Centre for Archaeology Report 54/2005

Geoarchaeology in Northern England I.

The Landscape and Geography of Northern England

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ISSN 1473-9224

. Centre for Archaeology Report 54/2005

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Geoarchaeology in Northern England I.

The Landscape and Geography of Northern England

Maria Raimonda Usai

Summary

This report presents a description of the landscape, solid and drift geology, drainage and climate of the northern region of England. Its purpose is to act, generally, as basis for the northern regional reviews of environmental archaeology, and in particular, as a companion document for the site-based review of geoarchaeology (Usai 2002).

Keywords

Geoarchaeology
Soil/Sediment

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Geoarchaeology in Northern England I.
The Landscape and Geography of Northern England.

Maria Raimonda Usai

1 Introduction

This study is one of a series commissioned by English Heritage with the aim of reviewing environmental archaeology in England. The series concerns three different regions: Northern England, the Midlands and Southern England, each with separate studies on plants, invertebrates, bones and soils/sediments in relation to archaeological interpretation.

The review is divided in two parts. The first (this volume) concerns the description of the landscape, solid and drift geology, drainage and climate. This is designed to provide background information on the natural environment of Northern England. The second part (Usai 2002) reviews site-based geoarchaeological studies in Northern England from the 1970s onwards.

Terminology clearly understandable within one particular area of research will be complex for readers from another field of study. Thus, whenever possible, specialist terms are avoided or accompanied by an explanation. On the other hand, it has been necessary to include some degree of detail so that workers in this and related fields can easily find some of the information they may need for reference.

2 Physical geography

2.1 Introduction

The main sources of the information given in this chapter section are Taylor *et al.* (1971) and King (1976) for the region as a whole, Kent *et al.* (1980) for the area from the Forest of Bowland to the Scottish Borders (including the Pennines) and Edwards and Trotter (1954) for some of the information on the Pennines area. Other references for specific issues are indicated in the text.

The landscape of Northern England has been strongly influenced by the presence and movements of the Pleistocene ice sheets. These had an erosive effect especially in the Lake District and on the uplands of the Pennines and the Borders, dislocating large quantities of material, creating some hanging valleys and over-deepening others. The courses of some rivers were modified as the ice occluded their original valleys, and erosive streams beneath and beside the ice created valleys now looking excessively large and deep for the small streams flowing through them.

The Solway Plain, the West Cumbria and Furness coastal strips are now occupied by glacial deposits, and glacial drift also occupies most of the lowlands in Northern England, with ground moraine (boulder clay) or with characteristic morphologies (as summarised in **4. Pleistocene Geology**). Blanket peats, formed during the middle Holocene, occupy the high wet Pennines and Border Fells, and thick deposits of lowland or basin peats formed in the less well-drained lowlands, as typified by areas in the Solway Plain, Fylde Lowland and Humberhead Levels. Deposits resulting from freezing and thawing occupy lowland areas or mantle hill slopes smoothing the topography. Raised beaches and benches on the eastern and western coasts testify to isostatic uplift after the recession of the ice load.

More in the past than the present day, human geography has been significantly affected by this landscape. The Romans developed their roads in dry scarp lands, often following the older roads of the Iron and Bronze Age. The alternative way for communication and transportation was water. Cities such as York grew up where Roman roads crossed major waterways, and the distribution of village names of Scandinavian origin demonstrates the extent to which invaders extensively used rivers for access. Villages are often aligned over what was once was drier ground in generally wooded and waterlogged regions, or in areas where springs were located below limestone relief, for example at the base of Lincoln Edge, near the Chalk scarp and on the flanks of the moorland heights of Cleveland. When the railways were built, natural scarp openings such as those of the Derwent and the broader Humber gap, were chosen as routes.

2.2 Relief

The main upland elements of the Northern region of England are the hills and mountains of the Lake District, Howgill Fells, the Pennines, the Cheviot Hills, the Northumbrian Fells, the Yorkshire Wolds, the Howardian Hills, the Cleveland Hills and North Yorkshire Moors.

Lowlands include the Lancashire Plain, the Cheshire and Solway Plains, the Eden Valley, the coastal and adjacent areas of Northumberland and Durham, the Tees Valley, the Vale of York, the Vale of Pickering, the Holderness Plain, the lowermost Trent Valley and the Lincoln Clay Vale and Edge in North Lincolnshire.

The Pennines and Cheviot Hills

The southern and central part of the Pennines (which include the Millstone Grit Series and The Peak) are characterised by hilly landscapes and deep valleys, often covered by peat mosses, with mainly unfertile soils, and suitable only for pasture. The rigid massif of the Askrigg Block is characterised by a karst landscape (with cliffs, caves, swallow holes and limestone pavements) where limestone is dominant, and by stepped topography where limestone is in cyclic sequences with shales and sandstone. Further north is the Alston Block, with faulted scarps at its western edge, gently dipping eastwards, and including the Whin Sill Dolerite. In the most northerly areas of the Pennines, separated from the Alston Block by the Tyne Valley, the limestone almost disappears, whilst sandstones and shales become dominant, with striking scarps throughout Northumberland. North of the Tyne, Hadrian's Wall follows the outcrops of and is often underlain by the Whin Sill.

North of the Pennines, the Cheviots are a range of steep rounded hills with volcanic rocks and a centre of granite denuded by erosion.

The coal fields and the Magnesian Limestone

Between the Alston Block and the sea, the Millstone Grit and Coal Measures of the Upper Carboniferous of Durham and Northumberland dip gently east giving rise to gentle slopes now covered by drift. Ironstone smelting from the Coal Measures was carried out from the Roman period and became a significant industry from medieval times. As a consequence, both the associated extractive industries have characteristic relief features in this area of Northern England. Coalfields also extend from Leeds southwards to Nottinghamshire.

Between the Coal Measures and the sea is the Magnesian Limestone, extending from the Tees to the Trent, with clear but low scarps facing west, or forming cliffs on the coast or westward-facing scarps in Durham. The overlying sandstones and marl are largely covered by drift.

Lake District and Howgill Fells

In the Lake District, three main formations are arranged in three east-west belts. The first to the north, the Skiddaw Slates, forms both steep and smooth rounded hills. The second, in the centre, is the Borrowdale volcanic Group whose resistant rocks form spectacular relief with a dome-like Ordovician core surrounded by peaks of younger rocks. Such heights contrast with the smoother relief features of the Silurian rocks belt to the south. Limestone pavements with rare caves are found on the north-eastern side of the Lake District and Howgill Fells.

*The Lancashire and Cheshire Plain*s

The Lancashire Plain extends from the coast of the Irish Sea to the Pennines, comprising high quality agricultural land lying below the 100 m contour, and areas of higher ground (hills of Parbold, Billinge, Ashurst Beacon). It widens to the south to form the large Cheshire Plain, where rich agricultural land is, as in the Lancashire Plain, associated with thick and extensive deposits of glacial drift. Similar fluvio-glacial deposits also occur to the north of this region (Eden Valley and Solway Plain).

North Lincolnshire

In North Lincolnshire, a north-south scarp, the Lincoln Edge, extends from the Humber southwards. Limestone is the dominant rock type in the lower slope of the scarp, and the positions of villages in the past have been determined by the location of springs flowing from the scarp. The plateau formed by the Lincolnshire Limestone has been farmed at least since Roman times and was traversed by a straight north-south Roman road, Ermine Street, which almost reaches the Humber estuary. From the Humber southwards, east of the Lincoln Edge is the Lincoln Clay Vale, with thick Quaternary deposits.

The areas to the north and west of the Humber

North of the Humber, Holderness is a gently undulating plain. The region, on a Chalk floor covered by thick boulder clay and other fluvio-glacial and more recent deposits, used to be marshy, but has been largely reclaimed for agriculture in the last few hundred years. On its seaward edge, bounded by cliffs up to 30 m in height, the area is constantly and rapidly eroded by the sea, resulting in a continuous loss of land and important archaeological evidence.

The Yorkshire Wolds consist of a Chalk upland extending from north of the Humber to the east coast (Flamborough Head). To the south and east, the Wolds gently slope down to Holderness and the valley of the River Hull, whilst the slopes at the western side extend down to the Vale of York and are crossed by deep valleys with small streams. The northern side of the Wolds terminates with steep slopes in the Vale of Pickering.

The area to the west of the Humber consists mainly of fenland, is extensively drained and very fertile.

The North York Moors, Cleveland, Howardian and Hambleton Hills, the Durham plain and the Tees, Trent, York and Mowbray Vales

The Howardian Hills are a line of hills up to 172 m high in North Yorkshire. The Cleveland Hills and the North Yorkshire Moors are a plateau mainly between 350 and 450 m in height. The northern part of the plateau is largely covered by moors, with steep scarps at the northern and north-eastern boundaries, and has mostly been used for pasture. To the west, the Moors are delimited by the Hambleton Hills, ending in the Vale of Mowbray with spectacular scarps. The southern part of the Moors is delimited by scarps of the Tabular Hills, which slope down gently to the Vale of Pickering and are cut by streams. The Vale is delimited by a Chalk scarp to the south and is covered by drift deposits of variable thickness, mainly fluvial and lacustrine muds. The eastern side of the Vale is delimited by a morainic relief which prevents drainage towards the sea. To the west, a small overflow valley links the Vale of Pickering to the Vale of York.

The Vale of York and the Tees Valley are characterised by morainic relief and sequences of glaciofluvial, glaciolacustrine and till deposits. In the Vale of York, drift thins northwards and moraines cross the Vale from its western to its eastern side, near York. These lowlands have been used for pasture and agriculture on the fertile alluvium resulting from the frequent flooding, which has occurred throughout historic times. The Durham plain is characterised by a hummocky landscape with drift deposits, including both recent and pre-Devensian till materials (described in Chapter 4). The Trent Valley is covered by Quaternary deposits overlying mudstone clays.

3 Solid geology

3.1 Introduction

This chapter discusses the lithology, distribution and *relative* age of the most important geological units in Northern England and their bearing on topography and landscape. Such units can be characterised by widely accepted names or described and identified on the basis of their origin, lithology, position, location, fossil content and dominant mineral assemblies. Though these details have only a small bearing on archaeology, they are examined to allow readers to identify and distinguish the related rocks and drift in samples, maps, memoirs and publications.

The geological outline of this chapter is based mainly on the publications by Kent *et al.* (1980) for Jurassic to Quaternary, Edwards and Trotter (1954) and Taylor *et al.* (1971). In addition, Jarvis *et al.* (1984) and Ragg *et al.* (1984) have been referred to for correlations of solid geology with soils. Other references for specific periods and topics are indicated in the text. The geological summary is written with reference to Dunham (1969), Institute of Geological Sciences (1979a and b), Edmonds (1977a and b). The geological periods represented in Northern England are described in order from the oldest to the youngest, concentrating on the solid geology in Chapter 3 (Ordovician to the Tertiary), and summarising Pleistocene and Holocene deposits (drift geology) in Sections **4** and **5**.

Pre-Quaternary rocks are significant to geoarchaeology in that they are the source of the most recent drift materials and are the basis for later, Pleistocene and Holocene relief and drainage systems. Many pre-Quaternary rocks in Northern England belong to the Paleozoic and Mesozoic eras, and the present distribution of uplands and lowlands has been strongly influenced by geological factors such as tectonics and surface processes, the latter mainly related to variations in hardness of the rocks and their resistance to erosion. Subsequently, the landscape has been strongly influenced by the presence and movements of the ice sheets, as described in Sections **4** and **5**. Thus, human geography, settlement distribution and land use in the Holocene and Pleistocene landscapes in Northern England is closely related to the solid and drift geology (see Chapter 2).

3.2 Ordovician-Silurian

Ordovician and Silurian rocks characterise the Lake District and include slates, mudstones, siltstones, and grits, constituting the Skiddaw Group, which is followed by the Borrowdale Volcanic Series in the central Lake District. The Skiddaw Group contains mainly subaerial volcanites, though some may have been formed during temporary submergence, ranging from fine to coarse-grained tuffs interbedded with andesite and rhyolite (both with brecciation, or vesicular and massive) and basaltic lavas. The Borrowdale volcanic group, some 1000 m in thickness, consists mainly of andesitic, basaltic and rhyolitic lava, conglomerates and tuff. In the lower part of the sequence, some conglomerates contain sandstones and volcanites, and acid volcanites with flow lines and streaky bandings can have columnar structure and include tuff fragments.

Silurian rocks, mainly in the southern Lake District and the Howgill Fells, are made of black graptolitic mudstone (Stockdale Shales) banded with grey mudstone, followed by greyish mudstone and dark bluish grey, graptolitic and laminated muddy siltstones (Wenlock), followed by greywackes (Ludlow) and by 1540 m thick dark grey mudstones banded with pale siltstones with sparse graptolitic bands.

3.3 Devonian

The Devonian is mainly found in the massif of the Cheviot Hills, which is the result of various stages of volcanism. Coarse ashes and agglomerates resulting from the first explosive volcanic episode are succeeded by lava flows. These volcanites were then intruded by a large plutonic core and dykes. The resulting complex is a large granitic core surrounded by some 600 km^2 of mainly andesitic lava flows and tuffs cut through with dykes. The landscape morphology also reflects a strong erosion of the granite core (Section 2.2).

3.4 Carboniferous

Carboniferous rocks are present in a large part of the region, both outcropping and beneath other rocks. The major divisions are:-

Upper Carboniferous: Coal Measures (Westphalian); sandstone (for example employed for building Durham cathedral and numerous churches and buildings), shale, seat earth and coal.

Lower Carboniferous: Millstone Grit Series (Namurian): including massive grit, sandstone, shale and coal.

Carboniferous Limestone Series (Dinantian; or Turnaisian-Visean): including grey limestone, shale, dolomite, sandstone and coal.

In Lancashire and the southern Pennines these three main divisions are clearly defined by coal-bearing layers succeeding grits which follow massive marine limestone. In other areas the differences between the Millstone Grit and the Carboniferous Limestone Series are less pronounced. The limestone is generally pale or grey, massive and hard, in places oolitic, in some areas highly fossiliferous and in other areas argillaceous. These main rock types are arranged in cyclical sequences (cyclothems) and, in general, the three series present significant variations in thickness and in facies. These are described in detail by Edwards and Trotter (1954) and Taylor *et al.* (1971).

Resistant sandstones, found in different horizons of the Carboniferous, have been used as building materials for the older parts of towns and villages near the outcrops. Lead ore found in veins in the Lower Carboniferous of the northern Pennines has been mined since Roman times, but the production reached its maximum during the second half of the 18th century (Edwards and Trotter, 1954).

Jarvis *et al.* (1984) describe the relationships between Carboniferous rocks, soils, drift, drainage and soil pH. Grey micaceous shales and mudstone have had the greatest influence on soil genesis, directly or as source of drift. Sulphides in the shales give extremely acid soil conditions. Fewer soils are developed directly from the grit and sandstone, which are thinner and in smaller outcrops than the shales. Grit and sandstone beds, however, form the main source of the coarser drift deposits and make up the majority of the stones in the clayey drifts. The soils developed from the coarser grits are usually deficient in bases because these rocks contain few weatherable materials. "Limestones, despite their widespread outcrops, had relatively little effect on the composition of the overlying soils because of their hardness, although the extensive jointing favours rapid drainage" (Jarvis *et al.,* 1984).

Carboniferous volcanic rocks include tuffs and basalts in the Cheviot Hills and around the western end of the Border region (Lower Carboniferous). Intrusive rocks include the Whin Sill and associated dykes (Upper Carboniferous; 295 MA, Fitch and Miller, 1967). The most important is the Great Whin Sill, a dolerite dyke which outcrops in Northumberland, Cumbria, along the Pennines and in Teesdale, very often within the Carboniferous Limestone. Hadrian's Wall is built either to the north or along the escarpments of the Whin Sill in Teeside. Dunstanburgh and Bamburgh Castles are built on the Sill near the coast in the vicinity of the Holy Island and Farne Islands, which also are made of the Sill's dolerite.

3.5 Permo-Trias

In the late Carboniferous and early Permian times sediments were deposited diachronously and in a variable topography, on a sub-Permian surface reddened by desert weathering. Permian and Triassic deposits are thus often grouped together and constitute the "New Red Sandstone". They include fine-grained limestones (Early Permian) and sandstones (generally reddish and medium-grained).

The early Permian outcrops between the north Durham Coast and Nottinghamshire. The Lower Magnesian Limestone is a fine-grained dolomitic limestone, in places oolitic and/or shelly and, in Yorkshire, it has provided the easily worked and beautiful stone used in many medieval churches and abbeys. The Middle Magnesian Limestone (Durham) is a white soft dolomite, in places oolitic or pisolitic. The Upper Magnesian Limestone includes grey limestones used for the production of agricultural lime.

Most other Permo-Triassic deposits are reddish. They are found in Cumbria (in the north, north-east and adjacent to the west coast), from north and west Lancashire down to almost the whole of Cheshire, and in a strip extending from Hartlepool through the Vale of Mowbray, the Vale of York, Doncaster and south to Nottinghamshire. In all these areas, however, the Permo-Triassic sandstones are frequently covered by drift, generally reddish or variable in colour and composition. The Sherwood Sandstone group (formerly the Bunter Sandstone) is the most extensive sandstone formation. In the northern regions it extends from Nottinghamshire to Northumberland, and from Lancashire through Cheshire and Yorkshire as far as Lincolnshire. In some areas this sandstone constitutes an outstanding aquifer but it tends to lose this quality in the muddier facies of Yorkshire. Mudstones and siltstones are also mainly reddish, but with variations in grain size and colour. The most extensive outcrop is the Mercian Mudstone (formerly the Keuper Marl).

The Lower Permian Marls consist of grey limey mudstones. Their middle and upper layers can be redder and contain variable quantities and thicknesses of gypsum, anhydrite or other rock salts. Although of limited outcrop, the Permian Marl strongly affects the composition of the local soils (Jarvis *et al.*, 1984).

3.6 Jurassic

The Lower Jurassic outcrops in the Cleveland Hills, the North York Moors, from the western side of the Yorkshire Wolds to Lincolnshire, and in the Midlands. It includes clay, mudstone, limestone, shales, sandstones (mainly Lower and Middle Lias), and ironstones (Middle Lias) - an economic source of iron ore. In the North York Moors sandstones are overlain by mudstone and shales with ironstone bands, which in the past have also been used for iron and steel production. In North Yorkshire, Black Jet obtained from the Upper Lias Jet Rock (bituminous ammonitic shale with calcareous concretions or "doggers") has been employed for jewellery industry since the Bronze Age and is often recovered, raw or worked, from archaeological deposits.

The upper Lias also contains the fossiliferous Alum Shales, from which alum[1] extraction started in Yorkshire in 1600 AD and continued for some 250 years. Extensive excavations have been made at Peak, Saltwick, Kettleness, Boulby and elsewhere, and alum shales have been quarried both at the top of the cliffs and inland along the Cleveland scarp.

In the Cleveland basin, the marine basal unit of the Middle Jurassic (Dogger) consists of conglomerates, limestones, ironstones, and sandstone. In the western part of the Cleveland basin and the Howardian Hills the Dogger consists of ferruginous sandstone or limestone. In the 12th Century, the Dogger near Terrington (Howardian Hills) was used for the construction of Sheriff Hutton Castle, Whitby Abbey, Covent Garden, the foundations of the old Waterloo Bridge and London Bridge.

Later deltaic and estuarine deposits are locally rich in plant fossils and include mainly clays and clay shales, and less frequent siltstone, coals, ironstone and sandstone, of which the sandstones of the Saltwick Formation have been used for the construction of many public buildings.

In North Lincolnshire and from the Humber to Market Weighton, the Upper Estuarine Beds (sands followed by mudstones) overlie marine ferruginous silts, coral bearing oolitic beds, coral beds, limestones and shales. Among these, the Cave Oolite from the Humber region was used in building the Holderness monasteries and Hull Docks.The Upper Jurassic starts with clay overlain by unconsolidated sands, often followed by grey silty clays, clay shale and shelly beds, sandstone and limestone. The next formation is the Corallian, one of the most important Jurassic formations with regard to soil development. In North and East Yorkshire, the Corallian consists of calcareous sandstones (in places containing ammonites), mudstone and limestones (in places with ammonites and belemnites), oolites and coral reefs with different lithologies. The Upper Jurassic ends with the Kimmeridge Clay, mostly covered with thick drift.

3.7 Cretaceous

The sea extended during the Cretaceous such that most of the British Isles was inundated and a variety of sedimentary materials deposited. Thick deposits of chalk are found in the

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[1] alum = hydrated aluminium potassium sulphate and related compounds.

Wolds, the East Riding of Yorkshire and Lincolnshire. Sequences of clays, however, constitute the basal Cretaceous in North Lincolnshire and elsewhere north of the Humber and in Yorkshire. Overlying these sediments are either marls or the Carstone, consisting of ferruginous, micaceous and brown sands. The next formation is the Red Chalk, an impure limestone, from pink to red in colour, with rounded quartz grains and many fossils. The subsequent Cretaceous material consists of Chalk, a very fine grained white limestone almost entirely made of calcium carbonate (coccoliths) together with larger foraminifera, ostracod valves, bryozoa, shell and echinoderm debris, calcispheres and flints, the latter well known for their use in implement manufacture during the Palaeolithic and Mesolithic. They consist of microcrystalline chalcedony and are found in sheets and nodules often arranged parallel to the bedding.

3.8 Tertiary

Eocene-Pliocene

After the Cretaceous, a marine regression caused the British Isles to almost completely emerge. Thus, at present there are only very few outcrops represented by a few tholeiitic dykes, in Durham, Northumberland, and from Cumbria to Cleveland. The dykes have been extensively quarried or mined for roadstone material.

4 Pleistocene geology

4.1 Introduction and chronology

The Pleistocene is usually defined as the geological time between 2 ma and 10,000 BP, when the Holocene started. However, the Holocene has also recently been defined as the last part of the Pleistocene, which would therefore represent the entire Quaternary (Jones and Keen, 1993). In this review, the first definition is adopted because of its wider acceptance and in order to achieve comparability with other English Heritage regional reviews.

The Pleistocene is characterised by dramatic climatic changes including an alternation of periods of temperate and cold or glacial climate. In Table 1, stages of cold and temperate climate alternation in England are correlated with cultural stages.

Spark and West (1972), West (1977), Ehlers *et al.*, (1991) and Jones and Keen (1993) can be consulted for an accurate description of the colder and warmer Quaternary periods and the sediments, rocks and forms deriving from such climate changes. During the temperate stages of the Pleistocene, the landscape condition was to some extent similar to today, except for human impact on the environment. Forests covered the land and sea levels were similar to the present. Conversely, during the cold stages sea levels were much lower, as much as one hundred or more metres below the present, and vegetation was mainly herbaceous or absent. Thus soils were unstable - especially on the slopes - and rivers, flowing to much lower sea levels, were more active in eroding and reshaping the landscape.

Although the landscape of Northern England, its morphology and superficial deposits have been strongly affected by several past glaciations and by the presence and movements of the ice sheets, the present landscape and superficial deposits in Northern England are more the result of the last (Devensian) glaciation than of the previous ones. Superficial deposits may be of glacial/periglacial, colluvial, alluvial, aeolian, lacustrine, fluvial or marine origin.

Table 1. Glacial and periglacial periods in England and correlation with NW Europe (adapted from Jones and Keen 1993; Sparks and West ,1972).

Stage and climate	^{14}C age BP and cultures	Start Date (ma BP)	North-Western Europe	Older terms for drift
Holocene (Interglacial)	2000 AD Post medieval period Late Medieval period Norman conquest 1000 AD Scandinavian settlement Earlier Medieval period Anglo-Saxon settlement Roman Invasion 2000 BP/0 AD Iron Age 3000 BP/1000 BC Late Bronze Age Early Bronze Age 4000 BP/2000 BC Late Neolithic 5000 BP/3000 BC Early Neolithic 6000 BP/4000 BC Late Mesolithic 7000 BP/5000 BC 8000 BP/6000 BC 9000 BP/7000 BC Late Upper Palaeolithic//Earlier Mesolithic 10000 BP/8000 BC	0.01		
Devensian (Glacial) Loch Lomond (Stadial)	Upper Palaeolithic	0.115	Weichselian	Newer Drift

Stage and climate	^{14}C age BP and cultures	Start Date (ma BP)	North-Western Europe	Older terms for drift
Windermere (Interstadial). Dimlington (Stadial)				
Ipswichian (Interglacial)	Middle Palaeolithic	0.135	Eemian	
Wolstonian (Glacial)			Saalian	Older Drift
Hoxnian (Interglacial)	Lower Palaeolithic	0.3	Holsteinian	
Anglian (Glacial)			Elsterian	Older Drift
Cromerian (Interglacial)		0.5		
Beestonian (Glacial)				
Pastonian (Interglacial) Pre-Pastonian (Glacial) Bramertonian (Interglacial) Baventian (Glacial) Antian (Interglacial) Thurnian (Glacial) Ludhamian (Interglacial) Pre-Ludhamian (Glacial)		2		

4. 2 Glacial till

Glacial tills are complex deposits widely represented particularly in the lowlands of Northern England. They are heterogeneous, and are characterised by matrix-supported rock fragments, lack of sorting or bedding and often by the presence of erratic stones. In Northern England, till can include erratics from as far away as, for example, Scandinavia (Catt and Penny, 1966; Penny and Catt, 1967 and Sparks and West, 1972). In general, the complicated processes resulting from successive glacial and interglacial stages means that the lithology of the drift does not often reflect a single provenance. So, whilst for various types of soils and sediments composition may give information on their parent material transportation and provenance, this is not always the case for the glacial drift. Jarvis *et al.* (1984), however, stress that the finer fraction of the till is often derived mainly from the basal ice and has travelled shorter distances.

The distribution and types of till are shown on the BGS map at 625,000 (Edmonds, 1977a and b), in the 1: 250,000 soil association maps of Soil Survey of England and Wales (1983a and b) and in the maps and text of Jarvis *et al.* (1984) and Ragg *et al.* (1984). The latter two groups of authors describe the till distribution: it occupies most of the lowlands west of the Pennines and the Cheshire and Lancashire Plains, and extends from Northumberland to the Vale of Mowbray and to the north of the Vale of York, though further to the south is only along the margins of the Pennines and it is almost absent south of the Aire. The generally thin till of the Pennines has been affected by subsequent downslope movement. Most glacial till in Northern England is fine textured, though sandy or very stony tills are also found. Some deposits consist of till combined with other materials. The youngest till deposits in the Tyne and Wear lowland, for example, south west of Northumberland and in Durham, could derive from a flow till combined with solifluction deposits (Boulton, 1972, cited by Jarvis *et al.*, 1984), or periglacial redistribution of till with all other pre-existing deposits (Smith, 1981).

4.3 Head

Other cold-climate slope deposits called Head contain angular and unsorted clasts like till, but they do not contain far-travelled erratics and are often closely related to the local topography. Although similar to landslides formed under temperate conditions, head materials are often thicker and composed of clasts of a very variable source. In Northern England head has accumulated on footslopes as the result of solifluction and gelifluction and, though less compact and more permeable than till, is often indistinguishable without detailed analysis or in the absence of deep sections (Jarvis *et al.* (1984) and Ragg *et al.*, 1984). Head deposits are more frequent in those parts of the southern Pennines, the North York Moors and the Wolds which were not covered by ice of the last glaciation, and chalky head is present at the foot of the northern and western Yorkshire Wolds (Jarvis *et al.* (1984) and Ragg *et al.*, 1984).

4.4 Glaciofluvial and glaciolacustrine sediments

Glaciofluvial sediments, in contrast to head, are stratified and clearly differ from till. However, they can be very similar to or indistinguishable from interglacial or postglacial river terraces deposits (Jarvis *et al.*, 1984). Catt (1991a) records that "glaciofluvial sands occur mainly in valleys, such as the eastern Vale of Pickering, the Aln and Till Valleys in Northumberland, the North and South Tyne valleys, the Wear Valley north of Durham, the Tees Valley between High Force and Darlington, the Gilling Beck Valley north of Richmond, the Swale Valley between Richmond and Northallerton, parts of Wensleydale and Bishopdale, the Aire Valley below Leeds, and the Ouse Valley between York and Goole".

Hummocky landscapes around Brampton, Wooler and Durham have been interpreted as derived from glaciofluvial deposits transported from the uplands and then accumulated on the flanks of melting ice (Jarvis *et al.*, 1984). Glaciofluvial deposits are widespread along moraines on the Cheshire-Shropshire border and occurring widely on river terraces flanking the Mersey and other small rivers.

Glaciolacustrine drifts include deposits from the Pleistocene Lake Lapworth in Cheshire and finely laminated stoneless waterlain clays and silts underlying the flat featureless Lancashire-Cheshire-Shropshire till plains (Ragg *et al.*, 1984), as well as in small hollows in the till plain in Northumberland and Tyne and Wear and the clayey stoneless deposits in the Vales of York and Pickering (Jarvis *et al.*, 1984). Glaciolacustrine deposits, widely distributed in the Vale of York, but most widespread in its western and southern parts, were deposited by Lake

Humber (as described later in this chapter). Other important similar deposits occur in the western side of the Vale of Pickering, in the Leven Valley (North Yorkshire), in the Lower Tees Valley, in the Wear Valley south of Durham, north of Newcastle-upon-Tyne, in eastern Northumberland. All are found within 54 km from the coast and were probably deposited by past lakes between the coastal ice and the higher ground (Catt, 1991a). Laminated clays, brown sands with lenses of stony clay, termed as the Tyne and Wear Complex in the Sunderland and Newcastle areas, have been interpreted as derived from a single large lake (Lake Wear) (Catt, 1991a). A series of small lakes in the Cleveland Hills between the Vale of Pickering and the Tees estuary, with the largest in Eskdale, Kildale, Glaisdale, Wheeldale, Harrowdale and the Hackness Valley have been interpreted as periglacial lakes (Kendall, 1902 - cited by Catt, 1991a), but several more recent studies suggest that they are subglacial deposits (Catt, 1991a).

4.5 Sequences of Pleistocene deposits

Different types of superficial deposits can be correlated to a large number of climatic changes, as summarised in Table 2, describing the British Quaternary stages from the Baventian and main associated deposits (from Catt, 1996, after Mitchell at al, 1973 and Funnel *et al.*, 1979, cited in Catt, 1996).

Table 2. Quaternary stages and deposits, from Catt (1996) after Mitchell et al. (1973) and Funnel et al. (1979).

Stage: (T) = temperate; (C) = cold	Main deposits
Holocene or Flandrian	alluvium, peat, colluvium
Devensian (C)	Till, loess, coversand, head, gravel
Ipswichian (T)	lake and river deposits
Wolstonian (C)	till, loess, head, fluvial and glaciofluvial gravels
Hoxnian (C)	lake deposits, peat
Anglian (T)	Till, loess, fluvial and glaciofluvial gravels
Cromerian (C)	peat, estuarine sands
Beestonian (T)	river gravels, sands
Pastonian (C)	peat, gravels, marine silts
Pre-Pastonian (T)	river gravels, marine sands
Bramertonian (C)	shelly marine sands, beach gravels
Baventian (T)	marine silts

4. 6 Pre-Devensian glacial deposits

The distribution of Wolstonian 'Basement Till' on the north-eastern England coast is very patchy (Catt, 1991b). Basement Till with erratics from North-Eastern England, Norway, Scandinavia and Scotland, and made of different types of rock, including chalk, flint, limestone, igneous and metamorphic rocks, clays and silts, is found along the coast from Filey to Spurn Head, on Flamborough Head, on the foreshore near Reighton Gap, on New Closes Cliff, near Horden in County Durham, on the Holderness coast between Kilnsea Beacon and Hompton and in Holderness on the foreshore between Bridlington and Sewerby, (Catt and Penny, 1966; Penny and Catt, 1967; Catt, 1991b). At many of these sites, the Wolstonian till can be correlated to that in Lincolnshire (Welton-le-Wold) which overlies deposits containing Hoxnian artifacts and bones (Catt, 1991b).

The higher parts of the Wolds and North Yorkshire Moors were glaciated at least once before the Devensian (Catt, 1991b). A few pre-Ipswichian outcrops of till, sand and gravel are found around the Vale of Pickering (Kent *et al.*, 1980) and in the North Yorkshire Moors and Yorkshire Wolds (Catt, 1977, 1981 and 1991b), with erratics from the Lake District, Pennines, North-Eastern England or other unidentified areas. Patches of strongly weathered pre-Wolstonian, possibly Baventian till and glacial gravel are found in the uplands of the Yorkshire Wolds above the limit of the Devensian glaciation (Catt, 1982). Flints of possible glacial origin and of pre-Wolstonian age were found beneath a Roman villa near Staxton, south of Scarborough (Catt, 1982). In the Vale of York, the presence of laminated clays associated with pre-Devensian glacial till deposits has led to the suggestion that there was a pre-Devensian Lake Humber, as well as the late Devensian one (Catt, 1991b). Other pre-Devensian glacial deposits are found in the Southern Vale of York (Gaunt, 1981), at Gainsborough (Smith *et al.*, 1973) and in the Sheffield area (Eden *et al.,* 1957).

4.7 Pre-Devensian interglacial deposits

Deposits from the Hoxnian interglacial are limited. However, silts containing Clactonian and Acheulean worked flints, estuarine molluscs, plant debris and peat on deposits within a pre-Ipswichian channel between Kirmington and Immingham in North east Lincolnshire, and sands and silts with estuarine molluscs overlying the Basement Till at 30 m OD in Filey Bay, are both possibly attributable to the Hoxnian interglacial (Kent *et al.*, 1980).

Ipswichian deposits are also limited and fragmentary; however the existence of this interglacial has been established between approximately 135,000 and 115,000 BP (Table 1). In the Pennine region the Ipswichian was mainly characterised by valley cutting and erosion, but alluvial beds with bones of *Hippopotamus,* post-dating the period of valley cutting, were found in Leeds (Edwards and Trotter, 1954). In the eastern part of the region, Ipswichian clay floors with animal bones were found in Kirkdale Cave.

The sea level rose from -12 m OD at the beginning of the interglacial, to +1 or 2 m OD at the end of the Ipswichian, as shown by Ipswichian deposits from the Vale of York (Gaunt *et al.*, 1974 and Taylor et al., 1971).

Evidence that soils on pre-Devensian surfaces are better developed than Holocene soils formed on deposits of the Devensian glaciation (Catt, 1996) led to the classification of all reddish 'paleoargillic' soils as older than any soils formed on Devensian deposits (Avery, 1980). Furthermore, comparison between the depth of weathering of the pre-Devensian Troutbeck paleosols (Boardman, 1985) and of Holocene soils on till, suggested that in the north-eastern Lake District the development of the pre-Devensian paleosols could have occurred over a period up to 100,000 years long, including the early or middle Devensian (with no glaciations in this area), and may suggest the absence of the Wolstonian glaciation here (Catt, 1996). Red mottled paleosols of the Harwood Dale Moor (near Scarborough), sandstones with red rinds at Langdale Forest (north of the Vale of Pickering), clayey weathering of feldspathic stones near Scarborough, and white horizons with ferruginous concretions in the same area (10 km north of Pickering) have all been attributed to the Ipswichian interglacial or earlier (Bullock *et al.*, 1973).

4.8 Devensian stage

The Devensian stage corresponds to the earlier part of the Upper Palaeolithic (Table 1) when hunter/gatherers attempted to exploit whatever resources were available within the limits of their technologies. The Devensian cold stage started approximately 115,000 BP and finished about 10,000 BP (Table 1), but the glacial activity only lasted a few millennia when the polar front was south of the British Isles, after 20,000 BP (Jones and Keen, 1993). The Devensian has been divided into Early (pre-50,000 BP), Middle (50,000-26,000 BP) and Late (26,000-10,000 BP) Devensian.

Early Devensian
During the Early Devensian, the climate was continental, with long cold dry winters (Jones and Keen, 1993).

Middle Devensian
During the Middle Devensian, the arctic environment was characterised by an open, treeless landscape, as shown by a sequence in Oxbow (Aire Valley), and very low temperatures, as suggested by features indicating a continuous permafrost and then ice in the Craven district in deposits dated 85,000-35,000 BP (Jones and Keen, 1993). It has been estimated that the mean temperature in February was about -11°C and in July approximately 15°C (Coope, 1977). Prior to the beginning of the late Devensian glacial stage, periglacial conditions become dominant, with the formation of patterned ground and other evidence of cryoturbation, including ice wedge pseudomorphs, whilst aeolian deposits and head were formed in various places. Examples are found at Sewerby and in the Dimlington Cliff (Penny *et al.*, 1969).

Late Devensian
During the Late Devensian glaciation, ice originating simultaneously from centres in Scotland, the Cheviot Hills, the Lake District and parts of the Pennines, deposited large amounts of till (Taylor *et al.*, 1971) resulting in a topography which reflected the underlying solid geology, except in drumlin fields. At the height of the glaciation, Northern England was almost entirely covered with ice. The sea level decreased to a minimum, and it has been suggested that at the end of the late Devensian, the level of the North Sea was at least 110 m below the present (Jansen *et al.*, 1979), exposing large parts of the North Sea. With base level this low, rivers incised their courses to a considerable depth below OD (Jones and Keen, 1993).

A period of climatic deterioration (the Dimlington stadial) occurred about 26,000 to 13,000 BP. Between 13,000 and 11,000 BP was the Windermere interstadial, followed by another stadial deterioration (the Loch Lomond stadial, between 11,000 and 10,000 BP), marking the end of the Devensian glacial and cold stage (Jones and Keen, 1993). During the colder periods of such climatic cycles, solifluction and head deposition occurred, and permafrost conditions, including involutions of sands and gravels, modified the previously deposited materials, as represented in coastal cliffs of Durham. Morainic deposits marked advances and retreats of the ice. Deposits filling hollows, left as the main ice retreated, are found in Cumbria, Northumberland and Durham. Here, scarcely fossiliferous sediments correspond to the cold spells whilst milder spells are recorded in peats, pollen and other plant remains indicating the reconstitution of plant cover (Taylor *et al.*, 1980).

4.8.1 Devensian deposits in North Eastern England north of the Tees

The most widespread superficial deposit in this area is late Devensian till, generally assumed to be of Dimlington Stadial age. In the uplands, the Devensian till is patchy, very variable and generally thicker in the valleys draining the uplands. It is divisible into a lower clay-rich lodgement till and an upper, sandier, and less compact flow till, the two being often separated by a thin bed of sand and gravel (Catt, 1991a).

In the lowlands, Devensian glacial deposits are less variable and in many areas can be divided into two or more units, whose relationship with the main mechanisms of ice movement has been suggested by Taylor *et al.* (1980) to be as follows:-

Lower units
In a final phase of the glaciation, thin reddish till-like stony clay was deposited in low lying parts of the Solway basin and along the coast of North-West Cumbria. The northeast was a receiving area for the ice, and became almost completely covered by ice streaming down the eastern sides of the hills, particularly strongly along the Tyne and Stainmore Gaps. The ice from south-west Scotland and the Lake District flowed generally eastwards and southwards and deposited 6-9 m of brown or grey boulder clay over almost the whole of Northumberland and Durham. Deposits included mainly till with many large stones from local sources. The unit is overlain by an upper reddish-brown till with fewer and smaller far-travelled stones (Catt, 1991a).

Youngest units
After the ice retreat, the boulder clay surface left behind was generally of low relief. Whilst the western ice withdrew westwards, leaving behind large expanses of sands and gravels (the 'Middle Sand') in low lying areas along the present coast and in the major valleys of Northumberland and Durham, Scandinavian ice east of the coast was able to advance inland, depositing a reddish-brown boulder clay over the Middle Sands and the boulder clays previously produced by the western ice. The stagnation of the western ice caused the formation of kame and kettle moraines and of a large lake where thick laminated clays and sands were laid down. The Teesside clay, a reddish-brown stony clay up to 6 m thick, is the uppermost major lowland deposit overlying earlier deposits below about 90 m OD. The *Teesside Till* in Cleveland probably resulted from periglacial redistribution of pre-existing deposits" (Smith, 1981).

Coastal units
In the coastal areas of Tyne and Wear, County Durham and north Cleveland, a greyish-brown till (the 'Lower Boulder Clay') with far-travelled erratics including red sandstones, volcanites and plutonic rocks, is overlain by sands and by an 'Upper Boulder Clay' containing Cheviot erratics (Catt, 1991a).

4.8.2 Devensian deposits in North-Eastern England south of the Tees (lowlands)

The late Devensian ice originated in Southern Scotland and in Northern England and advanced into the Vale of York, bordering the North Yorkshire Moors and reached coastal zones. Till deposits are found in various areas, including the whole of Yorkshire and Lincolnshire.

North Yorkshire Moors
Ice engulfed the northern part of the North Yorkshire Moors when ice from Stainmore moved down the Vale of York, and sealed both sides of the Vale of Pickering, where Lake Pickering was formed (Jones and Keen, 1993). Here, clays, littoral and deltaic gravels, and sands were deposited (Kent *et al.* 1980), and the lake eventually overflowed via the Kirkdale Abbey Gorge. A single till layer (reddish-brown to grey clay, with erratics including limestone, sandstone and Paleozoic rocks from the Lake District) was deposited in the Vale of York. This single layer contrasts with multiple till sequences further north, especially in Cleveland, e.g. at Hartlepool and on the banks of the River Tees (Catt, 1991a).

Two other large glacial deposits, the York and Escrick moraines, curve north-eastwards and join the tills, sands and gravels of the Howardian Hills and Hambleton Hills. The Escrick moraine was cleared of ice before about 12,400 BP (Kent *et al.*, 1980).

Meltwater channels are found around the Cleveland Hills and north Yorkshire Moors, particularly in Eskdale. Other meltwater channels were also formed across the eastern part of the Yorkshire Wolds. Ascribed to the Windermere interstadial are deposits with flint artefacts associated with horse bones at Flixton in the Vale of Pickering (Catt, 1987b).

Holderness
Further south, ice from the North Sea passed through Holderness and reached the Humber Gap blocking the drainage from the Vale of York, and the Trent and Ancholme Valleys, giving rise to the Skipsea and Withernsea Till. The lower, Skipsea Till, a brownish-grey clay with chalk fragments and Carboniferous rock erratics, extends from the Humber to the slopes of the Wolds and overlies both Ipswichian deposits and silts with moss dated 18,250-18,500 BP at Dimlington (Catt, 1987b and 1991a; Catt and Penny, 1966, Penny *et al.*, 1969). Ascribed to the Windermere interstadial date are deposits with flint blades in the Skipsea Withow Gap in Holderness (Catt, 1987b). A gravel ridge on this till includes marine molluscs, bivalves and mammals derived from pre-existing deposits. The overlying, less extensive Withernsea Till, grey with a pinkish tone and less chalk than the Skipsea till, is represented by a narrow arcuate outcrop in the coast of Holderness, south of Hornsea. The topography of Holderness (representative of recent glacial deposition) is characterised by subdued drumlins, kettle holes, moraine-like ridges and kamiform sand deposits (Kent *et al.,* 1980).

Lake Humber and Lake Pickering
Blocking the Humber gap caused the development of Lake Humber south of the ice front. The lake occupied much of the Vale of York, into which the Derwent, Goodmanham and other channels discharged. The initial margins of this 'high level' lake are marked at 33m OD by thin and patchy near-shore deposits, the *High level sand and gravel* derived from reworking of older deposits, overlying periglacial landforms and bone fragments formed below these deposits dated 18,000 BP (Penny *et al.*, 1969).

After the 'high level' lake, a 'low level' lake was established, as witnessed by narrow outcrops of the *Low level sand* deposits and laminated clays up to 20 m thick (the *'25 Foot Drift Silt and Clay'),* overlying the lower periglacial landscape. Between the high and low level phases, the lake level fell to 4 m OD and temporarily to -4 m OD. The low-level lake lasted for a long time, as shown by the thickness of the laminated silts (Gaunt, 1981), and ended at a minimum of 11,100 BP (Gaunt *et al.*, 1971).

4.8.3 Devensian deposits in North Western England

During the Devensian glaciation, a few of the highest parts of the Pennines may have been nunataks even at the summit of the glaciation, with intense physical weathering taking place (Edwards and Trotter, 1954; Jones and Keen, 1993). Many periglacial deposits in this area may date from the Loch Lomond Stadial or from the main Devensian glaciation. Retreating from the Yorkshire Dales, glaciers left a series of frontal moraines and drumlins (Edwards and Trotter, 1954). Some late glacial sediments have been found in Victoria Cave, Settle, with later Upper Palaeolithic occupation deposits of approximately 12000-11000 BP (Campbell 1977).

The Lake District was probably entirely glaciated during the Late Devensian, with ice of *c.* 1600 m thick, and glacial products including sands, gravels and laminated sediments (Jones and Keen, 1993). Till of local origin accumulated in the valleys and moraines were formed in various places, each representing ice advancement and retreat. Products of ice from Scotland include till and drumlins in the Solway, Eden Valley and Furness area, followed by younger deposits in the Cumbrian lowlands.

In the Cheshire-Lancashire Plain, two Early Devensian tills are found overlying gravels and silts (Jones and Keen, 1993). Late Devensian glacigenic deposits produced by the Irish Sea Ice, including till, outwash and lacustrine deposits, are also found in the Cheshire Plain. The recession of the ice front was directed westwards into the Lancashire-Cheshire plain and towards the Lake District. The final clearance of the ice from these lowlands was marked by a large glacial lake which drained southwards.

4.9 Other Late Devensian deposits

Before the late Devensian ice reached its extreme limits, a thin layer of loess derived from Devensian glacial debris was deposited in various areas of North Eastern England, including the areas surrounding Durham and parts of the Wolds, Hambleton Hills, Holderness and further south (Catt, *et al.,* 1974). In the area west of Hull the loess has been dated to *c.* 17,500 BP (Catt, 1987a). During the Loch Lomond Stadial,(10-11,000 BP) the climate was cold and dry, with considerable accumulation of wind blown sand, particularly in north-western Lincolnshire and along the eastern margin of the Vale of York. In York, aeolian sands overlie peat of 10,700 BP and are in turn followed by organic material of 9,950 BP, and more sand (Jones and Keen, 1993). A periglacial land surface with ice wedge casts and desert pavement, developed on the top of the Late Devensian glacial deposits, are also found in the Vale of York.

Archaeological evidence from the Windermere and Loch Lomond deposits

Environmental information on the last (Windermere) interstadial is also given by plant, invertebrates and bone evidence at many sites in Northern England, including Seamer Carr and Starr Carr, both containing Palaeolithic flints, in the Vale of Pickering and many other sites in Durham, Northumberland, Yorkshire and Holderness, as described by Dobney and Stallibrass (in prep), Huntley and Hall (in prep) and Kenward (in prep).

During the late Devensian, humans migrated northwards to inhabit caves and open areas, as shown by several sites with cultural evidence, of which the earliest (Upper Palaeolithic), dated from 12,000 to after 11,000 BP, include mainly caves containing Creswellian artifacts, for example the Victoria Cave, Settle (Catt, 1987b). At the open site of Seamer Carr (Vale of Pickering), cultural evidence dating from the Windermere Interstadial is overlain by coversands of the Loch Lomond Stadial. At Withow Gap, Skipsea in Holderness, flint blades date back to the Windermere Interstadial, and a similar date is placed on flint artefacts associated with horse bones at Flixton, in the Vale of Pickering (Gilbertson *et al.,* 1984; Catt, 1987b). Numerous artifacts in the area date from the very end of the late Devensian to the earlier Holocene, including 'Maglemosian' barbed bone points or harpoons from Brandesburton in Holderness and from the Withow Gap at Skipsea. The latter dated 10,000 and 10,450 BP and are associated with remains of reindeer and giant elk.

5 The Holocene

5.1 Introduction and chronology

The Pleistocene period is followed by the current interglacial, the Holocene, starting at 10,000 radiocarbon years BP and continuing until the present. Table 3 defines the sub-divisions of the Holocene for England and Wales.

Table 3. Sub-divisions of the Holocene for England and Wales (Jones and Keen, 1993).

^{14}C years BP, approximate age of start	Period	Pollen Zones	Chronozones
2000	Sub-Atlantic	VIII	Fl III
5000	Sub-Boreal	VIIb	
7000	Atlantic	VIIa	Fl II
	Boreal	VI	
9000		V	Fl I
10,000	Pre-Boreal	IV	

The beginning of the Holocene is characterised by a climatic amelioration and a prolonged marine transgression (the *Flandrian* transgression). Lesser climatic and sea level changes occurred again and again during this period (see Section 6.4 on climate changes). As for other interglacials (with higher average relative level between sea and land in comparison with the previous colder period) geomorphological changes occurred in relation to drainage base-level changes. The landscape morphology, soils and sediments have also been affected by, and have influenced human occupation. Issues concerning man's effect on Holocene landscape change and soil development, where the principle of uniformitarianism can be applied more confidently, are discussed in Usai (2002). It covers both Holocene and pre-Holocene materials, including evidence from archaeological and geoarchaeological studies, as well as sections on the main issues relevant to geoarchaeology in Northern England.

5.2 Coasts and sea level changes

The coastal landforms of Northern England have been affected by sea level changes during the glacial and Holocene periods. As mentioned above, the initial part of the Holocene is characterised by a prolonged marine transgression (the *Flandrian transgression)* and by a worldwide increase of sea level. The marine transgression and change of drainage base-level caused the formation of the so-called 'submerged forests', peat deposits sunk in various positions along the coast of Northern England. In Hartlepool, for example, they extend at least to 15 m below present sea level (Taylor *et al.*, 1971).

Many of these peats cover, contain or underlie Mesolithic flint and bone implements, animal bones, especially deer, and tree remains. In Hartlepool Bay, for example, late Mesolithic and early Neolithic coastal occupation is shown by flint artifacts, struck flakes (including those made of tuff from Langdale), stone axes (including one made of Borrowdale volcanics from Langdale again), pottery and worked wooden objects all contained in peat beds within the intertidal zone. The same deposits also contain an early Neolithic skeleton buried in detrital gyttja which later become eroded (Tooley, 1978b). The variety of habitats and associated resources made the coastal areas attractive to prehistoric man, but were liable to change as a result of the variations in sea level. In his words "a relative rise of sea level would result in a marine transgression in low lying areas, pushing landward coastal plant communities and along cliff coasts accelerating erosion. Conversely, a fall in sea level would result in shore progradation and the dilation of productive herbaceous plant communities".

The position of fresh-water peat in relation to the coast gives information on the date and speed of transgressions/regressions. South of Kilnsea Warren, in Holderness, for example, 6200 year-old peat overlying marine clay at -2.4 m OD indicates that the marine transgression was then very rapid, whilst younger deposits in the Humber estuary and elsewhere indicate slower transgression with minor regressions until recently (Kent *et al.* 1980). In the area of the Hartlepool-Tees estuary, the earliest dated sea level indicator is given by peat of 9680 BP underlying marine deposits at -10.6 m OD in the lower Tees Valley. In the same area, various episodes of transgressive overlaps[2] and regressive tendencies were dated in the period 6050-5240 BP at depths between -2.39 and -0.34 m OD (Shennan, 1983) .

In the Humber estuary information from unconsolidated Holocene deposits has been complemented by dates on Bronze Age trackways and rafts, indicating that a basal woody detrital peat started to accumulate at 6970 BP at -11.55 OD at Hull, with a later transgressive overlap at 6890 BP at -9.7 OD and *Alnus* wood of 6681 BP found at -9.14 OD (Shennan, 1983). At Stoneferry, Hull[3] marine conditions started between 5240 and 3775 BP, whilst in other parts of the same area transgressive and regressive tendencies occurred in different periods (e.g. at Barrowhaven (TA0622) regressive tendencies are dated 2335 BP and transgressive tendencies to 1980 BP).

Sea level changes in the North-western coast have been studied extensively by Tooley (1974, 1976, 1977, 1978a, 1982, 1985). These studies are the main sources for the summary that

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[2] Sea level advances landward over a previous landsurface, with replacement of terrestrials sediments by, first, littoral facies and, later, neritic facies (Tooley, 1982).

[3] 5240 year old peat overlying freshwater organic clay at -4 m OD and underlying shelly sand of 3775 to 3435 BP at 3.8 OD

follows, with other references mentioned specifically in the text. The temporal pattern of the transgressive and regressive sequences for the North West Coast have been identified on the basis of eighty-five radiocarbon dates from three regions between the Mersey estuary and the Solway Firth (Liverpool Bay, Morecambe Bay and Cumbria) between 9,000 BP and the present day (see Figure 1 from Tooley, 1982). The pattern is representative of the whole of North-West England and includes twelve regressive[4] and twelve transgressive overlap sequences. Figure 1 shows that, whilst regressive overlaps started at -17/18m OD between 9000 and 10,000 BP, a rapid rise of sea-level was characterised by transgressive overlaps occurring at significantly different elevations between 7600 and 8000 BP and is related to the final catastrophic disintegration of ice sheets after 8000 BP. After the rapid rise of sea level was completed (*c.* 6000 BP), fluctuations occurred at various times, not more than 4m in both directions, possibly indicating either local coastal variations or regional eustatic variations.

Peat deposits with trunks and stools of oak, alder and willow with marshy vegetation and animal bones represent an example of submerged forest in the estuaries of the Dee and Mersey and northwards, with a famous example in the outcrops on the foreshore near Liverpool (Blundellsands-Hightown), which indicates a period of low sea level, probably Mesolithic, just before the formation of a Neolithic 25 ft raised beach (Edwards and Trotter, 1954). Other forest trees, probably of Atlantic age, are found beneath the alluvium of the Calder and Aire rivers in Yorkshire.

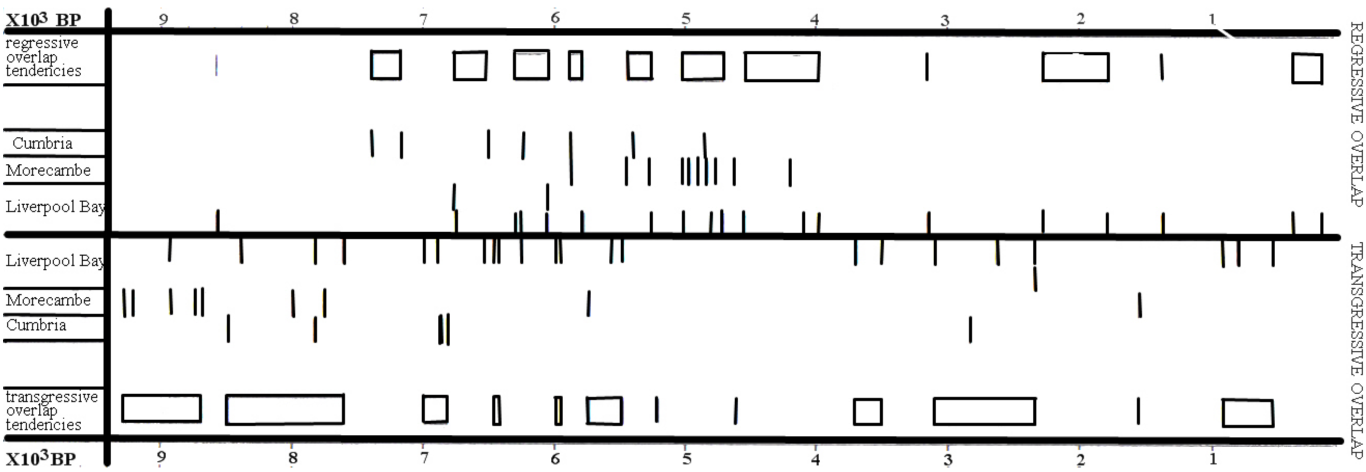

Figure 1. Transgressive and regressive overlap tendencies from sites in Cumbria (including the Isle of Man), Liverpool Bay and Morecambe Bay. Each bar is an uncorrected radiocarbon date from transgressive and regressive overlaps or from sand dune paleosols. For the whole of North West England these can be resolved into 12 transgressive and 12 regressive overlap tendencies, represented by the rectangles (summarized from Tooley, 1982).

[4] Regressive conditions occurring with retreat of the sea and shallowing water, so that neritic facies can be replaced by littoral and finally non-marine terrestrial facies.

The Holocene rise in sea level caused shortening and silting up of existing valleys, deposition of clays, silts, sands and gravel along the coasts and in the estuaries and valleys (Kent *et al.* 1980) and the inundation of fresh-water swamps by marine water (Taylor *et al.*, 1971). Depressions along the coasts of Fylde and South Lancashire, where drift was the main deposit, were rapidly filled with marine sediments. Alluvium in river flood-plains is the most common and extensive of the recent deposits and in many areas its accumulation is continuing till the present day.

Aeolian sands and silts were deposited in many places, particularly with the destruction of the natural forest cover during historic time. Wind-blown sands have accumulated in some parts of the region and Devensian wind blown sands have been partly redistributed (Kent *et al.* 1980). The formation of blown sands in Lancashire and Cheshire started in the Holocene and has continued until recently, with dunes on the coast near Southport, for example, having covered large areas (Edwards and Trotter, 1954).

5.3 Peat

The following description of the distribution of peat formed during the Holocene in Northern England is mainly summarised from Jarvis *et al.* (1984) and Ragg *et al.* (1984).

Peat is formed when soil organisms are not sufficient to decompose plant residues, especially in conditions of waterlogging. Blanket peat, formed in acid conditions, develops when very high rainfall causes persistent wetness. In some places, peat formed on permeable soils when these contained a continuous iron pan which caused permanent waterlogging. It is widespread and thick on the Pennines plateau, the hills of the Scottish Border, with less in the North York Moors and only few patches in the Lake District.

Fen, fen-carr and raised-bog peat develop in depressions in lowlands under warmer and less acid conditions than in the hills (Jarvis *et al.*, 1984). Fen peat, growing in a nutrient-rich environment, forms flat surfaces and is found in the North Cumbrian plain, Vales of Mowbray, Pickering and York. Fen-carr peat, moderately base-rich is found in the Vale of Pickering and in Durham. Raised-bog peat forms a convex surface, the upper layers having grown above the groundwater level, and occurs mainly near the Solway Firth and Morecambe Bay, Hale Moss in South Cumbria, Thorne Waste and Hatfield Moors in South Yorkshire, Stainmore, Pennines and uplands to the north of Hadrian's Wall. Distribution and characteristics of raised bog peat in the Humberhead Levels are described in detail by Van der Noort and Ellis (1997). The descriptions of Jarvis *et al.* (1984) and Ragg *et al.* (1984) are summarised in Table 4.

During the Holocene, peat mosses were formed in lowlands such as Chat Moss, near Manchester, and Thorne and Hatfield in Yorkshire, or in the Pennines moorlands above 305m OD, where they are about 1.8m thick (Edwards and Trotter 1957). In many areas of the Pennines, small flint implements and chips have been found within and beneath the peat (Edwards and Trotter, 1957). Extensions of blanket bog peat resulting from the Holocene rise in sea level and the onset of oceanic climate occurred in low-lying ill drained areas, during later Holocene time (Kent *et al.*, 1980). More information on peat distribution and type are found in Van de Noort and Ellis (1995) for Holderness and in Van de Noort and Ellis (1998) for the Ancholme and Lower Trent valleys. Peat distribution, type and stratigraphy in the Wetlands of North-western England has been described by the North West Wetland Surveys:

for North Lancashire by Leah *et al.* (1995b), for Cheshire by Leah *et al.* (1997), for Greater Manchester by Leah *et al.* (1995a) and for Merseyside by Leah *et al.* (1994).

Upland peat development often accompanies podzolisation, and a review of the geoarchaeological significance of upland peat and its distribution in Northern England is given in Canti (1992). Though there are many published works describing Mesolithic blanket bog, the main development occurred during the Neolithic and Bronze Age associated with clearance and settlement approximately in 4400-3400 BP, and many areas of deep peat started to form during the Iron Age, including areas of the North York Moors. In contrast, in the Southern Pennines blanket peat probably started during the Mesolithic (Canti, 1992).

Canti (1992) describes various studies on the cause of peat development: some include suggestions that peat formation may have been initiated by tree-clearance, which reduced evapotranspiration and allowed waterlogging, and other studies suggest that the use of fire by man caused failure in the regeneration of forests. Different *localised* factors (such as drainage) may have caused a wide range of dates and duration for the process (Canti, 1992).This has also been observed in sites in the Stainmore area of Northern Pennines (McHugh, 1992a).

Table 4. Peat types and distribution in Northern England (summarised from Jarvis et al., 1984 and Ragg et al., 1984).

Peat type	Description	Environmental conditions	Source plant types	Soil, environment and landscape	Distribution
Blanket peat	Black, mainly amorphous, often laminated.	Cold, anaerobic, extremely acid.	Acid tolerant, mainly Sphagnum moss, cotton grass, other grasses.	High rainfall, minimal evapotranspiration, impermeable substratum and level ground causing permanent waterlogging, or on permeable soil with continuous iron pan.	Pennines plateaux (largest and thickest), mainly above 300 O.D.; Forest of Bowland (mainly above 300 m O.D.); Scottish Border hills; less extensive in North Yorkshire Moors; patches in the Lake District.
Fen peat	Yellowish brown or brown, with fibrous or semi-fibrous leaf remains within a root matrix.	Nutrient rich environment, warmer and less acid conditions than in the hills.	Reed and sedges.	Lowland depressions. Forms a flat surface.	North Cumbrian plain; Vales of Mowbray, Pickering and York; hollows of glaciated morainic landscapes of Cheshire and on the Lancashire coastal plain (where they form flat surfaces).
Fen carr peat	Very dark brown, generally well humified. Contains many woody remains in varying stages of decomposition.	Moderately base-rich.	More varied botanical make-up.		Near Mardon in Durham; Vale of Pickering; hollows of glaciated morainic landscapes of Cheshire and on the Lancashire coastal plain (where they form flat surfaces).

Peat type	Description	Environmental conditions	Source plant types	Soil, environment and landscape	Distribution
Raised bog peat	Dark brown, highly humified and dense passing upwards to little decomposed, yellowish brown to dark reddish brown spongy peat near the surface.	Very acid	Mainly Sphagnum moss, cotton grass, heather.	Forms a convex surface.	Near Solway Firth and Morecambe Bay; Hale Moss in Cumbria; Thorne Waste and Hatfield Moor in South Yorkshire; Lancashire: Chat Moss (with smaller patches at Winmarleigh, Rawcliffe, Leighton, Red and Simonswood Mosses); Stainmore; Pennines; uplands to the north of Hadrian's Wall

5.4 Climate

5.4.1 Holocene climatic changes

Climatic changes during the Holocene have been described by different authors, including Lamb *et al.* (1966), Osborne (1976), Lamb (1977 and 1982), Atkinson *et al.* (1987), Grove (1988) and Jones and Keen (1993), on which the following summary is based. Specific information on Holocene climatic changes in relation to plants, invertebrates and vertebrates in Northern England is described separately in the reviews by Dobney and Stallibrass (in prep), Huntley and Hall (in prep) and Kenward (in prep).

After the last Devensian cold stage, a very rapid climatic amelioration occurred. Around 10,500 BP summer and winter temperatures started to rise dramatically and continued to do so during the centuries around 10,000 BP, when the rise of mean annual temperature was as high as 1.7°C per century.

An optimal mean annual temperature was established before approximately 7000 BP, and it has been suggested that summer temperatures were 2°C higher than today between 8000 and 6000, after which they increased to even higher values until circa 5000 BP. After that, atmospheric circulation in Europe changed, and between approximately 3000 and 2300 BP (1000 - 300 BC) average temperatures probably decreased by up to 2°C and precipitation increased. Subsequently, until 1300 AD, interpretations suggest that the average weather was warmer and drier, though there were some wetter and colder periods (Lamb *et al.* 1966).

Before the 5th century AD summers were warm and dry, whilst the weather was colder and less stable during the 6th, 8th and 9th centuries. From the late 10th century to early 14th century the climate became warmer, after which it became colder and precipitation increased. From the middle of the 15th to the middle of the 19th century the weather become very cold. During the 17th until the late 18th century, some of the northern parts of the British Isles had permanent snow and probably some glaciers, and rivers froze in winter. In the last part of the 17th century, lowlands were characterised by temperatures of about 1°C lower than the 20th century, whilst they were even lower in the uplands (in Scotland, for example, temperature was 2°C lower).

An irregular climatic recovery seems to have started after 1700, but a clear warming trend only started after the late 19th / early 20th century.

5.4.2 Present day climate

Temperatures
Significant changes in the mean daily range of temperature occurred in the British Isles during different periods of this and the last century.

The mean daily range of temperature for the thirty years between 1906 and 1935 was approximately 10°C in the areas around the West and East coast of Northern England, but temperatures were 2 degrees higher in the proximity of the Eden estuary whilst more inland the mean daily range of temperature for the same period was 12 to 14°C (Dudley Stamp *et al.*, 1954). The mean annual range of temperature between 1921 and 1935 was between 18 and 20°C in the coastal areas of Northern England and at various distances landward. The rest of Northern England was between 20°C and 22°C - south of the 20°C isotherm running from the Yorkshire coast more inland toward Scotland and then bending back towards the south from the Eden estuary down to the Mersey (Dudley Stamp *et al.*, 1954).

During the period between the 20s and 1950 the weather was warmer than both the previous and the following periods, with snowfall decreasing, winds becoming more westerly and rainfall increasing. A cooling took place between 1950 and 1980, followed by a warming during the last twenty years (Jones and Keen, 1993).

Data on the average present-day British temperatures are summarised by Stirling (1997). The average daily maximum and minimum are both higher in the western than in the eastern parts of the country. In Northern England, the mean daily maximum for January is 6 to 7°C in the west coast and 6°C in the east. The mean daily maximum for July is 18 to 19°C near the west coast, 19°C more inland, and 17, 18 and subordinately 19°C (Hull area) in the east coast and eastern part of the region. The mean daily minimum for January is 1 or 2°C near or along the west coast, and 1°C near the east coast, whilst the central area, including the Pennines, has an average January minimum of -1 to 0°C. The average daily minimum for July is 12°C in the western part of the regions, and 11°C in the eastern except, again, the area around Hull, with an average of 12°C.

Mean daily temperatures for January vary between approximately 4°C on the coasts and 3°C more landwards and in the central part of the region. Mean daily temperatures for July are around 15°C from the west to the east coast, but south of the area between the Humber and the Mersey they are around 16°C. At present the Vale of York is the warmest area of Northern England, followed by the lowlands of Holderness, Cumbria and the North East. The Pennines, Lake District and Cheviots are the coldest areas.

Rainfall

As Stirling (1997) remarks, in Northern England, as in Britain as a whole, the distribution of relief has an important effect on the distribution of rainfall, resulting in more rain over the mountains than in the lowlands. In Northern England, the presence of highlands such as the Pennines, Lake District and Cheviots, causes the air from the moist, dominantly westerly winds to rise and loose moisture as precipitation. As a result, the wettest areas are the Cumbrian mountains, followed by the western flanks of the Pennines, whilst the driest area is the east coast followed by the North Yorkshire Moors and Wolds, as shown by average rainfall maps such as the 1:1,000 000 map by the Meteorological Office and Ordnance Survey for the 1961-1990 period (Ordnance Survey, 1996), the simplified rainfall maps of Stirling (1997) and, for the 1941-1970 period, Jarvis *et al.* (1984) and Ragg *et al.* (1994).

These show that the average annual rainfall in Northern England increases from east to west, with the lowest values of 600 mm/year along the east coast and in the Tees Valley. Also from the southern part of the Vale of York down to the Trent Valley precipitation is around 600 mm/year, whilst in the northern part of the Vale of York and in the Tyne Valley values are slightly higher, between 600 and 700 mm/year. The Yorkshire Moors and Wolds have 700 mm/year in the lower parts and reach 800 mm/year in the highest. The part of the Cheviot Hills included in this region has between 700/800 mm/year on the lower eastern flanks to 1000/1200 on the highest parts. The more westerly areas of the Kielder and Wark Forests rainfall is around 1200 mm/year.

Rainfall increases from 600 or 700 mm/year to 1000 or 1200 on the eastern flanks of the Pennines. It reaches 1600 mm/year in the highest parts, then decreases to values around 1000 and 1200 on the western side. From here to the west coast rainfall decreases to 1000 or 800 mm/year but doesn't reach values as low as on the east coast. In the lower part of the Eden Valley average annual rainfall is around 800 mm/year and increases with altitude both along the eastern (Pennines) and western (Lake District) flanks. In the Ribble Valley rainfall is around 1000 mm/year, with values of 1200 mm/year in the Forest of Pendle and 1200 to circa 1600 in the Forest of Bowland. The Lancashire Plain has values between 1000 and 800 mm/year, and the Cheshire Plain values between 700 mm/year (Chester area) and 800 mm/year. In the Lake District, average rainfall increases from 1000 mm/year in the lower parts to 3200 mm/year in the highest. At Spinkling Tarn 4.3 m/year (the maximum average rainfall for Britain) were recorded between 1961 and 1990.

The whole of lowland England lies within the area where soil moisture deficit can equal or exceed the reserves of moisture held over from winter within rooting depth (Limbrey, 1978). This emphasises the potential influence of climate on the degree of waterlogging in lowland areas in Northern England.

6 Drainage

The main sources of information for this section are the same as for Section **2**, with more information obtained from King (1976) and some data from Kent *et al.* (1980) and Taylor *et al.* (1971). Other specific references are quoted in the text.

Though the major drainage lines flow from the uplands to the sea, some do not follow the most obvious and simple paths. Streams draining the Pennines, from the Aire, Ure and Wharf to the south to the Tyne and Coquet to the north, flow mainly eastwards to the east coast. Other important Rivers are the Eden and the Lune. The Eden flows northwards, west of the Pennines. The Lune flows south, draining most of the Howgill Fells and flows into the Irish Sea near Lancaster. In general, however, rivers flowing to the Irish Sea tend to be short and steep. In the eastern part of the region, most of the water from the North Yorkshire Moors flows into the river Esk and hence towards the east coast, while the Derwent carries much of the rest, as well as drainage from the Tabular Hills. Drainage in the Vale of Pickering is now in the direction of the Derwent because the eastern side of the Vale is blocked by morainic deposits which prevent drainage towards the sea. Before the Devensian glaciation the drainage was directed eastwards. The reversal of the drainage direction to the west resulted from a blockage by ice and boulder clay on both ends of the Vale of Pickering and the resulting formation of a lake which filled the Vale. Eventually the waters overflowed into the Vale of York via the lowest point in the Howardian Hills, near Malton (Catt, 1977), and cut a passage towards the Vale of York in the Kirkham Abbey Gorge. North of the Vale of York, in the Vale of Mowbray morainic hills divide the drainage system into two directions: northwards, towards the Tees, and southwards towards the Ouse. Some streams from the Wolds are drained towards the Derwent, but the river Hull collects most drainage from the Wolds down through Holderness to the Humber. The Wolds are traversed by a well developed pattern of extended valleys. Many and varied explanations have been suggested as to their origin, but most authorities support a partly periglacial origin. The hypothesis of Sparks and West (1972) is that the Chalk dry valleys have been developed by periglacial processes acting on previously existing valleys. In northern Lincolnshire, the Rivers Trent and the Ancholme flow northwards into the Humber. In West Yorkshire, many streams also flow towards the Humber.

Although in Northern England many streams follow structural elements, the majority are not directly related to the rocks on which they flow. The present drainage pattern carries traces of older drainage patterns and there are many discordant rivers. For example, in the Alston Block, the present pattern carries characteristics of the ancient easterly flowing drainage: the easterly flowing streams of the North Tyne, Upper Pont and Seaton Burn are relics of what was previously one stream; the Wear, the upper Derwent and a very large part of the Tyne may also represent relics of what was once one stream. After the last glaciation, a series of lakes were formed in this area with the retreat of the ice (e.g. the Talking Tarn and other tarns near Brampton, east of Carlisle and south of Hadrian's Wall).

In many cases, however, tectonic depressions have become major lines of drainage. The river Eden flows in the syncline of the Eden depression, and the main Tyne Valley and the South Tyne, follow the faulted syncline of the north of the Alston Block while to the south of the same block the Lune, Balder and Greta follow the Stainmore depression (a structural line) and flow east to the Tees. Dry valleys also result from processes different from the periglacial ones which may have developed the dry valleys in the Wolds; such other causes include river captures. For example, the pre-glacial Wear flowed into the relatively weak rocks of the Coal measures, cut back streams that originally reached the east coast, reached the Tyne near Newcastle and eroded its valley southwards to reach the Wear and Gaunless, thus leaving a number of valleys of the streams now dry because of this series of river captures.

Likewise, in preglacial times the South Tyne flowed westwards to join the Eden. However, the action of ice meltwaters caused the diversion of the South Tyne eastwards when a glacio-fluvial lake, called Lake Eden, was drained. The lake was between the West Allen (draining east) and the South Tyne which drained west. The Irthing once flowed east to the North Tyne but was captured by the Lower Irthing.

In the Lake District the radial drainage pattern is emphasized by the lakes. The drainage pattern of the Howgill Fells used to be a northerly drainage, but a series of phenomena during Tertiary and Pleistocene, including captures and breaching of the former east-west watershed, created the present drainage pattern, a number of dry valleys and the strange pattern of the river Lune.

The Ure flows east to the Humber, but part of its drainage was captured by the Clough, a tributary of the Lune, leaving a dry col near Garsdale, and the highest headstreams of the Ure have been captured by the Eden. Capturing of the Ure is still going on, with the Eden and Lune drainages capturing the upper part, which will therefore be diverted to the west.

Devensian meltwater channels between Ripon and Wetherby, through which water escaped south from the eastern side of the Pennines, caused the permanent diversion of the River Nidd at Knaresborough and of the Wharfe at Boston Spa (Edwards and Trotter, 1954).

In the area north of the Howgill Fells, the original drainage pattern, probably with many streams all flowing to the Eden at right angles to the Carboniferous limestone, was disrupted by subsequent development in the weaker strata, stream captures and drainage adjustments. This resulted in relic drainage features such as valleys and gaps.

The drainage pattern of the igneous area of the Cheviot Hills is radial and best developed in the east. It possibly resulted from a previous Tertiary, north-flowing pattern, modified by differential resistance to erosion of the different rock types, with the igneous rocks offering better resistance, changes of watershed positions and diversions of the direction of flow, leaving the igneous area preserved as upland. Relic dry drainage features, such as the Eglingham dry gap, mark some of the former pattern. Other major diversions occurred in the Cheviots during the glacial period, and drainage meltwater channels are also common. An example of a complex anastomosing pattern is found near Wooler, with the channels up to 18m deep, cut into a valley and a col. Glacial lakes in the Cheviots contributed to changing parts of the drainage patterns and directions.

In Lancashire, the drainage pattern of the Lancashire plain is recent and mostly formed on glacial debris, except in the upper areas and the Ribble. The course of the Mersey is largely artificial, as the course of river has been moved into the Manchester ship canal, although in some parts it joins its original course. On the edge of the Lancashire Plain there is a series of drainage channels formed by glacial meltwaters. The Calder is linked to the Ribble by the Whalley gap, where water flowed in different directions during postglacial and preglacial times. In the gap, the Calder is now cut into glacial outwash sediments.

The present drainage pattern of the Forest of Bowland is crossed by the Trough of Bowland, a deep ice meltwater channel cutting across the main watershed. Drainage channels of different size and shape are distributed in the Pennines. Many of these channels are now dry.

Acknowledgements

My thanks go to Matthew Canti, John Catt, John Dalrymple and Donald Davidson for advice, editing and proofreading the manuscript

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