British Middle Jurassic Stratigraphy

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Chapter 3

The Middle Jurassic stratigraphy of the Cotswolds

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INTRODUCTION

B.M. Cox

The Cotswold Hills, which extend for approximately 90 km from Bath in Somerset northwards to near Chipping Norton in Oxfordshire (Figure 3.1), are formed of Aalenian–Bathonian rocks. Those of Aalenian–Bajocian age are dominated by ooidal and peloidal, variably shelly limestones that were deposited in a shallow shelf-sea. The shoreline lay to the east and was probably not too far distant, as land marginal facies are present in the East Midlands (see Chapter 4). The overlying Bathonian rocks of the Cotswolds are also predominantly shallow shelf-sea carbonates but, as with the Aalenian–Bajocian strata, a change occurs in the north-east of the area and beyond (see Chapter 4), with brackish-water and freshwater terrigenous sediments indicating a coastal zone of saltmarshes. The Cotswold Hills, which are typified by picturesque villages and

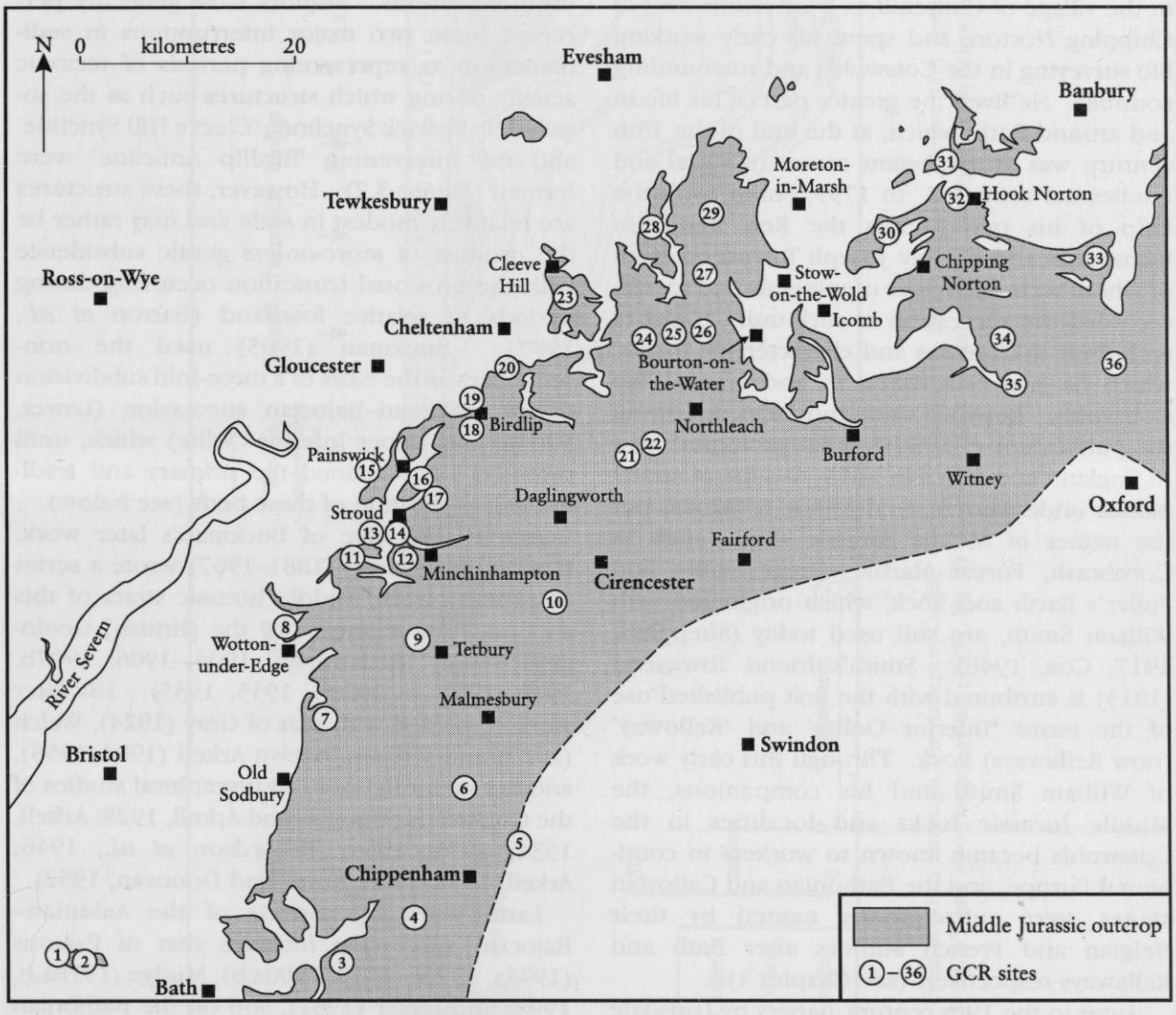


Figure 3.1 Geological sketch map showing the location of the GCR sites described in Chapter 3. (1) Barns Batch Spinney; (2) South Main Road Quarry; (3) Brown's Folly; (4) Corsham Railway Cutting; (5) Kellaways–West Tytherton; (6) Lower Stanton St Quintin Quarry and Stanton St Quintin Motorway Cutting; (7) Hawkesbury Quarry; (8) Nibley Knoll; (9) Veizey's Quarry; (10) Kemble Cuttings; (11) Woodchester Park Farm; (12) Minchinhampton; (13) Leigh's Quarry; (14) Fort Quarry; (15) Haresfield Hill; (16) Frith Quarry; (17) Swift's Hill; (18) Knap House Quarry; (19) Crickley Hill; (20) Leckhampton Hill; (21) Foss Cross; (22) Stony Furlong Railway Cutting; (23) Rolling Bank Quarry; (24) Hampen Railway Cutting; (25) First Cutting West of Notgrove; (26) Harford Cutting; (27) Huntsmans Quarry; (28) Jackdaw Quarry; (29) Snowshill Hill (Hornsleasow Quarry); (30) Cross Hands Quarry; (31) Sharps Hill; (32) Hook Norton; (33) Horsehay Quarry; (34) Ditchley Road Quarry; (35) Stonesfield; (36) Shipton-on-Cherwell Cement Works and Whitehill Farm Quarry.

drystone walls built of the rich, cream-coloured local Middle Jurassic limestones, gradually peter out in north Oxfordshire and Northamptonshire. This may be partly due to the north-eastwards facies change but is largely due to much later landscaping by Quaternary glaciation and an associated cover of drift deposits.

The Middle Jurassic rocks of the Cotswold area have a long history of geological investigation, and feature prominently in the history of geology itself. William Smith (1769–1839), the so-called 'Father of English Geology', was born in the village of Churchill, *c.* 5 km south-west of Chipping Norton, and spent his early working life surveying in the Cotswolds and surrounding counties. He lived the greater part of his life in and around Bath, which, at the end of the 18th century, was an important centre of social and intellectual activities. In 1799, Smith, with the help of his two friends the Rev. Benjamin Richardson and the Rev. Joseph Townsend, both of whom were collectors of minerals and fossils, recorded the succession of rock units, together with their thicknesses and characteristic fossils, which he had established in and around the Cotswolds. Between then and 1816, following the publication of Smith's great geological map of England and Wales in 1815, this list of stratal names underwent several minor revisions, but the names of Middle Jurassic strata, such as Cornbrash, Forest Marble, Great Oolite and Fuller's Earth and Rock, which originated with William Smith, are still used today (Sheppard, 1917; Cox, 1948). Smith's friend Townsend (1813) is attributed with the first published use of the terms 'Inferior Oolite' and 'Kelloway' (now Kellaways) Rock. Through this early work of William Smith and his companions, the Middle Jurassic rocks and localities in the Cotswolds became known to workers in continental Europe, and the Bathonian and Callovian stages were subsequently named by their Belgian and French authors after Bath and Kellaways respectively (see Chapter 1).

Later in the 19th century, papers by Lonsdale (1832), Murchison (1834, 1845), J. Buckman (1842), Brodie (1851, 1853), Wright (1856, 1860), Witchell (1880, 1882a,b, 1886), Wethered (1891) and S.S. Buckman (1889a, 1890, 1892, 1893a, 1895, 1897, 1901, 1905), as well as [British] Geological Survey memoirs by Hull (1857) and Woodward (1894), provided further details of the local Middle Jurassic succession. The work of Sydney Savory Buckman (1860–1929) is of particular note for he recognized the two major non-sequences that interrupt the Aalenian–Bajocian succession. At these levels, the strata above the non-sequences overlap or overstep the older beds beneath. The episodes of erosion that caused these non-sequences were referred to by Buckman (1901) as the Aalenian and Bajocian denudations. They are marked by eroded, planed and bored, oyster-encrusted hardgrounds. Later, Arkell (1933) used the terms Bajocian and Vesulian transgressions for the renewed deposition that followed the denudations. Authors have generally perceived these two major interruptions in sedimentation as representing periods of tectonic activity during which structures such as the so-called 'Painswick Syncline', 'Cleeve Hill Syncline' and the intervening 'Birdlip Anticline' were formed (Figure 3.2). However, these structures are relatively modest in scale and may rather be the product of more-or-less gentle subsidence with the erosional truncation occurring during periods of relative lowstand (Barron *et al.*, 1997). Buckman (1905) used the non-sequences as the basis of a three-fold subdivision of the Aalenian–Bajocian succession (Lower, Middle and Upper Inferior Oolite) which, until recently, has remained the primary and traditional classification of these beds (see below).

Around the time of Buckman's later work, Linsdall Richardson (1881–1967) wrote a series of papers on the Middle Jurassic strata of this area and two memoirs for the [British] Geological Survey (Richardson, 1904, 1906, 1907b, 1910, 1911a,b, 1929b, 1933, 1935). His later work coincided with that of Gray (1924), Welch (1927) and William Jocelyn Arkell (1904–1958), another major figure in stratigraphical studies of the Cotswolds (Douglas and Arkell, 1928; Arkell, 1931, 1933, 1934; Richardson *et al.*, 1946; Arkell, 1951–1958; Arkell and Donovan, 1952).

Later work on aspects of the Aalenian–Bajocian succession includes that of Parsons (1974a, 1976b, 1979, 1980a,b), Mudge (1978a,b, 1995) and Baker (1981), and on the Bathonian succession that of Green and Donovan (1969), Sellwood and McKerrow (1974), Palmer (1979), Penn and Wyatt (1979) and Sumbler (1984), and unpublished theses by Barker (1976), Bradshaw (1978) and Cripps (1986). [British] Geological Survey memoirs by Cave (1977) and Horton *et al.* (1987) include accounts of the Middle Jurassic successions in the Malmesbury and Chipping Norton districts respectively. More recent

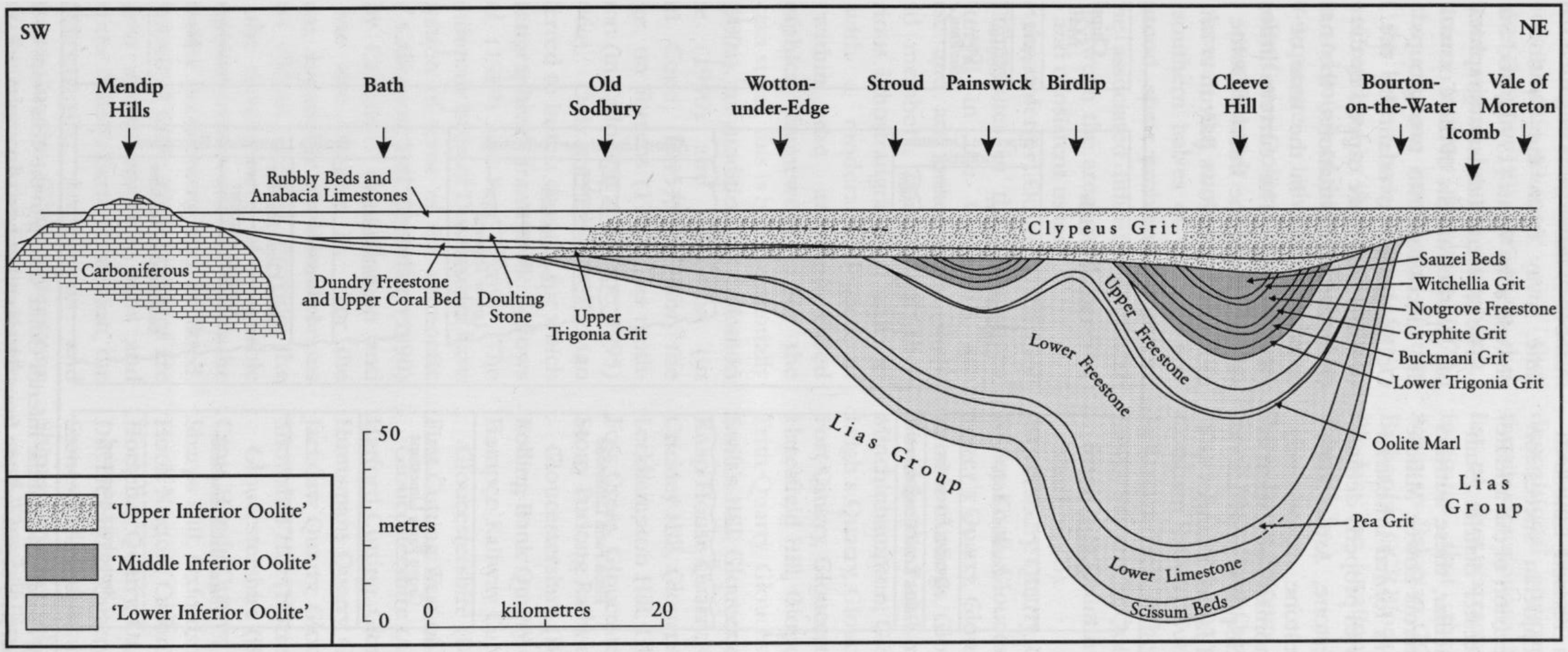


Figure 3.2 Diagrammatic cross-section through the Inferior Oolite Group showing the Painswick and Cleeve Hill 'synclines', and the intervening 'Birdlip Anticline'. (After Akell, 1933, fig. 35; see also Barron *et al.* (1997, fig. 5) which shows a similar section through the 'synclines' based on more recent data and with revised lithostratigraphy.)

Survey work has led to a revised lithostratigraphy for the Aalenian–Bajocian succession (Barron *et al.*, 1997), and revision of the Middle Jurassic strata of the Cirencester district (Sumbler *et al.*, 2000). In particular, these authors abandoned the use of the terms Lower, Middle and Upper Inferior Oolite in formal lithostratigraphy and replaced them with properly defined formations – Birdlip Limestone, Aston Limestone and Salperton Limestone, respectively. The correlation of the Bathonian succession of the Cotswold area, which displays rapid lateral and vertical lithological and faunal changes as a number of facies belts migrated basinwards with time, away from the London Landmass, is discussed by Wyatt (1996a) and Sumbler (1999).

The current lithostratigraphical scheme for the Middle Jurassic of the Cotswold area divides the succession into two groups – the Inferior Oolite Group overlain by the Great Oolite Group – which are capped by the Kellaways and Oxford Clay formations; the names of these units originated in the time of William Smith (see above). The current lithostratigraphical subdivision of the Inferior Oolite Group shown in Figure 3.3 follows Barron *et al.* (1997) and is

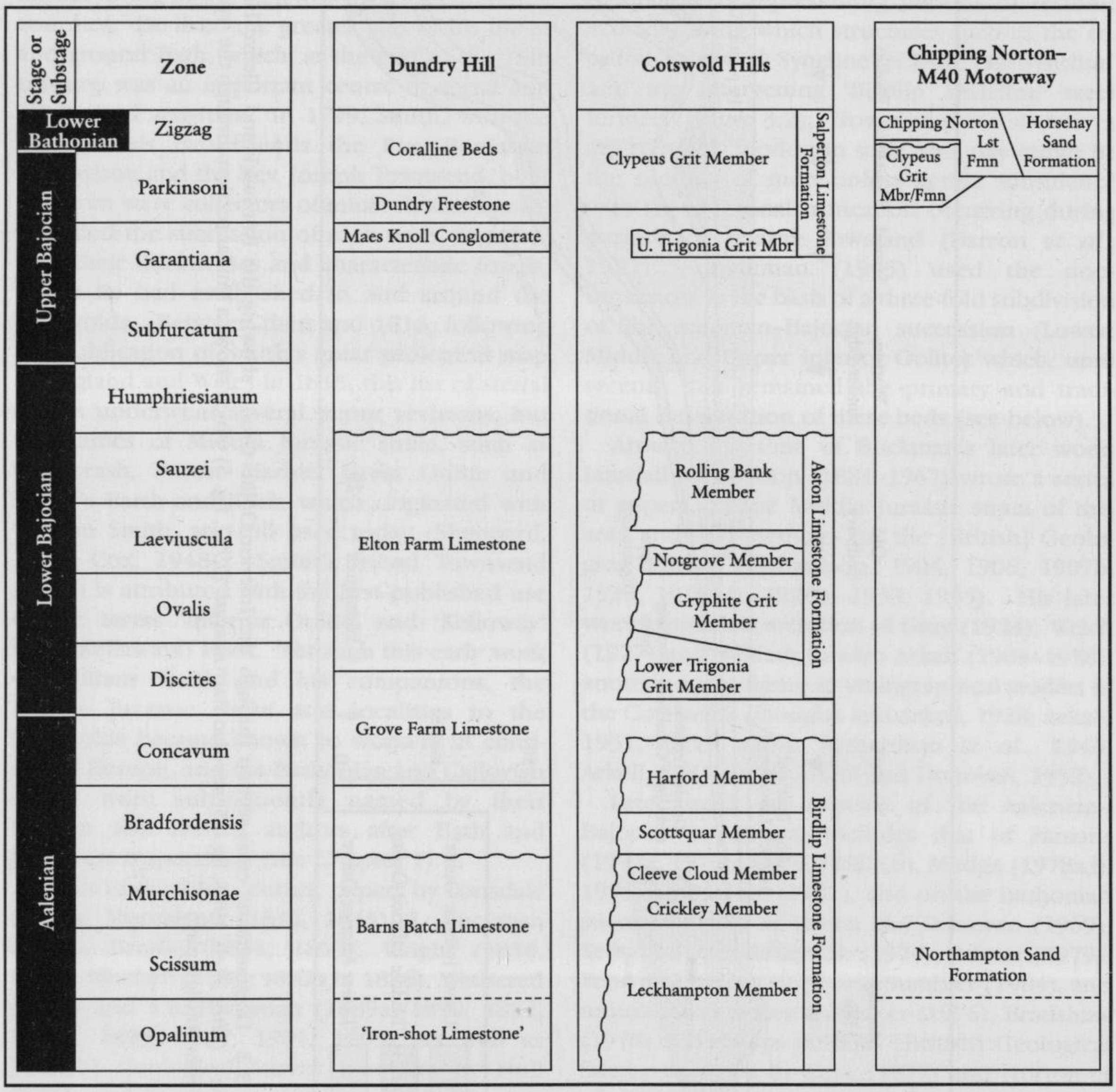


Figure 3.3 Lithostratigraphical classification of the Inferior Oolite Group in the Cotswolds as shown in sites in Chapter 3. Columns are deliberately separated one from the other because of complexities of correlation and non-sequence. Vertical ruling indicates non-sequence. (Based on data in Barron *et al.*, 1997; Parsons, 1979, 1980a; and Wyatt in Sumbler, 1996.)

applicable to all of the Aalenian–Bajocian sites described in this chapter with the exception of the Dundry Hill outlier, in the extreme southwest where, for the time being, the nomenclature follows Parsons (1979, 1980a). In the extreme north-east of the Cotswold area, the lowest beds of the Inferior Oolite Group are replaced by the Northampton Sand Formation and much of the rest is missing owing to non-sequence. Lithostratigraphical subdivision of the Great Oolite Group (Figure 3.4) is more complicated. Although the relationships between the successions in the northern and southern halves of the area are broadly understood, some problems remain in rationalizing the associated lithostratigraphical nomenclature between the areas, and agreeing an appropriate and consistent usage.

Apart from the Inferior Oolite Group of Dundry Hill, ammonites in the Aalenian to Bathonian interval in the Cotswolds are generally sparse and are unknown in some formations and members; nonetheless, they enable the various lithostratigraphical units to be placed, with a moderate degree of confidence, within the ammonite-based chronostratigraphical framework. For the Aalenian–Bajocian strata, this is based essentially on Parsons (1980a), as modified by Callomon and Chandler (1990) and Callomon (in Callomon and Cope, 1995); and for the Bathonian Stage, on Torrens (1980b), as modified by Callomon (in Callomon and Cope, 1995) and Page (1996a). Only the Lower Callovian Substage is referred to in this chapter, for which the chronostratigraphical framework follows Callomon *et al.* (1989) and Page (1989). The highly ammonitiferous beds of Dundry Hill have enabled recognition of some of the ammonite biohorizons of Callomon and Chandler (1990) as modified by Callomon (in Callomon and Cope, 1995; see also Chapter 1). For the Bathonian Stage, apparently quasi-isochronous event horizons (Wyatt, 1996a) provide the potential for the development of a reliable chronostratigraphical framework into which the scattered ammonite occurrences may be fitted. The most important of these event horizons are the *Praeexogyra acuminata*-rich beds and Echinata Bed in the Fuller's Earth Formation, the Excavata, Langrunensis, Ardleyensis and Bladonensis beds in the White Limestone Formation, and the bases of the Forest Marble and Cornbrash formations.

Details of the main lithologies and depositional environments are included in the site descriptions that follow. In the following list of sites (arranged south to north), (A) indicates that the site belongs to the Aalenian–Bajocian GCR Block, (B) indicates the Bathonian GCR Block and (C) the Callovian GCR Block. The location of the sites is shown in Figure 3.1.

Barns Batch Spinney, Somerset (A)
South Main Road Quarry, Somerset (A)
Brown's Folly, Somerset (B)
Corsham Railway Cutting, Wiltshire (B)
Kellaways–West Tytherton, Wiltshire (C)
Lower Stanton St Quintin Quarry and
 Stanton St Quintin Motorway Cutting,
 Wiltshire (B)
Hawkesbury Quarry, Gloucestershire (A)
Nibley Knoll, Gloucestershire (A)
Veizey's Quarry, Gloucestershire (B)
Kemble Cuttings, Gloucestershire (B)
Woodchester Park Farm, Gloucestershire (B)
Minchinhampton, Gloucestershire (B)
Leigh's Quarry, Gloucestershire (A)
Fort Quarry, Gloucestershire (A)
Haresfield Hill, Gloucestershire(A)
Frith Quarry, Gloucestershire (A)
Swift's Hill, Gloucestershire (A)
Knap House Quarry, Gloucestershire (A)
Crickley Hill, Gloucestershire (A)
Leckhampton Hill, Gloucestershire (A)
Foss Cross, Gloucestershire (B)
Stony Furlong Railway Cutting,
 Gloucestershire (B)
Rolling Bank Quarry, Gloucestershire (A)
Hampen Railway Cutting,
 Gloucestershire (B)
First Cutting West of Notgrove,
 Gloucestershire (A)
Harford Cutting, Gloucestershire (A)
Huntsmans Quarry, Gloucestershire (B)
Jackdaw Quarry, Gloucestershire (A)
Snowshill Hill (Hornsleasow Quarry),
 Gloucestershire (B)
Cross Hands Quarry, Warwickshire (A)
Sharps Hill, Oxfordshire (B)
Hook Norton, Oxfordshire (B)
Horsehay Quarry, Oxfordshire (B)
Ditchley Road Quarry, Oxfordshire (B)
Stonesfield, Oxfordshire (B)
Shipton-on-Cherwell Cement Works
 and Whitehill Farm Quarry, Gibraltar,
 Oxfordshire (B)

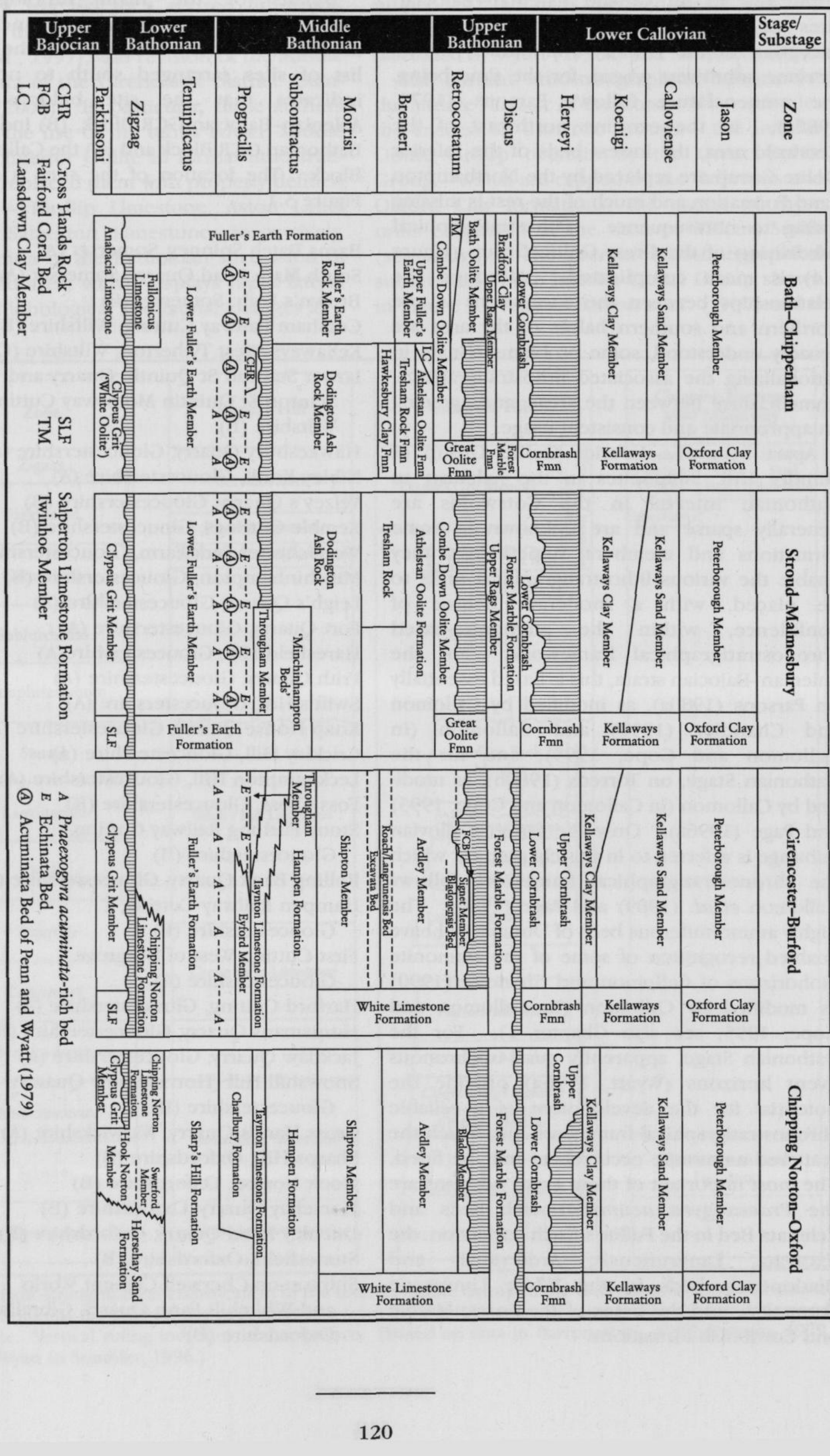


Figure 3.4 Lithostratigraphical classification of the Great Oolite Group and overlying beds in the Cotswold area. Columns are deliberately separated one from the other because the nomenclature as used in different areas is in need of rationalization. Vertical ruling indicates non-sequence. (Based on data in Cave, 1977; Horton *et al.*, 1987; Page 1989, 1996a; Sumbler *et al.*, 2000; Wyatt in Sumbler, 1996; and herein.)

BARNS BATCH SPINNEY AND SOUTH MAIN ROAD QUARRY, SOMERSET (ST 557 659, ST 566 654)

B.M. Cox

Introduction

Barns Batch Spinney and South Main Road Quarry are two of the many localities where the highly fossiliferous Inferior Oolite Group of the outlier at Dundry Hill, near Bristol, has been exposed (Figure 3.5). The quarries, as well as underground galleries, hereabouts were opened for the exploitation of the Dundry Freestone but it is the underlying, richly ammonitiferous beds of the lower parts of the Inferior Oolite Group that have made the area so famous. Dundry Hill is the type locality of many species of ammonites, gastropods, bivalves and brachiopods, while belemnites, echinoids, corals, sponges and other fossils abound (Macfadyen, 1970). By the 1890s, many of the quarry sections were becoming obscured as the Dundry Freestone was worked out, but through the pioneer work of Buckman and Wilson (1896, 1897), their place in the study of Aalenian and Bajocian stratigraphy has been secured for all time. These authors produced the first descriptions of both sites (Buckman and Wilson, 1896). Barns Batch Spinney appears not to have featured again in the literature until the section was re-described by Parsons (1979). In contrast, Buckman and Wilson's (1896) section at South Main Road Quarry, probably the most famous quarry on Dundry Hill, has been quoted by Tutcher (in Crookall *et al.*, 1930; Tutcher, 1903) and Macfadyen (1970). A re-excavated section there was described by Parsons (1979). More recently, both sites have featured in the review of Aalenian and Lower Bajocian ammonite bio- and chrono-stratigraphy undertaken by Callomon and Chandler (1990), and are covered by the British Geological Survey memoir for the Bristol district (Kellaway and Welch, 1993). The key workers on both sections have concentrated on the ammonites and consequently other faunas are under-represented in the published descriptions; the non-ammonite faunas that feature in the descriptions below are taken from Buckman and Wilson (1896) and Macfadyen (1970). At the time of Parsons' (1979) work, Barns Batch Spinney exposed the lowest levels of the Inferior Oolite Group on Dundry Hill, whereas South Main Road Quarry exposed a more complete succession through the higher beds.

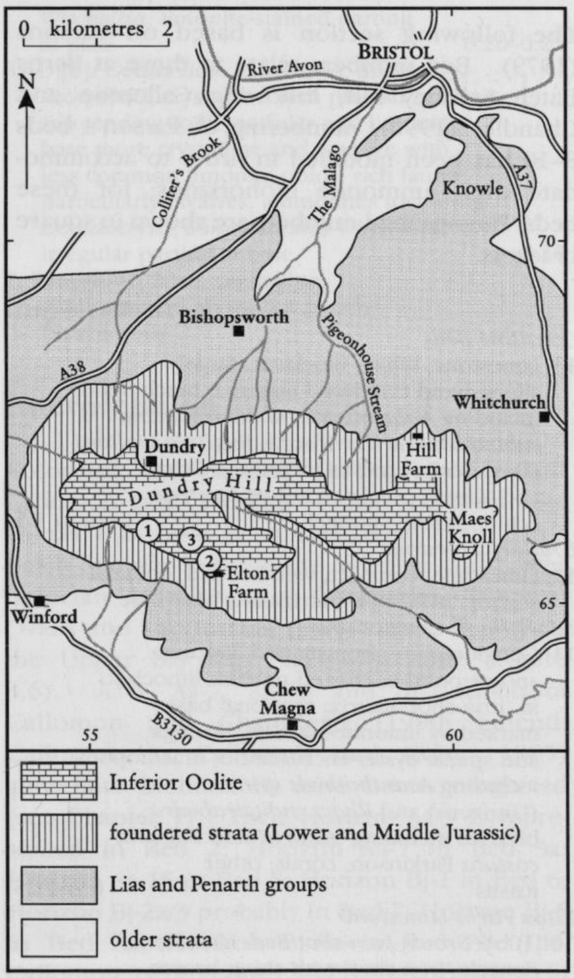


Figure 3.5 Geological sketch map showing the location of the GCR sites (1) Barns Batch Spinney and (2) South Main Road Quarry. The site of (3) the BGS Elton Farm Borehole is also shown. (After Ivimey-Cook, 1978, fig. 1; and Kellaway and Welch, 1993, fig. 45.)

Description

Barns Batch Spinney

The following section and bed numbers are based on Parsons (1979) but, following Callomon and Chandler (1990), numbering of Parson's beds 8–9 has been modified in order to accommodate their ammonite biohorizons; for these beds, Parsons' bed numbers are shown in square brackets.

Thickness (m)

Coralline Beds

13: Limestone, white, rubbly, bioclastic, mainly disturbed and slipped material; bivalves, brachiopods, echinoids and 'numerous corals' recorded by Buckman and Wilson (1896); planed, limonite-stained surface at base — seen to 0.30

Elton Farm Limestone

8c–d [9]: Limestone, conglomeratic, 'iron-shot'; most of fauna, including the ammonites *Docidoceras*, *Emileia* and *Witchellia*, rolled and worn (derived from bed below); irregular, limonite-stained surface at base — 0.0–0.10

8a–b: *Ovalis Bed*: Limestone, cream-grey, rubbly, with numerous, small limonite ooids (8b) becoming pinker and more crystalline below (8a); highly fossiliferous with fauna mainly concentrated at 0.10–0.15 m and 0.25 m below top, latter level with brittle fracture; ammonites including *Bradfordia*, *Docidoceras*, *Emileia*, *Sonninia*, *Strigoceras* and *Witchellia*; bivalves including *Ctenostreon*, 'myids', pectinids and *Trigonia*; belemnites; irregular sandy parting at base — 0.25–0.45

7: Limestone, hard, massive, crystalline, 'iron-shot' with pink matrix; poorly fossiliferous with a few belemnites, bivalves and the ammonite *Hyperlioceras*; irregular sandy parting, with adjacent limestone sandier and more nodular, divides bed into two; 0.05 m-thick brown, sandy marl at base — 0.35–0.53

Grove Farm Limestone

6: Limestone, hard, nodular, crystalline with minor marl intercalations, softer and whiter towards base; weak parting divides bed roughly in two; extensively bioturbated, moderately fossiliferous but preservation mainly as distorted internal casts; ammonites including *Hyperlioceras*; bivalves including *Gresslya*, 'myids' and pectinids; marl parting at base — 0.30

5: Soft marl with hard, pinkish-grey, slightly 'iron-shot' limestone nodules; numerous, mainly distorted poorly preserved ammonites (*Graphoceras*) as internal casts of body chambers — 0.20

4: *Eudesi Bed*: Limestone, pinkish-grey, harder and more massive than beds above; divided into three courses; middle course with the brachiopod *Sphaeroidothyris eudesi* (Oppel) (abundant); basal course darker, more crystalline with derived pisoids; rare ammonites and bivalves including *Modiolus* — 0.40

Barns Batch Limestone

3b: Layer of laminated limonite — 0.02–0.04

3a: *Pleurotomaria Bed*: Limestone, hard, pinkish-grey, 'iron-shot' particularly towards very irregular, highly conglomeratic top with '*Lithophaga*' borings, large pisoids, serpulid- and limonite-encrusted ammonites and small 'snuff-boxes'; particularly hard and massive towards base (forms topographic feature); ammonites including *Brasilia*? and *Ludwigia*; abundant pleurotomariid gastropods; marl parting at base — 0.50

2: Limestone, hard, pinkish-grey, crystalline, sandy, sparsely ooidal, very nodular, with some marl layers; well bioturbated, probably by *Pleuromya* (seen in growth position); ammonites including *Ludwigia*; sandy, marl parting at base — 0.28–0.30

1: Limestone, massive, buff-coloured, sandy with small limonite flecks — seen to 0.85

South Main Road Quarry

The following section is based on Parsons (1979). Bed numbers relate to those at Barns Batch Spinney but, following Callomon and Chandler (1990), numbering of Parson's beds 8–10 has been modified in order to accommodate their ammonite biohorizons; for these beds, Parsons' bed numbers are shown in square brackets.

Thickness (m)

Coralline Beds

13: Limestone, white, bioclastic, largely slipped and cambered material; brachiopods including *Aulacothyris*, *Rhactorhynchia subtetrahedra* (Davidson); *Rugitela waltoni* (Davidson); bivalves including '*Ostrea*' and '*Lima*'; corals including *Isastrea*; echinoderms; sponges — seen to 1.5

?Dundry Freestone

12: Limestone, compact, well bedded, ooidal, slightly 'iron-shot' particularly near base — 1.0

?Maes Knoll Conglomerate

11: Conglomerate, iron-stained, limonite and serpulid-encrusted pebbles/lithoclasts in 'iron-shot' matrix; erosional base marked by limonite-staining, borings and sparse oyster-encrustation; brachiopods including *Acanthothiris spinosa* (Linnaeus) and *Rhact. subtetrahedra*; bivalves including '*Astarte*' and *Trigonia costata* Parkinson; corals; other fossils — 0.2–0.25

Elton Farm Limestone

10 [10b]: *Brown Iron-shot Bed*: Limestone, densely 'iron-shot' with shiny, brown, limonite ooids in purple-stained matrix; bivalves and gastropods; base marked by bivalve-rich parting with *Liostrea* and *Ctenostreon* (very flat hardground); many well-preserved ammonites including *Emileia*, *Labyrinthoceras*, *Protoecotraustes*, *Sonninia*, *Stephanoceras* and *Witchellia* — 0.15–0.22

	Thickness (m)
9 [10a]: *Witchellia Bed*: Limestone, 'iron-shot', with fewer limonite ooids than bed above and with whiter, soft, 'pastey' matrix; ammonites including *Witchellia* (abundant) with *Bradfordia*, *Emileia*, *Frogdenites*, *Shirbuirnia* and *Strigoceras*; irregular limonite-coated surface at base	0.25–0.28
8c–d [9]: *Limonitic Bed*: Limestone, 'iron-shot', extremely nodular, hard, bioturbated, with appearance of conglomerate; upper surface thickly coated with limonite and some incipient 'snuff-boxes'; many fossils (mainly distorted and badly preserved, or difficult to extract); bivalves including *Ctenostreon*; ammonites including *Docidoceras*, *Emileia*, *Lissoceras*, *Mollistephanus*, *Shirbuirnia*, *Witchellia*; limonite-stained parting at base	0.20–0.25
8a–b [8]: *Ovalis Bed*: Limestone, finely 'iron-shot', crystalline with pinkish matrix; top tending to be nodular and limonitic, base more crystalline and massive with less common limonite ooids; rich fauna particularly bivalves; ammonites including *Docidoceras*, *Sonninia* and *Witchellia*; irregular parting at base	0.30
7: Limestone, hard, crystalline, similar to bed above but poorly fossiliferous	seen to 0.10

Interpretation

According to Parsons (1974a, 1979) and Callomon and Chandler (1990), the ammonite faunas that have been recovered from Barns Batch Spinney indicate the Aalenian and Lower Bajocian Murchisonae, Concavum, Discites, Ovalis and Laeviuscula (part) zones, as well as the Upper Bajocian Parkinsoni Zone (Figure 3.6). Aa-5, Aa-7, Aa-15 and Bj-1–?Bj-8b of Callomon and Chandler's (1990; emend. Callomon in Callomon and Cope, 1995) ammonite biohorizons have been recognized (see Chapter 1). Their Horizon Aa-5 is represented in Bed 2; Horizon Aa-7 in Bed 3a; Horizon Aa-15 in Bed 5; Horizon Bj-1 in Bed 6; Horizon Bj-2a/3 probably in Bed 7; Horizon Bj-5 in Bed 8a; Horizon Bj-6b in Bed 8b (J.H. Callomon, pers. comm., 1997), Horizon Bj-7b in Bed 8c; and Horizon Bj-8b probably in Bed 8d.

At South Main Road Quarry, the rich ammonite faunas indicate the Discites Zone (part), Ovalis Zone, Laeviuscula Zone, and Sauzei Zone of the Lower Bajocian Substage, as well as the Garantiana and Parkinsoni zones of the Upper Bajocian Substage (Figure 3.6). Bj-5 to Bj-11a of Callomon and Chandler's (1990; emend. Callomon in Callomon and Cope, 1995) ammonite biohorizons have been recognized. Their Horizon Bj-5 is represented in Bed 8a; Horizon Bj-6b and Bj-6c in Bed 8b (J.H. Callomon, pers. comm., 1997); Horizon Bj-7b in Bed 8c; Horizon Bj-8b probably in Bed 8d; Horizon Bj-10, one of the most diversely fossiliferous horizons in the whole of the Bajocian Stage, in Bed 9; and Bj-11a in Bed 10. Discussion of these ammonite biohorizons and their contained species is given in Callomon and Chandler (1990).

The prevalence of limonite ooids, 'snuff-boxes' (limonite concretions), limonite encrustation, thick-shelled bivalves and abundant ammonites in beds 1–10 suggests a very slow rate of deposition in a shallow shelf-sea, interspersed with erosional and non-depositional breaks, the causes of which were almost certainly predominantly tectonic with differential subsidence on a relatively local scale (Parsons, 1979; Callomon and Cope, 1995). At South Main Road Quarry, the upper surface of these lower 'iron-shot beds' is a prominent hardground overlain by a conglomerate (Bed 11), which indicate an erosional break, and then limestone strata (beds 12–13) of quite different aspect. On the eastern side of Dundry Hill, this erosion removed the underlying beds of the Inferior Oolite Group altogether, and cut down into the uppermost beds of the Lias Group. Maes Knoll, which is sited there, gives its name to the conglomerate (Buckman and Wilson, 1896; Buckman, 1902b; Richardson, 1907b). At the western end, it cuts down to the level of Bed 8b. The fuller succession in the central part of the hill, where Barns Batch Spinney and South Main Road Quarry are sited, is thought to have been preserved in a small local 'downwarp' (Parsons, 1979), as illustrated by Buckman (1902b, fig. 8). At Barns Batch Spinney, the conglomerate itself is absent (Figure 3.6).

Conclusions

When d'Orbigny (1850a) first divided the Jurassic System into stages, he nominated Dundry as the English 'type section' for the Bajocian Stage (including Aalenian strata), and since then it has been a famous locality for Aalenian–Bajocian palaeontological and stratigraphical research, with the Inferior Oolite

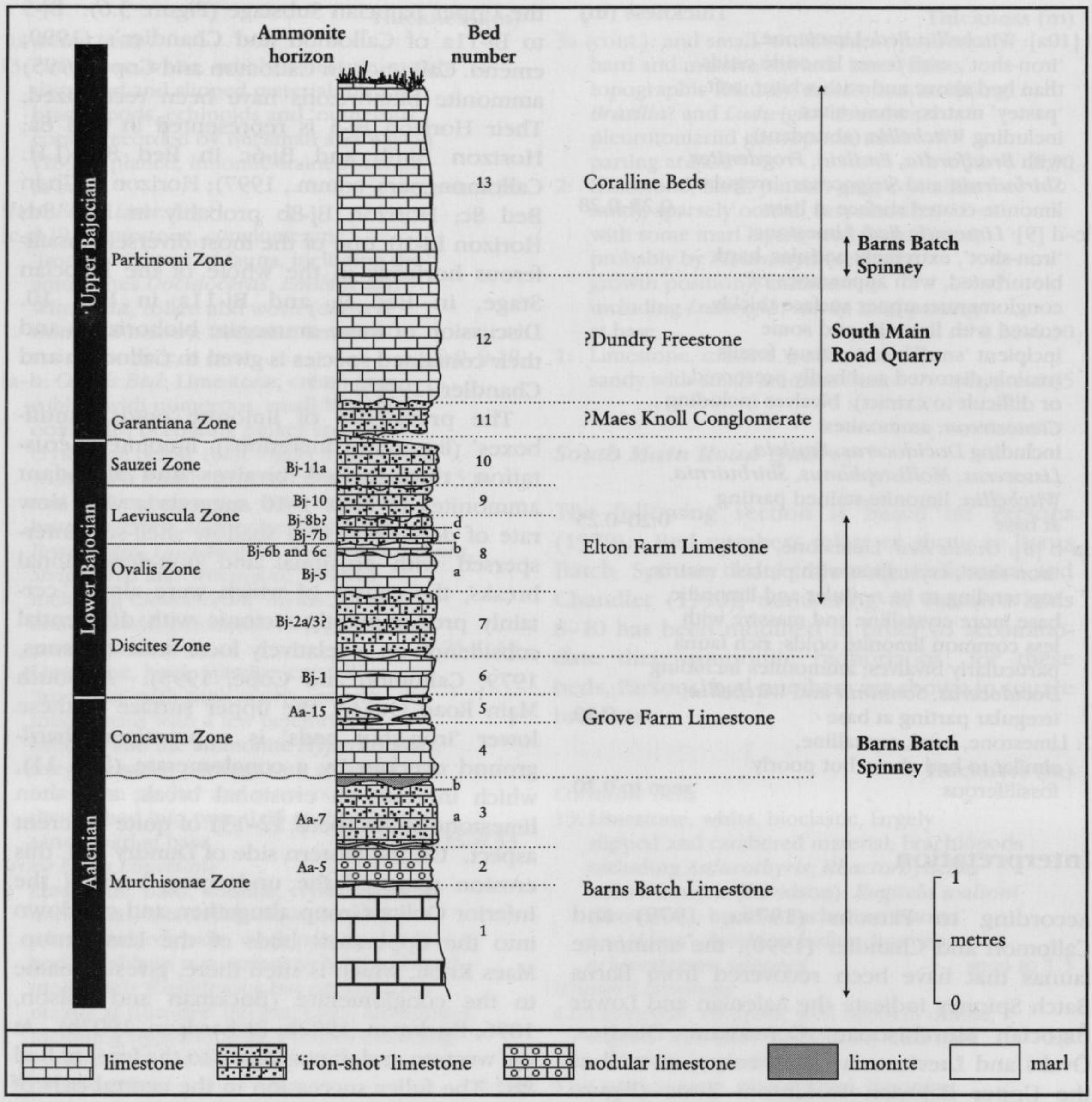


Figure 3.6 Composite graphic section of the two GCR sites at Dundry Hill. Beds 1–8b are based on Barns Batch Spinney, beds 8c–13 are based on South Main Road Quarry. (After Callomon and Chandler, 1990, fig. 4.) Horizon numbers have been updated following Callomon in Callomon and Cope (1995). The thickness of Bed 10 is somewhat greater than that given by Parsons (1979). (MCG = Maes Knoll Conglomerate.)

Group there having a reputation for being one of the world's most fossiliferous deposits. It is the type locality for many fossils, particularly ammonites and brachiopods, although published descriptions of the section are largely biased towards the former. The contrast between the lithologies of the lower 'iron-shot' beds (of Dorset and northern France aspect) and those of the highest beds (of Cotswolds aspect) is strong evidence for movements of the Mendip Axis during early Late Bajocian times at the time of the 'Bajocian denudation' of Buckman (1901). These sites are thus also important for palaeogeographical research.

BROWN'S FOLLY, SOMERSET (ST 795 663–ST 794 652)

R.J. Wyatt

Introduction

The main exposures adjacent to Brown's Folly (ST 7947 6606) are located in the crags that extend about 1.5 km along the upper part of the densely wooded, steep hillside to the east of the River Avon, near Bathford, Somerset (Figure 3.7). Another major exposure is present *c.* 300 m due north of Brown's Folly, about halfway down the hillside. The area is owned by The Wildlife Trust, Bristol, Bath and Avon (the operating name of Avon Wildlife Trust). Together, the exposures have revealed an Upper Bathonian succession ranging from close to the base of the Great Oolite Formation up into the lower part of the Forest Marble Formation; this includes the most complete succession of the Great Oolite Formation in the Bath district. Included in the succession are the oolite free-stones of the Bath Oolite Member that were formerly mined as the 'Farleigh Down Stone', and the Corsham and Bradford coral beds in the lower part of the Forest Marble Formation, which are characterized by scattered small coral reef-knolls. The succession was described in detail by Green and Donovan (1969) and, briefly, by Hawkins (1977).

Figure 3.7 Exposure of Great Oolite Formation on the wooded slopes below Brown's Folly. (Photo: M.G. Sumbler.)

Description

The following section (see also Figure 3.8) is based on that recorded by Green and Donovan (1969).

	Thickness (m)
Forest Marble Formation	
Limestone, brown, shelly, flaggy; lower 3.4 m cross-bedded	*c.* 4.9
Gap	*c.* 1.5
Limestone, detrital, buff, cross-bedded, ooidal; well-preserved fossils, including *Digonella digona* (J. Sowerby), on bedding planes	1.5
Marl, brown, sandy, passing into ragged, shelly marly limestone; passing down into	0.3
Clay, grey, fossiliferous with *Apiocrinus*, *Digonella digona*, numerous rhynchonellids, oysters etc.; sharp base	0.23
Upper Rags Member	
Bradford Coral Bed: Limestone, brown, shelly, hard, detrital, weathering ragged and cavernous; top surface oyster-encrusted; some beds weathering to rubbly ochreous marl; abundant fossils including corals, brachiopods and large thick-shelled bivalves (including oysters); in places, apparently channelled into bed below, otherwise downward passage	2.7–3.0
Oolite, detrital, creamy-buff, fairly massive; in parts, rather fine grained and marly particularly towards top; some burrows; top locally bored	1.8–2.6
Corsham Coral Bed: Coralline limestone, pale-buff, hard, massive; coarse ooids and coarsely shelly with boring molluscs; top surface extensively bored and oyster-encrusted ('Roof Bed' of Bath Oolite mines)	1.5
Great Oolite Formation	
Bath Oolite Member	
Pure oolite-freestone (formerly mined), fine grained; top surface slightly bored	2.1
Gap (white oolite seen in places)	*c.* 5.0
Twinhoe Member	
Winsley facies: Limestone, yellowish, hard, detrital, massive	1.1
Marl, ochreous; sharp base	0.15
Freshford facies: Oolite, cream-coloured, soft, coarse grained; marly with scattered shell-debris	0.9–1.1
Limestone, fawn to yellowish, marly, pisolitic, detrital; irregular bedding	1.1

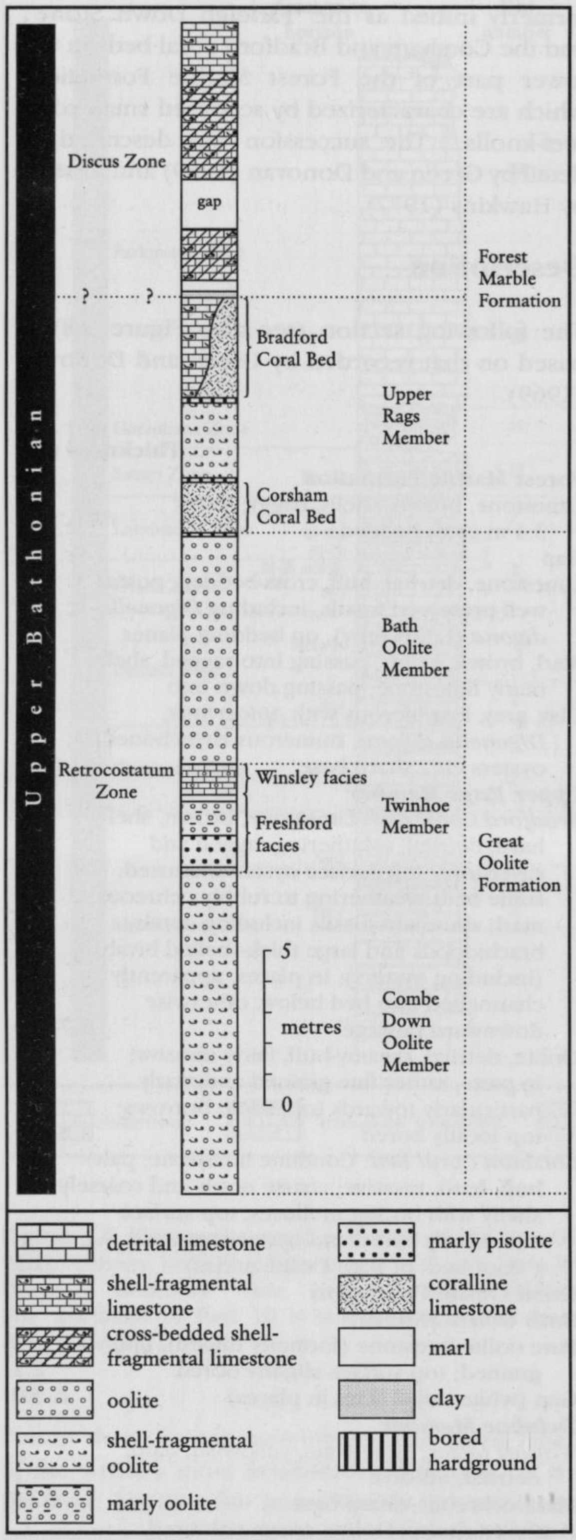


Figure 3.8 Graphic section of the Bathonian succession at Brown's Folly.

	Thickness (m)
Limestone, buff, shelly, soft, rubbly, pisolitic, marly; very fossiliferous with abundant bivalve casts	0.7–0.8
Clay and marl, yellowish-brown; sharp base with pocketing into beds below	0.1
Combe Down Oolite Member	
Limestone, fawn, fine grained, detrital, ooidal; ramifying burrows; 0.31 m-thick brachiopod-rich bed in middle part with *Kallirhynchia* cf. *superba* S.S. Buckman and abundant *Obovothyris* cf. *obovata* (J. Sowerby); sharp base but joined on to bed below	0.9
Oolite, fawn, massive, fairly hard, current-bedded, shelly with many shell-detrital layers (mined for building stone)	4.6–4.9

An even more complete succession in the lower beds is seen in crags (ST 7943 6634) 300 m north of Brown's Folly. Here, a total of 8.5 m of the Combe Down Oolite Member is present, only a metre or so short of its total thickness hereabouts. The junction of the Bath Oolite and Twinhoe members is sharp, with the oolite piping down into the latter.

Interpretation

The cross-bedded, shell-fragmental oolites of the Combe Down Oolite Member, which rarely yield whole fossils, were deposited by mobile sand-waves in a high-energy, shallow-water, carbonate shelf-sea with strong currents, where benthic organisms were unable to colonize. However, periodical stabilization of the substrate is indicated by ramifying burrows, which can be seen locally, as in the uppermost bed at Brown's Folly, and by the well-preserved brachiopods of that bed. Burrow-fills at the top of this bed suggest a break in sedimentation before the basal clay and marl of the Twinhoe Member were deposited. Elsewhere, locally, the upper surface of the Combe Down Oolite Member is planar, extensively bored and oyster-encrusted, attesting to such a depositional break, with concomitant lithification of the substrate.

The limestones of the Twinhoe Member (Freshford facies), which comprise coarse ooids, pisoids and shell debris in a fine-grained marly matrix, are inferred to have been deposited in somewhat deeper, quieter waters than the Combe Down Oolite Member, where calcareous mud and silt predominated. Ooids and pisoids commonly have an algal coating, the development of which supports the prevalence of less turbulent conditions. The uppermost detrital limestone (Winsley facies) is deemed by Penn and Wyatt (1979) to represent the deepest-water phase in a transition from the oolites of a shallow shelf-sea to the mudstones (Frome Clay Formation) of the Wessex Basin margin.

Piping of the overlying Bath Oolite Member into the top of the Twinhoe Member indicates a depositional break. This oolite represents a return to high-energy, current-dominated conditions, in which a constantly mobile substrate led to the development of pure, even-grained, well-sorted oolites. Borings at the top of the Bath Oolite Member imply a further depositional break.

Turbulent, shallow-water conditions continued during deposition of the Upper Rags Member of the Forest Marble Formation, but sorting by currents was now much less effective. The basal Corsham Coral Bed, although coralline, does not display the discrete reef-knolls that are so characteristic in the **Corsham Railway Cutting** (see GCR site report, this volume). The bored top of the bed represents yet another depositional break, during which sessile oysters encrusted the sea floor. The uppermost Bradford Coral Bed is lithologically similar, but a passage into a typical reef-knoll, up to 3 m thick, is seen *c.* 45 m north of Brown's Folly.

As at **Corsham Railway Cutting** (see GCR site report, this volume), the clay above the Upper Rags Member reflects an influx of muddy and sandy terriginous sediment, which in part contains elements of the so-called 'Bradford Clay fauna'. The limestones that form the remainder of the succession are witness to the renewal of carbonate sand sedimentation, in which the influence of strong currents is demonstrated by the dominance of cross-bedding structures.

The high-energy, shallow-water, carbonate shelf-sea in which the bulk of the succession at Brown's Folly was deposited, extended north-eastwards well into Oxfordshire; its southern margin was located about 9 km south of the site, trending west–east through Trowbridge. However, the lithologies of the Twinhoe Member, which represent foreslope deposits at the edge of the Wessex Basin, indicate a temporary northward shift of the shelf-sea margin to just north of Brown's Folly. These carbonate rocks, which are characteristic of the Bath district as a whole, have been compared with sediments currently being deposited on the Andros Platform of the Great Bahamas Bank, and in the Persian Gulf (Green and Donovan, 1969).

No biostratigraphically useful ammonites are known from the Brown's Folly succession, but the occurrence of *Procerites hodsoni* Arkell in the lower part of the Combe Down Oolite Member just north of Bath assigns these lower beds to the Retrocostatum Zone. Ammonites characteristic of this zone have also been collected from the Twinhoe Member south of Bath. Since this member passes laterally northwards into the lower part of the Bath Oolite Member, the latter, and probably also its upper part, are included in the Retrocostatum Zone. *Clydoniceras hollandi* (S.S. Buckman) is present in the Bradford Clay at its type locality, indicating that beds of the Forest Marble Formation above the Upper Rags Member belong to the Discus Zone (Hollandi Subzone). The Upper Rags Member, which has not yielded diagnostic ammonites, were referred to the Discus Zone by Penn and Wyatt (1979) and Wyatt (1996a), but to the *orbis* (now Retrocostatum) Zone by Torrens (1980b).

Conclusions

The composite section at Brown's Folly exposes an Upper Bathonian succession that includes most of the Great Oolite Formation and the lower part of the Forest Marble Formation. It demonstrates a period of sedimentation during which oolites and shell-fragmental limestones, deposited in a high-energy, shallow-water, carbonate shelf-sea covering the western portion of the London Platform, were dominant. Deeper-water, foreslope deposits (Twinhoe Member), which represent a transition into the mudstone succession of the steadily subsiding Wessex Basin to the south, are also exposed. The succession may be viewed as a 'fossilized' equivalent of the present-day sediments that characterize the Great Bahamas Bank and the Persian Gulf. Features of special interest in the Brown's Folly section include the formerly commercial Bath Oolite Member freestone (Farleigh Down Stone) and the Bradford and Corsham coral beds, in which small reef-knolls are locally characteristic. Bored and burrowed beds, associated with planed and oyster-encrusted surfaces, provide evidence of periodic pauses in sedimentation with local lithification of the substrate. Overall, the section illustrates the general character of the Upper Bathonian succession of the Bath district.

CORSHAM RAILWAY CUTTING, WILTSHIRE (ST 863 694)

R.J. Wyatt

Introduction

The exposures in Corsham Railway Cutting, on the main railway line from London to Bath, lie between the former Corsham Station and the eastern portal of Box Tunnel, *c.* 6 km south-west of Chippenham, Wiltshire. They reveal an Upper Bathonian succession that includes the upper part of the Bath Oolite Member of the Great Oolite Formation, in a locally commercial free-stone facies (Corsham Down Stone), and the lower part of the Forest Marble Formation, characterized by its basal coralline facies (Figure 3.9). Woodward (1894) referred to the exposures, but the only published measured section is that of Green and Donovan (1969), whose account includes a diagram illustrating the most informative part of the section (Figure 3.10). This account assigned the Upper Rags Member, including the coralline limestones, to the Great Oolite Formation, but Penn and Wyatt (1979) regarded these beds as the basal part of the Forest Marble Formation, which oversteps the Great Oolite Formation to the north.

Description

The following description, including bed numbers, is based on Green and Donovan (1969).

	Thickness (m)
Forest Marble Formation	
8: Limestone, brown, grey-hearted, shelly and ooidal, thinly bedded, cross-bedded	up to *c.* 2.2
7: Clay, grey and brown, shelly with 'Bradford Clay' fauna (see below); base sharp and pocketing into beds below	up to 0.4
Upper Rags Member	
6: Oolite, cream, shell-fragmental, massive, planar-bedded; abundant shell-debris; upper surface commonly oyster-encrusted; thin marl parting at base	2.4

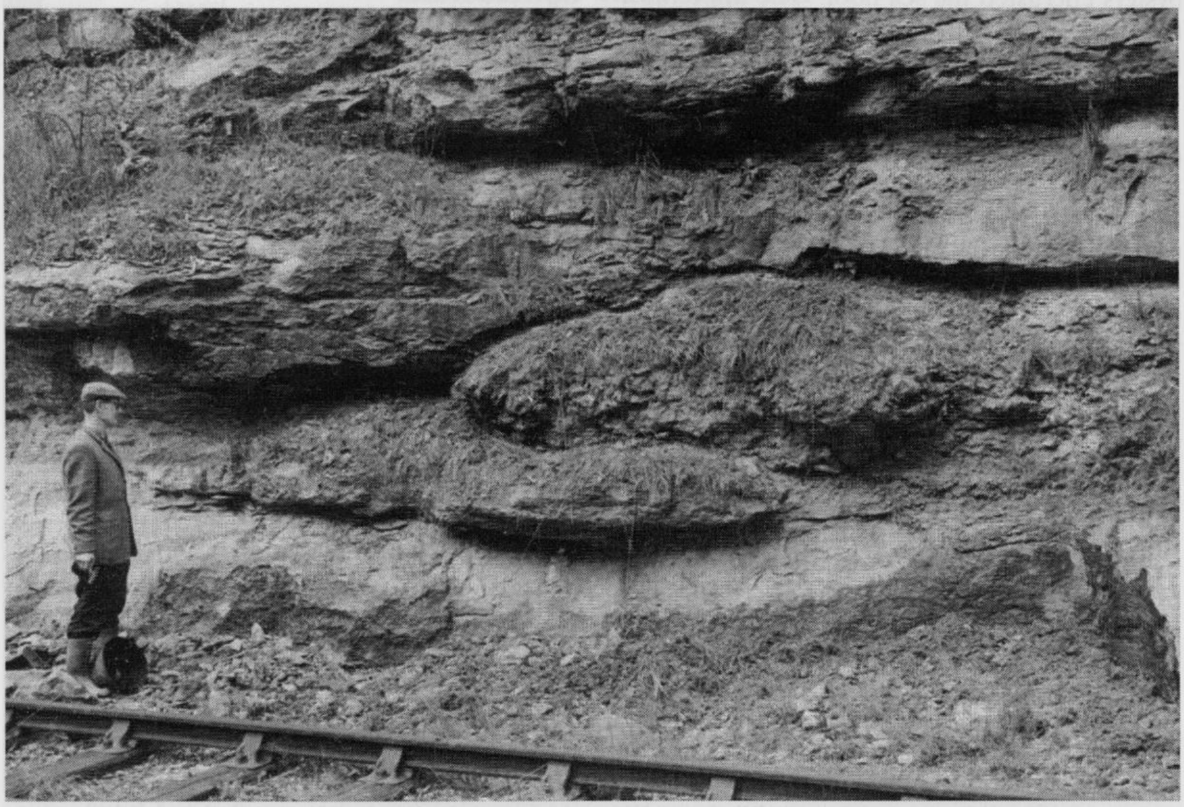


Figure 3.9 North side, Corsham Railway Cutting; current-bedded shell-fragmental limestones and shelly ooidal limestone rest on a rubbly bedded patch-reef immediately west of mile post 99. The hammer-head rests on top of the underlying oolite freestone (Bath Oolite Member). (Photo: British Geological Survey, No. A10913; reproduced with the permission of the Director, British Geological Survey, © NERC, 1967.)

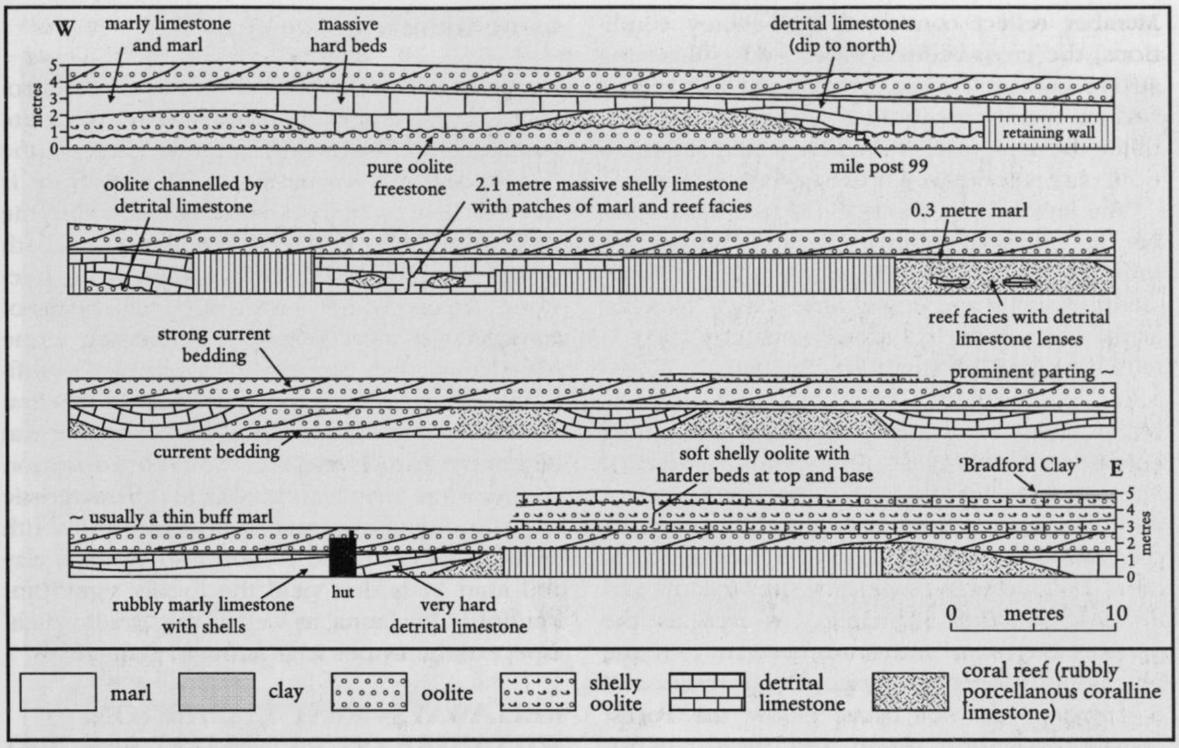


Figure 3.10 Diagrammatic section of the north side of Corsham Railway Cutting. (After Green and Donovan, 1969, fig. 6.)

	Thickness (m)
5: Oolite, cream, shell-fragmental, strongly cross-bedded	1.4
4: Marl, persistent, more-or-less planar; locally lapping on to coral reef-knolls of Bed 3	0.3
3: Limestone, massive and shell-fragmental, marly and shelly, and cross-bedded oolite; gently undulating clear-cut base; intermittent sections through mounds of rubbly, porcellaneous, white-weathering limestone (*Corsham Coral Bed*), up to 18.3 m long and 2.4 m high, with masses of commonly recrystallized compound corals (including *Cladophyllia*, *Cyathopora* and *Isastrea*), as well as bivalves, gastropods including *Bactroptyxis bacillus* (d'Orbigny) and brachiopods (including *Avonothyris*, *Dictyothyris coarctata* (Parkinson), *Epithyris oxonica* Arkell and *Eudesia cardium* (Lamarck)); tops of mounds truncated by sharp base of overlying beds	up to 2.6
Great Oolite Formation	
Bath Oolite Member	
1–2: Oolite freestone, cream, well sorted with little or no shell-debris; shelly lens locally developed at top with corals, gastropods, brachiopods including *Dictyothyris*, *Epithyris*, *Kallirhynchia* and *Rhactorhynchia*, and abundant bivalves; otherwise poorly fossiliferous with rare *Mytilus* (*Falcimytilus*) *sublaevis* J. de C. Sowerby; upper surface slightly bored	up to 1.2

Interpretation

The uniform, even grain-size of the Bath Oolite Member freestone reflects deposition in a high-energy, shallow-water, carbonate shelf-sea, in which strong currents constantly mobilized the substrate to produce good sorting of the constituent ooids. The unstable nature of this sediment probably made it unsuitable for most benthic organisms, which would account for the sparse macrofauna in the member. The bored upper surface of the member indicates lithification of the substrate during a depositional break, before renewed sedimentation occurred.

The shell-fragmental limestones and oolites of the succeeding Corsham Coral Bed also suggest a high-energy, shallow-water environment with a mobile substrate. Although the associated coral reef-knolls demanded active currents to convey micro-organisms to the coral polyps, they also required a stable sea-floor on which to flourish. Probably, the lithified top of the Bath Oolite Member allowed their establishment and growth before deposition of the accompanying sediment restricted further colonization. The overlying shell-fragmental oolites of the Upper Rags

Member reflect continued high-energy conditions, the cross-bedded lower beds suggesting strong currents. The oyster-encrusted upper surface, together with the sharp, pocketing base of the overlying part of the Forest Marble Formation, may represents a break in sedimentation.

The lowest beds above the Upper Rags Member at Corsham Railway Cutting indicate an influx of muddy sediment before renewed deposition of shelly and ooidal limestones. Notably, at the base, there is a fossiliferous clay (Bed 7) with the so-called 'Bradford Clay fauna'. Where fully developed, this fauna contains a characteristic association of brachiopods including common *Avonothyris*, *Digonella digona* (J. Sowerby), *D. digonoides* S.S. Buckman, *Epithyris bathonica* S.S. Buckman and *Rhactorhynchia obsoleta* (Davidson), and much less common *Dictyothyris coarctata* (Parkinson) and *Eudesia cardium* (Lamarck), as well as the bivalves *Oxytoma* and *Radulopecten*. Of the brachiopods, only *D. digona*, *D. coarctata* and *E. cardium* do not occur below the Forest Marble Formation (Penn and Wyatt, 1979). However, the Bradford Clay faunal assemblage is not confined to the stratigraphical level of its type locality at Bradford-on-Avon, but occurs in at least three well-defined clay beds, including the equivalent of the one (Bed 4) that rests on the Corsham Coral Bed in Corsham Railway Cutting. Elements of the fauna also occur disseminated throughout the Upper Rags Member.

The diagnostic elements of the Bradford Clay fauna are the only fossils of biostratigraphical significance in the cutting. No ammonites, which are rare in the Bath Oolite Member and the Forest Marble Formation, have been collected from the cutting to date the succession. However, Penn and Wyatt (1979) considered the lower part of the Bath Oolite Member to be laterally equivalent to the Twinhoe Member south of Bath, which has yielded Retrocostatum Zone ammonites; they inferred that the whole of the Bath Oolite Member might belong in this zone (then called the *aspidoides* Zone). *Clydoniceras hollandi* (S.S. Buckman) occurs in the Bradford Clay of the type locality, indicating that the Forest Marble Formation above the Upper Rags Member belongs to the Hollandi Subzone of the Discus Zone. Penn and Wyatt (1979) favoured inclusion of the Upper Rags Member in the latter zone, but Torrens (1980b) included them in the *orbis* (then *aspidoides*, now Retrocostatum) Zone.

Conclusions

Corsham Railway Cutting presents a fine exposure of the upper part of the Bath Oolite Member and the overlying basal beds of the Forest Marble Formation. The section is through Late Bathonian strata, falling within the Retrocostatum and Discus zones. The Bath Oolite Member is present in a uniform, freestone facies, which historically has been of considerable local value as a building stone (Corsham Down Stone). Of particular significance are the sections through intermittent coral reef-knolls developed within the Corsham Coral Bed at the base of the Forest Marble Formation (Upper Rags Member), in a facies characteristic of this stratigraphical level in Wiltshire and south Gloucestershire. The section also exhibits clay and marl beds that yield the locally significant Bradford Clay fauna, as well as the 'Bradfordian' aspect of the Upper Rags fauna in general.

KELLAWAYS–WEST TYTHERTON, WILTSHIRE (ST 947 757–ST 943 744)

K.N. Page and B.M. Cox

Introduction

The Kellaways–West Tytherton GCR site comprises small exposures in the banks of the River Avon, to the west and south of Kellaways (ST 947 757), Wiltshire (Figure 3.11). The main stratum exposed there is the 'Kelloway Rock' of Townsend (1813) or 'Kelloways Stone' of William Smith (1817), more recently known as the 'Kellaways Rock'. This is a relatively local calcareous sandstone facies of a unit that elsewhere in southern and central England is developed as softer, mainly uncemented sands and silts. Together these comprise the Kellaways Sand Member of which the GCR site is the type locality (Page, 1989). The underlying Kellaways Clay Member is also seen here; the Bristol Avon River Authority Tytherton No. 3 Borehole (Cave and Cox, 1975), sited at ST 9440 7445 on the eastern side of the river adjacent to the GCR site, is its proposed type section as well as that of the parent Kellaways Formation (Page, 1989). As well as these lithostratigraphical units, the locality gives its name (in latinized form) to the ammonite *Sigaloceras calloviense* (J. Sowerby) (Figure 3.12) which itself gives its name to the Calloviense Zone and Subzone, and to the Callovian

Figure 3.11 The Kellaways Sand Member exposed in the banks of the River Avon west of West Tytherton (Kellaways–West Tytherton GCR site). (Photo: B.M. Cox, 1970.)

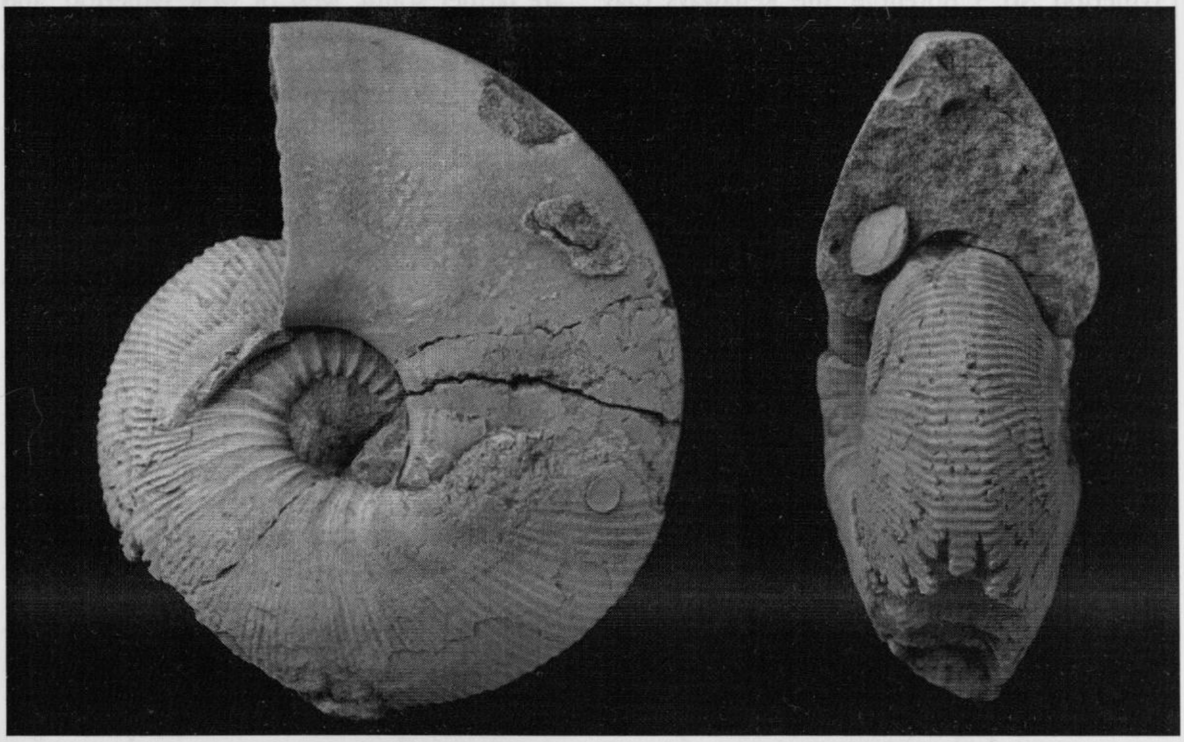


Figure 3.12 Lectotype of *Sigaloceras calloviense* (J. Sowerby); The Natural History Museum, London, specimen No. 43924a; *c.* 95% natural size. (Photo: © The Natural History Museum.)

Stage. The GCR site includes the type sections, as defined by their bases, of both these zonal units, and the site and its vicinity have yielded the type specimens of a number of fossil taxa. The overlying Oxford Clay Formation is exposed at the southern end of the site (Page, 1988).

Description

The geology of the site was first recorded by Townsend (1813) and later by Lonsdale (1832) and Woodward (1895). It was included in the [British] Geological Survey memoir of White (1925) and, subsequently, Cave and Cox (1975) provided the only complete record of the Kellaways Clay Member hereabouts based on cored boreholes. The succession is shown graphically in Figure 3.13.

As proved in the Tytherton No. 3 Borehole, the Kellaways Clay Member is a predominantly pale to medium greenish-grey, silty and, in part, sandy clay in which bivalves, including *Chlamys*, *Entolium*, *Grammatodon*, *Meleagrinella*, *Modiolus*, *Myophorella*, *Oxytoma*, *Pleuromya*, *Protocardia*, *Thracia* and small oysters, are common. The gastropod *Procerithium* is also present as well as the ammonites *Kepplerites*, *Macrocephalites* and *Proplanulites*. In the Tytherton No. 3 Borehole, the Kellaways Clay Member is 17.32 m thick; the basal 1.87 m correlate with the Cayton Clay Formation of the Cleveland Basin (see Chapter 5), and Page (1988, 1989) assigned them to that unit. White (1925) and Cave and Cox (1975) recorded ammonitiferous 'blue sandy clay with septaria' belonging to this member in a side stream at *c.* ST 945 748, and at least 2.25 m of bluish-grey sandy clay (= Bed 1 of Page, 1988) are exposed above water level in the west bank of the river near the footbridge at ST 944 749.

At the base of the overlying Kellaways Sand Member, a *c.* 0.15 m-thick shelly sand infills burrows in the top of the Kellaways Clay Member, and passes up into thinly bedded sandstone (Bed 2 of Page, 1988) with occasional harder, cemented shelly lenses. The fauna includes abundant *Gryphaea* (*Bilobissa*) *dilobotes* Duff (first appearing at this level) with *Microthyridina* cf. *ornithocephala* auctt. as well as *Oxytoma*, *Pleuromya* and the belemnite *Cylindroteuthis*. The bed is capped by a thin, flaggy calcareous sandstone (0.10–0.15 m thick) with occasional shelly lenses (= Bed 3a) but generally with fewer fossils than the bed below. The ammonite fauna of beds 2 and 3a comprises *Sigaloceras* (*S.*) *calloviense* (J. Sowerby) (including the lectotype; Figure 3.12), *Sigaloceras quinqueplicata* (S.S. Buckman) (including the holotype), *Cadoceras sublaeve* (J. Sowerby) trans. α of Callomon and Page (in Callomon *et al.*, 1989), *Proplanulites* ex gr. *petrosus* S.S. Buckman, *P. crassicosta* (S.S. Buckman) and *Parapatoceras calloviense* (Morris). The overlying *c.* 0.6–0.65 m of calcareous sandstone contains, in its lowest part, a *c.* 0.15 m-thick bed (Bed 3b) with common shelly lenses rich in well-preserved fossils that often weather out at the surface. The fauna is rich in bivalves (including *Isocyprina*, *Oxytoma*, *Trautscholdia* and small oysters) with gastropods (*Dicroloma* and *Procerithium*), rhynchonellid brachiopods, scaphopods and ammonites. The latter include *Sigaloceras* (*S.*) *micans* S.S. Buckman, *Cadoceras sublaeve* trans. β Callomon and Page (in Callomon *et al.*, 1989), and *Proplanulites* ex gr. *petrosus* S.S. Buckman and *P. crassicosta* (S.S. Buckman). Most of the early collections of fossils probably came from a few shallow excavations and the adjacent river bank exposures south of Mauds Causeway (e.g. Woodward, 1895); a small exposure still exists in the west bank of the river at *c.* ST 946 756. However, the best exposures are farther south, west of West Tytherton, and these and the adjoining fields are likely to have been the source of most of the known Kellaways Rock material collected from the late 19th century onwards (Page, 1988). In addition, excavations for a flood-control channel around ST 944 749–ST 938 744 are likely to have been a key source of museum material (J.H. Callomon, pers. comm., 1996).

Higher parts of the Kellaways Sand Member are poorly exposed. Loose blocks around ST 942 745, apparently dredged from the river, are presumably from a higher level than seen in the above exposures and comprise a grey sandstone with poorly preserved *S.* (*S.*) cf. *micans*, *P.* ex gr. *petrosus*, *Gryphaea dilobotes*, *Microthyridina* cf. *calloviensis* (d'Orbigny), rhynchonellids, *Oxytoma*, *Pleuromya*, *Trautscholdia* and other bivalves. A similar bed is seen *in situ* at the base of the river bank on a bend at ST 945 745; it is overlain by the Oxford Clay Formation, comprising 0.4 m of grey-weathered clay with fragments of indeterminate kosmoceratid ammonites, which is overlain by alluvium. An exposure in the base of a nearby ditch, around 2–3 m higher, showed about 0.3 m of

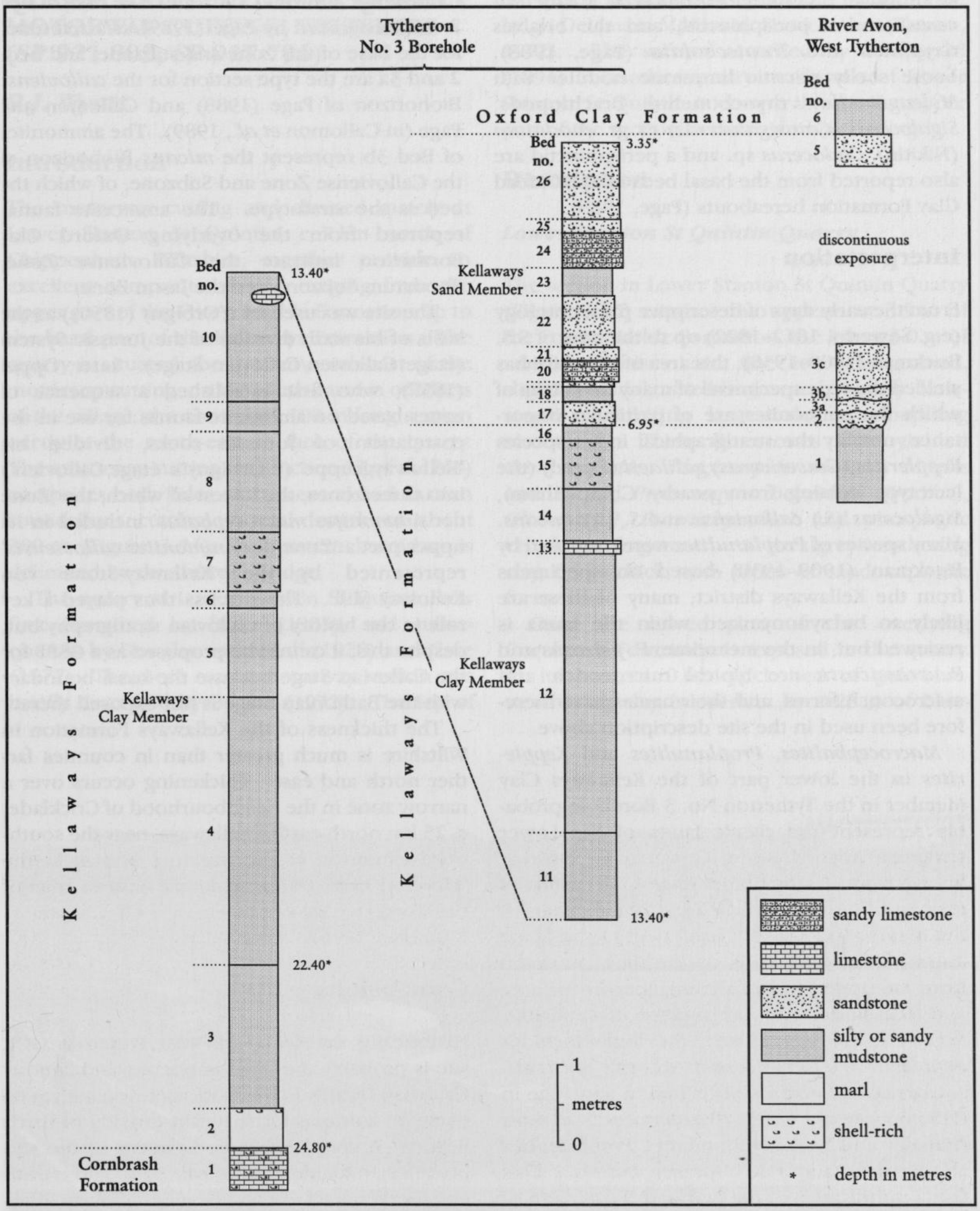


Figure 3.13 Graphic section showing the correlation between the cored Tytherton No. 3 Borehole and the exposures in the banks of the River Avon, west of West Tytherton (Kellaways–West Tytherton GCR site). (After Page, 1988.) Bed numbers follow Page (1988).

bluish-grey clay with crushed aragonitic ammonites including *Kosmoceras* (*Gulielmiceras*) and a perisphinctid, and the bivalves *Gryphaea* and *Trautscholdia* (Page, 1988). Loose shelly micritic limestone nodules with *Meleagrinella*, rhynchonellid brachiopods, *Sigaloceras* (*Catasigaloceras*) ex gr. *enodatum* (Nikitin), *Cadoceras* sp. and a perisphinctid are also reported from the basal beds of the Oxford Clay Formation hereabouts (Page, 1988).

Interpretation

From the early days of descriptive palaeontology (e.g. Sowerby, 1812–1822) up to the time of S.S. Buckman (1909–1930), this area of Wiltshire has yielded the type specimens of many fossil taxa of which the ammonites are of particular importance, notably the stratigraphical index species *Kepplerites* (*Gowericeras*) *galilaeii* (Oppel) (the lectotype coming from nearby Chippenham), *Sigaloceras* (*S.*) *calloviense* and *S.* (*S.*) *micans*. Many species of *Proplanulites* were proposed by Buckman (1909–1930) based on specimens from the Kellaways district; many of these are likely to be synonymized when the fauna is reviewed but, in the meantime, *P. petrosus* and *P. crassicosta* are typical microconch and macroconch forms, and their names have therefore been used in the site description above.

Macrocephalites, *Proplanulites* and *Kepplerites* in the lower part of the Kellaways Clay Member in the Tytherton No. 3 Borehole probably represent the classic fauna of the Lower Callovian Koenigi Zone, Gowerianus Subzone known from nearby Chippenham. The fauna of *Proplanulites* and *Kepplerites* in the top part of the member is probably equivalent to the fauna known from calcareous concretions excavated from the upper part of the member in the area and occasionally found on the river banks. According to Page (1988), the latter includes *Kepplerites* (*Gowericeras*) ex gr. *galilaeii*, *Cadoceras* sp. nov. D (of Callomon and Page in Callomon *et al.*, 1989), *Parapatoceras distans* (Baugier and Sauzé) (abundant), *Proplanulites* aff. *petrosus* and rare *Macrocephalites*. This fauna is indicative of the *galilaeii* Biohorizon of the Koenigi Zone, Galilaeii Subzone (see Figure 1.4, Chapter 1). The pale bluish-grey calcareous matrix and white shell preservation are unmistakable.

The ammonite fauna of the lower part of the Kellaways Sand Member (Bed 2 of Page, 1988) indicates the *calloviense* Biohorizon of the Calloviense Zone and Subzone. The base of Bed 2 was designated by Page (1989) as a reference for the base of this zone and subzone, and beds 2 and 3a are the type section for the *calloviense* Biohorizon of Page (1988) and Callomon and Page (in Callomon *et al.*, 1989). The ammonites of Bed 3b represent the *micans* Biohorizon of the Calloviense Zone and Subzone, of which the bed is the stratotype. The ammonite faunas reported from the overlying Oxford Clay Formation indicate the Calloviense Zone, Enodatum Subzone and the Jason Zone.

The site was used by d'Orbigny (1850a) as the basis of his sixth division of the Jurassic System (étage Callovien/Callovian Stage). Later, Oppel (1857), who first established a sequence of zones based on ammonite faunas for use in the correlation of Jurassic rocks, divided his 'Kellowaygruppe' (d'Orbigny's 'étage Callovien') into three zones, the lowest of which, the 'Zone der *Ammonites macrocephalus*' included in its upper part a 'Zone der *Ammonites calloviensis*' represented by the 'Kellaway-Stone von Kelloway Mill'. The site has thus played a key role in the history of Callovian stratigraphy but, despite this, it cannot be proposed as a GSSP for the Callovian Stage because the basal boundary with the Bathonian Stage is not exposed there.

The thickness of the Kellaways Formation in Wiltshire is much greater than in counties farther north and east. Thickening occurs over a narrow zone in the neighbourhood of Cricklade, *c.* 25 km north-east of Kellaways, near the southward extension of the structure known as the 'Moreton Axis', which marks the eastern edge of the Worcester Basin (see Figure 1.6d, Chapter 1) (Sumbler, 1996).

Conclusions

Historically, the Kellaways–West Tytherton GCR site is probably the most important and famous Callovian locality in the world because it gives its name, in latinized form, to this division of Earth history. A cored borehole adjacent to the site provides valuable additional data and stratigraphical control. Several Lower Callovian lithostratigraphical, biostratigraphical and chronostratigraphical units, as well as fossil taxa, have their type localities here; in particular, the ammonite faunas, on which stratal subdivisions used in correlation are based, are of international importance.

LOWER STANTON ST QUINTIN QUARRY AND STANTON ST QUINTIN MOTORWAY CUTTING, WILTSHIRE (SP 921 805, SP 917 796)

R.J. Wyatt

Introduction

The motorway cutting and disused quarry at Lower Stanton St Quintin, *c.* 7 km north of Chippenham, Wiltshire, together provide an excellent composite section ranging from the upper part of the Forest Marble Formation up to the basal part of the Kellaways Formation. The quarry is situated about 1 km north-east of the motorway cutting, on the south-eastern outskirts of the village; the conserved 100 m-long section occupies the south-eastern face of the quarry. The motorway cutting (at Junction 17 of the M4) comprises both sides of the central and eastern roundabout cutting, a total length of about 300 m (Figure 3.14); the western boundary is delimited by the western bridge.

The quarry at Lower Stanton St Quintin was first described by Blake (1905), and subsequently by Douglas and Arkell (1928) and Cave (1977). The more recent motorway section was briefly described by Barron (1972). The top of the Forest Marble Formation, which is seen in the quarry section, is also exposed locally in the Leigh Delamere Motorway Service Area (Barron, 1972). The section recorded by Woodward (1894) in another quarry north-west of Lower Stanton St Quintin is comparable to the upper part of the section in the motorway cutting.

Description

Lower Stanton St Quintin Quarry

The section in Lower Stanton St Quintin Quarry (Figure 3.15) exposes the uppermost 3.9 m of the Forest Marble Formation, the lower 3.0 m of which comprises hard, fine- to coarse-grained, slightly ooidal, shell-fragmental, sparry limestones, exhibiting large-scale cross-bedding structures. These limestones have yielded *Camptonectes*, *Placunopsis socialis* Morris and Lycett, *Praeexogyra hebridica* (Forbes), *Globularia*?, *Burmirhynchia*? and phosphatic vertebrate fragments. A dark-grey-weathering clay, 0.9 m thick, with layers of sand, caps the formation.

Only the lower part of the overlying Cornbrash Formation is exposed in the quarry. At its base, a 0.6 m-thick bed of pale-blue-weathering clay is overlain by 0.25 m of blue-

Figure 3.14 Exposure of Cornbrash on the south side of the M4 motorway cutting (part of the Lower Stanton St Quintin Quarry and Stanton St Quintin Motorway Cutting GCR site). (Photo: M.G. Sumbler.)

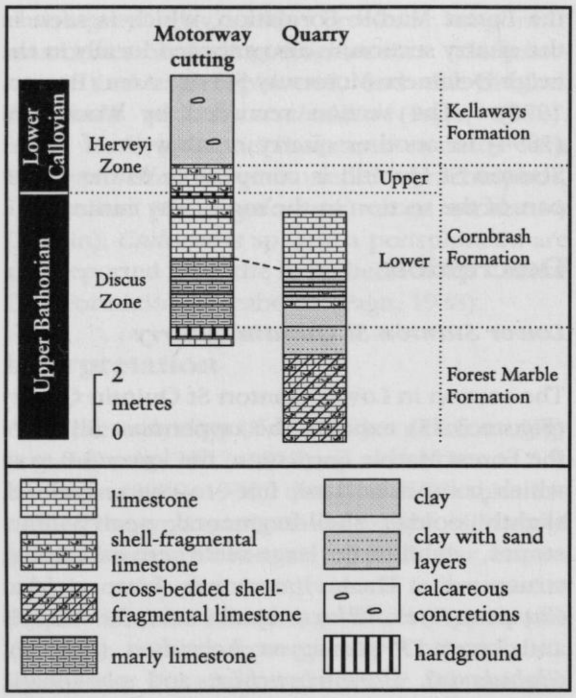


Figure 3.15 Graphic section of the Bathonian–Callovian succession from the two locations that comprise the Lower Stanton St Quintin Quarry and Stanton St Quintin Motorway Cutting GCR site.

weathering limestone with clay intercalations. Above this, there is 0.9 m of very fossiliferous, rubbly weathering, shell-fragmental, micritic limestone interbedded with clay. This limestone has yielded *Ornithella foxleyensis* Douglas and Arkell, a brachiopod known only from the Lower Cornbrash of this district, *O. obovata* (J. Sowerby), the bivalves '*Exogyra*', *Meleagrinella echinata* (Wm Smith), *Pleuromya*, *Protocardia*, *Pseudolimea* and *Rollierella minima* (J. Sowerby), the echinoids *Acrosalenia*, *Holectypus* and *Nucleolites*, and serpulids. However, there is now some doubt about the provenance of two specimens of *Clydoniceras discus* (J. Sowerby) housed in Devizes Museum (Geological Collection, Nos 1197, 1207), which Douglas and Arkell (1928) cited as coming from this unit (A. Tucker, pers. comm., 1996). A thin but prominent bed of harder, shell-fragmental, sparry limestone, 0.15–0.30 m thick, overhangs these more readily weathered beds and is, in turn, overlain by 1.6 m of strata comprising similar but softer limestone with *Pleuromya*?, *Clypeus*? and *Acrosalenia*, passing up into harder, well-cemented limestone containing common *M. echinata*.

Stanton St Quintin Motorway Cutting

At the base of the motorway cutting section (Figure 3.15), the uppermost 0.60 m of the Forest Marble Formation is seen to be a grey, silty limestone, its upper surface eroded and bored. Above it, there is a complete succession of the Cornbrash Formation, in which Lower and Upper Cornbrash can be recognized. The lowest 0.60 m of the Lower Cornbrash is a grey, argillaceous limestone with well-preserved fossils, including *O. obovata*. This is overlain by 1.50 m of argillaceous, shell-fragmental, micritic limestone, with some silty clay interbeds, which has yielded the bivalves '*Exogyra*', *Pseudolimea* and *Meleagrinella*, the echinoid *Acrosalenia*, and the brachiopod *Cererithyris*. As at Lower Stanton St Quintin Quarry, this unit is overlain by a prominent bed of hard, shell-fragmental, sparry limestone, which overhangs the less resistant beds below. This bed is the lowest of three, each 0.15–0.20 m thick, that contain *M. echinata*, *Modiolus*, oysters and terebelloid worm tubes. A thin, muddy parting above is succeeded by a 0.60 m-thick bed of similar limestone with *M. echinata* and sporadic inclusions of coarse shell-debris; then by a softer, slightly argillaceous limestone, 0.20 m thick, with *Anisocardia*?. The Lower Cornbrash is completed by a 0.75 m-thick bed of massive, well-cemented, fine- to medium-grained, shell-fragmental, sparry limestone, the top surface of which is a goethite-coated hardground, encrusted by large oysters (*Lopha marshii*? Arkell) which are in turn encrusted by small oysters ('*Exogyra*'); *M. echinata* is common in this limestone, and *Anisocardia*, *Modiolus* and *Obovothyris*? also occur.

The Upper Cornbrash is only 0.9 m thick and consists of silty limestone with abundant *Pleuromya*? in life-position. Other fossils include '*Exogyra*', *Lopha marshii*, *Rhynchonelloidea cerealis* S.S. Buckman and *Tetraserpula*. The motorway section is completed by the basal 3.0 m of the Kellaways Formation, which consist of dark-grey, silty clay, with sporadic calcareous concretions, becoming more sandy towards the base. *Macrocephalites* has been collected from this clay.

Interpretation

Only up to 3.6 m of the Forest Marble Formation are exposed in these sections, but they are sufficient to hint at the diversity of lithology associated with the formation. In this district, it is known that much of the upper part of the formation is composed of clay, commonly with lenticles or partings of calcareous siltstone or fine-grained sandstone. Additionally, there are sporadic, thick, lenticular inclusions of varied limestones, commonly cross-bedded, and sandstone. The clays imply prevailing low-energy conditions of deposition, but the limestones and sandstones, which represent periodic influxes of coarser sediment, suggest intermittent increased wave or current activity, perhaps associated with storms. This sediment was probably deposited in the form of isolated sand waves or banks. These characteristics imply a sedimentary environment comparable to modern intertidal or subtidal flat deposits. The eroded and bored upper surface of the formation in the motorway section indicates a distinct pause in sedimentation before deposition of the Cornbrash Formation; the borings imply concomitant lithification of the substrate.

The Lower Cornbrash is clearly divisible into two distinct units, the lower of which is characterized mainly by marly, shell-fragmental micritic limestone with clay interbeds. These lithologies imply relatively low-energy depositional conditions, although the commonly abraded nature of the shell debris, characteristic of the Cornbrash Formation, suggests repeated winnowing by gentle currents. The clay interbeds are witness to the periodic input of terrigenous mud into a carbonate shelf-sea, perhaps derived from the London Landmass. A further break in sedimentation at the top of the Lower Cornbrash is indicated by its goethite-coated and oyster-encrusted upper surface. The upper part of the Lower Cornbrash, comprising massive, coarser-grained, less argillaceous, sparry limestones, indicates higher-energy conditions, which inhibited deposition of fine-grained sediment. This facies is comparable to that a little farther south, nearer Chippenham, where it is known as the 'Corston Beds'.

The basal clays of the Kellaways Formation probably indicate deposition in relatively quiet, deeper waters in a shelf sea, the bottom of which was now beginning to subside gradually. The sandy content at the base is associated with the early stage of transgression that initiated this new regime.

Callovian ammonites have been collected from the upper part of the motorway section (Barron, 1972), and Bathonian ammonites are believed to have come from the Lower Cornbrash of the Lower Stanton St Quintin Quarry nearby (Douglas and Arkell, 1928). These are consistent with assignment of the Upper Cornbrash and basal Kellaways Formation to the Lower Callovian Herveyi Zone, and the Lower Cornbrash to the Discus Subzone of the Discus Zone. It is notable that the Bathonian–Callovian boundary coincides with the oyster-encrusted hardground that separates the Lower from the Upper Cornbrash. In contrast, there is no significant stratigraphical break between the Upper Cornbrash and the Kellaways Formation. No ammonites have been collected from the Forest Marble Formation in these sections; however, the formation is believed to belong to the Hollandi Subzone of the Discus Zone.

Conclusions

The exposures at Lower Stanton St Quintin Quarry and the Stanton St Quintin Motorway Cutting (Junction 17 of the M4) together provide an important reference section through the complete local Cornbrash Formation. They exhibit the abrupt contact with, and the nature of, the underlying Forest Marble Formation, as well as the boundary of the Cornbrash Formation with the overlying Kellaways Formation. They also show the characteristic development of the Cornbrash Formation in the south Cotswolds, including the presence of the local Corston Beds facies in the Lower Cornbrash and the distinct stratigraphical break that caps this unit. The exposed rocks at both sites are fossiliferous and yield a well preserved and widely characteristic Cornbrash Formation fauna, together with more localized species such as the brachiopod *Ornithella foxleyensis*. Ammonites collected from the sections have confirmed the Bathonian and Callovian ages of the Lower and Upper Cornbrash, respectively.

HAWKESBURY QUARRY, GLOUCESTERSHIRE (ST 771 873)

M.G. Sumbler

Introduction

The GCR site at Hawkesbury Quarry, *c.* 5 km south of Wotton-under-Edge, Gloucestershire, provides one of the few sections showing much of the attenuated Inferior Oolite Group of the south Cotswolds. A generalized sequence at Hawkesbury given by Richardson (1910) is probably largely based on this quarry. The location (ST 772 875) given by Mudge (1978a,b) for his graphic section of an exposure showing *c.* 12 m of Lower Inferior Oolite (Birdlip Limestone Formation) at 'Hawkesbury Knoll' cannot be correct and, in all probability, the section relates to the Hawkesbury Quarry described herein.

Description

The following section is based on the description by Cave (1977), with revised lithostratigraphical classification by the present author.

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
Oolite, yellow to cream, rubbly ('White Oolite')	1.83
Limestone, yellow-fawn, hard with scattered large yellow (limonitic?) ooids; rubbly in upper *c.* 0.30 m; *Rhactorhynchia subtetrahedra* (Davidson), *Arcomytilus*?, *Entolium corneolum* (Young and Bird)	2.13
Limestone, brown, hard, compact, in layers up to 0.2 m thick with rubbly marly partings; *Acanthothiris spinosa* (Linnaeus), *Stiphrothyris* sp., *Oxytoma inequivalve* (J. Sowerby)	0.76
Upper Trigonia Grit Member	
Limestone, grey to brown, shell-fragmental; *A. spinosa*, *Aulacothyris carinata*? (Lamarck), *Stiphrothyris tumida* (Davidson), *Cucullaea* sp., '*Lucina*' sp., *Parallelodon* cf. *hirsonensis* (d'Archiac), *Pholadomya* sp., *Pinna* sp., *Trigonia costata* Parkinson	1.37
Birdlip Limestone Formation	
Oolite, fawn, rather coarse-grained, shell-fragmental (including echinoid debris), in thick cross-bedded layers; top surface planed and oyster-encrusted; uppermost part hardened and brown	1.52
Limestone, brownish-yellow, hard, cross-bedded, sandy; and limestone, finely ooidal, sandy, crystalline	1.22
Oolite, yellow, massive; some shell detritus	4.27
Obscured	3.35
Leckhampton Member	
Limestone, yellowish-brown, finely sandy; shell detritus and large irregular brown pellets	0.91
Marl, brown, rubbly, with brown clay layers	0.15–0.20
Limestone, pale-yellow to brown, fine grained, sandy; small dark-brown ferruginous ooids	0.10
Limestone, brown, sandy with bivalve shell detritus; and limestone, soft-weathering, knobbly, containing ?limonitic ooids	0.76
Limestone, brown, hard, sandy, rather knobbly, crystalline; large, brown, ferruginous brown ooids	0.46

In 1996, all of the units described above were readily apparent, with the Leckhampton Member visible in a small section at the southern end of the quarry, and the remaining and greater part of the section visible in the main face (Figure 3.16). The Salperton Limestone Formation is well displayed at the eastern end of the quarry.

Interpretation

Hawkesbury Quarry lies towards the southern limit of the extent of the Birdlip Limestone Formation (Lower Inferior Oolite). While some 12.8 m are present at Hawkesbury Quarry, the formation is cut out entirely by the succeeding Salperton Limestone Formation (Upper Inferior Oolite) only a few kilometres to the south. As elsewhere in the south Cotswolds, the Aston Limestone Formation (Middle Inferior Oolite) is absent. This non-sequence is marked by a planar erosion surface encrusted by oysters and other epifauna.

Figure 3.16 Exposure at the western end of Hawkesbury Quarry showing the Upper Trigonia Grit Member overlying the Birdlip Limestone Formation. The boundary is marked by a black arrow. The quarry face is approximately 5 m high. (Photo: M.G. Sumbler.)

The lowest beds seen are rather sandy, ferruginous limestones belonging to the Leckhampton Member, formerly known as the 'Scissum Beds'. This forms the basal unit of the Birdlip Limestone Formation (and Inferior Oolite Group) throughout the Cotswolds, resting on the Lias Group. Some 2.4 m of Leckhampton Member were recorded by Cave (1977; see above); this must represent virtually the total thickness of the unit (see Richardson, 1910).

The succeeding beds of the Birdlip Limestone Formation comprise massively bedded, fine- to coarse-grained, ooidal grainstones, with signs of cross-bedding at some levels. Traditionally these beds have been assigned to the Lower Limestone that is now included in the Crickley Member (Barron *et al.*, 1997). However, the strata are of significantly different facies to the Lower Limestone of the Cheltenham type area (see **Leckhampton Hill** and **Crickley Hill** GCR site reports, this volume) and for this reason Mudge (1978a,b) introduced the term 'Frocester Hill Oolite' for the supposedly equivalent beds in the south Cotswolds, such as at Hawkesbury Quarry. Assuming that the lateral correlation of these strata is correct, the Frocester Hill Oolite may be regarded as a facies variant of the Crickley Member. Towards the top of the succession (?beneath the topmost bed of the Birdlip Limestone Formation in the section above), Mudge (1978a, fig. 3) noted another oyster-encrusted hardground. Largely on this basis, he assigned the succeeding beds to the Fiddler's Elbow Limestone, now included in the Cleeve Cloud Member (Barron *et al.*, 1997), i.e. the former Lower Freestone, although Cave (1977) was of the opinion that the latter unit was overstepped by the Salperton Limestone Formation some distance to the north of Hawkesbury Quarry.

The Upper Trigonia Grit Member, the basal part of the Salperton Limestone Formation, forms a massive post of extremely shelly limestone, and again is capped by a planed, oyster-encrusted hardground. Only the lower part of the succeeding Clypeus Grit Member is exposed; Richardson (1910) gave the full thickness (beds 2 and 3) as 6.0 m. In the south Cotswolds, Richardson (1910) recognized a tripartite sequence within the beds now included in this member, the lower two parts of which are claimed to be present at Hawkesbury Quarry. However, in the section as currently exposed, the distinction between them is rather indefinite. The lower part (the 'Clypeus Grit Beds' of Cave, 1977) includes rubbly peloidal packstones and grainstones not dissimilar to those that characterize the Clypeus Grit Member at its type locality (see **First Cutting West of Notgrove** GCR site report, this volume), but the basal bed is less typical, comprising a fairly massive, medium- to fine-grained slightly sandy, ooidal grainstone more akin to the 'Doulting Stone' better developed farther south in the Bath–Mendips district (see **Doulting Railway Cutting** GCR site report, this volume). The uppermost beds, assigned to the 'White Oolite', are slightly finer grained, and are more uniformly ooidal; this unit is again better developed farther south.

Conclusions

Hawkesbury Quarry shows one of the most southerly remaining sections of the Birdlip Limestone Formation (Lower Inferior Oolite) in the south Cotswolds. It shows a truncated succession overlain by the Salperton Limestone Formation (Upper Inferior Oolite); the Aston Limestone Formation (Middle Inferior Oolite) is absent owing to overstep. The character of the Salperton Limestone Formation, notably of the Clypeus Grit Member, is of a facies transitional between its typical development in the north Cotswolds, and the higher-energy grainstone facies developed farther south.

NIBLEY KNOLL, GLOUCESTERSHIRE (ST 745 957)

M.G. Sumbler

Introduction

The GCR site at Nibley Knoll, Gloucestershire, comprises sections in the sides of an incised lane leading from the village of North Nibley, together with disused quarries at the top of the hill. The fine sections of the Bridport (or Cotteswold) Sand Formation (Lias Group) seen in the lane cutting and adjoining slopes are of Early Jurassic (Toarcian) age and will not be described further here. Middle Jurassic rocks, comprising the Birdlip Limestone and Salperton Limestone formations of the Inferior Oolite Group, form the plateau-like hilltop, and are seen in section in the large abandoned quarry (ST 745 957) 200 m north-east of the Tynedale Monument. The sections there were first described by Buckman (1888, 1889a) and his records were summarized by Woodward (1894). Additional information was given by Richardson (1910), and the locality was also described briefly by Ager and Donovan (1973) and by Murray and Hancock (1977).

Description

The Cephalopod Bed, at the top of the Early Jurassic Lias Group, was formerly exposed in the lane about 50 m from the quarry entrance (Murray and Hancock, 1977) but neither it nor the succeeding Leckhampton Member of the Inferior Oolite Group are now well exposed. Signs of brown, sandy limestone belonging to the latter member can be found in the lane near the entrance to the quarry (ST 7444 9578). It is probably about 3 m in total thickness here (Buckman, 1888, beds 4 to 7). In the main quarry, there is excellent exposure of the higher part of the Inferior Oolite Group (Figures 3.17 and 3.18). The following measured section is based mainly on Richardson (1910).

Figure 3.17 Upper Trigonia Grit Member overlying Birdlip Limestone Formation at the quarry at Nibley Knoll. The hammer-head marks the bored hardground between the two. (Photo: M.G. Sumbler.)

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
1: Limestone, whitish-grey, with small, soft, pisoid-like spherules weathering out to give rock pitted appearance; rare fossils including *Pleuromya subelongata* (d'Orbigny), *Entolium demissum* (Phillips), *Ceratomya striata* (J. Sowerby), serpulids, '*Terebratula*' *globata* (of authors *non* J. de C. Sowerby)	1.83
2: '*Upper Coral Bed*': Limestone, rubbly, whitish, coated with lime; '*Terebratula*' *subsphaeroidalis* Upton, *Clypeus hugii* Agassiz, *Acrosalenia pustulata* Forbes, *Ctenostreon pectiniforme* (Schlotheim), *Limatula gibbosa* (J. de C. Sowerby), *Plagiostoma bellulum* (Morris and Lycett), *Entolium demissum* (Phillips), *Chlamys articulata* (of authors), *Isastrea* sp	0.10
Upper Trigonia Grit Member	
3: Ragstone, very shelly; typical shelly fauna dominated by large bivalves including trigoniids; *Ctenostreon*, *Oxytoma inequivalve* (J. Sowerby), and *Pleuromya* cf. *uniformis* (J. Sowerby); and the brachiopods *Acanthothiris spinosa* (Linnaeus) (very abundant 0.10 m above base), *Aulacothyris* sp., *Rhactorhynchia* cf. *brevis* S.S. Buckman, *R. subtetrahedra* (Davidson), *R.* cf. *turgidula* S.S. Buckman, *Stiphrothyris tumida* (Davidson), and *Zeilleria* cf. *waltoni* (Davidson); *Acanthothiris spinosa* (Linnaeus) (very abundant 0.10 m above base) recorded by Cave (1977)	0.41
Birdlip Limestone Formation	
Crickley Member	
4: Limestone, well-developed hardground at top with borings extending downwards for up to 0.3 m; oysters and other epifauna encrusting upper surface	3.96
5: Rubbly layer; belemnites	0–0.15
6: Limestone; *Propeamussium* (*P.*) *pumilum* (Lamarck)	3.05
7: Rubbly layer; belemnites	0.13
8: Limestone, more massive; common *P.* (*P.*) *pumilum*	seen to 2.43

The total thickness of the Crickley Member is about 10.7 m (Buckman, 1888, beds 2 and 3). In 1996, about 4.8 m were visible in the main quarry, and *c.* 2 m of similar beds at a somewhat lower level were seen in a small exposure immediately to the north-east of the main quarry entrance. The strata comprise massive to flaggy and cross-bedded, coarse- to very coarse-grained, rather poorly sorted, shell-fragmental, ooidal grainstones, with some indefinite lenses of more rubbly, very coarse-grained peloidal limestone with rounded intraclasts, like beds 5 and 7 of the section given above. In 1996, only about 0.6 m of the Clypeus Grit Member was exposed within the subsoil rubble at the top of the section.

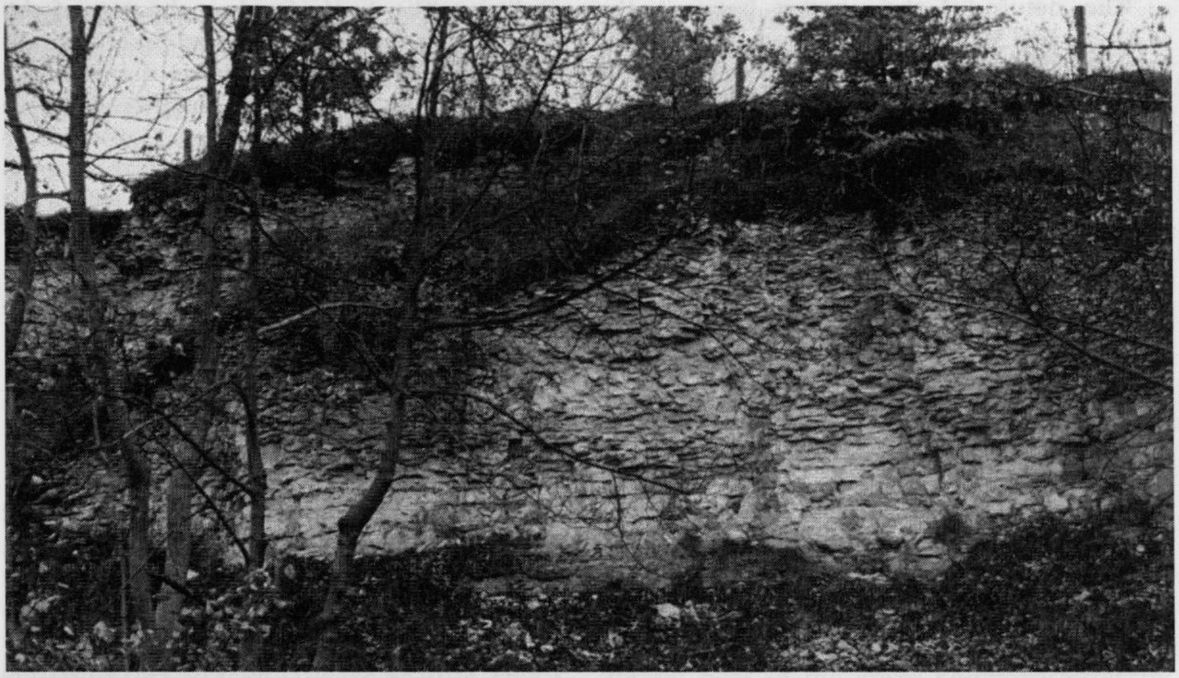


Figure 3.18 Exposure at the quarry at Nibley Knoll showing the Clypeus Grit and Upper Trigonia Grit members (*c.* 1 m) overlying the Birdlip Limestone Formation (*c.* 4.6 m). (Photo: M.G. Sumbler.)

A number of minor faults can be seen in the western side of the quarry, and Ager and Donovan (1973) also described a number of 'gulls' (widened joints or fissures) infilled with limestone rubble and travertine.

Interpretation

Beds 5 to 7 of the section recorded by Buckman (1888; see also Woodward, 1894) are *c.* 0.8 m of hard, 'iron-shot' limestones that constitute the Opaliniforme Bed of Aalenian age (Richardson, 1910). This bed is lithologically distinct from the underlying Toarcian part of the Cephalopod Bed (Buckman, 1888, beds 8–15) and, according to Richardson (1910), is separated from it by an erosional non-sequence. Consequently, it is now excluded from the Cephalopod Bed and Lias Group, and is regarded as the basal unit of the Inferior Oolite Group, being included in the Leckhampton Member (formerly Scissum Beds) of the Birdlip Limestone Formation (Barron *et al.*, 1997). From the median marly part (Bed 6), Buckman (1888) reported the ammonite *Leioceras opalinum* (Reinecke), the zonal index taxon of the lower Aalenian Opalinum Zone.

Richardson (1910) tentatively equated beds 5 to 7 of his own section (see above) with the 'Pea Grit' (see **Crickley Hill** GCR site report, this volume), and classified the remainder of the section accordingly, with Bed 8 assigned to the Lower Limestone and Bed 4 to the Lower Freestone. However, these rubbly lenses (cf. beds 5 and 7) occur at various levels within the succession, and there seems to be no firm basis for Richardson's subdivision; certainly, there seems to be no obvious non-sequence within the succession such as is thought to occur beneath the Lower Freestone (= Cleeve Cloud Member) elsewhere in the south Cotswolds (see **Hawkesbury Quarry** GCR site report, this volume). More probably, the whole of the succession should be assigned to the Frocester Hill Oolite within the Crickley Member – see Mudge's (1978a) classification of the section at nearby Wotton Hill (ST 754 938). Younger parts of the Birdlip Limestone Formation are absent owing to overstep by the Salperton Limestone Formation (Upper Inferior Oolite) and, as elsewhere in the south Cotswolds, the Aston Limestone Formation (Middle Inferior Oolite) is also absent at this locality. The non-sequence is indicated by the well-developed hardground at the top of the Birdlip Limestone Formation that marks the so-called 'Bajocian denudation' of Buckman (1901).

The nature of the contact between the Clypeus Grit Member and the underlying Upper Trigonia Grit Member, which is rather thin at this locality, could not be determined in the exposure seen in 1996 but, according to Richardson (1910) it was said to be a non-sequence. Partly for this reason, the so-called 'Upper Coral Bed' (Bed 2) recognized at various localities in the south Cotswolds (Richardson, 1910), is considered to be part of the Clypeus Grit Member. It contains sporadic corals such as *Isastrea*, but otherwise the fauna is not dissimilar to that of the Upper Trigonia Grit Member and perhaps on this basis was regarded as part of that unit by Cave (1977).

The superficial structures (minor faults and 'gulls') reported above are probably non-diastrophic features related to cambering, i.e. incipient landslipping around the margins of the hilltop plateau.

Conclusions

The GCR site at Nibley Knoll includes a section that spans the Toarcian–Aalenian stage boundary, and shows an attenuated section of the Birdlip Limestone Formation (Lower Inferior Oolite). The hardground at the top of this formation is well displayed and represents the important 'Bajocian denudation' that removed much of the younger Aalenian and Lower Bajocian succession in the south Cotswolds. A highly fossiliferous exposure of the Upper Trigonia Grit Member occurs at the top of the section.

VEIZEY'S QUARRY, GLOUCESTERSHIRE (ST 881 944)

R.J. Wyatt

Introduction

Veizey's Quarry is situated 1.6 km north-west of Tetbury, near the hamlet of Tetbury Upton, Gloucestershire. It provides a representative section through part of the Upper Bathonian succession, from the upper part of the Athelstan Oolite Formation up into the Forest Marble Formation. A measured section was recorded by Cave (1977) from a face that has been removed by renewed quarrying in recent years (Figure 3.19). However, the current section on the eastern side of the quarry is broadly similar,

Figure 3.19 Veizey's Quarry: thin-bedded limestones and clay of the Forest Marble Formation overlying shell-detrital oolites (Combe Down Oolite Member, Great Oolite Formation) and the Athelstan Oolite Formation at the base. (Photo: British Geological Survey, No. A10941; reproduced with the permission of the Director, British Geological Survey, © NERC, 1967.)

although lateral variation in lithology and bedding structure is known to occur.

Description

Up to 6.4 m of the Athelstan Oolite Formation are exposed at the base of the section, the lower 3.2 m of which consist of massive, thick-bedded, compact, ooidal, finely shell-detrital limestone with clay flakes or pebbles in part; the limestone beds are separated by thin clay partings. Bivalves (*Camptonectes annulatus* (J. de C. Sowerby)), brachiopods (*Avonothyris*), gastropods (*Fibula*, *Strophodus*), and wood and echinoid fragments have been recorded from these beds, which pass up into white, fine-grained, well-sorted, gently cross-bedded oolite in units up to 0.6 m thick, yielding a variety of epifaunal bivalves and several gastropods. Most fossil remains are fragmentary but the following taxa have been recorded (Cave 1977): *Astarte wiltoni* Morris and Lycett, *A.* (*Ancliffia*) *pumila* J. de C. Sowerby, *Barbatia*?, *Camptonectes* sp., '*Corbula*' *attenuata* Lycett, '*C*' *hulliana*? Morris, *Gervillella ovata* (J. de C. Sowerby), *Limopsis minima* (J. de C. Sowerby), *Placunopsis socialis* Morris, *Praeexogyra hebridica* (Forbes), *Pseudolimea* sp., *Tancredia angulata* Lycett, *T. extensa* Lycett, *Ceritella acuta* Morris and Lycett and *Procerithium* sp.. The top of the formation is capped by a brown, bored hardground bed. Boreholes drilled from the floor of the quarry have proved an additional 14.6 m of the Athelstan Oolite Formation below the exposed section.

Yellowish-fawn, shell-fragmental oolite, up to 3.5 m thick, overlies the Athelstan Oolite Formation. It is steeply planar cross-bedded in the lower part, below an ochreous, rubbly marl parting. There is a persistent, brown clay parting at the base. This oolite is assigned to the Combe Down Oolite Member of the Great Oolite Formation.

The succession is capped by the Forest Marble Formation, which consists mainly of brown, shelly, flaggy-weathering limestones, cross-bedded in part, with subordinate interbeds of grey clay containing thin partings of silty limestone. The basal limestone bed contains limestone pebbles and fish teeth, and there is a thin marl band at its base. The highest exposed bed in the quarry face is a 1.68 m-thick sandy limestone with clay pebbles, which weathers to a loose sand.

Interpretation

The cross-bedded oolites and ooidal limestones of the Athelstan Oolite Formation are interpreted as mobile barrier-bar shoal deposits, laid down in high-energy, shallow waters subject to vigorous currents at the outer margin of a carbonate shelf-sea. The gentle, bi-polar cross-bedding suggests a tidal influence. The good sorting of the upper oolites indicates a measure of current winnowing. The mudstone clasts in the lower ooidal limestones indicate erosion and transport of fragments eroded from nearby mudstone outcrops. The bored hardground at the top of the Athelstan Oolite Formation reflects a period of rapid lithification of sediment on the sea floor, associated with an interval of non-deposition and colonization of the substrate by boring organisms. The Great Oolite Formation was deposited under similar conditions; the planar, cross-bedded oolites with steeply inclined, foreset beds in the lower part were probably deposited in strong unidirectional currents.

The limestones of the Forest Marble Formation indicate a continuance of high-energy depositional conditions with strong current activity; an influx of sandy sediment is evident in the highest bed exposed. The clay interbeds reflect low-energy, probably deeper water, episodes during which terrigenous muddy sediment was fed into the carbonate shelf-sea.

No fossils of diagnostic biostratigraphical value have been found in Veizey's Quarry, but the Forest Marble Formation, and the Great Oolite and Athelstan Oolite formations are inferred to belong mainly to the Discus and Bremeri zones, respectively; most of the upper part of the Retrocostatum Zone is inferred to be absent below the Forest Marble Formation because of regional overstep by the latter (Wyatt, 1996a).

Conclusions

Veizey's Quarry is the best reference section, displaying the typical development, of the Athelstan Oolite Formation in the Tetbury district. The dominantly ooidal limestones of this and the Great Oolite Formation bear witness to the mobile oolite shoals of a barrier-bar at the margin of a carbonate shelf-sea. Various forms of cross-bedding structure are displayed, as well as a characteristic Bathonian bored hardground bed.

KEMBLE CUTTINGS, GLOUCESTERSHIRE (ST 975 976, ST 982 989, ST 985 973)

M.G. Sumbler

Introduction

The GCR site known as 'Kemble Cuttings' comprises three separate sections in railway and road cuttings near the village of Kemble, Gloucestershire. They include the type section of the so-called 'Kemble Beds' (Woodward, 1894), an ill-founded unit now absorbed into the Great Oolite and Forest Marble formations.

Description

Tetbury Branch Railway Cutting

The principal and best section of the Kemble GCR site lies within the cutting of the disused Kemble to Tetbury branch railway, about 1 km west of Kemble Station. The cutting is about 770 m in length (ST 9731 9741–ST 9791 9791) and up to *c.* 6 m deep (Figure 3.20). The beds are sub-horizontal so that essentially the same succession is present along the entire length of the cutting. The section was first described by Woodward (1894), on which the following description is based (with revised lithostratigraphical classification by the present author).

	Thickness (m)
Forest Marble Formation	
5: Pale false-bedded and fissile oolite with marly layers	1.82
4b: Brown and white marly clay, with occasional fissile beds of pale shelly oolite; abundant oysters	0.05–0.46
Great Oolite Formation	
'Kemble Beds'	
4a: Hard, irregular, marly limestone, weathering to a rubbly marl, impersistent; 'Fossil Bed' including *Epithyris oxonica* Arkell and *Plagiostoma cardiiformis* J. Sowerby	0.61–1.22
3c: Cross-bedded oolite, very shelly in places; including *Plagiostoma*; becoming more massive where capped by brown clay	1.68
3b: Irregular, impersistent, marly parting	?
3a: Cross-bedded oolite and thick beds of pale limestone including shell beds with *E. oxonica*, oysters and other fossils	2.43

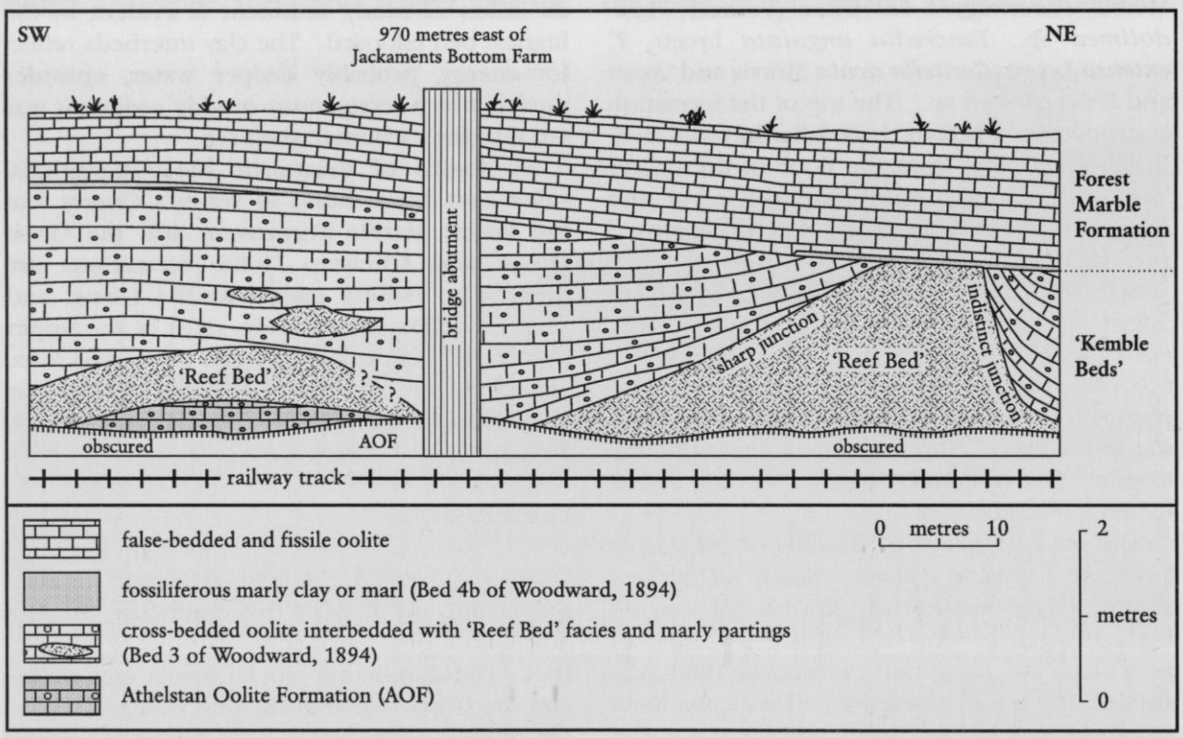


Figure 3.20 Diagrammatic section showing the lateral relationships in the 'Kemble Beds' (Great Oolite Formation) at Tetbury Branch Railway Cutting, Kemble Cuttings. (After Cave, 1977, fig. 18.) In other parts of the cutting (see description of Tetbury Branch Railway Cutting), the 'Reef Bed' facies is developed at the top of the 'Kemble Beds'.

	Thickness (m)
Athelstan Oolite Formation	
2b: White marly oolite with scattered ooidal grains; 'perforated' (?bored) in places	0.91
2a: Even beds of white oolite, and marly beds	2.13
1b: *Dagham stone*: Bluish limestone; top part compact and bottom part ooidal, with irregular 'perforations' (?burrows)	0.23–1.06
1a: White, more-or-less ooidal limestone, with 'tubiform markings' (?burrows)	0.30

At the time of writing, the cutting was overgrown in parts, althought there were good exposures along much of its length particularly on the north-west side, between the two overbridges (Figure 3.21). A composite section recorded (by the present author) in 1996 showed:

	Thickness (m)
Forest Marble Formation	
Limestone, grey to buff, flaggy and very fissile, low-angle cross-bedding; coarse- to very coarse-grained, shell-fragmental and ooidal grainstone	up to *c.* 3.0
Marl, fawn to brown, poorly laminated, rich in shell debris	0.05–0.30
Great Oolite Formation	
'Kemble Beds'	
'Reef Bed': Limestone, white to very pale-buff, rubbly to massive, very coarse-grained, shell-fragmental and peloidal packstone with abundant shells, mainly oysters (*Praeexogyra*), commonly in aggregates, with other bivalves, brachiopods and sporadic, small, recrystallized corals	0–*c.* 3.0
Limestone, pale-buff, massive to flaggy with marked cross-bedding in places, fine- to medium-grained, moderately well-sorted, uniform ooidal and shell-fragmental grainstone with pale ooids and coated shell fragments in a grey spar cement	up to *c.* 4.0

Tetbury Road Station Cuttings

The northernmost part of the GCR site lies near Thames Head, *c.* 1.5 km north of Kemble, and comprises some 550 m of railway cutting and adjoining quarry workings at the former Coates or Tetbury Road Station (ST 9804 9901–ST 9827 9852), together with *c.* 180 m of the cutting for the Foss Way road (A433), which

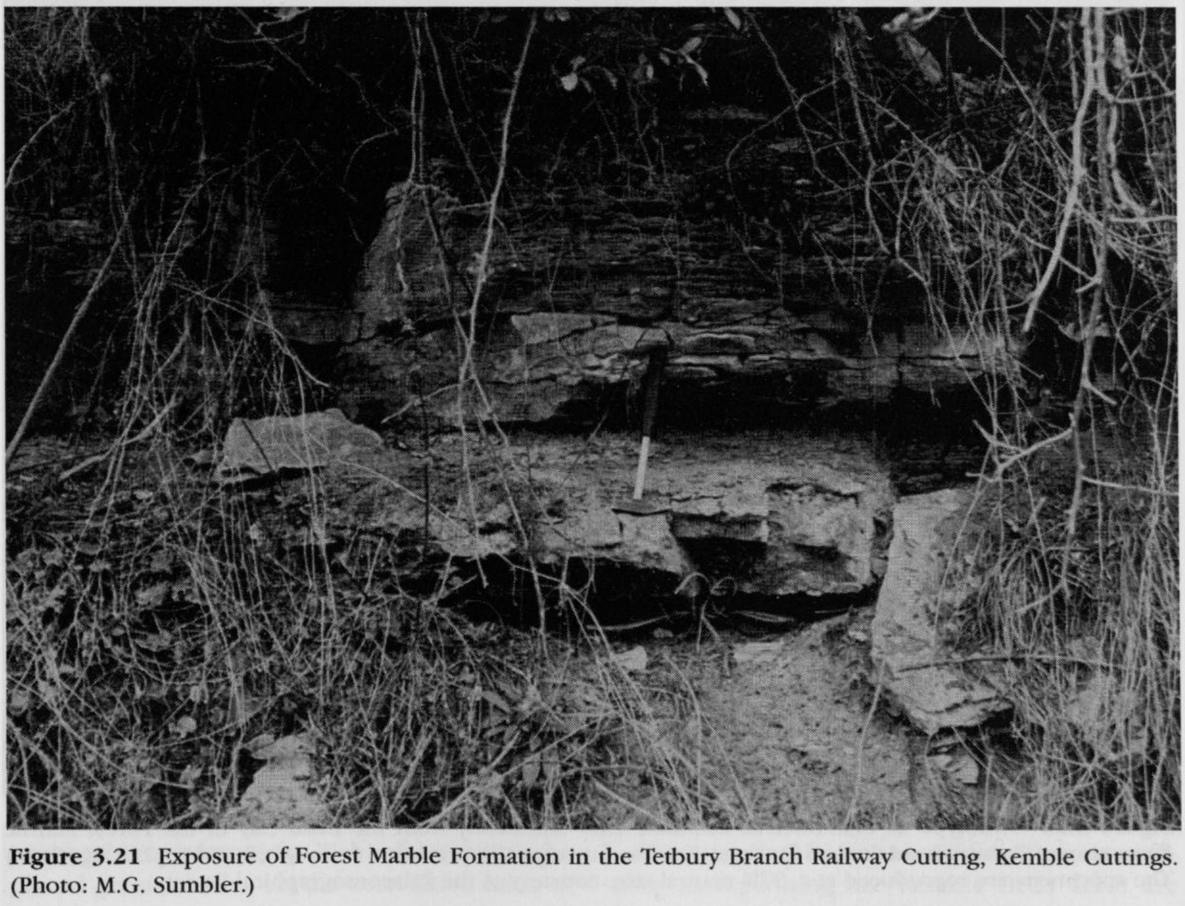


Figure 3.21 Exposure of Forest Marble Formation in the Tetbury Branch Railway Cutting, Kemble Cuttings. (Photo: M.G. Sumbler.)

passes beneath the railway. Woodward (1894) recorded a section in the road cutting, on which the following is based.

	Thickness (m)
Forest Marble Formation	
Rubble and tumbled masses of fissile, shelly oolite with lignite	?
Grey clay with thin rubbly beds of ooidal marly limestone; fossils fairly abundant ('Bradford Clay')	1.07
Great Oolite Formation	
'Kemble Beds'	
Pale shelly oolite	0.76
Brown marly oolite and hard, compact limestone with scattered ooidal grains	0.91
White and brown, false-bedded, shelly oolite	1.52

Present exposure is limited, but there are ample indications of flaggy Forest Marble Formation limestone in the railway cutting and a small exposure of ooidal limestone of the 'Kemble Beds' can be seen in the road cutting (ST 9816 9870). In 1966, a section showed white flaggy oolite of the Forest Marble Formation with 0.6 m of marl at the base, resting on a bored surface of 'Kemble Beds' limestone (P. Toghill, 1966, BGS Geological Sheet ST 99 NE).

At the base of the Forest Marble Formation here, J. Buckman (1858) recorded 2.13 m of fossiliferous clay that yielded, among other fauna, the type specimen of the ammonite *Clydoniceras hollandi* (S.S. Buckman) (Buckman, 1925; Arkell, 1933) (Figure 3.22).

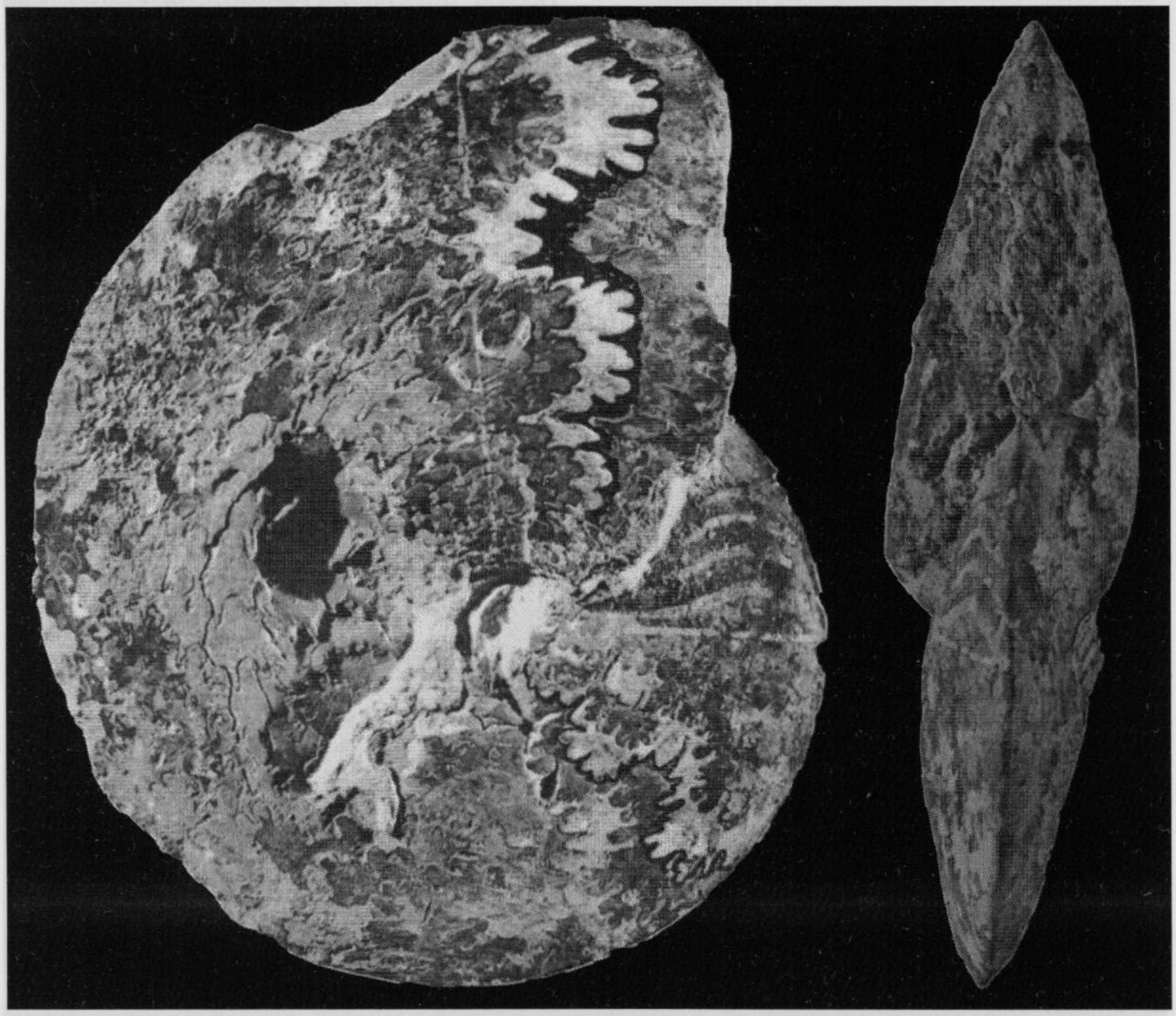


Figure 3.22 Holotype of *Clydoniceras hollandi* (S.S. Buckman) from the basal clay of the Forest Marble Formation of Tetbury Road Station Cuttings, Kemble Cuttings. (Reproduced from Arkell, 1951, pl. 1, figs 6a,b.) The specimens are reproduced at *c.* 97% natural size, courtesy of the Palaeontographical Society.

Kemble Station Cutting

The southernmost section comprises *c.* 260 m of cutting on the Gloucester to Swindon railway, between the road overbridge (ST 9854 9741) immediately south of Kemble Station, and the northern portal of Kemble Tunnel (ST 9858 9715). There, Woodward (1894) recorded *c.* 10 m of strata with *c.* 0.8 m of marl and clay near the base, yielding fossils such as '*Terebratula maxillata*' (= *Epithyris oxonica*) and '*Lima*' (=*Plagiostoma*) *cardiiformis*.

BGS mapping (Sheet ST 99 NE) by P. Toghill in 1966 indicated that the cutting is excavated mainly in beds of the Forest Marble Formation. The succeeding Cornbrash Formation occurs adjacent to a fault that crosses the cutting approximately midway between the bridge and the tunnel. In 1966, some 6 m of greyish-fawn, cross-bedded, fine- to coarse-grained, shell-fragmental oolite with marl seams belonging to the Forest Marble Formation were exposed just north of the tunnel; the underlying more massive oolite may represent the 'Kemble Beds'. The sides of the cutting are now overgrown with vegetation, and at the time of writing exposure (1996) was very poor.

Interpretation

Kemble Cuttings form the type locality for the 'Kemble Beds', a term introduced by Woodward (1894) for a 'considerable development of false-bedded oolites' that occurs in the upper part of the Great Oolite Group north-eastwards from the **Minchinhampton** area (see GCR site report, this volume). The top of the 'Kemble Beds' was defined by the base of the Forest Marble Formation, which, in the Tetbury Road Station Cuttings, was drawn at the base of the fossiliferous clay. This clay was thought to be a reliable, if impersistent, marker bed equating with the Bradford Clay. The latter was originally described from Bradford-on-Avon in Wiltshire (see Woodward, 1894; and **Gripwood Quarry** GCR site report, this volume), where it yielded a distinctive and well-preserved fauna including the crinoid *Apiocrinus* and brachiopods such as *Digonella digonoides* S.S. Buckman.

Arkell (1931) correctly equated the type 'Kemble Beds' with the upper part of the White Limestone Formation farther north-east but, like many other workers (e.g. Richardson, 1933), he placed great reliance on the correlative value of the 'Bradford Clay fauna'. Because he recognized this fauna within, and not at the base of, beds of typical Forest Marble Formation type in Oxfordshire, he concluded that 'Kemble Beds' of White Limestone Formation type passed laterally into Forest Marble Formation facies. For this reason, Arkell (1931, 1933) recommended the abandonment of the formational term 'Forest Marble', but later he used it to include the 'Kemble Beds' (Arkell, 1947b). The 'Kemble Beds' thus came to be regarded as the lower part of the Forest Marble Formation, and the term 'Wychwood Beds' (Arkell, 1931) was used for the upper part, above the supposed Bradford Clay. In fact, as is now recognized (Torrens, 1980b; Sumbler, 1984, 1991), the so-called 'Bradford Clay fauna' is essentially facies controlled and is of little value for correlation. For example, *D. digonoides*, a key element of the fauna, occurs at various horizons within the White Limestone and Forest Marble formations (see, for example, **Stony Furlong Cutting** GCR site report, this volume). Arkell's classification, based on invalid stratigraphical criteria, greatly confused attempts at correlation in the upper part of the Great Oolite Group, and the definition of the base of the Forest Marble Formation was a subject of debate for many years, as reviewed by Sumbler (1984). The varied and inconsistent usage of the term 'Kemble Beds' by different authors, variously encompassing a range of strata within the White Limestone and Forest Marble formations, has led to the term being abandoned. However, as originally conceived by Woodward (1894), it was a potentially valid unit, equating with the Signet Member (Cirencester district) or Bladon Member (Oxfordshire) at the top of the White Limestone Formation (Sumbler, 1984, 1991), or, to the south-west, the Upper Rags Member, the latter treated as part of the Forest Marble Formation by Cave (1977) and Wyatt (1996a) (as in the Bath type area; see **Brown's Folly** GCR site report, this volume; and Figure 3.4), but at Kemble, perhaps better considered as part of the Great Oolite Formation because the base of the Forest Marble Formation is now recognized as a regional erosive disconformity (Sumbler, 1984, 1991, 1999; Sumbler *et al.*, 2000) which locally cuts out the 'Kemble Beds' or their equivalents. It is readily traced once this important fact is recognized.

Woodward (1894) himself found great difficulty in separating his 'Kemble Beds' from the

Forest Marble Formation without the presence of a well-developed 'Bradford Clay' as in the Tetbury Road Station Cuttings. Thus, at Kemble Station and the Tetbury Branch Railway Cuttings, he included all of the beds now recognized as Forest Marble Formation in the 'Kemble Beds'. Conversely, Cave (1977) included much of the succession at these sites in the Forest Marble Formation, drawing the base of that unit at the bottom of the 'Reef Bed' facies (Figure 3.20), because of the occurrence of *D. digonoides* within it.

The exposures at Kemble Cuttings, most notably in the Tetbury Branch Railway Cutting may be interpreted with little difficulty in the light of knowledge of the succession in the Cirencester district (Sumbler *et al*., 2000). The base of the Forest Marble Formation is marked by a thin but fairly persistent marl (= Woodward's Bed 4b; see above), which broadly equates with the supposed 'Bradford Clay' of the Tetbury Road Station Cuttings. The limestones of the Forest Marble Formation and the 'Kemble Beds' are superficially rather similar, although the limestones of the latter are generally of a finer grain-size, and of a whiter, more chalky appearance. The top surface of the 'Kemble Beds' is hard and well cemented, and locally bored. Where the 'Reef Bed' facies is absent, the upper part is a grey to buff, pervasively burrowed, wackestone with abundant floating shell fragments and ooids, and is closely similar to the typical lithologies of the Signet Member, with which it equates (Sumbler, 1991). The 'Reef Bed' (Woodward's 'Fossil Bed', 4a) is lenticular and impersistent, passing laterally into, and apparently including bodies of, unfossiliferous limestone like that beneath. A sketch section illustrating these relationships is reproduced in Figure 3.20. In places, the contact between the 'Reef Bed' and surrounding limestones is sharp, and sporadically bored, but elsewhere it is gradational, and evidently the two types of limestone accumulated contemporaneously. The 'Reef Bed' yields large *Epithyris oxonica*, *Praeexogyra*, *Plagiostoma* and corals such as *Isastrea*, *Thamnasteria* and *Chomatoseris*, and in facies and fauna is much like the equivalent Fairford Coral Bed, which occurs at the top of the Signet Member 10–15 km to the north-east of Kemble (Sumbler, 1991). The contact with the limestones beneath the 'Reef Bed' is generally gradational in this cutting. Woodward's (1894) description of his Bed 2b (see above), the topmost unit of his 'White Limestone' (no longer exposed), is suggestive of the bored Bladonensis Bed, corresponding with the top of the Ardley Member of the White Limestone Formation or, as it has been termed in the Kemble area, the 'Athelstan Oolite Formation' (Cave, 1977; Wyatt, 1996a).

Conclusions

Kemble Cuttings form the type locality of the 'Kemble Beds'. This term has been compromised by misuse, and is widely misunderstood, and for this reason is now obsolete. The unit is now recognized as being equivalent to the better-defined Signet Member of the White Limestone Formation, which, in the Kemble Cuttings area, may be termed the 'Upper Rags Member', herein regarded as the sole local representative of the Great Oolite Formation at Kemble, but to the south-west as the basal member of the Forest Marble Formation. The Tetbury Branch Railway Cuttings shows a fine development of the 'Reef Bed', variously included in the 'Kemble Beds' or Forest Marble Formation, but now recognized as part of the Upper Rags Member, and equating with the Fairford Coral Bed to the north-east. At the Tetbury Road Station Cuttings, a clay at the base of the Forest Marble Formation, which has been equated with the Bradford Clay of Wiltshire, has yielded an ammonite indicating the Upper Bathonian Discus Zone, one of the few stratigraphically significant ammonites known from the formation.

WOODCHESTER PARK FARM, GLOUCESTERSHIRE (SO 810 009)

R.J. Wyatt

Introduction

The GCR site known as 'Woodchester Park Farm' is a quarry located about 6.5 km south-west of Stroud, just north-east of Nympsfield in Gloucestershire. It is sited adjacent to the buildings of the former Woodchester Park Farm, until recently known as 'Easter Park Farm' and now called Thistledown Farm. After progressive deterioration and gradual infilling over many years, recent excavation has revealed a 4.5 m-thick section (Figure 3.23), which may be extended in the future. The section, originally up to *c*. 6 m

Figure 3.23 Dodington Ash Rock Member overlying 'Minchinhampton Beds' in the quarry at Woodchester Park Farm. The boundary is marked by a black arrow. (Photo: M.G. Sumbler.)

thick, exposes part of the local Middle Bathonian succession, in which the Dodington Ash Rock Member of the Fuller's Earth Formation overlies the upper part of the 'Minchinhampton Beds' (Figure 3.24). The original section was first described by Witchell (1882a), and more recently by Channon (1950), Arkell and Donovan (1952) and Cave (1977).

Description

The basal 3.2 m of the original section comprised 2.5 m of buff, thinly bedded, finely shell-detrital oolite and ooidal limestone, with sporadic oysters; these beds pass gradually up into 0.7 m of hard, buff, white-weathering, porcellanous, micritic limestone with ferruginous grains. Small marl-filled pocks are present on the top surface. These rocks, of which the uppermost *c.* 1.5 m are currently (1997) exposed, are now assigned to the 'Minchinhampton Beds' (Wyatt, 1996a). They are overlain by the Dodington Ash Rock Member of the Fuller's Earth Formation. This has a persistent marl parting at the base, succeeded by massive- to well-bedded and, in part, cross-laminated, ooidal packstones and grainstones. These are *c.* 1 m thick in the present section but previous authors have recorded up to 1.4 m. Their top surface is smooth and pitted, and is succeeded sharply by 0.9 m of buff and brown, very hard, semi-porcellanous, incipiently nodular, shelly, fine-grained limestone with a varied fauna including bivalves (*Isognomon*, *Neocrassina*, *Plagiostoma*, *Ceratomya*), brachiopods, echinoids (*Clypeus*), gastropods (*Bactroptyxis*) and the ammonite *Morrisiceras*. This unit passes gradually up into buff to cream, hard, rubbly, sparsely ooidal, semi-porcellanous, thinly bedded limestone that makes up the topmost *c.* 1 m of the section.

Interpretation

The sediments preserved at Woodchester Park Farm were deposited in the zone of transition between a barrier-bar, shoal-facies belt at the margin of a shallow carbonate shelf-sea to the east, and deeper water, foreslope facies to the west. The former facies is represented by the high-energy, shell-fragmental oolites of the 'Minchinhampton Beds' of, for example, the common at **Minchinhampton** (see GCR site report, this volume); the latter facies by the relatively quiet-water, fine-grained, detrital and micritic limestones of the Dodington Ash Rock

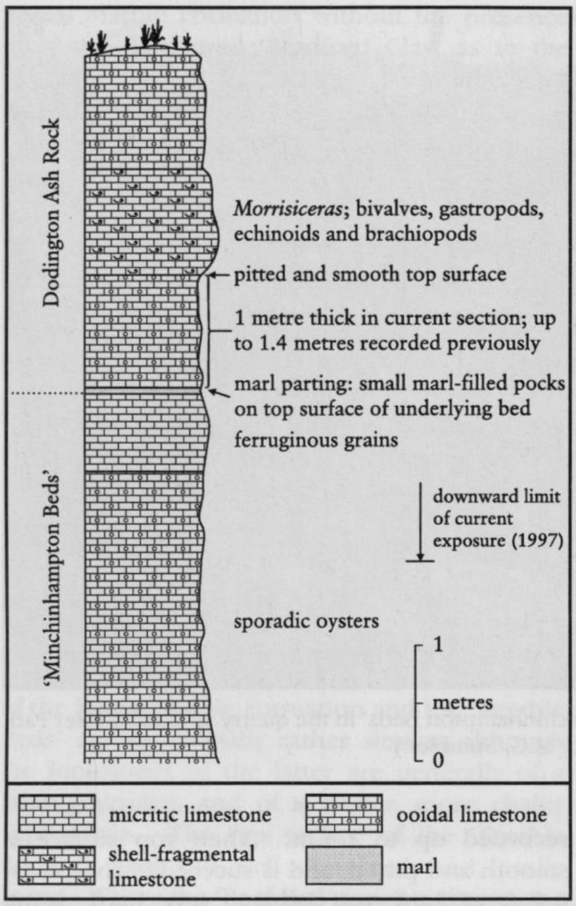


Figure 3.24 Graphic section of the Bathonian succession at Woodchester Park Farm.

Member south-west of Nympsfield. Both facies are represented at Woodchester Park Farm. The facies transition is completed as the oolites pass laterally into the lower part of the Dodington Ash Rock Member to the south-west of the quarry. Formerly, the whole section was assigned to the Cross Hands Rock (e.g. Cave, 1977), but recent work (Wyatt, 1996a) has shown that this term was used erroneously for, at its type locality near Chipping Sodbury, that unit is now known to lie near the top of the Lower Fuller's Earth Member. Cave (1977) believed that the highest bed exposed in the section was the topmost bed of the Dodington Ash Rock Member (his 'Cross Hands Rock') hereabouts.

At two levels in the succession, there are beds capped by porcellanous limestone and/or by a planar, pitted surface, which suggest slight pauses in sedimentation following their deposition. Such stratigraphical discontinuities are regionally developed throughout the Bathonian succession and have been used as a basis for wide-ranging correlation; they define the boundaries between rhythmic, depositional units (Wyatt, 1996a). The Dodington Ash Rock Member, as developed in the south Cotswolds, has been shown to comprise up to four discrete units separated by bored hardgrounds, pebbly beds and burrowed horizons, in a condensed sequence that is locally as little as 1.5 m thick. The three units exposed in the expanded succession at Woodchester Farm Park, which embraces the 'Minchinhampton Beds' facies, may well correlate with the topmost three of these.

Seven specimens of the ammonite *Morrisiceras* have been recorded here, more than at any other locality in corresponding beds north of Bath; they include *M. comma* S.S. Buckman and *M. morrisi* (Oppel), which are diagnostic of the Morrisi Zone. Species of *Morrisiceras* have also been recorded from the upper part of the Dodington Ash Rock Member in the M4 motorway cutting at Tormarton (Torrens, 1968b) and at nearby Dyrham Park (Curtis, 1978), some 12 km north of Bath. Species of *Tulites*, indicating the underlying Subcontractus Zone, have been collected at both these localities from the lower part of the Dodington Ash Rock Member (although not *in situ*). *Tulites* has not been found at Woodchester Park Farm, but the lower beds of the section could conceivably fall within the Subcontractus Zone. Ammonites of both the Subcontractus and Morrisi zones occur in the corresponding succession at **Minchinhampton** (see GCR site report, this volume), about 5 km to the east.

Conclusions

The quarry at Woodchester Park Farm is particularly important because of its Middle Bathonian Morrisi Zone ammonite fauna, which is otherwise rare in the Cotswolds. It is therefore of special biostratigraphical value for regional correlation of the Bathonian succession. The section, which is one of the few satisfactory exposures of the Dodington Ash Rock Member, is also of special interest for demonstrating the eastward transition from the fine-grained foreslope limestones of the south Cotswolds to the coarser, barrier-bar, ooidal limestones at **Minchinhampton** (see GCR site report, this volume). The presence of discrete, rhythmic, depositional units, separated by depositional breaks, can be inferred in the section.

MINCHINHAMPTON, GLOUCESTERSHIRE (SO 856 017)

R.J. Wyatt and M.G. Sumbler

Introduction

The common at Minchinhampton, near Stroud, Gloucerstershire, is a steep-sided plateau area of high open grassland, owned by the National Trust. Bathonian limestones were once extensively quarried here for building materials, and during the 19th century numerous quarries became celebrated fossil-collecting sites. In particular, the locality features prominently in the monographs of Morris and Lycett (1851–1855) and Lycett (1863) who described many new species of bivalves and gastropods from the Great Oolite Group hereabouts; this work was subsequently revised by Cox and Arkell (1948–1950).

Since the late 19th century, almost all of the limestone quarries on the common at Minchinhampton have been abandoned and infilled. Now, much of the area, with its hummocks and hollows, is used as a golf course. The GCR site at Gate Quarry (Figure 3.25) was never infilled, but lacked any exposure until excavations in 1984 produced two new faces, on the north-eastern and south-western sides of the quarry. It is believed to be the quarry described by Lycett (1848, 1857) and Morris and Lycett (1851–1855); it was also later referred to by Witchell (1882a) and Woodward (1894). In modern times, the section was cited by Arkell and Donovan (1952), when the quarry was still being worked. More recently, Wyatt (1996a) has re-assessed the stratigraphical relationships of the Bathonian succession, as originally exposed in the quarry.

Description

The south-west face exposes *c.* 1.8 m of massively bedded, fine- to medium-grained, ooidal and peloidal packstones with some more marly, shelly and rubbly beds, overlain by *c.* 2.5 m of medium-grained, white to pale-buff, well-sorted, ooidal and shell-fragmental grainstone in one large co-set. Brachiopods, crustacean remains and small oysters were noted by R. Cottle in 1992 (unpublished English Nature records).

The north-east face exposes *c.* 2 m of coarse-grained, shelly, shell-fragmental and ooidal grainstone with large-scale cross-bedding, overlain by *c.* 2 m of less massive, flaggy, medium-grained, white to pale-buff, cross-bedded, ooidal grainstone with some very shelly layers on foresets including, in particular, small bivalves and shell debris.

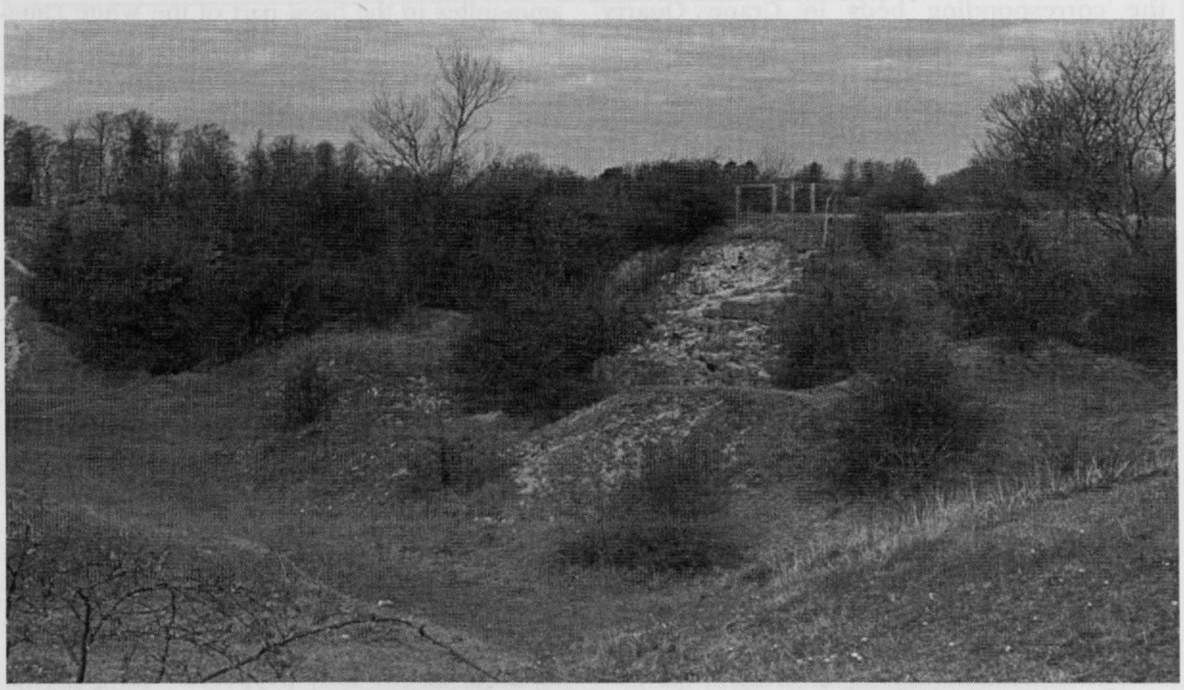


Figure 3.25 General view of Gate Quarry, Minchinhampton, looking north. (Photo: M.G. Sumbler.)

Interpretation

The stratigraphical position of the exposed limestones is not self-evident from the lithologies, which represent recurring facies of the Great Oolite Group. The large number of small bivalves is, likewise, not diagnostic, but could suggest that the shelly strata are the beds known by the old quarrymen as the 'Planking', from which some believe most of Morris and Lycett's (1851–1855; Lycett, 1863) molluscan fauna came. However, the most reliable means of identifying the stratigraphical position is by comparison with the section recorded by Woodward (1894) in the former Crane Quarry, about 150 m to the south-east of the present site, which was infilled and levelled by 1955. The top part of the section there, quoted by Channon (1950), exposed the lower part of what is now known as the 'Athelstan Oolite Formation', comprising 'The Scroff' (0.45–0.58 m thick), overlain by 2.5 m of cross-bedded 'Planking', 0.30 m of hard, smooth limestone and 1.8 m of 'Dry Wall-Stone' and rubble. In previous descriptions of the succession here (e.g. Arkell and Donovan, 1952), the 'Planking' was described as massive, brownish, shell-fragmental, ooidal, cross-bedded limestone with the gastropod *Purpuroidea* at its base. The shelly limestones of the 'Planking' in nearby Simmond's Quarry (SO 862 015) (Channon, 1950) intimated that the corresponding beds in Crane Quarry probably contained an abundance of bivalves and gastropods. The limestones in Gate Quarry are manifestly more-or-less equivalent to the 'Planking' of the former Crane Quarry and are therefore inferred to be that unit although higher beds of the Athelstan Oolite Formation (undifferentiated) may also be present above.

The coarsely shell-fragmental, ooidal, cross-bedded limestones of the Athelstan Oolite Formation were deposited as mobile, carbonate sand-shoals that formed part of a barrier-bar complex at the margin of an extensive shallow lagoon to the east. Deposition occurred in high-energy, shallow-water conditions characterized by strong currents. However, the presence of numerous gastropods and bivalves, and sporadic brachiopods, corals and crustaceans in the 'Planking', suggests a measure of substrate stabilization at times, associated with a reduction in both sedimentation rate and turbulence.

Although Arkell and Donovan (1952) suggested that the biostratigraphically significant ammonites collected by Morris and Lycett (1851–1855; Lycett, 1863) came from the 'Planking', others (Cave, 1977; Torrens, 1980b; Wyatt, 1996a) claimed that this was unlikely and that they came from a lower stratigraphical level (the 'Minchinhampton Shelly Beds and Weatherstones', otherwise known as the 'Minchinhampton Beds'), not exposed in Gate Quarry. Consequently, these latter authors assigned the Minchinhampton Beds to the Middle Bathonian Subcontractus and Morrisi zones because Morris and Lycett's ammonite fauna included the type specimens of the index species of these zones. However, according to Sumbler (1999), the lectotype of *Tulites subcontractus* (Morris and Lycett) (BGS specimen No. GSM25610) is preserved in white, coarse-grained, shelly ooidal grainstone that can be matched lithologically with the Minchinhampton Beds, whilst the holotype of *Morrisiceras morrisi* (Oppel) (BGS specimen No. GSM25617) is preserved in a brownish micro-oolite that closely matches the succeeding Dodington Ash Rock Memer of Wyatt (1996a). Thus, it seems likely that the Minchinhampton Beds belong, at least in part, to the Subcontractus Zone, but there is no reason to suppose that they extend up into the Morrisi Zone. Farther east, the Subcontractus Zone is indicated by ammonites in the basal part of the White Limestone Formation (Shipton Member).

The diverse gastropod fauna of the 'Planking' is unique within the British Bathonian Stage (Barker, 1976), although it has little biostratigraphical significance. It includes the thick-shelled *Purpuroidea* (Figure 3.26), which, at Minchinhampton, is found only in and above the 'Planking'. According to Barker (1976), this genus is known in Bathonian strata at only one other place, near Burford, in the strongly current-bedded shelly oolites (White Limestone Formation, Ardley Member) above the Excavata Bed.

Conclusions

The common at Minchinhampton is an important Bathonian locality, where complex vertical and lateral facies changes have long hindered interpretation of the local stratigraphy. Although at one time peppered with quarries,

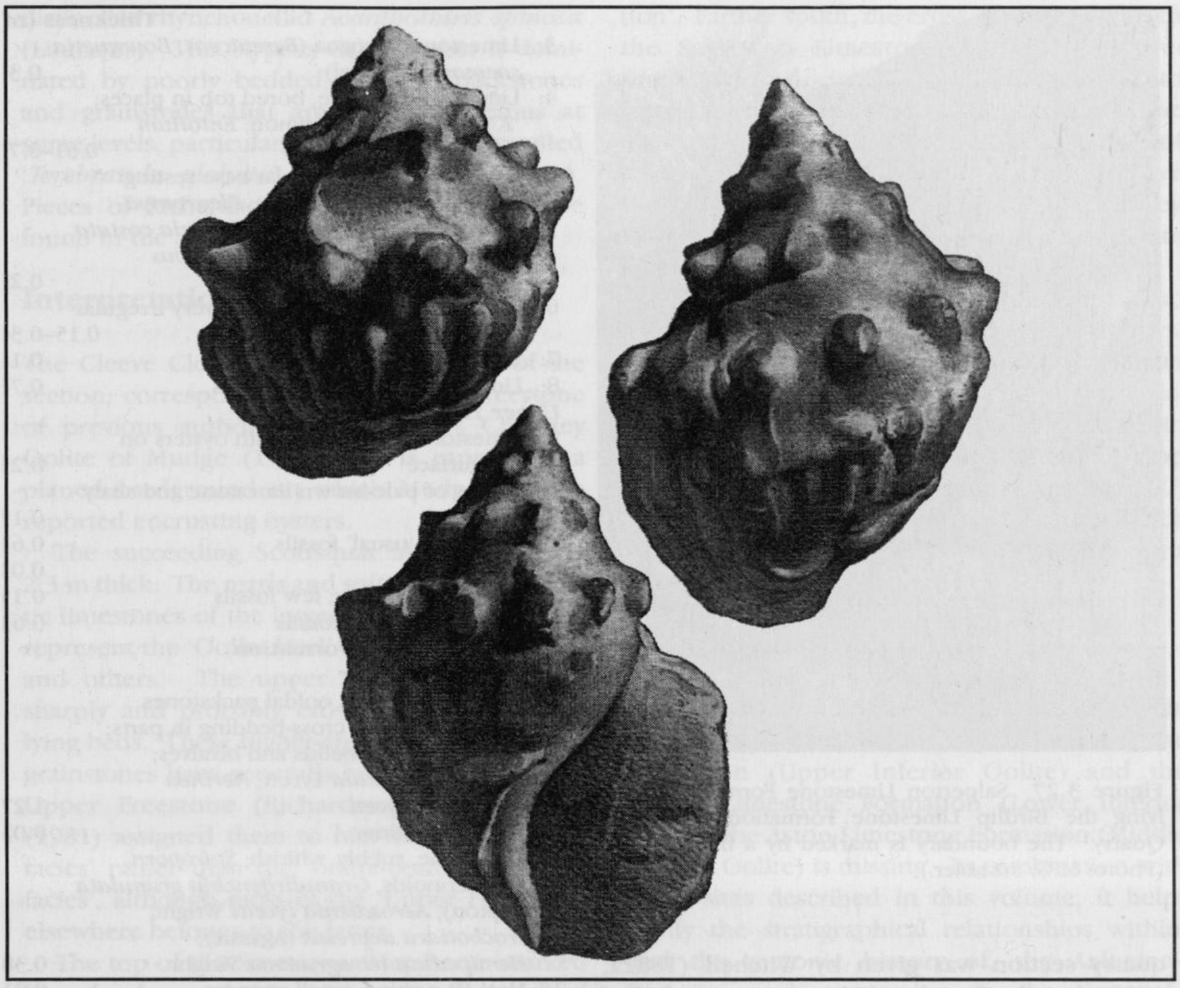


Figure 3.26 *Purpuroidea lycettea* Hudleston and Wilson. (Reproduced from Morris and Lycett, 1851, pl. 5, figs 1–2.) Approximately natural size.

no major sections remain and the GCR site at Gate Quarry exposes only a small part of the Bathonian succession once more visible hereabouts. It is, nonetheless, representative of the extensively worked limestones of the Great Oolite Group, Athelstan Oolite Formation, at Minchinhampton, and features the 'Planking', which is the source of a diverse Bathonian bivalve and gastopod fauna. Although the stratigraphical relationships within the Minchinhampton succession and its correlation with adjacent districts have recently been clarified (Wyatt, 1996a; Sumbler, 1999), local problems of correlation still exist and exposures, such as those at Gate Quarry, are important in elucidating the stratigraphy.

LEIGH'S QUARRY, GLOUCESTERSHIRE (SO 826 026)

M.G. Sumbler

Introduction

Leigh's Quarry, sited about 3 km south-west of Stroud in Gloucestershire, lies at the southern end of the extensive Selsley Common SSSI. There were several quarries on Selsley Common (or Selsley Hill) as mentioned by Lycett (1857) (see Richardson, 1910, fig. 4) but, of these, Leigh's Quarry features most frequently in the literature, and still provides an excellent section through the upper part of the Inferior Oolite Group (Figure 3.27). A brief description of the

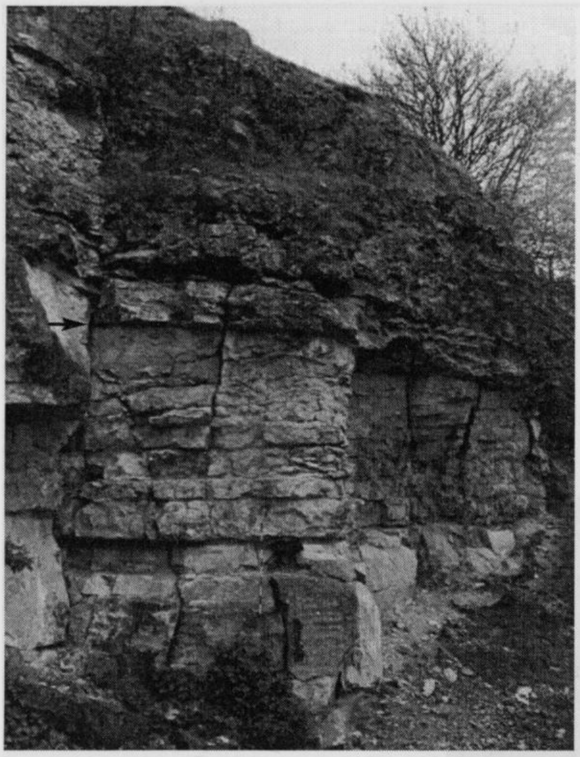


Figure 3.27 Salperton Limestone Formation overlying the Birdlip Limestone Formation at Leigh's Quarry. The boundary is marked by a black arrow. (Photo: M.G. Sumbler.)

quarry section was given by Witchell (1882a, 1890), but the first detailed account was that of Richardson (1910). This formed the basis for various subsequent guides and accounts of field excursions (e.g. Ager, 1956, 1969; Ager and Donovan, 1973; Murray and Hancock, 1977).

Description

The following section is based mainly on Richardson (1910) with revised lithostratigraphical classification by the present author.

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
1: Debris of white ooidal limestone	0.30
2: Limestone, somewhat flaggy, broken up and mixed with some marl; fossils including *'Terebratula globata'* of authors (*non* J. de C. Sowerby), *'T.' globata* var. *birdlipensis* Walker, *'T' permaxillata* S.S. Buckman, *Rhactorhynchia hampenensis* S.S. Buckman, *Amberleya hudlestoni* Richardson, *Ceratomya striata* (J. Sowerby), *Limatula gibbosa* (J. Sowerby), *Holectypus depressus* (Leske)	1.52
3: Limestone; bryozoa (*Berenicea*), *Bourguetia saemanni* (Oppel)	0.38
4: Limestone, massive, bored top in places; *'T.' globata* very common; *Entolium demissum* (Phillips)	0.61–0.76
5: Limestone, with irregular base resting upon lumps of limestone; *Pleuromya subelongata* (d'Orbigny), *Trigonia costata* (Parkinson) (common), *Holectypus depressus* (Leske)	0.20
6: Limestone, grey-brown, with very irregular top; few fossils	0.15–0.30
7: Limestone	0.18
8: Limestone, rubbly; few fossils	0.76
Upper Trigonia Grit Member	
9: Limestone, very shelly, with oysters on top surface	0.25
10: Lumps of pale-brown limestone and shaly marl	0.15
11: Ragstone; 'usual' fossils	0.61
12: Parting	0.03
13: Limestone, rubbly; few fossils	0.15
14: Ragstone; 'usual' fossils	0.63
Birdlip Limestone Formation	
Scottsquar Member	
15: Limestone, white, ooidal packstones and grainstones; cross-bedding in parts; top bored by annelids and bivalves; *Trigonia costatula* Lycett, *Nerinea oppelensis* Lycett	1.27
16: Marl (?) parting	0.03
17: Limestone, rubbly, whitish; *Spiropora*, pentacrinoids, *Granulirhynchia granulata* (Upton), *Acrosalenia lycetti* Wright, *Trochotiara depressa* (Agassiz), *Hemipedina tetragramma* Wright	0.38
18: Marl (?) parting; small sponges	0.01
19: Limestone; *Plectothyris fimbria* J. Sowerby, *Globirhynchia subobsoleta* (Davidson), *G. witchelli* (Richardson and Upton)	0.61
20: Marl; same fossils as in Bed 19, and *Epithyris submaxillata* Morris, *Granulirhynchia granulata* (Upton)	0.02–0.10
Cleeve Cloud Member	
21: Limestone, white, massive-bedded, ooidal grainstones showing large-scale cross-bedding	seen to 3.96

The section exposed at the time of writing was much as described above, although the lower part of the Cleeve Cloud Member was covered by talus. Lower parts of the succession are exposed in quarries at the northern end of the common (see Richardson, 1910; Mudge, 1978a,b).

The Upper Trigonia Grit Member, at the base of the Salperton Limestone Formation, is typically developed as an irregularly bedded, shell-fragmental, fossiliferous calcarenite. The 'usual' fossils referred to by Richardson (1910) are large bivalves, and brachiopods such as the distinctive rhynchonellid *Acanthothiris spinosa* (Linnaeus). The Clypeus Grit Member is dominated by poorly bedded, peloidal packstones and grainstones that are very fossiliferous at some levels, particularly with the large, so-called '*Terebratula globata*' (= *Stiphrothyris* spp.). Pieces of Richardson's (1910) Bed 1 may be found in the subsoil at the top of the quarry.

Interpretation

The Cleeve Cloud Member, at the base of the section, corresponds with the Lower Freestone of previous authors, or the Devil's Chimney Oolite of Mudge (1978a). It is capped by a planed hardground on which Mudge (1978b) reported encrusting oysters.

The succeeding Scottsquar Member is only 2.3 m thick. The marls and soft, burrowed micritic limestones of the lower part (beds 16 to 20) represent the 'Oolite Marl' of Richardson (1910) and others. The upper part (Bed 15) rests sharply and probably erosively on the underlying beds. These higher-energy packstones and grainstones have generally been assigned to the Upper Freestone (Richardson, 1910); Baker (1981) assigned them to his 'micritic marginal facies' rather than the 'oolite-dominated shoal facies', although most of the 'Upper Freestone' elsewhere belongs to the latter.

The top of the Scottsquar Member is marked by a hardground that represents a substantial break in the succession, for it is succeeded by the Salperton Limestone Formation (Upper Inferior Oolite). As in the Cotswolds farther south, there is no Aston Limestone Formation (Middle Inferior Oolite) present at this locality. Witchell (1882a) erroneously recorded 0.61 m of 'Gryphite Grit', but the beds he identified are actually a part of the Upper Trigonia Grit Member, and the Aston Limestone Formation is overstepped by the Salperton Limestone Formation within Rodborough Hill, a short distance to the north-east (see **Fort Quarry** GCR site report, this volume; also Buckman, 1901, pl. 46; and Barron *et al.*, 1997, fig. 4). Indeed, it was the absence of the distinctive Middle Inferior Oolite strata on Selsley Common and to the south, and the regional pattern of its overstep, that led Buckman (1901), building on an idea suggested by T.T. Groom, to the theory that, after deposition of the Middle Inferior Oolite, an episode of gentle flexure was followed by erosion, which he termed the 'Bajocian denudation'. Farther south, the erosion surface beneath the Salperton Limestone Formation, representing the 'Bajocian denudation', cuts down to lower levels in the Inferior Oolite Group; the Scottsquar Member is cut out just south of Leigh's Quarry (see Cave, 1977) and the Cleeve Cloud Member is apparently absent at **Nibley Knoll** and **Hawkesbury Quarry** (see GCR site reports, this volume).

The Upper Trigonia Grit Member is also capped by a hardground encrusted by oysters, though this marks a relatively minor break in deposition compared to the 'Bajocian denudation'; other depositional breaks occur within the succeeding Clypeus Grit Member (at the top of Bed 4, for example). Richardson (1910) assigned his Bed 1 to the 'White Oolite', which forms the middle part of the Clypeus Grit Member in the south Cotswolds.

Conclusions

Leigh's Quarry shows the unconformable relationship between the Salperton Limestone Formation (Upper Inferior Oolite) and the Birdlip Limestone Formation (Lower Inferior Oolite); the Aston Limestone Formation (Middle Inferior Oolite) is missing. In combination with other sites described in this volume, it helps clarify the stratigraphical relationships within, and the tectonic history of, the Aalenian–Bajocian rock succession in the Cotswold region.

FORT QUARRY, GLOUCESTERSHIRE (SO 850 040)

M.G. Sumbler

Introduction

Fort Quarry, *c.* 1 km south of Stroud in Gloucestershire, is situated adjacent to Rodborough Fort, at the northern end of the extensive Rodborough Common SSSI. As one of several quarries on Rodborough Hill, it features frequently in the early literature on the Inferior Oolite Group of the Cotswolds and has yielded the type specimens of various fossil taxa described by Lycett (1853; Lycett in Wright, 1860) and Witchell (1880, 1882a). Wright (1860) recorded a section through the upper part of the succession, and additional details are given by Buckman (1895) and Richardson (1907b).

Description

The following section is based mainly on that held on file by English Nature, with revised lithostratigraphical classification by the present author.

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
4: Limestone, brown, very hard, compact, bioclastic; very rare shells and shell fragments	0.75
Upper Trigonia Grit Member	
3b: Limestone (biomicrite), grey-brown, ferruginous, thinly bedded; very shelly with numerous oyster fragments	0.30–0.35
3a: Limestone (biomicrite), ferruginous, massive; very shelly, with *Trichites* and numerous brachiopods including *Acanthothiris spinosa* (Linnaeus) and *Rhactorhynchia hampenensis* (S.S. Buckman); marl parting at base	0.60
2d: Limestone (biomicrite), grey-brown, ferruginous, soft; highly fossiliferous with *Trigonia costata* Parkinson and numerous brachiopods in clusters; *Acanthothiris spinosa*, *Rhactorhynchia hampenensis*; base penetrates crevices and irregularities in top of Bed 2c below	0.15–0.20
Aston Limestone Formation	
Gryphite Grit Member	
2c: Limestone, hard, yellow-brown, slightly limonitic, sandy, uneven top, with some vertical borings; relatively unfossiliferous but including '*Astarte*', *Ctenostreon* and *Gryphaea* (see also Lycett in Wright, 1860) and the brachiopod *Lobothyris buckmani* (Davidson)	0.12–0.16
Lower Trigonia Grit Member	
2b: Limestone (biomicrite), grey-brown, soft, more massive than rest of Bed 2; numerous well-preserved bivalves such as *Gryphaea*, *Quenstedtia* and *Tancredia* (see Richardson, 1907b; Lycett, 1857; Lycett in Wright, 1860); also corals and ammonites (*Darellia* and *Docidoceras*, and '*Ammonites sowerbyi* Miller' recorded by Lycett (in Wright, 1860))	0.16–0.25
2a: Limestone, brown, soft, marly	0.05
Birdlip Limestone Formation	
Scottsquar Member	
1b: Limestone (oosparite), massive, hard, in several courses; sparsely bored hardground at top	1.0
1a: Limestone (oosparite), thinly bedded, softer than Bed 1b above; shelly	seen to 1.0

Interpretation

The lowest beds seen in Fort Quarry belong to the Scottsquar Member of the Birdlip Limestone Formation (Lower Inferior Oolite), of which 3.65 m were recorded by Richardson (1907b). The member incorporates both the 'Oolite Marl' and 'Upper Freestone' of previous accounts (Barron *et al.*, 1997). The strata at Fort Quarry are entirely of high-energy 'Upper Freestone' facies, being composed of cream to white ooidal grainstones (Baker's (1981) oolite-dominated shoal facies). They contrast markedly with the lower-energy micritic 'Oolite Marl' facies (Baker's (1981) micritic marginal facies and marl-dominated trough facies) seen, for example, at **Leigh's Quarry** and **Frith Quarry** (see GCR site reports, this volume). As well as borings, Buckman (1895) and Richardson (1907b) recorded encrusting oysters in the hardground at the top of the Scottsquar Member.

Although only some 0.4 m of the succeeding Aston Limestone Formation (Middle Inferior Oolite) is now exposed, comprising the oldest part of the formation (Lower Trigonia Grit and Gryphite Grit members), slightly thicker successions (up to 1.1 m; Wright, 1860) have been recorded in the past. In other quarries farther south on Rodborough Common, the formation is entirely absent, and the Salperton Limestone Formation rests directly on the Birdlip Limestone Formation (Buckman, 1895; Richardson, 1907b). The regional pattern of the overstep of the Middle Inferior Oolite led Buckman (1901) to his concept of the 'Bajocian denudation', and its disappearance on Rodborough Common defines the southern limb of the so-called 'Painswick Syncline' (see **Frith Quarry** GCR site report, this volume).

The Lower Trigonia Grit Member at the base of the Aston Limestone Formation is very thin, and probably for this reason was not recognized in the Stroud area by either Lycett (1857) or Witchell (1880, 1882a) who included it in the Gryphite Grit Member. However, it was correctly identified by Wright (1860) who gave its thickness as 0.3 m. Richardson (1907b) described it as 'iron-shot', which is very typical of this unit. The ammonite fauna of this member is indicative of the Lower Bajocian Discites Zone. The succeeding Gryphite Grit Member incorporates the Gryphite Grit and Buckmani Grit of earlier accounts. The latter, comprising the lower part of the unit, was not definitely recognized here until Richardson (1907b) discovered the eponymous brachiopod *Lobothyris buckmani* (Davidson) within Bed 2c. The highly irregular, fissured hardground at the top of the Gryphite Grit Member marks a major non-sequence, with several zones 'missing' beneath the Salperton

Limestone Formation (Upper Inferior Oolite) (Figure 3.28).

The Upper Trigonia Grit Member, at the base of the Salperton Limestone Formation, is highly fossiliferous; over 40 taxa (including '*Ammonites parkinsoni* Sow.' and '*A. martinsii* d'Orb.') are listed by Lycett (in Wright, 1860), although these may include specimens from beds that would now be assigned to the Clypeus Grit Member, of which Richardson (1907b) recorded a total of 2.13 m. The ammonite fauna of the Upper Trigonia Grit Member is everywhere taken to be indicative of the Upper Bajocian Garantiana Zone. In contrast with the unfossiliferous beds of the Clypeus Grit Member presently exposed, the higher beds of the member were apparently highly fossiliferous with myacean bivalves, '*Terebratula*' *globata* of authors, and *Clypeus ploti* Salter. Witchell (1880) described and figured many fossils from the Clypeus Grit of 'Rodborough Hill', undoubtedly including specimens from Fort Quarry.

Conclusions

Fort Quarry exposes a section through the upper part of the Birdlip Limestone Formation (Lower Inferior Oolite), the Aston Limestone Formation (Middle Inferior Oolite) and basal Salperton Limestone Formation (Upper Inferior Oolite). The Birdlip Limestone Formation is represented by the Scottsquar Member of 'Upper Freestone' facies. The Aston Limestone Formation succession is thin and attenuated owing to the location of the site on the southern limb of the 'Painswick Syncline'; the formation is overstepped by the succeeding Salperton Limestone Formation a short distance to the south. Parts of the Aston Limestone Formation and Salperton Limestone Formation are highly fossiliferous and have yielded many type and figured specimens, particularly of bivalves.

HARESFIELD HILL, GLOUCESTERSHIRE (SO 819 088)

M.G. Sumbler

Introduction

Haresfield Hill, an outlier of the main Cotswold hill-mass, lies some 5 km north-west of Stroud, Gloucestershire. The GCR site is situated at the western extremity of that part of the hill known as 'Haresfield Beacon'. The site encompasses a face, some 8 m high, that exposes the basal part of the Inferior Oolite Group and the underlying

Figure 3.28 Upper Trigonia Grit Member (Salperton Limestone Formation) overlying thin Aston Limestone Formation at Fort Quarry. The formational boundary is marked by a black arrow. (Photo: British Geological Survey, No. A10482; reproduced with the permission of the Director, British Geological Survey, © NERC, 1966.)

Cephalopod Bed at the top of the Lias Group (Figure 3.29). The section is essentially a natural scar caused by landslipping, owing to failure of the Lias mudstones that form the main slope of the hill. As in many other such instances along the Cotswold scarp (e.g. see **Crickley Hill** GCR site report, this volume), the exposure may have been accentuated by a modest amount of quarrying. The section (at 'Beacon Hill') was first recorded by Wright (1860) and repeated by Witchell (1882b). Buckman (1888) gave a generalized section of the escarpment at Haresfield Hill, which was summarized by Woodward (1894) and which also forms the basis of Richardson's (1904) abbreviated record.

Description

The section given below was recorded by the present author in 1997. It can be related to that of Buckman (1888) with a considerable degree of confidence, and bed numbers and most of the faunal data are taken from his account.

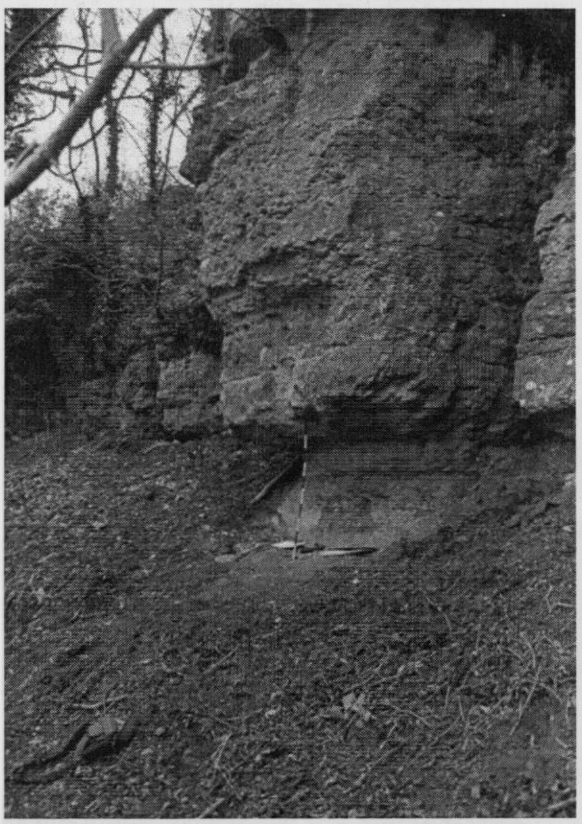


Figure 3.29 Overhang of the Leckhampton Member (Birdlip Limestone Formation) above the Cephalopod Bed (Lias Group) at Haresfield Hill. (Photo: M.G. Sumbler.)

	Thickness (m)
Birdlip Limestone Formation	
Crickley Member	
4: Limestone, buff, medium-grained, well-sorted, ooidal and sparsely shell-fragmental grainstone, massive, with cryptic cross-bedding in places, weathering rather flaggy; not exposed in continuous section	*c.* 3.0
Leckhampton Member	
5–6: Limestone, brown and grey mottled, slightly sandy, somewhat rubbly, moderately shelly	1.15
7: Limestone, yellow-brown, very sandy, soft, with irregular, grey-hearted, well-cemented doggers; sporadic ammonites and bivalves	0.35
8–13: Limestone, brownish-grey, yellow-brown-weathering, somewhat sandy, coarse-grained, poorly sorted, peloidal and shell-fragmental packstone; massive, though markedly rubbly appearance on weathered faces due to preferential cementation around burrows; sporadic impersistent partings and softer layers; poorly preserved '*Leioceras ambiguum*? S.S. Buckman' in middle part (Bed 10)	1.95
14: Limestone, pinkish-grey, weathering brown, hard, poorly sorted, slightly sandy, peloidal and shell-fragmental packstone; massive, uniform appearance on weathered surfaces; marl parting at base	0.40
15–16: Limestone, as Bed 14 above; hard, forming overhang; sharp base; abundant large *Leioceras opalinum* (Reinecke) with *L. comptum* (Reinecke) in upper part (Bed 15); small *L. opalinum*, *Pleydellia aalensis* (Zieten), *Myophorella ramsayi* (Wright) in lower part (Bed 16)	0.35
Lias Group	
Cephalopod Bed	
17–19: Limestone, soft, somewhat marly, brown-ochreous-weathering, strongly burrowed and highly fossiliferous, particularly with belemnites but also ammonites and bivalves; marl seams 0.20 m and 0.40 m above base; sharp, markedly convoluted, loaded base; *Homoeorhynchia cynocephala* (Richard), '*Terebratula haresfieldensis*' Davidson, *Dumorteria moorei* (Lycett), *Lytoceras wrighti* S.S. Buckman	0.55
Bridport [Cotteswold] Sand Formation	
20: Sand, orange-brown to ochreous, very fine-grained, tough, partially cemented, becoming brownish-grey with deformed, brown ferruginous peloids in topmost *c.* 0.15 m	0.43

Interpretation

Buckman (1888) assigned beds 17 to 19 (and perhaps parts of Bed 16) to the Cephalopod Bed, although later (Buckman, 1903) he apparently amended this, quoting a total thickness of 0.6 m, probably represented by beds 16 to 19. Richardson (1904) who, like Buckman, was influenced more by fauna than lithology or sedimentology, also included Bed 15 in the Cephalopod Bed but, as classified herein, the latter comprises only beds 17 to 19, which together form an obvious sedimentological unit near the bottom of the face, resting with a sharp, loaded junction on the underlying Bridport Sand Formation. The ammonite fauna of the Cephalopod Bed shows that it is a condensed unit of latest Toarcian (Early Jurassic) age. Here, it is very much thinner than farther south in the Cotswolds, for example at **Nibley Knoll** (see GCR site report, this volume) where it is some 4 m thick, but its ammonite fauna shows that it is also less complete with a substantial non-sequence, not present farther south, at its base.

Beds 5 to 15 are mainly brown-weathering rubbly, rather sandy limestones that constitute the Leckhampton Member, the basal unit of the Inferior Oolite Group, and the most widespread and lithologically uniform unit of the Lower Inferior Oolite in the Cotswolds. It totals 4.2 m in thickness at Haresfield Hill, a little less than at the type locality (see **Leckhampton Hill** GCR site report, this volume). Beds 5 to 7 were formerly regarded as part of the Lower Limestone (now Crickley Member), although this is hard to justify on lithological grounds. At the base, beds 15 and 16, respectively the so-called 'Opaliniforme Bed' and 'Aalensis Bed' (Richardson, 1904; Buckman in Richardson, 1910), together form a single sedimentological unit. Buckman (1888) recorded the ammonite *Leioceras opalinum*, indicative of an earliest Aalenian age, throughout this unit, but the lower part (Bed 16) also yielded *Pleydellia aalensis*, indicating a latest Toarcian age. The succeeding part of the Leckhampton Member (beds 8 to 14) corresponds with the Ferruginous Beds of Witchell (1882b) or the Scissum Beds of Richardson (1904) and later workers. Richardson (1904) recorded small *Quadratirhynchia subdecorata* (Davidson) and *Pleuromya* within the Leckhampton Member, and the ammonite *Pseudolioceras* is recorded in English Nature files; the latter probably came from Bed 7, in which ammonites are conspicuous.

The basal part of the succeeding Crickley Member exposed in the current section belongs to the Lower Limestone of Witchell (1882b) and later authors. These beds are, at Haresfield Hill, dominated by cross-bedded, ooidal limestones assigned by Mudge (1978a) to his Frocester Hill Oolite.

Conclusions

The section at the Haresfield Hill GCR site is important for its exposure of the Cephalopod Bed at the top of the Lias Group, and the overlying Leckhampton Member at the base of the succeeding Inferior Oolite Group. Indeed, it is one of the few localities in the Cotswolds where this junction, corresponding with the Lower–Middle Jurassic boundary, can be examined, and so is significant in stratigraphical and palaeontological studies. Ammonites and brachiopods from this locality have featured in palaeontological monographs.

FRITH QUARRY, GLOUCESTERSHIRE (SO 867 082)

M.G. Sumbler

Introduction

The section at Frith Quarry, near Painswick, Gloucestershire, was first described by Buckman (1895) and parts of his section were repeated by Richardson (1904). Subsequent to these accounts, the quarry seems to have been largely overlooked, and is not recorded again in the literature, although the lower part of the succession (Birdlip Limestone Formation, Scottsquar Member) is figured by Baker (1981, fig. 2). The quarry is the source of numerous type and cited specimens of fossil taxa. It should not be confused with the smaller quarry (SO 866 083) immediately to the north-west of the GCR site, also referred to as the Frith Quarry by some authors, in which beds lower in the Inferior Oolite Group succession have been recorded.

Description

The following section is based on an account of the quarry (by C.F. Parsons) held on file by English Nature, with revised lithostratigraphical classification by the present author.

	Thickness (m)
Aston Limestone Formation	
Gryphite Grit Member	
18: Limestone, brown, thin-bedded, sandy, bioclastic, interbedded with brown, sandy marl; *Gryphaea bilobata* J. de C. Sowerby	1.0
17: Limestone, brown, massive, sandy, bioclastic, in three to four courses; highly irregular base; *Gryphaea bilobata*	0.80–0.90

	Thickness (m)
16: Sand, yellow, fine grained, becoming brown and marly downwards	0.30–0.35
15: Limestone, hard, shelly, ferruginous, bioclastic; highly fossiliferous, with *Gryphaea* and abundant *Ctenostreon* on bedding surfaces	0.70–0.90
Lower Trigonia Grit Member	
14: Marl, brown; impersistent, sandy, nodular limestone towards middle; *Sonninia* (*Fissilobiceras*), *Pholadomya*	0.10–0.28
13c: Limestone (oobiomicrite), rubbly, ferruginous, finely 'iron-shot', highly bioturbated, mixed with soft marl; highly fossiliferous with abundant bivalves, including *Trigonia costata* Parkinson, *Ctenostreon pectiniforme* (Schlotheim), *Pholadomya* and *Trichites*, with shells replaced by limonite; *Hyperlioceras* (*H.*) *rudidiscites* S.S. Buckman	0.37–0.60
13b: Marl, brown, impersistent	0–0.05
13a: Limestone, similar to Bed 13c, but harder and slightly less fossiliferous	0.20–0.30
12b: Marl, pale orange-brown, rubbly, slightly 'iron-shot', calcareous; paler towards top where there are numerous yellow-stained pebbles	0.15–0.20
12a: Limestone (oomicrite), pale orange-brown, burrowed, similar to Bed 12b though more indurated; fissure infill with *Trichites* fragments and limonite-stained pebbles deeply penetrating Bed 11 below	0.18–0.22
Birdlip Limestone Formation	
Scottsquar Member	
11: Limestone (oobiomicrite), brown, hard; undulating, bored, oyster-encrusted hardground top surface; very shelly in lower part with sparse, orange-coloured, limonitic pisoids; bioturbated with soft, white, micritic burrow-fills	up to 0.35
10: Marl, orange-brown, soft, laminated, ooidal; dark-brown, with common shell-fragments in basal 0.05 m; abundant *Homoeorhynchia cynomorpha* (S.S. Buckman)	0.66–0.72
9: Limestone (micrite), white, weathering pale pink-grey, marl seam 0.03 m thick, 0.24 m below top; species of the ammonite *Brasilia* in lower part; *Blastinoidea frithica* Richardson and Thacker	0.90
8: Clay, yellow becoming brown in lower part, soft, sticky	0.10–0.13
7d: Limestone (micrite), pale pink-grey, soft with sparse, orange-coloured limonitic pisoids; *Globirhynchia tatei* (Davidson)	0.30
7c: Marl, pale-brown	0.05–0.10
7b: Limestone (oomicrite), pale-grey, soft, with small yellow-orange ooids; *Plectothyris*	0.10–0.15
7a: Limestone (oomicrite), orange-brown, moderately hard; bioturbated with densely packed ooids interspersed with patches of grey micrite; gradational base; abundant *Plectothyris fimbria* (J. Sowerby), also *Globirhynchia* and poorly preserved bivalves	0.15–0.20
6: Limestone (oobiomicrite), cream, hard, massive, nodular, shelly, with small well-packed ooids; softer and more sparsely ooidal towards base where there are sporadic *Plectothyris*	1.20–1.40
5: Limestone (oomicrite) and marl, pale pink-grey, soft, rubbly with small orange-coloured ooids; indurated towards top, softer and browner near base; *Plectothyris fimbria*, *Epithyris*	0.50–0.80
4: Limestone (micrite), pale pink-grey, moderately hard, with small, sparse, pale orange-coloured ooids and limonite-stained patches; sparsely burrowed; poorly fossiliferous; *Plectothyris*	1.40
3: Limestone (oomicrite), pale grey-brown, soft, orange-stained with small, sparse, pink ooids; more indurated at the top; softer, more marly towards base; *Plectothyris* cf. *fimbria*, *Epithyris*, *Globirhynchia* aff. *subobseleta* (Davidson)	1.80–1.85
2: Clay, blue and orange-streaked, limonite-stained	0.05–0.10
Cleeve Cloud Member	
1: Limestone (oobiosparite), hard, shelly, massive, densely ooidal freestone; flat, limonite-stained, bored hardground at top	seen to 2.60

The above section (as measured in the 1970s) is comparable with that described by Buckman (1895), although slightly more of the Cleeve Cloud Member (i.e. Lower Freestone, Buckman's Bed 31) was then exposed and there is difficulty in recognizing some of Buckman's finer bed divisions in the overlying succession. The strata are disturbed by cambering effects, with associated minor faults and fissures (gulls), which makes correlation of beds across the face somewhat problematic.

Interpretation

Frith Quarry (Figure 3.30) shows the middle part of the Inferior Oolite Group within the so-called 'Painswick Syncline' (Buckman, 1901) in which a largely complete succession of the Birdlip Limestone Formation (Lower Inferior Oolite) and the Aston Limestone Formation (Middle Inferior Oolite), comparable with that developed near Cheltenham, is preserved. Only the lower part of the Aston Limestone Formation is exposed; higher parts can be seen at **Swift's Hill** (see GCR site report, this volume), *c.* 2 km to the south-east.

The Cleeve Cloud Member at the base of the section is capped by a planed and bored hardground as is generally the case (e.g. see **Leckhampton Hill** GCR site report, this volume). The section of the succeeding Scottsquar Member, *c.* 7.8 m thick, is one of the best in the Cotswolds. This unit (Barron *et al.*, 1997), which combines the Oolite Marl and Upper Freestone of previous accounts, is here entirely

Figure 3.30 Aston Limestone Formation overlying Birdlip Limestone Formation at Frith Quarry. The boundary is marked by a white arrow. (Photo: M.G. Sumbler.)

of Oolite Marl facies, comprising pale chalky marls and micritic limestones. This low-energy facies is quite distinct from the high-energy oolite shoal facies of the Upper Freestone, better developed at sites such as **Leckhampton Hill** (see GCR site report, this volume). It has been interpreted as accumulating in relative lows or troughs in the sea floor (Baker, 1981). According to Baker (1981), there is an irregular scour or possibly karstic surface 3.2 m above the base of the member, i.e. probably at the top of Bed 4 of the section given above. The succession is highly fossiliferous at some levels, and is particularly rich in brachiopods. The marly Bed 10 of the above section (which incorporates Buckman's (1895) Bed 18) yields abundant *Homoeorhynchia cynomorpha* and is the source of the type specimens figured by Buckman (1895) (Figure 3.31). *Plectothyris fimbria* and *Globirhynchia tatei* are also common. The member here has yielded a number of ammonites; Buckman (1895) recorded several species 'aff. *Ludwigia Murchisonae*' from amongst Edwin Witchell's collection (see **Swift's Hill** GCR site report, this volume) and Bed 9 (= Buckman's Bed 20) has yielded *Brasilia* cf. *bradfordensis* (S.S. Buckman) and *B.* aff. *baylii* (S.S. Buckman) suggestive of the Aalenian Bradfordensis Zone (Parsons, 1980a, emend.). The Scottsquar Member at Frith Quarry has also yielded a number of species of sponges, including the type specimens of *Blastinoidea frithica* (Richardson and Thacker, 1920).

The eroded, bored hardground at the top of the Scottsquar Member (Bed 11) represents the 'Aalenian denudation' of Buckman (1901); locally, the erosion surface is highly irregular and it apparently extends down in crevices into the underlying bed. Owing to inadequate exposure,

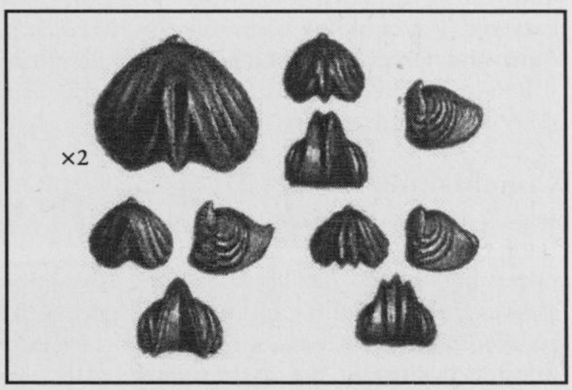


Figure 3.31 Type material of *Homoeorhynchia cynomorpha* (S.S. Buckman) from Frith Quarry. (Reproduced from Buckman, 1895, pl. 14, figs 2–4.)

the pattern of erosion is somewhat difficult to establish, but there may be a second period of erosion represented within Bed 11. If so, this could conceivably represent that seen elsewhere beneath the Harford Member (the youngest part of the Birdlip Limestone Formation; Barron *et al.*, 1997), and remnants of that member may be preserved locally close to the axis of the 'Painswick Syncline'. The Harford Member is otherwise known only in the area of the analogous 'Cleeve Hill Syncline' (see **Leckhampton Hill** GCR site report, this volume) and north Cotswolds.

The Lower Trigonia Grit Member, at the base of the Aston Limestone Formation, comprising 'iron-shot' limestones and marls, has yielded a large number of often well-preserved ammonites, in marked contrast to the rest of the Inferior Oolite Group of the Cotswolds where ammonites are generally rare and poorly preserved. They most probably come from Bed 13 (= Buckman's Bed 8), and were first described by Witchell (1882a), although he mistakenly assigned them to the Gryphite Grit Member (see Buckman, 1895). Witchell's extensive collection, now in the Natural History Museum, London, was utilized by Buckman (1887–1907) in his substantial monograph on Inferior Oolite Group ammonites and, together with other specimens from the site (in Stroud Museum and elsewhere), make up one of the most extensive faunas from the Lower Bajocian Discites Zone in England. The topmost bed of the member (Bed 14) has yielded *Sonninia* (*Fissilobiceras*) aff. *fissilobata* (Waagen) indicating the succeeding Ovalis Zone (Parsons, 1980a, emend.).

Some 2 m or so of the succeeding Gryphite Grit Member (incorporating the Gryphite Grit and Buckmani Grit of earlier accounts) are exposed. It contains common *Gryphaea bilobata* (the 'Gryphite' of the name) and Buckman (1895) also recorded *Lobothyris buckmani* (Davidson) from the basal part.

Conclusions

Frith Quarry shows a fine section through the upper part of the Birdlip Limestone Formation (Lower Inferior Oolite) and the lower part of the succeeding Aston Limestone Formation (Middle Inferior Oolite) in the axial region of the so-called Painswick Syncline. The Scottsquar Member, of 'Oolite Marl' facies, is richly fossiliferous and has yielded some of the few zonally significant ammonites known from this level. The Lower Trigonia Grit Member is also highly fossiliferous and has yielded an extensive Discites Zone ammonite fauna.

SWIFT'S HILL, GLOUCESTERSHIRE (SO 878 067)

M.G. Sumbler

Introduction

The quarry at Swift's Hill is sited about 3 km north-east of Stroud, Gloucestershire, at the northern side of Swift's Hill SSSI. It exposes much of the middle part of the Inferior Oolite Group, and has a special place in the history of Cotswold geology because Edwin Witchell (Figure 3.32) suffered a fatal heart attack there on 20th August 1887, whilst collecting fossils. Witchell, a solicitor in Stroud, was an amateur geologist who contributed much to the study of

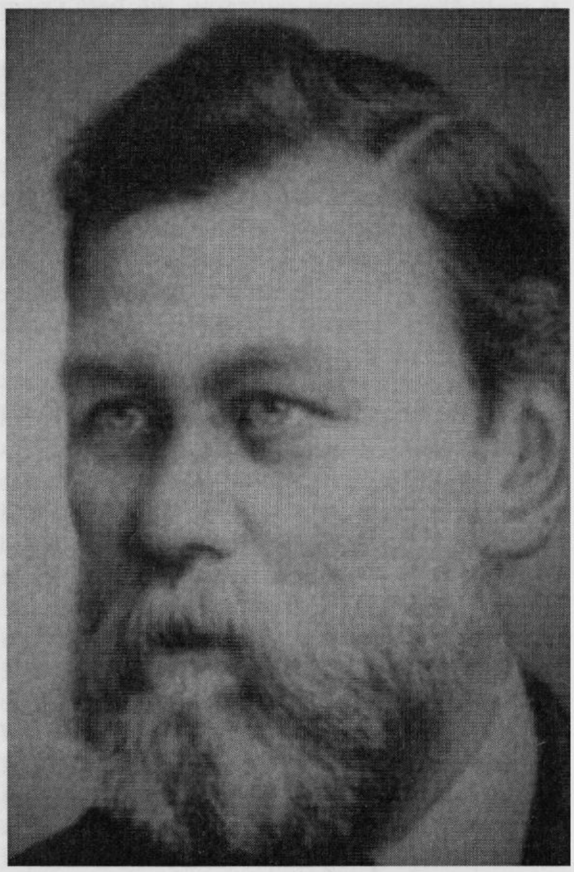


Figure 3.32 Edwin Witchell (1823–1887). (Reproduced courtesy of the Cotteswold Naturalists' Field Club.)

Cotswold stratigraphy and palaeontology, mainly through the activities and publications of the Cotteswold Naturalists' Field Club (Anonymous, 1887; Judd, 1888; Lucy, 1890a; Vaughan, 1998). The quarry at Swift's Hill is alluded to by Woodward (1894), and described in some detail by Buckman (1895). The latter's record was summarized by Richardson (1904) but, surprisingly, the quarry does not seem to feature in subsequent literature despite the excellent exposure (Figure 3.33).

Description

The following section is based on that recorded by Buckman (1895) with revised lithostratigraphy by the present author.

	Thickness (m)
Salperton Limestone Formation	
Upper Trigonia Grit Member	
1: Limestone, 'ragstone'; '*Terebratula*' *globata* of authors (*non* J. de C. Sowerby), *Rhactorhynchia subtetrahedra* (Davidson), *Trigonia*	c. 1.52
Aston Limestone Formation	
Gryphite Grit Member	
2: Limestone, 'ragstone', bluish-grey, much stained with iron, vertical borings	0.05–0.18
3: Limestone, 'ragstone', grey, sparsely shelly	0.28
4: Limestone, 'ragstone', grey, hard, sandy, some shelly beds; *Gryphaea* in partings, more common in lower part	2.13
5: Sandy 'ragstone', mostly very shelly; with numerous small bivalves in some parts; base very uneven	1.52
6: Fine-grained yellow sand	0.10–0.15
7: Mudstone, purplish-grey, sandy, with numerous broken shells; scarce *Lobothyris buckmani* (Davidson)	0.08–0.15
8: Limestone, 'ragstone', grey, shelly, bored in places; *Acanthothiris* at top	0.46
Lower Trigonia Grit Member	
9: Limestone, 'ragstone', yellowish, somewhat 'iron-shot', shelly with a few bivalves; highly bored in places; '*Rhynchonella*' *bajinensis* Szajnocha	1.52
10: Marl, yellowish	0.08
Birdlip Limestone Formation	
Scottsquar Member	
11: Ooidal debris	0.13
12: Limestone, white, ooidal	0.96
13: Marl, brown	0.03
14: Marl, grey; *Globirhynchia tatei* (Davidson), scarce *Plectothyris fimbria* (J. Sowerby), *Trigonia*	0.23
15: Marl, yellow	0.03
16: Limestone, white shelly, ooidal	?

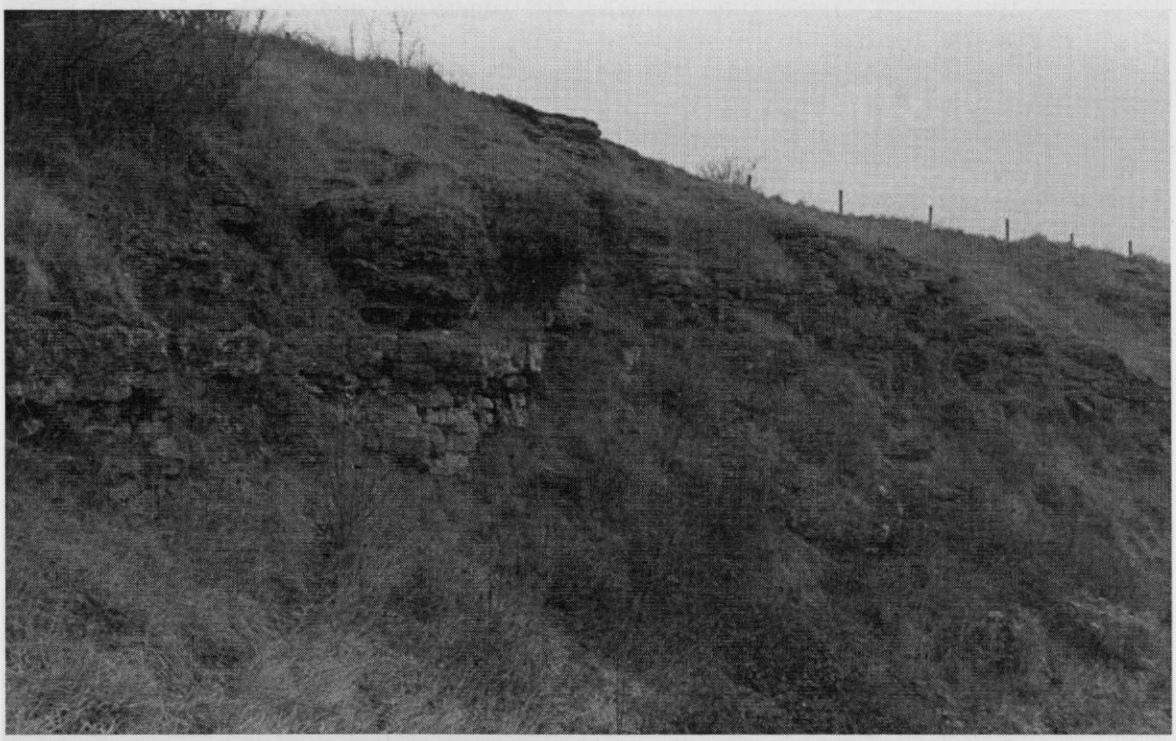


Figure 3.33 General view of the exposure of Aston Limestone Formation at Swift's Hill with a small outcrop of the overlying Upper Trigonia Grit Member at centre top. (Photo: M.G. Sumbler.)

At the time of writing (1997), only the upper part of the succession (beds 1 to 9) was exposed in continuous section. The strata are somewhat disrupted by minor faults, probably a result of cambering on the steep hillside, but there is little difficulty in recognizing the units described by Buckman (1895); the sand and marl of beds 6 and 7 form a particularly obvious marker. Lower strata are largely concealed by rubble, although at the southern end of the site there is a small exposure of cream-buff, peloidal wackestone with *Plectothyris*, belonging to the Scottsquar Member of the Birdlip Limestone Formation (Lower Inferior Oolite), as mentioned by Baker (1981).

Interpretation

Swift's Hill is sited in the axial region of the so-called Painswick Syncline (Buckman, 1901) in which a largely complete succession of the Birdlip Limestone Formation (Lower Inferior Oolite) and the Aston Limestone Formation (Middle Inferior Oolite) is preserved. The Birdlip Limestone Formation is presently not well exposed at Swift's Hill; it is, however, better exposed at **Frith Quarry** (see GCR site report, this volume), only 2 km to the north-west. Together with **Haresfield Hill** (see GCR report, this voume), these quarries form the basis of the generalized section for the Painswick area given by Parsons (1980a).

The Aston Limestone Formation (Middle Inferior Oolite) is 6.35 m thick at Swift's Hill, whereas on the axis of the 'Birdlip Anticline' to the north-east (e.g. **Knap House Quarry**, see GCR site report, this volume) and south-west (e.g. **Leigh's Quarry**, see GCR site report, this volume), it is entirely absent. It is, however, much thinner than in the Cleeve Hill area, its area of maximum development, where it reaches some 22 m in thickness (Barron *et al*., 1997). This relative thinness is due principally to the absence of the uppermost part of the Cleeve Hill succession (see **Rolling Bank Quarry** GCR site report, this volume), beneath the unconformable base of the Salperton Limestone Formation (Upper Inferior Oolite). Only the Lower Trigonia Grit and Gryphite Grit members are present at Swift's Hill.

The Lower Trigonia Grit Member comprises 'iron-shot' limestones and marls as at **Frith Quarry** (see GCR site report, this volume) where it has yielded an extensive fauna of (Lower Bajocian) Discites Zone ammonites. The basal marl, not now exposed, includes pebbles of a whitish limestone (Buckman, 1895; Richardson, 1904) presumably derived from the underlying Scottsquar Member. The top of the succeeding Gryphite Grit Member (total thickness *c*. 4.75 m) is marked by a well-developed hardground with borings and abundant encrusting oysters. Buckman (1895) classified the topmost bored beds (2 and 3) as Notgrove Freestone (= Notgrove Member) because of the presence of borings, but the 'ragstone' lithology is typical of the Gryphite Grit Member. The Notgrove Member, in its typical oolite facies is, however, present farther to the north-west in the 'Painswick Syncline', for example at Kimsbury Castle (SO 868 118), where the Gryphite Grit Member totals 7 m in thickness (Buckman, 1895). The Gryphite Grit Member (Barron *et al*., 1997) incorporates the Buckmani Grit of Buckman (1895, beds 5–8) in which the eponymous brachiopod *Lobothyris buckmani* occurs rather sparsely. Parsons (1980b) recorded the ammonites *Docidoceras* (*Emileites*) *liebi* (Maubeuge) and *Witchellia* (*W.*) *romanoides* (Douvillé) from the Gryphite Grit Member of Swift's Hill, indicating the Lower Bajocian Ovalis Zone.

Only the lower part of the succeeding Salperton Limestone Formation is exposed at Swift's Hill. The strata comprise ooidal packstones, with lenses of richly fossiliferous rubbly limestone, belonging to the Upper Trigonia Grit Member.

Conclusions

Swift's Hill exposes the whole of the Aston Limestone Formation (Middle Inferior Oolite) together with the basal part of the succeeding Salperton Limestone Formation (Upper Inferior Oolite). In combination with other GCR sites, it provides a representative section of the Inferior Oolite Group within the so-called 'Painswick Syncline'.

KNAP HOUSE QUARRY, GLOUCESTERSHIRE (SO 925 147)

M.G. Sumbler

Introduction

The small complex of disused workings known as 'Knap House Quarry' lies on the Cotswold

Scarp just north of the village of Birdlip, Gloucestershire. It is sited approximately on the axis of the so-called 'Birdlip Anticline', a localized axis of relative uplift in the Bajocian Stage characterized by an incomplete Inferior Oolite Group succession. Sections at Birdlip illustrating this attenuated succession have been referred to by many authors (Ager, 1956, 1969; Ager and Mudge, 1973; Murray and Hancock, 1977; Baker, 1977, 1981); these relate chiefly to the road cutting (SO 925 144), now obscured, just to the south of the GCR site, where the succession is very similar.

Description

The lower part of the succession is exposed in a precipitous quarry face adjoining the Cotswold Way footpath in the northern part of the site; the higher, and more important part of the succession can be seen in a smaller quarry at a higher level in the southern part (Figure 3.34). The following section is based on records by C.F. Parsons (English Nature files) and the present author (1997).

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
Limestone, brown, massive to rubbly, peloidal packstone, softer and marly for 0.75 m at base; *Clypeus ploti* Salter, *Pleuromya uniformis* (J. Sowerby), *Stiphrothyris tumida* (Davidson)	2.80
Upper Trigonia Grit Member	
Limestone, brownish-grey, hard, massive, ooidal, peloidal and shell-fragmental packstone, very shelly in parts	1.40
Birdlip Limestone Formation	
Scottsquar Member	
Limestone, pale pinkish-grey to buff, massive to poorly bedded, coarse-grained, poorly sorted, ooidal, peloidal and variably shell-fragmental grainstone to packstone with sporadic micritic (wackestone) lenses in lower part; replaced by 'reef' of soft, cream-white, slightly argillaceous micrite and finely granular packstone in middle part of face; topmost 0.15 m grey, hardened and recrystallized with annelid borings and encrusting oysters	1.60
Obscured	?
Limestone, yellowish-buff, massive, ooidal grainstone; sharp, planar base	1.50
Cleeve Cloud Member	
Limestone, pale-grey to buff, medium-grained, poorly sorted, ooidal grainstone with sporadic shell-detrital bands; well bedded with large-scale cross-bedding at some levels; planar top with sporadic encrusting oysters	*c.* 10

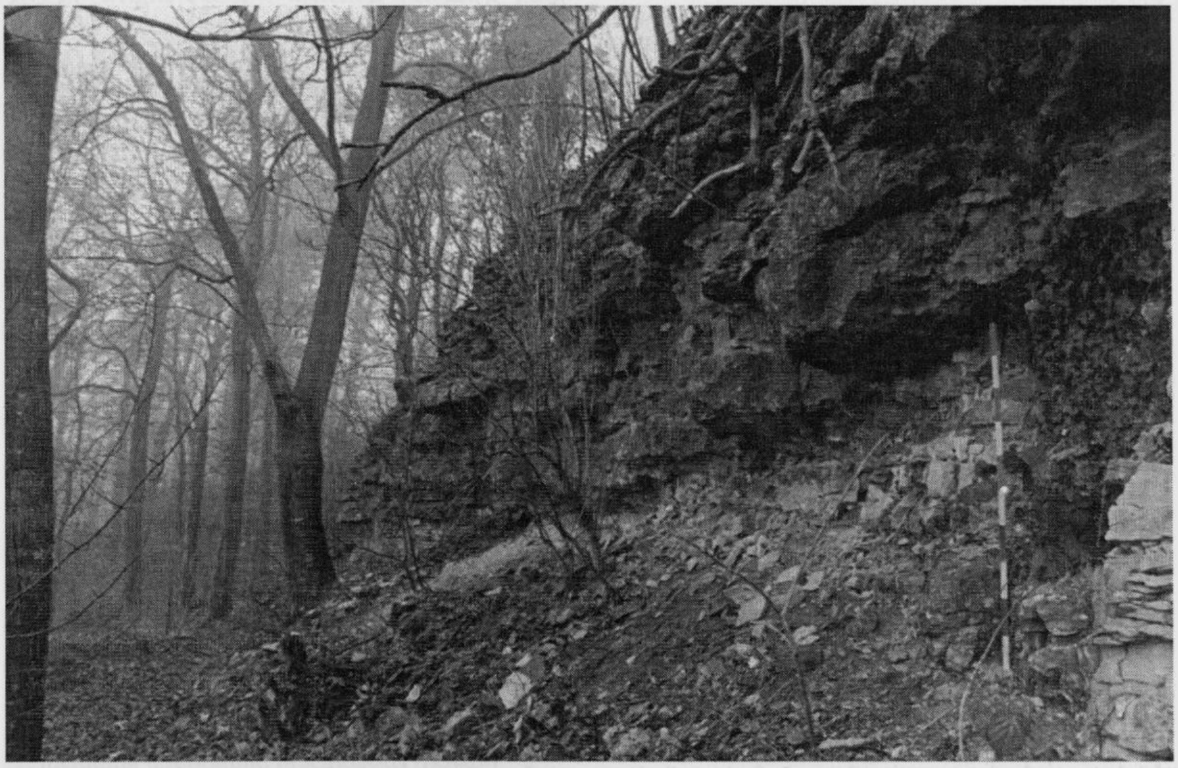


Figure 3.34 Upper Trigonia Grit Member (Salperton Limestone Formation) overlying Scottsquar Member (Birdlip Limestone Formation) at Knap House Quarry. (Photo: M.G. Sumbler.)

Interpretation

The Cleeve Cloud Member (the former Lower Freestone) is exposed in the northern part of the site; its overall lithology is much like that at the type locality (see **Leckhampton Hill** GCR site report, this volume). The succeeding Scottsquar Member is mainly developed as an ooidal and peloidal grainstone, the facies of the so-called 'Upper Freestone', but in the southern part of the site, it is replaced by marly micrites, the Oolite Marl of authors. The latter material forms a 'reef', containing sporadic bivalves, brachiopods and corals, about 10 m in diameter (briefly mentioned by Baker, 1981); the surrounding grainstones interdigitate and drape over the reef. The obvious equivalence between the Upper Freestone and the Oolite Marl, well illustrated at this locality, is the main reason why the two units are now combined as a single lithostratigraphical entity, the Scottsquar Member (Mudge, 1978a; Barron *et al.*, 1997).

The total thickness of the Scottsquar Member (Upper Freestone and Oolite Marl of earlier accounts) is hard to estimate because of the separation of the two parts of the section, but is unlikely to be much more than 5 m, which is considerably less than at other localities such as **Leckhampton Hill** (see GCR site report, this volume). Evidently the youngest part of the succession is missing at Birdlip; the top surface is planed and eroded, and is succeeded by the Upper Trigonia Grit Member, the basal unit of the Salperton Limestone Formation (Upper Inferior Oolite). This erosion surface, marked by borings and encrusting oysters, represents Buckman's (1901) so-called 'Bajocian denudation'. The fact that the Upper Inferior Oolite (Upper Bajocian) rests directly on the Lower Inferior Oolite (Aalenian) at this locality, whereas only a short distance away (e.g. at Tuffley's Quarry SSSI (SO 932 159); Richardson, 1904) Middle Inferior Oolite (Lower Bajocian) intervenes, led Buckman (building on a suggestion by Groom) to the idea that a phase of folding preceded the 'denudation'. The geographical distribution of the various units within the Inferior Oolite Group led him to recognize an axis of relative uplift (the 'Birdlip Anticline'), characterized by attenuated Lower and Middle Inferior Oolite successions, flanked by the Painswick and Cleeve Hill 'synclines', in which thicker and more complete Inferior Oolite Group successions occur (Buckman, 1901, pl. 6; Arkell, 1933, fig. 36; Barron *et al.*, 1997, fig. 4).

Whilst Buckman correctly interpreted the pattern of overstep of the Lower and Middle Inferior Oolite, the same relationships (shown with a vertical exaggeration of over 300 in Figure 3.2) could be merely a result of submarine erosion of the sediment pile during a sea-level lowstand without any folding being involved; it remains unclear to what extent the 'synclines' and 'anticlines' represent sedimentary troughs and highs, and how much they relate to differential erosion during the 'Bajocian denudation' (Barron *et al.*, 1997; Sumbler *et al.*, 2000).

Conclusions

Knap House Quarry, sited on the axis of the 'Birdlip Anticline', shows a section in which the Salperton Limestone Formation (Upper Inferior Oolite) rests directly on the Birdlip Limestone Formation (Lower Inferior Oolite), in contrast to other localities where the Aston Limestone Formation (Middle Inferior Oolite) intervenes. This relationship led Buckman (1901) to his important concept of the 'Bajocian denudation'.

CRICKLEY HILL, GLOUCESTERSHIRE (SO 924161–SO 932 160)

M.G. Sumbler

Introduction

The impressive exposures of the Birdlip Limestone Formation (Lower Inferior Oolite) on the Cotswold escarpment at Crickley Hill, near Birdlip in Gloucestershire (Figure 3.35), have attracted the attention of geologists since the early days of the science. They are of particular interest for the fine development of the famous 'Pea Grit', and have recently been designated as the type locality of the Crickley Member (= Lower Limestone plus Pea Grit of previous authors). The GCR site at Crickley Hill lies about 1.5 km north of the village of Birdlip, and extends for nearly 1 km. It encompasses the steep, cliff-like south face of the hill, together with an area of old quarries at the western end.

Description

The finest exposures occur on the south face, and accounts of the sections are given by numerous authors including Brodie (1851,

Figure 3.35 Exposure of the Crickley Member (Birdlip Limestone Formation) at Crickley Hill. (Photo: M.G. Sumbler.)

1853), Wright (1860), Witchell (1882b), Lucy (1890b), Woodward (1894) and Richardson (1904). All of these accounts differ in detail, but a useful generalized section (Figure 3.36), based on the exposures near the eastern end of the site (SO 930 160) where the Leckhampton Member (formerly Scissum Beds) is poorly exposed, is given by Ager (1969). The following section is largely based on Ager (1969), with revised lithostratigraphical classification and some additional detail by the present author.

	Thickness (m)
Birdlip Limestone Formation	
Cleeve Cloud Member	
Oolite, flaggy; shell debris, pentacrinoids, *Liostrea*, bryozoans	5.8
Calcilutite, rubbly; shell debris, brachiopods, bryozoans	1.9
Calcilutite, bioclastic, massive, bioturbated; bryozoans in life position	1.3
Oolite; ferruginous pisoids at base	1.2
Oolite	0.8
Crickley Member	
'Pea Grit'	
Pisolite, well bedded, with inter-bedded oolite; diverse fauna with many micromorphic forms including terebratulid brachiopods (notably *Zeilleria*), bivalves, echinoids and gastropods; other fossils locally abundant	3.3
'Lower Limestone'	
Oolite, massive, thick-bedded, locally bioturbated; *Pseudoglossothyris*, echinoids in life position, *Liostrea* and shell debris at base	8.4
Oolite, bioturbated; *Trichites*, echinoids in life position, *Pseudoglossothyris simplex* (J. Buckman) at base	4.0
Leckhampton Member	
Limestone, sandy and silty, yellowish-brown, ferruginous, somewhat argillaceous, strongly bioturbated; burrowing bivalves including *Pholadomya* in life position; brachiopods including *Homoeorhynchia cynocephala* (Richard) in lower part, and *Rhynchonelloidea subangulata* (Davidson) in upper part; bone bed at base	3.4
Lias Group	
Bridport [Cotteswold] Sand Formation	
Shale, black, fossiliferous	1.25
Silt, ferruginous, micaceous, thinly bedded; calcareous doggers near top	seen to 2.0

Interpretation

The steep, cliff-like scarp face of Crickley Hill can be viewed from across the valley at Barrow Wake (SO 931 154), Birdlip, from where it can be appreciated that the crags of Inferior Oolite Group originated as a natural landslip scar,

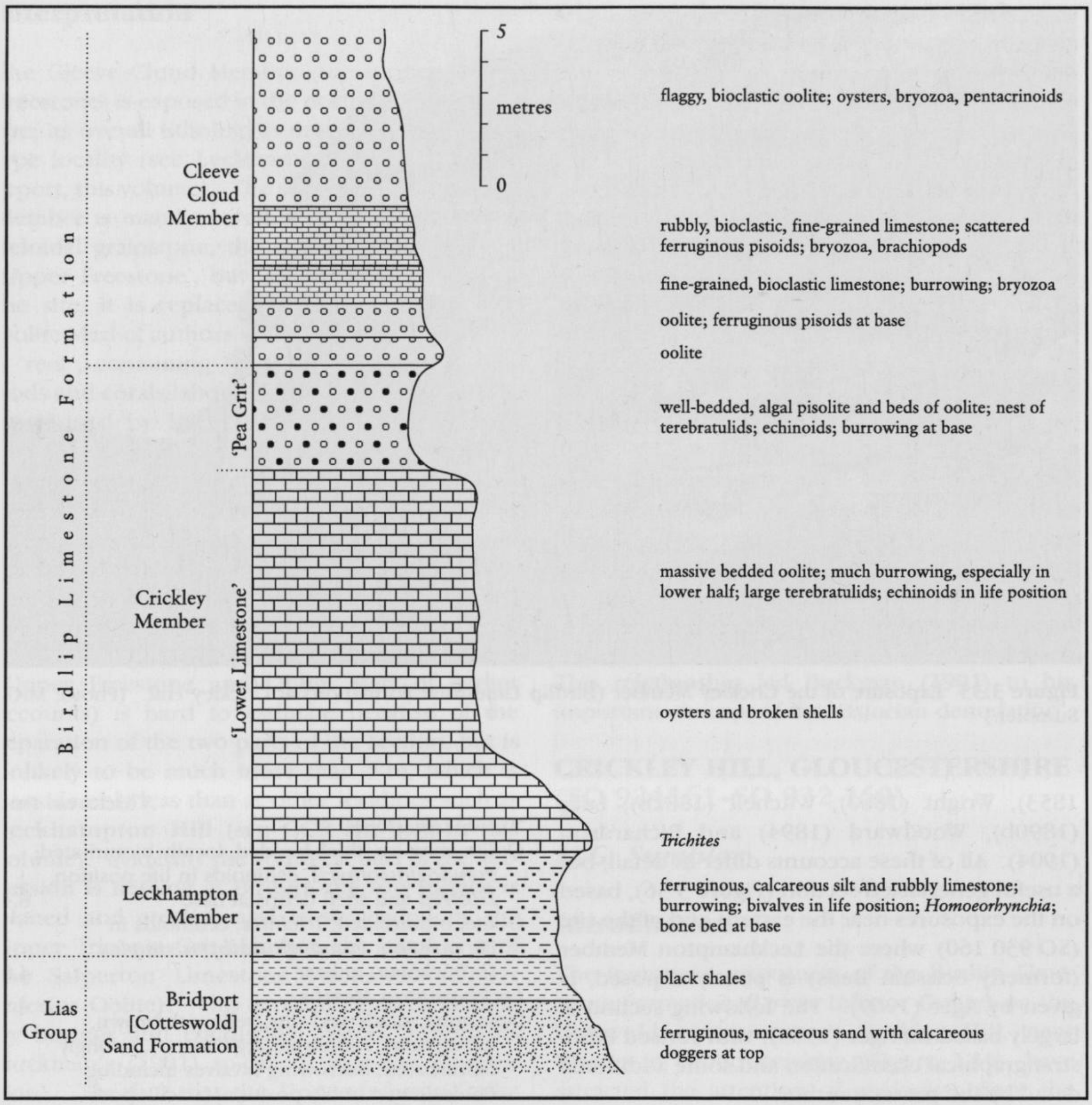


Figure 3.36 Graphic section of the strata exposed at Crickley Hill. (After Ager, 1969, fig. B14.) See text for detailed lithological description.

resulting from failure of the underlying mudstones and siltstones of the Lias Group, but the outcrops of bare rock have since been greatly accentuated by quarrying. The exposures at Crickley Hill constitute the type locality of the Crickley Member of the Birdlip Limestone Formation, although the actual bed-numbered measured section on which it is based (Mudge, 1978b) lies on the north-west side of Crickley Hill (SO 929 163), just outside the GCR site.

The Leckhampton Member, the basal unit of the Inferior Oolite Group throughout the north and mid-Cotswolds, rests non-sequentially on the Lias Group; Ager's (1969) 'bone bed' at the base probably includes reworked and phosphatized fossil material from the Bridport [Cotteswold] Sand Formation at the top of the Lias Group.

The upper part of the succeeding Crickley Member contains seams and beds of pisolite; this constitutes the 'Pea Grit' (or Crickley Oncolite of Mudge, 1978a), but the separation from the underlying 'Lower Limestone' (or Crickley Limestone of Mudge, 1978a) is rather indefinite as is evidenced by the variety of different thicknesses accorded to these units by different authors. It is for this reason that the units are now combined into the Crickley Member, which is dominated by well-bedded, medium- to coarse-grained, rather poorly sorted, ooidal and peloidal, bioturbated limestones (Barron *et al.*, 1997). The term 'Pea Grit Series' was used in the same sense by some authors (e.g. Arkell, 1933) although, as originally used by Wethered (1891), this term also included the beds of the Leckhampton Member.

The 'Pea Grit' is confined to a relatively small area of the Cotwolds near Cheltenham, stretching from a little south of Birdlip to Cleeve Hill. It is most impressively developed at Crickley Hill. The typical 'Pea Grit' is a pisoidal packstone, in which the pisoids ('pea-stones') are typically flattened ovoids of about 5–7 mm diameter (Figure 3.37). They comprise a shell-fragment nucleus surrounded by layers of micrite in which microscopic examination reveals tube structures, for example of carbonate-secreting algae or cyanobacteria such as *Girvanella* (Wethered, 1891). As such, the pisoids appear to be true oncoids, i.e. carbonate-coated grains formed largely as a result of microbial activity. The micrite layers are commonly assymmetrical about the nucleus, suggesting accretion on the upper surface of the grain, which was periodically flipped over, perhaps as a result of storm action. The combined presence in the 'Pea Grit' of a significant micromorphic fauna (Mudge, 1978a) and oncoids in a micrite matrix suggests accumulation in a shallow, generally quiet-water environment with a rich algal flora.

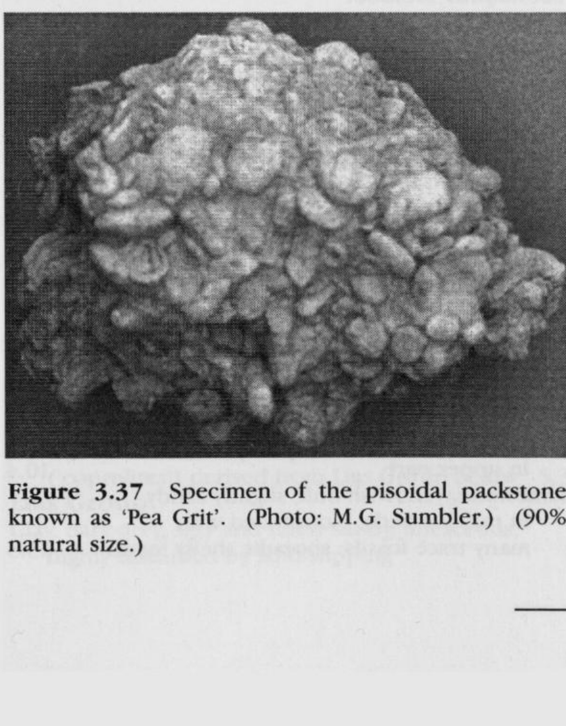


Figure 3.37 Specimen of the pisoidal packstone known as 'Pea Grit'. (Photo: M.G. Sumbler.) (90% natural size.)

In general, the dominant lithology of the succeeding Cleeve Cloud Member (formerly Lower Freestone) is cross-bedded oolite grainstone, as at **Leckhampton Hill** (see GCR site report, this volume). However, at Crickley Hill, this lithology is interbedded with lower-energy peloidal packstones. Mudge (1978a) termed this mixed facies, well seen towards the western end of the GCR site, the 'Fiddler's Elbow Limestone'. The lower part includes the so-called 'Crickley Coral Bed' of Lucy (1890b); this is a 3.3 m-thick detrital limestone containing debris of reworked corals such as *Montlivaltia*, *Isastrea* and *Thamnasteria* (Tomes, 1886; 1890). These may have been reworked from localized reefs growing on top of the 'Pea Grit' such as are known at several other localities, for example at Fiddler's Elbow (SO 887 142), about 5 km to the south-west of Crickley Hill (Channon, 1950), and near Cockleford (SO 979 140), about the same distance to the south-east (Sumbler *et al.*, 2000).

Conclusions

Crickley Hill exposes one of the best and most impressive sections of the lower part of the Birdlip Limestone Formation (Lower Inferior Oolite) in the Cotswolds, and is one of the few places where the base of the Inferior Oolite Group has been exposed. It is the type locality of the Crickley Member ('Lower Limestone' and 'Pea Grit' of previous authors). It is also noteworthy for the fine development of the 'Pea Grit', in the upper part of the member.

LECKHAMPTON HILL, GLOUCESTERSHIRE (SO 946 183–SO 952 187–SO 951 179)

M.G. Sumbler

Introduction

The extensive GCR site known as 'Leckhampton Hill' lies within the Leckhampton Hill and Charlton Kings Common SSSI, and includes all of the principal geological sections there. The quarries in the western face of the hill (Figure 3.38) provide the thickest single section through the Inferior Oolite Group in the Cotswolds and form the type section of the Birdlip Limestone Formation (Lower Inferior Oolite) (Figure 3.39).

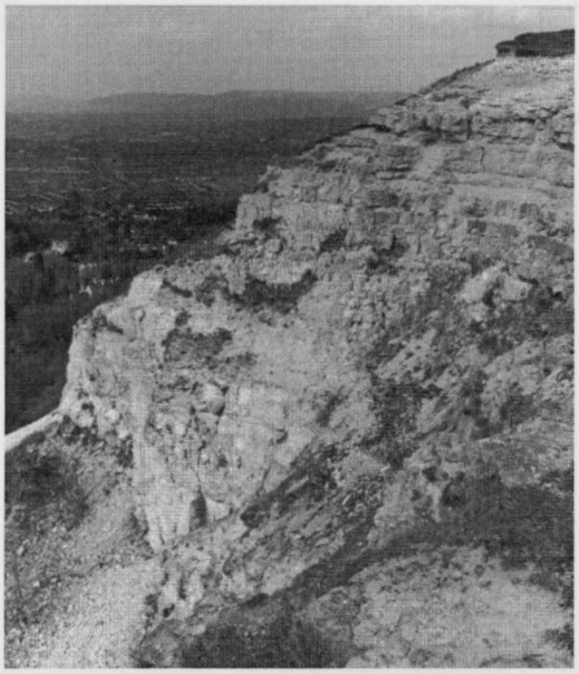


Figure 3.38 Birdlip Limestone Formation in the main face of Devil's Chimney Quarry (at the Leckhampton Hill GCR site) showing the Scottsquar Member ('Upper Freestone' and 'Oolite Marl') overlying the Cleeve Cloud Member. (Photo: M.G. Sumbler.)

When combined with the smaller quarries on the hilltop, they provide an almost complete section through the group, totalling over 50 m, with all of the component formations being represented. The sections at Leckhampton Hill have been described by numerous geologists from the time of Murchison (1834) (e.g. Brodie, 1851, 1853; Wright, 1860; Buckman, 1893a, 1895; Woodward, 1894; Richardson, 1904, 1906, 1933; Gray, 1924; Murray, 1968; Ager and Mudge, 1973; Murray and Hancock, 1977; Mudge, 1978a,b, 1995, and references therein). The accounts differ greatly in content and detail, and also in the thicknesses given for the various units exposed; these discrepancies relate both to differences of interpretation over the classification of the succession, and also the general difficulty of measuring some units in the steep and dangerous quarry faces.

Description

Particularly useful summary sections are given by Richardson (1906), Ager (1969) and Macfadyen (1970). The following is based largely on their accounts supplemented by data from the other sources cited above and personal observation. Some thicknesses (notably of the Gryphite Grit, Scottsquar and Cleeve Cloud members) remain slightly uncertain.

	Thickness (m)
Salperton Limestone Formation	
Upper Trigonia Grit Member	
Limestone, brown, ferruginous, irregularly bedded, shelly, bioclastic calcarenite; many fossils (mostly preserved as empty moulds) including *Trigonia costata* (Parkinson), *Liostrea*, *Trichites*, *Globirhynchia subobsoleta* (Davidson), *Nucleolites sinuatus* (Parkinson) and serpulids	1.6
Aston Limestone Formation	
Notgrove Member	
Limestone, pale-grey, ooidal grainstone, well bedded; oyster-encrusted top with abundant deeply penetrating worm-borings; sporadic disarticulated bivalves	0.6
Gryphite Grit Member	
Limestone, grey to brown; hard, bioclastic calcarenite, with some marly layers and bedding planes covered with *Gryphaea bilobata* J. de C. Sowerby in upper part; more sandy with *Lobothyris buckmani* (Davidson), burrowing bivalves, serpulids and oysters in lower part; bioclastic calcilutite at base	5.6
Lower Trigonia Grit Member	
Limestone, yellowish-brown, rubbly, bioturbated, bioclastic, 'iron-shot' (with ferruginous peloids), calcarenite; shelly with burrowing bivalves, colonial serpulids (*Sarcinella*), corals and the brachiopod *Aulacothyris meriani* (Oppel); conglomeratic in lower part (Macfadyen, 1970)	1.8
Birdlip Limestone Formation	
Harford Member	
Marl, yellowish-brown	0–0.46
Scottsquar Member	
'Upper Freestone'	
Limestone, pale-grey, well-bedded, poorly sorted, massive, peloidal and ooidal packstones and grainstones, shell debris and sporadic fossils; corals, bivalves and brachiopods including *Plectothyris fimbria* (J. Sowerby)	*c.* 7.5
'Oolite Marl'	
Limestone, cream to white marl and calcilutite with scattered ooids and peloids; rich and varied fauna of burrowing bivalves, brachiopods (notably *Plectothyris fimbria*), nerineid gastropods and corals	3.2
Cleeve Cloud Member	
Limestone, pale-grey, well-sorted, medium-grained, ooidal grainstone; poorly fossiliferous; strongly cross-bedded in upper part	10.4
Limestone, yellowish-buff, slightly sandy, in massive beds, bioturbated with many trace fossils; sporadic shelly fossils	13.3

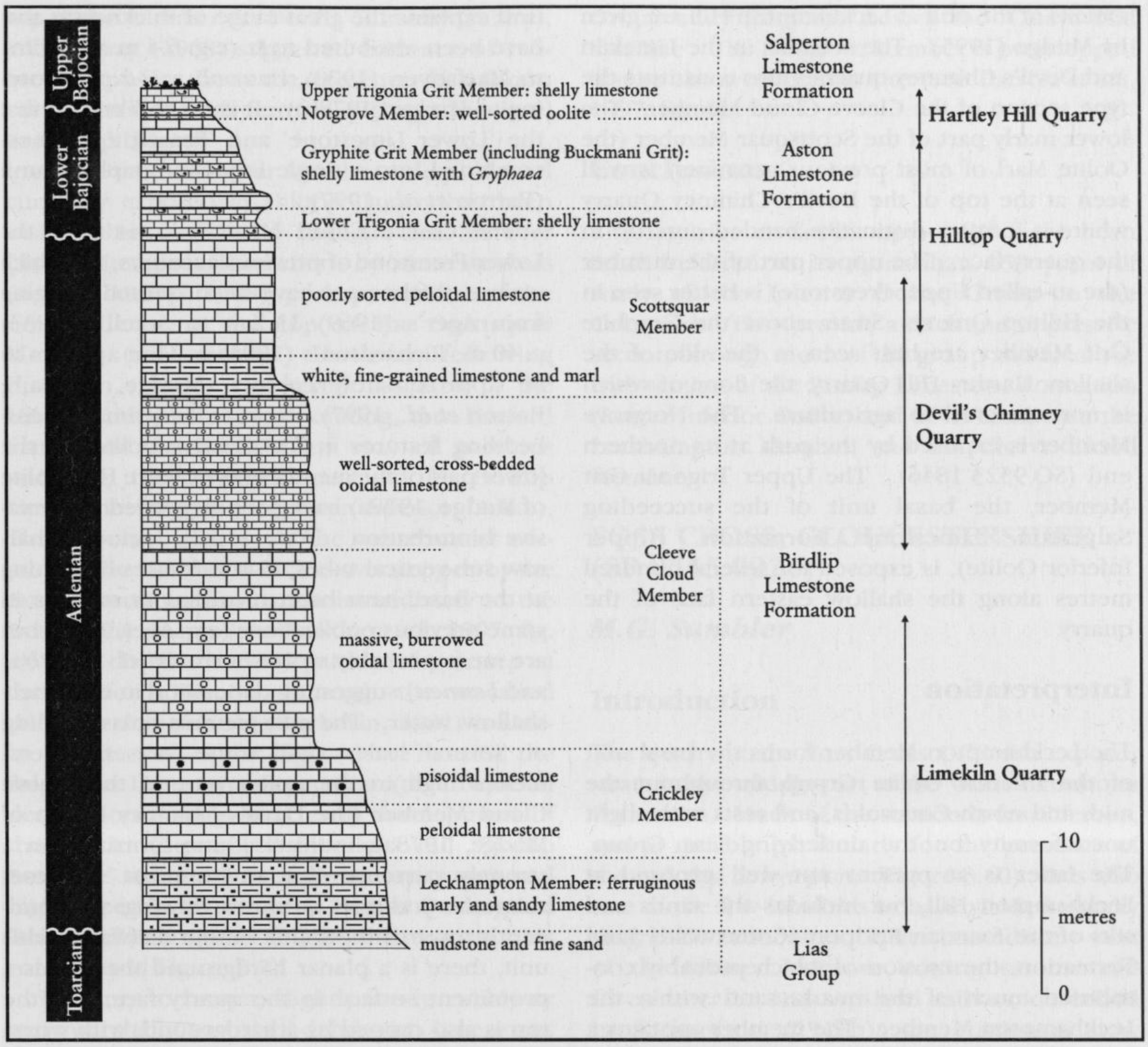


Figure 3.39 Graphic section of the succession at Leckhampton Hill. (After Ager, 1969, fig. B15; and Sumbler and Barron, 1996.) For details of lithologies, see text.

	Thickness (m)
Crickley Member	
Pea Grit	
Limestone, yellowish-buff, rubbly, pisoidal packstone; sporadic fossils including bivalves and brachiopods	3.7
'Lower Limestone'	
Limestone, yellowish-cream, shell-detrital, peloidal packstone, strongly bioturbated; sporadic pisoids in upper part	3.3
Leckhampton Member	
Limestone, yellowish to orange-brown, rubbly, ferruginous, bioclastic, sandy limestone with marly bands; many fossils including bivalves, brachiopods and belemnites; somewhat conglomeratic base with phosphatized material ('coprolites') derived from Lias Group below	5.3
Lias Group	
Clay, dark-grey, silty and finely sandy, micaceous, highly disturbed by land-slipping	?

The principal exposures occur at four sites named, following Sumbler and Barron (1996), the Limekiln Quarry (SO 949 285), Devil's Chimney Quarry (SO 946 184), Hilltop Quarry (SO 950 185) and Hartley Hill Quarry (SO 952 184). The stratigraphical ranges of these four sections are shown in Figure 3.39. The whole of the Birdlip Limestone Formation (Lower Inferior Oolite) is exposed in the conjoined Limekiln and Devil's Chimney quarries, which form the type section of the formation. The lowest strata at present (1996) exposed at Limekiln Quarry are rather 'dirty', ferruginous limestones belonging to the Leckhampton Member, of which this exposure forms the type section (Mudge, 1978a,b; Barron *et al.*, 1997).

Details of the unit at Leckhampton Hill are given by Mudge (1995). The sections in the Limekiln and Devil's Chimney quarries also constitute the type section of the Cleeve Cloud Member. The lower marly part of the Scottsquar Member (the Oolite Marl of most previous accounts) is well seen at the top of the Devil's Chimney Quarry where it forms a distinctive banded outcrop in the quarry face. The upper part of the member (the so-called Upper Freestone) is better seen in the Hilltop Quarry. Strata above the Gryphite Grit Member are best seen in the side of the shallow Hartley Hill Quarry, the floor of which is now restored to agriculture. The Notgrove Member is exposed by the path at its northern end (SO 9523 1846). The Upper Trigonia Grit Member, the basal unit of the succeeding Salperton Limestone Formation (Upper Inferior Oolite), is exposed for several hundred metres along the shallow eastern face of the quarry.

Interpretation

The Leckhampton Member forms the basal unit of the Inferior Oolite Group throughout the mid- and north Cotswolds, and rests with slight unconformity on the underlying Lias Group. The latter is at present not well exposed at Leckhampton Hill, but includes the sands and silts of the Toarcian Bridport [Cotteswold] Sand Formation, the erosion of which probably contributed much of the quartz sand within the Leckhampton Member. The member contains a typical Mid Jurassic shelly fauna which includes sporadic ammonites, notably *Leioceras*, the index genus for the early Aalenian Opalinum Zone. These strata correspond essentially with the former Scissum Beds, named from the ammonite *Tmetoceras scissum* (Benecke), although some workers (e.g. Richardson, 1906) assigned the upper part of this unit at Leckhampton Hill to the succeeding Lower Limestone.

The overlying Crickley Member comprises the Lower Limestone and Pea Grit of previous accounts (approximating to the Crickley Limestone and Crickley Oncolite of Mudge, 1978a,b). Algally accreted pisoids occur throughout much of the succession, but most abundantly in the uppermost part. These pisoids are the characteristic feature of the 'Pea Grit' (see **Crickley Hill** GCR site report, this volume), and the rather indefinite base of that unit explains the great range of thicknesses that have been attributed to it (e.g. 6.4 m according to Macfadyen (1970), but only *c*. 2.2 m according to Mudge (1978b)). It is for this reason that the 'Lower Limestone' and 'Pea Grit' are now combined into a single lithostratigraphical unit (Barron *et al*., 1997).

The Cleeve Cloud Member constitutes the Lower Freestone of previous accounts, for which various thicknesses have been quoted, ranging from Ager's (1969) 13.2 m to Arkell's (1933) *c*. 40 m; Richardson's (1906) *c*. 24 m appears to be approximately correct (Mudge, 1978a,b; Barron *et al*., 1997). Most of the primary cross-bedding features in the massive oolites of the lower part of the member (the Cleeve Hill Oolite of Mudge, 1978a) have been destroyed by pervasive bioturbation. Trace fossils, including narrow sub-vertical tubes, in some cases branching at the base, have been recorded as rootlets in some previous publications (e.g. Ager, 1969) but are more probably worm burrows (cf. *Skolithos* and *Lennea*) suggesting deposition in extremely shallow water. The conspicuous cross-bedding on several scales, with some foresets several metres high in the upper part of the Cleeve Cloud Member (the Devil's Chimney Oolite of Mudge, 1978a), indicates dune formation in a strongly current-swept environment. Foreset azimuths indicate currents flowing predominantly towards the south. About halfway up this unit, there is a planar hardground that forms a prominent surface in the quarry face, and the top is also capped by a hardground, with worm and bivalve borings and encrusting serpulid tubes and oysters. Such hardgrounds indicate stabilization and early lithification of the sea floor.

Within the Scottsquar Member, the boundary between the Oolite Marl and Upper Freestone is somewhat arbitrary, and the succession is laterally very variable; thicknesses ranging from 1.8 m to 5.2 m have been quoted for the Oolite Marl. Indeed, the massive peloidal and ooidal packstones and grainstones of the Upper Freestone seen in Hilltop Quarry were included in the Oolite Marl *sensu* Baker, 1981. Regionally, the two units cannot be consistently separated and for this reason are now combined (Mudge, 1978a; Baker, 1981; Barron *et al*., 1997). The facies and fauna of the Scottsquar Member are discussed in detail by Mudge (1978a, 1995) and Baker (1981). Mudge (1978a,b) recorded a bored and oyster-encrusted hardground at the top of the member (in Devil's Chimney Quarry), and Murray (1968) suggested evidence of sub-aerial exposure from the presence of solution cavities infilled with ferroan calcite at this level in Hilltop Quarry.

Above the Scottsquar Member, a lens of marl currently exposed in Hilltop Quarry has been assigned to the Lower Trigonia Grit Member (Aston Limestone Formation) by some workers (notably Murray, 1968), perhaps because of the non-sequence at the top of the Scottsquar Member (see above). However, following Buckman (1895), it is herein assigned to the Harford Member (incorporating the Harford Sands and Snowshill Clay, etc., of previous authors), the youngest part of the Birdlip Limestone Formation (Lower Inferior Oolite). This exposure represents the westernmost outcrop of the member, which is overstepped by the Aston Limestone Formation immediately to the west of the quarry (see Barron *et al.*, 1997, fig. 4). The distribution and pattern of overstep of the Harford Member beneath the so-called 'Aalenian denudation' (Buckman, 1901) is similar to that seen at the higher level beneath the Salperton Limestone Formation (the 'Bajocian denudation'), suggesting early development of the gentle 'Cleeve Hill Syncline' and 'Birdlip Anticline' structures as sedimentary trough and high respectively (see **Knap House Quarry** and **Rolling Bank Quarry** GCR site reports, this volume, and Figure 3.2).

The grey to brown, slightly sandy, rubbly or massive, shelly and shell-debris-rich limestones that are the predominant lithology of the Aston Limestone Formation (Middle Inferior Oolite) are traditionally known as 'grits'. They rest on the Harford Member, or where this is absent, the Scottsquar Member. Richardson (1906) recorded ammonites 'of the *Sonninia fissilobata* type' from the Gryphite Grit Member, the sandier lower part of which (no longer well exposed), with the brachiopod *Lobothyris buckmani*, was previously separated as the Buckmani Grit.

Fossils are generally rare in the overlying Notgrove Member, which is locally the youngest member of the Aston Limestone Formation, but Richardson (1906) recorded poorly preserved casts of sonniniid ammonites. The member is capped by a well-developed hardground, which marks the 'Bajocian denudation' of Buckman (1901), and an erosional non-sequence that progressively cuts through the Inferior Oolite Group away from the axis of the 'Cleeve Hill Syncline'. The Notgrove Member is overstepped just to the west of this site (see Barron *et al.*, 1997, fig. 4).

Conclusions

The quarries at Leckhampton Hill have been much referred to in more than 150 years of study of the Inferior Oolite Group in the Cotswolds. They provide a thick and impressive section through much of the group and form the type section of the Birdlip Limestone Formation (Lower Inferior Oolite) and of its basal unit, the Leckhampton Member, and the Cleeve Cloud Member.

FOSS CROSS, GLOUCESTERSHIRE (SP 0555 0927)

M.G. Sumbler

Introduction

The quarry at the Foss Cross GCR site exposes strata in the middle part of the White Limestone Formation. Much of the section is fossiliferous, and is notable particularly for the presence of the red alga *Solenopora* (Figure 3.40). It is also one of the few localities to have yielded zonally diagnostic ammonites. It lies immediately west of the former Aldgrove cutting on the old Cirencester to Andoversford railway, described by Richardson (1911b); the cutting is now largely infilled, but the present section in the quarry can be readily correlated with Richardson's published section. The site lies approximately 1.5 km south-west of **Stony Furlong Railway Cutting** (see GCR site report, this volume), also described by Richardson (1911b), where current exposures show strata at the same stratigraphical level as those at Foss Cross.

Description

Although most of the quarry at Foss Cross is now infilled by tipping, the face constituting the GCR site is preserved in the centre of the tipped area (Figures 3.41 and 3.42). The following section is taken mainly from Sumbler (1995). The fauna listed is mostly held in BGS collections; additional information is given by Torrens (1969d) and Barker (1976).

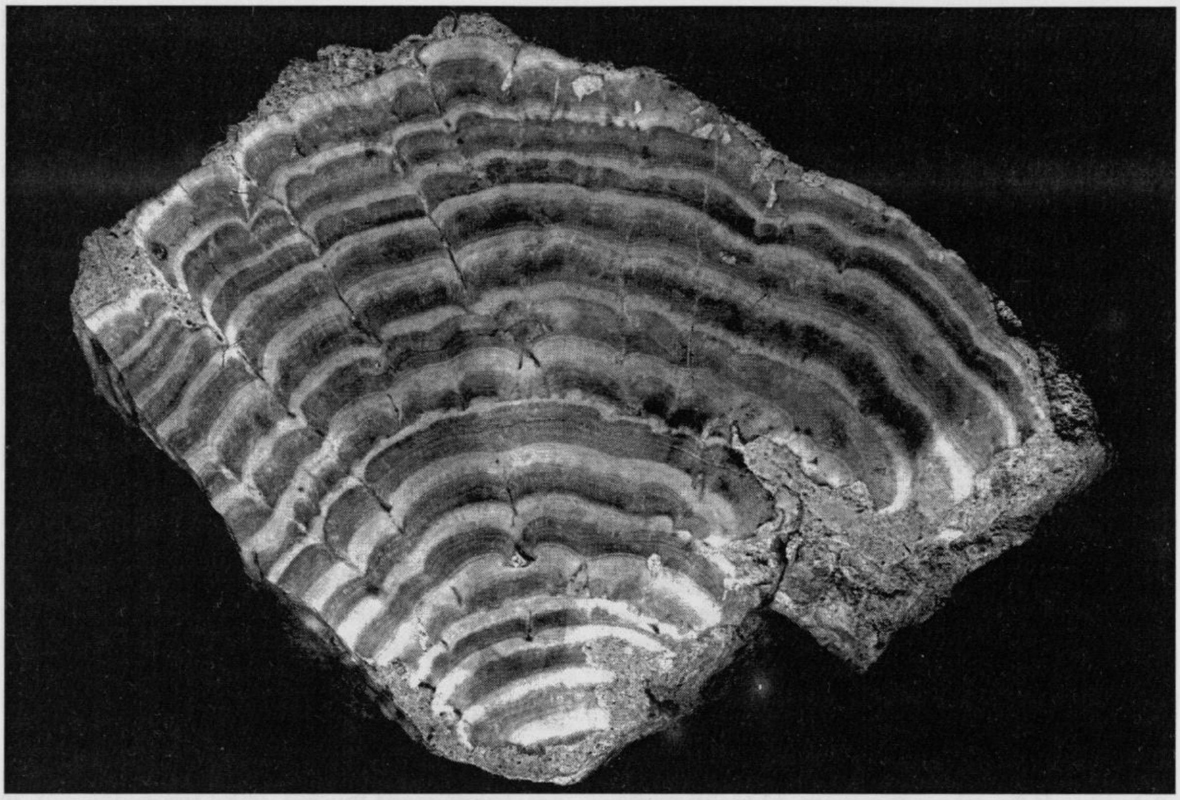


Figure 3.40 *Solenopora jurassica* Brown; BGS specimen No. GSM 119600, reproduced at *c*. 70% natural size. (Photo: M.G. Sumbler.)

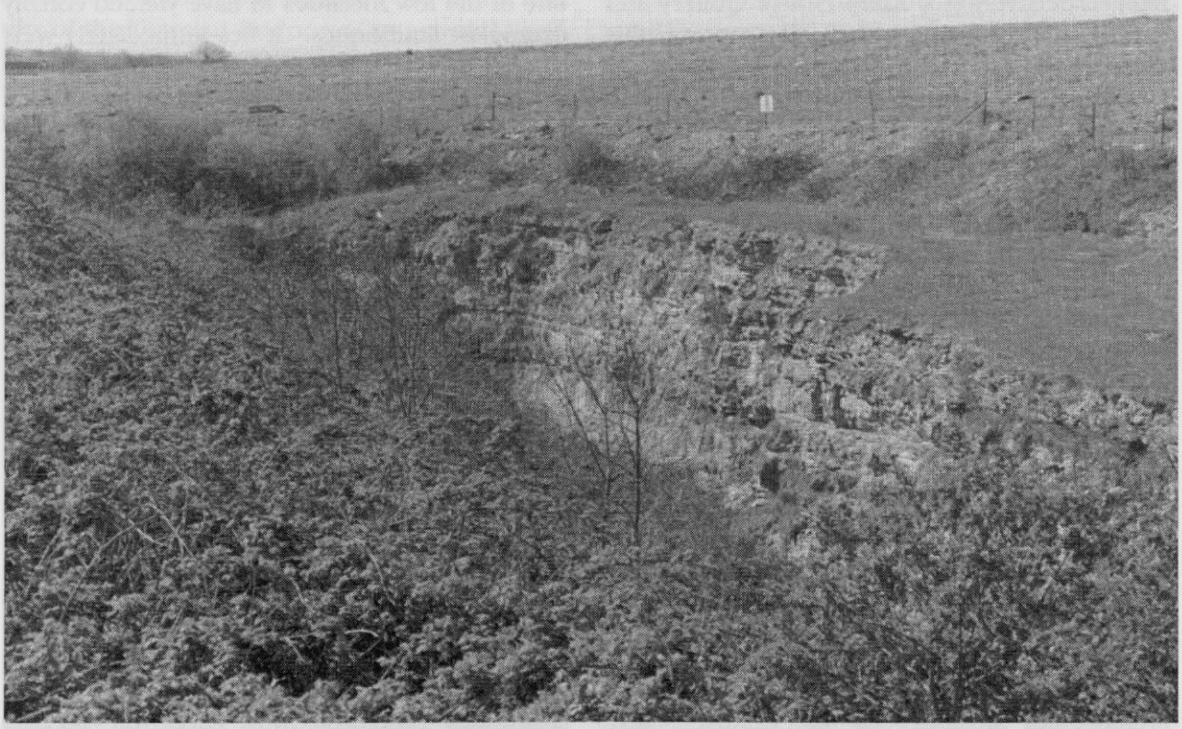


Figure 3.41 Exposure of the White Limestone Formation in the quarry at Foss Cross. (Photo: M.G. Sumbler.)

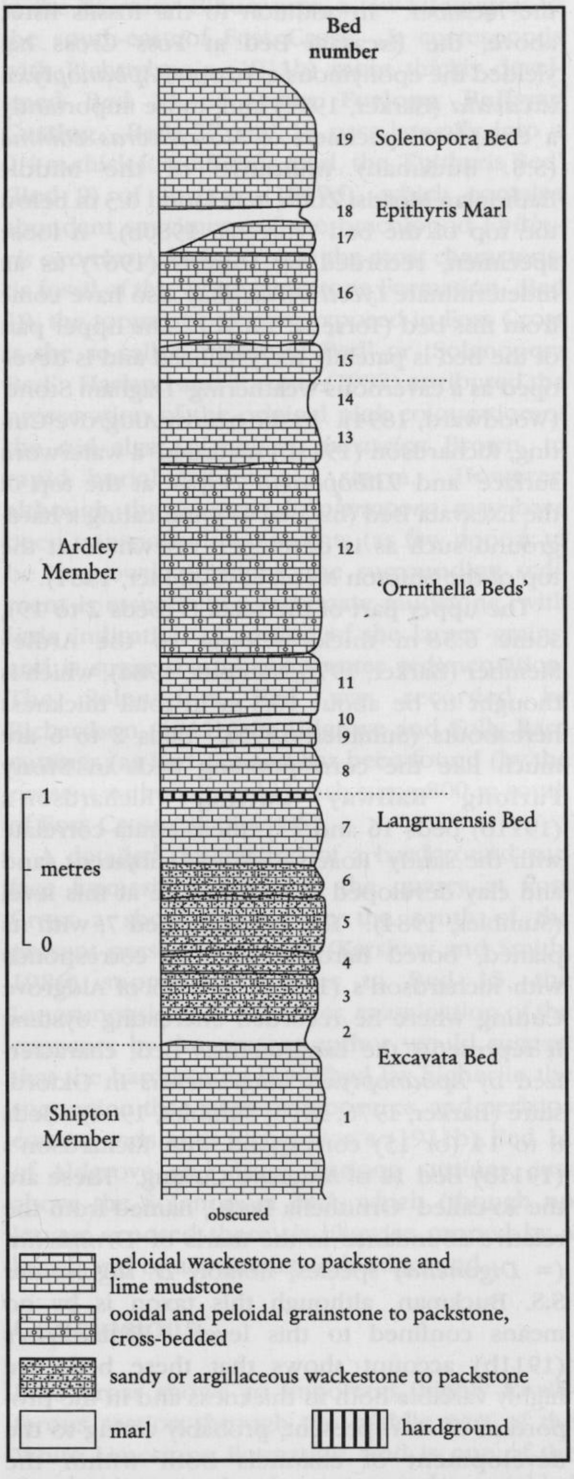


Figure 3.42 Graphic section of the White Limestone Formation in the quarry at Foss Cross.

	Thickness (m)
White Limestone Formation	
Ardley Member	
19: *Solenopora Bed*: Limestone, white to buff, rubbly, wackestone with scattered yellow peloids more abundant towards base; occasional large bivalves and pink/white-banded algal masses; *Solenopora jurassica* Brown, ramose coral fragments, bryozoan fragments, *Avonothyris*?, *Digonella digonoides* S.S. Buckman, *Epithyris oxonica* Arkell, *Kallirhynchia* sp., *Plagiostoma subcardiiformis* (Greppin), *Stiphrothyris capillata* Arkell	0.95
18: Marl, fawn with occasional bivalves; *Kallirhynchia* sp., *Epithyris oxonica* Arkell, *Lopha* sp., *Plagiostoma subcardiiformis* (Greppin)	0.08
17: Limestone ('Dagham Stone'); brown, recrystallized wackestone with scattered peloids, becoming softer and marly towards base; uneven top	0.22
16: Limestone, white to buff, well-sorted, cross-bedded, ooidal grainstone, flaggy weathering with harder recrystallized shell concentrations in basal 0.3 m	0.60
15: Limestone, white to brown, hard, recrystallized wackestone, with abundant large yellow peloids; forming prominent bed in the face	0.25
14: Marl, pale-grey and buff banded, with abundant peloids and shell fragments; sporadic oysters, brachiopods and limestone concretions; *Chomatoseris* sp., *Kallirhynchia* spp. including forms comparable with S.S. Buckman's *dromio*, *obtusa* and *oxoniensis*, *Digonella digonoides* S.S. Buckman, *Epithyris oxonica* Arkell, *Stiphrothyris* cf. *capillata* Arkell, *Anisocardia* sp., *Camptonectes* (*Camptonectes*) *laminatus* (J. Sowerby), *C.* (*Radulopecten*) *vagans* (J. de C. Sowerby), *Ceratomya striata* (J. Sowerby), *Corbula hulliana* Morris, *Limatula* sp., *Liostrea* cf. *undosa* (Phillips), *Lopha gregarea* (J. Sowerby), *Pholadomya lirata* (J. Sowerby), *Plagiostoma* sp., *Pleuromya*?, *Tancredia*?; nerineid gastropod	0.25
13: Limestone, white to brown, wackestone with scattered peloids becoming more abundant in parts, and grading to packstone or grainstone; sporadic pods with abundant bivalves and gastropods; highly burrowed top with marl-filled burrows; *Epithyris* sp., *Clypeus* sp., ostreid fragments, *Plagiostoma subcardiiformis* (Greppin), *Eunerinea eudesii*? (Morris and Lycett), *Fibuloptyxis* cf. *witchelli* (Cox and Arkell), *Globularia* sp.	0.30
12: Limestone, buff, soft, poorly sorted, peloidal and ooidal packstone to grainstone; cross-bedded in parts; several thin partings of grey marl, including one at base	1.30
11: Limestone, buff, poorly sorted, peloidal packstone; locally a poorly developed 'Dagham Stone'	0.40
10: Marl, buff	0.05
9: Limestone, brown, hard, wackestone with scattered peloids	0.15
8: Limestone, buff and white mottled wackestone with scattered peloids; persistent marl parting for 0.01 m at base	0.33

	Thickness (m)
7: Limestone, upper part a hard, recrystallized burrowed 'Dagham Stone' with sharp, bored hardground top surface cutting across fossils; passing down into softer, grey, lime mudstone; *Chomatoseris* sp., corals, echinoid fragments, *Camptonectes* sp., *Costigervillia crassicosta* (Morris and Lycett), *Falcimytilus sublaevis* (J. de C. Sowerby), *Inoperna* sp., *Liostrea* cf. *undosa* (Phillips), *Liostrea* sp., *Lopha* sp., *Lucina bellona* d'Orbigny, *Isognomon (Mytiloperna) bathonicus* (Morris and Lycett), *Modiolus imbricatus* J. Sowerby, *Pholadomya lirata* (J. Sowerby), *Plagiostoma cardiiformis* J. Sowerby, *P. subcardiiformis* (Greppin), *Pleuromya* sp., *Protocardia* sp., *Pteroperna* sp., *Quenstedtia* sp., *Trigonia* sp., nerineid and nerinellid gastropods including *Aphanoptyxis*?, *Bactroptyxis implicata* (d'Orbigny), *Eunerinea arduennensis* (Buvignier), *E. eudesii* (Morris and Lycett) and *Fibuloptyxis witchelli* (Cox and Arkell)	0.48
6: Limestone, grey to brown, soft, crumbly, slightly bituminous, peloidal wackestone; locally marly at base	0.20
5: Limestone, grey, hard, splintery, peloidal and shell-fragmental, slightly sandy wackestone to packstone; prominent bed in face	0.37
4: Limestone, greyish-brown, argillaceous, bituminous, soft and crumbly, with rippled laminae of clay	0.15
3: Limestone, peloidal and shell-fragmental, sandy wackestone to packstone, with grainstone patches; locally fairly hard and recrystallized	0.33
2: Marl, grey to white banded, sandy and ooidal	0.17
Shipton Member	
1: Limestone, white and cream with buff mottles, massive to rubbly; very sparsely peloidal wackestone with abundant fossils, mainly bivalves and corals; intensively bioturbated; topmost 0.3 m to 0.5 m hard and recrystallized, and upper 0.2 m a good 'Dagham Stone' with soft marl-filled burrows; *Chomatoseris porpites* (Wm Smith), *Montlivaltia* sp., thecosmiliid coral, *Anisocardia*?, *Camptonectes* sp., *Isocyprina* sp., *Lucina bellona* d'Orbigny, *Pleuromya*?, *Protocardia stricklandi* (Morris and Lycett), *Pterocardia pesbovis* (d'Archiac), *Trigonia*?, *Eunerinea* sp., *Fibuloptyxis witchelli* (Cox and Arkell), *Globularia* cf. *formosa* (Morris and Lycett), trochid and other gastropod fragments; lower part now obscured	max. seen 1.90

Interpretation

The basal 1.9 m of the section (Bed 1) are assigned to the Shipton Member (Barker, 1976; Sumbler, 1984). The lower, highly fossiliferous part of Bed 1 corresponds with the so-called '*Lucina* Beds' (Bed 19) of Richardson's (1911b) section of **Stony Furlong Railway Cutting** (see GCR site report, this volume). This unit passes upwards into the Excavata Bed (Barker, 1976, 1994; Sumbler, 1984), which marks the top of the member. In addition to the fossils listed above, the Excavata Bed at Foss Cross has yielded the eponymous gastropod *Aphanoptyxis excavata* (Barker, 1976) and, more importantly, a complete specimen of *Morrisiceras comma* (S.S. Buckman) indicative of the Middle Bathonian Morrisi Zone, was found 0.3 m below the top of the bed (Torrens, 1980b). A loose specimen, recorded by Torrens (1967) as an indeterminate *Lycetticeras*, may also have come from this bed (Torrens, 1969e). The upper part of the bed is patchily recrystallized and is developed as a cavernous-weathering 'Dagham Stone' (Woodward, 1894). In the nearby Aldgrove Cutting, Richardson (1911b) recorded 'a waterworn surface' and '*Lithophagus* crypts' at the top of the Excavata Bed (his Bed 17), indicating a hardground such as is developed elsewhere at the top of the Shipton Member (Sumbler, 1984).

The upper part of the section (beds 2 to 19), some 6.58 m thick, belongs to the Ardley Member (Barker, 1976; Sumbler, 1984), which is thought to be about 10.5 m in total thickness hereabouts (Sumbler, 1995). Beds 2 to 6 are much like the corresponding beds in **Stony Furlong Railway Cutting** (Richardson's (1911b) beds 16 and 17); these strata correlate with the sandy 'Roach Bed' and subjacent sand and clay developed in Oxfordshire at this level (Sumbler, 1984). The overlying Bed 7, with its planed, bored hardground top, corresponds with Richardson's (1911b) Bed 15 of Aldgrove Cutting where he recorded encrusting oysters. It represents the Langrunensis Bed, characterized by *Aphanoptyxis langrunensis* in Oxfordshire (Barker, 1976, 1994; Sumbler, 1984). Beds 8 to 14 (or 15) correspond with Richardson's (1911b) Bed 14 of Aldgrove Cutting. These are the so-called 'Ornithella Beds', named from the relative abundance in the marls of '*Ornithella*' (= *Digonella*) species, notably *D. digonoides* S.S. Buckman, although this taxon is by no means confined to this level. Richardson's (1911b) account shows that these beds are highly variable both in thickness and in the proportion of marl present, probably owing to the development of channels both within the 'Ornithella Beds' and above (see Torrens, 1969d; and **Stony Furlong Railway Cutting** GCR site report, this volume).

The cross-bedded, flaggy-weathering oolite of Bed 16 is the typical lithology of the middle and upper parts of the Ardley Member; such beds were formerly quarried and mined for freestone in the Barnsley–Bibury area, a few kilometres to the south-east of Foss Cross. It corresponds with Richardson's (1911b) more thickly developed Bed 13 of **Stony Furlong Railway Cutting**. Beds 17 and 18 pass laterally into a 0.4 m-thick fossiliferous marl, the 'Epithyris Bed' (Bed 9) of Torrens (1969d), which contains abundant specimens of the brachiopod *Epithyris oxonica* Arkell, perhaps the most characteristic fossil of the White Limestone Formation. Bed 19, the topmost bed now exposed in Foss Cross is the so-called 'Beetroot Bed' or 'Solenopora Bed'. Harland and Torrens (1982) attributed the preservation of the original pink colouration of the red alga *Solenopora jurassica* Brown, to rapid burial following a storm. However, although the masses of *Solenopora* may have been transported by currents (as few appear to be in growth position), the surrounding sediment is essentially a carbonate mudstone, with little indication of sorting of the larger grains, and is suggestive of quiet-water sedimentation. The Solenopora Bed was recorded by Richardson (1911b) in Aldgrove and Folly Barn cuttings (as Bed 12) and has been found (by the present author) in field brash some 800 m south of Foss Cross (SP 054 085).

A detailed description of a hardground surface formerly exposed in the quarry at Foss Cross a short distance to the south of the present preserved section (Kershaw and Smith, 1986) supposedly relates to Bed 15, the Langrunensis Bed. However, examination of the exposure by the present author would suggest that the hardground described lay higher in the succession than present exposures, and perhaps corresponds with Richardson's (1911b) Bed 11 of Aldgrove and Stony Furlong cuttings, just above the Solenopora Bed, which (though no longer exposed there) is likewise capped by a bored and oyster-encrusted hardground.

Conclusions

Foss Cross shows an important, highly fossiliferous section through the middle part of the White Limestone Formation, and is one of the few localities in that formation to have yielded zonally diagnostic Bathonian ammonites. Its proximity to **Stony Furlong Railway Cutting** (see GCR site report, this volume), where many of the same beds are exposed, allows pertinent comparisons and contrasts to be drawn, giving much information on palaeoenvironments in the seas fringing the London Landmass in mid Bathonian times.

STONY FURLONG RAILWAY CUTTING, GLOUCESTERSHIRE (SP 0605 1091–SP 0635 1027)

M.G. Sumbler

Introduction

The GCR site known as 'Stony Furlong Railway Cutting' exhibits an important section through the middle and lower part of the White Limestone Formation and formerly exposed strata of the underlying Hampen Formation. The section was first described during its construction by Harker (1892) and, later, by Richardson (1911b), in an influential paper that has been widely quoted by subsequent authors. The cutting (Figure 3.43), on the old Cirencester to Andoversford railway, which was closed in the

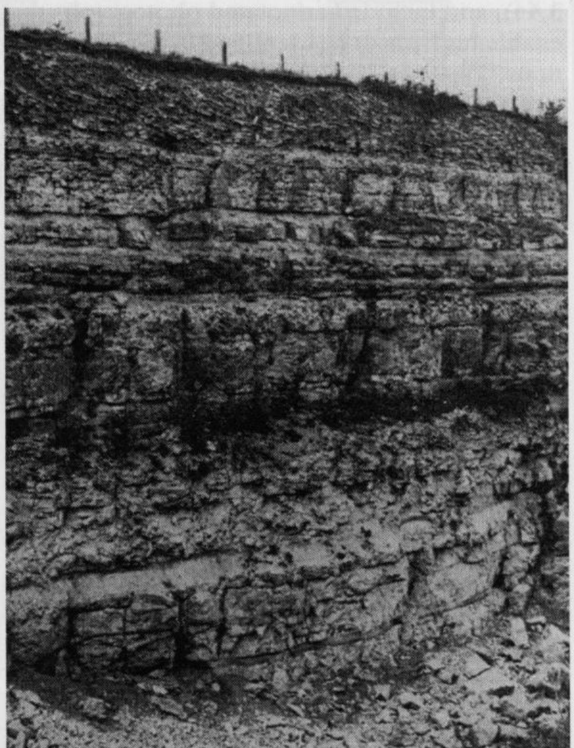


Figure 3.43 Exposure of White Limestone Formation (beds 13 (top) to 28 (bottom)) in Stony Furlong Railway Cutting. (Photo: British Geological Survey, No. A5758, 1929.)

1960s, lies immediately south of Chedworth village. Originally 1 km in length, it is crossed by a bridge (SP 0628 1063) that carries the minor road from the A429 Foss Way to Chedworth. That part of the cutting beneath and immediately to the north of the bridge is infilled, as is the north-western end of the cutting. The open cutting between forms the northern half of the GCR site, but exposures are unimpressive. However, the section to the south of the bridge, forming the southern half of the GCR site, still affords exposures showing much of the upper part of Richardson's (1911b) section, including the strata at the junction between the Shipton and Ardley members of the White Limestone Formation. The cutting is situated only 1.5 km from **Foss Cross** (see GCR site report, this volume) which also exposes these beds, allowing the possibility of interesting comparisons between the two sections.

Description

Richardson (1911b) described some 30 m of strata at Stony Furlong Railway Cutting (Figure 3.44), and included annotated photographs that enable his beds to be identified in the extant sections. His later graphic composite section of the Great Oolite Group exposed in the cuttings along the Cirencester to Andoversford railway (Richardson, 1933, fig. 2) is compromised by some probable errors in correlation between the different sections (Sumbler, 1995; Sumbler and Barron, 1995). In the following account, Richardson's bed numbers, starting from 8 at the top to 36 at the bottom, are used throughout.

According to Richardson (1911b), beds ?8 to 28 were visible in the southern and deepest part of the Stony Furlong Railway Cutting, south of the road bridge, and underlying strata were not seen until considerably farther to the north-west, near a second bridge (SP 0594 1101) that carried a trackway over the railway in a part of the cutting that is now infilled, outside the GCR site. There, the so-called 'Organic Band' (Bed 33) was exposed close to the south-western pier of the bridge. This unit, a brown clay rich in *Praeexogyra hebridica* Forbes (= *Ostrea sowerbyi* of Richardson, 1911b, 1933) is here classified as the topmost bed of the Hampen Formation. Underlying beds of that formation (beds 34 to 36) were described as marls and 'oolitic' limestones. Above the Hampen Formation, beds 32 to 28 of the White Limestone Formation (no longer exposed) are mainly peloidal limestones with some marl bands. Beds 13 to 28 were exposed in a deep 'gully' used as a quarry, on the western side of the railway, just to the south of the road bridge (Richardson, 1911b, pl. 18). A moderately good, though rather dangerous and partly inaccessible, section can still be seen at this point (SP 0628 1058); it shows some 8.5 m of strata extending from the upper part of Bed 21 up to Bed 13. The section (measured by the present author in 1994) is as follows.

	Thickness (m)
Topsoil, passing down into	
White Limestone Formation	
Ardley Member	
13c: Limestone, flaggy, thin-bedded, ?cross-bedded; inaccessible but presumed ooidal grainstone	1.2
14: Limestone, yellow-buff, poorly sorted, medium-grained, ooidal and peloidal packstone to grainstone, poorly bedded, in courses 0.05 m to 0.15 m thick, with occasional signs of cross-bedding	2.3
?14 (part): Marl, buff, laminated with nodular limestone midway	0.12
15: Limestone, cream, very coarse, peloidal and ooidal packstone to grainstone; signs of cross-bedding; hard, prominent bed	0.22
16: Marl to marly limestone, somewhat fissile, sandy, ooidal	0.25
17: Limestone, buff-cream, soft, poorly sorted, fine-grained, peloidal packstone, poorly bedded with softer yellowish, crumbly, fissile, somewhat sandy seams for 0.05 m to 0.08 m at base, and 0.65 m and 0.90 m above base	1.35
Shipton Member	
18 (part): Limestone, pink-fawn, very hard, recrystallized, splintery, uniform micrite; marl parting at base	0.15
18 (part): Limestone, buff, massive, poorly sorted, peloidal packstone; occasional corals; marl parting at base	0.50
19 (part): Limestone, buff, poorly sorted, peloidal packstone; very massive, raggy fracture, but weathering slightly cavernous (?burrows) in top 0.2 m	1.20
19 (part): Limestone, cream, very fine-grained, well-sorted, ooidal grainstone; rare small bivalves; massive, uniform, marly parting near base	0.24
19a: Silt, brown, marly	0.04
20: Limestone, cream to pale-fawn, with some ferruginous mottles; hard, recrystallized micrite or very fine-grained, recrystallized grainstone to packstone; massive, structureless, raggy fracture; burrows, but no obvious fauna	0.60
21: Marl, brown, fawn, slightly sandy, becoming hard and indurated at top; lower 5.6 m obscured to base of cutting	5.9+

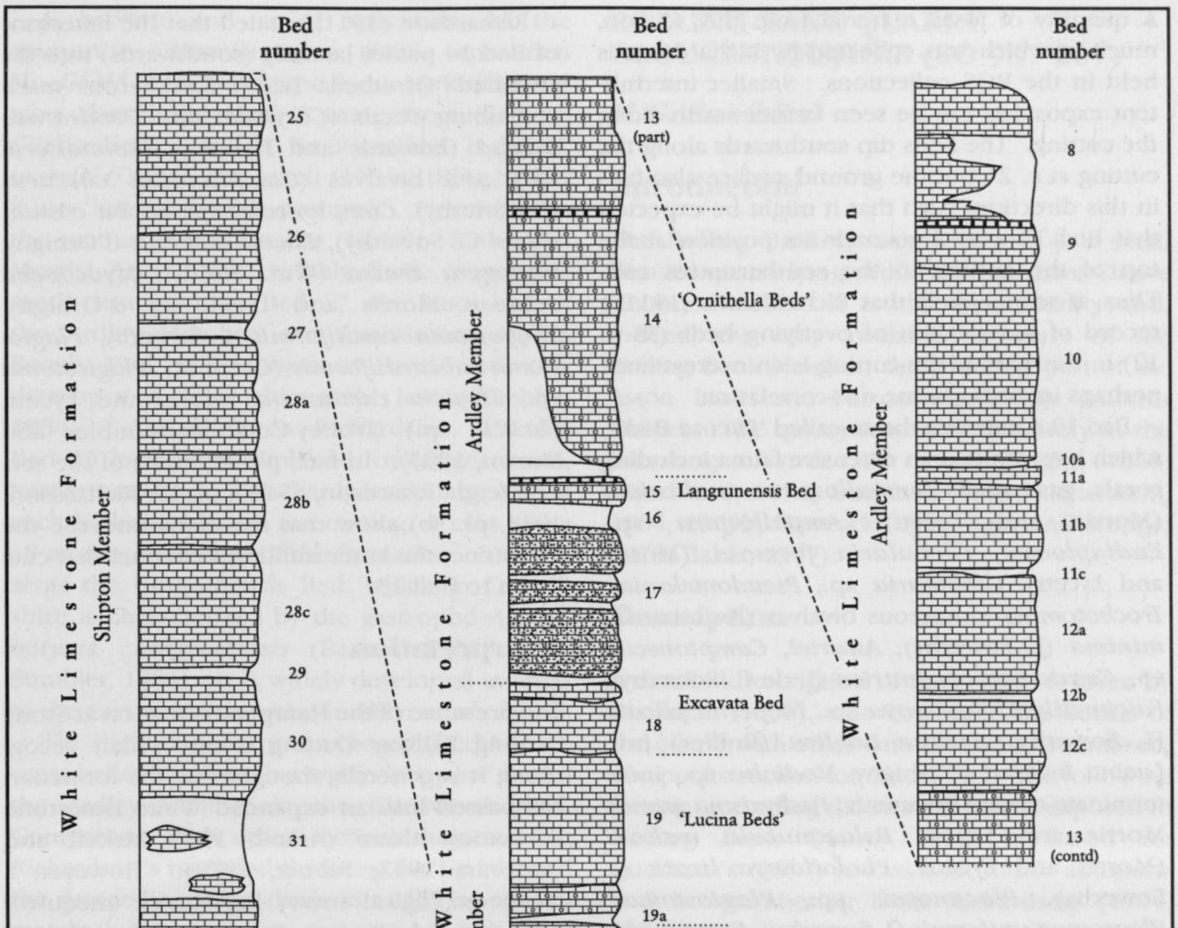


Figure 3.44 Graphic section of the Bathonian succession in Stony Furlong Railway Cutting. Beds 13–21 are as exposed in the extant section described in the text; the remainder is based on Richardson (1911b).

A quantity of fossil material from this section, much of which was collected by Richardson, is held in the BGS collections. Smaller intermittent exposures can be seen farther south along the cutting. The beds dip southwards along the cutting at *c.* 2°, but the ground surface also falls in this direction, such that it might be expected that Bed 13 would maintain its position at the top of the cutting to the southernmost end. Thus, it seems likely that Richardson's (1911b) record of some 6.3 m of overlying beds (?8 to 12) in this part of the cutting is an overestimate perhaps involving some mis-correlation.

Bed 19 comprises the so-called '*Lucina* Beds', which have yielded an extensive fauna including corals, gastropods (*Ampullospira canaliculata* (Morris and Lycett), *Ampullospira* sp., *Endiaplocus*?, *Globularia formosa* (Morris and Lycett), *Globularia* sp., *Pseudomelania*?, *Trochotoma*?), numerous bivalves (*Anisocardia minima* (J. Sowerby), *Astarte*?, *Camptonectes* sp., *Ceratomya concentrica* (J. de C. Sowerby), *Falcimytilus*?, *Homomya* sp., *Inoperna plicata* (J. Sowerby), *Lucina anglica* (Rollier) juv., *Lucina bellona* d'Orbigny, *Modiolus* sp., indeterminate ostreid fragments, *Pachyrisma grande* Morris and Lycett, *Palaeonucula waltoni* (Morris and Lycett), *Pholadomya lirata* (J. Sowerby), *Placunopsis* sp., *Plagiostoma*?, *Pleuromya uniformis* (J. Sowerby), *Protocardia* sp., *Pterocardia pesbovis* (d'Archiac), *Vaugonia*?) and echinoids (*Clypeus* sp., *Nucleolites* sp.) (Ivimey-Cook in Sumbler and Barron, 1995); Richardson (1911b) also recorded *Echinobrissus* (=*Nucleolites*) *woodwardi* Wright ('Chedworth buns') (Figure 3.45), and *Clypeus muelleri* Wright. Bed 18, the Excavata Bed, is very fossiliferous in parts with a fauna including *Nerinaea*, *Lucina bellona* d'Orbigny, *Tancredia extensa* Lycett, trigoniids and corals.

Figure 3.45 The 'Chedworth Bun' – *Nucleolites woodwardi* Wright. (Reproduced from Wright, 1854, pl. 12, figs 5a–e). Natural size.

Richardson (1911b) stated that the limestone of Bed 14 passes laterally (southwards) into the so-called 'Ornithella Beds', fossiliferous marls containing corals (*Corynella* sp., *Dendraraea excelsa* (Edwards and Haime), *Thamnasteria* sp.), and bivalves (*Camptonectes obscurus* (J. Sowerby), *Camptonectes* sp., *Lopha costata* (J. de C. Sowerby), *Lucina bellona* d'Orbigny, *Nanogyra crassa* (Wm. Smith), *Myoconcha actaeon* Morris and Lycett *ex* d'Orbigny, *Plagiostoma cardiiformis* J. Sowerby, *Plagiostoma subcardiiformis* (Greppin), *Plagiostoma* sp., *Thracia curtansata* Morris and Lycett, *Thracia* sp.) (Ivimey-Cook in Sumbler and Barron, 1995). In fact, photographs of the section (e.g. Richardson, 1911b, pl. 19; Richardson, 1933, pl. 3b) show that the marls underlie the limestone, the latter infilling a channel that cuts down to Bed 15.

Interpretation

The presence of the Hampen Formation at Stony Furlong Railway Cutting is not widely recognized; it is generally thought that the formation has passed into an expanded White Limestone Formation there (Arkell, 1933; Arkell and Donovan, 1952; Palmer, 1979). However, a recent geological survey has shown unequivocally that the Hampen Formation is present at Chedworth, in a facies much like that at the type section (see **Hampen Railway Cutting** GCR site report, this volume), albeit with a somewhat lower proportion of marl (Sumbler and Barron, 1995). The topmost bed of the Hampen Formation is regarded as Richardson's Bed 33, i.e. the so-called 'Organic Band' of Harker (1892).

Above the Hampen Formation, Richardson (1911b) recorded a total of about 26 m of White Limestone Formation strata. Comparison with the section at **Foss Cross** (see GCR site report, this volume), about 1.5 km to the south-west of the cutting, shows that Bed 18 (see below) corresponds with the Excavata Bed that marks the top of the Shipton Member (Barker, 1976, 1994; Sumbler, 1984, 1995), and that the thickness of the Shipton Member (i.e. Richardson's beds 18 to 32) is therefore 13.6 m, of which the uppermost 3 m are still exposed just south of the road bridge. The lowest bed seen (Bed 21) may equate with a bed of clay at approximately this level, which has been mapped locally in the Northleach area to the east.

A broken and worn specimen of the ammonite *Morrisiceras* (BGS specimen No. GSM52177) was found loose by Richardson who considered that it came from Bed 18 (Richardson, 1911b); he identified it as *M. morrisi* (Oppel) but Arkell (1954a) thought that it was 'not identifiable positively'. Nevertheless, the genus indicates the Middle Bathonian Morrisi Zone. The crumbly, fissile, somewhat sandy seams within Bed 17, the basal bed of the Ardley Member, are reminiscent of the Roach Bed and subjacent sand and clay developed in Oxfordshire at this level (Sumbler, 1984). According to Richardson (1911b), Bed 15 locally has a planed, oyster-encrusted, hardground top. This hardground, the lowest such bed recorded in the cutting, occurs some 15 m above the base of the formation. It represents the Langrunensis Bed, which in Oxfordshire is characterized by the gastropod *Aphanoptyxis langrunensis* (Barker, 1976, 1994; Sumbler, 1984). It is widely developed in areas to the east of Chedworth (Sumbler *et al.*, 2000).

The highest strata now exposed (Bed 13) are cross-bedded oolites that typify the upper part of the Ardley Member in the Chedworth area. Comparison with other sections suggests that Richardson's recorded thickness for Bed 13 and the succeeding strata (beds ?8 to 12) is approximately 2–3 m too great, and that his Bed 10 of Stony Furlong Railway Cutting includes the Solenopora Bed of **Foss Cross** (see GCR site report, this volume), i.e. Richardson's (1911b) Bed 12 of the Aldgrove Cutting. On this basis, the total thickness of the Ardley Member is approximately 12 m or 13 m at Stony Furlong Railway Cutting; the succeeding Signet Member (Sumbler, 1991) crops out a few hundred metres to the south-east of the cutting (Sumbler and Barron, 1995).

Conclusions

Stony Furlong Railway Cutting provides an important section through the middle part of the White Limestone Formation. The top of the Shipton Member is notable for having yielded the ammonite *Morrisiceras*, confirming the Mid Bathonian age of this part of the section. The north-westernmost part of the cutting, now infilled, formerly exposed beds extending down into the Hampen Formation, which although not previously recognized at this locality, is developed in fairly typical facies.

ROLLING BANK QUARRY, GLOUCESTERSHIRE (SO 987 267)

M.G. Sumbler

Introduction

The Rolling Bank Quarry GCR site is a small disused quarry lying within the extensive Cleeve Common SSSI. It is the type locality and, indeed, the only available exposure of the Rolling Bank Member, the youngest part of the Aston Limestone Formation (Middle Inferior Oolite). The quarry features extensively in the literature of over 130 years (Wright, 1860; Woodward, 1894; Buckman, 1897; Richardson, 1904, 1929b; Hancock, 1966; Ager and Mudge, 1973; Baker, 1977).

Description

A detailed description of the section is given by Buckman (1897), who combined the details of the quarry with other data to form a generalized, composite section for Cleeve Hill. The following section, recording the strata formerly exposed in Rolling Bank Quarry itself, is based on Buckman's (1897) record with minor additions and bed-numbering from Richardson (1904, 1929b).

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
1: Limestone, yellow, rubbly, pisoidal, with an admixture of marly material; '*Terebratula*' *globata* J. de C. Sowerby; pebbles of white limestone at base	3.66
Upper Trigonia Grit Member	
1b: Ragstone; planed surface locally with oysters attached; numerous *Trigonia* and '*Rhynchonella angulina* Davidson' (= *Rhynchonelloidella acutiplicata* (Brown))	2.74
Aston Limestone Formation	
Rolling Bank Member	
'*Phillipsiana Beds*'	
2: Limestone, bluish-grey, hard, sharp fracture; planed top surface bored by annelids and *Lithophagus*, with numerous oysters attached	0.10
3: Limestone, similar to Bed 2 but not bored; but somewhat nodular in places with pockets of sand	0.15
4: Limestone, similar to above, in three layers with sandy partings; sparse '*Terebratula*' *phillipsiana* Walker	1.52

		Thickness (m)
5:	Limestone, grey, similar to above, in two beds, with sandy partings, sandy at base; '*Terebratula*' *buckmaniana* Walker and '*T.*' *phillipsiana* abundant; *Acanthothiris* cf. *paucispina* Buckman and Walker, *Rhynchonella quadriplicata* Davidson *non* Zieten, *Zeilleria anisoclines* S.S. Buckman; oysters at base	0.69
6:	Limestone, massive, similar to above; *Rhynchonella quadriplicata*, '*Terebratula*' *phillipsiana*, *Bourguetia saemanni* (Oppel)	0.61
	'*Bourguetia Beds*'	
7:	Limestone, greyish, shelly, with brownish patches and infillings; *Bourguetia saemanni*, *Ctenostreon pectiniforme* (Schlotheim)	0.68
8:	Limestone, grey, in several beds; numerous large bivalves; *Lopha* cf. *flabelloides* (Lamarck), *Modiolus explanatus* Morris etc., *Nautilus* cf. *ornatus* Foord and Crick	2.13
9:	Limestone, grey, similar to above, somewhat bored	0.46
10:	Limestone, similar to above	0.23

For many years, only the upper part of the section remained visible because of gradual backfilling of the lower part of the quarry with debris. However, in 1997, part of the quarry was re-excavated to show some 5 m of strata below the Upper Trigonia Grit Member (Figure 3.46); the whole of the 'Phillipsiana Beds' are now exposed together with the upper part of the 'Bourguetia Beds' as recorded by Barron (1999a). The strata dip to the WNW at about 12° (Hancock, 1966).

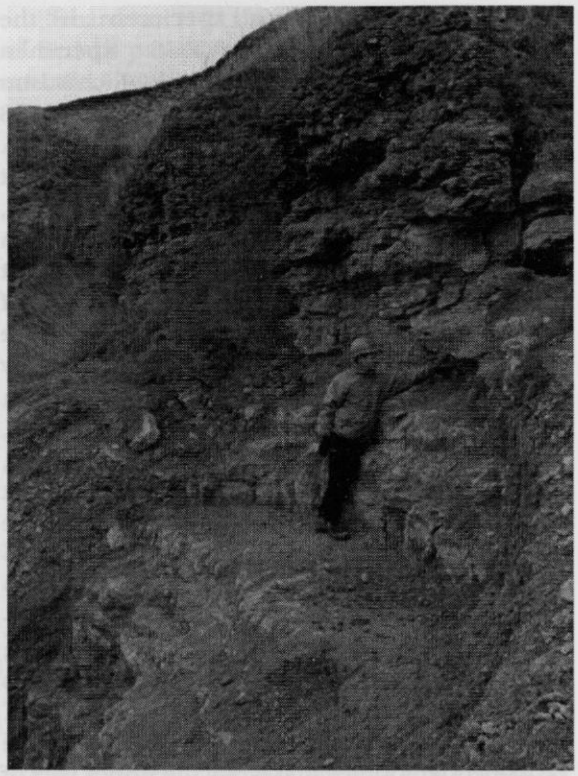


Figure 3.46 Section at Rolling Bank Quarry showing the rubbly Clypeus Grit Member overlying the more massive Upper Trigonia Grit Member, with 'Phillipsiana Beds' (Rolling Bank Member) below. The geologist's hand rests on the boundary between the Upper Trigonia Grit Member and the 'Phillipsiana Beds'. (Photo: M.G. Sumbler.)

Interpretation

The Rolling Bank Quarry was first mentioned by Wright (1860) who mistook the Upper Trigonia Grit Member (Upper Inferior Oolite) for Lower Trigonia Grit Member (Middle Inferior Oolite), consequently gaining a mistaken notion of the stratigraphical position of the underlying Phillipsiana ('Terebratula Phillipsi Bed') and Bourguetia ('Roadstone') beds. Buckman (1897) realized their true position beneath the Upper Trigonia Grit Member and, by combining the section at Rolling Bank Quarry with that seen in nearby quarries, established that the beds lay above the Notgrove (Freestone) Member, i.e. at the top of the Middle Inferior Oolite. The full succession between the Upper Trigonia Grit and Notgrove members at Cleeve Hill is as follows:

Phillipsiana Beds	3.1m
Bourguetia Beds	4.1 m
Witchellia Grit	1.2 m

The thicknesses given are those of Buckman (1897), although he acknowledged difficulties in making direct measurements. The recent re-excavation of the Rolling Bank Quarry and the nearby Pot Quarry (which shows the Witchellia Grit) suggests that they are approximately correct, although the presence of faulting between the sections precludes absolute certainty (Barron, 1999b). The Witchellia Grit, named after the ammonite genus *Witchellia*, comprises 'iron-shot' limestones. The Bourguetia Beds are notably rubbly, shelly limestones named after the large gastropod *Bourguetia saemanni* (Oppel), though more common and distinctive are large *Lopha* and the clam-like *Ctenostreon*. The Phillipsiana Beds are grey to yellowish, more-or-less well-cemented calcareous sandstones or sandy limestones with sporadic shelly beds; in Rolling Bank Quarry the topmost part (Bed 2) is hard and strongly cemented, with a markedly bored top surface with encrusting oysters. They take their name from the brachiopod *'Terebratula' phillipsiana* Walker, which is quite common in the lower part. These three units have recently been combined into the Rolling Bank Member of which Rolling Bank Quarry is the designated type locality (Barron *et al.*, 1997). The member is confined to a very small area of the Cotswolds, essentially to Cleeve Hill alone (Buckman, 1897, p. 46; Barron *et al.*, 1997, fig. 4); elsewhere, the succeeding Upper Trigonia Grit Member rests on older strata. From the pattern of overstep beneath the Upper Trigonia Grit Member, Buckman (1901) deduced that an episode of minor folding and erosion (the Bajocian denudation) preceded the deposition of the Upper Trigonia Grit Member, such that generally the Rolling Bank Member was eroded away, being preserved only in the core of the so-called Cleeve Hill Syncline; on the axis of the flanking Birdlip Anticline to the south-west, the Upper Trigonia Grit Member rests directly on the Birdlip Limestone Formation (Lower Inferior Oolite) (see **Knap House Quarry** GCR site report, this volume).

The Rolling Bank Member represents the youngest part of the Aston Limestone Formation (Middle Inferior Oolite). The Witchellia Grit, at nearby localities, has yielded ammonites indicating the younger part of the Lower Bajocian Laeviuscula Zone, but the only ammonite recorded from the Rolling Bank Quarry section itself is a stephanoceratid thought to come from Bed 7, near the top of the Bourguetia Beds (Buckman, 1897, pp. 609 (footnote), 613). Identified as *Skirroceras* aff. *leptogyrale* Buckman by Parsons (1980b), it is a form consistent with the Lower Bajocian Sauzei Zone.

The dip of the strata at Rolling Bank Quarry is contrary to the gentle south-eastward regional dip in this part of the Cotswolds and is due to local tectonic complications combined with cambering (incipient landslipping) at the margin of Cleeve Hill, a phenomenon resulting from the deformation of the mudstone-dominant Lias Group beneath the Inferior Oolite Group. Some minor faults and large, debris-filled fissures (gulls) which have at various times been noted at the quarry (e.g. Buckman, 1897, fig. 3) (Figure 3.47) are probably related to this latter process, although a more substantial tectonic fault

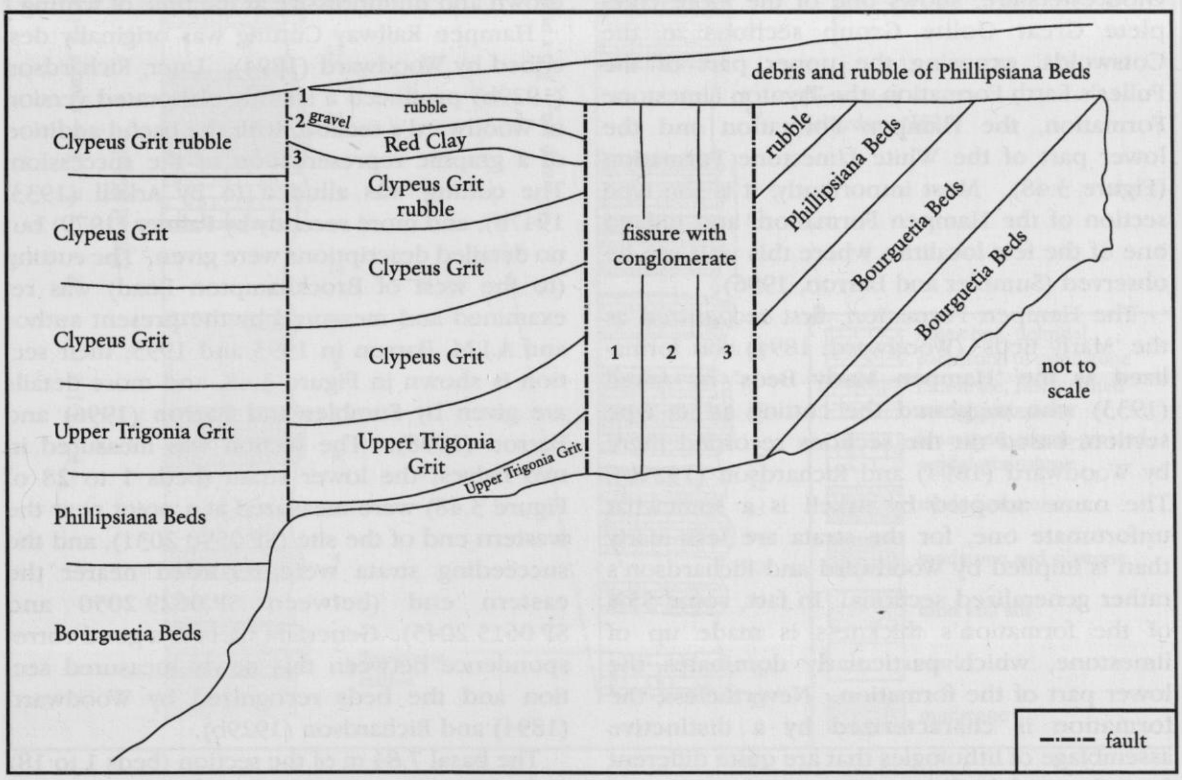


Figure 3.47 Minor faults and large debris-filled fissures at Rolling Bank Quarry as illustrated by Buckman (1897, fig. 3).

bringing in oolites of the Cleeve Cloud Member (Birdlip Limestone Formation) has recently been exposed by excavations in the northern part of the quarry.

Conclusions

Rolling Bank Quarry exposes the youngest part of the Aston Limestone Formation (Middle Inferior Oolite) in the Cotswolds, and is the only place where these strata can be seen in section. It is the type locality for the Rolling Bank Member, which comprises the strata traditionally known as the 'Witchellia Grit', 'Bourguetia Beds' and 'Phillipsiana Beds'.

HAMPEN RAILWAY CUTTING, GLOUCESTERSHIRE (SP 0590 2031–SP 0629 2050)

M.G. Sumbler

Introduction

Hampen Railway Cutting, on the disused Andoversford to Bourton-on-the-Water railway in Gloucestershire, shows one of the more complete Great Oolite Group sections in the Cotswolds, exposing the upper part of the Fuller's Earth Formation, the Taynton Limestone Formation, the Hampen Formation and the lower part of the White Limestone Formation (Figure 3.48). Most importantly, it is the type section of the Hampen Formation, and indeed one of the few localities where this unit can be observed (Sumbler and Barron, 1996).

The Hampen Formation, first recognized as the 'Marly Beds' (Woodward, 1894) was formalized as the 'Hampen Marly Beds' by Arkell (1933) who suggested the cutting as its type section, based on the sections recorded there by Woodward (1894) and Richardson (1929b). The name adopted by Arkell is a somewhat unfortunate one, for the strata are less marly than is implied by Woodward and Richardson's rather generalized sections. In fact, some 55% of the formation's thickness is made up of limestone, which particularly dominates the lower part of the formation. Nevertheless, the formation is characterized by a distinctive assemblage of lithologies that are quite different from those of the Taynton Limestone Formation below, and the White Limestone Formation above.

Description

Hampen Railway Cutting is, in total, over a kilometre in length, but the best sections are restricted to that portion between the Brockhampton Road, where the original bridge has been replaced by an embankment (SP 0638 2052) and the trackway bridge 650 m to the south-west (SP 0578 2024), which marks the western end of the GCR site. This section of the cutting is up to 15 m deep and, from east to west, exposes progressively lower beds owing to the combined effect of the westward downhill gradient of the old railway track bed, and the gentle eastward dip of the strata. Although parts of the section are overgrown with vegetation, or obscured by slipped material, much of the succession is well exposed, and the units described below should be readily recognizable (Figure 3.49). Adjacent to the Brockhampton Road, where Hampen Railway Cutting can be entered, the basal part of the White Limestone Formation is present in the highest part of the cutting. Succeeding beds of the formation are exposed in that part of the cutting to the east of the road, also part of the GCR site, but exposures there were heavily overgrown and unimpressive at the time of writing.

Hampen Railway Cutting was originally described by Woodward (1894). Later, Richardson (1929b) produced a slightly elaborated version of Woodward's section, with the useful addition of a graphic representation of the succession. The cutting was alluded to by Arkell (1933, 1947b), and more recently by Palmer (1979) but no detailed descriptions were given. The cutting (to the west of Brockhampton Road) was re-examined and measured by the present author and A.J.M. Barron in 1993 and 1995; their section is shown in Figure 3.48, and more details are given by Sumbler and Barron (1996) and Barron (1998). The section was measured in two halves; the lower strata (beds 1 to 28 of Figure 3.48) were measured at a point near the western end of the site (SP 0590 2031), and the succeeding strata were recorded nearer the eastern end (between SP 0629 2050 and SP 0615 2045). Generally, there is a good correspondence between this newly measured section and the beds recognized by Woodward (1894) and Richardson (1929b).

The basal 7.84 m of the section (beds 1 to 18) are assigned to the Fuller's Earth Formation. The lowest bed now exposed (Bed 1) is a grey, shaly mudstone that represents the topmost part

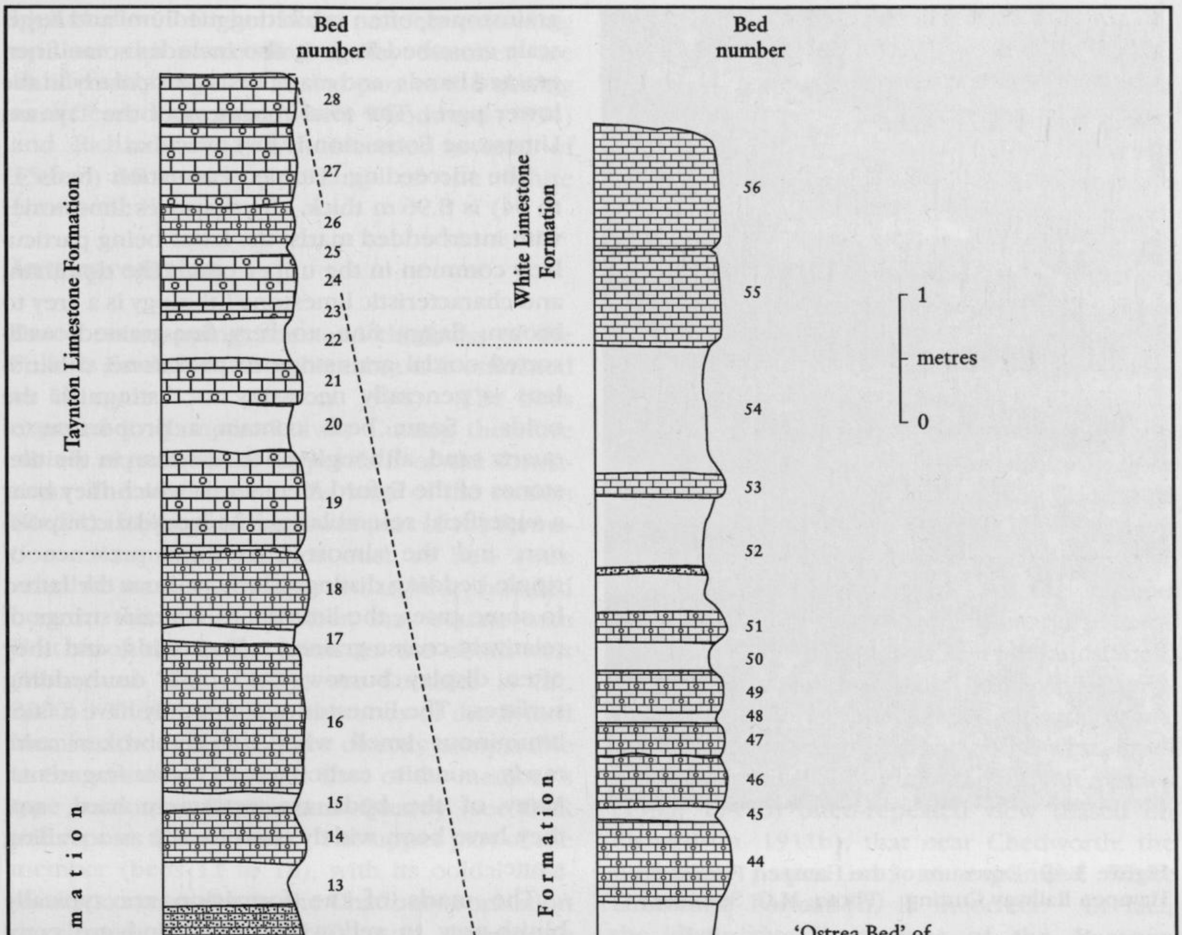


Figure 3.48 Graphic section of the Bathonian succession at Hampen Railway Cutting. Bed numbers follow Sumbler and Barron (1996) and Barron (1998).

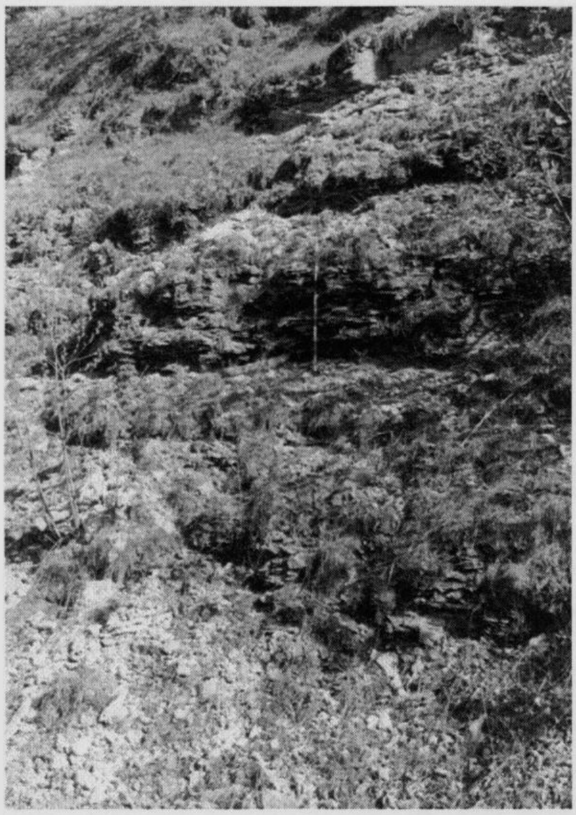


Figure 3.49 Exposure of the Hampen Formation in Hampen Railway Cutting. (Photo: M.G. Sumbler.)

of the 10 feet (3.05 m) of bluish-grey shales with bands of hard, pale-grey marl and thin layers of fissile, sandy limestone recorded by Woodward (1894) and Richardson (1929b) at the bottom of their section. The overlying beds 2 to 18 are assigned to the Eyford Member. The lower part is dominated by fissile, calcareous, sandy limestones ('tilestones') interbedded with shaly silts and marls, and, near the base, decalcified, buff-yellow sand. The basal bed (Bed 2) is a hard, micritic limestone, very sandy in the upper part. The lower part is packed with the small lunate oyster *Praeexogyra acuminata* (J. Sowerby), forming an 'Acuminata marble'. The upper part of the Eyford Member includes coarsely shelly and peloidal grainstones (Bed 11) not unlike the Taynton Limestone Formation, and finely ooidal tilestones with sporadic strings of coarser, white ooids, rather similar to those of the Hampen Formation (beds 14 to 18).

The overlying Taynton Limestone Formation (beds 19 to 30) is made up mainly of medium- to coarse-grained, shell-fragmental and ooidal grainstones, often exhibiting medium- and large-scale cross-bedding. It also includes some finer-grained bands, and marly beds particularly in the lower part. The total thickness of the Taynton Limestone Formation is just over 4 m.

The succeeding Hampen Formation (beds 31 to 54) is 8.96 m thick. It comprises limestones with interbedded marls, the latter being particularly common in the upper part. The dominant and characteristic limestone lithology is a grey to brown, flaggy, fine- to very fine-grained, well-sorted ooidal grainstone to packstone; a hand-lens is generally necessary to distinguish the ooids. Some beds contain a proportion of quartz sand, although much less than in the tilestones of the Eyford Member to which they bear a superficial resemblance; their ooidal composition and the almost ubiquitous presence of ripple bedding distinguish them from the latter. In some cases, the limestones contain strings of relatively coarse-grained white ooids, and they often display burrows and trails on bedding surfaces. The limestones commonly have a faint bituminous smell when freshly broken and, rarely, contain carbonaceous plant-fragments. Many of the beds are extremely hard, and they have been widely used locally as a walling stone.

The marls of the formation are typically bluish-grey to yellowish-brown, and are commonly laminated and rather sandy; they tend to pass laterally into soft, rather shaly limestones. Like the limestones, the marls contain a proportion of organic material giving rise to a bituminous odour, and commonly contain scattered ooids and shell debris. The latter often includes oyster material, notably *Praeexogyra hebridica* (Forbes), which is particularly abundant in Bed 43 (the Ostrea Bed of Richardson (1929b)). The upper 2.1 m of the formation are composed almost entirely of marl, with only a thin (0.2 m) bed of limestone (Bed 53), which is a pale-grey, strongly bioturbated peloidal packstone more like the lithologies of the overlying White Limestone Formation than the limestones lower in the Hampen Formation.

About 7.6 m of the White Limestone Formation is represented to the west of Brockhampton Road, although only the basal *c.* 1.7 m (beds 55 and 56) are cleanly exposed. These beds, assigned to the Shipton Member (Sumbler, 1984), comprise off-white to pale-brown, ooidal and peloidal packstones to grainstones, with a massive character resulting from pervasive bioturbation. Higher beds, possibly extending up into the succeeding Ardley Member, are indifferently exposed in that part of the cutting to the east of the road, where Woodward (1894) and Richardson (1929b) recorded a total of 35 feet 10 inches (10.92 m) of the White Limestone Formation.

Interpretation

Based on mapping, the total thickness of the Fuller's Earth Formation hereabouts is estimated to be some 15 m (Barron, 1998). The beds exposed in Hampen Railway Cutting therefore mainly represent the upper half of the formation. The mudstone at the base of the section (Bed 1) is typical of the lower part of the formation. 'Acuminata marbles' such as Bed 2 are valuable markers; this particular bed, included here in the Eyford Member, may equate with Unit 6 of the Bath region to the south-west (Penn and Wyatt, 1979; see Sumbler *et al.*, 2000). The succeeding tilestones of the Eyford Member (beds 3 to 12) are directly comparable to the so-called Cotswold Slate of the member's type section at **Huntsmans Quarry** (see GCR site report, this volume). The upper part of the member (beds 11 to 18), with its ooidal limestones, corresponds to the Charlbury Formation developed below the Taynton Limestone Formation in Oxfordshire (Boneham and Wyatt, 1993; Wyatt, 1996a). The Eyford Member was included in the 'Stonesfield Beds' or 'Stonesfield Slate Series' by Woodward (1894), Richardson (1929b) and Arkell (1933), although the famous Stonesfield Slate of the type area (see **Stonesfield** GCR report, this volume) is now known to lie within the Taynton Limestone Formation.

The Taynton Limestone Formation was formerly valued as a freestone, and is still worked for this purpose near Soundborough Farm, just over 1 km north-west of the site. Details of Woodward's (1894) section show that his 'Freestone' corresponds exactly with the Taynton Limestone Formation as classified herein, but his recorded thickness of 'about 30 feet' (*c.* 9 m) is greatly excessive. Richardson (1929b) quoted Woodward's 30 feet of Taynton Limestone Formation but, as he excluded beds 19 to 22 (1.9 m thick) from the formation (including them in the 'Stonesfield Slate Series'), his figure should have been reduced accordingly. Although these beds are dominated by typical Taynton Limestone Formation lithologies, Richardson interpreted them as the 'Sevenhampton Marl' (Bed 20), Ostrea acuminata Limestone (Bed 21) and Rhynchonella Bed (Bed 22) which, at their type locality of Sevenhampton Common (SP 018 222), underlie the Taynton Limestone Formation (Richardson, 1929b). However, there seems to be no reason to believe that these beds, either in Hampen Railway Cutting or at the various other localities in which they have been said to be present, necessarily correlate to those of the type section.

The thickness of 8.96 m for the Hampen Formation recorded herein is satisfactorily close to 8.61 m of 'Marly Beds' recorded by Woodward (1894) and Richardson (1929b). The formation at this locality represents a passage between the non-marine and paralic facies of the Rutland Formation, developed in the land-marginal areas of the London Platform and East Midlands Shelf, and the more open marine, oolite shoal environment offshore (Palmer, 1979; Horton *et al.*, 1995). Thus, to the west and south-west, limestones become ever more dominant, but Arkell's (1933, 1947b) often-repeated view (based on Richardson, 1911b), that near Chedworth, the formation passes into an expanded White Limestone Formation, is incorrect. In fact, the distinctive limestones of the Hampen Formation are well developed there (see **Stony Furlong Railway Cutting** GCR site report, this volume).

The 11 m or so of White Limestone Formation represents the lower half of the formation, the total thickness in this area being in the order of 25 m. The beds are generally of a higher-energy facies than those in the type area of the Cherwell Valley in Oxfordshire, illustrating the westward transition to a more open marine, offshore environment represented by the Athelstan Oolite Formation of the Malmesbury district (e.g. **Veizey's Quarry** and **Kemble Cuttings**, see GCR site reports, this volume).

Conclusions

Hampen Railway Cutting exposes much of the Great Oolite Group, including parts that are seldom exposed elsewhere, notably the Fuller's Earth Formation, Hampen Formation and basal White Limestone Formation. It is particularly important as the stratotype of the Hampen Formation.

FIRST CUTTING WEST OF NOTGROVE, GLOUCESTERSHIRE (SP 0830 2083–SP 0884 2106)

M.G. Sumbler

Introduction

The GCR site known as 'First Cutting West of Notgrove' is situated on the disused Andoversford to Bourton-on the-Water railway in Gloucestershire (Figure 3.50). It lies close to the village of Salperton, but about 2.5 km from Notgrove; it takes its name from Buckman's (1890) description of it as the 'first cutting west of Notgrove Station', and it should not be confused with Notgrove Station Cutting. The site exhibits one of the best sections of the uppermost part of the Inferior Oolite Group in the Cotswolds, and has recently been designated the type section of the Salperton Limestone Formation (Upper Inferior Oolite) and its two members (the Upper Trigonia Grit and Clypeus Grit) as well as the Notgrove Member of the Aston Limestone Formation (Middle Inferior Oolite) (Barron *et al.*, 1997).

Description

This cutting was first described by Buckman (1890) and later by Woodward (1894); Buckman's section was extended slightly by Richardson (1929b). Apart from the lowest beds, which are no longer exposed, the section is much as described by these authors. The currently exposed section, based on that reported by Barron (1998), is given below.

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
5: Limestone, very pale grey-brown, poorly bedded and rubbly, medium- to very coarse-grained peloidal, ooidal and shell-fragmental packstone with grain aggregates and common whole shells; particularly rubbly and rather soft near top, slightly harder and better bedded for *c.* 2 m in middle part, and in basal *c.* 1 m, which is somewhat finer-grained than above; limestone pebbles at base	*c.* 10.5–12.0
Upper Trigonia Grit Member	
4: Limestone, very pale yellow-brown, irregularly and unevenly bedded, medium-to coarse-grained, peloidal and shell-fragmental grainstone to packstone with common larger shell fragments, and whole shells; sharp, uneven top surface	1.05–1.20
3: Clay, grey-brown, shell-detrital	0–0.02

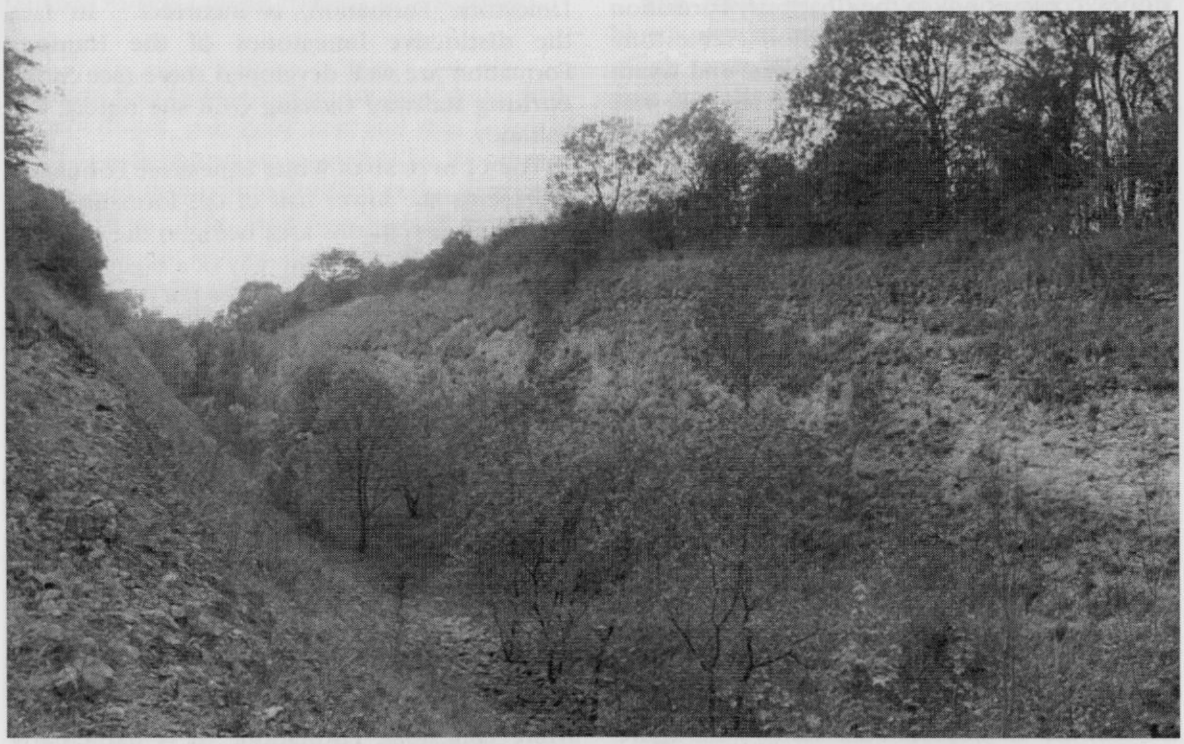


Figure 3.50 General view looking west in the First Cutting West of Notgrove, showing the eastward dip of the Clypeus Grit Member. (Photo: M.G. Sumbler.)

	Thickness (m)
Aston Limestone Formation	
Notgrove Member	
2: Limestone, very pale-grey, massive, hard and recrystallized, medium- to coarse-grained, ooidal grainstone with numerous pale-brown, very coarse, ovoid peloids, and minor proportion of shell debris; top oyster-encrusted and bored in places; thin (0.01 m) clay seam at base	up to 0.31
1: Limestone, off-white to very pale-brown, unevenly bedded in upper part, massive below; medium- to coarse-grained, ooidal grainstone with subordinate peloids and shell debris as Bed 2; bored in upper part in places; fairly common sub-vertical burrows throughout	seen to 1.51

The beds dip gently (up to 5°) towards the north-east, so that the oldest beds are seen at the western end of the section, to the west of the overbridge (SP 0848 2090) (see Woodward, 1894, fig. 43). The underlying beds were formerly exposed; as originally described by Buckman (1890, beds 8 to 10), some 3.3 m of the Gryphite Grit Member was seen, with '*Gryphaea sublobata*' in the lower part. This member of the Aston Limestone Formation (Middle Inferior Oolite) may be inspected at other localities in the vicinity, notably **Leckhampton Hill** and **Harford Cutting** (see GCR site reports, this volume). The Notgrove Member was previously exposed to its full thickness of 3.9 m (Buckman, 1890, beds 6 and 7), but only the upper part is now visible. Formerly known as the 'Notgrove Freestone', it is a fairly uniform and massive, poorly fossiliferous oolite. The top surface is a well-developed hardground, with a somewhat uneven, eroded surface, locally encrusted by oysters and serpulids; the underlying limestone is recrystallized and intensely hard, forming an irregular but prominent bed in the face (Bed 2). Narrow, sub-vertical, tubular annelid borings extend down from the hardground surface by up to 0.3 m, in some cases extending into the underlying Bed 1.

The succeeding Upper Trigonia Grit Member is richly fossiliferous, with common brachiopods (such as *Rhactorhynchia hampenensis* (S.S. Buckman) and the distinctive *Acanthothiris spinosa* (Linnaeus)) and bivalves, including large myaceans and trigoniids, often preserved as empty external moulds. It has also yielded ammonites; Buckman (1890) recorded '*Ammonites parkinsoni*', and in 1995 a poorly preserved parkinsoniin was found immediately above the base (Barron, 1998).

The Clypeus Grit Member is well exposed throughout much of the cutting east of the bridge; up to *c.* 12 m are seen, representing almost the total thickness of the formation, and probably the most complete section in the Cotswolds. Richardson (1929b), adding to Buckman's (1890) data, noted a total of 12.34 m, capped by 0.3 m of 'Upper Estuarine Clay'. The latter probably represents the Fuller's Earth Formation (Great Oolite Group). Although this formation is not currently exposed, mapping indicates that its basal beds skirt the northern side of the cutting, and a thin lenticular development of the Chipping Norton Limestone Formation occurs between the Fuller's Earth Formation and the Clypeus Grit Member in the field just to the north of the bridge. The Clypeus Grit Member is richly fossiliferous, particularly with brachiopods (notably *Stiphrothyris*) and large myacean bivalves. The eponymous echinoid *Clypeus ploti* Salter (Figure 3.51) is especially common in the uppermost beds, and is probably in large part responsible for the pervasive burrowing and consequent rubbly character of these beds.

Interpretation

The Notgrove Freestone was so named by Buckman (1890) after the section at the First Cutting West of Notgrove. The unit has recently been formalized as the Notgrove Member (of the Aston Limestone Formation (Middle Inferior Oolite)), and this cutting is designated as the type section (Barron *et al.*, 1997). Here, the Notgrove Member is the youngest unit of the Aston Limestone Formation, and the hardground at the top marks a substantial erosional non-sequence. Although the member is characteristically poorly fossiliferous, it is known to belong to the Lower Bajocian Laeviuscula Zone from its stratigraphical position in more complete sections elsewhere (e.g. see **Rolling Bank Quarry** GCR site report, this volume).

The Upper Trigonia Grit Member and, more especially, the Clypeus-Grit Member are very well exposed in this section. Together, these units constitute the Upper Inferior Oolite, which is of Late Bajocian to Early Bathonian age. Recently, the units have been combined into one lithostratigraphical formation, the Salperton Limestone Formation, of which the Upper Trigonia Grit and Clypeus Grit are constituent members (Barron *et al.*, 1997). The First

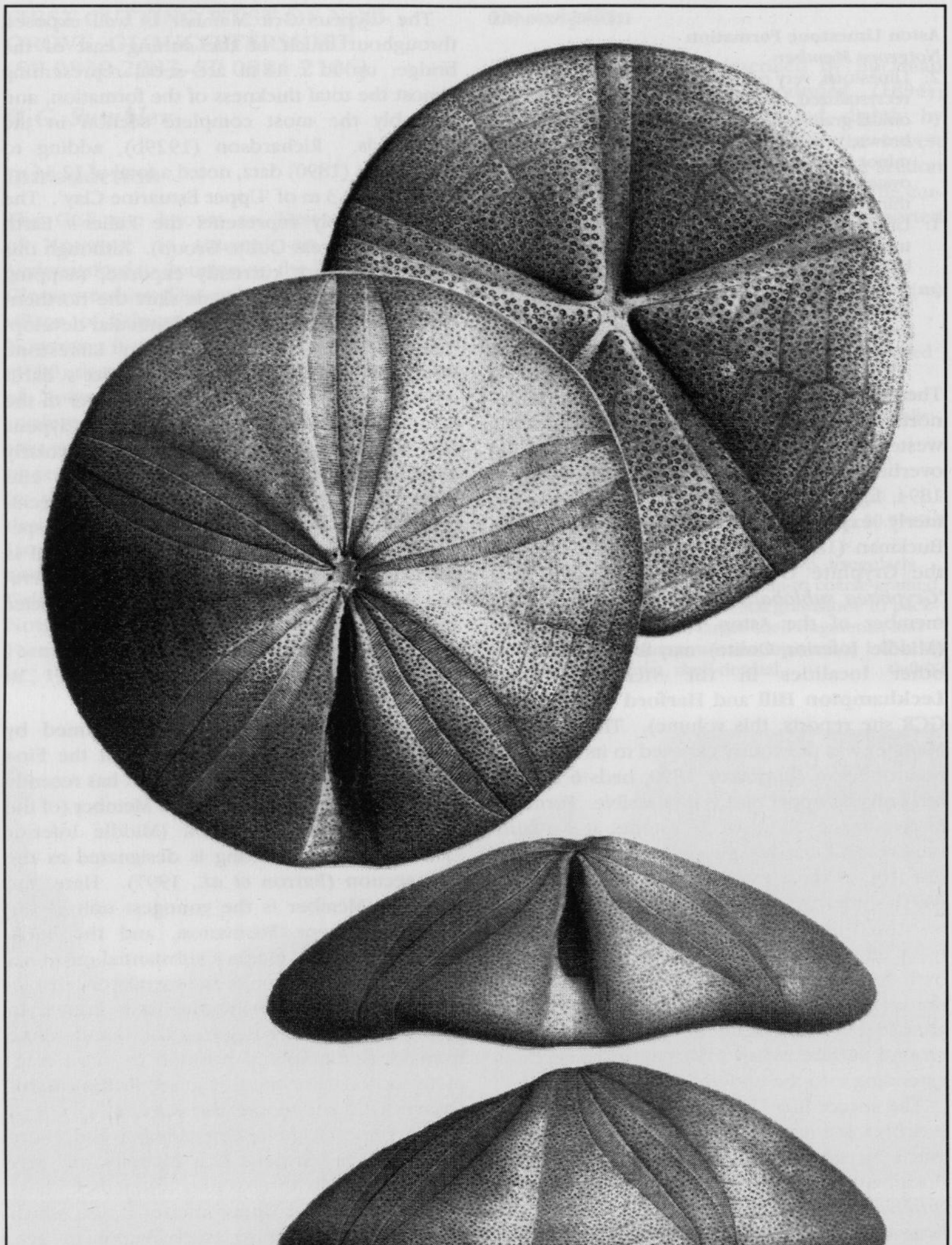


Figure 3.51 *Clypeus ploti* Salter. Reproduced from Wright, 1859, pls 28,29, at approximately 90% natural size.

Cutting West of Notgrove is the type section for all three units. The ammonites recorded from the Upper Trigonia Grit Member, both here and elsewhere, indicate that the member belongs to the Acris Subzone of the Garantiana Zone (Upper Bajocian). The characteristic ammonites of this interval are *Garantiana* and early forms of *Parkinsonia*. The sharp junction between the Clypeus Grit and Upper Trigonia Grit members, and the presence of limestone pebbles at the base of the former, suggests, as at some other sites, a minor non-sequence at this level.

Conclusions

The First Cutting West of Notgrove exposes one of the best and most complete sections of the upper part of the Inferior Oolite Group in the Cotswolds. It is of particular importance as the stratotype of the Notgrove Member (Aston Limestone Formation), the Salperton Limestone Formation and its two members, the Upper Trigonia Grit and Clypeus Grit.

HARFORD CUTTING, GLOUCESTERSHIRE (SP 1356 2184–SP 1410 2159)

M.G. Sumbler

Introduction

Harford Cutting (Figure 3.52) is situated on the disused Andoversford to Bourton-on-the-Water railway in Gloucestershire, about 3 km north-west of Bourton. It exhibits fine sections through the middle and upper parts of the Inferior Oolite Group of the Cotswolds, and is the type section of both the Harford Member of the Birdlip Limestone Formation (Lower Inferior Oolite), and the Aston Limestone Formation (Middle Inferior Oolite) (Barron *et al*., 1997).

Description

This long cutting, up to about 15 m deep, still exposes an excellent section showing the succession from the upper part of the Birdlip Limestone Formation (Lower Inferior Oolite), to the middle part of the Salperton Limestone Formation (Upper Inferior Oolite). It was first described by Buckman (1890), who termed it the 'Third cutting west of Bourton'. Some additional information was given by Richardson

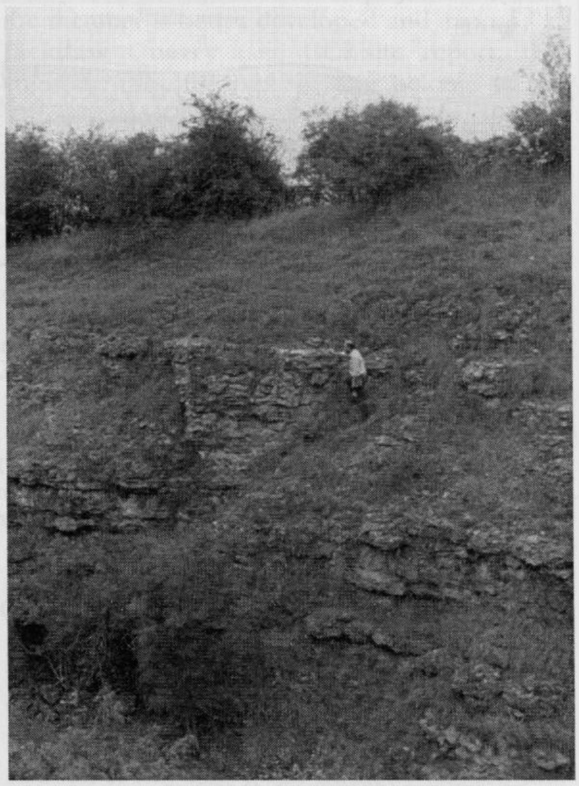


Figure 3.52 Exposure of the Aston Limestone Formation in Harford Cutting. The geologist's hand rests on the planar top surface of the Notgrove Member. (Photo: M.G. Sumbler.)

(1929b), who also revised the stratigraphical classification of the beds, and the succession was summarized by Arkell (1947b). Woodward (1894) mentioned it only briefly, but provided an instructive sketch-section along the cutting (fig. 43, cutting Q) indicating a considerable amount of faulting (Figure 3.53; see also Barron, 1999b). The exposures were re-examined and described by Parsons (1976b), and the following section is based on his account.

	Thickness (m)
Salperton Limestone Formation	
Clypeus Grit Member	
12: Limestone, very fossiliferous, pisolitic, bioclastic, with layers rich in poorly preserved bivalves alternating with horizons rich in brachiopods; harder and more massive towards base, where also less pisolitic; *Parkinsonia (P.)* cf. *eimensis* (S.S. Buckman *non* Wetzel), *P. (P.)* sp., *P. (Okribites?)* cf. *parkinsoni* (S.S. Buckman *non* Sowerby), *Stiphrothyris tumida* (Davidson), *Pleuromya uniformis* (J. Sowerby)	3.0

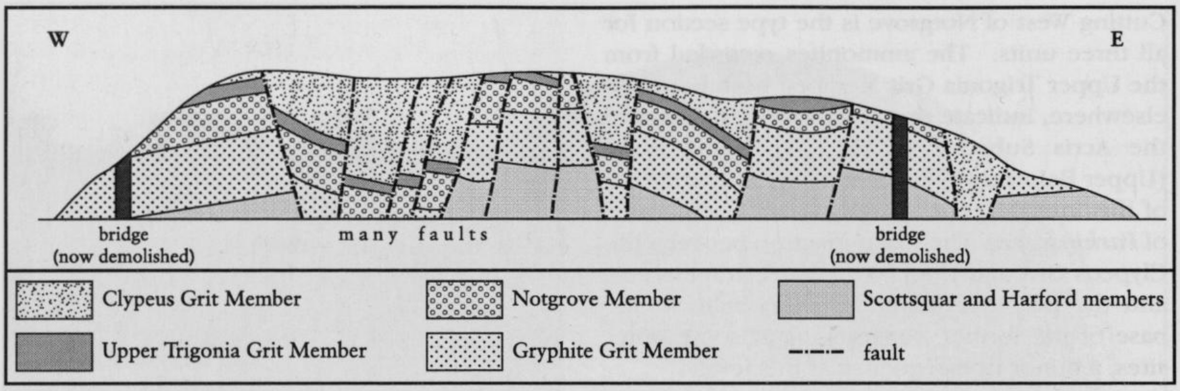


Figure 3.53 Sketch section illustrating the northern face of Harford Cutting. (After Woodward, 1894, fig. 43.) Total length of section *c.* 550 m; maximum depth *c.* 15 m. Vertical bars are bridges, now demolished. Recent examination of the cutting indicates that this diagram is not accurately drawn to scale; for example, the width of the graben near the western end of the section is greatly exaggerated. However, it gives a reasonable impression of the section's complexity.

	Thickness (m)
Upper Trigonia Grit Member	
11: Limestone, sandy, limonite-rich, slightly 'iron-shot', bioclastic; highly fossiliferous with numerous brachiopods; softer towards base; in three courses, lowest slightly conglomeratic; *Strenoceras* (*Garantiana*) *garantiana* (d'Orbigny), *S.* (*G.*) sp., *S.* (*Pseudogarantiana*?) cf. *quenstedti* (Wetzel), *Rhactorhynchia hampenensis* (S.S. Buckman)	1.0
Aston Limestone Formation	
Notgrove Member	
10b: Limestone, hard, white, ooidal, well bedded and forming prominent ledge; bored and oyster-encrusted top surface, with vertical borings passing through full thickness of bed	0.40
10a: Limestone, hard, white, ooidal, broken up and tufa-coated; thinning towards east	0–2.30
Gryphite Grit Member	
9: Limestone, grey-brown, sandy, bioclastic, in four or five courses separated by sandy partings; very shelly, especially towards base; top surface flat and bored; lowest course highly burrowed; *Gryphaea bilobata* (J. de C. Sowerby)	1.40
8: Limestone, brown, sandy, bioclastic, softer than Bed 9; very fossiliferous, with shells of infaunal bivalves replaced by yellow-orange clay; highly burrowed and upper part bored; *Sonninia* aff. *ovalis* (S.S. Buckman ex Quenstedt), *Gryphaea bilobata*, *Pleuromya* sp.	0.40
7: Marl, brown, sandy; common serpulid-encrusted *Gryphaea*	0.28
6b: Limestone, brown, sandy, bioclastic, very shelly, in two or three irregular courses; sandy marl parting at base	0.40
6a: Limestone, hard, grey, sandy, bioclastic, very fossiliferous, with many shells replaced by limonite; *Sonninia* cf. *patella* (Waagen)	0.40

	Thickness (m)
5b: Marl, very sandy	0.08
5a: Limestone, brown, very sandy, in one to two courses; sandy marl parting at base	0.28–0.14
4: Limestone, hard, grey, sandy, bioclastic limestone, sparsely flecked with limonite and with soft, red sandy material infilling burrows; in two courses; *Cenoceras* sp., *Darellia* aff. *toxeres* S.S. Buckman, *Euhoploceras* aff. *alternata* (S.S. Buckman), *Hyperlioceras subsectum* (S.S. Buckman), *H. rudidiscites* S.S. Buckman, *Reynesella* sp., *Discocyathus* sp., *Pinna cuneata* Phillips, *Pseudomelania* sp., *Trigonia costata* Parkinson	0.60
Lower Trigonia Grit Member	
3: Limestone, soft, rubbly, 'iron-shot', weathering to marl; harder, conglomeratic for 0.06 m at base; highly fossiliferous with many bivalves, notably *Pleuromya*	0.25
Birdlip Limestone Formation	
Harford Member	
'Tilestone'	
2b: Limestone, pale-cream; numerous soft, pale-brown ooids; very fossiliferous, with many poorly preserved shells; top surface bored, basal part more coarsely ooidal, and conglomeratic with limonite-coated pebbles	0.60
2a: Limestone, sandy, blue-hearted, weathering brown; bored at top; fossiliferous with numerous small fish teeth and crinoid ossicles (latter replaced by limonitic clay); *Graphoceras* cf. *apertum* (S.S. Buckman) probably from this bed	seen to 0.38
Obscured	?
'Harford Sand'	
1: Sand, yellowish-brown, with sandstone doggers, poorly exposed	*c.* 0.60

The 'Harford Sand' is now only poorly and sporadically exposed, but indications of its presence can be found, particularly near the remains of the overbridge towards the eastern end of the cutting. There, Buckman (1890, beds 15 to 17) recorded 1.9 m of yellow sand with a 0.6 m-thick bed of brown sandstone. The succeeding 'Tilestone', up to 1.5 m thick (Buckman, 1890) is moderately well exposed.

The succeeding beds are well exposed throughout much of the cutting, particularly on its northern side. The Notgrove Member (formerly the Notgrove Freestone), is the most prominent and distinctive bed in the section, and can be readily traced along almost the full length of the cutting. It is readily identified by its heavily bored upper part, and the well-developed hardground top surface. It shows a marked thinning along the section, from *c.* 2.4 m in the west to only *c.* 0.3 m in the east.

Interpretation

Harford Cutting still exposes almost all of the succession described by Buckman (1890), and the units identified by Parsons (1976b) in the section above can be identified with relative ease. There are a number of minor faults in the section, as illustrated by Woodward (1894, fig. 43; Figure 3.53). A recent geological survey of the area (Barron, 1999b) revealed that most of these are of non-diastrophic origin, being connected with camber and gull structures, which are spectacularly developed in the fields immediately to the south and south-east of the cutting. A gull that crosses the cutting *c.* 150 m from its western end is revealed as a graben some 35 m wide, with step-faulted margins, in which the strata are down-faulted by *c.* 5 m.

The 'Harford Sand' (Bed 1), the lowest horizon recorded in the section, was first described and named by Buckman (1890) at this locality. Parsons (1976b) deduced, on the basis of its matrix, that a specimen of *Graphoceras* cf. *apertum* (S.S. Buckman) in the Oxford University Museum came from the overlying 'Tilestone' (Bed 2a), though the species is not of precise zonal significance. As recognized by Parsons (1976b) and Mudge (1978a,b), the stratigraphy at the level of the 'Harford Sand' and 'Tilestone' is complex and laterally variable and, for this reason, these two units, together with the associated Snowshill and Naunton clays (Buckman, 1897; Richardson, 1929b) have been combined into one unit, the Harford Member (Mudge, 1978a,b; Barron *et al.*, 1997). Harford Cutting is the designated type section, although the member is better developed and exposed at **Jackdaw Quarry** (see GCR site report, this volume). The Harford Member belongs to the late Aalenian Concavum Zone (Parsons, 1980a), and constitutes the topmost unit of the Birdlip Limestone Formation, which corresponds with the Lower Inferior Oolite in the Cotswolds region (Barron *et al.*, 1997).

The strata comprising the Lower Bajocian beds previously referred to as the 'Middle Inferior Oolite' (i.e. beds 3 to 10 of the section above, together up to about 6.2 m thick) have recently been combined into a properly defined lithostratigraphical unit, the Aston Limestone Formation, of which this cutting is the type locality (Barron *et al.*, 1997). Parsons (1976b) collected a considerable and important ammonite fauna from the Gryphite Grit Member, indicating that whilst the greater part of the member probably belongs to the Laeviuscula Zone (Ovalis Subzone), the basal part at this locality (Bed 4) extends down into the underlying Discites Zone, which also encompasses the Lower Trigonia Grit. The Gryphite Grit Member (Barron *et al.*, 1997) was formerly divided into two units, the lower part (the Buckmani Grit of Buckman, 1895) being characterized by the brachiopod *Lobothyris buckmani* (Davidson), and the upper (the Gryphite Grit of Buckman, 1895) by *Gryphaea bilobata*, but the distinction is insufficient to justify this separation (Parsons, 1976b; Barron *et al.*, 1997). *G. bilobata* is quite common throughout the upper half of the member, and Richardson (1929b) recorded *L. buckmani* from a level possibly corresponding with Bed 8.

The marked thinning of the Notgrove Member is due to the erosional non-sequence at its top, the so-called 'Bajocian denudation' of Buckman (1895). The thinning is particularly marked in this area because of its proximity to the Vale of Moreton Axis (Arkell, 1933; Sumbler *et al.*, 2000). The Notgrove Member is cut out entirely a short distance beyond the eastern end of the cutting, and is absent from the Aston Farm Cutting (the 'second cutting west of Bourton-on-the-Water') 500 m to the south-east, where the hardground and bored bed is developed on an attenuated Gryphite Grit Member (mistakenly identified as Notgrove Freestone by previous authors, e.g. Richardson, 1929b; Arkell, 1947b). Immediately beyond that cutting, mapping shows that the whole of the Aston Limestone Formation is cut out (Barron, 1999b).

The youngest beds seen in the section belong to the Salperton Limestone Formation (corresponding to the Upper Inferior Oolite) but this formation is better exposed at its type locality, the **First Cutting West of Notgrove** (see GCR site report, this volume). At its base, the Upper Trigonia Grit Member has yielded specimens of *Strenoceras*, indicating the Upper Bajocian Garantiana Zone. Parsons (1976b) recorded 3.0 m of the succeeding Clypeus Grit Member, but up to *c.* 7 m are represented in the graben described above. Parsons (1976b) collected *Parkinsonia* spp. from the basal part, which he assigned to the Bomfordi Subzone of the Upper Bajocian Parkinsoni Zone. In this area, the Clypeus Grit Member is known to extend into the Lower Bathonian Zigzag Zone (Sumbler *et al.*, 2000).

Conclusions

Harford Cutting is an important section in the Inferior Oolite Group of the Cotswolds, showing the succession from the Harford Member in the Birdlip Limestone Formation up to the Clypeus Grit Member of the Salperton Limestone Formation. It shows an excellent section through the Aston Limestone Formation (Middle Inferior Oolite), of which it is the type section, and is one of the few places where thinning of the latter towards the Vale of Moreton Axis can be seen in one exposure. The strata have yielded an important collection of ammonites that confirm the zonation of the succession, which ranges from late Aalenian to latest Bajocian in age.

HUNTSMANS QUARRY, GLOUCESTERSHIRE (SP 123 255)

M.G. Sumbler

Introduction

Huntsmans Quarry, near Naunton, Gloucestershire, is representative of the quarries around Eyford Hill that worked the so-called Cotswold Slate (Figure 3.54). This unit has long been famous for its suite of fossils, particularly those of reptiles, insects and plants, which have traditionally been ascribed to the 'Stonesfield Slate' (see **Stonesfield** GCR site report, this volume). However, the unit from which they came is somewhat older and is now assigned to the Eyford Member (Fuller's Earth Formation), of which the quarry is the type locality.

Figure 3.54 The Cotswold Slate at Huntsmans Quarry. (Photo: M.G. Sumbler.)

Description

A section of a quarry 'at Summerhill, Eyford', at or very close to the present Huntsmans Quarry, was recorded by Hull (1857) and reproduced by Woodward (1894). A section in Huntsmans Quarry (SP 125 254) and nearby pits at Eyford Hill (SP 135 254) were described by Richardson (1929b). A somewhat extended section, in the southern part of the present quarry (SP 126 254), was noted by Kennedy, Sellwood and McKerrow (in Ager *et al.*, 1973), and is reproduced below (with minor modifications and revised stratigraphical classification by the present author).

	Thickness (m)
Taynton Limestone Formation	
Quarry spoil	0.4
Limestone, coarse grained, ooidal, slightly sandy, trough cross-bedded; oysters and pectinid bivalves; nerineid gastropods	2.0
Limestone, coarse grained, shelly, ooidal, intraclastic calcarenite, planar cross-bedded; abundant *Trigonia*; *Thalassinoides* burrows at base descending into bed below	1.5
Fuller's Earth Formation	
Eyford Member	
3: Sandstone, grey, very fine-grained, trough cross-bedded; symmetrically-rippled surfaces penetrated by numerous *Skolithos* burrows; sharp eroded top surface; abundant *Placunopsis* and bone fragments	2.0
2: Sandstone, fine grained with planar lamination and ripples; burrows descending from top of bed; abundant *Kallirhynchia*, *Placunopsis*, *Vaugonia impressa* (Broderip) and *Plagiostoma* concentrated towards base where bored limestone clasts are also present	0.30–0.60
1: Sandstone, fine grained, calcareous with small-scale, trough cross-bedding and planar lamination, and well-developed symmetrical ripples exposed on fallen blocks; sharp eroded top surface; abundant *Placunopsis* on some surfaces	2.30

A somewhat similar section, exposing virtually all of the Eyford Member, was observed by the author in 1993 in the working area of the quarry, just to the north (SP 127 257). There, 2 m of Taynton Limestone Formation rested upon *c.* 5.6 m of Eyford Member (Sumbler, 2000).

Bradshaw (1978) recorded 6.8 m of Eyford Member at Huntsmans Quarry, which must be virtually the total thickness, as signs of grey mudstone in the bottom of the quarry represent the top of the underlying mudstone unit of the Fuller's Earth Formation. Boreholes drilled in the quarry floor indicate the mudstones are *c.* 3–5 m thick, and rest on the Chipping Norton Limestone Formation, which crops out to the north.

The indigenous invertebrate marine fauna of the Eyford Member is unremarkable, being dominated by bivalves, although specimens of the ammonite *Procerites* have also been recovered. The vertebrate fauna (mainly teeth and bone fragments) includes the marine crocodilians *Steneosaurus* and *Teleosaurus*, the dinosaur *Megalosaurus*, and the pterosaur *Rhamphocephalus*. As well as reptiles, numerous fish have been recorded, and the beds have also yielded plants, such as the conifer *Podozamites stonesfieldensis* Seward and the ginkgo *Ginkgoites digitata* (Brongniart), as well as fossil insects (Savage, 1963).

Interpretation

Huntsmans Quarry is almost the only remaining site where Cotswold Slate is worked. The stratum, lying between the mudstones of the Fuller's Earth and Taynton Limestone formations (Arkell, 1933), was formerly quarried as a source of tilestone for roofing at several sites in the immediate neighbourhood, the area of their thickest development. It can be traced for some distance to the south, to the neighbourhood of Cold Aston (SP 128 198), near Bourton-on-the-Water (Sumbler *et al.*, 2000). Details of the methods of working are given by Arkell (1947c). Despite a significant demand for natural tilestones, most of the material is currently merely crushed for use as aggregate, although some stone is used for rustic walling.

Cotswold Slate has traditionally been equated with, and assigned to, the Stonesfield Slate Series' (Hull, 1857; Woodward, 1894; Richardson, 1929b), but the type Stonesfield Slate, though of approximately the same age, is now known to occur within the overlying Taynton Limestone Formation (Boneham and Wyatt, 1993; see also **Stonesfield** GCR site report, this volume). The term 'Eyford (Sandstone) Member' was introduced by Kennedy, Sellwood and McKerrow (in Ager *et al.*, 1973) for the 'sands and siltstones with ooliths around Eyford, west of Stow on the Wold' (Sellwood and McKerrow, 1974), i.e. for the Cotswold Slate. Huntsmans Quarry, lying 1 km west of Eyford Hill, is the best exposure of these strata, and may be regarded as the type section of the Eyford Member. As originally defined, this member was included in the

Sharp's Hill Formation but the latter term is best restricted to regions of Oxfordshire where the strata have non-marine characteristics transitional to the Rutland Formation of the East Midlands (Arkell, 1947c; Bradshaw, 1978; see **Sharps Hill** GCR site report, this volume). The Eyford Member is better regarded as a part of the Fuller's Earth Formation, which comprises the marine strata between the Chipping Norton Limestone Formation (or Inferior Oolite Group, where the Chipping Norton Limestone Formation is absent) and the Taynton Limestone Formation in the Cotswolds, to the west of the Vale of Moreton Axis (Arkell, 1933; Sumbler *et al.*, 2000). The member typically comprises grey sandy limestone or calcareous sandstone, with sporadic ooid strings, in beds usually 0.3 m thick, interbedded with soft, brown, fissile, poorly cemented bituminous sand. The limestones include massive types, in which the primary sedimentary structures have been destroyed by bioturbation, and well-laminated fissile types, without burrows. The latter yielded the tilestones, which, depending on the cementation characteristics of the bed, could either be split into 'slates' straightaway ('presents') or after frosting ('pendle'). The topmost bed is a soft, brownish-grey, highly fissile, somewhat bituminous sandstone, *c.* 0.6 m thick; it probably corresponds with 'The Crop' bed recorded by Richardson (1929b), and the main source of 'presents'. From the sedimentary and biogenic structures, including footprints (Sarjeant, 1975), the Eyford Member evidently accumulated in very shallow water. The laminations preserved in some beds suggest rapid deposition; they have been interpreted as high-energy, upper flow regime characters (Sellwood and McKerrow, 1974), or they could have been formed by rapid deposition of sediment from shoaling storm waves (Bradshaw, 1978).

Although the Eyford Member has yielded the ammonites *Procerites progracilis* Cox and Arkell and *P. mirabilis* Arkell, indicating the Middle Bathonian Progracilis Zone (Arkell, 1958a,b; Torrens, 1969e), the chief interest of its fossil content is the vertebrate fauna, cited above and more fully described in the companion GCR volume on *Fossil Reptiles of Great Britain* (Benton and Spencer, 1995). The terrestrial component, and perhaps the sandy sediment of the member, was presumably derived from the land area (London Landmass) in the interior of the London Platform, which lay to the east.

The overlying Taynton Limestone Formation, a cross-bedded, coarse-grained, well-sorted grainstone, is evidently a high-energy sediment, probably deposited as subaqueous dunes in the shallow sea bordering the London Landmass. The cross-bedding indicates that the predominant current flow was towards the south or SSE (not west, as recorded by Sellwood and McKerrow, 1974). This current direction, also seen at other Taynton Limestone Formation localities in the region, would suggest tidal currents flowing roughly parallel to the coast to the east.

Conclusions

Huntsmans Quarry provides the best remaining exposure of the Cotswold Slate facies, which constitutes the Eyford Member of the Fuller's Earth Formation, and is the type locality of that member. Since the 19th century, the strata have yielded a rich and diverse fauna of reptiles, and a flora of considerable interest, as well as zonally diagnostic Middle Bathonian ammonites.

JACKDAW QUARRY, GLOUCESTERSHIRE (SP 077 309)

M.G. Sumbler

Introduction

The GCR site known as 'Jackdaw Quarry' is a disused quarry near Stanway, Gloucestershire, which provides a fine section through the upper part of the Birdlip Limestone Formation (Lower Inferior Oolite). The quarry was first described by Woodward (1894), when only the lower part of the succession was exposed, and higher beds in the Hornhill Quarry, a short distance to the north, were described by Buckman (1901); see also Richardson (1929b). Subsequent working extended the Jackdaw Quarry northwards, such that by 1972, the two quarries were conjoined. The quarry is now partly backfilled and landscaped, but excellent exposures remain in the northern face (Figure 3.55).

Description

The succession visible in 1972 was described by Parsons (1976b), and the following section is based on his account.

Figure 3.55 Exposure at Jackdaw Quarry showing 'White Guiting Limestone' in the lower face overlain by Scottsquar Member and the Harford Member. The Lower Trigonia Grit Member is just visible at the top of the section in the middle. (Photo: M.G. Sumbler.)

	Thickness (m)
Aston Limestone Formation	
Notgrove Member	
18: Limestone, hard, heavily bored, with numerous *Entolium demissum* (Phillips) (seen as rubble in field behind quarry)	?
Gryphite Grit Member	
17: Limestone, brown, sandy, iron-stained, bioclastic, with numerous fossils (exposed as loose rubble at top of section)	?
Lower Trigonia Grit Member	
16: Limestone, hard, white, iron-stained, burrowed, bioclastic, weathering to loose rubble, harder and more compact towards base; numerous burrowing bivalves including *Pholadomya lirata* (J. Sowerby), *Pleuromya uniformis* (J. Sowerby) and *Inoperna plicata* (J. Sowerby); *Graphoceras* (*G.*) sp., *Hyperlioceras* sp., *Euhoploceras* sp	0.45
15b: Limestone, brown, slightly 'iron-shot' limestone; flat top, softer towards base, grading into Bed 15a below; highly fossiliferous; *Hyperlioceras* aff. *subsectum* (S.S. Buckman)	0.25–0.30
15a: Limestone, yellow-brown, soft, marly, 'iron-shot'; many fossils, especially rolled and broken corals and belemnites; iron-stained, sandy limestone pebbles (derived from Bed 14) commonly thickly coated with limonite, serpulids and bryozoa; *Haplopleuroceras* cf. *mundum* S.S. Buckman, *Cladophyllia* sp., *Isastrea limitata* (Lamouroux), *Latomeandra gregaria* (McCoy), *Thamnasteria* sp., *Peronidella tenuis* Hinde, *Lopha marshi* (J. Sowerby)	0.10–0.30

	Thickness (m)
Birdlip Limestone Formation	
Harford Member	
'Tilestone'	
14: Limestone, brown, sandy, slightly 'iron-shot', especially towards top which has numerous small, rounded, commonly limonite-coated pebbles; flat, bored hardground upper surface	0.45–0.60
'Snowshill Clay'	
13: Clay, brown, very sandy, calcareous, abundant shell-debris; more indurated towards base; lowest 0.12 m locally a calcareous sandstone	0.26–0.43
12: Clay, blue, mottled with red limonite-rich bands; browner and sandier in upper part, with strongly limonite-stained top	0.40
11b: Clay, strongly limonitic	0.03
11a: Limestone, blue-hearted, bioclastic; browner and sandier towards limonite-stained top	0.23
10: Clay, grey, calcareous, interbedded with thin beds of shelly limestone	0.22
9: Clay, calcareous, limonitic	0.01–0.04
8: Clay, pale purple-grey with orange-coloured, limonitic streaks, tenacious, with much shell-debris towards base	0.26–0.33
'Harford Sand'	
7: Sand, orange-coloured, fine grained	0.18–0.20
6: Sand, grey-blue, fine grained; clayey, particularly near top but very sandy near base; intensely bioturbated with orange-coloured, coarse-grained sand in burrows piping into underlying bed; poorly preserved, internal casts of bivalves near top	0.56–0.71

	Thickness (m)
'Naunton Clay'	
5: Clay, dark-grey, abundant squashed bivalves and lignite fragments	0.20
4c: Clay, dark-brown; small calcareous concretions at base	0.05–0.10
4b: Clay, yellow-brown, with numerous crushed oysters towards top; *Liostrea* sp.	0.20
4a: Clay, yellow-brown, laminated, sparsely sandy, numerous 'pseudo-ooliths', gradational base; poorly preserved bivalves including *Pinna cuneata* Phillips and *'Lucina'* cf. *bellona* (d'Orbigny)	0.23–0.25
Scottsquar Member	
3: Limestone, brown, blue-hearted, sandy, ooidal, in three courses separated by sandy marl partings; top packed with poorly preserved, crushed but articulated, bivalves; *'Lucina'* cf. *bellona*	1.0–1.16
2b: Limestone, yellow, finely laminated, argillaceous and micritic, and densely ooidal to coarsely sandy with layers of clay, ooidal marl and biosparite layers; becoming paler, off-white and sandier with sandy marl partings towards top; numerous limonite-coated surfaces, lenses of shell debris and micrite-filled burrows; *Homoeorhynchia* aff. *cynomorpha* (S.S. Buckman)	1.60–3.00
2a: Marl, limonitic	0.01–0.10
?Cleeve Cloud Member	
'White Guiting Limestone'	
1: Limestone, cross-bedded, ooidal with yellow ooids in blue-grey spar matrix limestone, well bedded, more massive in lower part; softer and more marly towards planar top with numerous burrows filled with soft micrite and faecal pellets, and numerous poorly preserved bivalves, brachiopods and rare nerineid gastropods; *Globirhynchia tatei* (Davidson), *Plectothyris fimbria* (J.Sowerby), *Bactroptyxis* aff. *bacillus* (d'Orbigny)	seen to 9.0

The section now (1999) visible in the northern face is much as described by Parsons (1976b), with beds 1 to 14 being seen in one, more-or-less continuous, exposure. The general nature of higher beds can be made out from sporadic exposures in Hornhill Quarry immediately to the north of the face, which, however, is now largely backfilled and planted with trees.

Interpretation

In the southern part of the quarry, isolated exposures of massive, yellowish-brown oolite represent the so-called 'Yellow Guiting [Lime]stone' (Richardson, 1929b), named the 'Jackdaw Quarry Oolite' by Mudge (1978a,b), with this site as its type section. This unit has been claimed to be an atypical development of the Pea Grit and Lower Limestone (Crickley Member) of the Cheltenham area (see **Crickley Hill** and **Leckhampton Hill** GCR site reports, this volume) (Richardson (1904, 1929b), which has led to the use of the confusing and unsatisfactory terms 'Pea Grit Equivalent' or 'Pea Grit Series' (e.g. Richardson, 1929b; Arkell, 1933). However, this supposed correlation is not well substantiated. Although it is likely that the Crickley Member passes into the lower part of the Yellow Guiting Stone, it is possible that the former is cut out by a non-sequence beneath the latter as the Vale of Moreton Axis is approached (Sumbler *et al.*, 2000). Irrespective of lateral correlation, the Yellow Guiting Stone is now assigned to the Cleeve Cloud Member (the former Lower Freestone) on the basis of its lithology and overall stratigraphical position (Barron *et al.*, 1997).

The lowest beds now seen in continuous section (Bed 1) comprise Richardson's (1929b) White Guiting [Lime]stone. This was assigned to the Devil's Chimney Oolite by Mudge (1978a,b) and is now regarded as the upper part of the Cleeve Cloud Member. Again, however, the correlation of the White Guiting [Lime]stone is somewhat uncertain, but the possibility that it should be included in the succeeding Scottsquar Member, suggested by the presence of the brachiopod *Plectothyris fimbria*, was rejected by Parsons (1976b) because of relationships observed in the nearby ARC Guiting Quarry (SP 79 302).

As described by Parsons (1976b), the character of the Scottsquar Member (beds 2a and 2b) change somewhat across the quarry face, the beds on the west being described as thicker-bedded and 'more oolitic'. In general, this member is characterized by rapid lateral facies changes, and the previous separation into Oolite Marl (low-energy marls and carbonate mudstones) and Upper Freestone (high-energy peloidal and ooidal grainstones) was somewhat arbitrary as recognized by Buckman (1895). For this reason, the two divisions are now combined into a single member (Mudge, 1978a,b; Baker, 1981; Barron *et al.*, 1997). Bed 2 is not well exposed, but the lower part includes somewhat sandy marls with lenses of carbonate mudstone, and the upper part includes well-bedded oolite. The succeeding Bed 3 is herein included with the Scottsquar Member on lithological grounds, but Parsons (1976b) grouped it with the overlying beds (now Harford Member) presumably because of the similarity of the fauna to that from Bed 4a, and the gradational contact between the two.

Jackdaw Quarry shows a complete section through the Harford Member (compare **Harford Cutting**; see GCR site report, this volume), the youngest part of the Birdlip Limestone Formation. At this locality, the member is *c.* 2.8 m thick (beds 4a to 14). It comprises the 'Naunton Clay', 'Harford Sand', 'Snowshill Clay' and 'Tilestone' of Buckman (1890, 1897, 1901) and Richardson (1929b) but, as discussed by Parsons (1976b), these subdivisions are of limited value. As in the Scottsquar Member, there are rapid lateral facies variations, as is apparent from the very different succession exposed in the Guiting Quarry (Mudge, 1995) and, for this reason, the strata are now combined into a single member (Mudge, 1978a,b; Barron *et al.*, 1997). Except for the so-called 'Tilestone' at the top, the succession is dominated by clays and sandy clays with oysters, *Lucina* and *Pinna*, and Parsons (1976b) also recorded lignite layers. The facies is similar to – albeit more 'marine' than – the broadly equivalent Grantham Formation of the East Midlands, and was probably laid down in a shallow water, coastal environment. It has yielded no ammonites, but is thought to belong mainly to the Concavum Zone (Aalenian); Parsons (1976b) showed that Buckman's (1901) record of *Graphoceras* from the 'Snowshill Clay' at Stanway in fact came from the succeeding Lower Trigonia Grit Member. The 'Tilestone' is of more fully marine aspect, and has yielded ammonites (see **Harford Cutting** GCR site report, this volume). It is capped by a bored hardground, representing the 'Aalenian denudation' of Buckman (1901). Lithologically, it is rather similar to the succeeding Lower Trigonia Grit Member, although at other localities it is of an entirely different facies.

The Lower Trigonia Grit Member, the basal unit of the Aston Limestone Formation (Middle Inferior Oolite; see **Harford Cutting** GCR site report, this volume), is not now well exposed. The basal bed (15a) is conglomeratic and contains abundant ferruginous peloids ('ironshot'). Parsons (1976b) also recorded a number of concentric limonite concretions ('snuffboxes'; probably oxidized siderite nodules) such as typify the condensed Inferior Oolite succession in Dorset. He suggested that these features related to the proximity of the positive 'Moreton Swell', i.e. the Vale of Moreton Axis. *Haplopleuroceras* recorded from this bed indicates the Lower Bajocian Discites Zone.

Conclusions

Jackdaw Quarry is particularly important in exhibiting a complete section through the Harford Member, the topmost unit of the Birdlip Limestone Formation, and is designated a primary reference section for that member (Barron *et al.*, 1997). This member comprises the units formerly known as the 'Naunton Clay', 'Harford Sand', 'Snowshill Clay' and 'Tilestone' of the Lower Inferior Oolite.

SNOWSHILL HILL (HORNSLEASOW QUARRY), GLOUCESTERSHIRE (SP 131 323)

M.G. Sumbler

Introduction

Hornsleasow Quarry, formerly generally known as 'Snowshill Hill', shows a fine section through the lower part of the Great Oolite Group, from the Chipping Norton Limestone Formation up to the Taynton Limestone Formation (Figure 3.56). The underlying Clypeus Grit Formation (Inferior Oolite Group) is also poorly exposed. The middle part of the succession is regarded herein as an attenuated representative of the Fuller's Earth Formation, and is of a facies transitional between that formation, as typically developed farther south in the Cotswolds, and the Sharp's Hill Formation of Oxfordshire. Much of the succession is fossiliferous. Of particular interest are the Coral Bed (in the Fuller's Earth Formation) and the Hornsleasow Clay (within the Chipping Norton Limestone Formation); the latter has yielded an extensive vertebrate fauna. Both the Clypeus Grit and Taynton Limestone formations have yielded age-diagnostic ammonites.

Description

Hornsleasow Quarry was briefly mentioned by Richardson (1929b), but the first published section was that of Channon (1950). A somewhat extended section was recorded by Torrens (1968b) and, in more detail, by Barker and Torrens (in Torrens, 1969d), and later by Kennedy, Sellwood and McKerrow (in Ager *et al.*, 1973). A certain amount of additional information was given by Sellwood and McKerrow (1974), Bradshaw (1978) and Mudge (1995),

Figure 3.56 Snowshill Hill (Hornsleasow Quarry). The floor of the quarry here is the level from which the Hornsleasow Clay has been excavated from the Chipping Norton Limestone Formation; the latter forms the bench with Fuller's Earth Formation above. (Photo: M.G. Sumbler.)

and an account relating chiefly to the important vertebrate-bearing Hornsleasow Clay was produced by Metcalf *et al.* (1992). These various accounts differ somewhat in their detailed classification of the succession, illustrating the difficulty in dealing with this section, which is isolated from the main outcrop of the formations represented. The best and most detailed description is by M.J. Barker and H.S. Torrens (in Torrens, 1969d); it forms the basis of the following abbreviated record, classified by the present author (see also Figure 3.57; Barron, 2001).

	Thickness (m)
Taynton Limestone Formation	
5: Limestone, buff, flaggy, cross-bedded, ooidal and shell-fragmental grainstone, with scattered plant-material; upper surfaces ripple marked; sharp, basal erosion surface	2.5
Fuller's Earth Formation	
4j: *Upper Nerinea Bed*: Clay, greenish-grey and brown, ooidal, poorly fossiliferous	0.45+
4i: Limestone, pink, soft, ooidal, rubbly, becoming flaggy near top; numerous vertical burrows	0.50
4h: *Middle Nerinea Bed*: Marl, greenish-grey, ooidal, passing down into orange-brown ooidal clay with gastropods and oysters	0.45
4g: Limestone, brownish-buff, fine-grained, ooidal, shell-fragmental grainstone, cross-bedded; lenses of sandy tilestone	2.50
4f: Clay, blue, shaly, grading up into brown, friable marl	0.50
4e: *Coral Bed*: Clay, bluish-grey, highly fossiliferous	0.10–0.30
4d: Clay, blue to brown, shaly with oysters	0.40
4c: Clay, shaly; ripple-marked upper surface with burrows and serpulids	0.05
4b: Limestone, shelly, overlain by blue and brown clays with oysters and other fossils	0.20
4a: *Lower Nerinea Bed*: Limestone, orange-brown, sandy, soft, ooidal, passing up into greenish-grey clay	0.35
Chipping Norton Limestone Formation	
3: Limestone, ooidal and shell-fragmental grainstone, cross-bedded, with intercalated softer, orange-coloured, ooidal marls	1.50–2.0
2: Limestone, as above with softer intercalations, cross-bedded in places	*c.* 10
Obscured	?
Clypeus Grit Formation	
1: Limestone, yellow, rubbly, coarse ooidal (almost pisoidal) with marl patches; *Parkinsonia* sp.	5

Most of this section is still well exposed except for the Clypeus Grit Formation, although *c.* 2 m of coarsely ooidal and peloidal, shelly packstone typical of that formation can be seen close to the quarry entrance.

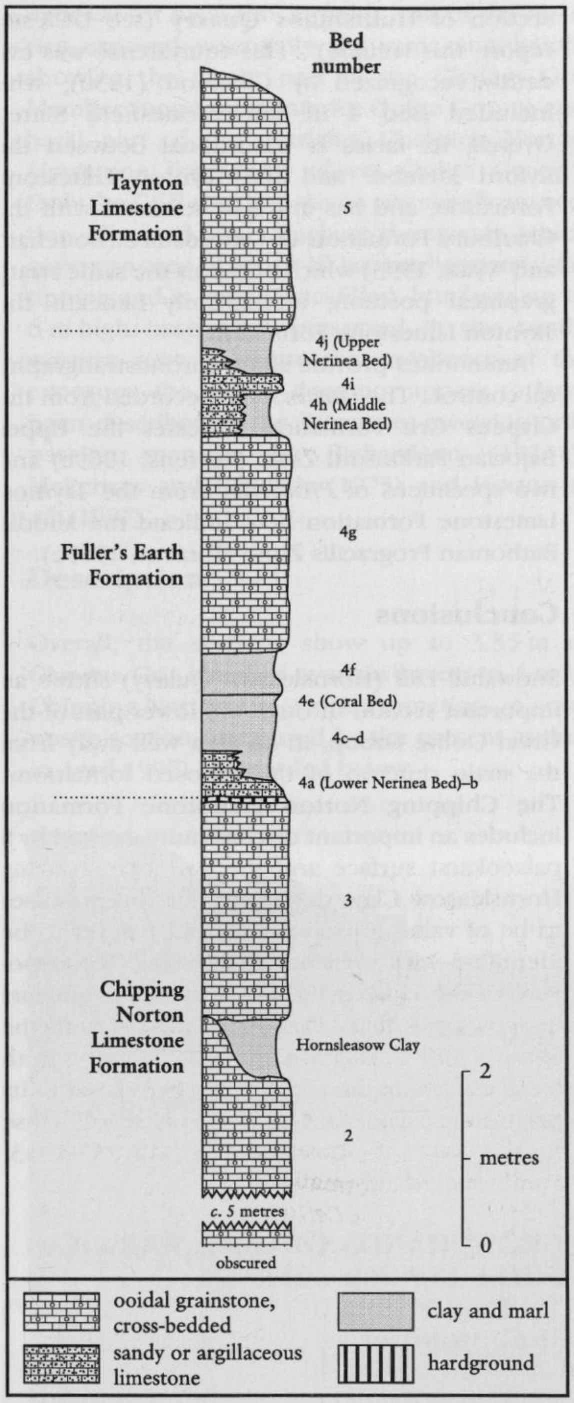


Figure 3.57 Graphic section of the succession at Snowshill Hill (Hornsleasow Quarry). (After Torrens, 1969d.)

Remnants of the lenticular 'Hornsleasow Clay', which has been intermittently exposed at the base of Bed 3 within the Chipping Norton Limestone Formation (Channon, 1950; Metcalf *et al.* (1992), can still be examined in the easternmost part of the quarry, where they occur in a steep-sided channel incised up to 0.8 m into the underlying limestones. The sides and base of the channel are ferruginized and somewhat cavernous; this distinctive surface can be traced along the quarry face where the clay is absent. The clay contains abundant plant-material including rootlets, as well as non-marine molluscs such as the gastropod *Viviparus*. Importantly, it has yielded an extensive fauna of fossil vertebrates, including salamanders, lizards, crocodiles, dinosaurs, turtles, mammal-like reptiles and 'eupanothere' mammals (Metcalf *et al.*, 1992).

The basal part of the Fuller's Earth Formation (beds 4a–4f) is highly variable, comprising shelly clays that pass laterally into limestones with gastropods such as *Aphanoptyxis eulimoides* (Lycett), *Neridomus* and *Pseudomelania*, and bivalves such as *Modiolus imbricatus* J. Sowerby. The lowest beds as now seen (within beds 4a–4b) include a shell bank, packed with the small oyster *Praeexogyra* (mainly *P. hebridica* (Forbes)). The Coral Bed (Bed 4e) is perhaps the most fossiliferous in the section, having yielded abundant, well-preserved corals, particularly *Cyathopora pratti* Edwards and Haime, *Isastrea limitata* (Lamouroux), *Dendrarea* (*Microsolena*) *excelsa* Edwards and Haime, and *Thamnasteria lyelli* (Edwards and Haime) (Negus and Beauvais, 1975). The upper part of the formation (beds 4i–4j) and the contact with the succeeding Taynton Limestone Formation (Bed 5) is not now exposed, although brown to white, poorly sorted, coarse-grained, shelly, ooidal grainstone typical of the latter is poorly exposed in the highest, northern parts of the quarry. It contains a fairly rich fauna including *Praeexogyra hebridica* (Forbes), trigoniid bivalves and brachiopods such as *Burmirhynchia*.

Interpretation

The cross-bedded oolites of the Chipping Norton Limestone Formation appear to be about 12.5 m thick in total. Although, in gross lithological terms, it is fairly uniform throughout, the formation has previously been subdivided into a Hook Norton Member below (Bed 2), and Chipping Norton Member above (Bed 3) (see Sellwood and McKerrow, 1974, for an explanation of these terms). This subdivision was based on the presence of a discontinuity noted by

Channon (1950), who recorded a lenticular black clay, up to 0.3 m thick, at the base of the upper unit. The clay was not seen by later workers, but a similar lens was uncovered by quarrying in 1987. This 'Hornsleasow Clay' forms the basis of an account by Metcalf *et al.* (1992). The clay has a high kaolinite content, generally regarded as indicative of weathering in a warm, humid climate, and thus supporting the idea that the underlying surface represents a 'palaeokarst' formed subaerially. The karstified surface evidently marks an important break in sedimentation during the deposition of the Chipping Norton Formation, and is likely to be of more than local significance. However, the correlation of this event horizon with sections elsewhere remains unproven, and formal division into Hook Norton and Chipping Norton members at Snowshill Hill (Hornsleasow Quarry) is unjustified. Above the Hornsleasow Clay, the upper part of the Chipping Norton Limestone is capped locally by a bored and oyster-encrusted hardground (Kennedy, Sellwood and McKerrow in Ager *et al.*, 1973) although this is not well developed in current exposures, and the contact with the overlying strata appears to be conformable, albeit a rapid transition.

The overlying strata (beds 4a–4j) have generally been included in the Sharp's Hill Formation, although this term is best restricted to Oxfordshire, where the strata have some non-marine characteristics transitional to the Rutland Formation of the East Midlands (Arkell, 1947b; Bradshaw, 1978; see **Sharps Hill** GCR site report, this volume). A more appropriate term is Fuller's Earth Formation; this name is applicable to the marine strata developed between the Chipping Norton Limestone and Taynton Limestone formations in the Cotswolds to the west of the Vale of Moreton Axis (Arkell, 1933; Sumbler, 1999; Sumbler *et al.*, 2000). However, the formation is thinner (5.4 m) than is general in areas farther south, and it appears likely that the lower, mudstone-dominated part of the formation present to the south of Snowshill Hill (Hornsleasow Quarry) (e.g. **Huntsmans Quarry** and **Hampen Railway Cutting**, see GCR site reports, this volume) is absent. Bed 4g has been included in the Sharp's Hill Formation by most workers, but in the Taynton Limestone Formation by Kennedy, Sellwood and McKerrow (in Ager *et al.*, 1973). As currently exposed, it is much like parts of the Eyford Member of the Fuller's Earth Formation as developed at its type section of **Huntsmans Quarry** (see GCR site report, this volume). This equivalence was evidently recognized by Channon (1950), who included Bed 4 in the 'Stonesfield Slate'. Overall, its facies is transitional between the Eyford Member and the Taynton Limestone Formation, and has much in common with the Charlbury Formation of Oxfordshire (Boneham and Wyatt, 1993) which occupies the same stratigraphical position, immediately beneath the Taynton Limestone Formation.

Ammonites provide some chronostratigraphical control. The *Parkinsonia* recorded from the Clypeus Grit Formation indicates the Upper Bajocian Parkinsoni Zone (Torrens, 1969e) and two specimens of *Procerites* from the Taynton Limestone Formation here indicate the Middle Bathonian Progracilis Zone (Torrens, 1969e).

Conclusions

Snowshill Hill (Hornsleasow Quarry) shows an important section through the lower part of the Great Oolite Group, in an area well away from the main outcrop of the exposed formations. The Chipping Norton Limestone Formation includes an important discontinuity marked by a palaeokarst surface and the vertebrate-bearing Hornsleasow Clay; this event horizon promises to be of value in correlation, but has yet to be identified with certainty elsewhere. The exposure of the Fuller's Earth Formation is unusual in showing a facies that is transitional with the Sharp's Hill Formation of Oxfordshire. Both these aspects of the section may be related to its position marginal to the London Platform, close to the Vale of Moreton Axis (Arkell, 1933; Sumbler *et al.*, 2000).

CROSS HANDS QUARRY, WARWICKSHIRE (SP 269 291)

M.G. Sumbler

Introduction

The GCR site at Cross Hands Quarry lies 5 km north-west of Chipping Norton in the northern quadrant of the junction of the A44 Chipping Norton to Moreton-in-Marsh road, and A436 to Stow-on-the-Wold, just within the county of Warwickshire. It is one of several quarries clustered around the crossroads that were originally opened during the Second World War to provide material for local RAF airfields. All of the quarries exposed essentially the same succession, showing the upper part of the Clypeus Grit Member (uppermost Inferior Oolite Group) and basal part of the overlying Chipping Norton Limestone Formation (Great Oolite Group). Only the GCR site now shows any significant section (Figure 3.58). Much of the quarry, which covers an area of about 10 ha, has been used for tipping and is largely backfilled, but faces up to 6 m high have been preserved in the south-western part. Despite the excellence of the exposure, the quarry does not appear to have been described in the literature, receiving only passing mention by Richardson (1911a), McKerrow and Kennedy (1973) and Horton *et al.* (1987).

Description

Overall, the sections show up to 3.35 m of Clypeus Grit Member overlain by up to 4 m of Chipping Norton Limestone Formation. A composite section (measured by the present author in April 1997) is recorded below.

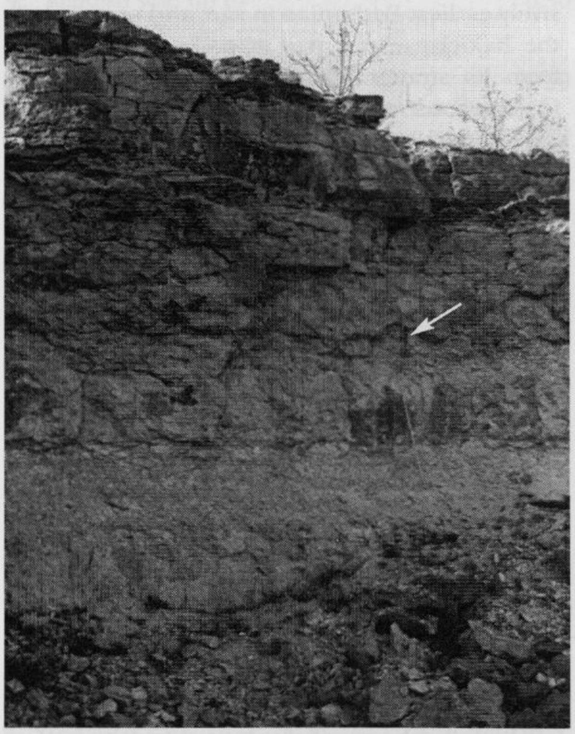


Figure 3.58 Chipping Norton Limestone Formation overlying Clypeus Grit Member (Salperton Limestone Formation) at Cross Hands Quarry. The hammer-head (arrowed) marks the formational boundary. (Photo: M.G. Sumbler.)

	Thickness (m)
Great Oolite Group	
Chipping Norton Limestone Formation	
7: Limestone, yellowish-brown, slightly sandy and ferruginous, fine- to medium-grained, fairly well-sorted ooidal and moderately shell-fragmental grainstone in several massive beds, each becoming somewhat more flaggy upwards and showing signs of cross-bedding; common specks of carbonaceous plant-material and fairly common bone fragments up to several centimetres in length; burrows common, often infilled with brown, limonitic clay; some well-preserved *Diplocraterion* in lowest 0.5 m; grey to brown clay parting at highly uneven base, perhaps channelling into Bed 6 below	up to 4 m
6: Limestone, pale-fawn to brown, hard, rubbly, coarse-grained, peloidal and shell-fragmental packstone; common small gastropods together with oysters and large serpulids; fairly common bone fragments; variable thickness	0.25–0.30
5: Clay, marly, brown, shelly	0.02
Inferior Oolite Group	
Salperton Limestone Formation	
Clypeus Grit Member	
4: Limestone, pale-buff, soft, rubbly, coarse-grained ooidal and peloidal packstone to wackestone; fossils abundant and often perfectly preserved	0.25
3: Limestone, white to pale-brown, soft, massive, rubbly weathering, coarse-grained, ooidal, peloidal and shell-fragmental packstone to wackestone	0.60
2: Marl, white and fawn banded, made up largely of coarse (up to 1.5 mm) peloids in slightly argillaceous micrite matrix; patchily cemented into soft limestone in places; forming persistent, distinctive bed in face	0.50
1: Limestone, white to pale-fawn, soft, massive, rubbly weathering, coarse-grained, ooidal and peloidal packstone to wackestone; poorly sorted, structureless, with large, often brownish-skinned and irregularly shaped composite ooids (aggregate grains) in matrix with finer-grained ooids and peloids	up to 2.0
Obscured (to quarry floor)	1.9

The quarry spoil heaps provide an opportunity to examine the fauna. The Clypeus Grit Member yields abundant brachiopods including rhynchonellids and terebratulids (particularly *Stiphrothyris*), and many bivalves including myaceans, pectinids and oysters. Several genera of irregular echinoids occur, most notably the eponymous *Clypeus*, as well as gastropods, serpulids and solitary corals (J.D. Radley, pers. comm., 2001).

Macrofauna is very sparse in the Chipping Norton Limestone Formation, although bivalves such as *Camptochlamys* and *Camptonectes* occur sporadically, and a more extensive fauna occurs in Bed 5. A new species of the bryozoan *Mesenteripora* (Warwickshire Museum, specimen No. G15409; J. Crossley, pers. comm., 1997) has also been collected. Bones of dinosaur have been recovered (Birmingham and Oxford University museums) and small bone fragments occur quite commonly; plant material is also present and wood (?*Ginkgo*) has allegedly been found.

A number of substantial, sub-vertical gulls can be seen in the section; these are widened joints, up to *c*. 1 m in width, which are more-or-less infilled with rock debris and travertine.

Interpretation

The section of the Clypeus Grit Member represents the upper part of the member, the total thickness of which is probably less than 5 m at this locality (Horton *et al*., 1987, fig. 26). Despite this, the member hereabouts makes up the greater part of the Inferior Oolite Group, which is much reduced compared with farther west in the Cheltenham area where it is up to 100 m or more in thickness. To the north-east (see **Hook Norton** GCR site report, this volume), the Clypeus Grit Member dies out altogether and is overstepped by the Chipping Norton Limestone Formation. The micrite matrix of the rock suggests a low-energy environment, although episodes of higher energy are implied by the presence of coarse-grained peloids and shell debris. This material is now dispersed through the rock probably as a result of intense burrowing activity by creatures such as *Clypeus*. Shallow infauna is generally disturbed by burrowing but deeper infauna, such as the bivalves *Pholadomya* and *Pleuromya*, typically remain in life position.

The overlying Chipping Norton Limestone Formation, which comprises high-energy oolite facies limestones, is the basal unit of the Great Oolite Group. It rests sharply on the underlying Inferior Oolite Group and, given the likelihood of progressive overstep of the latter, there is presumably an erosive non-sequence at the base. There is, however, no indication of a bored surface such as has been described at this level elsewhere (Sumbler *et al*., 2000). Apart from the basal limestone (Bed 6), which incorporates material (coarse peloids) reworked from the underlying Clypeus Grit Member, the Chipping Norton Limestone Formation is of markedly different facies to that of the latter, having a distinctive brownish colour and being somewhat sandy with scattered specks of black plant-material. This facies, which characterizes the lower part of the Chipping Norton Limestone Formation throughout the region, has been ascribed to the Hook Norton Member, although the validity of this formational subdivision is debateable (Horton *et al*., 1987; Sumbler *et al*., 2000; see also **Snowshill Hill** and **Hook Norton** GCR site reports, this volume). Bone and plant material, together with the substantial component of quartz sand, reflect the influence of the London Landmass.

The sub-vertical gulls reported above are associated with an early stage of landslipping known as 'cambering'. This phenomenon is common throughout the Cotswolds in situations, such as that at Cross Hands Quarry, where limestone beds crop out on a hilltop or scarp edge, above slopes of incompetent Lias Group mudstone.

Conclusions

The Cross Hands Quarry GCR site displays the boundary between the Inferior and Great Oolite groups. The exposed beds are probably exclusively earliest Bathonian in age, and very close to the Bajocian–Bathonian stage boundary. Apart from its stratigraphical interest, it is a highly fossiliferous site yielding an abundance of brachiopods and bivalves, as well as echinoids and corals, to the many educational groups (particularly school parties) that have visited during the past 20 years. Dinosaur remains have also been found. The strata show indications of the influence of the London Landmass during the Mid Jurassic Epoch, and the site is thus of interest for regional palaeogeographical studies.

SHARPS HILL, OXFORDSHIRE (SP 338 358)

M.G. Sumbler

Introduction

The GCR site known as 'Sharps Hill' comprises Sharps (or Sharp's) Hill Quarry, *c*. 1.5 km south-west of Sibford Ferris, Oxfordshire. It is the type locality – and one of the best remaining exposures – of the Sharp's Hill Formation of the Great Oolite Group. The quarry also exposes the underlying Chipping Norton Limestone and Northampton Sand formations. The succession in the Sharp's Hill Formation is richly fossiliferous; the gastropod fauna of the so-called 'Viviparus Marl' and discoveries of dinosaur remains are of particular interest.

Description

The strata at Sharps Hill were first noted by Walford (1883) and Woodward (1894). A section giving more detail was subsequently described by Walford (1906) and Richardson (1911a). Summaries of the section were given by Arkell (1933, 1947b), McKerrow and Kennedy (1973) and Torrens (1968b). Additional details, including the first record of strata below the Clypeus Grit Formation, were given by Horton *et al.* (1987). However, there is no modern published description of the important section through the Sharp's Hill Formation. The following record is based on Richardson (1911a); bed numbering is that of Walford (1906) as applied by Richardson who was unable to recognize Walford's beds 7–10.

	Thickness (m)
Sharp's Hill Formation	
1: Reddish soil; up to	0.30
2: Marl, yellowish, clayey, crowded with oysters; '*Rhynchonella*', *Camptonectes annulatus* (J. de C. Sowerby)	0.30
3: Clay, brown and dirty greenish-grey at top, darker towards base	*c.* 0.30
4: Clay, marly; crowded with whitened oysters	0.15
5: Clay, tough, dark-brown, bluish and greenish, with discontinuous bed of brown sandstone, up to 0.05 m thick, near top	0.76
6: Clay, black (in places almost a coal-seam), overlying seam of rich-brown clay	0.05–0.20
11: *Viviparus Marl*: Marl, pale-purplish, with numerous pebbles and concretions, some ochreous, others phosphatic; *Bathonella scoticus* (Tate), *Ataphrus labadyei* (d'Archiac), nerineids	0–0.40
12: Limestone, generally hard but rubbly in places, passing locally into whitish-grey marl; large *Eunerinaea* ex gr. *eudesii* (Morris and Lycett) common; *Melanioptyxis* sp., *Neridomus cooksonii* (Deslongchamps) at base; *Corbula buckmani* Lycett, *Anisocardia loweana* (Morris and Lycett) (dwarfed form), *Bakevellia waltoni* (Lycett), ostreiids, *Modiolus imbricatus* J. Sowerby	0.35–0.61
13: Marl, greenish-grey, with numerous white concretions and irregular limestone layers; *Melanioptyxis altararis* (Cossmann), *Bakevellia waltoni*, *Isognomon isognomonoides* (Stahl), *Placunopsis socialis* Morris and Lycett, *Palaeonucula waltoni* (Morris and Lycett), ostreiids, *Modiolus imbricatus*; *Cyathopora bourgueti* (Defrance), principally at base	0–0.64
14: Limestone, pale-green when fresh, with abundant nerineids; at western end of section represented by occasional nodule only; *Cyathopora bourgueti* near top; *Anisocardia loweana* (dwarfed form), *Burmirhynchia concinna* (Davidson), '*Astarte*', nerineids; 0.05 m-thick clayey marl at base	0–0.30
15: Limestone mixed with marl, pale-green when fresh, harder portions blue and shelly; *Isognomon* cf. *isognomonoides*, *Palaeonucula waltoni*, *Modiolus imbricatus*, procerithiids; 0.02–0.08 m-thick greenish clayey marl at base	0–0.20
16: Limestone, pale-yellow or whitish, blue-hearted; procerithiids, *Amberleya* aff. *bathonica* Cox and Arkell, *Protocardia buckmani* (Morris and Lycett), *Palaeonucula waltoni*, ?*Pseudomelania subglobosa* (Morris and Lycett)	0–0.25
17: Limestone	0–0.13
18: Marl and stone, pale-yellow, greenish and bluish; *Isognomon oxoniensis* (Paris), *I. isognomonoides*, *Bakevellia waltoni*, *Protocardia lingulata* (Lycett), *Pachymya* cf. *unioniformis* (Morris and Lycett), *Modiolus imbricatus*, *Ataphrus labadyei*, procerithiids	0.3–0.46
19: Sand; reddish-brown with nodules and masses of blue shelly limestone with numerous ostracods; *Isognomon*, *Placunopsis socialis*, *Bakevellia*, *Modiolus*, procerithiids	0–0.20
20: Clay, black and reddish-brown	0.58
Chipping Norton Limestone Formation	
21: Limestone, perforated with tubular holes infilled with black clay	0.46–0.81
21a: Clay, tough	0–0.05
22: Limestone, fine grained, siliceous, fawn but blue-hearted with numerous fragments of black lignite	1.42
23: *Signata Bed*: Limestone, fawn, blue-hearted, sandy, hard; abundant trigoniid bivalves	0.41
24a: Limestone, fine grained, siliceous, blue, weathering brown, with numerous fragments of lignite	0.71
24b: Conspicuous layer of ironstone	0–0.10
24c: Limestone, similar to Bed 24a; 0.61 m seen but according to Walford (1906)	2.74
Clypeus Grit Formation below.	

Lower strata of the Inferior Oolite Group below the Clypeus Grit Formation can be seen immediately upon entering the quarry from the north (Figure 3.59). Horton *et al.* (1987) gave a detailed section of these beds; the strata comprise 4.06 m of brown to purplish-brown calcareous sandstone, with scattered ooids and shell fragments at some levels. The beds dip steeply because of valley-bulging and cambering; the mudstones of the Lias Group probably occur within 1.5 m of the base of the section. The basal bed seen is a hard, grey-hearted, sandy, ooidal limestone with many fossils including *Montlivaltia lens* Edwards and Haime,

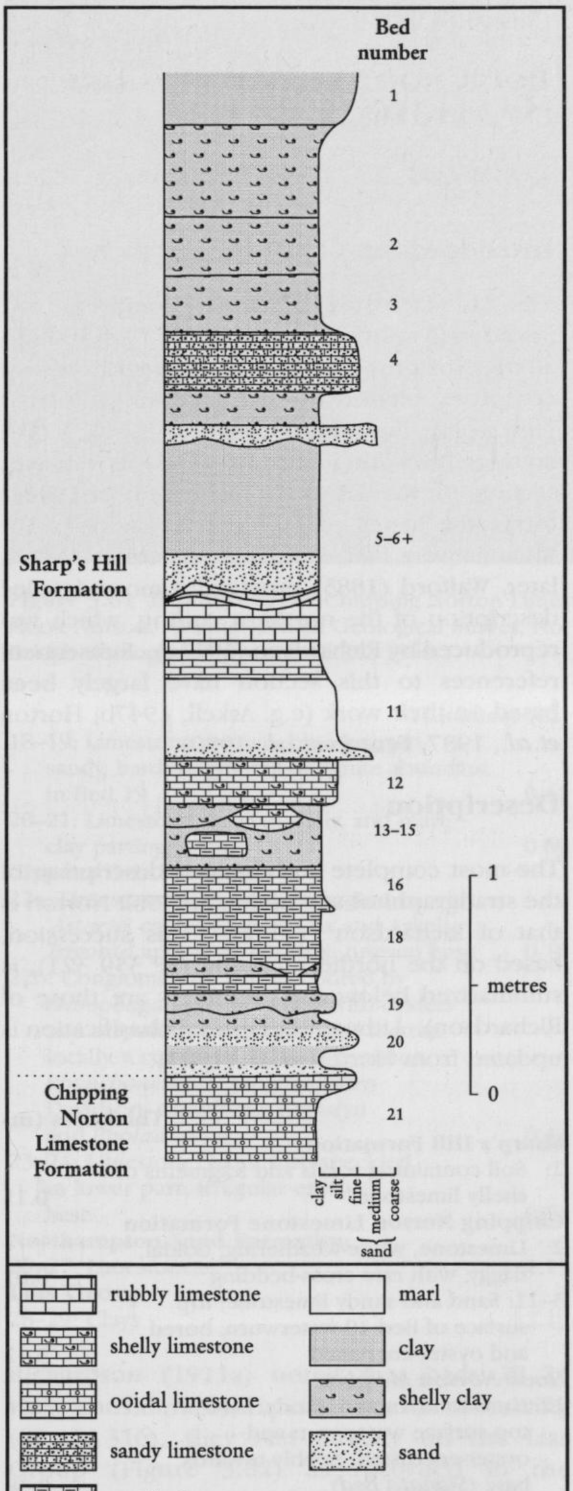
Figure 3.59 Exposure of Northampton Sand Formation near the entrance of the quarry at Sharps Hill; the steep dip is due to valley-bulging and cambering. (Photo: M.G. Sumbler.)

Millericrinus?, indeterminate echinoid, *Sarcinella*, *Kallirhynchia*, terebratulid fragments, bivalves including *Propeamussium*, the gastropods *Aptyxiella subconica* (Hudleston), *Eunerinea* sp., as well as the ammonite *Bredyia* cf. *subinsignis* (Oppel) and belemnite fragments. The Clypeus Grit Formation is not now well exposed, but good sections of the succeeding Chipping Norton Limestone Formation can be seen. The Sharp's Hill Formation occurs in the higher, southern part of the quarry. Owing to the nature of the strata, it is currently rather poorly exposed, but trenching in 1990 revealed most of the succession (Boneham and Forsey, 1992). The Taynton Limestone Formation, which succeeds the Sharp's Hill Formation, has never been exposed in the quarry faces, but is probably present in the southern and western, unworked portion of the GCR site.

Recent investigations involving trenching in the quarry (Figure 3.60) yielded disarticulated remains of a stegosaurian dinosaur from several horizons beneath the Viviparus Marl (i.e. within Arkell's (1947b) Lower Sharp's Hill Beds); this is thought to be the earliest stegosaur yet recorded (Boneham and Forsey, 1992).

Interpretation

Horton *et al*. (1987) assigned the lowest sandy beds at Sharps Hill to the Northampton Sand Formation, although the strata are rather less ferruginous than farther to the north-east, where the Northampton Sand Ironstone is developed. The facies is transitional to the Leckhampton Member (formerly Scissum Beds) of the Birdlip Limestone Formation (Lower Inferior Oolite) (Barron *et al*., 1997; Sumbler *et al*., 2000), which comprise sandy, ooidal limestones, typically developed in the North Cotswolds to the west of the Vale of Moreton Axis. The overlying Clypeus Grit Formation (equivalent to the Clypeus Grit Member of the Salperton Limestone Formation (Upper Inferior Oolite) of areas farther south) is recorded as 0.36 m thick, and is very close to its eastern limit, beyond which it is overstepped by the Chipping Norton Limestone Formation (Horton *et al*., 1987); indeed, it appears to be absent in extant exposures (1996). Walford (1906) recorded various fossils from this unit, though the eponymous echinoid *Clypeus* and the brachiopod *Stiphrothyris*, which characterize the formation farther west in the Cotswolds, have not been recorded in this neighbourhood.



◂**Figure 3.60** Graphic log of a trench section through the Sharp's Hill Formation (beds 1–20) and uppermost Chipping Norton Limestone Formation at Sharps Hill. (Based on B. Boneham MS (English Nature files); see Boneham and Forsey, 1992.) Bed numbering follows Richardson (1911a) but this slightly expanded section may include representatives of Walford's (1906) beds 7 to 10 (see text). Stegosaur remains were found in the lower part of the Sharp's Hill Formation.

According to Richardson (1911a), partly based on Walford (1906), some 5.8 m of Chipping Norton Limestone Formation are present, as quoted in the section above, but, according to Horton *et al.* (1987), the thickness is only 4.5 m based on their composite record of the quarry section. Bed 23, the so-called 'Signata Bed' (or 'Knotty Bed'), named after the bivalve *Myophorella signata* (Agassiz), has been considered to be a critical marker, and forms the basis of subdivision of the Chipping Norton Limestone Formation. The strata below the top of the Signata Bed have been termed the 'Hook Norton Beds' (or Member) (Walford, 1906; Richardson, 1911a; Arkell, 1933, 1947b; Sellwood and McKerrow, 1974; see **Hook Norton** GCR site report, this volume). The term 'Chipping Norton Limestone Formation' was restricted by Walford (1906) to the beds above the Signata Bed, and this usage was formalized by Sellwood and McKerrow (1974) with their use of the term 'Chipping Norton Member'. Richardson (1911a) introduced the term 'Swerford Beds' for sands that take the place of the Chipping Norton Limestone Formation in north-east Oxfordshire. He defined these beds as lying above the Signata Bed, although as the latter is absent where the Swerford Beds are best developed, this relationship has never been properly established (Sellwood and McKerrow, 1974). Richardson's (1911a) use of the term at Sharps Hill is doubly inappropriate, as the beds are not of typical Swerford Beds facies; indeed, there is no significant lithological difference between the beds below the Signata Bed and those above. Horton *et al.* (1987) doubted the correlative value of the Signata Bed, calling into question the whole basis for subdivision of the Chipping Norton Limestone Formation throughout the region.

The Sharp's Hill Formation comprises the beds originally known as the 'Neaeran Beds' (Walford, 1906). Arkell (1933) introduced the name 'Sharp's Hill Beds', restricting it to those strata between the Viviparus Marl and Chipping Norton Limestone Formation (i.e. beds 12 to 20 of Richardson's section above). Later, he extended the term to cover all of the clay-dominated beds between the Chipping Norton Limestone and Taynton Limestone formations, and divided the succession into Lower and Upper parts at the base of the Viviparus Marl, which is a non-sequence as indicated by the records of pebbles (Arkell, 1947b). The name was formalized by McKerrow and Kennedy (1973). The strata exposed in Sharps Hill, probably representing almost the whole of the formation, total *c*. 5 m in thickness (Boneham and Forsey, 1992), the thickest succession known. In general terms, the formation is made up of greenish-grey mudstones and marls with subordinate sandy and argillaceous micritic limestones, which are particularly prominent in the lower part. Individual beds lens out laterally, making Richardson's (1911a) correlations between different localities highly speculative. The fauna is dominated by fully marine forms (corals, rhynchonellid brachiopods and echinoids as well as a variety of bivalves, particularly *Praeexogyra*, and gastropods). However, the presence of the gastropod *Bathonella* ('*Viviparus*') in association with ostracods and charophytes in the so-called 'Viviparus Marl' (Sylvester-Bradley, 1948b; Sellwood and McKerrow, 1974) suggests an intermittent freshwater influence. The proximity of land is also suggested by the abundance of plant material, notably the richly lignitic Bed 10, and by stegosaurs. Seatearth textures and rootlets are recorded from most sections (Horton *et al*., 1987), suggesting extremely shallow 'estuarine' conditions such as typify the Rutland Formation of the East Midlands, into which the Sharp's Hill Formation passes when traced to the north-east (Bradshaw, 1978). Such non-marine characters are herein regarded as diagnostic of the Sharp's Hill Formation, which is thus restricted to the area to the east of the Vale of Moreton Axis.

Conclusions

Sharps Hill is the type locality of the Sharp's Hill Formation, in the area of its thickest development. The succession is richly fossiliferous and is of particular interest because of the presence of a freshwater fauna at one level. The underlying Chipping Norton Limestone Formation is also exposed. An attenuated representative of the Clypeus Grit Formation is one of the most easterly occurrences of this unit, and the underlying Northampton Sand is of a facies transitional to the Leckampton Member (formally Scissum Beds), typically developed in the Cotswolds to the west.

HOOK NORTON, OXFORDSHIRE (SP 358 316, SP 359 321)

R.J. Wyatt

Introduction

The Hook Norton GCR site comprises two abandoned railway cuttings, about 1 km south of Hook Norton, Oxfordshire, which expose a complete section of the Chipping Norton Limestone Formation (Figure 3.61). The cuttings have long been regarded as the type section of the Hook Norton Member, which forms the lower part of the formation. The sections were first described by Beesley (1877); later, Walford (1883) provided a more detailed description of the northern cutting, which was reproduced by Richardson (1911a). Subsequent references to this section have largely been based on their work (e.g. Arkell, 1947b; Horton *et al*., 1987; Fenton *et al*., 1980).

Description

The most complete and detailed description of the stratigraphical succession at Hook Norton is that of Richardson (1911a). This succession, based on the northern cutting (SP 359 321), is summarized below (bed numbers are those of Richardson). Lithostratigraphical classification is updated from Horton *et al*. (1987).

	Thickness (m)
Sharp's Hill Formation	
1: Soil containing corals and fragments of shelly limestone	0.15
Chipping Norton Limestone Formation	
2: Limestone, white-weathering, ooidal, flaggy, with rare cross-bedding	0.61
3–11: Sand and sandy limestone; top surface of Bed 10 waterworn, bored and oyster-encrusted	3.12
Hook Norton Member	
12: Limestone, brown, sandy, hard; top surface waterworn and oyster-encrusted; pebbly towards base (*Signata Bed*)	0.38
13–17: Interbedded sand, clay and shelly limestone	0.99

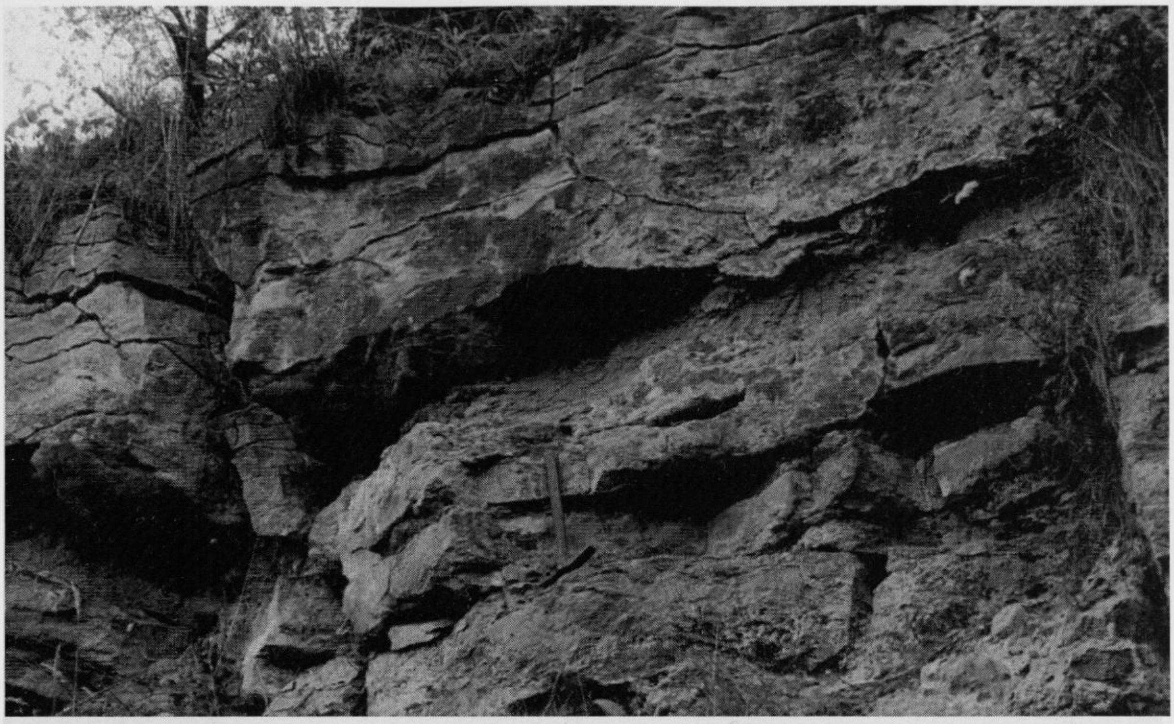


Figure 3.61 Exposure of the Chipping Norton Limestone Formation at the north end of the railway cutting at Hook Norton. (Photo: British Geological Survey, No. A9829; reproduced with the permission of the Director, British Geological Survey, © NERC, 1960.)

	Thickness (m)
18–19: Limestone, brown, blue-hearted, sandy, hard; fragments of lignite abundant in Bed 19	0.41
20–21: Limestone, brown, shaly, and marl; clay parting at top	0.69
Clypeus Grit Formation	
22a: Limestone, very hard, ferruginous, with '*Astarte*' *cotswoldensis* Cox and Arkell, *Trigonia* and *Acanthothiris*; uneven base	0.15
22b: Conglomerate; pebbles bored by *Lithophaga* and encrusted with oysters and serpulids, in a sandy marl matrix; locally, a coral bed at base; common *Rhynchonella* cf. *subtetrahedra* Davidson, *Cucullaea*, *Gresslya* and *Pholadomya*	0.13
23–24: Limestone, hard, iron-speckled in lower part; irregular erosive base	0.23
Northampton Sand Formation	
25–27: Limestones	2.13
Lias Group	
28–29: Clays	12.19

Richardson (1911a) noted that beds 22–24 vary considerably; in the southern cutting (SP 358 316), they rest directly on the Lias Group (Figure 3.62) as recorded in the following section modified from Horton *et al.* (1987).

	Thickness (m)
Clypeus Grit Formation	
Limestone, brownish-grey, sandy, ooidal, rather flaggy, with some small black limestone pebbles; outer layers of ooids ferruginous and limonitized; much shell-debris; large wood fragments	0.25
Marl, mauve-coloured, sandy, passing upwards into brown clay; bands of white shell-fragments including *Cucullaea* sp., *Praeexogyra* cf. *hebridica* (Forbes), *Vaugonia* (*Orthotrigonia*) *gemmata* (Lycett), *Plicatula* sp	0.18
Limestone, bluish-grey- to brown-weathering, with small black limestone pebbles; *Dimorpharea defranciana* (Michelin), *Chlamys viminea* (J. de C. Sowerby), *Cucullaea* sp., oysters including *Praeexogyra* aff. *acuminata* (J. Sowerby), *Procerithium vetustus-majus* (Hudleston)	0.10–0.15
Limestone, brown, weathering grey, with black limestone pebbles up to 25 mm diameter; large flattened compound corals; highly fossiliferous with *Montlivaltia trochoides* Edwards and Haime, *Thamnasteria* sp., *Barbatia pulchra* (J. de C. Sowerby), *Chlamys* cf. *viminea*, *Praeexogyra* cf. *hebridica*, *Pseudolimea* sp	0.10–0.15
Limestone, brownish-grey, and marly clay with black limestone pebbles; much shell-debris; fossils including *Montlivaltia trochoides*, *Thamnasteria* sp., *Chlamys viminea*, oysters and *Modiolus* sp.	0.08–0.10
Lias Group	
Mudstone	seen to 1.2

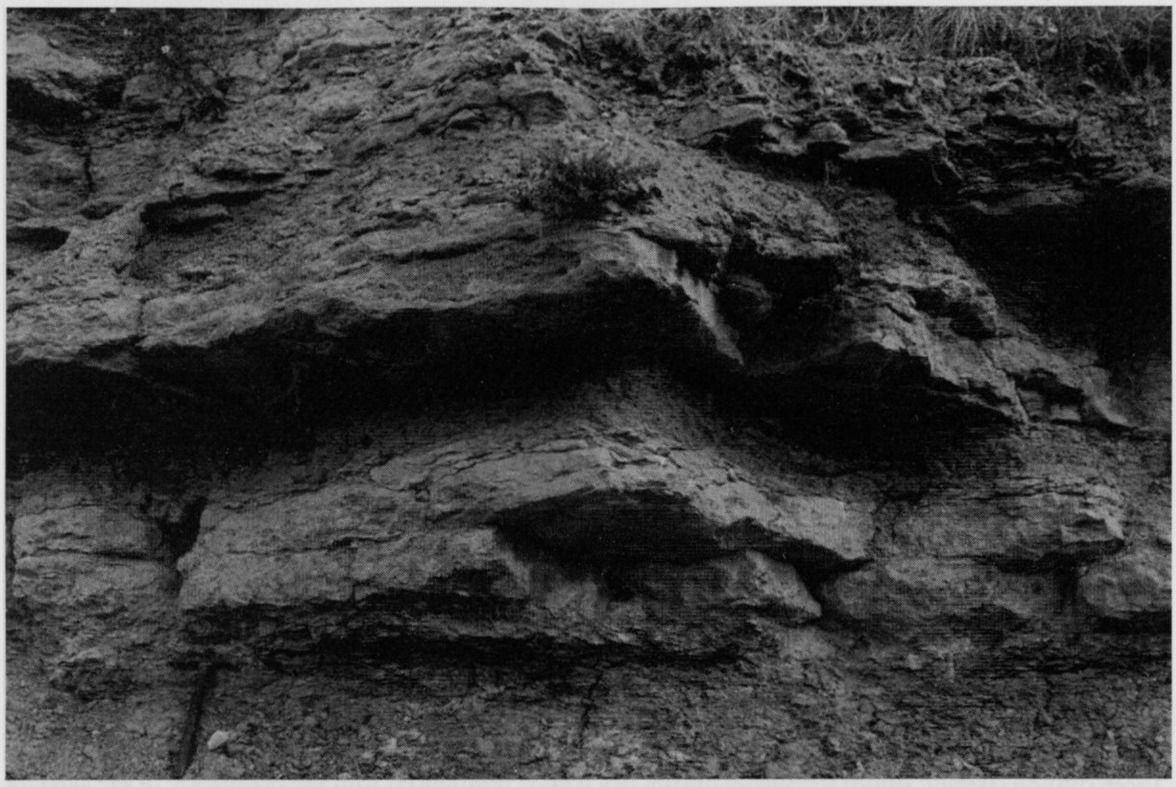


Figure 3.62 Clypeus Grit Formation resting on clays of the Lias Group at Hook Norton. (Photo: British Geological Survey, No. A9820; reproduced with the permission of the Director, British Geological Survey, © NERC, 1960.)

Interpretation

The bored encrusted pebbles and the abraded shell-fragments in the conglomeratic limestones of the Clypeus Grit Formation indicate slow, minimal deposition and some contemporaneous erosion of a cemented sea-floor nearby. These basal beds probably represent the initial coarse lag deposit of a Late Bajocian transgression.

Since the time of Walford (1883), the Chipping Norton Limestone Formation of this area has been divided into two units (the lower now known as the 'Hook Norton Member'), using the Signata Bed (named after the bivalve *Myophorella signata* (Agassiz)) as a lithostratigraphical marker horizon. Although Walford did not actually recognize this bed at Hook Norton, Richardson (1911a) and subsequent authors have taken Walford's Bed 12 with its oyster-encrusted hardground to be it, and to define the upper limit of the Hook Norton Member. However, Horton *et al.* (1987) found no evidence whilst mapping the district to substantiate Walford's and Richardson's belief that the Signata Bed is a discrete, traceable horizon. It also has to be noted that a further hardground was recorded by Richardson (1911a), 0.30 m above the top of the Signata Bed. Although the validity of the Hook Norton Member as a lithostratigraphical unit has been questioned, the cuttings nevertheless remain as its type locality (Bradshaw, 1978).

The succession at Hook Norton lies close to the eastern limit of the Chipping Norton Limestone Formation where, at first, the upper part passes laterally into the very sandy, shell-detrital limestones of the Swerford Member, and then, within 2 km, the whole formation has passed into the 'White Sand' facies of the Horsehay Sand Formation (see **Horsehay Quarry** GCR site report, this volume).

The sandy, flaggy, mainly planar-bedded limestones of the Chipping Norton Limestone Formation, which yield only a few unbroken, thick-shelled bivalves, probably formed in the shallow, turbulent waters of a carbonate shelf-sea in which the substrate was mobile. The quartz sand content of the limestones relates to the eastward passage into the Horsehay Sand Formation. Deposition of these sands occasionally extended farther west, accounting for the interbedded sands in the cuttings. Clays in the Hook Norton Member reflect quiet-water episodes when terrigenous mud accumulated. The abundance of lignitic plant-debris in beds 18 and 19 also suggests the influence of the land to the east.

No ammonites have been collected from the cuttings, and dating of the succession therefore relies on evidence from the Hook Norton Member of the upper quarry at Chipping Norton Workhouse (Arkell, 1947b, 1956b). *Parkinsonia* (*Durotrigensia*) cf. *crassa* Nicolesco, figured by Arkell (1956b), is recorded from the lowest bed of the member there, suggesting that the Chipping Norton Limestone Formation extends down into the Upper Bajocian Parkinsoni Zone, Bomfordi Subzone. However, most of the known ammonites from the formation come from the Signata Bed at the top of the Hook Norton Member; they include *Parkinsonia* (*Gonolkites*) *subgaleata* S.S. Buckman, *P.* (*Durotrigensia*) *oxonica* Arkell and *Procerites subprocerus* (S.S. Buckman), which indicate the Lower Bathonian Zigzag Zone, Convergens Subzone (Arkell, 1947b; Torrens, 1969e). A single specimen of *Zigzagiceras* (*Procerozigzag*) *pseudoprocerus* (S.S. Buckman) from the Signata Bed confirms the presence of the next youngest Macrescens Subzone (Arkell, 1958a,b, wherein the locality is mistakenly referred to as 'Hook Norton Workhouse quarry'; W.M. Edmunds, pers. comm., 1963). Two poorly preserved specimens of *Oppelia* (*Oxycerites*), known from the Chipping Norton Limestone Formation at Oakham and Lower Swell (Richardson, 1911a, 1929b), suggest that the formation there extends up into the Yeovilensis Subzone (Torrens, 1969e). A possible non-sequence is inferred by Torrens (1980b) beneath beds of the latter subzone, corresponding with the top of the Hook Norton Member.

The ammonite zonation discussed above implies that the Hook Norton Member is coeval with much of the Clypeus Grit Member of districts to the west (Torrens, 1980b). It has now been established that the Chipping Norton Limestone Formation is broadly equivalent to the Horsehay Sand Formation (see **Horsehay Quarry** GCR site report, this volume) to the east (Fenton *et al.*, 1994, 1995). The palynological evidence also places the Bajocian–Bathonian boundary close to the base of the Chipping Norton Limestone Formation (Fenton *et al.*, 1980).

Conclusions

The railway cuttings at Hook Norton provide one of the most important sections of the Late Bajocian–Early Bathonian Chipping Norton Limestone Formation in its type area; they also serve as the type section of the Hook Norton Member, despite doubts as to the validity of this lithostratigraphical unit. The sections are significant in the interpretation of Middle Jurassic stratigraphy, particularly to an understanding of the lateral facies changes of the Chipping Norton Limestone Formation and corresponding beds. The sections occur in an area where the formation is transitional between an almost completely terrigenous, nearshore, brackish-water sand facies to the east, and a fully marine, carbonate sand facies to the west. Although no biostratigraphically significant macrofossils have been obtained from the sections, the succession can be adequately dated by reference to diagnostic ammonites collected from nearby sites. Palynological investigations have placed the Bajocian–Bathonian stage boundary close to the base of the Chipping Norton Limestone Formation.

HORSEHAY QUARRY, OXFORDSHIRE (SP 456 277, 459 274)

R.J. Wyatt and M.G. Sumbler

Introduction

The Horsehay Quarry GCR site comprises two quarry sections near Duns Tew, Oxfordshire, one traditionally known in the literature as 'Horsehay Quarry' (SP 459 274), the other as 'Cullimore's Quarry' (SP 456 277). They exhibit a fine Middle Jurassic succession ranging from the Northampton Sand Formation up to the Taynton Limestone Formation (Figures 3.63–3.65). The quarries also provide the type section for the newly defined Horsehay Sand Formation (Sumbler, in press), formerly known as the 'White Sands', a unit that is only poorly exposed elsewhere in Oxfordshire. The lithologically varied Sharp's Hill Formation is also fully exposed in the two quarries. The sections were first described in detail by Sellwood and McKerrow (1974), and later by Horton *et al.* (1987).

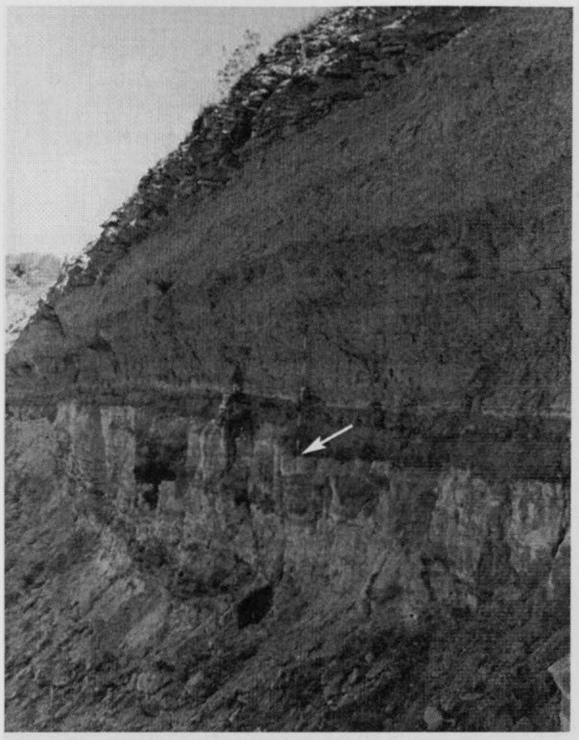


Figure 3.63 Horsehay Sand Formation overlain by the Sharp's Hill Formation and the Taynton Limestone Formation at Horsehay Quarry. The base of the rule (arrowed) rests on top of the Horsehay Sand Formation. (Photo: M.G. Sumbler.)

Description

The strata exposed include sands, fossiliferous clays and ooidal limestones. Varying descriptions of the succession, recorded at different times (e.g. Sellwood and McKerrow, 1974; Horton *et al.*, 1987), reflect the marked variations in the succession that are revealed as quarrying progresses. For example, in the following description (based on Sellwood and McKerrow, 1974), thicknesses for the Sharp's Hill and Rutland formations are 6.7 m and 10.8 m respectively but as exposed in May 1997, they are 2.55 m and 2.45 m respectively.

	Thickness (m)
Taynton Limestone Formation	
Oolite, large-scale cross-bedded, containing disarticulated oyster-shells	0.7
Sharp's Hill Formation	
4: Clay, yellow, ooidal, with horizontal burrow-fills; *Eomiodon*, abundant *Liostrea*, *Pleuromya*, rhynchonellids and *Hemicidaris*	1.1
3: Oolite, strongly cross-bedded, with oyster-shell debris; foresets bear drapes of green clay; interburrowed contact at top	0.8
2: Oolite, shell-fragmental, with clay drapes on foresets and bipolar cross-bedding; load casts at base	2.3
1: Clay, greenish-grey, mottled, ooidal, calcareous, regularly bedded; *Eomiodon*, abundant *Liostrea*, *Modiolus*, pectinids, *Pholadomya*, *Pinna*, *Pleuromya*, rhynchonellids and corals; thin brown laminated sand at base; uneven, erosive base	2.5
Horsehay Sand Formation	
5: Sand, white, rippled, with rare clay-drapes	0.5
4: Sand, brown, rippled and planar-bedded, with drapes of plant debris	3.1
3: Sand, brown, flaser-bedded, with some persistent clay laminae and low-angle cross-bedding	0.4
2: Sand, yellowish-brown, low-angle cross-bedded and rippled	4.5
1: Sand, brown, trough cross-bedded and flat-laminated, with flaser-bedded and iron-stained sand and clay; fauna disarticulated; *Astarte*, *Liostrea* and *Lucina*	2.3
Northampton Sand Formation	
Ironstone, reddish-brown, sandy, pervasively limonitized with 'boxstone' structures (Figure 3.65)	3.0

A large channel, 30 m wide and 2 m deep, at the top of the Horsehay Sand Formation has been recorded in Cullimore's Quarry. It is filled with trough cross-bedded sand containing abundant shell-debris, intra-formational clay-clast conglomerates and much fine plant-detritus draped on foresets.

Interpretation

A long interval of erosion and/or non-deposition separates the deposits of the Northampton Sand Formation from those of the overlying Horsehay Sand Formation, although this does not necessarily manifest itself in the section. Sellwood and McKerrow (1974) interpreted these sands as dominantly shallow-water, intertidal to subtidal, sand-flat sediments; the dominance of low-angle cross-bedding and ripple-lamination in the sands indicates high-energy conditions, rapid deposition and a mobile substrate. The low-diversity bivalve fauna in Bed 1 is probably a reflection of low-salinity conditions. Sporadic bi-polar cross-bedding suggests intermittent tidal activity. The mixed cross-bedded and flaser-bedded, ferruginous sands and clays of Bed 1 are indicative of a marginal marine, deltaic depositional environment. The large channel-fill at the top probably represents a transient tidal channel.

In the absence of chronostratigraphically significant macrofossils, the age and correlation of

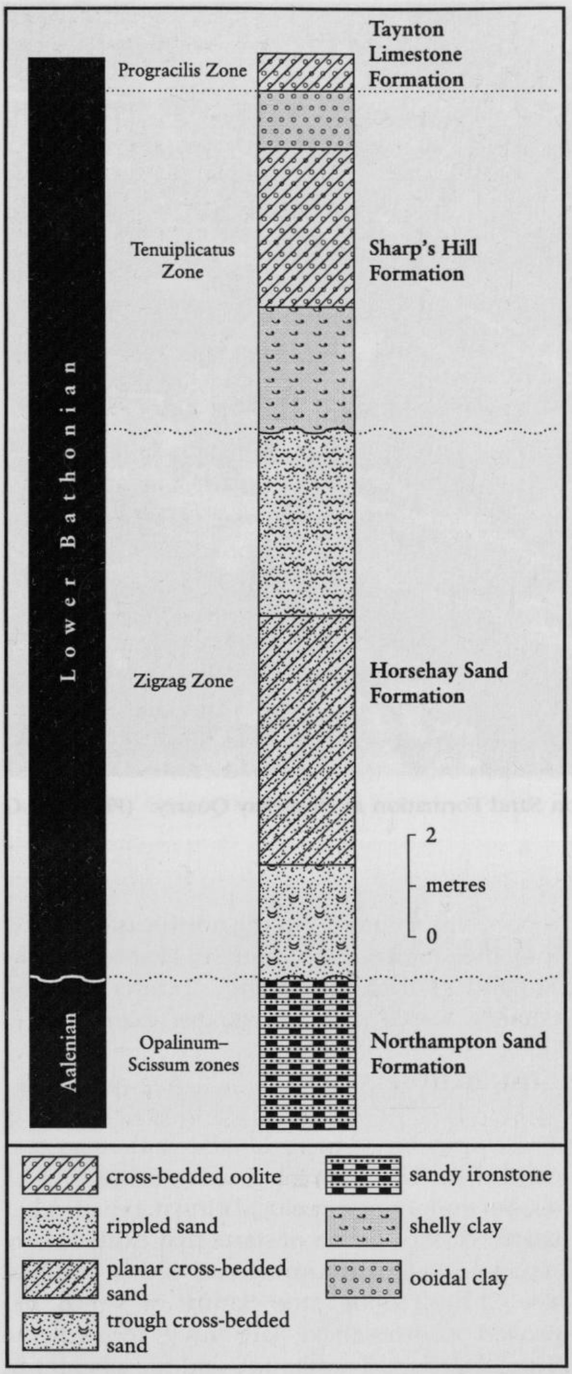


Figure 3.64 Graphic section of the succession at Horsehay Quarry.

the beds now termed the 'Horsehay Sand Formation' has proved controversial. Sellwood and McKerrow (1974) termed them the 'Swerford Member', which, following Richardson (1911a), Arkell *et al.* (1933) and Arkell (1947b), they treated as part of the Bathonian Chipping Norton Limestone Formation. However, Horton (1977) and Horton *et al.* (1987) argued that they represent the Aalenian 'Lower Estuarine Series' (i.e. the Grantham Formation of the East Midlands) and called them the 'White Sands', a name that derives from their development near Northampton (Sharp, 1870). As argued by Bradshaw (1978) on essentially circumstantial evidence, it is more likely that all of the supposed Grantham Formation or 'White Sands' from near Peterborough to near Chipping Norton equate with the lower part of the younger Rutland Formation farther north. This view was supported by Fenton *et al.* (1994, 1995) on the basis of a palaeoflora of dinoflagellate cysts. Whilst a sample from Horsehay Quarry proved to be barren, samples from near the base of the sands at New Duston (SP 15 627), Northampton and Swalcliffe (SP 680 3585) to the north-west of Horsehay Quarry, yielded an assemblage of late Bajocian to Bathonian dinoflagellate cysts similar to that of the Chipping Norton Limestone Formation of Oxfordshire and the Rutland Formation of Lincolnshire; rare, poorly preserved Aalenian cysts are probably derived from the subjacent beds. As previous names are unsatisfactory for several reasons, the strata are now termed the 'Horsehay Sand Formation' (Sumbler, in press), of which the present section is the stratotype.

A sedimentary break at the base of the overlying Sharp's Hill Formation is indicated by its erosive basal contact, and was particularly obvious in the section exposed in May 1997 when the topmost 0.7 m of the Horsehay Sand Formation was seen to be leached and rootleted, indicating possible emergence. The varied clay-oolite succession indicates rapidly changing depositional conditions. The ooidal clays reflect influxes of terrigenous mud and relatively low-energy conditions, and their varied fauna of marine, burrowing bivalves suggests a stable substrate. Corals in Bed 1 probably represent patch reefs, which are present elsewhere in the Sharp's Hill Formation. Ooids in the clays were probably derived from areas of carbonate sand deposition nearby. The cross-bedded, shell-fragmental ooidal limestones indicate much more turbulent waters, in which fine-grained terriginous sediment was confined to clay drapes on foresets. The interburrowed top of Bed 3 probably represents a break in sedimentation when burrowing organisms established themselves before clay deposition resumed. The Sharp's Hill Formation has nowhere yielded age-

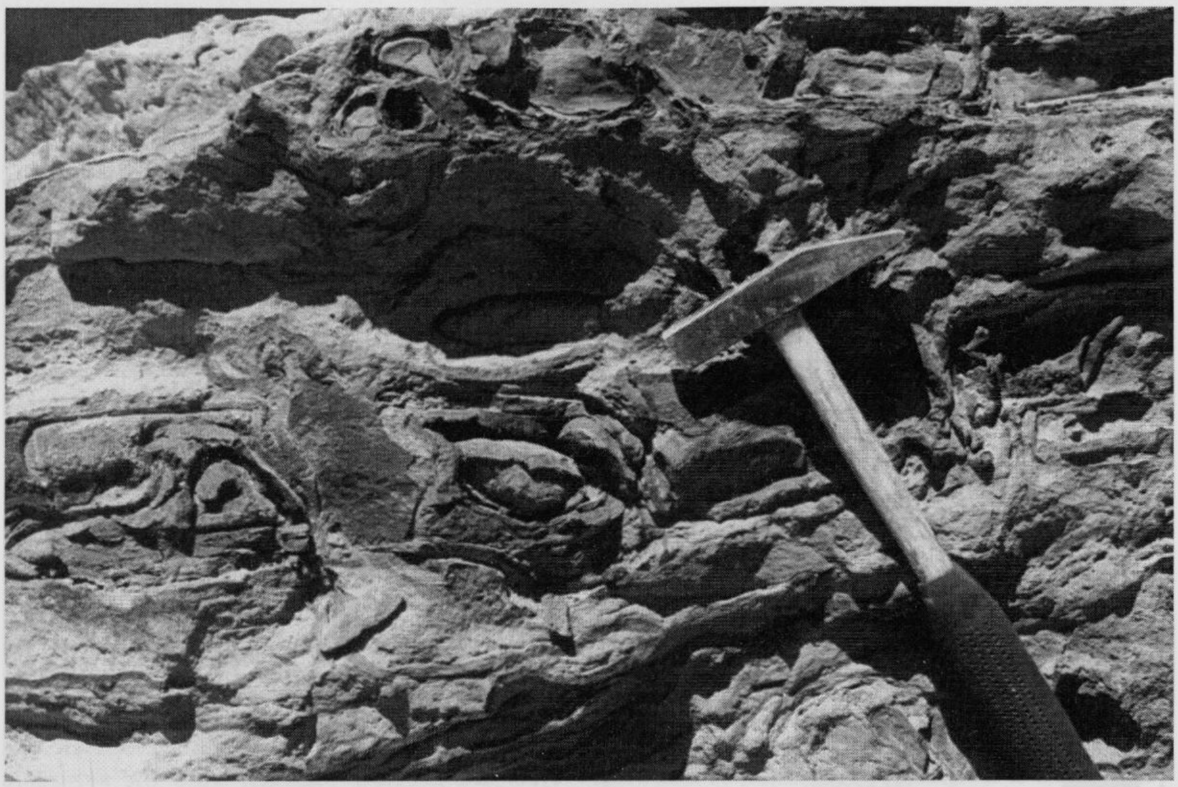


Figure 3.65 'Boxstone' weathering in the Northampton Sand Formation at Horsehay Quarry. (Photo: M.G. Sumbler.)

diagnostic fossils; however, its stratigraphical position implies the Lower Bathonian Tenuiplicatus Zone.

The highest bed in the Horsehay Quarry section is assigned to the Taynton Limestone Formation, comprising cross-bedded, shell-fragmental limestones that witness a change to high-energy, current-dominated depositional conditions in slightly deeper water. It can be assigned to the Middle Bathonian Progracilis Zone by comparison with the succession at **Stonesfield** (Boneham and Wyatt, 1993; see GCR site report, this volume).

Horsehay Quarry has special significance in interpreting the rapid and pronounced facies changes that affect the Horsehay Sand Formation and coeval strata in this district. To the west, within 5 km of the quarry, the upper part of the formation has passed laterally into sandy, ooidal limestones of the Chipping Norton Limestone Formation (for which the name Swerford Member may be appropriate), whilst the lower part has passed into the Hook Norton Member, consisting of less sandy limestones containing plant detritus (see **Hook Norton** GCR site report, this volume). To the north-east, it passes into the non-marine Stamford Member of the Rutland Formation (type locality **Ketton Quarry**, see GCR site report, this volume).

Conclusions

The Upper Bajocian to Middle Bathonian succession in the Horsehay Quarry GCR site is of special importance in elucidating regional correlation within a group of strata that exhibits considerable lateral thickness and facies changes. The 'White Sands', the dating of which has proved controversial, are now termed the 'Horsehay Sand Formation', and are thought to be of Late Bajocian–Early Bathonian age and to be coeval with the Chipping Norton Limestone Formation to the west. The complete Sharp's Hill Formation here demonstrates its characteristic variety of lithology and depositional environments, and includes fossiliferous beds in which an abundance of oysters is typical. Within the Taynton Limestone Formation, cross-bedded, ripple-laminated and flaser-bedded sedimentary structures are well displayed.

DITCHLEY ROAD QUARRY, OXFORDSHIRE (SP 368 198)

R.J. Wyatt

Introduction

Ditchley Road Quarry, also known as 'Town Quarry', at Charlbury, Oxfordshire, exhibits a fine section ranging from the Chipping Norton Limestone Formation up to the Taynton Limestone Formation (Figures 3.66 and 3.67). Formerly, the section included the upper half of the Clypeus Grit Formation at the base; this is currently (1999) not visible, but future development of the quarry may re-expose it. The quarry offers one of the few complete sections of the Chipping Norton and Sharp's Hill formations in Oxfordshire, and is also the type section of the Charlbury Formation. The succession comprises a range of lithologies, some very fossiliferous, which represent a variety of depositional environments. The section was described in outline by McKerrow and Kennedy (1973) and also by Sellwood and McKerrow (1974). More detailed descriptions were published by Horton *et al.* (1987) and Boneham and Wyatt (1993), the latter including details of the newly defined Charlbury Formation.

Description

The greater part of the section given below is based on Horton *et al.* (1987) and Boneham and Wyatt (1993). Details of the Taynton Limestone Formation were recorded by the present author in April 1997.

	Thickness (m)
Taynton Limestone Formation	
Soil and subsoil	0.35
9: Limestone, grey, fine grained, finely ooidal, flaggy-weathering; locally only sparsely ooidal	0.40
8: Marl, brown, finely shell-detrital, thinly bedded, forming prominent bed; small lenses and lenticles of fine-grained limestone in upper half	0.40
7: Limestone, creamy-grey, fine grained, compact, rubbly weathering; passing down into increasingly ooidal and shell-fragmental rubbly weathering limestone	0.40
6: Limestone, fawn, coarse grained, ooidal, shell-fragmental, locally gently cross-bedded; sporadic mudstone clasts	0.25–0.30

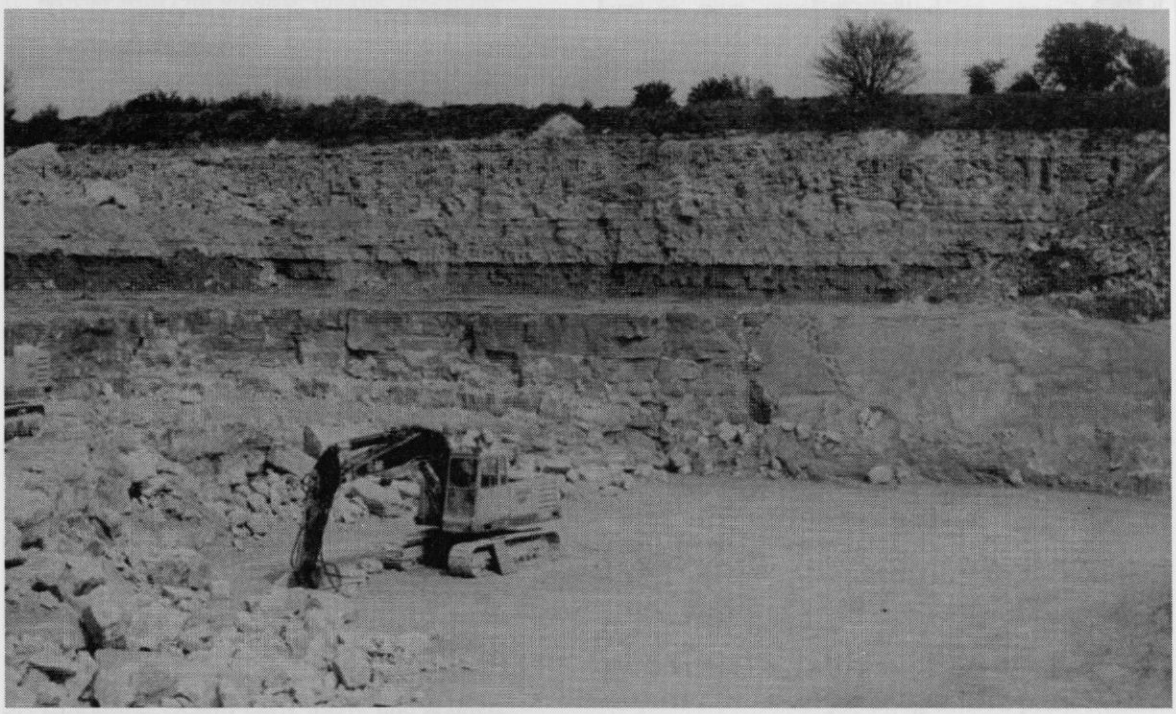


Figure 3.66 Ditchley Road Quarry. The lower part of the quarry is excavated in Chipping Norton Limestone Formation, which is locally the basal unit of the Great Oolite Group. This is overlain by dark-grey clays of the Sharp's Hill Formation, which are, in turn, succeeded by the buff marls and marly limestone of the Charlbury Formation with the paler Taynton Limestone Formation above. (Photo: British Geological Survey, No. A15217; reproduced with the permission of the Director, British Geological Survey, © NERC, 1991.)

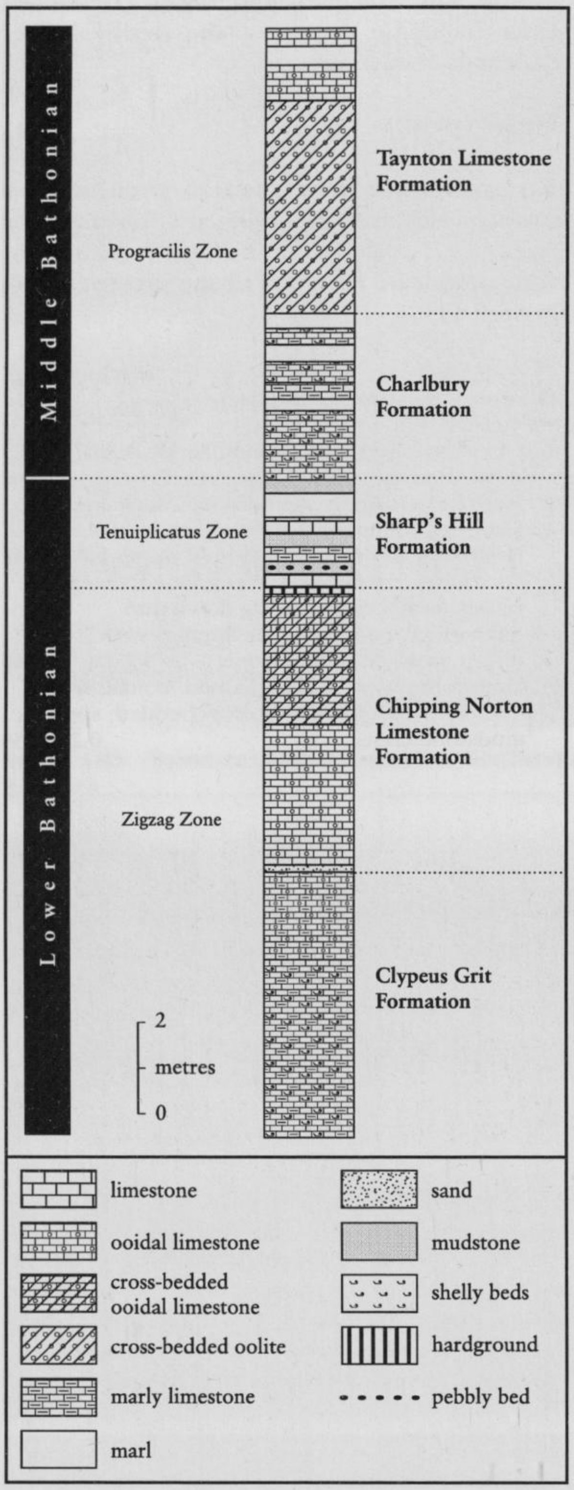


Figure 3.67 Graphic section of the Bathonian succession at Ditchley Road Quarry.

	Thickness (m)
5: Limestone, buff, weathering to cream, fine- to medium-grained, sparsely ooidal; thinly bedded, locally gently cross-bedded, fissile calcarenite; sporadic, thin, impersistent, laminated, darker-buff marl seams	0.08–0.15
4: Oolite, pale-cream, medium- to coarse-grained, shell-fragmental, sparry, with prominent planar cross-bedding; impersistent thin seams of thinly bedded, fissile calcarenite; scattered larger shell-fragments including *Praeexogyra hebridica* (Forbes); also unbroken shells of small immature bivalves; planar top, undulating base	0.05–1.00
3: Limestone, cream, fine-grained, very thinly bedded, fissile calcarenite; locally absent	0–0.08
2: Oolite, similar to above but creamy-white and with less prominent cross-bedding but with individual beds showing internal cross-bedding structure	1.40
1: Oolite, pale-cream, medium- to coarse-grained, shell-fragmental, sparry, thick-bedded, with large-scale trough cross-bedding; fawn, very hard, 'raggy' in basal 0.15 m, with large shell-fragments including *Isognomon*; sharp planar base	1.45
Charlbury Formation	
11: Marl, buff, laminated; clay partings with carbonaceous plant-debris; lenticular beds of shell-detrital, sparry limestone	0.20–0.32
10: Limestone, buff, very marly, shell-fragmental, bivalve fauna including *Camptonectes*, *Ceratomya* cf. *concentrica* (J. de C. Sowerby), *Eocallista antiopa* (Thevenin), *Mactromya*, *Modiolus imbricatus* J. Sowerby, *Pachymya* (*Arcomya*), *Pinna*, *Pleuromya*? and *Protocardia* cf. *stricklandi* (Morris and Lycett); also the gastropod *Ampullospira stricklandi* (Morris and Lycett) and the echinoid *Nucleolites woodwardi* (Wright)	0.45
9: Marl, brown, finely shell-detrital	0.25
8: Limestone, brown, ooidal, shell-fragmental, hard, sparry; partings at top and base with many *Isognomon* shells	0.30
7: Limestone, buff, very marly, thinly bedded, fine calcarenite	0.30
6: Limestone, fawn, ooidal, shell-detrital, hard, sparry	0.15–0.30
5: Marl, brown, with lenses of hard, ooidal, shell-fragmental sparry limestone	0.23–0.30
4: Limestone, brown, shell-detrital, slightly marly, banded, hard, with scattered oyster shells; *Camptonectes* and *Antiquicyprina loweana* (Morris and Lycett)	0.18–0.30
3: Limestone, buff, very marly, shelly, shell-fragmental, ooidal with abundant *Praeexogyra hebridica* (Forbes) and other bivalves including *Camptonectes* (*C.*) *auritus* (Schlotheim), *Isognomon*, *Modiolus*, *Plagiostoma* and *Pleuromya*?; also *Kallirhynchia* cf. *bella* S.S.Buckman; an *hebridica* lumachelle up to 0.15 m-thick locally in middle	0.55–0.80
2: Limestone, brown, shell-fragmental, slightly ooidal, hard, sparry; coarsely shell-fragmental at base	0.16–0.20

	Thickness (m)
1: Limestone, buff, very marly, shell-fragmental, very shelly, soft, with many bivalves including *Camptonectes* and *Isognomon*, and rhynchonellids including *Epithyris 'maxillata'* of authors, *Kallirhynchia bella* and *K.* cf. *decora* S.S. Buckman; sharp base	0.15–0.40
Sharp's Hill Formation	
8: Clay, mainly dark bluish-grey with sporadic *Placunopsis*; crudely layered oyster-shell debris at base	0.25–0.32
7: Clay, black, peaty, with abundant white, decalcified, oyster-shell fragments	0.02–0.03
6: Marl, brown, shelly, unevenly bedded; abundant *Praeexogyra hebridica* and *Epithyris oxonica* Arkell; sporadic *Modiolus*	0.55
5: Limestone, bluish-grey, weathering greenish-buff; shell-fragmental, with crudely bedded oyster-shell debris; oyster-encrusted planar upper surface; thin layer of fibrous gypsum at base	0.30–0.35
4: Clay, dark bluish-grey to black, with many carbonaceous plant-fragments, partings of quartz sand and a few streaks of yellowish marly 'race'; abundant *Placunopsis* in lower part	0.18–0.40
3: Limestone, greenish-buff, marly, sandy, shell-fragmental; many bivalves including *Placunopsis*	0.20–0.42
2: Clay, dark-grey, weathering rusty-brown, with lenticles of quartz sand; locally a shell sand or clay with *Placunopsis*; micritic limestone conglomerate at uneven base	0.15–0.33
1: Limestone, pale-fawn, sparsely ooidal, micritic; hard and porcellanous at top; passing down into pale-grey marly, more ooidal limestone with scattered quartz grains and small gastropods (*Bathonella*?); carbonaceous plant-debris near uneven base	0.10–0.40
Chipping Norton Limestone Formation	
3: Limestone, cream to white, fine- to medium-grained, shell-fragmental, ooidal; small-scale cross-stratification and rippled surfaces; hard, brownish and recrystallized at top	3.00
2: Limestone, pale-cream, fine grained, sandy, finely ooidal; thickly bedded and compact	3.10
1: Sand, orange-brown, marly, with impersistent limestone ribs; shell debris and shells	0.10–0.15
Clypeus Grit Formation	
7: Clay with *Stiphrothyris globata* (of authors)	0.05–0.15
6: Limestone, cream, marly, ooidal, sparsely pisolitic	1.80
5: Limestone, pale-orange to cream, soft, marly, shell-fragmental	0–0.10
4: Limestone, yellowish-cream, marly, ooidal, shell-fragmental; many brachiopods and bivalves	0.50–0.75
3: Limestone, creamy-fawn, marly, fine grained, sparsely ooidal; many brachiopods, bivalves, some gastropods; two thin beds of sand	2.13
2: Limestone, pale-brown and buff, soft, very marly, shell-fragmental, sparsely ooidal	0.90
1: Limestone, brown, hard, marly, sparsely ooidal, shell-fragmental	seen to 0.25

Boreholes drilled in the floor of the quarry proved a further 5.8 m of the Clypeus Grit Formation, indicating a total thickness of 11.7 m for the formation.

Interpretation

The succession in Ditchley Road Quarry records a period in which depositional environments varied between shallow-water, unrestricted, carbonate shelf-sea; marine, quiet-water, protected, carbonate lagoon; and brackish-water, near-shore, sub-littoral mudflat.

At the base of the succession, the micritic matrix of the Clypeus Grit Formation suggests a generally low-energy environment in which the deposition of carbonate mud was dominant. It is inferred that the matrix-supported ooids and pisoids were washed into the depositional area from nearby sources during higher-energy events. A stable substrate encouraged the development of a large and varied, sessile and motile bivalve–brachiopod fauna, as well as species of shallow-burrowing echinoids.

The ooidal limestones of the overlying Chipping Norton Limestone Formation, which are in part current-rippled or cross-bedded, were deposited in the medium- to high-energy, shallow waters of an offshore, carbonate shelf-sea. The sandy nature of the lower beds indicates some input of terriginous sediment. The paucity and low diversity of the fauna and the rarity of burrowing organisms indicate an unstable substrate, conditions that have been compared to the mobile, carbonate sand-belts of Florida and the Bahamas (Sellwood and McKerrow, 1974). The hard, recrystallized top surface of the formation suggests a pause in sedimentation before deposition of the overlying unit commenced.

The Sharp's Hill Formation comprises lithologies ranging from dark, organic clay to oyster-rich shell-fragmental limestone, and contains a variety of fossils from fully marine (*Modiolus*, *Epithyris*) to brackish water (*Placunopsis*). These characteristics indicate rapid variations in depositional conditions from offshore, open marine to nearshore, brackish-water mudflat, the latter incorporating drifted plant-debris. The micritic limestone at the base of the formation reflects a shallow-water, low-energy, carbonate lagoonal environment. The presence of the freshwater gastropod *Bathonella* in the lower part suggests greater proximity to the shoreline, the gastropods having been washed into the lagoon from the hinterland. A depositional break is marked by the hardground that caps this bed and the conglomerate that overlies it. It should be noted that this limestone and the conglomerate are restricted to a part of the quarry (SP 3687 1985) that is not now visible.

The strata of the Charlbury Formation have formerly been included with the Taynton Limestone Formation but Boneham and Wyatt (1993) argued that they were of sufficiently different facies to warrant separation as a distinct formation. Its hard, sparry, shell-fragmental limestones, which are ooidal in part, point to clear, shallow, turbulent waters associated with a mobile substrate. By contrast, the soft, very marly limestones reflect a much less turbulent environment and a more stable substrate that supported a large and diverse bivalve fauna, accompanied by numerous brachiopods. The subordinate marl beds indicate quiet waters in which carbonate mud deposition dominated; the fine carbonate sand content was, perhaps, reworked from adjacent areas.

The succeeding Taynton Limestone Formation witnesses the establishment of a uniformly shallow water, high-energy, current-dominated shelf-sea in which deposition of shell-fragmental, cross-bedded carbonate shoal-sands dominated. Like the Chipping Norton Limestone Formation, a meagre, low-diversity fauna implies an unstable, mobile substrate.

The section at Ditchley Road Quarry has yielded no fossils of special biostratigraphical significance. However, the stratigraphy of a comparable nearby succession at **Stonesfield** (Boneham and Wyatt, 1993; see GCR site report, this volume) allows it to be dated satisfactorily. The Taynton Limestone Formation is assigned to the Middle Bathonian Progracilis Zone on the basis of a diagnostic ammonite fauna, including the zonal index taxon *Procerites progracilis* Cox and Arkell, in coeval beds at **Stonesfield** (see GCR site report, this volume). The underlying Charlbury Formation may be referred to the same zone on the evidence of a similar diagnostic fauna found in corresponding beds farther west in Gloucestershire. The Chipping Norton Limestone Formation is known to belong to the Lower Bathonian Zigzag Zone, Yeovilensis Subzone in the type area (Torrens, 1969e). The stratigraphical position of the Sharp's Hill Formation suggests that it belongs to the overlying Tenuiplicatus Zone. The exposed portion of the Clypeus Grit Formation at Ditchley Road Quarry is inferred to be equivalent to the bulk of the Hook Norton Member of the Chipping Norton Limestone Formation in the type area, which belongs to the Lower Bathonian Zigzag Zone, Macrescens and Convergens subzones (Torrens, 1969e). Much of the remainder, proved in boreholes, is probably coeval with the 'Hook Norton Conglomerate Beds' at **Hook Norton** (see GCR site report, this volume), which belong to the Upper Bajocian Parkinsoni Zone, Bomfordi Subzone.

Conclusions

Ditchley Road Quarry currently reveals a varied lithological succession ranging from the Lower Bathonian Chipping Norton Limestone Formation (Zigzag Zone), to the Middle Bathonian Taynton Limestone Formation (Progracilis Zone). The section is of considerable importance in establishing the depositional history of the lower part of the Bathonian succession in this part of Oxfordshire, and in interpreting the lateral lithological changes that characterize the Sharp's Hill Formation. The latter formation is characterized at Ditchley Road Quarry by the local development of a basal micritic limestone bed, which is capped by a hardground and which contains freshwater gastropods. The quarry is the type section of the Charlbury Formation, which, though regionally widespread, is nowhere else satisfactorily exposed; this perhaps explains why it has hitherto been overlooked. The section exhibits well-developed cross-bedding structures.

STONESFIELD, OXFORDSHIRE (SP 379 172, SP 392 172, SP 387 171, SP 387 168)

R.J. Wyatt

Introduction

Stonesfield, in Oxfordshire, is historically famous as the source of the Middle Bathonian Stonesfield Slate, a high-quality roofing stone used extensively throughout surrounding districts. The tilestone is restricted to an approximately oval area within 1.5 km of Stonesfield village (Figure 3.68), where old waste tips, shafts and an adit bear witness to the thriving industry of the 18th and 19th centuries, when freshly

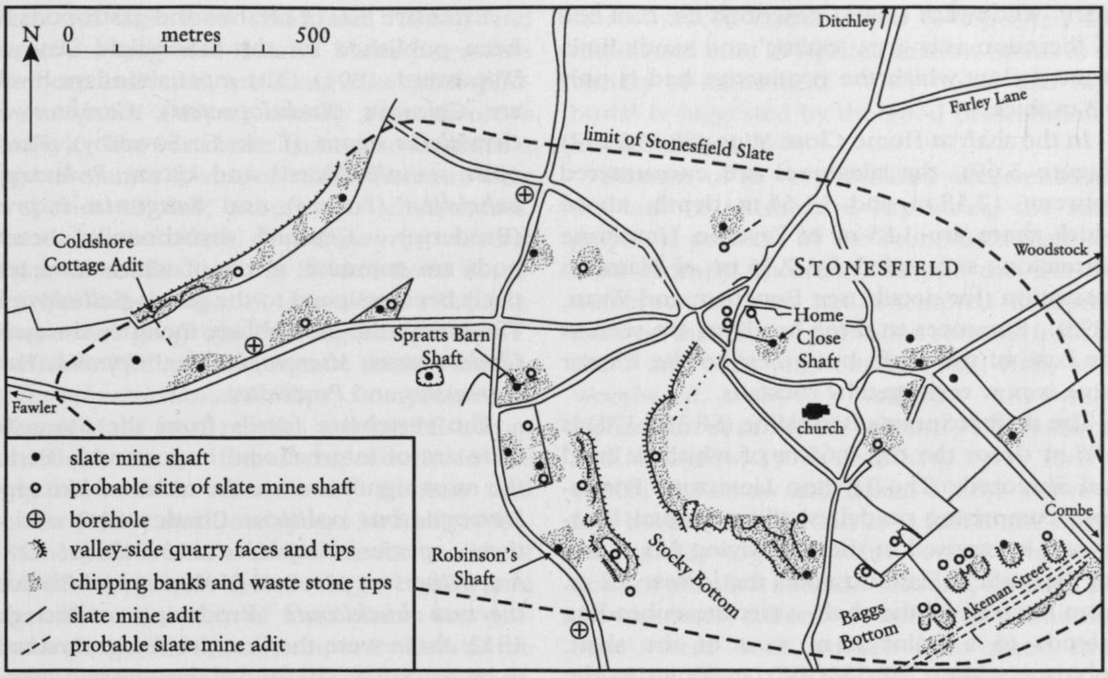


Figure 3.68 Sketch map showing the distribution of the Stonesfield Slate. (After Benton and Spencer, 1995, fig. 6.6.)

mined stone was exposed to winter frosts to facilitate splitting into roofing slates. Stonesfield may also be regarded as one of the most important Bathonian localities in the Cotswolds. It is known internationally for its prolific, diverse and stratigraphically significant fossil fauna and flora, which contain an unusual mixture of marine, freshwater and terrestrial forms, including a great variety of reptiles, early mammals, insects and plants.

The Stonesfield GCR site comprises four former slate mines known as Coldshore Cottage, Home Close, Robinson's and Spratt's Barn mines; these form elements of the type locality of the Stonesfield Slate. Coldshore Cottage Mine is served by a hillside adit, the others by shafts. A number of other shafts, up to 22 m deep, are identified in Aston's (1974) account of the former slate mining industry. Of the numerous published accounts of Stonesfield Slate, that of Boneham and Wyatt (1993) is the most recent and comprehensive; others are noted below.

Description

The commercially exploited tilestones comprise grey and fawn, commonly well-laminated, fissile, calcareous, fine-grained, quartzose sandstone and siltstone, and subordinate sandy limestone, with shelly partings. Impersistent oolite laminae or scattered ooids are common and, locally, the tilestone is interbedded with fissile, fine-grained oolite. Although regular horizontal lamination is characteristic, small-scale cross-lamination picked out by silt or ooidal partings is not uncommon. The best of the roofing tiles came from concretions, known as 'potlids', set in beds of uncemented sand. A layer of hard, bored, oolite pebbles is said to run through the best slate bed although, as shown below, this specific bed cannot be identified. The maximum recorded thickness is 1.8 m (Fitton, 1828), in a shaft thought to be in the eastern part of the village, although the thickness is commonly much less; the 'potlid' bed is only 0.46 m thick.

The adit at Coldshore Cottage Mine (SP 379 173) exposes the basal beds of the Hampen Formation resting on Stonesfield Slate, including its roof bed. The former comprises 1.20 m of buff, shell-detrital marl with scattered oyster shells and sporadic *Burmirhynchia concinna* (Davidson), overlain by 0.18 m of khaki, greenish-grey mottled, silty clay with 'race' nodules near the base and scattered carbonaceous plant-fragments, and then 1.3 m of ooidal, shell-fragmental marly limestone and marl. Woodward (1894) described the roof bed of the mine as a grey, 'oolitic' and sandy limestone, below which the productive bed is only 0.3 m thick.

In the shaft at Home Close Mine (SP 392 172) (Figure 3.69), the tilestones are encountered between 12.58 m and 13.64 m depth, above which there are 1.85 m of Taynton Limestone Formation, succeeded by 7.75 m of Hampen Formation (for details, see Boneham and Wyatt, 1993). Entrances to three headings are seen at the base of the shaft, but access to the former mine is now restricted by rockfalls.

The shaft at Spratt's Barn Mine (SP 387 171) is 7.85 m deep, the top 3.65 m of which is lined and obscured. The Taynton Limestone Formation, comprising ooidal, shell-fragmental limestones, is exposed in the underlying 3.0 m and the Stonesfield Slate occupies the lowest 1.2 m. From the base of the shaft, a circuitous heading extends to a point 28 m west of the shaft. Robinson's Mine (SP 388 168), *c.* 400 m to the SSE, is accessed by an 11.3 m-deep shaft (Bradshaw, 1978) to the floor of the mine heading. The slate worked here is at, or close to, the top of the Taynton Limestone Formation.

Extensive lists of bivalves and gastropods have been published for the Stonesfield Slate (e.g. Woodward, 1894). The most abundant bivalves are *Chlamys* (*Radulopecten*), *Camptonectes*, *Gervillella ovata* (J. de C. Sowerby), *Placunopsis socialis* Morris and Lycett, *Praeexogyra hebridica* (Forbes) and *Vaugonia impressa* (Broderip). Crushed rhynchonellid brachiopods are common, a few of which have tentatively been assigned to the genus *Kallirhynchia*. The ammonite assemblage includes the genera *Clydoniceras*, *Micromphalites*, *Oppelia*, *Paroecotraustes* and *Procerites*.

The vertebrate fossils from the Stonesfield Slate are of international importance. Perhaps the most significant are the mammal-like reptile *Stereognathus ooliticus* Charlesworth and the three species, *Amphilestes broderipi* Owen, *Amphitherium prevosti* (V. Meyer) and *Phascolotherium bucklandi* (Broderip), collected in 1812; these were the first pre-Tertiary mammals to be recorded. All four of these vertebrates are valuable in reconstructing the early evolution of mammals from reptilian stock. Dinosaurs known from Stonesfield include *Megalosaurus bucklandi* Meyer, the first dinosaur to be recog-

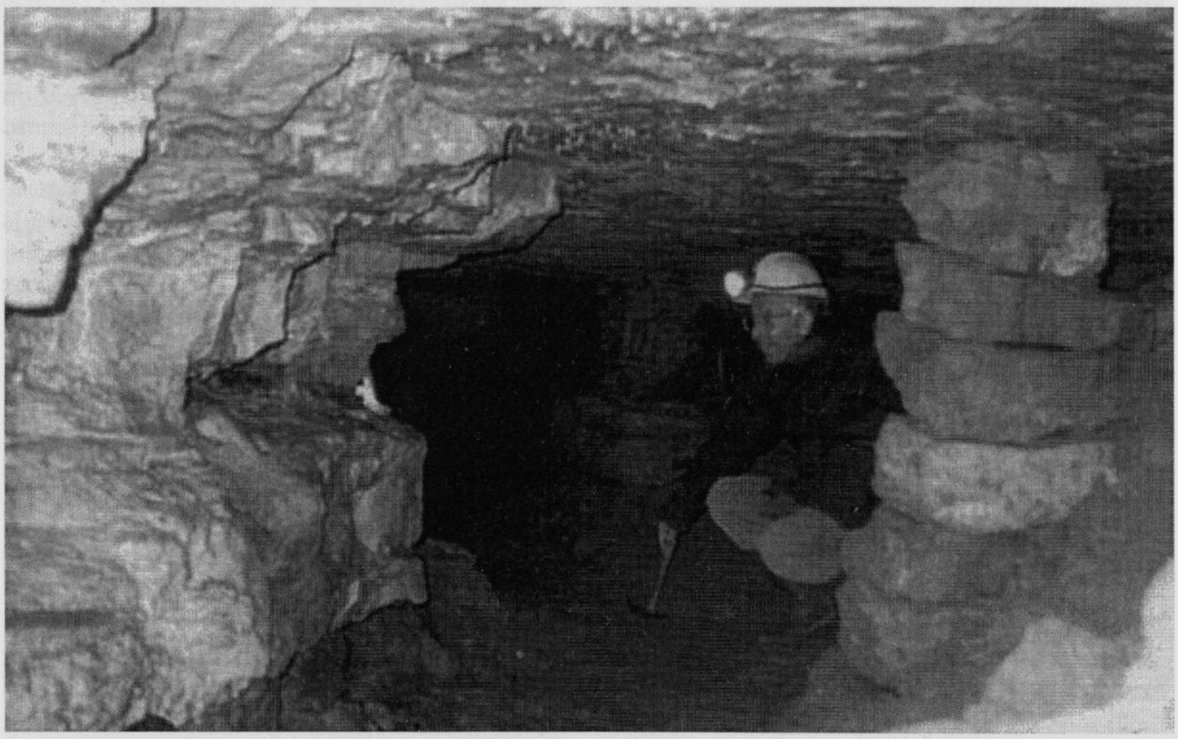


Figure 3.69 Typical Stonesfield Slate mine close to the shaft at Home Close Mine beneath Stonesfield village. The area on the right-hand side of the photo has been worked out, and the roof is supported by pillars of waste material. (Photo: M.G. Sumbler.)

nized and described (Buckland, 1824), and *Iliosuchus incognitus* Huene. Three pterosaurs have been collected, including *Rhamphocephalus bucklandi* (Meyer) and *R. depressirostris* (Huxley). The vertebrate fauna also contains a range of marine forms, of which there are over 30 species of fish; others are ichthyosaurs, plesiosaurs including *Cimoliosaurus,* several marine crocodiles, such as *Steneosaurus boutilieri* Deslongchamps, *S. brevidens* (Phillips), *Teleosaurus? geoffroyi* Deslongchamps and *T. subulidens* Phillips, and aquatic turtles, including *Testudo stricklandi* Phillips. Comprehensive accounts of the fossil reptiles and fossil fish from Stonesfield can be found respectively in the companion GCR volumes by Benton and Spencer (1995) and Dineley and Metcalf (1999).

Stonesfield is also a classic site for studies of fossil insects, which include large beetles and dragonflies. A variety of fossil plants has provided a glimpse of the contemporary flora of the London Landmass; they comprise ferns, cycads, conifers and ginkgos, as well as the enigmatic '*Phyllites* sp.', which appears to be a dicotyledonous angiosperm leaf. If confirmed, this would be the oldest angiosperm fossil (other than pollen) known from anywhere in the world. The flora is broadly comparable to that of the same age in Yorkshire but there are several forms unique to Stonesfield, such as *Podozamites stonesfieldensis* and *Sphenozamites belli*, both of which were first described by Seward (1904).

Interpretation

The dominance of horizontal lamination in the Stonesfield Slate, associated with subordinate cross-lamination, suggests that it was deposited under shallow-water, high-energy, 'upper flow regime' conditions. The tilestones represent periodic influxes of silt and fine sand into the shallow-water, carbonate shelf-sea in which the ooidal, shell-fragmental limestones of the Taynton Limestone Formation accumulated. The provenance of the silt and sand is uncertain, but it was probably derived directly or indirectly from erosion of sandstone rocks on the London Landmass to the east. The occurrence of freshwater and terrestrial organisms in tilestones with a dominantly marine fauna certainly indicates derivation of some material from the landmass. Sellwood and McKerrow (1974) suggested that a concentration of bone and plant material was picked up from a shoreline strand by strong storm-induced currents and re-deposited with the silt and sand in isolated shallow basins in the vicinity of Stonesfield. They noted that rapid burial is suggested by the good preservation of insect remains.

Because of its very localized occurrence and the lack of informative exposures, the stratigraphical position of the Stonesfield Slate was until recently uncertain, despite the fact that numerous authors had attempted interpretations on the basis of published sections from old shafts and adits (e.g. Fitton, 1928; Hull, 1859; Woodward, 1894; Walford, 1894–1896; Richardson *et al.*, 1946; Arkell, 1947b; Sellwood and McKerrow, 1974; Bradshaw, 1978; Torrens, 1980b; McKerrow and Baker, 1988). However, four boreholes drilled in 1991 just to the west of Stonesfield, together with revised interpretations of old shaft and adit sections, revealed that the tilestones, collectively known as 'Stonesfield Slate', were once worked from three stratigraphical levels – at the top, within and at the base of the Taynton Limestone Formation (Boneham and Wyatt, 1993). The lowest bed was worked from shafts in the eastern part of Stonesfield; the middle bed from shafts in the western part; and the middle and upper beds from shafts and adits just west of the village. The tilestones at all three levels are impersistent and localized. A consequence of these conclusions is that, because fossils comprising the specialized fauna and flora of the tilestones were not accurately documented when collected, they cannot now be assigned to any particular bed.

The ammonite fauna of the Stonesfield Slate, like that of the accompanying beds of the Taynton Limestone Formation, is typical of the Middle Bathonian Progracilis Zone. The most diagnostic of the ammonites are *Procerites mirabilis* Arkell and the zonal index taxon *P. progracilis* Cox and Arkell.

Conclusions

Stonesfield was once the scene of a locally important roofing industry, the evidence for which is the presence of old mine headings served by adits and shafts, now mostly inaccessible. The village is also of world renown for the diverse and spectacular fauna and flora it yielded during the years when tilestones were split to produce the famous Stonesfield Slate. Of special interest are the mammal-like reptile and three mammals that together have particular significance in the early evolution of the Class Mammalia. A wide variety of reptiles, both marine and terrestrial, includes the first dinosaur to be recognized, and represents what is probably the most important Middle Jurassic fossil reptile assemblage in the world. A fossil leaf, the identity of which is problematical, could well be the oldest angiosperm leaf known. The remaining flora and a large number of well-preserved insects add to the special palaeontological importance of the Stonesfield Slate. Ammonites, rare in the Bathonian succession, form part of the extensive fauna and are valuable in attributing the Stonesfield Slate and its host formation, the Taynton Limestone Formation, to the Progracilis Zone.

SHIPTON-ON-CHERWELL CEMENT WORKS AND WHITEHILL FARM QUARRY, GIBRALTAR, OXFORDSHIRE (SP 473 177, SP 478 186)

R.J. Wyatt

Introduction

Shipton-on-Cherwell Quarry Cement Works at Shipton-on-Cherwell, Oxfordshire, exposes a section from close to the base of the White Limestone Formation up to the Cornbrash Formation (Figures 3.70 and 3.71). The nearby Whitehill Farm Quarry exhibits a less extensive stratigraphical succession, but includes an unusual facies of the White Limestone Formation. The two localities together characterize well the local Middle to Upper Bathonian stratigraphy of the district, in which considerable facies variations occur at several levels. Shipton-on-Cherwell Cement Works is the type locality of the Shipton Member of the White Limestone Formation, and is also of historical importance as the site from which many fossil reptile remains were collected, including crocodiles and dinosaurs.

The earliest reference to the quarries is by Phillips (1871) who described the fossil reptile finds. Later, Odling (1913) and Arkell (1931) provided descriptions of the lithological succession. Allen and Kaye (1973) examined the sedimentary facies of the upper part of the White Limestone and Forest Marble formations, Palmer (1979) considered the palaeoecology and sedimentology of the White Limestone Formation, whilst Sumbler (1984) clarified the stratigraphical classification. Richardson *et al.* (1946) largely reiterated Arkell's (1931) account, and Page (1989) provided a detailed log of the Cornbrash Formation.

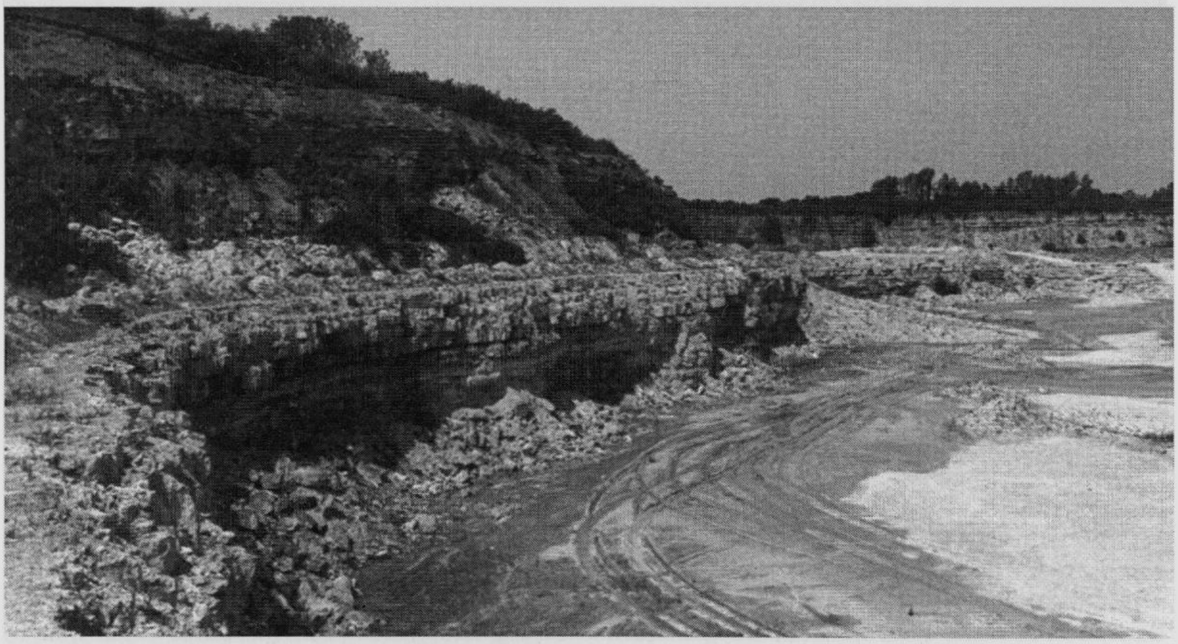


Figure 3.70 Shipton-on-Cherwell Cement Works. The lower face is the Ardley Member (White Limestone Formation), overlain by the Bladon Member (covered by scree), Forest Marble Formation and then remanié Cornbrash Formation. (Photo: M.G. Sumbler.)

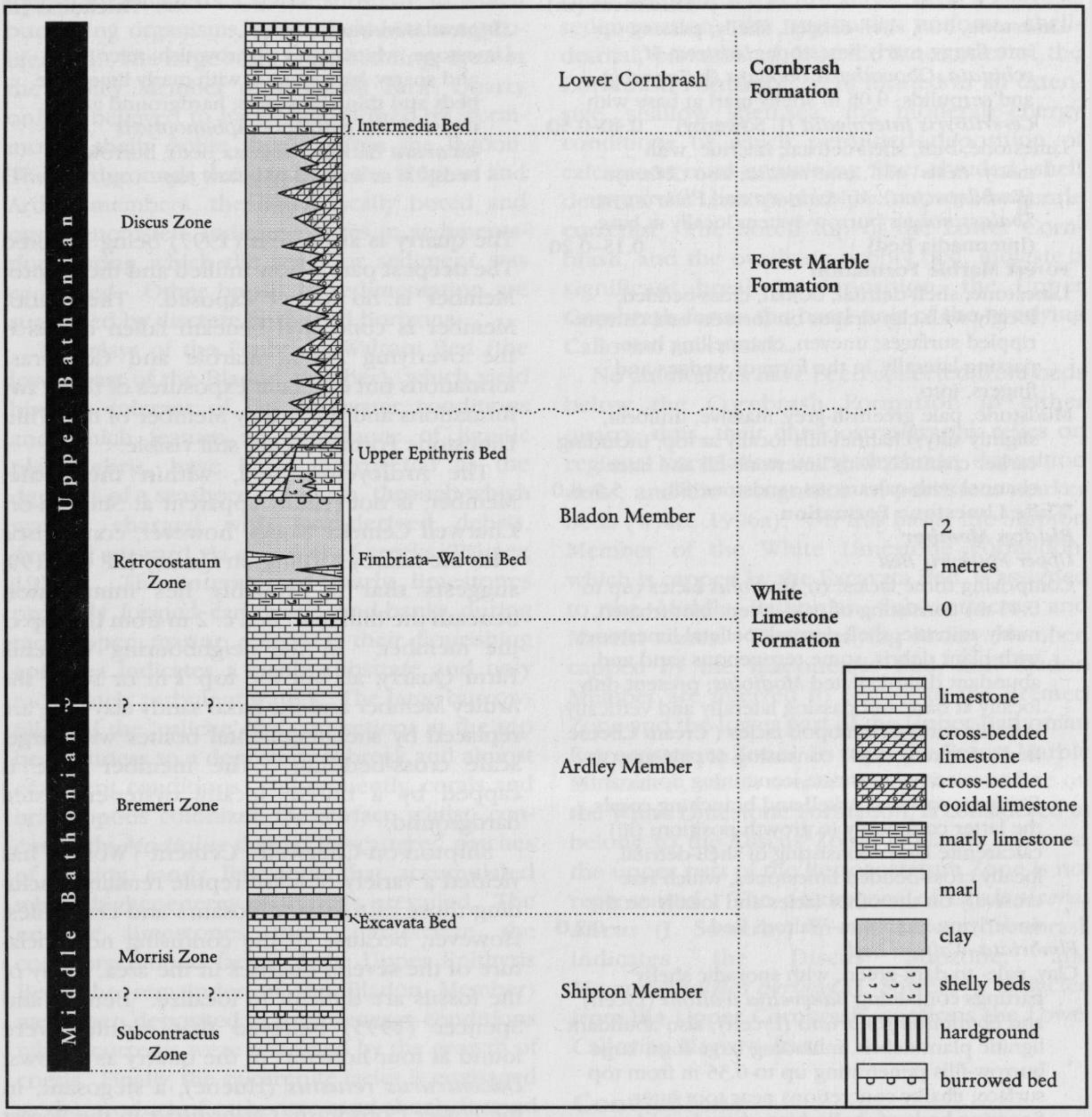


Figure 3.71 Graphic section of the Bathonian succession at Shipton-on-Cherwell Cement Works.

Description

The following section at Shipton-on-Cherwell Cement Works is based on Arkell (1931), Richardson *et al*. (1946), Allen and Kaye (1973), Palmer (1979), Sumbler (1984) and Page (1989).

	Thickness (m)
Cornbrash Formation	
Upper Cornbrash	
Limestone, brown, shell-detrital, sandy, with rare *Macrocephalites*; marl seam at base yielding *Microthyridina* cf. *lagenalis* (Schlotheim), (cont.): *Rhynchonelloidea cerealis* S.S. Buckman and *Lopha* cf. *marshii* Arkell; thin seam of pebbly, dark-flecked limestone at base, cemented to and infilling borings in underlying bed	0.25
Lower Cornbrash	
Limestone, grey, shelly, micritic, capped by a bored hardground; *Neocrassina hilpertonensis* (Lycett), *Trigonia*, *Meleagrinella echinata* (Wm Smith); also *Clydoniceras discus* (J. Sowerby) (Astarte–Trigonia Bed of Page (1989))	0.70–1.05
Limestone, marly, rubbly, with marl seams; common bivalves including *Gresslya*, *M. echinata* and *Pleuromya*	0.95–1.05

	Thickness (m)
Limestone, buff, shell-detrital, shelly; passing up into flaggy, marly limestone; *Liostrea*, *M. echinata*, *Obovothyris obovata* (J. Sowerby) and serpulids; 0.05 m shelly marl at base with *Cererithyris intermedia* (J. Sowerby)	0.40–0.50
Limestone, buff, shell-detrital, micritic; with many 'nests' of *C. intermedia*; also *Chlamys* (*Radulopecten*), *M. echinata* and *Pleuromya*; *Thalassinoides* burrow-system locally at base (Intermedia Bed)	0.15–0.20
Forest Marble Formation	
Limestone, shell-detrital, ooidal, cross-bedded, locally with clay drapes on foresets and current-rippled surfaces; uneven, channelling base; passing laterally, in the form of wedges and fingers, into	
Mudstone, pale greenish-grey, massive, uniform, slightly silty; channel-fills locally at top, including earlier channels with limestone-fill and later channel with calcareous sandstone-fill	5.0–8.0
White Limestone Formation	
Bladon Member	
Upper Epithyris Bed	
Comprising three facies: (i) *Modiolus* facies (up to 0.45 m) consisting of pale-green, bioturbated, marly, micritic, shell-detrital, pelletal limestone, with plant debris, some terrigenous sand and abundant disarticulated *Modiolus*; present only locally at base and passing laterally and vertically into (ii) coral–brachiopod facies ('Cream Cheese Bed' of Arkell, 1931) consisting of pale-grey to white micritic limestone, containing dominantly *Epithyris oxonica* Arkell and branching corals, the latter commonly in growth position; (iii) calcarenite facies consisting of shell-detrital, locally cross-bedded limestones, which rest erosively on the other facies and locally on the underlying Fimbriata–Waltoni Bed	0-2.0
Fimbriata–Waltoni Bed	
Clay, pale- to dark-green, with sporadic shelly partings containing *Bakevellia waltoni* (Lycett) and *Eomiodon fimbriata* (Lycett); also abundant lignitic plant-debris, including large logs; large burrow-fills penetrating up to 0.35 m from top surface; chalky concretions near top; inter-fingering beds of shelly, bioturbated, marly, shell-detrital limestone, mainly in lower part, with many oysters	*c.* 2.0
Limestone, pale-grey, shell-detrital, pelletal, micritic, marly, with abundant *Epithyris oxonica*, as well as *Modiolus*, oysters and sporadic stands of branching corals (Middle Epithyris Bed of Arkell, 1931)	*c.* 1.0
Ardley Member	
Limestone, white or pale-buff, micritic and sparry, pelletal, bioturbated, commonly shell-detrital, with sporadic marly limestone beds; locally, a hardground at top; thin marl *c.* 2 m below top with locally abundant *Epithyris* above it ('Lower Epithyris Bed' of Arkell, 1931); burrowed bed *c.* 2 m below top; massive, well-cemented, sandy limestone bed at base	6.5
Clay, grey, sandy, shell-detrital; passing down into marl	0.5
Shipton Member	
Limestone, whitish-grey or brownish, micritic and sparry, bioturbated, with marly limestone beds and thin clay-seams; hardground at top with the gastropod *Aphanoptyxis excavata* Barker (Excavata Bed); burrowed beds 0.8 m and 2.3 m below top	4.0

The quarry is at present (1997) being restored. The deepest part is now infilled and the Shipton Member is no longer exposed. The Bladon Member is concealed beneath fallen debris of the overlying Forest Marble and Cornbrash formations but excellent exposures of those two formations and the Ardley Member of the White Limestone Formation are still visible.

The Ardleyensis Bed, within the Ardley Member, is not readily apparent at Shipton-on-Cherwell Cement Works; however, comparison with the nearby Kirtlington Quarry (SP 494 199) suggests that it probably lies immediately beneath the thin marl bed *c.* 2 m from the top of the member. In the neighbouring Whitehill Farm Quarry, all but the top 1 m or so of the Ardley Member and the basal sandy clay bed, are replaced by shell-fragmental oolites with large-scale cross-bedding. The member here is capped by a bored, locally oyster-encrusted hardground.

Shipton-on-Cherwell Cement Works has yielded a variety of fossil reptile remains, including those of turtles, dinosaurs and crocodiles. However, because of the confusing nomenclature of the several quarries in the area, many of the fossils are difficult to localize. Benton and Spencer (1995) believed that reptiles were found at four horizons in the quarry as follows: *Dacentrurus retustus* (Huene), a stegosaur, in the Lower Cornbrash; *Cetiosaurus* in the Forest Marble Formation; *Teleosaurus* and other crocodiles, plus *Cetiosaurus*, in the Fimbriata–Waltoni Bed; crocodile remains in the Ardley Member. A comprehensive list is given by Benton and Spencer (1995).

Interpretation

The micritic limestones of the White Limestone Formation (Shipton and Ardley members) were probably deposited in the shallow but low-energy waters of an extensive, protected, carbonate lagoon, located between the London Landmass and a carbonate sand-barrier shoal-belt to the west. Common bioturbation in the limestones suggests a stable substrate in which burrowing organisms, particularly bivalves, proliferated. The large-scale cross-bedding, seen in the Ardley Member of Whitehill Farm Quarry only, is believed to have been formed by storm-moved shelly oolite shoals within the lagoon. The hardgrounds that cap both the Shipton and Ardley members, the latter locally bored and oyster-encrusted, indicate pauses in sedimentation during which the sea-floor sediment was cemented. Other breaks in sedimentation are suggested by discrete burrowed horizons.

The clays of the Fimbriata–Waltoni Bed (the lower part of the Bladon Member), which yield bivalves tolerant of brackish-water conditions and which feature an abundance of lignitic plant-debris, have been interpreted as the deposits of a seashore saltmarsh, through which waters, charged with land-derived debris, drained seaward via a system of creeks (Palmer, 1979). The intercalated marly limestones probably formed carbonate sand-banks during more open marine episodes; their flourishing epifauna indicates a stable substrate and only moderately turbulent waters. The large burrow-fills and the 'caliche'-like concretions at the top bear witness to a depositional break and almost emergent conditions. Subsequently, corals and brachiopods colonized the surface whilst, concurrently, *Modiolus* thrived in scattered patches of muddy, sandy limestone that accumulated where higher-energy conditions prevailed. The micritic limestones that characterize the coral–brachiopod facies of the Upper Epithyris Bed (the remainder of the Bladon Member) were then deposited in lower-energy conditions where currents were restricted by the growth of corals. Finally, the calcarenite facies is envisaged as the product of carbonate sand-shoals formed in shallow, turbulent waters, which scoured the sea floor to produce the erosive channelling base. It should be noted that beds of the Bladon Member were included within the Forest Marble Formation ('Kemble and Wychwood Beds') by Allen and Kaye (1973).

The cross-bedded, ooidal limestones of the Forest Marble Formation are interpreted as a large, elongate sand-shoal formed in a high-energy environment, which was flanked by quieter and deeper waters where mud accumulated (Allen and Kaye, 1973) (Figure 3.72). Polygonal desiccation cracks have been noted in the muddy bottomset beds and mud drapes of the limestones, suggesting that the top of the shoal was exposed at low tides. After a pause in sedimentation, the regionally uniform, shell-detrital, bioturbated, micritic limestones of the Cornbrash Formation were formed in an extensive, shallow shelf-sea, the moderate-energy conditions of which permitted deposition of calcareous mud containing fine, abraded, shell detritus, the latter probably winnowed by gentle currents. The bored top of the Lower Cornbrash, and the overlying pebbly bed, indicate a significant break in deposition; the Upper Cornbrash forms the basal unit of the overlying Callovian succession.

No ammonites have been collected from beds below the Cornbrash Formation in either quarry; thus, their chronostratigraphy relies on regional correlation using rhythmic, deposition units, and the recognition of persistent marker beds (Wyatt, 1996a). On this basis, the Shipton Member of the White Limestone Formation, which is capped by the Excavata Bed, is assigned to the Middle Bathonian Subcontractus and Morrisi zones. The overlying Ardley Member, capped by the Bladonensis Bed, and Bladon Member are inferred to belong to the Bremeri Zone and the lower part of the Upper Bathonian Retrocostatum Zone. In turn, the Forest Marble Formation, which overlies an erosion surface on the White Limestone Formation, is considered to belong to the Discus Zone, Hollandi Subzone; the upper part of the Retrocostatum Zone is not represented. The occurrence of *Clydoniceras discus* (J. Sowerby) in the Lower Cornbrash indicates the Discus Subzone, and *Macrocephalites herveyi* (J. Sowerby), collected from the Upper Cornbrash, confirms the Lower Callovian Herveyi Zone.

Conclusions

Shipton-on-Cherwell Cement Works and Whitehill Farm Quarry together display a typical Middle to Upper Bathonian succession, ranging from the base of the White Limestone Formation to the top of the Lower Cornbrash; it includes the type section of the Shipton Member of the White Limestone Formation. Hardground beds in the White Limestone Formation provide evidence of depositional breaks associated with cementation of sea-floor sediment. Very shelly beds in the formation yield well-preserved fossils, especially brachiopods and bivalves. Large-scale, cross-bedded limestones in the Ardley Member, seen in this district only in

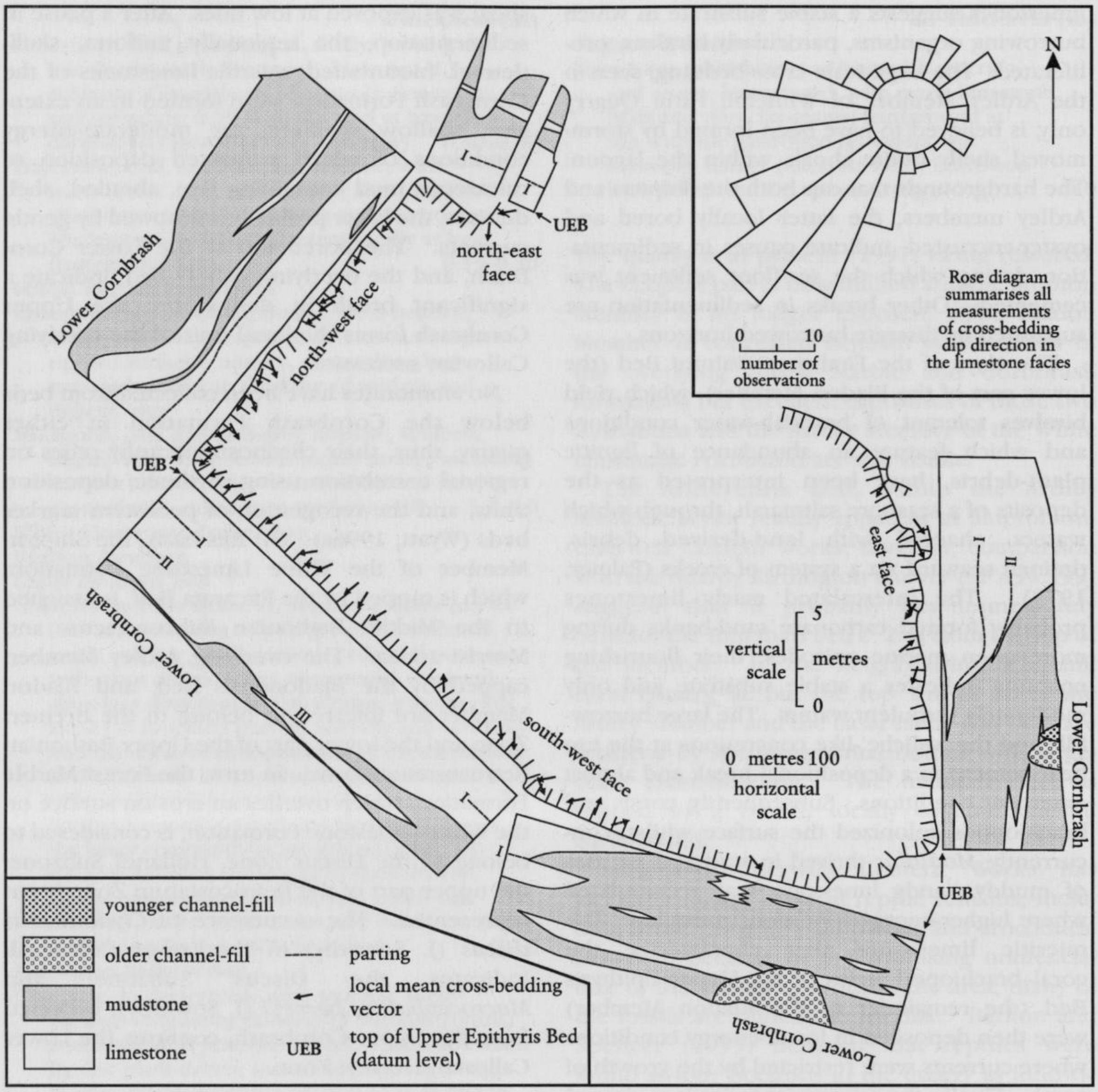


Figure 3.72 Facies variation in the Forest Marble Formation of Shipton-on-Cherwell Cement Works. (Based on Allen and Kaye, 1973, fig. 3.)

Whitehill Farm Quarry, demonstrate the locally rapid facies changes that may occur in the White Limestone Formation. The section of the Forest Marble Formation is remarkable for the pronounced lateral facies changes that are displayed. In the greater part of the section at the GCR site, the formation is composed of limestone but in the eastern part of the quarry, beyond the GCR site, the upper and greater part of the formation has passed into mudstone. Both the White Limestone and Forest Marble formations have been the subject of exhaustive palaeoecological, sedimentological and general facies studies, and still afford opportunities for further research. The Cornbrash Formation in the quarries has yielded ammonites diagnostic of the Upper Bathonian Discus Zone and Lower Callovian Herveyi Zone. Shipton-on-Cherwell Cement Works has proved to be the best source of Middle Jurassic crocodiles in Britain, and has also yielded the bones of turtles and dinosaurs.