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**Geological notes and local details for
1:10 000 Sheet SP 01 SE (Chedworth)**

Part of 1:50 000 Sheet 235 (Cirencester)

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1 INTRODUCTION

This account describes the geology of 1:10 000 Sheet SP 01 SE (Chedworth). The first geological survey of the area was undertaken by E Hull during the 1850s; it was published as part of Old Series One-Inch Geological Sheet 44 in 1856, and described by Hull (1857). This survey was re-issued with minor amendments as New Series One-Inch Geological Sheets 217 (Moreton-in-Marsh) and 235 (Cirencester), published in 1929 and 1933, respectively. For the Chedworth area, the only change from Hull's original survey was the addition of alluvium and river terrace deposits along the River Coln by H G Dines. The geology of the 1933 sheet 235 is described by Richardson (1933).

The Chedworth area was surveyed at the 1:10 000-scale during 1993-4, as part of the resurvey of Sheet 235 (completed late 1994). The eastern and central southern part of the area (c. 12.5 km²) was surveyed by M G Sumbler, the north-western part (c. 9km²) by A J M Barron, and the south-western part (c. 3.5 km²) by A N Morigi. This report is based mainly on this latest work, but also incorporates data from Richardson (1933) and other sources where appropriate. The account of the Triassic rocks of the Stowell Park Borehole is in part based on Warrington (1993). The biozonation of the Lias Group of the borehole is from Ivimey-Cook (1993a), and biostratigraphical information relating to exposed formations is mainly from Ivimey-Cook (1993b) and Cox (1994, 1995). Measured sections of exposed strata from the lettered localities indicated on the map and referred to in the text are given in Appendix 1.

The Chedworth area forms part of the broad, gently south-south-easterly-dipping plateau of the Cotswolds. It is dissected here by the meandering valleys of the River Coln and of its minor tributaries. The A 429 Foss Way crosses the ground in the south-east; Cirencester is 10 km to the south-west, Stow-on-the-Wold 15 km to the north-east. The village of Chedworth and the hamlets of Lower Chedworth, Coln St. Dennis and Calcot lie along the slopes of the valleys, the village of Yanworth stands on a spur in the north. Much of the ground is owned by the Stowell Park estate; the house is just off the Foss Way in the east. The upland is given over mainly to arable farming with some copses and plantations; the valley slopes are largely utilised for grazing and forestry - the extensive areas of Chedworth and Compton woods lie in the north-west. The line of the Andoversford to Cirencester railway (Midland and South Western Junction Railway), closed in the 1960's, crosses the area in the west, and its cuttings still afford fine exposures of the strata. Part of the line is a nature reserve maintained by the Gloucestershire Trust for Nature Conservation.

This report is best read in conjunction with 1:10 000 Geological Sheet SP 01 SE. This map indicates the outcrop limits of deposits which are mostly concealed beneath soil and vegetation; the geological boundary lines are inferred from indirect evidence such as the form of the ground surface and soil type, or are extrapolated from adjoining ground. The map is thus the subjective interpretation of the surveyor, and all geological boundaries carry an element of uncertainty. Boundaries of solid geological formations which (in the opinion of the surveyor) can be located to an accuracy of about 10m or less on the ground, are shown as unbroken lines on the map; all others are shown broken.

Dyeline copies of the 1:10 000 map can be purchased from BGS, Keyworth, where

records of boreholes may also be consulted. National Grid References are given in square brackets throughout; all lie within 100 km grid square SP (or 42)

QUATERNARY:

LANDSLIP

HEAD up to c. 3

ALLUVIUM up to c. 3

RIVER TERRACE DEPOSITS up to c. 4

MIDDLE JURASSIC:

GREAT OOLITE GROUP:

Forest Marble Formation 6+

White Limestone Formation 23 to 30

Hampen Formation 6 to 11

Taynton Limestone Formation 2 to 14

Fuller's Earth Formation 12 to 20

INFERIOR OOLITE GROUP:

Salperton Limestone Formation 10 to 15

Clypeus Grit Member 9 to 13

Upper Trigonia Grit Member 1 to 3

Aston Limestone Formation 3 to 15

Notgrove Member up to c. 9

Gryphite Grit Member c. 4

Lower Trigonia Grit Member c. 2

Birdlip Limestone Formation 30 to 60

Harford Member 0 to 0.3

Scottsquar Hill Member 7 to 10

Cleeve Cloud Member 15 to 40

Crickley Member 2 to 7

Leckhampton Member 3 to 10

LOWER JURASSIC

LIAS GROUP:

Upper Lias 98.22

Marlstone Rock Formation 1.78

Dyrham Siltstone Formation 54.23

'Lower Lias' 341.78

TRIASSIC

PENARTH GROUP 16.79

MERCIA MUDSTONE GROUP 440.18

SHERWOOD SANDSTONE GROUP 297.23+

Table 1. Geological sequence proved within Sheet SP 01 SE (Chedworth), giving approximate thicknesses in metres. Strata below the Birdlip Limestone Formation are not exposed at the surface, but were proved in the Stowell Park Borehole. Nomenclature for the Inferior Oolite and Lias groups is provisional. The basal part of the Lower Lias is of Triassic age.

2 CONCEALED ROCKS: PRE-TRIASSIC

The Stowell Park Borehole [0835 1176] was drilled by the Geological Survey in 1949-51, in order to prove the Mesozoic succession to the west of the 'Vale of Moreton Axis', and more especially to investigate the Palaeozoic rocks, and prove the presence or otherwise of Coal Measures (Green and Melville, 1956). As is now known from geophysical investigations, the borehole is sited close to the north to south trending axis of the Worcester Basin, in which a thick Mesozoic sedimentary succession is preserved. Due to drilling difficulties, the borehole terminated at 1372.49m, whilst still within Triassic beds, and so the Palaeozoic floor in this part of the Worcester Basin remains unproven. However, seismic data and boreholes in adjoining areas show that although Coal Measures are present on the London Platform, to the east of the Vale of Moreton Axis (e.g. in the Sherborne No 1 Borehole [1562 1393], 7.5km to the east-north-east of Stowell Park (Sumbler, 1994a), and in the BGS Upton Borehole [2315 1313], 15km east of Stowell Park (Worssam, 1963; Sumbler, 1994b)), there are none preserved in the Worcester Basin. The Guiting Power Borehole [0855 2451] some 12.5km north of Stowell Park entered probable Devonian strata beneath the Triassic and ?Permian, and the Cooles Farm Borehole [0164 9214], 20km to the west-south-west of Stowell Park, proved a thick Ordovician (Tremadocian) succession below Triassic beds.

Above the Palaeozoic, the Guiting Power Borehole proved 186.2m of strata dominated by orange to red-brown, fine to medium-grained, argillaceous sandstone, with some 'marl', shale and siltstone. This succession probably represents the Bridgnorth Sandstone of Permian age, which reaches outcrop in the west Midlands. These strata may well be present at depth in the Chedworth area.

3 CONCEALED ROCKS: TRIASSIC

3.1 SHERWOOD SANDSTONE GROUP (1075.26m to 1372.49m)

The oldest beds proved in the Stowell Park Borehole are assigned to the Sherwood Sandstone Group, of early Triassic age. The Triassic succession was not bottomed, and whilst only 297.23m of Sherwood Sandstone was proved, the total thickness of the group may be very much greater. Some 814m were proved in the Guiting Power Borehole, and the succession at Stowell Park may well be similar in both thickness and in its component units. Such a thickness compares with only 213.7m of Sherwood Sandstone in the Sherborne No. 1 Borehole, and 32.08m in the Upton Borehole (Worssam, 1963; Sumbler, 1994a, b). At both Guiting Power and at Cooles Farm, and also in the Sherborne No 1 Borehole, the basal part of the Triassic succession is assigned to the Kidderminster Formation (formerly Bunter Pebble Beds). This succession of conglomerates and sandstones, probably about 60 to 70m thick, is likely to be present beneath the Chedworth area. The succeeding Wildmoor Sandstone Formation (formerly Upper Mottled Sandstone), is also probably present; it comprises reddish brown sandstones, mainly of fluvial origin. Borehole geophysical logs suggest it may be of the order of 250m thick at Guiting Power, but it is probably overstepped by younger beds at Sherborne (Sumbler, 1994a).

In the Stowell Park Borehole (Green and Melville, 1956), the Sherwood Sandstone was proved between a depth of 1075.26m and the bottom of the borehole at 1372.49m; all these strata are assigned to the Bromsgrove Sandstone Formation (formerly Lower Keuper Sandstone). The succession consists mainly of calcareous, micaceous cross-bedded sandstones, with bands of reddish brown mudstone and siltstone ('marl'). In its type area in the Redditch district, to the south of Birmingham, the Bromsgrove Sandstone Formation is divisible into three members (Old et al., 1991); these can be tentatively identified in the Stowell Park succession.

The basal part of the succession (between 1168.86m and 1372.49m depth) resembles the Burcot Member; it is dominated by sandstones, mostly red to dark red, with paler flesh coloured bands, and often conglomeratic with quartz and quartzite pebbles, and intraformational mud-flakes.

The overlying beds (from 1083.06m and 1168.86m depth), have many of the features of the Finstall Member. They comprise relatively thick sandstones, mostly whitish to yellowish brown, with some thin mudstones. The succession is organized in fining-upwards, fluvial-type sedimentary cycles; these typically comprise a coarse-grained, conglomeratic sandstone with an erosional base, passing upwards into finer-grained sandstone, and 'marl'. Within the conglomerates, mudstone intraclasts are common, and extraformational pebbles include sandstones, quartz and perthitic feldspar but not, apparently, quartzite. Coaly streaks and possible plant debris were recorded at several levels.

The uppermost c. 8m of the Bromsgrove Sandstone Formation (between 1075.26m and 1083.06m depth) show similarities to the Sugarbrook Member of Old et al. (1991), which was formerly known as the Keuper Waterstones. These beds were placed in the 'Keuper Marl' by Green and Melville (1956). They comprise relatively thinly interbedded sandstones, argillaceous sandstones and red, green and grey mudstones, and include small patches of anhydrite.

3.2 MERCIA MUDSTONE GROUP (635.08m to 1075.26m)

The Stowell Park Borehole proved the Mercia Mudstone Group (formerly Keuper Marl) between 635.08m depth, and the top of the Bromsgrove Sandstone at 1075.26m depth. This classification differs from that of Green and Melville (1956) who, in their original account of the borehole, placed the base of the 'Keuper Marl' at 1083.06m, to include the sandy beds now regarded as the Sugarbrook Member of the Bromsgrove Sandstone (1075.26m to 1083.06m depth; see above).

The total thickness of the group, 440.18m, is close to that proved at Guiting Power (446.23m) and Cooles Farm (406m), which also lie within the axial zone of the Worcester Basin. However, it is somewhat greater than in the Sherborne No. 1 Borehole (c. 318.2) on the margin of the London Platform (Sumbler, 1994a), and considerably more than in the Upton Borehole (127.94m), which is sited farther east. Nevertheless, the thickness changes are less pronounced than in the underlying Sherwood Sandstone Group (see above). Wills (1970, 1976) recognised a number of 'miocyclothem' within the Mercia Mudstone succession, based essentially on the proportion of evaporites to

clastic sediment, and used them to correlate the succession at Stowell Park with those elsewhere. If correct, his correlation indicates that the thin succession at Upton is largely complete, i.e. that the thinning is due to overall condensation, and not loss of beds by overlap.

The Mercia Mudstone Group of the Worcester Basin is divisible into four formations, namely the Eldersfield Mudstone (formerly 'Lower Keuper Marl'), Arden Sandstone ('Upper Keuper Sandstone'), Twynning Mudstone ('Upper Keuper Marl') and Blue Anchor (Tea Green Marl) formations, in ascending order (Barclay et al., in press). The succession is dominated by reddish brown mudstones, silty mudstones and siltstones ('marls'). Evaporitic anhydrite is present throughout most of the succession, but very little gypsum was recorded. Green and Melville (1956) recognised two 'zones' of anhydrite occurrence, with early anhydrite (as concretionary blebs and patches) in the upper part of each zone, but only later veins and strings in the lower part. They suggested that this indicated two separate phases of primary anhydrite deposition.

The **Eldersfield Mudstone Formation** (785.65 to 1075.26m depth) is 289.61m thick, and consists largely of red marls with some thin beds of green and grey marl, particularly in the higher part. Green mottling is developed in the lower and upper parts, but seems to be absent from the middle. Anhydrite is present as small veins, speckles and patches throughout, with larger patches (up to 0.1m) between 857.4 and 901.3m depth, at the top of the 'lower zone' of anhydrite development recognised by Green and Melville (1956).

The **Arden Sandstone Formation** (765.68 to 785.65m depth) is 19.97m thick. It comprises lower (3.81m) and upper (7.78m) units of thinly-bedded, fine-grained, green-grey and white sandstone with minor marl beds, separated by 8.38m mainly composed of red, purple and green marls. The sandstones in the upper unit are cross-bedded, with common desiccation cracks in mudstone intercalations. Veins and small patches of anhydrite occur sporadically.

The **Twynning Mudstone Formation** (643.97 to 765.68m depth) is 121.71m thick. It consists largely of red-brown marls. Thin beds of green marl occur in the lower and upper parts, and green mottling is also present near the top. Anhydrite is present throughout the lower 93m of the formation but is absent from the higher beds. It occurs largely as specks and larger patches, up to 0.1m in size. Six irregular bands of anhydrite, up to 0.1m thick, were noted between 682.75 and 701.04m; veins are rare.

The **Blue Anchor Formation** (635.08 to 643.97m depth) is 8.89m thick in the Stowell Park Borehole. It consists largely of pale green and greenish white, slightly sandy mudstones with some pyrite; a few fish scales were found at c. 638.9m depth. The basal c. 4m are somewhat sandy, with rare grains and granules of quartz (0.5 to 1.5mm diameter). Interbedded dark green mudstones impart a banded appearance to the middle part of the sequence; small-scale brecciation and injection structures occur in these banded units. The base of the formation is marked by a change to red marls below, but there is no other lithological difference, nor any sign of a break in sedimentation (Green and Melville, 1956).

3.3 PENARTH GROUP (618.29 to 635.08m depth)

The Penarth Group (formerly the 'Rhaetic'), comprises the Westbury Formation and the succeeding Lilstock Formation, the latter divided into lower (Cotham) and upper (Langport) members (Warrington et al. 1980). In earlier accounts (e.g. Green and Melville, 1956) the Langport Member was, as the 'White Lias', treated as the lowest unit in the Lias succession, and considered to be of Jurassic age. The Penarth Group is now known to be latest Triassic (Rhaetian) in its entirety (Cope et al. 1980; Warrington et al. 1980).

The group is 16.79m thick in the Stowell Park Borehole; similar thicknesses (in the range c. 12 to c. 20m) were proved elsewhere in the region, and the formation seems little affected by the Vale of Moreton Axis, although eastwards it pinches out towards an inferred shoreline on the London Platform in the Oxford - Bicester area. There is a mild disconformity at the base (often marked by the 'Rhaetic Bone Bed').

The **Westbury Formation** (629.56 to 635.08m depth) is 5.52m thick. At the base, a thin (25mm) bed of brownish grey, argillaceous sandstone, with rolled bones and teeth, rests on a slightly uneven and probably eroded surface of the Blue Anchor Formation. There is no sign of transition beds comparable to the Grey Marls of Somerset, despite the location of Stowell Park in the deepest part of the Worcester Basin. The overlying beds comprise 2.08m of black pyritous mudstone, with sporadic pale grey sandy partings, which pass upwards into 3.40m of black, finely laminated, pyritous shales with sandy partings throughout and some grey-green calcareous mudstone interbeds in the upper 0.76m, which herald the transition to the succeeding Cotham Member of the Lilstock Formation.

The macrofauna is dominated by a few taxa of bivalves, notably *Eotrapezium* (*E. germari* (Dunker) and *E. concentricum* (Moore)), *Protocardia rhaetica* (Merian) and *Rhaetavicula contorta* (Portlock), with sporadic *Cercomya praecursor* (Quenstedt), *Chlamys valoniensis* (Defrance), *Modiolus hillanoides* (Chapuis & Dewalque), '*Modiolus*' *sodburienensis* Reynolds & Vaughan, and rare *Lyriomyophoria postera* (Quenstedt) and *Tutcheria cloacina* (Quenstedt). Gastropods, including *Actaeonina ovalis* (Moore) and traces of '*Natica*' sp., and ophiuroid fragments also occur, and a specimen of the small fish *Pholidophorus higginsii* Egerton (more commonly reported from the Cotham Member), was found near the top of the formation.

The **Cotham Member** (623.75 to 629.56m depth) comprises 5.81m of greenish-grey, finely laminated calcareous mudstone with streaks and laminae of white to pale grey ripple-bedded sandstone. At the top, 0.18m of dark grey silty mudstone was included in the 'White Lias' (Langport Member) by Green and Melville (1956). Bivalves (*Chlamys*, *Eotrapezium*, *Gervillia*, *Protocardia*) occur in the basal part of the member, but different taxa are found in the darker mudstones at the top, where *Meleagrinella fallax* (Pflücker), *Modiolus langportensis* (Richardson & Tutcher) and fish fragments are common. A single conchostracan crustacean (*Euestheria minuta* (Alberti in Zieten)) was found at 626.46m. This fauna contrasts with that in the Upton Borehole, where bivalves are rare, but ostracods and conchostracans relatively common, suggesting reduced salinity and

perhaps an environment adjacent to land.

The **Langport Member** (618.29 to 623.75m depth) comprises 5.46m of hard, pale grey, massive recrystallized limestone with dark grey mudstone and silty shale interbeds in the basal 0.23m; pyrite occurs at the base and stylolites and irregular bands and patches of black clayey material are common in the higher beds. A 1.09m-thick unit in the middle of the member has a brecciated appearance. The member yielded a few macrofossils including *Atreta [Dimyopsis] intusstriata* (Emmrich), *Modiolus hillanoides* (Chapuis & Dewalque) and fish fragments.

4 CONCEALED ROCKS: LIAS GROUP (122.28m to 618.29m)

In the Stowell Park Borehole, the Lias Group was penetrated between 122.28m and 618.29m, a total thickness of 496.01m. This figure is slightly less than that quoted by Green and Melville (1956), due to a revision of both the upper and lower boundaries. The following stratigraphical account is based principally on the lithological log of Green and Melville (1956). The stratigraphical palaeontology of the borehole, based on a collection of nearly 5000 specimens held in the BGS collections, is described by Spath (1956) and Melville (1956) and summarised by Green and Melville (1956). In the following account, Spath's ammonite nomenclature has been reinterpreted, and the biozonation updated by Ivimey-Cook (1993). The Zones and Subzones are in most cases defined by first appearances of certain ammonite taxa, and the depths quoted refer to individual specimens in the BGS collection. Non-ammonite taxa are listed by Melville (1956).

4.1 LOWER LIAS (276.51m to 618.29m)

The Lower Lias was proved between the base of the Dyrham Siltstone Formation at 276.51m and the top of the Penarth Group at 618.29m. The total thickness, therefore, is 341.78m. This figure is somewhat less than the thickness of 366.67m (1203ft) quoted by Green and Melville (1956), as their Lower Lias also included the Langport Member ('White Lias') of the Penarth Group at the base, and the lower part of the beds now assigned to the Dyrham Siltstone Formation at the top: the top of their Lower Lias was defined by the base of the *Amaltheus margaritatus* Zone.

The Lower Lias is dominated by dark grey, more or less calcareous mudstones, within which a number of separate divisions can be recognised, as summarised by Green and Melville (1956, p. 21). It is a basinal sequence, and the sediments contain principally nektonic faunas with some benthic bivalves.

Basal Mudstones 597.28 to 618.29m

The basal 21.01m of the Lower Lias (597.28 to 618.29m depth) comprises very dark grey to black, finely-laminated, somewhat pyritous mudstone ('paper shales'), yielding scattered bivalves such as *Astarte*, *Cardinia*, *Lucina*, *Modiolus*, *Plagiostoma*, *Parallelodon* and *Pteromya*, the latter common only in the lowest two metres. Following Cope et al (1980), the base of the Jurassic System (and of the Hettangian Stage and the

Zone and Subzone of *Psiloceras planorbis*) is taken at the first record of the ammonite *Psiloceras*, at 617.51m. The underlying 0.78m of Lias mudstone, down to the top of the Langport Member is thus of latest Triassic (Rhaetian) age. These 'Pre-Planorbis Beds' are somewhat thinner than in adjoining areas to the west (where they are typically of the order of 3m thick), which may indicate some thinning of the succession towards the eastern margin of the Worcester Basin.

Above, the greater part of the mudstones belong to the *P. planorbis* Zone (606.00 to 617.51m). The *P. planorbis* Subzone is indicated by common, but rather small, *Psiloceras* sp.. The succeeding *Caloceras johnstoni* Subzone is poorly substantiated, with *Caloceras* cf. *johnstoni* (J. de C. Sowerby) being recovered only from 606.09m. Above 606.00m, the mudstones are assigned to the *Alsatites liasicus* Zone from the presence of *Waehneroceras*, which occur sparsely. These strata probably belong entirely to the *Waehneroceras portlocki* Subzone, although this is poorly proved: none of the *Waehneroceras* can be identified to species level, and the only other ammonite taxon found was *Alsatites*, which ranges throughout the *A. liasicus* Zone.

Blue Lias 560.48 to 597.28m

Above the basal mudstones, 36.80m of strata (between 560.48 and 597.28m depth) comprise grey calcareous to black, shaly mudstones, with interbeds of grey, fine-grained somewhat argillaceous limestone ('cementstone'). This facies of interbedded mudstones and limestones, traditionally termed 'Blue Lias', is widespread in this part of the Lower Lias throughout England and Wales. The limestones, about 31 in number, range from 0.05 to 0.53m in thickness and are typically about 0.18m thick. They make up some 14 per cent of the thickness of this succession. The Blue Lias of Stowell Park ranges from the upper part of the *A. liasicus* Zone to the lower part of the *Arietites bucklandi* Zone, and as such corresponds with the middle part only of the Blue Lias of other areas such as the Dorset coast, Bristol Channel and Warwickshire, where limestones make up a greater proportion of the sequence (between 20 and 40 per cent). This reflects the more basinal situation of Stowell Park, and a relatively expanded succession, with a correspondingly weak development of limestone.

Below 586.58m depth, the strata are assigned to the *A. liasicus* Zone; most of this interval belongs to the *Laqueoceras laqueus* Subzone, proved above 594.39m depth. The range of *Schlotheimia* (s.s.) up to the appearance of arietitid ammonites indicates the succeeding *Schlotheimia angulata* Zone (570.92 to 586.58m). A specimen of *Schlotheimia* cf. *complanata* (von Koenen) at 575.76m, indicates the *S. complanata* Subzone; by default, the underlying beds, forming the greater part of the Zone, are assigned to the *S. extranodosa* Subzone. The topmost part of the Blue Lias, above 570.92m depth, falls within the *Arietites bucklandi* Zone. Specimens of *Vermiceras* indicate the *Coroniceras conybeari* Subzone, and *Coroniceras* cf. *rotiforme* at 561.12m marks the base of the succeeding *C. rotiforme* Subzone.

The non-ammonite macrofauna of the Blue Lias includes brachiopods (*Lingula*, *Calcirhynchia*) and bivalves such as *Gryphaea*, *Liostrea*, *Lucina*, *Modiolus*, *Placunopsis*, *Plagiostoma* and *Pseudolimea*.

Beds above the Blue Lias 276.51m to 560.48m

The upper 283.97m of the Lower Lias is dominated by mudstone, with certain units recognisable from both the lithological and geophysical (gamma ray) logs. These include the '70', '85' and '100 geophysical marker 'members' first described by Horton and Poole (1977) in the Chipping Norton district, which form notable leftward (low count) peaks on the gamma ray log (Green and Melville, 1956, plate 1). These markers can be related to more calcareous units in the cores, despite minor depth discrepancies which presumably result largely from inaccuracies in the depth marking of the cores. As well as an extensive and varied ammonite fauna, these beds contain a variety of gastropods (e.g. *Ataphrus*, *Coelostylina*, *Coelodiscus*, *Procerithium*, *Solariella* and *Trochoturbella*), bivalves (e.g. *Anningella*, *Antiquilima*, *Arcomya*, *Astarte*, *Bakevella*, *Camptonectes*, *Chlamys*, *Gervillia*, *Grammatodon*, *Gryphaea*, *Hippopodium*, *Lucina*, *Mactromya*, *Meleagrinella*, *Modiolus*, *Oxytoma*, *Palaeoneilo*, *Palaeonucula*, *Parallelodon*, *Pholadomya*, *Pleuromya*, *Plagiostoma*, *Protocardia*, *Pseudolimea*, *Pseudopecten*, *Ryderia*, *Semuridia* and *Tutcheria*) sparse brachiopods (e.g. *Cincta*, *Discinisca*, *Lobothyris*, *Spiriferina*, *Rimirhynchia*, *Tropiorhynchia*), and sporadic echinoids and crinoids. Occasional belemnites also occur, the oldest was found in the *Asteroceras obtusum* Zone.

Below c. 491.64m, the strata comprise dark grey and black calcareous mudstone, commonly indurated, with occasional limestone nodules and beds. These beds belong to the *Arietites bucklandi* Zone (*Coroniceras rotiforme* Subzone) and *Arnioceras semicostatum* Zone, the base of the latter Zone being defined by the appearance of *Arnioceras* at 532.62m depth. The *Coroniceras lyra* Subzone extends from 532.62m up to the first probable *Agassicerias* at 527.67m, which marks the base of the succeeding *Agassicerias scipionianum* Subzone. Above, the base of the *Euagassicerias resupinatum* Subzone is defined by the first appearance of the index taxon at 512.52m. As well as a varied ammonite fauna, these beds contain sparse rhynchonellids and gastropods and bivalves such as *Astarte*, *Lucina*, *Modiolus*, *Oxytoma*, *Palaeonucula*, *Pinna*, *Placunopsis*, *Plagiostoma*, and *Pleuromya*.

Overlying beds, between 491.64m and the base of the 85 Marker at 335.43m depth comprises grey mudstones, more shaly in the lower part, with rare limestone nodules and beds. These strata range in age from the latest *A. semicostatum* Zone, to the early *Tragophylloceras ibex* Zone.

The base of the *Caenisites turneri* Zone is inferred from the appearance of *Microderoceras* at 488.15m. In the absence of *Caenisites*, the *Caenisites brooki* Subzone in the basal part of the *C. turneri* Zone is not recognised. Spath (1956, p.152) concluded that this Subzone was absent due to a non-sequence (at 488.29m), but there is no indication of such a break from the lithological log. *Microderoceras birchi*, which occurs above 487.22m, indicates the younger *M. birchi* Subzone.

The base of the *Asteroceras obtusum* Zone is marked by the appearance of *A. obtusum*

at 471.80m, and the *A. obtusum* Subzone is taken as the range of the index taxon (461.52 to 471.80m). The overlying *Asteroceras stellare* Subzone is less well defined as the index species was not recorded by Spath (1956), but is taken up to the appearance of *Eparietites* at 445.14m, which marks the base of the *Eparietites denotatus* Subzone.

The *Oxynoticeras oxynotum* Zone is taken from the appearance of *Oxynoticeras* at 444.32m, up to the first definite *Cruciloboceras* at 439.52m. Regionally, the Zone is regressive (Donovan et al., 1979), but the basinal sequence of dark grey mudstones at Stowell Park shows that this was a continuing area of deposition at this time. The Zone is, however, thin; this may be due to a non-sequence at the base of the succeeding *Echioceras raricostatum* Zone, as in the Upton Borehole (Worssam, 1963; Sumblar, 1994b) although there is no indication of this from Green and Melville's (1956) log. The *E. raricostatum* Zone is defined from the earliest *Cruciloboceras* sp., at 439.52, up to the appearance of *Phricodoceras* at 389.70m, giving a thickness of 49.82m, in which all the four subzones of the zone can be identified.

The *Uptonia jamesoni* Zone extends upwards from the first record of *Phricodoceras* at 389.70m, and all three subzones can be recognised. The oldest is the Subzone of *Phricodoceras taylori* which encompasses the range of *Phricodoceras* up to 382.52m. Above, the 70 Marker forms a prominent leftward peak on the gamma-ray log (373 to 381m depth); this appears to correspond with an interval of 'grey and slightly bluish grey indurated mudstone' with some interburrowed beds ('fucoid beds' of Green and Melville, 1956), recorded between 372.87 to 379.17m. As such, the '70 Marker' lies within the upper part of the combined Subzones of *Polymorphites polymorphus* and *Platypleuroceras brevispina* (382.52 to 376.48m), and the lower part of the *Uptonia jamesoni* Subzone (372.77 to 376.48m).

The base of the *Tragophylloceras ibex* Zone is taken at 372.77m, at the appearance of the genus *Tropidoceras*. The Zone is divisible into three subzones. The basal beds are assigned to the *Tropidoceras masseanum* Subzone, although the subzonal index species was not identified. The appearance of *Acanthopleuroceras maugenesti* (d'Orbigny) at 369.58m marks the base of the *Acanthopleuroceras valdani* Subzone, which extends up to 333.24m. In the uppermost part of this subzone the 85 Marker is notable on the gamma ray log (333 to 341m depth). In the cores, this would appear to correspond with calcareous, often highly fossiliferous mudstones, with some indurated bands, and some calcareous nodules.

Above the 85 Marker, the strata consist of grey calcareous mudstones, with scattered sideritic ('clay ironstone') nodules. The greater part belongs to the *Beaniceras luridum* Subzone of the *T. ibex* Zone, which comprises beds containing *Beaniceras* between the last occurrence of *Acanthopleuroceras* (at 333.24) and the base of the *Prodactylioceras davoei* Zone (and *Androgynoceras maculatum* Subzone) at 292.00m at the first appearance of *Androgynoceras*. At approximately the junction of the two zones, the 100 Marker (289 to 297m depth) corresponds with an interval of mudstones with laminae of sand and silt, and with common sideritic nodules. Overlying mudstones are somewhat silty. The top of the Lower Lias is drawn at the base of the Dyrham Siltstone Formation, taken at 276.50m depth, about 13m above the 100 Marker.

4.2 DYRHAM SILTSTONE FORMATION 222.28m to 276.51m depth

The Dyrham Siltstone Formation, 54.23m thick, comprises the unit of sands and silts between the mudstones of the Lower Lias and the Marlstone Rock Formation. In essence it corresponds with the Middle Lias (excluding Marlstone) of previous accounts such as that of Green and Melville (1956), although the base of their Middle Lias was defined at the base of the *Amaltheus margaritatus* Zone (of Melville, 1956), rather than at the base of the lithostratigraphical unit of sands and silts.

The base of the Dyrham Siltstone is drawn at 276.51m (907ft 2in) depth, which corresponds with a general increase in the arenaceous content of the sediments. This change is a well-marked horizon from the core specimens and the lithological log of Green and Melville (1956). On the gamma ray log, it is indicated by a significant leftward swing in the gamma-ray response log, which is traceable in other boreholes in the region.

The lower c. 24m of the formation comprise dark grey very finely sandy or silty mudstones with wisps and laminae of pale grey fine grained sand, and with rare sideritic nodules. Above 252.45m depth, the strata are dominated by grey and greenish grey very fine- to fine-grained, often cross-laminated sand. Conglomeratic horizons noted at c. 247m, 241.30m and 225.17m depth may give an indication of cyclicity. At 227.00m, 1.83m of dark green muddy sand with abundant fine grained berthierine ooids (the 'oolitic ironstone' of Green and Melville, 1956) is overlain (at 225.17m) by finely sandy mudstone with scattered berthierine ooids, conglomeratic at the base.

The fauna of the Dyrham Siltstone is dominated by bivalves (such as *Goniomya*, *Grammatodon*, *Mactromya*, *Modiolus*, *Parallelodon*, *Pinna*, *Pleuromya*, *Protocardia* and *Pseudolimea*) and ammonites, often preserved uncrushed in the sandy beds.

Aegoceras capricornus from c. 275m in the basal sand bed of the Dyrham Siltstone indicates that the lower part of the formation belongs to *A. capricornus* Subzone of the *P. davoei* Zone, and *Oistoceras* at 267.37 and above indicate the succeeding *Oistoceras figulinum* Subzone. The appearance of *Amaltheus* at 256.06m marks the base of the *Amaltheus margaritatus* Zone i.e. of the Upper Pliensbachian 'Middle Lias'. Green and Melville (1956), following Spath (1956), however, drew the base at the lower level of 257.25, immediately above the last *Oistoceras*. The *A. margaritatus* Zone is divided into three subzones named after the dominant species of *Amaltheus* in each. The *A. stokesi* Subzone is proved below 242.95, and higher beds yield a small number of poorly preserved *Amaltheus* cf. *subnodosus* (Young & Bird) up to 226.16m. No ammonites were recovered from the overlying 3.88m of the topmost Dyrham Siltstone, and so there is no evidence for the presence of the *Amaltheus gibbosus* Subzone, which is either thin or absent below the non-sequence inferred at the base of the Marlstone Rock Formation at 222.27m. The subzone is thinly developed elsewhere in Gloucestershire, e.g. at Nottingham Hill [SO 98 29] and Stanley Hill [SP 010 298] (Simms, 1990).

4.3 MARLSTONE ROCK FORMATION (220.50m to 222.28m)

The Marlstone Rock Formation, 1.78m thick, is a pale grey and slightly brownish grey, hard, compact, medium-grained shell fragment and ooid wackestone to packstone, with some darker, rather argillaceous layers. The ooids are internally structureless, and are composed of a soft, whitish mineral, probably kaolinite, a diagenetic replacement of berthierine. The brownish tinge of the rock suggests that a small proportion of iron is present, but the formation is markedly less ferruginous than is usual at outcrop in adjoining areas. At some levels the Marlstone Rock contains abundant brachiopods including *Gibbirhynchia micra* Ager, *Rudirhynchia* and *Tetrarhynchia* in addition to a small fauna of bivalves and some belemnites. These give little information of age, but the Marlstone Rock is assumed to belong to the *Pleuroceras spinatum* Zone as in adjoining areas.

4.4 UPPER LIAS (122.28m to 220.50m)

The Upper Lias does not crop out in the Chedworth area, but it was proved in the Stowell Park Borehole, where it is dominated by dark grey mudstones. The thickness, 98.22m, is slightly less than that given by Green and Melville (1956) as, at the top, they included sands now regarded as the lower part of the Leckhampton Member (Inferior Oolite Group; see below). The revised classification preferred here takes the base at 122.28m, at the base of these sands. The uppermost beds of the Upper Lias (i.e. below 122.28m) are silty, moderately fissile mudstones, and no Cotteswold Sand is present. In the following account, the ammonite zonation is based on a re-examination of the ammonites by Dr M. K. Howarth (summarised in Cope et al, 1980).

The basal beds are dark calcareous shales, which rest, sharply, and probably non-sequentially, on the Marlstone. Below 219.42m depth, the beds are attributed to the *Dactylioceras tenuicostatum* Zone. They contain *Tiltoniceras antiquum* (Wright) and *Dactylioceras* cf. *semicelatum* at 219.84m, indicating the *D. semicelatum* Subzone. The earlier subzones of the *D. tenuicostatum* Zone are probably absent, but could conceivably be represented in the uppermost part of the Marlstone. As well as ammonites, these beds include small brachiopods such as *Nannirhynchia* cf. *pygmaea* (Morris) and *Gibbirhynchia* cf. *tiltonensis* Ager. The overlying 11.62m of strata (below 207.79m) belong to the *Harpoceras falciferum* Zone. The lower part includes dark grey and brown paper shales with fish debris, and abundant ammonites. The earliest ammonite (at 219.42m) is referred to *Cleviceras exaratum*, which characterises the middle part of the *C. exaratum* Subzone; older beds, normally characterized by *Eleganticeras elegantulum* (Young & Bird) were not proved. Other macrofossils present, much scarcer than the ammonites, include gastropods (small *Coelodiscus*, *Dicroloma* and *Procerithium*) and bivalves such as *Grammatodon*, *Lucina*, *Parallelodon* (*Catella*) and *Pseudomytiloides*. The Subzone of *Harpoceras falciferum*, containing abundant *Harpoceras falciferum* (J. Sowerby) is proved above 214.42m. Only a very sparse bivalve fauna is present with *Grammatodon*, *Meleagrinella*, *Pseudomytiloides* and *Propeamussium*.

The base of the succeeding *Hildoceras bifrons* Zone has been taken at 207.79m where a

Pseudolioceras, generally indicative of the *bifrons* and later zones occurs. A conglomeratic bed, presumably marking a minor non-sequence, is noted at this level by Green and Melville (1956). The *Dactylioceras commune* Subzone is poorly proved as the nominal species was not identified, but the succeeding *Peronoceras fibulatum* Subzone is recognised above the earliest *Peronoceras* at 180.42m. Bivalves are fairly sparse in these beds, though *Dacromya*, *Lucina*, *Palaeoneilo* and *Propeamussium* are recorded. The base of the *Catacoeloceras crassum* Subzone is taken at 173.73m. These beds contain a diverse fauna; as well as ammonites, bivalves such as *Myophorella*, gastropods and crustaceans occur. A nodular bed with berthierine ooids occurs at 157.28m; above, the mudstones become somewhat silty and very finely sandy. The youngest *Hildoceras* at 130.65m depth, is taken as the upper limit of the the *C. crassum* Subzone and of the *H. bifrons* Zone.

In the overlying beds, comprising dark, somewhat pyritous mudstones with some silty wisps, only one further ammonite was recovered; a *Hammatoceras?* from 122.37m, immediately below the top of the formation as classified here. This ammonite suggests a broadly post-*Haugia variabilis* Zone age, but Spath (1956) considered the specimen to be from the latest Toarcian *Dumortieria levesquei* Zone; the genus is very common in the basal (*dispansum*) subzone of that Zone. *Hammatoceras* was also found in Cotteswold Sand facies in the Harnhill Borehole [0683 0007], 12km south of Stowell Park (Sumbler, 1995a), and Richardson (1930) recorded *Haugia*, indicating the *H. variabilis* Zone, within 4m of the top of the Cotteswold Sand at Leckhampton Hill, Cheltenham. These facts would suggest that the absence of the Cotteswold Sand at Stowell Park is due to their lateral passage into mudstone facies.

5 MIDDLE JURASSIC: INFERIOR OOLITE GROUP

The Inferior Oolite Group of the north Cotswolds is traditionally divided into three parts; Lower, Middle and Upper Inferior Oolite (Arkell, 1933). These units are now known respectively as the Birdlip Limestone, Aston Limestone and Salperton Limestone Formations.

5.1 BIRDLIP LIMESTONE FORMATION

Four of the component members of the Birdlip Formation have been differentiated in the Stowell Park Borehole (Appendix 2) where they total 55.8m in thickness. In addition, a fifth, very thin and uppermost member is present at an exposure in the west of the area. However, it has not been possible to separate these members on the face of the map due to vegetation cover and lack of exposure. The base of the formation does not crop out, and the estimated thickness range of 30 to 60m is very approximate.

The Birdlip Formation crops out along the lower slopes of the Coln valley between the north-west corner of the sheet and Raybrook Farm [076 121], where it is truncated by the Stowell Park Fault. No evidence was seen on the outcrop of the Leckhampton or Crickley members (see below), which are inferred to be below the level of the valley bottom. Therefore, only the Cleeve Cloud, Scottsquar Hill and Harford members appear

at outcrop.

The **Leckhampton Member** is not present at outcrop, but information from adjoining areas suggests a thickness range of about 3 to 10m. In the Stowell Park Borehole the member is 9.83m thick. This is somewhat more than quoted by Green and Melville (1956) who drew the base (of the 'Scisum Beds') at 118.62m (389ft 2in) depth, at an arbitrary level (1956, p.16) within a continuous run of fairly uniform sand, the lower part of which they included in the Upper Lias (Cotteswold Sand; see above). The revised classification preferred here takes the base of the Leckhampton Member at the base of these sands (122.28m (401ft 2in)), a level which may correspond with the considerable non-sequence to be expected at this horizon; the underlying beds are mudstones. This classification is consistent with the limited macropalaeontological evidence: *Leioceras* sp. (*opalinum* Zone) at 117.60 and *Hammatoceras?* (late Toarcian) at 122.35m. Additional confirmation that this revised classification is valid is provided by the presence of the pollen *Callialasporites* (Middle Jurassic) and of the dinoflagellate cyst *Nannoceratopsis dictyambonis* Riding 1984 (typically Aalenian to Bajocian) in samples from 119.99 and 122.07m depth (i.e. in the Cotteswold Sand of Green and Melville, 1956). These forms are absent in a sample from the underlying mudstones at 122.68m (Riding, 1994).

The **Crickley Member** of the Birdlip Formation is approximately equivalent to the 'Pea Grit Series', i.e. the Lower Limestone plus the Pea Grit of authors (see Arkell, 1933). It is not thought to reach outcrop in this area, and the estimated thickness range of 2 to 7m allows for thicknesses in adjoining areas. In the Stowell Park Borehole, the member comprises 6.94m of shell-detrital, sandy, pisoidal and ooidal limestone (Green and Melville, 1956) between 105.51m and 112.45m.

The **Cleeve Cloud Member** corresponds with the Lower Freestone of previous accounts. It is estimated to range from 15 to 40m in thickness, and accounts for much of the area of the Birdlip Formation outcrop. It is dominated by off-white to cream, well-bedded, well-sorted medium-grained ooid grainstone, with fine- to coarse-grained shell debris in places. Many of the ooids are cored by fine sand grains. At outcrop, the strata produce a brown loamy soil, with abundant small angular fragments of white oolite and loose ooids. The member is exposed in a large disused quarry at Locality J [0590 1377].

In the Stowell Park Borehole, the Cleeve Cloud Member is represented by the interval between 74.68m and 105.51m depth, giving a thickness of 30.83m. Green and Melville (1956) also included overlying beds (up to 71.12m (233ft 4in)) in their 'Lower Freestone', but these beds are lithologically distinct, and are included in the Scottsquar Hill Member of this account (see below). The beds assigned to the Cleeve Cloud Member are dominated by medium-grained, very well sorted grainstones, containing ooids typically with pale 'chalky' coatings over a darker, brownish core. This lithology is closely similar to the 'Yellow Stone' (Richardson, 1933) of the Bourton Hill and Farmington areas (Sumbler, 1995b, c). Between c. 94 and 102m, the limestones are sandy and slightly argillaceous, and commonly contain a proportion of carbonaceous debris, including some large plant fragments.

The **Scottsquar Hill Member** corresponds with the Upper Freestone and Oolite Marl of

previous accounts; the work of Mudge (1978), and Baker (1981), together with the present mapping, shows that the latter are best regarded as two contrasting facies within one lithostratigraphical unit, and Mudge's nomenclature (abridged from Scottsquar Hill Limestone Member) is accepted here.

The member crops out along the slopes of the Coln valley below the Aston Limestone Formation, and from field evidence (brash and topographic features) is estimated to be between 7 and 10m thick. It comprises pale grey and brown peloidal limestones, lime mudstones and 'marls'. These are shelly in parts, and at the surface the soft, pale, fine-grained weathered material, with loose brachiopods and bivalves, is commonly seen in the soil, and is preferentially burrowed into by rabbits, foxes and badgers. This can be observed in the woods around the Roman villa [053 134, 054 136], and pale marl with the brachiopods *Aulacothyris carinata*, *Globirhynchia?* and *Charltonithyris microtrypa* was seen south of Yanworth [0803 1325].

The uppermost 0.8m of the member is exposed in the Tumulus Cutting [0500 1404] (Locality A; Bed 1), where it comprises hard pale orangish brown peloidal grainstone, and is overlain by the Harford Member. Woodward (1894, p.127) asserts that the 'Upper Freestone' is exposed in his Cutting L to the south-west of the Roman villa (i.e. Locality D [0523 1320]), but this is now inferred to be the Notgrove Member of the Aston Limestone Formation (see below).

In the Stowell Park Borehole, the Scottsquar Hill Member (66.45m to 74.68m depth) is dominated by poorly sorted peloidal packstones to grainstones of 'Upper Freestone' facies, but also contains grey 'marls' of 'Oolite Marl' type between 69.42m and 71.12m depth. Green and Melville (1956) classified the beds below the 'Oolite Marl' with the Lower Freestone (i.e. Cleeve Cloud Member of this account) they are closely similar to those overlying the 'Oolite Marl', and so are included in the Scottsquar Hill Member.

The **Harford Member** is equivalent to the Harford Sands Member as defined by Mudge (1978), and incorporates the Harford Sands, Snowhill Clay and Tilestone of previous accounts (see Buckman 1895, 1897; Richardson, 1929). It is thought to be present only in the western part of this area, where it may be up to 0.3m thick. It is exposed in the Tumulus Cutting [0500 1404] (Locality A; Beds 2 to 4) where it comprises 0.22m of grey and brown shell-detrital sandy clay. This locality has been the subject of some controversy over the precise identity of the unit exposed (Richardson, 1933, p. 27-28), which is overcome by the portmanteau definition of the Harford Member.

Richardson (1933) infers the absence of the 'Snowhill Clay' (Harford Member) from Cutting L of Woodward (1894, p. 127) to the south (i.e. Locality D) due to Woodward's misidentification of the units present there. In fact it is very probably present in this area; a clay bed (presumably the Harford Member) is inferred from the presence of a perennial spring feeding the baths at the nearby Roman villa (see Water Supply).

5.2 ASTON LIMESTONE FORMATION

The Aston Limestone Formation is equivalent to the Middle Inferior Oolite of previous authors. It is present throughout the Chedworth area between the Birdlip and Salperton

formations, its thickness range of 3 to 15m being the result of differential erosion prior to the deposition of the latter (the 'Bajocian Denudation' of Buckman, 1895, p. 390). In this area, the Aston Limestone Formation comprises three members; in ascending order the Lower Trigonina Grit, Gryphite Grit (including Buckmani Grit) and Notgrove members, but it has not been possible to differentiate them on the face of the map. All three are exposed in the Chedworth Wood railway cuttings (Appendix 1; Localities A and D), where they were originally described by Buckman (1890, 1895) and Woodward (1894, pp 125-129).

The Lower Trigonina Grit Member is exposed in the Chedworth Wood Tumulus Cutting [0507 1392 to 0500 1404] (Locality A (Beds 5 to 9); = Woodward's cutting K (1894, pp 126-129)). It comprises some 1.8m of thinly, unevenly bedded grey and brown shelly peloidal wackestone, packstone and grainstone. The peloids are subrounded, fine- to medium-grained and ferruginous, giving the rock a characteristic orange-brown speckled appearance. The fauna is dominated by bivalves, but the distinctive colonial serpulid worm *Sarcinella*, commonly seen in the member elsewhere, was not observed. Some beds show signs of burrowing. Thin lenticular seams of clayey sand occur in the middle and at the top of the member; the former is the 'Meriani Bed' of Buckman (1895).

Away from the cuttings, the Lower Trigonina Grit is exposed in a small disused pit in Chedworth Woods [0684 1336] (Locality K), where it is also 1.8m thick, although the top and base are not exposed. Debris of rubbly shelly limestone with strands of *Sarcinella*, attributed to the member, was found in several places on or near the outcrop [e.g. 0531 1487, 0505 1443, 0549 1409, 0672 1342, 0700 1365, 0801 1327, 0774 1231], implying its presence through most of the area, although its absence may be inferred in places. In the Stowell Park Borehole (Appendix 2), the member comprises some 1.15m of ?bioturbated, shelly, sandy, ironshot ooidal limestone.

The **Gryphite Grit Member** includes both the Buckmani Grit and Gryphite Grit of Buckman (1895) as it has proved near impossible to distinguish them in the field during the present survey despite Buckman's claim, supported by Richardson (1933, p. 17), that the former is sandy and rich in terebratulid brachiopods, and the fauna of the latter is characterised by abundant *Gryphaea* and little else.

The Gryphite Grit Member is exposed in the Tumulus Cutting (Locality A; Beds 10 to 15), where it is best seen in the west face at the northern end [0500 1404] overlying the Lower Trigonina Grit Member. Further south, on the east face [0505 1395], the contact with the overlying Notgrove Member is well exposed. There, the Gryphite Grit comprises between 3.6 and 4.0m of rubbly bedded, grey and brown, variously shelly, shell-fragmental, sandy peloidal limestones. Burrowing and *Gryphaea* are common in the higher beds (Bed 15), the colonial worm tube *Sarcinella* was seen in the lower beds (Beds 12 and 14). Near the base, two clay beds and an intervening limestone (Beds 11 to 13) form a conspicuous notch.

Away from the cuttings, the Gryphite Grit Member is thought to be present throughout the Aston Limestone Formation's outcrop as its rubbly brash was seen in the soil at a number of places [e.g. 0551 1303, 0696 1368, 0593 1424]. Specimens of the bivalve *Pleuromya* and brachiopod *Stiphrothyris?* found in Chedworth Woods [0688 1330] are

probably from the member.

In the Stowell Park Borehole, the Gryphite Grit Member (including Buckmani Grit) is 3.17m thick. The boundary between the Gryphite and Buckmani grits is gradational; the depth of 64.77m is based principally on the presence of the lowest *Gryphaea* (specimen number Bj744) at this depth) and the highest *Lobothyris buckmani* (Bj755) just below, at 64.87m depth. The top of the Gryphite Grit is taken at 62.13m, above a specimen (Bj640) of typical Gryphite Grit lithology showing annelid and bivalve borings, overlain by Upper Trigonina Grit lithologies. This horizon is somewhat higher than that chosen by Green and Melville (1956), who drew the top of the Gryphite Grit at 62.79m depth, based on the presence of abundant *Gryphaea* below.

The **Notgrove Member** is equivalent to the Notgrove Freestone of Buckman (1887), and is the highest member of the Aston Limestone Formation present in the Chedworth area. It is well exposed in the Chedworth Woods railway cuttings (Localities A and D), where it is at least 8.65m thick, and is non-sequentially overlain by the Salperton Formation, implying erosion of the uppermost part of the member. Therefore, a maximum thickness of at least 9m is deduced. Nevertheless, this is the greatest thickness definitely proved in the Cirencester district, although the member may be a little thicker (10m) thick in the Andoversford area (SP 01 NW).

In the Tumulus Cutting, east face [0505 1395] (Locality A), the Notgrove Member comprises 7.65m of light brownish grey, medium bedded and cross bedded, poorly sorted, medium- to coarse-grained peloidal and ooidal grainstone (Bed 17), on 1.0m of shelly, medium-grained peloidal and ooidal wackestone (Bed 16). About 0.3m of obscured strata below may be part of the member. At this point, the top of the member is not seen, but Buckman's (1895) estimate of 30 feet (9.1 m) is well within reasonable limits.

At Locality D [0523 1320], the uppermost 0.55m of the Notgrove Member is exposed overlain by the Upper Trigonina Grit; it is extremely hard, riddled with fine borings to a depth of about 10 cm, and its upper surface is encrusted with oysters. Nearby [0521 1326], the uppermost 1.90m of the member are exposed just to the south of the path from the Roman villa. Here too, the top of the member is developed as a bored and oyster-encrusted hardground, indicating early cementation of the seabed.

Elsewhere on the Aston Limestone Formation outcrop, Notgrove Member material, including bored pieces, were seen in Compton Wood [0593 1424], west of Yanworth [0693 1374 and 0714 1348] and as far east and south as Church Farm [0810 1380], Stowell Mill [0802 1290] and Raybrook Farm [0777 1239]. However, no evidence of the member was seen on the eastern valley side opposite Church Farm, and it is absent from the Stowell Park Borehole (Appendix 2). Thus, the member thins to zero eastwards and southwards due to erosion prior to hardground formation (Buckman's 'Bajocian Denudation', 1895, p. 390), and is overstepped by the Salperton Formation .

5.3 SALPERTON LIMESTONE FORMATION

The Salperton Limestone Formation (= Upper Inferior Oolite) is subdivided into the

Upper Trigonía Grit Member, overlain by the Clypeus Grit Member. Its thickness range (10 to 15 m) in the Chedworth area is fairly typical for the north Cotswolds in general. The formation crops out along the middle slopes of the Coln valley and the lower slopes of the Chedworth valley but in many places its outcrop is obscured by landslipped Fuller's Earth material (see Engineering Hazards). The formation is well exposed in the Chedworth Woods railway cuttings (Localities B to E).

In the Stowell Park Borehole, evidence of misplacement of cores of the basal Clypeus Grit and Upper Trigonía Grit was discovered from a comparison of the borehole gamma ray log, and radioactivity measurements on the core specimens (Ponsford in Green and Melville, 1956, p. 63). After inversion of the suspect run of cores (58.83m (193ft) to 61.87m (203 ft)), Green and Melville corrected the depths on their published lithological log. Re-examination of the registered core specimens shows that, unfortunately, this revision took place after collection and numbering of the specimens, as the depths recorded for the specimens do not accord with the published lithological log; specimens representing 1.73m of Clypeus Grit (Bj551-609) occur within the run of specimens of Upper Trigonía Grit (Bj516-550 and Bj610-639). The top of the Upper Trigonía Grit is marked by an oyster-encrusted surface (Specimens Bj516 and 517), marked 193ft 0in. The corrected depth is 60.55m (198 ft 8in), as stated by Green and Melville (1956). The base of the Upper Trigonía Grit is taken at 62.13m depth (see above) giving a total thickness of 1.58m. The Clypeus Grit is represented by specimens Bj395-515 and Bj551-609, which, after correction (see above) corresponds with depths of 49.02 to 60.55m, giving a thickness of 11.53m.

The **Upper Trigonía Grit Member** is present throughout the Chedworth area, and it is differentiated on the map (and indexed UTG) where outcrop width etc permit. It comprises between 1 and 3m of very hard grey and brown very shelly shell-detrital moderately ooidal packstone and forms medium to thick beds, generally rather rubbly. The fauna is dominated by large bivalves, chiefly preserved as empty moulds, including trioniids and pectinaceans, and brachiopods. These, and the hardness of the rock make the member very conspicuous in exposures, and generally easy to locate in open fields, where the weathered limestone forms large, rubbly, conspicuously shelly, orange-brown slabs in the brash.

The member is exposed in a number of the Chedworth Woods railway cuttings, including Localities D and E, where it overlies the bored and encrusted top of the Notgrove Member. At Locality D [0523 1320] it is 2.55m thick, and 400m to the north [0510 1368], it is 2.5m thick and forms 7 or 8 rubbly beds. The uppermost 0.8m of the member are also exposed in a quarry near Coulsty Barn (Locality L [0742 1274]). In the Stowell Park Borehole, the member is 1.58m thick (see above).

The **Clypeus Grit Member**, forming the greater part of the Salperton Formation, comprises pale grey and brown, rubbly, finely shell detrital fine- to coarse-grained ooid and peloid grainstone with abundant very coarse-grained orange skinned subrounded aggregates or grapestones, and common whole shells. Some of the aggregates may be intraclasts. The fauna is most abundant in the higher beds, and includes myid bivalves, terebratulid brachiopods and the characteristic echinoid *Clypeus ploti* Salter.

The Clypeus Grit is well exposed in the Chedworth Woods railway cuttings, including Localities B, C, D and E, although its full thickness is not seen in any one location. It is inferred to be about 9 to 10m thick here, more than the 4.6m inferred by Woodward (1894, p. 126), or the 6.1m of Richardson (1933, p. 27). At Locality B [0508 1391], the uppermost bed (Bed 4), which is overlain by the Fuller's Earth, comprises 1.05m of 'ironshot' limestone. Richardson (1933) tentatively equated this bed with the Chipping Norton Limestone, and the underlying 3 inch bed of 'paste' to the Roundhill Clay (part of the Chipping Norton Limestone Formation). The strata in question are quite unlike the Chipping Norton Limestone, which forms the basal unit of the Great Oolite Group in adjoining areas to the east, and undoubtedly form part of the Clypeus Grit.

6 MIDDLE JURASSIC: GREAT OOLITE GROUP

6.1 FULLER'S EARTH FORMATION

The Fuller's Earth Formation, equivalent to the Lower Fuller's Earth Clay of the Malmesbury district (Cave, 1977), is the basal unit of the Great Oolite Group in the Chedworth area. It comprises here some 12 to 20m of grey, moderately shelly, silty mudstone with thin beds of sandy limestone and shelly limestone mainly in the upper part. Cambering and landslip (see Engineering Hazards) render accurate thickness estimates very difficult, but the formation is inferred to thicken from the north-east to the south-west across the sheet. It is very poorly exposed in the area, but the basal c. 2.5m of beds are visible faulted down in the east face of the Tumulus Cutting (Bed 5, Locality B, [0508 1391]).

The outcrop of the Fuller's Earth is easily traced on the ground from its heavy grey-brown clay soil and the frequency of landslips, with a characteristically uneven terrain, on valley slopes, (see Engineering Hazards). Cambering (see Structure) is extensive in the Chedworth area, and is largely responsible for the apparent reduced thickness and narrow outcrop of the Fuller's Earth in some places, notably around Yanworth [07 13] and Lower Chedworth [06 11].

The largely impermeable formation also causes springs to emerge at the base of the overlying limestone units, although in many cases they may emerge within landslip areas (see Water Supply).

In the Stowell Park Borehole, the Fuller's Earth Formation is 16.23m thick. The upper part of the formation (down to c. 34.62m (113ft 7in)) contains sandy tilestones and oyster-rich shell fragment limestones included by Green and Melville (1956) in the 'Stonesfield Slate Beds'. These probably correspond with the Eyford Member of the Fuller's Earth (Moreton-in-Marsh district) and the approximately equivalent Charlbury Formation of Boneham and Wyatt (1993) (Witney district).

6.2 TAYNTON LIMESTONE FORMATION

The Taynton Limestone is present throughout the Chedworth area, forming a generally narrow outcrop along the slopes of the Coln valley and tributaries. At outcrop in most

places, the formation appears to be about 5m thick, but it is subject to considerable local thickness variation, generally thinning towards the west or south-west. The log of borehole No. 23 at Stowell Park Covered Reservoir [0960 1418] indicates a thickness of c. 14m, as in the adjoining Northleach area (SP 11 SW; Sumbler, 1994c), but in the BGS Stowell Park Borehole, 2.5km to the south-west, it appears to be only c. 2.3m thick (N.B. this borehole was incorrectly classified by Green and Melville (1956); see Appendix 2, and discussion of Hampen Formation, below).

The Taynton Limestone is characteristically a white, cream or pale brown, coarse-grained, generally well-sorted ooid and shell fragment grainstone that forms a flaggy brash in the fields. The ooids generally have a relatively large shell fragment nucleus, with a thin, white, soft 'chalky' coating of accreted carbonate; they often appear in marked colour contrast to the darker groundmass of the rock. The shell debris is typically concentrated in thin bands on cross-bedding foresets. Exposures (e.g. localities M and N of Appendix 1) show that the strata are almost invariably cross-bedded. Also included in the formation are fine-grained ooid grainstones more typical of the Hampen Formation (see below); such rocks become progressively more common to the west, making the separation of the two formations on lithological criteria somewhat arbitrary.

The Taynton Limestone was formerly valued as a building stone, and there are many old quarries along the outcrop, all now disused, and many infilled or ploughed over.

6.3 HAMPEN FORMATION

The Hampen Formation (formerly Hampen Marly Beds/Formation) is present throughout the area. It forms narrow outcrops along the valley of the River Coln, and its dry tributary valleys, and also forms broader outcrops at Stowell [089 134] and to the north-east of Chedworth [065 123]. Estimates based on mapping suggest that the formation varies from about 6 to 11m in thickness, but to some extent the apparent variation may be due cambering of the overlying White Limestone, and the somewhat gradational nature of both the upper and lower boundaries. No systematic trend to the variation is apparent. A section at Oxpens Farm (Locality S [0865 1451 to 0869 1448]) showed 8.94m of strata, with neither the top nor base of the formation exposed, and at Chedworth Station cutting (Locality G [0547 1162 to 0551 1150]) the formation is at least 9.1m thick.

The formation comprises limestones with interbedded marls, the latter particularly common in the upper part of the formation and in the eastern part of the area. In the section at Oxpens Farm (Locality S), marls dominate the upper part of the section, but overall make up only some 28 per cent of the total thickness of the exposed strata. This is considerably less than at the type locality of Hampen railway cutting [SP 061 204], some 6.5km north-west of Oxpens, where marls or marly limestones make up about 45 per cent of the formation (Richardson, 1929; Barron and Sumbler, MS section). Marls become still rarer to the south-west, for example in the Chedworth Station Cutting (Locality G), and although the formation is still recognisable on account of its distinctive limestone lithologies, most workers (e.g. Arkell, 1933, p. 276; 1947, p.42; Palmer, 1979, p. 191) have taken the view that the formation is thin or absent, having passed into an expanded White Limestone succession. This idea was reinforced by

Green and Melville (1956) who considered the formation to be absent in the Stowell Park Borehole. In fact, re-examination of the limestone core specimens shows that the formation is 9.57m thick at Stowell Park (Appendix 2).

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, and where particularly sandy, these rocks grade into calcareous sandstone. In some cases, the limestones contain strings of relatively coarse-grained white ooids (like those of the Taynton Limestone), and 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 and ?rootlet traces. In ploughed fields, these limestones produces a slabby or flaggy brash, superficially somewhat similar to the 'tilestones' of the Fuller's Earth, although their ooidal composition, and the almost ubiquitous presence of ripple bedding, distinguishes them.

Lenses of coarse, shell-fragmental oolite grainstone resembling the Taynton Limestone also occur sporadically; they have been separately mapped (indexed 'ol') where possible. They occur particularly in the lower part of the formation [e.g. 064 126], but a bed of this lithology has also been noted at the top of the formation in a number of places, e.g. south of Oxpens Farm [088 135] and also in the Stowell Park Borehole (20.93 to 24.23m depth; Appendix 2); these strata were classified as Taynton Limestone by Green and Melville (1956) who consequently did not recognise the presence of the Hampen Formation. Such lenses of coarse grainstone indicate an interdigitation between the characteristic facies of the Taynton Limestone and Hampen Formation, and hint at a degree of lateral passage of the one formation into the other.

The marls of the formation, as seen in the section at Oxpens Farm (Locality S), are typically grey to yellowish buff, often with abundant shell debris, mainly of oysters, notably *Praeexogyra hebridica* (Forbes). They are commonly rather sandy, and laminated and tend to pass into soft, rather shaly limestones, as noted by Richardson (1911) in Chedworth Station Cutting (Locality G). At outcrop, they contribute to a brownish clayey soil.

The Hampen Formation was formerly exposed in Chedworth Station and Stony Furlong cuttings (Localities G and H; see Appendix 1). Richardson (1911), in his description of the cuttings, did not specifically discuss the formation, even though the 'Marly Beds' had been described at Hampen [061 204] by Woodward (1894, p. 293) some years earlier. However, he drew the base of his 'Great Oolite, Upper Division' (see Woodward, 1894, p. 292) at the base of bed 32, implying that the 'Marly Beds' either lay above, or were absent. Later, Richardson (1933, fig. 2) tentatively identified the 'Marly Beds' as beds 29 to 36 (part) of the cutting. In the present account, the topmost bed of the Hampen Formation at Chedworth is regarded as Richardson's Bed 33, i.e. the so-called Organic Band of Harker (1890), a brown clay rich in *Praeexogyra hebridica* Forbes (= *Ostrea sowerbyi* of Richardson, 1911; 1933). This classification is based on the assumption that peloidal limestone of White Limestone facies, currently exposed at the top of Chedworth Station Cutting, represents Bed 32, the topmost of Richardson's section there. The underlying Bed 33 is obscured, but the sporadic exposures below are

of brownish, platy, fine-grained ooidal grainstones of typical Hampen Formation type, with some of Taynton Limestone facies in the lower part of the cutting. Mapping indicates that the cutting lies entirely within the the Hampen Formation which is probably about 10m in total thickness there.

East of Oaks Bottom [0779 1496], brash from an horizon near the top of the formation (? the 'Organic Band') yielded *Praeexogyra hebridica*, the button coral *Chomatoseris porpites* and the echinoid *Clypeus*. Nearby [0778 1482], another echinoid *Nucleolites woodwardii* was also found at this level.

6.4 WHITE LIMESTONE FORMATION

The outcrop of the White Limestone Formation covers almost half of the Chedworth area. It caps the highest ground, forming extensive plateaux in the south and east, with smaller outliers between the valleys in the central and northern part of the area. Where complete (see below), the formation thickens from perhaps as little as 23m in the eastern part of the area (confirmed by a borehole in the adjoining Northleach area (SP 11 SW; Sumbler, 1994c), to perhaps 30m or more in the west. The White Limestone Formation is divisible into the Shipton, Ardley and Signet members, in ascending order.

The **Shipton and Ardley members** together comprise the greater part of the thickness of the White Limestone, probably amounting to some 20 to 28m or more. The two members are not readily divisible by except by recognition of marker beds, and are shown undifferentiated on the map. The strata are dominated by pale grey to white micritic limestones, generally containing a greater or lesser proportion of large (often 1mm or more) peloids (wackestones and packstones). The peloids, commonly slightly ferruginous and yellowish in colour, include faecal pellets, intraclasts and true ooids. Such rocks form a characteristic brash of white angular fragments in the soil of arable fields. At some levels, partial cementation has taken place around burrows, to give a cavernous-weathering 'Dagham Stone' (Woodward, 1894, p. 286); such beds are generally lenticular, but in some cases they are surmounted by cemented hardgrounds which can be traced over large areas, and are the basis of regional correlation (Sumbler, 1984). Marl seams are particularly common in the Shipton Member, and ooidal grainstones are widespread in the middle part of the Ardley Member.

All of the Shipton Member, and most of the Ardley Member were formerly exposed in the Chedworth Station and Stony Furlong railway cuttings recorded by Richardson (1911) (Localities G and H of Appendix 1; see also Richardson, 1933, plate 3). Limestones at the base of the White Limestone, and in the underlying Hampen Formation are still poorly visible in the Chedworth Station cutting [0547 1162], confirming that the base of the White Limestone lies immediately above the 'Organic Bed' already described. Much of the Stony Furlong section (bed 22 and below) is now obscured, as the northern half of the cutting is infilled. However, Richardson's record gives a total of about 26m of White Limestone above the Organic Bed (bed 33). Comparison with the section at Foss Cross Quarry [0555 0927], about 1.5km to the south-west of the cutting, shows that Bed 18 corresponds with the Excavata Bed which marks the top of the Shipton Member (Barker, 1976; Sumbler, 1984; 1995d), and that therefore the thickness of the Shipton Member (i.e. Richardson's beds 18 to 32) is

13.6m, significantly more than the 10 to 11m estimated from borehole numbers 23 and 35 at the Stowell Park Covered Reservoir [096 142].

The uppermost 3m of the Shipton Member are still exposed [0628 1058] just south of the railway bridge near Denfurlong Farm. The lowest bed seen (bed 21) is a brown, somewhat sandy marl, which may conceivably equate with a bed of clay at approximately this level, which has been mapped locally in the Northleach and Sherborne areas to the east (sheets SP 11 SW and SE). The Excavata Bed (Bed 18) is a buff, poorly sorted, peloidal packstone, recrystallized to a very hard, pinkish fawn, microcrystalline limestone in its upper part. Richardson (1911, p. 111) found a loose specimen of the ammonite *Morrisiceras*, which he considered may have come from this bed. The specimen, held in the BGS collections (GSM52177) is broken and worn, and though recorded as *M. morrisi* (Oppel) by Richardson, was noted as 'not identifiable positively' by Arkell (1954). Nevertheless, the genus indicates the mid-Bathonian *M. (M.) morrisi* Zone.

About 5.44m of overlying beds (beds 13c to 17) of the Ardley Member are still exposed in the same section. The basal bed (17) of the member, resting on the Excavata Bed, contains crumbly, fissile somewhat sandy seams reminiscent of the Roach Bed and subjacent sand and clay developed in Oxfordshire at this level (Sumbler, 1984). Above, Bed 15 is a hard, partly recrystallised packstone to grainstone, with locally (according to Richardson, 1911) a planed, oyster-encrusted hardground top. This hardground, the lowest such bed recorded in the cutting, is some 15m above the base of the formation. It represents the bed characterised by the gastropod *Aphanoptyx* cf. *langrunensis* of Oxfordshire (Sumbler, 1984), and is widely developed in areas to the east of Chedworth (see Sumbler 1994c). Debris of such a hardground surface found at several localities in the Chedworth area [e.g. 074 111; 089 107; 097 147; 099 137] in most cases probably represents this same bed.

The highest beds now exposed are buff, cross-bedded ooid grainstones of Bed 13, also exposed in nearby Denfurlong Farm Quarry [0657 1055] (Locality I). These oolites appear to form a dip-slope adjoining the quarry and railway cutting and Bed 13 would therefore be expected to be the highest unit seen in the southern part of the cutting; the relationship of this inferred dip surface with the outcrop of the Signet Member some 500m to the south-east, suggests that the oolites (of Bed 13) lie very close to the top of the Ardley Member (as is generally the case in the Chedworth area; see below). This interpretation is hard to reconcile with Richardson's (1911) record of some 6.3m of overlying beds (apparently mostly oolites) in the more southerly part of the cutting, and suggests the likelihood of some mis-correlation in Richardson's account, i.e. that the true interval was somewhat less than he stated. A possibility supported by correlation with other sections (including the extant Foss Cross Quarry), is that Richardson's Bed 14 (with its lenticular development of marl, and planed top surface), corresponds with beds 15 to 17 of the extant section, and that 11 (b and c) and 12 repeat bed 13, i.e. that Richardson's section is approximately 2 to 3m too thick. It also seems probable that Richardson's bed 10 of Stony Furlong includes the *Solenopora* Bed of Foss Cross Quarry (i.e. Bed 12 of the Aldgrove Cutting).

Elsewhere in the Chedworth area, oolites continue to dominate the Ardley Member. In

the north-east [around 097 141], well-sorted ooid grainstones overlie the hardground characterised by *A. cf. langrunensis*. There, they form a well-developed dip-slope, and have been separately mapped (and indexed 'ol'). They are overlain by perhaps 1 to 3m of white micritic limestone, generally almost devoid of peloids or shell debris, which is in turn overlain by the Signet Member (see below). Locally in the area to the east (SP 11 SW), this bed contains nerineid gastropods, and is capped by a bored hardground (Sumbler, 1994c); it probably represents the Bladonensis Bed of Oxfordshire (Sumbler, 1984).

In the railway cutting, Bed 9, near the top of Richardson's section, is a planed and oyster-covered hardground. Using Richardson's recorded thicknesses for the beds in the cutting, and the dip implied by them, Bed 9 would lie some 11.03m above the base of the Ardley Member and several metres below the top, giving a total thickness for the member of approximately 17m. A more conservative estimate, given the likelihood of errors in the upper part of Richardson's section (see above), is that the Ardley Member is approximately 12 or 13m in thickness; this compares with c. 10.5m estimated for the area to the south (Sumbler, 1995d).

The **Signet Member** (Sumbler, 1991), constituting the topmost part of the White Limestone Formation, is estimated to be up to 6m thick. It appears to be absent locally in the Pindrup Moor area [074 109; 078 101], where the younger Forest Marble Formation rests directly on the Ardley Member. The Signet Member represents an environmental transition between the Ardley Member and the Forest Marble, and includes a variety of lithofacies, some of which can be matched in either the underlying or the overlying units. Locally this may cause problems in defining its upper boundary, particularly in the eastern part of the area, where the outcrops now recognised as Signet Member in the Northleach area were mapped as Forest Marble by Hull (c. 1856; see the 1933 edition of Sheet 235). The transitional nature of the beds was recognised by Richardson (1933), who in some cases used the term 'Kemble Beds' for these strata (see Sumbler, 1991, for a discussion of this obsolete terminology).

The most typical lithology of the Signet Member, widespread in the area, is a rubbly to platy, grey to brown, sandy, micritic limestone, typically containing scattered shell fragments (generally bluish grey in colour) and commonly small specks of lignite. Ooids occur in places, but are not generally common in this facies. Oysters, and other shells, notably large *Plagiostoma*, are common locally. In a few places [095 129; 096 107; 095 112], white marls and micritic limestones with large *Epithyris oxonica* Arkell and/or corals occur. In most places, these limestones are associated with interbeds of brown clay, and clays dominate the upper part of the member east of Calcot [096 104 area] and near Stowell Lodge [095 128].

6.5 FOREST MARBLE FORMATION

The youngest bedrock formation of the Chedworth area is the Forest Marble Formation. Only the lower part of the formation is represented; it forms outliers capping the high ground in the south-eastern part of the area. The largest outlier, with the thickest succession, occurs around Pindrup Moor [077 103], where up to 6m or 8m of strata are preserved. In the area to the south (Sheet SP 00 NE), the full thickness of about 21m of

Forest Marble is present beneath the succeeding Cornbrash Formation. The Forest Marble rests on a channelled surface of the White Limestone Formation; this erosive relationship accounts for the absence of the Signet Member of the White Limestone Formation near Pindrup Moor (see above).

Within the Chedworth area, the succession is made up predominantly of strongly cross-bedded limestones which characteristically form a brash of large flags in arable fields. The most common lithology at the base of the formation (and making up most of the eastern outliers) is a grey to buff, coarse-grained, shell fragment and ooid grainstone. Such limestones commonly contain large pieces, or whole shells, of pectinaceans and oysters, together with intraformational mud-flakes, and small pieces of lignite. Small sections showing limestones of this type were recorded at localities O and P (Appendix 1). Similar, but finer-grained 'compact' limestone containing distinctly bluish shell fragments, also occurs locally at the base of the formation in the east [e.g. 098 111; 098 118]; such rocks resemble lithologies in the underlying Signet Member (White Limestone Formation).

Higher in the succession at Pindrup Moor, beds of mudstone occur; where these have been distinguished on the map, they are indexed 'FMb'. At outcrop, they form brown clay soils, which often contain lenticles of brown or bluish grey recrystallised shell fragment grainstone. The highest unit of the succession, forming an outlier around Upper Chedworth Telephone Exchange [074 104], gives rise to a very loamy clay soil, containing flags of brown sandy limestone, commonly with ripple marks.

7 STRUCTURE

Regionally, the Jurassic strata in the mid-Cotswolds dip very gently (0.5 to 1.5°) to the south-east. Locally, dips steeper and in other directions than this may be seen, but these usually relate to faulting or non-diastrophic, superficial structures (cambering, see below).

The pattern of major faulting observed in the area accords closely with that recorded by Hull in the original (1850s) survey of the district. A number of additional minor faults were identified in the current survey. Two dominant fault trends are evident. The major fault to the south of Stowell Park trends west-south-west to east-north-east, and throws down to the south, with a maximum displacement of up to 40m [092 129]. It can be traced for a total of 9km in this and the adjoining area to the east. Several other minor faults with the same trend occur in the southern part of the Chedworth area; one crosses the Stony Furlong cutting and is alluded to by Harker (1890). In the north, a number of faults trend west-north-west to east-south-east, the predominant regional trend. A major fault cuts across the plateau between the Coln valley and Oaks Bottom. In the extreme west [050 140], a block of Inferior Oolite strata, upthrown about 25 m, lies between outcrops of Fuller's Earth. The bounding faults coalesce at both ends of the block (west end on sheet SP 01 SW).

In places, the throws deduced near to the surface may be modified by cambering (see below). Only in the Tumulus Cutting is a fault exposed, but they can be pinpointed in

many places by sharp changes in the brash in fields.

In many places, cambering has profoundly affected the strata cropping out along valley sides. It takes place where beds of resistant, permeable rocks (e.g. limestone) overlie impermeable clay or mudstone (which weathers and softens to clay). The superincumbent load coupled with water movement along the interface cause the soft and plastic material to squeeze or wash out. Intervening sand beds may exacerbate the effect, but even where such permeable beds are absent, large thicknesses of clay may be lost by squeezing. As a result, the vertical thickness of the clay beds reduces, and the limestone strata are lowered as a 'camber', comprising blocks separated by series of minor faults ('dip and fault structure') parallel to the valley axis. The displacements on the faults is usually quite small (1 to 3 m), and they may be undetectable at the surface other than in excavations. Outward movement of the blocks can cause voids to open (gulls), which are likely to fill with loose rock and soil. Cambering, initiated by Pleistocene periglacial conditions, is a gradual but ongoing process, and may be a precursor to landslide. It must be considered a potential engineering hazard.

Cambering affects the Taynton Limestone, Hampen and White Limestone formations overlying the Fuller's Earth Formation, most conspicuously near Star Wood [060 148], Yanworth [075 140 and 080 146], north of Stowell [087 145], around Parkway Farm [08 11], west [070 123] and south [074 114] of Raybrook Barn, and in many of the slopes surrounding the Chedworth valley.

8 QUATERNARY

8.1 RIVER TERRACE DEPOSITS

Small tracts of river terrace deposits flank the floodplain of the River Coln in three places. At Hutnage [056 139], a deposit with an upper surface up to 4m above the modern alluvium level comprises subangular, very poorly sorted limestone gravel, still visible in a small pit at the northern end which Dines (in Richardson, 1933, p. 88) reports once exposed 1.8m of buff-coloured, bedded and partially indurated limestone gravel. At Stowell Mill [082 128], a similar gravel deposit lies at about the same level above the alluvium, and on the opposite side of the valley a little farther downstream [082 125] tract of gravelly sand lies about 1m above the floodplain. None of these deposits is likely to exceed more than 3 to 4m in thickness.

On the 1933 edition of Sheet 235, a very small tract of terrace deposits is also shown at the sawmill [0570 1357] which Dines (in Richardson, 1933, p. 88) notes as poorly exposed and only a few feet above the river level. This is now obscured by the woodyard and road, and there is insufficient evidence to show it on the current map. However, it is notable that this instance, and the deposits at Hutnage and Stowell Mill are all on the inside of major bends in the river valley, which has assisted their preservation.

8.2 ALLUVIUM

The River Coln is flanked by a continuous tract of alluvium from the extreme north-west corner of the sheet to the southern edge near Calcot. The floodplain ranges from 20 to 150m across and is flat-topped. The alluvial deposits comprise grey-brown silty clay and silt, with dark organic (peat) layers in places, and lenses and a basal lag of limestone gravel. Information from adjoining areas (e.g. Dury, 1953) suggests that the deposits are unlikely to exceed 2 to 3m in maximum thickness. The deposits forming the narrow alluvial tract in the Chedworth valley are of similar composition, but are unlikely to exceed 2m in thickness.

8.3 HEAD

Many of the dry (or seasonally wet) valleys in the Chedworth area have accumulations of brown stony clay in the bottom. These may be in part solifluctate but also include hillwash (colluvium) of more recent origin. These deposits are typically flat-topped, and may be difficult to distinguish from, and grade into alluvium. In addition, steeper cones and spreads of head border the Coln floodplain for instance around Stowell Mill [082 129] and Raybrook Barn [076 121]. None of these deposits is likely to exceed 3m in thickness.

8.4 LANDSLIP

Landslips result from failure of slopes, normally in non-cohesive materials (e.g. clay or sand), where gravity overcomes the strength of the material or its ability to support itself. Extensive landslipping affects the outcrops of the Fuller's Earth Formation in the Chedworth area. Many of the slips are complex, involving a combination of translational and rotational slides and flows. The landslips are recognised by the disrupted and hummocky topography of the slipped areas. Commonly there is also a distinct scar at the top of the slip, for instance near Yanworth [072 136], near Oxpens Farm [081 148] and in Chedworth Woods [065 130 and 066 128]. Reverse slopes may develop where rotational slips have taken place, for instance in Oaks Bottom [076 148] and in the Chedworth valley [059 116]. It is possible that older slips which have become degraded and indistinct through natural processes and farming activities may have gone unrecognised. Slipped Fuller's Earth clay commonly overrides parts of the Inferior Oolite outcrops, notably in Chedworth and Yanworth woods, and in Chedworth village. The slips may also incorporate slabs of limestone material from the overlying beds.

9 ECONOMIC GEOLOGY

9.1 LIMESTONE and SAND and GRAVEL

Most of the limestone formations which crop out in the sheet area have been worked at some time. The small quarries and degraded pits on their outcrops bear witness to this; most are degraded or completely filled and obscured. Any of the limestone strata may have been used for lime-burning or roadstone. The dry stone walls which are so characteristic of the Cotswolds are, in the Chedworth area, mainly constructed of stone

from the Taynton, Hampen and Forest Marble formations which naturally break into large flat slabs resistant to frost. Most of the small pits recorded on the plateau area are likely to have been for this purpose. The thinly bedded sandy limestones of the Hampen Formation may also have been used as tilestones for roofing.

It is not known whether any stone has been quarried and dressed for building stone in this area. The Taynton Limestone is the most likely candidate (see Richardson, 1933, p. 101) and disused quarries near Oxpens Farm [086 143] and Stowell [085 135] may have been for this purpose. The most extensive stone workings were at the sawmills [058 138], where pits and tips, now largely overgrown, covers several hectares. The beds worked belong to the Cleeve Cloud Member of the Birdlip Formation, which elsewhere in the north Cotswolds (e.g. Cleeve Hill and Leckhampton Hill) was previously a major source of building stone.

There is a small degraded pit in the river terrace deposit at Hutnage, in which limestone gravel was formerly worked (see 8.1). Dines, (in Richardson, 1933, p. 88) also reports pits working suballuvial gravel at Coln St. Dennis [possibly 0843 1100] and Calcot. It is unlikely that any of the river terrace or alluvial deposits are of any current economic interest.

9.2 WATER SUPPLY

In the past, all the villages and farms would have been supplied with water from nearby springs and wells (Richardson, 1930). It is likely that most are now on mains water, although some local sources may be maintained for emergencies or non-domestic purposes. All the wells draw from either the Great Oolite or Inferior Oolite or both.

During the survey (October 1993-November 1994), a number of springs were observed in the area, feeding small covered reservoirs, ponds and streams. Those not depicted by Ordnance Survey on the 1978 1:10 000 topographic map have been added to the geological map. The majority issue at or near the base of the Taynton Limestone Formation, where the water is thrown out by the subjacent impermeable clay strata. Particularly strong springs were noted in several places along the bank south of Oxpens Farm [0867 1420 to 0854 1395] issuing from this level. However, a number appear within the landslips on the Fuller's Earth Formation outcrop, where the water is presumed to have percolated down through displaced limestone beds or fissures and shears in the clay. The spring [c. 0521 1352] feeding the 'nymphaeum' at the Roman villa is inferred to issue from above the Harford Member, as may that by the roadside at Turpin's Green [0534 1428]. Both had a fairly weak flow in May 1994.

The spring water is highly calcareous, and minor deposits of lime (tufa) may coat vegetation and stones around the springs, for instance south of Oxpens Farm (see above) and in Listercombe Bottom [0658 1308, 0714 1198].

9.3 ENGINEERING HAZARDS

Slopes in clay formations (e.g. Fuller's Earth) are naturally potentially unstable, and identifiable landslips are depicted on the map (see 8.4). Changes to the conditions, such

as loading, steepening and altering drainage, may increase the propensity of a slope to fail. Clay or clay-rich formations are also subject to swelling and shrinkage, depending on moisture content, which can be affected not only by drainage but by vegetation, notably trees. This can pose foundation stability problems. River alluvium commonly includes organic (peat) layers, which may compress under additional loading (e.g. artificial structures).

Limestone formations are prone to fewer problems, but where they suffer cambering along valley sides (see 7.2), voids filled with soil and loose rock can form (gulls), which may be obscured over time. The possible presence of old, infilled pits and quarry workings should also be considered.

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APPENDIX 1. SECTIONS

Thicknesses are given in metres. Some of the sections below are paraphrased from other publications; in these cases, although the stratigraphic classification may have been revised, the nomenclature used for fossils has not generally been updated. Some of these older sections have been renumbered from the base.

A-E [0500 1404 to 0538 1286] Chedworth Woods railway cuttings

These railway cuttings were described by Buckman (1890 and 1895, p. 425), Woodward (1894, pp 125-129, cuttings K-M) and Richardson (1933, pp 27-28). The railway is now disused, but the cuttings are still superbly exposed, and are now a Nature Reserve under the guardianship of the Gloucestershire Trust for Nature Conservation, who maintain them, and have inserted numbered pegs at 100m intervals along the track. Locality A logged by A J M Barron and A N Morigi, remainder logged by AJMB, all in 1994.

A and B Tumulus Cutting (pegs 11 to 13)

A minor fault crosses this cutting near the southern end [0506 1392], throwing the beds on the south side down about 20 m. The beds exposed to the north are described in A, those to the south in B.

A [0507 1392 to 0500 1404]

Topsoil with limestone rubble.	0.1
<i>Aston Limestone Formation; Notgrove Member (8.65)</i>	
17. Limestone, light brownish grey, medium- to coarse-grained poorly sorted peloidal and ooidal grainstone, with some coarser paler. superficial ooids; packstone texture in places, medium bedded (0.1-0.3) and closely blocky jointed, monotonous, more flaggy at top, cross-bedded to south/south-west in places.	7.65
16. Limestone, light brownish grey, shelly moderately peloidal and ooidal wackestone, medium-grained.	c. 1.0
Obscured.	c. 0.3
<i>Aston Limestone Formation; Gryphite Grit Member (3.6-4.0)</i>	
15. Limestone, pale to medium grey, shelly and shell fragmental finely peloidal grainstone, with abundant <i>Gryphaea</i> , mainly convex upwards, echinoids and pectinaceans, common large curved ochre-filled burrows, thickly rubbly bedded, less shelly in parts.	2.7-3.2
14. Limestone, greyish orangish brown, finely to coarsely shell-detrital, ?finely sandy, fine- to medium-grained ovoid ochreous peloids, <i>Sarcinella</i> , rare curved burrows 3mm across; more shelly in basal 0.1	0.36
13. Clay, light greyish brown, highly shell-detrital.	0.07
12. Limestone, greyish orangish brown, similar to 14. <i>Sarcinella</i> specimen collected.	0.12
11. Clay, olive brown, irregular; 11 to 13 form conspicuous notch	0.04
10. Limestone, orangish yellowish brown, finely to coarsely shell-detrital, fine- to medium-grained orange-brown ovoid peloids in ?packstone texture, upper surface apparently encrusted with shells.	0.19

Aston Limestone Formation: Lower Trigonina Grit Member (c. 1.8)

- | | |
|---|---------|
| 9. Limestone, pale brownish grey, floating orange-brown medium-grained irregular peloids in wackestone texture, rare whole ribbed shells; soft at base, 0.02 bed of yellowish brown clayey fine- to medium-grained sand at top forming notch. | 0.24 |
| 8. Limestone, light greyish brown, fine- to medium-grained orange peloids in packstone texture with sparry pockets, no fine shell debris, but common to numerous large whole bivalve shells | 0.48 |
| 7. Sand, yellowish brown, fine-grained, clayey. | 0-0.035 |
| 6. Limestone, pale brownish grey matrix with common orange-brown fine- to medium-grained subrounded peloids in wackestone texture, sparse burrows 15mm diam, in upper 0.12 of bed. | 0.45 |
| 5. Limestone, pale grey-brown with orange-brown well-sorted medium- to coarse-grained ochreous peloids in grainstone texture, with micritic pockets, common poorly-sorted shell detritus and shells, including echinoid plates, a few ooids. | 0.58 |

Birdlip Limestone Formation: Harford Member (0.22)

- | | |
|--|------|
| 4. Clay, yellowish brown, finely sandy (quartz) and slightly micaceous, possibly finely laminated. | 0.11 |
| 3. Clay, dark grey, smooth, sparse shell fragments. | 0.02 |
| 2. Clay, greyish brown, ferruginous, highly shell detrital. | 0.09 |

Birdlip Limestone Formation: Scottsquar Hill Member (0.8+)

- | | |
|---|-----|
| 1. Limestone, pale orangish brown, very well-sorted medium- to coarse peloidal grainstone, with yellowish grey spar cement, peloids near spherical, bioclasts absent; in top 0.1, peloids have nuclei, and rock is thin bedded, lowest 0.7 is massive, top uneven and partially obscured, bed forms distinct bench at north-west end of cutting. Dip 1.5-4.0° to S. | 0.8 |
|---|-----|

B [0508 1391]

Fuller's Earth Formation

- | | |
|---|-------|
| 5. Clay, pale grey, olive brown and orange-brown mottled and streaked, silty and shaly in parts, scattered fine- to coarse-grained shell debris, scattered race in upper 1.5, basal 0.7 orange, partly slipped, dip c.10° N into fault. Bed covered by masonry on west side of cutting. | c.2.5 |
|---|-------|

Salperton Limestone Formation: Clypeus Grit Member

- | | |
|---|--------|
| 4. Limestone, light greyish orange, abundant dark orange medium- to coarse-grained subrounded peloids in wackestone texture ('ironshot'), variably shell detrital, slightly to very rubbly with massive 0.25m bed at top (?Chipping Norton Limestone of Richardson 1933) | 1.05 |
| 3. Limestone, light orange brown, fine-grained, slightly shell-detrital and ooidal, massive. | 0.47 |
| 2. Clay, mid olive brown, slightly finely shell detrital | c.0.10 |
| 1. Limestone, pale orange-grey, fine- to coarse-grained ooidal grainstone with common medium-grained coated shell detritus, coarse ooids and very coarse-grained subrounded orange-brown coated intraclasts, a few larger uncoated shell fragments, scattered terebratulids, thick bedded, rather rubbly in part. | c.4.9 |

The Clypeus Grit Member is exposed in several places between pegs 10 and 11.

C [0509 1381 to 0510 1375] (west side, between pegs 9 and 10)

Salperton Limestone Formation: Clypeus Grit Member

2. Limestone, pale orange-grey, fine- to coarse-grained ooidal grainstone with common medium-grained coated shell detritus, coarse ooids and very coarse-grained subrounded orange-brown coated intraclasts, a few larger uncoated shell fragments, scattered terebratulids, thick bedded, rubbly, flat lying at northern end of section. c.8.4

Salperton Limestone Formation: Upper Trigonia Grit Member

1. Limestone, pale grey and orange brown speckled, shell detrital packstone, very shelly; bivalves, pectinaceans, trigoniids, moderately ooidal, hard, in three rough beds up to 0.55 thick, dip 3.5° to north. 1.3

The Clypeus Grit, Upper Trigonia Grit and Notgrove members are variously exposed at several places between pegs 5 and 9

D [0523 1320] (west side, at peg 4)

Salperton Limestone Formation: Clypeus Grit Member

3. Limestone, pale orange-grey, fine- to coarse-grained ooidal grainstone with common medium-grained coated shell detritus, coarse ooids and very coarse-grained subrounded orange-brown coated intraclasts, as rubble. c.1.0

Salperton Limestone Formation: Upper Trigonia Grit Member

2. Limestone, pale grey and orange brown speckled, shell detrital packstone, very shelly, ooidal. 2.55

Aston Limestone Formation: Notgrove Member

1. Limestone, pale brownish grey, well sorted medium-grained peloidal and ooidal grainstone, slightly shelly, in slightly uneven medium beds, with very hard intensely bored oyster-encrusted upper surface beneath Upper Trigonia Grit. 0.55

E [0539 1290] (between tunnel mouth and peg 1)

Salperton Limestone Formation: Clypeus Grit Member

2. Limestone, pale orange-grey, fine- to coarse-grained ooidal grainstone with common medium-grained coated shell detritus, coarse ooids and very coarse-grained subrounded orange-brown coated intraclasts, rubbly. at least 8.3

Salperton Limestone Formation: Upper Trigonia Grit Member

2. Limestone, pale grey and orange brown speckled, shell detrital packstone, very shelly, ooidal. c.1.5

The Notgrove Member is inferred to be present at trackbed level in the cutting. The Fuller's Earth Formation, partially landslipped, is present above the tunnel entrance.

F [0539 1240 to 0537 1216] Chedworth Tunnel approach cutting. The cutting is now degraded, with no exposure, except for some landslipped, and steeply inclined Taynton Limestone. Richardson (1911, p. 113) recorded:

Fuller's Earth Formation

Clay, greenish-yellow, with numerous masses of blue shelly limestone crowded with *Ostrea acuminata* (Sow.). Other fossils include rare; *Rhynchonella concinna* auctt., *Cylindrites excavatus* M. & L. (no thickness given).

G [0547 1162 to 0551 1150] Chedworth Station Cutting. The cutting was recorded by Richardson (1911, p.113). The cutting is now largely obscured, but some outcrops of rock protrude from the west side of the cutting [0550 1151], and descriptions thereof (recorded by A N Morigi and M G Sumbler, 24/11/94) are given in square brackets, with depth measured from the top of the cutting.

White Limestone Formation

32 Limestone, ooidal. [At c. 0.45m depth: Limestone, pale brownish grey, poorly sorted, medium- to coarse-grained peloid grainstone, with sporadic shells and ?micritic angular clasts up to 20 mm across]. c. 1.22

Hampden Formation

33. [Organic Bed of Harker, 1890]. Brown clayey marl with oysters. 0.15

34. Yellowish marl. c. 0.61

35. Limestone [At c. 1.9m depth: Limestone, yellowish grey, well-bedded, fine to medium-grained, moderately well-sorted, ooid grainstone, with sporadic coated shell fragments]. c. 0.30

36 (part). Limestone, as below, weathered to an ooidal marl. 0.61

36 (part). Series of limestones, occasionally fairly massive, shelly oolite with small *Ostrea* and *Placunopsis socialis* M. & L., but more generally brown shaly deposits with burrows and trails. [At top (c. 2.8m depth): Limestone, greyish brown, flaggy, very poorly sorted, fine to medium-grained ooid grainstone, with floating coarser-grained white ooids, and common shell fragments, mostly coated. In middle (c. 4.8m depth): Limestone, greyish brown, tiley to thinly-bedded, fine-grained ooid grainstone, grading to fine to medium-grained ooid grainstone with shell fragments]. c. 3.96

Richardson (1911) did not record lower beds, but present exposures show:

At c. 7.9m depth: Limestone, yellowish brown, moderately well-bedded, very poorly sorted, coarse-grained ooid grainstone with very common large shell fragments (rather like Taynton Limestone), resting on fine- to very fine-grained ooid grainstone.

At c. 8.8m depth: Limestone, as above but tiley or thinly-bedded.

At c. 9.8m depth: Limestone, very pale brown, platy, very fine-grained ooid grainstone.

At c. 10.3m depth (bottom of cutting): Limestone, pale brown, fine- to medium-grained, ooid grainstone, with scattered coarser white ooids.

The lowest two units are typical Hampden Formation limestone, giving a total thickness of at least 9.1m of Hampden Formation in the cutting, although the presence of this

formation has not been recognised by previous workers (see main text). Fossils (AC1435-47) collected in 1966 by K J Ackerman from a bed of grey-brown, flaggy, richly shell-detrital limestone in this cutting (probably from Richardson's Bed 36) include *Kallirhynchia*?, rhynchonellid fragments, *Meleagrinella* sp., *Modiolus* sp., ostreid fragments, *Placunopsis socialis* Morris & Lycett, *Pseudoptera*? and *?Praeexogyra hebridica* (Forbes).

H [0635 1035 to 0572 1118] Stony Furlong Cutting The following section is based on that of Richardson, 1911, pp110-111, but is slightly paraphrased in part, and also incorporates additional information for beds 14 to 28 (marked by an asterisk) based on a section recorded by P Toghil and K J Ackerman in May, 1966, in that part of the cutting immediately north and south of the road bridge [0627 1064] (BGS archive). Richardson's fossil specimens from beds 13, 14, 17, 19 and 25 are held by BGS (Zd4102 to 4203), as are Toghil and Ackerman's collection from beds 18, 19, 23 and 25 (AC1367-1434); these fossils have been reassessed by Ivimey-Cook (1993b) and are listed in the section below. The fauna from other beds, given in square brackets, is quoted from Richardson (1911).

White Limestone Formation (Ardley Member)

?8. Limestone, rubble.	0.30 to 0.61
?8. Marl with limestone at the centre and in the lower portion;. Beds gradually replaced by limestone at the extreme southern end of cutting.	0.61 to 0.91
9. Limestone, white 'flinty', sparsely ooidal, top planed and oyster-covered. Not always well marked off from bed 10 below.	0.46
10. Limestone, rather shattered appearance about the middle; echinoid radioles, small gastropods.	1.68
10a. Marl. 0.03 to 0.13; generally	0.05
11a. Limestone, top planed, oyster-covered and bored.	0.15
11b. Limestone, white, ooidal, some borings extend down from bed above.	0.76
11c Shale.	0.03
12a. Limestone, similar to 11b.	1.07
12b. Well-defined parting with tough clay in places; up to	0.03
12c. Limestone similar to 12a, but lower portion when weathered forms a well marked parting.	0.86
13 Limestones, variously irregularly, cross- or massive-bedded, weathers poorly at base, and forms a marked division line. <i>Endiaplocus</i> ?, <i>Lucina bellona</i> d'Orbigny (Zd 4197-4203).	2.31
14. Limestone, generally massive, planed top. In the centre of the section is a lenticular mass of fossiliferous marl; its bottom-portion passes northwards into a bed full of branching corals and this into bed of ordinary oolite. The marl bed contains <i>Corynella</i> sp., <i>Dendraraea excelsa</i> (Edwards & Haime), <i>Thamnasteria</i> sp., <i>Camptonectes obscurus</i> (J. Sowerby), <i>Camptonectes</i> sp., <i>Lopha costata</i> (J. de C. Sowerby), <i>Lucina bellona</i> d'Orbigny, <i>Nanogyra crassa</i> (Wm. Smith), <i>Myoconcha actaeon</i> Morris & Lycett ex d'Orbigny, <i>Plagiostoma cardiiformis</i> J. Sowerby, <i>Plagiostoma subcardiiformis</i> (Greppin), <i>Plagiostoma</i> sp.,	1.83

<i>Thracia curtansata</i> Morris & Lycett, <i>Thracia</i> sp. (Zd 4139-96).	
15*. Limestone (Dagham Stone), hard, fine-grained buff oolite, locally porcellanous, with planed oyster-covered surface.	0.20
16. Marl, greenish-grey, black-speckled, ooidal.	0.15 to 0.30
17*. Limestone, flaggy, fissile and fine grained, locally ooidal, faintly bituminous and argillaceous, with a bed of marl for 0.08 at base, and of sandy clay for 0.30, at 0.38 above base. <i>Bakevellia waltoni</i> (Lycett), <i>Camptonectes laminatus</i> (J. Sowerby), <i>Eomiodon fimbriatus</i> (Lycett), <i>Lucina bellona</i> d'Orbigny (Zd 4134-38).	1.22 to 1.52
<i>White Limestone Formation (Shipton Member)</i>	
18*. Limestone (Dagham Stone), white, fine-grained, porcellanous, ooidal; the most conspicuous bed in the section. Very fossiliferous in places, especially with <i>Nerinaea</i> and corals. <i>Lucina bellona</i> d'Orbigny, <i>Tancredia extensa</i> Lycett, trigonid indet. (AC 1367-8). <i>Morrisiceras</i> (GSM 52177) found ex situ possibly from this bed.	0.53
19*. <i>Lucina</i> Beds. Limestone, massive, pale fine grained; similar to the bed above, but less white; rather cavernous at top, and fine grained buff oolite in basal 0.3; very shelly; corals indet. (recorded but not found 1993), gastropods indet., <i>Ampullospira canaliculata</i> (Morris & Lycett), <i>Ampullospira</i> sp., <i>Astarte</i> ?, <i>Camptonectes</i> sp., <i>Endiaplocus</i> ?, <i>Falcimylus</i> ?, <i>Globularia formosa</i> (Morris & Lycett), <i>Globularia</i> sp., <i>Homomya</i> sp., <i>Pseudomelania</i> ?, <i>Trochotoma</i> ?, <i>Anisocardia minima</i> (J. Sowerby), <i>Ceratomya concentrica</i> (J. de C. Sowerby), <i>Inoperna plicatus</i> (J. Sowerby), <i>Lucina anglica</i> (Rollier) juv., <i>Lucina bellona</i> d'Orbigny, <i>Modiolus</i> sp., ostreid fragments indet., <i>Pachyrisma grande</i> Morris & Lycett, <i>Palaeonucula waltoni</i> (Morris & Lycett), <i>Pholadomya lirata</i> (J. Sowerby), <i>Placunopsis</i> sp., <i>Plagiostoma</i> ?, <i>Pleuromya uniformis</i> (J. Sowerby), <i>Protocardia</i> sp., <i>Pterocardia pes-bovis</i> (d'Archiac), <i>Vaugonia</i> ?, <i>Clypeus</i> sp., <i>Nucleolites</i> sp., echinoid fragments (AC1369-1404; Zd 4103-4133). [Richardson (1911) also recorded <i>Echinobrissus woodwardi</i> Wr. ('Chedworth buns'), <i>Clypeus mulleri</i> Wr., steneosaurian bones etc.].	1.42
19a*. Marl, slightly sandy, yellowish-brown.	0.08
20*. Limestone, massive, hard, very fine-grained, porcellanous and marly; top surface irregular and waterworn, hard but not bored; irregular base [<i>Steneosaurus</i>].	0.61
21*. Brown laminated silty clay, passing down into sandy marl; passing to	c. 0.30
22*. Limestone, white, rubbly and sandy, with calcite lumps (?recrystallised corals); crystalline in the centre and very hard, quartz pebbles [<i>Echinobrissus woodwardi</i> , <i>Camptonectes lens</i> (Sow.), <i>Lucina bellona</i> , etc.].	0.61
23*. Limestone, massive, porcellanous, with marly layers; top 0.3 particularly massive and porcellanous; a very hard "flinty" bed in places at the base. <i>Globularia</i> sp., <i>Anisocardia</i> ?, <i>Isocyprina</i> ? (AC 1405-9).	1.32
24. Marl, brown, noticeable horizon.	0.08
25*. Limestone, orange-white, fine-grained oolite, porcellanous in	

places; curiously "knotty" composed of indurated marl and white irregular crystalline limestone masses weathering to have the appearance of Dagham Stone. Weathers into an ooidal marl. <i>Naricopsina</i> sp., gastropods indet., <i>Anisocardia</i> cf. <i>loweana</i> (Morris & Lycett), <i>Barbatia</i> ?, <i>Ceratomya concentrica</i> (J. de C. Sowerby), <i>Ceratomyopsis</i> ?, <i>Falcimylus</i> ? <i>Gervillia monotis</i> (J. A. Eudes-Deslongchamps), <i>Pholadomya</i> ?, <i>Placunopsis</i> sp., <i>Protocardia</i> sp., <i>Tancredia</i> sp., echinoid fragments (AC1410-34; Zd 4102).	0.61
26. Limestone, massive, cavernous about the centre; may split up into two beds.	1.52
27*. Marl, brown, sandy, noticeable horizon.	0.10 to 0.15
28a*. Limestone, massive, pale brown, occasionally porcellanous, ooidal.	1.02
28b*. Limestone, as above.	0.86
28c*. Limestone, as above [<i>Echinobrissus</i> and <i>Solenopora</i>].	1.07
29. Marl, sometimes dark and at others pale brown: 0 to 0.15; average	0.08
30. Limestone, sometimes present as a fairly massive bed; elsewhere a lumpy marl, ooidal.	1.07
31. Marl, pale brown and often whitish, rather stony near the centre, but limestone-beds also appear obliquely in lower portion.	c. 0.91
32. Limestone, in four beds.	1.37
<i>Hampden Formation</i>	
33. ['Organic-Bed' of Harker, 1890] Clay dark-brown, crowded with oysters [<i>Ostrea sowerbyi</i> M & L.]	0.53
34. Marl, hard, yellow and grey [<i>Pinna ampla</i> Sow.].	1.07
35. Limestone, ooidal.	0.36
36. Limestone; some beds hard, others almost indurated ooidal marl; not well exposed in this section. c. 2.44 to	2.74

According to Richardson's account, beds ?8 to 28 were visible south of the road bridge [0627 1064], the lowest beds being exposed in a deep 'gully' on the western side of the railway there, which was used as a quarry. This showed beds 13 to 28 (Richardson, 1911, Plate 18). This was the deepest portion of the cutting, and underlying strata were not seen until considerably further to the north west, near the 'second' bridge [0594 1101]. There, the so-called 'Organic Bed' (33), which is here taken as the topmost of the Hampden Formation (see main text), was exposed close to the south-western pier of the bridge.

Much of the cutting is now infilled, but moderately good (though largely inaccessible) sections remain in the 'gully' to the south of the road bridge [0628 1063], where the following section was recorded by MGS (6/10/94); numbering follows Richardson (1911).

Topsoil, passing down into

White Limestone Formation (Ardley Member)

13c. Limestone (inaccessible), flaggy, thin-bedded, ?cross-bedded, presumed oolite grainstone.	1.2
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14. Limestone, yellow-buff, poorly-sorted medium-grained ooidal and peloidal packstone-grainstone, poorly-bedded, in courses 0.05 to 0.15 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 to 0.08 at base, and 0.65 and 0.90 above base.	1.35
<i>White Limestone Formation (Shipton Member)</i>	
18 (part). Limestone, pink-fawn, very hard, recrystallised, splintery, uniform micrite. Marl parting at base.	0.15
18 (part). Limestone, buff, poorly sorted, peloidal packstone. Massive. Occasional corals. Marl parting at base. (? <i>A excavata</i> Bed).	0.50
19 (part). Limestone, buff, poorly sorted peloidal packstone. Very massive, raggy fracture, but weathering slightly cavernous (?burrows) in top 0.2.	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, recrystallised micrite or very fine grained recrystallised grainstone-packstone. Massive, structureless, raggy fracture. Burrows, but no obvious fauna.	0.60
21. Marl, brown, fawn, slightly sandy, becoming hard and indurated at top.	0.30+
Obscured, to base of cutting.	5.6

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 cut right to the southernmost end. Thus, it seems possible that Richardson's (1911) record of 6.61m of overlying beds (?8 to 12) in this part of the cutting is an overestimate (see main text).

I [0657 1055] Denfurlong Farm Quarry. This formerly extensive quarry (c. 4ha), is now largely obscured, and partly restored to grassland. A small section remains in the eastern face (MGS, 1994)

White Limestone Formation

Obscured to bench.	1.7
Limestone, white to pale buff, medium grained, well sorted peloid and ooid packstone to grainstone; very flaggy, strongly cross-bedded (currents from north).	1.5
Obscured to floor of quarry.	0.6

The exposed beds probably equate with bed 13, exposed at the top of the adjoining Stony Furlong cutting (see above).

J [0590 1377] Sawmills Quarry. The quarry and associated spoil heaps cover a large area, and appear to be occasionally worked for roadstone for farm tracks (AJMB, 1994). This is probably the freestone 'quarry on Yanworth Common' mentioned by Woodward (1894, p. 127).

Limestone rubble, cream ooid grainstone; may be scree or spoil. c. 1

Birdlip Limestone Formation, Cleeve Cloud Member

Limestone, cream, moderately sorted, fine- to medium-grained ooid grainstone, slightly shell-detrital, thin to thick bedded, slightly disturbed. c. 2.5

K [0684 1336] Small pit in Chedworth Woods (AJMB, 1994).

Aston Limestone Formation, Lower Trigonina Grit Member

Limestone, grey, very rubbly, shelly, shell-detrital, with ferruginous peloids and ?ooids, giving an orange-brown speckled appearance. 1.8

L [0742 1274] Disused quarry near Coulsty Barn. (Beds near flat-lying)

Topsoil, orange-brown, with limestone rubble and loose ooids. 0.3

Salperton Limestone Formation, Clypeus Grit Member (c. 2.3)

Limestone, pale orange-brown, very rubbly, shelly, finely shell-detrital, fine- to coarse-grained ooid grainstone, with some peloids/intraclasts, larger ones orange skinned, common brachiopods; finer grained and better bedded downwards. c. 2.3

Salperton Limestone Formation, Upper Trigonina Grit Member (0.8)

Limestone, mid grey-brown, fairly well bedded, very shelly (whole bivalves), finely highly shell-detrital grainstone, bioturbated, with common fine- to medium-grained ooids and micritic pockets; beds up to 0.3m thick. 0.6

Limestone, mid greyish brown, finely shell-detrital grainstone with common ooids 0.2

M [0799 1207] Small face at site of sewage works for the former Stowell Park Polish Assistance Camp (MGS, 1994).

Hampden Formation

Limestone, brown, flaggy, fine-grained sandy ooid grainstone, poorly exposed. 2.5

Taynton Limestone Formation

Limestone, yellow-buff, massive, cross-bedded, very coarse-grained, poorly sorted, shelly ooid grainstone. 0.8

N [0895 1129] Section at spring, Coln St Dennis (MGS, 28/04/94). Section generally rather poorly exposed, especially at top; beds collapsing into valley, with variable southward dip.

Taynton Limestone Formation

5. Limestone, pale buff to cream, coarse-grained shell fragmental oolite grainstone and grey to white poorly sorted oolite with large shell debris; broken and disturbed rubble at top, becoming less broken downwards, in thin flaggy beds. 1.4
4. Limestone, grey to cream, massive, coarse-grained, oolite grainstone, with large grey shells and shell debris. Sporadic ovoid pebbles of grey sandstone (as below). Planar bedded, in courses 0.08 to 0.25 thick. 0.80
3. Marl, grey to buff, slightly sandy, indurated in parts. c. 0.6
2. Limestone, grey to white, massive, very fine grained sandy oolite grainstone; passing to 0.40

Fuller's Earth Formation

1. Sandstone, grey, hard, fine-grained, poorly and unevenly laminated; more fissile in parts. 1.2
- [mudstone inferred below; water issues at this level]

O [0924 1240] Temporary excavation c. 150m south of Parkway Farm Quarry (Locality P)(MGS, 09/94).

Forest Marble Formation

Limestone, bluish-grey to brown, flaggy, coarse-grained shell fragment and ooid grainstone. 0.8

?White Limestone Formation: Signet Member

Clay, bluish grey. 0.5

P [0927 1258] Parkway Farm Quarry. Old quarry, now largely infilled with miscellaneous debris, including pig carcasses (MGS, 09/94).

Forest Marble Formation

Limestone, greyish brown, flaggy, and strongly cross-bedded, coarse-grained shell fragment and ooid grainstone. Bedding disturbed by cryoturbation near surface. 1.3

Q [09431303] Temporary section recorded during construction of Esso Midline oil pipeline (AJMB and A Horton, 06/85)

White Limestone Formation

Topsoil, clayey, reddish brown, with limestone debris. 0.3

Limestone, pale grey, ooidal with rounded shell debris and some irregular peloids. 0.1

Limestone, pale grey to buff; wackestone with pale brown, irregular, coated peloids, up to 1mm diameter; some broken shells including gastropoda and brachiopods; very rubbly-weathering. c. 0.9

?Hamper Formation

Limestone, pale orange brown, with coarse, generally irregular peloids and sparse large shell fragments 0.15

R [0935 1375] Temporary section recorded during construction of Esso Midline oil pipeline (AJMB and A Horton, 06/85)

White Limestone Formation

Limestone; where fresh, a greenish grey micritic silty limestone with some bands of coarse ooids and shell debris; soft and friable in parts and weathering brown and marly.	0.5
Marl, off-white with scattered brown ooids; shelly, nodular with better-cemented masses.	0.8
Limestone, pale grey to off white, hard, massive peloidal, with coarser ?ooids; porcellanous hardground at top.	0.4

S [0865 1451 to 0869 1448] Oxpens Farm: Section behind barns. Recorded by MGS, 22/4/94. Composite section starting at north-western corner of the cutting (where the beds dip c. 10° to the west) and working south-east (where dip diminishes to approximately zero. The section totals 8.95m; all the limestones weather to a brownish colour.

Hampden Formation

13. Limestone, brownish grey, soft to hard, generally very fine-grained ooid grainstone; sporadic coarser shell fragmental layers and strings of larger white ooids; sporadic layers of soft, partly decalcified, laminated sandstone. Becoming hard, massive, poorly sorted fine-grained ooid grainstone with scattered shell fragments at base.	1.25
12. Marl, yellow to buff, patchily cemented; abundant shells and shell debris, mainly small oysters; some moulds of bivalves including myids and 'Pinna'; becoming slightly sandy towards base.	0.94
11. Limestone, brownish yellow, massive, moderately hard, very fine-grained, slightly silty ?ooidal packstone (superficially resembles a siltstone). Passing to	0.50
10. Marl, grey to buff, laminated, finely sandy.	0.12
9. Limestone, pale greyish brown, hard, well-bedded (in courses 0.05 to 0.15 thick), very fine-grained, well-sorted ?finely sandy ooid grainstone (superficially resembles a sandstone); much coarser-grained, poorly sorted, with scattered large ooids and shell debris in basal c. 0.08.	0.45
8. Marl, yellow to buff, vaguely colour-banded, finely sandy and ooidal, patchily cemented into a soft limestone; abundant moulds of small bivalves and common <i>P. hebridica</i> , generally small. Coarsely sandy in parts.	0.83
7. Limestone, brown, massive, rubbly; medium grained sandy and peloidal; uneven top and base.	0.35
6. Marl, as bed 8, becoming sandy and laminated towards base; passing to	0.50
5. Limestone, pale grey, well-bedded to very fissile, sandy fine-grained ooid grainstone ('tilestone'), in beds typically 0.15 thick, interleaved with softer, brown, ripple-bedded laminated sandstone with burrows and	

trails. Individual beds impersistent(? low angle cross-bedding).	1.20
4. Limestone, as bed 5, but more massive and harder. Ripple bedded; sporadic mudflakes; seam of soft, ripple-laminated sandstone in top part. Passing to	0.65
3. Limestone, brownish yellow, very fine-grained, uniform peloidal packstone. Massive bed, but with cross-bedding evident on weathered faces.	0.40
2. Marl, yellowish brown, sandy, finely ooidal.	0.10
1. Limestone, greyish brown, massive, hard, recrystallised, poorly sorted medium grained ooid and shell fragment grainstone; unevenly interbedded with finer-grained, unevenly rippled, soft limestone and marl.	1.65

APPENDIX 2 STOWELL PARK BOREHOLE SP 01 SE/1 [0835 1176]

SL +170.7

A detailed log of the borehole is given by Green and Melville (1956), but the following summary log includes many revised formational depths. The changes to the Jurassic succession are based on reappraisal of core specimens in the light of findings from mapping the area around the borehole site; depths of formational boundaries have been chosen to correspond with bed junctions noted by Green and Melville (1956). For the Middle Jurassic, the registration numbers of the relevant specimens are quoted. The ammonite zonation for the Lower Jurassic is from Ivimey-Cook (1993); most quoted depths refer to individual fossil specimens, not bed boundaries.

GREAT OOLITE GROUP

White Limestone Formation 0 to 20.93m (68ft 8in) Bj1-64

Hampen Formation 20.93 to 30.50m (100ft 1in) Bj65-149

Taynton Limestone Formation 30.50 to 32.79m (107ft 7in) Bj150-192

Fuller's Earth Formation 32.79 to 49.02m (160ft 10in) Bj193-394

including Eyford Member 32.79 to 34.62 (113ft 7in) Bj193-196

INFERIOR OOLITE GROUP

Salperton Limestone Formation:

Clypeus Grit Member 49.02 to 60.55m (198ft 8in) Bj395-515; 551-609

Upper Trigonia Grit Member: 60.55 to 62.13m (203ft 10in) Bj516-550; 610-639

Aston Limestone Formation:

Gryphite Grit Member 62.13 to 65.30m (214ft 3in) Bj640-760

including Buckmani Grit 64.77 (212ft 6in) to 65.30m Bj751-760

Lower Trigonia Grit Member 65.30 to 66.45m (218ft 0in) Bj761-798

Birdlip Limestone Formation:

Scottsquar Hill Member (Upper Freestone/Oolite Marl) 66.45m to 74.68m (245ft 0in) Bj799-869

Cleeve Cloud Member (Lower Freestone) 74.68 to 105.51m (346ft 2in) Bj870-952

Crickley Member 105.51 to 112.45m (368ft 11in) Bj953-1018 including:

Pea Grit 105.51 to 110.44m (362ft 4in) Bj953-987

Lower Limestone 110.44m to 112.45m (368ft 11in) Bj988-1018

Leckhampton Member (Scissum Beds) 112.45 to 122.28m (401ft 2in) Bj1019-1105

LIAS GROUP

Upper Lias 122.28 to 220.50m (723ft 5in)

Zone uncertain 122.28 to 130.65m

Hildoceras bifrons Zone 130.65 to c.207.79m

Harpoceras falciferum Zone 207.79 to 219.42m

Dactylioceras tenuicostatum Zone 219.42 to c.220.50m

Marlstone Rock Formation 220.50 to 222.28m (729ft 3in), corresponding approximately with the *Pleuroceras spinatum* Zone

Dyrham Siltstone Formation 222.28 to 276.51m (907ft 2in)

Amaltheus margaritatus Zone ('Middle Lias') 222.28m to 256.06m (840ft 1in),

Prodactylioceras davoei Zone (upper part) 256.06 to 276.51m

'Lower Lias' 276.51m (907ft 2in) to 618.29m (2028ft 6in)

Beds above the Blue Lias 276.51 to 560.48m

Prodactylioceras davoei Zone (lower part) 276.50m to 292.00m

Tragophylloceras ibex Zone 292.00 to 372.77m

Uptonia jamesoni Zone 372.77 to 389.70m

Echioceras raricostatum Zone 389.70 to 439.52m

Oxynoticeras oxynotum Zone 439.52 to 444.32m

Asteroceras obtusum Zone 444.32 to 471.80m

Caenisites turneri Zone 471.80 to 488.15m

Arnioceras semicostatum Zone 488.15 to 532.62m

Arietites bucklandi Zone (upper part) 532.62 to 560.48m

'100' Marker c. 289 to 297m on gamma ray log

'85' Marker c. 333 to 341 on gamma ray log

'70' Marker c. 373 to 381m on gamma ray log)

Blue Lias 560.48m (1838ft 10in) to 597.28m (1959ft 7in)

Arietites bucklandi Zone (lower part) 560.48m to 570.92m

Schlotheimia angulata Zone 570.92 to 586.58m

Alsatites liasicus Zone (upper part) 586.58 to 597.28m

Basal Mudstones 597.28 to 618.29m

Alsatites liasicus Zone (lower part) 597.28m to 606.00m

Psiloceras planorbis Zone 606.00 to 617.51m

Pre-*planorbis* Beds (Triassic) 601.06m (2026ft 0in) to 618.29m (2028ft 6in)

PENARTH GROUP 618.29 (2028ft 6in) to 635.08m (2083ft 7in)

Lilstock Formation:

Langport Member (White Lias) 618.29 to 623.75m

Cotham Member 623.75 to 629.56m

Westbury Formation 629.56 to 635.08m

MERCIA MUDSTONE GROUP 635.08 to 1075.26m (3527ft 9in)

Blue Anchor Formation 635.08 to 643.97m

Twynning Mudstone Formation 643.97 to 765.68m

Arden Sandstone Formation 765.68 to 785.65m

Eldersfield Mudstone Formation 785.65 to 1075.26m (3527ft 9in)

SHERWOOD SANDSTONE GROUP 1075.26m (3527ft 9in) to 1372.49m (TD)

Bromsgrove Sandstone Formation:

Sugarbrook Member 1075.26m to 1083.06 (3553ft 4in)

Finstall Member 1083.06 to 1168.86m (3834ft 10in)

Burcot Member 1168.86 to 1372.49m (TD)