

LGA

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Field Visit Reports Summer 2018



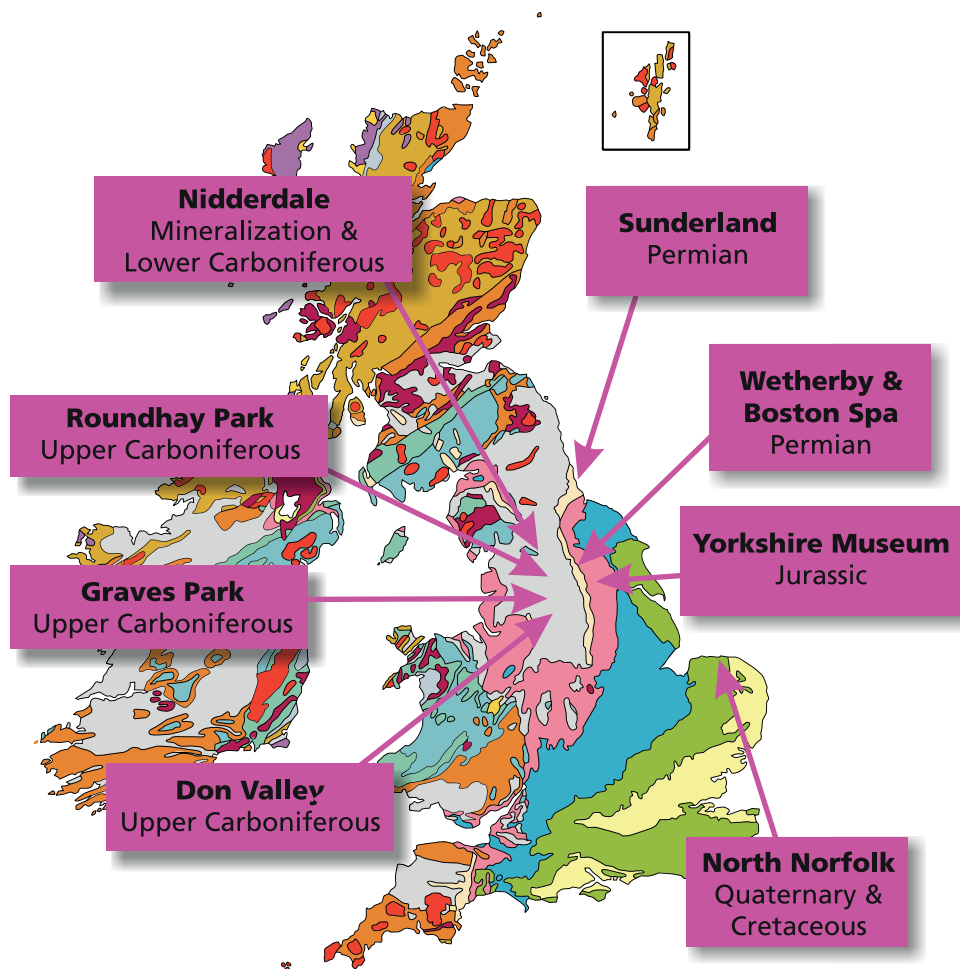
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LGARocks

18

Where did we go?



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2018 Field Visit Locations

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Thanks are due to the Field Visits Secretary, David Holmes, for arranging the programme, to the leaders who gave up their time to take us and to the authors of the reports and photographs: Alan Blackburn, Bill Fraser, David Holmes, Paul Kitson, Gareth Martin, Ann Roberts, David Taylor, Tony Warnes.

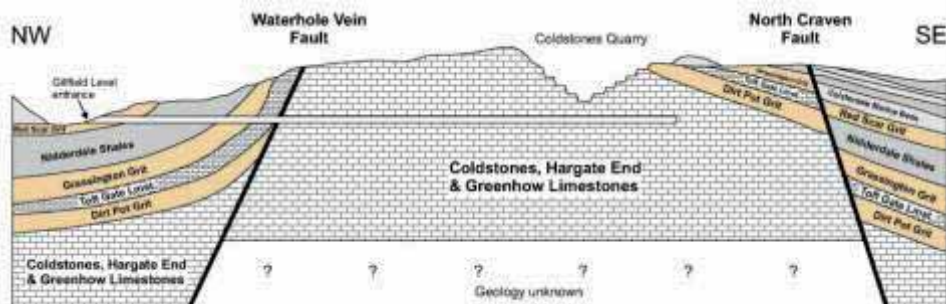
Cover Picture: Sand volcano in Wharnccliffe Edge Rock, Don Valley

Gillfield Mine, Greenhow Hill, Nidderdale Saturday 12th April

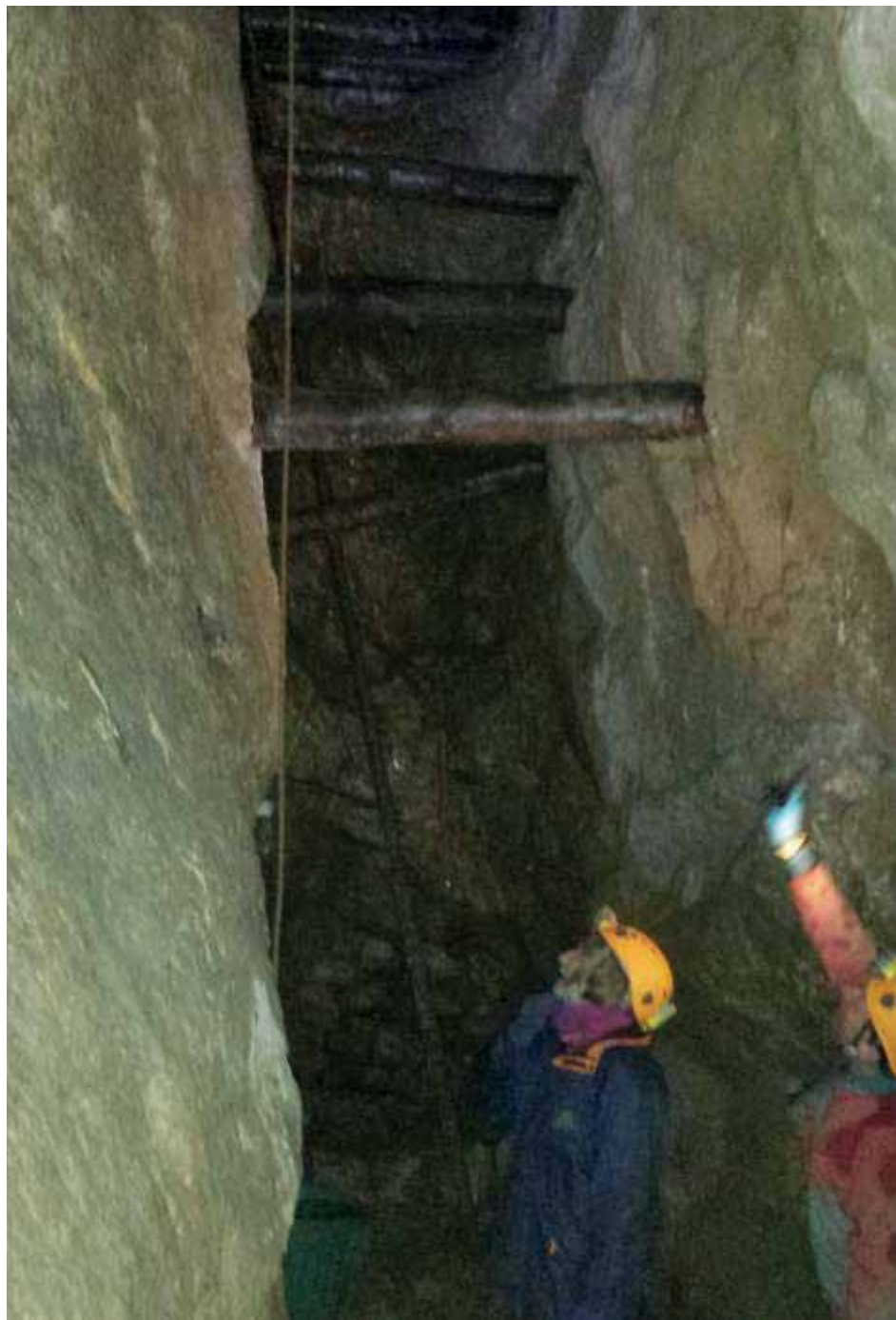
Leader: Shirley Everett, previously Coldstones Quarry Manager, Hanson Aggregates
7 Members present

We met at the edge of the enormous Coldstones Quarry with Shirley Everett and Richard, members of the Mine Preservation Society, for an overview of the geology of the area as seen from the viewing platform. We were shown the Dirt Pot Grit surrounding the underlying Coldstones, Hargate End and Greenhow Limestones and bedding planes and erosion surfaces (known as hard grounds) caused by sea level falls during times of limestones deposition. The mineralised Sun and Garnet Veins were pointed out and Gulfs (old sink-holes infilled with glacial debris) as well as the Skipton Anticline, running roughly east to west, that had brought the solid rock to the surface.

In the office we looked at some maps and cross sections (see diagram below) of the Greenhow anticline including those from Sir Kingsley Dunham and Wilson's memoir 'Northern Pennine Orefield, Vol. 2' before sharing cars down the rough track north of the quarry, to the bottom of the steep sided Brandstone Beck valley. After collecting our hard hats and lights we made our way into the stone vaulted arch of the adit, cut to drain water from the higher workings. The initial section, in the less competent Colsterdale Marine Beds, had to be roofed to protect the miners from roof falls. Paddling onward through 10cms of fast flowing water and water dripping from the ceiling (that we were told was much less than three days earlier!) we reached the Red Scar Grit. This fine grained sandstone was reassuringly self-supporting and we could see the tool marks where it had been hand cut with picks. Next we came into the Nidderdale Shales, lying at an increasingly steeper angle as we went into the northern limb of the anticline. We passed a marine band, about 30cms wide and full of small marine shells and leaching calcite, plus a low grade coal seam rich in sulphur. The mine walls here were now stained black with manganese, red with iron and white with calcite. Next the coarser and steeper angled Grassington Grit was passed through before reaching the



Section through Coldstones Quarry showing Gillfield Mine. Nidderdale Area of Outstanding Natural Beauty, Geology Trail Booklet GREENHOW Shirley Everett www.nidderdaleaonb.org.uk



Examining the slickenside on the fault

crinoid rich Toft Gate Limestone. This was largely covered with calcite, obscuring the crinoids but a few thin shale beds could still be seen.

Reaching the ENE- WSW cross cutting fault that hosted the Waterhole Vein we entered the Greenhow Limestone. The original hand-cut workings searching for galena had been enlarged in the 1930s by larger more industrial workings for fluorite. We made our way up a very steep ladder resting on the slickenside (see photo previous page) that formed one side of the workings where a horizontal smearing of calcite and galena showed the direction of movement of the fault. Here we saw an abandoned ore wagon (see photo below) roughly 1 metre high and 1 metre long but only very narrow. It was set on some rails but must have been dangerously unstable when used fully loaded. Back down the ladder we followed another adit up into the Sun Vein. Here we saw some of the Gulfs here filled with boulders, fine sands and clay of probable glacial origin, that we had seen on the surface. These were dangerous areas for the miners but have been made safe by the preservation group. This part of the mine lies just above the present day water table and we carefully walked the plank over the old flooded workings. A squeeze up a steep and narrow slope brought us into a void where some beautiful cubic fluorite crystals up to 8cms long, which had been overlooked by the miners, were encrusted on the roof. We made our way past the well preserved wooden ore shoot for filling the wagons with galena, fluorite or spoil and followed their route out of the mine to where a turntable would, in the past, have separated the various loads at the adit entrance. Here our leaders were thanked for an excellent tour before we departed.



Abandoned ore wagon

Permian rocks around Boston Spa, Thorpe Arch and Wetherby

Sunday 15th April

Leaders: Jeremy Freeman LGA and Malcolm Barnes
Present: 8 members

The purpose of this visit was to examine the Permian, Cadeby Formation, formerly known as the well-loved and descriptive 'Lower Magnesian Limestone' and plotted famously and so accurately by William Smith on his map of 1815 and coloured by him in the blue so familiar on today's BGS maps. Meeting in Aberford Road, Bramham on a cool and slightly misty morning our day commenced with an eloquent and informative introduction and safety briefing by our leader and LGA member, Jeremy Freeman, who provided us all with maps, sections and descriptions. Most of the locations to be visited lie in the study area that formed the basis of the recent paper published in the Proceedings of the Yorkshire Geological Society that Jeremy was a contributor to.

At the end of the Carboniferous Period the Variscan Orogeny caused folding, faulting and uplift of the Carboniferous rocks of the area. Desert conditions then prevailed forming the lowest beds, the Yellow Sands, which are not exposed in this area. Inundation then created a shallow sea (The Zechstein) whose levels rose and fell many times due to barrier reefs that separated a shallow lagoon from the deeper waters which stretched eastward to what is now Poland. The first deposits in this sea, the Marl Slate, were laid down in an anoxic basin as run-off from the land and contain traces of organic remains. These are not exposed in our area but are proved by a borehole in Clifford. What we were to see was the Cadeby Formation which rests unconformably on Carboniferous rocks and is of Upper Permian age forming a series of evaporite sequences referred to as ZS1 and ZS2 (see table overleaf) approximately 260 Ma, with the base of the Permian being 290 Ma. The Cadeby Formation is predominantly a dolomitic limestone, is creamy buff in colour, soft, and mainly oolitic (pisolithic and shelly in the lower beds). It is divided into the lower, Wetherby Member and the upper Sprotbrough Member. They are separated by the Hampole Beds which comprise thin marls between an Upper and Lower Dolomite. The Lower Dolomite rests on an eroded surface which represents a time of low sea level and this, the Hampole Discontinuity, is now considered to be the Wetherby/Sprotbrough boundary. The discontinuity was not exposed at any of the locations seen on the field trip but is probably one or two metres below the quarry floor at the first location in Bowcliffe Wood.

Period	Zechstein sequence (Tucker 1991)	Formation		Water depth. 0 Metres 12	Energy levels	Facies
Upper Permian	Z54	Brotherton Formation	(not present in area visited)			Shallow carbonate shelf
	Z53	Hayton Anhydrite Edlington Formation				Basin Evaporites Non marine continental
	Z52	Cadeby Formation	Sprotbrough Member		Low High Medium	Intertidal Shallow sub tidal
	Z51		Hampole Beds		Very low	Supratidal
				<i>Hampole Discontinuity</i>	Low	Intertidal
				Wetherby Member	Medium Medium	Shallow Sub tidal
		Marl Slate	(subsurface only)			Anoxic basin
	Yellow Sands	(Not visible)			Aeolian	
<i>Permo-Carboniferous Unconformity</i>						
Carboniferous						

Stratigraphic succession and facies for the Cadeby Formation and adjacent strata in the locations visited . (not to scale)

Reproduced from TYMON et al., 2017, PYGS vol.61 part 4, fig.3,
by kind permission of the Council of the Yorkshire Geological Society.

A short walk, crossing the road that skirts Bramham village and Park, took us to our first location, Bowcliffe Wood Quarry. We entered the gated wood, the floor of which was deep in slippery and pungent garlic, to examine an exposure of the Hampole Beds in the main face of the old quarry (evidenced by old drill marks). It comprised well bedded, thin, hard beds of buff coloured dolomitic limestone with evidence of bryozoan patch reefs, separated by soft, thin, clay layers (see photo opposite). The rocks have undergone diagenetic changes and also been invaded by percolating fluids depositing calcite and barite. These were seen to great effect in the road cutting opposite the wood where well developed veins of barite have formed allowing some fine specimens to be collected.

A short drive, passing through the village of Clifford which shows good use of local stone, took us to Deepdale in Boston Spa where we met in the car park of the Community Centre in Deepdale Lane. Here Jeremy introduced us to our archaeology leader, Malcolm Barnes, who, with the aid of his i-pad, outlined the long history of human occupation of the area including geological features modified by man, a Romano-British trackway, use of the well-drained land for both stock and crops as evidenced by strip fields and flints from the east coast which had been knapped for tools and weapons and later crushed for pottery use.



Clay and limestone of the Hampole Beds

Deepdale is a glacial meltwater gorge, cut through the Wetherby Member, which leads down to the River Wharfe where the limestone forms vertical cliffs, 7-10 m high. These display prominent algal reefs, evidence of solution and have many calcite vugs and shelly remains. The opposite side of the river consists of a broad flood plain and river terraces beyond which the beds forming the far cliffs belong to the Sprotbrough Member, indicating the presence of an (as yet) unlocated fault. Walking east along the top of the river bank cliffs, very steep in places, we scrambled down to West End Quarry (1768 carved in the face). Here the Wetherby Member has developed reef structures and contains many pisoids (see photo back cover), suggesting deposition in a high energy environment, as well as reef debris and remains of gastropods.

After lunch adjacent to Boston Spa Church we walked down the very appropriately named Hampole Way to our third location, Holgate, a glacial run off channel cut through the clayey and sandy limestones of the Wetherby Member and widened for access to the ford crossing of the River Wharfe. The walk continued eastwards along the riverbank and under Boston Spa bridge (5 arches, built 1770, replacing the ancient ford). About 350 meters downstream from the bridge beds of the Wetherby Member dip at 12 degrees suggesting a monocline, close to the now inaccessible Spa Wells mineral springs. Crossing the bridge we turned east to Thorp Arch Holloway, again a run off channel widened for access to the ford. The well laminated Sprotbrough Member beds that form the river cliff here contain fossilised worm burrows, often with mineralised outer walls standing proud of the surface.



The Permo-Carboniferous Unconformity at Newsome Bridge

Returning to our cars we then drove to the Riverside car park in Wetherby and walked to our fourth location to view the horizontal Sprotbrough Member beds exposed in the cliffs, the bottom of which show about half a metre of the top of the Hampole beds with a narrow marl band visible near the base. The dolomitic limestone of the Sprotbrough Member shows cross-bedding, mineralised vugs and worm burrows as well as containing a lens of breccia, up to 600mm thick, indicating a flash flood event that brought Carboniferous debris in from desert pavements to the west. Karstic erosion surfaces are evident showing a period of exposure of the sea floor. Under the old A1 bridge red coloured marl of the Edlington Formation is exposed showing that the top of the Cadeby Formation has been reached.

Our final location was Newsome Bridge Quarry adjacent to the River Crimple between North Deighton and Spofforth to view the Carboniferous / Permian unconformity. (see photo above) This shows a mostly clean swept, domed erosion surface composed of massively bedded, coarse grained, Namurian sandstone, the Upper Plompton Grit, overlain by the Cadeby Formation. This is largely massive and is inferred as a bryozoan -algal reef. Laterally it becomes crudely and thinly bedded soft dolomite with ooidal and pisoidal grains. There is evidence of diagenesis with percolating fluids forming well developed mineralised cavities. At the eastern end of the quarry large, angular fragments of the Plompton Grit resting at various angles, are incorporated into the bottom layer of the Permian rocks.

Our day concluded with thanking Jeremy for a most informative and enjoyable day.

Roundhay Park Geology Trail

Wednesday evening 9th May

Leader: Bill Fraser

Present: 5 members and 9 visitors

This meeting was an LGA contribution to 'Yorkshire Geology Month' co-ordinated by the Yorkshire Geological Society and was also included in 'GeoWeek 2018', a new event co-ordinated by BGS. Both these events aim to encourage people into earth science and this is the level at which the walk is pitched. It had also been advertised by The Friends of Roundhay Park (with whom the trail was developed) so it was pleasing to see a good turnout of non-members.

The group followed the marked trail which is explained in the booklet 'Roundhay Park: A walk back in time' with plenty of discussion at all 10 points meaning that the 2km walk took around 2.5 hours. Let's hope that some of those visitors translate to members of the future.



***Brachyphyllum mamillare* collected in 2014 by Paul Kitson**

Yorkshire's Jurassic World exhibition - Yorkshire Museum Thursday 7th June

Leader: Dr Sarah King, Natural Science Curator, Yorkshire Museum

Present: 5 members

Meeting at the Museum entrance the group spent time examining some interesting stones on the terrace walls before moving inside where our Field Visit Secretary negotiated an entrance fee at a very reasonable rate. We then spent the next 45 minutes perusing the excellent specimens of the exhibition which cover all aspects of life during the Jurassic Period and are supported by display panels that clearly inform visitors about conditions at this time. Meeting up with Dr King she explained the rationale behind the exhibition, some of the work that had to be carried out to the building for it to be set up, its layout and the source of the specimens.

The exhibition came about as it was felt something new was required to boost footfall. A fairly recent find of a sauropod vertebrae (which has proved to be possibly the oldest in the UK) and the development of a 3D interactive package were felt to be a good core to an exhibition that would allow the museum to display more of its large collection of Jurassic fossils. The exhibition is laid out to first, in what is titled The Discovery Hall, introduce visitors to the concept of geological time. This room had to be slightly modified to accommodate the exhibition. One specimen that certainly attracted our attention here was that of the 4.5 billion year old 'Middlesbrough Meteorite' which landed in a railway yard on the afternoon of 14 March 1881, yards from where a group of men were working. Fortunately Victorian scientists recognised the importance of this and it was recovered from the soft ground where it fell as well as a mould being taken of the (surprisingly small) impact crater. While the British Museum wanted it for their collection the NE Railway Company deemed that, because it fell on their land, it was 'lost property' and insisted it stayed in Yorkshire!

The majority of the specimens in the display belong to the museum but where there are gaps in the local record these have been filled with specimens from other parts of the country. The museum collection has been built up over many years and comes mainly from donations. A great example of this is in a display that features life on land during the Middle Jurassic where, amongst specimens of dinosaur footprints, is a large block of sandstone covered with plant fossils (see photo previous page). The specimen label identifies this as ***Brachyphyllum mammilare*** and was collected in 2014 by Paul Kitson, an LGA member who, on our visit to Whitby led by Dr Liam Herringshaw with

Sarah King in attendance in August 2013, had first become aware of plant fossils in this locality. Paul kindly provided the following account of the visit and subsequent events:

“Even though I had been collecting fossils at this location for a long time, I was unaware of the plant fossils that could be found at the base of the cliffs in this small section. (Maybe a bit of “tunnel vision”, as my main interest is the many different species of ammonites found along this coastline.) Once it was pointed out what could be found there I started examining some of the fallen blocks of sandstone and was lucky to find a large slab that clearly contained plant fossils. Liam was the first to spot the significance of what I'd found. He said they were what looked like small pine cones in two distinct sizes that may indicate male and female of the species. He called Dr Sarah King over to look. Once again luck was playing its part, not only was Sarah the collection facilitator at the Yorkshire Museum, but her field of expertise is plant fossils. Sarah and her friend Leyla, who was also a paleo-biologist, examined the specimen which they said showed very unusual preservation and that they had not seen anything like it before. I asked them if they would like to keep the specimen and Sarah explained the formal procedure at the museum for accepting new items. I dropped off the fossil at the museum and received an email from Sarah thanking me again for bringing the specimen in and agreeing to donate it as it was such a good one and that they didn't have anything like it in their collection. In May 2014 I returned to the location and among the 13 plant fossils that I collected were two more large slabs containing the same pine cones.”

Paul also donated these to the Museum and It is one of these that appears in the current exhibition. It first went on display in 2015 in the entrance foyer of the museum but then, in 2018, Paul was told it was going to be included in the new exhibition and asked if he would like to have his name included on the label. Following his positive reply he received an invitation to (and attended) the official opening of the exhibition on 23 March which was carried out by Sir David Attenborough.

After thanking Sarah for her time and her inside knowledge of museum exhibitions we then moved upstairs to view the William Smith Room before members made their various ways back home.

A walk on the banks of the River Don and Wharnccliffe Craggs

Saturday 28th July.

Leader: Gareth Martin, Leeds Geological Association & West Yorkshire Geology Trust

Present: 5 members

The purpose of this visit was to examine contrasting palaeo-environments in two late Carboniferous (Pennsylvanian), Pennine Lower Coal Measures Group sandstone formations; the Loxley Edge Rock and the Wharnccliffe Rock. We met on a bright and breezy morning on the banks of the Don at Deepcar despite the misleading road closure signs encountered en route. Before leading us to the first exposure Gareth explained how he had come across the sites in the course of his hydrological work on the Don and that, despite their outstanding features, there appears to have been very little formal study of the rocks.

A short walk along the banks of the River Don, which here flows in a pronounced gorge, brought us to the first exposures of the lower of the two formations to be examined, the Loxley Edge Rock. These were the lower part of the Formation and found to be well bedded, fine to medium grained, buff



Intensely burrowed sandstones at the base of the Loxley Edge Rock

coloured sandstones with thinner layers of siltstone. The striking feature of these rocks was their degree of, what were taken to be, burrows. (see photo opposite). These occurred in the sandstone layers and some penetrated the full 15-20 cm thickness of the beds. Discussion took place as to the organisms that may have created these and the environment which the beds represent. The nature of the beds, the burrows and the long wavelength, symmetrical ripples that also were seen, suggest these being crevasse splays forming temporary lakes in which the sediments settled.

Moving further along the river bank brought us into a substantial, but overgrown quarry, opened in the Loxley Edge Rock above the beds previously seen. The vertical back wall of the quarry was up to 15m high and, as the rocks dipped gently to the north, the two exposures allowed examination of the full thickness of the Formation, estimated to be here approximately 20-30m thick. In the quarry the sandstone was of medium to fine grain size and quite micaceous but the units much thicker than in the previous outcrop and with no sign of any burrows. Good examples of low angle cross-bedding and scouring were displayed which, together with the massive bedding and lack of any burrows, suggest a change to a main river channel environment as opposed to the low energy lake of the underlying beds.

Climbing out of the quarry we then made our way up hill through woodlands passing several small ponds, channels, trackways and railway lines that are probably remains of earlier mining and iron industry. Clearing the wooded area we found ourselves standing on Wharncliffe Crag which commanded fine views of the heavily wooded Don Valley and moorland tops with the steel works at Stocksbridge in the middle distance.

The Crag is created by the Wharncliffe Rock which lies above the Loxley Edge Rock with the ground between being made up of mudstones and thin coal seams. They form a prominent cliff line, approximately 15m tall, which represents the thickness of the Wharncliffe Rock. This was very different to that seen in the previous exposures, consisting of massive, cross-bedded units of extremely coarse grained, poorly sorted sandstone with some very interesting structures caused by some beds having been distorted prior to lithification. (see photo overleaf) Some of this may have been due to slumping on the cross-bedded surfaces but the most dramatic were sand volcanoes formed during dewatering of the unconsolidated sediment. While many (of various sizes) were seen in cross-section there were also some particularly fine 3D examples on fallen blocks. One in particular took the form of a mould and cast (see photo on front cover) and beautifully preserved the size and shape of the original structure which must have stood at least 30 cm tall. These features show that the Wharncliffe Rock was formed as a result of rapid deposition in deep, high energy river channels, a marked contrast to the

much lower energy environments of the underlying Loxley Edge Rock.

At this point Gareth was thanked for such an interesting visit and the group returned to their vehicles, reaching them just before the forecast rain showers appeared.



Distorted bedding at Wharncliffe Crag

The Geology of Graves Park Sheffield

Sunday 5th August

Leaders: Dr Andrew Howard. Honorary Research Associate, British Geological Survey, President of Yorkshire Geological Society. Professor Colin Waters. Honorary Professor. University of Leicester. BGS retd.

**Present: At the invitation of the Yorkshire Geological Society
2 LGA members joined this field meeting**

Our two leaders explained that for many years they had taken new recruits to the BGS mapping team into the countryside to give them some extra practical training after they had finished their degrees. In 2001 the Foot and Mouth epidemic prohibited access to their favoured areas of the Pennine Lower Coal Measures so Graves Park was introduced as a stop-gap training ground. It was subsequently used for training for many years, partly because of ease of access but also because it provided realistic experiences for BGS geologists working on urban projects. Also it became a proving ground for techniques of high-precision geological mapping and for the development of digital data methods using tablet PCs which are now widely used in BGS international programmes.

The Park lies on the southern limb of the Norton-Ridgeway Anticline with typical dips of 5-7° to the S or S.E. The bedrock geology of the Park is mainly formed by two resistant sandstone beds creating a staircase appearance on the hillsides. These are the Greenmoor Rock and the Grenoside Sandstone as well as a minor, unnamed, distributary mouth-bar sandstone, all with their associated mudstones and siltstones. We walked around the large park accompanied by loud fairground music to look at the expressions of the geology in the landscape and to examine the sandstones where they were exposed in quarries and in streams.

The uppermost sandstone was the Grenoside Sandstone, fine-grained, grey and very micaceous, showing it was derived from an eroding young mountain range lying to the north. The lower named sandstone was the Greenmoor Rock, very fine grained with greenish grey colouring and containing less and smaller pieces of mica. The colour is due to chloritic clay minerals from low grade, green-schist metasediments in a source area to the west.

The smaller distributary sandstone at the very top, draped over the Grenoside Sandstone, was of a similar content and source as the Greenmoor Rock though we didn't actually see it exposed. We were told the main sandstones are topped by important coal seams. In the quarry where lunch was taken we looked at the styles of deposition which showed good climbing ripples and

plant material. The landscape was a series of three gentle dip slopes ending in steep scarps which, in places, were over emphasised by quarrying. Walking out of the Park we were able to see how this landscape could be related to the surrounding urban landscape and the complicated topography of hilly Sheffield.

Returning to the Park we undertook some practical field work. First we were asked to take readings with a pocket sized surveying tool which resulted in mixed degrees of success. We were then taken to a large open area that lay near the extension of a 4 metre fault we had seen earlier in the stream bed and asked for our thoughts as to where it was in the landscape which resulted, again, with very differing ideas being offered as to its direction and effects.

It was a very interesting day in the field, with the benefit of very experienced leaders and the YGS are thanked for the invitation.

Claxheugh Rock, Ford Quarry and Castletown, Sunderland Saturday, 1 September

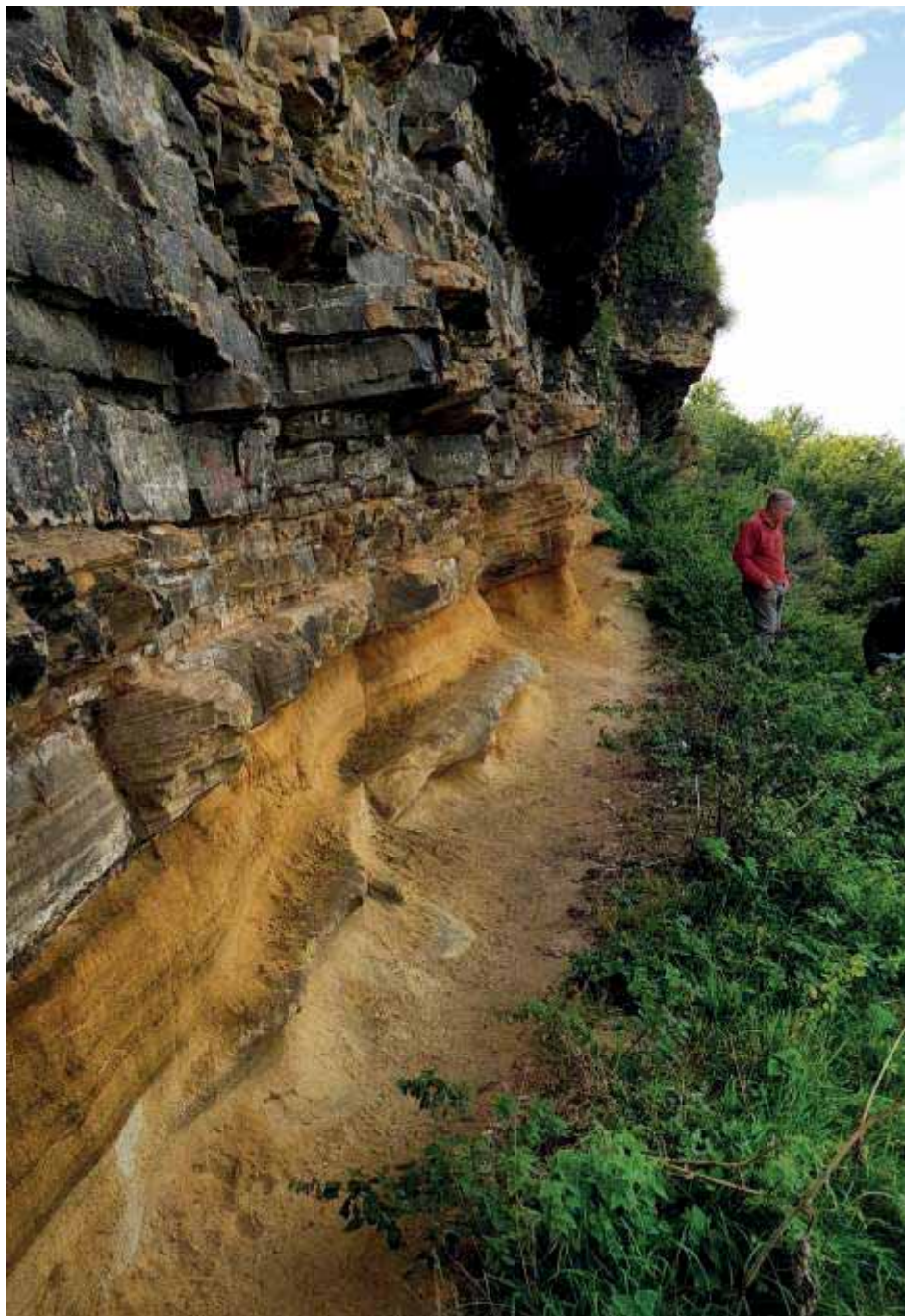
Leader: Dr Michael Mawson, Durham University
Present: 5 members and 2 visitors

We met on the banks of the River Wear at South Hylton on the western edge of Sunderland where Mike, who had provided superb handouts, pointed out some of the key features of our visit; the impressive monolithic Permian exposure of Claxheugh Rock, the exposures of the Permian Yellow Sands Formation and the Upper Carboniferous Coal Measures sandstones on the northern bank of the river. These exposures occupy a downward faulted block separated by two NW-SE trending faults. Mike also acknowledged the immense contribution of the legendary Denys Smith to our understanding of the Permian.

After an ascent up a steep, wooded slope we reached the exposures at the base of Claxheugh Rock. Standing on a relatively narrow edge with ~20m of rock above, Michael detailed the palaeogeography of the Zechstein Basin, a landlocked basin formed after the Variscan Orogeny. The basin was split into northern and southern sub-basins and the UK Zechstein deposits formed on the western margin of the southern basin. The base of the exposure (see photo overleaf) shows ~1.5m of the Yellow Sands Formation, a weakly cemented and well-sorted, windblown sandstone consisting of rounded quartz grains, deposited in the basin in an arid desert environment. The sands form at least ten, large (kilometre-scale) linear ridges aligned roughly NE-SW, with this site being situated on the crest of one of them. The sands showed a wide range of structures, including cataclastic fracturing. The importance of the rock was highlighted with the Yellow Sands Formation equivalent (Leman Sandstone) holding the Dutch Groningen Field, the largest gas field in Europe.

Directly overlying the Yellow Sands Formation here is ~1.2m of the metal-rich and commonly fossiliferous Marl Slate, a finely laminated, organic rich, calcareous mudstone which was deposited during the marine transgression that formed the Zechstein Sea. Due to this transgression the top of the Yellow Sands Formation is commonly reworked and burrows in the top 0.1m of sand at this exposure show this. The transgression occurred rapidly and counting of the individual paired layers in the Marl Slate suggests it was deposited in ~18,000 years.

Overlying the Marl Slate is ~3m of well bedded, muddy, middle ramp carbonates of the Raisby Formation which were deposited between fair-weather and storm wave base in a low energy marine environment. The Raisby Formation shows gentle folding due to compactional drape over relict dune topography, preserved at the top of the Yellow Sands. Overlying the



The Yellow Sands Formation at the base, overlain by the Marl Slate with Raisby Formation and massive Ford Formation reef forming the overhang.

Raisby Formation is the reefal Ford Formation comprising fore-reef (with clinoforms) as well as massive reef facies. The reef, which has a framework composed of bryozoans, shows E to SE basinward progradation. A large overhang surface at the contact between the Raisby and Ford Formations represents a submarine slide plane (the Downhill Slide) formed by gravitational collapse of the Raisby carbonate platform after a widespread sea level drop. The plane is equivalent to the Hampole Discontinuity in Yorkshire. On the underlying bedding plane are linear grooves indicating E-NE movement of the slide into the basin. The slide blocks are exposed at Trow Point on the coast ~9km to the NE. The slide plane cuts downwards into the underlying rocks leaving the Ford Formation directly overlying the Yellow Sands Formation at the eastern end of the site.

After a short walk we stopped at the top of Claxheugh Rock for lunch. Here we were treated to magnificent views over the surrounding area, with the wider topography indicating the continuation of the reef to the north. Mike noted the reef can be traced for ~30km southwards to where it is present in the subsurface beneath Teeside.



The massive reef facies of the Ford Formation on the left with bedded lagoonal facies overlying it and to the right.

After lunch we visited Ford Quarry. Here a beautiful ~12m high cross-section through the Ford Formation reef is exposed (see photo previous page). Bedded lagoonal and back-reef facies pass laterally into the massive reef facies of the Ford Formation at its western end, these facies eventually overlying the upper surface of the reef. The reef exhibits a “fall-in geometry” where the reef crest is at a lower elevation than the lagoon and back-reef behind it. This was formed by the reef growing eastwards down the slope of the pre-existing Yellow Sands draas (large scale dune bedforms) into the basin. Mike passed round cut examples of the different rocks from the quarry and prior to leaving the quarry we searched for (and found) examples of fossil nautiloids.

After a short drive to Castletown on the north bank of the Wear and a scramble down a steep bank onto the muddy foreshore we were treated to some superb ~5m high exposures of the aeolian Yellow Sands Formation at the type area of the rock. The exposures showed laminar and cross-bedded units representing deposition by grain fall and flow (settling out and avalanching). Of great interest here is the fact the sands lie on reddened sandstones of the youngest Carboniferous (Westphalian) Coal Measures strata exposed in the Durham coalfield, an unconformity of 40 million years (see photo below).

After a brief scramble back up the river bank we ended the trip, all offering warm thanks and huge appreciation to Mike for another outstanding walk full of amazing geology.



The Permian-Carboniferous unconformity between the Yellow Sands Formation and underlying reddened Carboniferous sandstones.

North Norfolk Coast Residential 28-30 September

Leaders: David Waterhouse, Senior Curator of Natural History, North Norfolk Museums. Peter Hoare, Visiting Academic, The British Museum, Hon. Senior Research Fellow, Queen Mary Univ.

Present: 13 Full Members, 2 Associate Members, 3 Guests

Early arrivals in Cromer on Friday took the opportunity to visit the local museum where they were able to view some of the spectacular fossils that the Quaternary deposits of the North Norfolk coast have yielded over the years. The next morning we drove a short distance west of Cromer to meet our leaders for the weekend, Peter Hoare and David Waterhouse. At Wiveton Downs SSSI, under blue skies and a warm sun, Peter outlined the plan for the two days. We would be visiting 6 separate sites between Happisburgh in the east and Morston in the west to view a range of glacial and related sediments and structures that ranged in age from around 1 Ma to 18Ka. In describing some of the problems associated with these deposits he stressed that there was more 'gap than record' of these upper Quaternary times and that there were problems of establishing accurate ages of some of the sediments.

The car park at Wiveton turned out to be on the top of a section of the NW to SE aligned Blakeney Esker which is 3.5 to 4 km long, varies in width from 40 to 100 m, is up 20 m high and claimed by many to be best example of such a feature in the UK. In the recent past there has been quarrying and gravel extraction carried out along the length of the esker which has resulted in what must be a modified silhouette to that of the original. Traditionally the esker has been estimated at Marine Isotope Stage (MIS) 12, (~ 450 ka) but there are some current suggestions, based on OSL dating, that it may be significantly younger and belong to MIS 10 which is ~350 ka. Much of the esker was covered in dense gorse bushes but a small section had been cleared for us by the leaders to enable us to take a close look at the sediments. This showed coarse grained deposits consisting entirely of flint cobbles in a matrix of sand which had been transported beneath the ice before being deposited as a matrix supported mass. A faint imbrication could be seen in the cobbles which indicated that the water was flowing from NW to SE, ie driven upslope by hydrostatic pressure (see photo overleaf top). It was pointed out that the deposits near to the surface vary slightly from those below due to the effects of freezing and thawing, resulting in clasts being arranged with their long axes in a vertical manner.

We then moved on a short distance to the west to Bilsey Hill where a, now disused, pit had been opened at the start of World War II to provide aggregate for the construction of nearby RAF Langham, leaving a 20 m deep hole in the otherwise flat landscape. The deposit worked here was the same flint cobbles and sand of glacio-fluvial origin as seen at the previous location. Here though, instead of forming a positive feature, they are embedded within a thick deposit of glacial till which could be seen forming the walls of



Imbricate structure in glacio-fluvial material



Glacial and glacio-fluvial deposits in Happleburgh Cliffs

the quarry. Due to the large amount of chalk in the till it is very pale in colour and is known as the Marly Drift. Even where not exposed, clues to the chalk content of the till could be seen by the number of lime tolerant plants. This site is interpreted as being a point where sub-glacial streams carved a valley in the drift below the ice which was subsequently filled with the coarse grained, matrix-supported sediments. Further exploration around the site using ground penetrating radar has revealed that the gravels extend beyond the quarry in two channel shaped bodies.

Following a lunch stop in the pleasant Georgian town of Holt we drove to the coastal village of Happisburgh where the cliffs are composed entirely of soft glacial material of Anglian age (MIS12) which results in some rapid rates of erosion - up to 12 m /yr. Walking a short distance along the beach we came to a section which clearly showed a sequence of changing environments at the margins of the British Ice Sheet as deposits switched from glacial to glacio-fluvial ones (see photo opposite bottom). The base of the cliff was composed of a layer of dark-grey clay containing scattered clasts of flint and chalk. This was the Happisburgh Till Member, a lodgement till laid down at the base of a moving ice sheet as indicated by the crushed and streaked nature of some of the chalk clasts. Above this was a layer of finely stratified silts and clays, the Ostend Clay Member, that had been deposited in freshwater lakes. Next was a bed of sand which was rippled at its base but passed upwards into larger scale cross-bedding and interpreted as being a delta prograding into a lake. Both these beds indicate a retreat of the ice front but ice returned as they are overlain by a brown, sandy, matrix-supported diamicton, the Corton Till Member, which was deposited subaqueously from ice that had entered a lake. Again the ice must have retreated as this is overlain by another layer of cross-bedded sand, the Corton Sand Member, which again was deposited as deltas prograded into shallow lakes. A sharp boundary at the top of these with a pale coloured, silty clay, the Walcot Till member, shows another advance of ice. The majority of erratics in the tills are from local rocks and the North of England and Scotland with just a few from Scandinavia. The latter, larvikite and rhomb-porphyry from the Oslo Fjord, were most probably reworked from earlier ice advances.

Walking back along the beach we came to the important archaeological site where the oldest known hominin footprints outside of Africa were found in 2013. The site was known to be important as flint artefacts and cut bones had previously been recovered from here. Unfortunately (for us) the sediments in which they occur, laminated silts deposited as tidal flats on a river margin that lie beneath the Happisburgh Till seen earlier, were covered by sand but David had brought along a mould of one of the footprints that had been taken on site (see photo overleaf). This elongated depression, one of 49 recorded, clearly showed the arch, front and back of the foot as well as impressions of the toes. Various sizes of prints occurred on the surface which suggest a group of adults and juveniles ranging between 0.93 and 1.73 m tall and, by their orientation, following a southerly direction of travel. The only known human species in Western Europe of a similar age, foot size and height to these prints is ***Homo antecessor*** which has been found in Spain.



A step back in time - a mould of an early human footprint

Sunday

The party assembled on the cliff top at Overstrand before descending to the beach where we saw the main feature of this site; two large chalk 'rafts', each carrying a layer of the overlying, unconformable Wroxham Crag, embedded within the Happisburgh Till Member, and extending approximately 200 m along the cliff. The northern raft has been thrust over the southern one and while the rafts retain their integrity, they have each been folded into an anticline with flint bands (which show that this is Upper Chalk) highlighting the deformation (see photo below). The rafts are known to be the correct way up due to the presence of echinoids which are found preserved in their life position. The only species found in Norfolk is *Echinocorys scutata* of which David had brought along a fine example to show us. The rafts were emplaced as a cold-based ice sheet, frozen to the chalk bedrock somewhere off the current shoreline, moved south. This detached the blocks, which are approximately 10 m thick, along a plane of weakness before carrying them, along with their cover of Crag, inland an unknown distance, deforming them and lifting them above their original level to leave them embedded within the younger drift.

Pieces of the pre-glacial Wroxham Crag were examined where they had fallen to the beach. It is a coarse rock (see photo overleaf) composed of sands, gravels, silts and clays cemented by iron giving it a deep rust-red colour. It is a rock limited to eastern Norfolk and north-eastern Suffolk and was deposited on an eroded chalk surface in either an estuarine or near-shore marine environment at a time when sea levels were comparable to those of today.



Chalk rafts with overlying Wroxham Crag embedded in glacial drift



Fallen block of Wroxham Crag

The beach material here, as at the other sites along this coast, is largely of flint along with some glacial erratics. Flint originates in the Chalk but its formation is not fully understood. The source of the silica is sponges which were abundant in chalk seas. These needed to be dissolved before being precipitated around an organic nucleus to form a flint nodule.

After lunch in or near the cafe on the cliffs at West Runton we walked down to the beach. David was now carrying a large brown "bone" which raised a few eyebrows from passers-by. On the beach we walked to a low outcrop at the bottom of the cliff about 500 m away. This was the West Runton Freshwater Bed (WRFB), a layer of soft, dark brown, organic rich mud, the type site for the Cromerian Stage in the British Quaternary succession and estimated at around 700 – 600 ka. Here, following a storm in December 1990, the 'West Runton Elephant' was found. Its enfolding story was a truly interdisciplinary one and was recounted by David as we stood in the square remains of the excavation where the animal was found. The first find, by a couple walking their dog, was a hip socket which was identified as the pelvic bone of a large elephant. More large bones (see photo opposite) were revealed by another storm and the site was declared a SSSI. An exploratory excavation was carried out in 1992 followed by a major one in 1995 (during this time the site was guarded day and night) after which 85 % of the skeleton had been found enabling it to be identified as a male Steppe Mammoth, *Mammuthus trogontherii*, aged about 40, the largest and next to the



David with replica of one of the mammoth's tibia

oldest of the 4 elephantids which, over time, lived in this area. Being twice as big as the largest living elephants it needed a lot to eat. Experts from other geological disciplines were called in to produce a full picture of the environment in which this animal lived. Analysis of sediments, pollen, insects and other fauna show that the site was part of a braided river system, approximately one mile from the sea, with a southern Scandinavian climate and vegetation of grasses, oak, pine, and birch; so it too would have experienced the sharp wind and cool blue sky that we were. It is thought that the animal was injured, possibly in a fight, which dislocated its right knee, a serious injury for a 10 ton beast. There is some healing on the bones showing it lived for several months so did it hobble to the site, get stuck in the mud and die? While there is no evidence of hominids in the WRFB the carcass had been scavenged. Tooth marks on bones and coprolites recovered at the site would suggest Spotted Hyenas were the culprits. The skeleton is now stored in the Norwich Castle Museum where it is curated by David.

The final stop of the weekend was to look at the Morton raised beach in the Morton Cliff SSSI. This site is important as it is one of the few places in Britain where clear evidence of warm stage deposits separating glacial sediments have been preserved. The exposure is approximately 2 m high but Peter described how he and various colleagues had investigated it by digging and auguring (hard work in gravel!) to around 6 m. The visible exposure (see photo opposite) showed a thin layer of soil resting on a layer of weathered, reddish-brown, sandy mud which is identified as the Hunstanton Till of Late Devensian age (MIS2). These beds extend all around the NW Norfolk coast and show that ice from the north only just encroached onto the current coastline. If the ice had reached as far as the Blakeney Esker, which we had seen on Saturday, it would have been flattened by the surge.

Below the till, separated by a sharp junction and continuing to the visible base, were layers of matrix and clast-supported, well-rounded and sorted, gravels and cobbles. Below them, in the parts investigated by digging and auguring, are around 2 m of sands. The gravels and sands are beach deposits and have been found to contain well-preserved temperate pollen assemblages. Normally considered to have formed during the Ipswichian Interglacial (MIS 5e), OSL dating of the sands has given a considerably older age of MIS 7/6. The sands sit on a pale, calcareous, gravelly mud which is considered to be the same Marly Drift of Anglian age (MIS12) that we had seen the day before at Bilsey Hill.

At this point David Holmes warmly thanked Peter and David for providing us with such a well planned and executed visit which, along with their lucid explanations, enabled us to see such a detailed picture of more recent geological events than is our norm - and with such excellent weather. This was backed by all members of the group.



Raised beach deposits overlain by Hunstanton Till

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Pisoids in the Wetherby Member