Temporary sections in Jurassic strata near Leadenham, Lincolnshire

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Abstract: Sections through the Brant Mudstone, Marlstone Rock, Whitby Mudstone, Northampton Sand, Grantham and Lincolnshire Limestone formations, recently exposed during construction of the Leadenham By-pass, are described, and are discussed in relation to other sections in the Leadenham area.

Introduction

The village of Leadenham lies at the intersection of the A17 Newark to Sleaford trunk road with the A607 Lincoln to Granaham road. The Leadenham By-pass, first proposed in the early 1970s, diverts the A17 southwards from the village of Leadenham, avoiding some notorious bends (Fig. 1). Construction of the by-pass, during the late summer and autumn of 1994, revealed sections of strata ranging from the Brant Mudstone Formation (Lower Jurassic, Lias Group) to the Lincolnshire Limestone Formation (Middle Jurassic, Inferior Oolite Group). The new road passes beneath the A607 about 1km south of the village, at a point [SK 9504 51112] where the latter road runs along the crest of the escarpment formed by the Marlstone Rock Formation. The deep cutting here (Mill House Cutting), and the excavations for the bridge that carries the A607 over the by-pass, were visited by the East Midlands Geological Society during the field excursion of 3rd September 1994, and are the chief subject of this account. Eastwards, the by-pass climbs the steep escarpment (the so-called Lincoln Edge) capped by the Lincolnshire Limestone Formation. The shallow Fulbeck Hilltop Cutting at the crest of the escarpment [SK 959 908] exposed, rather indifferently, the topmost Whitby Mudstone, the overlying Northampton Sand and Grantham formations, and the basal part of the Lincolnshire Limestone Formation.

Mill House Cutting (Figs. 2 and 3)

The cutting, about 400m in length and up to 8m deep, displayed the uppermost part of the Brant Mudstone Formation and the overlying Marlstone Rock Formation. In the following section (measured by MGS, 28/08/1994), beds 8 to 18 were examined and measured in the sub-vertical face excavated for the northern bridge pier. Lower beds were visible in the sloped cutting face to the north-west; thicknesses were calculated by measuring down the slope, and then correcting for the gradient (17 to 18 degrees). The thicknesses so determined agree closely with those obtained from boreholes drilled during site investigations in 1988. Partial cores from two of these boreholes, 11R (on the site of the south-eastern bridge pier [SK 9504 5110]) and 17A (about 150m to the south [SK 9499 5096]) were examined (by HCI-C) in 1988, and representative specimens are held by BGS (specimen numbers BDZ3195-3272; BDZ3280-3403). Information from these boreholes has been used to supplement this account.

Marlstone Rock Formation (2.20m seen)

19. Limestone ferruginous, and ironstone, yellow to rust-brown; a fine-grained ooid grainstone, with yellowish brown limonite ooids in a grey crystalline calcitic or brownish sideritic cement, which is patchily replaced by yellowish brown amorphous limonite. Some calcite shell debris. A few unweathered, greenish grey patches with pale green berthierine ooids. Upper part paler, flaggy and cross-bedded; lower part richer brown, more ferruginous, more poorly bedded, with irregular, subhorizontal calcite veins in some cases marking bedding surfaces; some secondary limonite seams and patches. Brachiopods (as solid calcite casts), including *Lobothyris punctata* (J. Sowerby) and *Tetrarhynchia tetrahedra* (J. Sowerby) both as sporadic individuals and abundantly in local "nests", belemnites; bivalves including *Entolium* and *Placunopsis*, serpulids, echinoid and crinoid debris. 1.85m

18. Ironstone, hash of black to rust-brown secondary limonite. 0.05m

17. Ironstone, yellowish brown, a medium-grained limonite ooid grainstone to packstone, similar to Bed 19. Sporadic shell debris, commonly preserved as large fragments. Basal 0.15m contains common well-rounded ovoid pebbles, typically 5 to 100mm diameter, mainly of pale brown, finely sandy sideritic ironstone with floating ooids. 0.30m

Brant Mudstone Formation (10.9m seen)

16. Ironstone, hash of black to rust-brown secondary limonite. 0.06m

15. Sideritic ironstone, concretionary, silty to finely sandy, pale grey to brown, with scattered white (kaolinite, after berthierine) to brown (berthierine) ooids, also voids left by solution thereof. Much of the bed is altered to black to rust-brown limonite. 0.14m

14. Ironstone, hash of black to rust-brown secondary limonite, very sandy in places. 0.10m

13. Mudstone, silty, micaceous, well laminated, greenish to ochreous brown with pale grey banding. Gradational base. 0.35m

12. Mudstone, silty to finely sandy, micaceous, bluish grey, fissile; lenticles (ripples) of paler grey fine-grained sandstone in lower half; largely sandstone in basal few cms. 0.30m

11. Sideritic ironstone nodules, silty, pale greenish grey, weathering to cream, with brown limonite on joints and infilling moulds of bivalves. Up to 0.10m

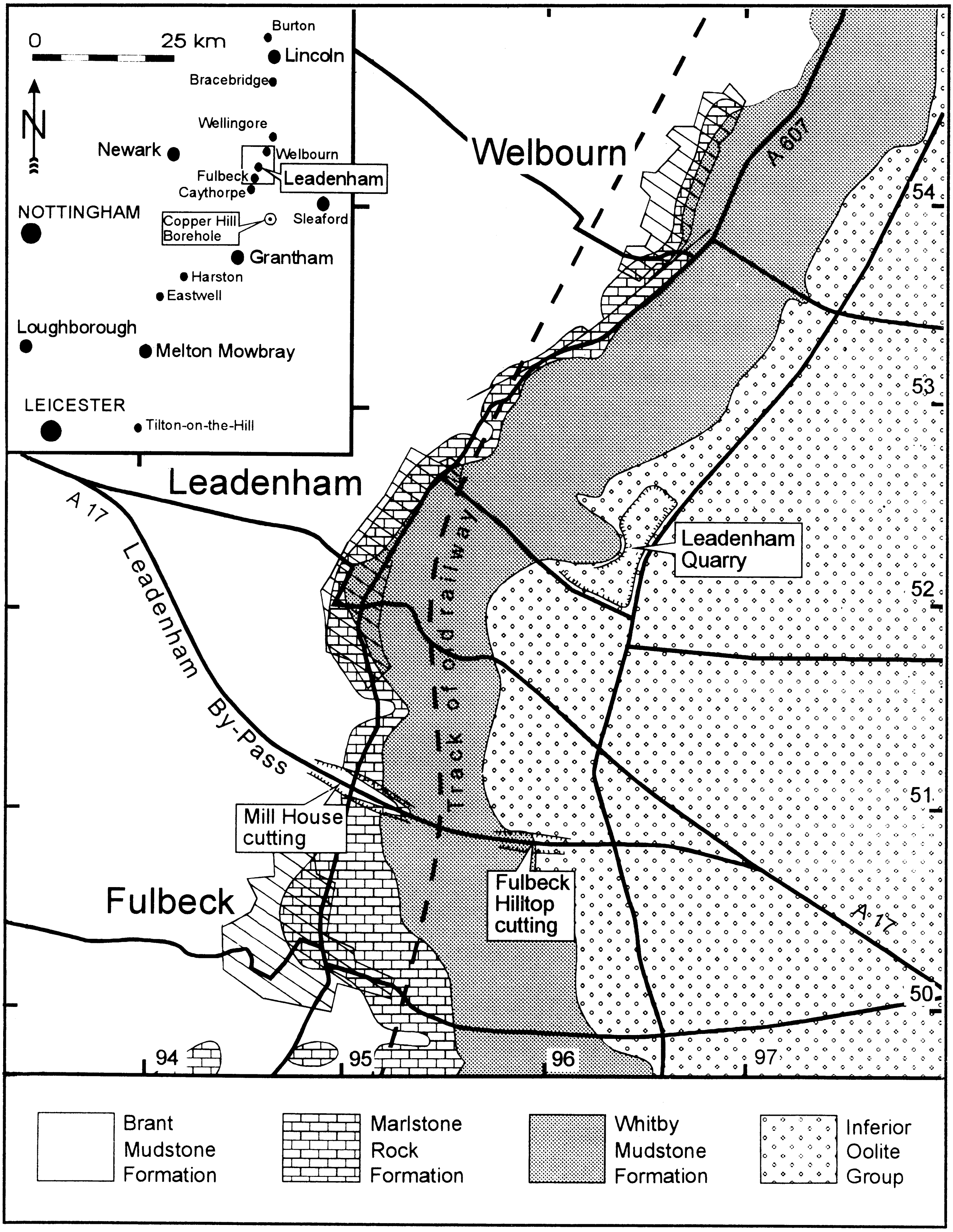

Fig. 1. Geological sketch-map of the Leadenham area, based on British Geological Survey 1:10 000-scale maps. Inset shows other localities mentioned in the text. The Inferior Oolite Group of the area comprises, in ascending order, the Northampton Sand, Grantham and Lincolnshire Limestone formations, with the Lincolnshire Limestone occupying the greater part of the Inferior Oolite outcrop (see Fig. 4).

10. Sandstone, fine-grained, grading to siltstone, micaceous, mid-brownish grey, with darker muddy lenticles. Occasional seams of secondary limonite. Layers of small, pale brownish grey, ovoid incipient sideritic nodules at base and 0.10m above base. Bivalves including *Ryderia doris* (d'Orbigny) and fairly common 'myids' such as *Gresslya* or *Homomya*; ammonites *Amaltheus gibbosus* (Schlotheim) and *A. margaritatus* de Montfort; carbonised wood fragments. 0.42m

9. Mudstone, sandy, grey, micaceous, with abundant lenticles (ripples) and burrow fills of paler sandstone, as above. Bivalves including *Dacryomya* and *Palaeoneilo*. This and overlying Bed 10 give rise to a small amount of groundwater seepage. 0.33m

8. Mudstone, slightly silty, dark grey, moderately fissile; sporadic seams and lenticles of paler grey siltstone. Sporadic bivalves and ammonites, including two specimens of *Amaltheus subnodosus* (Young & Bird) from c. 1m below top. c. 2.75m

7. Sideritic ironstone, concretionary, with pale brown ironstone concretions around burrows, separated by greyish, less sideritic mudstone. Abundant dark green berthierine ooids; some squashed and deformed. 0.15m

6. Mudstone, silty, brownish grey, containing irregular, pale brown sideritic concretions. *Amauroceras*? 0.15m

5. Sideritic ironstone nodules, silty, brownish grey, individual nodules up to 0.7m diameter. Rare small bivalves and gastropods. up to 0.15m

4. Mudstone, grey, generally smooth-textured, but somewhat silty in patches and lenticles; occasional micaceous laminae, particularly in upper part. [Fauna from borehole 11R and 17A includes *Camptonectes*, *Dentalium*, *Goniomya* (including *G. hybrida* Münster), *Modiolus*, *Palaeoneilo galatea* (d'Orbigny), *Palaeonucula*?, *Pleuromya*?, *Protocardia* (including *P. truncata* (J. de C. Sowerby), *Pseudolimea*, *Pseudopecten*, and *Amaltheus* spp. including *A. striatus* Howarth from 0.55m above base (BDZ3219), *A. margaritatus* from 2.05m above base (BDZ3213) and *A. wertheri* from 2.55m above base (BDZ3208)]. A few small, reworked sideritic nodules at base. 3.80m

3. Sideritic ironstone, concretionary, pale brown, with diffuse grey burrow mottling; scattered pale bluish green berthierine ooids. Common *Pseudopecten equivalvis* (J. Sowerby), 'myid' bivalves and rare belemnites; indeterminate liparoceratid ammonite, possibly *Liparoceras (Becheiceras) nautiliforme* (J. Buckman). 0.25m

2. Mudstone, grey, smooth-textured, slightly similar to Bed 4. [Fauna from borehole 11R and 17A includes *Camptonectes*, *Dacryomya*?, *Oxytoma inequivalvis*, *Pseudolimea*, *Palaeoneilo galatea*, *Plicatula*, *Protocardia*, *Pseudopecten*, *Zygopleura*? and *Amaltheus*]. At base, a layer of pebbles of sideritic ironstone (similar to Bed 1) up to 50mm diameter, and smaller, superficially bored, subangular clasts of dark grey phosphatic material, together with mudstone flakes and sporadic berthierine ooids. 1.75m

1. Sideritic ironstone nodules, pale brown, with darker, reddish brown limonitic weathering; an almost continuous bed. Up to 0.10m

Brant Mudstone Formation. The Brant Mudstone Formation (Brandon *et al.*, 1990; Sumbler, 1993b; Berridge *et al.* in press), is about 110m thick in the Leadenham area. It comprises the upper part of the Lower Lias, together with the overlying 'Middle Lias silts and clays' of some previous accounts. The exposed beds are part of the latter unit, although the term 'Middle Lias', is best avoided in formal lithostratigraphical nomenclature, as it has also been frequently applied in an alternative chronostratigraphical context, equivalent to the Upper Pliensbachian Substage. The same objections apply to the terms 'Lower Lias' and 'Upper Lias'.

The exposed strata are dominated by grey mudstones, becoming somewhat silty, with sandy lenticles in the upper part. Beneath Bed 1, a further 3 to 4m of mudstones are seen at the western end of the cutting (Figs. 2 and 3), but these lie close to the original ground surface and are highly weathered. Borehole 11R proved a second pebble bed, similar to that at the base of Bed 2, at a level 2.60m below the base of Bed 2. Such pebble beds evidently mark minor erosional events, perhaps induced by shallowing or severe storms. The pebbles at the base of Bed 2 include material apparently derived from Bed 1. This pebble bed was recovered in boreholes 11R and 17A, but Bed 1 was not recorded in either borehole, possibly due to erosion.

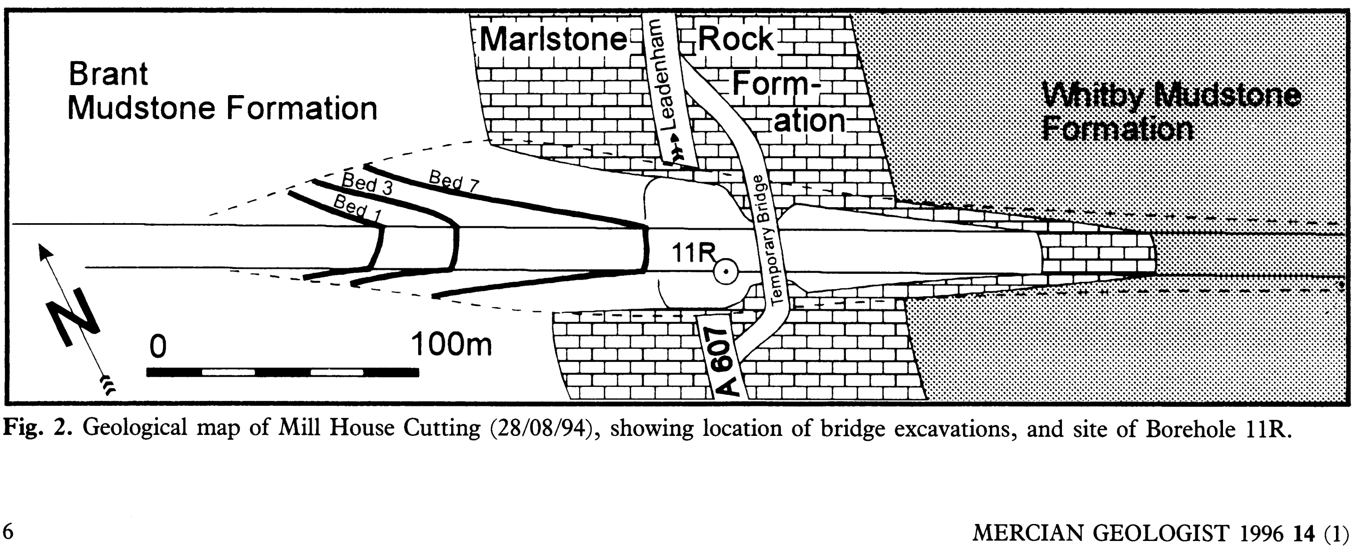

Fig. 2. Geological map of Mill House Cutting (28/08/94), showing location of bridge excavations, and site of Borehole 11R.

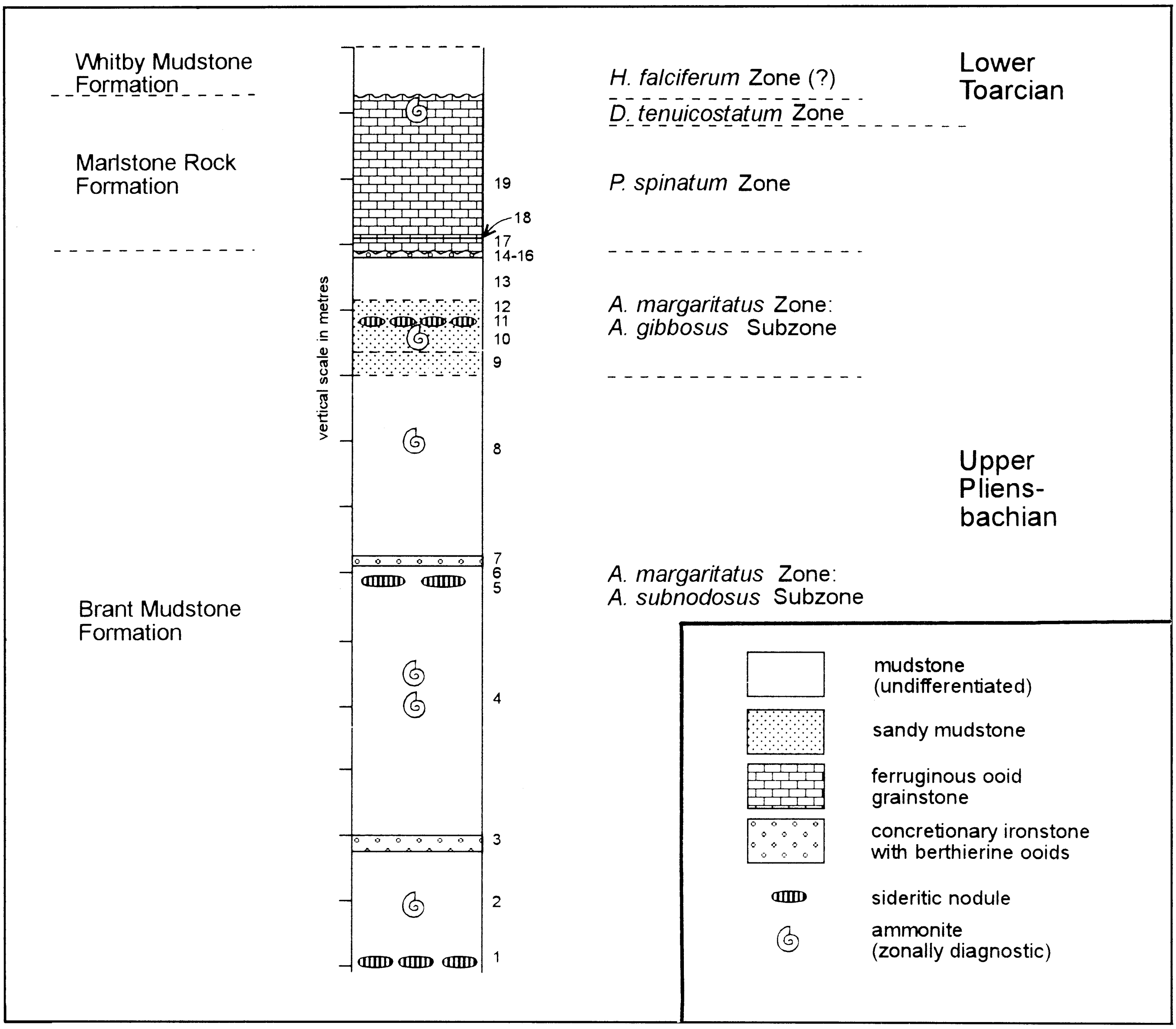

Fig. 3. Geological section exposed in Mill House cutting (28/08/94).

The section contains several concretionary beds (Beds 3, 7 and 15) and layers of nodules (Beds 1, 5 and 11). All contain a certain amount of calcareous matter, but their distinctive buff grey colour (typically Munsell code 10YR 7/2) suggests that they contain a large proportion of siderite (iron carbonate); petrographically, they are argillaceous siderite mudstones (''clay ironstones''). Their colour changes relatively quickly on exposure. Specimens from Bed 3, collected from boreholes 11R and 17A in 1988, were originally buff-grey but, although kept in dry storage at BGS, are now (September 1994) reddish brown in colour (2.5YR 5/6), presumably due to the development of hematite by oxidation of the finely divided siderite. Similarly, borehole specimens from the nodule Bed 5 are now a purplish brown colour. In the cutting, these sideritic rocks have been altered to varicoloured limonite in the subsoil as a result of natural weathering; the limonite Beds 14 and 16 are probably the altered upper and lower parts of Bed 15. The nodules in Beds 1, 5 and 11 have developed a concentrically layered structure. Within about 2.5m of the original ground surface, the sideritic beds and nodules break down into a hash of limonitic fragments, and individual beds are hard to recognise.

All the concretionary ironstones (Beds 3, 7 and 15) contain scattered rounded grains of berthierine (an iron silicate, often erroneously termed chamosite, which is not generally found in Jurassic rocks). The grains, typically 0.2 to 0.3mm in diameter, range from dark brownish green to pale green in colour, depending on the degree of alteration. Those in Bed 15 are entirely altered to a white mineral, probably kaolinite. These grains are termed ooids here because of their rounded form, though generally they appear internally structureless, with neither concentric laminae nor nuclei apparent. Particularly in Bed 7, they tend to be concentrated in burrow-fills, suggesting that they may be diagenetically-altered faecal pellets. The recurrence of these distinctive beds at regular intervals in the succession (Fig. 3) indicates rhythmic sedimentation; the mudstones probably represent relatively quiet water sedimentation, and the ooidal ironstones (Beds 3, 7 and 15) somewhat higher energy conditions, perhaps related to minor transgressive events. The ooidal beds can be recognised in the BGS Copper Hill Borehole [SK 9787 4265] near Ancaster, some 10km to the south-east (Berridge *et al.*, in press), and the rhythms may well be traceable over a much greater area. Other distinctive beds of the section can also be recognised in the Copper Hill Borehole, notably the pebble bed at the base of Bed 2 and the sandy Beds 9 and 10. The excellent lithological correlation between the two sites indicates that there is an extra metre or so of strata above Bed 16 at Copper Hill, removed at Leadenham as a result of differential erosion at the base of the overlying Marlstone Rock Formation.

The fauna collected from the cutting, mostly from the mudstone beds, is dominated by bivalves and ammonites, generally preserved in pinkish aragonite and commonly uncrushed. The ammonite fauna is dominated by amaltheids, on which the standard zonation is based. The strata fall within the *Amaltheus margaritatus* Zone (defined by the range of *Amaltheus* prior to the appearance of *Pleuroceras*); comparison with the slightly more complete section at Copper Hill suggests that this zone is about 24m thick at Leadenham. The *A. margaritatus* Zone is divisible into three subzones based on the appearance of successively more inflated, strongly keeled and tuberculate forms of *Amaltheus*. Correlation with the Copper Hill Borehole, from which more extensive ammonite collections were made, suggests that the lowest beds of the Leadenham section belong to the lower part of the *Amaltheus subnodosus* Zone; at Copper Hill, the underlying *Amaltheus stokesi* Subzone is about 9m thick. The presence of *Amaltheus striatus* in Bed 4 of Borehole 11R, and of *Amaltheus subnodosus* about 1m below the top of Bed 8 in the cutting (the same level as the highest *A. subnodosus* in the Copper Hill Borehole) confirms the *Amaltheus subnodosus* Subzone. The succeeding *Amaltheus gibbosus* Subzone is confirmed by *Amaltheus gibbosus* in Bed 10 of both the cutting and the Copper Hill Borehole. Taking the *subnodosus/gibbosus* subzonal boundary at the base of the sandy Bed 9, this gives the following thickness at Leadenham: *gibbosus* Subzone c. 2m; *subnodosus* Subzone c. 13m; *stokesi* Subzone c. 9m.

Marlstone Rock Formation. Although only 2.20m of Marlstone Rock were recorded at the point measured, only the uppermost c. 0.30m is missing, since Borehole 11R shows that the total thickness at the bridge site is 2.50m. The Marlstone Rock at this locality is a yellowish to rust-brown (generally in the range 10YR 7/6 to 5/8), variably shelly rock. Close examination shows that it is essentially a fine-grained ooid grainstone, with yellowish brown limonitic ooids, typically 0.2 to 0.3mm diameter, in a grey crystalline calcitic or brownish sideritic cement. In patches, this cement is replaced by yellowish brown limonite, and the rock is texturally a packstone. Many of the ooids show a concentrically layered internal structure, suggesting accretion around a nucleus, though others appear structureless like those described in the underlying Brant Mudstone. Despite the arenaceous texture of the rock, there is very little quartz sand present; most of the sand-grade material is calcareous shell debris. The so-called Sandrock, a calcareous sandstone widespread below the ooidal ironstone facies of the Marlstone Rock elsewhere in Lincolnshire and Leicestershire (Hallam, 1955; 1968) is absent in the Leadenham area (see Berridge *et al.*, in press).

The basal bed of the Marlstone Rock is Bed 17. On cursory inspection, the underlying Beds 14-16, being composed of ironstone, might be included in the formation, but the lithology of the fresh material (Bed 15) is quite unlike the overlying Marlstone Rock. It has more in common with Beds 3 and 7 of the Brant Mudstone and probably, like them, marks the commencement of a sedimentary rhythm. The basal part of Bed 17 is a conglomerate, containing many pebbles that can be matched with the underlying Bed 15. Such conglomerates have been recorded at the base of the Marlstone Rock at many other localities in England, and indicate a widespread phase of erosion prior to deposition.

The Marlstone Rock was formerly worked as an iron-ore (Lamplugh *et al.*, 1920; Whitehead *et al.*, 1952) and there are extensive workings dating from 1890 to 1930 in the area just a few hundred metres south of the cutting [e.g. SK 951 507]; all these are now restored to agriculture and there are no sections visible, making the new exposures all the more important. A record of workings some 800m south-south-east of the bridge site [SK 953 503] (Wedd *in* Lamplugh *et al.*, 1920, p. 124) illustrates the same bipartite development of the Marlstone Rock as seen in the cutting, with flaggy, pale yellowish brown beds in the upper half, and a more massive, more ferruginous brown ironstone in the lower. The downward increase in iron content, reaching up to 30% (Wedd, *in* Lamplugh *et al.*, 1920, p. 125) results from leaching of iron from the upper layers of the formation, and secondary enrichment of the lower part.

Due to the presence of other components, the proportion of iron in the unweathered and unoxidised Marlstone Rock is relatively low, and for this reason working generally ceased where the mudstone overburden became greater than about 3m. The nature of the unweathered Marlstone Rock was well seen some 200m south-east of the bridge site [SK9521 5103], where debris from deep drainage excavations included Marlstone Rock material from beneath a cover of Whitby Mudstone. There, the Marlstone Rock is a dark greenish grey (10GY 4/1) rock, composed of berthierine ooids in darker green berthierine-rich mud matrix, or blackish crystalline siderite cement. However, even beneath the protective mudstone cover, the topmost few centimetres of the Marlstone Rock are leached to a pale buff colour, with little or no iron present, although calcareous fossils are apparently unaffected. Ooids are altered to a white powdery mineral, probably kaolinite.

The Marlstone Rock Formation belongs largely to the *Pleuroceras spinatum* Zone (defined by the range of the genus *Pleuroceras*), although diagnostic ammonites are rare in the Midlands. *Pleuroceras* has been recorded from Tilton-on-the-Hill in Leicestershire, and from

Knipton, Woolsthorpe and Harston in the Vale of Belvoir (Fig. 1; Hallam, 1955; Howarth, 1958; 1980). More recently, a specimen was found in debris from an excavation [SK 9001 3625] in Grantham (Berridge *et al.*, in press). To some extent, the presence of the brachiopods *Lobothyris punctata* and *Tetrarhynchia tetrahedra*, which are abundant at Leadenham, is also suggestive of the *P. spinatum* Zone (Ager, 1954; 1956; Hallam, 1955; Howarth, 1980). Of particular interest, then was the finding of a specimen of the ammonite *Dactylioceras* sp. indet. amongst the loose debris at the top of the section immediately east of the bridge. From its position and the nature of the attached rock (a thin "flag" of yellowish brown ferruginous limestone coated with tufaceous calcium carbonate), there is no doubt that the specimen originated from just below the ground surface, in the uppermost part of the Marlstone Rock.

The presence of *Dactylioceras* indicates the basal Toarcian, *Dactylioceras tenuicostatum* Zone (the base of which is defined by the appearance of *Dactylioceras* after the disappearance of *Pleuroceras*). At Harston and Tilton-on-the-Hill, the uppermost one metre or so of the Marlstone Rock (including the so-called Transition Bed) has been shown to belong to the *D. tenuicostatum* Zone (Howarth, 1980); *Dactylioceras* has also been noted at Eastwell (Fig. 1; Kent, 1937). The new record from Leadenham may indicate that Marlstone Rock of Toarcian age is more widespread in the Leicestershire-Lincolnshire area than generally realised.

The uppermost surface of the Marlstone Rock, as seen in debris from the pits south-east of the bridge, is rather uneven and interpreted as an erosional disconformity. Apart from a thin (1 to 2mm) intervening crust of secondary limonite, mudstones rest directly on this eroded surface. These mudstones, comprising the "Upper Lias" of former accounts, are herein termed the Whitby Mudstone Formation (Powell, 1984), following the usage of that name by Berridge *et al.* (in press). The basal part of the Whitby Mudstone Formation comprises fissile, dark bluish grey mudstones. They probably belong to the basal (*Cleviceras exaratum*) Subzone of the *Harpoceras falciferum* Zone as at Tilton and Harston (Howarth, 1980). The ammonite succession in the Copper Hill Borehole (Berridge *et al.*, in press) would seem to confirm this; even though no ammonites were found in the basal 1.65m of the Whitby Mudstone, *Cleviceras elegans* and *C. exaratum*, indicative of the upper part of the *C. exaratum* Subzone, are common above. *Dactylioceras* also occurs in these beds, but there seems to be no ammonite evidence to support Trueman's (1918) inclusion of the basal few metres of the Whitby Mudstone of the area (Grantham and Caythorpe; Fig. 1) in the *D. tenuicostatum* Zone (see Howarth, 1992).

Northwards from Leadenham, the Marlstone Rock gradually thins, and at Welbourn [SK 957 542], the outcrop becomes difficult to trace (Sumbler, 1993a). Beyond Welbourn, the formation seems to be absent as far as the village of Burton [SK 962 746], on the northern outskirts of Lincoln, c. 20km to the north (Ussher *et al.*, 1988, p. 24). However, in the railway cutting at Wellingore [SK 976 570], some 3km north of Welbourn, Holloway and Ussher (*in* Jukes-Browne, 1885, pp. 37 and 41) recorded a ferruginous, ooidal bed, containing "concretions [?pebbles] like those often found at the base of the Marlstone Rock Bed". Nearby, the unit was recorded as c. 0.46m thick, and was "irregularly overlain by hard compact grey nodules at the base of the shale above". Specimens from this locality (specimen numbers JR 88-97; BGS collection) include dark reddish-grey, slightly sandy, probably sideritic ironstone with small, pale grey ?phosphatic peloids and larger ?phosphatic pebbles. The fauna includes *Lobothyris punctata* and *Tetrarhynchia*, together with *Pleuroceras* (preserved in solid limonite and possibly reworked) indicative of the *P. spinatum* Zone. It also includes *Dactylioceras semicelatum* (preserved in solid calcite), indicative of the youngest (*D. semicelatum*) subzone of the *D. tenuicostatum* Zone. A similar development of the Marlstone Rock occurs in Lincoln where, at the former Albion Brickworks, Trueman (1918) noted 0.3m of ironstone with *Lobothyris* and *Tetrarhynchia*, overlain by ferruginous sandstone with *Dactylioceras*. This mixed fauna in such a thin bed shows that the Marlstone Rock at these localities is highly condensed, perhaps with some reworking. Thus, the northward thinning of the Marlstone Rock is not simply due to downcutting at the base of the overlying Whitby Mudstone, despite the likelihood of an erosional non-sequence at this level. At the former Bracebridge Pit [SK 971 671], south of Lincoln, the Marlstone Rock is absent and shales of the Whitby Mudstone Formation, with a bed of phosphatic pebbles at the base, rest on Brant Mudstone of *A. gibbosus* Subzone age (Trueman, 1918; Howarth, 1958; 1980). There (and probably also at the Albion Brickworks), the basal part of the Whitby Mudstone belongs to the *D. semicelatum* Subzone, but it is probably slightly younger than the Marlstone of *D. semicelatum* Subzone age at Leadenham and elsewhere.

Fulbeck Hilltop Cutting (Fig. 4)

Although Mill House Cutting extends into the outcrop of the Whitby Mudstone Formation (Upper Lias) at its south-eastern end, these beds are poorly exposed beneath a cover of loamy head (slope deposits), and are highly weathered. It was not possible, therefore, to measure a reliable section. Nevertheless, mudstones from the base of the formation were seen as debris from pits (see above). Higher beds of the formation form the main slope below the Lincolnshire Limestone scarp, and the topmost beds were rather poorly exposed in a shallow cutting adjoining Fullbeck Hilltop Plantation [SK 959 508]. They consist of dark bluish grey, fissile, somewhat pyritous mudstones which develop yellow jarosite and small selenite (gypsum) crystals where weathered. The total thickness of the formation here, derived from mapping (Sumbler, 1993a) and the additional data from the by-pass, is about 45m. Few fossils were collected, but there is no reason to doubt that, as in the Copper Hill Borehole, the formation belongs to the *Harpoceras falciferum* and *Hildoceras bifrons* zones (Lower Toarcian).

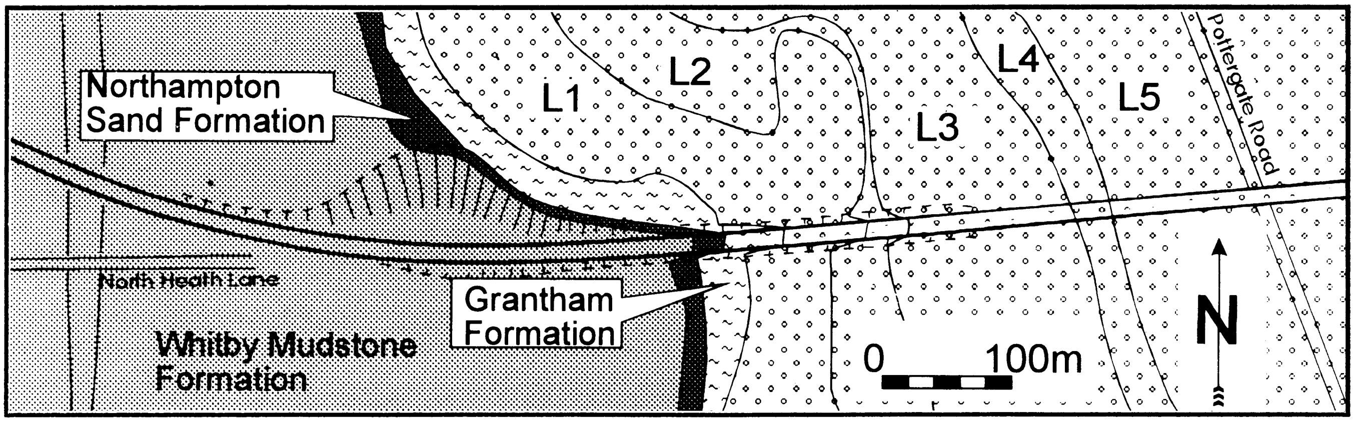

Fig. 4. Geological map of Fulbeck Hill Cutting (10/09/94). L1-5 are units within the Lincolnshire Limestone Formation (see text).

The overlying Northampton Sand Formation was represented by debris at the top of the cutting. The thickness of the formation is proved by two boreholes nearby [SK 9591 5082; SK 9603 5082] and varies from 2.65m and to 1.6m respectively. The rock is very indurated with a lustrous calcite and siderite cement where moderately fresh, but is much softer where decalcified on joint faces. Weathering penetrates inwards from the joints, giving rise to loose blocks with concentric layers of limonite-enriched ironstone around cores of less weathered material. In general appearance, the rock appears much like the Marlstone Rock, and it was likewise formerly worked near Leadenham [SK 961 524] as an iron ore (Lamplugh *et al.*, 1920; Hollingworth and Taylor, 1951). Unlike the Marlstone Rock, however, it is quite sandy and fossils are extremely rare. Close examination shows that it contains whitish ooids of calcium carbonate and possibly also of opaline silica (both probably replacements of berthierine) in a limonitic matrix. Fresher material has a greenish tinge, and probably contains berthierine and siderite.

The Northampton Sand is of Aalenian age, and is the basal unit of the Inferior Oolite Group. There is a considerable non-sequence at the base; at least three ammonite zones are 'missing' from the Whitby Mudstone, compared with the type sequence on the Yorkshire coast (Powell, 1984), which encompasses virtually all of the Toarcian. This suggests a considerable amount of erosion prior to deposition, although this is not evident from the section. A small drainage gulley showed that sandy ironstone, as described above, rests directly on the shaly clay of the Whitby Mudstone; there is no indication of a conglomerate at the base of the Northampton Sand.

Above the Northampton Sand, the Grantham Formation, formerly known as the Lower Estuarine Series, is very poorly exposed. It is highly variable in lithology, but consists essentially of clays and silts, interbedded with quartz sands and calcareous sandstones of various types. A small section [SK 9595 5084] showed, beneath head deposits, 0.6m of pale grey to ochreous yellow sand, somewhat loamy and with a layer of pale grey clayey silt near the top. Previously, debris from nearby trial pits [SK 9592 5084; SK 9586 5088] had shown hard grey massive sandstone, soft brown laminated sandstone, and rubbly, greyish brown sandstone with bivalve shell fragments and clay wisps (Sumbler, 1993a). Just to the north, material thrown out from badger setts [SK 9568 5130] comprised white, unconsolidated sand and soft, white to orange well-bedded sandstone with clay laminae and lignite fragments. The formation is also highly variable in thickness, but in the neighbourhood of the by-pass seems to be little more than 1 or 1.5m. Elsewhere in the area, the formation may be up to 5m thick; generally it thickens at the expense of the underlying Northampton Sand, presumably as a result of channelling at the base.

The beds above the Grantham Formation belong to the Lincolnshire Limestone Formation, which is essentially of Bajocian age, thcugh the lowest part may be late Aalenian. Around Leadenham, the total thickness of the formation is about 25m, of which the basal 8m or 9m are exposed in the very shallow easternmost part of the cutting [SK 9595 5084 to SK 9613 5084]. These strata belong to the Lower Lincolnshire Limestone, and correspond to Units L1 to L3 of Sumbler *et al.* (1991) and Sumbler (1993a), as exposed at Leadenham Quarry [SK 962 523] about 1.5km to the north of the cutting. Due to the shallow depth of the cutting, the beds lie in the disturbed subsoil zone, and could not be measured accurately. The thicknesses given below relate to Leadenham Quarry; mapping of these units indicates that their thicknesses are remarkably constant throughout the Leadenham area.

At the base, Unit L1 (4.4m), comprises cream to pale brownish wackestones with scattered, rather large, yellow or brown ferruginous peloids or ooids. The lowest part is rather sandy, ferruginous and argillaceous, and seems to be transitional in lithology with the underlying Grantham Formation. The unit has been quarried immediately north of the cutting, [SK 960 509], but the pit is ploughed over with no exposure. This unit (or the lower part thereof) probably corresponds with the Sproxton Member of Ashton (1980). The overlying Unit L2 (1.9m) comprises buff calcarenite with a very uniform texture. It is a well-sorted, very fine-grained rock, composed of calcium carbonate sand, probably including some minute ooids, with a proportion of quartz sand. Larger fragments are rare, except in occasional burrow-fills. The unit, or at least the lower part, corresponds with the "Wragby Bed" of Ashton (1980) at Leadenham Quarry. The highest beds represented in the cutting belong to the lower c. 3m of Unit L3, which is 5.2m thick in total. It is dominated by very pure lime mudstones (micrites) and white peloidal wackestones, typically containing scattered, large (2mm) yellowish peloids. In part, this unit corresponds with the Greetwell Member of Ashton (1980).

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