Gallois, R. W. 2004. Geoscience in south-west England, **11**, 21-29.

THE STRATIGRAPHY OF THE UPPER GREENSAND (CRETACEOUS) OF SOUTH-WEST ENGLAND.

R.W. GALLOIS

Gallois, R.W. 2004**.** The stratigraphy of the Upper Greensand (Cretaceous) of south-west England. *Geoscience in south-west England*, **11**, 21-29.

The Upper Greensand Formation, in part capped by the Chalk, forms a broad, highly dissected plateau in east Devon and south Somerset. The formation is poorly exposed inland, but the coastal cliffs between Sidmouth and Lyme Regis provide the most extensive and most complete exposures of the Upper Greensand in Britain. De la Beche (1826) divided the formation in Devon into three parts, in ascending order the Cowstone Beds (or Sands), Foxmould and Chert Beds. A recent survey has confirmed two of these subdivisions (redefined here as members) and has added a third. Each of the three proposed members is separated by a major erosion surface that marks a change in overall lithology. The proposed type sections for all three are exposures in cliffs on the east Devon coast. The Foxmould Member, which includes the Foxmould and Cowstones of De la Beche, consists of weakly cemented sandstones that crop out mostly on steep slopes below precipitous cliffs formed by the higher parts of the formation. The Chert Beds of De la Beche have been divided into two members, the Whitecliff Chert Member and the overlying Bindon Sandstone Member. Both are markedly more calcareous than the Foxmould Member and give rise to extensive sections that reveal marked lateral variations which reflect high-energy, shallow-water, marine environments. The ages of the lowest and highest parts of the formation are well constrained by ammonite assemblages. However, much of the middle part of the succession, in particular the Whitecliff Chert Member, although locally rich in bivalves, gastropods and foraminifera, has yielded few *in situ* age-diagnostic fossils.

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INTRODUCTION

The Upper Greensand crops out over an area of about 30km by 30km in east Devon, west Dorset and south Somerset where it forms a highly dissected plateau that stretches northwards from the Devon coast to the Blackdown Hills (Figure 1). The formation is poorly exposed throughout most of this region, with the notable exception of the sea cliffs between Sidmouth,

east Devon and Lyme Regis, west Dorset where the whole of the formation, locally protected by a capping of Chalk, is well exposed (Figure 1). Almost complete sections, in which the upper part of the formation is affected by dissolution, occur west of Sidmouth at Peak Hill and High Peak, and east of Lyme Regis at Black Ven, Stonebarrow and Golden Cap.

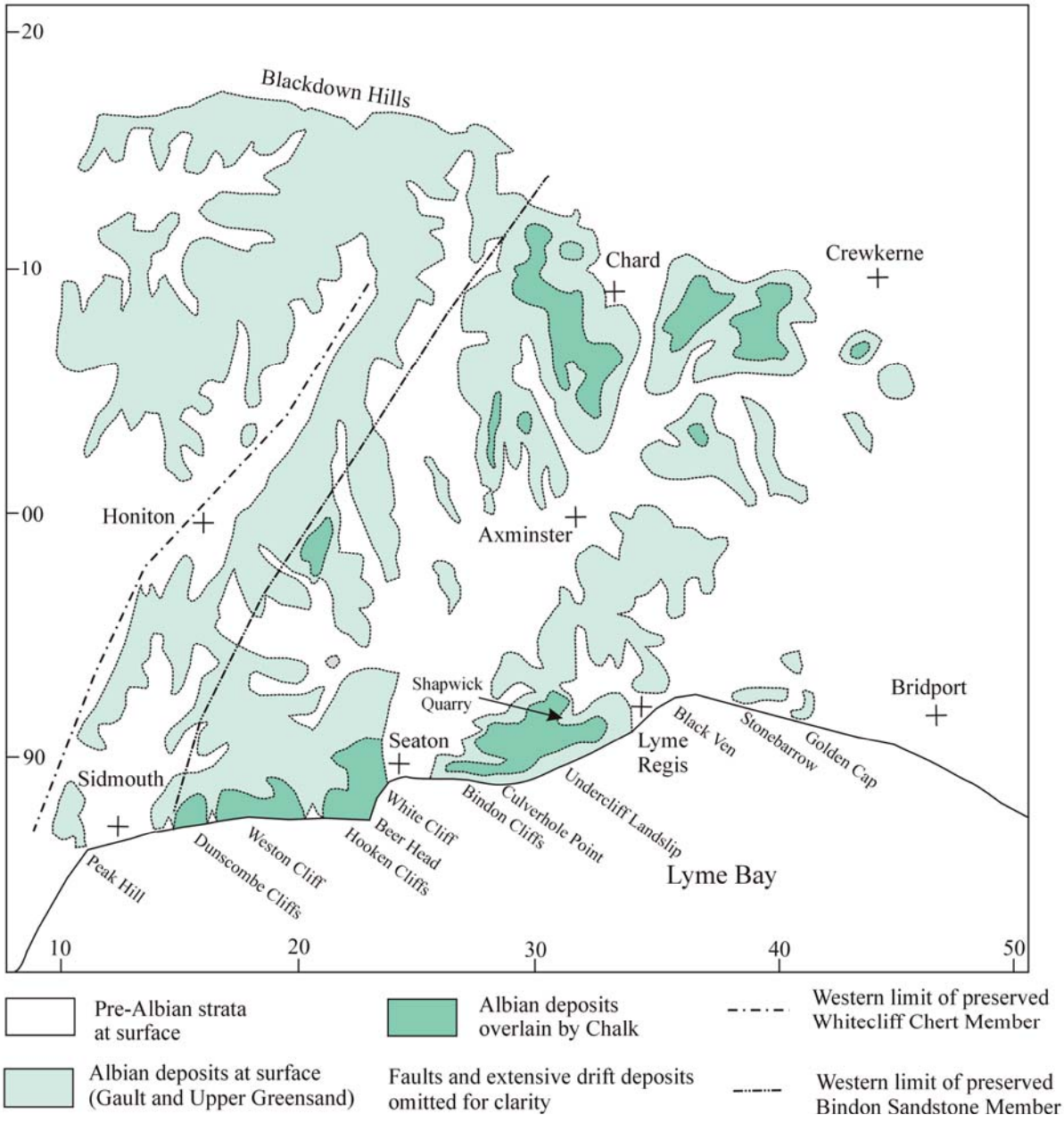

***Figure 1**. Geological sketch map showing the positions of the outcrop and subcrop of the Upper Greensand Formation in south-west England, and localities referred to in the text.*

The formation can be divided into two roughly equal parts, a less lithified lower part that gives rise to steep slopes on the coast, and a calcareously cemented upper part that gives rise to precipitous cliffs. The lower part of the formation is generally poorly exposed, but more or

less complete sections occur from time to time in Dunscombe Cliffs, below Hooken Cliffs, at White Cliff (Whitecliff on older maps) and at Culverhole Point. The higher, more calcareous part of the formation is well exposed, but mostly in less accessible cliffs. Unweathered sections occur in Dunscombe, Weston and Hooken cliffs, and in the back faces of the Undercliff Landslip complex between Seaton and Lyme Regis. Complete sections occur at beach level beneath Beer Head and adjacent to White Cliff.

Much of the inland outcrop of the Upper Greensand Formation is overlain by a thick (up to 15m) layer of Clay-with-flints that is largely derived from what was originally a continuous cover of Chalk. The higher, more calcareous part of the formation is commonly extensively decalcified beneath the Clay-with-flints, and karstic features are well displayed in those coastal sections where the Upper Greensand is not protected by an overlying layer of Chalk. The presence of large amounts of chert in the Clay-with-flints, referred to as "Clay with Flints and Chert" on the older Geological Survey maps of the region (Woodward and Ussher, 1911; Ussher, 1906), indicates that much of the upper part of the Upper Greensand has been lost to dissolution. Over much of the Blackdown Hills, the younger part of the formation is now only represented as derived cherts in the drift deposits.

The Upper Greensand of the east Devon and west Dorset coastal area was divided by De la Beche (1826) into three divisions, in ascending order the Cowstone Beds (or Sands), Foxmould and Chert Beds. Jukes-Browne and Hill (1900) noted a chert-free "Calcareous Sandstone" at the top of the formation: this was subsequently named the Top Sandstones by Smith (1961a). The Foxmould, Chert Beds and Top Sandstones were defined as members of the Upper Greensand Formation by Williams (1991).

Attempts to map out the boundaries of these divisions during the resurvey of Geological Survey Sheet 326 (Sidmouth) proved largely unsuccessful. Early descriptions of the Cowstone Beds refer to them as grey sands with calcareous sandstone doggers (up to 2x2x1m) that weather out to form extensive beach aprons. Their name, which can be traced back to the 13th century, derives from the imagined similarity of the beach accumulations to a herd of resting cows. The doggers occur within glauconitic sands that are indistinguishable from the overlying Foxmould, and the whole succession weathers to a similar foxy brown sand. The Foxmould itself contains lenses, doggers and discontinuous tabular beds of calcareous sandstone. De la Beche's (1826) original division into Cowstone Beds and Foxmould seems to have been based on unweathered sections on the coast east of Beer Head. Westwards from there, calcareously cemented beds are

common at this stratigraphical level, but the distinctively shaped 'cowstones' are rare. The boundary between the Cowstone Beds and Foxmould is not clearly defined even in the coastal exposures, is laterally impersistent, and cannot be recognised in weathered sections.

The Chert Beds, or more precisely the tough calcareous sandstones and calcarenites that enclose them, form a distinctive steep, commonly afforested, inland feature that has a sharp base marked by springs and seepages. This is readily mappable where not obscured by decalcified sands derived from the higher parts of the division. The top of the feature is marked by a sudden lessening of slope angle and change of soil type at the base of the Chalk. The absence of chert in the highest part of the formation is not a stratigraphically persistent feature and cannot be used to distinguish a 'Top Sandstones' from the underlying Chert Beds (see below).

De la Beche (1826, 1839), Fitton (1836) and Meyer (1874) recorded sections in the Upper Greensand on the East Devon coast and, in a comprehensive account, Jukes-Browne and Hill (1900) described all the principal sections that were accessible to them (notably those in the Undercliff Landslip, at White Cliff, Hooken Cliffs, Kempstone Rocks [NGR SY 162 881], Dunscombe Cliffs and Peak Hill). Tresise (1961) discussed the nature and origin of chert in the Upper Greensand Formation in south-west England, and introduced the term 'Blackdown facies' for the more siliceous variety of the Foxmould that crops out in the western and northern part of the region. Smith (1957, 1961a, 1961b) described aspects of the sedimentology of the highest part of the formation, mostly adjacent to Beer. Hamblin and Wood (1976) correlated the Upper Greensand succession of the Haldon Hills outlier with that of the east Devon coast. Williams (1991) made a detailed study of the stratigraphy and sedimentology of the Upper Greensand, based largely on coastal sections between Sidmouth and Beer, with particular respect to depositional environments and sequence stratigraphy. There have been few systematic studies of the biostratigraphy other than those by Hart and others (e.g. Hart 1970, 1973, Carter and Hart, 1977, Hart and Williams, 1990), although most of the above references describe occurrences of age-diagnostic ammonites.

LITHOSTRATIGRAPHY

Where completely preserved beneath a cover of Chalk on the east Devon coast, the full thickness of the Upper Greensand is between 50m and 55m. The boundaries of the formation are lithologically and biostratigraphically clearly defined throughout the region, except for two small areas. Westwards from Culverhole Point the formation rests with marked unconformity on

Triassic rocks, mostly red mudstones. Eastwards from there it rests on Lower Jurassic mudstones. The Upper Greensand is overlain disconformably by the lithologically distinctive Cenomanian Beer Head Limestone Formation throughout the region. The junction of the two formations is marked by a distinct sedimentary break that includes evidence of uplift and desiccation (Ali, 1975). The two exceptional areas are eastwards from Lyme Regis, where the Upper Greensand passes down into sandy Gault clay (Wilson *et al*., 1958), and at Hooken Cliffs. There, the lower part of the Beer Head Limestone passes locally into a glauconitic sandstone (Wilmington Sand Member) that is lithologically similar to the underlying Upper Greensand, but which is separated from it by a major erosion surface.

The formation has been divided in the present study into three members, in ascending order the Foxmould Member, Whitecliff Chert Member and Bindon Sandstone Member. Each of these is separated by a laterally persistent sedimentary break that is marked by one or more mineralised (hardground) surfaces (Figure 2).

Foxmould Member

The proposed type section of the Foxmould Member is White Cliff, Seaton [NGR SY 2350 8963] where Fitton (1836) and Jukes-Browne and Hill (1900) measured the full thickness of the member. The latter described this as the "most complete and most accessible [Upper Greensand] section in Devon". In recent years the full thickness of the Foxmould, including the unconformable junction with the underlying Mercia Mudstone Group and the conformable junction with the Whitecliff Chert Member, has been exposed at different times. The Foxmould Member crops out there in the lower part of an unstable cliff with the result that the exposures change markedly almost every year. At any one time about half to two thirds of the member is well exposed, the lower beds being commonly covered by debris. All except the lowest few metres of the Foxmould Member are well exposed at the relatively accessible western end [NGR SY 148 878] of Higher Dunscombe Cliff and, close to beach level, at Under Hooken [NGR SY 221 879]. The upper half of the member is exposed at beach level at Culverhole Point [NGR SY 277 893] in a series of large, intact landslipped blocks. Williams (1991) proposed a type section for the Foxmould at and adjacent to Under Hooken [NGR SY 226 878]. However, the base of the member has not been recorded there for many years and the sections are discontinuous and difficult to correlate with one another.

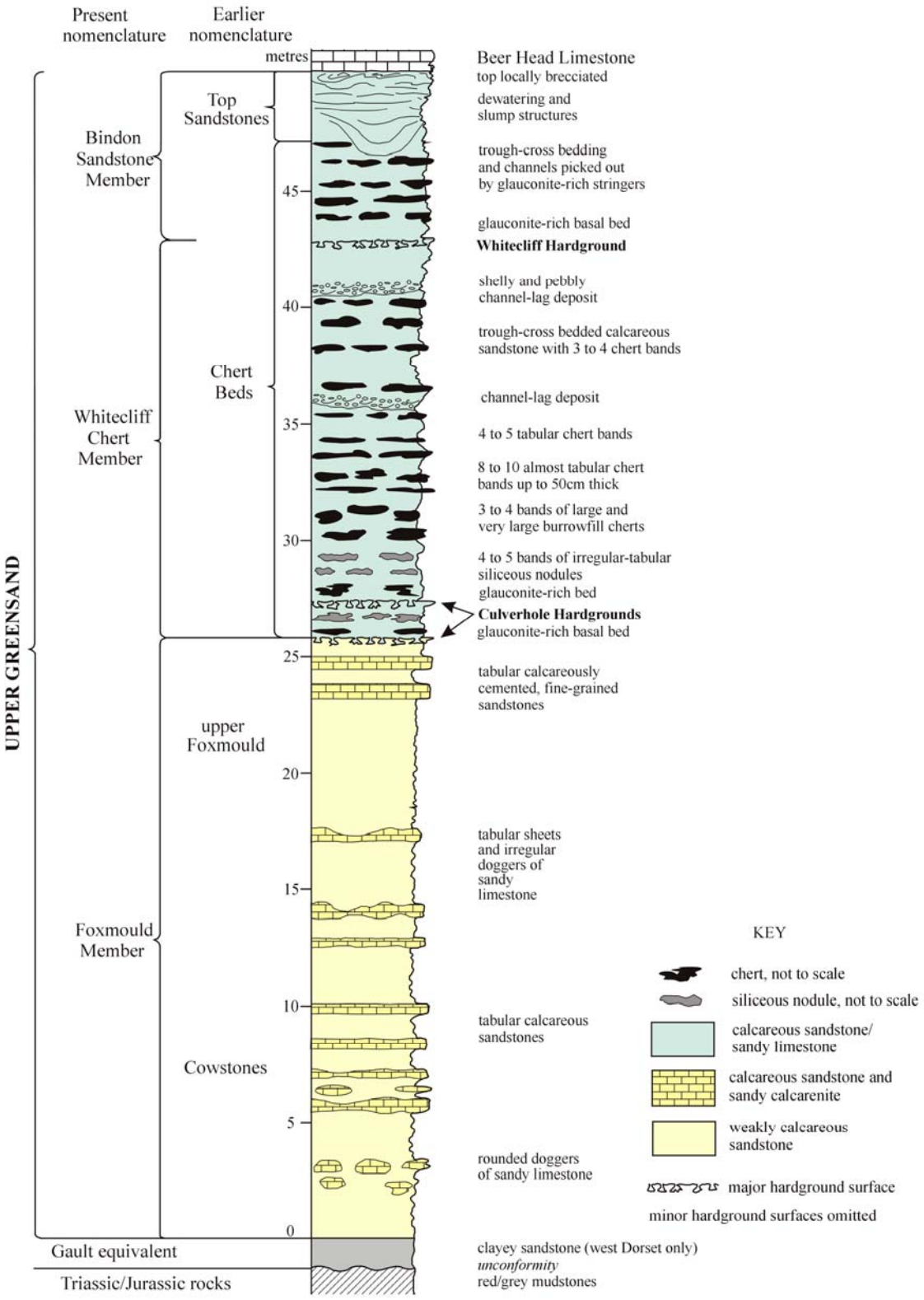

***Figure 2**. Generalised lithostratigraphy of the Upper Greensand Formation based on coastal exposures between Beer and Lyme Regis. See text for details of lateral variations.*

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The junction of the Foxmould Member with the Triassic rocks at White Cliff, and in temporary exposures westwards from there at Branscombe Mouth [NGR SY 211 880] and Littlecombe Shoot [NGR SY 182 882], is marked by a basal pebble bed that is let down by intense burrowing into red mudstones. East of White Cliff, the junction is well exposed 500 m west [NGR SY 272 894] of Culverhole Point where the basal pebble bed rests on a burrowed and bored surface of White Lias limestone.

At outcrop on the east Devon coast the Foxmould Member comprises 25 to 30m of fine- and medium-grained, weakly cemented sandstones composed of variable amounts of silica, glauconite and calcium carbonate. The member appears to thicken eastwards into west Dorset where it is about 40m thick at Black Ven and over 50m thick at Golden Cap. The fauna and sedimentary structures indicate deposition in relatively deep subtidal environments above storm wave base. When fresh the sandstones range from soft to very hard depending on the amount of calcareous or silica cement, and from faintly greenish grey to bright green. On weathering, all the lithologies break down to soft, grey, yellow or brown sands with residual clasts of calcareous and/or siliceous sandstone. Shell debris and broken shells, mostly oysters, pectinids and serpulids, are abundant at many levels, and weakly mineralised (hardground) surfaces occur locally at a few levels in the upper part of the member.

There is a progressive lateral variation from east to west in the bulk composition of the member. At White Cliff and all localities east of there in east Devon and in west Dorset, all the harder beds in the Foxmould, whether tabular or concretionary, are calcareously cemented. The most easterly siliceously cemented horizons recorded in the Foxmould Member in the present study are in the upper part of the member below Beer Head [NGR SY 224 879]. Westwards from there, although calcareously cemented horizons remain common as far west as Weston Cliff, they are less common than siliceously cemented beds at the western end of Dunscombe Cliffs and are absent at Salcombe Hill [NGR SY 140 877] and Peak Hill (Jukes-Browne and Hill, 1900).

Whitecliff Chert Member

The proposed type section of the member is White Cliff, Seaton which exposes the full thickness of the member and the junctions with the underlying Foxmould Member and the overlying Beer Head Limestone Formation. The higher part of the cliff face is difficult to access, but a low northerly dip brings the complete succession down to beach level at the

adjacent King's Hole [NGR SY 233 891]. Williams (1991) proposed a type section at Under Hooken [NGR SY 226 878] and although the full thickness can be accessed between there and the foot of Beer Head [NGR SY 226 879], the White Cliff section has the advantage that it is continuous with the type section of the Foxmould Member. In addition to the sections at White Cliff and below Beer Head, the full thickness of the member can be accessed, with care, at Culverhole Point [NGR SY277 893] and the western end of Higher Dunscombe Cliff [NGR SY 149 878]. All but the lowest 1-2m of the member has been exposed at Shapwick Quarry, Uplyme [NGR SY 313 918] in recent years.

The junction of the Foxmould and Whitecliff Chert members is wholly exposed and readily accessible at all four of the coastal localities listed above. The base of the Whitecliff Chert Member is taken at the base of a dark green, pebbly, glauconite-rich sand that infills an irregular erosion surface marked by mineralisation and intense burrowing. This sedimentary break marks a major upward change in lithology and depositional environments from weakly cemented sandstones that were deposited in relatively quiescent environments to strongly cemented calcareous sandstones and sandy calcarenites that were deposited in turbulent, shallow-water environments. At most localities, including the type section, the basal glauconite-rich sandstone is overlain by a second mineralised (hardground) surface. Both hardgrounds are particularly well exposed at Culverhole Point, from which they take the name Culverhole Hardgrounds (Edwards and Gallois, in press). In most of the east Devon cliff exposures the glauconite-rich bed weathers back to form a distinctive green-sand slot. This distinctive bed and weathering feature was recognised by Jukes-Browne and Hill (1900) to mark the boundary between the Foxmould and Chert Beds throughout east Devon and west Dorset.

Cherts are absent below the lower of the Culverhole hardgrounds, they may occur between the hardgrounds where two are present, and are everywhere abundant above the upper hardground. The lower chert layers are accompanied by one or more lines of lithologically distinctive quasi cherts, pale coloured partially silicified sandstone masses commonly with dark chert centres.

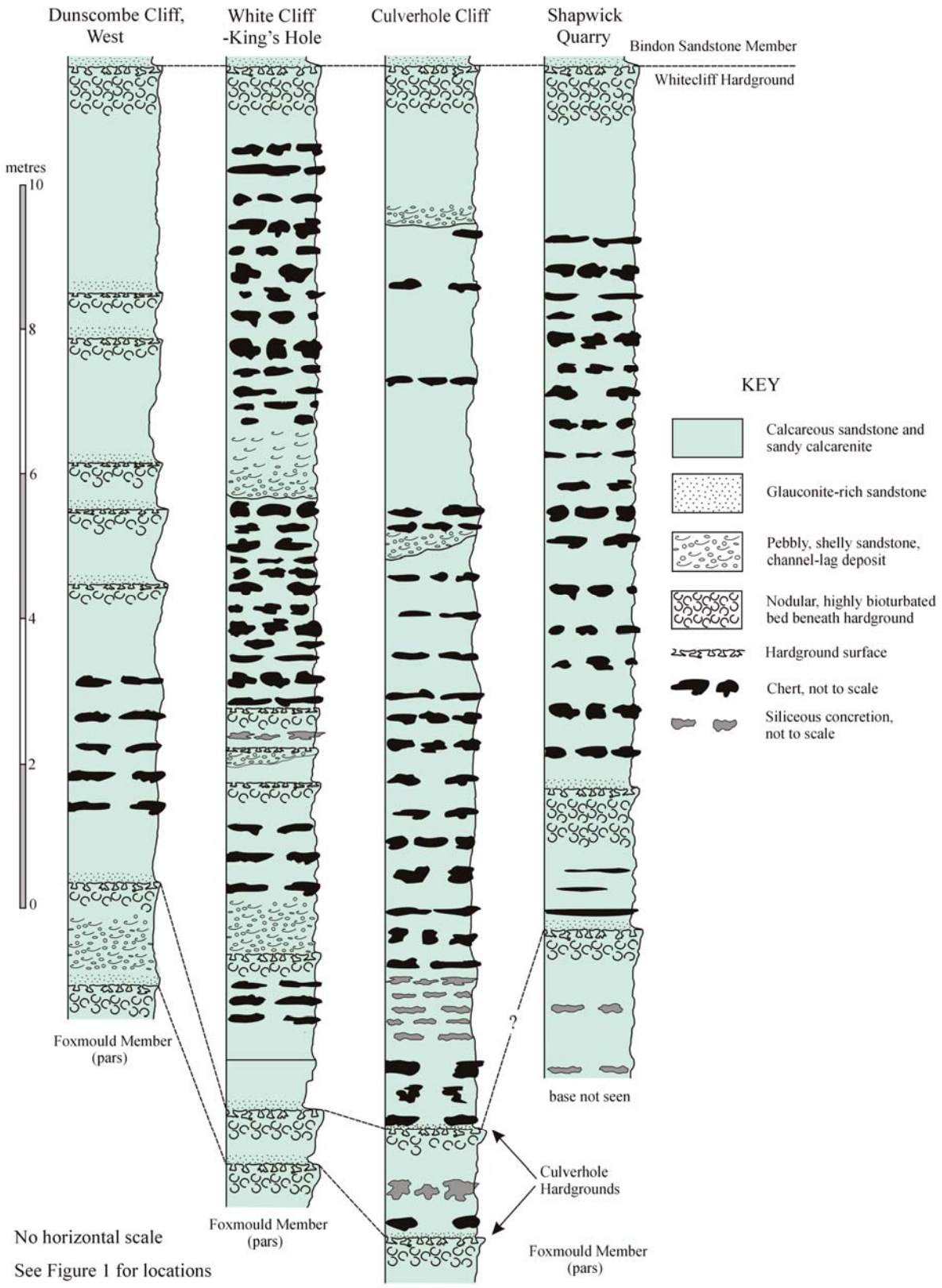


Figure 3. *Lateral variations in the Whitecliff Chert Member between Dunscombe Cliffs and Shapwick Quarry, Uplyme.*

The Whitecliff Chert Member exposed on the east Devon coast consists of 12 to 18m of predominantly sandy medium-grained calcarenites, much of which are composed of comminuted shell debris, in which beds of nodular or tabular chert are concentrated in the more carbonate-rich beds. The cherts are mostly translucent dark brown, commonly with pale inclusions derived from shell material or burrowfills. In places, they enclose well preserved cross bedding and/or bioturbation. They mostly occur in crude beds within which the character and shapes of the individual cherts is relatively constant. In the more chert-rich parts of the succession the cherts, mostly 0.15 to 0.3m thick but some as much as 0.5m thick, make up 40% of the total volume of the rock.

Mineralised (hardground) surfaces, commonly overlain by scour hollows infilled with clast-rich and shell-debris-rich sands, occur throughout the member. The clasts vary from well-rounded pebbles of glauconitic sandstone, mostly 50mm to 300mm in diameter, to angular sandstone blocks more than 0.2m across. The lithofacies indicate deposition in shallow, strongly current agitated marine environments that at times might have been intertidal. In the absence of palaeontological control, none of these erosion surfaces has yet been shown to be sufficiently persistent laterally to be used as a stratigraphical marker bed.

There is marked lateral change in the bulk lithology of the Whitecliff Chert Member when traced westwards in the east Devon cliffs. The number of chert horizons decreases westwards and chert is confined to the lower part of the member. This change is accompanied by an increase in winnowing and the number of sedimentary breaks represented by hardgrounds, and an overall thinning (Figure 3).

Bindon Sandstone Member

The junction of the ‘Chert Beds’ and the ‘Top Sandstones’ was defined by Smith (1961a) in the area west of Seaton as the base of a bed of pebbly greensand (which he named the ‘Coarse Band’) that weathers out to form a prominent recess in the cliffs. East of Seaton, where this bed was not recognised, he placed the base of the ‘Top Sandstones’ at the top of the highest bed of chert. Smith’s ‘Coarse Band’ is analogous to the basal bed of the Whitecliff Chert Member, a pebbly, glauconite-rich sandstone that infills irregularities in a prominent hardground surface. The hardground is prominently exposed at White Cliff and in all the coastal sections as far west as Higher Dunscombe Cliff and as far east as Golden Cap, and it has been recorded at inland sections throughout the region. Contrary to Smith’s

(1961a) description, the 'Coarse Band' does not separate beds with chert from beds without chert. Below Beer Head there is an abrupt lateral change in the succession within a distance of tens of metres in which cherts occur above (to the east) and below (to the west) the 'Coarse Band'. To the east, chert is everywhere present above the Whitecliff Hardground as far east as Golden Cap [NGR SY 405 921] and inland as far as Chard. Westwards, the highest chert occurs at progressively lower stratigraphical levels in the Whitecliff Chert Member until, at Higher Dunscombe Cliff, chert is confined to the lower part of the member. The presence or absence of chert is not, therefore, a stratigraphically diagnostic feature on its own. However, the Whitecliff Hardground, its associated erosion surface and the overlying glauconite-rich bed are stratigraphically consistent features throughout south-west England.

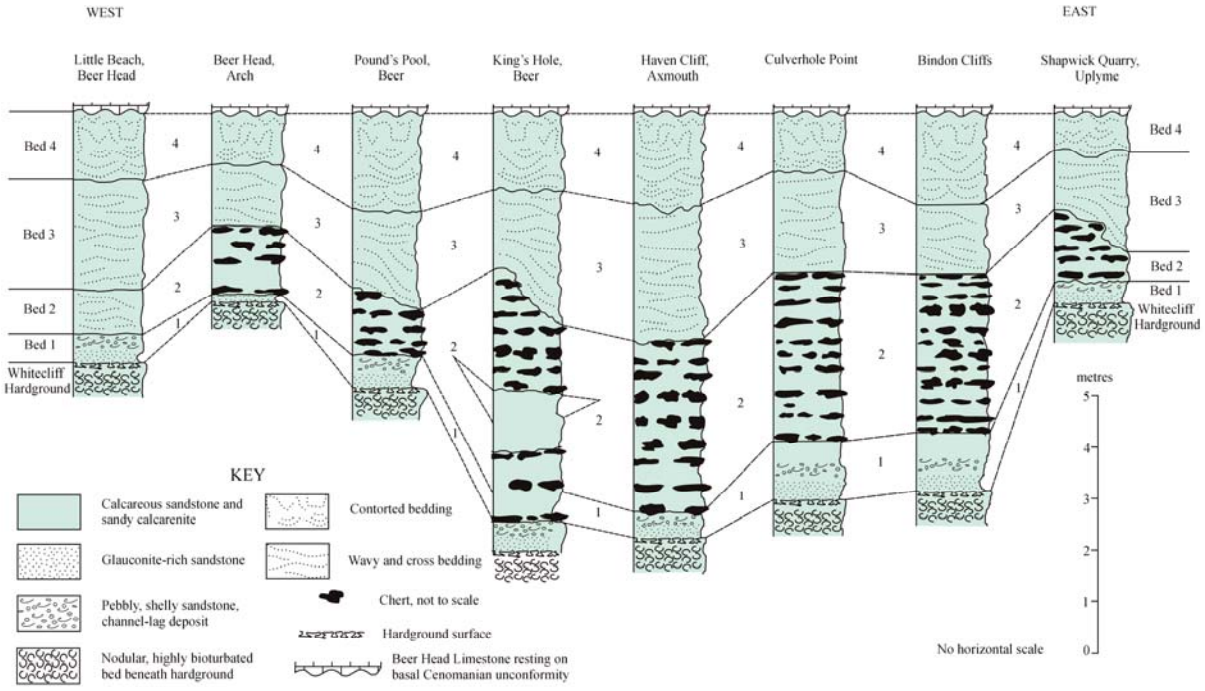
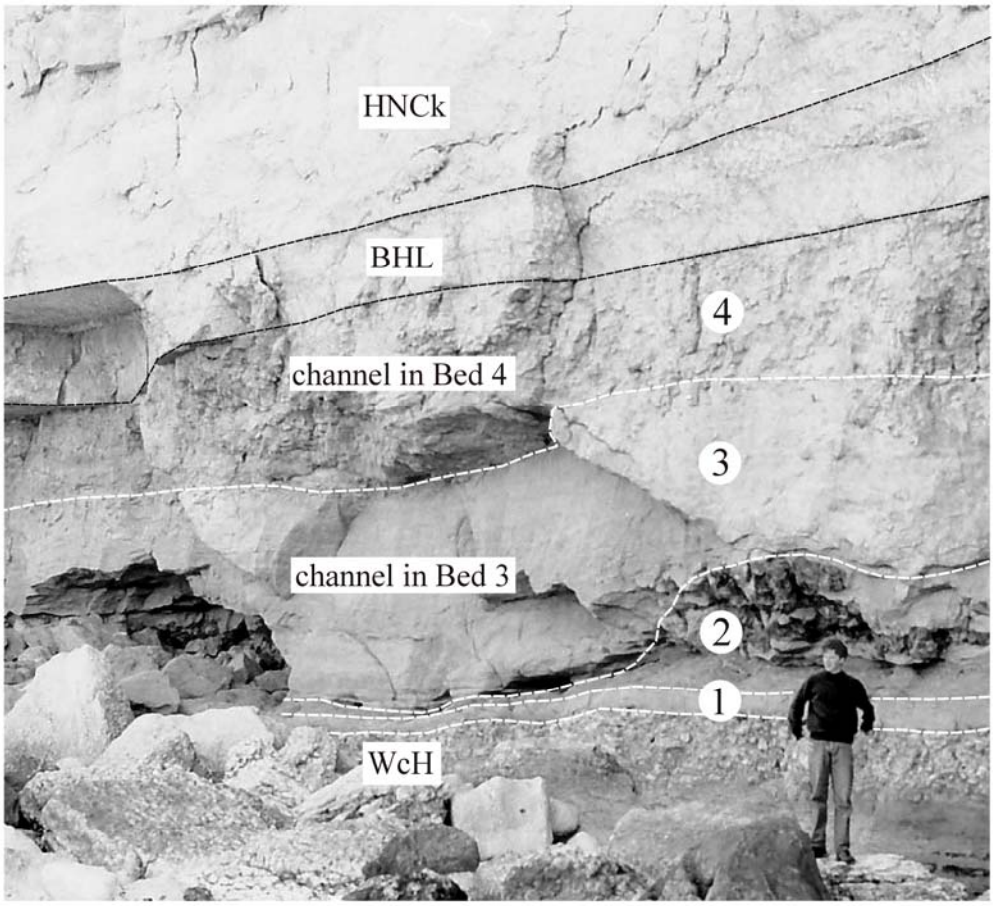


***Figure 4**. Lateral variations in the Bindon Sandstone Member between Beer Head and Shapwick Quarry, Uplyme*

The name Bindon Sandstone Member has therefore been proposed for the beds between the Whitecliff Hardground and the unconformity at the base of the Beer Head Limestone Formation (Edwards and Gallois, in press). The proposed type section is Bindon Cliffs [NGR SY 275 894] where the member, including its lower and upper junctions, is wholly exposed and accessible. The member is also fully exposed in the cliffs on the south side of Goat Island [NGR SY 277 895], where it reaches its maximum recorded thickness of over 8m, and in numerous cliff sections between Beer and Sidmouth, and at Shapwick Quarry.



HNCk.....Holywell Nodular Chalk Formation
BHL.....Beer Head Limestone Formation
WcH.....Whitecliff Hardground
1 to 4.....Divisions of the Bindon Sandstone Member

***Figure 5**. Channels in the Bindon Sandstone Member at Pound's Pool, Beer. Figure is 1.85m tall.*

In the east Devon coastal sections, the Bindon Sandstone Member comprises 3 to 8m of glauconitic, fine-, medium- and coarse-grained calcarenites and calcareous sandstones. Inland, and on the west Dorset coast, the member is commonly reduced to 1 to 2m of chert-rich rubble by dissolution (Gallois, this volume). The succession is laterally variable, but can be divided into four distinct beds throughout most of the region (Figure 4). Bed 1 comprises the pebbly, glauconite-rich basal bed referred to by Smith (1961a) as the 'Coarse Band'. Bed 2 is a glauconitic calcareous sandstone/calcarenite with up to six chert horizons, including individual cherts up to 0.6m thick. The matrix of Bed 3 is lithologically similar to that of Bed 2 with wavy and low angle trough cross bedding picked out by glauconite-rich stringers, but chert is absent. The junction with Bed 2 is locally sharp and channeled to produce chert-free channel fills that cut out much or all of Bed 2 (Figure 5). Bed 4 is sedimentologically

distinctively different from the underlying beds. It displays 'festoon' trough-cross bedding, and in its highest part contorted bedding due to slumping and/or de-watering is locally common. These highest beds contain concretionary shell accumulations rich in bivalves and gastropods, one of which has yielded the only ammonites found *in situ* to date in the Bindon Sandstone (see below).

BIOSTRATIGRAPHY

Extensive faunal collections have been made from the Upper Greensand in south-west England, as evidenced by the collections of the British Geological Survey, the Natural History Museum in London, and those of Exeter, Taunton and other local museums. Taken together, the specimens show that the Upper Greensand Formation is fully marine at all stratigraphical levels and contains a rich and diverse fauna. However, the permeable nature of much of the succession makes it unsuitable for fossil preservation other than for robust calcitic shells, and the stratigraphical and geographical distribution of the preserved material is uneven. The siliceous preservation of the 'Blackdown facies' of the Foxmould Member has yielded particularly well preserved specimens in which aragonite and calcite shells have been replaced by silica at an early stage of diagenesis, and ammonites are largely uncrushed. The calcareous lithologies of the Foxmould, Whitecliff Chert and Bindon Sandstone members of the east Devon coast have yielded much less material. The zonal and subzonal designations of the three members are summarised in Table 1.

The preserved fauna of the Upper Greensand is dominated in numbers and variety by bivalves, gastropods, echinoderms, brachiopods and serpulids. Jukes-Browne and Hill (1900) recorded over 50 species from Peak Hill in east Devon, probably all from the Foxmould, including 34 species of bivalve and 17 species of gastropod. Almost none of this material is age diagnostic. *In situ* ammonites are rare or absent in the middle and upper parts of the formation with the result their ages are still not accurately known. Attempts to use foraminifera (Carter and Hart, 1977, Hart and Williams, 1990), locally common at these stratigraphical levels, to correlate with the standard ammonite zones has so far proved to be of limited success.

The following summary of the ammonites from the Blackdown Hills and the Devon coast housed in the Natural History Museum, London, and their stratigraphical significance, is based on an unpublished account by Owen (MS 2002).

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Locality	Member/Bed	Subzone	Zone
Devon coastal and inland sites	Beer Head Limestone Formation	*Neostlingoceras carcitanense*	*Mantelliceras mantelli* (pars)
Shapwick Quarry, Uplyme, Devon	Bindon Sandstone Member (Bed 4)	*Arraphoceras (Praeschloenbachia) briacensis*	*Stoliczkaia (S.) dispar*
	Bindon Sandstone Member? *ex situ*	*Mortoniceras (Durnovarites) perinflatum*	
	not recorded	*Mortoniceras (M.) rostratum*	
Devon coast	Whitecliff Chert Member? Foxmould Member? recorded *ex situ*	*Callihoplites auritus*	*Mortoniceras (M.) inflatum*
Devon coast and Blackdown Hills; Stonebarrow, Dorset	Foxmould Member sandy 'Gault'	*Hysteroceras varicosum*	
Blackdown Hills	Foxmould Member?	*Hysteroceras orbignyi*	
	not recorded	*Dipoloceras cristatum*	

***Table 1**. Zones and subzones of the Upper Albian Substage and basal Cenomanian Stage recorded in the Upper Greensand Formation in south-west England. Zonal/subzonal scheme based on Owen (1999).*

The siliceous horizons in the Foxmould of the Blackdown Hills have yielded beautifully preserved ammonites and age-diagnostic bivalves, most of which are simply labelled "Greensand" or "Upper Greensand, Blackdown, Devon". Downes (1882) thought that most of the ammonites came from the lower concretionary beds (his Beds 2-9), with one or two specimens of *'Ammonites varicosus'* from Bed 10. However, the principal distribution of the bivalve *Actinoceramus sulcatus* (Parkinson) suggest that Beds 5 and 6 are of *Hysteroceras orbignyi* Subzone age. The distribution of *A. concentricus* (Parkinson) suggests that Beds 8 to 10 are of *Hysteroceras varicosum* Subzone age in the European Faunal Province sense. Most of the ammonites from the Blackdown Hills are unequivocally of *varicosum* Subzone age and their preservation suggests Bed 10 of Downes (1882). They include species of *Hysteroceras*, including the zonally significant *Hysteroceras varicosum* (J. de C. Sowerby) and *H. binum* (J. Sowerby), together with species of *Epihoplites*, *Euhoplites*, *'Semenoviceras'*, *Mortoniceras* (*Deiradoceras*) and *Goodhallites*. The type specimens of *H. varicosum*, *'Semenoviceras'*

gracilis (Spath), *Mortoniceras* (*Deiradoceras*) *albense* Spath and *M*. (*D*.) *devonense* Spath came from this bed at Blackdown.

Far fewer ammonites, numerically and specifically, have been recorded from the Foxmould Member of the Devon coast, despite the extensive exposures. Most of those in museum collections are in calcareous sandstone preservation (commonly referred to as 'cowstone') and have been found *ex situ*. The earliest subzone recorded at Black Ven and more westerly exposures is that of *Hysteroceras varicosum*, with an ammonite assemblage that is closely similar in genera and species to that of the same subzone at Blackdown. Other ammonites recorded *ex situ* (Hancock, 1969, M. Foster pers. comm.) from the east Devon coast in what has been presumed to be Foxmould preservation include species of *Callihoplites* indicative of the *C. auritus* Subzone.

The recorded faunas of the Whitecliff Chert and Bindon Sandstone members are sparse in comparison with those of the Foxmould Member. This is probably more a reflection of their abrasive high-energy environments and less favourable preservation matrix than the abundance and diversity of their faunas. The fauna of the Whitecliff Chert Member is dominated by thick-shelled oysters, with other bivalves, serpulids, brachiopods and echinoderms the only other common fossils. No *in situ* ammonite has been recorded, but a few chert casts have been found in the landslip at Black Ven. One of these, collected by Mr D. Sole and identified as a *Mortoniceras (M.) commune* by Dr H. G. Owen (pers. comm.), is indicative of the *C. auritus* Subzone. It seems likely, on age grounds alone, to have come from the Whitecliff Chert Member. Specimens of *Stoliczkaia* collected loose by Mr Sole and by Spath (1926) from the same area are indicative of the *S. dispar* Zone and probably came from the Bindon Sandstone Member (see below). A specimen of *Arraphoceras* (Grimsdale Collection, Natural History Museum Catalogue No. C41977) from White Cliff, east Devon is indicative of a *Mortoniceras (Durnovarites) perinflatum* Subzone age (H. G. Owen, pers. comm.). This also, seems more likely to have come from the Bindon Sandstone Member than from the Whitecliff Chert Member.

An indigenous ammonite assemblage indicative of latest Albian age was collected from an *in situ* concentration of shells in Bed 4 of the Bindon Sandstone Member at Shapwick Quarry [NGR SY 3130 9190] (Hamblin and Wood, 1976). It includes species of *Callihoplites*, *Discohoplites*, *Hyphoplites*, *Idiohamites*, *Stoliczkaia* and *Stomohamites* which, taken together, are indicative of the *Arraphoceras (Praeschloenbachia) briacensis* Subzone of the

Stoliczkaia dispar Zone (Owen, pers. comm.). The proximity of this assemblage to the unconformity at the base of the Beer Head Limestone (basal Cenomanian *Neostlingoceras carcitanense* Subzone age at this locality) makes it most unlikely that any part of the Upper Greensand there is of Cenomanian age.

CONCLUSIONS

The Upper Greensand Formation throughout south-west England can be divided into three members, in ascending order the Foxmould, Whitecliff Chert and Bindon Sandstone, each of which is bounded by a sedimentary break marked by a prominent erosion surface. Notwithstanding their continuity over an area of several hundred square kilometres, there are marked lateral variations within each member. The Foxmould Member consists of relatively uniform fine- and medium-grained glauconitic sandstones, but with siliceous cements and concretions in the west and north (including the whetstone horizons of the Blackdown Hills) and calcareous cements and concretions (including the 'cowstones') in the east. In the Whitecliff Chert Member exposed on the Devon coast the proportion of chert decreases from east to west and the number of hardground surfaces increases in the same direction. Much of the chert in the higher part of the member is represented by calcareous concretions west of Branscombe, and chert is confined to the lower part of the member. The Bindon Sandstone Member shows a similar lateral variation in chert content, chert being ubiquitous east of Beer Head and absent to the west. Much of the important local building stone worked under the name Salcombe Stone came from this chert-free part of the Bindon Sandstone Member.

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