The geology of Hanson Cement’s ‘Grange Top’ Quarry at Ketton

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SAFETY

Wearing of hard hats, high-viz jacket or waistcoat and eye protection is compulsory on Ketton site.

The jointing in the Lincolnshire Limestone, Blisworth Limestone and Cornbrash together with the presence of jointed limestones on top of plastic clays creates a significant hazard from rock falls. Quarry faces must therefore be assumed to be unstable, and should not be approached closely. Ground conditions are likely to be uneven with tripping hazards, so due care must be taken when moving about. Open fissures in the top of the Lincolnshire Limestone are a significant hazard in some places.

In the quarry the local management may lift the requirement for eye protection provided the conditions are not too dry and dusty. However, eye protection is required when using a hammer. Everyone must have eye protection available.

Robust boots must be worn. Wearing of trainers will not be permitted.

These and additional matters will be addressed in a Risk Assessment, which will be issued before access to the quarry will be permitted. Compliance with the risk assessment is mandatory.

1 Introduction
There are extensive outcrops of Middle Jurassic strata in Ketton quarry. The succession is continuously exposed from the Northampton Sand Ironstone to Kellaways Formation. A small exposure of the junction between the Lias and the Northampton Sand Ironstone can also be seen when the water table is low.

2 Acknowledgements
Thanks and acknowledgements for the sedimentary logs are due particularly to Professor John D Hudson and Dr Roy G Clements of Leicester University, and also ultimately to Drs M. Ashton and M.J. Bradshaw.

3 Notes on the main formations
Notes on the main formations follow (youngest first), including the superficial deposit of boulder clay:-
**Boulder clay**
The boulder clay at Ketton contains derived fossils such as *Gryphaea*, belemnites and ammonites from the Jurassic. Ammonites from the chalk may also be found. Cobbles of chalk and flint are common.

**Oxford Clay**
A very limited exposure has been identified by Professor John Hudson. It is not easy of access and will not normally be visited.

**Kellaways Formation**
Locally brought down by faulting, Kellaways Formation rests on the Cornbrash. The argillaceous lower member, the Kellaways Clay (about 3m) passes gradationally into the Kellaways Sand (about 5.5m). Belemnites and *Gryphaea* are quite common, but the exposure can only be reached via a small landslip which can be extremely boggy.

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**Fig 1:** Rutland Formation to Kellaways Formation

**Abbotsbury Cornbrash Formation**
The Cornbrash is a massive limestone, weathering brown. The brachiopod, *Obovothyris magnobovata* at its base indicates Lower Cornbrash. The main part is Upper Cornbrash.
A brachiopod ‘nest’ containing about 2000 terebratulid brachiopods has been found (by the author) within the Cornbrash, probably the Upper Cornbrash. This is thought to represent a living community.

**Fig 2:** Boulder from Cornbrash containing brachiopod ‘nest’

**Fig 3:** End view of boulder in Fig 2.
Fig 4: Section through boulder of Fig 2 with geopetals marked.

Large oysters, *Lopha marshii*, can be seen on the top surface of the Upper Cornbrash. Brachiopods and bivalves are common. The limestone is not oolitic. The nature of the top 200mm or so of the Upper Cornbrash merits discussion.

*Thalassinoides* burrows are found at the contact between the Blisworth Clay and Lower Cornbrash. *Pholadomya sp.* is found in life position in this horizon.

**Blisworth Clay Formation**
The lower part contains ostracods and is taken to be marginal marine. The central part consists of varicoloured bedded clays and silts, with more than one horizon preserving truncated rootlets.
Blisworth Limestone Formation

Within the confines of the quarry the Blisworth Limestone is variable both in thickness and in character. It is not oolitic. It tends to weather grey.

The oyster *Praeexogyra hebridica* is abundant. Also found are terebratulid and rhynchonellid brachiopods and fully marine bivalves such as *Pholadomya irata*. The echinoid, *Clypeus*, can also occasionally be found. In one area *Modiolus* is found in abundance, in random orientation and with both valves preserved.

The top is taken to be the prominent bed of cone-in-cone calcite.
Fig 6: Bivalve in Blisworth Limestone

Fig 7: Cone-in-cone calcite at top of Blisworth Limestone

**Rutland Formation**
This was formerly known as the Upper Estuarine Series.

The Stamford Member at its base consists of quartz rich silts with conspicuous truncated rootlets. The darker facies of the Stamford
Member contain trilete megaspores. There are at least two distinct horizons with an erosion surface between. Bradshaw (1978) described these units as ‘back swamp’ or ‘freshwater marsh’ facies. The silts contain abundant quartz grains (with whole rock average oxide analysis 76% SiO$_2$, 11% Al$_2$O$_3$ and 2% Fe$_2$O$_3$). They are probably leached soils.

The ‘rhythmic’ succession above the Stamford Member was interpreted by Bradshaw (1978) as a series of six transgressive-progradational cycles across a coastal plain. Bradshaw was able to trace most of the rhythms from Oxfordshire to Lincolnshire, a distance of approximately 150 kilometres. Several truncated rootlet surfaces are evident. Rhythm 1 (counting from the base) contains the brachiopod *Lingula* just above its base as well as bivalves. Rhythm 4 contains an oyster bioherm and rhythm 5 consists mainly of carbonate mud pierced by rootlets. The base of rhythm 1 shows clear evidence of marine or marginal conditions. A low grade coal marks the top of the rhythm 2. Hudson & Clements (2007) have renumbered the rhythms using R1 for the Stamford Member, so Bradshaw’s rhythm 6 is Hudson’s R7.

When freshly exposed these mud rocks are spectacular at both large and small scales.

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**Fig 8:** Rutland Formation, south end of quarry. Quarry floor is the top of the Lincolnshire Limestone. The top of (Bradshaw’s) rhythm 2 is marked by a low grade coal.
Fig 9: Rutland Formation, north end of quarry. The top of (Bradshaw’s) rhythm 2 is marked by a low grade coal.

Fig 10: Rutland Formation, top of rhythm 2.
Lincolnshire Limestone Formation
The Lincolnshire Limestone weathers brown. The brown colour derives from the weathering of microscopic pyrite. The limestone has been much used in buildings, such as in some of the Cambridge colleges. Centres of some thicker, fine grained, well cemented units are blue/grey because the pyrite there remains un-oxidised.

Both Lower and Upper Lincolnshire Limestone are present, but the boundary between them is inconspicuous at Ketton. The junction between Lower and Upper Lincolnshire Limestone is several units below the plane between the horizontally bedded units and the cross sets, just above a unit rich in nerineid gastropods. It is not accessible (and the author has never been able to identify it). Several hardgrounds are present.

The lowest 0.5 m of the Lincolnshire Limestone consists of uncemented quartz sand, probably the residue of limestone leached by acid ground water. The three metres or so above this consist of fine grained limestone. Average oxide analysis is 20% SiO₂, Fe₂O₃ <1.5%, Al₂O₃ <1.5%, so there is clearly free quartz. The quartz residue from dissolution of the calcareous fraction in HCl is mainly silt-sized, <63 micron. This is the Collyweston facies, from the base of which the eponymous slate was mined at nearby Collyweston. There is no slate quality material in the quarry, but locally signs of layering can be observed just above the quartz sand. The slate consists of quartz sand cemented by calcite. In Grange Top quarry the cementation is in bands from 10 to 20mm thick, separate by barely cemented horizons. The miners would leave large blocks outside for water to permeate the less cemented horizons and for frost to separate the slates. There appears to be cross bedding in the slate facies, so it is likely that the phenomenon is bedding related. However, no evidence has been found (yet) of why the cementation is in layers.

Fig 11: Collyweston facies above the 0.5 m of uncemented quartz sand at the base of Lincolnshire Limestone. Burrowing appears to be present at the lowest level.
Fig 12: Cut section through Collyweston facies ‘slate’.

The author recently recovered examples of Collyweston Slate from a builder’s skip. They are thinner than found in the quarry, these examples no more than 10mm thick. One exhibits sole structures, another has a bedding plane containing small bivalves.

Fig 13: Sole structures on Collyweston Slate
Wood fragments are commonly found within this facies and less commonly belemnites. There is evidence of burrowing, ripples and small-scale graded bedding with bioclasts of gastropods and calcareous worm tubes at the base.
Fig 16: Burrowing in lower part of Lincolnshire Limestone
Fig 17: Graded bed and burrowing about 3 metres above the base of the Lincolnshire Limestone. The coarse grains in the graded bed are bioclasts, mainly calcareous worm tubes. Thickness of graded bed is about 125mm.

Further up the succession the siliceous content is low and below the highest hardground the limestone is oolitic. In some areas, marked by cross sets, there is no cement and the ooliths are 'welded' together to form the famous Ketton freestone.

Close to the freestone the rock is locally an oosparite with impressive coarse poikilotopic ferroan-calcite cement (Emery 1988). Single calcite crystals up to about 4 cm long enclose the grain-supported ooliths. On a
bright sunny day the reflective fracture surfaces, which are cleavage planes, are readily observed.

An oyster-encrusted bored hardground can be seen towards the north of the quarry about 1.5 metres below the topmost surface. Loose blocks of this have been set aside for study.

That these are borings, not burrows, is clear from the thin section shown in Figure 18c below. The ooliths have been cut through by the boring organism. The blue colour is not the true colour of the calcite. The thin section has been stained in such a way that ferroan calcite is blue while non-ferroan calcite remains white.

Both Trypanites and Gastrochaenolites are dwelling borings (domichnia). *Trypanites* are polyphyletic worm borings mostly driven by chemical means and are indicative of subtidal and intertidal carbonate environments. *Trypanites* is known from the Early Cambrian to the Holocene. *Gastrochaenolites*, a bivalve boring, became common in the Jurassic. In modern marine environments the Gastrochaenidae produce flask-shaped borings with a narrow aperture and a larger ovoid chamber. Most modern coral-boring bivalve species are restricted either to living or to dead coral. Fossil bivalve borings often preserve the trace-maker and bioglyphic ornament from the rasp-like shell.
Fig 18b: Bivalve within its boring in modern coral (West Indies)

Fig 18c: Upper hardground showing *Trypanites* cutting through ooliths

The top 1 to 2 metres, above the hardground, weathers darker brown and is cross-bedded with an abundance of skeletal debris. Secondary gypsum, sometimes ‘satin spar’, fills joints in the limestone. The gypsum and iron staining are derived from the breakdown of pyrite in the Rutland Formation above. It is not clear when this took place.
There is a sharp lithological break at the top of the limestone and a significant time gap is reported, but there is no evidence of karstic erosion of the limestone.

Loose oolitic sand was once quarried for pebble dashing. Some have postulated that this oolitic sand was never cemented. Close inspection of some of the ooliths reveals indentations that are identical to those found when freestone has been broken up by freeze thaw cycles in a domestic deep freeze (when my wife wasn’t looking). Oolitic sand has only been found within less than 2m of the present ground surface.

**Grantham Formation**

The Grantham Formation was formerly known as the Lower Estuarine Series. Silts and clays of the Grantham Formation are exposed in a pit in the quarry floor. In this locality the quartz sand of the Lincolnshire Limestone overlies silts and fine sands with one or two horizons of truncated rootlets. In places the rootlets penetrate the top of the ironstone.

![Fig 19: Northampton Sand Ironstone, Grantham Formation and base of Lincolnshire Limestone.](image)
Fig 20: Rootlets in Grantham Formation

Northamptonshire Sand Ironstone Formation

Ironstone is exposed in a pit in the quarry floor. A recent local chemical (oxide) analysis of the ironstone gave 21% SiO$_2$ 6% Al$_2$O$_3$ 44% Fe$_2$O$_3$ and 10% CaO, with minor S, Mg, Na and K. The ironstone was opencast-mined north and south of Ketton along strike, but the limestone and mudstone cover was too great to make such mining worthwhile at Ketton. The lower part of the succession consist mainly of iron-stained quartz sand.

BGS did extensive work on the ironstones, and this is published in two memoirs dating from 1949 and 1951. Both memoirs refer to the greenish iron mineral as chamosite. It is now described as berthierine; the term
chamosite is restricted to true chlorite species. The structure of berthierine is similar to serpentine.

The local geological map, sheet 157 Stamford, shows many square kilometres which have been opencast mined for ironstone.

A sample of the basal bed with *Thalassinoides* has been set aside for study.

**Fig 21:** Base of Northampton Sand ironstone with *Thalassinoides*

**Fig 22** Base of Northampton Sand Ironstone, showing *Thalassinoide* and pebbles etc.

Ironstone working took place in Roman times. Domesday Book records the presence of iron forges at Corby in Edward the Confessor’s Time; (Edith Weston, not far from Ketton, is named after his wife). The
Lincolnshire Limestone was used for fluxing, and the sands of the Lower Estuarine Series (now Grantham Formation) for refractories. Ore transport was almost entirely by rail. In 1942 a record output of 10.5 million tons was produced, and during the six years 1939 to 1945 the ore provided raw material for considerably more than half the total British production of iron.

**Lias**

The Lias can only be seen if the water table is very low. It is only weakly cemented and is responsible for valley bulge phenomena in the area. Valley bulge 'may' be responsible for some of the faulting at the north end of Ketton's quarry. It certainly presented challenges for the builders of Rutland Water, located on the Lias a few miles west of Ketton. In the north west of Ketton's quarry *Dactyomya ovum* has been found in core from near the top of the Lias. At Whitby this bivalve is found in the Alum Shales.

4 What to look out for!

**Limestones and ironstone:-**
oolitic facies, freestone, muddy facies, sandy facies, hard grounds, borings, shell beds, secondary gypsum, graded bedding, burrowing, cross bedding, blue/grey hearted limestone, poikilotopic cements, evidence for cyclicity, lateral variability, oxidation, ripples, spheroidal weathering, boxstone weathering, variable cementation, flowstone calcite

**Siliclastics:-**
rootlets, low grade coal, truncated rootlets, transparent crystalline gypsum, bivalve shell beds, burrows (rare), grain size variation, concretionary horizons, pyrite, ostracods

**Structures:-**
jointing, faults (one spectacularly exposed), slickensides, joint fills, cone-in-cone, structures on blue/brown boundary in blue-hearted limestone blocks

**Palaeontology:-**
wood, bivalves (*Modiolus, Pholadomya, Lopha, Gryphaea* etc.), ostracods, calcareous worm tubes, belemnites, gastropods (both nerineid and others), brachiopods, bryozoa, echinoids (*Clypeus* and others), crinoids, corals (rare, mainly in Blisworth Limestone)

**Trace Fossils:-**
*Trypanites, Gastrochaenolites, Thalassinoides*, other burrows
5 Geological time

The rocks exposed in the quarry are from the Middle Jurassic, a period that spans about 20 million years.

Fig 23: The Middle Jurassic period put in the context of the age of the earth. Acknowledgements to Manchester Museum for use of the Geological Column reproduced on the left of the diagram.
6 What do the rocks tell us about the original depositional environment?

The rocks record deposition in marine and terrestrial environments and in marginal marine environments which were previously described as 'estuarine' but are now described as ‘paralic’.

Significant changes in relative sea level must have taken place. These were caused by a combination of eustatic sea level change and more local variations in the level of the land surface due to volcanic activity in the North Sea. As the Jurassic was not an ‘ice-house earth’ period, it is likely that the igneous activity in the North Sea was an important local driver of relative sea level change through its impact on local topographic levels – see Figs 24-27.

Fig 24 Diagram showing relative sea level change derived from the rocks at Ketton – indicative only and not to scale
### Fig 25
Stratigraphy of central and northern North Sea in relation to major tectonic controls on sea level. From Geological History of Britain and Ireland, Nigel Woodcock and Rob Strachan eds. Blackwell Science 2000 (their figure 17.10).

However the global sea level curve derived by Haq, shown in Figure 26 below, indicates that there was eustatic sea level change in the Jurassic. While there is not universal agreement on the cycles in Haq’s curve, the overall shape showing eustatic sea level increase during the Jurassic and most of the Cretaceous is widely accepted.

There are not thought to have been any continents in polar locations during the Jurassic and there is no evidence for glaciations during that
period either. It is likely that a major driver for eustatic sea level change was the break-up of Pangaea. This would have led to an increase in the number and overall length of mid-oceanic ridges. These would have displaced a significant volume of sea water and later, as the new crust cooled, that displacement would have been reduced. This is not to suggest that this was the only process responsible for eustatic sea level change during the Jurassic and Cretaceous periods but it seems likely that it was a major contributor.

**Fig 26** Relative sea level curves. No allowance has been made for continental ice volume. From Skelton, The Cretaceous World, Cambridge University Press 2006 (his figure 3.10).
The Lincolnshire Limestone, marine, is overlain by the Rutland Formation, mainly non-marine. A similar juxtaposition of marine and non-marine sediments can be seen in the Everglades region of Florida where mangrove swamps overlie oolitic limestone and there are vast tracts (square kilometres) of oyster beds close to the coast. However, although there are some parallels, the principle of uniformitarianism must be applied with caution as the organisms in today's sediments are not the same as those that existed in the Jurassic.
7 Bibliography

Geological map, BGS Stamford, sheet 157 solid and drift, 1:50000 series.


Clements, Roy G. 2002. Notes for field excursion for University of Leicester (2nd year stratigraphy) with updated logs from Lincolnshire Limestone to Kellaways beds. Logs were originally drawn by J.D.Hudson, also from University of Leicester.


Sedimentary logs

Kellaways Formation

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Kellaways Formation

Original log – courtesy of Prof John Hudson
Additions by PdelS

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This horizon is readily identified but access is difficult without scrambling and is not recommended in wet weather.

We shall discuss what this surface represents.
Blisworth Limestone to Cornbrash

original log – courtesy of Prof John Hudson
additions by PdelS

some beds with abundant *Modiolus*, both valves preserved, random orientation

*Thalassinoides*
Rutland Formation

weathers brown, usually well cemented

siderite nodules, encasing roots

usually very pale quartz rich horizon with undulating top surface and abundant roots

Pronounced boundary between pale and dark facies

original log – courtesy of Prof. John Hudson
additions by PdelS
oolitic, either with poikilotopic ferroan calcite cement, or with two phases of cementation - calcite followed by ferroan calcite.

In this area, at least two graded beds with calcareous worm tubes and small gastropod bioclasts; burrowed unit beneath.

Original log – courtesy of Prof John Hudson
Additions by PdelS
Lias to Lincolnshire Limestone

original log – courtesy of Prof John Hudson
additions by PdelS relate to pit in quarry floor not seen by JH

Collyweston slate, not in doggers where currently exposed

Extensive Thalassinoides burrowing and Chondrites scale burrowing in top of Lias
East west section across the north end of the quarry, approximately 200m south of the Empingham Road.

This was prepared for the Anglia Water Authority when they built Rutland Water. Anglia Water Authority kindly let me have a photocopy of this drawing many years ago, for which thank you AWA. I have added NGR references and some dimensions for scale. The quarry is located east of the Shacklewell fault.

Geological section through course of water pipeline