The Cotswold Cephalopod Bed Member and the Bridport Sand Formation

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General description

The upper part of the Toarcian Stage in the central and southern Cotswolds is developed in a predominantly arenaceous facies, which for many years was termed the 'Cotteswold Sands'. This was recognized as being lithologically and stratigraphically equivalent to similar sands in northern and southern Somerset (the Midford Sands and Yeovil Sands) and, still farther south, in Dorset (the Bridport Sands). Consequently it has now been subsumed within the Bridport Sand Formation (Sumbler *et al.,* 1999). The lithology and facies of the formation in the Cotswolds does not differ significantly from that seen farther south, in the Wessex Basin. Typically it comprises friable, dull yellow silty sands with fairly regular bands of harder calcareous sandstone. Bioturbation commonly is intense and has largely destroyed any small-scale sedimentary structures, although cross-bedding, ripple cross-lamination, or individual burrows are evident in certain beds. Fossils generally are rather scarce, except at certain levels, while the friable nature of much of the formation leads to rapid weathering and degradation of exposures. Consequently it is rather poorly documented although some exposures are described in Cave (1977) and the formation as a whole was discussed by Davies (1969). The three GCR sites described here all expose the upper part of the formation. An aspect of the Bridport Sand Formation that has long intrigued geologists is the diachronous nature of its top and base between Gloucestershire (older) and Dorset (younger) (Buckman, 1889; Davies, 1969).

In the central Cotswolds the upper part of the Bridport Sand Formation is developed in a condensed, carbonate-rich facies commonly rich in ammonites and other fossils. The Cotswold Cephalopod Bed Member ('Cephalopod Bed' of earlier accounts) of the Bridport Sand Formation (formerly the 'Cotteswold Sands' in this area) was well documented by geologists in the late 19th and early 20th centuries, notably J. Buckman (1879) and his son S.S. Buckman (1887–1907, 1889), on account of its rich ammonite fauna. Important descriptive accounts published more recently are those of Davies (1969) and Cave (1977). Several of the classic sections exposed in quarries and sunken lanes are still accessible. Three sections, at Wotton Hill, Haresfleld Hill and Coaley Wood (Figure 4.16), have been selected for inclusion in the GCR as representative of the member, and to demonstrate the nature of lateral variations within it (Figure 4.17).

The Cotswold Cephalopod Bed Member comprises a series of centimetre- to metre-scale units composed of highly bioclastic, extensively bioturbated, yellow and brown marls and marly limestones commonly rich in limonite ooids. These include abundant dark-brown ferruginous ooids, or occasionally pisoids, often marginally abraded and with a nucleus of limonite-coated, algal-bored, shell material. The member contains a rich and diverse shelly benthic and nektonic fauna. Ammonites, bivalves and belemnites are particularly conspicuous, with the ammonites documented by Buckman (1887–1907) and the belemnites by Doyle (1990–1992). Brachiopods are also present (Ager, 1956–1967) together with crinoid and echinoid debris. Much of the fossil material is fragmentary, extensively bored by algae and coated with limonite, though intact shells mostly are unbored and lack the limonite coating. Horizontal and U-shaped burrows occur in some of the units and bioturbation is ubiquitous. Lithologically, the several discrete units that together form the Cotswold Cephalopod Bed Member are distinctive and, in the context of the British Lower Jurassic sequence, unique. A well-defined lithostratigraphy was established for this succession more than a century ago (Buckman, 1887, 1889; Richardson, 1910b) and continues to be used to this day. The member derives its name from a rich and diverse ammonite fauna, and from its restricted outcrop distribution in the mid-Cotswolds. The stratigraphical value of the ammonites was recognized by these early workers and enabled correlation between the local lithostratigraphy and the ammonite sequence. This has demonstrated that the succession, although barely exceeding 4 m in maximum thickness, encompasses a fairly complete sequence through the top four ammonite zones of the Toarcian Stage (Figure 4.17).

In its fullest development, at sites such as Wotton Hill, seven named, lithostratigraphical units have been recognized above the typical facies of the Bridport Sand Formation ('Cotteswold Sands') below. These can be tied in to the ammonite succession (revised here by K.N. Page) with some precision (Figure 4.17). The lowest unit, the 'Striatulum Bed', is a slightly sandy, bioclastic limestone with abundant echinoderm debris and limonite superficial ooids. It contains ammonites indicative of the lower part of the Thouarsense Zone (= Striatulum Subzone of Dean *et al.,* 1961). The succeeding 'Pedicum Bed', or 'Linseed Bed' is distinguished by an abundance of ellipsoidal ferruginous ooliths in a soft marl. Above, the 'Struckmani Bed' is a calcite-cemented, very sandy biomicrite containing ellipsoidal ferruginous ooliths, and pisoids up to 4 mm across in its base. The Pedicum and Struckmani beds together represent the Fallaciosum and Fascigerum subzones of the Thouarsense Zone. The 'Dispansum Bed' is a calcite-cemented marl with scattered large ferruginous ooliths, which contains a Dispansum Zone fauna. It is succeeded by a sandier, calcite-cemented marl of the 'Dumortieria Bed', containing fauna indicative of the Levesquei Subzone of the Pseudoradiosa Zone, and is the only bed to contain intraclasts of the host lithology. The 'Moorei Bed' can comprise two distinct facies units in its fullest development; a lower, calcite-cemented, iron-oolitic sandstone and an upper, calcite-cemented, iron-oolitic marl. Its fauna is indicative of the Pseudoradiosa Subzone. This is overlain by the Aalensis Bed', a marl unit that locally contains reworked limestone pebbles more similar to the Opaliniforme Bed. It is the highest unit of the Cotswold Cephalopod Bed Member in this area and its fauna indicates the Aalensis Zone.

The Cotswold Cephalopod Bed Member is overlain at the three GCR sites by the Birdlip Limestone Formation at the base of the Middle Jurassic Inferior Oolite Group. The basal bed of the Birdlip Limestone Formation is a thin, bioclastic limestone with ferruginous peloids, which contains ammonites indicative of the Opalinum Zone of the Aalenian Stage. It was termed the 'Opaliniforme Bed' by Richardson (1910b).

The ammonite and lithostratigraphical evidence indicates that a marked thinning of the Cotswold Cephalopod Bed Member between Wotton Hill and Haresfield Hill is associated with the loss of some of the distinctive lithostratigraphical units and increased condensation of others (Figure 4.17). This is most strikingly seen at Haresfield Hill, where the lower ammonite zones present at Wotton Hill (Dispansum and Thouarsense zones) are absent and the Dumortieria Bed (Levesquei Subzone) rests on an irregular erosion surface, on lower Thouarsense Zone sediments of the underlying Bridport Sand Formation. At Coaley Wood, both of these lower zones are present. There too the lowest unit, the Striatulum Bed, was described by Buckman (1887–1907) as 'filling irregularities in the bed below', clearly indicating a hiatus caused by a period of erosion and/or non-deposition between the Cotswold Cephalopod Bed Member and the underlying sands. Only the Dumortieria Bed (Levesquei Subzone) would appear to be absent at Coaley Wood, despite its presence in the more attenuated sequence at Haresfield Hill. The other units of the Cotswold Cephalopod Bed Member at Coaley Wood are considerably more condensed than at Wotton Hill, with some lithostratigraphical units containing evidence of more than one ammonite subzone. The thickness of the succeeding Leckhampton Member, at the base of the Middle Jurassic succession, is broadly comparable across the three sites (2.74 m at Wotton Hill, 2.14 m at Coaley Wood, and 2.63 m at Haresfield Hill), contrasting with the variations seen in the Cotswold Cephalopod Bed Member beneath.

The Cotswold Cephalopod Bed Member is limited in its geographical extent along the Cotswold scarp, extending from the area north of Stroud southwards to Old Sodbury (18 km north-east of Bristol). To the south it passes laterally into sands of the Bridport Sand Formation ('Midford Sands'). Northwards it passes into typical Bridport Sand Formation ('Cotteswold Sands') or into Whitby Mudstone Formation (Green, 1992). The member is thickest along the scarp between Wotton-under-Edge and Nibley Knoll, (see (Figure 4.18), Wotton Hill GCR site report) attaining a thickness of a little over 4 m. The GCR site at Wotton Hill shows the Cotswold Cephalopod Bed Member at its measurable thickest of 4.11 m: It thins along a NNE line linking the three GCR sites. At Coaley Wood, it is reduced to 0.79 m, and it is only 0.55 m thick on Haresfield Hill. It has been traced eastward from outcrop, thinning to as little as 0.08 m between Tetbury [ST 890 930] and Nailsworth [SO 000 850], where it contains representatives of the Striatulum and Pseudoradiosa subzones, before thickening northeastwards to as much as 1.83 m in a borehole 10 km east of Tetbury (Cave, 1977).

Interpretation

Early Toarcian sedimentation in the Cotswolds was dominated by mudrocks, the Whitby Mudstone Formation, reflecting a eustatic sea-level rise following the close of the Pliensbachian Age (Bradshaw *et al.,* 1992). Thin, marly, ironshot limestones, assignable to the Barrington Member of the Beacon Limestone Formation, occur to the south-west on the 'Avon Platform' (Chidlaw, 1987), with similar facies also developed towards the base of the Toarcian Stage in the Severn Basin itself (Whittaker and Ivimey-Cook, 1972), as at the Alderton Hill Quarry GCR site. Davies (1969) interpreted the mudrocks as deposited in deeper, low-energy conditions, and the limestones in shallower water often disrupted by strong currents. The mudstones are succeeded by the Bridport Sand Formation, considered by Davies (1969) to represent a sand-bar complex that advanced southwards from the Cheltenham area between mid-Toarcian times (Bifrons Zone, Crassum Subzone) and early Aalenian times (Opalinum Zone). Boswell's (1924) heavy-mineral analysis of the Bridport Sand Formation suggested that Armorican metamorphic rocks of Brittany were a likely source. Davies (1969) suggested that the sediment was eroded from rocks there when they were exposed as a land area situated in what is now the Western Approaches of the English Channel. The sand was then carried north-eastwards by longshore currents to where the bar commenced formation upon meeting more powerful currents flowing towards the south-west. However, throughout its outcrop between Dorset and the Cotswold Hills, the Bridport Sand Formation lacks the extensive development of cross-bedding and contrasting lithologies that might be expected either side of the putative bar complex. Instead the facies represented are fine grained and silty, suggesting a rather lower-energy environment, such as a shelf sand blanket facies. Davies (1969) noted that sedimentary structures in the sands are difficult to observe owing to the fine grain-size, lithological uniformity and extensive bioturbation, but when seen they include mainly ripple-formed cross-laminations, with infrequent development of large-scale cross-stratification. In addition, biostratigraphical evidence (Green, 1992) shows that not only did the sands migrate to the south through time, but they also began to be deposited in the Cheltenham and north Cotswold areas from Variabilis Zone through to Aalensis Zone times. However, the Armorican metamorphic rocks are no longer considered the only possible source area for the sands. While uplift of land or marine regression in west and south-west England is implied to have generated the sands, extensive erosion of post mid-Bifrons Zone sediments occurred from Oxfordshire to Yorkshire before Aalenian deposits were laid down (Bradshaw *et al.,* 1992). It has been suggested that part of this eastern area (the London Platform) could have been the source of the sands, although, if so, its transportation into the western and central parts of the Severn Basin could not have been direct, as the sands pass into mudstone-dominated sediments beneath the eastern Cotswolds and Oxfordshire (Green, 1992).

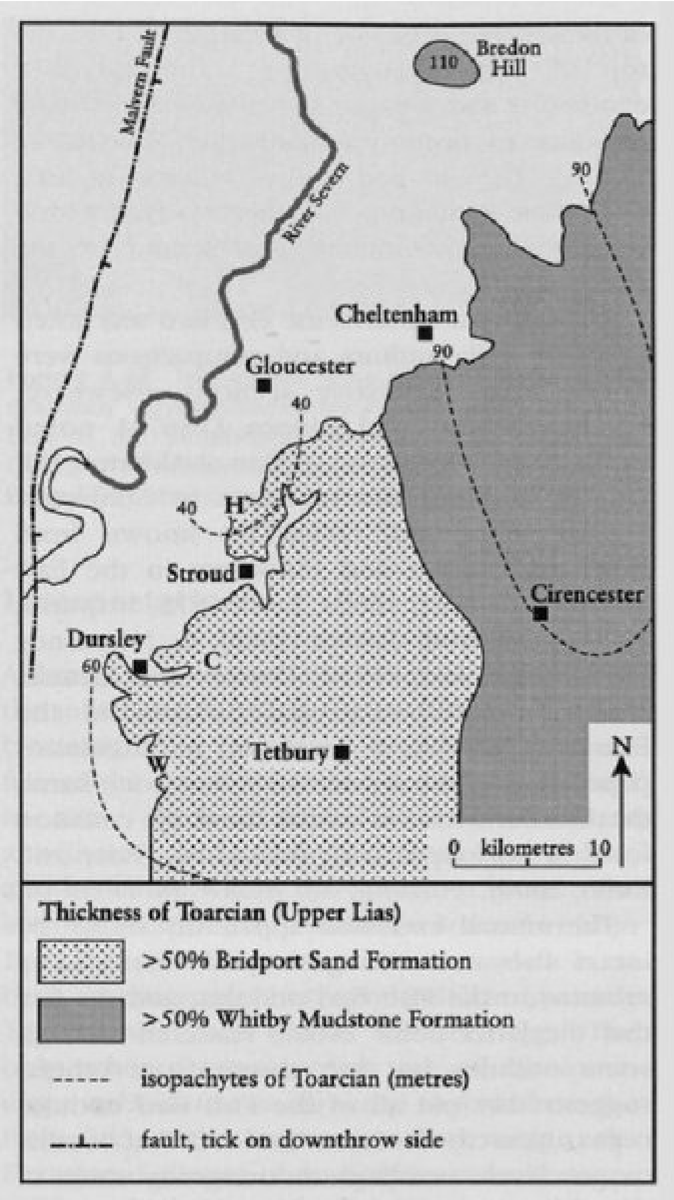
The Cotswold Cephalopod Bed Member is similar in several respects to the highly condensed Sinemurian and Lower Pliensbachian succession of the Radstock district. In both successions ferruginous ooids are a significant component at some levels, and both can be divided into distinctive individual units that can be correlated on the basis of their abundant ammonite assemblages. The highly condensed nature of the Cotswold Cephalopod Bed Member succession indicates that low subsidence rates played a significant role, and sedimentary breaks and the occasional presence of intraclasts at some sites indicates that erosion was important locally. Tectonic controls on sedimentation are well documented for the Severn Basin (Whittaker, 1972b, 1985; Simms 1990a) and clearly exerted a considerable influence on deposition of the Cotswold Cephalopod Bed Member. Chidlaw (1987) noted a similar pattern of lateral thickness variation for the Upper Pliensbachian succession (the Dyrham and Marlstone Rock formations) in the Severn Basin. He attributed this to syn-sedimentary extensional movement in a block-faulted basement, with deposition of the most condensed successions on sediment-starved highs. Farther north in the Severn Basin the succession is strikingly different, with mudstones dominating much of the Toarcian succession correlative with the Bridport Sand Formation farther south. Nonetheless, there does appear to be an increase in arenaceous sediments in the late Toarcian succession even on Bredon Hill, representing the deepest part of the basin (Whittaker and Ivimey-Cook, 1972). This suggests that there was at least a minor eustatic component to the development of the Cotswold Cephalopod Bed Member.

In the Cotswold Cephalopod Bed Member, the abundance of fragmentary shell material and presence of marginally abraded ooids suggests a fairly high-energy environment in which the lime-mud matrix may have been produced largely from the disintegration of skeletal material, including calcareous green algae. Despite predominantly high-energy conditions, this lime mud remained in the environment through its entrapment by algal mucilage and macrophytes, indicating an algal-rich environment. This developed in response to an abrupt termination of sand supply, perhaps associated with regional uplift rather in the manner suggested for the succession seen at the Ham Hill GCR site, creating improved conditions both for algae and for the shelly fauna, which rapidly colonized the sea floor. Remains of the abundant benthic and nektonic fauna were often fragmented and comminuted by strong currents, and extensively bio-eroded by endolithic algae. However, the typically unbored and unencrusted preservation of the intact ammonites indicates that they cannot have lain exposed on the sea floor for any length of time but must have been buried fairly rapidly. This suggests that the richness of the ammonite fauna here did not arise from a slow accumulation of ammonite conchs but more probably reflects a general abundance of this group in the living fauna, with periodic episodes of sediment re-suspension, perhaps due to storms, burying recently dead materials along with the bored and encrusted fragments of other shells. Early diagenetic cementation and subsequent erosion of the manly sediment produced intraclasts on at least one occasion.

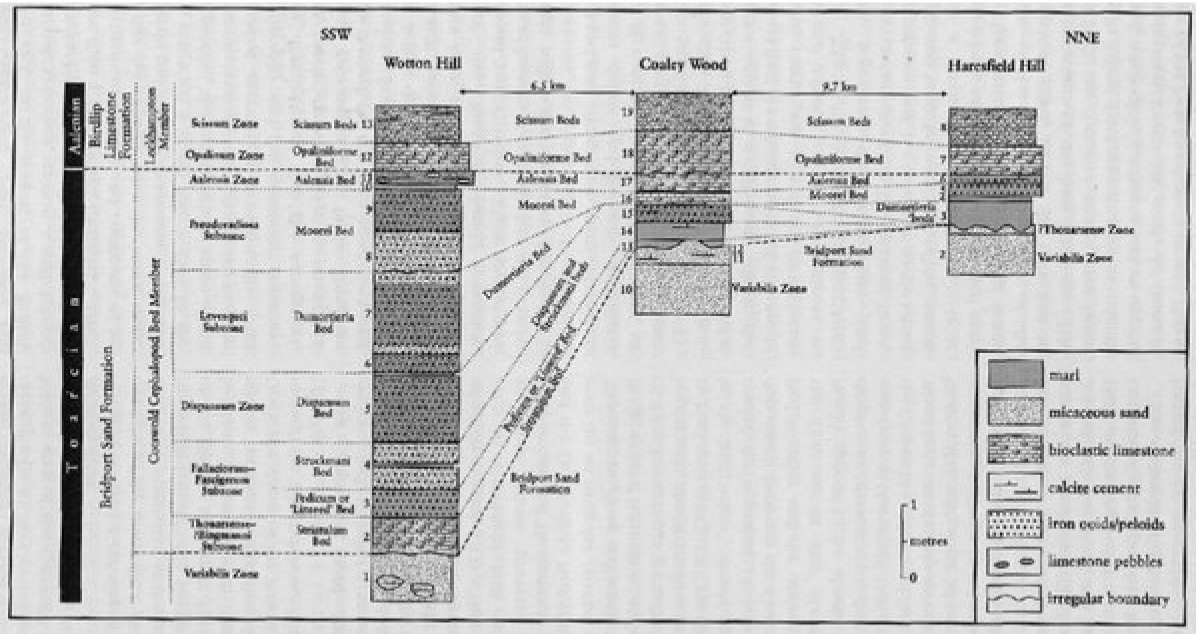
In contrast, Davies (1969) concluded from the dominantly micritic matrix that the environment of deposition was essentially one of low energy, interrupted only occasionally by more powerful currents that produced the intraclasts and brought abraded ooliths, pisoliths and shell fragments into the area from dominantly higher energy conditions to the north-east. However, this appears unlikely, since that area is occupied by the Bridport Sand Formation ('Cotteswold Sands') and Whitby Mudstone Formation, both of which are relatively low-energy deposits.

An extensive facies belt broadly analogous to the Cotswold Cephalopod Bed Member, and similarly composed of shelly lime mudstones with limonitic ooids and intraclasts, is present on the 'Avon Platform' as the Marlstone Rock Formation (Chidlaw, 1987). Here too, ooid nuclei consist of shell fragments and siltstone and, like much of the thick-shelled macrofauna, are sometimes broken. Chidlaw discounted the possibility of the limonitic ooids here having been introduced from adjacent lithofacies belts, since ferruginous ooids from the latter are noticeably different in size and structure.

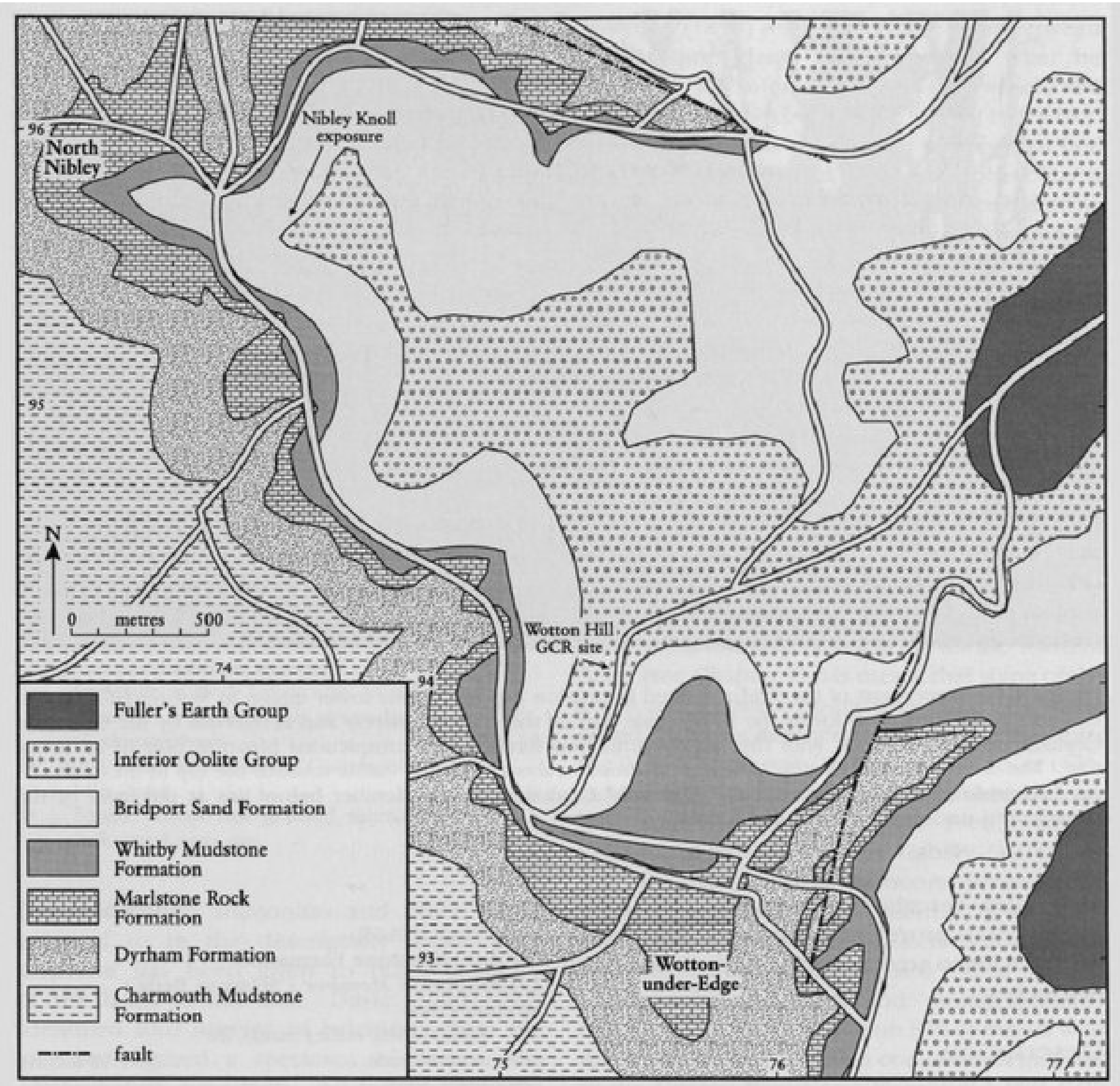
References



(Figure 4.16) Outcrop/subcrop map of Toarcian strata in the Severn Basin, showing the geographical distribution of sand-dominated (Bridport Sand Formation > Whitby Mudstone Formation) and clay-dominated successions. The location of the three Cotswold Cephalopod Bed Member GCR sites is indicated: W — Wotton Hill; C — Coaley Wood; H — Haresfield Hill. After Green (1992).



(Figure 4.17) Lithostratigraphical and biostratigraphical correlation of named units within the Cotswold Cephalopod Bed Member (Bridport Sand Formation) at the GCR sites of Wotton Hill (from new observations by Chidlaw), Coaley Wood (after Richardson, 1910b) and Haresfield Hill (after Buckman, 1887–1907; and Richardson, 1904). Ammonite zonal stratigraphy revised by K.N. Page.



(Figure 4.18) General geology and location map for the Wotton Hill GCR site and the Nibley Knoll exposure.