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The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phases Priority 1 and 2

Geology and Landscape England Programme

Commissioned Report CR/06/012



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND LANDSCAPE ENGLAND PROGRAMME

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The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phases Priority 1 and 2

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Front cover

Roade cutting, looking north – west from Bridge 209 (P693582, *Photographer P Witney*).

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) of the geology of strata exposed at Roade railway cutting in Northamptonshire, during the first and second of three phases of engineering works. It was commissioned by Network Rail, through its subcontractors Birse Rail and EDGE Consultants, at the behest of Natural England (formerly English Nature).

Roade cutting cuts through an almost complete sequence of the Bathonian (Middle Jurassic) strata occurring in the East Midlands, and as such is probably unique in the region. It has been afforded Site of Special Scientific Interest (SSSI) status on geological grounds, and hence has certain protections administered by English Nature. The cutting lies on the main railway lines between London, and Birmingham and Northampton.

Engineering works deemed necessary for safety by Network Rail will render very difficult any future access to much of the exposed strata here and Natural England have required Network Rail to commission a re-description of the geology. The study included measuring and making descriptions (logging) of the exposed strata in the cutting sides at the available sections, collecting rock and biostratigraphical samples for further description and determination, and close-up and systematic distant photography.

Logging and close up photography was undertaken by M A Woods, A J M Barron and T H Sheppard, systematic photography by P Witney, and biostratigraphical determinations by B M Cox (macropalaeontology; formerly of BGS) and J B Riding (palynology).

In addition to the contractual tasks, BGS funded laser-scanning of parts of the cutting, to make a 3-dimensional model. This was undertaken by P R N Hobbs and D Boon, with processing by L Jones and B R Napier.

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The authors would like to thank several staff at the Roade cutting site, including J Dunn (Birse Rail) and M Wilkinson (CAN).

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Summary

This report describes the geology of the bedrock strata exposed by engineering works between 2005 and 2006 and made available to BGS at the Roade railway cutting, near Northampton. The strata, totalling about 8.5 m in thickness, belong entirely to the Blisworth Limestone Formation of the Great Oolite Group, which is of Middle Jurassic age, but the base and top of the formation are not exposed. The report includes text and graphic sections of the localities examined, a plan of the cutting showing locations and the distribution of the strata, close-up photographs of the bedrock exposed, and photographic panoramas of the cutting sides.

1 Introduction

This report describes the geology of the bedrock strata exposed by engineering works in 2005 to 2006 and made available to BGS at the Roade railway cutting, near Northampton (Figure 1). The strata belong entirely to the Blisworth Limestone Formation of the Great Oolite Group, which is of Mid Jurassic age. The report includes text and graphic sections of the localities examined, a plan of the cutting showing locations and the distribution of the strata, close-up photographs of the bedrock exposed, and photographic panoramas of the cutting sides.

The cutting – almost 3 kilometres long – goes through an almost complete sequence of the Bathonian (Middle Jurassic) strata occurring in the East Midlands, and as such is probably unique in the region. These rock strata are a sequence of fossiliferous limestone, mudstone and sandstone beds, overlain in places by clayey Quaternary glacial deposits, and were geologically described when the cutting was widened at the turn of the 19th century. However, the softer mudstone and sandstone beds and the clay deposits are now obscured by retaining walls or soil and vegetation and only the limestone-dominated portion of the sequence is now exposed – which is entirely within the Blisworth Limestone Formation. This forms mural exposures up to 6.5 m high, at angles of between 45 and 60° and some hundreds of metres in length along the lower portions of both north-east and south-west faces of the cutting. The strata are more-or-less flat lying, and are generally not affected by any disturbances (faulting or folding).

The Blisworth Limestone Formation is a sequence of relatively well-bedded, pale-coloured fossiliferous, bioclastic and peloidal limestones, with subordinate intercalated darker grey sandy and bioclastic mudstone beds in the lower part. Its macrofossil content is largely facies-controlled, is dominated by bivalves, and is of limited biostratigraphical value. However, the fauna includes some brachiopods, and these, together with the vertical changes in lithology, may enable the division of the formation into two members – the Roade Member below (named after this cutting), and the Irchester Member above.

All National Grid References fall in 100-km square SP, and are given in square brackets.

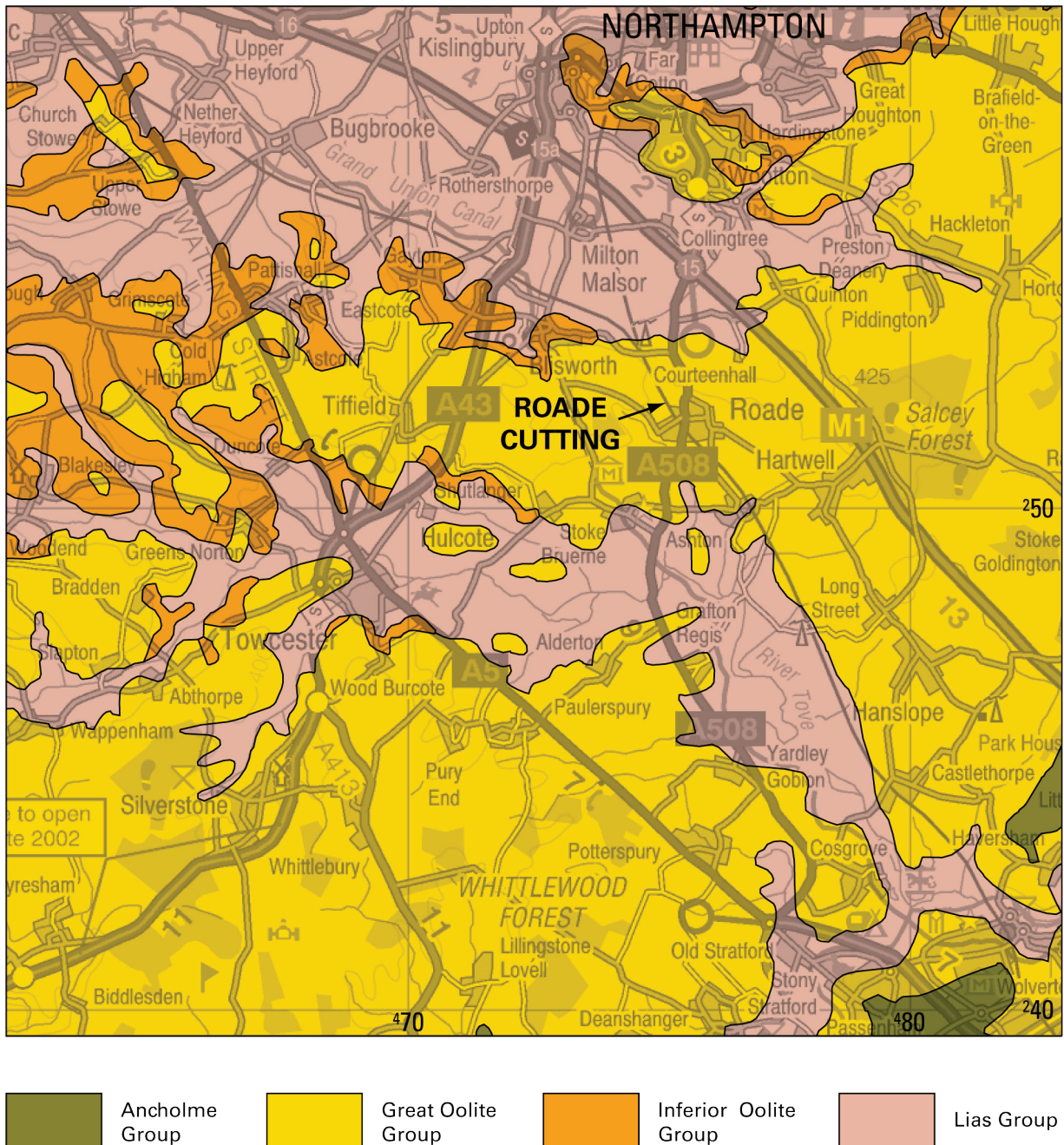


Figure 1. Regional location map showing simplified bedrock geology

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2 History of geological studies

During previous engineering works, part of Roade cutting was examined and described around one hundred years ago by a respected Northamptonshire geologist (Thompson, 1924). His principal account describes the rocks exposed north from Bridge 210 (his Bridge 3), and the bedrock formations visible then ranged from the Upper Lias (now termed the Whitby Mudstone Formation of the Lias Group (Lower Jurassic)), upwards through the Northampton Sand (now a Formation of the Inferior Oolite Group (Middle Jurassic, Aalenian)), the Lower Estuarine Beds and Upper Estuarine Beds (now Rutland Formation), Great Oolite Limestone (now Blisworth Limestone Formation), Great Oolite Clay and Forest Marble (now Blisworth Clay Formation) and Cornbrash (now a formation; all of the Great Oolite Group (Middle Jurassic, Bajocian to

Callovian)). Thompson also named many of the beds or groups of beds. The bedrock strata were recorded as overlain throughout by Glacial Beds of 'chalky boulder clay' (now known as Oadby Member (till)) and gravel or sand (Pleistocene in age).

Torrens (1967), in his account of the Great Oolite Limestone (Blisworth Limestone Formation) of the Midlands, reproduced part of Thompson's 1924 description, renaming some of the beds, and also describes a nearby quarry at Blisworth [715 533] commenting "This section [Roade] shows numerous separable divisions within the Great Oolite Limestone...These sections also show the rather bewildering changes in lithology and faunas which take place over short distances in this formation. The Roade and Blisworth sections are only just over 2 miles apart yet correlation in detail is almost impossible".

Thompson's account was recently recounted and lithostratigraphically reclassified (as above) by former BGS geologists R J Wyatt and M G Sumbler (Cox and Sumbler, 2002) with further information and commentary.

3 The current project

3.1 OBJECTIVES, METHODS AND PRODUCT

List below is from the scope document provided to BGS by English Nature (now Natural England) on 6th October 2005.

Objectives:

- Provision of a modern description of the geology of the site with particular reference to the lithostratigraphy, biostratigraphy and palaeontology of the site.
- Identification of any areas of the site that contain features that are particularly critical for the understanding/interpretation of the geology of the site, both within the context of the site and more broadly on a regional, national or international scale.
- Identification of exposures that would be visible from viewing points (e.g. over-bridges) and show characteristic or representative sections through the stratigraphy.

Methods:

Details need to be agreed between Network Rail and BGS, but are likely to involve the presence of one or more geologist on site, recording, sampling and collecting material from cleared exposures.

Timing and health and safety issues to be agreed between Network Rail and BGS.

Product:

- Report documenting the geology of Roade Cutting SSSI. To include.
 1. Scaled plans of the cutting showing the distribution of the strata and any other structures such as faults if identified..
 2. Graphic logs of sections recording lithologies, sedimentary and biogenic structures, and faunal assemblages.
 3. Brief and preliminary assessment of the site in terms of its biostratigraphy and sequence stratigraphy.
- Recommendation of areas within the cutting that would provide visible and typical sections through the stratigraphy that might be retained without mesh.

Natural England provided further guidance on 3rd September 2008, including:

- **Network Rail** will employ a suitably qualified geologist(s) to survey geological features exposed during the Phase [Priority] 1 initial clearance works. The draft specification provided in e-mail by **English Nature** on 21 September 2005 should form the basis for the scope of the initial survey.
- A photographic record of the geological features exposed during the initial Phase 1 clearance work; and detailed “hands on” survey of those exposed areas, subject to access and health and safety issues.
- It is expected detailed surveys are undertaken of at least 50% of exposed areas within the constraints of availability.
- In order to optimise this availability **Network Rail** will employ 2 geologists and a palaeontologist to work concurrently.
- Detailed analysis of results is not part of this survey. The objective being to survey and record in the time available on the site, during the possession.
- Subsequent to the survey the report will be relinquished to **English Nature** to disseminate under the acknowledgement that it is at the courtesy of **Network Rail**.
- **Network Rail** bears no responsibility for the accuracy of the contents of the report.

3.2 CUTTING LAYOUT AND ENGINEERING PROJECT

Road cutting is in total 2800 m long (i.e. about 5600 m of cutting sides), and up to 23 m deep (from Thompson’s figures). The cutting holds four rail lines: Up and Down ‘Fast’ lines from London Euston to Carlisle – the ‘West Coast Main Line’ – known in short as **LEC**, on the south-west side, and Up and Down ‘Slow’ lines from Hanslope junction to Northampton and Rugby – the ‘Northampton Loop’ – known as **HNR**, on the north-east side (see folded plan in wallet). There are overhead high-voltage electrical lines on gantries. The bridges are numbered by Network Rail outwards from Euston, and north of Bridge 210, the level of the HNR lines fall, such that the cutting becomes much deeper than on the LEC side, until the HNR lines split off into a separate cutting. It is here that the stratigraphically lowest beds were exposed and viewed by Thompson.

The current engineering project lies between Bridge 208 in Roade village, and Bridge 210, which is 830 metres to the north-west (Figure 2). The works include netting over the steeper parts of the cutting sides to prevent rockfalls, and will render very difficult any future access to much of the exposed strata here. The cutting sides were divided up into lengths designated as Priority Netting 1, 2 and 3 (in yellow, pink and brown respectively on Figure 2 and the folded plan). These comprise eleven separate sections of cutting sides with a total length of about 1034 metres (as indicated on Drawing No. 473.17B/002 as supplied to BGS on 7/10/2005). Four are on the north-east (HNR) side and seven on the south-west (LEC) side.

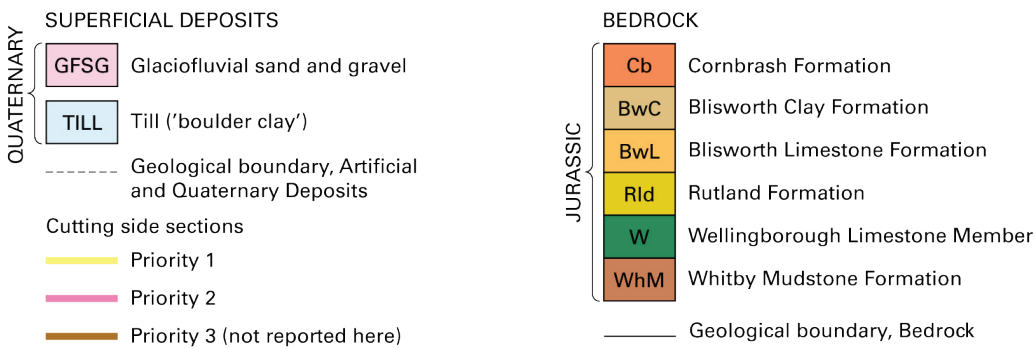
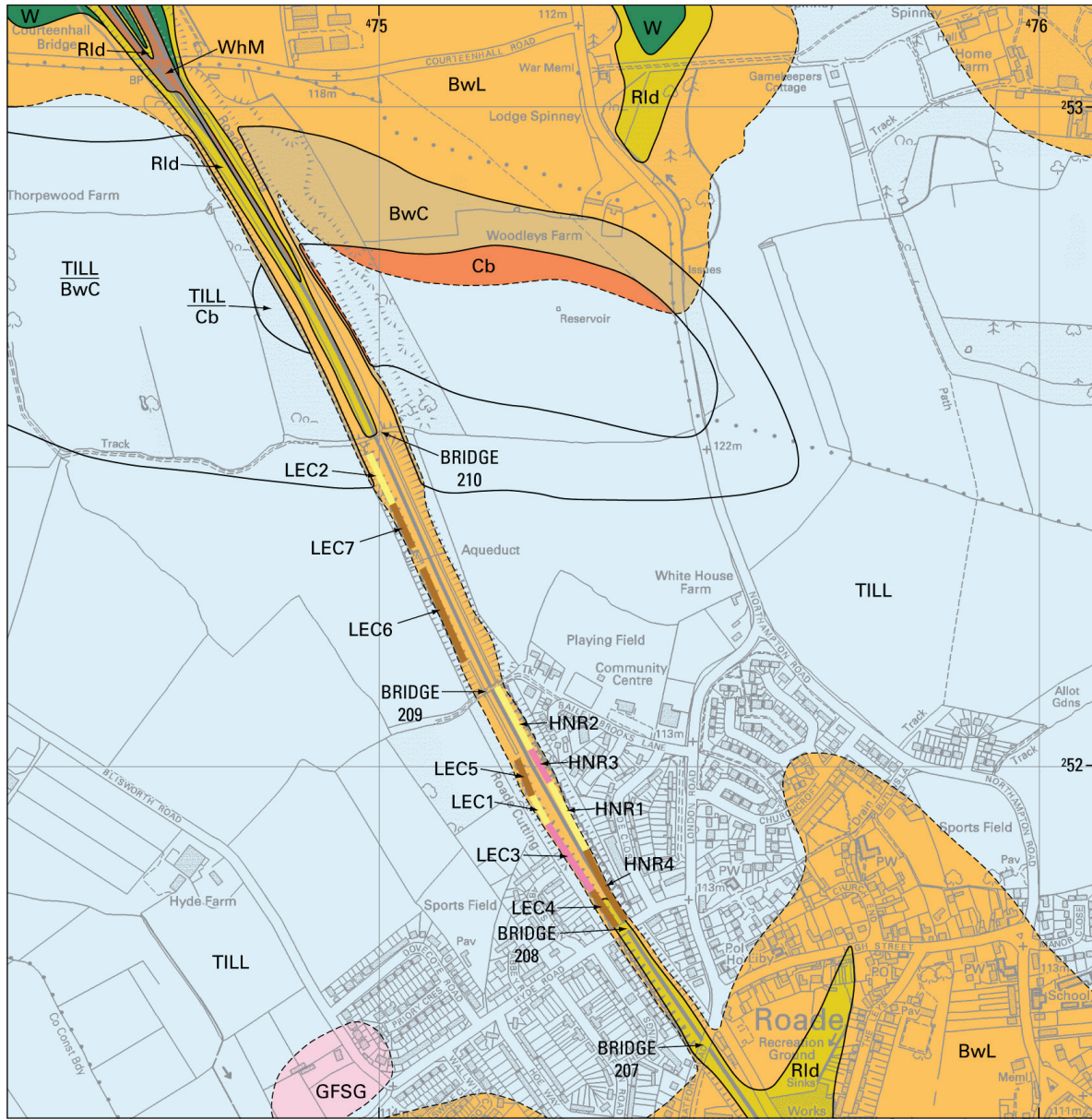


Figure 2. Roade cutting geology map with section locations

Geological mapping BGS © NERC. OS topography © Crown copyright 100037272/2010.

3.3 GEOLOGICAL STUDY PROJECT

BGS were commissioned through EDGE Consultants (as a contractual intermediary) to report on the strata exposed by devegetation and descaling (removal of loose soil and rock) in the cutting

sides. Due to circumstances outside the engineering and geological study projects, only Priority 1 and 2 sections were worked on in 2005 and 2006, and then they were both suspended/postponed. On resumption in 2010, the contractual intermediary had changed from EDGE Consultants and an entirely new contract was placed. Thus the present report has been prepared to fulfil the original contract to EDGE, and reports on the geological study of Priority 1 and 2 sections (plus the photographic campaign and a laser-scanning exercise). This involved work on six sections of cutting sides with a total length of about 527 metres. Three are on the north-east (HNR) side, numbered here HNR1 to HNR3, and three on the south-west (LEC) side, LEC1 to LEC3 (Figure 2).

The localities which were logged generally had to be further cleared or dug out by BGS before being measured, described, photographed close up and rock and fossil specimens collected. These are further numbered e.g. **HNR1Loc2**, **LEC3Loc1**, and the descriptions below are related to these. Bed numbering is provisional, and localities may have a unique number sequence, prior to completion of logging of the entire cutting, when a unified scheme may be erected. In addition, the intervening lengths of cutting side were examined as far as possible from line-side to draw correlations between the localities, and guide the annotation of the panoramas.

The results are presented below as locality by locality text logs, graphic logs, fossil and rock specimen lists and close-up photos (4.2 to 4.11), and as a scaled plan of the cutting showing the positions of the localities with correlation lines drawn between numbered beds. The panoramas are annotated with the logged localities and bed correlation lines (section 6). All specimens collected (numbers commencing WMD) and photographs taken (official numbers commencing P) are registered and retained by BGS.

In addition, BGS at our own expense conducted laser-scanning of both sides of the cutting at HNR1 and LEC1. A brief description and images from this are also presented (Section 5).

The authors have also published an article on the project in *Geology Today* (Woods et al., 2007).

3.4 ACCESS PROVISIONS AND TIMING

For rail operational reasons, access for any work to the lower parts of the cutting sides, which at the base are about 3 m from the nearest railway running track, was restricted to periods of a few hours at weekends, commonly early on Sunday mornings. Special facilities were provided by Birse Rail (a man-riding basket on the telescopic arm of a road-rail vehicle - MEWP) to access the higher parts of the cutting sides, up to 7 m above and away from the track. BGS staff attended on the nights of 12th to 13th November 2005, 20th November 2005, 10th to 11th December 2005, 7th to 8th January 2006, and on the 19th February 2006. Total time trackside for measuring and making descriptions (logging) of the exposed strata at the available sections, collecting rock and biostratigraphical samples for further description and determination, and close-up photography was 25 hours. All work was at night, with varying lighting arrangements, except on 20th November, when work took place between 04:00 and 13:00 hrs; partly in daylight.

In addition, systematic photography of the cutting sides was undertaken on four occasions between 18th November 2005 and the 16th July 2007, in daylight from the crests of the opposite sides (under Network Rail supervision). This included not only the devegetated Priority 1 and 2 sections, but the untouched Priority 3 sections, totalling about 13 hours on site. These photographs were processed to build panoramas (see section 6 and pages 44 to 50), and are included on the enclosed DVD in annotated and un-annotated form.

4 Roade cutting: geological description

4.1 PHYSICAL CONTEXT

Thompson's account (1924) includes a diagram showing a longitudinal section along almost the entire cutting (his Bridge 6 (now Bridge 208) to beyond his Bridge 1), which indicates that between Bridges 210 and 209, the bedrock formations likely to be seen are the top of the Rutland Formation (with lower beds seen on the HNR side due to fall of rail), overlain by the full thickness of the Blisworth Limestone Formation (Thompson's beds 7 to 18), overlain directly by glacial till. However, from observations made during visits, it is evident that the top of the Rutland Formation is below track level here, as a result either of later addition of ballast, or because of errors in Thompson's observations or projections. Additionally, the upper beds of the Blisworth Limestone Formation above Thompson's Bed 10 (including the Coral Bed and the Plant Beds) were not seen at any of the sections visited. Along the entire length of the cutting, the upper parts of the sides are bevelled back to a low angle (about 15°) and are presumed to be underlain by clay-dominated deposits (Blisworth Clay and Cornbrash formations and glacial deposits). No strata are exposed here normally, nor as a result of the current engineering operations, and the presence of Blisworth Limestone beds above Thompson's bed 10 cannot be verified. In addition, the mudstone/clay and sandstone/sand-dominated lower strata, which include the Whitby Mudstone, Northampton Sand and Rutland formations, and in places the lower part of the Blisworth Limestone Formation, are concealed by brick retaining walls, mainly on the HNR side.

The following descriptions are in alphanumerical order, which does not follow the order they are seen in the cutting (see folded plan).

4.2 HNR1LOC1

NGR: SP 75300 51888 (logged 20/11/05)

HNR1Loc1 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION AS SEEN	
1 (undiv.)	LIMESTONE, light yellowish brown 2.5Y6/4, medium-grained peloidal packstone or grainstone with much medium- to coarse-grained shell debris, irregularly laminated with wackestone with similar grains, platy weathering, numerous bivalve fragments and debris including <i>Anisocardia?</i> and mytilid.	0.50 seen
2A1	LIMESTONE, white 2.5Y8/1, peloidal wackestone with calcilutite matrix, peloids medium- to coarse-grained, dark grey and yellow, sparse bioclasts, blocky, nodular weathering	0.3
2A2	MUDSTONE, orangish grey, much sand-grade calcareous grains of shell debris and peloids	0.07

Local bed number	Description	Thickness (m)
2A	LIMESTONE, pale yellow 2.5Y8/4, medium bioclastic wackestone, calcisiltite matrix, common medium-grained coated peloids, weathering soft, marly and reddish yellow 7.5YR7/8, whole bivalves including <i>Anisocardia</i> and 'myids' including <i>Pholadomya lirata?</i> (J. Sowerby); tiny echinoid (<i>Nucleolites?</i>) and shell fragments/debris including ?echinoid spine.	0.55
2B	LIMESTONE, grey, bivalves, small echinoid, rubbly weathering	0.5
3A	LIMESTONE, thinly bedded, cross-bedding less apparent	0.27
3B	CLAY, grey, sandy with medium carbonate sand grains, weathering yellowish-brown	0.04-0.05
3C	LIMESTONE, pale yellow 2.5Y8/2, medium-grained peloidal wackestone, moderately bioclastic (medium- to coarse-grained), thinly and, slightly irregularly interbedded with similar packstone, calcilutite matrix, signs of rhythmicity (cycles of laminae thinning up)	0.98
4	LIMESTONE, very hard, rather sparsely fossiliferous	0.52
5	CLAY	0.03-0.04
6A	LIMESTONE, pale yellow 2.5Y7/4, medium- and medium to coarse-grained peloidal packstone, moderately bioclastic (medium- to coarse-grained), rather friable	0.23
6B	LIMESTONE, highly bioclastic, grey weathering	0.32
6C	MUDSTONE	0.13
7	LIMESTONE, bioclastic; forms strong rib	0.32
8A	MUDSTONE, dark grey	0.40
8B1	hard, grey	0.28
8B2	LIMESTONE, argillaceous	0.02-0.03
8B3	LIMESTONE	0.60 seen
	BASE OF SECTION AS SEEN	

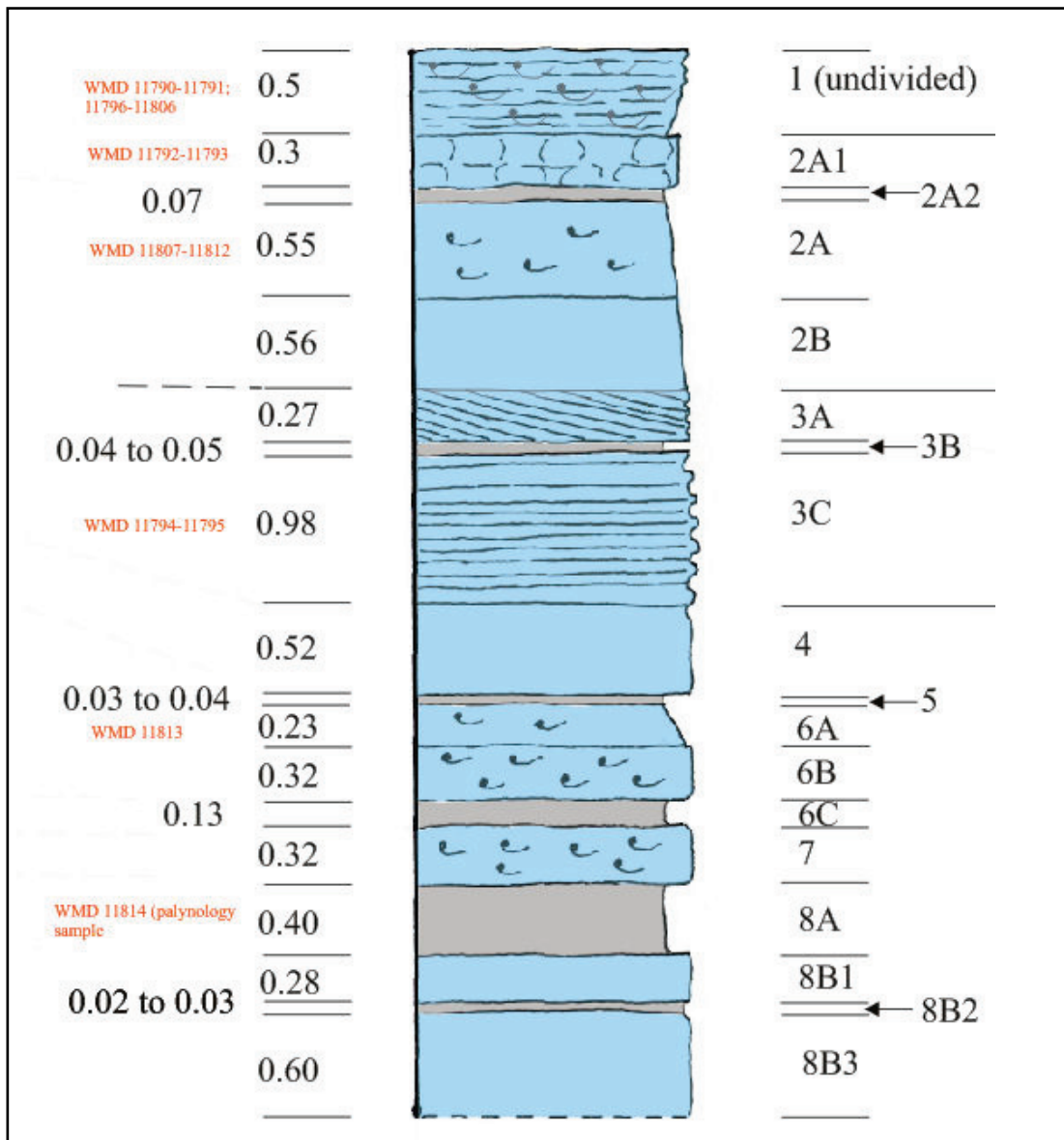


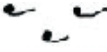



Figure 3. HNR1Loc1 Graphic log

Key to Graphic sections

Profile of right-hand side of column indicates degree of weathering back of bed. Thicknesses in metres on left hand side, local bed number on right hand side.

-  Limestone
-  Mudstone/calcareous mudstone
-  Shells or coarse bioclastic material
- Fe** Iron staining
-  Brachiopod(s)

Bed number	BGS sample number	Description/identification
1	WMD11796-11806	Bivalve fragments and debris including <i>Anisocardia?</i> and mytilid.
2A	WMD11807-11812	Bivalves including <i>Anisocardia</i> and 'myids' including <i>Pholadomya lirata?</i> (J. Sowerby); tiny echinoid (<i>Nucleolites?</i>) and shell fragments/debris including ?echinoid spine.
6A	WMD11813	Indeterminate or undetermined.
8A	WMD11814	See Appendix (palynology report)

Table 1. HNR1Loc1 List of specimens with fossil identifications

HNR1Loc1 close-up photographs

None.

4.3 HNR1LOC2

NGR: SP 75287 51926 (logged 13/11/05).

HNR1Loc2 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION AS SEEN	
8A	MUDSTONE, grey 2.5Y5/1, finely very sandy (silica, mica and carbonate grains), and sparse crushed and abraded shell fragments.	0.45
8B	LIMESTONE, light grey 2.5Y7/1 medium-grained peloidal packstone-wackestone with scattered medium-grained dark grey bioclasts. Impressions of bivalves and a possible brachiopod specimen. (Plate 1)	0.70
9	LIMESTONE, light grey hearted 2.5Y7/1, to 2.5Y7/2 weathered medium-grained bioclastic packstone-wackestone, calcisiltite matrix, possibly recrystallised. Fauna: bivalves including ? <i>Anisocardia loweana</i> (Morris & Lycett).	0.75 seen
	BASE OF SECTION AS SEEN	

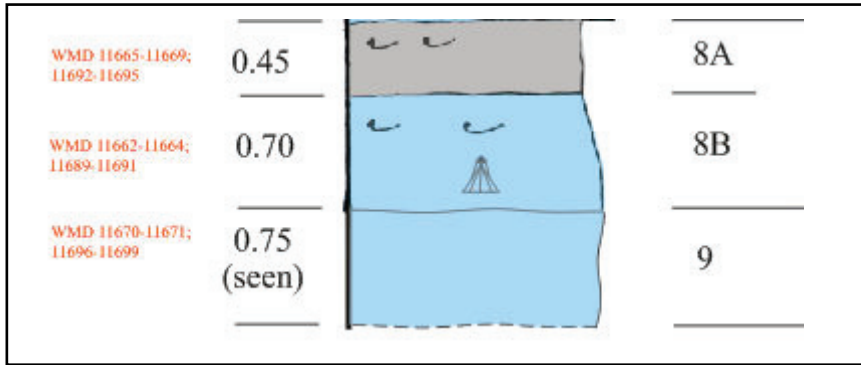


Figure 4. HNR1Loc2 Graphic log

Bed number	BGS sample number	Description/identification
8A	WMD11692-11695	Indeterminate or undetermined.
8B	WMD11689-11691	Bivalve fragments
9	WMD11696-11699	Bivalves including ? <i>Anisocardia loweana</i> (Morris & Lycett).

Table 2. HNR1Loc2 List of specimens with fossil identifications

HNR1Loc2 close-up photographs

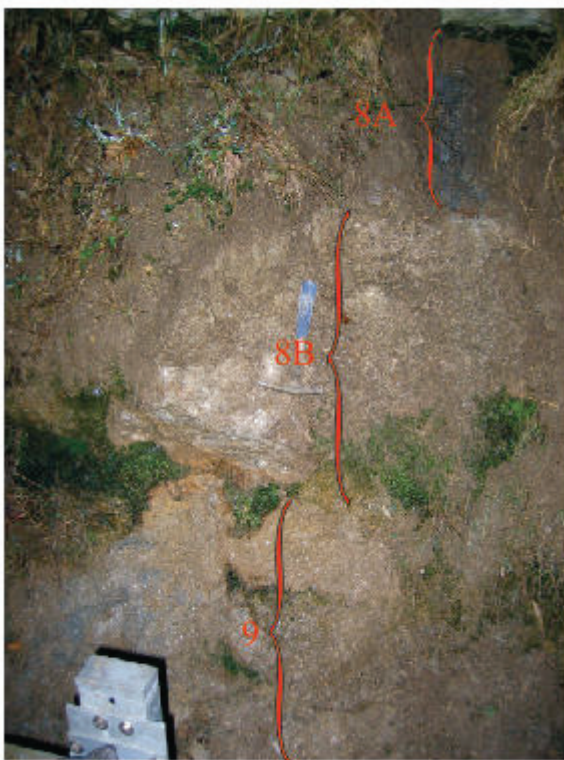


Plate 1. HNR1Loc2, close-up of beds 8A to 9 (P728560)

4.4 HNR1LOC3

NGR: SP 75265 51973 (20/11/05)

HNR1Loc3 text log

Local bed number	Description	Thickness (m)
1 (undiv.)	LIMESTONE, platy weathering	0.35
2A	LIMESTONE, orange weathering	0.70
2B	LIMESTONE, grey weathering	0.60
3A	LIMESTONE, cross-bedded	0.35
3B	LIMESTONE, light yellowish brown 2.5Y6/4, medium-grained bioclastic packstone, soft, clayey, sandy, with light brownish grey 2.5Y6/2 mud wisps; variable thickness	Up to 0.09
3C	LIMESTONE, interbedded thin, hard limestone and softer muddy and sandy limestone; hard limestones in 8 to 9 beds, each 0.05-0.08 thick, muddy limestones weather recessively and are 0.02-0.03 thick (Plate 2)	0.79
4	LIMESTONE, very hard	0.48
	BASE OF SECTION AS SEEN	

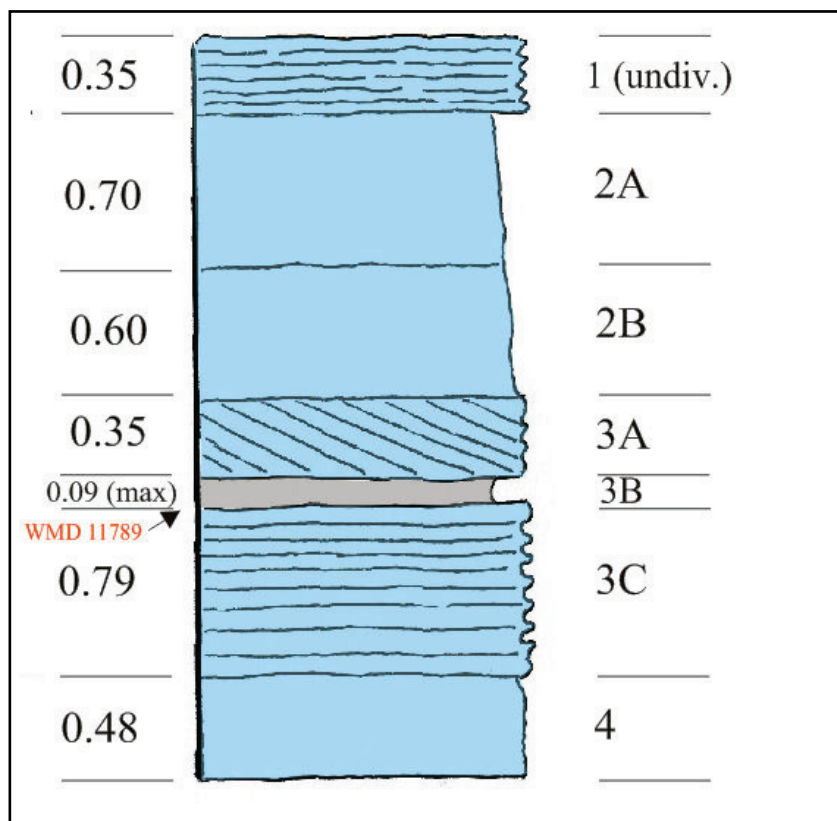


Figure 5. HNR1Loc3 Graphic log

No fossil specimens collected.

HNR1Loc3 close-up photographs



Plate 2. HNR1Loc3, bed 3C (P728569)

(Hammer is 0.3 m long)



Plate 3. View north-west from HNR1Loc3 (P728568)

4.5 HNR2LOC1

NGR: SP 75226 52042 (logged 13/11/05)

South-east from HNR2Loc1, close to the gantry a conspicuous thinly-bedded unit appears between bed 3B and 4, termed 3C.

HNR2Loc1 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION AS SEEN	
1A	LIMESTONE, light grey 2.5Y7/1-2, flaggy-bedded fine- to medium-grained ooidal packstone, grainstone texture dominant in parts; forming lensoid beds usually less than 0.01 thick, possibly with thin interbedded clay drapes, coated grains preserved as cortex only, in packstones cortex is normally infilled by buff-coloured matrix, nuclei may have been lost to selective dissolution during early diagenesis, scattered large darker shell fragments	0.90
1B	LIMESTONE, light grey 2.5Y7/1-2, flaggy-bedded fine-grained ooidal packstone to grainstone, lithologically similar to unit W1A; also flaggy, but more thickly bedded with individual beds up to 0.03 thick and not as lenticular; no evidence for clay drapes. Units 1A and 1B weather to form a bluff. (Plate 4)	0.70
2A	LIMESTONE, impure, argillaceous calcilutite; many yellow 10YR8/8 and brownish yellow 10YR6/6 ovoid medium and coarse coated grains (peloids) in variable pale yellow 2.5Y8/2-4 packstone-wackestone texture, scattered small dark bioclasts including shell fragments, traces of burrowing, large pockets of white 2.5Y8/1 calcite mud with floating peloids. ?Branching coral replaced by coarse spar seen. Weathers to yellow 10YR7/6 and forms a recess.	0.83
2B	LIMESTONE, light grey 2.5Y7/1 to pale yellow 2.5Y8/2-4 medium to coarse-grained peloidal bioclastic packstone-wackestone, calcilutite matrix, common coarse-grained dark shell fragments, harder (better cemented?) than bed W2A, with parallel tractional current lamination; basal part of bed is white 2.5Y8/1 with conspicuous ferruginous pink 7.5YR7/3 medium- to coarse-grained peloids and many coarse dark grey shell fragments in parts, small vugs with sparry calcite (presumed brachiopods) and rhynchonellid fragment; pyritized blebs and flecks; ?plant debris; iron-stained ooids; bivalve impression; contact with underlying unit W3 is sharp.	0.68

Local bed number	Description	Thickness (m)
3	LIMESTONE, white to pale yellow 2.5Y8/1-2, flaggy, medium- and coarse-grained peloidal ooidal packstone with many dark bioclasts, arranged in prominent unimodal cross-bed sets which have an apparent dip (in the NW-SE trending cutting face) to the south-east. Locally patches of milky spar occlude the matrix producing a cemented grainstone texture. Individual cross-beds vary from less than 0.01 to around 0.06 in thickness. Unit weathers to form a bluff with a bench at the top.	1.35
3B	MUDSTONE, yellow-brown, shaly.	0.015
4	LIMESTONE, light grey 2.5Y7/1, calcisiltite, medium-grained peloid and bioclastic packstone-wackestone, conspicuous large shell fragments, with some isolated coated grains. Fauna: bivalves including <i>Anisocardia</i> , <i>Pleuromya?</i> and <i>Vaugonia moretoni?</i> (Morris & Lycett); rhynchonellid fragment.	0.43
5	MUDSTONE, dark greyish brown 2.5Y4/2, interlaminated with MUDSTONE, light olive brown 2.5Y5/4, medium-grained peloidal and bioclastic, crumbly	0.08
6	LIMESTONE, light grey 2.5Y7/2 to pale yellow 2.5Y8/2, medium-grained bioclastic and medium-grained peloidal packstone, highly fossiliferous, argillaceous, weathering back and poorly exposed. Fauna: bivalves including <i>Pleuromya?</i> and trioniid.	1.20
7	LIMESTONE, light grey 2.5Y7/1-2 medium-grained peloidal and bioclastic packstone with numerous bivalves including <i>Homomya?</i> and <i>Vaugonia moretoni?</i> (Morris & Lycett); also nerineid gastropod (<i>Cossmannea?</i>) fragment. Hard and weathers out to form a prominent rib.	0.36
	BASE OF SECTION AS SEEN	

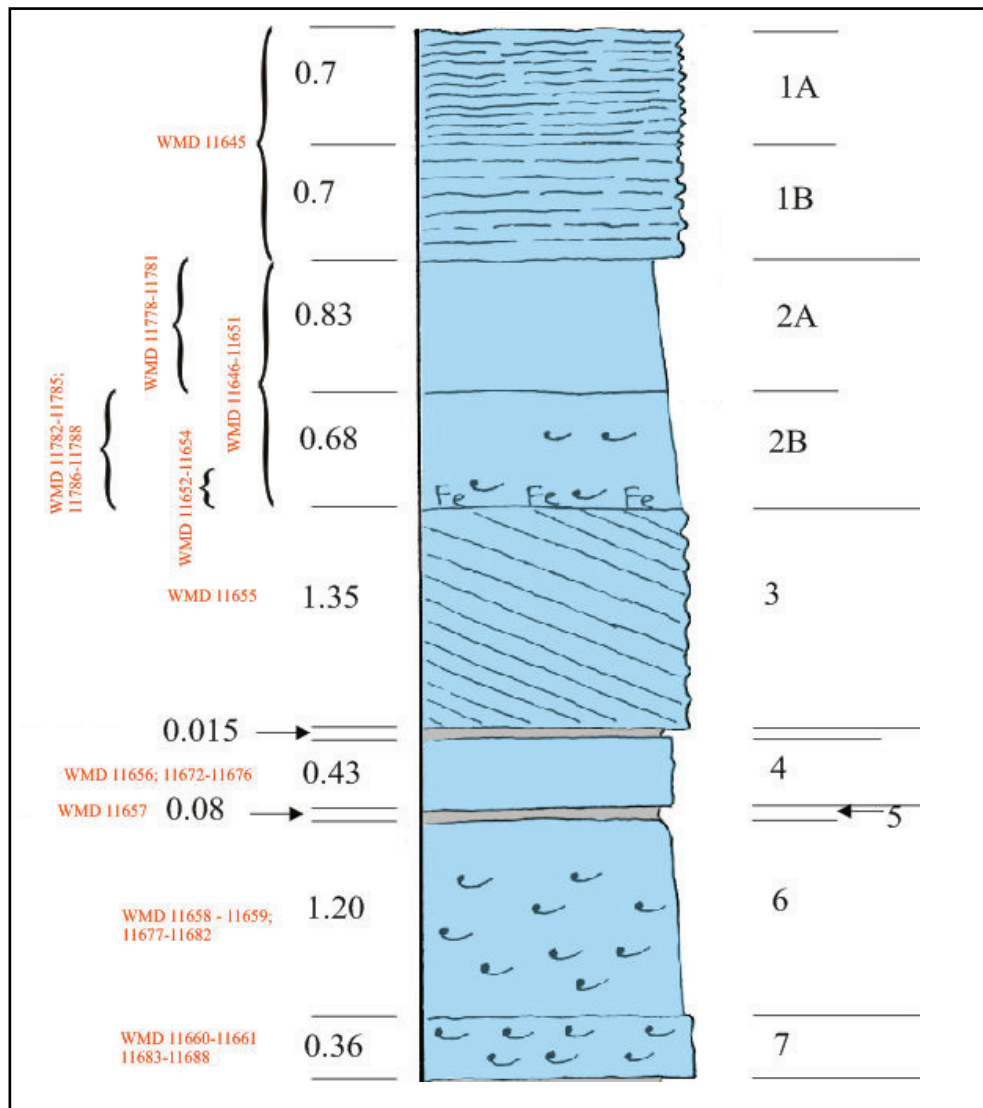


Figure 6. HNR2Loc1 Graphic log

Bed number	BGS sample number	Description/identification
2B	WMD11786-11788	Small vugs with sparry calcite (presumed brachiopods) and rhynchonellid fragment; pyritized blebs and flecks; ?plant debris; iron-stained ooids; bivalve impression.
4	WMD11672-11676	Bivalves including <i>Anisocardia</i> , <i>Pleuromya?</i> and <i>Vaugonia moretoni?</i> (Morris & Lycett); rhynchonellid fragment.
6	WMD11677-11682	Bivalves including <i>Pleuromya?</i> and trigoniid.
7	WMD11683-11688	Bivalves including <i>Homomya?</i> and <i>Vaugonia moretoni?</i> (Morris & Lycett); nerineid gastropod (<i>Cossmannea?</i>) fragment.

Table 3. HNR2Loc1 List of specimens with fossil identifications

HNR2Loc1 close-up photographs



Plate 4. HNR2Loc1, close-up of beds 1A and 1B (P728547)



Plate 5. HNR2Loc1, close-up of beds 3 to 6 (P728553)

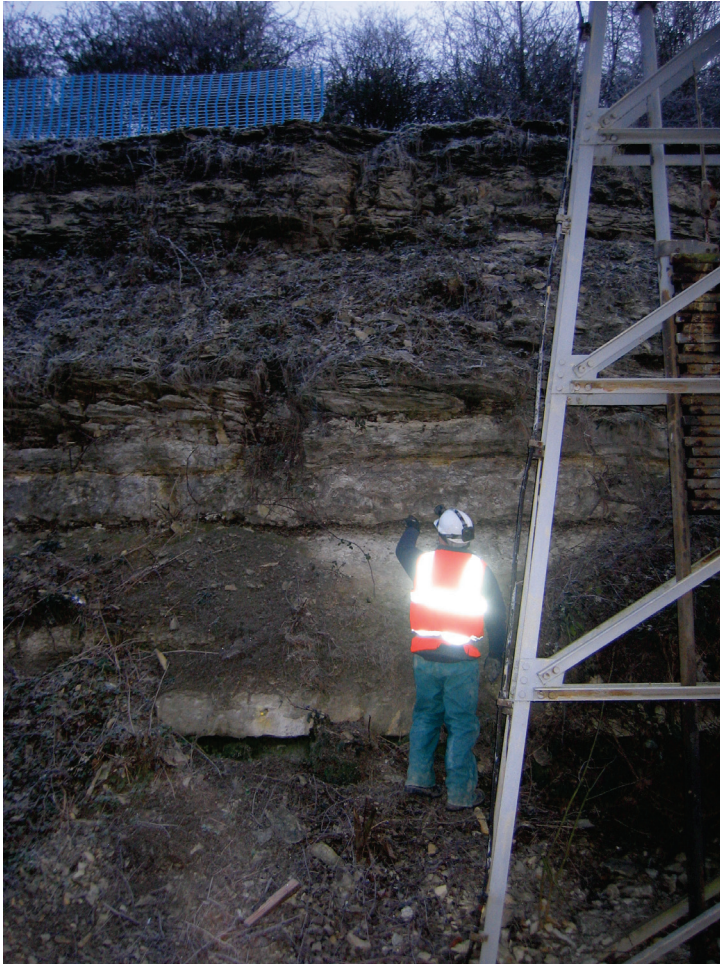


Plate 6. Extreme SE end of HNR2, 17 m SE of HNR2Loc1 (P728566)

M Woods pointing at bivalve-rich bed 4. Bed above (3C) thins and pinches out north-west towards HNR2Loc1.

4.6 HNR2LOC2

NGR: SP 75183 52121 and 75194 52092 (logged 20/11/05)

This locality is split between two locations about 30 m apart. Beds -7 to 5 and 9 to 11 are best displayed at and described from SP 75183 52121; beds 6 to 8 are described from 75194 52092.

HNR2Loc2 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION AS SEEN	
-7	LIMESTONE, thinly platy bedded, inaccessible here	
-6	LIMESTONE, massive, rubbly and flaky weathering, sharp top, forms ledge	About 0.35
-5	LIMESTONE, jointed	0.35
-4	LIMESTONE, pale grey, massive	0.5

Local bed number	Description	Thickness (m)
-3	LIMESTONE, white 2.5Y8/1 weathering to pale yellow 2.5Y8/2, medium-grained bioclastic medium- to coarse-grained peloidal packstone-wackestone, calcisiltite matrix, some larger shell fragments and scattered quartz sand grains, irregularly thinly bedded	0.9
-2	GAP, talus	About 0.5
-1	LIMESTONE, white 2.5Y8/1 to light grey 2.5Y7/1, weathering to pale yellow 2.5Y8/2, medium- and coarse-grained ooidal and peloidal grainstone, coarsely to very coarsely bioclastic, including very dark grey shell fragments and white very coarse ?crinoid debris, peloids commonly pale yellow 2.5Y8/4; packstone texture in parts; prominently thinly cross-bedded to 130°, cross beds 0.02-0.05 thick, unfossiliferous, sharp base (Plate 7)	0.65
0	LIMESTONE, pale yellow 2.5Y8/3, soft medium-grained bioclastic packstone, calcisiltite matrix, some coated grains and medium- to coarse-grained quartz sand, bed recessed.	0.19
1	LIMESTONE, light grey 2.5Y7/1-2, medium-grained peloidal and coated bioclastic packstone with grainstone texture pockets (?recrystallised), some large shell fragments, hard; sharp slightly irregular base, sharp top	0.48-0.52
2	MUDSTONE, sandy, calcareous, recessively weathered	0.15
3	LIMESTONE, white 2.5Y8/1 weathering to pale yellow 2.5Y8/3, medium-grained peloidal and medium- and coarse-grained bioclastic packstone with grainstone texture pockets, slightly harder than B1, highly fossiliferous – bivalves, including <i>Anisocardia bathensis?</i> Cox or <i>truncata?</i> (Morris), <i>Homomya?</i> , <i>Isognomon?</i> , <i>Mactromya?</i> , <i>Modiolus?</i> , <i>Opis?</i> , oyster fragments including <i>?Praeexogyra hebridica</i> (Forbes), <i>Pleuromya</i> and trigoniid; crushed rhynchonellid and ?fragments.	0.50
4	LIMESTONE, bluish grey hearted 5B6/1 weathering to light grey 2.5Y7/1-2, medium-grained bioclastic packstone, scattered medium sand grains, some burrow traces and large shell pieces, bioclasts coated and a few peloids, matrix ?recrystallised in parts, rare dark brown lignite fragments, highly fossiliferous; grades into wackestone in parts, softer than B3	0.65
5	LIMESTONE, harder than above, prominent [=W7] Fauna: bivalves including <i>Anisocardia?</i> , <i>Homomya?</i> and <i>Pholadomya?</i> ; ?rhynchonellid fragments and small ?epithyrid.	0.30
6	MUDSTONE, grey when fresh, weathering orangish	0.35

Local bed number	Description	Thickness (m)
7	LIMESTONE, light grey 2.5Y7/1 weathering to pale yellow 2.5Y7/3, medium peloidal and bioclastic wackestone, common whole shells, generally massive [W8B]. Fauna: bivalves including <i>Anisocardia</i> , <i>Isognomon?</i> and mytilid?; impressions of rhynchonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood).	0.28
8	MUDSTONE, grey	0.06-0.08
9	LIMESTONE, grey hearted 2.5Y5/1 to light grey 2.5Y7/2, finely sandy fine- to medium-grained bioclastic packstone, scattered coarse-grained dark shell fragments, very hard and compact; forms conspicuous rib. Fauna: bivalves including <i>Anisocardia?</i> , <i>Isognomon?</i> , <i>Modiolus?</i> , <i>Pleuromya?</i> , <i>Praeexogyra?</i> and trigoniid; ?echinoderm debris; small rhynchonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood). Also ?plant fragment.	0.33
10	MUDSTONE, recessively weathered	0.06
11	LIMESTONE, marly, tough	0.37
	BASE OF SECTION AS SEEN	

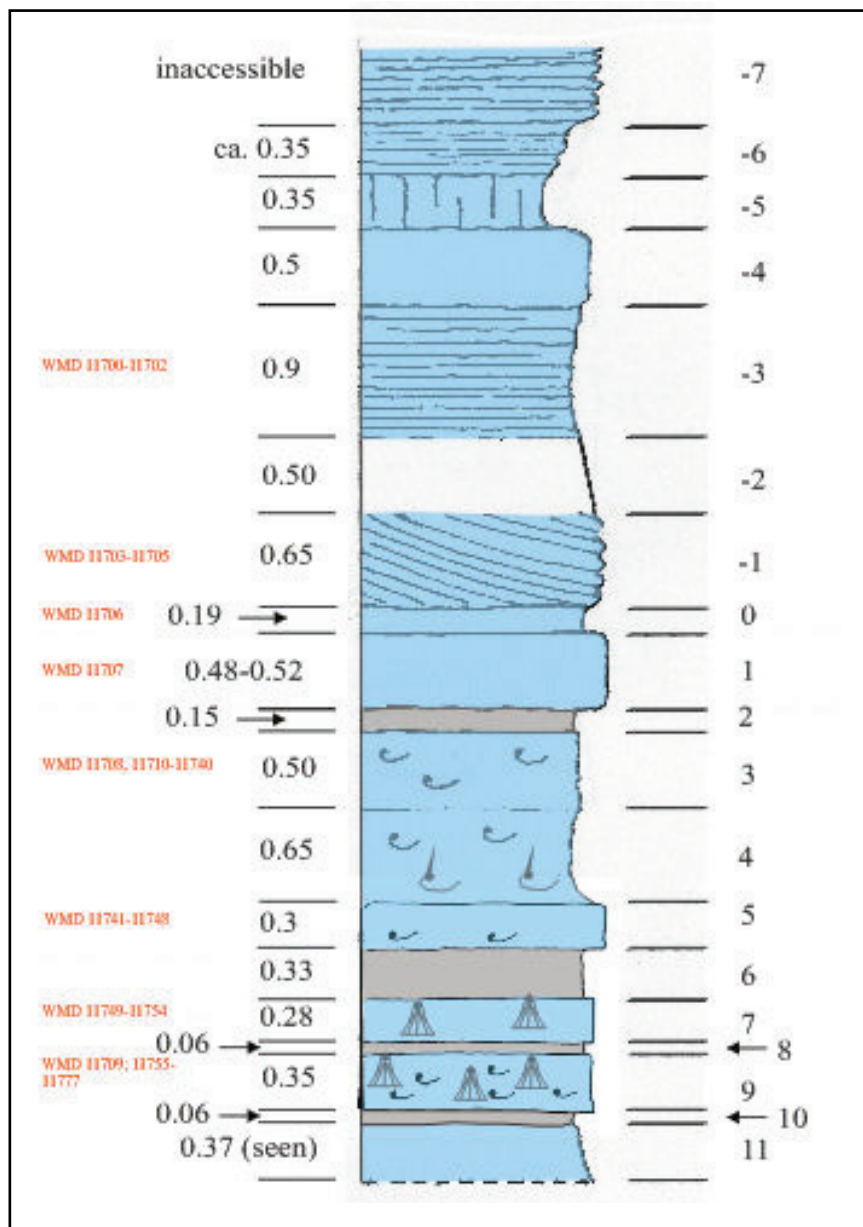


Figure 7. HNR2Loc2 Graphic log

Bed number	BGS sample number	Description/identification
3	WMD11710-11740	Bivalves including <i>Anisocardia bathensis?</i> Cox or <i>truncata?</i> (Morris), <i>Homomya?</i> , <i>Isognomon?</i> , <i>Mactromya?</i> , <i>Modiolus?</i> , <i>Opis?</i> , oyster fragments including <i>?Praeexogyra hebridica</i> (Forbes), <i>Pleuromya</i> and trigoniid; crushed rhynchonellid and ?fragments.
5	WMD11741-11748	Bivalves including <i>Anisocardia?</i> , <i>Homomya?</i> and <i>Pholadomya?</i> ; ?rhynchonellid fragments and small ?epithyrid.
7	WMD11749-11754	Bivalves including <i>Anisocardia</i> , <i>Isognomon?</i> and mytilid?; impressions of rhynchonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood).

Bed number	BGS sample number	Description/identification
9	WMD11755-11777	Bivalves including <i>Anisocardia?</i> , <i>Isognomon?</i> , <i>Modiolus?</i> , <i>Pleuromya?</i> , <i>Praeexogyra?</i> and trioniid; ?echinoderm debris; small rhynchonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood); ?plant fragment.

Table 4. HNR2Loc2 List of specimens with fossil identifications

HNR2Loc2 close-up photographs



Plate 7. HNR2Loc2, beds -1 to 1 (P728565)

(Rule is 1 m long)

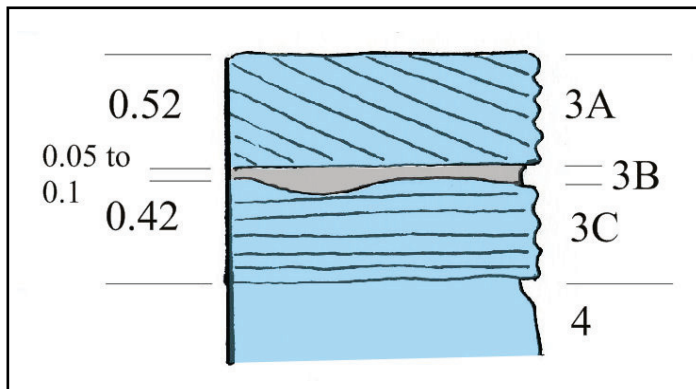
4.7 HNR3LOC1

NGR: SP 75244 51999 (20/11/05)

Between HNR3Loc1 and HNR2Loc1, close to the gantry a thinly-bedded unit appears (3C) between bed 3B and 4. It thickens south-east, the parallel bedding becomes more conspicuous and it persists throughout HNR1.

HNR3Loc1 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION AS SEEN	
3A	LIMESTONE, cross-bedded	0.52
3B	MUDSTONE	0.05-0.1
3C	LIMESTONE, thinner and less clearly rhythmic in its bedding	0.42
4	LIMESTONE	seen

**Figure 8. HNR3Loc1 Graphic log**

No fossil specimens collected.

HNR3Loc1 close-up photographs

None.

4.8 LEC1LOC1

NGR: SP 75244 51959 (logged 8/1/06, 19/2/06)

LEC1Loc1 text log

Local bed number	Description	Thickness (m)
	Topsoil	0.4
60	Limestone, light grey 2.5Y7/1, coarsely bioclastic, medium to coarse-grained peloid-grainstone/packstone, weathering pale yellow 2.5Y7/3, very fissile	0.3
60a	Thin mudstone	0.02-0.04
61	Limestone, light grey 2.5Y7/2, medium to coarse-grained peloid-grainstone/ packstone, scattered coarse bioclasts, rare poorly preserved bivalve shells, less fissile weathering than Bed 60	0.25
z61a	Thin mudstone.	?0.02

Local bed number	Description	Thickness (m)
62	Limestone, light grey 2.5Y7/2, medium to coarse-grained bioclastic medium-coarse-grained peloid-grainstone; more massive weathering than overlying units	0.4
63	Limestone, pale yellow 2.5Y7/3, bioclastic, possibly ooidal, medium to coarse-grained peloid-grainstone/packstone, with scattered large sparry shell fragments and some poorly preserved bivalve shells; very thin mudstone lamina at top. Upper surface of limestone is irregular and iron-stained (? incipient hardground).	0.38
64	Mudstone weathering to clay, light olive brown 2.5Y5/4, packed with coarse peloids and very coarse bioclasts, including oyster fragments; sticky	0.08
65	Limestone, pale yellow 2.5Y8/3, medium-coarse-grained peloidal wackestone grading in parts to packstone, common coarse bioclasts, moderately soft	0.18
66	Limestone, medium-coarse-grained peloid-packstone grading in parts to wackestone, light grey 2.5Y7/1 groundmass, speckled with grey 2.5Y5/1, scattered dark grey coarse bioclasts, some poorly preserved bivalve shells, hard, weathering to pale yellow 2.5Y8/4 ("blue-hearted")	0.33
67	Limestone, pale yellow 2.5Y8/4 weathering, medium-coarse-grained peloid-packstone with scattered coarse bioclasts, hard	0.15
68	Limestone, medium-coarse-grained peloid-packstone grading in parts to wackestone, light grey 2.5Y7/1 groundmass, speckled with grey 2.5Y5/1, pale yellow 2.5Y8/4 weathering ("blue-hearted"), with scattered coarse bioclasts and larger shell fragments. Might be equivalent of cross-bedded unit seen in other sections, but no cross bedding seen here.	0.47
69	Limestone, light grey 2.5Y7/1 weathering to pale yellow 2.5Y8/2, medium-grained peloid-packstone/grainstone, very hard, with common medium bioclasts and scattered larger shell fragments.	0.22
70	Mudstone, thin, grey	0.03
71	Limestone, grey 2.5Y5/1, weathering to white 2.5Y8/1, medium grained bioclastic, medium-grained peloid/ooid grainstone, traces of fine ripple lamination, hard	0.07
72	Calcite-mud, olive brown 2.5Y4/3, packed with fine to coarse peloids and bioclasts	0.09
73	Limestone, light grey 2.5Y7/1 weathering to pale yellow 2.5Y8/2, medium grained bioclastic, medium-grained peloid-packstone, hard	0.22

Local bed number	Description	Thickness (m)
74	Mudstone, grey	0.025
75	Limestone, light grey 2.5Y7/1, medium-grained peloid-packstone/grainstone, with common dark grey medium grained bioclasts and scattered larger shell fragments, hard	0.13
75a	Mudstone, grey	?0.02
76	Limestone, grey 2.5Y5/1, medium-grained peloid-packstone/grainstone, with common dark grey medium grained bioclasts and scattered larger shell fragments, hard with irregular base.	0.26 – 0.36
77	Calcite-mud, olive brown 2.5Y4/4, packed with medium to coarse peloids and bioclasts	0.05-0.1
78	Limestone, white to pale yellow 2.5Y8/1-8/2, highly bioclastic medium-coarse-grained peloid-packstone grading in parts to wackestone, numerous poorly preserved shell moulds (bivalves) Pale orangey-grey weathering in contrast to darker weathering limestone above.	0.6
78a	Mudstone ?sandy, very thin.	0.005
79	Limestone, light grey 2.5Y7/2 weathering to pale yellow 2.5Y8/4, bioclastic medium to medium-coarse-grained peloid-packstone with lime mud-filled burrows and common poorly preserved shell moulds (bivalves)	0.2
80	Mudstone, olive brown 2.5Y4/3, grading to muddy calcarenite, light olive brown 2.5Y5/6, with abundant medium peloids and bioclasts and large whole bivalve.	0.2
81	Limestone forming very hard rib	0.35
82	Mudstone.	0.4
83	Limestone, dark greyish brown 2.5Y4/2, medium-grained peloid-packstone, argillaceous with rhynchonellid brachiopods, very soft; lowest 0.15 m is very mud-rich.	0.38
84	Limestone, white to light grey 2.5Y8/1-7/1, conspicuously coarsely bioclastic and peloidal packstone to wackestone with common whole shells, including possible rhynchonellid brachiopods, forms hard rib.	0.45
84a	Mudstone.	0.03
85	Limestone, light grey 2.5Y7/1 weathering to pale yellow 2.5Y8/2, medium-grained peloidal bioclastic packstone	0.15 (seen)
	BASE OF SECTION AS SEEN	

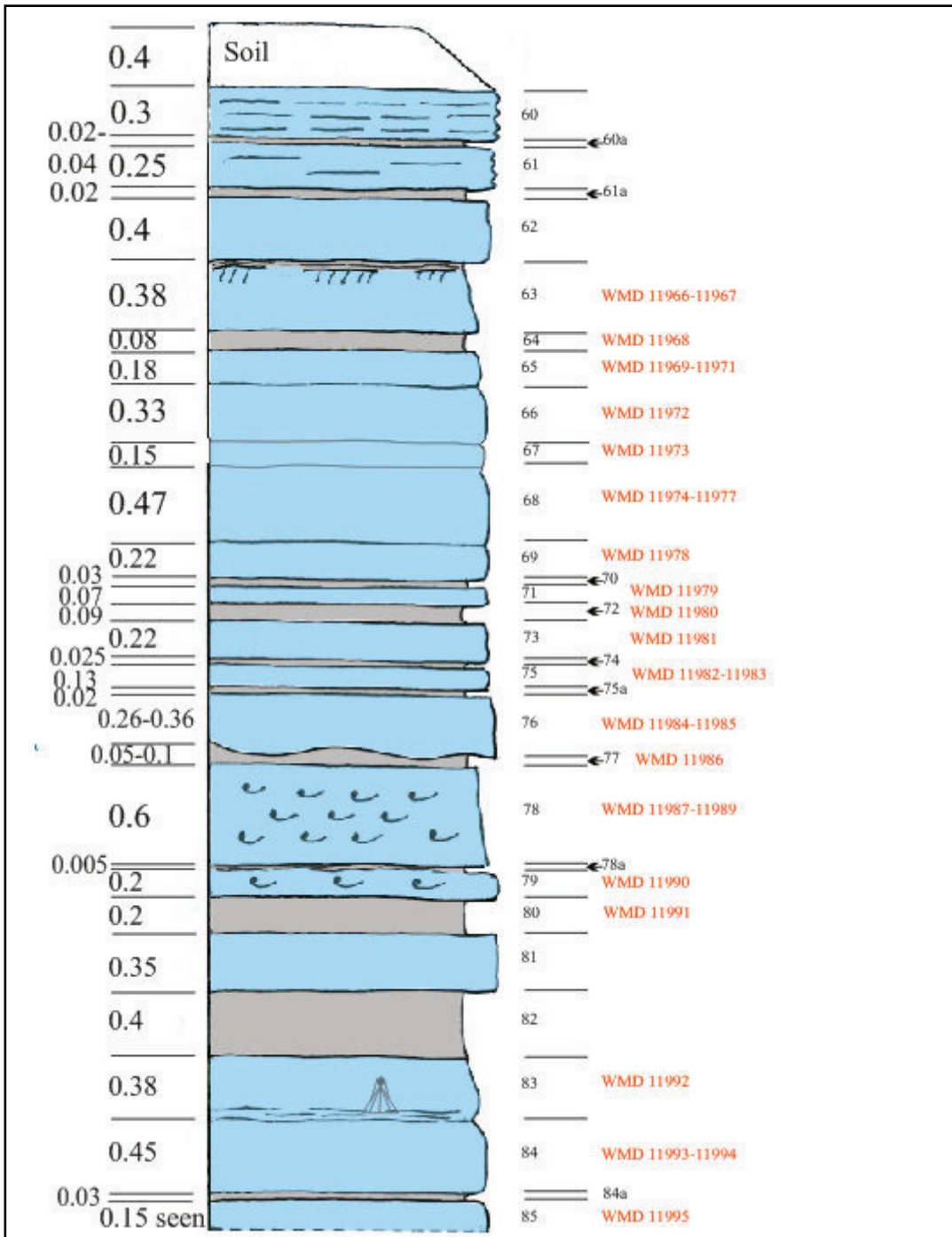


Figure 9. LEC1Loc1 Graphic log

Bed number	BGS sample number	Description/identification
63	WMD11996-11997	Poorly preserved, mainly indeterminate bivalves and fragments but including <i>Modiolus</i> ?; pyritized blebs and flecks; ?plant debris.
78	WMD11998-12002	Poorly preserved, largely indeterminate bivalves and fragments but including <i>Isognomon</i> ?, <i>Modiolus</i> and probably <i>Anisocardia</i> .
80	WMD12003	<i>Pholadomya deltoidea</i> (J Sowerby) - paired valves.

Bed number	BGS sample number	Description/identification
84	WMD12004	Poorly preserved, small rhynchonellid brachiopods and impressions (presumed <i>Kallirhynchia sharpi</i> Muir-Wood) and other shell fragments.

Table 5. LEC1Loc1 List of specimens with fossil identifications

LEC1Loc1 close-up photographs

None taken

4.9 LEC2LOC1

NGR: SP 74999 52479 (logged 11/12/05)

LEC2Loc1 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION INACCESSIBLE LEDGE	
90	LIMESTONE, light yellowish brown 2.5Y6/4, medium to coarse-grained peloidal packstone with much coarse- to very coarse-grained generally uncoated shell debris, some green ('glaucitic') staining, hard, with some light olive brown muddy wisps, forming four ribs; interbedded with CLAY, mottled light olive brown 2.5Y5/4 and dark greyish brown 2.5Y4/2, silty, sandy (medium grained quartz), medium- to coarse-grained bioclasts and brown peloids, numerous valves, fragments and clusters of <i>Praexogyra hebridica</i> (Forbes). (Plate 8)	1.20 seen
91	LIMESTONE, pale yellow 2.5Y7/4, medium-grained bioclastic packstone with angular to subangular grains	0.12
92	LIMESTONE, pale yellow 2.5Y8/2 speckled with 2.5Y8/4, medium- and medium to coarse-grained bioclastic packstone, recrystallised in parts, locally a grainstone, scattered dark bioclasts and larger shell fragments, compact, apparently unbioturbated	0.38
93	LIMESTONE, white 2.5Y8/1 to light grey 2.5Y7/1 speckled with pale yellow grains 2.5Y8/4, medium- and medium to coarse-grained peloidal and ooidal packstone-wackestone, scattered coarse shell fragments, rather friable. Indeterminate/undetermined bivalve and shell debris.	0.50
94	LIMESTONE, pale yellow 2.5Y8/3 mottled with yellow 2.5Y8/6, medium to coarse-grained and coarse-grained bioclastic packstone, grains angular, with subordinate medium to coarse-grained dusty peloids, some medium sand grains including dark green glauconite, flaggy	0.60

Local bed number	Description	Thickness (m)
	weathering	
95	LIMESTONE, pale yellow 2.5Y8/2 speckled with 2.5Y8/4, medium-grained coated peloidal grainstone with numerous medium to coarse- to coarse-grained bioclasts, some coated; less flaggy than W94	0.30
96	LIMESTONE, white 2.5Y8/1 to pale yellow 2.5Y8/3, coarse- to very coarse-grained bioclastic grainstone with many coated peloids and some larger dark shell fragments; <i>forms weakly cross-bedded unit, beds 0.03-0.06 thick</i> (Plate 9)	0.85
97		0.01-0.02
98	LIMESTONE, light grey 2.5Y7/2, medium- and medium to coarse-grained coated peloidal grainstone with numerous medium to coarse- to very coarse-grained angular and rounded and coated shell fragments, with pockets of pale yellow 2.5Y8/2 packstone texture and many large calcisiltite-filled oblique burrows weathering light grey 2.5Y7/1. Some yellow patches 2.5Y7/6. Hard and compact	0.44
99	LIMESTONE, white 2.5Y8/1 to pale yellow 2.5Y8/3, medium- to medium to coarse-grained coated ovoid peloidal packstone-wackestone with pyritized blebs, common whole shells and some sparry shell fragments. Bivalve-rich including <i>Isognomon?</i> , mytilid, <i>Pleuromya?</i> , trioniid?, veneroids (including <i>Anisocardia?</i>); small vug with sparry calcite (?brachiopod). Shells impart nodular appearance	0.70
100	SILT, light brownish grey, 2.5Y6/2 mottled with light yellowish brown 2.5Y6/4, quartzose, clayey, finely very sandy, fine- to medium-grained bioclasts	0.26
101	LIMESTONE, light grey 2.5Y7/2 to pale yellow 2.5Y7/4, peloidal wackestone, calcisiltite matrix, slightly sandy (fine quartz), traces of many silt-filled burrows, pockets of packstone texture, common smooth shell impressions. Fauna: bivalves including mytilid and other fragments.	0.20
102	LIMESTONE, grey hearted 2.5Y5/1 weathering pale yellow 2.5Y8/3, medium- to medium to coarse-grained coated peloidal and bioclastic grainstone, some larger shells including gastropods with sparry calcite infill and indeterminate bivalve, and possible crinoid fragments	0.20
103	CLAY, olive brown 2.5Y4/3 (wet), very silty, finely quartz sandy, highly bioclastic (fine- to medium-grained)	0.36
104	LIMESTONE, light grey 2.5Y7/1, calcisiltite wackestone, with common fine- to medium-grained bioclasts, sparse medium peloids, and scattered whole	0.18

Local bed number	Description	Thickness (m)
	dark grey or yellow shells of bivalves including ?mytilids and ?veneroids.	
105	MUDSTONE	0.05
106	LIMESTONE, light grey 2.5Y7/1, calcisiltite wackestone, with numerous fine- to medium-grained bioclasts, and scattered large shell fragments, some pyrite coated. Fauna: bivalves including ?mytilid and <i>Pholadomya</i> (paired valves and ?juveniles); shell debris including ?echinoderm and ?rhynchonellid.	0.15
107	MUDSTONE, with poorly preserved and crushed small rhynchonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood); <i>Praeexogyra</i> fragments.	0.08
108	LIMESTONE, argillaceous, with bivalves including <i>Anisocardia?</i> and <i>Entolium corneolum</i> (Young & Bird); several <i>Kallirhynchia sharpi</i> Muir-Wood.	0.16 seen
	BASE OF SECTION AS SEEN	

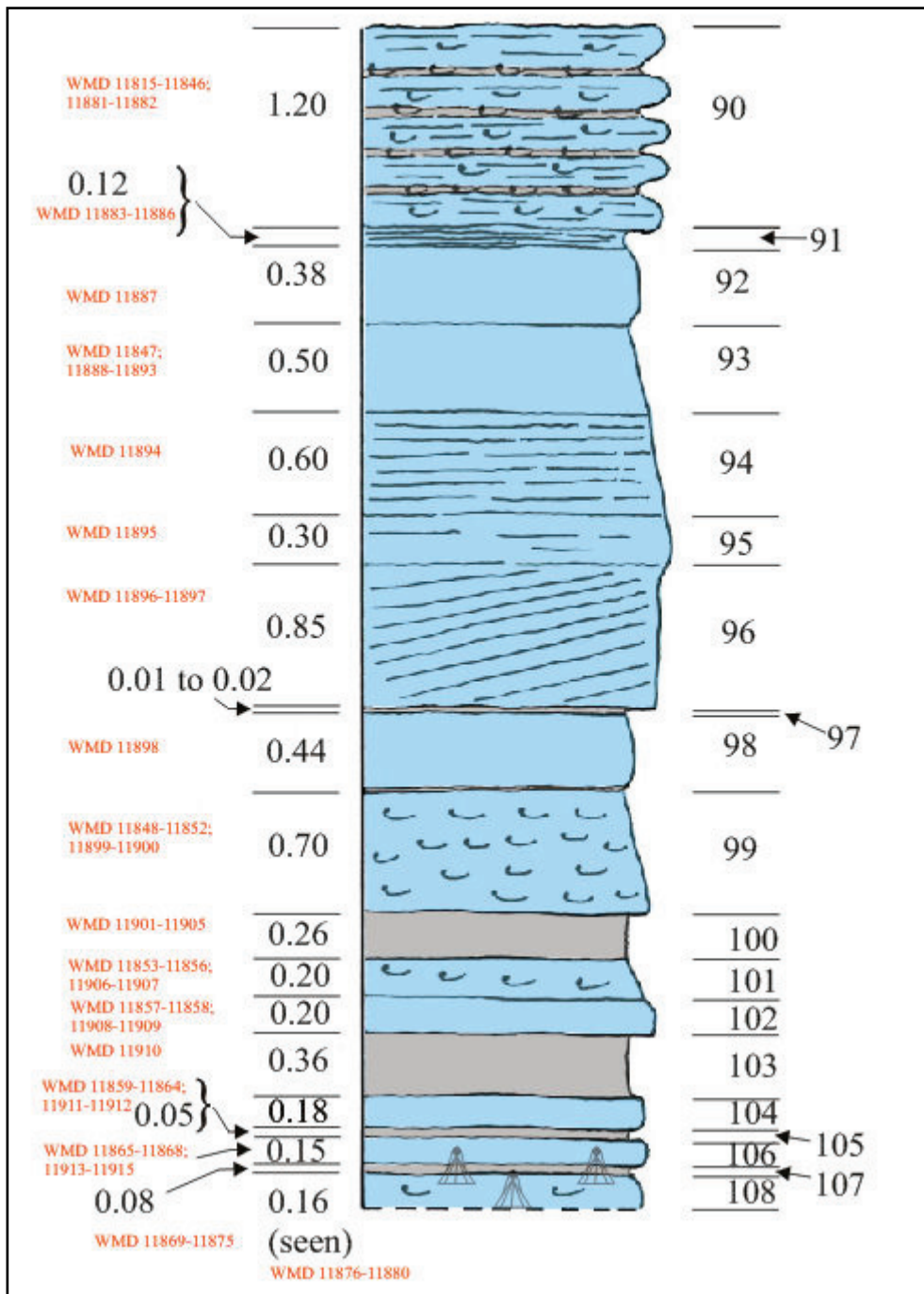


Figure 10. LEC2Loc1 Graphic log

Bed number	BGS sample number	Description/identification
90 (muddy limestone above lowest rib)	WMD11815-11834	<i>Praeexogyra hebridica</i> (Forbes) valves and fragments; green ('glauconitic') staining.
90 (just above lowest rib)	WMD11835-11846	<i>Praeexogyra hebridica</i> (Forbes) valves, fragments and clusters.
93	WMD11847	Indeterminate/undetermined bivalve and shell debris.
99	WMD11848-	Bivalve-rich including <i>Isognomon?</i> , mytilid, <i>Pleuromya?</i> , trioniid?, veneroids (including

Bed number	BGS sample number	Description/identification
	11852	<i>Anisocardia?</i>); pyritized blebs; small vug with sparry calcite (?brachiopod).
101	WMD11853-11856	Bivalves including mytilid and other fragments.
102	WMD11857-11858	Gastropods with sparry calcite infill and indeterminate bivalve.
104	WMD11859-11864	Bivalves including ?mytilids and ?veneroids.
106	WMD11865-11868	Bivalves including ?mytilid and <i>Pholadomya</i> (paired valves and ?juveniles); shell debris including ?echinoderm and ?rhyntonellid.
107	WMD11869-11875	Poorly preserved and crushed small rhyntonellids (presumed <i>Kallirhynchia sharpi</i> Muir-Wood); <i>Praexogyra</i> fragments.
108	WMD11876-11880	Bivalves including <i>Anisocardia?</i> and <i>Entolium corneolum</i> (Young & Bird); several <i>Kallirhynchia sharpi</i> Muir-Wood.

Table 6. LEC2Loc1 List of specimens with fossil identifications

LEC2Loc1 close-up photographs



Plate 8. LEC2Loc1 Bed 90 (P728543)



Plate 9. LEC2Loc1 Bed 96, cross-bedded (P728545)

4.10 LEC2LOC2

NGR: SP 75006 52462 (logged 11/12/05)

LEC2Loc2 text log

Local bed number	Description	Thickness (m)
	TOP OF SECTION INACCESSIBLE LEDGE	
90	LIMESTONE, greyish brown 10YR5/2 weathering pale brown 10YR6/3, medium to coarse to coarse-grained peloidal and ?oidal grainstone with much coarse-grained coated and uncoated shell debris, many peloids, some glauconitic, forms four flaggy ribs interbedded with softer argillaceous LIMESTONE	1.5 seen
91	[no sample]	0-0.01
92	LIMESTONE, pale yellow 2.5Y8/2 speckled with 2.5Y7/3, medium- and medium to coarse-grained ooid grainstone, scattered coated bioclasts and larger dark uncoated shell fragments, white weathering	0.5 seen
93	[not exposed]	
94	[not exposed]	
95	[not exposed]	
96	LIMESTONE, pale yellow 2.5Y7/3, medium-grained coated peloid and medium- to very coarse-grained bioclastic grainstone [cross-bedded unit]	(not measured)

(No graphic log, specimens or photographs)

4.11 LEC3LOC1

NGR: SP 75301 51873 (logged 19/2/06)

LEC3Loc1 text log

Local bed number	Description	Thickness (m)
170	Limestone, very fissile weathering	0.3
171	Limestone, light brownish grey 2.5Y6/2, fine- to medium-grained peloid-grainstone with scattered medium-grained bioclasts, quartz sand present; platy weathering forming tiles	0.5
172	Limestone; base of unit forms prominent overhang	0.55
173	Limestone, white to pale yellow 2.5Y8/1-8/2, weathering yellow speckled 2.5Y7/8, medium-grained peloid-wackestone, with some bioclastic material including poorly preserved whole shells, burrow traces. Incipient hardground (?) overlain by thin mudstone at top of unit.	0.4
174	Limestone, light grey 2.5Y7/1 weathering pale yellow 2.5Y7/3, medium-coarse-grained peloid-wackestone, very quartz sandy (medium-grained), common coarse shell fragments and some burrow traces	0.45
175	Limestone, light grey 2.5Y7/1 weathering pale yellow 2.5Y7/4, medium- to coarse-grained bioclastic and peloid-grainstone/packstone, forms thin, tabular beds	0.4
176	Limestone bounded by thin mudstone beds above and below.	0.12
177	Limestone, light grey 2.5Y7/1, quartz sandy medium-grained peloid-wackestone to packstone, with some medium-grained bioclastic material, hard.	0.34
178	Mudstone	0.1
179	Limestone, pale yellow 2.5Y8/2, medium-grained peloid-packstone, with lime-mud-filled burrows, underlain by thin mudstone.	0.12
180	Limestone, light grey 2.5Y7/1 weathering pale yellow 2.5Y7/3, medium-coarse-grained peloid-packstone, irregular bedding traces, common medium-grained bioclastic material	0.11
181	Mudstone.	0.03
158	Limestone, light grey 2.5Y7/1, medium-grained peloid-packstone, with common medium- to coarse-grained shell fragments, hard with irregular base.	0.3 to 0.24
157	Limestone, light grey 2.5Y7/1, medium-grained peloid-wackestone to packstone, with much medium- to coarse-grained bioclastic material and common whole poorly preserved shells, rubbly weathering	0.1 to 0.15

Local bed number	Description	Thickness (m)
156	Limestone, light grey 2.5Y7/2, highly bioclastic medium-grained peloid-packstone, with common whole poorly preserved bivalve shells	0.18
155	Mudstone	0.1
154	Limestone, white 2.5Y8/1, light grey 2.5Y7/1 and pale yellow 2.5Y8/3, medium to very coarse-grained highly bioclastic medium-grained peloid-packstone, with common whole poorly preserved bivalve shells	0.4
153	Limestone, light grey 2.5Y7/1 weathering to pale yellow 2.5Y8/2, medium-grained peloid-wackestone with common medium-grained bioclastic material forming hard rib.	0.2
152	Limestone, light grey 2.5Y7/2, finely very sandy medium-grained peloidal packstone/wackestone, scattered medium- to coarse-grained bioclasts, with common poorly-preserved bivalves; friable, soft	0.3
151	Limestone, light grey 2.5Y7/2, finely very sandy medium-grained peloidal packstone, scattered coarse to very coarse bioclasts, harder than above	0.23
150	Mudstone	0.22 (seen)

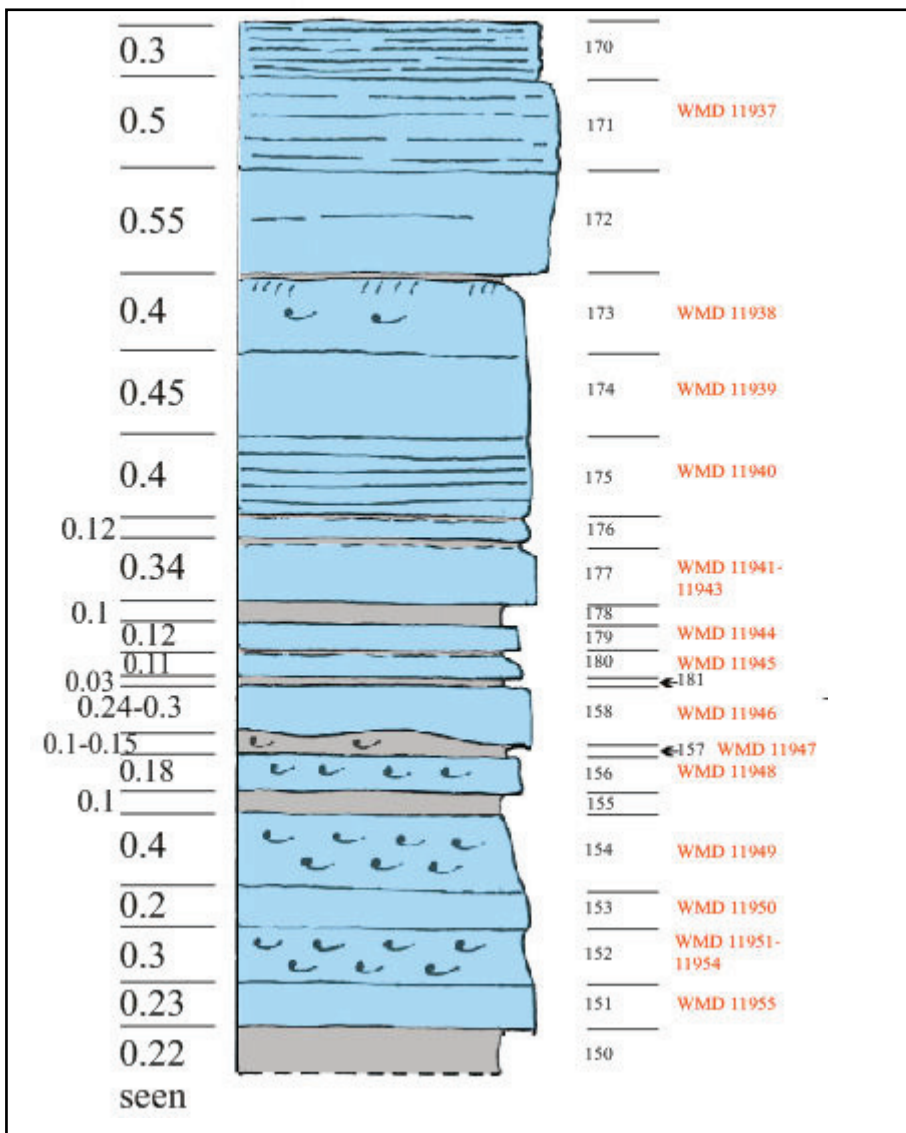


Figure 11. LEC3Loc1 Graphic log

Bed number	BGS sample number	Description/identification
173	WMD11956-11957	Indeterminate bivalve bits and pieces, shell debris and ooids.
157	WMD11958-11961	Poorly preserved shell fragments and impressions, mainly indeterminate bivalves but including <i>Isognomon?</i> and echinoid.
156	WMD11948	Bivalve moulds and fragments including ?oyster.
152	WMD11962-11965	Bivalves and fragments including paired valves of <i>Anisocardia?</i> and <i>Pholadomya cf. lirata</i> (J Sowerby), and <i>Pleuromya?</i> .

Table 7. LEC3Loc1 List of specimens with fossil identifications

LEC3Loc1 close-up photographs

None taken.

5 Laser-scanning HNR1 and LEC1

For proving and demonstration purposes a short campaign of laser-scanning was undertaken, from both crests of the cutting in the vicinity of sections HNR1 and LEC1. The laser scanner acquires around 1000 XYZ points per second, and is used in conjunction with geodetic-quality dGPS (global positioning). The range-finding accuracy is +/- 1.5 cm. Combined with an automated metric high resolution digital camera, it allows accurate digital 3D models to be created, which may be draped with authentically coloured images (Figure 12, Figure 13). The output can be viewed interactively in a 3D visualisation suite, such as that operated by the BGS, providing a virtual-reality tour of the cutting and allowing appreciation of the geological details from different angles.

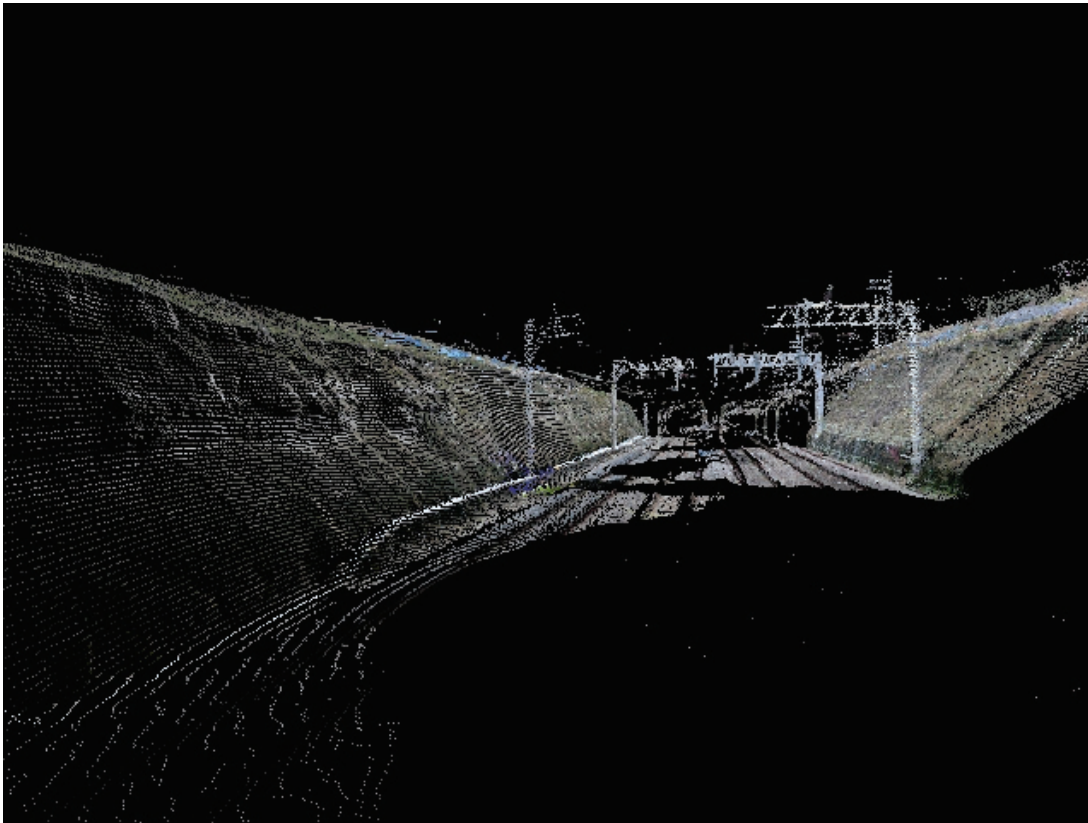


Figure 12. Perspective view of coloured 'point-cloud' image.

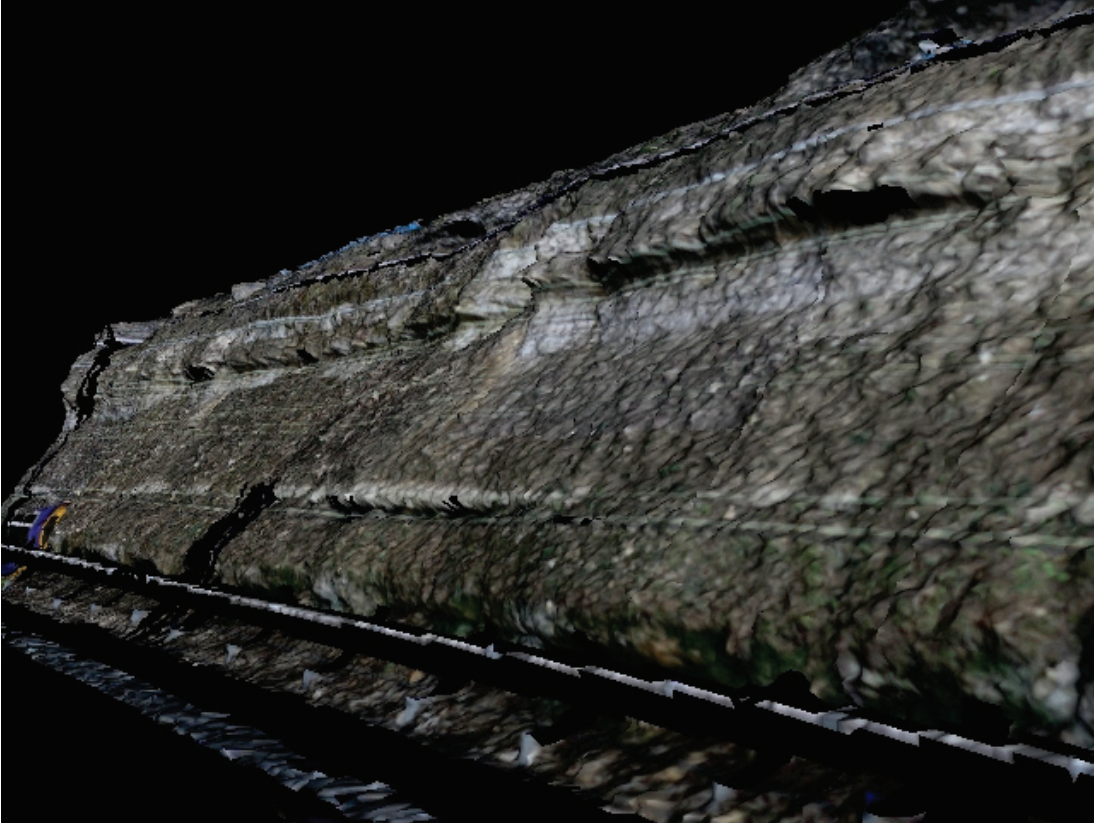


Figure 13. Perspective view of texture-filled image with draped digital photo.

6 Creation of panoramas

Panoramic images were created from multiple photographs taken from the opposite cutting crests. These are reproduced at the end of the report, annotated with the positions of the localities logged and figured above (Section 4), and with indications of correlations of strata between. High resolution annotated and raw versions are provided on the enclosed DVD. Confident correlations are in unbroken lines, dashed lines indicate uncertainty in correlation or position of bed boundary beneath talus or vegetation. The colours of the correlation lines are arbitrary, chosen for clarity. The bed numbering is provisional pending the examination of the Priority 3 sections, when a unified scheme will be erected.

For location of cutting side sections see Figure 2 and the folded plan.

7 Assessment

The strata exposed by the current (Priority 1 and 2) engineering project at Roade Cutting belong entirely to the Blisworth Limestone Formation and neither the top nor the base were observed. Only the lower part of the formation is seen, and it is not straightforward to reconcile our observations directly with the description of Thompson (1924), as paraphrased by Cox and Sumbler (2002, pp. 252-255). It is thought that the exposed strata range from Thompson's Bed 10 (one of his 'Intermediary Beds') down to his Bed 15c ('Rhynchonella and Pholadomya Beds'). Torrens (1967) dubbed the Rhynchonella and Pholadomya Beds the 'Kallirhynchia Sharpi Beds', followed by Cripps (1986), later shortened to Sharpi Beds (Cox and Sumbler, 2002). Thompson recognised a non-sequence (which he also termed an 'inferential unconformity') at the top, which may be of regional significance. Early study of our observations appears to locate this at the top of our Bed 6 of localities HNR1Loc1 and HNR2Loc1.

Further interpretation and correlation awaits finalisation of the study following recording of the Priority 3 sections.

Appendix 1 A palynological study of a sample of the Blisworth Limestone Formation from Roade Railway cutting, Northamptonshire

James B Riding

(extracted from BGS Internal Report IR/06/037R)

INTRODUCTION

A single sample of dark mudstone from Bed 8a of the Blisworth Limestone Formation at Roade railway cutting, Northamptonshire was submitted for palynological analysis in order to derive age and palaeoenvironmental determinations. The location of the sample is SD 75300 51888. The sample was collected by M A Woods and A J M Barron during late 2005, the collector's number is WMD 11814, and is registered as BGS biostratigraphy sample MPA 54832.

PALYNOLOGY

The sample produced a relatively abundant organic residue and palynoflora; the preservation of palynomorphs is good. The kerogen components are overwhelmingly dominated by palynomorphs and fragments of wood and other plant tissues. A full listing of all the palynomorph taxa recognised, including semiquantitative data, is held on the respective BGS micropalaeontology/palynology data sheet, which has been archived. The palynoflora is also listed in Appendix 1.

The palynoflora is dominated by spores and pollen grains. Marine microplankton, principally dinoflagellate cysts, was also observed, thereby indicating that the sample was deposited in an open marine depositional setting. No discernible reworking was observed. The presence of common *Callialasporites* is indicative of the Middle Jurassic, especially the Bathonian Stage. This genus has its range base close to the Early-Mid Jurassic transition (Riding et al., 1991) and no characteristic Late Jurassic-Early Cretaceous species are present.

The dinoflagellate cyst association of *Ctenidodinium sellwoodii*, *Korystocysta* spp., *Meiourogonyaaulax reticulata*, *Pareodinia ceratophora*, and *Wanaea acollaris* is highly characteristic of the Bathonian Stage (Riding et al., 1985; Riding et al., 1991; Riding and Thomas, 1992). Furthermore, the best reference section is the Nettleton Bottom Borehole, Lincolnshire (Riding, 1983, 1987). An acme of *Meiourogonyaaulax reticulata* was discovered in the lowermost Blisworth Clay Formation of this borehole (Riding, 1983, 1987). The occurrence of *Meiourogonyaaulax reticulata* means that this sample is typical of the Blisworth Clay Formation of the East Midland Shelf. Further evidence for this conclusion comes from the BGS Walks Farm Borehole where *Meiourogonyaaulax reticulata* is confined to the uppermost Rutland Formation, Blisworth Limestone Formation and Blisworth Clay Formation (Riding, 1992). Moreover, palynomorph assemblages from the Rutland Formation are dominated by miospores and the marine microplankton associations, where present, are of lower diversity than recorded here.

CONCLUSIONS

The sample from the Blisworth Limestone Formation at Roade railway cutting, Northamptonshire produced a palynomorph assemblage entirely typical of the Bathonian stage and this important lithostratigraphical unit.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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HNR2 north-west detail (18/11/2005)



HNR2 north-west (18/11/2005)



HNR2 south-east (18/11/2005)



Bed numbering provisional

HNR3 (18/11/2005)



HNR1 north-west (18/11/2005)



HNR1 south-east (18/11/2005)



Bed numbers provisional

HNR4 north-west, devegetated (16-07-2007)



HNR4 north-west, pre-devegetation (13-02-2006)



HNR4 south-east, devegetated (16-07-2007)



Bed numbering provisional

LEC4 devegetated (16/07/2007)

B
r
i
d
g
e
2
0
8



LEC3 south-east (13/02/2006)



LEC3 north-west (13/02/2006)



Bed numbering provisional

LEC1 (21/12/2005)



LEC5 devegetated (16/07/2007)



LEC5 pre-devegetation (13/02/2006)



Bed numbering provisional

n
e
a
r
B
r
i
d
g
e
2
0
9

LEC6 south-east, pre-devegetation (13/02/2006)



B
r
i
d
g
e
2
0
9

LEC6 south-east, devegetated (16/07/2007)



LEC6 centre, devegetated (16/07/2007)



LEC6 north-west (13/02/2006)



A
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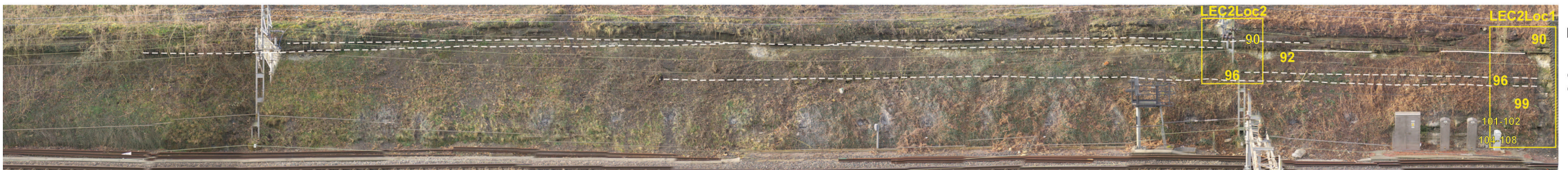
LEC7 south-east (13/02/2006)



LEC7 north-west (16/07/2007)



LEC2 (21/12/2005)



Bed numbering provisional