The Geology and Landscapes of Lancashire

Edited By

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Edited by Keith Williams and Jennifer Rhodes
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Health and Safety

Many of the sites mentioned in this document are on private land. Access to most locations is possible using public rights of way, but if visitors need to leave these footpaths, permission from the landowner should always be sought. This is particularly important in the case of existing or abandoned workings.

The Geology and Landscapes of Lancashire

Introduction

The geology of Lancashire is considerably more straightforward than many other parts of western Britain yet its influence can be seen everywhere, in town and countryside alike. That influence extends from the nature of the overlying soils, through the vegetation and other wildlife, building materials, the location of settlements and main communications; it has played a continuing role in the economy of the North West and determined in no small measure the distribution of upland, river valley and plain, whose detailed characteristics are also a reflection of subtle differences of rock type, dip and fold. It is not possible to account fully for either the natural or human landscapes without some understanding of the underlying geology.

The physical topography of Lancashire flows directly from the interplay of rocks – whether soft or solid – and the energy streams provided over the past 350 million years by the sun, rivers, the sea and ice sheets. Another unseen player has been the vast store of heat held in the earth’s core which has led to the shifting of those huge jigsaw pieces which make up the crust and in turn determine in large measure what sort of rock has been formed at any particular place and time. Today, within a distance of a few kilometres there is evidence in the rocks of desert sand-dunes, tropical seas and swamps then the frozen wastes of great icesheets which completely buried this land a mere twenty thousand years ago.

The only type of geological activity for which there is little evidence in Lancashire is that of vulcanicity and other igneous activity. Only two tiny outcrops of basalt to the north and south of the Bowland Fells speak of molten rock and the source of that was probably well outside the confines of the county. Nor were there ever mountain chains of Himalayan proportions here though the impact of mountain-building from Cornwall to Germany and beyond followed by the upthrust of the Alps, has left its mark in the great rippling folds and shattering faults of the Pennines and adjacent lowlands.

While the rocks of Lancashire may be simple compared to that of the Scottish Highlands or even our near-neighbour the Lake District, it forms a distinctive part of Britain whose complex geology was among the first to be comprehensively mapped. It was in Britain also that many of the key principles of geological science were developed at a time when its rocks were the source of so much wealth at the height of the Victorian period. In short, it is the geology of Britain which has played such a great role in determining so much of the character of this land – natural, physical, human and economic. It would appear self-evident that we should look after it.

Yet beyond the set-piece exhibits such as the Giant’s Causeway, the Great Glen, Lulworth Cove and the chalk cliffs of Dover, the geological community has not achieved the sort of success in engendering public interest in rocks and landscape as biologists have in plants, animals and perhaps, especially birds. Only recently has geoconservation begun to scratch a toe-hold on government agendas and an organisational structure, let alone a protective shield of legislation, begun to emerge as a necessary part of civic life. It is true that some geological sites of national importance have had a measure of protection as
Sites of Scientific Interest for many years but the concept of ‘geodiversity’ followed long after ‘biodiversity’ was almost a household term, and protection of local geology and landforms hardly existed before 1990, when the county RIGS groups started to be formed.

RIGS are regionally important geological and geomorphological sites and are loosely equivalent to local nature reserves, though they vary much more in area and character. They may be as small as an erratic boulder moved and dumped by ice far from its original source or as large as a drumlin field. They may be more of interest for their role in the development of geological science or a fine collection of building stones featuring in a town trail. In Lancashire there are currently 104 RIGS added to eighteen geological SSSIs. All have been adopted by the County Council and district councils as Geological Heritage Sites which has afforded them a measure of protection. This is now set to be modestly increased by a number of official moves which have begun to put geodiversity on the same level as biodiversity within the planning system.

Regrettably, it cannot be said that the teaching of earth science is currently a high priority in our schools and is also declining at university level. What is also clear, however, is that people of all ages are fascinated by the history of planet Earth – and not just dinosaurs – when they have an opportunity to explore it further.

This handbook has the modest aim of providing an outline of not just the geology of Lancashire but the relationship between that and the processes which have moulded it into the physical landscapes which we see today. Nine distinctive landscape ‘units’ have been identified covering all the rural parts of the county. Each of these is the outcome of the interaction between rocks, moving water and ice over varying lengths of time in different climatic settings.

The RIGS and geological SSSIs are set within each of these landscape types and often provide particularly good examples of the geology or landforms which characterise them. They can often be regarded as a sort of window which offers a particularly good or detailed view into that particular landscape. In this way, the intimate relationship between rocks and landscape is developed, but that is only the start of the story. The rocks form the foundations and on top of them – and often peculiar to them – are the soils, the plants, insects – the whole edifice of life including Homo sapiens, whose cultural landscapes are draped over so much of the Earth’s surface. To make sense of these, you need to know about the rocks.
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1.0 A Brief Geological History of Lancashire

Lancashire's landscape is the result of a complex geological history, the oldest vestiges being subsurface rocks dating back to probable Cambrian times some 500 to 540 million years ago (Ma). Our surface landscape owes much to Carboniferous and younger sedimentary rocks where, over the past 360 million years, it has been the site of deep seas, shallow tropical lagoons with coral atolls, large deltas and swamps, deserts, ice sheets and lakes. Many fossils can be seen in the Carboniferous shales, limestones and coal measures. Significant changes in surface elevation are located along major fractures in these sedimentary rocks, though igneous and metamorphic rocks are notably absent from the Lancashire area.

1.1 Carboniferous Limestone (Dinantian)

Limestones, shales and sandstone rocks formed 360 to 325 Ma ago in the Lower Carboniferous period are very resistant to erosion. These form the rounded hills around Morecambe Bay, Leck Fell and the Bowland fells, the moorlands on Pendle Hill and the Forests of Trawden and Rossendale to the south-east. The oldest of these (the 'basal conglomerates') occur as shallow marine sediments in the far north-east of the county. Above them is the Great Scar Limestone which was deposited in shallow tropical seas. These rocks occur around Morecambe Bay and in the Ribble Valley near Clitheroe, where they are quarried for rock as hardcore material and cement manufacture.

At the same time limestones, sandstones, calcareous (limey) shales and reef-forming limestones were deposited in layers in the Bowland area and the Ribble valley. Today the reef-forming limestones and submarine mud mounds form the isolated rounded hills and rocky knolls around Clitheroe. These rocks show a story of fluctuating sea levels which were caused by variations in the size of the south polar ice sheet. In addition, the formation of uplifted land blocks and subsiding marine basins linked to faulting and folding as a result of plate tectonic movement.

1.2 Millstone Grit (Namurian) and Coal Measures (Westphalian)

Coarse sandstones and gritstones were deposited into these basins during the Namurian, forming slowly subsiding deltas and large river floodplains and estuaries. These rocks were later uplifted and today they outcrop in the high ground such as the Bowland Fells, to the north and the West Pennine and Rossendale Moors to the south. Over time alternating beds of limestones, sandstones and shales (Yoredale Series) formed the Forest of
Bowland to the north. To the south, massive beds of sandstones with alternating bands of gritstones, shales and occasional thin coals were dominant in what are now the West Pennine Moors, and the Forests of Trawden and Rossendale. Over time, coastal mangrove-style environments developed on river deltas and swamps, especially in these latter areas resulting in the beginnings of coal formation. These Westphalian sediments outcrop between Chorley and Skelmersdale and along the Calder and Darwen valleys where the industrial towns of Blackburn, Accrington and Colne developed. The remains of old mine workings survive here as a reminder of the once widespread coal industry which was used to power the cotton mills of East Lancashire. The coal seams are inter-bedded with sandstones, shales, mudstones and fireclays which also provide building stone and clay for the manufacture of bricks.

1.3 Permo-Triassic

At the end of the Carboniferous Period the climatic conditions became more arid with the Lancashire area moving north of the equator into the drier desert conditions of the Permian and Triassic periods (300 to 200 Ma). At the same time the British Isles, including the Lancashire area, was being subjected to, leading to folding and faulting as tectonic plates collided to the south. This led to a marked change from coastal shallow and marine deposition to erosion and terrestrial deposition as the main geomorphological processes. The dominant deposits of this period are calcareous mudstones (marls), which occur largely to the north-west of the Westphalian deposits near Chorley.
Terrestrial sandstones extend north to Heysham, and include silty red clays deposited in ephemeral playa lakes and shallow seas that went through several phases of evaporation. This resulted in the creation of rock salt deposits upon which the chemical industries at Thornton Cleveleys and Preesall were founded. Without doubt, the predominant environment was one of continental braided river and flash flood deposits left by streams flowing from the recently formed mountains in southern England and northern France. At the end of the Permo-Triassic we enter the Jurassic period with marine flooding of the region. No rocks survive from the Jurassic (200 to 145 Ma) or the subsequent Cretaceous
and Tertiary times (145 to 2.5 Ma) in the Lancashire region, as a result of either non-deposition or widespread erosion before the Pleistocene.

1.4 Pleistocene and Holocene

During the last Ice Age (Pleistocene and Holocene periods, less than 2.5 Ma) softer unconsolidated deposits of clays, sands and gravels were left by retreating ice sheets, glacier lobes and meltwater. (See Sections 5.2, 5.3 and 5.4 below.)

In the Holocene (the last 10,000 years), frequent changes in sea level have resulted in the deposition of unconsolidated sands and silts to be along the Fylde and Sefton coasts, the Ribble estuary, the river Douglas and extensively in the Morecambe Bay area. These variable sands were deposited as sandy beaches and dunes and as marine and freshwater flood deposits which are found today thinly and sporadically in beds throughout West Lancashire and parts of the Fylde. More recently, wind blown sand deposits built up along the coasts of West Lancashire and the Fylde to form extensive sand dune systems. Only a remnant now remains due to agricultural and urban development, especially the holiday resorts of Southport, Lytham, St Annes, Blackpool, and Fleetwood. Elsewhere deposits of lowland peat formed in low lying, waterlogged coastal areas, particularly across South and West Lancashire.

Peat formed in upland areas in the West Pennines, Trawden, Rossendale and the Forest of Bowland, where blanket bog developed in the damp climate. Streams and rivers, whose drainage patterns were changed during the last Ice Age, continue to transport large amounts of sand and silt from upland areas, especially during flood. This forms the alluvial terraces and flood plains of the rivers Wyre, Lune, Ribble, Douglas, Darwen and Calder, which now support lush agricultural grassland. At the present day these are the processes, along with anthropogenic interference that are contributing to our ever-changing landscape.

2.0 The Structural Geology of Lancashire

The three-dimensional structure of rocks is partly controlled by their response to tectonic forces developed within the earth's crust. This can result in strata either deforming and crumpling to produce fold structures, or fracturing and shifting to generate faults. Two major phases of earth movements, the Variscan and Alpine Orogenies (mountain-building periods) are largely responsible for producing the dominant fold and fault structures in Lancashire. The rocks exposed at the surface are of Carboniferous and Permo-Triassic age, and these are largely blanketed by post-glacial superficial deposits such as alluvium, peat and till. All these are underlain by older rocks that are only revealed by borehole and geophysical data. The structure of this older, Lower Palaeozoic basement was determined by the Caledonian Orogeny and is known to have influenced that of the overlying, younger rocks.

2.1 Folds and Faulting

Very late Carboniferous to early Permian times saw the phase of Variscan earth movements responsible for the generation of the northeast to southwest trending folds that form the Ribblesdale Fold Belt, Pendle Monocline and Rossendale Anticline. The Ribblesdale Fold Belt includes the Slaidburn and Clitheroe anticlines and Sykes and Brennand periclines and
Map 3 The Structural Geology of Lancashire

is thought to extend westwards towards Southport below a thick cover of Permo-Triassic rocks. The Sykes pericline is clearly exposed in a series of natural outcrops and abandoned quarries through the Trough of Bowland. Detailed research suggests that parts of the Ribblesdale Fold Belt reflect the shearing along sub-parallel fractures developed in the underlying Lower Palaeozoic basement. Around Lancaster, folds affecting Carboniferous rocks are aligned on a more northerly trend.
Not all Carboniferous strata are as strongly tilted as it is on the limbs of the folds of the Ribblesdale Fold Belt. The Burnley and South Lancashire coalfields are gentle synclinal structures, while Millstone Grit sandstones exposed on the west side of Anglezarke Moor are horizontal.

Permo-Triassic strata that underlie the Fylde and West Lancashire Plain are almost horizontal with dip values usually less than 5°. Very gentle post-Triassic warping during the Alpine Orogeny produced the Weeton and Elswick anticlines, and Kirkham syncline, all of which display a north-south trend.

Faults that trend from almost north/south to northeast/southwest dominate the structural geology of Lancashire. Some of these faults are clearly post-Triassic, where Permo-Triassic rocks are faulted against each other, or against Carboniferous rocks. Some faults were of Variscan age, but these may have been rejuvenated by post-Triassic, probably Alpine, events. Shearing within the Lower Palaeozoic basement is thought to have influenced fault structures developed in the Carboniferous cover.

Faulting of Carboniferous rocks has generated many northwest to southeast trending faults, with smaller numbers trending approximately west/east. A northwest trending fault zone passes through the Wigan area. Individual faults within the zone display throws of up to 350 metres. The north/south trending Permo-Triassic/Carboniferous contact in West Lancashire is partly faulted and partly unconformable. (An unconformity is a gap in the rock sequence). The faults cutting Triassic strata are downthrown to the west. This faulting extends into Morecambe Bay and the East Irish Sea Basin with the key fault zone displaying a horst structure.

2.2 The Carboniferous/Permo-Triassic boundary

Towards the end of Carboniferous times the Variscan Orogeny brought about the uplift, folding, faulting and partial erosion of Carboniferous rocks. During this phase no sedimentary rocks were deposited. The close of the Variscan Orogeny was followed by deposition of Permo-Triassic sedimentary rocks so that these unconformably overlie the Carboniferous strata. This considerable phase of non-deposition can be recognised by significant differences between the Carboniferous and succeeding Permo-Triassic rocks in terms of fossil content, environment of deposition and dip of strata.

3.0 Economic Geology

Lancashire’s industrial heritage is reflected in the wide range of minerals mined and quarried in the county. Some extraction continues today, for instance limestone at Clitheroe for cement manufacture and salt in the Preesall area for various chemical industries. There are large numbers of abandoned workings, such as the sandstone quarries in the Rossendale area, while the evidence for other activities has largely been lost to landscaping and redevelopment. Some abandoned workings have been developed as nature reserves, such as those at Longton Brickcroft, Higher Brockholes and Mere Sands Wood.

Selected sites of mineral extraction, past and present, are shown on the geological map of Lancashire (Map 2). The Lancashire Coalfield corresponds to the approximate extent of the Westphalian, though parts of it are concealed beneath younger deposits. Aggregates are an important mineral resource both in the form of fluvio-glacial and
dredged sands, and crushed hard rocks. The main on-shore sources of sand and gravel are the southern part of the so-called ‘Chorley Moraine’ and the eastern end of the Kirkham Moraine. Hard rock resources are focussed on the limestone outcrops north of Lancaster and the Clitheroe area with a small number of quarries exploiting the Namurian.

Water is a vital resource. Drainage of the Millstone Grit moorlands of the West Lancashire Pennines feeds reservoirs such as Anglezarke, Rivington and Belmont. Some Triassic sandstones are very permeable and these act as aquifers in lowland Lancashire providing valuable underground water supply.

4.0 Landform Processes

The land surface of the earth has been modelled into an assemblage of landforms by a variety of agencies. Some of these are geological in that they result from processes occurring within the earth’s crust such as faulting. Most processes, however, result from water in various forms, wind and gravity, interacting with the surface materials. Rivers, glaciers and the sea, for instance, all move surface materials around and create landforms associated with their erosion on the one hand and deposition on the other. It is convenient, therefore, to classify landforms according to the agency and whether they are broadly erosional or depositional in origin.

4.1 Erosional Landforms

Weathering is the process of breakdown and small incremental movements of surface materials in situ by chemical, mechanical and biological processes, often combined with gravity. Erosion involves the detachment and removal of rock fragments by a moving agency such as wind, water or ice.

4.1.1 Fluvial Erosion

The erosional effects of rivers are characterised by channels and valleys which may range in scale from tiny rills to integrated valley systems covering millions of hectares. More localised erosional features include, for instance, gorges and waterfalls.

4.1.2 Glacial and Meltwater Erosion

The notion of glacial erosion has only become accepted over the past 150 years, which is perhaps surprising considering its dramatic impact, first recognised in the huge U–shaped troughs in the Alps which are glacially-modified river valleys. The shaping of lowland bedrock by icesheets has now also become accepted and a range of landforms is recognised from individual grooves and flutes to enclosed basins and troughs which are now often infilled with sediment or lakes.
Meltwater tends to accumulate around the edges of icesheets, especially when these happen to be located against a confining slope. Water volumes may be sporadically very high, leading to the formation of deep, steep-sided channels. At the time of formation, these meltwater channels may run in, off or beneath the ice margin leading to their characteristically disjointed drainage pattern.

4.1.3 Karst – Erosional landforms

Karst landscapes are those produced on limestone rocks. They often display a range of features which reflect weathering rather than erosion. Where erosion has occurred, it sometimes shows distinctive landforms reflecting the particular ways in which limestone responds to flowing water and ice - clints and grikes, for example.

4.1.4 Others

Erosional landforms produced by wind and wave action are globally important but are of little significance in Lancashire being confined to a few small areas of rocky coastline.

4.2 Depositional Landforms

If erosion involves the detachment and movement of rock fragments by major dynamic agencies, deposition focuses on the destination of the moving sediment. Taken together, the two sets of processes reflect fluctuations in the levels of energy supplied by wind, water and ice. Deposition characteristically occurs when volumes and velocities of these decrease, as at the end of a flood, or when there is insufficient energy available to continue moving the sediment already in motion. Depositional landforms are typically assemblages of unconsolidated sediments modelled into forms which reflect the particular processes inherent in the way that the river, glacier or wind moves.

4.2.1 Fluvial Deposition

Deposition by rivers occurs when discharges fall. Its impact is disproportionately important in rivers which experience a wide range of discharges and which are supplied with significant loads of coarse sediment (> 1.0mm diameter). Finer sediments (< 0.5mm diameter) tend to remain mobile once set in motion unless water velocity drops to near zero or becomes stationary.
Depositional landforms produced by rivers may be contemporary though many date back to critical environmental events. These events include climate change in late glacial times or periods of important land-use change such as woodland clearance in the Neolithic period.

4.2.2 Glacial and Meltwater Deposition

These two related agencies account for by far the greatest proportion of deposits in Lancashire whether measured by area or volume. This reflects the fact that the whole area was covered with ice many hundreds of metres thick during the last glacial phase.

Under certain conditions, ice passing over bedrock may abrade or quarry the rock surface, detaching particles large and small which often become incorporated into the basal ice. Subsequently, this rock debris may be released from the ice and draped over the subglacial surface as a typical lodgement till. Till – or boulder clay as it was formerly known – is characteristically unsorted, being made up of coarse particles held in a finer matrix, deposited in beds which may be highly compacted. The character of till varies widely reflecting the changing ratio of fine to coarse components. Included beds of sand and gravel may cause considerable variety in the appearance of till exposures.

Most meltwater is produced during the final dissolution phase of an icesheet. Meltwater (fluvio-glacial) streams often flow at high velocity through areas of abundant unconsolidated sediment which they repeatedly pick up and re-deposit. Thus areas of meltwater erosion tend also to be those of greatest deposition.

Where meltwater is free to flow away from a retreating ice front into a flat open ‘apron’, thick tabular masses of sand are often laid down, sometimes with locally thin beds of intercalated silts produced by fluctuating flows into temporary ponds and lakes. Where a more active icesheet has provided a ready supply of sediment to a more or less stationary ice front, however, linear masses of hummocky deposits – sand, gravel and clayey tills - may have built up producing a low ridge topography often with local meltwater channels. Where the static ice over a wide area has melted, an extensive zone of hummocky ground (dead ice features) will often result, made up of low sand and gravel hills separated by meltwater channels and enclosed hollows or kettleholes.
4.2.3 Karst and Other Forms of Deposition

The majority of karst deposition takes places underground in cave systems of which Lancashire has few.

Coastal deposition both by waves and wind are characteristic of the Lancashire coast between the major estuaries of the Ribble and Lune. The ultimate source of these sediments is almost certainly the extensive meltwater deposits which are carried into the off-shore zone by these rivers. From there, sand is transported to and from the beaches during alternating periods of quiet and stormy weather.

There is evidence to support the view that the dune belt which probably once extended along the whole of the inter-estuary coast was originally deposited during a period of strong westerly airflow at the end of the last glaciation. The extensive open beach deposits provided a ready source of sediment then as they still do today.
5.0 Landscape Units

5.1 Fluvial landforms

Map 4 Fluvial landscapes
5.1.1 The Evolution of the drainage system

Three main river catchments drain the majority of Lancashire – the Lune, Wyre and the Ribble. A significant area of the Ribble catchment now lies in Yorkshire and within Lancashire it includes the important sub-catchments of the Hodder and the Calder. Their evolution – influenced by the structure and lithology of the underlying rocks - has taken place over millions of years and the present-day character of the main valleys has been determined as much by glacial action as by running water. Put another way, the pattern of drainage goes back to the emergence of the land from beneath the Cretaceous seas 60Ma; the generally broad, open shape of the main valleys is the legacy of repeated glaciations, and finally the present-day river channels and valley floors bear the detailed imprint of the most recent activity by today’s rivers.

5.1.2 The glacial legacy

The last glaciation resulted, at the glacial maximum about 18-20,000 years ago, in an icesheet covering the whole of the county. That said, over the highest ground the ice may have accumulated from local snowfall rather than have flowed from the Yorkshire Dales or the Irish Sea icesheets.

This ice was thickest in the valleys and was the last to melt over the ensuing 2–3,000 years. The re-establishment of a drainage system over this period led to parts of the pre-glacial river valley system remaining buried under masses of glacial deposits. This resulted in new sections of river channel/valley being sometimes cut through relatively resistant bedrock. This process of ‘glacial diversion’ has sometimes led to considerable contrasts in successive river sections, typified by broad, open lengths of valley linked by gorges.

![Diversion gorge on the R. Darwen](image)

These diversions are particularly obvious in the smaller catchments such as the Darwen, the Garstang Calder and the Brock. The first of these has no fewer than five such gorges below Wittton Park while the much larger Irwell has three and it could be argued that the whole of the Ribble valley below Clitheroe is one huge diversion, the pre-glacial Ribble having flowed north of Longridge Fell.
5.1.3 **Terraces and floodplains**

As the final melting of the ice masses took place about 15,000 years ago, it is safe to say that the valleys as we know them today would have been occupied by rivers whose discharge was boosted very considerably by meltwater. This increase in available energy coupled with the presence of copious supplies of loose surface sediments, led to the early rivers frequently carrying very high loads of coarse material. This was subsequently deposited across the valley floors in what older geological maps refer to locally as ‘Late Glacial Flood Gravels’ though in fact their presence is quite widespread.

![Terraces in the Hodder Valley](image)

At a later phase in the de-glaciation process, relative sea-levels started to fall though this appears to have been a ‘pulsed’ series of events rather than a smooth decline. The impact of these sea level falls was to trigger the rivers to start downcutting through the layer of coarse Late-glacial deposits leaving remnants of them perched above the new flood plain or valley bottom. Since this sequence of events repeated itself on a number of occasions, the result seen today is a series of steps or river terraces in all of the main river valleys. They can be seen particularly well at Burholme Bridge on the R. Hodder (SD 657 480).

5.1.4 **Meanders**

The scientific study of fluvial processes has shown these to be rather more complicated than early notions of riverine landscapes suggested. This has in turn required recognition that fluvial landforms reflect complex energy flows and interactions with transported sediment which do not equate with the comfortable notion of *youthful, mature and old age river valleys* of the last century.

The Ribble meander belt *downstream* of Ribchester superficially appears to be a textbook example but it actually displays a number of anomalous features. The first of these is that the present-day Lancashire section of the river channel is overwhelmingly cut into solid rock throughout its whole length from Paythorne to Penwortham and nowhere is this more the case than the along the meander belt below Ribchester. Rock cut (incised) meanders *are* found throughout the world but they usually imply a more protracted and complex history than would seem to be the case with the Ribble.
Secondly, meander dimensions are causally related to historical discharge patterns – the bigger the discharge, the bigger the meanders. Measurement of the Ribble meanders reveals that they are up to ten times larger than they should be. Nor do they appear to be migrating significantly, as meanders typically do, across the flood plain. This can be demonstrated by the fact that encroachment by the river across the site of the Roman fort at Ribchester has been restricted to probably less than 100m in 2000 years. Downstream, many of the meanders are constrained by the rocky river cliffs which mark the edges of the valley trench.

5.1.5 Development of the lower Ribble catchment

During the protracted early part of the last glacial phase – which lasted more than 100Ka – sea levels were up to 100m lower than today which in turn led to the coastline of NW England being moved SW to the southern Irish Sea basin. During this period there were no glaciers here and rivers in this area eroded valleys down to the lower sea level, their lower reaches later being infilled with glacial sediments. Most post-glacial rivers then broadly re-established themselves on top of these sediments above their pre-glacial valleys.

Measurement of the meanders between Ribchester and Preston shows them to be remarkably consistent in size and form with dimensions which indicate that they were originally formed by a river with a discharge ten times greater than the present Ribble. The last time that such discharges occurred was at the end of the Pleistocene at the point when the last ice was melting.

It appears that the lower Ribble, as it was re-establishing itself at the end of the last ice age, took up occupancy of a sub-parallel tributary valley which had almost certainly been opened up considerably by ice streaming southwest from Yorkshire. The new, present-day, route lies well to the south of its earlier line which was located through the much larger Chipping Vale north of Longridge. This valley has been shown to be very much deeper than the present Ribble valley, extends well out under the South Fylde and is filled with a prodigious thickness of glacial deposits. It contrasts sharply with the present smaller Ribble valley etched into the bedrock surface which is only 3.3m below AOD at Preston Dock.
5.2 Till Lowlands

Map 5 Till lowlands
5.2.1 Location

Both glacial deposition and the preceding erosion are broadly favoured by relative thick ice. Within an extensive ice sheet these are most likely to occur in the lower-lying parts of the landscape – basins, plains and deep valleys.

5.2.2 Nature of the deposits

Till is deposited beneath and often directly from, ice. It is characteristically unsorted, being made up of coarse particles held in a finer matrix which is deposited in massive unstructured beds which may be highly compacted by the weight of overlying ice. The character of till varies widely reflecting the changing ratio of fine and coarse components. Other intercalated sand and gravel materials may also vary the appearance of till exposures considerably. The coarse particles – typically pebbles but even large boulders – frequently display a preferred orientation of their long axes which reflects the direction of ice flow.

The lithology of till also reflects the types of rock which the ice sheet has passed over. Most of the till fabric is locally derived but also contains fragments of more competent material which have travelled great distances. These rocks of Scottish and Lakeland origin – glacial erratics – often, literally, add considerable colour to an otherwise uninteresting material. The larger ones encountered by Victorian sewer builders were frequently displayed prominently where they remain today. A good example is the huge boulder at Crossens (SD 377 207).

5.2.3 The Origin of the Deposits

Under certain conditions, ice passing over bedrock may abrade or quarry the rock surface detaching particles large and small which often become incorporated into the basal ice. Subsequently, this rock debris may be released from the ice and draped over the sub-glacial surface as a typical lodgement till.

The deposition of sand and gravel is by meltwater either under the ice or beyond the ice margins, while the morainic deposits represent clastic load deposited directly from ice in the final phase of melting. It has often been at least partially re-worked by meltwater.

5.2.4 Associated deposits

Two other sorts of materials are also frequently found associated with lodgement till. These are - often extensive - beds of sand and gravel (see Section 5.3) together with an upper layer of moraine or ‘flow till’. Superficially this morainic deposit resembles till but its
low compaction, more angular fabric and occurrence in beds showing dynamic structures, reflects its origin at the melting ice margin.

5.2.5 Till lowlands

Much of the county lying below 100m has till exposed at the surface or within the top 10m of superficial deposits.

There are two main departures from this broad distribution, however. In the west of the coastal plain – much of which lies below 10m AOD – extensive areas of peat mossland developed on top of the till as sea levels fluctuated at the end of the last glaciation and into the Holocene.

Secondly, a corridor of fluvio-glacial deposits, probably marking a period of stillstand of the icesheet margin, runs north-south to the west of the lowland-upland boundary, with a secondary east-west limb extending through the south Fylde.

Finally, the re-establishment of drainage in the major river valleys of the Lune, Wyre and Ribble led to the re-working of much of the till which was presumably deposited within them, leaving fluvial landforms dominant today.

5.2.6 Landscape characteristics

The core areas of till lowland are largely devoid of bold landforms. The till deposit occupying the broad trough between the Rossendale and Bowland uplands forms only part of a complex landscape. This is characterised by the close proximity of several landscape units with the till typically being draped over the lower slopes of hill masses such as Pendle and Longridge which have traditionally been the home of beef production.

North-east of Lancaster and north of Barnoldswick there are areas of till characterised by drumlin fields extending SW from the higher land of North Yorkshire. This so-called ‘basket-of-eggs’ topography with its succession of low, elongated, rounded hills is markedly different from the flat plains of West Lancashire and the Fylde. Where the drumlins occur in close proximity to other landscape units – as in the Lune valley – they add another theme to the visual interest of the landscape. In NE Lancashire they are locally the dominant landform whose swells and troughs lend an almost marine dynamic to the landscape.
5.3 Fluvio – Glacial Landforms

Map 6 Fluvio-glacial landscapes
5.3.1 General Features

At the maximum of the last glaciation 18-20,000 years ago, ice covered the whole of the county up to at least 450m AOD. At this altitude the ice would have been thin and produced by local snowfall but over the main valleys and lowlands it would have been many hundreds of metres thick. When it began to melt it would have done so from the top and around the edges leaving the lowest areas to become ice-free last of all. Fluvio-glacial sand and gravel result primarily from the action of the meltwater produced during this dissolution phase of the icesheet.

These landforms may be eroded or depositional features and reflect the location of the meltwater processes in relation to the icesheet. The main locations are: at or below lateral ice margins; beneath and within the main body of the icesheet and lastly, in recently de-glacierised pro-glacial zones. Since each of these locations progressively shifted as the ice sheet melted, features formed, for instance, beneath the ice at the onset of de-glaciation may subsequently have been reworked by ice-margin or pro-glacial processes as the icesheet shrank across this area.

5.3.2 Erosional Processes

Meltwater tends to accumulate around the edges of icesheets, especially when these happen to be located against a confining slope. Water volumes may be sporadically very high leading to the formation of deep, steep-sided channels. At the time of formation these may run in, off and beneath the ice margin leading to their characteristically disjointed pattern.

5.3.3 Depositional Processes

Meltwater flows typically are highly volatile resulting in the low-water deposition of sediments picked up during the preceding high-water phase. Thus many meltwater channel areas are also coated with sand and gravel which may be re-worked to give low, rounded forms between channels.

Fluvio-glacial sand, Adlington

Where meltwater is free to flow away from a retreating ice front into a flat open ‘apron’, thick tabular masses of sand are often laid down, sometimes with local thin beds of
intercalated silts produced by fluctuating flows into temporary ponds and lakes. Where a more active icesheet has provided a ready supply of sediment to a more or less stationary ice front however, linear masses of hummocky deposits – sand, gravel and clayey tills - may have built up producing a low ridge topography often with local meltwater channels. Where the ice has become stagnant over a wide area, an extensive zone of hummocky ground (dead ice features) will often result. This is characterised by low hills separated by meltwater channels and enclosed hollows or kettleholes.

5.3.4 Distribution

Broadly speaking, the distribution of meltwater landforms falls into five often overlapping areas.

1. Upland valley sides where the concentration of meltwater flows between ice and hillside has led to predominantly erosional landforms.
2. An important transitional belt on the eastern edge of the Lancashire Plain which grades from erosional to depositional forms.
3. Lowland areas - including lower river valleys – where late in the de-glaciation process there were vast volumes of meltwater which was free to flow in a less confined way. This has led to mainly depositional landforms.
4. Smaller areas characterised by dead ice forms.
5. Local instances of glacial diversion.

The upland valley side areas which have been affected by fluvial-glacial erosion are dominated by systems of meltwater channels. From north to south these are the Littledale/Clougha system east of Lancaster; the Wasnop Edge channels east of Burnley, and the suite of channels extending SE from above Edenfield and Bury into the Rochdale area. In each case the channel systems have been eroded by mainly marginal and sub-marginal meltwater flows though with some channels showing the typical humped profile produced by subglacial meltwater flowing uphill under hydrostatic pressure. The Wasnop and Clougha channel suites form sequences of progressively lower and bigger channels cutting through a moorland interfluve and marking the downward shift of the ice margin consequent upon progressive melting.

The transitional belt extends from the foot of the main lowland/upland boundary westwards into the Lancashire Plain, a distance of between five and eight kilometres. The upland
edge of the belt is typified by the presence of large meltwater channels which carried water south and eventually east into the Manchester embayment and ultimately into the ice-free Yorkshire Calder. The western edge of the belt – for instance, south of Chorley - has progressively fewer channels and more in the way of extensive sand deposits, though in some areas these are masked by thin spreads of later material.

The lowland fluvio-glacial sands are mostly a depositional channel-free westward extension of the transition belt. Where this area crosses the major valleys of the Lune/Conder and Ribble, fluvio-glacial deposition has extended along these valleys, to be locally reworked and added to by later fluvial activity. The middle section of the Douglas valley between Adlington and Standish, together with the Euxton area west of Chorley, are particularly notable for their deep and extensive areas of fluvio-glacial sands. In the southern Fylde, approximately along the line of the M55 motorway, there is a further belt of sand and gravel deposits, forming a series of low ridges associated with a stillstand of an ice front which led to enhanced dumping of fluvio-glacial materials hereabouts.

Two significant dead-ice areas are located north of Garstang and around Brindle near Chorley. A third one underlies much of Pleasington, west of Blackburn. The Garstang area is west of the transition belt and contains the best kettleholes in the county and probably the only eskers. The Brindle area, however, is well within the transition belt with major meltwater channels to both the east and west, extensive hummocky ground and possibly a former shallow lake site. The Pleasington (SD 640 265) deposits by contrast are thickly spread over and round the western extremity of Billinge Hill with the R. Darwen to the south and lower land of Samlesbury to the north.

Finally – but of great importance to early industry in Lancashire – are the many glacial diversion gorges found in the river valleys at the edge of the uplands. These have been included here since they mainly fall within the area of other fluvio-glacial landforms. Although their formation occurred right at the end of the de-glaciation phase in each of their respective locations, the dominant agent in at least the initial erosion of these gorges was almost certainly meltwater. This drained from below the last remaining masses of ice in the valley bottoms. The most significant examples are the Halton Gorge, Lancaster,
Dinckley Gorge east of Ribchester and smaller ones on the Wyre and Brock. Although outside the main fluvio-glacial area, there are also major diversion gorges in the Irwell valley at Stacksteads and Summerseat and the Ribble valley at Gisburn.
5.4 Glacial Troughs

Map 7 Glacial troughs
5.4.1 Upland and lowland troughs

Glacial troughs are typically the ‘U’ shaped valleys so characteristic of glaciated mountains. What has come to be realised over the past 30 years is that these features are not confined to uplands but frequently occur at lower altitudes across northern Europe and North America.

The distinctive characteristics of glacial troughs are their frequently oversteepened slopes with truncated spurs; broad, low-gradient floors and undulating long profiles whose hollows are often the sites of former or present-day lakes. The effects of glacial erosion are most marked in the valleys because the ice was thicker here and probably flowed at a higher velocity leading to increased erosion.

These features are readily visible in areas of mountain glaciation and their origin obvious where major glaciers still exist. This is less the case in the lowlands which were covered by Quaternary icesheets because the valleys lie wholly or partially buried by later deposition. Lancashire is no exception.

View SE across the Irwell Valley towards the Cheesden Brook meltwater channels

5.4.2 Buried rock-head topography

Extensive areas of the rock-head topography of North West England have been mapped revealing a buried landscape of significant amplitude, especially below the lowlands, compared to the present-day surface. The key feature of this buried landscape is a series of major glacial troughs aligned broadly with the south to southeast direction of ice flow in the eastern Irish Sea basin.

It can also be seen that many of these buried valleys – but not all - connect with major rock-head valleys which cut through the uplands in the eastern half of the county and
which are occupied today by the principal rivers. All of them display to a greater or lesser extent the characteristic glacial trough form, even though the orientation of the main upland valleys –northeast/southwest – reflects both structural controls and the influence of ice flowing southwest from the Yorkshire Dales.

In the Rossendale uplands, the direction of Irish Sea ice flow covering the whole area during the last glacial maximum coincides with the lineation of fault-controlled valleys as at Belmont, Darwen/Cadshaw, Accrington/Bury and Cliviger/Walsden.
5.5 Saltmarsh landscapes

Map 8 Saltmarsh landscapes
5.5.1 Location, formation and character

Saltmarsh environments can be seen along much of the Lancashire coastline, from the Hest Bank/Silverdale Marshes in the north, through the Lune estuary, the marshes at Pilling and Cockerham and the Wyre estuary, to the large Ribble estuary marshes in the south. These open coastal saltmarshes have all formed since the melting of the last glaciers some 16,000 to 14,000 years ago and the consequent sea level rise, together with redistribution of glacial deposits from the Irish Sea floor and from inland locations via the river estuaries.

Saltmarshes are characterised by a maze of winding creeks, channels, drainage ditches and pools forming distinctive dendritic patterns in the often vegetated mud and sand of the inshore sediments. They are often backed by low cliffs of glacial deposits, cut as sea level rose, and show signs of being eroded at their edges, or of extending once more along the coastlines and estuaries depending on local coastal conditions. To seaward the unvegetated sandbanks, mudflats and shallow waters provide an ever changing and fertile environment for fish, shellfish and worms. The whole marsh forms an internationally recognised habitat for feeding and nesting wildfowl and waders, being vital staging posts for migrating species.

5.5.2 Vegetation

Most of the current saltmarshes have formed between high and low water marks since sea level dropped from its post-Roman high of 5.4m. AOD to its current 4.2m AOD. In sheltered coastal bays and estuaries, sandbanks and mudflats form by the deposition of current/tide borne fine sediments from the floor of the Irish Sea, from sites of erosion of coastal sediments and from inland river systems. The upper shorelines of these flats start being colonised by pioneer salt-tolerant species. *Salicornia spp.* (glasswort) and the introduced *Spartina anglica* (cordgrass) rapidly spread into saltlings dominated by grasses such as *Puccinellia maritima*, *Agrostis stolonifera* and *Festuca rubra*. The end product is the mature, rarely inundated marsh of creeks, partially infilled saltpans and mature species-rich flora.
At the present day, saltmarshes throughout the region are generally spreading, for example to the south of the Ribble estuary, though occasional areas of minor erosion occur, for example at Silverdale. Locally, areas of saltmarsh may be eroded by shifting estuarine channels and with future sea levels set to rise fairly rapidly, changes in the nature and positioning of the coastal saltmarshes are likely to take place.
5.6 Lowland mosses
5.6.1 Location and formation

Situated on the low-lying areas towards the coast of the county, the peat deposits which form Lancashire’s lowland mosses present a characteristically flat landscape which was once a wide-ranging series of raised mires. Extensive drainage and reclamation for agriculture, along with peat cutting has resulted in a largely agricultural landscape and little of the original character of the mosses remains. Some of the best examples of the lowland moss landscape and habitat are Pilling and Winmarleigh Mosses in Wyre, Heysham Moss and Much Hoole moss near Preston.

5.6.2 Character and vegetation

Lancashire’s mosslands started to develop over thick glacial deposits around 9000 years ago, in waterlogged areas where kettleholes existed in the glacial tills. Plant material accumulated where it was not able to decompose in the oxygen-deficient water. The mosslands rose above the influence of the mineral-rich groundwater and the peat which began to form was fed by mineral-deficient rainwater alone. At this point the fen vegetation gave way to the characteristic sphagnum mosses and cotton grasses, forming raised mires or mosses. Shallow estuarine lakes may have made the transition from open water to raised bog relatively quickly, perhaps in as little as 500 years; the deeper inland depressions took much longer, possibly in excess of 2000 years. In their natural state, raised mires have a very gently curved, domed shape, although this is not evident today on the Lancashire mosses due to de-watering, peat cutting and cultivation.

Open water was also once a characteristic of the mossland landscape, most notably the large late-glacial lake of Martin Mere in West Lancashire, which was drained during the eighteenth and nineteenth centuries for agriculture. The lake of Marton Mere near Blackpool was formed by similar processes.

5.6.3 Water levels

Many of the mosslands of West Lancashire are situated below the mean high tide level and are protected from marine inundation by the dune complexes on the coast and also by large pumping stations such as those at Altmouth and Crossens.

Lancashire’s mosslands are now predominantly an arable agricultural landscape, characterised by narrow raised roads bordered by ditches and expansive views. Some localities have remained uncultivated and often characterised by areas of heathland and birch scrub where drainage has resulted in conditions too dry for sphagnum moss growth.

Lancashire’s mosslands offer more than a characteristic landscape. They provide habitats for the rare and uncommon assemblages of plants and animals that depend on them, whilst the layers of peat can give an insight through the pollen and plant remains that they contain, into the environments and climate changes of the past.
5.7 Gritstone uplands

Map 10 Gritstone uplands
5.7.1 Location and character

Lancashire’s moorland plateaux typically lie between 200m and 540m AOD and are confined to the eastern half of the county. Apart from Pendle Hill and Waddington Moor, they lie in two dissected blocks – the Bowland Fells in the north and Rossendale Forest in the south. Essentially they are westerly extensions of the main Pennine monocline but whereas the latter is normally marked on its western flank by faulting and westerly dipping beds, the bedding in the Lancashire uplands is remarkably level apart from some local warping in Bowland.

Their landscapes, however, are subtly different in character despite being underlain by rocks of a similar age, with some parts being characterised by Namurian gritstones while others have Dinantian limestones at the surface. This difference in rock type can be clearly seen in the drystone walls with the lighter limestone-rich walls dividing greener fields, while the dark gritstone walls frequently surround areas of coarser dark grass, sedge and rush.

The high annual rainfall on the widespread flat surfaces encouraged vegetation growth which during the climatic optimum of Atlantic times (approximately 5000 years ago) led to the widespread accumulation of peat. Though this most recent of geological deposits has been damaged by air pollution, artificial drainage and locally by feet and machines, it still contributes hugely to the wildness characteristic of the moors and is a significant repository of a distinctive NW European habitat.

The economic value of the moorlands continues to be exploited. Local deposits of coal and lead were probably among the first to be mined though they were of little significance compared to the stone itself, which with the coming of railways led to one of the most extensively quarried areas of Britain. This was particularly true of Rossendale leading to Rough Rock gritstone and Haslingden Flags being exported round the world in the 1870’s. High rainfall and peat have made these moorlands particularly suitable as water catchment areas for nearby towns and later, for Liverpool. More recently, recreation has been an increasingly important land-use and with pressure to develop renewable energy, the proliferation of wind farms has begun.
5.7.2 Formation

Viewed from almost anywhere in Lancashire the gently undulating summits of these moors are an outstanding feature and appear broadly to correspond to the underlying bedding. A key question however, though one which has received little attention recently, is whether – or to what extent – the uniform level of the moorland tops is causally related to the structure and/or is the result of denudation processes operating over tens of millions of years.

It is widely accepted that most of western Britain was submerged beneath the sea which resulted in the deposition of the Cretaceous rocks now are largely restricted to eastern England. At the end of the Cretaceous period 65 Ma ago, the sea retreated, Britain gradually became dry land and was tilted eastwards. This initiated an eastward-flowing river system with the main English watershed located to the west of its present position. These rivers over eons of time removed all the western Chalk and possibly some underlying older rocks as well.

According to a number of quite different theories, the long-term result of such protracted ‘denudation’ – provided that relative sea-levels remain stable - is the production of a more-or-less flat surface at low level. In the event of a major geological disturbance such as mountain-building or the onset of widespread glaciation, relative sea levels would fall leaving the low-level ‘peneplain’ in a more elevated position.

It is quite possible that denudation theories provide a good account of the level upland surfaces which have been traced across extensive areas of western Britain. Such surfaces have been demonstrated to show no respect whatever for geological structures which locally they cut right across, even on a small scale as in Bowland. Where they correspond to the structure, as in most of Lancashire, it may be simply a matter of coincidence that the erosional processes were assisted by geological structure. However they were produced, the upland expanses of the Lancashire hill country account for a large and distinctive area of the county which continues to play a critical role in the lives of visitors and local residents alike.

5.7.3 Rossendale and Bowland Fells

The Rossendale Moors viewed from the slopes of Winter Hill can be seen as serried ranks of flat-topped hills with stepped slopes caused by the differential rates of weathering of the softer shales and harder sandstones. The Namurian rocks are almost horizontally bedded, with the more competent strata such as Rough Rock, Woodhead Hill Rock and Haslingden Flags forming the plateaux.

These hills extend northeast from Winter Hill, each broadly covered to a greater or lesser degree by blanket peat, fragmenting at the edges and characterised by small amounts of heather (*Caluna vulgaris*), cotton grass (*Eriophorum angustifolium/vaginatum*) in the extensive wet areas, and vast swathes of purple moor grass (*Molinia caerulea*) on damp ground. Where the remains of quarries and other mineral extraction such as lead mining occur, the improved drainage and effect of disturbance by man, results in a vegetation including bilberry (*Vaccinium myrtillus*) wavy hair-grass, (*Deschampsia flexuosa*) and heather.

Bowland has more wooded valleys, is less densely populated, less industrialised and has large areas managed as grouse moor, while other areas are managed for water supply to the Lancashire towns. The area was granted AONB status in 1964. Geologically, it is a
complex pericline with rocks of Carboniferous age at the surface. The hardest sandstones, the Warley Wise Grit, form the highest ground including the summits of Clougha Pike and Ward's Stone and the crags on Tarnbrook Fell. Below about 400m AOD much of the area is blanketed by glacial deposits - till, sands and gravels - overlying Namurian rocks. These are mainly sandstones, mudstones and shales overlain by Westphalian (Coal Measures) sediments at the margins of the moorland. The oldest Carboniferous rocks, of Dinantian age (Carboniferous Limestone), occur around the edges of the Bowland Forest. The area is a large plateau dissected by deep valleys of the Ribble and Lune tributaries with more detached blocks lying to the south in Longridge Fell.

5.7.4 Forest of Pendle and Waddington Fell

These uplands, which comprise part of the Forest of Bowland AONB, are formed by the limbs of an anticline eroded to form an inverted landscape with the axis of the anticline having been eroded to create the Ribble valley. The rocks are once again of Carboniferous age, mainly Namurian gritstones such as Pendle Grit and Pendleside Sandstone with areas of Dinantian (Carboniferous Limestone).
5.8 Moorland margins

Map 11 Moorland margins
5.8.1 Location, formation and characteristics

The moorland margin is the transitional zone between high gritstone moors and the adjacent major river valleys and plains. It typically slopes steeply from the moorland plateaux as seen in the north sides of Pendle Hill and Darwen Hill down to more gentle lower slopes that merge into the till lowlands and river valleys. The boundary between the moorland margin and till lowland is often unclear, with glacial deposits feathering into solifluction and mass movement features.

Moorland margin, Rossendale

In some areas, notably the Rossendale valley slopes, there is strong lithological control of the stepped slope form with resistant sandstones displaying strong, vertical joint sets being reflected in steep sections, while the weaker shales give rise to flatter benches. In the past, these benches provided enough moorland pasture to lead to the creation of many upland farms and the ruins of these are clearly visible strung out above many valleys.

The sub-horizontal bedding of the main hill masses has led to virtually no dip and scarp forms which are so characteristic of the Pennine margins east of Manchester. There are a number of prominent escarpments, however, such as those on Pendle Hill, Longridge Fell and Stronstrey Bank, east of Chorley, though these oversteepened slopes are largely a product of lateral glacial erosion with faulting making a significant contribution in the latter case.

5.8.2 Mass movement

Solifluction processes and landslips have influenced the development of moorland margin slopes extensively and quite dramatically in some areas, such as the Cliviger valley, (SD 870 290). The instability which is demonstrated by these features resulted mainly from two interrelated processes, active during the transition from a glacial to post-glacial climate and have continued in a modified form to the present day.

The saturation of surface deposits by meltwater both weakened them and provided a lubricated lower surface over which they could easily slide. In some localities the melting of permafrost at exactly the same time as glacial support of steep slopes was being removed also led to large rotational landslips. Finally, it would appear that some de-glacierised
areas experienced a periglacial climate long enough for frost shattering of sandstone crags to give rise to unstable boulder fields and screes such as those in the Clougha Pike (SD 540 620) area and on the steep slopes south of White Coppice (SD 618 185).

The extent and density of plant colonisation of soliflucted material reflect the chronology of this event. In some areas such as Windy Clough, near Clougha Pike (SD 544 596), rotational shear surfaces provide the mechanism for movement while extensive ridges and hummocks of soliflucted material are sometimes developed towards the base of the fell sides as in the Dunsop valley (SD 656 510).

5.8.3 Meltwater

The impact of meltwater on the moorland margins is widespread, especially on west-facing slopes and above major river valleys such as the Irwell and the Lune. This has taken the form of both erosion and deposition, frequently in the same areas since these were where the meltwater was locally concentrated. Channel systems are particularly well developed on the north and west flanks of the Bowland Fells, especially near Clougha Scar (SD 544 596) and north- of Garstang (SD 533 488); around the West Pennine Moors, east of Chorley (SD 615 165); and on the ridge separating the Irwell and Cheesden valleys (SD 815 155). Deposition adjacent to the channels is often reflected in the low, rounded hills of sand and gravel which, where they have been cleared of native broom and gorse vegetation, make for improved pasture on the well-drained soils. (See also Section 5.3 on fluvi-glacial landforms.)

Soil formation shows more clayey characteristics towards the lower levels of moorland margins grading upslope into more peaty, sandy soil in keeping with upland peat development and weathering of sandstone bedrock. Upper, steeper parts of the zone are characterised by typical upland vegetation: coarse grasses, bracken and heather while lower, gentler slopes provide pasture on improved land. There is some reclamation of steeper slopes for pastoralism and forestry.
5.9 Karst landscapes – a special case

The karst landscapes of Lancashire are best seen in the north of the county around Morecambe Bay in the vicinities of Silverdale, Hutton Roof, Kellet and to a lesser extent, Leck Fell. These are developed on Dinantian limestone which was deposited in warm, shallow, tropical seas between 330 and 350 Ma ago. Today these rocks form a landscape produced by a series of large upstanding fault-bounded limestone masses, often blanketed by Quaternary glacial materials. Where exposed, they produce steep-sided, sometimes scree-mantled, hills supporting a range of classic karstic features.

The range of such features - produced by the solution of limestone under sub-aerial conditions - includes caves, limestone pavements, dolines and poljes, with examples of
sops, water sinks and blind valleys. Although the best examples of karst phenomena are seen in the modern landforms, there is evidence of karstification of the landscape during the Carboniferous itself, where the rocks are interbedded with palaeokarst surfaces, and during Tertiary times, where sops (doline-like solution cavities, often controlled by faults and infilled with haematite) are seen.

Most of the karst landscape was formed during either the late Tertiary (up to 15 Ma ago) or the Quaternary (up to 1.8 Ma ago). These landscapes contain excellent examples of karst landforms which are characterised by dry valleys and water sinks where surface drainage descends to cave systems below.

The oval-shaped doline depressions formed by solution and surface collapse along the Silverdale fault complex, contain late-glacial windblown silts (loess) formed some 11,000 years ago. These dolines probably formed in stages between 200,000 years and 1 million years ago, their size perhaps being reduced by periods of glacial erosion during the last ice age.

The Hawes Water polje (SD 477 767) is a rare British example of these large-scale enclosed depressions. This polje is approximately 0.39 square kilometres in area, has steep sides, a flat lacustrine sediment-filled floor and has a varying water depth depending on local groundwater levels. Inflow and outflow from the basin is by subsurface karstic routes.

Probably the best known aspect of karst landscape is the limestone pavement and Hutton Roof Crag (SD 555 780) is amongst the best known in Britain. Limestone pavement developed where the rock was been exposed, possibly by early glacial activity, allowing preferential solution to take place along joints and fractures forming metre deep grikes and isolating the clints. These ‘karren’ landforms are covered by small solution runnels across the clint surfaces called rinnenkarren which are typically a few centimetres deep and wide.

In these landscapes permanent streams are generally absent, soil cover is thin and alkaline with patches of more acidic loess-based soils. Rich calcareous grassland, scrub and coppiced ash and hazel dominate woodland cover over much of the area. Lime kiln sites and both active and abandoned limestone quarries are typical features of the landscape along with improved pasture and parkland.
Map 13 Geological SSSIs in Lancashire
Map 14 RIGS/GHS in Lancashire
Glossary

Anticline – upfolded rock structure
Base level - the lowest level to which a river can down-cut; usually the sea or large lake
Braided channel – a multithread gravel channel network
Catchment – area of land drained by a river
Clast – a fragment of rock of any size
Climatic optimum – Post-glacial period when the climate was at its warmest, about 7000 years ago.
Clint – block limestone surrounded by grikes
Conglomerate – rock made up of rounded pebbles set in a matrix of fine sediment
Dead ice – glacier ice which has become cut off from an ice source and is usually melting
Dendritic – branching like a tree
Deposition – laying down sediment by a moving agency such as a river or the wind
Dinantian – modern name for the Carboniferous Limestone period
Doline – a solution hollow in limestone
Drumlins – Low streamlined hills typically occurring in swarms in lower land adjacent to upland ice source
Erosion – removal of rock fragment by a moving agency such as a river or glacier
Esker – elongated and sinuous ridge of fluvio-glacial origin
Fault-bound – block of rock bounded by faults and therefore of a different age to the surrounding rocks
Fireclay – or seatearth: old soils occurring beneath coal seams.
Fluvial – relating to rivers
Fluvio-glacial – relating to glacial meltwater
Geomorphology – the study of landforms
Glacial trough – a valley that has been shaped by an ice stream
Grikes – vertical partings in limestone widened by solution to form a system of deep gashes around clints
Gritstone – a very coarse sedimentary rock of Namurian age
Holocene – the time following the last glaciation to the present-day
Humped profile – the up-and-down long profile of glacial troughs and some sub-glacial meltwater channels
Ice-contact – deposits laid against ice which has since melted
Igneous – ‘fire rocks’: formerly molten
Interfluve – the land between neighbouring rivers
Inverted landscape – a valley formed along the axis of an anticline or ridge along a syncline
Ka - thousand years
Karst – distinctive landforms/landscape formed on limestone rocks
Karren – small-scale solutional features formed on limestone surfaces
Kettlehole – hollow in fluvio-glacial or dead-ice deposits by the melting of a block of ice
Lacustrine – relating to lakes, esp. sedimentation within lake basins
Limestone – rocks derived from calcareous materials within the sea-water in which it is deposited
Lithology – rock characteristics
Lodgement till – stiff till deposited from ice beneath an ice sheet
Ma – million years
Meander – bend in an alluvial river channel produced by the erosion and deposition in response to river discharge patterns
Meltwater channel – channel cut by meltwater: frequently unrelated to present-day drainage system
Mass movement – downslope movement of rock material under gravity
Metamorphic – rocks which have been changed various means
Moraine – a) unsorted material deposited by ice b) a linear landform made of such material
Namurian – modern name for the Millstone Grit period
Palaeokarst – karst landforms buried beneath later rocks then re-exposed by erosion
Palaeozoic – rocks dating between the Cambrian and Carboniferous periods (approx. 400Ma – 325Ma)
Penepplain – a theoretical plain to which a landmass would be ultimately reduced after protracted erosion
Pericline – domed structure
Pioneer species – the first plant species to colonise an area or alien environment
Playa lake – ephemeral and often saline, lakes on hot desert plains
Polje – an extensive elongated limestone basin
Quaternary – time since the beginning of the Pleistocene period
River terrace – stepped bench above a river channel produced by rapid down-cutting of the river
Sandstone – a sedimentary rock made up of cemented sand particles
Sedimentary rocks – rocks of cemented particles or precipitates laid down in layers
Shale – clay deposits turned into rock
Solifluction – the unchannelled movement of normally-frozen surface sediments during periods of melting
Syncline – a downfold
Tectonic – earth movement, as in plate tectonic
Till – poorly sorted sediment deposited by a glacier of ice sheet
Unconformity – a break in the succession of sedimentary rocks due either to non-deposition or erosion (removal) of part of the sequence prior to renewed deposition
Weathering – the breaking down in situ of rock. This is often subsequently moved either by gravity or moving agent such as wind, water or ice
Further Reading


Craven and Pendle Geological Society - [www.cpgs.org.uk](http://www.cpgs.org.uk)


Lancashire County Council, 2000, *A Landscape Strategy for Lancashire*


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The solid rocks of Lancashire are broadly dominated by those of Carboniferous age east of the M6 motorway and the Permo-Trias to the west. The Carboniferous rocks are more varied and forming the uplands areas, are much more exposed than the Permo-Trias. Outcrops of the latter are generally confined to a few quarries, cuttings and the coast.

Overlying most of the solid rocks up to at least 300m are unconsolidated deposits of Pleistocene (Ice Age) and Holocene (post-glacial) times.