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The ammonite faunas of the Osmington Oolite Formation (Jurassic, Middle Oxfordian) of the Dorset coast

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ABSTRACT

A detailed study of the lithologies of each of the beds present in the Osmington Oolite Formation of south Dorset is used to allocate numerous loose-collected ammonites to their correct stratigraphic horizons. Much new material has been collected by the author in addition to the limited amount of material available in museum collections. The age of the faunas of the three constituent members of the Osmington Oolite Formation is each assessed and placed into the context of Middle Oxfordian ammonite sequences elsewhere in England and in Europe.

1. Introduction

The Osmington Oolite Formation, one of the principal members of the Corallian Group, is exposed at a number of localities on the south Dorset coast east of Weymouth from Redcliff to Bran Point, and near Weymouth in the cliffs southeast of the town at Rodwell on Defence Research Agency land not accessible to the public, and southwest of Weymouth at Wyke Regis in the low cliffs of the Fleet Lagoon (Fig. 1). The sections are visited by numerous geologists each year: an excellent introduction to the potential of these rocks for field study is given by West (2010).

Surprisingly few ammonites have been recorded from the Osmington Formation. In his classic monograph on the ammonites of the English Corallian beds, Arkell (1935–48) cited only six ammonites from the formation, mostly very poorly preserved and specifically unidentifiable. An additional 2 specimens were recorded by Arkell (1947a). Arkell's specimens are now stored in the Oxford University Museum. In 2008, there were no ammonites from the Osmington Formation the collections of the Dorset County Museum in Dorchester (Cripps. *pers. comm.*, 2008). Callomon (*pers. comm.*, 1980) noted one specimen in the British Geological Survey Collection.

Considering that there are excellent coastal exposures of this 20 m thick formation (Figs. 2 and 3), with the frequent contributions of new material by landslips and rock falls, this situation seems incongruous. However, some of the facies present, i.e., cross-bedded oolites, are generally unsuitable for ammonite preservation. Other more suitable facies, such as the deeper water argillaceous nodular clays, often have extensive encrustation of ammonites by Ostreidae, with early decalcification of the ammonite shell followed by incorporation of the often crushed ammonite mould and surrounding matrix within concretions and nodules. This frequently makes it impossible to prepare specimens adequately. Four of the better preserved specimens in the author's collection are illustrated in Fig. 6. Ammonites are not infrequent in the Osmington Formation – there are 34 in the author's collection now donated to the Dorset County Museum, plus one each in the Portsmouth and Plymouth university collections, in addition to the eight cited by Arkell. These faunas contribute significantly to our understanding of Middle Oxfordian stratigraphy.

2. Previous research on the ammonites, zones and subzones of the Middle Oxfordian

Substantial numbers of ammonites collected elsewhere from Middle Oxfordian exposures in England have been figured in the literature. Most of the excellently preserved ammonites figured by Arkell (1935–48) came from condensed shell beds in the Highworth (Wiltshire) – Oxford area. Arkell allocated all these ammonites, consisting of 29 nominal species of perisphinctid, eight of aspidoceratid and 36 of cardioceratid, to the one Plicatilis Zone. He provisionally subdivided the zone into three subzones (Arkell, 1947b, pp. 98, 99), though later (Arkell, 1935–48, p. 385) he seemed to have second thoughts, commenting that "the subzones

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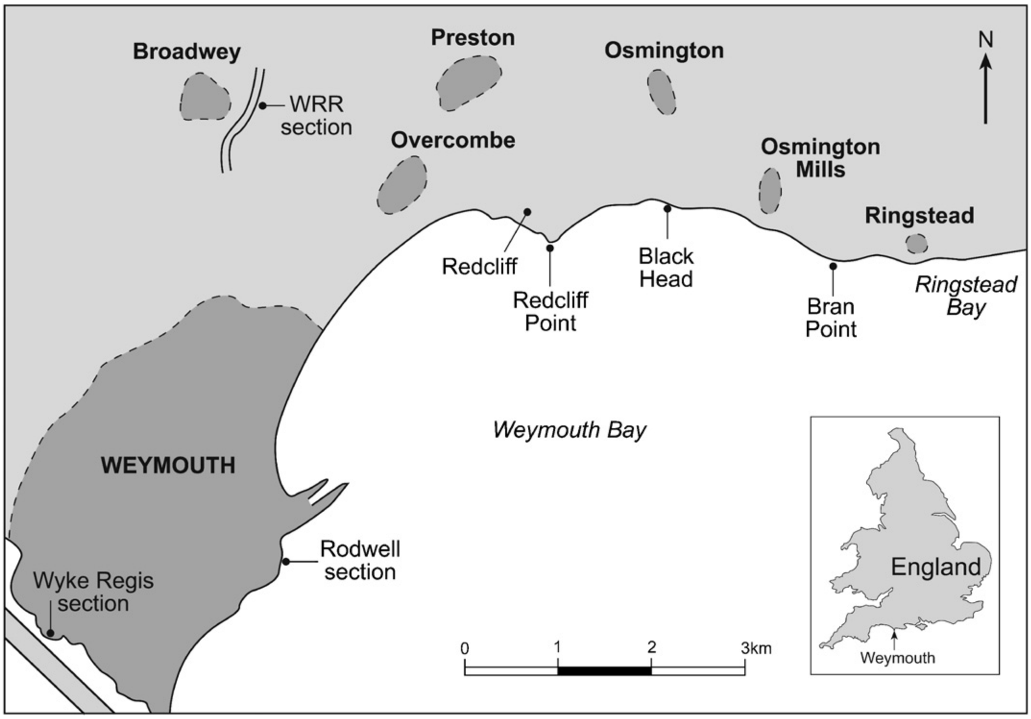

Fig. 1. Map of the south Dorset coastal area showing principal villages and localities mentioned in the text. WWR = Weymouth Relief Road.

are not altogether satisfactory, but are the best that can be suggested". Callomon (1960) retained two of the subzones (Vertebrale and Antecedens subzones), formerly defining them for the first time, and introduced a new third subzone, the Parandieri Subzone (Fig. 4). The subzones were based largely on perisphinctid ammonites. Later Callomon (1964) set these subzonal faunas into the context of European Middle Oxfordian faunas.

In their major study of Middle and Upper Oxfordian ammonite faunas from Britain, Sykes and Callomon (1979) were faced with the problem that the previous subdivisions of the Middle Oxfordian into zones and subzones, being based largely on ammonites belonging to the family Perisphinctidae, were not suitable for the UK as a whole. Though the perisphinctids were abundant in the shallow water carbonate successions of England, in large areas of, for instance, eastern England and western Scotland, clay facies Middle Oxfordian rocks yielded ammonite faunas largely belonging to the family Cardioceratidae. The cardioceratids originated in the Boreal province, and a new Boreal zonal/subzonal scheme based on cardioceratids was set up by Sykes and Callomon (1979). In areas in Britain where cardioceratids predominate, this Boreal zonal scheme is used.

The perisphinctids originated in the Mediterranean/Sub-Mediterranean faunal provinces, but use of one of the Sub-Mediterranean zonal schemes of continental authors in England is not practicable, as these are based in part on ammonites such as *Gregoryceras* which do not occur in England. In areas of England where the perisphinctids predominate, use is made of the original Arkell/Callomon zonal/subzonal scheme, as revised by Sykes and Callomon (1979), with the subdivision of the Middle Oxfordian

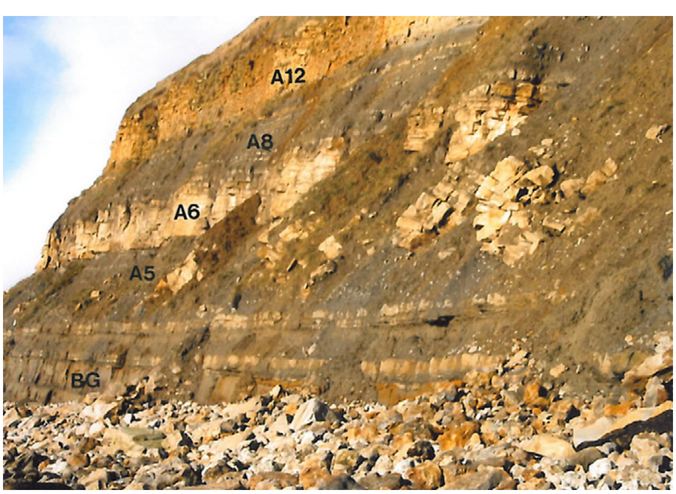

Fig. 2. View of the cliffs west of Bran Point, showing the thick development of the Middle White Oolite (A6) separating the clayey developments of the Upton Member Nodular Clay (A5) and the Shortlake Member clay (A8). Massive Bencliff Grit (BG) at the bottom and Nodular Rubble (A12) at the top. Height of cliff 40 m.

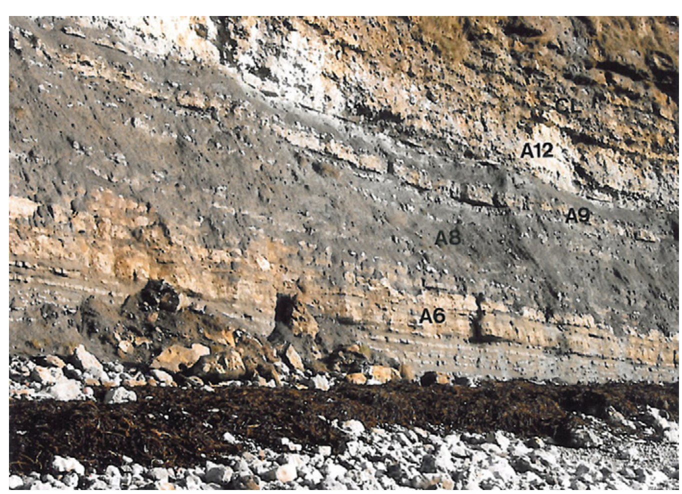

Fig. 3. View of the cliff near Bran Point, showing the thin development of Middle White Oolite (A6) near the base, with clayey Bed A8, thin Upper White Oolite (A9), and thicker, whiter Nodular Rubble (A12) and darker Clavellata Member (CL). Height of cliff 30 m.

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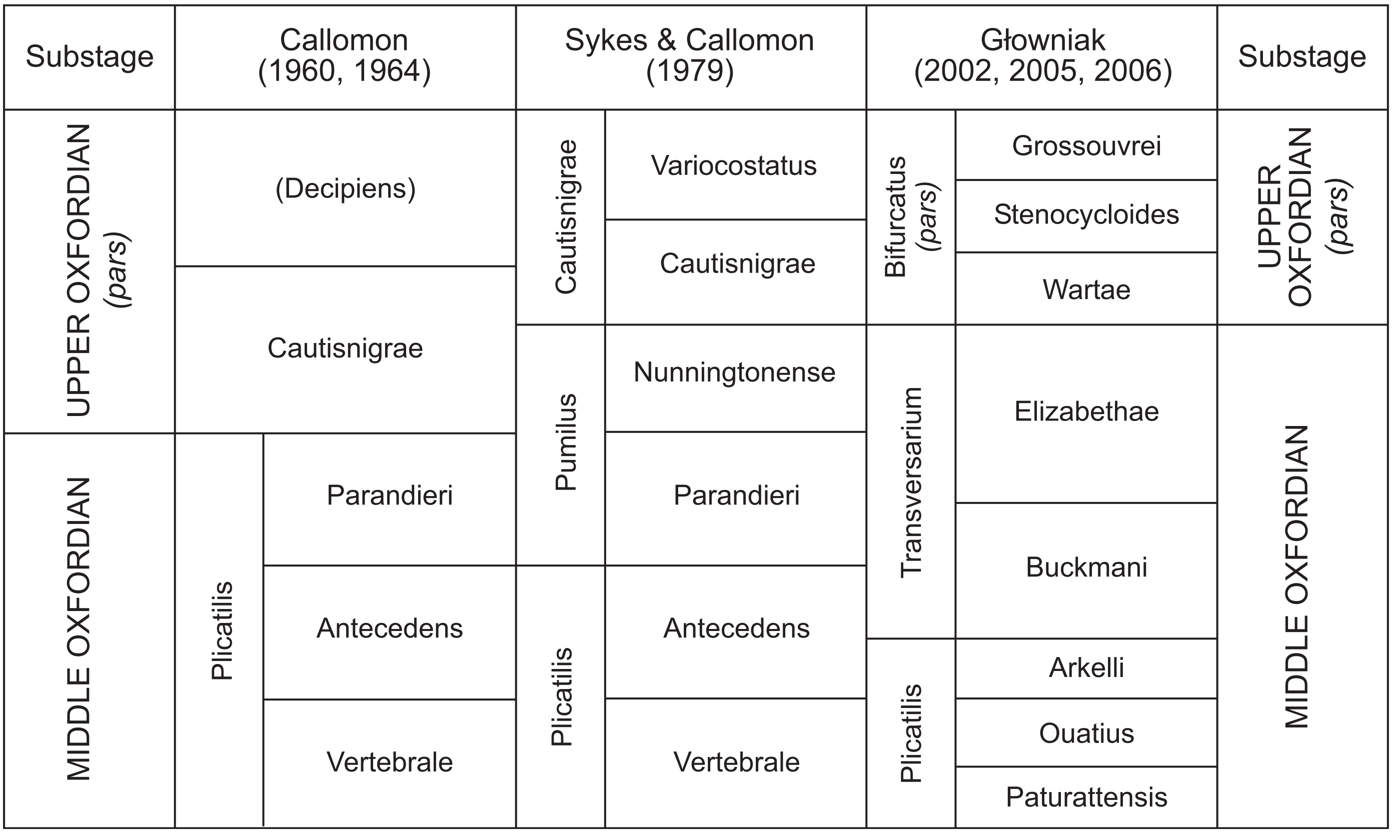

Fig. 4. Diagram showing Middle Oxfordian zones and subzones of the Sub-Boreal Province used by previous authors. Polish scheme of Głowniak (2002, 2005, 2006) included for comparison. Correlation with the UK zonal scheme (Sykes and Callomon, 1979) provisional.

into the Plicatilis and Pumilus zones (Fig. 4). This is known as the Sub-Boreal zonal/subzonal scheme. The correlation of the Boreal and Sub-Boreal schemes is known fairly accurately (Fig. 4).

The zonal/subzonal scheme based on the family Cardioceratidae has stood the test of time. However, that based on the Perisphinctidae has presented problems for some continental workers. The major subdivision of the Sub-Boreal Middle Oxfordian in Sykes and Callomon's (1979) scheme was into the Plicatilis and Pumilus zones, whereas on the continent, the Middle Oxfordian has been subdivided into the Picatilis and Transversarium zones (Fig. 4). Głowniak (2002) proposed that the first appearance of the subgenus *Perisphinctes s.s.* and its microconch counterpart *P. (Dichotomosphinctes)* should mark the major transition from the Plicatilis to the Transversarium zones. *Perisphinctes s.s.* and *Dichotomosphinctes* appear within the Plicatilis Zone as defined by Sykes and Callomon (1979), and their appearance in Britain does not mark a major subdivision of Sykes and Callomon's scheme.

As a contribution to attempts to solve the problem of what level within the Middle Oxfordian *Perisphinctes s.s.* and *Dichotomosphinctes* make their first appearance, this study takes a close look at English Middle Oxfordian ammonite faunas within the thick, continuously exposed sequence of Middle Oxfordian strata in south Dorset. Here perisphinctid ammonites occur throughout a sequence of strata belonging to both the Plicatilis and Parandieri zones.

Elsewhere in England, less stratigraphic information is available. The newly exposed Middle Oxfordian ammonite-bearing sequence at Upware (Cambridgeshire) described by Wright et al. (2000) has contributed a useful but stratigraphically limited amount of information, Plicatilis Zone strata being present to only a very limited extent. The thick Yorkshire Middle Oxfordian sequence described by Wright (2009) has yielded numerous ammonites in the past, referable to the complete Plicatilis/Pumilus zone sequence, but the horizons of the specimens in museum collections are frequently uncertain, coastal Middle Oxfordian exposures are minimal, and new, accurately located material is scarce.

3. Description of the stratigraphic sections

As was noted above, the Dorset coast offers the only sequence through the southern English Middle Oxfordian where ammonites occur bed by bed through 43 m of strata. These strata are contained within two formations, the Redcliff Formation (24 m) and the Osmington Oolite Formation (19 m). The Redcliff Formation [otherwise the Nothe Formation of BGS (2000)], was divided by Wright (1986) into the Preston Grit, Nothe Clay and Bencliff Grit members (Fig. 5). Wright (2001) added the Nothe Member. The Redcliff Formation yields late Early Oxfordian and early Mid Oxfordian ammonites; these have been discussed and figured by Arkell (1935–48) and Wright (1986, 1997).

The Osmington Oolite Formation, the subject of the present study, is divided into the Upton, Shortlake and Nodular Rubble members (Fig. 5). The exposures have been described by the author previously (Wright, 1986), and described and discussed in a sequence stratigraphic context by Coe (1995). Though a considerable number of ammonites are known from the Osmington Formation, most of these have been collected from fallen blocks on the beach. It has proved necessary to study carefully the lithology of each bed in the Osmington Oolite sequence in order to allocate these ammonites by their matrices to their correct stratigraphic level. The detailed sequence of beds is listed below, concentrating on the distinctive characters of each bed which enable fallen blocks from the Osmington Formation to be allocated to the correct source. Bed numbers with 'A' prefixes from Arkell (1935–48), with subdivisions from Coe (1995). Lithological terms of Arkell (1947a) in square brackets. Graphic logs of the sequence have been published by Arkell (1947a), Wright (1986) and Coe (1995).

3.1. Rock platform and sea cliffs at Bran point and Black Head

3.1.1. The section

The following section was measured at the base of the cliffs in the gently dipping sequence west of Bran Point (Figs. 2 and 3).

Section 1. The Osmington Oolite Formation at Bran Point, Osmington Mills, Dorset [SY 748 813]

section seen 1.5 km to the west at Black Head [SY 727 819], Beds A5f, A6a and A6b are not present, having been removed by erosion beneath Bed A6c of the Shortlake Member. Here the sequence dips steeply into the cliff and being partly hidden by beach gravel, is less productive of ammonites, only three having been collected here by the author.

3.1.2. Recognition of the largely ooidal limestone matrices

At Bran Point and Black Head, beds A1a, b are distinctive as a soft, sandy oolite. Bed A2 is a tough, ooidal shelly limestone at Bran Point, and is comprised 0.65 m of tough, fine-grained, sandy, shelly ooidal limestone at Black Head (*n.b.* this bed is not absent at Black Head as stated by Coe (1995), p. 159 – though in Coe's fig. 9, A2 is drawn and A1 is missing). The pisolite (A4) is instantly recognisable. Of the Shortlake Member oolites, only A6b, c are densely ooidal and fine grained. At Bran Point, A7a, A7b are very distinctive, coarse-grained, micritic oolites, and yield occasional well preserved ammonites. At Black Head, A7a and A7b have combined into a thick (4 m) succession of ooidal marls and bioturbated oolites,

(Erosion surface at base of the overlying Sandy Block of the Clavellata Formation; a layer consisting of 5–10 cm of sandy marl extends down as much as 50 cm in oblique burrows dug into the Nodular Rubble)		Metres
Nodular Rubble Member		
A12	Nodular, sporadically oolitic, micritic, spicular limestone, nodules large and rounded, merging in to one another, with 3 cm diameter in-filled *Thalassinoides* burrows. Frequent *Bourguetia striata* (J. Sowerby) and micrite-coated shell fragments	3.10
–	Erosion surface	–
Shortlake Member		
A11	Oolite with *Liostrea* sp. [Upper White Oolite continued, only present at Black Head]	
A10	Medium to dark grey clays with calcareous, micritic nodules at the base, and seams of oolitic clay towards the top	1.15
A9	Poorly sorted shelly oosparite [Upper White Oolite] with abundant *Nanogyra nana* (J. Sowerby). In places cross-bedded, elsewhere level bedded with *Arenicolites* burrows, and intensely burrowed in the top surface	0.58
A8	Medium-grey clay with three bands of very irregularly formed limestone concretions showing strong burrowing and bioturbation. That at 1.8 mm above the base (A8f) is micritic, with abundant, finely comminuted shell fragments, tiny turreted gastropods and sporadic ooids. That at 1.3 m above the base (A8d) is a very finely ooidal micrite, tending towards a very fine sparite, with lenses of tiny gastropods and pyrite crystals and pyrite replacement of shells and ooids. That at 0.93 m above the base (A8b) is highly ooidal, micritic, with abundant tiny, immature ooids and micrite- and clay-filled burrows	2.11
A7b	Grey clay with ooidal burrows and concretions, passing up through ooidal marl into a coarse, shelly oomicrite, and becoming a coarsely shelly, concretionary limestone at the top with a very fine oosparite matrix. Many horizontal burrows in-filled with medium-grey clay	1.06
A7a	Tough, fine-grained, well sorted oomicrite with ooidal marl beds and sub-horizontal burrows infilled with medium-grey clay. More medium grained towards the top. Contains *Isoperna* sp.	0.55
A6c	Massive, fine-grained, poorly sorted oosparite with numerous *Arenicolites* burrows in the lower part, the top surface heavily bioturbated; passes westwards into cross-bedded oolite. [Middle White Oolite cont.]	0.55
A6b	Sandy oolite containing *Arenicolites* burrows in the lower part, passing up into sandy marl with only sporadic ooids. At Bran Point, better cemented in irregular layers which stand out. [Middle White Oolite, part]	Maximum 0.72
Erosion surface below A6c cuts down westwards, cutting out A6b, with ooid-filled burrows descending into A6a		
Upton Member		
A6a	(= upper part only of A6a of Coe (1995)) Bioturbated, very fine grained, sandy marl, passing up into argillaceous quartz sand, variably calcareous and partially cemented into harder sandy limestone bands and concretions	Maximum 0.39
A5f	(= lower part of A6a of Coe (1995)) Silty, sandy, calcareous clay with regular rows of generally small limestone nodules developed in or around *Thalassinoides* burrows. The nodules are of fine, pelletal biomicrite with quartz sand, occasional mica flakes and small fragments of charcoal	0.95
A5e	Mudstone with at the top a band or double band of large (35–40 cm) concretions with undulating infilled burrows. These contain scattered 0.75 mm ooids with abundant immature ooids, tiny turreted gastropods and large oyster fragments	0.85
A5d	Mudstone with frequent rows of nodules and concretions. These consist of fine, shelly oobiomicrite with pyrite traces and 0.3–0.7 mm ooids	0.70
A5c	Shelly, silty clay	0.40
A5b	Rubbly bedded limestone consisting of pelletal micrite with scattered ooids and layers of ooidal micrite. Shelly, with bivalves and small, turreted gastropods, and numerous micrite-filled burrows	0.50
A5a	Fine, plastic grey clay with ooids and pisoids at the base, passing up into shelly, pyritic clay with nodules of fine, shelly biomicrite with numerous turreted gastropods and bivalve fragments, and with a 20 cm continuous pelletal micritic limestone band towards the top	1.60
A4	[Pisolite] Tough, argillaceous, pisoidal oo-biomicrite, with abundant *Nanogyra nana* and bivalve fragments	0.46
A3	Grey-buff calcareous clay. approx.	1.00
A2	[Chlamys qualicosta bed] Bioclastic, poorly sorted, ooidal, micritic limestone with numerous well-preserved small bivalves, especially *C. qualicosta*, *Nanogyra nana*, and also *Nautilus* sp.	0.58
A1b	Soft, argillaceous, bioturbated, finely oolitic marl	0.94
A1a	Heavily bioturbated, sandy oolite	0.81
–	Bored erosion surface	–
Redcliff Formation, Bencliff Grit Member		
Tough, calcareous, fine grained sandstone		

Almost all the above section can be inspected in the cliff and rock platform at Bran Point as the strata dip gently eastwards (Figs. 2 and 3). This section is the primary exposure of the Osmington Formation, yielding the majority of ammonites. Westwards, Bed A6c cuts down so that the Upton Member sequence becomes progressively thinner. Thus in the similar

	Formation	Member
CORALLIAN GROUP (pars)	Osmington Oolite	Nodular Rubble
		Shortlake
		Upton
	Redcliff	Bencliff Grit
		Nothe Clay
		Preston Grit
		Nothe Grit

Fig. 5. Stratigraphic subdivisions of the south Dorset Middle Oxfordian strata.

whereas A8 is hidden by beach boulders. The shelly oosparite (A9) does not appear to have yielded any ammonites.

Above, the Nodular Rubble is a distinctive, micritic, shelly limestone with finely comminuted shell debris and sponge spicules. The Sandy Block Member of the overlying Clavellata Formation occasionally yields poorly preserved perisphinctid ammonites preserved in distinctive, fine grained, sporadically ooidal, bioclastic limestone.

3.1.3. Ammonites preserved in concretions and nodules

Initially, it might be thought impossible to be certain of the provenance of ammonites preserved in concretions and nodules derived from Upton Member clays (Nodular Clay, A5) and Shortlake Member clays (A8, A10). Both matrices can be noticeably ooidal, with abundant immature ooids, and seams of small turreted gastropods and bivalves. However, there are differences. Shortlake Member concretions are more recrystallised, approaching a fine sparite, whereas Upton Member concretions from A5a to A5d are more micritic. A5f concretions are noticeably sandy and lack ooids. Of the larger concretions, those from the Nodular Clay are large and rounded, heavily bioturbated with thin, micrite-filled and clay-filled burrows, and heavy oyster encrustation. Concretions from the Shortlake Member are more irregularly formed, with irregularly weathering in-filled burrows and with bivalves such as *Pteroperna* sp.

3.2. Red Cliff

Hundreds of blocks derived from the large landslip present in the cliffs west of Redcliff Point litter the undercliff and beach [SY 705 818 to SY 709 817]. Many blocks have fallen from the Middle White Oolite, but numerous concretions, occasionally yielding ammonites, originated in beds A5 and A8. Though Arkell (1947a) noted that 2 m of clay (Bed A8) with bands of nodular mudstone is seen above the Middle White Oolite at the cliff top, with Nodular Clay (A5) beneath it, in his measured section (the only one ever published), Arkell did not distinguish between the matrices of concretions from the different levels. The Osmington Formation forms a vertical cliff face at the top of Red Cliff, and an easily accessible, rotated slipped block at [SY 707 818] enables the following section to be measured. Suggested correlation with Arkell's bed numbers in brackets:

Section 2. The Osmington Oolite Formation at Red Cliff [SY 707 818]

Shortlake Member		Metre
12	(?A8) Nodular limestone with irregular clay partings. More massive at the base, where the bed is coarsely ooidal and shelly, with well preserved bivalves (*Pecten* sp, etc.). Above is more nodular, shelly micrite with scattered coarse ooids	Seen to 1.4
11	(?A7) Shelly, ooidal mudstone with coarsely ooidal, shelly micrite bands and nodules	0.70
10	(A6c, part) Thin-bedded to massive, cross-bedded, very poorly sorted oosparite	1.30
9	(A6c, part) Mudstone with bands of very fissile, fine grained, sandy, spary limestone	0.70
8	(A6c, part) Thin-bedded to massive, cross-bedded, very poorly sorted oosparite	1.90
7	Mudstone with *Nanogyra nana*	0.15
6	(?A6b, part) Rubbly weathering, densely ooidal micrite, described by Arkell (1947a,b) as "weathering pellety"	0.65
5	(?A6b, part) Thick bed of coarsely shelly oomicrite	0.40
Upton Member		
4	(?A5f) Sandy marl, with ooidal and shelly grains, and two 0.15 m bands of nodular, argillaceous micrite with immature ooids	1.15
3	(?A5d) Nodular calcareous mudstone with six bands of nodules of micritic limestone, largely with scattered ooids, but with ooid-filled burrows in places	1.30
2	(?A5c) Medium grey, silty mudstone with scattered small ooids	0.50
1	(?A5b) Nodular, micritic limestone with very scattered 0.5 mm ooids, numerous immature, 0.1 – 0.2 mm ooids, and containing thin, curving burrows	Seen to 0.45

The ooids of the Upton Member beds are small, between 0.5 and 0.7 mm diameter. Beds 3 and 4 thus have the distinctive presence of concretions with numerous immature ooids. Beds 5 and 6 were labelled by Arkell the Lower White Oolite, distinguished by lack of cross-bedding from beds 8 to 10, the Middle White Oolite. Limestones from beds 5 to 10 are easily distinguished, being quite densely ooidal. Beds 11 and 12 from the Shortlake Member contain concretions which have distinctly coarser ooids than the Upton Member concretions, the ooids frequently exceeding 1 mm in diameter. Examination of the matrices of ammonites in the author's collection from Red Cliff shows that all came from the Upton Member.

Arkell (1947a) noted that the facies of the Middle White Oolite at Red Cliff is transitional, resembling that of the Forest Marble of the Cotswolds. The prevalence of very poorly sorted ooids, as well as laminated mudstone, in both formations, shows that the water was deeper, with no sorting or re-working of ooids by currents. At Red Cliff, the Middle White Oolite is passing, in this case westwards, into deeper water clay facies. Thus, it should have come as no surprise to research workers (though it did) that, 3.5 km to the west in 2009, as the Weymouth Relief Road was cut through Littlemore Hill east of Broadwey at SY 673 834, the Osmington Formation was revealed to be substantially clayey in facies. A series of 1–2 m thick clay beds was revealed, separated by thin, 10–20 cm thick, nodular ooidal micritic limestone bands. Only at the base were there two 40 cm thick oomicrite beds (West, 2010). To the southwest, in the low cliffs at Wyke Regis, the succession is largely limestone. However, it is not possible to use Arkell's standard bed numbers (Wright, 1986). No ammonites have been recorded from this section.

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Table 1
Bed by bed list of ammonites present in the Osmington Oolite Formation.

Arkell bed no.	Ammonite species present
A12 (Nodular Rubble)	*Perisphinctes* (*Perisphinctes*) cf. *chloroolithicus* Gümbel[a], *P.* (*P.*) cf. *tumulosus* Buckman[a], *P.* (*P.*) *pumilus* Enay[d], *P.* (*P.*) cf. *parandieri*[e] de Loriol, *P.* sp. (3 specimens)[a]
A9–A11 (Upper White Oolite)	No ammonites known
A8	*Perisphinctes* (*Dichotomosphinctes*) aff. *dobrogensis* Simionescu, *P.* (*Otosphinctes*) cf. *arkelli wysokae* Głowniak, *P.* (*Liosphinctes*) aff. *cumnoriensis* Arkell
A7	*Perisphinctes* (*Perisphinctes*) *parandieri* de Loriol, *P.* (*P.*) *tumulosus Buckman*, *P.* (*Liosphinctes*) *apolipon* Buckman
A6 (Middle White Oolite)	*Perisphinctes* (*Dichotomosphinctes*) *antecedens* (Salfeld) (2 specs), *Cardioceras* (*Maltoniceras*) *maltonense* (Young and Bird)[a]
A5 (Nodular Clay)	*Perisphinctes (Kranaosphinctes) maximus* (Young and Bird) (*4 specs*)[a], *P.* (*K.*) aff. *ariprepes* (Buckman) (2 specs), *P.* (*K.*) *oxoniensis Arkell*, *P.* (*K.*) spp (3 specs), *P.* (*Perisphinctes*) aff. *parandieri* de Loriol, *P.* (*P.*) cf. *martelli* (Oppel)[c], *P.* (*P.*) sp., *P.* (*Otosphinctes*) *ouatius* Buckman, *P.* (*O.*) *arkelli* Głowniak, *P. (Dichotomosphinctes) antecedens* Salfeld, *Goliathiceras* aff. *elegans* Arkell
A4 (Pisolite)	*Perisphinctes* (*Kranaosphinctes*) cf. *maximus* (Young and Bird), *P.* sp.[a], *Cardioceras (Maltoniceras) vagum* Ilovaisky (3 specs)[a,b]
A3	No ammonites known
A2 (Chlamys qualicosta Bed)	*Perisphinctes* (*Kranaosphinctes*) *decurrens Buckman*
A1	*Perisphinctes* (*Kranaosphinctes*) *ariprepes* Buckman.

[a] Specimen(s) of each species in the Arkell Collection, Oxford University Museum.
[b] One specimen in the Portsmouth University Collection.
[c] Specimen in the Plymouth University Collection.
[d] Specimen in the British Geological Survey Collection.
[e] Specimen in the J.H. Callomon Collection.

3.3. Stratigraphic list of the ammonites

All ammonites listed in Table 1 below are in the author's collection, to be donated to Dorset County Museum, unless otherwise stated. On the basis of the descriptions above, the following ammonites have been allocated by matrix to these subdivisions (see Table 1):

4. Zones and subzones of the Middle Oxfordian

The term Middle Oxfordian only began to be used in Britain in the second half of the twentieth century, Arkell (1935–48, 1936) having preferred to use just Lower and Upper Oxfordian. However, Continental workers had begun to use Middle Oxfordian (Zeiss, 1957), and its use in Britain was initiated by Callomon (1964), who allocated only the Plicatilis Zone to the substage. Subsequently, to match better continental usage (Sykes and Callomon, 1979), the Plicatilis Zone and the overlying Pumilus Zone were both included (Fig. 4).

4.1. Sub-Boreal scheme

Callomon's (1960) scheme (Fig. 4) was based on the perisphinctid faunas of the condensed Middle Oxfordian Corallian sequences developed between Oxford and Highworth (Wiltshire) collected and figured by Arkell (1935–48). The lowest subzone of the Plicatilis Zone is the Vertebrale Subzone (index *Cardioceras (Vertebriceras) vertebrale* J. Sowerby), a recognition of the importance of *Cardioceras* in the early Middle Oxfordian, occurring along with *Perisphinctes (Kranaosphinctes)* spp., *P. (Liosphinctes)* spp. and *P. (Otosphinctes)* spp.

Above comes the Antecedens Subzone (index *P. (Dichotomosphinctes) antecedens* Salfeld), marking the first appearance of *Perisphinctes s.s.* and its microconch counterpart *Dichotomosphinctes*, occurring along with the perisphinctid subgenera listed above for the Vertebrale Subzone, and with the appearance of *Cardioceras (Maltoniceras*) spp.

The Parandieri Subzone, placed in the Pumilus Zone by Sykes and Callomon (1979), then marks the acme of *P. s.s.* and *Dichotomosphinctes*, with few if any perisphinctids belonging to the other subgenera. The overlying Nunningtonense Subzone is similarly rich in *Perisphinctes s.s.* and *Dichotomosphinctes*, with the first occurrence of *Decipia*, and with the replacement of the associated fauna of *Cardioceras* spp. by *Amoeboceras* spp. The Nunningtonense Subzone fauna of the basal Upper Calcareous Grit Formation of North Yorkshire was subsequently figured by Wright (1996a,b).

4.2. Sub-Mediterranean scheme

As explained in the introduction, this zonal and subzonal scheme for the Middle Oxfordian of southern England conflicts with the Polish Sub-Mediterranean scheme of Głowniak (2002). Oxfordian perisphinctid genera and species are renowned for their restricted geographical ranges, and correlation of zonal and subzonal schemes produced in locations so far apart might be expected to be problematic, confounding attempts to correlate the sequence of British perisphinctid faunas with that of forms living in the Polish Jura Chain of Central Poland, 1500 km east of Oxford. Głowniak's scheme has two principal zonal subdivisions, the Plicatilis Zone and the Transversarium Zone. Within the Polish Plicatilis Zone, Głowniak was only able to find Sub-Boreal species of *Kranaosphinctes*, *Liosphinctes* and *Otosphinctes*, without *Perisphinctes s.s.* and *Dichotomosphinctes*. She divided the Plicatilis Zone in Poland into three subzones with index species *P. (Otosphinctes) paturattensis* de Loriol, *P. (O.) ouatius* Buckman and *P. (O.) arkelli* Głowniak (Fig. 4).

Gregoryceras transversarium (Quenstedt) is rare in Poland, and the principal marker for the base of the upper zone is the major change in perisphinctid faunas from ones containing largely the perisphinctid subgenera *Otosphinctes*, *Kranaosphinctes* and *Liosphinctes* to ones containing almost exclusively *Perisphinctes s.s.* and *Dichotomosphinctes*. Głowniak (2002) introduced the Buckmani Subzone of the Polish Transversarium Zone to encompass this fauna.

4.3. Problems with the correlation of the Sub-Boreal and Sub-Mediterranean schemes

Callomon (1960) had noted that a significant thickness of strata in the middle of the substage around Oxford, allocated by Callomon to the Antecedens Subzone, contains a mixture of all of these Sub-Mediterranean Arkelli and Buckmani subzone species. Repeatedly, *Dichotomosphinctes* spp. occur in the same bed as *P. (Kranaosphinctes)* spp. and *P. (Liosphinctes)* sp., with occasional *P. (Otosphinctes) arkelli* (Callomon, 1960, pp. 180–186). There is not thus in England a sudden major change in perisphinctid fauna from one dominated by *Kranaosphinctes/Otosphinctes/Liosphinctes* to one containing almost exclusively *Perisphinctes s.s./Dichotomosphinctes*.

Neither Callomon (1960) nor Głowniak (2002) had ideal conditions to deal with however. Callomon's specimens came from a condensed series of beds, and as surmised by Callomon himself, it is possible that a mixture of forms from different but closely associated levels had been included within one subzone. Both Głowniak and Callomon often had only a limited amount of material to deal with, with only two or three specimens of critical species from important horizons, and thus the ranges of species given are not entirely reliable. Absence of a species at a particular level could be due to collection failure.

In addition, there is the possibility that in the middle of Głowniak's succession is a non-sequence equivalent in age to the period of the mixed Antecedens Subzone fauna of Callomon (1960). Thus, the correlation of Sykes and Callomon's and Głowniak's schemes given in Fig. 4 is only tentative. However, one thing is clear. All recent work on the English Middle Oxfordian, including the present work, tends to confirm Callomon's (1960) view that the appearance of *Perisphinctes s.s./Dichotomosphinctes* in England was gradual, progressively becoming the dominant element of the fauna over a considerable period of time.

5. Recognition of the standard Sub-Boreal Middle Oxfordian subzones in the south Dorset successions

5.1. Vertebrale Subzone

In the Vertebrale Subzone, cardioceratids and perisphinctids are usually about equal in number, cardioceratids being somewhat more common at the base. The Preston Grit, Nothe Clay and Bencliff Grit all appear to belong here. Most ammonites have come from the Preston Grit. Cardioceratids are much the most common ammonite, there being 15 specimens of *Cardioceras* in the author's collection (species listed by Wright, 1997), and eight specimens of *Cardioceras* and two of *Goliathiceras* cited by Arkell (1935–48, p. 386) in Oxford University Museum. Only four specimens of *Perisphinctes* are known, *P.* sp. and *P. (Arisphinctes)* cf. *helenae* de Riaz in the author's collection, and *P. helenae* and *P. (Kranaosphinctes)* sp. cited by Arkell (1935–48, p. 385). Five specimens of *Aspidoceras* are also known. The Nothe Clay has only yielded a single *Perisphinctes* fragment, and the Bencliff Grit two *Goliathiceras* spp. and one perisphinctid fragment. The preponderance of cardioceratids over perisphinctids is typical of the lowest Vertebrale Subzone (Wright, 1997).

5.2. Antecedens Subzone

In the Antecedens Subzone, perisphinctids of the *Liosphinctes/Kranaosphinctes/Otosphinctes* groups are predominant, but occur in association with the first *Perisphinctes s.s.* and its microconch counterpart *Dichotomosphinctes*. Several of the cardioceratids characteristic of the Vertebrale Subzone continue up from below, with the first appearance of *C. (Maltoniceras)* spp. The Upton Member fits perfectly, with 16 specimens belonging to the *Kranaosphinctes/Otosphinctes* group, four specimens belonging to the *Perisphinctes s.s./Dichotomosphinctes* group (Fig. 6C), and four cardioceratids, mostly *Maltoniceras*.

The change in fauna compared with that of the Preston Grit is marked. In particular the presence of *Maltoniceras* indicates the

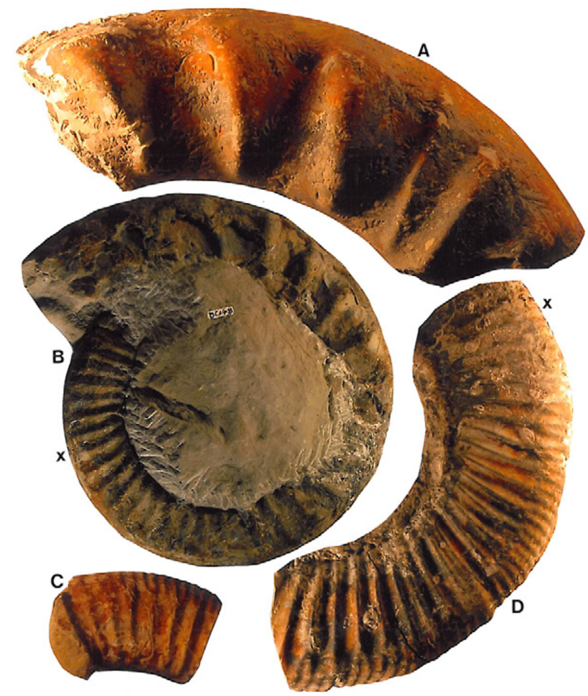

Fig. 6. Perisphinctid ammonites from the Upton and Shortlake members of the Dorset coast. ×0.43 except 6B. An '×' indicates the last septum. (A) *Perisphinctes (Perisphinctes) parandieri* de Loriol, matrix of Bed 7a, cliff west of Bran Point, entirely septate fragment of the outer phragmocone of a macroconch, DC186; (B) *Perisphictes (P.) tumulosus* Buckman, ×0.19, matrix of Bed 7a, cliff west of Bran Point, macroconch adult with most of the body chamber preserved, DC148; (C) *Perisphinctes (Dichotomosphinctes) antecedens* Salfeld, matrix of Bed A5, cliff west of Bran Point, fragment of body chamber of microconch adult with last constriction and lappet partially preserved, DC185; (D) *Perisphinctes (Liosphinctes)* aff. *cumnoriensis* Arkell, matrix of Bed A7, Black Head, body chamber fragment of macroconch, possibly juvenile (cf. Arkell, 1935-48, fig. 54, p. 164), DC43.

Antecedens Subzone (Callomon, 1960), though the presence of only a few of the *Perisphinctes s.s./Dichotomosphinctes* group suggests the lower Antecedens Subzone. The specimen allocated to *P. (P.)* cf. *martelli* (Oppel) is intriguing. It has the densely ribbed inner whorls and the coarsely ribbed outer whorl typical of *P. martelli*, the holotype of which, however, came from the Transversarium Zone (=Pumilus Zone) of the Jura (Arkell, 1935–48, p. 99). Precise attribution is thus unlikely.

The Shortlake Member has only yielded nine ammonites. The presence of *Liosphinctes* spp (two specimens – Fig. 6D) is a good indication that we are still in the Antecedens Subzone (Callomon, 1960). The *Perisphinctes s.s.* (Fig. 6A and B) and *Dichotomosphinctes* fit, though the scarcity of *Kranaosphinctes* and *Otosphinctes* suggests that the Shortlake Member ammonite fauna is distinct from that of the Upton Member. This is something that is suggested again by the presence of the specimen of *P. (D.)* aff. *dobrogensis* Simionescu, which is found in the lower Parandieri Subzone at Upware (Wright et al., 2000). At the very least the Shortlake Member belongs to the upper Antecedens Subzone.

5.3. Parandieri Subzone

Four specimens of *Perisphinctes s.s.* are recorded from the Nodular Rubble; a fragmentary specimen recorded by Arkell (1935–48, p. 386) (*P. (P.)* cf. *chloroolithicus*), together with *P. (P.)* cf. *tumulosus* Buckman in Oxford University Museum, and *P. (P.) pumilus* Enay and *P. (P.)* cf. *parandieri* de Loriol recorded by Wright (1986). Several fragmentary perisphinctids have also been found. These records are typical of the Parandieri Subzone.

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6. Conclusions

Study of rock samples collected bed by bed from the Osmington Oolite Formation on the Dorset coast has shown that it is possible to match the matrices of almost all ammonites collected loose from beach blocks to their correct stratigraphic horizons. The Upton Member has yielded a distinctive ammonite fauna representative of the lower Antecedens Subzone. The Shortlake Member belongs to the uppermost Antecedens Subzone, and Nodular Rubble Member fauna indicates the Parandieri Subzone.

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