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Up a Bathonian backwater – a review of the ammonite evidence for correlating sequences with interdigitating non–marine facies in central and northern England

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(With 4 figures)

In southern England, Bathonian ammonite sequences are relatively complete and show a strong affinity with those recorded in Submediterranean Province areas, such as eastern France and north eastern Spain. From Oxfordshire, in southern central England, however, to North Yorkshire, north–east England, a gradual replacement of normal marine deposits by non–marine and quasi– or restricted marine facies inevitably leads to a corresponding decrease in the ammonite occurrence. Despite the general absence of these key guide fossils, there have been various attempts to correlate central and northern English Bathonian facies using other fossil groups such as brachiopods, ostracods and dinoflagellates. Lithostratigraphical correlation inevitably predominate, however. Further north into East and North Yorkshire, and ultimately Scotland no Bathonian ammonites are known, an inevitable consequence of the virtual absence of any marine influence within regions dominated by fluvial sedimentation. This belt of non–marine facies completely separates a typical Northwest European [ammonoid] Province, from the Boreal Sea to the north. A review of the known ammonite occurrences in central and northern Britain region is provided, including taxonomic and stratigraphical revisions of ammonite faunas described by previous authors, in particular W J. ARKELL in a classic monograph.

This revision is used, in combination with stratigraphical information derived from other fossil groups, to present a provisional revised correlation of Bathonian lithostratigraphical units in central and eastern England (Oxfordshire to East Yorkshire).

Introduction

Bathonian sequences from Oxfordshire, southern central England, to North Yorkshire, north–east England, show a gradual replacement of normal marine deposits by non–marine and quasi– or restricted marine facies. Inevitably there is a corresponding decrease in the occurrence of marine stratigraphical indices, especially ammonites, with records gradual disappearing northwards.

First to disappear are Lower and Middle Bathonian ammonite faunas, with Zigzag to Morrisi chronozone assemblages (*Zigzagiceras*, early species of *Procerites*, *Tulites*, etc) which are apparently unknown north of Oxfordshire. Upper Bathonian records persist, with *Homoeoplanulites* of the Retrocostatum Chronozone, present in Northamptonshire and *Procerites* from similar levels last recorded in south Lincolnshire. The northernmost Bathonian ammonite faunas belong to the Discus Subchronozone (Discus Chronozone) of the terminal Bathonian, with both *Clydoniceras* and *Homoeoplanulites* known in central Lincolnshire. Further north into East and North Yorkshire, and ultimately Scotland no Bathonian ammonites are recorded, obviously linked to the virtual absence of any marine influence within regions dominated by fluvial sedimentation.

Ammonites only return in the Lower Callovian, within the shallow marine facies of the Fleet Member of the Abbotsbury Cornbrash Formation, but even then the lowest subchronozone of the substage (Keppleri Subchronozone, Herveyi Chronozone) is missing in more northern areas within a non sequence (PAGE 1986). This belt of non–marine facies completely separates a typical North West European [ammonoid] Province, from the Boreal Sea to the north, even though marine facies with Boreal Province, Bathonian cardioceratid faunas are already known in the southern North Sea (CALLOMON 1985). Further south in England, ammonite sequences are more complete and formed the basis of the review of

PAGE (1996), subsequently integrated within the proposed Submediterranean Standard Zonation of PAGE & MELÉNDEZ (1999).

Despite the general absence of suitable guide fossils, there have been various attempts to correlate central and northern English Bathonian facies, most notably by TORRENS (1969; 1980). Litho–stratigraphical correlations inevitably predominate, including the identification of correlatable sedimentary cycles in both marine and non marine / quasi marine facies. Other fossil groups, including brachiopods (e.g. in DOUGLAS & ARKELL 1932), nereneid gastropods (e.g. in BARKER 1994), ostracods and dinoflagellates are also locally useful (Sleaford memoir).

A review of the known ammonite occurrences in central and northern Britain region is provided below, including taxonomic and stratigraphical revisions of ammonite faunas described by previous authors, in particular by W. J. ARKELL in his classic monograph of English Bathonian ammonite faunas (1951–1958). This revision is used, in combination with stratigraphical information derived from other fossil groups, to present a revised correlation of the complex lithostratigraphy of the Bathonian in central and eastern England (Oxfordshire to East Yorkshire), the northern–most backwaters of the North West European Province.

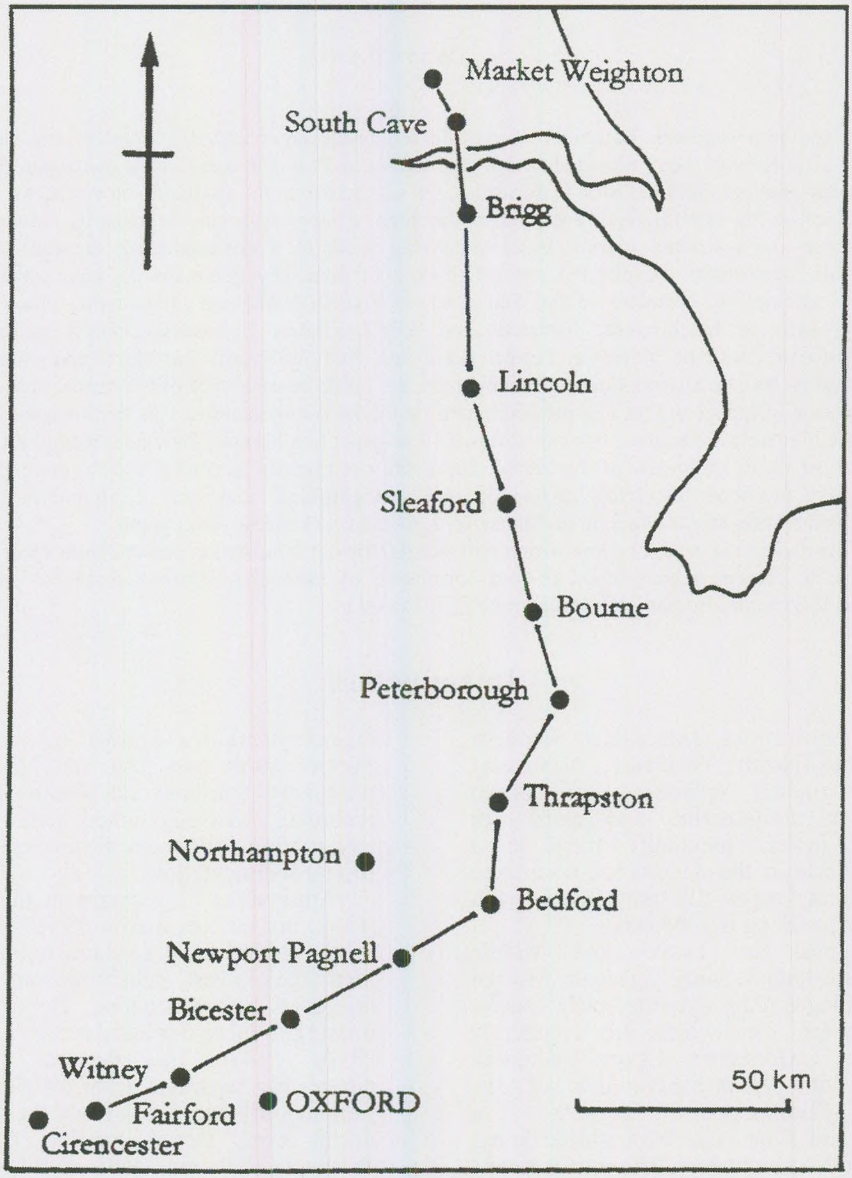

Figure 1· Central and northern England, showing major towns and the line of the section of Figure 3.

Bathonian ammonite faunas of central and northern England

The following review and discussion utilises the standard zonation of PAGE & MELÉNDEZ (1999). * indicates the source of a type specimen of a nominal species.

(a) *Upper Bajocian, Parkinsoni Chronozone, ?Bomfordi Subchronozone*: Evidence of the upper part of the Bajocian is last recorded in southwestern Oxfordshire in the Hook Norton district. ARKELL records and figures *Parkinsonia* ["*Durotrigensia*"] cf. *crassa* NICOLESCO apparently from the lowest part of the Chipping Norton Limestone (i.e. in the Hook Norton Limestone Member) of Workhouse Quarry at Chipping Norton (ARKELL 1951–1959, p. 162, text fig. 58 (right hand figure), 163). The Bajocian rather than Bathonian age of this fauna was later confirmed by TORRENS (1968, p. 228;1969c, p. 75). This specimen, if correctly interpreted, is very important as it indicates that the Chipping Norton Limestone Formation, at least locally, extends down into the Upper Bajocian and hence includes the Bajocian–Bathonian boundary (the formation is often restricted to the upper part of the Zigzag Chronozone, e.g. in SUMBLER et al.2000, table 12).

(b) *Lower Bathonian, Zigzag Chronozone, Convergens Subchronozone*: A number of sites in the North Cotswolds, spanning the Gloucestershire–Oxfordshire border have yielded rare ammonites of early Bathonian, Zigzag Chronozone age from the Chipping Norton Limestone Formation. Faunas of the Convergens Subchronozone appear to be the most frequent and include *Parkinsonia subgaleata* S. BUCKMAN at both Eyford and Longborough, near Stow–on–the–Wold (ARKELL 1951–1958, p. 160). *Parkinsonia*. sp. cf. ?*pachypleura* S. BUCKMAN from a "coarse shelly brownish oolite with many broken *Ostrea* cf. *acuminata*" at Fulwell Quarry, near Enstone (ARKELL 1951–1958, p. 150), would also be of a similar age, as possibly is the *Parkinsonia* (sp.) recorded by SUMBLER et al. (2000, p.56) from between Aston Blank and Clapton.

The *Trigonia signata* Bed at the top of the Hook Norton Limestone Member in Workhouse Quarry, Chipping Norton has also yielded, according to ARKELL (1951–1958), *Parkinsonia* (*Gonolkites*) *subgaleata* S. BUCKMAN (p.160) and the closely related **P.* (*Durotrigensia*) *oxonica* ARKELLL (p. 160–162, text fig. 39 = Holotype), in association with *Procerites subprocerus* (S. BUCKMAN), (p. 185). *Procerozigzag pseudoprocerus* (S. BUCKMAN) is also recorded here (ARKELL 1951–1958, p. 181), suggesting that higher levels in the quarry (in the Chipping Norton Limestone Member) are of Macrescens Subchronozone age. The locality is described by ARKELL (1947, p.32) and noted by TORRENS (1968, p. 228; 1969c, pp. 74–5).

(c) *Macrescens Subchronozone*: *Zigzagiceras* (*Procerozigzag*) *pseudoprocerus* from the Chipping Norton Limestone of Hook Norton Workhouse Quarry (ARKELL 1947, p. 32; TORRENS 1969c, p. 74; 1980, p. 39), indicates the Macresecens Subchronozone, as at Workhouse Quarry, Chipping Norton, as noted above, presumably also in Chipping Norton Limestone Member facies. *Oppelia limosa* (S. BUCKMAN) from Oakham Quarry, near Great Rollright and Lower Swell near Stow–on–the–Wold (ARKELL 1951–1958, p. 61 and pl. 6, fig. 5; TORRENS 1969c, p. 74) is likely to represent a Zigzag Chronozone species, but without associated parkinsonids or perisphinctids cannot be reliably assigned to any subchronozone.

Northwards and eastwards from the Hook Norton–Chipping Norton district there are no further records of Zigzag Chronozone ammonite faunas, although field mapping evidence suggests that the lowest member of the dominantly quasi–marine Rutland Formation (the Stamford Member) may be a lateral equivalent of the Chipping Norton Limestone Formation (M. SUMBLER pers. comm., 2001).

(d) *Zigzag Chronozone, Yeovilensis Subchronozone to Progracilis Chronozone, Orbignyi Subchronozone*: There are no clear records of this interval, and indeed the earlier part of the Zigzag Chronozone, from Oxfordshire north–eastwards – lithostratigraphical relationships suggesting that this is in part due to the presence of either quasi–marine facies (as indicated above) and possibly also a non–sequence between the basal Stamford Member of the Rutland Formation (previously known as the "Upper Estuarine Series"; TORRENS 1980, etc) and younger units.

(e) *Progracilis Chronozone, Progracilis subchronozone*: In the North Cotswolds, the development of fissile calcareous sandstones, suitable for use as roofing tiles, in the Eyford Member of the Fuller's Earth [or "Sharps Hill"] Formation, led to an important historical industry.

These "Cotteswold Slates" have yielded a characteristic fauna of the Progracilis Subchronozone from a number of localities, including from Eyford (with **P vineta* ARKELL 1951–1958; p. 203, pl. 27, fig. 4, text figure 72.7 = Holotype; *P.* aff. *progracilis*, text fig. 72.3, pl. 28.1; *Procerites progracilis* (COX and ARKELL) 1951–1958, p. 199; **P. mirabilis* ARKELL, 1951–1958, p. 201, 203, text fig. 75, = Holotype, text fig. 72.5, pl. 27, fig. 3, pl. 28, fig. 9; and **Oxycerites oxus* (S. BUCKMAN), ARKELL 1951–1958, text fig. 16.2, pl. 6, fig.8 = Holotype. SAVAGE 1963, p. 181; TORRENS 1969c, p;. 71–72; SUMBLER et al. 2000, p.58), Huntsman Quarry, Naunton (section described by RICHARDSON 1929, p. 114: with *P mirabilis*, ARKELL 1951–1958, p. 201, pl. 28, fig. 8; TORRENS 1969c, p. 72; ARKELL also records *P.* aff. *vineta* ARKELL from "Naunton", (p. 203, pl. 28, figs. 5), although notes that this small specimen could also be a "young *Choffatia*" (= *Homoeoplanulites*), Kiveton Thorns Quarry to the north of Naunton (with *P.*cf. *progracilis,* TORRENS 1969c, p.72) and from a temporary excavation northwest of Hazleton ("a large *Procerites*"; SUMBLER et al. 2000, p. 58).

Similar faunas are also known from the lithologically similar "tilestone" facies of the geologically famous "Stonesfield Slate" of Oxfordshire, a facies developed at at least four sucessive levels in the Taynton Limestone Formation (*sensu* SUMBLER 1999), as demonstrated by BONEHAM & WYATT (1994, although these authors divide the unit into separated Taynton Limestone and Charlbury formations). This sampling of a greater number of levels could account for the apparently greater diversity of the ammonite fauna from Stonesfield, when compared to that of the Eyford Member of the Cotswolds although the more extensive development of mines around Stonesfield, and a longer and more intensive period of working could also be significant. BONEHAM & WYATT believed that the typical Progracilis Chronozone ammonite fauna came from levels solely within their restricted Taynton Limestone Formation, obviously influenced by records by TORRENS (1980, p. 38), although they were unable to provide further proof through direct observation.

The fauna of the tilestone facies at Stonesfield includes: *Procerites progracilis* COX and ARKELL (ARKELL 1951–1958, p. 199), *P.* cf. *progracilis* (= pl. 27, fig. 5, pl. 28, fig. 3, 4), *P. mirabilis* ARKELL (pl. 28, fig .6), **P. magnificus* ARKELL (p. 201, 203, pl. 27, fig. 6 = Holotype, text fig. 72.5), **Micromphalites micromphalus* (PHILLIPS), (1951–1958, p. 47, pl. 4, figs. 1–6, fig. 4 = Lectotype), * "*Clydoniceras*" *tegularum* ARKELL (1951–1958, p. 42, pl. 4, fig. 7, text fig. 7.1 = Holotype – the specimen is very worn, however, and the apparently simplified *Clydoniceras*–like suture could be simply an artefact of this abrasion; generic assignment must therefore be considered tentative), *Oppelia* cf. *limosa* (S. BUCKMAN) ARKELL 1951–1958, p. 61, pl. 6, fig. 6) and "*Paroecotraustes*" *formosus* ARKELL (1951–1958, p. 22, pl. 8, figs. 8–10).

The Taynton Stone Formation has also yielded an apparently similar Progracilis Subchronozone fauna, with *P. mirabilis* Arkell (TORRENS 1968, p. 232; 1969c, p. 73; 1980, p. 38) and possibly also *P. progracilis* (ARKELL, 1951–1958, p. 199, text fig. 74) from Slade Quarry, Salperton, *Procerites* sp. at Snowshill Quarry (TORRENS 1968, p. 253; 1969a, p. 16) and *Procerites* "cf. *tmetolobus*" at Farmington Quarry (SUMBLER et al. 2000, p. 60).

**Procerites* ["*Zigzagites*"] *imitator* (BUCKMAN) from near the base of the Hampen Formation of Fritwell cutting near Bicester (TORRENS 1980, p. 385; ARKELL 1951–1958, 173 p. 192, 193, pl. 26, fig. 2, text fig. 69.2) appears to represent a post–*progracilis* fauna. The species is also recorded from the Acuminata Beds immediate below the Fullers Earth Rock of Somerset (TORRENS 1980, p. 385; ARKELL 1951–1958, pp. 173 ,192, 193), although records from higher horizons, such as the Twinhoe Ironshot Member, certainly include forms belonging to different species and possibly even genera (PAGE 1996, e.g. ARKELL, 1951–1958, pl. 26, fig. 3). The type section of the Hampen Formation has been redescribed by SUMBLER (1996) and a second *Procerites* from the Formation, at Northleach, recorded by SUMBLER et al. (2000, p. 60).

(f) *Subcontractus Chronozone*: The Sub–contractus Chronozone is clearly proved from Oxfordshire southwestwards, by the presence of *Tulites* ex grp. *modiolaris* (W. SMITH) in the Shipton Member of the White Limestone Formation. Records include *Tulites mustela* ARKELL, from around 1 m above the top of Hampen Marly Formation, WNW of Salperton Church (ARKELL 1951–1959, p. 103, pl. 12, fig. 1; = *Tulophorites tulotus* S. BUCKMAN *in* RICHARDSON 1929, p. 119; also recorded by SUMBLER et al. 2000, p.64); "*Tulites* cf. *subcontractus*" (MORRIS and LYCETT), from "16' to 18'" (= around 4.8 – 5.4 m) below the top of the White Limstone at Asthall, (ARKELL 1933, p. 292; 1931, pp. 607–8); **Tulites glabretus* (S. BUCKMAN) from near Ardley Wood (ARKELL 1951–1958, pp. 100–103, text fig. 32 = Holotype; "very probably....from the basal bed of the White Limestone" according to TORRENS 1980, p. 36; 1969c, p. 69 and probably also recorded by ARKELL 1933, p. 292); *Tulites* sp. from Kirtlington Station (GREEN 1864, p. 25; TORRENS 1969c, p. 69); and *T. glabretus* from ?Bed 1, Eton College Quarry, Asthall, Witney (ARKELL 1931, pp. 607–8, 1951–1958, p. 103, pl. 11, fig. 1; TORRENS 1980, pp. 36–37).

Tulites from the district are also noted by TORRENS (1988, p. 238), ODLING (1913, p. 490), BUCKMAN (1931, p. 52) and ARKELL et al. (1933, p. 344).

(g) *Morrisi Chronozone*: The Morrisi Chronozone is not recorded north of Gloucestershire, the most important locality in this region of the North Cotswolds being the well known Foss Cross Quarry. Records from here are all from the Shipton Member and include *Morrisiceras* sp. indet from the *Lucina* Beds (=Beds 18–19 of RICHARDSON 1911, p. 11), *Morrisiceras comma* (S. BUCKMAN) from 0.3 m below the top of Bed 2 of CALLOMON & TORRENS (*in* TORRENS 1969, p. 13; = "*Lycetticeras* sp."; also recorded by SUMBLER et al. 2000, p. 64) and *Morrisiceras* and "*Lycetticeras*" at around 0.9 m below the top of the Excavata Beds (BARKER 1976, fig 1.7 – "*Lycetticeras*" is a macroconch *Morrisiceras*).

Other scattered records include *Morrisiceras morrisi*, apparently from Bed 18 in Stony Furlong Cutting (TORRENS 1980, p. 35) and *M.* cf. *morrisi*, *c.*12–15 m above the base of the White Limestone in Chedworth Railway Cuttings (ARKELL 1951–1959, p. 121, TORRENS 1969c, p. 20).

(h) *Bremeri Chronozone*: There is no definitive evidence of the Bremeri Chronozone in central and northern England, the northernmost clear record being the type locality of **Bullatimorphites bullatimorphus* S. BUCKMAN (1921, p. 47, 1922, pl. 262) from the topmost White Limestone Formation at Tiltups End south of Nailsworth in Gloucestershire (ARKELL 1951–1958, pp. 12, 87, 106, 107. Text fig. 24 = Holotype. See also TORRENS 1980, p.32–33, ARKELL & DONOVAN 1952, p.241, CAVE 1977, pp. 143, 175, 196 and WITCHELL 1886).

Circumstantial evidence, however, suggests that at least one of the specimens of *Homoeoplanulites* from the Blisworth Limestone of Northamptonshire could belong to this chronozone. The specimen, a large macroconch around 325 mm in diameter, is recorded by ARKELL (1951–1958, pp. 219–222) and TORRENS (1980, p.40) as very likely to have come from within 0.4 m of the top of the *Kallirhynchia sharpi* Beds at the base of the formation, at Bank's Pit, Kingsthorpe, near Northampton itself (= Bed 11 of SHARPE 1870, pp. 357, 360). In the latter district a Nerinea Bed, up to 0.9 m thick is developed at this level, immediately above the *Kallirhynchia sharpi* Beds (TORRENS 1968), and is therefore highly likely to be the source of the specimen. This bed yields, according to TORRENS (1980, pp. 40–41), a fauna including *Eunerinea arduennensis* (BUVIGNIER), *Nerinella* cf. *acicula* (D'ARCHIAC), which is also characteristic of the Roach Bed at the base of the Ardley Member of the White Limestone Formation in Oxfordshire.

The latter bed lies above the Subcontractus and Morrisi Chronozone faunas of the topmost Shipton Member, and apparently below records of Quercinus Subchronozone faunas (lowest Retrocostatum Chronozone, as detailed below) at higher levels in the Ardley Member, i.e. in an interval likely to embrace the Bremeri Chronozone. *Procerites* sp. indet. associated with *Procerites* sp. ("transitional to *Choffatia*") from the base of the Ardley Member, or 0.5 m above the base, in a quarry at Croughton (TORRENS 1980, p. 38, a locality also described by PALMER 1974) could also represent elements of a similar Bremeri Chronozone fauna.

(i) *Retrocostatum Chronozone, Quercinus Subchronozone*: Large *Procerites*, especially *P* ex grp *quercinus* ARKELL ?non TERQUEM & JOURDY is characteristic of the Quercinus Subchronozone throughout much of Europe, and central England is no exception. Records are few and scattered, but the fauna consistently occurs in the Ardley Member of the White Limestone Formation and includes *P. quercinus* from "above Bed 18" in railway cuttings between Chedworth and Cirencester (RICHARDSON 1911b; ARKELL 1931, 1933; ARKELL & DONOVAN 1952; p. 246; CALLOMON & TORRENS *in* TORRENS 1969, pp. 12–3) and also from Bed 3 of Dagham Downs / Daglingworth Quarry (TORRENS 1967, p.87, BARKER 1976, fig. 1; SUMBLER et al. 2000, p. 66), around 4.8 m above the top of the Shipton Member. Additional records from the Ardley Member in Oxfordshire include *Procerites* sp. from the "Great Oolite Bottom hard about half way down in quarry" at Enslow Bridge, probably from the Ardley Member, possibly from Bed 12 (of PALMER 1974, p. A13; TORRENS 1980, p. 38; BARKER 1976, fig. 1.19).

North–eastwards, the White Limestone Formation passes into the Blisworth Limestone Formation, which shows quasi–marine influence at various levels (including oyster–rich beds). Remarkably a few very rare ammonites have also been recovered, as far north as south Lincolnshire. In this region vast opencast ironstone mines were formerly active, working the Aalenian Northamptonshire Ironstone Formation, below a Bajocian–Bathonian sequence. Considering the enormous volume of material worked, it is not surprising, therefore, that a few ammonites were also recovered.

Procerites quercinus is again recorded in Northamptonshire, from close to the junction of Beds 5–6 of TAYLOR (1963, p. 96) at Twywell Ironstone Pit, around 0.3 m above the highest recorded *Kallirhynchia sharpei* of the *Kallirhynchia sharpi* Beds (TORRENS 1980, p. 40; see also 1968, p. 242, = Bed 4 of Pittham, 1970, p.63). Note that the Nerinea Bed is not present in the latter district and the presence of *P quercinus* at an apparently lower level in the Blisworth Limestone–Ardley Member succession than in Oxfordshire, may suggest that a non–sequence is developed at the top of the *Kallirhynchis sharpi* Beds.

P. quercinus is also recorded by ARKELL (1951–59, p. 194–196) from Bed 9 of SHARP (1870, p. 377–8) and THOMPSON (1927, p. 33), near the base of the Blisworth Limestone and also from not far above the top of the *Kallirhynchia sharpi* Beds in a quarry "to the east" [of Blisworth] (TORRENS 1967, p. 69). The relationship between this specimen and the possible Bremeri Chronozone *Homoeoplanulites* discussed above is unclear, however, and it is not known whether the Blisworth specimen was obtained from within or above a development of, or level equivalent to the Nerinea Bed. As *Homoeoplanulites* is often very rare elsewhere in Europe in the Quercinus Subchronozone (cf. PAGE & MELÉNDEZ 1999), some stratigraphical separation of the two faunas is most likely. The specimen of *P quercinus* figured by ARKELL (1951–9, p.194–195, text fig. 71) from a quarry at Kingsthorpe described by SHARPE (1870) is typical of the species, although regrettably unhorizoned. A possible "*Siemirazkia*", the microconch partner of *Procerites*, is also recorded from Field Burcote (TORRENS 1967, p. 81).

Smaller specimens of *Procerites* sp. are known from south Lincolnshire, including from Stamford (SHARPE 1873, p. 249, 264; TORRENS 1967, p. 79) and possibly also Belmesthorpe (ARKELL 1951–59, p. 15; TORRENS 1967, p. 81). Given that most Northamptonshire and Oxfordshire specimens of *Procerites* from the White Limestone appear to belong to the *quercinus* group, it is reasonable to suppose that these Lincolnshire specimens represent the northernmost limits of the same group.

(j) *Retrocostatum Chronozone, Hodsoni and Histricoides Subchronozones*: A single, worn nucleus of a possible ?*Homoeoplanulites* sp., although compared to "*Siemiradzkia pseudorjazanensis* (LISSAJOUS)" by ARKELL (1951–1958, p.228), from the Signet Member at the top of the White Limestone Formation (*teste* SUMBLER et al. 2000, p.67) near Westwell in Oxfordshire, is the only indication of a post–Quercinus Subchronozone fauna in the formation. The specimen came from field brash and was formerly, and mistakenly, referred to the "Kemble Beds" of the Forest Marble Formation (e.g. by ARKELL et al. 1961).

Further north, *Homoeoplanulites* sp. (or "*H.* cf. *cerealis*" in TORRENS 1967, p. 71) from Bed 5 (the "Paving") at Moulton Park House Pit, near

Kingsthorpe in Northamptonshire (THOMPSON 1927, p. 40; TORRENS 1967, p. 71; 1980, p. 40; ARKELL 1951–59, p. 219, text fig. 80.2), around 2.8 m above the top of the *Kallirhynchia sharpi* Beds also suggests a post–Quercinus fauna. *Homoeoplanulites* is typical of the highest part of the Retrocostatum Chronozone, the Histricoides Subchronozone, in Spain (cf. PAGE & MELÉNDEZ 1999) and this suggests a possible correlation for the specimen. In addition, as noted above, *Homoeoplanulites* is typically quite rare in Quercinus (and also Hodsoni) Subchronozone faunas, but is abundant and typical in the Histricoides Subchronozone.

Although no ammonites are present northwards into central and northern Lincolnshire, ostracod faunas prove the presence of the Quercinus–lower Hodsoni Subchronozones (= "Hodsoni Zone" auctt.) and the upper Hodsoni–Histricoides Subchronozones (BERRIDGE et al. 1999: GAUNT et al. 1992) in Rutland Formation and Blisworth Limestone facies respectively. The former indicate that the Rutland Formation–Blisworth Limestone base is diachronous, at least across Lincolnshire. The latter would confirm that at least part of the Blisworth Limestone is likely to be of Histricoides Subchronozone age, thereby lending credence to a suggestion that the *Homoeoplanulites* from Kingsthorpe may indeed be a specimen of *H.* ex grp. *rotundatus* (ROEMER), as is very characteristic of the upper part of the Histricoides Subchronozone in Spain (PAGE & MELÉNDEZ 1997; 1999).

A number of intriguing but unconfirmed old records from the Blisworth Limestone of the district include "*Ammonites bullatus* D'ORBIGNY" from between Alwalton and Peterborough (SHARP 1873, p. 279; ARKELL 1951–59, p. 244; TORRENS 1967, p. 80) and "a large example of *Ammonites macrocephalus*" from near Uffington (TORRENS 1967, p. 79; 1980, p. 42; SHARPE 1873, p. 258). Neither specimen has been traced, although it is not impossible that they represented nautiloids, which are occasionally found in the district.

A single *Macrocephalites*, however, in Peterborough Museum collections (see discussion below under Lower Callovian, Keppleri Subchronozone faunas, section (m)) is somewhat problematic as regards morphology and lithology and it cannot be ruled out that it could genuinely have come from the higher part of the Blisworth Limestone, and be of Upper Bathonian age

(k) *Discus Chronozone, Hollandi Subchronozone*: Confirmation of the age of the Forest Marble Formation is available to the southwest, in southern Gloucestershire near Cirencester, the type locality *of* **Clydoniceras hollandi* (S. BUCKMAN) itself (ARKELL 1951–1958, pp. 41–42, pl.1, figs 6a,b), and also to the northeast, where it passes into Blisworth Clay facies and has yielded ostracods typical of the Discus Chronozone (BERRIDGE et al. 1999, p.77). The "*Siemiradzkia pseudorjazanensis* " recorded by SUMBLER et al. (2000, p. 68) and others (ARKELL 1958; TORRENS 1974; PAGE 1996) from the Forest Marble Formation just south of Cirencester, is most likely to be a small Homoeoplanulites (i.e. a nucleus or a microconch).

(l) *Upper Bathonian, Discus Chronozone, Discus Subchronozone*: Discus Subchronozone ammonite faunas are the most persistent in the Bathonian in Britain, recorded from the Dorset coast in the south (as reviewed by PAGE 1996, etc) to northern Lincolnshire, in northern eastern England. Throughout this geographical range, the faunas occur solely in the thin, often shelly facies of the Berry Member of the Abbotsbury Cornbrash Formation (*sensu* PAGE 1986 = "Lower Cornbrash" auctt.).

At least two successive biohorizons can be recognised in southern and central England, the lower with *Clydoniceras* ex grp *discus* (J. SOWERBY) *sensu stricto* (probably including the microconch form "*Delecticeras*" *delectum* ARKELL) and possibly also very rare *Homoeoplanulites* ex grp *homoeomorphus* S. BUCKMAN, and the upper with *Clydoniceras* ex grp *discus*, including *C. hochstetteri* (OPPEL), and more frequent *Homoeoplanulites* ex grp *homoeomorphus* (see PAGE 1996). The presence of two successive *Clydoniceras* faunas in the Oxford district was first recognised by PRINGLE (1926). Known occurrences of Discus Subchronozone faunas are described below on a county by county basis along the outcrop, from south to north:

(i) *North Gloucestershire*: In the dip slopes of the north Cotswolds, on the northern edge of the wide Oxford Clay vales, scattered small quarries formerly showed sections in the Abbotsbury Cornbrash Formation.

Although just to the southwest of the present study area, recent quarrying operations have re–exposed one such section, as formerly visible in the now filled–in Shorncote Quarry of DOUGLAS & ARKELL (1928). *Homoeoplanulites* ex grp. *homoeomorphus* S. BUCKMAN is not infrequent in the new quarry, and was also recorded by DOUGLAS & ARKELL at the old locality, in both cases in apparent association with *Clydoniceras* ex grp *discus* (1928; ARKELL 1958, p. 227; PAGE 1988, p. 149; *pers obs.* 1993–5).

At least some of the *Clydoniceras* and *Homoeoplanulites* appear to come from Astarte–Trigonia Bed facies, at the top of the Berry Member (cf. Bed1 of DOUGLAS & ARKELL 1928), and the relative frequence of the latter suggests that the *hochstetteri* Biohorizon is potentially recognisable at Shorncote, although *C. hochsetteri* itself is not yet confirmed.

Additional records of *C.* ex grp. *discus* from the district include from the "Three Magpies Inn" quarry near Fairford (DOUGLAS & ARKELL 1928, p.133) and *C. hochsttetteri* from "Fairford", figured by BUCKMAN (1924) (SUMBLER et al. 2000, p.69) – the latter at least suggesting that the *hochstetteri* Biohorizon is recognisable here.

(ii) *Oxfordshire*: To the northeast and into Oxfordshire, *Clydoniceras* is not uncommon, records including *C. hochstetteri* from Filkins (ARKELL 1951–1958, pl. 3, figs. 2, 4; SUMBLER et al. 2000, p.69) and

Brize Norton (BLAKE 1905, pl. 6, fig. 2) and *C.* ex grp. *discus* "var. *crenellatus*" from Ducklington Lane, Witney (ARKELL 1951, pl. 3, fig. 1) – the *hochstetteri* Biohorizon, at least, being indicated.

Around Long Handborough, the terminal Bathonian – basal Callovian sequence is best characterised in Britain, as the Swan Inn Quarry is the only known locality in England where *Kepplerites keppleri* (OPPEL) of the basal Callovian *keppleri* Biohorizon has been recorded *in situ* (CALLOMON, 1971, p.124). Notably, the latter was recorded in the topmost Berry Member (= "Lower Cornbrash") facies, and not the Fleet Member (= "Upper Cornbrash") as already observed by PAGE (1988, pp.155–156; 1989). The succession of faunas in the Berry Member of the Swan Inn Quarry is as follows (bed numbers after DOUGLAS & ARKELL, 1928, p.129):

Bed 4: *K. keppleri, Homoeoplanulites* sp (*keppleri* Biohorizon).

Bed 3 (Astarte–Trigonia Bed): *Clydoniceras* incl. *C. hochstetteri* (*hochstetteri* Biohorizon).

Bed 1· *Clydoniceras* sp. incl. *C. discus* (Intermedia Bed) (*discus* Biohorizon, part?).

The locality is also recorded by POCOCK (1920, p. 15), PRINGLE (1926, p. 21) and RICHARDSON (1946, p.76).

The Long Handborough area has historically yielded a significant amount of additional, important material, but unfortunately without adequate stratigraphical information and often poorly localised (PAGE 1988, pp. 155–156). These faunas include a few additional *K. keppleri*, from Bed 4 or an equivalent, common *Homoeoplanulites* ex grp. *homoeomorphus* from beds 3 or 4 (including * "*H.* [*Loboplanulites*] *longilobata*" BUCKMAN 1925, pl. 596, = Holotype; ARKELL 1951–1958, text figs. 79.5, 81,= Holotype refigured, pp. 222–223; "*Choffatia subbakeriae*" (D'ORBIGNY), p. 218, pl. 32, fig. 9 and "*C. kranaiformis*" ARKELL, p. 225, pl. 31, fig.7, p. 225) and *Clydoniceras* ex grp. *discus* including "*C.* var. *crenellatus–hochstetteri*" probably from an equivalent of Bed 3 (ARKELL 1951, pl. 3, fig. 3, recorded as from "Lays Pit").

Additional perisphinctids from the district, presumably also from the Berry Member, include "*H. arisphinctoides* ARKELL" from near Charlbury (ARKELL 1951–1958, p. 219) and *H. homoeomorphus* from "near Oxford" (ARKELL, p. 229, pl. 31, fig. 1), although it is impossible to say whether they are of terminal Bathonian or basal Callovian age.

As noted above, PRINGLE (1926) was the first to record a sequence of *Clydoniceras* species in the Oxford district, for instance at Islip Quarry (p.20), Oxfordshire (not to be confused with Islip, Northamptonshire) with *C. discus* s.s. in his "1st *Clydoniceras* Bed" (= DOUGLAS & ARKELL 1932, p.124, Bed 3) and *C. discus* "var. *hochstetteri*" in a "2nd *Clydoniceras* Bed" (= DOUGLAS & ARKELL, Bed 5). Islip quarry is also described by WOODWARD (1892, p. 48), BLAKE (1905, p. 13), POCOCK (1908, p. 211), RICHARDSON (1946, p. 79) and reviewed by PAGE (1988, p. 158).

Clydoniceras also occurs at two levels in the Berry Member in the large and more recently disused Shipton–on–Cherwell Quarry, in Beds 3–5 and in Bed 8 (= Astarte–Trigonia Bed; PAGE 1988, pp. 150–162; 1989) and again at two levels in the nearby Upper Greenhill Quarry, Enslow Bridge (PRINGLE 1926, p. 24), although the presence of *C. hochstetteri* in the upper fauna is not yet confirmed. These sites are also described by DOUGLAS & ARKELL (1928, p. 130; 1935), RICHARDSON (1946, p. 77) and ARKELL (1947, p. 59) and *C. discus* from Shipton–on–Cherwell has been figured by ARKELL (1951–1958, pl. 2, fig. 5) and other specimens from the Enslow Bridge area include: *C.* "var. **digitatus* ARKELL" (1951–1958, pl. 2, fig. 6), *C.* "var. *blakei–crenellatus* ARKELL" (pl. 2, fig. 3), *C.* "var. *digitatus–crenellatus* ARKELL" (pl. 3, fig. 6), *C.* "aff. var. *blakei* ARKELL" (pl. 2, fig. 10) and, significantly, *C. hochstetteri* itself (pl. 3, fig. 7). *C. thrapstonense* ARKELL is also recorded from Enslow Bridge (1951, p. 41), although its stratigraphical significance here is unclear (PAGE 1988, p. 163 – although see discussion below regarding it's position in Northamptonshire). *C.* "var. *blakei*" is also recorded from Kidlington, nearer Oxford itself, by ARKELL (1951–1958, text fig. 5).

(iii) *Buckinghamshire*: There are scattered records of *Clydoniceras* in Buckinghamshire, including *C. discus* from Blackthorn Hill (ARKELL 1951–1958, p. 4, text fig. 6.18). An isolated record of *Homoeoplanulites* (as "*C. cerealis* ARKELL"), from Rectory Farm, Emberton, Olney (1951–1958, p. 222, pl. 31.3) may be of Bathonian age, although the relative frequence of *Macrocephalites* in old collections from this area (as reviewed by PAGE 1988), may suggest that a Callovian age is not impossible.

(iv) *Bedfordshire*: The most important records of *Clydoniceras* in Bedfordshire are from Bedford itself, the type locality of **C. discus* (J. SOWERBY) (ARKELL 1951, pl. 2, fig. = Holotype refigured, fig. 4, fig. 1, fig. 9) and also its microconch partner * "*Delecticeras*" *delectum* Arkell (1951–1958, text fig. 8.1, pl. 4, fig. 12 = Holotype). ARKELL also records from Bedford a range of his sutural "varieties", including *C.* "var. *discus* "(pl. 2, fig. 1), *C.* "var. **blakei* (pl. 2, fig. 4 = type of variety, text fig. 69A, B) and *C.* "var. *blakei–hochstetteri*" (pl. 1, fig. 9).

Unfortunately there is no recorded stratigraphy for any of these forms, and the Abbotsbury Cornbrash Formation is reduced to a very thin and hard band only 0.6 – 0.9 m thick which has also yielded early Callovian faunas, including the holotype of **Macrocephalites bedfordensis* SPATH (figured by BLAKE, 1905, pl.4, fig.1), a member of *M.* ex grp. *terebratus* (PHILLIPS) (PAGE 1988, p. 167–170) – there is little possibility here, therefore, of confirming the position of *C.discus*, *sensu stricto,* in a sequence with *C. hochstetteri* above. Sections near Bedford are also described by WOODWARD (1894, p. 451), CAMERON (1889) and DOUGLAS & ARKELL (1932, p. 123), although none now remain exposed.

(v) *Northamptonshire*: The Rushden district in Northamptonshire was formerly an important source of "Cornbrash" fossils (BLAKE 1905) and in addition to Callovian *M.* ex grp. *terebratus*, has yielded further *Clydoniceras,* including *C. discus* (ARKELL, 1951, pl. 3, fig. 10) and the microconch form "*Delecticeras" legayi* RIGAUX and SAUVAGE (1951, p. 44, pl. 4, figs. 11).

Much more significant, however, are the *Clydoniceras* faunas from the Thrapston district, to the northeast. The Berry Member here is reduced to a very thin development, only a few centimetres thick, but a significant number of specimens of *Clydoniceras* have relatively prominent secondary ribs, unlikely virtually all specimens found elsewhere in Britain, and were described as by ARKELL (1951) as *Clydoniceras thrapstonense* ARKELL (p. 41, pl. 3, figs. *12 = Holotype, 13). The type and topotype of the latter species came from a pit at nearby Islip (DOUGLAS & ARKELL 1932, p. 131; PAGE, 1988, p. 175) from a level equivalent to Bed 1 at the much better known "Thrapston Railway Station Pit", as described by DOUGLAS & ARKELL (1932, p. 130), PAGE (1988, pp. 173–175), TORRENS (1968, p. 249), TAYLOR (1963, p. 130) and others.

Amongst the various other *Clydoniceras* recorded from the district are *C. discus*, *s.s.* (including ARKELL 1951, pl. 3, fig. 9) and several *C. hochstetteri*, the latter from both Islip (1951, pl. 3, fig. 5) and Thrapston itself (ARKELL 1951, pl. 3, fig. 8), which provide some circumstantial evidence to suggest that the *thrapstonense* fauna occurs in the upper part of the Discus Subchronozone, although further confirmation is needed from elsewhere where successions are much more complete. The apparent absence of *Homoeoplanulites*, however, which is common in the *hochstetteri* Biohorizon further south, is significant and could, in contrast, suggest that the *thrapstonense* fauna predates the typical *hochstetteri* fauna of Oxfordshire. Rare specimens of *C. thrapstonense* in the latter county (see (i) above), which could help resolve this question, are unfortunately unhorizoned.

An isolated outlier of Berry Member at Stowe Nine Churches, west of Northampton has also yielded *Clydoniceras* ex grp. *discus* (DOUGLAS & ARKELL 1932, p. 129; PAGE 1988).

(vi) *Cambridgeshire*: *Clydoniceras* ex grp. *discus* is known near Peterborough, including between Stilton and Yaxley, south of the city (JUDD 1875, p.229, 291; WOODWARD 1894, p.453; DOUGLAS & ARKELL, 1932, p.33) and on Ailsworth Heath, immediately to the north (JUDD 1875, p.224; WOODWARD 1894, p.454). More typically, however, the Berry Member is absent in the district, removed by a widespread non–sequence at the base of the Fleet Member which can be traced from northern Cambridgeshire into southern Lincolnshire (PAGE 1988, 1989).

(vii) *Lincolnshire*: In central Lincolnshire, Berry Member facies reappear and again yield *Clydoniceras* ex grp. *discus*, most significant at Sudbroke near Lincoln, including the microconch form "*Delecticeras legayi"* RIGAUX and SAUVAGE (ARKELL 1951, pl. 4, figs. 9, 10) and *C. discus* "var. **blakei* ARKELL" (1951, pl. 2, fig. 8 = type of "variety", as previously figured by BLAKE 1905, pl. 6, fig. 1) (ARKELL 1951–1958; DOUGLAS & ARKELL 1932; PAGE 1988, pp. 203–204). *Homoeoplanulites* ex grp. *homoeomorphus* (recorded as "*Choffatia cerealis* ARKELL" (1951–1958, p. 224, text fig. 29.3, p. 222, pl. 31,fig. 5), is also recorded from Sudbroke, but it is unclear whether the specimens are of Discus or Herveyi chronozone age (i.e. Bathonian or Callovian).

Northwards, the last known occurances of *Clydoniceras* ex grp. *discus* include scattered records near Aunsby (DENNISON 1955, p. 253; TORRENS 1968, p. 251). Towards the Humber estuary, as the Jurassic thins and virtually disappears over the Market Weighton "axis" (KENT 1955), the Berry Member appears to persist as far as the Appleby district (USSHER 1890, p.88; CROSS 1874, pp. 122, 125; WOODWARD 1894, p.457), north of Scunthorpe, where brachiopods typical of the member in central and southern England (including *Obovothyris obovata* (J. SOWERBY)) prove the Discus Subchronozone.

(m) *Lower Callovian, Herveyi Chronozone, Keppleri Subchronozone*: The lowest Callovian, Keppleri Subchronozone is generally missing in central and eastern England and is only proved at a handful of localities in north Gloucestershire and Oxfordshire (PAGE 1988, 1989).

The basal *keppleri* Biohorizon of the subchronozone is only known in a few thin bands at the very top of the Berry Member, very locally preserved below a Terebratus Subchronozone erosive surface in Oxfordshire. Records of *Kepplerites keppleri*, include "* *Cereiceras cereale*" BUCKMAN (1922, pl. 286; ARKELL 1951–1958, p. 117, text. fig. 42,) from near Witney, several specimens from Kidlington, north of Oxford, in a preservation similar to that of the specimen from Bed 4 in the Swan Inn Quarry, Long Handborough (as discussed above) and the four other specimens from the same quarry in Oxford University Museum collections (PAGE 1988, p. 156). Some of the perisphinctids recorded from the district (and cited previously) are certainly of *keppleri* Biohorizon age as well, but without more precise records, it is presently impossible to correctly assign them to the terminal Bathonian or basal Callovian.

To the southwest, and into Gloucestershire, the Fleet Member sequence is more complete, but appears to lack the basal *keppleri* Biohorizon, the lowest faunas apparently being mainly *Macrocephalites* ex grp. *verus* BUCKMAN (e.g. in Beds 2–3 of the original Shorncote Quarry, ARKELL 1933, pl. 35, DOUGLAS & ARKELL 1928; PAGE 1988, pp. 148, 149, and at an equivalent level in the "new" quarry, *pers. obs.* 1993–5).

An ammonite from Poulton, recorded by DOUGLAS & ARKELL (1928, p.134) that *"may be a perisphinctid or even a stephanoceratid"* is the only tentative suggestion that *Kepplerites* might also occur in the area (PAGE 1988, p. 151), but the specimen has not yet been traced. The Fleet Member near Fairford has also yielded *H.* ex grp. *homoeomorphus* (= **H. stabilis* BUCKMAN 1924, pl. 515 = Holotype); despite being from an unrecorded level, the specimen is most likely to be of Keppleri Subchronozone age as there are no confirmed records of *Homoeoplanulites* in the Terebratus Subchronozone in Britain (PAGE 1988, p. 152; ARKELL 1958, p. 225–226, pl. 30.).

From Oxfordshire northwards, the lower part of the Fleet Member generally yields *Macrocephalites* ex grp. *terebratus* (PHILLIPS) indicating a widespread non–sequence at the base of the Callovian. An isolated specimen labelled "Peterborough", however (Peterborough Museum 282/G; PAGE 1988, p. 189, pl.1, figs 3a,b), appears to either represent *M. jacquoti* (DOUVILLÉ), a species of the *keppleri* Biohorizon, or an even earlier form of the latest Bathonian. It is preserved in a bluish–grey limestone, more closely recalling Blisworth Limestone lithologies than the Fleet Member in the district, which makes the specimen even more problematic.

Late Bathonian *Macrocephalites* do occur in Europe, both in the late Hodsoni–Histricoides subchronozone interval (= "Orbis Zone" auctt.) and in *hochsttetteri* Biohorizon faunas in Germany (DIETL 1981, 1997). The Peterborough specimen, an incomplete macroconch, is published here for the first time (Figure 2). The specimen is unique in Britain in that it has a relatively strongly triangular whorl section and very fine ribbing, and is closely comparable to specimens of *M. jacquoti* from the basal Callovian *keppleri* Biohorizon in southern Germany (PAGE 1988; CALLOMON et al. 1989, etc.), but also earlier forms figured by DIETL (1997) from the Discus Subchronozone. The specimen is so unusual, however, that until its source level is confirmed by new finds or lithological /palynological analysis, a definitive determination or correlation is not possible.

Correlations

The ammonite faunas detailed above provide a backbone or a structure for correlating the Bathonian sequences of central and northern eastern England, although the only really continuous "datum" is that provided by the lateral persistence of the Berry Member and it's Discus Subchronozone faunas.

In the absence of ammonites there has traditionally been little real age–control, with correlations being largely dependent on lithostratigraphical arguments (e.g. in TORRENS 1980 and earlier reviews). A range of other fossil groups are, however, present, including both macro– and microfaunal and floral elements, all with biostratigraphical potential. In compiling Figure 3, such information has been incorporated from various sources, including correlations based on Nereneid gastropods in the White Limestone Formation of the north Cotswolds and Oxfordshire (after BARKER 1994), brachiopods in the Berry and Fleet Members of the Abbotsbury Cornbrash Formation (after DOUGLAS & ARKELL 1928, 1932 and PAGE 1988, 1989) and ostracods in the Rutland, Blisworth Limestone and Blisworth Clay formations (after BERRIDGE et al. 1999 and GAUNT et al. 1992). Palynological information is also potentially very valuable in dominantly non–marine and quasi–marine formations, for instance in North Yorkshire outwith of the present study area complimentary new results will be published elsewhere (N. HOGG pers. comm., 2000).

As a considerable amount of work on the region remains unpublished, and in the absence of systematic contemporary micropalaeontological studies of much of the East Midlands sequence (especially the Rutland and Blisworth Limestone formations), the correlations presented as Figure 2 are inevitably provisional. Assumptions made regarding the chronostratigraphical age are often based on lithostratigraphical arguments – these require further independent testing. Key assumptions and correlative links include:

1. The Chipping Norton Limestone Formation appears to pass laterally into the Horsehay Sands Formation (formerly "White Sands") of Buckinghamshire, into the Stamford Member and ultimately the Thorncroft Sands of GAUNT et al. (1992), all are therefore likely to be of Zigzag Chronozone age (M. SUMBLER pers. comm., 1992).

2. The Taynton Limestone Formation passes laterally into the Wellingborough Limestone Formation (formerly the "Upper Estuarine Limestone") (M. SUMBLER pers. comm., 1992).

This and the assumed age of the Sharpi Beds of Northamptonshire constrain the age of the upper part of the Rutland Formation as Progracilis Subchronozone to pre Bremeri Chronozone (?Subcontractus Chronozone).

3. The Rutland Formation sequence comprises a succession of sedimentary rhythms, showing apparent cycles of progradation of saltmarsh–type conditions. Attempts have been made to correlate these rhythms (e.g. in TORRENS 1968) and even establish a lithostratigraphical terminology by naming various "cycles" (BRADSHAW 1978).

Each cycle has an erosive base, and the local absence of certain cycles has often been taken to indicate the presence of non–sequences. Nevertheless, although short distance correlations may be reliable, there is presently no independent biostratigraphical control on the assumptions made in correlating such cycles over larger distances. These cycles are therefore shown diagrammatically on Fig. 2.

Figure 2: *Macrocephalites* sp. cf. *jacquoti* (DOUVILLÉ); a problematic specimen preserved in matrix more closely resembling Blisworth Limestone Formation (Upper Bathonian, Retrocostatum Chronozone) than the expected Abbotsbury Cornbrash Formation, Fleet Member (Lower Callovian, Herveyi Chronozone). Locality given as "Peterborough" (Peterborough Museum, PM 282/G). Actual size (see text discussion on Herveyi Chronozone, Keppleri Subchronozone faunas, section (m

4. There is *no* independent stratigraphical control on the age of the pre–Wellingborough Limestone Formation / post Stamford Member Rutland Formation.

5. According to CRIPPS (19), the Shipton Member of the White Limestone Formation passes laterally into the Sharpi Beds at the base of the Blisworth Limestone Formation. If this assumption is true, then the latter is of Subcontractus or Morrisi Chronozone age and a non–sequence is therefore likely between this level and the succeeding Blisworth Limestone, especially where the Nerinea Bed, of presumed Bremeri Chronozone age (see discussion previously) is absent (i.e. the lower part of this succeeding sequence already yields *Procerites* ex grp. *quercinus* of the lower Retrocostatum Chronozone).

6. The detailed succession and position of erosional levels in the White Limestone Formation of north Cotswolds and Oxfordshire largely follows SUMBLER (1984 – as modified by BARKER 1994, Figure 4).

7. Evidence for the diachroneity of the Blisworth Limestone–(upper) "Rutland Formation" / Upper Priestland Clay (of GAUNT et al. 1992) junction is based on ostracod faunas cited under the discussion of Retrocostatum Chronozone faunas above. As the post Stamford Member / pre Sharpi Beds Rutland Formation appears to be equivalent to the "Lower Priestland Clay" of north Lincolnshire, it may be necessary to restrict the use of the lithostratigraphical term "Priestland Clay" solely to the mudrock–dominated unit into which the Blisworth Limestone appears to laterally pass in this area.

8. The lower part of the Blisworth Clay Formation appears to pass laterally into the Bladon Member of the White Limestone Formation in Oxfordshire (London and Thames Regional Guide; M. SUMBLER pers. comm., 2001).

9. The detailed correlation of the Abbotsbury Cornbrash Formation follows PAGE (1988, 1989).

Lithostratigraphical assignments on Figure 2 follow SUMBLER (1984, 1999, pers. comm., 2001), PAGE (1988, 1989) and the Grantham and Sleaford memoirs (GAUNT et al. 1992).

Conclusions

The general sequence of ammonite faunas in central and northern eastern England is summarised below. Other taxa are present in the region, as discussed above, although are excluded from this table as they are currently difficult to reliably place in the succession. Nominal species marked with an asterix (*) indicate the source level of type specimens, most of which are figured by ARKELL (1951–1958):

Lower Callovian, herveyi Chronozone, terebratus Subchronozone

Macrocephalites ex grp *terebratus* (PHILLIPS) (including **M. bedfordensis* SPATH?) [*terebratus* α Biohorizon; Abbotsbury Cornbrash Formation, Fleet Member =Upper Cornbrash auctt.; north Gloucestershire/ Oxfordshire to North Yorkshire coast]

Keppleri Subchronozone

Kepplerites keppleri (OPPEL) (including **Cereiceras cereale* S. BUCKMAN), *Homeplanulites* ex grp *homoeomorphus* S. BUCKMAN [*keppleri* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; Oxfordshire]

Upper bathonian, discus chronozone, discus Subchronozone

12. *Clydoniceras* ex grp *discus* (J. SOWERBY), including *C. hochstetteri* (OPPEL) and *Homoeoplanulites* ex grp *homoeomorphus* [*hochstetteri* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; north Gloucestershire/ Oxfordshire to North–amptonshire]

11. **Clydoniceras* ex grp *discus* (including *"*Delecticeras*" *delectum* ARKELL [m]); *Homoeoplanulites* ex grp *homoeomorphus* may also occur, although very rarely [*discus* Biohorizon; Abbotsbury Cornbrash Formation, Berry Member = Lower Cornbrash auctt.; north Gloucestershire/ Oxfordshire to ?mid Lincolnshire]

Hollandi Subchronozone

10. ? *Homoeoplanulites* sp. [Forest Marble For–mation, north Gloucestershire]

Retrocostatum Chronozone, ?histricoides Subchronozone

9. *Homoeoplanulites* sp. [Blisworth Limestone Formation, Northamptonshire]

Hodsoni Subchronozone (no confirmed records)

Quercinus Subchronozone

8. *Procerites* ex grp. *quercinus* ARKELL ?non TERQUEM and JOURDY, *Homoeoplanulites* sp. [including *quercinus* Biohorizon; White Limestone Formation, Ardley Member; north Gloucestershire/ Oxfordshire to Blisworth Limestone Formation, Northamptonshire]

Bremeri Chronozone

7. *Homoeoplanulites* sp. [?Nerinea Bed, Blisworth Limestone Formation, Northamptonshire]

Morrisi Chronozone

6. *Morrisiceris* ex grp. morrisi (OPPEL) [*morrisi* Biohorizon, White Limestone Formation, topmost Shipton Member; north Gloucestershire]

Subcontractus Chronozone

5. Tulites ex grp *modiolaris* (W. SMITH) (including **T glabretus* S. BUCKMAN) [*modiolaris* Biohorizon, White Limestone Formation, Shipton Member; north Gloucestershire/ Oxfordshire]

Progracilis Chronozone, progracilis Subchronozone

4. **Procerites imitator* (BUCKMAN) [*imitator* Biohorizon, Hampen Marly Formation; Oxfordshire]

3. Procerites ex grp *progracilis* COX and ARKELL (including **P mirabilis* ARKELL, **P. vineta* ARKELL and **P. magnificus* ARKELL), **Micromphalites micromphalus* (PHILLIPS), *?*Clydoniceras tegulum** ARKELL and **Oxycerites oxus* (S. BUCKMAN) [*progracilis* Biohorizon; Eyford Member, Sharps Hill Formation, north Gloucestershire and Taynton Limestone Formation, "Stonesfield Slate" facies, Oxfordshire]

Orbignyi Subchronozone and tenuiplicatus Chronozone (no confirmed records)

Zigzag Chronozone, yeovilensis Subchronozone (no confirmed records)

Macrescens Subchronozone

2. Zigzagiceras [*Procerozigzag*] *pseudoprocerus* (S. BUCKMAN) [*macrescens* Biohorizon, Chipping Norton Limestone Formation; Oxfordshire]

Convergens Subchronozone

1. Parkinsonia ex grp *convergens* (S. BUCKMAN) (?including **P. oxonica* ARKELL) [*convergens* Biohorizon, Chipping Norton Limestone Formation; north Gloucestershire/ Oxfordshire]

Upper Bajocian, parkinsoni Chronozone, ?bomfordi Subchronozone

Parkinsonia [*Durotrigensia*] cf. *crassa* NICOLESCO [?basal Chipping Norton Limestone Formation, Oxfordshire]

The diversity of Bathonian ammonite faunas decreases significant from southern to northern Britain and there appears to be some ecological control on the northern known limits of various taxa. From south to north, various genera disappear successively, creating the impoverished faunas formerly considered to be characteristic of a Subboreal Province (e.g. in MANGOLD & RIOULT (1997). In reality, as discussed by PAGE (1996) and PAGE & MELENDEZ (1999), there are no fundamental differences between these so–called "Subboreal" faunas and those typical of Submediterranean areas, except the increasing impoverishment northwards. The latter is undoubtedly an ecological consequence of lowered salinities and unstable environments close to fluctuating low–lying coastlines surrounding the embayments and gulfs which characterised the northern margins of the seas which covered much of Europe at this time.

Figure 3 shows the northern limits of various genera known to occur contemporaneously in France and Spain for the pre Discus Chronozone Bathonian, in particular for the Bremeri–Retrocostatum Chronozone interval, which includes marine–influenced deposits at least as far north as northern Lincolnshire (i.e. the absence of various taxa in the most northerly areas is not, therefore, due to non–sequences). Disappearances are as follows ?*Epistrenoceras* / *Prohecticoceras* (Somerset), *Oxycerites* (Somerset), *Bullatimorphites* (Gloucestershire), *Homoeoplanulites* (Northamptonshire), *Procerites* (south Lincolnshire). The last two genera, however, are typically recovered in northern areas as very rare and scattered, large mature specimens – the drifting and subsequent sedimentation of empty shells can also therefore be invoked to place them so far north.

Discus Chronozone faunas do not quite fit this pattern, however, not least because the Berry Member of the Abbotsbury Cornbrash Formation is remarkably uniform lithologically across England, and that *Clydoniceras* is almost always recorded where the Berry Member is exposed. Although *Homoeoplanulites* is also present, possibly as far north as central Lincolnshire, it is generally absent or very rare (excepting the *hochstetteri* Biohorizon faunas of Oxfordshire and southwards) and it is the relative frequence of *Clydoniceras* that is noteworthy. The latter genus is most typical of northern European faunas, including in Britain, Normandy and northern Germany (WESTERMAN 1958, DOUVILLÉ 1943, etc), but apparently considerably rarer to the south (e.g. in southern Germany; DIETL 1997) or absent (e.g. in Spain; PAGE & MELÉNDEZ 1999). Unlike all other Bathonian taxa, there does genuinely appear to be a preferred northern distribution here, and perhaps *Clydoniceras* really is characterising a northern subprovince on the margins and in the backwaters of the Submediterranean Province seas which covered most of the rest of Europe in the latest Bathonian.

When ammonites are absent, "conventional" Jurassic correlation can fail.

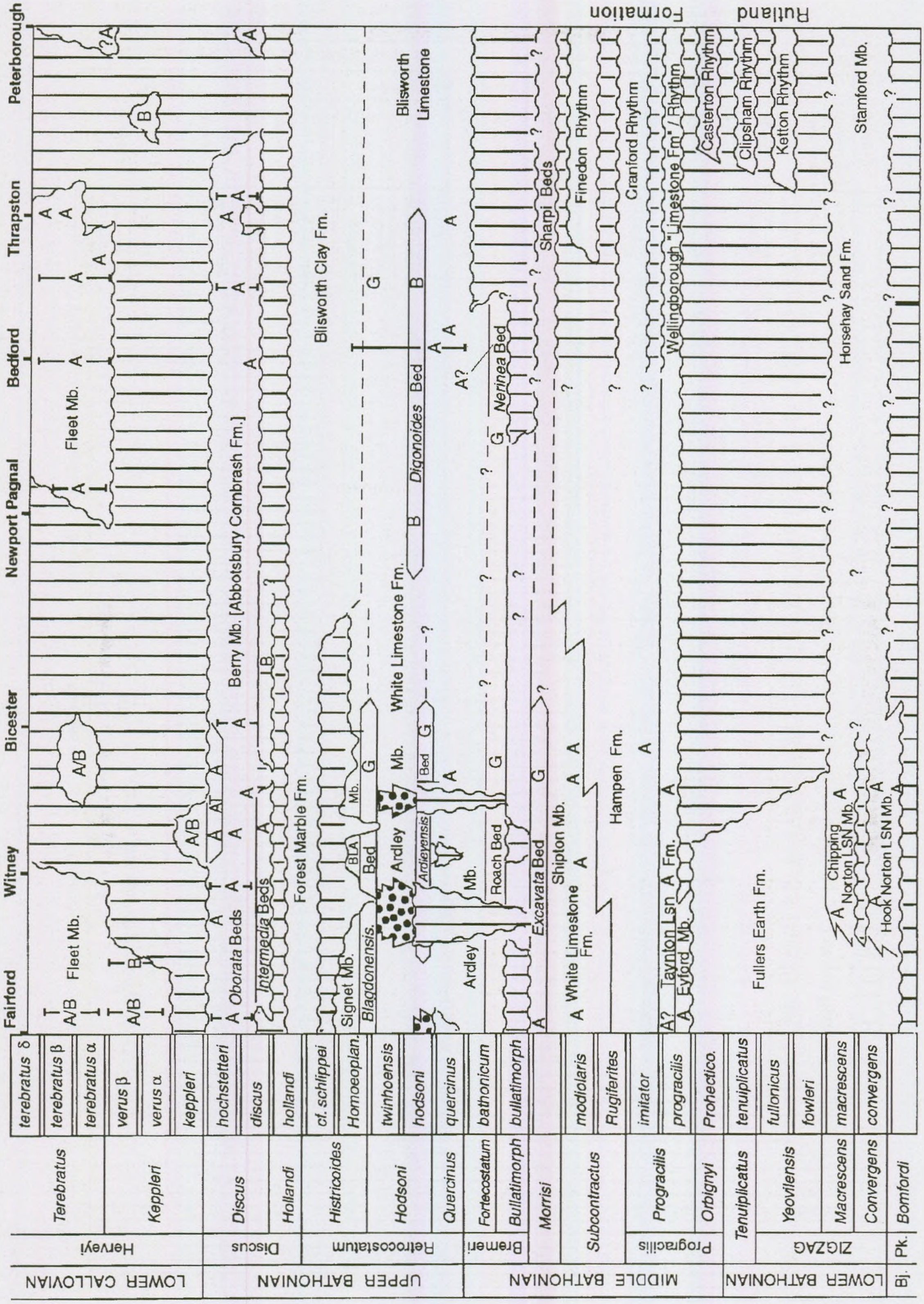

Figure 3a: A provisional correlation of Bathonian rocks in central and northern England. See text for discussion and sources of information. A = Ammonite; B = Brachiopod; G = Gastropod.

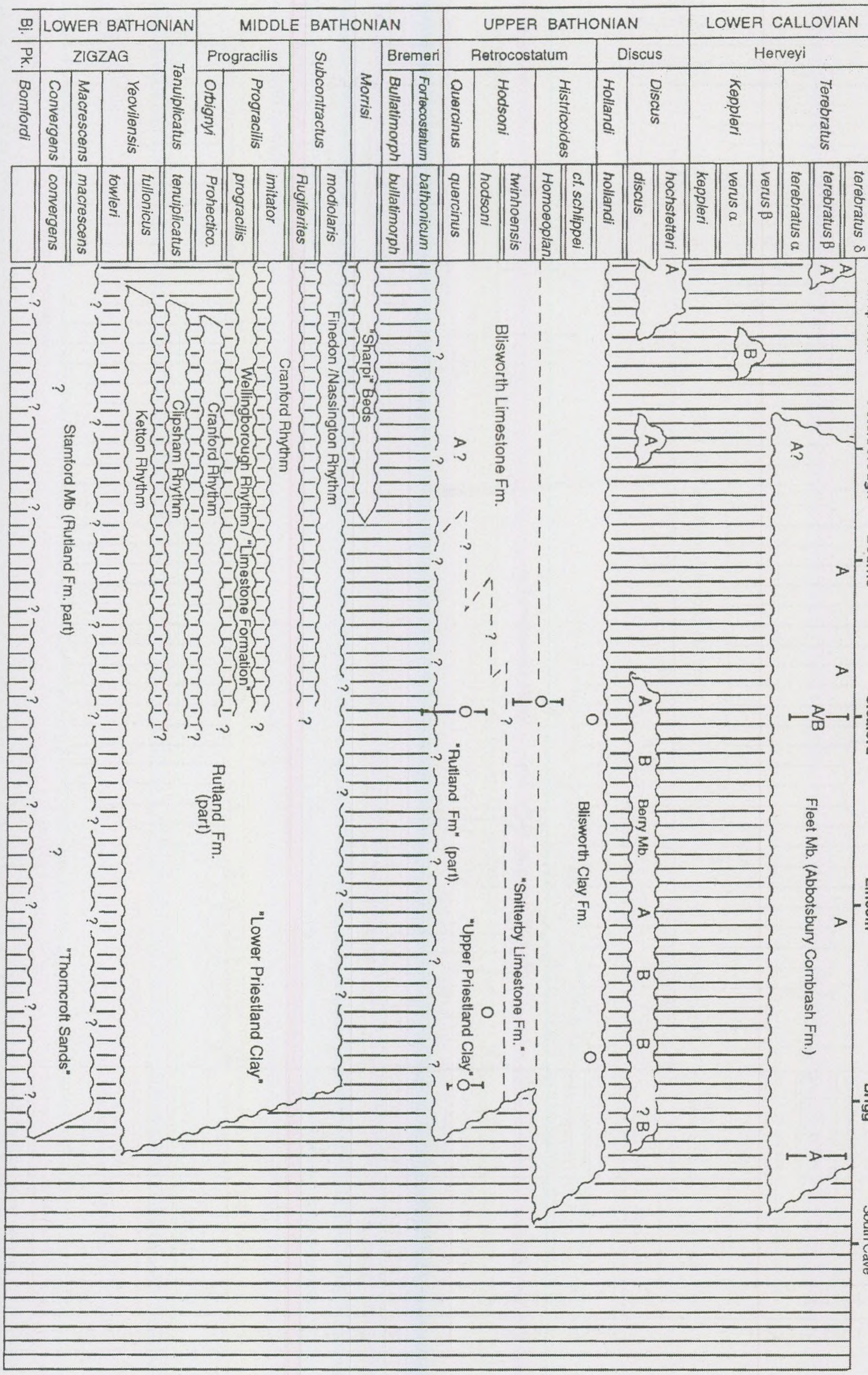

Figure 3b: A provisional correlation of Bathonian rocks in central and northern England. See text for discussion and sources of information. A = Ammonite; B = Brachiopod; G = Gastropod.

Nevertheless, it is clear from the Bathonian of central and northern England, that brachiopods, gastropods, ostracods and dinoflagellates can now offer a stratigraphical resolution, at least as refined as ammonite zones and occasionally, at least locally, as good as subzones. Combining such information together can only strengthen the use of standard chronozones in the Jurassic – considering ammonite-named zones solely as biozones, as is common, for instance in Britain, is clearly denying the full potential of the chronostratigraphical method for producing fully integrated correlation schemes and reliable correlations of facies where ammonites are rare or absent.

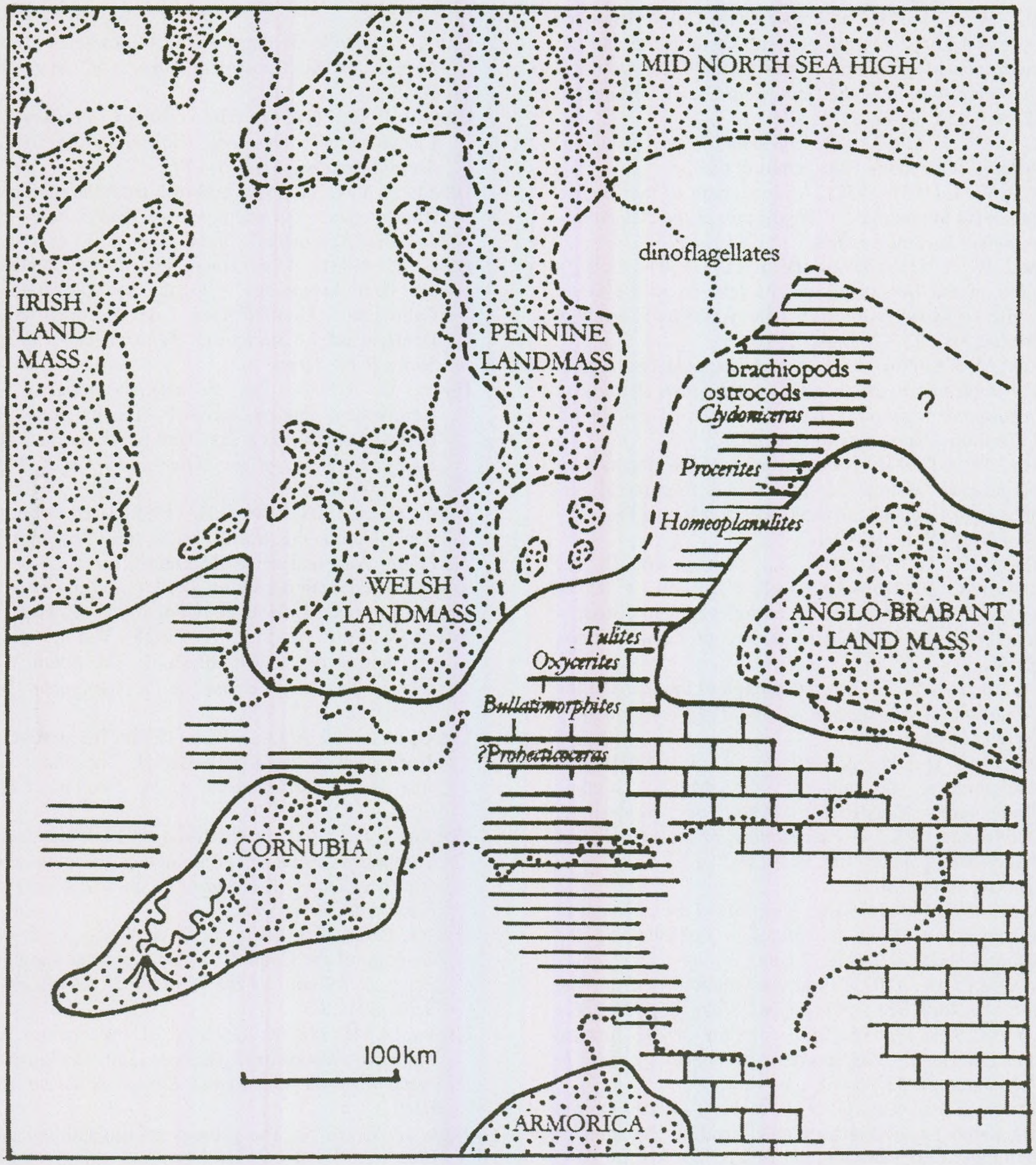

Figure 4: Palaeogeographical map of Britain and adjacent areas based on in COPE (1995), showing the northern limit of various characteristic Bathonian ammonite taxa.

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