GLNP
GREATER LINCOLNSHIRE
NATURE PARTNERSHIP

The geology of Greater Lincolnshire

Back to bedrock

The landscapes of Greater Lincolnshire reflect the simple geology of the area and make it the ideal place to get to know more about the world under our feet. This leaflet takes you from the area's oldest Triassic rocks, through the Jurassic and Cretaceous to the relatively recent Quaternary sands, silts, clays and gravels.

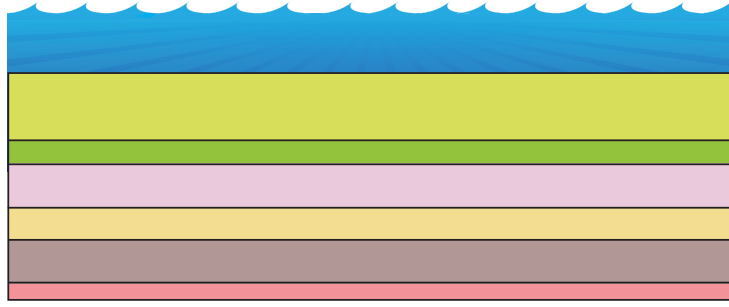
How did our rocks get here?

Over time different rocks were formed in layers – the younger rocks on top of the older ones as these were formed by deposition at the bottom of a sea that, at different times, covered most or all of Greater Lincolnshire (1). Around 60 million years ago this rock sandwich was tilted west to east (2). The years have eroded a slice off the top of this rock sandwich, leaving the harder rocks (such as limestone) as ridges (3). Across Greater Lincolnshire it is therefore possible to see the same rocks running north to south but there are different bands (or beds) west to east. Remembering that the younger rocks were on top before the land was tilted, as you move towards the coast the rocks become younger and the older rocks are buried underneath them.

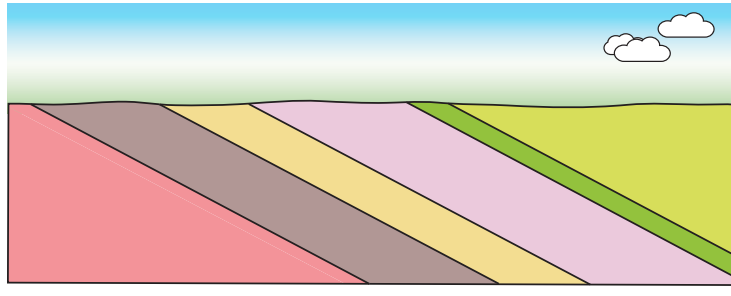
In most recent geological times, the Quaternary, deposits of till (boulder clay), sands and gravels were laid down like a blanket on top of the tilted bedrock sandwich (4). But this blanket is not even everywhere, it is thicker in some places as the gravels and silts were laid down in drifts, much like snow drifts against the side of hills or even your house!

The sections inside this leaflet describe all of these different rocks and how they have formed the landscape you can see across Greater Lincolnshire.

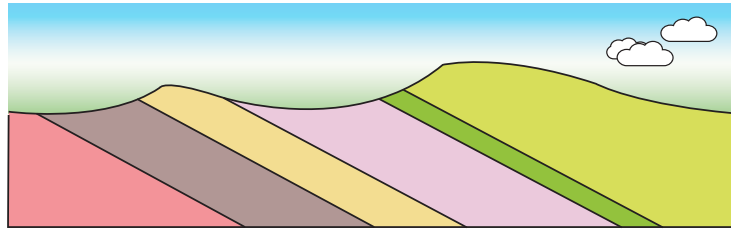
1



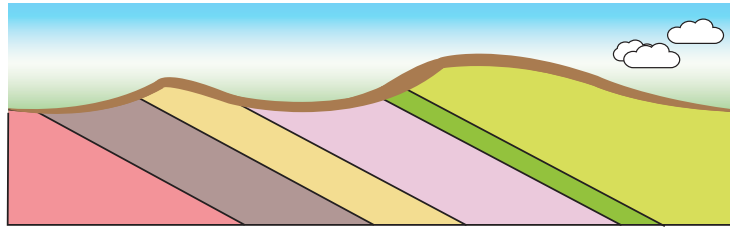
2



3



4



The geology of Greater Lincolnshire

The 63 million year gap

Between the end of the Cretaceous and the start of the Quaternary, about 63 million years, much happened, but none of it has been recorded. Most of the rocks that were laid down at this time were uplifted and eroded, along with many of the rocks already here. In addition, it was at this time that the rock sandwich was lifted and tilted – as all of the UK's rocks were, in a long period of mountain building across continents that also created the Alps!

Barrow blow wells
Chalk and glacial till

South Ferriby cliff
Silt and sand on chalk

Dragonby
Tufa

Atkinsons Warren
Coversands

Axholme Railway Cutting

Tealby Church
Tealby Limestone

Viking way
Spilsby Sandstone
Pavement

Welton-le-Wold
Gravels

Hubbards Hills

Red Hill
Red and White Chalk

Mill Hill
Chalk quarry

Gibraltar Point beach
Gravel bars and erratics

Sudbrooke
Erratic

Lincoln Castle and Cathedral
Lincolnshire Limestone

Wilsford road cutting
Lincolnshire Limestone

Harlaxton Village
Marlstone

Stamford Town
Lincolnshire Limestone

Stantons Pit
Sand

Toft Tunnel
Mudstones

BARTON UPON HUMBER
SCUNTHORPE
GRIMSBY
EPWORTH
MARKET RASEN
LOUTH
DRAMATIC SCENERY ON THE BLUESTONE HEATH RD
LINCOLN
HORNCASTLE
SKEGNESS
THE A607 FOLLOWS THE LINCOLNSHIRE LIMESTONE RIDGE
SLEAFORD
BOSTON
GRANTHAM
THE A16 GIVES VIEWS OF THE SILT FEN LANDSCAPE
HOLBEACH
SPALDING
STAMFORD

AGES	PERIOD	EPOCH	
3 – 0 mya	Quaternary	Alluvium	Sands & Gravels
145 – 66 mya	Cretaceous	LATE	
		EARLY	
201 – 145 mya	Jurassic	LATE	
		MIDDLE	
		EARLY	
252 – 201 mya	Triassic		

- Quaternary: Alluvium
- Quaternary: Sands & Gravels
- Upper Cretaceous
- Lower Cretaceous
- Upper Jurassic
- Middle Jurassic
- Lower Jurassic
- Triassic

All sites on the map are publicly accessible at the time of printing, please act responsibly

© Paul Hildreth

Triassic mudstones

The Triassic

The oldest rocks in Greater Lincolnshire occur either side of the River Trent in the north-west and were formed during an interval of time called the Triassic Period (which began 252 million years ago).

They consist of dark reddish brown and green coloured limey mudstones and siltstones, called marls, that were laid down in a coastal plain close to the shoreline of a very shallow sea, in a very hot arid climate. Geologists refer to these deposits as the Mercia Mudstone Group.

These mudstones were formed by violent thunderstorms and flash floods intermittently depositing layers of muds and silts in temporary (playa) lakes formed in the lowest parts of the area. A great deal of evaporation was taking place from the hypersaline waters of these lakes, leading to the formation of thin layers of a mineral called gypsum. Rock salt (halite) crystals were also formed, but these dissolved again leaving moulds that became filled with more sediment, to form little cubic features called pseudomorphs. Ripple marks and rain prints can also be found in these deposits.

These features along with very rare reptile footprints from adjacent parts of Nottinghamshire lead us to believe that during the late Triassic the area would have been similar to the modern day coastal plains of Saudi Arabia. The Triassic period ended 201 million years ago when a series of marine incursions (sea level rises) progressively flooded the area. The mudstones and thin limestones resulting from the incursions can be found in boreholes and excavations in the Gainsborough area and are known by geologists as the Penarth Group.

Ripples in mudstone (above)
Salt pseudomorphs in mudstone (below)
© Fran Smith

Marlstone at Harlaxton church

Frodingham Ironstone is full of fossils

The Lower Jurassic

Mudstones, limestones and ironstones are the main rocks formed in the Lower Jurassic period and occur along the western side of Greater Lincolnshire from the Humber to as far south as Grantham.

The limestones and ironstones form ridges where they occur. These rocks range in age from 201 million to 174 million years old. The fossils found in the mudstones include the remains of free-swimming creatures such as ammonites and belemnites together with rare fossils of plesiosaurs and ichthyosaurs. These rocks are typically dark grey in colour when seen at the surface. The mudstones and limestones generally formed in deeper water than that which formed the Ironstones. Two Ironstones dominate in this period – the Frodingham Ironstone and the Marlstone Rock.

The Frodingham Ironstone is so rich in iron that in North Lincolnshire it founded the Scunthorpe steel industry. This Ironstone was laid down in a warm, shallow sea. Abundant fossil shells, including ammonites and bivalves, such as Gryphaea ('Devil's toe-nails') and Pecten, show that the sea was rich in life. There are also rare fossils of starfish and brittle stars found in this deposit. The fossils from this ironstone often have a distinctive green colour.


Frodingham Ironstone fossils are greenish in colour © Mike Oates

In the central and southern parts of Lincolnshire similar ironstones formed at slightly later times in the muddy sea, when the still, shallow, oxygenated water provided suitable conditions for their formation. The Marlstone Rock is one of these ironstones and forms a distinctive bed that initially forms a step in the hillsides to the south of Lincoln, before becoming a separate ridge that swings away south-west near Grantham.


© Lincolnshire County Council

Lincoln cathedral is made from Lincolnshire Limestone


© Paul Hildreth

Lincoln cathedral stone as it is taken from the quarry

The Middle Jurassic

The Middle Jurassic rocks consist of limestones, mudstones, sandstones and ironstones, most of which are only a few metres thick.

The Lincolnshire Limestone sequence is different in that it is much thicker, varying from less than twenty metres in the north of Greater Lincolnshire to a maximum of 40 metres near Grantham. These rocks range in age from 174 million to 163 million years old.

The Lincolnshire Limestone is a marine deposit that contains ooids. These are grains of calcium carbonate which have been rounded by being rolled backwards and forwards by waves. The size of the ooids show how much energy was in the waves when they were formed. Look at the size of ooids in the limestones used in Lincoln Cathedral and compare them to those in the churches of South Lincolnshire. Another indicator of high wave energy is shell fragments and again you can see these at Lincoln Cathedral. Later when the sea became calm and lost its energy we can see this as mudstones were formed without ooids or shell fragments. This lagoon would have been something like the Bahamas today. All of these limestones are more resistant to erosion than the older beds underneath, so they form a prominent ridge (the Lincoln Edge) running south through Greater Lincolnshire until it broadens out into the area between Grantham, Stamford and Bourne.

Ooids (above) and sea snail fossils (below) in Lincolnshire Limestone
© Fran Smith and Paul Hildreth

The (younger) rocks above the Lincolnshire Limestone show a change to more coastal environments as the sea retreated. Until the end of the Middle Jurassic the sea level fluctuated with thin deposits of clay and mudstone deposited in deeper water and limestones in shallow water

The unusual Elsham Sandstone

Yellow bricks in Brigg made from local mudstone

The Upper Jurassic

A deepening of the sea marks the start of this time period which ranges from 163 million to 145 million years ago.

Most of the rocks deposited are soft mudstones,clays and shales and as a result have been eroded over the years forming the low areas to the east of the limestone ridge laid down in the Middle Jurassic. In the Fens these rocks form a wide area beneath the younger sediments, but they thin and narrow northwards towards the Humber along the valley of the River Ancholme. These muddy rocks belong to the Ancholme Clay Group.

A very localised deposit of sandstone occurs within these mud-dominant rocks at Elsham. This bed, the Elsham Sandstone contains ammonites and represents a local, temporary shallowing of the sea.

In the past these mudstones were frequently quarried for brick and tile making in areas where building stones were not easily available. Houses made of these bricks can be seen in Brigg and Lincoln. One genus of ammonite that lived during this period and found near Market Rasen in the nineteenth century was given the scientific name *Rasenia uralensi* (see front cover) so Lincolnshire even has its own special fossils.

Geologists would strive to find remains of marine reptiles like the ichthyosaurs and plesiosaurs, which ate the ammonites, with little luck in Greater Lincolnshire. However, remains of a 155 million year-old pliosaur were discovered in 2018 from mudstones of the Kimmeridge Clay at South Ferriby. Following restoration, a reconstruction of the marine reptile will be displayed in the North Lincolnshire Museum, Scunthorpe.

At the end of the Upper Jurassic there is a return to shallow water environments locally with the deposition of the sands which form the lower beds of the Spilsby Sandstone.

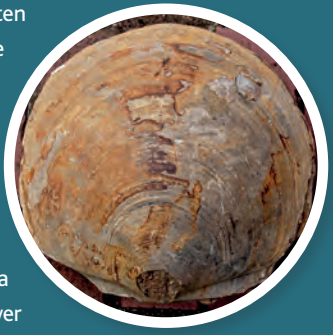
Spilsby Sandstone pavement at Tealby

The Lower Cretaceous

A sea covering Greater Lincolnshire remained a feature in the Lower Cretaceous, from 145 million to 100 million years ago. This sea became shallower with a low-lying coastline north of the present-day Humber.

The rocks of this time period start in the southern Wolds with the Spilsby Sandstone, whose deposition started in the final part of the Jurassic times and continued into the Cretaceous. We know this from the ammonite fossils found in this rock. Thinner in the north and east Spilsby Sandstone is most extensive in the southern end of the Wolds where most of the Medieval churches of the area are built of this distinctive dark green to brown coloured stone that gains its colour from the iron mineral glauconite. Unfortunately many churches, including Horncastle, are showing the effects of weathering on this often poorly cemented sandstone with a patchwork effect developing where other rocks e.g. the Lincolnshire Limestone, are used for repairs.

Rocks above the Spilsby Sandstone in the sequence are mainly clays, but include the Claxby Ironstone, formerly mined near Nettleton; local areas of limestone near Tealby; and the Roach Ironstone (a mixture of limestone, sandstone and ironstone). The Carstone is the youngest rock of the Lower Cretaceous sequence. It is a gritty sandstone that gets finer to the south and as with all of the Lower Cretaceous rocks it thins towards the north. All but the Carstone are gradually overstepped by the Upper Cretaceous deposits between Caistor and Grasby.



Fossils can be quite large in the Claxby Ironstone!
© Fran Smith

© Fran Smith

Red and White chalk at Red Hill

Barnetby St Marys Chalk church © Paul Hildreth

The Upper Cretaceous

The primary rock deposited in the Upper Cretaceous was the Chalk. The northern and eastern part of the Wolds and its extension eastwards beneath the coastal marshes is made up of chalk.

This variety of limestone consists of the microscopic remains of animals that make up zooplankton (coccoliths). Rare ammonite and shark teeth fossils represent life in the near surface waters of the Cretaceous Sea. These rocks range in age from 100 million to 66 million years old.

The Chalk is made up of two layers: at the base of the white Chalk there is a distinctive thin bed of Red Chalk that extends into Norfolk and East Yorkshire, but does not occur elsewhere in the British Isles. There has been much debate about the origin of this red colour and Greater Lincolnshire is lucky to have such a unique feature! The two main theories are that with the coast close by land-derived materials added the colouring; alternatively it may be due to the erosion of distinctive red Triassic beds on the floor of the Cretaceous Sea. The Red Chalk can clearly be seen at Red Hill near Goulceby and also on the other side of The Wash at Hunstanton.

Another mystery about the Chalk is the flint it contains. The origin of flint is much debated by geologists. Is it silica from sponges or the burrows of invertebrates?

Different rocks of the Upper Cretaceous are the thin lime-rich clays called marls. Some of these are thought to be the result of the deposition of volcanic dust from distant eruptions. Others are thought to represent periods of time when the sea bed was very depleted in oxygen, so called anoxic events when only muds and dust were deposited.

© Fran Smith

Bands of Quaternary gravels and till at South Ferriby cliffs

© Paul Hildreth

The Quaternary

This is our current geological period and covers the last three million years. See the map to find out what happened in the 63 million years since the Upper Cretaceous.

This period saw some of the most dramatic changes. The temperature has dropped, compared with the warm sea of other times, to the extent that there are several Ice Ages.

In the coldest Ice Age Greater Lincolnshire was probably covered by several hundred metres of ice. During a glaciation the rocks beneath the ice were ground to a powder, while harder rocks were carried along until the glaciers melted. The materials left behind were a mixture of clays, sands, gravels and larger stones, called glacial till. This glacial till forms a 'blanket' of deposited material on top of the tilted bedrock sandwich. Large boulders that fell into the ice are called erratics and were carried great distances and left behind during the melting. The Millennium Stone at Sudbrooke near Lincoln is a stone from North Yorkshire. At the end of the last glacial, very fine sand was blown across large parts of the north of Greater Lincolnshire. These 'coversands' are quarried for glass manufacture and foundry sand.

During the advance and melting of the ice-sheets new rivers were formed and existing rivers were often diverted. These rivers left behind sand and gravel deposits which have been quarried for aggregate. At Welton le Wold there is evidence of two glacial events, including signs that people lived in Lincolnshire during one of the interglacials. Melting of ice-sheets about 10,000 years ago raised world sea-levels, creating submerged fossil forests on the Lincolnshire coast; and blocking rivers, forming the peat in the Fens and the coastal marshes east of the Wolds.

© Fran Smith

A nodding donkey

The Hidden Geology of Lincolnshire

Although Greater Lincolnshire has a simple geology on the surface things at depth are a little more complicated.

The first rock that we encounter at depth (and which is not visible at the surface anywhere in Greater Lincolnshire) is the Sherwood Sandstone, a pebbly rock formed in an arid climate by a river system which probably originated in northern France. This rock is found at the surface in Nottinghamshire and it is an important underground reservoir (store) of water for Nottingham. Beneath the Sherwood Sandstone are a group of rocks of Permian age. These were deposited on the margins of a salty sea which extended across much of northern Europe. There are three types of these Permian rocks: dolomites (a type of limestone), marls and evaporites (like gypsum and rock salt). The Permian rocks rest on older Carboniferous rocks which have been faulted, folded and eroded prior to later deposition.

These older rocks from the Carboniferous Period consist of Coal Measures at the top with sandstones, mudstones and limestones beneath. One feature of these rocks in Lincolnshire is the presence of a number of small oilfields. The largest of these is in the Gainsborough area where oil is pumped from sandstone reservoir rocks in the Carboniferous sequence at depths of around 1200 metres. The pumps used are often referred to as 'nodding donkeys'.

The oldest rocks encountered in boreholes are igneous and metamorphic rocks in the south of Lincolnshire. These ancient rocks (more than 500 million years old) are comparable to those you can see exposed in Charnwood Forest, Leicestershire.

Books

The Geology of Lincolnshire, HH Swinnerton and PE Kent, Lincolnshire Naturalists' Union, 2nd edition 1975, ISBN 09500353 5 1

The Lincolnshire Landscape: An Exploration, Jon Fox, 2015, ISBN 978-09932696 0 8

Leaflets

Building Stones of Greater Lincolnshire, Greater Lincolnshire Nature Partnership

Geology of the Lincolnshire Wolds, Lincolnshire Wolds Countryside Service

Online resources

- Geology of Lincolnshire: ***http://en.wikipedia.org/wiki/Geology_of_Lincolnshire***
- Greater Lincolnshire Nature Partnership: ***www.glnp.org.uk/our-services/geodiversity-strategy***
- British Geological Survey Geology Viewer ***www.bgs.ac.uk/map-viewers/bgs-geology-viewer***

GLNP
GREATER LINCOLNSHIRE NATURE PARTNERSHIP

This leaflet is produced by the Geodiversity Group of the Greater Lincolnshire Nature Partnership (GLNP). It is dedicated to Malcolm Fry for writing the text and thanks go to everyone who has contributed images.The GLNP is a Partnership of 49 organisations working to achieve more for nature across Greater Lincolnshire. For more on who we are and what we do please visit **glnp.org.uk**

Museums

You can also find more information about the geology of Lincolnshire by contacting the museums listed below. They have exhibitions or displays about the geology of their local area. Opening hours vary, so please contact the museum before setting out.

- Anderby Drainage Museum
  01507 328095
  https://lmdb.wmc-idbs.org.uk/about-us/heritage

- The Collection, Lincoln
  01522 782040
  www.thecollectionmuseum.com

- Grantham Museum
  01476 568783
  www.granthammuseum.org.uk

- Louth Museum
  01507 601211
  www.louthmuseum.org.uk

- North Lincolnshire Museum, Scunthorpe
  01724 297055
  www.northlincolnshiremuseum.co.uk/

- Peterborough Museum & Art Gallery
  01733 864663
  www.peterboroughmuseum.org.uk

- Sir Joseph Banks Centre, Horncastle
  01507 700012
  www.joseph-banks.org.uk