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The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phase Priority 3 sections and overall assessment

Geology and Landscape England Programme

Commissioned Report OR/10/039

BRITISH GEOLOGICAL SURVEY

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The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phase Priority 3 sections and overall assessment

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Front cover

Display section by Bridge 208 (P731889, *Photographer* A J M Barron).

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) of the strata exposed at Roade railway cutting in Northamptonshire. It comprises descriptions of two localities in sections of the cutting sides exposed during the third of three phases of engineering works and an assessment of the entire site, including sections examined in the first and second phase, reported by Barron and Woods (2010). It was commissioned by Network Rail, through its subcontractors Forkers Ltd and Whitcher Wildlife Ltd, at the behest of Natural England.

Roade cutting transects an almost complete succession of Bathonian (Middle Jurassic) strata, and as such is probably unique in the East Midlands region. Because of this, it has been afforded Site of Special Scientific Interest (SSSI) status, and hence has certain protections administered by Natural England. 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 the geological succession here and Natural England have required Network Rail to commission a survey and description of the geology. The study included measuring and geological description (logging) of the strata exposed in the available sections, collecting rock and biostratigraphical (fossil) samples for further description and determination, and close-up and systematic distant photography.

Logging and close-up photography was undertaken by M A Woods and A J M Barron, and systematic photography by P Witney.

Acknowledgements

The authors would like to thank Forkers staff at the Roade cutting site, particularly Malcolm Kirkbride. Figures were drawn by the authors, and R J Demaine, H Holbrook and S Ward of CartoGIS, BGS. The final report benefited from constructive suggestions by M G Sumbler (formerly BGS).

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Summary

This report describes the geology of the bedrock strata at the Roade railway cutting (a Site of Special Scientific Interest), near Northampton, exposed by engineering works between 2006 and 2010 and made available to the BGS for detailed examination. Strata exposed previously during engineering works between 2005 and 2006 (engineering phases Priority 1 & 2) are described in a companion report (Barron and Woods, 2010). The exposed strata, totalling about 8 m in thickness, belong entirely to the Blisworth Limestone Formation of the Great Oolite Group, which is of Mid Jurassic age. Neither the base nor top of the formation are exposed. The current report includes text descriptions and graphic sections of the localities examined, a plan of the cutting showing locations and the distribution of the strata with correlations, close-up photographs of the bedrock exposed, and photographic panoramas of the cutting sides. It also includes an assessment of the exposed strata in terms of their sedimentary facies and lateral variability.

1 Introduction

This report describes the geology of the bedrock strata exposed by engineering works at the Roade railway cutting, near Northampton (Figure 1), between 2005 and 2010. Strata exposed between 2005 and 2006 (engineering phases Priority 1 & 2) are described more fully in a companion report (Barron and Woods, 2010). The present report describes two further localities made available in 2010 in the Priority 3 phase of the engineering works, plus an overall résumé of the previous work and a synthesis of the geology as a whole. The correlations shown on the panoramas and plan in the Priority 1 & 2 report have been reviewed and revised in the light of new data gathered during the latest work phase; the interpretations shown on the enclosed panoramas and plan entirely supersede those in Barron and Woods (2010).

The strata exposed belong entirely to the Blisworth Limestone Formation of the Great Oolite Group, which is of Mid Jurassic age. The report includes text descriptions 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. It also includes an overall assessment of the exposed strata in terms of their sedimentary facies and lateral variability (Section 6). A local bed numbering system is used for each locality, but is complemented by one that enables correlation of units of strata between localities as shown in Figure 6.

The cutting, which is nearly 3 kilometres long, cuts through an almost complete sequence of Bathonian (Middle Jurassic) strata, and as such is probably unique in the East Midlands region. These strata comprise a succession of fossiliferous limestone, mudstone and sandstone beds, which are overlain in places by clayey glacial deposits of Quaternary age, and were first geologically described when the cutting was widened late in the 19th century. However, the softer mudstone and sandstone beds and the clay deposits are now obscured by retaining walls or soil and vegetation, such that only the limestone-dominated Blisworth Limestone Formation is currently exposed. This forms steep mural exposures up to 6.5 m high, 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 structural disturbances (faulting or folding).

The Blisworth Limestone Formation comprises a succession of relatively well-bedded, pale-coloured sandy, fossiliferous, bioclastic and peloidal limestones, with subordinate intercalated darker grey sandy and bioclastic mudstone beds mainly in the lower part. The formation's bivalve-dominated macrofossil content is largely facies-controlled and is also long-ranging, and consequently is of limited biostratigraphical value. However, the fauna includes some brachiopods, and their distribution, in conjunction with the vertical changes in lithology, enable the division of the formation into two formal members – the Roade Member below (named after this cutting), and the Ardley Member above (see section 6.7).

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

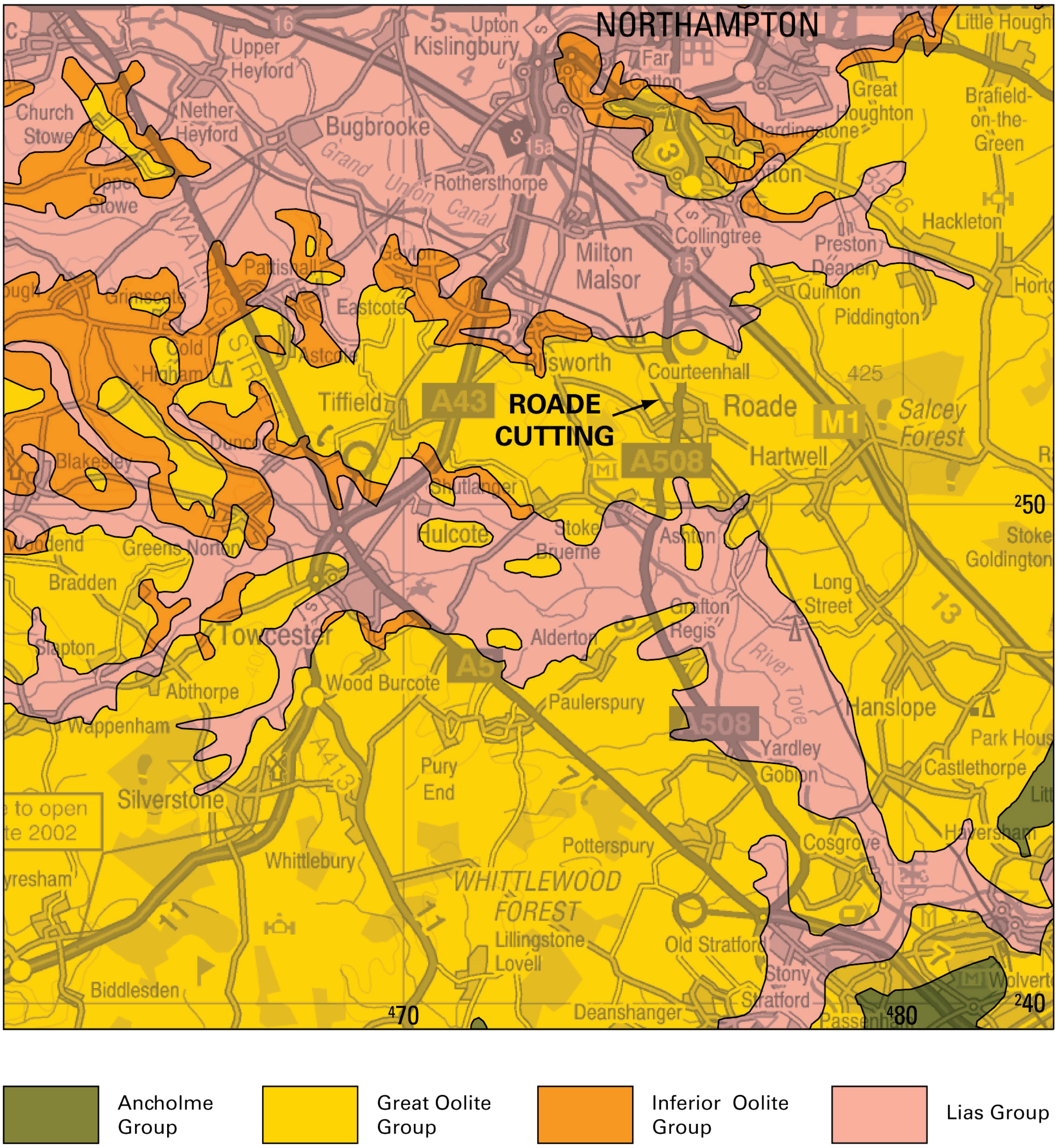

Figure 1. Regional location map showing simplified bedrock geology

Geological mapping extract from BGS 1:250 000 scale map © NERC. OS topography © Crown copyright 100037272/2010.

2 History of geological studies

Roade cutting was originally dug in the 1830's as part of the London–Birmingham railway. It was widened to take a line to Northampton in about 1880, and a geological description was given by Woodward (1894, p 399). However, there were difficulties with inflow of water from the limestone beds and instability caused by the exposed clay beds. This necessitated substantial engineering works in the 1890's, and during these part of the cutting was examined and described by a respected Northamptonshire geologist (Thompson, 1924). His principal account described the rocks exposed north from Bridge 210 (his Bridge 3), but he drew a section of the entire cutting. This is reproduced here (Figure 2) in amended form, showing his bed

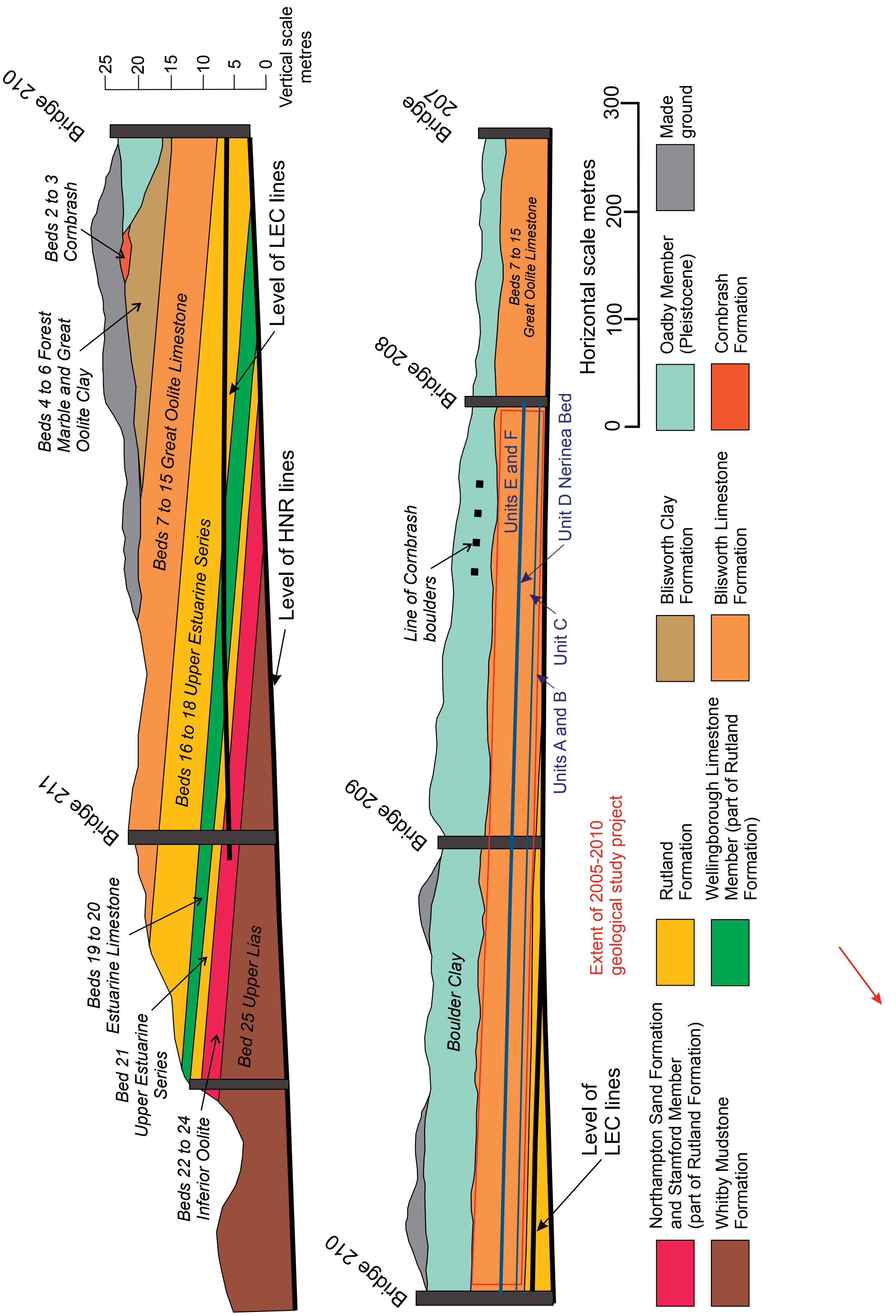

Figure 2. Geological section of Roade Cutting

Adapted from figure in Thompson (1924) with his classification in italics, and the area of current geological study in red and current interpretation shown in blue.

numbering and other observations in black italic, and our interpretation in blue. Modern lithostratigraphic terms are used in the key, with colours matching Figure 3. The oldest bedrock then visible belonged to the Early Jurassic Upper Lias (using Thompson's terminology; now termed the Whitby Mudstone Formation of the Lias Group). Above this occurred the Mid Jurassic Northampton Sand (now a Formation of the Inferior Oolite Group, of Aalenian age) and overlying Great Oolite Group (Bajocian to Callovian age), the last named comprising in ascending order: 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). Thompson also informally named many beds and 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, all of Pleistocene 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 describing a nearby quarry at Blisworth [715 533]. He commented: "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".

The area around Roade was geologically surveyed at 1:10 560-scale by BGS in 1961 and 1964, as part of the 1:63 360-scale sheet 202 (Towcester) although the cutting was not re-examined. Figure 3 is an extract from this map.

A description of the Middle Jurassic of the cutting based largely on Thompson's account was recently given by 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

The list below is from the scope document provided to BGS by English Nature (now Natural England) on 6th October 2005. The 'site' is taken to refer to the area undergoing engineering works in 2005-2010, to which access was provided, not the entire cutting.

Objectives:

- Provision of a modern description of the geology of the site with particular reference to the lithostratigraphy, biostratigraphy and palaeontology.
- 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

Roade 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; see Figure 2). The cutting holds four rail lines: Up and Down ‘Fast’ lines from London Euston to Birmingham and 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. North of Bridge 210 the level of the HNR lines falls, such that the north-east side of 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 3). The works include netting over the steeper parts of the cutting sides to prevent rockfalls, and this will render future access to the strata here very difficult particularly once vegetation is re-established (Plate 1). The cutting sides were divided up into lengths designated by Network Rail as Priority Netting 1, 2 and 3 (in yellow, pink and brown respectively on Figure 3 and the folded plan). These are referred to here **sections** and generally end at gantries or other built structures. There are 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.

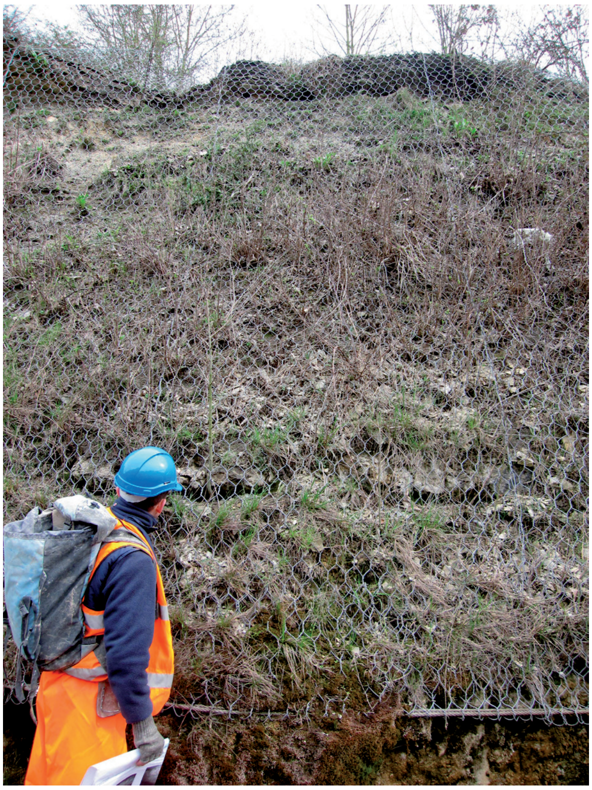

Plate 1. HNR1Loc1 revisited in 2010 showing netting and developing vegetation
(P731895)

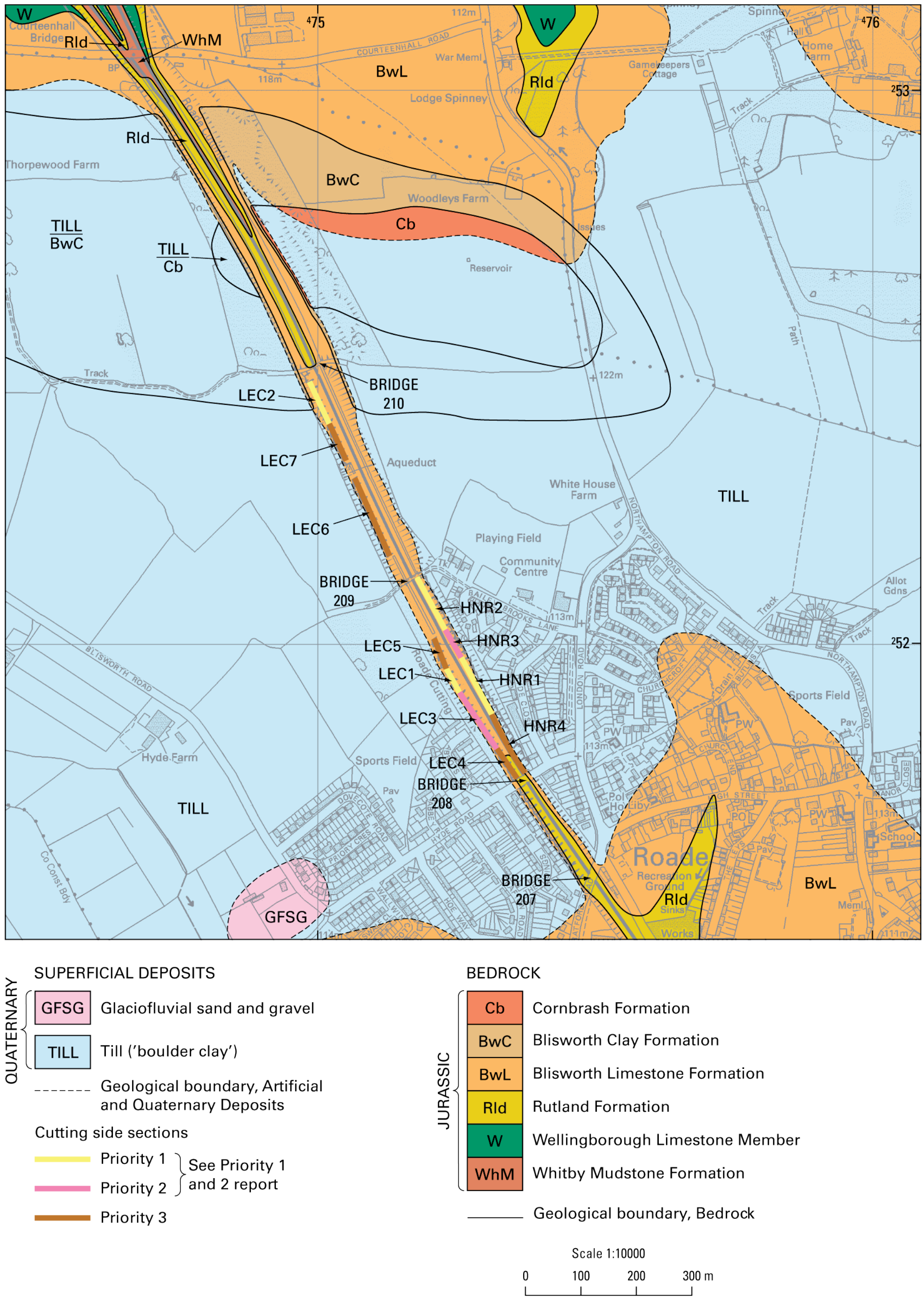

Figure 3. Roade cutting geology map with section locations

Geological mapping extract from BGS 1:50 000 map data © NERC. The outcrops of the beds recorded by Thompson as intervening between the Whitby Mudstone and Rutland formations (the Northampton Sand Formation and lowest beds of the Rutland Formation; see Figure 2) are too narrow to depict at this scale.

3.3 GEOLOGICAL STUDY PROJECT

BGS were originally commissioned through EDGE Consultants Ltd (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, with suspension/postponement of work in mid-2006. On resumption in 2010, the contractual intermediary had changed to Whitcher Wildlife Ltd and an entirely new contract was placed. The Priority 1 and 2 sections and photographic campaign were described by Barron and Woods (2010) to fulfil the original contract to EDGE. With the permission of Network Rail and EDGE, the authors have also published an article on the project in *Geology Today* (Woods et al., 2007), publicising the project and showing early results. The Priority 3 sections were made available in 2010, and comprised five sections of cutting sides with a total length of about 508 metres. One is on the north-east (HNR) side, designated here HNR4, and four on the south-west (LEC) side, LEC4 to LEC7 (Figure 3). In addition, on 11th April, HNR1 was revisited.

Within the cutting-side sections, geological logging was carried out at locations selected by the BGS staff to be representative or well exposed, and these are referred to here as **localities**. As a result of what could be reached from the MEWP (see below), especially at height, these were generally only a metre or two wide. The localities worked on by BGS had generally to be further cleared or substantially dug out before being measured, described, photographed close up and sampled. These are numbered for example **HNR4Loc1**, **LEC6Loc1**, and the descriptions below are related to these. At each locality the succession was numbered bed-by-bed at the time of logging. In addition, the intervening lengths of cutting side were examined as far as possible from the line-side in order to draw correlations between the localities, and guide the annotation of the panoramas. All specimens collected (numbers commencing WMD) and photographs taken (official numbers commencing P) are registered and retained by BGS. Rock specimens were further examined by A J M Barron under a stereo binocular microscope to determine grain characteristics and textures, and these observations are integrated into the field descriptions (Section 4).

A succession of beds that are judged to be of similar facies have been grouped into packages. These are termed here **units**, labelled upwards **Unit A** to **Unit F** and are described in Section 6 and used to draw correlations between localities. This scheme is related to earlier descriptions and current lithostratigraphical schemes.

The results are presented below as locality by locality text and graphic logs and close-up photos (4.3 to 4.4), and as a scaled plan of the cutting showing the positions of the localities with correlation lines drawn between labelled units of beds. The panoramas are annotated with the logged localities and unit correlation lines as far as possible (section 5 and pages 31 to 37).

3.4 ACCESS PROVISIONS, TIMING AND LOGGING PROCEDURE

For operational reasons, railside access for work on 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 Forkers (a man-riding basket on the extendable arm of a road-rail vehicle – a mobile elevated working platform or MEWP) to access the higher parts of the cutting sides, up to 7 m above the track level. Following discussions with Network Rail and based on the limited number of working opportunities (Track Possessions) in the Priority 3 phase (early 2010) and the need for BGS to coordinate with engineering works, only two visits were made to the site. BGS staff attended on the night of 21st February 2010 (LEC6 section), and during the day on 11th April 2010 (HNR4 section). Total time trackside for measuring and making descriptions (logging) of the strata exposed at the localities in the available sections, collecting rock and biostratigraphical specimens for further description and determination, and close-up photography was 10 hours.

This meant that it was not possible to visit all cutting side sections. In the case of LEC4 and LEC5, even after devegetation they were not well exposed, but as they are adjacent to logged localities the judgment was made that this was not a significant omission. Only one locality (LEC6Loc1) was recorded in the long section (LEC 6 & 7) between Bridge 209 and LEC2, but nevertheless, thorough devegetation has enabled confident correlations of strata Units to be made (Section 6).

The systematic photography of the cutting sides was undertaken under the EDGE contract 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 Priority 3 sections, both prior to and post-devegetation. These photographs were combined to build panoramas (see section 5 and pages 31 to 37).

4 Roade cutting: geological description

4.1 PHYSICAL CONTEXT

Thompson's (1924) account included a diagram showing a longitudinal section along almost the entire cutting (his Bridge 6, now Bridge 207, to beyond his Bridge 1 on the HNR lines), 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), capped by glacial till. Figure 2 is an adaptation of this diagram also showing the current interpretation. In the course of the current work we have found that the top of the Rutland Formation is now below track level hereabouts, possibly as a result of later addition of ballast. 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 in 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 15º) and are underlain at least in the upper part by clay-dominated deposits with minor thicknesses of limestone (Blisworth Clay and Cornbrash formations and glacial deposits), and it must be presumed that Thompson's Beds 7 to 9 are also present below. No strata are exposed here normally, and none were seen as a result of the current engineering operations. In addition, the mudstone/clay and sandstone/sand-dominated lower strata, originally recorded by Thompson (1924) in the northern part of the cutting, mainly on the HNR side, 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.

4.2 ROCK DESCRIPTION

In the descriptions following, rock specimens are given BGS registered collector numbers prefixed with WMD. Grain size follows the Wentworth scale. Where qualified with an alphanumeric suffix (e.g. 2.5Y 6/3) the colours given were determined from the (dry) specimens collected and use the Munsell soil colour description (1994 edition), and so where no Munsell colour is given no specimen was available. Localities are described from top to bottom. A glossary is provided at the end for technical terms.

4.3 HNR4LOC1

NGR: SP 75379 51778 (logged 11/04/10).

This section has been thoroughly cleaned and left un-netted providing a representative section of the strata (see *cover photograph*) that can be viewed over the parapet of Bridge 208.

HNR4Loc1 text log

Stratal unit	Local bed number	Description	Thickness (m)
		Topsoil	0.2
F	1	LIMESTONE, light yellowish brown 2.5Y 6/3, peloidal, fine and medium-grained bioclastic packstone, very thin bedded, oyster-rich; conspicuous whole oyster shells (WMD 14801–14802)	0.32
	2	LIMESTONE, thicker bedded, peloidal; less obviously bioclastic than Bed 1	0.18
	3	LIMESTONE, thin-bedded unit comprising lenses of bioclastic limestone intercalated with mud-rich laminae (Plate 2); no whole bioclasts	0.15
E	4	LIMESTONE, light grey 2.5Y 7/2, nodular, medium-peloidal with fine sand cores, bioclastic packstone locally wackestone containing whole oyster and bivalve shells, medium-grained sandy; iron-stained, ?glauconite (WMD 14803–14807)	0.23
	5	MUDSTONE, light olive brown 2.5Y 5/4, locally orange-stained, with shell fragments and whole oysters *Praeexogyra* (WMD 14808)	0.030–0.040
	6	LIMESTONE, white 2.5Y 8/1, soft, very fine-grained, scattered fine sand, bioclastic wackestone, whole bivalves (Plate 3); with conspicuous patches of sparry calcite near top; becomes softer calcareous mudstone near base (WMD 14809–14812)	0.27
	7	LIMESTONE, light grey 2.5Y 7/2 wackestone, soft, orange-yellow weathering, common light brown peloids, rare fine sand, not conspicuously bioclastic (WMD 14813)	0.16
	8	MUDSTONE, dark yellowish brown 10YR 5/4, highly peloidal and bioclastic (WMD 14814)	0.040
	9a	LIMESTONE, white 2.5Y 8/1, medium to medium–coarse peloid-packstone, abundant medium-grained bioclasts and common large shell fragments, hard (WMD 14817); mudstone parting at base; top of unit is serpulid-encrusted and very irregular (?current scoured / hardground) (WMD 14815–14816)	0.18
	9b	LIMESTONE, pale yellow 2.5Y 8/2-4, hard, peloid-packstone to wackestone, small bioclasts (WMD 14818–14822), mudstone parting at base	0.16
	9c	LIMESTONE, light grey 2.5Y 7/1, very fine grained, common fine bioclasts in wackestone, hard, sparsely peloidal, large lime-mud-filled burrows (WMD 14823); very nodular lowest 0.08 m lime-mudstone, pale yellow 2.5Y 8/2, pockets of peloids and bioclasts (WMD 14824-14826)	0.22
	10	MUDSTONE parting, calcareous, light grey, very pale brown-weathering 10YR 7/4, highly finely bioclastic (WMD 14827)	
	11	LIMESTONE, pale yellow 2.5Y 8/2, peloidal wackestone to packstone, highly bioclastic, muddy, scattered sand, pale yellow 2.5Y 8/4 and orange weathering (WMD 14828)	0.08

Stratal unit	Local bed number	Description	Thickness (m)
E cont	12	MUDSTONE, bright orange-yellow	0.015–0.020
	13	LIMESTONE, pale yellow 2.5Y 8/2, fine- to very coarse-grained bioclast-grainstone, weathering to very pale brown 10YR 7/4 (WMD 14829)	0.1
	14	LIMESTONE, light grey 2.5Y 7/1 to pale yellow 2.5Y 7/3, coarse bioclast-packstone to grainstone, moderately medium- to coarse-grained peloidal, numerous micromorphic gastropods (WMD 14830); locally cross-bedded	0.25
	15	LIMESTONE, pale yellow 2.5Y 8/2, sandy bioclast-packstone to wackestone with grainstone pockets, scattered yellow peloids, hard, muddy, massive weathering (WMD 14831–14832)	0.27
	16	MUDSTONE parting	0.010
	17	LIMESTONE, light grey 2.5Y 7/1, moderately sandy bioclast-wackestone, scattered orange peloids, muddy, rather nodular, with thin mudstone beds 0.2 m below top and 0.23 m above base; bed forms oblique weathered profile (WMD 14833–14836)	0.75
D	18	MUDSTONE, grey, orange-yellow weathering	0.015–0.020
	19	LIMESTONE, pale yellow 2.5Y 8/2 weathering light grey 2.5Y 7/2, highly peloidal packstone / wackestone, with a moderate amount of coarse shell debris, and common large bivalves and other shell fragments, very hard, some pale grey, mud-filled burrows (WMD 14837–14841)	0.5
	20	MUDSTONE, brownish-yellow 10YR 6/6, highly peloidal and bioclastic (WMD 14842)	0.030–0.040
C	21	LIMESTONE, pale yellow 2.5Y 7/4, weathering orange-yellow, sandy, peloidal, bioclast-packstone to wackestone, soft, with very common large bioclasts and whole bivalve shells (including ?*Camptonectes*) (WMD 14843–14845)	0.3
	22	LIMESTONE, light grey 2.5Y 7/1, hard, finely sandy, moderately peloidal, fine-grained bioclast-packstone, with some larger bioclasts, less abundant than in Bed 21 (WMD 14846, 14848–14849); large smooth-shelled bivalve (WMD 14847)	0.21
	23	MUDSTONE, light olive brown 2.5Y 5/3, calcareous, numerous yellowish brown medium peloids, sparsely bioclastic (WMD 14850), a few small smooth bivalves (WMD 14851)	0.23
	24	LIMESTONE, grey 5Y 6/1, weathering to light grey 2.5Y 7/2, very hard, sandy, fine- to very coarse bioclast-packstone (WMD 14852–54, 14856), with bivalves (WMD 14855, 14859) and solitary coral (WMD 14857, 14858), forms a distinct ledge	0.3
B	25	MUDSTONE, grey 2.5Y 5/1, soft, finely very sandy, common medium bioclasts, burrowed (WMD 14860–14864)	0.5
A	26	LIMESTONE, light grey 2.5Y 7/1-2, finely sandy, fine- to medium peloidal, fine-grained bioclast-packstone, hard (WMD 14865) with bivalves and the brachiopod *Kallirhynchia* (WMD 14866–14868)	0.56
	27	MUDSTONE, grey	0.020
	28	LIMESTONE, light grey, finely sandy, fine-grained bioclast-packstone to wackestone, with lenses of harder limestone and thin layers of softer mudstone; common whole bivalves and sparse *Kallirhynchia* (WMD 14869–14874)	0.46
	29	MUDSTONE, dark grey 2.5Y 4/1, silty, common fine-grained mica sand and scattered coarse shell fragments, soft (WMD 14875)	0.030–0.040

Stratal unit	Local bed number	Description	Thickness (m)
A cont	30	LIMESTONE, grey 5Y 6/1, with light grey 5Y 7/1 lime-mud-filled burrows, fine-grained bioclast-packstone with much coarse shell detritus, whole bivalves, some black (pyritised?) and *Kallirhynchia* (WMD 14876–14880)	0.25 seen
		BASE OF SECTION AS SEEN	

N.B. In the cutting side, Bed 26 here, and elsewhere this or other limestone beds close above the track-bed are commonly tufa and moss-covered. This indicates that water is issuing from them and precipitating calcium carbonate (as tufa). This may be more-or-less continuous, depending on local groundwater conditions.

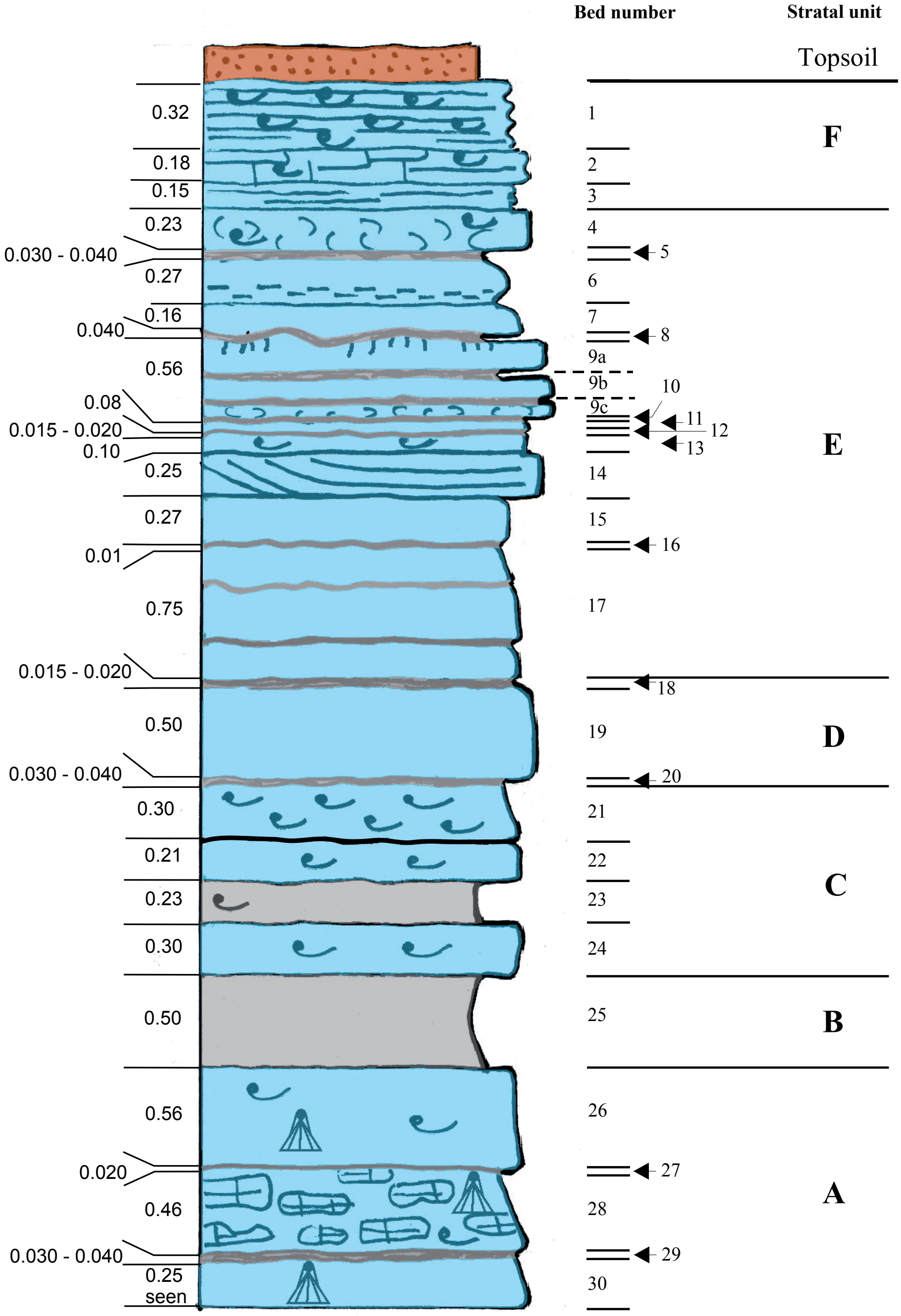

Figure 4. HNR4Loc1 Graphic log

Key to Graphic sections

Profile of right-hand side of column gives an indication of the weathered profile of the bed in the cutting side. Thicknesses in metres on left hand side.

Limestone

Mudstone/calcareous mudstone

Shells or coarse bioclastic material

Fe Iron staining

Brachiopod(s)

Hardground

Planar bedding

Cross bedding

Nodular

Burrowing

HNR4Loc1 close-up photographs

Bed 2

Plate 2. HNR4Loc1, close-up of beds 1 to 6, Units E and F

Thinly-bedded nature of unit very apparent (P731896)

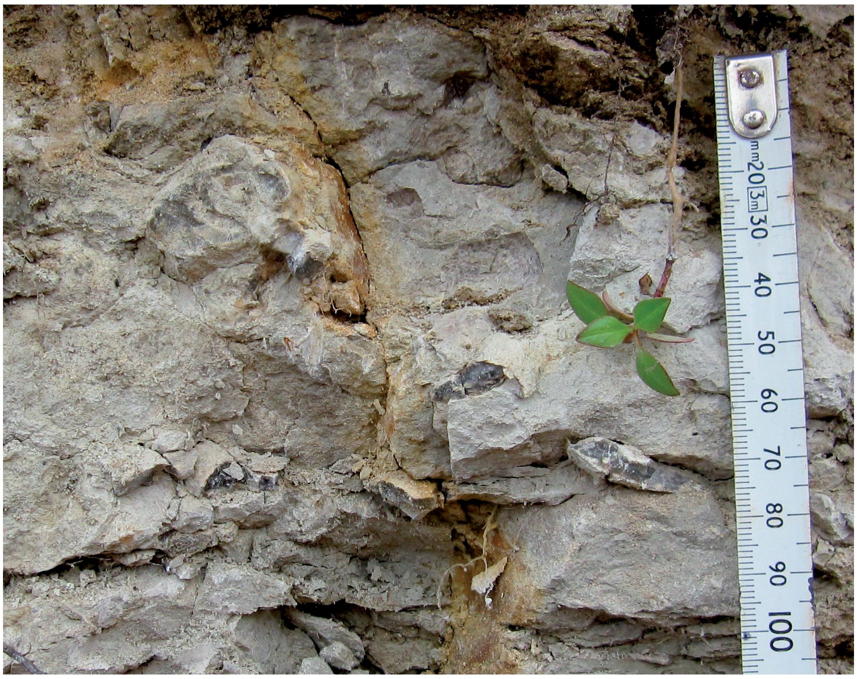

Plate 3. HNR4Loc1, close-up of Bed 6 (Unit E) showing bivalves

(P731897 cropped)

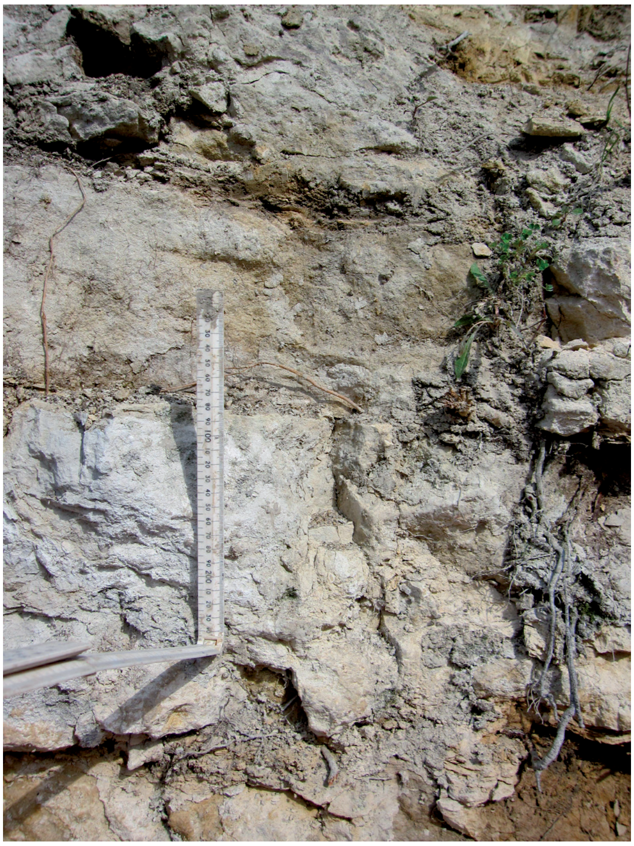

Plate 4. HNR4Loc1, close-up of beds 9a to 9c and 10, Unit E
Scale in cm. (P731899)

Plate 5. HNR4Loc1, close-up of beds 9 to 17, Unit E
Scale in cm. (P731900)

Bed 19. ‘Nerinea Bed’

Plate 6. HNR4Loc1, close-up of beds 17 to 19, Unit E to Unit D

Scale in cm. (P731903)

Bed 24

Plate 7. HNR4Loc1, close-up of beds 23 to 25, Unit C to Unit B

Scale in cm. (P731905)

Bed 25

Plate 8. HNR4Loc1, close-up of beds 24 to 25, Unit C to Unit B

Scale in cm. (P731907)

Bed 26; 0.56 m thick

Plate 9. HNR4Loc1, close-up of beds 24 to 30 (lowest visible), Unit C to Unit A

Bed 26 is tufa and moss-covered (P731890)

4.4 LEC6LOC1

NGR: SP 75105 52233 to 75110 52228 (logged 21/02/10)

LEC6Loc1 text log

Strata Unit	Local bed number	Description	Thickness (m)
F	1	*Inaccessible unit* LIMESTONE, medium-grey weathering, hard, nodular; thins out laterally (lenticular); comprises several thin-bedded units.	est. 0.15–0.25
	2	*Inaccessible unit* LIMESTONE, thin-bedded, muddy, with small, oval and elongated pale-coloured burrow structures weathering proud, with thin mud-rich laminae	est. 0.6
	3	*Inaccessible unit* LIMESTONE, muddy, hard; flat-topped; uneven base	est. 0.1
E	4	MUDSTONE, with thin limestone lenticle	0.06–0.08
	5	LIMESTONE, pale yellow 2.5Y 8/2, fine- to coarse-grained bioclastic medium-grained peloid packstone, locally with grainstone pockets, with numerous whole and articulated bivalves; hard, muddy (WMD 14772)	0.18–0.2
	6	LIMESTONE, light grey 2.5Y 7/1, finely sandy, finely peloidal, fine- to medium-grained bioclast-packstone, some very coarse bioclasts, thin bedded (1 to 2 cm thick) separated by mud-rich laminae; soft (WMD 14773–14777)	0.5
	7	MUDSTONE, dark greyish brown 2.5Y 4/2, finely sandy, fine- to medium-grained bioclastic, laminated, yellow-orange stained at base (WMD 14778)	0.1
	8	LIMESTONE, white 2.5Y 8/1 to pale yellow 2.5Y 8/2, coarsely and richly bioclastic, medium- to coarse-grained coated peloid-packstone, hard, resistant-weathering (WMD 14779)	0.3
	9	LIMESTONE, light grey 2.5Y 7/1, finely sandy, coarse-grained shell fragments and light orange medium-grained peloids in wackestone, locally packstone texture; in flat beds several cms thick, separated by mud-rich laminae (WMD 14780–14782)	0.75
	9b	MUDSTONE, soft, calcareous, orange-yellow weathering; very sharp base	0.03
	10a	LIMESTONE, pale yellow 2.5Y 8/2, coarsely bioclastic medium-grained coated peloid grainstone, cross-bedded, hard weathering (WMD 14783) ; base is an erosion surface at which there is a change in the angle of the cross-bedding	0.25
	10b	LIMESTONE, pale yellow 2.5Y 8/2, medium-grained peloidal, medium- to coarse-grained bioclast-grainstone, cross-bedded (steep), tabular cross beds are 0.01 to 0.05 m thick, separated by thin muddy partings up to 0.005 m thick, soft (WMD 14784)	0.3
	10c	LIMESTONE, pale yellow 2.5Y 8/2, fine- to medium-grained peloidal, medium- to coarse-grained bioclast-grainstone, cross-bedded (shallow); sharp base (WMD14785)	0.25
D	11	LIMESTONE, light grey 5Y 7/2, finely sandy, medium-grained pale orange peloidal, medium-grained bioclastic wackestone, hard; very sharp base (WMD 14786–14791)	0.3

Strata Unit	Local bed number	Description	Thickness (m)
C	12	LIMESTONE, pale yellow 2.5Y 8/2, medium-grained peloidal, medium- to coarse-grained bioclast-packstone, recessively-weathering; rather soft and yellow-grey weathering in upper part, becoming harder and pale grey downwards (WMD 14792–14793)	1.0
	13	MUDSTONE, ?calcareous, greyish yellow, soft	0.12
	14	LIMESTONE, and muddy limestone, yellow-weathering and bioclastic	0.45
	15	LIMESTONE, grey 5Y 6/1, weathering to light grey 2.5Y 7/2, finely peloidal, fine- to coarse-grained bioclast-packstone, scattered whole bivalves, hard (WMD 14794)	0.2
B	16	MUDSTONE, ?calcareous, grey, mottled	0.4
A	17	LIMESTONE, muddy, relatively soft	0.3
	18	MUDSTONE, ?calcareous	0.06
	19	LIMESTONE, hard	0.6 seen
		BASE OF SECTION AS SEEN	

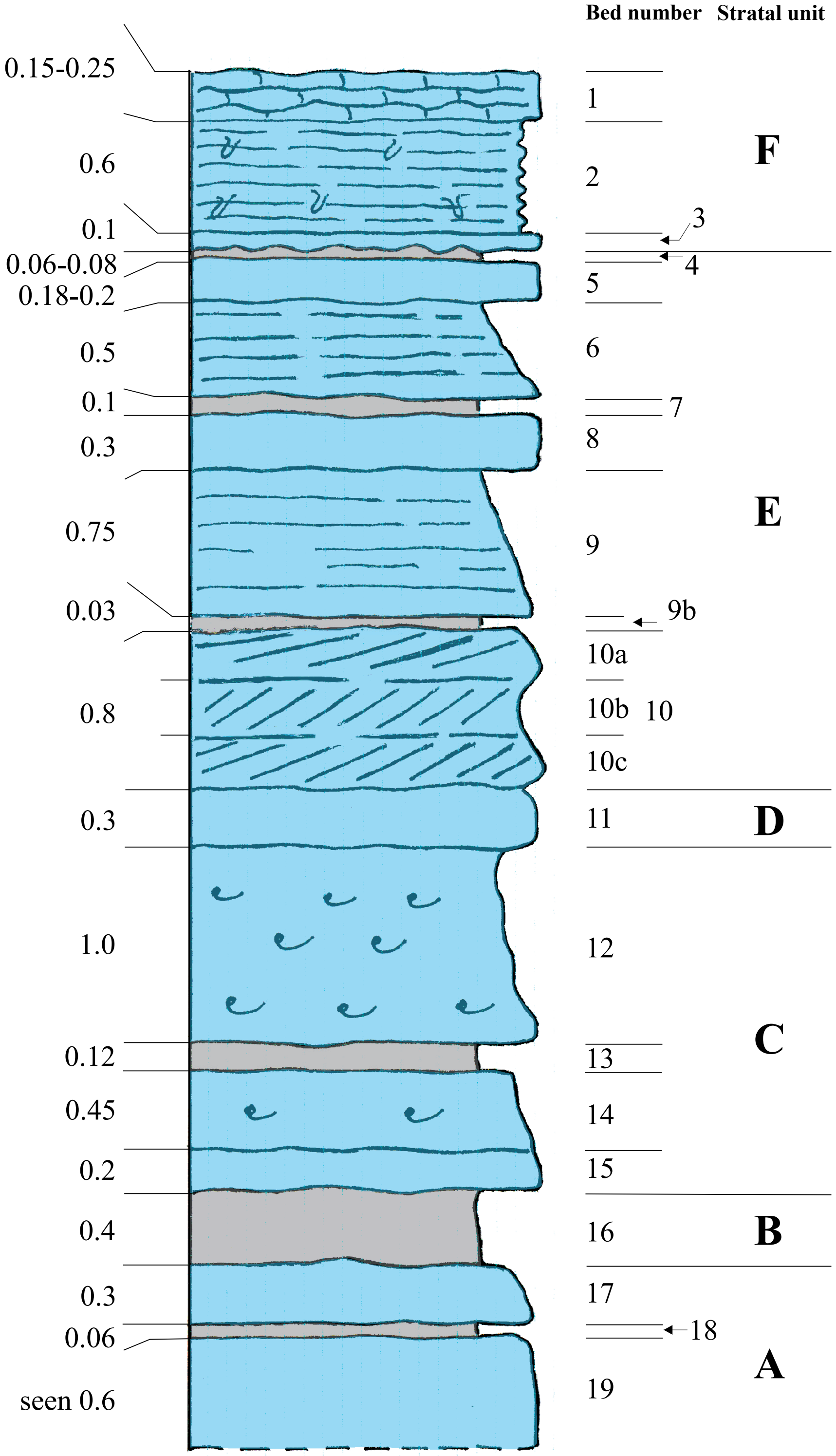

Figure 5. LEC6Loc1 Graphic log

LEC6Loc1 close-up photographs

Plate 10. LEC6Loc1, close-up of beds 1 to top of 3, Unit F

Bed 1 displays nodular texture. (P726568)

Plate 11. LEC6Loc1, close-up of beds 2 to 3, Unit F

(P726566)

Bed 6; 0.5 m thick

Plate 12. LEC6Loc1, close-up of beds 3 to 7, Unit F to Unit E
(P726569)

Plate 13. LEC6Loc1, close-up of Bed 9, Unit E
Scale section 25 cm long. (P726572)

Bed 10; up to 0.8 m thick

Plate 14. LEC6Loc1, close-up of beds 9 to top of 12, Unit E to Unit C

Bed 10 (cross-bedded) in middle (P726573)**.**

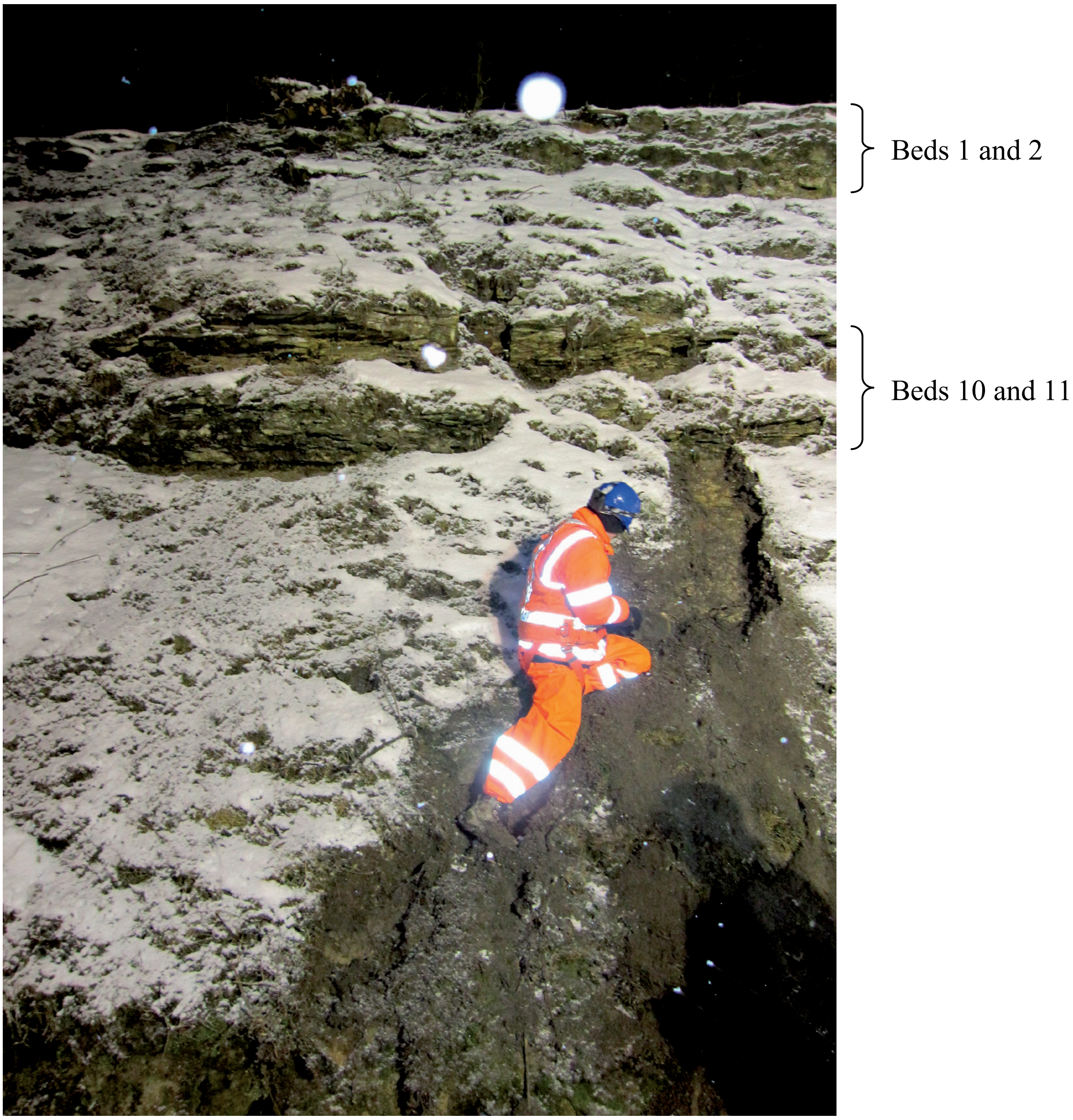

Plate 15. LEC6Loc1, general view of beds 1 to top of 19, Unit F to Unit A
(P726578) (White blotches are falling snow)

5 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 (pp. 31-37), annotated with the positions of the localities logged and figured above (Section 4), and with indications of correlations of units of strata between. High resolution annotated and raw versions are provided on the enclosed CD. Confident correlations are indicated by unbroken red lines, whereas dashed red lines indicate uncertainty in correlation or position of unit boundary beneath talus or vegetation. Readers should be aware that the overhead power lines are intrusively visible in some panoramas, to the extent that they may cause some confusion.

For location of cutting-side sections see Figure 3, Figure 6 and the folded plan.

6 Overall geological assessment

The strata exposed by the engineering project (Priority 1, 2 & 3 sections) at Roade Cutting belong entirely to the Blisworth Limestone Formation although neither the top nor the base of the formation are exposed. The nature and mutual associations of the sediments and their contained fossils (litho- and biofacies), together with the general palaeogeographic situation in the Mid Jurassic (see Bradshaw *in* Cope et al., 1992) indicates that the formation was deposited in fully marine conditions on a shallow seafloor in a warm, probably sub-tropical climate. Conditions were predominantly tranquil (low-energy), conducive to the accumulation of fine carbonate mud, and the development of a prolific mollusc-dominated bottom-dwelling fauna. The clay, and non-carbonate (probably largely quartzose) fine-grained sand and silt that is present in greater or lesser proportions in nearly all of the succession (packstone and wackestone-textured limestone and mudstone; see below) is thought to have been derived from the London (or Anglo-Brabant) Landmass some tens of kilometres to the south-east: this was transported to the sea by rivers.

Sedimentation was probably more or less continuous allowing a build up of soft sediment which hosted a prolific infauna, evidenced by a general disturbance of bedding structure and common presence of burrow traces. However, at some levels the presence of brachiopods and serpulids indicates phases of non-deposition and contemporaneous sea-floor hardening and cementation. Also there are indications that the tranquil environment was sporadically interrupted by periods of higher energy, current-dominated conditions in which finer sediments were washed away. These are indicated by sharp breaks in the rock sequence (minor non-sequences) and in some cases by coarser-grained, commonly cross-bedded limestone. Such events may have included storms but progressive changes in coastal configuration consequent upon relative sea-level changes may have altered the sedimentary regime.

In general, the rocks at Roade display many common characteristics distinctive of the Blisworth Limestone Formation. Both the limestone and mudstone beds are almost universally highly bioclastic, with fine to very coarse grains of broken shells mostly of bivalves, plus subordinate brachiopods and gastropods. The non-carbonate sand and silt is found in the matrix and the peloids, and as the cores of the rare ooids. The limestone beds are mainly packstone (grain-supported, lime-mud matrix) or wackestone (matrix-supported) texture (but see 6.5 below), and individual burrows and less conspicuous bioturbation is present particularly in the wackestone-textured rocks. Peloids, seen in many of the limestone and mudstone beds, are generally of medium grain size, almost always with coatings which are commonly more orange or brown in colour than the main rock mass, because of their slightly raised iron content (in an oxidised Fe^{3+} state).

The macrofossil content is dominated by bivalves, which are seen throughout the section, and a wide variety of genera have been observed and collected (see Barron and Woods, 2010), including *Anisocardia*, *Modiolus*, *Isognomon?* and *Pleuromya?* in the central part of the section, and abundant oysters (for example *Praeexogyra hebridica* (Forbes)) in the upper part. Brachiopods were collected mainly from the lower beds during the current work, where they are conspicuous and are mostly the rhynchonellid *Kallirhynchia sharpi* Muir-Wood. A more diverse fauna has previously been recorded from the Blisworth Limestone Formation, including gastropods, the corals *Thamnasteria* and *Chomatoseris*, the echinoids *Clypeus* and *Acrosalenia*, and the terebratulid brachiopods *Kutchithyris*, *Epithyris?* and rhynchonellid brachiopod *Burmirhynchia?* (Cox and Sumbler, 2002).

Examination of the correlation diagram of the logged sections (Figure 6) confirms Torrens' (1967, p. 70) comment regarding the lateral variability of the formation, notably the lenticularity of many of the beds, and this has discouraged any attempt to establish a unified bed-by-bed numbering scheme. Instead, the exposed strata have been divided into six packages labelled upwards Unit A to Unit F. Two of these (B and D), however, are single persistent beds which are traced throughout, and form divisions, and the remainder display certain internal lithological and/or faunal similarities.

The entire succession here may be regarded as part of a parasequence in sequence stratigraphy terms (Van Wagoner et al., 1988). The Blisworth Limestone Formation conformably overlies a succession of predominantly non-marine, paralic strata – the Rutland Formation, which may be referred to a 'lowstand systems tract'. As described above, the facies of the Blisworth Limestone indicates fully marine conditions and so also a relative sea-level rise. This conforms to a 'transgressive systems tract to highstand systems tract' although signs of erosion at some levels, including a hardground horizon are indicative of periodic regressive events.

6.1 UNIT A

Unit A comprises medium bedded, finely sandy, fine- to medium-grained bioclastic, medium-grained peloidal packstone and wackestone limestones with intercalated thin sandy and bioclastic mudstone beds, and moderately common rhynchonellid brachiopods (*Kallirhynchia*) and whole bivalves. Although the most poorly exposed part of the succession in the cutting, including commonly being tufa-encrusted (Plate 9), these beds appear to persist laterally and do not vary significantly in lithology. The base of the unit is not seen so its full thickness is unknown, but up to 1.4 m of exposed strata are seen at HNR1Loc2.

The facies of Unit A indicates that its shallow marine depositional environment was clearly protected from strong current action, and the substrate was sufficiently stable and possibly moderately lithified, for brachiopods to colonise.

6.2 UNIT B

Unit B comprises a single persistent and generally conspicuous bed of dark grey to olive brown very silty, finely sandy, fine- to medium-grained bioclastic mudstone (see panorama HNR4 south-east on p. 31). It is about 0.4 m thick throughout, but thickens to 0.5 m at the south-east end (HNR4Loc1, Bed 25, Plate 8). This may have been deposited in a single, though possibly prolonged, episode of terrigenous sediment input that choked the existing benthonic fauna. Bioclasts were incorporated by reworking from the unlithified sea bed.

6.3 UNIT C

Unit C comprises medium-bedded, finely sandy, medium-grained peloidal and medium- to very coarse-grained bioclastic packstone or wackestone limestones, with a rich fauna including a large variety of bivalves and rare brachiopods (rhynchonellids and ?terebratulids) and solitary corals, plus some conspicuous burrows and scattered lignite fragments. This unit is only moderately well exposed (see especially panoramas on p. 29), and although the lateral continuity of its limestone beds is uncertain, a median calcareous and peloidal mudstone bed appears to be fairly persistent (Plate 7). Its thickness ranges from 1.05 to 1.8 m, generally thickening north-west, and its facies is generally similar to that of Unit A.

6.4 UNIT D

Unit D comprises a single massive pale medium-grained peloidal packstone or wackestone limestone bed, with medium to coarse bioclasts, burrows and common whole shells, mainly bivalves, and is commonly underlain and overlain by thin mudstone beds. The base may be irregular. It is noticeably hard and prominent (see especially panoramas on pp. 29 and 34). In the extreme north-west (LEC2Loc1) coated peloidal and bioclastic grainstone texture is recorded in parts. It is between 0.4 and 0.55 m thick, locally a little less and is very probably the Nerinea (or Nerinaea) Bed of Thompson (1924), who recorded a variety of bivalve genera, plus corals, gastropods and ooids in this unit. This assemblage implies a relatively stable, well oxygenated substrate.

6.5 UNIT E

Unit E is the thickest and internally the most variable unit in the cutting. Most of the limestone beds are medium- to coarse-grained peloidal and medium- to coarse-grained bioclastic packstone and wackestone, but vary in habit from nodular to massive or parallel bedded. Compared with the rest of the succession they are not conspicuously fossiliferous. The facies are as described in 6 above, except as modified below.

In the north-west, a cross-bedded, medium-grained ooidal and peloidal, coarse-grained bioclast-grainstone unit about 0.8 m thick lies at the base. It probably persists throughout the cutting, with a predominant cross-bedding direction to the south-east, and thickens to 1.35 m at HNR2Loc1, but south-eastwards it thins to 0.25 m and a thinly parallel-bedded sandy peloidal bioclast-wackestone unit appears below it (compare panoramas of HNR2 south-east and HNR1 north-west), attaining a metre thick at HNR4Loc1. This unit displays characteristics that indicate relatively higher energy conditions, with strong currents which have winnowed the fines. The unimodal cross-bedding may suggest a single event, such as a storm, rather than tidal influence, and so the ooids are likely to have been swept in rather than formed on this part of the shelf.

Above this, signs of hardground formation (sea floor cementation) were seen at the same level at some localities (HNR4Loc1, LEC3Loc1, LEC1Loc1), suggesting a period of shallowing and non-deposition. This horizon is tentatively correlated on Figure 6 (dotted line), and although such a break would be a good natural level to place a unit top, the failure to recognise it throughout the site has prevented this. Ooids are noted in some beds, possibly reworked from the cross-bedded unit and there are scattered glauconite grains in the higher beds; this mineral further indicates a period of low sedimentation rate. The uppermost bed is noted as nodular at several localities.

6.6 UNIT F

The beds of Unit F form the crest of the steep cutting sides, and are generally the best exposed and can be traced throughout. However, even from the MEWP they proved inaccessible in places, preventing sampling and description. They comprise thin- to very thin-bedded, sandy, coarse- to very coarse-grained bioclastic and fine- to coarse-grained peloidal packstone or grainstone with thin mudstone partings. The beds are typically oyster-rich, with common *Praeexogyra*.

The unit appears as several ‘ribs’ in the north-west (LEC2Loc1 and 2) but the lowest of these clearly lenses out south-eastwards, reappearing in LEC7 (see panoramas on p. 35) but not clearly traced through LEC6. As the highest unit examined, the unit’s total thickness cannot be given, but up to 1.4 m of beds were seen at HNR2Loc1. The alternation of thin limestone and mudstone beds implies quiet shallow marine conditions interrupted by pulses of terrigenous mud input.

6.7 CORRELATION AND CONCLUSIONS

Only the lower part of the Blisworth Limestone Formation is seen, and it is not straightforward to reconcile all our observations directly with the description of Thompson (1924), as paraphrased and revised by Cox and Sumbler (2002, pp. 252-255). This may be in part due to lateral variability in that Thompson’s description concentrates on the succession north-west of Bridge 210. However, 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). Unit A with its common rhynchonellid brachiopods can be confidently included in the Sharpi Beds, but the affinity of the overlying beds is less certain. As stated above, Unit D is very probably Thompson’s (1924) Nerinaea Bed (bed 13), and although brachiopods are rare in Unit C it seems likely that it is Thompson’s bed 15a, with Unit B his bed 15b. Thompson recognised a non-sequence (which he also termed an ‘inferential unconformity’) above his bed 15, which may be of regional significance. Our observations suggest that this may be between Units C and D.

Above, the cross-bedded unit within Unit E is very distinctive and conspicuous, and must be Thompson’s (1924) ‘Intermediary’ bed 12, although he did not record ooids/peloids. However, the overlying strata in Units E and F are difficult to reconcile with Thompson’s account. Unit E (typically 2 m thick above the cross-bedded unit) is not notably fossiliferous, and certainly seems to lack the terebratulid brachiopods of Thompson’s (1924) (0.3 m-thick) bed 11. On grounds of thickness and the lack of macrofossils, Thompson’s (1924) bed 10 could be the upper part of Unit E, although it is not comparatively hard. This would make Unit F Thompson’s ‘Coral Bed’ (9), but the habit and faunal content appear to belie this correlation – viz our observations of abundant ostreid oysters and lack of corals and other bivalve genera. Cripps (1986, p. 79) noted the impersistence of the Coral Bed.

Relating the Roade Cutting succession to the wider area, the Sharpi Beds are regionally recognised (Torrens, 1967). It was proposed by Torrens (1967, p.70) that the ‘Digonoides Beds’ observed at Rectory Farm quarry, Blisworth 3.5 km to the west, may be Thompson’s (1924) ‘Terebratula Bed 11’ (Torrens’ ‘Upper Terebratula Bed’ 6), despite lacking the index terebratulid species *Digonella digonoides* (S S Buckman). However, Wyatt and Sumbler (p. 254 in Cox and Sumbler, 2002) placed their horizon lower and regarded them as absent through erosion beneath the Nerinea (Nerinaea) Bed.

Relating the succession to the modern lithostratigraphy of the area, it is proposed here that Units A to C (Sharpi Beds) are the **Roade Member** of Cox and Sumbler (in press), for which the cutting is the type section, despite not exposing the base. The remaining strata are referred to the **Ardley Member**, as proposed by Cripps (1986, p. 79). In the wider regional context, it is thought (M G Sumbler, personal communication 12/7/2010) that Unit D may be equivalent to the ‘Langrunensis Bed’ of the White Limestone Formation of Oxfordshire (Sumbler, 1984). The higher-energy nature of some of the beds above is reminiscent of parts of the Ardley Member there. The notably sandy and lignitic content of the upper part of Unit C is similar to that of the ‘Roach Bed’ of the same area which underlies the Langrunensis Bed. In addition, the lowest bed of Unit C may be equivalent to the Excavata Bed – the highest bed of the Shipton Member (lowest member of the White Limestone Formation). This interpretation would mean that the Roade Member is not directly equivalent to the Shipton Member.

Glossary

Bioclasts – fragments of skeletal grains, commonly of shells

Grainstone – a grain-supported limestone texture in which there is little matrix or the interstices are filled with spar

Ooid – a coated grain with a cortex that is smoothly and evenly laminated

Packstone – a grain-supported limestone texture with matrix, generally of mud-grade sediment

Peloid – a generally rounded or subrounded microcrystalline carbonate grain lacking internal structure. It may have coating.

Wackestone – a matrix-supported limestone

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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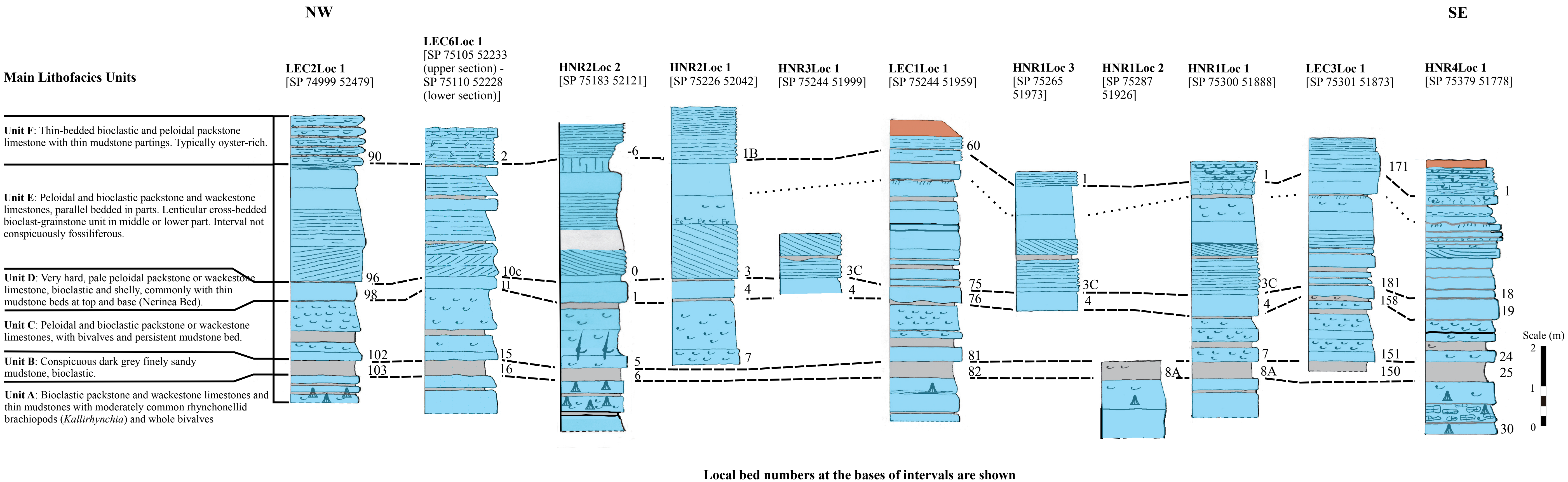


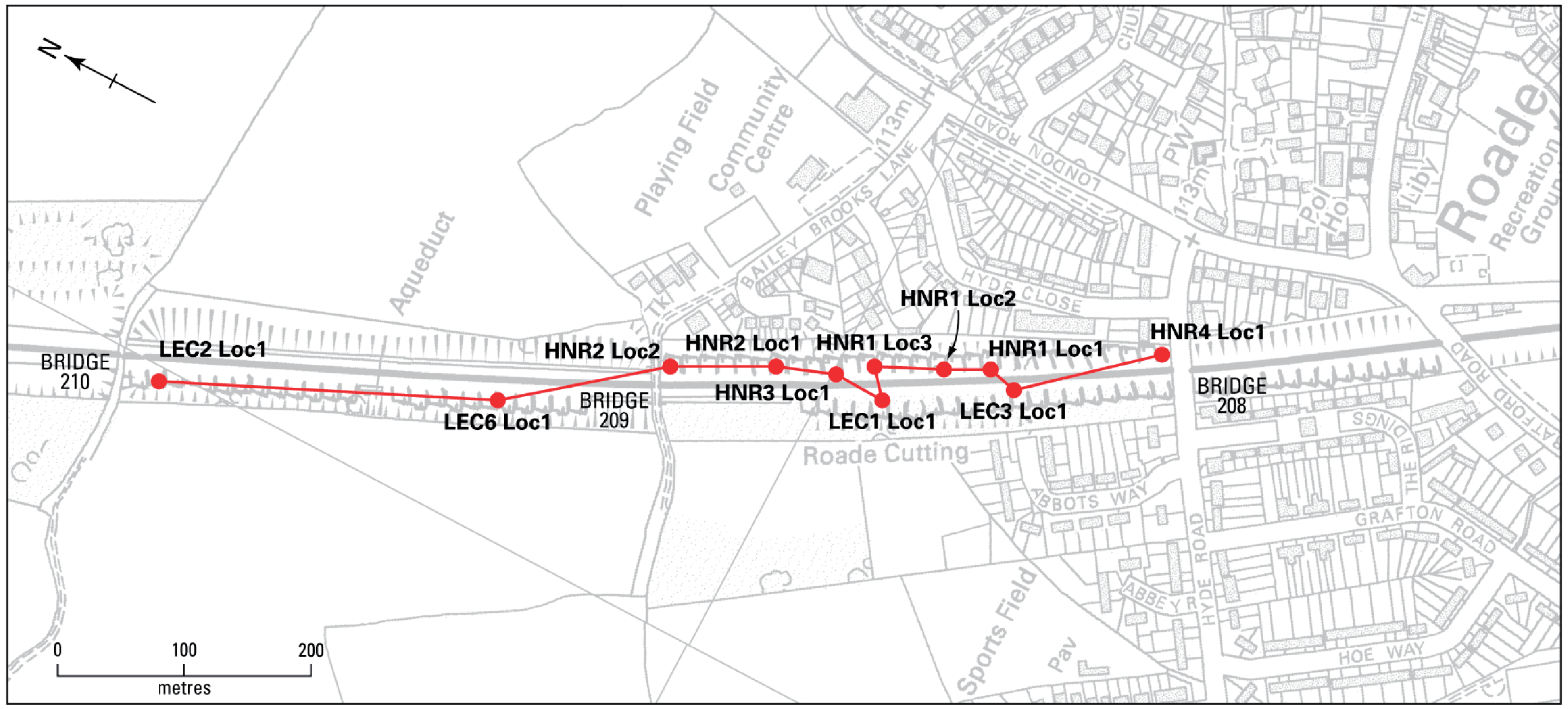
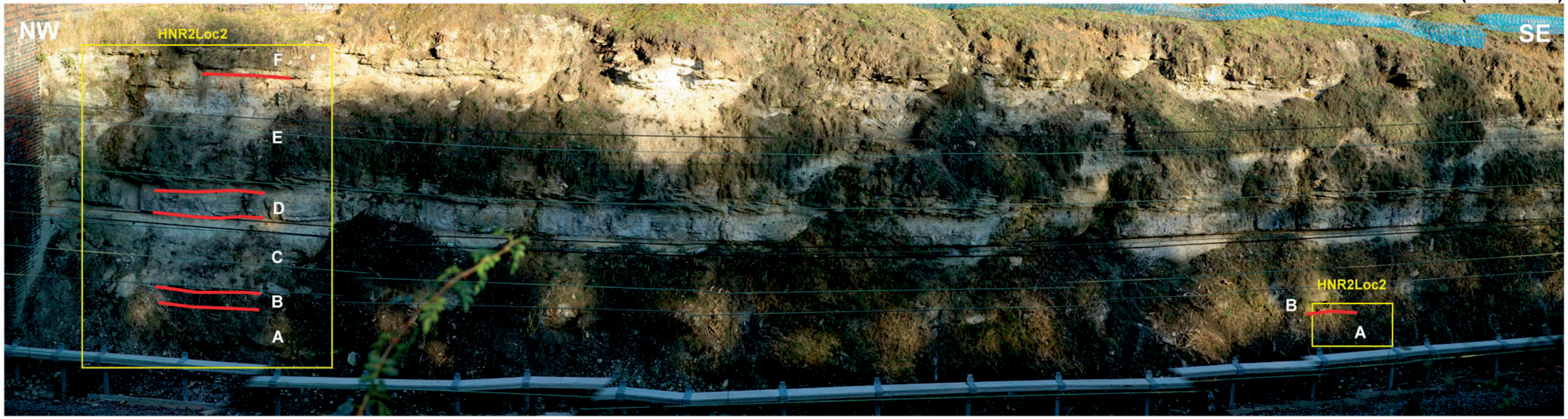


Figure 6. Correlated section of logged localities

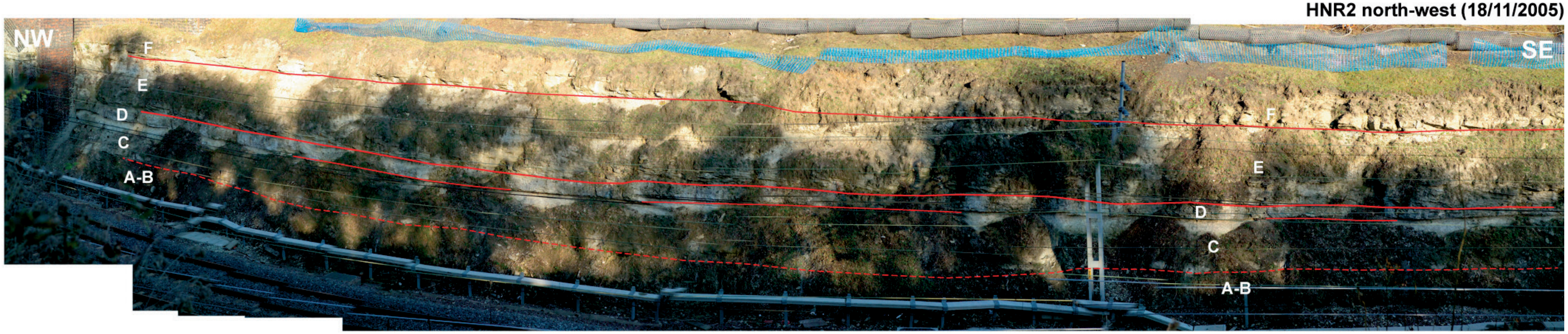
HNR2 north-west detail (18/11/2005)

Bridge 209



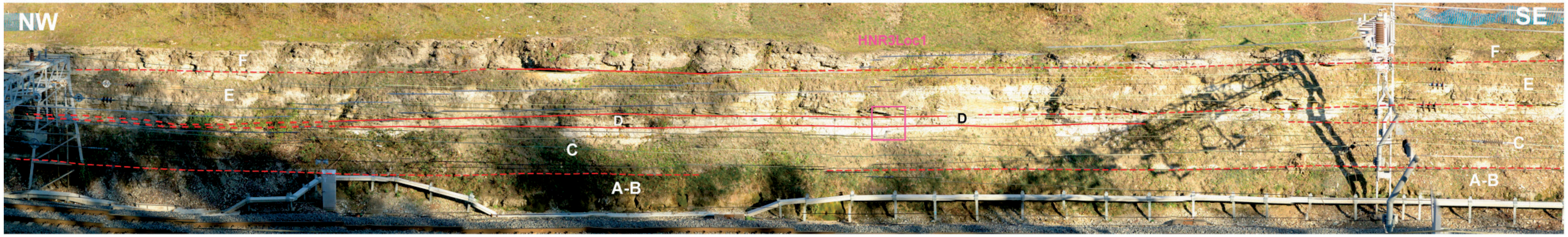
HNR2 north-west (18/11/2005)

Bridge 209

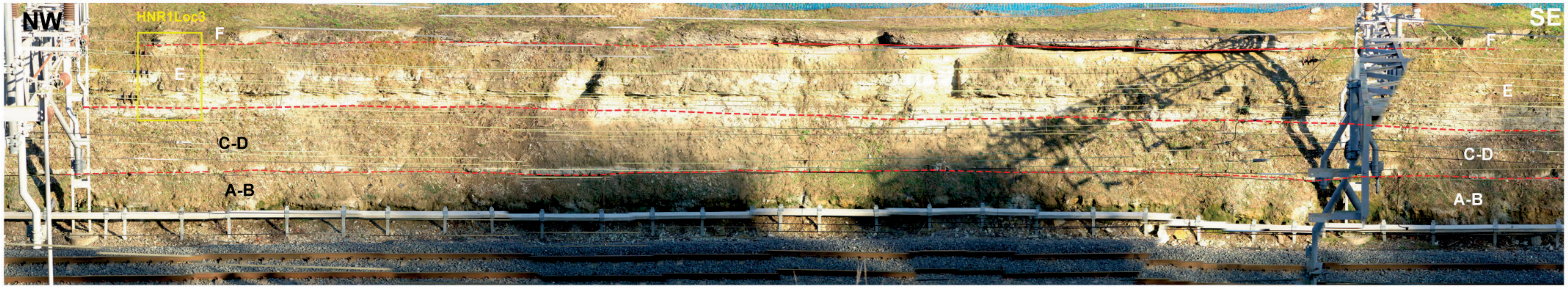


HNR2 south-east (18/11/2005)

HNR3 (18/11/2005)

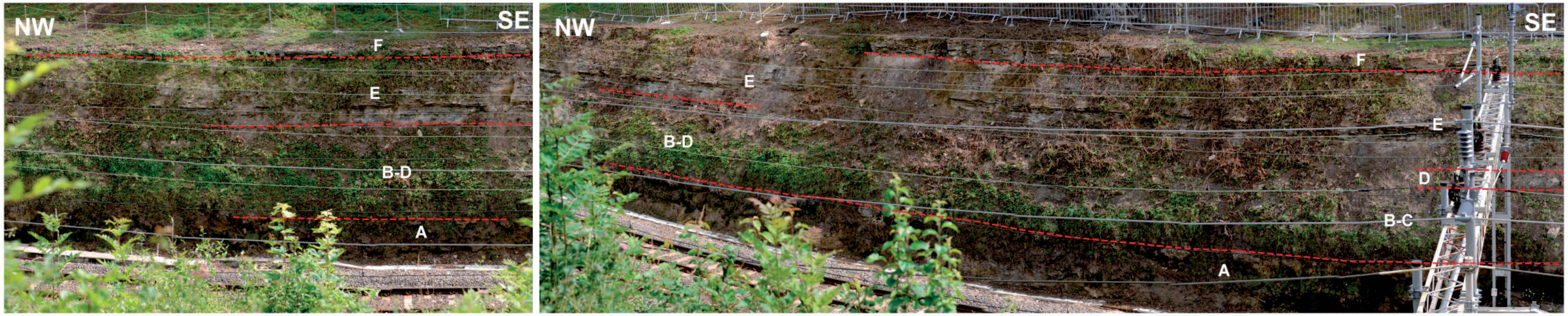


HNR1 north-west (18/11/2005)



HNR1 south-east (18/11/2005)

HNR4 north-west devegetated (16/7/2007)

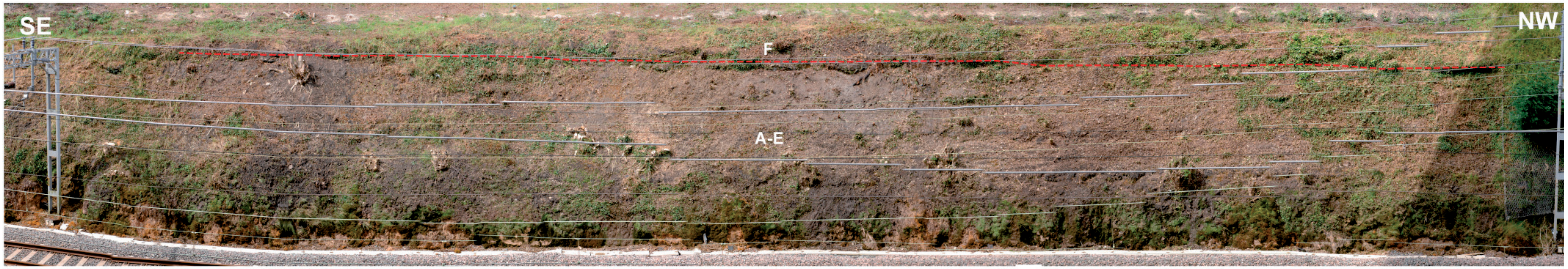


HNR4 north-west pre-devegetation (13/2/2006)

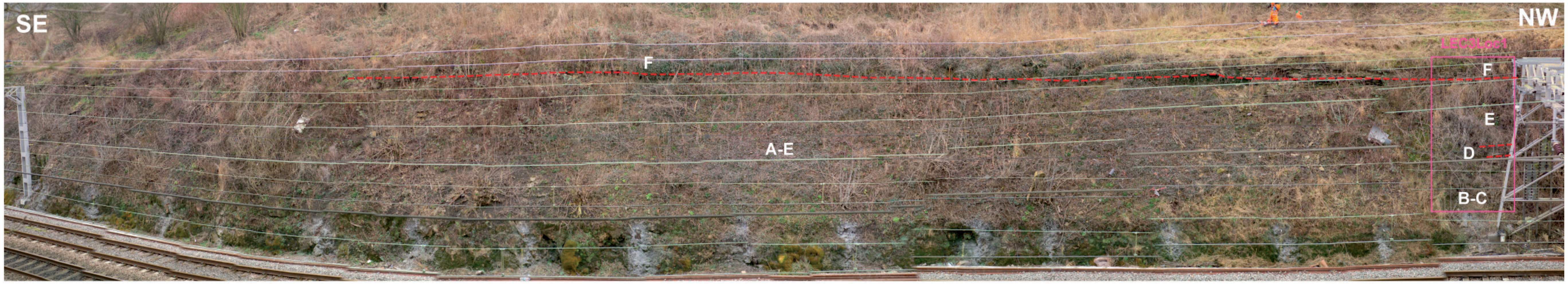
HNR4 south-east (16/7/2007)

LEC4 devegetated (16/07/2007)

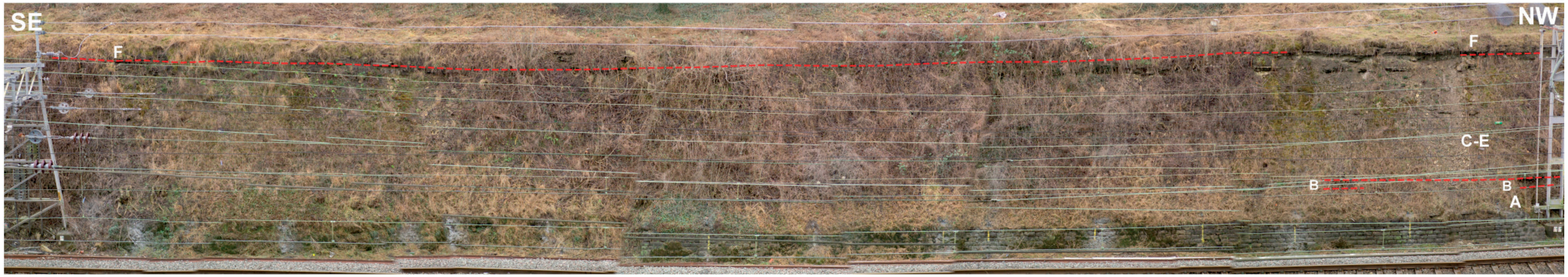
Bridge 208



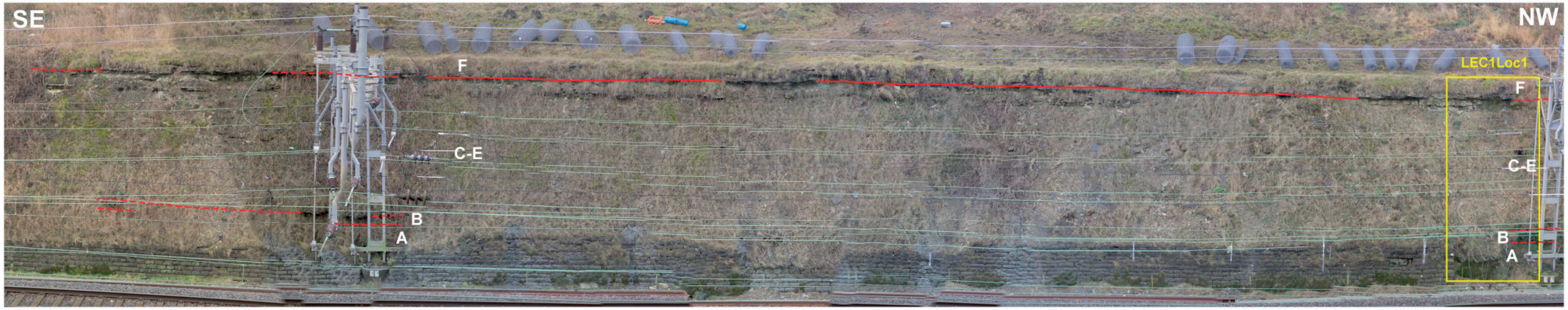
LEC3 south-east (13/02/2006)



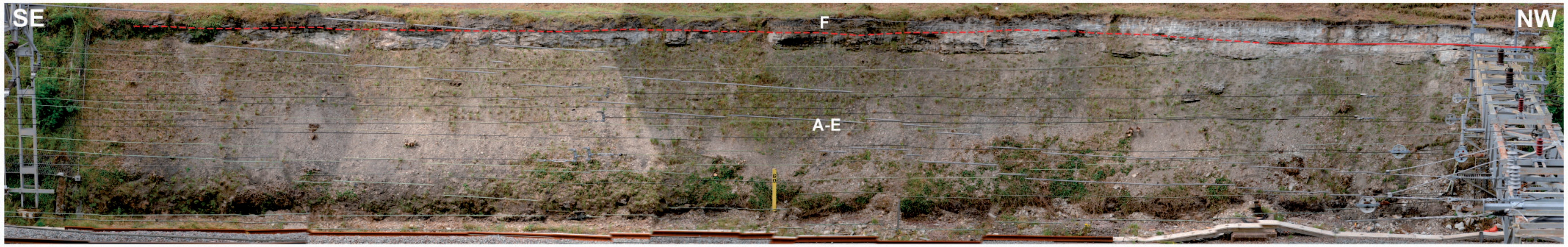
LEC3 north-west (13/02/2006)



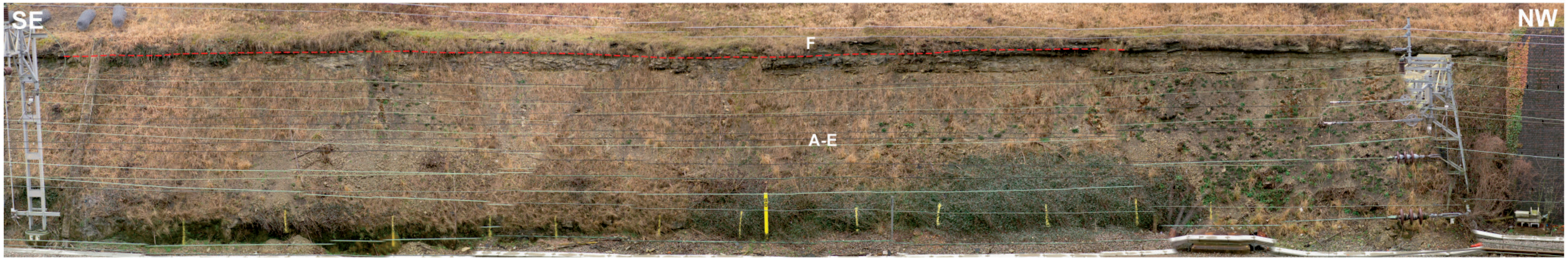
LEC1 (21/12/2005)



LEC5 devegetated (16/07/2007)

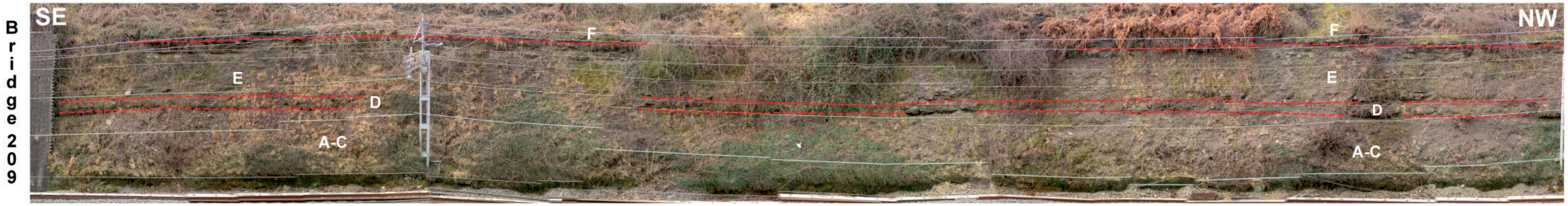


LEC5 pre-devegetation (13/02/2006)

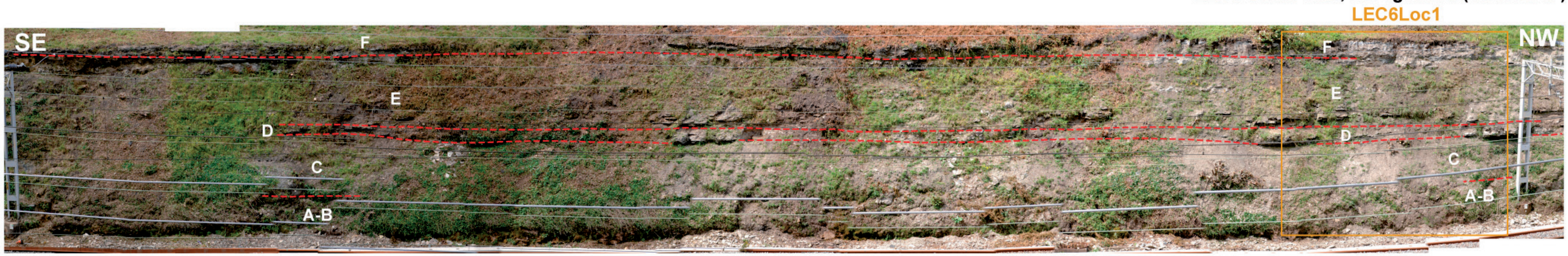


near Bridge 209

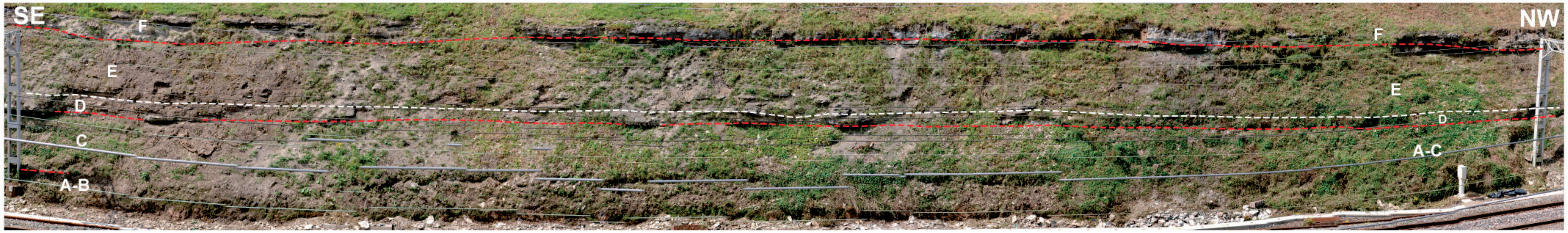
LEC6 south-east, pre-devegetation (13/02/2006)



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

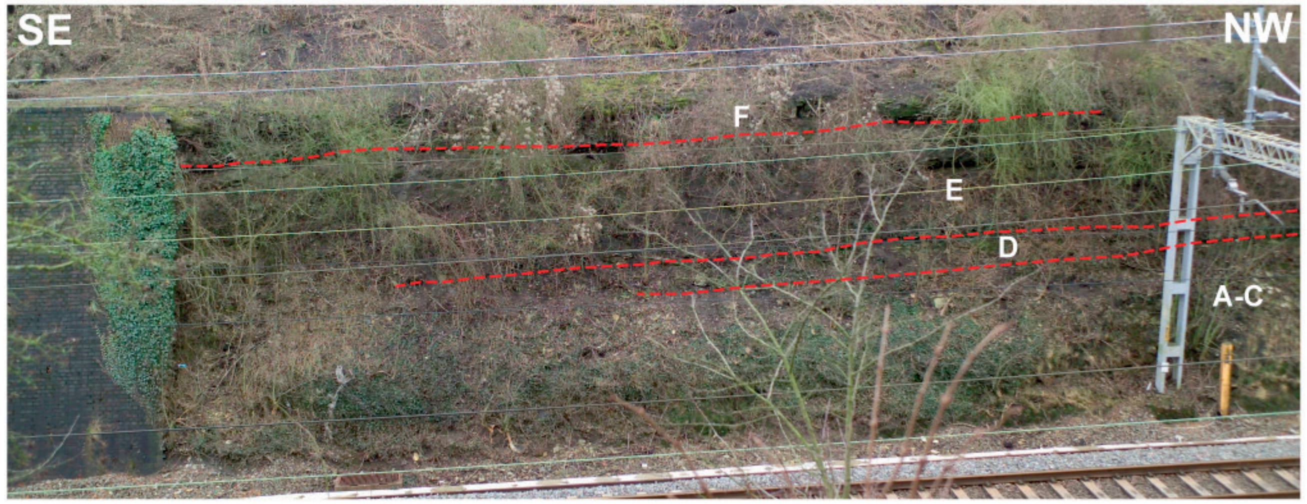


LEC6 centre, devegetated (16/07/2007)

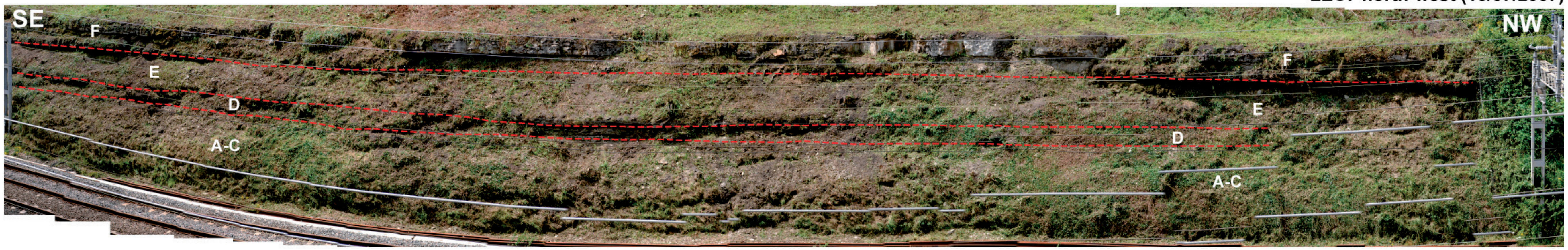


LEC6 north-west (13/02/2006)

LEC7 south-east (13/02/2006)



LEC7 north-west (16/07/2007)



LEC2 (21/12/2005)