Integrated stratigraphical study of the candidate Oxfordian Global Stratotype Section and Point (GSSP) at Redcliff Point, Weymouth, Dorset, UK

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ABSTRACT: Ham Cliff near Redcliff Point, Weymouth, Dorset (SW England) exposes one of Europe's most complete Callovian-Oxfordian boundary sequences and has consequently been identified as a potential candidate GSSP for the base of the Oxfordian Stage. The boundary sequence lies within the thick mudrock facies of the Oxford Clay Formation and is abundantly fossiliferous, cardioceratid ammonites in particular being conspicuous. By convention, the stage boundary is drawn at the first occurrence of the genus *Cardioceras* here represented by *C. redcliffense* Page, Meléndez and Wright at the base of the Scarburgense Subchronozone of the Mariae Chronozone. Associated Perisphinctoidea (including *Peltoceras, Alligaticeras* and *Euaspidoceras*) provide additional biostratigraphical information. Other macrofossil groups show less discernible changes, although frequent belemnites (*Hibolithes*) provide new high-resolution carbon and strontium isotope data which are consistent with global curves and continuous sedimentation across the boundary interval. Magnetostratigraphic information is also available. Foraminiferal assemblages are dominated by epistominids but include a flood of early planktonic forms, including ?*Globuligerina oxfordiana* (Grigelis) immediately above the boundary. Well-preserved nannofloras are dominated by *Watznaueria* with conspicuous *Zeugrhabdotus*, podorhabdids and *Stephanolithion* indicating the NJ14 Biozone. Ostracoda and holothurian spicules are also recorded. These results are synthesised to provide a multidisciplinary, integrated review of the suitability of Redcliff Point for the definition of an Oxfordian GSSP. Correlations with the French candidate site in Haute-Provence are discussed and proposals made for formally establishing a GSSP for the base of the Oxfordian Stage in Europe.

INTRODUCTION

Although the city of Oxford in southern central England inspired d'Orbigny's selection of a name for the seventh stage (or "*étage*") of his Jurassic System (1842-1849), no suitable localities exist in the area at where the Stage can be defined according to contemporary GSSP methodologies

(Page 2004). Initial discussion on the formal designation of the Stage in the UK consequently focussed on the coast near Scarborough, NE England, the type locality of the index fossil of the lowest subchronozone of the lowest chronozone of the stage, *Cardioceras scarburgense* (Young and Bird) (Callomon 1964, 1990). The boundary interval and ammonite faunas in this area had been described in detail by Wright (1968, 1983) but lie in highly condensed, chamosite-oolite sandstone and limestone facies and significant faunal discontinuities are locally demonstrable. They are consequently unsuitable for detailed magnetic, isotopic, geochronometric and micropalaeontological studies as required by the International Commission on Stratigraphy for any GSSP proposal (Remane *et al*. 1996). As discussed by Page (2004) most other known UK localities are equally unsuitable.

In contrast, an expanded section across the stage boundary has been known for some years at Ham Cliff, near Redcliff Point, east of Weymouth on the Dorset coast, SW England (Arkell 1947; Wright 1986; Wright *in* Wright and Cox 2001; Page *in* Cox and Sumbler 2002). The section is in mudrock facies of the Oxford Clay Formation and the characteristic ammonite fauna is abundant, well preserved – although typically crushed – and with frequent complete specimens. Only recently, however, have descriptions become available of the section (Callomon 1993; Callomon *in* Callomon and Cope 1995; Chapman 1999; Page 1994; Page *in* Cox and Sumbler 2002; Page *et al*. 2003) although correlation between these has often been difficult due to the variable condition of the exposure and the impersistance of various beds taken as marker horizons by different authors.

Subsequent study, however, including micropalaeontological sampling, confirmed the site's GSSP potential (Page *et al*. 2003) and in 2003 a multidisciplinary, international task force was assembled to rigorously record and sample the boundary interval. As well as producing a remarkable sequence of over 30 ammonite faunas across 8 m of terminal Callovian, Lamberti Subchronozone and the basal Oxfordian, Scarburgense Subchronozone sediment, rich assemblages of foraminifera and nannofossils, together with ostracods and holothurians have now been recovered. In addition, frequent belemnites have provided key information on carbon and strontium isotopes which not only indicate continuous sedimentation across the boundary, but also provide new high resolution data for the refinement of global curves. Crucially, a repeatable lithological sequence has now been established and the 2003 section was re-validated in June 2006.

The new results are presented here in the context of a formal proposal of the Ham Cliff section near Redcliff Point as a candidate GSSP for the Callovian-Oxfordian boundary. Correlations and comparisons with the candidate site at Savournon / Thuoux in SE France (Fortwengler and Marchand 1994a, b, 1997) are included.

STRATIGRAPHICAL CHARACTERISTICS OF THE BOUNDARY INTERVAL

Description of the section

The Callovian-Oxfordian boundary section lies within a block of near-horizontally bedded Oxford Clay Formation around 200 m east of Redcliff Point in a location referred to by Arkell (1947, p. 34) as "Ham Cliff" (National Grid Reference SY 714817; Fig. 1). The general sequence is described below (see also Figs 2 and 3). Annotation of biohorizons follows Page (2004) as modified by Page, Meléndez and Wright (2009) (this volume). Stratigraphical terminology follows Wright *in* Wright and Cox (2001). "Transient" species as referred to below are chronological subspecies (see Page 1995).

WEYMOUTH MEMBER, FURZEDOWN CLAY BEDS [Oxfordian: Mariae Chronozone, Scarburgense Subchronozone]

Bed 3 [2 m+ exposed]. Dark grey, plastic clays with abundant, mainly juvenile oxytomid bivalves. *Dicroloma* (gastropod) also present. Belemnites (*Hibolithes*) uncommon. Pyritic ammonite nuclei with crushed, aragonitic middle and outer whorls common at certain levels. Transitional boundary with silty Jordan Cliff Clay Beds above. Ammonite fauna includes:

– *Cardioceras* (*Pavloviceras*) ex gr. *scarburgense* (Young and Bird) (including common morph *mariae*) (*c.* 6.1-6.2 m above base of Bed 2) [*scarburgense* Biohorizon (Ox3), part].
– *C.* (*P.*) ex gr. *scarburgense* (morph *scarburgense* dominant with occasional morph *mariae*); occasional *Peltoceras* (?*Peltomorphites*) sp. juv. (4.5-4.7 m above the base of Bed 2) [*scarburgense* Biohorizon (Ox3), part].

Bed 2 [*c*.4.3 m]. Dark grey clays with paler marl bands and frequent thin pyritic burrow fills. Common crushed aragonitic ammonites in bands; pyritic nuclei infrequent and only preserved at certain levels; occasional, partial phosphatic infil of body chambers. Benthos generally limited to a few oxytomid bivalves, but with a band of *Gryphaea* ex gr. *dilatata* (J. Sowerby). *Hibolithes* frequent; *Mecochirus* (crustacean) frequent in lower part of bed. Includes several sub-continuous marker horizons: shell-rich seam with small ferruginous nodules at 1.2 m above base (= Bed 3 of Callomon 1993); band of *Gryphaea* at 2.15 m above base; impersistant band (?locally double), of ferruginous lenticles at around 2.5 m above base. Ammonite fauna includes:

- *Cardioceras* (*Pavloviceras*) *woodhamense* Arkell abundant (3.1-3.2 m above base) [*woodhamense* Biohorizon (Ox2)].
- *Cardioceras* (*Pavloviceras*) *redcliffense* Page, Meléndez and Wright (2.4-2.5 m above base) [*redcliffense* Biohorizon (Ox1)].

[Callovian: Lamberti Chronozone, Lamberti Subchronozone]

- *Quenstedtoceras paucicostatum* (Lange) transient γ Page, Meléndez and Wright abundant; juvenile *Peltoceras* (*Peltoceratoides*) frequent (2.2-2.3 m above base) [*paucicostatum* transient γ – *Peltomorphites* Biohorizon (LL3d)].
- *Quenstedtoceras paucicostatum* transient γ common; rare *Alligaticeras* sp. (?1.55-2.1 m above base) [*paucicostatum* transient γ Biohorizon (LL3c)].
- *Quenstedtoceras paucicostatum* transient β common (= *Q. paucicostatum* Lange *sensu stricto*). *Euaspidoceras hirsutum* (Bayle) frequent. (0.85-1.45 m above base) [*paucicostatum* transient β Biohorizon (LL3b)].
- *Quenstedtoceras paucicostatum* transient α Page, Meléndez and Wright common; rare *Hecticoceras* sp. and ?*Poculisphinctes* sp. (0.1-0.8 m above base) [*paucicostatum* transient α Biohorizon (LL3a)].

STEWARTBY MEMBER, TIDMOOR POINT CLAY BEDS

Bed 1. Marl, medium-pale grey and relatively hard, especially when dry. Top *c*. 15 cm full of fine shell debris, sometimes recognisable as fragments of *Oxytoma*. *Meleagrinella* cf. *braamburiensis* and *Dicroloma* also present; *Mecochirus* frequent.

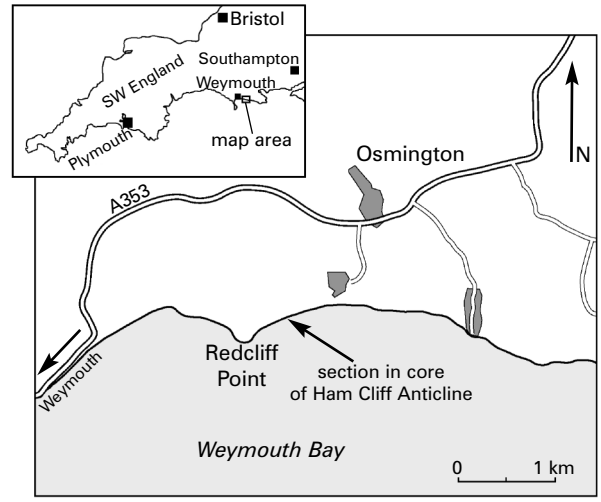

Fig. 1. The location of the Ham Cliff section, Redcliff Point in SW England (see Page *et al*. 2003 for further details).

Ammonites commonest in lower part of exposed unit and include frequent uncrushed pyritic nuclei. The top of Bed 1 provides the most reliable and persistent datum in the section and has been used as a reference for all sampling. Ammonite faunas from Bed 1 include:

- *Quenstedtoceras* sp., *Euaspidoceras hirsutum* (Bayle), *Hecticoceras* (*Putealiceras*) sp., *Alligaticeras* (*A*.) *alligatum* (Leckenby), *Kosmoceras* (*K*.) ex gr. *spinosum* (J. de C. Sowerby) (0.5-0.2 m below top of Bed) [*Quenstedtoceras* sp. 1 Biohorizon (LL2b), part?].
- *Quenstedtoceras* sp. (including common "*Vertumniceras"* morphs), *K.* (*K*.) ex gr. *spinosum*, *Hecticoceras* (*Putealiceras*) sp., *Grossouvria (Poculisphinctes) poculum* (Leckenby) (*c*. 1.65-0.95 m below top [*Quenstedtoceras* sp. 1 Biohorizon (LL2b), part?].
- *Quenstedtoceras lamberti* (J. Sowerby) s.s. typical, associated fauna not currently well characterised at Redcliff (*c*. 2 m + below top) [*lamberti* Biohorizon (LL2a)].
- *Quenstedtoceras praelamberti* (R. Douvillé) and *Euaspidoceras* (recorded by Callomon 1993 at 3.0-*c*.2.75 m below the top of their Bed 1; not exposed in 2003) [*praelamberti* Biohorizon (LL1)] [*c*. 2m exposed above storm beach level in 2003-2006].

Ammonite faunas and standard zonations (KNP, JKW, GM, JB)

By convention, the base of the Oxfordian Stage has been drawn at the first occurrence of the genus

Cardioceras, which has been interpreted as corresponding to the transition between "*Quenstedtoceras" paucicostatum* (Lange) of the terminal Callovian, Lamberti Subchronozone (Lamberti Chronozone) and basal Oxfordian *Cardioceras* ex gr. *scarburgense* (Young and Bird) of the Scarburgense Subchronozone (Mariae Chronozone). This transition is well seen at Redcliff and the base of the Oxfordian Stage is here placed immediately below the first cardioceratid transient species in which *scarburgense* morphs become prominent (at around 20% of the total cardioceratid fauna), but in association with persistent *paucicostatum* morphs. This fauna is described by Page, Meléndez, Wright (2009) (this volume) as *Cardioceras* (*Pavloviceras*) *redcliffense* sp. nov. and is first recorded at 2.4 m above the top of Bed 1 which has been taken as a datum for all measurements (see section above).

This fauna is succeeded by an assemblage rich in relatively coarsely ribbed forms referred by Callomon (1993) to *Cardioceras* (*Pavloviceras*) *woodhamense* Arkell, indicating the *woodhamense* Biohorizon (MS1b/Ox2) and then by finely ribbed *Cardioceras* (*Pavloviceras*) *scarburgense* (Young and Bird) *sensu stricto* of the *scarburgense* Biohorizon (MS2/Ox3). Fauna Ox4 (MS3) with *Cardioceras* (*Pavloviceras*) aff. *scarburgense*, a species transitional to *C. praecordatum* Douvillé, is present at higher levels but not in continuous exposure with the stage boundary succession.

Other macrofossils (KNP, GDP)

No discernible change in the associated molluscan macrofauna is discernible at Redcliff Point, although the facies present is unsuitable for diverse benthic assemblages. Elsewhere in the UK, however, the terminal Callovian Lamberti Chronozone, including the Lamberti Subchronozone, is characterised by relatively small (*i.e.* around 10 cm) *Gryphaea* (*Bilobissa*) *lituola* (Lamark) which is replaced in the Lower Oxfordian by large (up to 20 cm in width), broad, relatively flattened *G.* (*B.*) *dilatata* J. Sowerby (Duff 1991). Early examples of the latter, with a depressed *dilatata*-shaped shell but similar in size to *lituola* are recorded in a band at the extreme top of the Lamberti Subchronozone at Redcliff Point.

Belemnites offer some potential for broadly correlating the boundary as terminal Lamberti Chronozone faunas often show an association of the Boreal *Lagonibelus* ex gr. *beaumontiana* (d'Orbigny) and Tethyan *Hibolithes* ex gr. *hastata* Montfort, with Mariae Chronozone assemblages dominated by the latter (although the former persists but is rare). There is some stratigraphical suggestion that Lamberti Chronozone forms of the latter species are more slender than Lower Oxfordian forms which are more bulbous, but confirmation is required before taxonomic separation is attempted (*cf.* Doyle and Page 1991, p. 150). Trans-boundary forms from Redcliff Point, however, all appear to belong to the earlier, more slender form.

Foraminifera (MBH)

The Oxford Clay at Redcliff yields rich assemblages of agglutinated and calcareous foraminifera including many epistominids. The extensive fauna includes many well known taxa, some of which have been figured by Hart *in* Page *et al.* (2003, fig. 8) and further work is in progress. In the measured section across the boundary (Fig. 2) the diversity of the fauna increases slightly up section. Many of the species occur throughout, including *Lenticulina muensteri* (Roemer), *Planularia beierana* (Guembel), *Saracenaria oxfordiana* Tappan, *Frondicularia pseudosulcata* Barnard, *Trochammina squamata* Parker and Jones, *Ammobaculites agglutinans* (d'Orbigny), *Opthalmidium strumosum* (Guembel) and *Nubeculina bigoti* Cushman. The epistominids (largely *Epistomina mosquensis* Uhlig) are variable in abundance and dominate some assemblages. As members of this family have aragonitic tests they are usually poorly preserved and are often infilled with pyrite.

The discovery of planktic foraminifera in the Mariae Chronozone (Furzedown Clays) of the Weymouth area is very significant and was the first record of these taxa in the UK (Oxford *et al.* 2002). The same three taxa have been found in the Redcliff succession, although the dominant form is that described as *"Globuligerina oxfordiana"* (Grigelis). The generic assignment of this taxon, however, is problematic and has recently been discussed by Hudson *et al.* (2005) and further work is in progress. These taxa are also preserved as pyritic steinkerns, the original aragonitic wall having been removed.

Ostracoda (MBH)

Ostracods are common and well preserved in most samples from Redcliff. The well known Upper

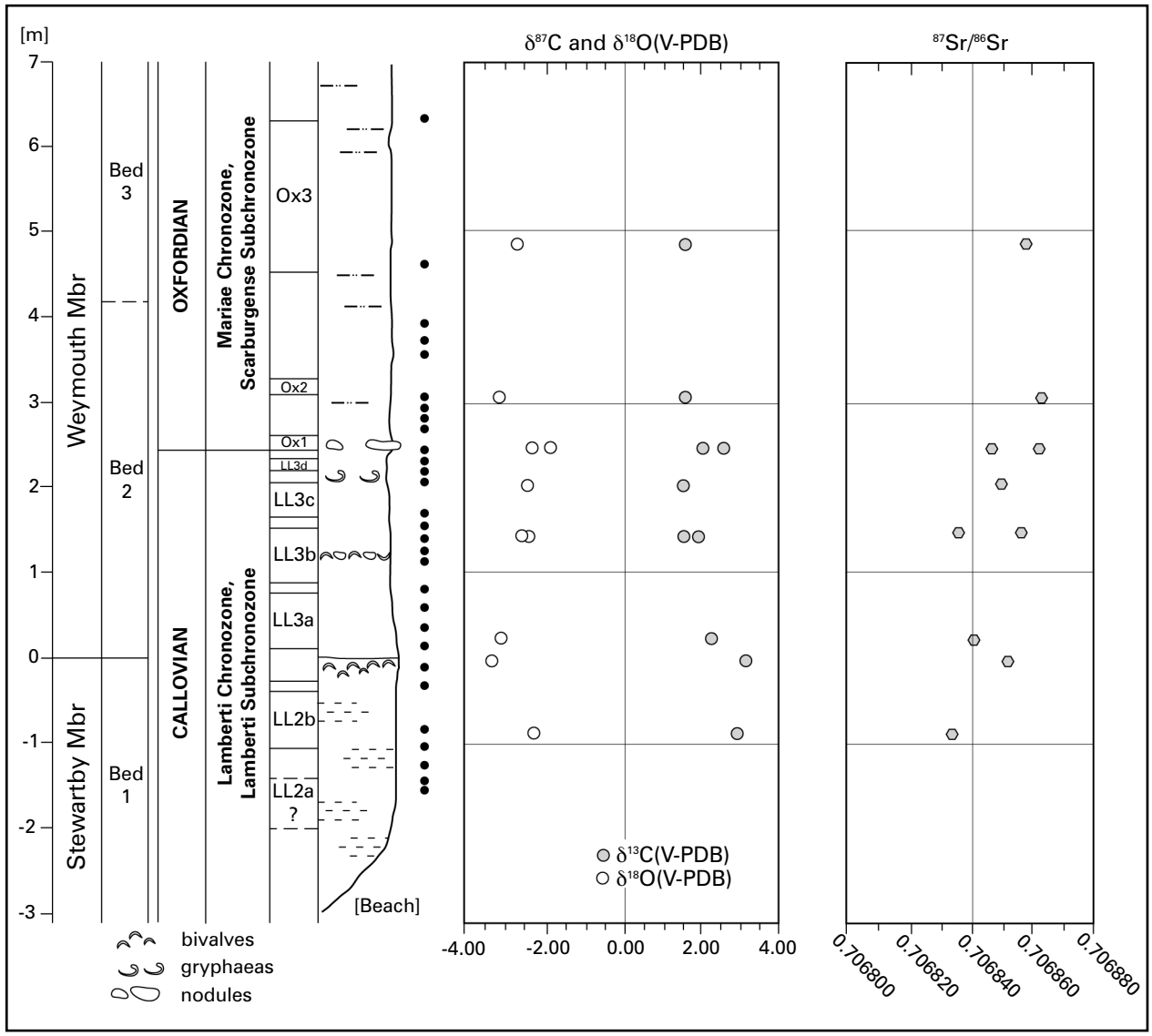

Fig. 2. The Callovian-Oxfordian boundary sequence at Ham Cliff / Redcliff Point, near Weymouth, Dorset. Ammonites biohorizons indicated (see text for explanation); dots indicate levels yielding ammonite faunas. Strontium, carbon and oxygen isotope data included.

Callovian to Lower Oxfordian species *Lobocythere scabrabucki* Lutze is dominant and has been figured from here by Hart *in* Page *et al.* (2003, fig. 8). The most recent works on faunas of this age are those of Kilenyi (1978) and Wilkinson and Whatley (2009).

Holothurians (MBH)

Holothurians sclerites are exceptionally abundant in the Oxford Clay at Redcliff and were first described by Hodson *et al.* (1956). A number of new taxa were described, including *Rhabdolites dorsetensis* Hodson, Harris and Lawson from Redcliff, some of which may have stratigraphical significance. The fauna of the Middle and Upper Jurassic is quite extensive and has been figured by Henderson *et al*. (1992).

Calcareous nannofossils (PB)

All samples yielded common to abundant, well preserved nannofossil assemblages with a species richness of over 30. The assemblages are typical of the Middle to lowest Upper Jurassic and dominated by *Watznaueria britannica* with conspicuous *Zeugrhabdotus erectus,* podorhabdids and *Stephanolithion bigotii*. The latter species comprises

a plexus with two end member subspecies, *S. bigotii bigoti* and *S. bigoti maximum*. The latter is a zonal marker species and recognised by its more rounded outline and less symmetrically arranged lateral spines. As well as *in situ* species, there are rare to frequent reworked elements, especially in the lower part of the section. The presence of *Stephanolithion bigotii maximum* throughout, places the samples within the NJ14 Zone (Lamberti-Cordatum chronozones) of Bown *et al.* (1988). The reworked nannofossils are Early Jurassic, including early Toarcian, Pliensbachian and Sinemurian forms.

Isotope stratigraphy (GDP)

Specimens of the belemnite *Hibolithes hastata* from several levels in the section were selected and processed for strontium, oxygen and carbon isotope analysis. Carbon and relatively low Mn and Fe concentrations (>150 ppm Fe or >50 ppm Mn) are consistent with values from modern organisms and can be assumed to reflect good preservation.

The use of carbon isotope stratigraphies for regional to global correlations has been demonstrated in numerous studies (*e.g.* Bartolini *et al.* 1996; Jenkyns *et al.* 2002). For the Callovian-Oxfordian interval a composite bulk ^{13}C from Jenkyns (1996) and Bartolini *et al.* (1996) shows two small ^{13}C excursions during the mid-late Callovian, a decline in values across the Callovian/Oxfordian boundary and a marked positive excursion of Middle Oxfordian age. The carbon-isotope values of the belemnite calcite through the sampled section show a decline in values from ~ 3.2 ‰ at the base to ~1.6 ‰ in the upper part, consistent with the composite bulk ^{13}C curve. The sampling interval and resolution is not sufficient to detect any further stratigraphic patterns (Fig. 2). Further discussion of carbon and oxygen isotope analyses of molluscan faunas from Redcliff Point is provided by Price and Page (2008)

A detailed curve for the evolution of $^{87}Sr/^{86}Sr$ ratios in Jurassic seawater has been constructed (Jones *et al.* 1994; Podlaha *et al.* 1998), including samples collected from Dorset. These studies show that correlations based on Sr-isotope values would be of particular value for Early and Mid Jurassic time, and further suggest that stratigraphic breaks may be identified in successions by the presence of abrupt changes in strontium-isotope values across short stratigraphic intervals (Jones *et al.* 1994). The $^{87}Sr/^{86}Sr$ data from Redcliff show a narrow range of values that are entirely consistent with the Jones *et al.* (1994) and Podlaha *et al.* (1998) $^{87}Sr/^{86}Sr$ curve. Furthermore the lack of an abrupt change in the strontium isotope values through the section supports the view that sedimentation was relatively continuous (Fig. 2).

Magnetostratigraphy

The Oxford Clay Formation at Ham Cliff has yielded positive magnetostratigraphic results including four reversed polarity intervals across the Callovian/Oxfordian boundary (J. Ogg and A. Coe *pers. comm.* 2006). These results will be fully described elsewhere, but demonstrate the suitability of the section for correlations using this technique.

SATISFACTION OF ICS GSSP CRITERIA

Remane *et al.* (1996) review the ideal requirements of a candidate GSSP, but accept that not all sections are likely to fulfil every requirement. These requirements are listed below with an assessment of the suitability of the Redcliff Point / Ham Cliff section as a GSSP.

"4.1 Geological requirements"

(a) "Exposure over an adequate thickness": A continuous sequence at least 12 m thick across the Callovian/Oxfordian boundary has been recorded at Redcliff Point, with at least a further 7 m of Lower Oxfordian succession in discontinuous exposures above. The terminal Callovian, Lamberti Subchronozone alone is around 4.9 m thick with the basal Oxfordian, Scarburgense Subchronozone at least 4 m thick.

(b) "Continuous sedimentation": The relative expansion of the boundary sequence when compared to other localities in the UK and across Europe facilitates the recognition of at least 5 ammonite biohorizons in the Lamberti Subchronozone and at least 4 in the Scarburgense Subchronozone – including transitional faunas not known from elsewhere. This indicates a remarkably complete stratigraphical record which is confirmed by the isotope record which suggests continuous sedimentation without significant breaks or condensation.

(c) "The rate of sedimentation": The relative thickness of the boundary sequence and the position

of the boundary within a major mud-rock unit indicates a high rate of sedimentation. The presence of ammonite faunas not known elsewhere indicates that successive events can be adequately distinguished.

(d) "Absence of synsedimentary and tectonic disturbances": There are no significant synsedimentary or tectonic disturbances which affect the boundary sequence and although the area is subject to contemporary landslipping, continuous cross-boundary sequences remain available.

(e) "Absence of metamorphism and strong diagenetic alteration": The area is free from metamorphism and significant diagenetic alteration (excepting compaction). Near surface material may be affected by contemporary weathering and oxidation but fresh samples can be readily obtained beneath.

"4.2 Biostratigraphic requirements"

(f) "Abundance and diversity of well-preserved fossils": Ammonite faunas are abundant at many levels across the boundary sequence and although typically crushed, original aragonite is often well preserved. Calcitic macrofossils are well preserved, as are the microfossils, including foraminifera, ostracods, holothurian sclerites and calcareous nannofossils. Aragonitic foraminifera including early planktonic forms are also present although mainly as corroded fragments or pyritic infillings.

(g) "Absence of vertical facies changes": The boundary interval lies within a thick sequence of mudrocks with no significant litho- or biofacies changes across the boundary.

(h) "Favourable facies for long-range biostratigraphic correlation": The succession was laid down in an open-marine environment and most of the taxa present are known to have a wide geographical range (the typical ammonite genera, in particular, are very wide ranging and known from Boreal, Arctic Province to Tethyan, Mediterranean Province regions in Europe).

"4.3 Other methods"

(i) "Radioisotopic dating": The technique has not been attempted.

(j) "Magnetostratigraphy": Positive results obtained by J. Ogg and A. Coe (unpublished).

(k) "Chemostratigraphy": The section has yielded important high resolution carbon and strontium isotope data which is consistent with global curves.

(l) "Regional paleogeographical context" and "facies relationships": During the boundary interval the area was well connected to both Boreal and Tethyan realms and the use of ammonites as the key correlation tool means that there is no significant facies control of the diagnostic faunas in open marine environments. The flood of planktic foraminifera recorded in the Mariae Chronozone across the Wessex Basin and Northern France (Oxford *et al.*, 2002, fig. 2) is clearly a response to either sea level change and/or changes in water mass movements.

"4.4 Other requirements"

(m) "Permanently fixed marker": The soft nature of the mudrock outcrop makes the placing of a permanent marker problematic. Nevertheless, the lithological change at the Stewartby-Weymouth member boundary provides a reliable datum for any study of the section.

(n) "Accessibility": The site is freely accessible along public rights of way and along the coastal foreshore. A high storm beach means that under normal weather conditions the site remains accessible at high tide.

(o) "Free access": Public access along rights of way (footpaths) and along the foreshore is guaranteed under English law.

(p) "Guarantees from the respective authority concerning free access for research and permanent protection of the site": The site is protected under national conservation law [Wildlife and Countryside Act 1981, Conservation (Natural Habitats, and others) Regulations 1994, and the Countryside and Rights of Way Act 2001] and lies within the legally designated South Dorset Coast Site of Special Scientific Interest (SSSI). The land is private owned and permission should be sought before any sampling of in-situ material is carried out. Advice concerning protocols for sampling programmes and other enquiries should be directed to Natural England at Slepe Farm, Wareham, Dorset, UK. The site is also included within the non-statutory Dorset and East Devon "Jurassic Coast" World Heritage Site.

ZONATION		UK BIOHORIZONS	SE FRANCE FAUNAS/HORIZONS	
OXFORDIAN	Mariae Chronozone, Scarburgense Subchronozone		?	Woodhamense (*sensu* Fortwengler and Marchand)
		Ox4: aff. *scarburgense*		
			8B-?9	Scarburgense
		Ox3: *scarburgense*		
		Ox2: *woodhamense*		
			8A	
		Ox1: *redcliffense*		
CALLOVIAN	Lamberti Chronozone, Lamberti Subchronozone		6B-7B	Thouxensis (?)
		LL3d: *pauci.* γ, *Peltomorphites*		
		LL3c: *paucicostatum* γ		Paucicostatum
		LL3b: *paucicostatum* β		
			6A?	
		LL3a: *paucicostatum* α		
			5A-5B	Lamberti
		LL2b: *Quenstedtoceras* sp. 1		
		LL2a: *lamberti*		
				Praelamberti
		LL1: *praelamberti*		

Fig. 3. Correlation of the sequence of Subboreal biohorizons recognised at the UK candidate GSSP at Redcliff Point with the sequence of Submediterranean Horizons and faunas recognised by Fortwengler and Marchand (1997) at Savournon and Thuoux, SE France for the terminal Callovian and basal Oxfordian.

CORRELATION AND COMPARISON WITH THE ALTERNATIVE CANDIDATE GSSP IN HAUTE PROVENCE

The characteristic trans-boundary sequence of cardioceratid faunas at Redcliff is typical of that recorded throughout most of Europe, with the exception of the most southerly areas such as Iberia and Italy where bioprovincial controls appear to have excluded the group. Sections in SE France, however, including the alternative candidate GSSPs at Savournon and Thuoux (Fortwengler and Marchand 1994a, b, 1997), include a greater mixing of northern (*i.e.* Boreal) Cardioceratidae and southern (*i.e.* Tethyan) Perisphinctinae and Oppeliidae. Elements of these more typical Tethyan faunas do, nevertheless, occur in the Redcliff section and provide valuable additional correlative tools (Page, Meléndez, Wright, 2009, this volume).

Although the SE France sections are also very expanded, the Scarburgense Subchronozone alone being around 48 m thick at Savournon, the ammonite fauna is far less abundant. In addition, specimens often less complete, being dominated by nuclei without corresponding body chambers. The ammonite 'horizons' recognised by Fortwengler and Marchand (1994 a, b, 1997; conceptually sub-subchronozones or 'zonules' *sensu* Page 1995) can be closely correlated with the biohorizons recognised in the UK (Fig. 3 – see Page, Meléndez, Wright, 2009, this volume, for further discussion) and reveals that although they are thinner, the Redcliff Point section currently offers the potential for higher resolution correlations using ammonites than those in SE France. The crucial boundary level with *Cardioceras redcliffense* (the *redcliffense* Biohorizon nov.; MS1a/Ox1), however, can be relatively easily correlated between the UK and SE France and corresponds to the first occurrence of *C. scarburgense* morphs towards the middle of the Elizabethae Horizon of Fortwengler and Marchand (1994 a, b), in association with persistent *paucicostatum* morphs. The base of the subsequent Scarburgense Horizon would, therefore, correlate with the base of the *woodhamense* Biohorizon (MS1b/Ox2), as both *mariae* and *scarburgense* morphs are present but no *paucicostatum* morphs. This correlation is supported by the presence of common *Peltoceras* (*Peltoceratoides*) immediately below Ox1 at Redcliff, a local expression of the typical fauna of the French Elisabethae Horizon.

Correlations with the revised scheme of Fortwengler and Marchand (1997), however, are slightly less clear as the Thuouxensis Horizon, which replaced the Elisabethae Horizon is difficult to use where hecticoceratids are rare, as in Britain. The apparent association of *scarburgense* morphs and *paucicostatum* morphs in the lower part of the Scarburgense Horizon (Fortwengler and Marchand 1997: fauna 8 A; table 1 and p. 526), however, would probably include the Ox1 Biohorizon (although *mariae* morphs are first recorded slightly lower, in the upper Thuouxensis Horizon, fauna 7B). The presence of *Cardioceras redcliffense* in SE France is now independently confirmed, however, through new sampling at Savournon (April 2007) and an initially analysis appears to confirm these correlations (Meléndez, Atrops, Page 2007).

Supporting microfossil and geochemical information is also now as available for SE France, in particular from Savournon, and includes stable isotopes, foraminifera, calcareous nannofossils, ostracoda and dinoflagellates. These results will published in full elsewhere and will facilitate further correlations with the Redcliff sections. The magnetostratigraphy of the French sections has also been tested, although meaningful results could not be maintained (J. Ogg *pers. comm.* to JKW, 2006).

CONCLUDING REMARKS

The results of this interdisciplinary international study indicate that the section at Redcliff demonstrates the most complete Callovian-Oxfordian boundary sequence known in the UK. The sequence of ammonite faunas is excellent and, as it is closely comparable to that known from the alternative candidate GSSPs in Haute-Provence, it is of proven international value for high-resolution correlations. The Redcliff locality has now also yielded important supporting microfossil, isotopic and magnetostratigraphic data across the boundary and therefore has a wider potential for international correlation. Although exposures are seasonally variable, sampling over the last 14 years has confirmed that the boundary level itself has remained permanently exposed thus confirming the potential of Redcliff Point / Ham Cliff section as an ideal candidate Global Stratotype Section and Point for the base of Oxfordian Stage of the Jurassic System.

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