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THE CALLOVIAN-OXFORDIAN BOUNDARY IN BRITAIN: A REVIEW OF KEY SECTIONS AND THEIR CORRELATION WITH THE PROPOSED GLOBAL STRATOTYPE SECTION AND POINT FOR THE OXFORDIAN IN HAUTE PROVENCE, FRANCE

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Abstract. The historical type area of the Oxfordian Stage and its lowest subchronozone (Scarburgense Subchronozone of the Mariae Chronozone) are in Great Britain, in southern central (Oxford) and north eastern England (Scarborough), respectively. In neither district, however, are sequences sufficient complete to satisfy ICS requirements for a GSSP. Subsequent work in Haute Provence, south east France, however, has revealed considerably expanded sequences in Terre Noire facies which satisfy most ICS criteria and a GSSP for the Oxfordian Stage has now been formally proposed in this region. One British section, however, on the Dorset coast near Weymouth (Ham Cliff/ Redcliff Point), is relatively expanded and has the potential to complement the French candidate GSSP by yielding additional information on microfossil assemblages (e.g. ostrocods, foraminifera, coccoliths and holothurians). The sequence of ammonite faunas across the stage boundary at this and other key UK localities is reviewed, synthesised and correlated with the candidate GSSP in Haute Provence. This correlation can provide a framework within which additional information derived from UK sites, for instance from microfossil or geochemical studies, can be integrated to assist global correlation of the base of the Oxfordian Stage.

Riassunto. L'area tipo storica dell'Oxfordiano e della sua subcronozona più bassa (Subcronozona a Scarburgense della Cronozona a Mariae) si trovano in Gran Bretagna, rispettivamente nell'Inghilterra centro-meridionale (Oxford) ed orientale (Scarborough). In nessun dei due distretti, tuttavia, le sequenze sono sufficientemente complete da soddisfare le richieste ICS per un GSSP. Uno studio successivo in Alta Provenza, Francia sudorientale, ha però rivelato sequenze considerevolmente espanse nella facies delle Terre Noire che soddisfano la maggior parte dei criteri ICS, ed ora è stato formalmente proposto in questa regione un GSSP per l'Oxfordiano. Una sezione britannica, tuttavia, sulla costa del Dorset vicino Weymouth (Ham Cliff / Redcliff Point), è relativamente espansa ed ha il potenziale di completare il candidato francese al GSSP fornendo informazioni aggiuntive sulle associazioni a microfossili (es. ostracodi, foraminiferi, coccoliti ed oloturie). Viene passata in rassegna la sequenza di faune ad ammoniti attraverso il limite di piano in questa ed altre località-chiave del Regno Unito, sintetizzandole e correlandole con il candidato GSSP in Alta Provenza. Questa correlazione può fornire uno schema nel quale si possono integrare informazioni aggiuntive derivate dai siti inglesi, per esempio da studi sui microfossili o sulla geochimica, per aiutare la correlazione globale della base dell'Oxfordiano.

The Callovian-Oxfordian boundary in England

The term Oxfordian was proposed by d'Orbigny (1842-1849) as the lowest of his four divisions (étages) of what would now be termed "Upper Jurassic". By implication the region around Oxford in southern central England would be the type area of the stage. Inevitably therefore, as understanding has developed on the diagnostic faunas of the Oxfordian, especially the ammonites, there has been a strong focus on British and especially English sites, most particularly by workers such as Buckman (1909-1930), Arkell (1933, 1935-1948, 1939, 1941, 1947), Callomon (1964, 1968, 1990) and Wright (1968, 1983).

In addition, the index fossil of the accepted lowest subchronozone of the lowest zone of the stage, *Cardioceras scarburgense* (Young & Bird), came from the North Yorkshire coast (north east England) at or near Scarborough (Callomon 1964, 1990) (Fig.1). Callomon (1990) consequently attempted to stabilise the use of the subchronozone by proposing that a section in the latter region, at Osgodby Nab (section described by Wright 1968, 1983), should be established as a stratotype for the subchronozone and therefore define the base of the Oxfordian Stage. The sections in the Scarborough dis-

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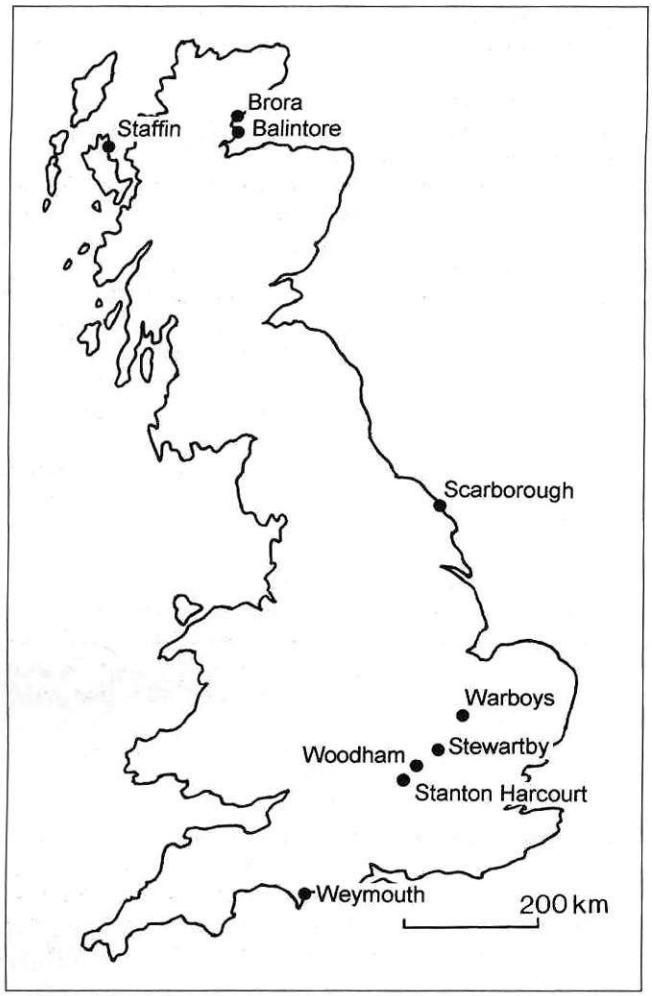

Fig. 1 - Map of Great Britain showing the main Callovian-Oxfordian boundary localities mentioned in the text.

trict, however, are very thin and highly condensed in chamosite-oolite sandstone and limestone facies, and very significantly, faunal discontinuities are locally demonstrable. Their potential for magnetic, isotopic, geochronometric and micropalaeontological studies, as recommended by the International Commission on Stratigraphy (Remane et al. 1996), is therefore much reduced. Nevertheless, as characteristic faunas do occur and the area has been the source of many type specimens, the district is still important for discussions of the stage boundary.

In contrast an expanded, albeit periodically poorly exposed, section near Redcliff Point, east of Weymouth in Dorset (south west England; Arkell 1947; Wright 1986; Callomon & Cope 1995; Page 1994; Page in Cox & Sumbler 2002, pp. 31-34; Chapman 1999), has few of these drawbacks, and available fossil evidence indicates that a more expanded and complete sequence is present, frequently with better preserved and more diverse faunas (for instance, the terminal Callovian *paucicostatum* Biohorizon may be 4 m or so thick, as compared to a maximum of 0.45 m in Yorkshire). The section is also entirely in mudrock facies (Weymouth Member, Oxford Clay Formation - formerly Upper Oxford Clay) and although the ammonite fauna is frequently crushed, at several levels nuclei are pyritised and very occasionally body chambers may be partly phosphatised. No assessment of microfossil assemblages is currently available, although preliminary work indicates that there is a good foraminiferan and holothurian fauna (M. Hart, pers. com. 2002) and the lithologies present (calcareous clay) suggest that good assemblages of ostracods and coccoliths might also be recoverable. Indeed, the section has the potential to complement the current candidate GSSP for the base of the Oxfordian Stage, in Haute Provence, south east France (Fortwengler & Marchand 1994, 1997), where information of microfossil successions is limited.

Elsewhere in Britain other known Callovian-Oxfordian boundary localities are typically stratigraphically incomplete (e.g. Woodham, Buckinghamshire and Warboys, Cambridgeshire), or faunally too impoverished (e.g. Staffin Bay, Isle of Skye, Scotland) to form primary reference sections. They nevertheless yield additional information on the boundary and its characteristic faunas and are reviewed below. Following Callomon (1993) and Callomon & Cope (1995) the base of the Oxfordian is drawn at the base of a *woodhamense* Biohorizon, as utilised here, and not the base of the *paucicostatum* Biohorizon, which is now considered to be terminal Callovian (Fortwengler & Marchand 1994, 1997; Thierry et al. 1997).

1. Staffin Bay, Isle of Skye, Scotland

The Callovian-Oxfordian boundary is well exposed on the Dunans shore in Staffin Bay [c. NG473700], as recorded by Anderson & Dunham (1966), Sykes (1975), Morton & Hudson (1995), Wright in Wright & Cox (2001), Page (in Cox & Sumbler 2002, pp. 405-408). Recent re-examination indicates that the Henrici Subchronozone is present in Bed SS5b (of Morton & Hudson 1995) of the Dunans Clay Member, Staffin Shale Formation and at least as high as 1.27 to 1.34 m above the base of Bed SS6 (with *Q.* cf. *henrici*).

The lowest recorded *Quenstedtoceras* of the Lamberti Subchronozone are present at around 1.7 m above the base of SS6, although the basal Lamberti Subchronozone, *praelamberti* fauna (see conclusions) is not yet recognised. Typical *lamberti* Biohorizon faunas are present between 1.7 to 2.05 m above the base of SS6, including typical *Q. lamberti* (J. de C. Sowerby) [m] and frequent *Euaspidoceras hirsutum* (Bayle) [M]. The base of the Oxfordian lies at around 3.54 m above the base of SS6, as indicated by *Cardioceras* cf. *woodhamense* Arkell *non* Marchand, with *Cardioceras* ex gr. *scarburgense* (Young and Bird) ([m] and [M]) at 4.81 m. The low diversity of these Boreal faunas, dominated by cardioceratids is apparent, although the presence of common *Euaspidoceras* at one level is notable, as at Brora (see below).

2. Brora, Sutherland, Scotland

Coastal exposures in the Brora estuary [NC909031 and inland, along the Brora River [e.g. NC 898038] provide sections in the Lamberti Chronozone (Sykes 1975), crucially including reference sections for the terminal Callovian, Henrici and Lamberti subchronozones, as proposed by Callomon & Sykes (1980). The former is recognised on the basis of the index species, in association with *Peltomorphites* sp. in the top 5 m or so of the Fascally Siltstone Member, Brora Argillaceous Formation. The overlying Fascally Sandstone Member yields fauna of

the lower part of the Lamberti Subchronozone, with *Q.* ex gr. *lamberti* and *Kosmoceras* ex gr *compressum* (Quenstedt) with the succeeding Clynelish Quarry Sandstone Member yielding a typical *lamberti* Biohorizon fauna with, in addition to the index, common *Euaspidoceras hirsutum* (including *E. clynelishense* Arkell) and some hecticoceratids (?*Putealiceras* sp.). The base of the Oxfordian is presumed to lie in the succeeding Brora Arenaceous Member, although no ammonites have currently been recorded (Sykes 1975; Page in Cox & Sumbler 2002, pp. 373-376).

3. Balintore, Rosshire, Scotland

The Callovian is exposed in this area on the shore at Cadh'h-an-Righ [NH851727 area], the boundary with the Oxfordian lying within the Shandwick Clay Member of the Brora Arenaceous Formation (Sykes 1975; Wright in Wright & Cox 2001; Page in Cox & Sumbler 2002, pp. 376-379). Faunal records are scanty however, although *Q. lamberti* is recorded at around 9.7 m above the base of the member with *C. scarburgense* at 12.3 m above the base.

4. Scarborough-Cunstone Nab, North Yorkshire, England

The boundary between the Callovian and Oxfordian stages lies at or close to the junction between the Hackness Rock Member of the Osgodby Formation (cf. Wright 1968, 1978) and the Oxford Clay Formation (formerly included in the "Upper Oxford Clay", but in a distinctive silty facies when compared to the more calcareous clays of the Weymouth Member of central and southern England).

The Hackness Rock is typically a thin (0-1.5 m) condensed chamosite oolite, often sandy or calcareous, primarily representing parts of the Athleta Chronozone and the late Lamberti Chronozone (terminal Callovian). Thickness variations of such a deposit inevitably means that the preserved sequence significantly varies from site to site. Nevertheless, good boundary sequences have been recorded at four locations - Scarborough Castle Hill [TA0589 area], Osgodby Nab [TA099830] (the proposed Stratotype for the Scarburgense Subchronozone of Callomon 1990), Cayton Bay foreshore and at Cunstone Nab [TA064854] (Wright 1968, 1983, in Wright & Cox 2001; Cox 1988; Callomon & Wright 1989; Page in Cox & Sumbler 2002, pp. 333-340; Cox & Page in Cox & Sumbler 2002, pp. 323-333).

The Henrici Subchronozone is not clearly recognisable in this area but the Lamberti Subchronozone yields rich faunas as described by Leckenby (1859), Buckman (1909-1930), Wright (1983), Cox (1988), Callomon & Wright (1989) and Page (1991), including *Quenstedtoceras* ex gr. *lamberti*, *Peltoceras* (*Peltomorphites*) *subtense* (Bean), *Grossouvria* (*Poculisphinctes*) *poculum* (Leckenby), *Euaspidoceras hirsutum*, *Binatisphinctes binatus* (Leckenby), *Hecticoceras* (*Putealiceras*) *putcale* (Leckenby) with rarer *Kosmoceras* (*K.*) gr. *spinosum* (J. de C. Sowerby) and *Alligaticeras* (*A.*) *alligatum* (Leckenby) and *Distichoceras bicostatum* (Stahl).

The fauna of the succeeding terminal Callovian *paucicostatum* Biohorizon, was first recognised in this area by Wright (1983), at Cunstone Nab and Cayton Bay foreshore, with *Quenstedtoceras paucicostatum* as figured by Wright (1983). This fauna is not recorded at Callomon's candidate Oxfordian stratotype (1990), although the early Oxfordian *scarburgense* Biohorizon is here better preserved. Similar levels also appear to yield a few *Peltomorphites* and *Euaspidoceras* in the district. Nevertheless, as none of the sites in the district appears to have yielded a basal Oxfordian *woodhamense* fauna, there may still be a small non-sequence at the stage boundary.

5. Warboys, Cambridgeshire, England

Warboys Pit [TL308818], now a waste disposal site and partly infilled, has long been known for its important sections in Weymouth Member clays of the Mariae Chronozone, as recorded by Spath (1939), Callomon (1968) and Wright (in Wright & Cox 2001). The base of the Oxfordian had never been recorded, however, until 1996, when excavations for landfill cells, revealed the top of the Stewartby Member below and hence the Callovian-Oxfordian boundary. This section was sampled for microfossil analysis but has not yet been described in full (the diagrammatic summary of Chapman (1999) is conjectural and correlations hypothetical).

The top of the Stewartby Member comprised around 2 m of greenish grey clays with two calcareous bands in its upper part – around 0.3 m above the higher band, a 0.2 m thick marl bed with abundant *Gryphaea* yielded a rich Lamberti Subchronozone faunas including *Quenstedtoceras* ex gr. *lamberti*, *Kosmoceras* (*K.*) *spinosum*, *Peltoceras* (*Peltomorphites*) cf. *subtense*, *Grossouvria* (*Poculisphinctes*) *poculum*, *Euaspidoceras hirsutum*, *Hecticoceras* (*Putealiceras*) *puteale* and *Reineckeia* (*Collotia*) *oxyptychoides* (Spath). The top of the bed is locally marked by a layer of broken shells, overlain by a darker, marly clay with a heavily burrowed base. This level marks the base of the Weymouth Member and yields typical coarsely ribbed *Cardioceras woodhamense* Arkell with frequent small, weakly ornamented hecticoceratids (possibly including *Fehlmannites* sp.). Higher levels in the Scarburgense Subchronozone are as recorded by Spath (1939) and Callomon (1968), the recently observed Callovian-Oxfordian boundary lying at 6 m below the base of limestone Bed A of these authors.

6. Stewartby, Bedfordshire, England

The disused Rockery Pit at Stewartby, near Bedford [TL015415] formerly showed a somewhat weathered section across the Callovian-Oxfordian boundary, spanning the Stewartby-Weymouth Member boundary. The locality is very briefly mentioned by Callomon (1990) and recorded by Page (1990) and showed a succession similar to that recorded by Callomon (in Wyatt et al. 1988) in temporary excavations at nearby Millbrook. The top of the Callovian is marked by a 0.2-0.35 m argillaceous limestone or "Lamberti Bed", although very locally the stage boundary lies within this bed. Around 2 cm of marl immediately below has yielded *Q. henrici*, *Kosmoceras* (K.) sp. and *Hecticoceras* sp. of the Henrici Subchronozone, and the bed itself has yielded *Quenstedtoceras* ex gr. *lamberti*, *Kosmoceras* (K.) ex gr. *spinosum*, *Hecticoceras* (*Putealiceras*) cf. *puteale*, ?*Euaspidoceras sp.*, *Grossouvria* (*Poculisphinctes*) sp., *Pachyceras* sp., etc.

Where the base of the Oxfordian lies within this bed it is marked by a line of rolled shells, including *Gryphaea*, and the lowest faunas recorded are relatively strongly ribbed *Cardioceras woodhamense*, as at Woodham (see below), associated with common *Taramelliceras* sp., also *Properisphinctes* sp.; *Q. paucicostatum* has not been recorded and as the Lamberti Subchronozone is only around 0.1-0.15 m thick and even locally absent, it is clear that a non-sequence is also present here at the boundary. Higher faunas in the 80 cm or so of clay above the Lamberti Bed have yielded typical *Cardioceras scarburgense* in association with *Properisphinctes* ex gr. *bernensis* (de Loriol), ?*Grossouvria* sp., *Hectococeras* ex gr. *bonarellii* de Loriol and, notably, a fragmentary large phylloceratid (?*Calliphylloceras* sp.).

7. Woodham, Buckinghamshire, England

The famous former brick pit at Woodham [SP7117], as described by Arkell (1939) and Callomon (1968) was lost in the 1970s due to infill by refuse, despite its supposed protected site status. The top of the Callovian is marked by the Lamberti Bed (= Bed C of Arkell), a 0.3 m thick marly limestone band at the top of the Stewartby Member of the Oxford Clay Formation, considered to be the type horizon for the Lamberti Subchronozone by Callomon in Cope et al. (1980). The fauna is abundant and dominated by *Quenstedtoceras* ex gr. *lamberti*, showing a remarkable range of presumed intraspecific variation (as illustrated by Callomon 1985), in association with *Peltoceras* (*Peltomorphites*) *subtense*, *Grossouvria* (*Poculisphinctes*) *poculum*, ?*Grossouvria trina* (Buckman), *Euaspidoceras hirsutum*, *Binatisphinctes binatus*, *Hecticoceras* (*Putealiceras*) *puteale*, *Kosmoceras* (*K.*) gr. *spinosum*, *Alligaticeras* (*A.*) *alligatum* and *Distichoceras bicostatum*. Great rarities include *Pachyceras* (*P.*) *lalandeauum* (D'Orbigny) and *Reineckeia* (*Collotia*) sp..

The overlying clays of Bed B, at the base of the Weymouth Member, yield pyritised *Cardioceras* spp. including *C. woodhamense* Arkell non Fortwengler & Marchand and *C.* ex gr. *scarburgense* - the

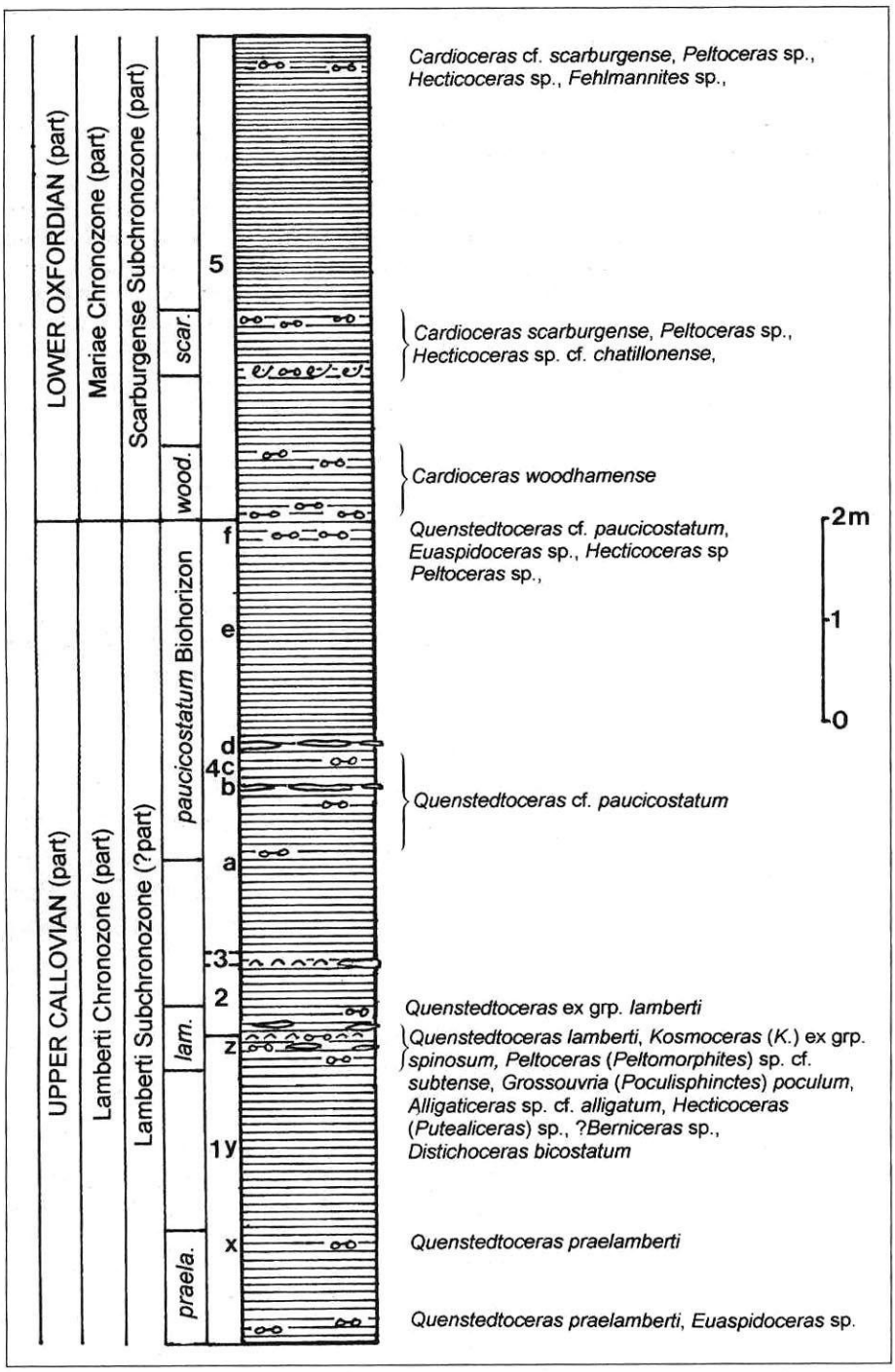

Fig. 2 - The Callovian-Oxfordian boundary sequence at Ham Cliff/Redcliff Point, near Weymouth, Dorset (bed numbers after Callomon in Callomon & Cope 1995).

latter also being present in Bed A above (these levels form the stratotype of the Scarburgense Subchronozone of Arkell 1941). The apparent absence of *Q. paucicostatum* amongst the thousands of ammonites known from this site suggests that, as elsewhere in central England, a non-sequence is present at the stage boundary.

8. Stanton Harcourt, Oxfordshire, England

Temporary excavations for refuse disposal operations below Pleistocene River Terrace gravels, near Stanton Harcourt, north-west of Oxford [NZ413047], revealed a Callovian-Oxfordian boundary sequence in Oxford Clay facies as described by Hollingworth & Wignall (1992), but without any analysis of the ammonite faunas.

In 1994, exposures were already in a poor condition and are now lost. Prominent at that time were Henrici Subchronozone faunas dominated by pyritised nuclei of *Q. henrici* (R. Douvillé), with occasional *Kosmoceras* (*K.*) *spinosum*, hecticoceratids and perisphinctids. Traces of large body chambers of poorly preserved *Quenstedtoceras* ex gr. *lamberti* were present in an overlying sequence of around 2.5 m of silty calcareous bands and marl. The overlying Mariae Chronozone was also present as Hollingworth & Wignall (1992, p.17) recorded at least 0.6 m of clays with *Cardioceras* spp., including *S. scarburgense* – although it is unclear whether cross-boundary *paucicostatum* or *woodhamense* biohorizon faunas are present.

Elsewhere in the district, in further temporary excavations at Linch Hill [NZ424036], the Lamberti Subchronozone yielded relatively well preserved *Quenstedtoceras* ex gr. *lamberti* in a preservation similar to that recorded at Woodham, although no section appears to have been recorded (per. obs. 1990).

9. Redcliff Point/ Ham Cliff, Dorset, England

Historically the Oxford Clay Formation of the Weymouth district has yielded rich terminal Callovian, Lamberti Chronozone faunas from now-obliterated brick pits and also from low slumped cliffs around Tidmoor Point (Arkell 1947; Callomon 1993; Callomon & Cope 1995; Chapman 1999; Cox & Page in Cox & Sumbler 2002, pp. 20-29). These faunas include the type specimen of *Q. lamberti* (J. de C. Sowerby) itself. Unfortunately no sections were recorded in the brick pits and the exposures of the Tidmoor Point area are low, slumped and degraded.

More complete exposures of these levels have nevertheless been known for many years near Redcliff Point, east of Weymouth at a locality often referred to as Ham Cliff [SY716818] (Arkell 1947; Wright 1986, in Wright & Cox 2001; Callomon 1993; Callomon & Cope 1995; Chapman 1999; Page in Cox & Sumbler 2002, pp. 31-34). Despite the quality of exposure being variable - as erosion is limited to exceptional storm events - a more complete stage boundary sequence has been recorded here than at Tidmoor Point. The latter was first published by Callomon (1993; see also Callomon & Cope 1995) but has recently been re-examined by Chapman (1999). As the two sections are difficult to compare, the subdivision into beds of the former scheme is reproduced here (Fig. 2 and below). Additions are based on pers. obs. and possible correlations with the section of Chapman (1999), which uses level or sample numbers rather than a division into beds.

MARIAE CHRONOZONE, SCARBURGENSE SUBCHRONOZONE

5) (part) Grey marl with scattered ammonites and a line of *Gryphaea* c. 1.5 m above the base, also yielding *C. scarburgense* [*scarburgense* Biohorizon, part]. The *Gryphaea* bed appears to be equivalent to level W73.1 of Chapman (1999), with level 75.1 around 0.5 m higher. The latter is reported to yield *C. scarburgense* (including Chapman 1999, fig. 6, G-N and fig.5, G-J, N-Y, the latter misidentified as "*C. paucicostatum*", also fig.6, O-T, identified as "*Quenstedtoceras*" *mariae*), *Hecticoceras* sp. cf. *chatillonense* (reported by Chapman 1999 as including a microconch form resembling "*Brightia*" *thuouxensis*; Fortwengler et al., fig. 7, H) and *Peltoceras* sp. (including Chapman 1999, fig. 7, I-O) [*scarburgense* Biohorizon, part]. An additional fauna, denoted W79, around 4 m higher, is reported as including *C. scarburgense* (including Chapman 1999, fig.8, G), *Hecticoceras* sp. (Chapman 1999, fig. 8, A-?F), *Fehlmannites* sp. (Chapman 1999, fig.8, H-N) and *Peltoceras* sp., although biohorizon assignment is uncertain ..... (6 m+);

5) (part) Grey marl with scattered ammonites including *Cardioceras woodhamense* (Arkell) non Fortwengler & Marchand and C. ["*Quenstedtoceras*"] *mariae* (d'Orbigny) (Callomon 1993) [*woodhamense* Biohorizon] ..... (c. 0.7 m);

LAMBERTI CHRONOZONE, LAMBERTI SUBCHRONOZONE

4e-f) Grey marl with scattered ammonites including *Q.* cf. *paucicostatum* (Lange) near the top (=Bed 4f). Probably equivalent to level W71.1 of Chapman (1999) with *C. paucicostatum* (including Chapman 1999, fig. 5, M), also *Euaspidoceras* sp., *Hecticoceras* sp. and *Peltoceras* sp. Includes level W71.1 with "*C.*"*paucicostatum*, probably at around 1.7 m above the top of Bed 4d [*paucicostatum* Biohorizon, part] ..... (c.1.2 m);

4b-d) Double row of calcareous lenticles. Probably equivalent to levels W65-W67 of Chapman (1999) [*paucicostatum* Biohorizon, part] ..... (c.0.4 m);

4a) Dark clays with *Q. paucicostatum* in upper c. 0.8m [= *paucicostatum* Biohorizon, part] ..... (c.1.8 m);

3) Grey marl with shelly seam and scattered calcareous lenticles. Equivalent to level W62.1 according to Chapman (1999) ..... (c.0.05 m);

2) Grey marl with some calcareous lenticles and in *Q. lamberti* in lower part [*lamberti* Biohorizon, part] ..... (c.0.7 m);

Bed 1, Level z) Grey marl with some calcareous lenticles. Common fauna, often with pyritised nuclei, includes abundant *Quenstedtoceras* ex grp. *lamberti*, *Kosmoceras* (*K.*) ex gr. *spinosum* (J. de C. Sowerby), *Peltoceras* (*Peltomorphites*) sp. cf. *subtense*, *Hecticoceras* (*Putealiceras*) sp., *Alligaticeras* sp. cf. *alligatum*. Probably includes level W61 of Chapman (1999), which is reported to yield: *Distichoceras bicostatum*, *Grossouvria* (*Poculisphinctes*) *poculum*, ?*Berniceras* sp. and a *Peltoceras* (*Peltomorphites*) sp. (figured by Chapman 1999, fig.7, B) [*lamberti* Biohorizon, part] ..... (c.0.4 m);

Bed 1, levels x-y) Grey marl with *Q. praelamberti* and *Euaspidoceras* sp. in lower part (= level x, c. 2m below the top of the bed [= *praelamberti* Biohorizon] ..... (c.2.6 m recorded).

The sequence of ammonite faunas across the Callovian-Oxfordian boundary

The following ammonite faunas or biohorizons (sensu Page 1995) characterise the Callovian-Oxfordian boundary interval in Britain. Examples of most of the taxa listed below are figured by Arkell (1939), Spath (1939), Wright (1983), Cox (1988) and Page (1991). Abbreviations used for denoting biohorizons derived from zonal assignment (e.g. LL = Lamberti Chronozone, Lamberti Subchronozone).

UPPER CALLOVIAN, LAMBERTI CHRONOZONE, LAMBERTI SUBCHRONOZONE

LL1: *praelamberti* Biohorizon. Reference: Lowest c.1.5 m of Unit 1, Stewartby/?Weymouth Member, Oxford Clay Formation, Redcliff Point/Ham Cliff, Weymouth, Dorset. Fauna: *Quenstedtoceras praelamberti* (R. Douvillé) and *Euaspidoceras* sp.. Comments: the *praelamberti* Biohorizon is presently the lowest distinguished in the Lamberti Subzone in Britain.

LL2: *lamberti* Biohorizon. Reference: upper c.40 cm of Unit 1, and Unit 2, Stewartby/?Weymouth Member, Oxford Clay Formation, Redcliff Point/Ham Cliff, Weymouth, Dorset. Fauna: *Quenstedtoceras lamberti* (J. de C. Sowerby) [often abundant, macroconchs very variable from inflated forms (including *Q. cadiforme* Buckman) to compressed (including *Q. lamberti* auct.) and from involute morphologies (including *Q. sutherlandiae* J. de C. Sowerby) to relatively evolute forms (including *Q. gregarium* Leckenby), as illustrated by Callomon 1985, text-fig. 5). Compressed acute ventered and intermediate forms with a short whorl section and an arched venter (including *Q. dissimile* Brown) dominate most assemblages (Page 1991). Typical microconchs have a characteristic ribbing style with three to four secondary ribs per primary (= *Q. flexicostatum* (Phillips), figured by Callomon & Wright 1989, pl. 95, figs. 2a, b, also Page 1991, pl. 17, figs. 7, 8); coarsely ribbed inflated varients include *Q. leachi* (J. Sowerby)); associated fauna includes *Peltoceras* (*Peltomorphites*) *subtense* (Bean) (including Page 1991, pl. 25, fig. 10, pl. 27, fig. 1), *Grossouvria* (*Poculisphinctes*) *poculum* (Leckenby) (including Page 1991, pl. 21, fig. 3, 4; Cox, 1988, text fig. 4, pl. 12, figs. 9, 11, 14, 16; pl. 13, figs. 1-5), ?*Grossouvria tri-*

na (Buckman) (Cox 1988, pl. 14, figs. ?2, also 3-5). *Euaspidoceras hirsutum* (Bayle) (including Page 1991, pl. 27, figs. 6, 7), *Binatisphinctes binatus* (Leckenby), *Hecticoceras* (*Putealiceras*) *puteale* (Leckenby) with rare *Kosmoceras* (*K.*) ex gr. *spinosum* (J. de C. Sowerby), *Alligaticeras* (*A.*) *alligatum* (Leckenby) (including Page 1991, pl. 20, fig. 15; pl. 21, figs. 5, 6; Cox 1988, pl. 23, figs. 3, 5, 6, 7) and *Distichoceras bicostatum* (Stahl). Great rarities include *Pachyceras* (*P.*) *lalandeanum* (D'Orbigny) and *Reineckeia* (*Collotia*) *oxyptichoides* (Spath). Comments: Rich *lamberti* Biohorizon faunas as known from the Scarborough district (North Yorkshire), Woodham (Buckinghamshire) and the Weymouth district, Dorset, especially from Tidmoor Point and Redcliff Point/Ham Cliff. Cardioceratids are the only truly diagnostic taxa, all other species being very close to earlier or later forms.

LL3: *paucicostatum* Biohorizon. Reference: Unit 4, Stewartby/?Weymouth Member, Oxford Clay Formation, Redcliff Point/Ham Cliff. Fauna: *Quenstedtoceras paucicostatum* (Lange) is typical and locally common; microconchs are most typical and characteristic forms have a continuous keel and ribbing which does not form ventral chevrons unlike typical *Q. lamberti* (figured by Wright 1983, pl. 18 figs. 1-3, also Page 1991, pl. 17, fig. 9; Chapman 1999, Fig.5, M); *Peltoceras* (*Peltomorphites*) sp. , *Euaspidoceras* sp. and *Hecticoceras* sp. are occasional and ?*Longaeviceras* sp. very rare (figured by Wright, 1983, pl. 18, fig. 8). Comments: following Callomon (1990) and Fortwengler & Marchand (1994, etc.), the *paucicostatum* fauna is included within the Callovian.

LOWER OXFORDIAN, MARIAE ZONE, SCARBURGENSE SUBZONE

MS1: *woodhamense* Biohorizon. Reference: lower c. 0.7 m of Unit 5, Weymouth Member, Oxford Clay Formation, Redcliff Point/Ham Cliff. Fauna: *Cardioceras* (*Scarburgiceras*) *woodhamense* Arkell non Marchand (including forms resembling *Q. mariae* R. Douvillé; teste Callomon 1993; probably includes specimens figured by Arkell 1939, pl. 10, figs. 2-4); typical coarsely ribbed compressed forms have carinate venters. Feebly ribbed hecticoceratids may be locally frequent (including ?*Febimannites* sp.), also *Taramelliceras* sp.. Comments: the *woodhamense* fauna is placed at the base of the Oxfordian following Callomon (1993) and in Callomon and Cope (1995), despite its apparent predating of a Yorkshire *scarburgense* fauna, selected by Callomon (1990) as the basal horizon of the stage (see comment to MS2). The carinate venter indicates that generic assignment to *Cardioceras* rather than *Quenstedtoceras* is probably most appropriate. *C. woodhamense* of Fortwengler & Marchand is a later form, from the upper part of the Scarburgense Subchronozone.

MS2: *scarburgense* Biohorizon. Reference: Weymouth Member, Oxford Clay Formation. Fauna: *C.* (*Scarburgiceras*) *scarburgense* (Young & Bird) sensu stricto is common (typical compressed variants have relatively straight primary ribs on their inner whorls and secondaries which curve on the outer half of the whorl side towards a carinate venter; includes Chapman 1999, Fig.5, G-J, N-Y, Fig.6, G-N, O-T), also *Hecticoceras* spp. (including Chapman 1999, Fig.7, H) and *Peltoceras* sp. (including Chapman 1999, Fig.7, I-O). Comment: the fauna figured by Wright (1983) from Bed 10 of the Oxford Clay Formation on the north side of Osgodby Nab, Scarborough (e.g. pl. 18, figs. 4-7; and Page 1991, pl. 17, figs. 10, 11, pl. 18, figs. 10, 11) may belong to a similar level as the Dorset reference, although further material is required to confirm. This Yorkshire fauna marked the base of the Oxfordian in the proposal of Callomon (1990).

MS3: aff. *scarburgense* Biohorizon. Reference: Bed 3, Weymouth Member, Oxford Clay Formation, Warboys Clay Pit, Cambridgeshire (Spath 1939; Callomon 1968). Fauna: *Cardioceras* (*Scarburgiceras*) aff. *scarburgense* is typical, a species including morphologies transitional to *C. praecordatum* (with a developing keel; includes specimens figured as *C. scarburgense* ?var. *crassa* nov." by Spath 1939, pl. 76, figs. 4 and 12, may also include var. *normandiana* Spath 1939, pl. 7, figs. 9). Comments: succeeding faunas are included in the Praecordatum Subzone. The aff. *scarburgense* Biohorizon is broadly equivalent to the "?middle subzone of the Mariae zone ?with *scarburgense* and *praecordatum*" of Arkell (1941) and the index species is broadly equivalent to *C. woodhamense* sensu Fortwengler & Marchand non Arkell.

Correlations with the candidate GSSP in Haute Provence

The very expanded sequences of the Terre Noire in south east France allowed Fortwengler and Marchand (1994, 1997) to construct a very detailed sequence of faunas across the Callovian-Oxfordian boundary – the Scarburgense Subchronozone, for instance, is around 48 m thick at Savournon, as opposed to a maximum of only around 9 m at Warboys and possibly similar at Redcliff Point/Ham Cliff. In addition, the Submediterranean/Mediterranean character of the faunas inevitably meant that assemblages were richer in Tethyan groups such as hecticoceratinids and peltoceratinids, thereby facilitating the recognition of a more detailed sequence of faunas than is currently possible in Britain, at least in the early Oxfordian. Not surprisingly, therefore, sections at Thuoux and Savournon were subsequently proposed to the International Subcommission on Jurassic Stratigraphy, in 1998, as a Global Stratotype Section and Point for the base of the Stage (although ratification has not yet been achieved).

Figure 3 shows the correlation of the current Submediterranean sequence of horizons (= "zonules" sensu Page 1995) as established by Fortwengler and Marchand (1994, 1997) and reviewed by Thierry et al. (1997) and Cariou et al. (1997) with that described here for Subboreal Province sequences in Britain. Correlation of the Subboreal *praelamberti* and *lamberti* biohorizons and the Submediterranean horizons of the same name is straightforward. The Submediterranean Thuouxensis (or Elisabethae) Horizon is more problematic however, as the cardioceratid fauna is dominated by *Q. paucicostatum*, but with occasional forms resembling true *C. scarburgense* (Cariou et al. 1997). As Subboreal *paucicostatum* Biohorizon faunas are relatively uncommon and therefore poorly characterised, it is not unlikely that they could span the Paucicostatum-Thuouxensis boundary and hence the Submediterranean Callovian-Oxfordian boundary (as shown on Fig. 3), especially if the less common *scarburgense* morphs have not been recovered in UK sections.

The position of the Subboreal *woodhamense* (sensu stricto) Biohorizon in the Submediterranean sequence is problematic, as the characteristic morphology is not clearly represented in assemblages figured from France. The relatively common occurrence of feebly ribbed hecticoceratids in Britain, however, suggests that the Bioho-

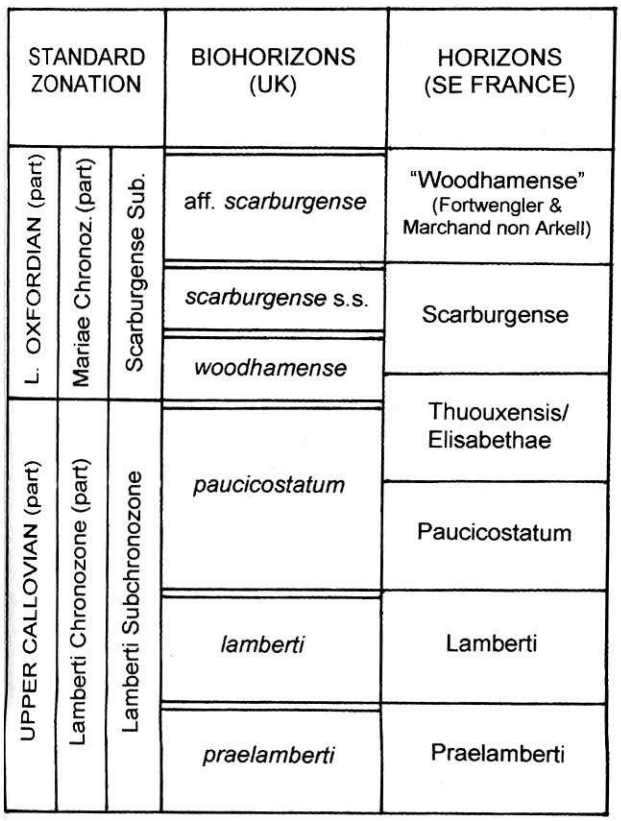

Fig. 3 - The correlation of the sequence of Subboreal biohorizons recognised in the UK (this work) with the sequence of Submediterranean horizons (after Fortwengler & Marchand 1994, 1997; Thierry et al. 1997 and Cariou et al. 1997) for the terminal Callovian and basal Oxfordian. The double line between adjacent biohorizons indicates the stratigraphical interval conceptually present between each defined unit (see Page 1995).

rizon corresponds with part of the Scarburgense Horizon, as described by Cariou et al. (1997). The Subboreal *scarburgense* Biohorizon would therefore correspond to a higher part of the same Horizon.

As indicated previously, *C. woodhamense* Fortwengler & Marchand non Arkell includes forms identical to *C.* aff. *scarburgense*, as interpreted here – a correlation between the subboreal aff. *scarburgense* Biohorizon and the Submediterranean *woodhamense* is consequently clear.

Conclusions

Although British sections have played a key role in the development of understanding of the Callovian-Oxfordian boundary, the majority are not suitable as GSSP candidates due to stratigraphical incompleteness. One key section, however, at Redcliff Point/Ham Cliff near Weymouth, Dorset, has the potential to yield stratigraphical information to complement any proposed or ratified GSSP, as the lithologies present are suitable for micropalaeontological analysis.

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