THE GEOLOGICAL AND GEOMORHOLOGICAL HISTORY OF GRASBY AND CLIXBY, LINCOLNSHIRE

Introduction

Grasby and Clixby were joined in 1934 to make a single, although still small, parish on the edge of the Wolds in north Lincolnshire. Their origins as English settlements can be traced back to the Domesday Book and before, with the "-by" suffix suggesting Viking influence. Fragments of Roman pottery found within the parish point to even earlier occupations of the current sites.

Although no Iron Age or Neolithic artefacts have been found in the parish, numerous finds nearby show clearly that the Wolds and vales were visited and perhaps part settled as long ago as c. 6,000 years and it is believed that tracts of forest were being cleared for agriculture as far back as c. 4,500 years ago.

Hominoids are now known to have occupied parts of Britain from as long ago as 700,000 years, coming and going as the land bridge between here and the rest of Europe emerged and submerged as the sea level fluctuated with the formation and melting of ice sheets, and disappearing completely during major ice advances. The recent history of Homo sapiens within Britain, however, dates back a mere c. 12,000 years to when the last ice finally disappeared from these shores.

The rocks which underlie Grasby and Clixby are some of the youngest in the country, but the history of the parish in terms of the presence of Homo sapiens is a mere blink of the eye in comparison to its geological history which spans more than 150 million years.

The "new" parish of Grasby and Clixby measures a little less than 3 miles from north to south and 1.7 miles from east to west, comprising an area of just under 3,000 acres. A walk from the southern to the northern boundary of the parish, through Grasby, begins on its oldest rocks, on the edge of North Kelsey Moor, and leads after ⅔ a mile to the edge of the village. Here the gradient increases noticeably across a series of younger rocks towards the church. After passing the old post office the road crosses onto chalk, the youngest rock type in the parish, and the gradient of this "scarp" slope becomes much steeper. A climb up to the Cross Keys, and then steeply up again out of the village onto Grasby Wold Lane, leads to the highest point in the parish. After this the land slopes gently down for about a mile to Grasby Bottoms and the woodlands of the Yarborough Estate in the parish of Great Limber. This variation of rock type and topography within such a small area is the end product of a long and complex story of landscape and biological evolution. This paper seeks to provide a chronological explanation of these processes and perhaps stimulate an interest in what lies, for the most part, hidden beneath our feet.

Chalk scarp at Clixby as seen from North Kelsey Moor

Solid Geology

Although overlain by thin superficial deposits laid down during the last ice age, the underlying bedrock of the parish is exposed in a number of places.

Jurassic

Kimmeridge Clay

It is in the southern parts of Grasby and Clixby that Kimmeridge Clay, the oldest of the rocks in the parish, comes to the surface. The clay is a sedimentary rock laid down in muddy seawater 151 to 156 million years ago during the later stages of the Jurassic period. It was during this time that the supercontinent, Pangaea, began to break up to form two smaller continents, Laurasia and Gondwana. Before this, during the Triassic period (213 to 145 million years ago), the northern parts of Pangaea had drifted from the equator to between 20^{o}- 30^{o} N before it split into Laurasia and Gondwana. “England”, at this time, became part of Laurasia which continued to drift to between 30^{o}- 40^{o} N, roughly the same latitude the Mediterranean occupies today. It was here that the Kimmeridge Clay was laid down when part of East England and the North Sea were inundated by a shallow sea 100-200m deep.

This clay underlies North Kelsey Moor, part of Caistor Moor which was previously over 2,000 acres of common land before it was enclosed in the early C19th, and extends northwards as far as both villages before disappearing under younger rocks. The wide sedimentary basin in which Lincolnshire was located had seen periods of repeated marine transgression and regression from the late Triassic through most of the Jurassic period (70 million years or so) before more quiescent, deeper water, open-sea muddy conditions set in, during which time the Ancholme Clay Group, of which Kimmeridge Clay is the youngest element, was laid down. This group of clays is up to 300m thick and made up of argillaceous (grain size less than 0.0625mm) sediment accumulating in water 100-200m deep with a subsiding sea-floor. This regime of clay deposition was interrupted in this area only once, by a flush of fast-flowing water during a short-lived period of shallowing, which brought clear quartz sand to form, just to the north, Elsham Sandstone, about 6 m thick, around Elsham village. This band of sandstone does not stretch as far south as Grasby.

Kimmeridge Clay varies from pale to dark grey and contains so little variation in its lithology (physical characteristics) it warrants no lithostratigraphical subdivision (stratigraphy is the study of the order and position of rock layers) and remains undifferentiated in this respect. Biostratigraphical zonation, however, is present and based on ammonite fossils. A locally named genus, Rasenia, was found in its hundreds during the 19thC in brickyards near Market Rasen (hence, the name "Rasenia"). Many ammonites have been exposed in the clay dug from just outside the SW part of the parish during the 1970s to create "Knapton's" reservoir (TA 076 035). Whether any of the species unearthed have ever been identified is unknown.

Spilsby Sandstone

Towards the end of the Jurassic a series of intermittent earth movements were renewed and some of the Ancholme Clay surface was eroded prior to the deposition of a narrow band of sandstone, Spilsby Sandstone, which was laid down unconformably on the clay (i.e. after a break in deposition during which the surface was exposed to erosion) 134 to 150 million years ago in Tithonian times, as a coastal sand spread. Its uneven base suggests the presence of filled-up tidal channels with sediment brought down by rivers draining metamorphic rock terrains similar to those of the present Scottish Highlands. This narrow band exists in the parish only from where Clixby Lane and Main Street meet, running ENE to the old Grasby Clixby parish boundary, before briefly crossing the A1084 into the mouth of a dry valley and then returning to the southern edge of the

A1084 in Clixby hamlet. From Caistor southwards the formation is estimated to be about 8 to 11m thick, but may reach 18m in places where it apparently fills the former incised channels. It represents the NW part of a marginal marine quartzose sand facies (a layer deposited under specific environmental conditions) laid down, following substantial erosion, between the uplifted Market Weighton High and London Platform. Its fauna shows that marine connections with the southern side of the London Platform were slowly severed, whilst a northerly arm of sea remained in continual contact with the Greenland Province of the Arctic Boreal Ocean. Much of this sandstone is unconsolidated (loose particles not cemented together), but it encloses irregular masses of hard sandstone with a calcite (calcium carbonate) cement. It outcrops in this area along the Wolds scarp and because of its high porosity is a useful aquifer and produces copious springs which have contributed to the development of landslips and mudflows. One spring, which runs all year into field drains can be seen at the side of the Viking Way on the edge of a spinney east of Grasby (TA 095 046), may derive from this sandstone – there is no doubt that there must have been a number of active springs in the vicinity of both villages in the past before the water table was lowered in more recent times.

In the sea bivalves, ammonites, belemnites, sea urchins and starfish were abundant during the Jurassic. On land gymnosperms, such as conifers and cycads, and ferns were the dominant vegetation. There were many types of dinosaur e.g. sauropods and stegosaurs, the first birds and lizards appeared as well as a few small mammals. CO_2 levels were 4 to 5 times higher than today, which helped to keep temperatures high.

Lower Cretaceous

The Spilsby Sandstone marks the boundary between the Jurassic and Cretaceous periods. After another break in deposition a series of Lower Cretaceous rocks were laid down which are found along the base of the Wolds scarp to the south of Clixby, but which are entirely absent in Grasby and Clixby. These are in ascending order: Claxby Ironstone, Lower Tealby Clay, the Tealby Limestone Formation and the Roach Formation and were laid down between 125 to 145 million years ago (the sequence - sandstone/clay/limestone/clay/sandstone witnessed deepening then shallowing of the sea). The removal of these rocks from Grasby/Clixby was the result of substantial uplift and erosion related to the Market Weighton High, more vigorous towards the north, around the middle Cretaceous which led to the removal not only of Lower Cretaceous rocks in the north, but also much of the Ancholme Clay towards and north of the Humber. The most complete sequence of this Lower Cretaceous series, therefore, lies to the south of Claxby and is about 50m thick. From here, the sequence is increasingly attenuated northwards through the parish and the feather edge of the Carstone (see below) gradually oversteps all older formations to rest directly upon the Ancholme Clay Group at Grasby (from the beginning of Clixby Lane westwards in a band that runs just north of Vicarage Lane).

Upper Cretaceous

Carstone

When the sea spread slowly over the district again, just before Upper Cretaceous times, which may span the Aptian-Albian boundary (113/114 million years ago), sublittoral (the area of the sea just offshore from the intertidal zone) reworking produced the sandy, locally pebbly, Carstone. In south Lincolnshire two members are recognisable: the Carstone sands and clays and the overlying Carstone Grit. Only the latter is preserved in the Grasby area.

The Carstone Grit is a gritty basement bed to the chalk. Its base is transgressive and it does not form a distinct topographical feature. North of Grasby downwash obscures the outcrop.   A small pit near Clixby exposes 0.9m of pebbly sandstone resting on the Spilsby Sandstone.

Chalk

As the inundation by the sea progressed to cover all but the highest portions of the British Isles the supply of clastic material (particles of broken down rock) reduced and deposition became dominated by calcareous sediments, made up of the skeletal remains of sea creatures, to form chalk. This area of chalk falls within the loosely defined “Northern Province” that extends from Flamborough Head to northern Norfolk and continues eastwards beneath the North Sea. The northern succession has much in common with correlatives in Germany and areas further east, and contrasts strongly with that in southern England, which constitutes the “Anglo-Paris Basin” Province. In general the Northern Province is characterised by chalks that are hard and thinly bedded compared with the relatively soft massive chalk to the south.

During this period of chalk deposition Laurasia and Gondwana were breaking up and world sea levels were higher than at any other time for the whole of the previous 600 million years. The reasons for these high sea levels were: bulging ocean basins (as a result of the late Cretaceous “super-plume”- a large upwelling in the mantle), when rising ocean floors expelled sea water onto the continents; CO_2 levels four times greater than at present which kept continental interiors and polar regions much warmer in winter; little or no water trapped as ice in the polar regions.

This was also a period of significant tectonic activity (volcanic activity, mountain building and earthquake activity) which led to frequent sea level changes on the continental margins causing periods of shallowing and deepening, and even surface erosion when land was pushed above sea level for (relatively) short periods. The maximum transgression is thought to have begun in the mid-Turonian (91 million years ago) and towards the close of the Cretaceous period (72 million years ago). When the opening of the Atlantic began the only parts of the UK which existed as dry land were east Scotland, parts of Ireland, SW England, south and SW Wales.

The Wood & Smith classification (1986) divides the chalk of the Northern Province into four formations. They are, in ascending order, the Ferriby, Welton, Burnham and Flamborough Chalk, respectively up to 26m, 53m, 150m and 20m thick. The flint-free Ferriby Chalk thins northwards towards and over the Market Weighton High Structure, but above this stratigraphical level there is no evidence that the structure had any control on sedimentation. South of the Humber, the Ferriby and Welton Chalks thicken southwards with, south of Brigg, an accompanying reduction in hardness and a significant increase in faunal diversity. The sediments are predominantly chalks i.e. extremely pure, micritic (fine-grained) pelagic (marine) limestones of biogenic origin mainly composed of debris derived from the calcitic plates (coccoliths) of a group of unicellular algae (nannoplankton). Calcareous nannoplankton didn’t evolve until Mesozoic times, hence the absence of chalk during earlier eras. It is now generally agreed that the chalk around the UK formed at depths of between 100m - 500m below the sea surface from the lime mud derived from the skeletal material of the nannoplankton, which bloomed in the surface waters. The chalk in the Northern Province is thought to have formed in deeper waters than that of the Anglo/Paris basin. At some horizons, notably the Ferriby Chalk, the chalks are coarse-grained being composed largely of shelly debris with little or no coccolith component, the original coccolith “flour” having been winnowed away by current action in relatively shallow water.

Upper Ferriby Chalk (left); Welton Chalk (right)

The chalks of the Ferriby Chalk Formation are relatively impure, containing clay minerals such as montmorillonite and illite, together with small amounts of quartz and feldspar. At some horizons, and particularly in the basal few metres comprising the "Red Chalk", the rock is red or pink due to the presence of finely divided haematite, but the Ferriby sediments are otherwise predominantly grey or off-white. The succeeding Welton and Burnham Chalks are extremely pure, white to off-white, and characterised by insoluble residues of the order of only 2% (see above).

Only the Ferriby and Welton Chalk Formations exist within the parish of Grasby/Clixby.   The boundary with the Burnham Formation is found just to the north east of Grasby Bottoms, within the Yarborough Estate woods, with the Burnham Formation extending towards Great Limber down the dip slope of the Wolds.

Ferriby Chalk - Hunstanton Member (Red Chalk)

The Ferriby Chalk Formation is subdivided into the lower Hunstanton Chalk Member or “Red Chalk” and upper Ferriby Chalk. The former is perhaps the most striking rock in the Wolds to the south of Caistor, but loses its colour towards Grasby and is white in Searby (but is red again further north at South Ferriby). It comprises a complex succession of marls and both nodular and massive indurated (hardened) chalky limestones of mid to late Albian age (101 to 106 million years ago). The upper limit of the member is marked by a clearly defined erosion surface but its lower limit sits conformably on the Carstone and more or less follows a line just to the south of the A1084 through Clixby and into Grasby, crossing Main Street and then following the line of the gardens at the back of the housing along the north side of Vicarage Lane.

Ferriby Chalk - Upper Member

The Upper Ferriby Member follows the same path, but north of the A1084 until Grasby Quarry before dropping south of the A1084, extending from the edge of the Hunstanton Chalk to more or less the road itself. The exception to this is where the upper Ferriby Chalk is exposed either side of the dry valley extending ENE from the A1084 at the old Grasby/Clixby parish boundary.

The Ferriby Chalk above the “Red Chalk” is exposed in the quarry face behind the houses built at the back of the old lime works in Grasby village (see below). It can also be observed in Bigby Quarry (TA 060 078). The succession maintains a thickness of 21m - 24m throughout the district and comprises a variety of strata including porcellanous (highly siliceous) chalks, argillaceous chalks, discrete marl bands, coarse-grained chalks and sand-grade chalks with much comminuted (crushed) shell debris. It is flintless throughout. The Totternhoe Stone band, a grey or brown sand-grade chalk about 11m above the “Red Chalk” upper boundary, underlain by a true hardground (a hard crust of carbonate material), may be distinct enough to be visible in Bigby Quarry.

Upper Ferriby Chalk Exposure, Old Lime Works, Grasby

Welton Chalk Formation

Above the Ferriby Chalk lies the Welton Chalk. Although up to 53m in thickness, only the bottom 30m or so of the formation is present in Grasby. The boundary between the Ferriby and Welton Formations lies to the north of the A1084 east of Grasby Wold Lane, before crossing through the old quarry and dropping just below the A1084 at the top of the primary school's playing field and is visible just below the road at the field edge between Owmby Hill and the end of Vicarage Lane (TA 084053).

The basal 5m of the Welton Chalk comprise marly sediments overlain by coarse grained bioclastic and, at some levels, pebbly chalks. There are numerous thin (less than 1cm) marls within these beds which represent an extremely condensed sequence, containing the so-called "Black Band" which has an orange stained and highly convolute upper erosion surface. This erosion surface is overlain by a 10cm bed of hard chalk and this succession is particularly clear at the top of Bigby Quarry. The Black Band is believed to have formed in deep water with near-anoxic bottom conditions.

Above the basal beds the Welton Formation is composed of extremely pure (99%) chalks and is relatively soft. About 13m above the Black Band is the “Grasby Marl”, which it is reasonable to assume is visible in the abandoned quarry on the other side of the A1080 in Grasby (TA 088 052). The chalk is relatively hard immediately above and below the Grasby Marl and forms the top of the main chalk scarp within this area. The highest part of the scarp in Grasby/Clixby is just over 275 ft (84m) OD, 50 ft (15m) higher than the top of the quarry face.

Welton Chalk, above Black Band, Old Quarry, Grasby

Flint

Embedded within chalk is frequently found flint. The formation of this hard and brittle substance is complex and still not fully understood. Essentially, organisms such as sponges and radiolaria/diatoms extract silica from sea water to make biogenic opal, from which they make their skeletons. When they die and the organic content of their bodies decays, the opal scatters and mixes with the rest of the accumulating sediment. This opal then breaks down within the sediment and enriches the pore water within the sediment with the silica. Further chemical reactions involving hydrogen sulphide rising from decaying material and oxygen diffusing down create an increasing concentration of hydrogen ions which act as a seeding agent for the precipitation of silica through a molecule-by-molecule replacement of chalk. Initially in the form of crystalline opal, this transforms over tome to quartz (flint) during further burial, which results in great pressure.

The chalk sea bed is deeply burrowed by many different organisms, such as shells, echinoids and worms. Some of the burrows are deep or branching, or have open living spaces. The burrows eventually fill with a sediment, but subtly different from the surrounding sediment, which acts as preferential pathways for the chemical replacement of chalk with flint. The shape of a burrow, therefore, often determines the nodular shape of many flints.

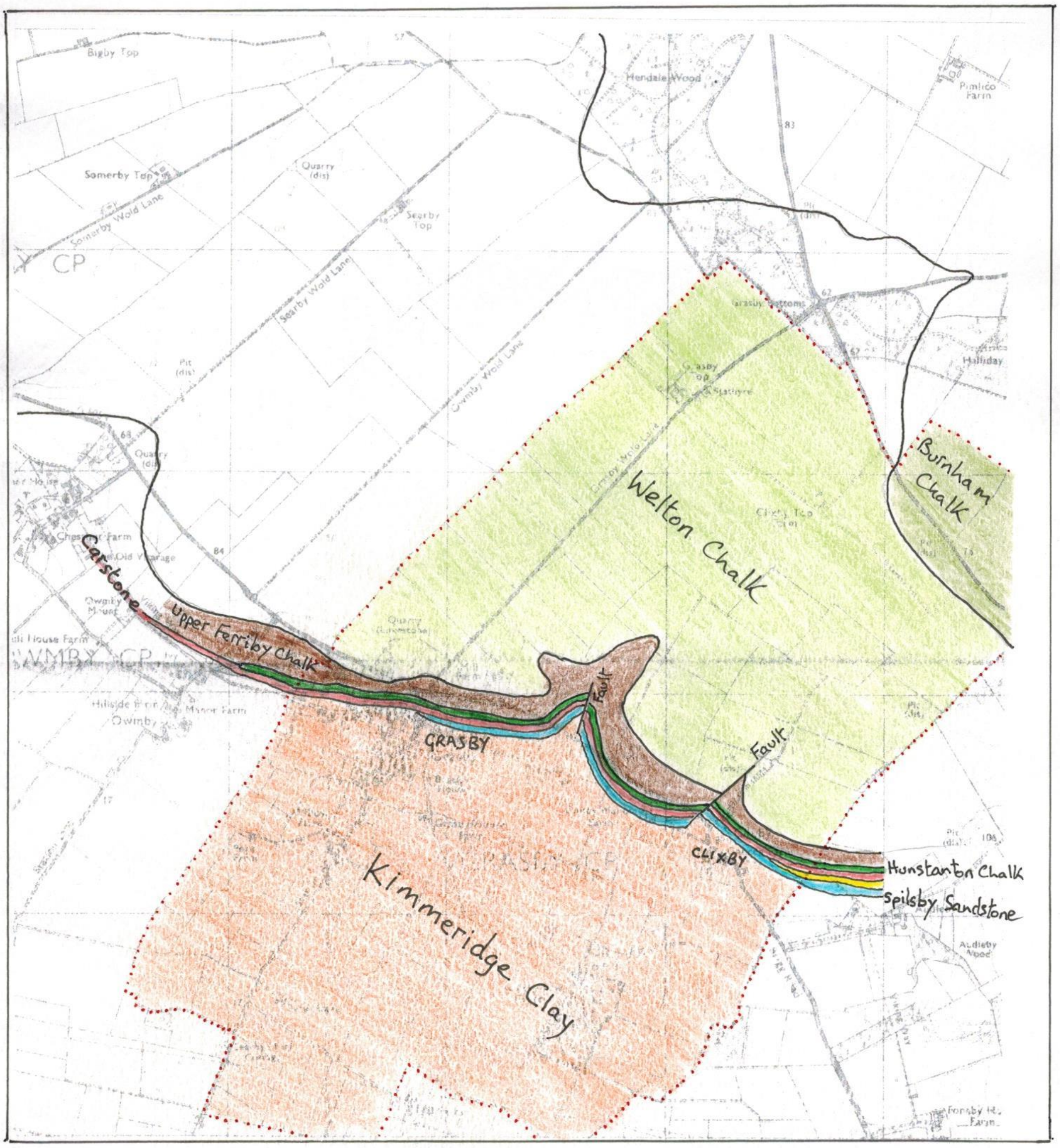
Flint is found throughout the greater part of the chalk group as nodules and tabular masses of flint. There are no flints in the Ferriby Chalk or in the basal few metres of the Welton Chalk, but above this level are nodular flints. The Burnham Chalk is characterised by tabular flints.

Nodule of flint in Welton Chalk, Grasby Quarry

Marl Bands

As already alluded to, marl bands are another significant feature of the succession, particularly in the Welton Chalk and lower part of the Burnham Chalk. They are from 1cm to 10cm thick and contain 30% to 65% of insoluble noncarbonated material, typically comprising a mixture of siliceous microfossils, clays and silts. It has long been suspected, however, that a significant number of marl seams originate from volcanic eruptions elsewhere and comprise decomposed ash. Rare earth element (REE) analyses in the Northern Province have allowed the differentiation of marls into detrital marls and those of volcanic origin.

By the close of the Cretaceous the chalk deposits had buried the whole of the country as it exists today. There then followed thermal uplift along the NW margin of Europe, a precursor to the opening of the Atlantic. Between 63 to 52 million years ago the last volcanic rocks in Britain were formed, mainly in Scotland and Northern Ireland. England was tilted from west to east, exposing the chalk above sea level in the west before the east. In the later part of the Cretaceous flowering plants were flourishing, new types of insect were evolving, as were modern fish, crocodiles and sharks. New types of dinosaur, such as Tyrannosaurs, had also appeared. It was at this point, however, over a period of possibly fewer than 200,000 years, that huge changes on Earth led to the mass extinctions of many fossil groups, including dinosaurs, ammonites, belemnites, bivalves and many chalk forming nannoplankton. This is generally believed to have been the result of increased volcanic activity before, during and after the meteorite impact in the Yucatan, creating a "nuclear winter". Most if not all of the evidence for this at the Cretaceous/Palaeogene (K/P) boundary has, however, been removed in Britain by subsequent erosion during the Cainozoic Era.



Sketch Map of Solid Geology Grasby/Clixby Parish

(see text for full explanation)

Summary Table of Bedrock Forming Periods in Grasby & Clixby

Period	**Epoch**	**Age**	**Bedrock**	**Start (million years ago)**
Tertiary			Uplift & Prolonged Period of Erosion	65
Cretaceous	Upper	Maastichtain		72
		Campanian	*{Flamborough Chalk}*	84
		Santonian	*{Flamborough Chalk}*	86
		Coniacian	*{Burnham Chalk}*	90
		Turonian	Welton Chalk	94
		Cenomanian	Upper Ferriby Chalk	100
	Lower	Albian	Carstone & Hunstanton (Red) Chalk	113
		Aptian	{*Roach Formation}*	125
		Barremian	*{Tealby Limestone}*	129
		Hauterivian	*{Lower Tealby Clay}*	132
		Valanginian	{*Claxby Ironstone*}	139
Jurassic	Upper	Tithonian	Spilsby Sandstone	152
		Kimmeridgian	Kimmeridgian Clay	156

Italics in brackets identify rocks removed by erosion from parish

The Effect of Structure on the exposed rocks in north Lincolnshire

The first uplift of Britain during the Tertiary period saw the formation of a dome-like structure, cracking along the Irish Sea and the central valley of Scotland. The English third of the dome tilted east because of a subsiding North Sea area. Prior to the chalk being laid down the Lower Cretaceous rocks had already been folded and truncated. These underlying structures coincide with the effects of Alpine folding which created a faulted monocline (a bend in the rock strata), trending WNW-ESE against the general tilt to the east, the axis of which is runs through Audleby. Described as the Audleby Monocline (but sometimes also as the Caistor Monocline), the downthrow or bend of the rocks is in the order of 100m on the north side. The combination of this bend in the rocks with faults of different ages within the Humber Gap has created, in a sense, a shallow "rift valley" under north Lincolnshire which, ultimately, helped create the Humber Gap through which the rivers which comprise the River Humber now drain into the North Sea.

The effect of Uplift and Erosion following the close of the Mesozoic Era

It has been during the present, Cainozoic, Era (formerly the Tertiary and Quaternary i.e. the last 65 million years), that between 700m to 2,500m of sedimentary strata have been removed by erosion from northern Britain after tilting. As the rocks emerged they were attacked at first by the sea and then, for a much longer period, the rain and rivers, frost, wind and glaciation. Eventually the Carboniferous rocks of the Pennines were exposed as were, moving east, the Permian, Triassic and Jurassic rocks, the latter on the Lincoln "Heath" (or "Cliff") and in the Ancholme Valley in

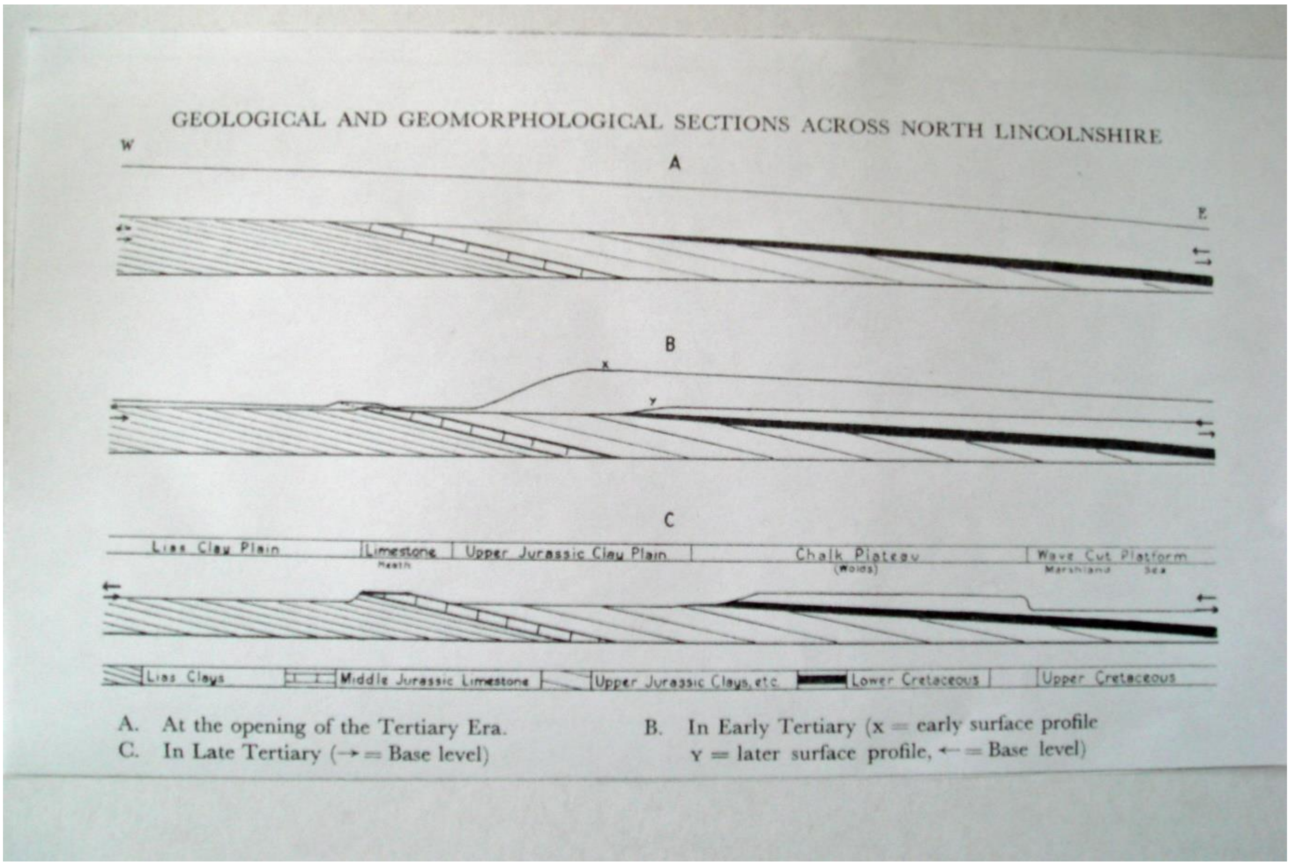
Lincolnshire. It is only on the Wolds that the chalk survives and still hides the older rocks now visible to the west.

For the first 5 million years or so of the Cainozoic (Paleogene epoch) the climate remained tropical. Modern genera and species of plants began to appear, mammal groups diversified and increased in size e.g. hippos and bears evolved. The Alpine Orogeny began as Africa and India collided with Asia (and the Audleby Monocline was formed). However, during the Eocene epoch (38-56 million years ago) the climate started to cool as Antarctica was reglaciated as it drifted to a south polar location and the polar ice cap reformed. An important factor assisting the reglaciation is believed to have been the massive blooming of the Azolla fern in the Arctic Ocean (then an enclosed large nutrient rich lake which captured much of the atmosphere's CO_2 reducing it from 3800 to 1500 ppm. An increasingly cold Antarctic then absorbed even more CO_2 reducing it further to 600 ppm.

When the floor of the sea first emerged to form an early, vast, chalky downland, rivers and streams flowed initially towards the east. Stage by stage the western margin of each formation was removed exposing it to the same forces of erosion and creating the belted arrangement of all the outcrops seen today.

The softer clays yielded more quickly and were worn down to a lower level than the more resistant limestones and chalk. Thus low lying plains came into existence separated by ranges of hills with steep scarps facing west and gently dipping surfaces sloping eastwards. The rivers continued to cut down along their original courses, producing gaps through the limestone and chalk, such as Barnetby Gap. Over time, however, the Ancholme and the Trent found paths along the softer clays to the north and flowed out into the Humber. As their headwaters cut back southwards along the softer rocks, tributaries of the east-flowing streams were gradually “captured” and some of these gaps, such as Barnetby Gap, in the more resistant rocks are no longer occupied by an east-flowing stream. Such gaps, however, have subsequently provided extremely useful pathways through the scarps and it is no accident that, when built in the 1840s, the railway followed this gap through the chalk at Barnetby.

One important factor in the gradual removal of a layer of hard rock overlying clay is the process of land-slipping. When the clay is worn below the level of the outcropping lower surface of the harder rock then the weight of the latter tends to squeeze out the clay which is supporting its edge. This undercut edge tends to break and slip down the slope. In the harder rock feature thus created the full thickness of the rock forms the dominant if not the whole face of the scarp. The crest of the hill then marks the dividing line between the scarp face and the dip slope. On the Wolds (and the Lincoln Heath), however, only a small fraction of the total thickness of the chalk crops out on the scarp, the crest having been bevelled and the tilted outcrop reduced to an almost flat, horizontal surface. This bevelling must have occurred during a long "still stand" or period of stationary base level. During this time the clay belts were worn down to base level and erosion ceased. The harder rocks continued to stand above the clays, but gradually they too were reduced to almost base level and by the late Pliocene (about 2 million years ago) the whole of Lincolnshire had been reduced to a low-lying plain or peneplain, and there is some evidence that yet again the sea flooded much of eastern England. The summits of the Wolds west of Ludford are bevelled, with Red Chalk lying on a flat surface at c. 150m (followed today by the line of Caistor High Street). This did not require the sea level to have risen 150m, for the whole area was subjected later to regional uplift. It could be that in advancing and receding the sea began to erode the clay vales and between the late Pliocene and early Pleistocene, as the sea gradually receded even further, rivers developed along them again and the scarps were pushed back a little more to give us, more or less, the topography we see today. The structure of the rocks, as described above, in northern Lincolnshire appears to have allowed the Humber to cross the chalk, gathering much water from the Pennine rivers and the Don.



The Formation of Scarps & Vales During Tertiary Era

Quaternary

The Effect of the Pleistocene Ice Ages on the landscape of north Lincolnshire

Over the past two million years, during the Pleistocene epoch, several ice ages and intervening warmer periods affected this area. In total there were 12 alternating cold and warm periods between the Anglian (cold) and present (warm) stage. These have been identified by measuring oxygen isotopes in marine sediments. Each cold or warm period is described as a “Marine Isotope Stage” (MIS), with odd numbers representing warm stages and even numbers representing cold stages. Not all cold stages brought ice sheets and glaciers to the British Isles. Glaciation in the Anglian Stage, MIS 12 (478,000 - 424,000 years ago) was, however, the most severe with a cover of ice up to 1,000m deep over northern Britain, thinning towards the south before ending in a line between Bristol and London. Various bits of evidence suggest that the clay vales in northern Lincolnshire had been lowered to about 60m OD by this time and that the scarps would not have been as prominent as they are today. Ice came down the east coast and initially into northern Lincolnshire through the Humber “rift valley” into central Lincolnshire. It picked up chalk and tabular flints from the Wolds and transported them as far as Milton Keynes. Later, much stronger ice coming down the Vale of York displaced the North Sea ice and swept SE across the Fen area carrying a lot of Jurassic clay across East Anglia as far as Lowestoft. The ice destroyed a major river system (Bytham River) that had drained the Midlands across south Lincolnshire to join the Thames in the Essex area. Any deposits left by this ice advance, however, are long gone from Lincolnshire.

The Anglian Stage was followed by MIS 11, the warm Hoxnian Stage (424,000 -374,000 years ago). Flint tools and early Hominoid remains have been found dating to this stage. The ice then came again during MIS 10, the Wolstonian Stage (352,000 - 130,000 years ago), stretching as far as Warwickshire, but not into Lincolnshire.

Following MIS 9 (the Purfleet Interglacial) the ice came again in MIS 8 (300,000 years ago) down the east coast, overspread the north Wolds and reached the Scunthorpe/Gainsborough area, before being shunted south by Vale of York ice which took chalk and flint as far as the Derby/Leicester area. All of Lincolnshire was covered at this time, with different ice streams jostling through time, some moving slowly, some more quickly. Over Grasby the ice would have been some 300m thick and it left behind the “Wragby Till” seen only today as cappings of the Howsham, Cadney and Kelsey “hills”, including one small patch of flint and chalk-rich grey clay capping a small hill of Kimmeridge Clay in Grasby/Clixby parish on the north west edge of

Audleby Low Covert, marked by an enclosed 100 ft (30 m) contour (TA 095 039). The ice must have pared back the chalk scarp somewhat, as well as scraping off up to 30m or so of chalk from the surface of the Wolds, and sat on Kimmeridge Clay, which was at a higher level than it is today. During a period of deglaciation ice remained for a time as a large decaying block in central Lincolnshire but, when finally gone, the Ancholme was left to drain this area of Lincolnshire whilst the Trent flowed through the Lincoln gap to the Fens and the North Sea.

From 243, 000 to 82,000 years ago (MIS 7 to 5) there were a series of cold and warm periods (without ice reaching Lincolnshire) during which sea levels repeatedly rose and fell. It was warmer and wetter at the height of these interglacials than the climate today (particularly during the Ipswichian stage, MIS 5e) and the hippo was found as far north as Leeds. The River Ancholme deepened and widened its valley, cutting through the glacial till and leaving just a few areas of glacial deposits forming the low isolated hills such as found at Howsham.

The last glacial period is called the Devensian and covered MIS 5d-2. It occurred from 71,000 - 12,000 years ago and was at its maximum about 22,000 years ago. There continues to be some debate about the number, timing and extent of different ice advances in this area. Professor Allan Straw argues that during MIS 4, c.40,000 years ago, ice surged down the east coast and a lobe penetrated the Humber Gap as far as Winteringham, which would have blocked the mouth of the Ancholme Valley. This lobe formed the Horkstow moraine which formed a southerly semi-circle from South Ferriby around to Winteringham, now breached by the Ancholme. As the surge continued down the east coast past the Humber the ice front rose up the dip slope onto the Wolds reaching as far west, in an undulating line starting from near Barton and extending south to Burnham, Wootton, Kirmington, Limber, Swallow, Wold Newton and onwards to the Wash and into Norfolk. The evidence, provided by channels cut into the chalk, points to meltwaters from this ice front flowing parallel to the front and not breaching the Wolds, with the exception of a flow west through Barnetby Gap into the Ancholme valley.

The ice plug at the mouth of the Ancholme is thought by Professor Straw to have lasted only a few thousand years, but this still begs the question of what happened to snowmelt flowing into the Ancholme during this time. There is a long held view that a pro-glacial lake (Lake Humber) formed in both the Ancholme and the Trent Valleys (the latter also blocked by ice flowing from the Vale of York) and stretched south as far as Lincoln and through the Lincoln Gap into the Fens. Professor Straw, however, believes that there is no compelling evidence of a lake shoreline extending south much beyond Brigg in the Ancholme Valley. It could be that the land in the valley was still considerably higher at this time than it later became and that the periglacial conditions (as in some present day tundra landscapes) may have been relatively dry and windy where, in summer, snowmelt quickly evaporates. Nevertheless, the clay vale between Brigg and Caistor (including North Kelsey Moor) would have been very poorly drained with, if not a lake, areas of bog and many large ponds.

Professor Straw believes that the Ancholme valley was significantly lowered by erosion during the period between the retreat of this MIS 4 ice and the end of another, the last, glacial advance in this area, mainly under periglacial conditions with little vegetation and a dry North Sea providing a low base level. Erosion would have slowed at any time during MIS 3 when sea levels rose and vegetation was established. Once the Ancholme had broken through the Horkstow/Winteringham moraine it and its tributaries, fed by large quantities of summer snowmelt in periglacial conditions, would have lowered the clay vale, leaving the scarp as relatively higher relief, the weight of which squeezed out underlying clay and caused cambering (bending) and faulting of the chalk. When sea levels were higher the Ancholme and its tributaries would have been constantly shifting laterally, transporting and reworking, season by season, year by year, a variety of materials from previous and current glacial advances.

The last glacial maximum (LGM) ice front in MIS 2 penetrated less far west than the previous advance and formed the Killingholme moraine between Habrough and Goxhill. The mouth of the Ancholme was not blocked but, nevertheless, another pro-glacial lake (Humber Lake 2) did form in the Humberhead area, witnessed by thick laminated silts and clays, extending through the Humber Gap and into the River Hull valley. It is believed also to have extended up the Ancholme Valley as far as Brigg.

There appears to be uncertainty and debate about the development of the landscape between MIS 4 and MIS 2, but there is no doubt that an ice sheet was present in this area, with periods of advance and retreat, from c. 21,000 years ago to c. 12,000 years ago. During this period of c. 9,000 years Grasby and Clixby would have been subject to periglacial conditions of weathering and erosion, which would also have continued following the final retreat of the ice for at least another thousand years or so until the present interglacial period became established and the climate warmed sufficiently for a forest cover to be re-established. Warming of the climate is believed to have been at its maximum between 9,000 and 5,500 years ago. Sea levels rose as the ice retreated, although these were to some extent balanced by rising land surfaces caused by isostatic adjustment (the earth's crust rising up to compensate for the weight of the retreating ice being removed). It wasn't until c. 6,500 years ago that the land bridge, extending from East Anglia to the Thames and across the North Sea to Europe (Doggerland) finally disappeared.

Superficial Geological Deposits in the present landscape

Superficial deposits rest on top of the bedrock and range in Grasby and Clixby from clay to gravel to peat. They result from a variety of depositional agencies including glacial, periglacial (notably solifluction and aeolian or wind), lacustrine, fluvial, estuarine and marine. They also include modern soil horizons.

As indicated above, glacial deposits of pre-Devensian age are confined to the Ancholme Valley around and south of Brigg. Evidence of glacial tills from MIS 8 ice is found as the cappings of the Kelseys, Howsham and Cadney hills, with one small deposit near the Viking Way between Grasby and Clixby. All other superficial deposits in the parish are of Devension or younger age.

Deposits similar to stream alluvium occur in most of the dry valleys cut into the chalk. There are two such valleys, or scarp gullies, dissecting the scarp in the parish, one on the old Grasby/Clixby parish boundary and one next to the church in Clixby. The deposits consist mainly of clayey and sandy silt, commonly with locally derived gravelly layers near and at the base. These dry valley sediments originated as alluvium during Devensian periglacial conditions, when frozen groundwater rendered the chalk impermeable. Huge cornices of snow would have accumulated on the scarp during winters, but in summers, even under periglacial conditions, snow can melt very quickly to form strong flows of surface water which created these scarp gullies and transported large quantities of chalk, already shattered by freeze/thaw action and carried down the sides of the gullies by solifluction (gravitational flow of saturated sediment over a frozen subsoil surface during summer melts), out into the clay vale. This material would have spread across the vale in the form of chalky/flinty gravels (some blocky through mass movement, some sorted by running water), fan-form sands and fine alluvial clays and silts deposited in temporary ponds or as over-bank sediments. Over thousands of years these sediments were laid down, reworked by streams and the wind, and slowly transported towards the Ancholme. The lack of any great depth of these sediments indicates that removal more or less kept pace with supply. Although North Kelsey Beck appears today to be the main tributary of the Ancholme draining this area, previously Nettleton Beck was much more active (still issuing today as a modest sized stream from a notable scarp gully c. 75m deep) and with a large catchment was probably the dominant agent of fluvial erosion and deposition in the eastern part of the Ancholme valley north of

Caistor. A proto-North Kelsey Beck would have been a tributary of Nettleton Beck.

South of Grasby and Clixby there is no detailed information available about the superficial deposits overlying the clay. The 1:50,000 Geological Survey map indicates a variety of glacio-fluvial and glacio-lacustrine sands, silts and clays, blown sands (cover sands) and some patches of alluvium and peat, but also areas with no superficial deposits recorded. The soils vary over short distances from heavy clay to medium clay and silt to pure sand. The banks of North Kelsey Beck, however, do provide some interesting profiles of these deposits.

North Kelsey Beck flows in an artificial cut from east to west through the parish. Enclosure maps show that c. 1800 the original stream followed a meandering course up to 50m south of the present stream. After the enclosure of Caistor Moor (1811-14), as well as drainage ditches being dug around all the new field boundaries, this stream was diverted into a new, deepened and straight drain cut east/west through the parish at just 17m OD. For nearly 180 years the beck has carried a varied bedload over, for the most part, a solid clay bed and been busy re-shaping a more natural course for itself with pools and riffles, small meanders, terraces and even a cut-off channel.

North Kelsey Beck

Cut-off channel and river cliff, North Kelsey Beck

Where undercut the bank often collapses to reveal a full soil to bedrock profile. One such profile was created in the winter of 2016 at TA 084036, ½ mile WSW from the mouth of the scarp gully at TA 097048. The height of the stream bank at this point is c. 1.8m. The profile comprises:

- I) Ao soil horizon, c.60cm, dark sandy soil
- II) Ae horizon, c.20cm, pale coloured sand leached of iron
- III) B/C horizon, c.60cm, blown sand with ferric iron nodules
- IV) Greyish brown fine sand, c.5-10cm
- V) Chalk/flint/sand gravel, c.30cm
- VI) Kimmeridge Clay bedrock

There is continuing debate about the actual age of superficial deposits in the Ancholme Vale, but the consensus (Straw, Connell, Bateman) is that here the above profile was most probably laid down during periglacial conditions at the close of the last ice advance in MIS 2.

The full profile is shown in the photograph below.

Full streambank profile with Kimmeridge Clay exposed at base (VI)

The chalk clast rich gravel layer (V) is derived from the scarp gullies to the north and ENE and the sand component will have come from the Spilsby Sandstone and Carstone underlying the chalk.   Some cross-bedding indicates that it has been deposited by flowing water. As this layer is so thin it might represent the toe of an apron of solifluction deposits, which have later been re-sorted by flowing water, or it may have been part the bedload of an active stream (further downstream, at TA 080037, this layer is still present, but distinctly blocky suggesting deposition by downslope mass movement i.e. solifluction).

Chalk clast rich gravel layer (V)

Chalk rich clast layer becomes more "blocky" downstream

The greyish brown fine sand mud layer (IV) may have been formed by fluvial deposition in slack water, over-bank (alluvial) deposition or lacustrine (lake or pond) deposition. The colour is due to "gleying" (formed in waterlogged, anaerobic, conditions where iron compounds are reduced or removed).

Greyish brown fine sand mud layer (IV)

The B/C horizon (III) is a cover sand, blown in from the west and/or fan sands reworked by the wind, that may also have been reworked by water at times. As the climate warmed, but before new forests were established, cover sands accumulated all along the base of the chalk scarp face, probably between c. 11,000 to 9,000 years ago. The darker colour and nodules of ferric oxide identify this as an “illuviated” layer of the soil formed by percolating water from above.

The Ae horizon (II) is also formed from a cover sand, but its pale colour indicates that it is an “eluviated” layer from which iron has been leached down into the B/C horizon.

Ae horizon (II) below Ao horizon (I)

Once woodland covered the area, by c. 8,000 years ago, the movement of sand was suppressed, until the clearances. Sand "blows" are not uncommon even today when the weather is dry and strong winds pick up "top soil" from newly ploughed and harrowed fields.

Moving closer to the Wolds, an elongated deposit of glacial "head" (a sheet of poorly sorted angular rock debris deposited by solifluction on slopes as low as 1^{o}) covers the slope below the chalk escarpment on which Grasby village, below Clixby and Vicarage Lanes, has been built.

Apart from the deposits already described in the floors of the scarp gullies, the British Geological Survey shows no superficial deposits on the Wolds within the parish of Grasby/Clixby. The soils of today in this part of the parish would seem, therefore, to have been derived almost entirely from the chalk bedrock.

Age (,000 years)	**Marine Isotope Stage**	**British Stage**	**Lincolnshire**
14-0	MIS 1	Holocene	Present day interglacial. Clay vale 17m OD in Grasby
29-15	MIS 2	LGM	Ice forms Killingholme moraine. Lake Humber 2. Scarp gullies form, present day superficial deposits laid down
57-30	MIS 3	Warm	Forest. Trent drains again into Humber
71-58	MIS 4	Devensian Cold	Ice blocks mouth of Ancholme, forms Horkstow & Kirmington moraines. Lake Humber 1. Grasby - tundra
130-72	MIS 5	Ipswichian Warm	High sea levels. Erosion during cold interludes
191-131	MIS 6	Wolstonian Cold	Valleys deepened, cutting through & removing till except on the "hills" of Cadney, Howsham & the Kelseys
243-192	MIS 7	Aveley Warm	Ancholme drains into Humber. Trent drains through Lincoln Gap
300-244	MIS 8	Cold	Complete ice cover, 300m thick. Wragby Till. NK Moor, 45-50 OD
337-301	MIS 9	Purfleet Warm	Full forest cover
374-338	MIS 10	Cold	N Sea dry. Erosion - vales lowered a little, scarp retreat
424-375	MIS 11	Hoxnian Warm	Full forest cover
478-425	MIS 12	Anglian Cold	Ice 1000m deep. N Sea & Vale of York ice. Complete ice cover. Clay vales lowered to c. 60m OD

Summary table of Pleistocene Ice Ages

The present day landscape of the parish

From the moment of the very first forest clearances in the parish, possibly as far back as c. 4,500 years, the “natural” landscape began to change. This accelerated with the cultivation of crops and the grazing of domestic animals. Eventually a landscape of large open fields, common land and waste land emerged during the Middle Ages, all of which were enclosed during the C19th. Although some hedges have been removed more recently, this C19th pattern of field boundaries is still clearly visible today.

The planting of hedges, digging of drainage ditches and installation of land drains following the enclosures did more to control the natural cycle of erosion and deposition than any other changes made to the landscape by the occupants of the two villages. There is no longer a single length of natural streamway in the parish, although the source of North Kelsey Beck is from chalk-fed springs which rise just to the north east of Caistor on Water Hills (TA 121016) which join to flow as a single stream ENE in a clearly defined scarp gully as far as the A1084 (TA 117018). Downstream of this point its flow has been managed in a channel that has been artificially straightened, deepened, embanked and even diverted completely from its original course at various places on its journey all the way to the Ancholme. Its tributaries comprise field boundary ditches and land drains. No permanently flowing water within any form of channel, however, exists on the Wolds chalk north of the A1084 within the parish.

As indicated above, however, North Kelsey Beck itself has been left largely unmanaged in recent times and exhibits all the natural processes of fluvial erosion, transport and deposition. It has a clearly observable mobile bedload of gravel, sand and silt with some pebbles and even the odd erratic. One notable and sizeable example of the latter is a piece of smoothed quartzitic sandstone found at TA 085034(see photograph below). This rock is an erratic frequently found in the Wragby Till and would have been derived from Coal

Measures well to the north of here and brought into this area by MIS 8 ice some 300,000 years ago. This large pebble would have been eroded out of the till and shunted around the Ancholme Vale for thousands of years. These quartzite erratics are extremely hard and survive the processes of erosion over very long periods.

Quartzite erratic found as part of bedload in North Kelsey Beck

In spite of it being a managed landscape, therefore, the natural processes of weathering, erosion, transport and deposition continue unabated albeit at an imperceptibly slow rate, except at times of (in human terms) extreme weather. Within living memory there have been a number of occasions during which hundreds, probably thousands, of tons of top soil have been either been blown or washed from the surfaces of fields, streams and rivers have overtopped their banks and snow and frost have loosened and shattered exposed rock in abandoned quarry faces (as well as damaging roads and buildings). Human intervention may slow, but never fully stop, the natural cycle of uplift, weathering, erosion, transport and deposition.

Summary

- The parish of Grasby and Clixby is underlain with, in geological terms, young sedimentary rocks laid down in oceans and seas over a period of about 84 million years during Jurassic and Cretaceous times. This period of deposition was interrupted several times when the land was raised above sea level and several strata (layers of rock) were entirely removed by erosion from the parish, although this rock sequence still exists in exposures on the edge of the Wolds south of Clixby.
- During the Tertiary Period, beginning 65 million years ago, uplift raised and tilted all the rocks of eastern England eastwards, exposing the youngest rock, chalk This has since been gradually eroded down, beginning in the west where the land was highest, to reveal in sequence the older series of rocks below so that, today, the chalk survives only on the Wolds. The older Kimmeridge Clay has been exposed on North Kelsey Moor where, being a softer, weaker rock it forms low lying level land, previously moorland but is today reclaimed farmland.
- By about 2 million years ago, in the late Pliocene, all the land had been reduced to, and at times below, sea level and formed a low lying flat plain (peneplain). As sea levels fell, however, the clays were lowered again leaving the chalk as a slightly higher plateau separated from the clay vale by a steep scarp slope. The shape of the landscape at the close of this period would have been broadly similar to that seen today, although North

Kelsey Moor would have been about 60m above sea level as opposed to its present height of 17m above sea level.

- During the Pleistocene Ice Ages which followed, the ice was at one time up to 300m thick over Grasby and Clixby. The scarp slope was pared back and up to 30m of chalk scraped off the Wolds leaving the Welton Chalk exposed in the parish. Various glacial deposits were left in the area, but most were removed by erosion during the warm interglacial periods. There remain only thin superficial deposits overlying the bedrock in Grasby and Clixby, resulting from a variety of depositional agencies both glacial and non-glacial.

Acknowledgements

First and foremost I wish to express my extremely grateful thanks to Professor Allan Straw, Lincolnshire born and bred, who left Louth Grammar School in 1954 and completed a long and illustrious career as Professor of Geography for 23 years before his retirement in 1994 from work, but not from his research. Not only has Professor Straw taken a keen interest in my work and shared with me his unrivalled knowledge of the geography and geology of Lincolnshire, but has also taken the time and trouble to read this paper and offer invaluable advice on its content and presentation.

I also wish to thank Professor Mark Bateman of Sheffield University and Roger Connell of Hull University for taking the time and trouble to answer my queries and point me towards various research papers based on work previously undertaken in this part of Lincolnshire.

Finally, I'm grateful to Colin Merry, a former colleague and geologist, for tramping around the parish with me in an endeavour to identify and interpret its key geological features.

Bibliography

- *GD Gaunt, TP Fletcher & CJ Underwood: British Geological Survey - memoir 1:50, geological sheets 80 & 89 (Kingston Upon Hull & Brigg) 1992*
- *HH Swinnerton & PE Kent: The Geology of Lincolnshire 1976*
- *A Straw: The Last Two Glaciations of East Lincolnshire 2008*
- *A Sraw: The Glacial Sequence in Lincolnshire (East Midland Geographer 2) 1958*
- *MD Bateman: Thermoluminescence Dating of the British Coversand Deposits (Quaternary Science Review Vol 14) 1995*
- *MD Bateman: The Origin & Age of Coversand in north Lincolnshire (Permafrost & Periglacial Processes 9) 1998*
- *MD Bateman J Murton & W Crowe: Late Devensian & Holocene Depositional Environments associated with Coversand around Caistor, north Lincolnshire (BOREAS - International Journal of Quaternary Research) 2000*