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The biostratigraphy of the Lower Jurassic
of the Stowell Park Borehole

H. C. Ivimey-Cook

Biostratigraphy and Sedimentology Research Group

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M.G. Sumbler

Dr B. Owens

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H. C. Ivimey-Cook

The biostratigraphy of the Lower Jurassic of the Stowell Park Borehole.

The ammonite biostratigraphy of the Lower Jurassic of the Stowell Park Borehole was originally compiled by L.F.Spath (1956) and summarised in Green and Melville (1956). For the present report it was considered impracticable to reidentify the nearly 5000 specimens used in these papers and also in Melville (1956). Spath's ammonite nomenclature has been reinterpreted to update the biozonation which is now based principally on Dean, Donovan & Howarth (1961), Cope and others (1980), Ivimey-Cook & Donovan (1983), Phelps (1985) and Howarth (1992). This updating has included the use of the generic synonymy lists compiled by Donovan, Callomon and Howarth (1981), and by revision of selected specimens. The results of this review are given in Figures 1a and 1b which also shows, against a metricated graphic log of the borehole, Spath's original zonation and this reinterpretation with the ranges of many of the recorded generic taxa. This revision supercedes the approximate zonal reinterpretation in Ivimey-Cook (1971, Fig. 5). The ammonite biostratigraphy of the British Sinemurian was also considered by Page (1992) who proposed a number of ammonite correlated 'Horizons'.

The following account of the biostratigraphy amplifies the data presented in Figure 1 and notes the occurrence of some other taxa. No attempt has been made at this time to update all* the non-ammonite taxa listed by Melville (1956). Studies on the microfaunas of the Lower Jurassic of the borehole are largely restricted to those made by Barnard (1956, 1957, 1959, 1960); and Copestake & Johnson (1981).

*references to *Tropiorhynchia* in Melville (1956) have been revised to *Piarorhynchia* as used in Ager (1962).

+ This version (WH 93/174A) has been revised to record notes and comments gratefully received from Prof.D.T. Donovan in March 1994.

Cope and others (1980) proposed that the base of the Jurassic System, the Hettangian Stage and the Zone and Subzone of *Psiloceras planorbis* should be taken at the first record of the ammonite genus *Psiloceras*. In Stowell Park the first *Psiloceras* is at 617.51m, at an horizon 0.77m above the top (618.28m) of the Langport Member [White Lias] of the Penarth Group. These intervening beds of latest Triassic age may be tectonically thinned; they are recorded as slickensided and minor faulting is likely as this part of the sequence is unusually thin. Tectonic thinning appears to have affected the sequence at several horizons, this may be related to the WNW-ESE faulting system which affects the northern part of the Sheet area.

Lithologically much of the Lower Lias comprises variably calcareous, dark grey, mudstones, often laminated and with some muddy limestones. It is a basal sequence and lacks the limestone dominant units e.g. the pre-planorbis Beds and higher, limestone-rich, units forming the Blue Lias, which are found in most sequences of this age around the Severn Basin are weakly developed or lacking. Faunally these sediments contain principally nektonic faunas with some benthic bivalves.

Horton and Poole (1977) describe the age relationships and use of certain geophysical marker beds ('70', '85' and '100' Markers) in Oxfordshire, The geophysical logs of Stowell Park were not refined enough to be used in that study but the probable positions of the marker horizons are suggested in the text and on Figure 1.

HETTANGIAN STAGE

Zone of *Psiloceras planorbis* (606.00 to 617.51m)

The *Psiloceras planorbis* Subzone is indicated by common, but rather small, *Psiloceras* sp. between 617.51m and 606.91m; a *Psiloceras* aff. *planorbis* (J. de C. Sowerby) was also identified from 609.7m. The higher Subzone, of *Caloceras johnstoni*, is poorly substantiated with *Caloceras* cf. *johnstoni* (J. de C.

Sowerby) being recovered only from 606.09m a horizon immediately below ammonites of the succeeding Zone of *Alsatites liasicus*. Spath also identified a juvenile ammonite (diameter c. 12mm) from 615.08m, as *Phylloceras* cf. *togatum* (Neumayr); whilst the specimen has a quite deep whorl and is fairly involute, it is not a convincing phylloceratid ammonite and is regarded as indeterminate.

The Zone yields a typical bivalve fauna with scattered *Astarte*, *Cardinia*, *Lucina*, *Modiolus* and *Plagiostoma*. *Liostrea* is rare, *Pteromya* occurs quite commonly only in the lowest two metres.

Zone of *Alsatites liasicus* (586.58 to 606.00m)

The oldest *Waehneroceras*, (Possibly requiring renaming as *Kammerkarites* (Spath 1924) (see Bloos & Donovan ?1995) at 606.00m, marks the base of this Zone. *Waehneroceras* is infrequent although younger specimens were recovered both from 604.4m and from between 598.65 and 598.11m. Other ammonites present include *Alsatites* cf. *liasicus* (d'Orbigny) at 596.18m, *Laqueoceras* and *Saxoceras*; however no further caloceratids are recorded. The top of the zone is taken at the appearance of *Schlotheimia* at 586.58m. Within these 19.42m of beds ammonites are generally scarce; the older Subzone of *Waehneroceras portlocki* is poorly proved as although *Waehneroceras* occurs no species level taxa of this genus are identified and the only other ammonite taxon found was *Alsatites* which ranges through the zone. The younger Subzone of *Laqueoceras laqueus* is proved by its nominal taxon at 594.39m. This subzone also yields *Saxoceras* above 592.25m. The bivalve fauna of the zone is similar to, but slightly more varied than, that of the underlying *planorbis* Zone - it also yields *Camptonectes*, some *Liostrea* - mostly with the large attachment areas of *Liostrea irregularis* (Münster), *Parallelodon*, more frequent *Plagiostoma* and *Pseudolimea*.

? not published yet.

Zone of *Schlotheimia angulata* (570.92 to 586.58m)

The Zone of *Schlotheimia angulata* comprises the range of

Schlotheimia (s.s.) up to the appearance of arietitid ammonites which are here found above 570.92m. The long ranging schlotheimiid taxon *Angulaticeras* (here used to include *Sulciferites* and *Charmasseiceras*) persists into much younger strata. Few of the specimens of *Schlotheimia* were definitively attributed to species; a specimen of *Schlotheimia* cf. *complanata* (von Koenen), from 575.76m, indicates the, younger, Subzone of which that taxon is index. The other macrofauna of this zone comprises *Calcirhynchia calcaria* S. S. Buckman, *Camptonectes*, *Gryphaea*, rare *Liostrea* and some echinoderm remains including *Isocrinus* columnals; it differs markedly from that of the underlying zone.

The recorded Hettangian macrofaunas are generally typical, although the lack of caloceratid ammonites from both the *johnstoni* Subzone and from the earlier parts of the *liasicus* Zone is unusual. The lithological log (Green and Melville 1956, p.47) records slickensides between 597.4 and 598.7m, these could indicate faulting which has reduced the strata of early *liasicus* Zone age.

SINEMURIAN STAGE

Lower Sinemurian Substage.

Fine grained sediments were also laid down throughout the Sinemurian with the area persisting as an offshore basin. Dark grey mudstones, with a few muddy limestones and some horizons of septarian limestone, continue into the Upper Sinemurian. Even the *bucklandi* Zone, which in most areas of southern Britain contains a predominance of limestones, is here dominantly mudstone and calcareous mudstone with only scarce thin limestones (Figure 1a).

Zone of *Arietites bucklandi* (532.62 to 570.92m)

The definition of the zone, and of the subzones comprising the Zone of *Arietites bucklandi* were revised by Ivimey-Cook and

Donovan (1983); they recommended that the zone ranges from the incoming of arietitid ammonites up to the appearance of the genus *Arnioceras*. This zone was divided into two subzones, an older Subzone of *Vermiceras conybeari* overlain by the Subzone of *Coroniceras rotiforme*. Page (1992) retained the, former, Subzone of *Arietites bucklandi* at the top of the zone.

In the Stowell Park Borehole a *Vermiceras* sp. at 570.92m is the earliest arietitid (*Vermiceras* as used here includes *Metophioceras* Spath), and other specimens include *V. longidomus* (Quenstedt) at 570.90m, *V. aff. rougemonti* (Reynès) at 570.41 and 563.04m, and *V. cf. conybeari* (J. Sowerby) up to 562.96m. These indicate the Subzone of *Coroniceras conybeari* which is extended upwards to below the oldest *Coroniceras cf. rotiforme* at 561.12m, a schlotheimiid ammonite occurs at 565.17m.

The non-ammonite macrofauna of the Subzone is relatively sparse it includes *Lingula*, *Calcirhynchia*, *Lucina*, *Modiolus*, and *Placunopsis*, together with some fish fragments.

The Subzone of *Coroniceras rotiforme* occurs above 561.12m where Spath identified a fauna with *Coroniceras cf. rotiforme* (J. de C. Sowerby) and *C. aff. rotator* Reynès, these, with other similar, taxa are common up to 557.63m, they were succeeded by *C. coronaries* (Quenstedt) at 557.46m, *C. schloenbachi* (Reynès) at 556.78m and *C. multicostatum* (J. Sowerby) at 556.42 and 553.21m. There are also other *Vermiceras* and abundant *Angulaticeras*. The oldest *Arnioceras* was a specimen from 532.62m, above which the genus is common. The non-ammonite macrofauna of this subzone is rather sparse with *Anningella cf. faberi*, scarce inoceramids, *Placunopsis*, *Plagiostoma*, *Isocrinus* and echinoid fragments.

Spath (1956) divided his *bucklandi* Zone into six subunits with three subzones (Figure 1a), the revised subdivisions used here put his "Upper" *Arietites bucklandi* Subzone into the overlying Zone of *Arnioceras semicostatum*.

In the beds here attributed to the uppermost part of the Subzone

of *Coroniceras rotiforme* Spath identified many ammonites with the taxa of *Epammonites* defined by Reynès, including *E. cf. compressaries*, *E. isis*, *E. parthenope* and *E. paolinae*. Donovan, Callomon & Howarth (1981) consider *Epammonites* a synonym of *Coroniceras* (*Coroniceras*), which occurs in both the *bucklandi* Zone and in the, younger, Zone of *Arnioceras semicostatum*. These taxa of *Epammonites* were attributed to the early part of the *semicostatum* Zone by Guèrin-Franiatte (1966), but here they appear to predate the appearance of *Arnioceras*, used by Ivimey-Cook & Donovan (1983) to define the base of the *semicostatum* Zone. Page (1992) refers these beds to Horizon 12, in his 'bucklandi Subzone' and below his 'lyra Subzone'.

Zone of *Arnioceras semicostatum* (488.15 to 532.62m)

The Subzone of *Coroniceras lyra* extends from 532.62m up to the first probable *Agassiceras* -recorded from 527.67m. These beds contain numerous *Arnioceras*, other ammonites are represented only by a few indeterminate specimens of *Paracoroniceras* above 530m. A sparse rhynchonellid, gastropod and bivalve macrofauna occurs with *Zygopleura*, *Astarte*, *Lucina*, *Modiolus*, *Oxytoma*, *Plagiostoma*, *Pleuromya* and *Semuridia?*. There are scattered, comminuted, plant fragments at 538.5m.

The Subzone of *Agassiceras scipionianum* ranges from the oldest *Agassiceras?* (527.67m) up to the oldest *Euagassiceras resupinatum* (Simpson) (recorded by Spath (1956) as *E. sauzeanum* (d'Orbigny) at 512.52m. The Subzone has a varied ammonite fauna, *Agassiceras* is rare, but *A. colesi* (J. Buckman) was recorded at 514.25m and *A. aff. scipionianum* (d'Orbigny) at 516.40m. *Arnioceras* is quite common. Spath referred these specimens to a range of species including *Arnioceras ceratitoides* *A. acuticarinatum* (Simpson), *A. miserabile*, *A. nigrum* (Blake) and *A. nodulosum* (J. Buckman). *Metarnioceras*, used by Spath for his species *pseudokridion* and *subpellati*, occurs between 515.95 and 514.60m, when discussing this occurrence Spath (1956, p.154) refers to the abundance of *M. pseudokridion* in Table Ledge (Bed 53) of the Dorset sequence

(Lang 1924). Bed 53 is currently placed at the top of the *scipionianum* Subzone (Cope and others, 1980). Page (1992) refers *Metarnioceras* Spath to *Arnioceras* and suggests that the range of *Arnioceras acuticarinatum* (Simpson) (516-517.5m) may form a useful unit as Horizon 18, *Eucoroniceras* aff. *sinemuriense* (d'Orbigny) was recorded at 517.39m, Page (op. cit. p.139) refers this species to *Pararnioceras* and to his Horizon 16 within the *lyra* Subzone. Page's Horizon 18 is succeeded by Horizon 19 with *Arnioceras pseudokridion* (Spath) recorded here from between 516-514.2m. The sequence also yielded *Coroniceras* (*Paracoroniceras*) aff. *gmuendensis* (Oppel) at 525.7m and *Arietites scunthorpensis* (Spath) at 526.55m (cf. Horizon 13, Page 1992). The, mainly benthic, bivalve fauna contains *Grammatodon*, *Lucina*, *Oxytoma*, *Palaeonucula*, *Pinna* and *Plagiostoma*.

The Subzone of *Euagassicerias resupinatum* is defined by the range of the index taxon up to the appearance of *Caenisites* (Dean, Donovan & Howarth 1961 p.454) who also refer to the possibility that the non-recognition of the *Caenisites brooki* Subzone, in the basal part of the *Caenisites turneri* Zone in Stowell Park, may be due to the presence of *Microderoceras* in earlier beds - as in southern Germany where they are reported in the top of the *semicostatum* Zone. Spath (1956, p.152) came to the conclusion that, in Stowell Park, there was a break in the succession at 488.29m and that the *brooki* Subzone was unrepresented. There is no sign of such a break in the lithological log and it seems unlikely in such a generally well developed and thick mudstone sequence. For the purpose of this revision, the first record of *Microderoceras* is taken as the base of the *turneri* Zone.

However Page (1992) points out that the top of the *resupinatum* Subzone on the Dorset coast is characterized by abundant *Arnioceras*, including *A. semicostatum* (Young & Bird), (cf. Horizon 23, from Beds 71-72). In Stowell Park, Spath recorded abundant *A. semicostatum* at 497.3m. There is no sign in this borehole of abundant *Angulaticeras* above these occurrences (= *Sulciferites sulcifer* S.S. Buckman, of Horizon 24; Page, 1992).

The *resupinatum* Subzone yields several species of *Euagassiceras* with *E. resupinatum* (501.16 to 512.52m) underlying *E. spinaries* (497.4 to 500.3m). Other ammonites recorded include *Metarnioceras* aff. *subpellati* Spath at 497.6m, *Pararnioceras?* at 492.31m and an *Angulaticeras* at 491.56m. Most abundant however are taxa attributed to *Arnioceras*. Spath identified over 15 species of this genus in these beds, including a new species- *A. pseudoturneri* Spath (1956, p.151). This genus, which ranges through the *semicostatum* and *turneri* zones and into the Zone of *Asteroceras obtusum*, requires reassessment to establish clear definitions of these taxa and their ranges. [DTD additional notes if available 1994]. Other taxa present in this subzone include a *Lingula*, *Zeillera sarthacensis* (d'Orbigny), some indeterminate rhynchonellids, a more diverse spectrum of bivalves than in the previous subzone, also echinoid spines and test fragments occur, all indicate quite well aerated bottom waters.

DTD
well contribute
extra notes
Arnioceras

Zone of *Caenisites turneri* (471.80 to 488.15m)

The position of the lower boundary of this Zone has been referred to above. Taken here at the first record of *Microderoceras*, at 488.15m the zone extends upwards to the appearance of *Asteroceras obtusum* at 471.80m and is treated as subzonally 'undivided'. The macrofauna is dominated by the presence of four ammonite taxa- *Microderoceras*, including *M. birchi* above 487.22m, *Caenisites* cf. *turneri* (= *Arietites* of *turneri* group of Spath, 1956, p.152), above 487.2m, *Cymbites* sp., including *C. laevigatus*, (cf. Horizon 29 of Page, 1992). and, higher in the borehole, abundant *Promicroceras capricornoides* (Quenstedt) between 486.61m and the the top of the zone where this taxon disappears (cf. Horizon 31 of Page, 1992). *Arnioceras* occurs but is much less common than in the preceding Zone. The higher beds also yield juvenile *Xipheroceras* and some fragments, referred to as asteroceratids?, at 472.74m and 477.46m, these are considered indeterminate and left in the *turneri* Zone. A single *Angulaticeras* was found at 487.68m. The other macrofauna occurs sparsely, it includes a few rhynchonellids, a variety of small gastropods - *Ataphrus*,

Coelostylinia, *Procerithium*, *Trochoturbella*; the bivalves *Anningella*, *Grammatodon*, *Gervillia*, *Lucina*, *Modiolus*, *Palaeonucula*, *Parallelodon*, *Plagiostoma* and *Semuridia*, and also some echinoid fragments.

Zone of *Asteroceras obtusum* (444.32 to 471.80m)

The Zone of *Asteroceras obtusum* is well developed and all three subzones are proved. From the appearance of *A. obtusum* at 471.80m it extends upwards to the base of the Zone of *Oxynoticeras oxynotum* which is marked by the first record of *Oxynoticeras* sp. at 444.32m.

The oldest Subzone of *Asteroceras obtusum* is taken to be coincident with the range of the index taxon (461.52 to 471.80m). *Asteroceras* is quite common and is accompanied by *Microderoceras* up to 471.14m; *Cymbites laevigatus* (J. Sowerby) and *Xipheroceras* occur throughout, the latter genus is represented by specimens of *X. binodulatum* S.S.Buckman and *X. dudressieri* (d'Orbigny). *Arnioceras* occurs in abundance up to 468m but is not recorded above this. *Promicroceras* was not recorded in this subzone. The non-ammonite macrofauna is sparse including *Anningella*, *Bakevella*, *Gervillia*, *Lucina*, *Oxytoma* and *Semuridia*.

The overlying Subzone of *Asteroceras stellare* is less well defined as the nominal species was not recorded by Spath, he referred the *Asteroceras* present to his species *A. margaritoides* and *A. marstonense*. The subzone also contains *Xipheroceras* up to 449.96m. *Cymbites laevigatus* is present and the youngest recorded *Angulaticeras* occur between 446.07 and 446.32m. *Epophioceras* cf. *landrioti* (d'Orbigny) was found at 460.23m. *Promicroceras* reappears and is common, with numerous specimens of *P. marstonense* Spath, *P. perplanicosta* Spath, *P. planicosta* (J. Sowerby) and *P. sp.* between 458.86 and the top of the subzone (cf. Horizons 38-40, Page, 1992). The bivalve fauna is more diverse with *Anningella*, *Astarte*, *Gryphaea*, *Lucina*, *Palaeonucula*, *Parallelodon*, *Pholadomya*, *Pleuromya*, *Plagiostoma*, *Protocardia*, *Pseudopecten*, *Semuridia* and *Tutcheria*, the oldest

belemnite recorded in the borehole was found in this subzone.

\The youngest Subzone of *Eparietites denotatus* is only thinly developed. This was recognised by Spath as a separate zone but later reduced to subzone status (Spath 1942). The subzone is here treated as the range of *Eparietites* below the occurrence of *Oxynoticeras*. In Stowell Park the earliest *Eparietites* is at 445.14m, and the earliest *Oxynoticeras* at 444.32m so the subzone is only 0.82m thick (cf. Horizon s43-4, Page, 1992). Dean, Donovan & Howarth (1961, p.456) note that this subzone appears to be better developed in Yorkshire where the earlier subzones are however less well proved. On the Dorset coast it is absent due to a non-sequence. Spath identified *Eparietites* aff. *collenoti* (d'Orbigny) and *E.sp.* in Stowell Park, accompanied by *Asteroceras* → —[now *Eparietites*] cf. *impendens*, *Asteroceras* cf. *marstonense* and *Cymbites*; the youngest *Promicroceras* was found at the base of the subzone. The bivalve fauna of this unit is very sparse.

Zone of *Oxynoticeras oxynotum* (439.52 to 444.32m)

Regionally the Zone of *Oxynoticeras oxynotum* is known to be one of regression (Donovan and others 1979). The essentially basinal type sequence of dark grey mudstones in Stowell Park shows that this was a continuing area of deposition at this time and there was little change in the nature of the accumulating sediments.

The range of the zone is from the appearance of *Oxynoticeras* at 444.32m up to the appearance of *Crucilobicerias*. There are however about 0.76m of beds with *Crucilobicerias?* and *Bifericeras* sp. between 439.52m and 440.28m which are of uncertain age; they are here left in the *oxynotum* Zone giving a zonal thickness of 4.8m. In many localities the older Subzone of *Oxynoticeras simpsoni* is characterised by *Gagaticeras* (Getty 1973) whilst the younger Subzone of *Oxynoticeras oxynotum* yields the nominal index, as well as *Palaeoechioceras* and *Bifericeras* sp. Getty (in Cope and others 1980) considered that the material identified by Spath from Stowell Park as *Gagaticeras* and "*Parechioceras*" were

indeterminate eoderoceratids that did not indicate the *simpsoni* Subzone which is consequentially unproved. *Oxynoticeras* occurs from 442.87 to 444.32m with *O. aff. oxynotum* at the higher level. *Bifericeras* sp. occurs between 439.67 to 443.79m and records include a specimen each of *B. bifer* (Quenstedt) and *B. bispinatum* (Geyer). Spath's genus "*Hypechioceras*" was assigned to *Palaeoechioceras* by Getty (1973), Getty (MS) reidentified specimens in this sequence as *Palaeoechioceras spirale* (Trueman & Williams) between 440.28 and 443.86m. Spath (1956) also noted numerous specimens of his genus *Leptonotoceras* between 439.67 and 443.86m, these were placed in the genus *Gemmellaroceras* (Donovan & Forsey, 1973, Donovan, Callomon & Howarth, 1981). The absence of *Gagaticeras* leaves no clear indication of the presence of the *simpsoni* Subzone in what appears to be a continuous sequence of dark mudstones. It is possible that it is faulted out as the log records slickensides at 443m, and some core is missing. These faunal distributions do not closely coincide with the faunas of Page's Horizons 47-49 (1992).

The non-ammonite macrofauna consists of the long-ranging taxa *Chlamys*, *Gervillia*, *Grammatodon*, *Lucina*, *Oxytoma*, *Palaeonucula*, *Parallelodon*, *Plagiostoma* and *Pseudolimea*. Whilst these are not of much significance as indicators of age, their presence does suggest quite normal oxygenated bottom conditions at this time..

Zone of *Echioceras raricostatum* (389.70 to 439.52m)

This Zone is quite thickly represented at Stowell Park, its range has been defined, following Getty (1973), as from the earliest *Crucilobiceras* sp., at 439.52, up to the appearance of *Phricodoceras* at 389.70m, giving a thickness of 49.82m (Figures 1a, 1b).

Within this thickness all the four subzones of the zone can be identified, The specimens of Echioceratidae from Stowell Park were reviewed by Dr T. A. Getty in 1973 (MS notes in BGS records), some data from that study was used in his paper on the generic classification of this family (Getty, 1973) as well as

in his thesis (Getty 1972).

The oldest Subzone of *Crucilobicerias densinodulum* extends from the incoming of *Crucilobicerias* to the appearance of *Echioceras*, recorded at 421.64m, giving a thickness of 17.88m.

The fauna of these dark grey shaly and blocky mudstones is dominated by ammonites. *Crucilobicerias* occurs throughout and includes specimens of *C. densinodulum* and *C. crucilobatum*. *Bifericeras* (here used to include *Hemimicroceras* (Donovan, Callomon & Howarth 1981)), is common above 429.5m; *Gemmellaroceras* also occurs throughout and, like *Crucilobicerias*, persists not only through this subzone but throughout the zone. A late *Palaeoechioceras spirale* was recorded at 436.32m, and *Eoderoceras* occurs above 439.4m. The bivalve fauna includes *Antiquilima*, *Arcomya*, *Gervillia*, *Hippopodium*, *Mactromya*, *Meleagrinnella*, *Oxytoma*, *Palaeoneilo*, *Parallelodon*, *Plagiostoma*, *Pseudopecten*, *Rollieria* and *Ryderia*, only a single belemnite was recorded.

The Subzone of *Echioceras raricostatoides* is much thinner, extending from 421.64 up to 418.55m where the first definite *Leptechioceras* was recorded by Dr Getty. The ammonite fauna comprises three principal genera, *Bifericeras* - including *B. [H.] serpentinum*, and *B. [H.] subplanicosta*, species of *Crucilobicerias* throughout, whilst *Echioceras quenstedti* (Schafhäutl) and *E. cf. raricostatoides* Vadasz are common. Bivalves include *Astarte*, *Anningella*, *Antiquilima*, *Astarte*, *Grammatodon*, *Gryphaea*, inoceramids, *Lucina*, *Palaeoneilo*, *Palaeonucula*, *Protocardia* and *Pseudopecten* and again rare belemnites.

The Subzone of *Leptechioceras macdonnelli* encompasses the range of this genus which was found between 414.25 to 418.55m giving a subzonal thickness of only 4.3m. The dark grey mudstones have a varied ammonite fauna. There are few specifically identifiable specimens of *Leptechioceras* although the nominal taxon was identified at 415.13m and *L. nodotianum* (d'Orbigny) at 417.65m. Further specimens of *Crucilobicerias*, *Eoderoceras*, *Gemmellaroceras* and *Gleviceras* occur, *Paltechioceras edmundi*

(Dumortier) and *P. favrei* (Hug) were also recovered. The bivalve fauna is similar to that of the preceding Subzone with the addition of *Camptonectes*, *Chlamys*, *Mactromya*, *Modiolus*, *Myoconcha*, *Placunopsis* and *Tutcheria*. Some small *Piarorhynchia* were also found.

The youngest Subzone of *Paltechioceras aplanatum* comprises the remainder of the *raricostatum* Zone up to the base of the *Uptonia jamesoni* Zone at 389.70m. The sequence of dark grey mudstones and shaly mudstones contains ammonites principally characteristic of the whole *raricostatum* Zone rather than this particular subzone. Several species of *Paltechioceras* occur including *P.* cf. *aplanatum* at 406.37m, *P.* cf. *aureolum* (Simpson) at 407.28m, *P.* cf. *favrei* (Hug) at 410.55m, *P.* aff. *tardecrecens* (Hauer) at 413.61m and *P.* cf. *regularis* (Trueman & Williams) at 410.26m. These are principally late *raricostatum* Zone taxa. Other longer ranging genera are *Bifericeras*, *Eoderoceras* and *Gemmellaroceras*, this last taxon is particularly abundant in the topmost 10m of the zone. *Radstockiceras* [*Metoxynoticeras* of Spath] is recorded in the higher beds together with some other small oxynotids which were attributed by Spath to "*Hypoxynoticeras*" cf. *flavum* (Simpson) and "*H.*" cf. *limatum* (Simpson). Between 395.17 and 395.93m, there occur specimens of the rare late Sinemurian liparoceratid *Vicininodiceras simplicicosta* (Trueman), which were referred by Spath (1956) to *Liparoceras* (*Parinodiceras*) *parinodum* (Quenstedt) and *L. (P.)* sp. Donovan (1990) reidentified the *Vicininodiceras* from this, and other material, and concluded that this taxon occurs late in the *aplanatum* Subzone, just below the *jamesoni* Zone (=Horizon 61, Page 1992). Specimens of *Apoderoceras?*, found down to 393.0m, are regarded as indeterminate. The other macrofauna of this subzone is more varied than that of the underlying beds and includes *Cincta*, *Lobothyris* and *Piarorhynchia*, and a more varied suite of bivalves which include burrowing forms such as *Arcomya* and *Pholadomya* as well as surface living taxa. Belemnites are still very scarce.

PLIENSBACHIAN STAGE

Lower Pliensbachian Substage

Zone of *Uptonia jamesoni* 372.77 to 389.70m)

This Zone extends from the first record of *Phricodoceras* at 389.70m, up to the base of the *masseanum* Subzone of the overlying Zone of *Tragophylloceras ibex*. The latter is taken here at 372.77m, at the sudden appearance of the genus *Tropidoceras*; although the subzonal index species was not identified in Stowell Park (Spath 1956, Phelps 1985 fig. 5 and p.345).

The *jamesoni* Zone is divided here into three subzones. The oldest is the Subzone of *Phricodoceras taylori* which encompasses the range of *Phricodoceras* up to 382.52m; this last record is also virtually coincident with the appearance of both the earliest *Platypleuroceras* sp. and also a juvenile polymorphitid at 382.24m. The *taylori* Subzone contains numerous *Phricodoceras*, especially *P. quadricornutum* (Simpson), *P. cornutum* (Simpson) and, rarer, *P. taylori* (J. de C. Sowerby). It also yields the oldest *Apoderoceras leckenbyi* (Wright) at 382.98m, whilst the *Gemmellaroceras* aff. *peregrinum* (Haug) at 382.66m is the highest record of this genus (see Spath 1942). The subzone is represented by dark grey mudstones with a similar bivalve fauna to that of the previous zone. There are some indications of the more characteristic elements of the *jamesoni* Zone macrofauna, which often yields abundant brachiopods and belemnites. *Discinisca*, some *Piarorhynchia*, a *Rudirhynchia?*, *Lobothyris*, scarce *Pseudohastites* and other belemnites are recorded.

This is about the probable position of the "70 Marker" which, to the east, is developed as the geophysical response to the presence in the sequence of a thin series of marls and limestones, it was dated as in the base of beds of *polymorphus/brevispina* Subzone age and just above beds of *taylori* Subzone age (Horton and Poole, 1977).

For a number of years the subzones of *Polymorphites polymorphus* and *Platypleuroceras brevispina* have been combined as there seems to be no reliable method of separating them. The best developed

faunas of this age were reported from the Port More borehole in N. Ireland where the *jamesoni* Zone is over 100m thick (Ivimey-Cook and Donovan in Wilson and Manning 1978,p.82). Here it was suggested that a *brevispina* Subzone based on the combined ranges of *Platypleuroceras* and *Polymorphites* may be of value. In that borehole the range of *Polymorphites* proved to extend into younger strata than *Platypleuroceras* rather than it occurring earlier. In another very thick sequence, the 130m of *jamesoni* Zone beds in the Mochras Borehole, the ranges of the ammonite taxa have not been established in sufficient detail, there *Platypleuroceras* ranges over some 40m but the range of *Polymorphites* is not established (Ivimey-Cook 1971, fig 16). In this account, a joint Subzone based on these two taxa will be used. The upper limit is placed at the youngest *Polymorphites* at 376.48m.

The subzone yields *Polymorphites* and *Platypleuroceras* throughout, *Tragophylloceras* sp. juv. cf. *numismale* (Quenstedt) occurs at 377.78m, Howarth & Donovan (1964) show that this species ranges up from the *taylori* Subzone into the *polymorphus/brevispina* Subzones. Also present are some *Uptonia* sp. and an *U. obsoleta* (Simpson) at 378.10m. The non-ammonite fauna is considerably more diverse in these paler grey, occasionally bioturbated, grey mudstones. Brachiopods include *Spiriferina*, *Rimirhynchia*, *Piarorhynchia*, *Cincta* and *Lobothyris*. Bivalves include most of the taxa of the previous subzone and also *Myoconcha*, *Palaeoneilo* and the earliest specimens of *Laevitrigonia troedssoni* Melville at 380.7m. The gastropod *Ptychomphalus* and columnals of the crinoid *Balanocrinus subteroides* (Quenstedt) provide further indicators for more aerobic conditions close to the sedimentary surface. A few belemnites also occur.

The Subzone of *Uptonia jamesoni* is only thinly represented with 3.71m of beds between 372.77 and 376.48m. The index fossil was not found. The only ammonites recorded belong to the genus *Uptonia* and include *U. bronni* (Quenstedt), *U. confusa* (Quenstedt) and *U. regnardi* (d'Orbigny). The non-ammonite fauna is sparse; taxa found below continue upwards through these beds.

Zone of *Tragophylloceras ibex* (292.00 to 372.77m)

The overlying Zone of *Tragophylloceras ibex* extends up to 292.00m where the earliest species of *Androgynoceras* (*Androgynoceras*) occurs. These 80m of beds can be subdivided between the three subzones of this zone, there are also indications of the finer units, described by Phelps (1985, see his Fig. 5 and text, recording his assessment of the sequence in the Stowell Park Borehole). The position of the base of the zone and of the *Tropidoceras masseanum* Subzone has been discussed above, the top of that Subzone is taken at the appearance of *Acanthopleuroceras maugenesti* (d'Orbigny) at 369.87m.

The *masseanum* Subzone was divided into two zonules by Phelps (1985). The earlier Masseanum Zonule comprises beds with abundant *Tropidoceras* and below the appearance of *Acanthopleuroceras arietiforme* (Oppel), a nucleus attributed to this species was identified by Spath (1956) at 371.14m.. Spath also identified *Tropidoceras ellipticum* (J. Sowerby) and *T.* sp. in this unit; other ammonites present include *Liparoceras* aff. *cheltiense* (Murchison), *Cymbites* sp. and *Tragophylloceras* cf. *loscombi* (J. Sowerby) between 372.77 and an ammonite nucleus which Spath (1956) identified as an *Acanthopleuroceras arietiforme* at 371.14m. These 1.63m of beds of the Masseanum Zonule (371.14 to 372.77m) also yield the brachiopods *Discinisca* and *Piarorhynchia*, small gastropods including *Coelodiscus*, *Procerithium* and *Solariella*, the bivalves *Dacryomya*, *Grammatodon*, and *Parainoceramus* and the belemnite *Angeloteuthis*.

The overlying Arietiforme Zonule is recognised by the range of *Acanthopleuroceras arietiforme* which here extends up to the earliest record of *A.* sp. aff. *maugenesti* (d'Orbigny), recorded at 369.58m. These 1.56m of beds (369.58 - 371.14m) also contain *Cymbites*, *Tragophylloceras* and *Liparoceras*, the gastropod *Solariella*, and bivalves including *Dacryomya*, *Grammatodon*, *Nucula?*, *Parainoceramus* and *Ryderia*.

The succeeding Subzone of *Acanthopleuroceras valdani* ranges from 369.58m up to the base of the Subzone of *Beaniceras luridum* Subzone which was placed (Phelps 1985) at the last occurrence of *Acanthopleuroceras lepidum* Tutcher & Trueman at 333.24m, after he re-assessed the faunas from Stowell Park and recognised the presence there of the Maugenesti, Valdani, Centaurus and Lepidum zonules.

The Maugenesti Zonule spans the range of *A. maugensti*, specimens recorded as *A. aff. maugensti* occur at 369.58m, the oldest *A. maugensti* was found at 368.06m. The zonule extends up to the earliest *A. valdani* at 367.25m. Other taxa present include the earliest *Tragophylloceras ibex* (Quenstedt), immediately below the top of the zonule at 367.36m, and *Tragophylloceras cf. undulatum* (W. Smith) between 369.55 and 368.6m. The earliest *Androgynoceras (Beaniceras) senile* S.S. Buckman was at 367.3m. The fauna includes a variety of small gastropods and occasional bivalves.

The next youngest, Valdani Zonule, corresponds to the range of its nominal taxon, here found between 362.13 and 366.94m. This also covers almost all the range of *T. ibex* found here between 362.106m and 368.6m. Other *Tragophylloceras* present can be referred to *T. numismale*, specimens at 366m were identified by Spath (1956) as *T. "robinsoni"* (Simpson) (= ?*T. loscombi* (J. Sowerby) in Howarth & Donovan, 1964). The earliest *Androgynoceras (Beaniceras) sp.* was reported from 365.6m. *Piarorhynchia*, a few small gastropods and scarce bivalves are also present.

The Centaurus Zonule is related to the range of *A. (Beaniceras) centaurus*. Phelps (1985) considered this unit to be about 28m thick in Stowell Park and to extend from above the last *Acanthopleuroceras valdani*, at 362.13m, to immediately below a resurgence of *Acanthopleuroceras* at 333.45m. The ammonites from Stowell Park are quite varied but not very diagnostic-*Tragophylloceras undulatum*, *T. numismale* and *T. sp.* occur throughout, *Liparoceras sp. cf. cheltiense* (Murchison) is present at 337.74 and 361.72m; several poorly preserved *Beaniceras* may be compared with *B. costatum* S. S. Buckman, *B. crassum* S. S. Buckman and *B. senile* S. S. Buckman, which suggests this horizon.

Spath (1956) also recorded *Tropidoceras stahli* (Oppel) at 355.85m and *T. aff. actaeon* (d'Orbigny) at 335.00m. These ammonites are accompanied by a diverse fauna of gastropods, bivalves, some brachiopods, belemnites and crinoids, they include several new taxa which are listed and described by Melville (1956).

The youngest, *Lepidum Zonule*, of this subzone was defined by Phelps (1985) as the range of *Acanthopleuroceras lepidum*, which was revised to include *A. calliplocoides* Spath (Phelps 1982). This taxon was identified in Stowell Park between 333.45 and 333.24m; it yielded ammonites which Spath (1956) identified as *Tropidoceras*, including *T. aff. actaeon* and *T. calliplocoides* Spath, together with a small number of bivalves.

The approximate position of the geophysical response named the "85 Marker", is indicated on Figure 1b, it was identified in the Upton Burford borehole where there are calcareous mudstones and limestones forming a thin unit within the mudstone dominant sequence. It was dated as about late *valdani* Subzone in age and was be traced north and eastwards (Horton and Poole, 1977).

The highest Subzone of the *ibex* Zone is that of *Beaniceras luridum*. It has been used for beds containing the index and "allied" species of *Beaniceras* which span the interval between the last occurrence of *Acanthopleuroceras* and the appearance of *Androgynoceras* (*s.s.*). Phelps (1985) redefined it to contain three (*Rotundum*, *Crassum* and *Luridum*) zonules based on nominal species of *Beaniceras*. He reidentified the material from Stowell Park and gave the following approximate ranges for these zonules (Phelps, 1985, fig.5), these have been metricated with the assistance of the known specimen depths. He identified the *Rotundum* Zonule between c.322.7m and c.333m; the *Crassum* Zonule from c.314m to c.322.7m; [unattributed c.308 to c.314m]; the *Luridum* Zonule c.302 to c.308m; [unattributed up to the base of the *davoei* Zone which he placed at 292.00m]. In the *Rotundum* Zonule he records *Beaniceras rotundum* S. S. Buckman between 330.84 and 331.92m, also *B. rotundum* trans. *crassum* S. S. Buckman at 322.70m. Above, he records *B. crassum* between 314.58 and 322.70m, indicating the *Crassum* Zonule but not its upper

boundary. Higher up *B. luridum* (Simpson) and *B. ?luridum* are recorded between 302.42 and 308.45m, representing part of the Luridum Zonule.

Other ammonites present in the *luridum* Subzone include *Tragophylloceras* which is present throughout and includes *T. cf. undulatum* between 322.81 to 324.33m and *T. aff. ibex* at 322.02m, *Liparoceras* including *L. cf. cheltiense* (Murchison) between 317.19 and 330.50m, "*L.*" *cf. geyeri* Spath at 324.06 and *L. cf. rusticum* Spath at 325.06..

*JDS geyeri may
not be Liparoc*

The non-ammonite fauna is dominated by a diversity of bivalves, and also rare rhynchonellids, also some echinoderms and crustaceans (Melville 1956).

The geophysical "100 Marker", which has been traced extensively in north Oxfordshire, relates to a thin unit of limestones, calcareous mudstones and locally rather pyritic beds which appear to overlie a minor non-sequence. The sharp peak in the resistivity log may relate to the non sequence. It appears to occur at about the base of the *maculatum* Subzone and may assist in determining the amount of erosion of the underlying *luridum* Subzone (Horton and Poole, 1977).

Zone of *Prodactylioceras davoei* (256.06 to 292.00m)

The range of the Zone extends from the appearance of *Androgynoceras* (*s.s.*) to the appearance of *Amaltheus*. In this borehole the zone is 35.94m thick. It is divided into three subzones - from below those of *Androgynoceras maculatum*, *Aegoceras capricornus* and *Oistoceras figulinum*. Phelps further subdivides these subzones into 6 zonules and illustrates their distribution in Stowell Park (Phelps, 1985, fig.5).

The Subzone of *Androgynoceras maculatum* is regarded as the range zone of *Androgynoceras sparsicosta* (Trueman) and *A. maculatum* (Young & Bird). The former taxon also indicates the Sparsicosta Zonule at the base of the zone. Phelps identified specimens,

recorded by Spath (1956) from between c.288m and 292.0m as *A. cf. heterogenes* (Young & Bird), *A. maculatum* and *A. aff. maculatum*, as ?*A. sparsicosta* (Trueman) and so probably indicating his Sparsicosta Zonule which was also proved higher in the borehole, at about 287m, with further specimens of *A. sparsicosta*. This suggests a thickness of about 5m for the zonule (not 10m as in Phelps 1985, p.351). Late forms of *Beaniceras* are also present. The overlying Maculatum Zonule was indicated at 282.61m by *A. maculatum* but its range is not well proved in either the lower or the higher parts of the subzone which extends up to the record of *Aegoceras capricornus* at c. 275m (Phelps 1985). The diverse bivalve fauna and the other macrofauna present in this subzone is detailed by Melville (1956)

Phelps (1985) redefined the Subzone of *Aegoceras capricornus* in terms of two zonules; it extends from c.275m to the earliest occurrence of *Oistoceras* at 267.37m, his concept of this latter subgenus however excluded *Aegoceras crescens* (Hyatt) which was formerly considered an *Oistoceras* (Dean, Donovan & Haworth 1961). Phelps divided the subzone into a lower, Capricornus Zonule extending up to the first record of *A. crescens* at about 270m, and a higher, Crescens Zonule, identified with the range of this species. In Stowell Park, Phelps (1985, fig.5) re-identified material from between 268.5 and 270.1m, which was attributed by Spath (1956) to *A. artigyrus* and *A. capricornus*, to *Aegoceras crescens*. Spath had recorded "*Oistoceras crescens*" only from 267.6m.

The Subzone of *Oistoceras figulinum*, is the youngest subzone in the Lower Pliensbachian (Carixian); it includes the continuation of the range of the aegoceratid ammonites up to the appearance of *Amaltheus*. This comprises a thickness of 10.94m of beds between 256.06 and 267m. Phelps (1985) further refined the sequence by defining two zonules. In Stowell Park, the lower, Angulatum Zonule, contains *Oistoceras angulatum* trans. *crescens* at the base and *O. angulatum* trans. *figulinum* at 264.9m. Above these are about 6m of beds not placed in either zonule, and then

beds attributed to the Figulinum Zonule which, between 257 and 258m, yielded *Oistoceras* sp. and *O. figulinum* trans. *angulatum* (Phelps, 1985, fig.5). The highest *Oistoceras* was recorded at 257.39m; this is 1.33m below the earliest *Amaltheus* at 256.06m.

Bivalves and other taxa from the *davoei* Zone were recorded and described by Melville (1956). Few of these taxa are of significance in assessing the zonal age of these beds, although combinations of taxa can be of local value.

Upper Pliensbachian Substage

In Green & Melville (1956) and Melville (1956), the beds between 257.25 and 220.5m are attributed to the "Middle Lias". These comprise an upper unit of grey and brownish-grey shell fragmental limestones and oolitic limestones, 1.8m thick, overlying almost 35m of sandy and shaly siltstones with some horizons of conglomerate - the Middle Lias Silts and Clays (Horton and others 1987). These arenaceous and calcareous beds coincide approximately with the period of dominance of the Amaltheidae. Ammonites of the genus *Amaltheus* are later joined by *Pleuroceras* and species of these two genera define the two zones and the component subzones of this substage.

Zone of *Amaltheus margaritatus* (c. 226 to 256.06m)

The Zone of *Amaltheus margaritatus* comprises those horizons with *Amaltheus* prior to the appearance of *Pleuroceras*. It is divided into three subzones named after the dominant species of *Amaltheus* in each - from below the *A. stokesi*, *A. subnodosus* and *A. gibbosus* subzones.

The base of the Subzone of *Amaltheus stokesi* is coincident with the base of the *margaritatus* Zone at 256.06m at which level *A. stokesi* (J. Sowerby) is recorded. This subzone extends up to about 242.95m. It also contains *Arietoceras* sp. at 253.56m, *Liparoceras* (*Becheiceras*) *nautiliforme* (J. Buckman) at 256.00m together with various small and juvenile amaltheids. Phelps

(1985) examined material from this subzone and concluded that there was evidence for the presence of his *Bifurcus* Zonule up to about 245.7m and for his, overlying, Wertheri Zonule between this level and 242m.

Higher beds in the Middle Lias yield a small number of poorly preserved *Amaltheus* cf. *subnodosus* (Young & Bird) between 226.16 and 241.55m, an *A.* cf. *margaritatus* de Montfort at 232.3m, *Lytoceras furcicrenatum* (J. Buckman) at 241.1m and *Amauroceras?* occurs between 241.8 and 241.98m. The subzone probably extends through these 16m, it may continue to above 226m, but no younger ammonites were recovered in the Middle Lias.

There is no evidence for the presence of the Subzone of *Amaltheus gibbosus*. Beds of this age are often absent in the non-sequences which are quite widespread at the base of the Marlstone Rock Formation, however Simms (1990) has found evidence of this subzone in Nottingham Hill [SO 98 29] and at Stanley Hill [SP 010 298], which are 20Km north-west of Stowell Park in Gloucestershire, There is no evidence for the ammonite zonal age of the beds between c.226 and 222.27m.

The non-ammonite fauna of these beds is listed by Melville (1956). The abundant bivalve fauna is supplemented by occasional gastropods, belemnites and crinoids. Some changes in the genera present may reflect the more arenaceous substrates available for colonization.

Zone of *Pleuroceras spinatum* (c. 220.50 and c.222.27m)

The Marlstone Rock Formation is only 1.8m thick in Stowell Park where it occurs between 220.50 and 222.27m. It thickens north and northeastwards, but is generally thinner, under 1m, to the north-west, in the hills around Cleeve Hill (Simms 1990). The Marlstone thickens again into Bredon Hill where, in the Lulu Barn Borehole, it was 6.02m thick, although here including a basal unit of 2m of sandstone, here it yielded *Pleuroceras spinatum* (Whittaker and

Ivimey-Cook, 1972). Ammonites found in the highest part of the Marlstone, particularly farther east, show that deposition of these calcarenitic and oolitic sediments continued into the earliest part of the Toarcian (Howarth 1980).

Simms (1990) records sections in beds of the *spinatum* Zone from a number of Marlstone sequences to the north-west of Stowell Park. He records evidence of both subzones of this zone in Oxenton Hill [SO 97 31], whilst Nottingham Hill [SO 98 29] yields *Pleuroceras* of the *hawskerense* Subzone, in Stanley Hill [SP 010 298] reworking within the Marlstone has produced an apparently inverted subzonal sequence.

The geographical and sequential distribution of the brachiopod faunas of the Middle Lias, and particularly of the Marlstone, were interpreted by Ager (1956). However Stowell Park yielded only a few specimens of *Gibbirhynchia micra* Ager, *Rudirhynchia* and *Tetrarhynchia* in addition to a small fauna of bivalves and some belemnite fragments, these give little information about its age.

TOARCIAN STAGE

In the Toarcian amaltheid faunas are displaced by genera of the Hildocerataceae and also numerous Dactylioceratidae. In Stowell Park the Lower Toarcian zones of *Dactylioceras tenuicostatum*, *Harpoceras falciferum* and *Hildoceras bifrons* are proved but above this, in the upper 12m of more sandy beds, age diagnostic elements in the faunas become very sparse. Dr M. K. Howarth re-examined the ammonites from Stowell Park and gave a summary of his results in Cope and others (1980 (T10)) these are amplified here. Howarth (1992, p.5-6) further reviews and refines the biostratigraphic sequence in the Toarcian with definitions of the bases of the subzones from localities on the north Yorkshire coast and revises the taxonomy of the Hildocerataceae..

Zone of *Dactylioceras tenuicostatum* (219.42 to c.220.50m)

The lowest 1m of dark calcareous shales, between 220.50 and

219.42m, rest on the Marlstone Rock and are attributed to this Zone. They contain *Tiltoniceras antiquum* (Wright) between 219.89 and 219.99m and *Dactylioceras* cf. *semicelatum* at 219.84m as well as further *Dactylioceras* sp. These taxa identify these beds with the *D. semicelatum* Subzone. There is no evidence here of beds representing any of the earlier subzones of this zone, these could be represented in the uppermost part of the Marlstone or be unrepresented -in the non-sequence at the base of the Upper Lias. Other taxa in these dark mudstones include small brachiopods, including *Nannirhynchia* cf. *pygmaea* (Morris) and *Gibbirhynchia* cf. *tiltonensis* Ager.

Zone of *Harpoceras falciferum* (c. 207.79 to 219.42m)

The overlying 'paper shales and fish-beds' are typical of the lower part of the Zone of *Harpoceras falciferum*. This thickness of 11.62m can be divided between the two subzones of this zone

The lower 5m (214.42 to 219.42m) comprises the Subzone of *Cleviceras exaratum*. This subzone is characterized by the ranges of three successive ammonites : *Eleganticeras elegantulum* (Young & Bird) in the lower part, *Cleviceras exaratum* (Young & Bird) in the middle part and *Cleviceras elegans* (J. Sowerby) in the upper part; *Harpoceras serpentinum* (Schlotheim) and *Hildaites* also occur (Howarth 1992, p.6). There is no evidence in Stowell Park for the presence of the earliest beds of the subzone as no *Eleganticeras* were confirmed. The earliest ammonites are referred to *Cleviceras exaratum*, which identifies the middle unit, from 219.42m up to 218.4m; they are succeeded by *Cleviceras elegans* recovered from between 215.31 and 218.2m proving the uppermost unit. Other ammonites present include *Harpoceras serpentinum* (Schlotheim) between 216.3 and 217.7m, confirming that it is a taxon from about the middle of the *exaratum* Subzone (Howarth 1992, p.117), and also *Dactylioceras* sp. Other macrofossils present are much scarcer than the ammonites although gastropods including locally abundant small *Coelodiscus*, *Dicroloma* and *Procerithium* occur, bivalves include *Grammatodon*, *Isodonta?*,

Lucina, *Parallelodon* (*Catella*), *Parvamussium*, *Pseudomytiloides* and *Steinmannia* are recorded; there are also some *Eodiadema* and fish fragments.

The Subzone of *Harpoceras falciferum* is proved above 214.42m. The subzone is characterised by *Harpoceras falciferum*, *Orthildaites* and other early species of *Hildoceras*, species of *Ovaticeras*, *Hildaites*, *Dactylioceras* and *Nodicoeloceras* (Howarth 1992, p.6). The boundary with the overlying *commune* Subzone of the *Hildoceras bifrons* Zone, is poorly marked, it has been taken here at 207.79m where a *Pseudolioceras* sp. was recognized, this genus is generally indicative of the *bifrons* and later zones. The 6.3m of beds below the boundary contain abundant *Harpoceras falciferum* (J. Sowerby), however this species persists, as virtually the sole species of this genus, throughout the *falciferum* Subzone and *commune* Subzone of the *bifrons* Zone above. *Dactylioceras*, including *D. anquiforme* (S. S. Buckman) occurs in the *falciferum* Subzone, also *Hildaites murleyi* (Moxon) at 213.13m and *Nodicoeloceras multum* S.S. Buckman at 212.50m and *N.* sp. above this depth. Only a very sparse bivalve fauna is present with *Grammatodon*, *Meleagrinnella substriata* (Munster), *Pseudomytiloides dubius* (J. de C. Sowerby) and *Propeamussium pumilum* (Lamarck), with rare belemnites.

Zone of *Hildoceras bifrons* (c. 130.65 to c.207.79m)

The zone is about 77m thick, between about 207.79m and the highest record of *Hildoceras* at 130.65m, these beds become increasingly arenaceous upwards.

The Zone comprises the subzones of *Dactylioceras commune*, *Peronoceras fibulatum* and *Catacoeloceras crassum*.

Characteristic ammonite taxa of the *commune* Subzone (Howarth op.cit) are *Dactylioceras commune* (J. Sowerby) - which is confined to the Subzone, *Hildoceras laticosta* Bellini (formerly *H. sublevisoni* Fucini), and *H. lusitanicum* Fucini. *Harpoceras falciferum* and *Nodicoeloceras* also occur. The *commune* Subzone in Stowell Park is poorly proved as the nominal species was not

identified. The top of the Subzone has been taken immediately below the earliest *Peronoceras* at 180.42m giving the subzone a thickness of 27.37m. These beds contain *Dactylioceras* cf. *praepositum* at 196.77m, *Harpoceras falciferum* up to 207.79m, and *Harpoceras* sp. above, *Hildoceras laticosta* at 207.79m and some *Hildoceras* sp. The bivalve fauna is very restricted with *Dacryomya*, *Lucina* and *Steinmannia*, also a variety of crustacean remains.

The *fibulatum* Subzone is "characterized by species of *Peronoceras* throughout the Subzone, especially *P. fibulatum* (J. de C. Sowerby); *Zugodactylites* is also common in some areas and *Porpoceras* occurs in the upper part of the subzone, *Harpoceras soloniacense* and *H. subplanatum* (Oppel) are present in some areas and the first *Phymatoceras* occurs in this subzone" (Howarth op. cit). In Stowell Park these characters suggest that the lower boundary of the *crassum* Subzone should be placed at 173.73m, so the *fibulatum* Subzone spans the recorded range of *Peronoceras*. *Peronoceras turriculatum* and *P. sp.* were found between 173.73m and 180.42m giving a thickness of 6.69m for this subzone. *Hildoceras bifrons* (Bruguière) occurs above 177.66m. The other macrofauna is confined to *Dentalium*, *Lucina*, *Palaeoneilo* and *Propeamussium*.

According to Howarth (1992, p.6) the *crassum* Subzone is "characterized by *Catacoeloceras*, which replaces *Porpoceras* of the *Fibulatum* Subzone. *Phymatoceras* occurs occasionally, but *Haugia* does not appear until the overlying *Variabilis* Zone". In Stowell Park other taxa have to be used to identify this subzone. Poorly preserved dactylioceratids occur in these beds and also a *Pseudolioceras?* at 171.0m, but the principal ammonites are *Harpoceras* and *Hildoceras*. *Harpoceras* cf. *subplanatum* (Oppel) was identified by Dr Howarth between 157.4 and 161.77m, he suggests that this taxon died out in the top of the *fibulatum* Subzone or in the *crassum* Subzone leaving no successors (Howarth 1990, p.140-1). *Hildoceras bifrons* continues its range up from the *fibulatum* Subzone up to 157.04m; *Hildoceras semipolatum* S. S.

Buckman was also identified at 158.95 and a *H. cf. semipolatum* at 130.65m. This latter specimen is taken as the upper limit to both the *crassum* Subzone and the *bifrons* Zone. Within this subzone there is a diverse fauna of other mollusca with a wide range of bivalves, including *Myophorella (Scaphotrigonia) literata* (Young & Bird) at 130.75m, also several taxa of gastropods, occasional *Acrocoelites* and also crustaceans.

The biostratigraphy of the higher beds cannot be analyzed from the ammonites as only one further ammonite was recovered - a *Hammatoceras?* from 122.37m. This ammonite indicates a broadly "post-*variabilis*" Zone age, Spath (1956) however considered the specimen was from the *Phlyseogrammoceras dispansum* Subzone of the *Dumortieria levesquei* Zone. It was found about 4m below the top of the Lower Jurassic, taken here at 118.63m. The base of the Middle Jurassic was taken below a bed of grey-brown calcareous sandstone which yielded a *Leioceras* sp. at 117.62m, indicating the Scissum Beds of the Lower Inferior Oolite. The upper beds of the Lower Jurassic consist of grey silty-sandy beds, with two horizons rich in chamosite, some dark grey-black, pyritous sandy-shale and a thin conglomeratic layer at 130.83m. Their macrofauna is quite sparse (Melville 1956) and not diagnostic. They can be referred to the Cotteswold Sands, there is no sign here of a "Cephalopod Bed" developed at the top. The Cotteswold Sands decrease in thickness to the north-east and are not found in the Chipping Norton area (Horton and others, 1987). To the north-west 8.28m of dark grey silty-clays, thin limestones and some yellowish sand interbeds was proved in the Lalu Barn Borehole on Bredon Hill, elsewhere in Bredon Hill there is evidence of the highest three zones of the Toarcian, but only the *aalensis* Subzone was proved was proved in Lalu Barn Borehole (Whittaker & Ivimey-Cook, 1972). To the west Richardson (1930) records a well on Leckhampton Hill where *Haugia*, indicating the *variabilis* Zone, was found within 4m of the top of the Cotteswold Sands;

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H. C. Ivimey-Cook

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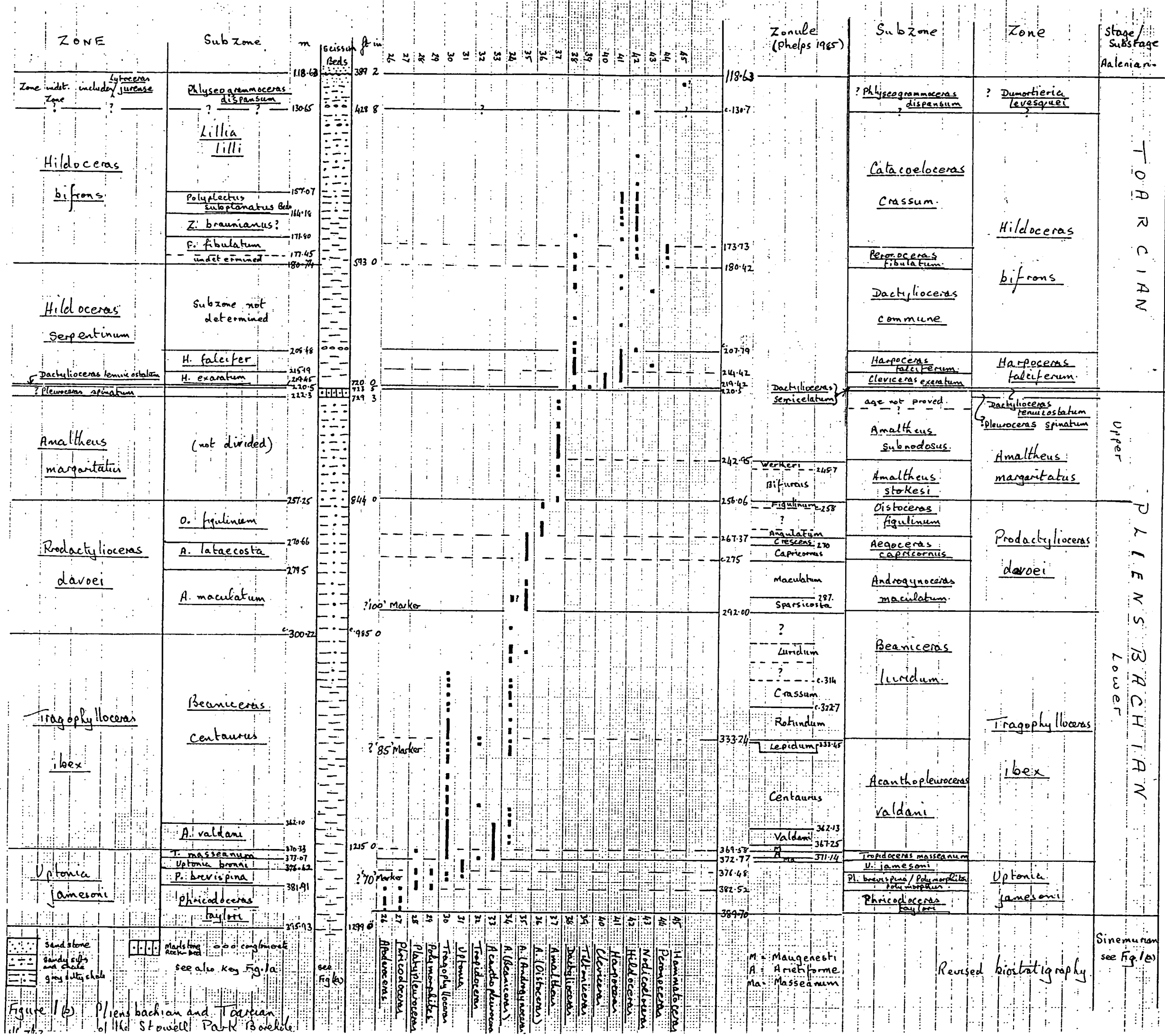


Figure 1(b) Pleistensbachian and Torrician of the Stowell Park Borehole

Revised biostratigraphy

Sinemurian see Fig. 1(a)

M = Maugestii
A = Arietiforme
Ma = Masseanum