone, shale, sandstone and grit and coal. This sequence indicates the changes in the Carboniferous seas from clear water oceans (limestones), through increasingly muddy seas (shales) to estuaries and deltas (current-bedded sandstones and grits). The Namurian shales contain marine fossils including bivalves and goniatites (cephalopod ancesters to the Mesozoic ammonites and particularly useful at zoning and correlating the sediments). During the cold periglacial climates of the Quaternary (the last 2 million years), frost weathering created the distinctive gritstone tors and edges of the area and helped to encourage surface weathering of the grits to form regoliths. Today the upland plateau is poorly drained and supports acid peat bogs and moorlands with poorly drained soils.

Key geological features:

- Exposures of Namurian rocks and their goniatite fossils
- Periglacial landforms including tors, edges and weathering regoliths
- Geological control on the character and soils of the Natural Area

Number of GCR sites:

Namurian of England and Wales: 7 Pleistocene/Quaternary of the Pennines: 1

Geological/geomorphological SSSI coverage: There are 8 (P)SSSI in the Natural Area containing 8 GCR SILs representing 2 different GCR networks. The coverage is dominated by sites showing exposures of the Namurian rocks (7 out of the 8 sites). Of these, Standedge Road Cutting SSSI exposes the deltaic Kinderscout Grit and Derby Delph Quarry SSSI shows the composition of the fluvial sandstones. Hodge Clough SSSI and Pule Hill SSSI both show the marine influence on the Namurian delta system, with well developed goniatite bands used in correlation of these rocks. Blackstone Edge SSSI shows the effects of periglacial weathering on the area with the development of a weathering regolith on the surface of the grits.

Key geological management issues:

- Need to safeguard and maintain exposures in man-made quarries and cuttings
- Potential conflict between mineral extraction industry, landfill and conservation
- Promoting the geological heritage of this upland scenic area
- Deterioration of existing sites due to vegetation growth and natural degradation

Key geological objectives:

1. Maintain and where possible enhance the existing geological exposures by agreeing management plans with owners and occupiers, including site clearance opportunities

2. Negotiate long-term conservation of exposures with mineral extraction companies at key sites

3. Encourage responsible fossil collecting at vulnerable sites and the creation and recording of both temporary and permanent exposures in the area as part of road schemes and other developments

4. Encourage site interpretation schemes such as thematic trails

Useful guides/references:

KELLING, G. & COLLINSON, J.D. 1992: Silesian *in* DUFF, P. McL.D. & SMITH, A.J. (eds), Geology of England and Wales. The Geological Society, London.

Earth science (P)SSSIs in the Natural Area:

- Blackstone Edge
- Derby Delph Quarry
- Crimsworth Dean
- Hodge Clough
- Standedge Road Cutting
- Ladcastle and Den Quarries
- Park Clough
- Pule Hill

Natural Area: 13. Coal Measures	**Geological Significance:** Considerable **(provisional)**

General geological character: The Coal Measures Natural Area is dominated by Upper Carboniferous rocks deposited on the eastern side of the Pennine anticline. Namurian (333-318 Ma) and Westphalian ('Coal Measures', 318-303 Ma) strata are exposed. During late Carboniferous times the British Isles were located in a tropical belt, environmentally dominated by fluvio-deltaic plains intermittently flooded by the sea. Namurian sediments (mudstones to pebbly sandstones) were deposited by deltas advancing from the north and east and are characterised by upward coarsening sands (associated with deltaic advance) capped by marine bands (associated with deltaic abandonment). During the Westphalian the area was dominated by extensive swamps crossed by rivers and dotted with lakes. Plant colonisation and accumulation led to the formation of peat deposits which today form numerous coal seams making the Westphalian one of the most economically important geological units on mainland Britain. Following the Carboniferous there is no record of deposition in the Natural Area until Pleistocene times. During the Pleistocene the area was affected by glacial advance on at least two occasions. Pre-Ipswichian glaciation (pre 128,000 years BP) is represented by the 'Older Drift'; boulder clays and gravels capping hilltops throughout the area while much younger river terrace gravels, sands and clays are associated with the Devensian glaciation (10,000 years BP).

Key geological features:

- Namurian stratigraphy and sedimentology
- Westphalian stratigraphy and sedimentology
- Economic resource - Westphalian 'Coal Measures'
- International importance - proposed stratotype and established type localities
- Palaeobotany

Number of GCR sites:

Westphalian: 11 Namurian of England and Wales: 2 Palaeozoic Palaeobotany: 2

Geological/geomorphological SSSI coverage: There are 14 (P)SSSIs in the Natural Area containing 15 GCR SILs representing 3 different GCR networks; several of the sites have potential international status. Two SSSIs expose Namurian rocks; Yeadon Brickworks and Railway Cutting and Great Dib Wood, the former being particularly important as the type locality for the Yeadonian Stage (320-318 Ma). Rocks of Westphalian A, B & C Stages are well represented by the remaining sites. Particularly important are Doe Lea Stream Section, the proposed stratotype for the base of Westphalian C Stage and Duckmanton Railway Cutting, the proposed stratotype for the base of Westphalian B Stage. Wharncliffe Crags also includes a Westphalian A Stage type section. Nostell Brickyard Quarry contains particularly well preserved plant fossils and Wadsley Fossil Forest the *in situ* remains of tree stumps demonstrating community structure and growth habit of now extinct arborescent club mosses.

Key geological management issues:

- Management of potential stratotypes and established type localities
- Management of palaeontological sites
- Conservation in working quarries
- Site assessment, new sites (e.g. new quarries and cuttings)
- Promotion of the value of the geological resource

Key geological objectives:

1. Maintenance and enhancement of the geological resource through a) enhancement of existing exposures, (proposed stratotypes and type localities given priority), b) development of local conservation strategies that include geology, c) continued assessment of educational/research value of new sites (e.g. quarries and cuttings, temporary or permanent).

2. Promotion of geological resource through a) assessment and promotion of site educational value (particularly relevant with the urban setting of the Natural Area), b) on-site interpretation (e.g. sign boarding, trail guides, leaflets), c) promotion of the link between geology and local habitats, scenery and the industrial development of the Natural Area (the link between geology and the former coal industry is particularly important).

Useful guides/references:

EDEN, R.A., STEVENSON, I.P. & EDWARDS, W. 1957: Geology of the Country around Sheffield. Memoir of the Geological Survey of Great Britain.

EDWARDS, W. & TROTTER, F.M. 1954: British Regional Geology, the Pennines and adjacent areas. Institute of Geological Sciences. HMSO, London.

MITCHELL, G.H. *et al.* 1947: Geology of the Country around Barnsley. Memoir of the Geological Survey of Great Britain.

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

SMITH, E.G., RHYS, G.H. & EDEN, R.A., 1967: Geology of the Country around Chesterfield, Matlock and Mansfield. Memoir of the Geological Survey of Great Britain.

WRAY, D.A. & MITCHELL, G.H. 1940: Geology of the Country around Wakefield. Memoir of the Geological Survey of Great Britain.

Earth science (P)SSSIs in the Natural Area:

- Bradgate Brickworks
- Doe Lea Stream Section
- Duckmanton Railway Cutting
- Great Dib Wood
- Carlton Main Brickworks
- Elland Bypass Cutting
- Honley Station Cutting
- Neepsend Brickworks
- Neepsend Railway Cutting
- Nostell Brickyard Quarry
- Stannington Ruffs
- Wadsley Fossil Forest
- Wharncliffe Crags
- Yeadon Brickworks and Railway Cutting