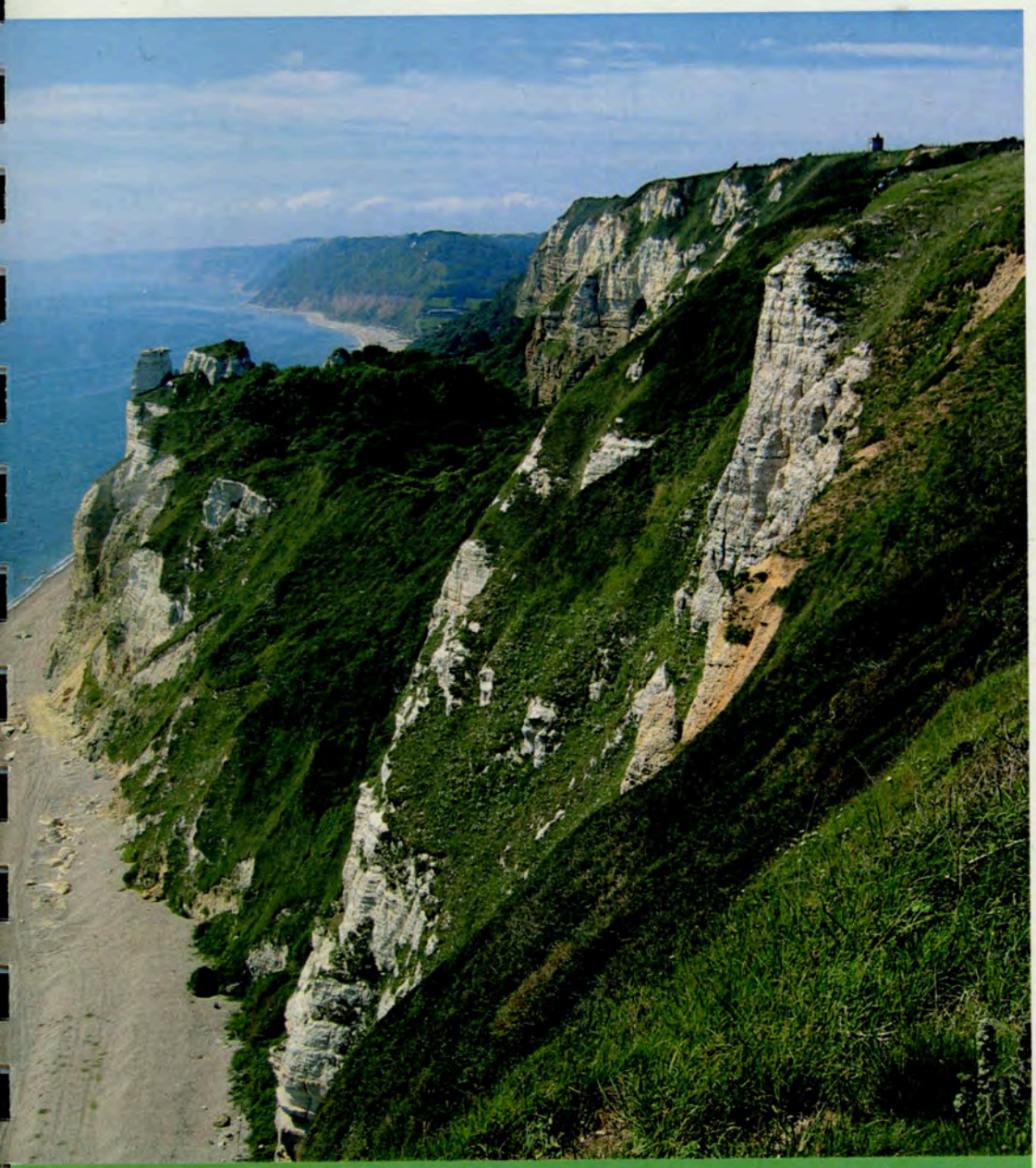
Plymouth University
6th - 12th September 09

8th International Symposium on the Cretaceous System

Convenors: Malcolm B. Hart and Gregory D. Price



Field Excursion to Dorset & Isle of Wight

Leaders: Andy Gale, Malcolm Hart, Stephen Hesselbo & Bill Wimbledon

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Field Excursion to Dorset and the Isle of Wight

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In 2001 the Dorset and east Devon Coast was inscribed on the UNESCO World Heritage List as a place of outstanding universal value on the basis of its geological succession, coastal processes and landforms and its place in the history of the development of geology (especially stratigraphy and palaeontology). Extending from Orcombe Point in the west to Studland in the east, this World Heritage Site's 85 miles of coastline contains a record of 185 million years of Earth history. At the time of the proposal being submitted to UNESCO there were discussions about whether the planned site could be extended westwards to Torquay, covering the Permian and the Devonian rocks of Teignmouth, Dawlish and Torquay or eastwards to include the Isle of Wight. For various reasons (mostly non-geological) it was decided not to expand the proposed site further, although the Isle of Wight would have been the natural extension of the site, including more of the Cretaceous succession as well as the marine Cenozoic succession of the Hampshire Basin. This excursion is, in reality, looking at what the expanded site would have included.

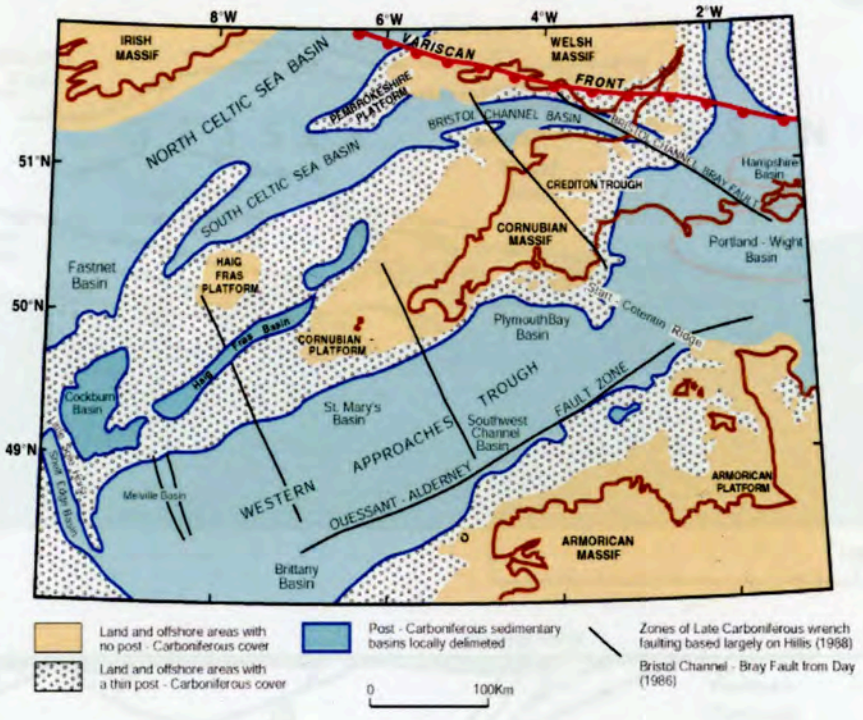


Figure 1. Major structural elements of South West England (after Hart, 1998).

The Dorset and east Devon Coast WHS sits on the western edge of the Portland-Wight Basin, which is often referred to as the Wessex Basin. The Isle of Wight is a part of this area, but the northern half of the island is most often referred to the Hampshire Basin. During much of the Mesozoic, even at times of high sea level, the basement massifs (Cornubian, Armorican, Welsh and Irish massifs) were often land, providing sediment for the subsiding parts of the basin. At times there were open marine connections (eastwards) through to the North Sea basin and (westwards) to the developing Atlantic Ocean. Many of the structures which control the Mesozoic sedimentary succession are related to the Variscan Orogeny and the E

Period	Group	Formation/Member	
Jurassic	Lias Group	Blue Lias Formation	
TRIASSIC	Penarth Group	Lilstock Formation	Langport Mbr
			Cotham Mbr
		Westbury Formation	
	Mercia Mudstone Group	Blue Anchor Formation	
		Branscombe Mudstone Formation	
		Dunscombe Mudstone Formation	
		Sidmouth Mudstone Formation	
	Sherwood Sandstone Group	Otter Sandstone Formation	
		Budleigh Salterton Pebble Beds	
	Aylesbeare Mudstone Group	Littleham Mudstone Fm	
		Exmouth Mudstone-and -Sandstone Formation	
Permian	Exeter Group	Dawlish Sandstone Formation	

Figure 3. The Triassic succession in S.E. Devon (after Hart, 2009).

conglomerates, sandstones and mudstones contain only rare plants, spores and vertebrate fossils. For many years the base of the Triassic was drawn at the base of the Budleigh Salterton Pebble Beds, although the boundary has now been placed at the base of the Aylesbeare Mudstone Group.

The **Budleigh Salterton Pebble Beds** form a dramatic cliff west of the town and can be traced inland for 18 Km as a prominent ridge (Woodbury Common). About 90% of the cobbles, boulders and pebbles in this formation are composed of a distinctive pale purple quartzite which can yield Ordovician brachiopods that are comparable to those in the *Grès Armoricain* of Northern France. The BSPB formed as a braided river system flowing north from the southern part of the Wessex Basin and one can see several examples of channels, pebble imbrications and levée systems in the cliffs. One of the most interesting features of the BSPB is the sharp and distinctive top surface, known as the **Ventifact Bed**. Within the secondary iron

Figure 4. The Ventifact Bed at the top of the Budleigh Salterton Pebble Beds at Budleigh Salterton (after Hart, 2009).

pan at the boundary can be found dreikanter or wind-faceted pebbles (many of which are polished and pitted). They all have a distinctive purple patina and this horizon can be traced inland through numerous quarries. The ablation surface represented by this horizon is of unknown duration. It is overlain by the base of the **Otter Sandstone Formation**, which in its lower part is represented by wind-blown sands. The higher parts of the formation are water-lain sands and mudstones that were deposited by successive eastward flowing rivers. Within these sandstones have been found the remains of rhynchosaurs and other vertebrates, although the most celebrated fauna is that of *Fodonyx spenceri*, an exceptional specimen of which was found by Malcolm Hart and University of Plymouth students on a field class (Benton *et al.*, 1993). The Otter Sandstone Formation is best seen in the cliffs of Ladram Bay.

The **Penarth Group** is intermittently exposed in the Axmouth – Lyme Regis Undercliff but is rather fragmented by landslipping. In Pinhay Bay the **Langport Member** (=White Lias) is well exposed and many of the sedimentary structures can be seen, including the pebbles beds, soft-sediment slumping and the fragmentary remains of *Liostrea hisingeri*. The topmost bed of the Langport Member (the Sun Bed) displays an array of "U-shaped" burrows (*Diplocraterion*). Above the Sun Bed are the distinctive mudstone/limestone cycles of the **Blue Lias**, with the first appearance of the ammonite *Psiloceras* being ~ 2 m above the lithological boundary.

Jurassic

A decision on the GSSP for the base of the Hettangian stage is awaited and, despite its merits, the Devon succession in Pinhay Bay is not a candidate (the Somerset Coast – with a similar succession – has been proposed). The Blue Lias succession, both east and west of Lyme Regis, is famous for the Milankovitch cyclicity, ammonite

Figure 5. Ladram Bay: Otter Sandstone Formation (after Hart, 2009).

Figure 6. *Fodonyx spenceri*: rhynchosaur found in Ladram Bay (after Hart, 2009).

fauna, trace fossils and – especially – the vertebrate fossils made famous by the collecting of Mary Anning (1799-1847). Standing on Seven Rock Point, just to the east of Pinhay Bay, the whole Jurassic succession up to the Purbeck Group can be seen in a dramatic panorama across Lyme Bay. Just to the east of Seven Rock Point is the famous Ammonite Pavement which forms the top of the Conybeari Subzone (Bed 29 of the Lang notation).

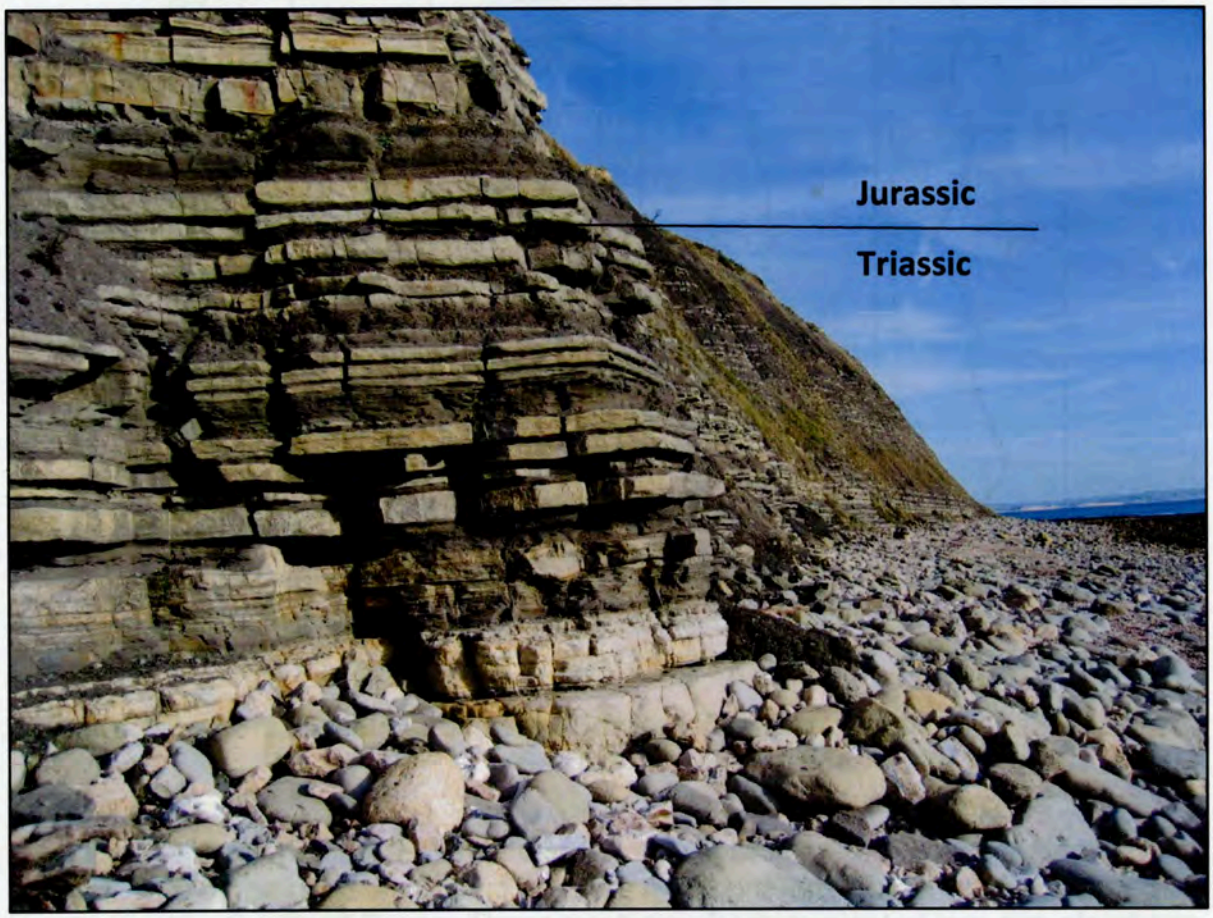


Figure 7. Triassic - Jurassic boundary based on appearance of *Psiloceras* (after Hart, 2009).

From Lyme Regis to Weymouth, and beyond to Swanage, almost every cliff is an important part of the Jurassic (and Cretaceous) succession. Weather permitting we will have just a few stops at which to look at parts of this famous succession. After Charmouth, the first of these is Burton Bradstock. Here the **Bridport Sand Formation** (Toarcian-Aalenian) is overlain by the **Inferior Oolite Formation** and the **Fuller's Earth Formation**. The Bridport Sand Formation is part of a diachronous Liassic sand complex that extends north to Yeovil, Bath and the Cotswold Hills. Its appearance on the coast is typical, although the cyclicity is often less visible in fresh, inland exposures. The overlying Inferior Oolite Formation is very thin and contains abundant evidence of reworking, hardgrounds, non-deposition and slow

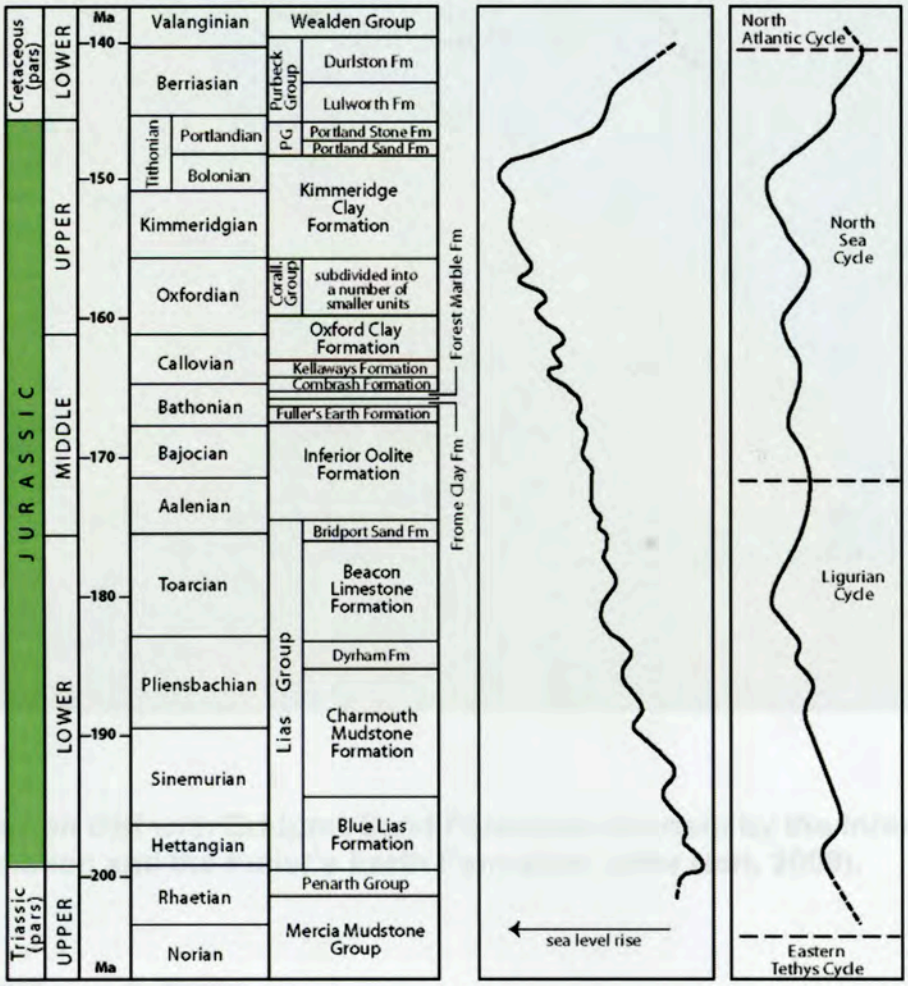


Figure 8. The Jurassic succession in Dorset (after Hart, 2009).

sedimentation. Ammonites, belemnites and other fossils are commonly found, although one of the most interesting features is the presence of large, iron-stained "concretions" – the Snuff Boxes. These are large, finely laminated iron-rich structures full of colonial bryozoan fossils and worm tubes. Each one was probably formed by non-photosynthetic, iron-oxidising bacteria, although an algal origin has also been suggested. The Fuller's Earth Formation is a grey clay that can be seen in the cliff-top, but which readily washes away as blocks fall to the beach. Recent work on the Wattonensis Beds (basal bed of the overlying Frome Clay) has yielded a diverse fauna of foraminifera, ostracods, otoliths and statoliths (stato-acoustic bones of coleoids).

East of Burton Bradstock, at the top of Abbotsbury Hill, there is a fine view of the Weymouth Lowlands. These are underlain by the Weymouth Anticline which has the **Oxford Clay Formation** in its core. In the distance can be seen the northern face of the Isle of Portland with the **Kimmeridge Clay Formation** at the base, which is overlain by the **Portland Group** and the **Purbeck Group**. The Isle of Portland is covered with quarries, all of which have removed the overburden to work the Portland Stone Formation as a valuable building stone. Large ammonites were

Figure 9 Burton cliff with Bridport Sand Formation overlain by the Inferior Oolite Formation and the Fuller's Earth Formation (after Hart, 2009).

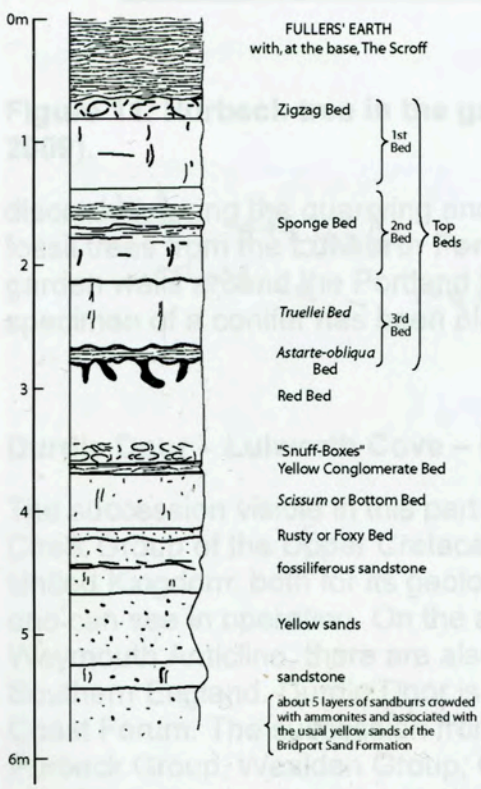


Figure 10, Inferior Oolite Formation at Burton Cliff (after Hart, 2009).

Figure 11. Purbeck tree in the garden of the Portland Heights Hotel (after Hart, 2009).

discarded during the quarrying and now appear in house walls and in gardens. The fossil trees from the **Lulworth Formation** (of the Purbeck Group) form most of the garden walls around the Portland Heights Hotel, although one large, magnificent specimen of a conifer has been placed near the hotel entrance.

Durdle Door – Lulworth Cove – Mupe Bay

The succession visible in this part of the coastline covers the Portland Group to the Chalk Group of the Upper Cretaceous. It is one of the geological highlights of the United Kingdom, both for its geological succession and the coastal processes that one can see in operation. On the almost vertical dipping northern limb of the Weymouth Anticline, there are also geological structures not seen elsewhere in Southern England. Durdle Door is an "icon" of the area and emblem of the Dorset Coast Forum. The succession from the Portland Stone Formation, through the Purbeck Group, Wealden Group, Gault Clay Formation, Upper Greensand Formation and Chalk Group can all be studied in a 500 m walk along the foreshore. Highlights

are the mid-Cenomanian non-sequence (Hart, 2008), the CTBE (Plenus Marls Member) and the chalk succession (Mortimore *et al.*, 2001).

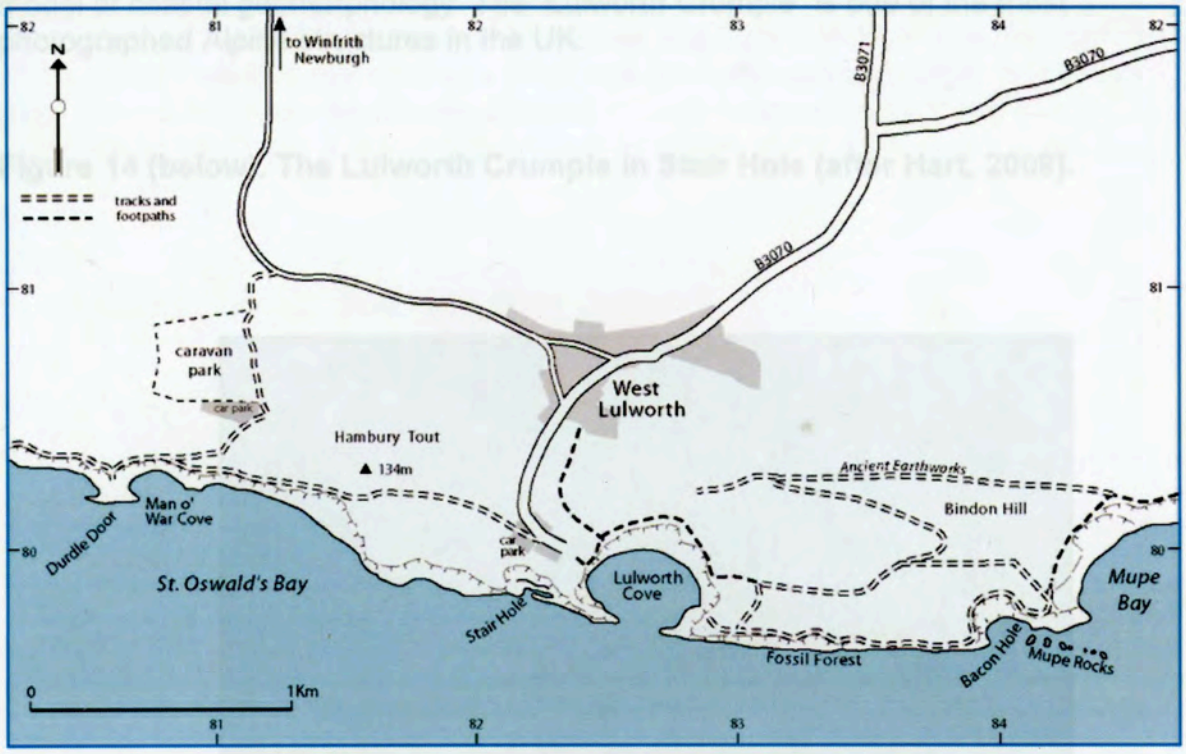
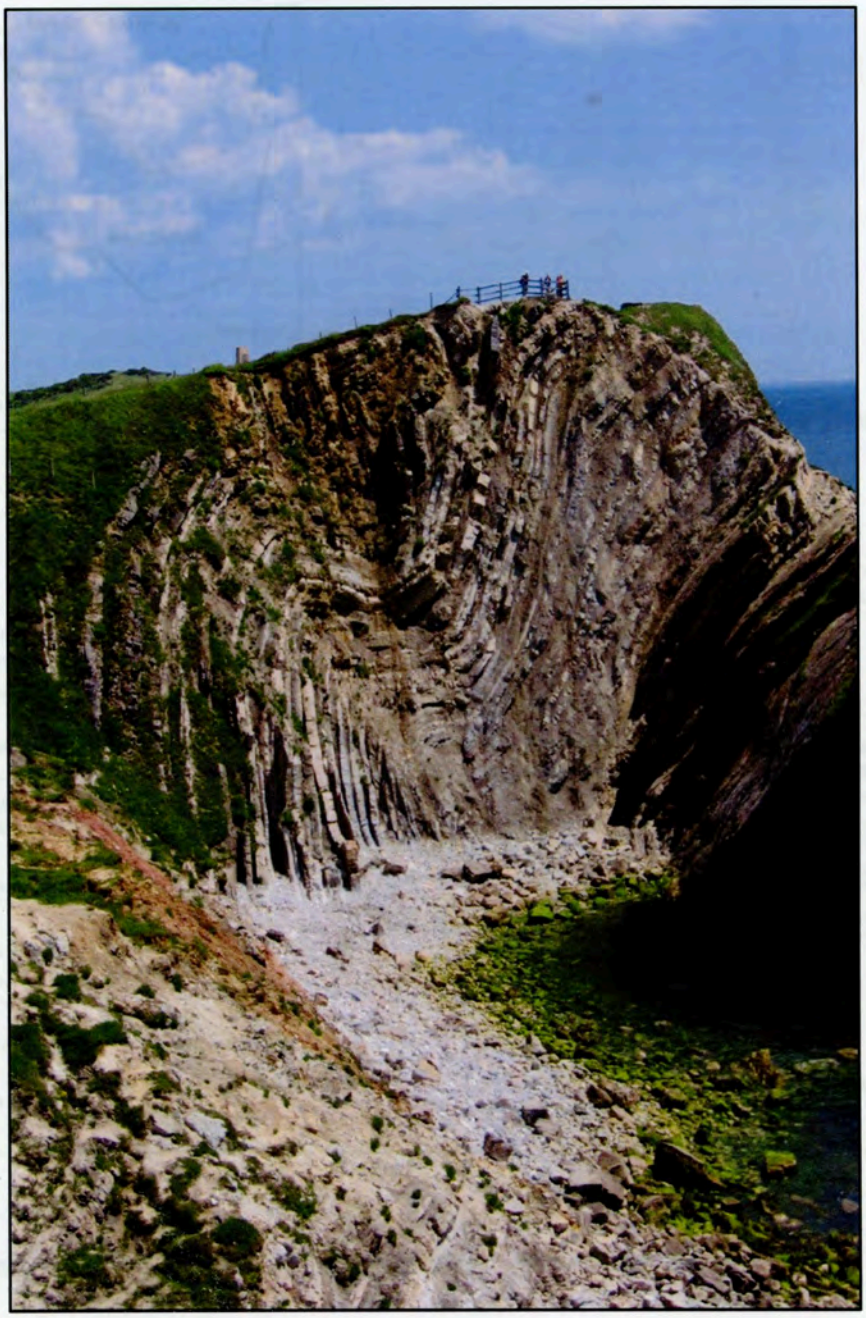


Figure 12. Locality map for Durdle Door, Lulworth Cove and Mupe Bay.

Figure 13. Durdle Door – icon of the Dorset Coast (after Hart, 2009).

After walking eastwards over Hambury Tout (Iron Age Hill Fort) there is a magnificent view of Lulworth Cove and the Isle of Purbeck beyond. The shape of the Bay, and the history of its formation (as depicted in the adjacent Stair Hole), are a model of coastal geomorphology. The "Lulworth Crumple" is one of the most photographed Alpine structures in the UK.

Figure 14 (below). The Lulworth Crumple in Stair Hole (after Hart, 2009).



To the east of Lulworth Cove is the Military Training Area that is only open at weekends and during the summer holiday season. One needs to access this area to see the Fossil Forest (in the lower part of the Lulworth Formation), the Mupe bay oil seep (in the Wealden group) and the famous Jurassic/Cretaceous boundarty succession of the Purbeck Group in Mupe bay and Bacon Hole. Within the confines of the Fossil Forest is evidence of a fossil soil, tree root systems, algal "burrs" that grew around the trees, limestones covered in fresh water ostracods and salt pseudomorphs. There is also a magnificent exposure of the enigmatic Broken Beds.

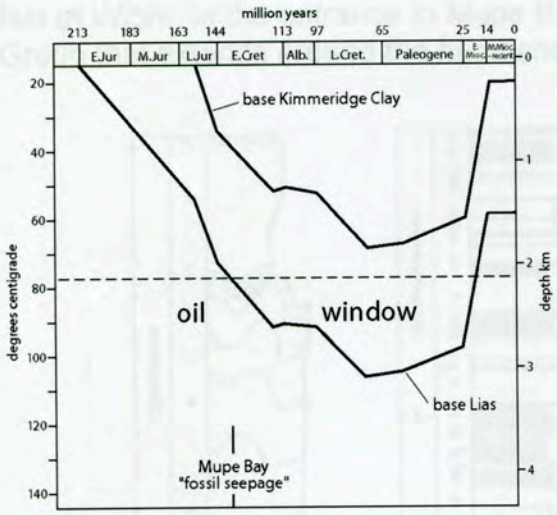


Figure 15. Burial Curve for the Dorset Coast (after Hart, 2009).

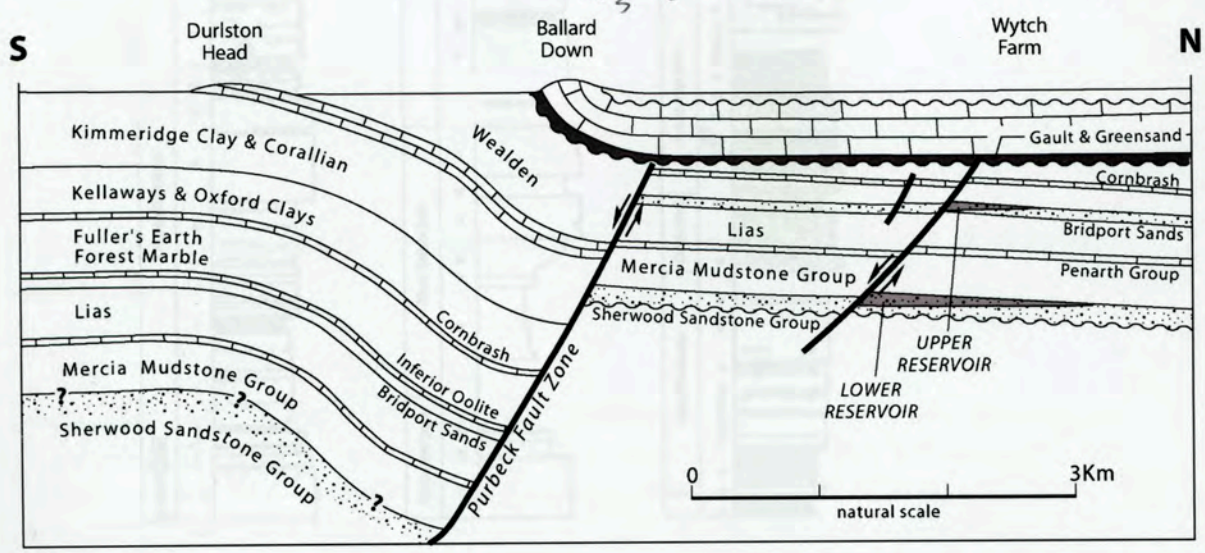


Figure 16. Cross-section of the Dorset oilfields (after Hart, 2009).

In Mupe Bay is the famous conglomerate of oil-impregnated boulders in a river channel within the lower part of the Wealden Group. If one constructs a burial curve for the rock succession of the Dorset Coast, it can be seen that the Blue Lias mudstones and limestones enter the oil window in the earliest Cretaceous and this may have caused the leakage of oil into the Wealden succession. The same burial curves show that the Oxford Clay Formation and the Kimmeridge Clay Formation, though containing sufficient TOC, cannot be the source rocks for the Dorset oilfields. Below the Wealden Group, in Mupe bay and Bacon Hole, is the Purbeck Group succession. To the east there is a fine view of Worbarrow Bay and the expanded Wealden Group succession that continues to thicken eastwards to Swanage and the Isle of Wight. In the entrance to Mupe Bay there is a good section of the Purbeck Group that extends around the headland into Bacon Hole.

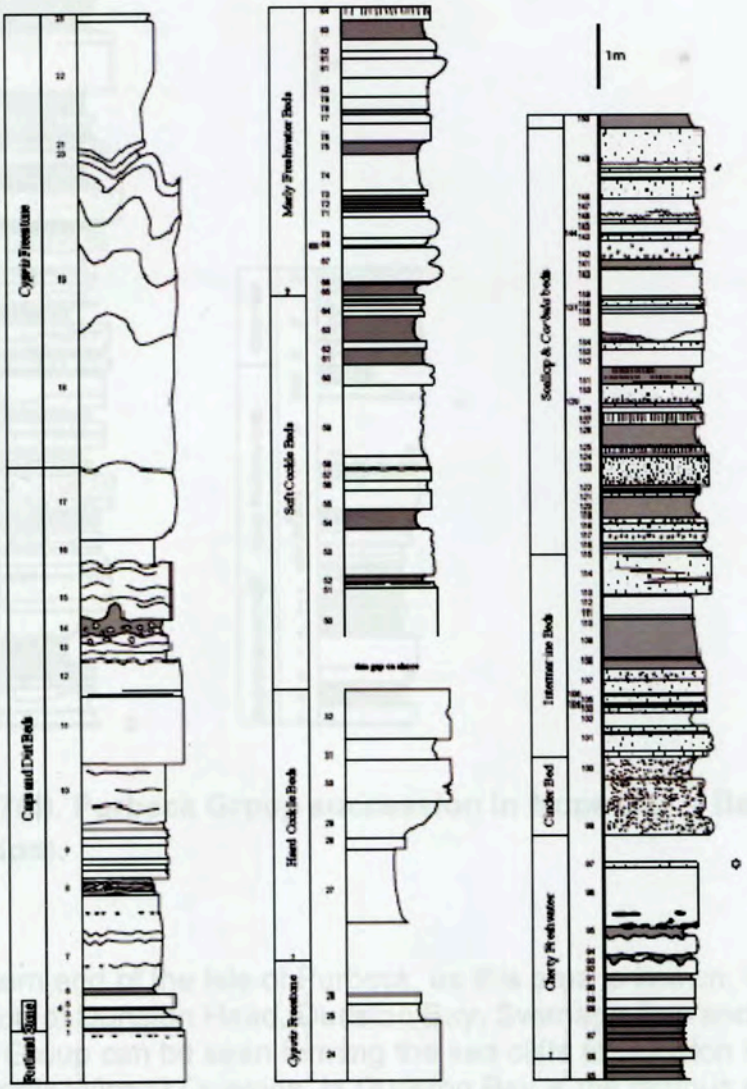


Figure 17(i). Purbeck Group succession in Mupe Bay – Bacon Hole (after Wimbledon).

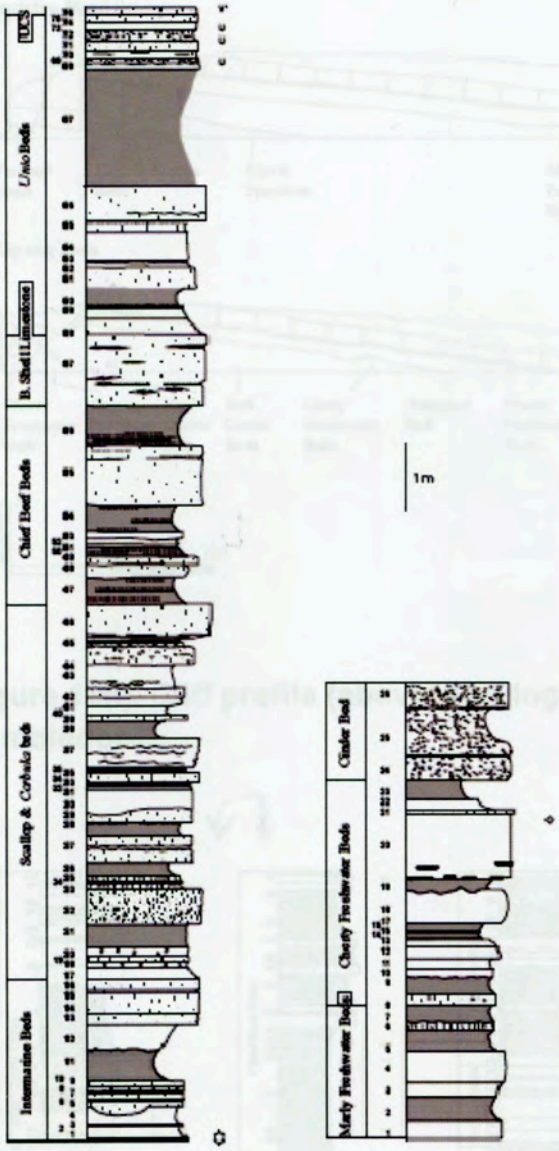


Figure 17(ii). Purbeck Group succession in Mupe Bay – Bacon Hole (after Wimbledon).

The eastern end of the Isle of Purbeck, as this area is known, is the famous succession of Durlston Head, Durlston Bay, Swanage Bay and Ballard Cliff. The Portland Group can be seen forming the sea cliffs at Durlston Head and along the cliffs towards Winspit Quarries. In Durlston Bay is the famous succession of the Purbeck Group which provides one of the key sections in the debate about the GSSP for the base of the Cretaceous System.

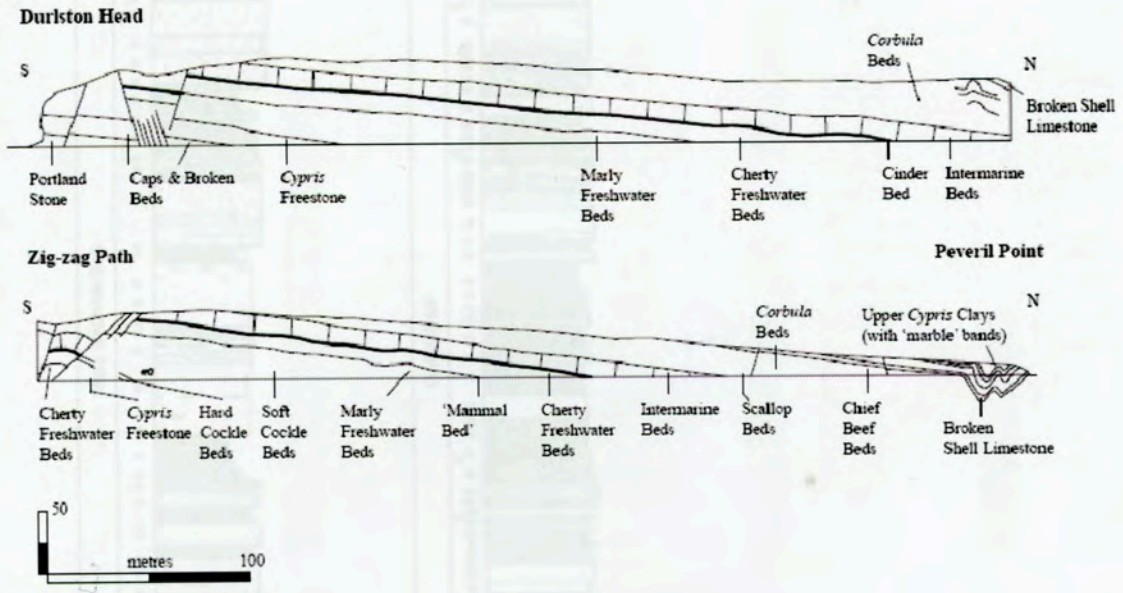
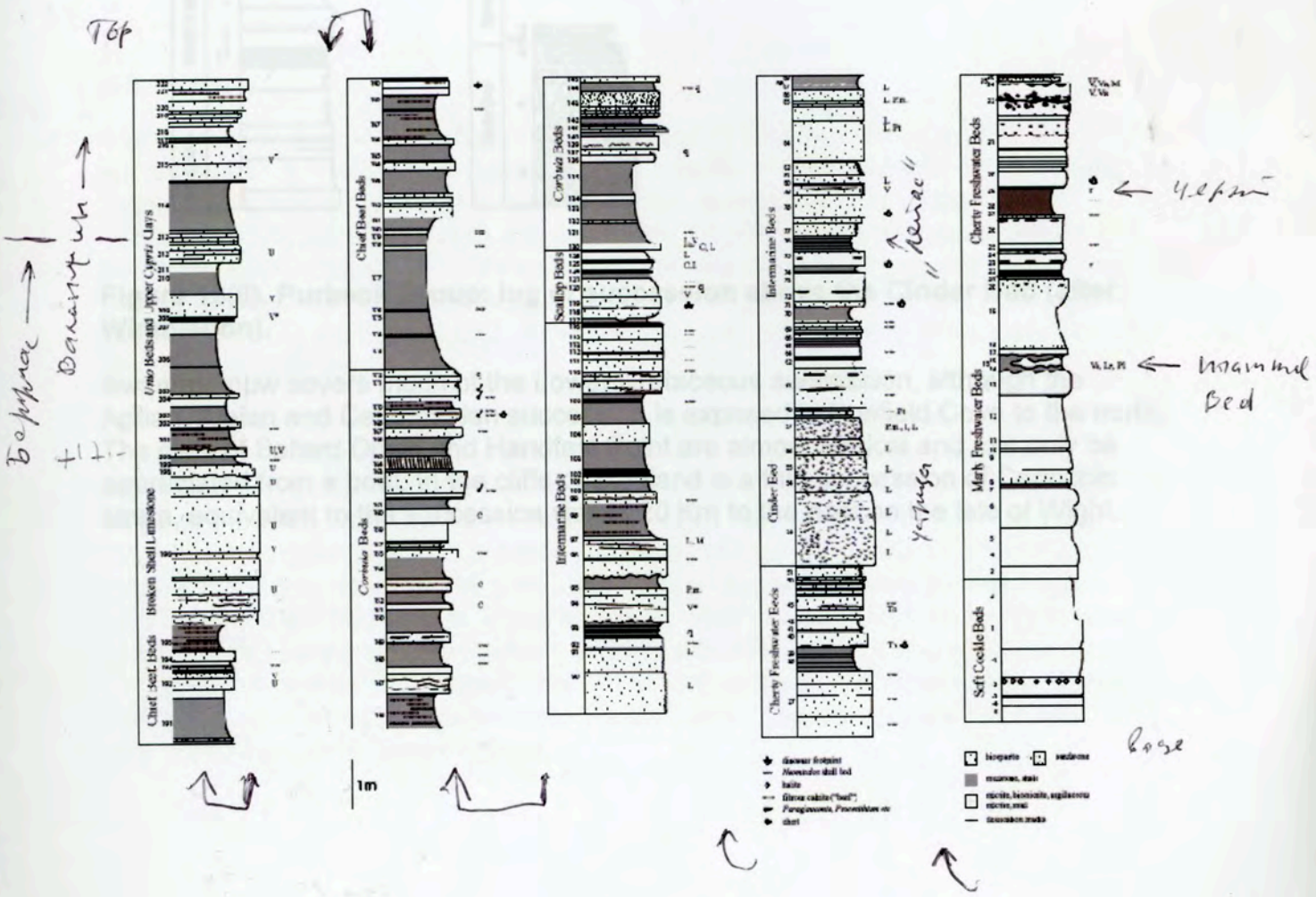


Figure 18(i). Cliff profile (above) and log (below) in Durlston Bay (after Wimbledon).



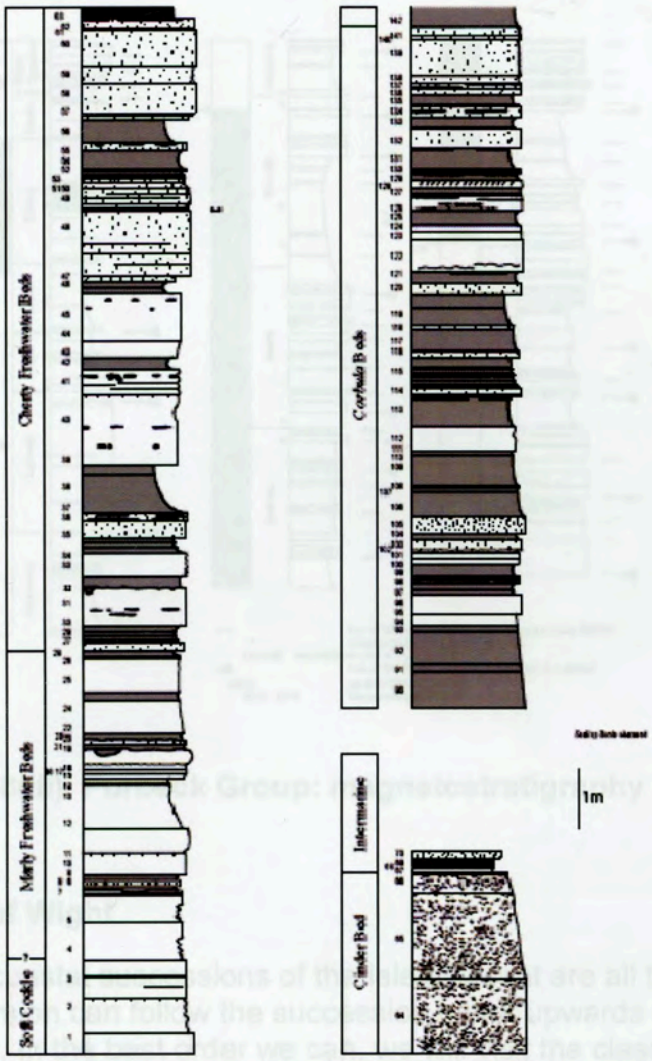


Figure 18(ii). Purbeck Group: log of succession above the Cinder Bed (after Wimbledon).

Swanage now covers much of the Lower Cretaceous succession, although the Aptian, Albian and Cenomanian succession is exposed in Punfield Cove to the north. The cliffs of Ballard Down and Handfast Point are almost vertical and can only be appreciated from a boat. In the cliffs of Studland is a thin succession of Cenozoic strata, equivalent to the succession visible 20 Km to the east on the Isle of Wight.

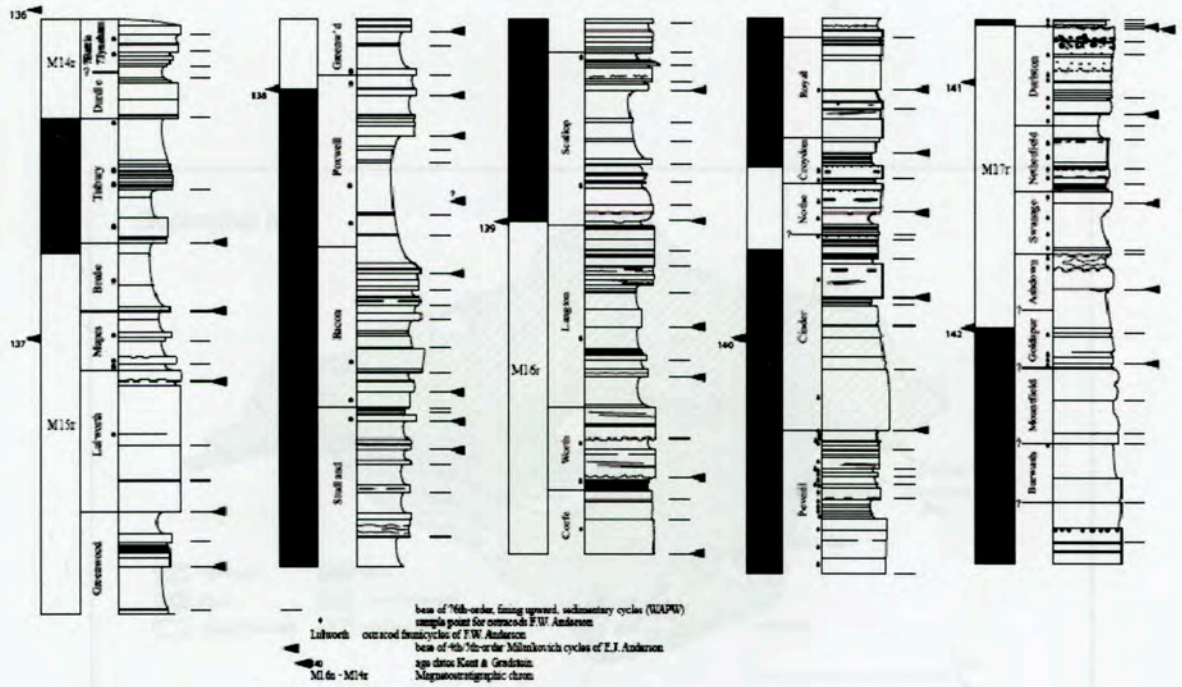


Fig.18(iii). Purbeck Group: magnetostratigraphy (after Wimbledon).

Isle of Wight

The coastal successions of the Isle of Wight are all tide-dependent and no field excursion can follow the succession either upwards or downwards in strict geological order. In the best order we can, we will visit the classic sections of the Lower Cretaceous (on the west coast) and the Lower – Upper Cretaceous succession of Sandown Bay – Culver Cliff – Whitecliff Bay on the east coast. Access to the Chalk Group, in Whitecliff Bay, necessitates walking past the most complete Palaeogene succession in N. W. Europe and, if there is time, we may be able to look at parts of this famous outcrop.

On the west coast of the Isle of Wight, between Compton Bay in the north and Chale Bay in the south the core of the anticlinal fold that dominates the island exposes the **Wealden Group** (**Wessex Formation** and **Vectis Formation**). The Wessex Formation is a thick succession of mudstones with intermittent sandstones (often forming channels) and plant debris beds. The overlying Vectis Formation is much thinner and has, near its base, a distinctive deltaic unit (the Barnes High Sandstone).The **Shepherd's Chine Member**, which can be seen on both the west coast and the east coast, contains thin fossiliferous limestones and shales crowded with almost monospecific assemblages of ostracods (e.g., *Cypridea tenuis*, *Cypridea fasciata*, etc.). The ostracods from the Purbeck and Wealden groups have recently been re-described by Horne (2009).

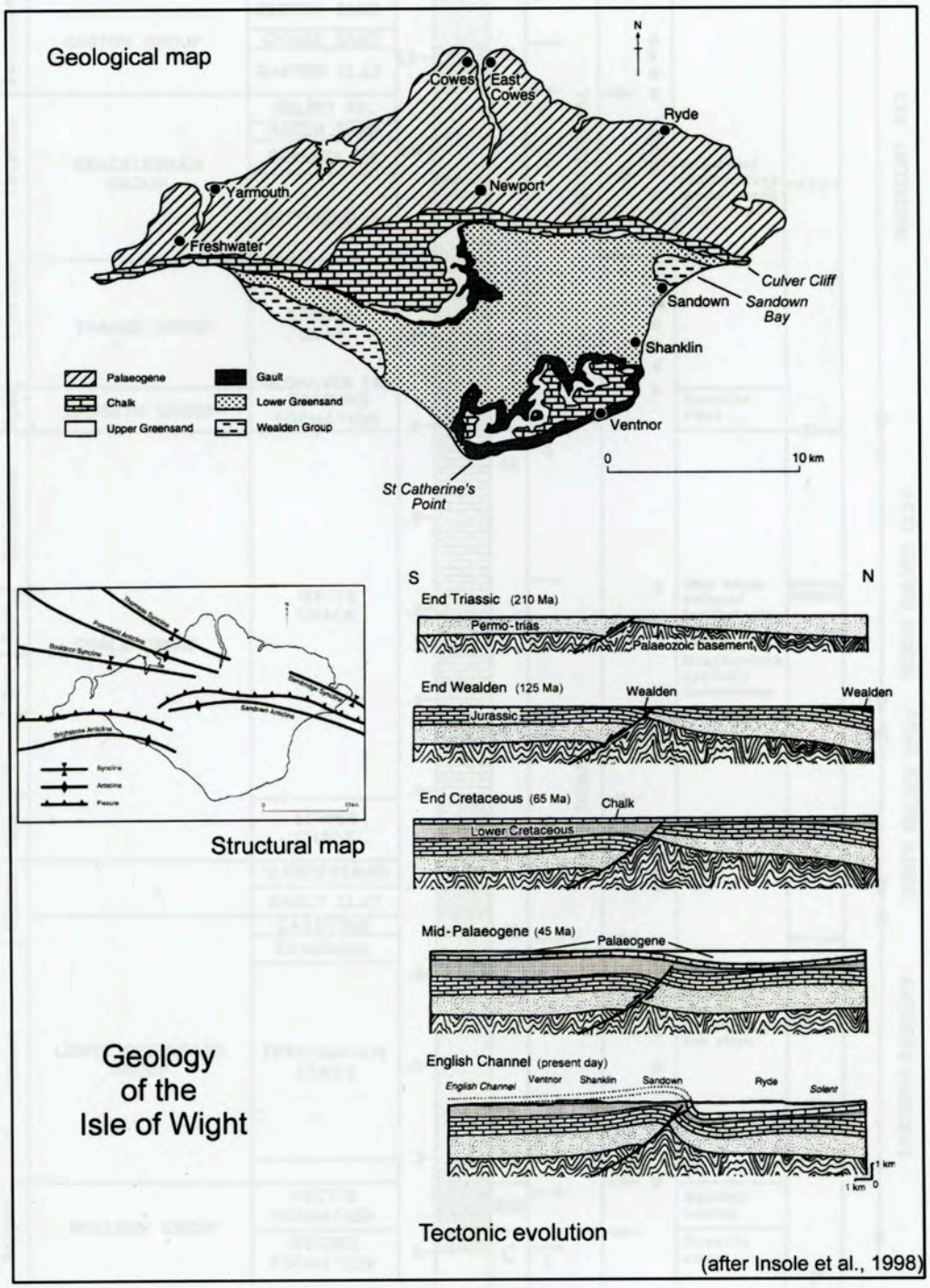


Figure 19. Geological map and sections of the Isle of Wight.

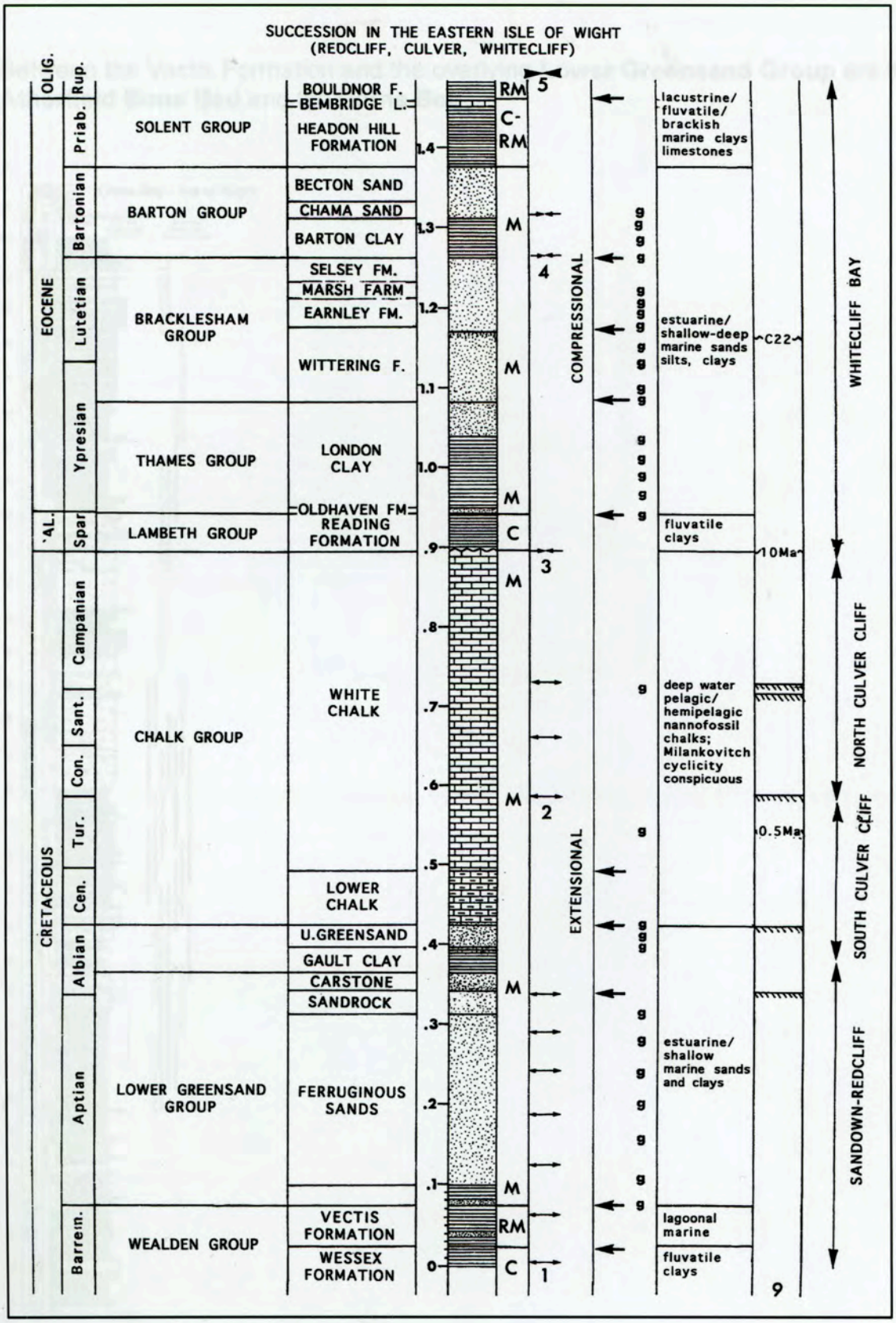


Figure 20. Isle of Wight succession.

Between the Vectis Formation and the overlying **Lower Greensand Group** are the **Atherfield Bone Bed** and the **Perna Bed**.

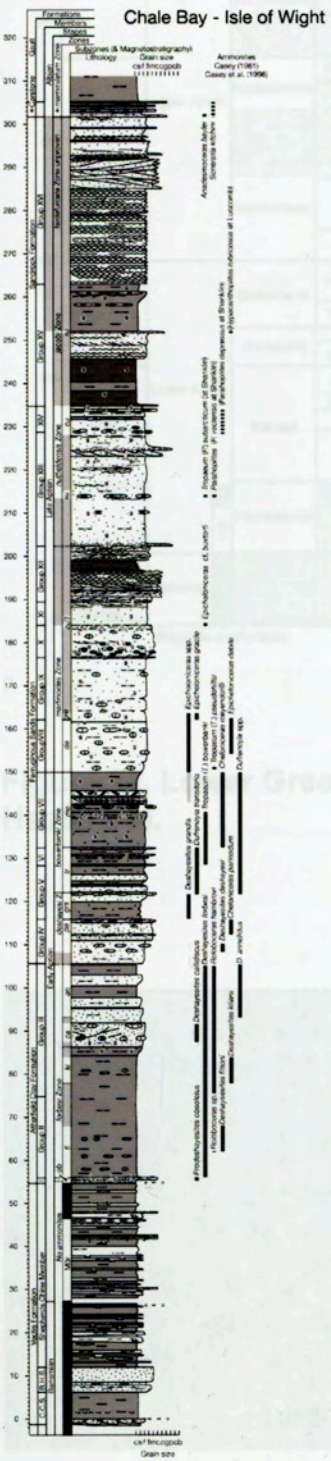


Figure 21. Lower Greensand Group.

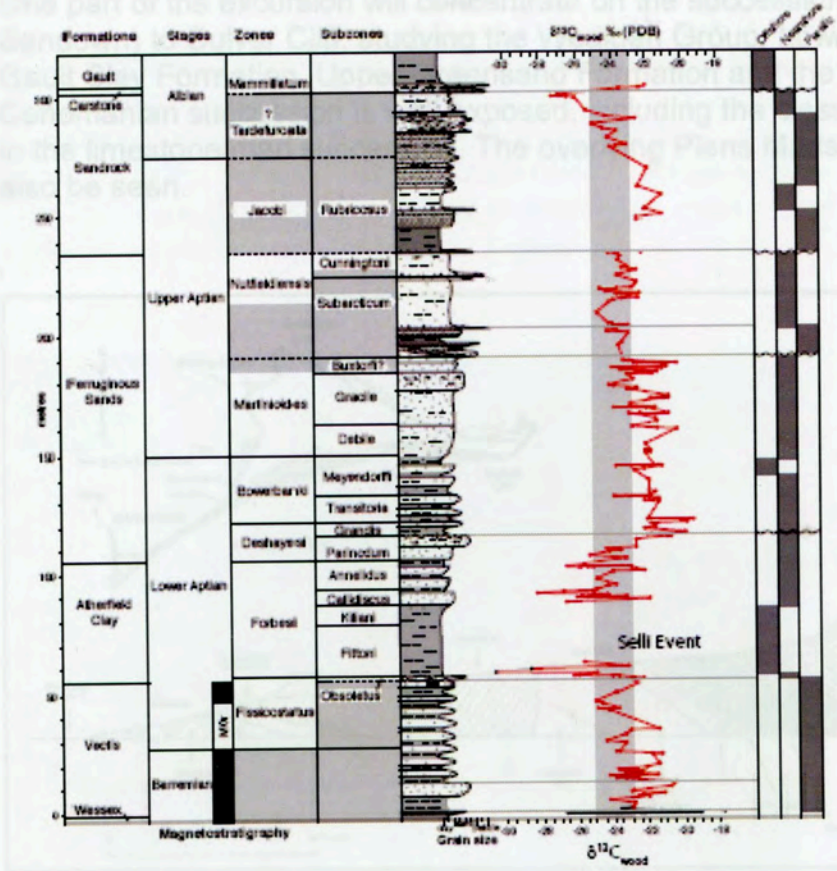


Figure 22. Lower Greensand Group of the Isle of Wight and $\delta^{13}C$ curve (after Hesselbo).

Figure 23. West coast of the Isle of Wight looking towards Compton Bay. Succession of Wealden Group through to the Chalk Group.

One part of the excursion will concentrate on the succession from Yaverland (near Sandown) to Culver Cliff, studying the Wealden Group, Lower Greensand Group, Gault Clay Formation, Upper Greensand Formation and the Chalk Group. The Cenomanian succession is well-exposed, including the classic Milankovitch cyclicity in the limestone/marl succession. The overlying Plens Marls Member (OAE2) will also be seen.

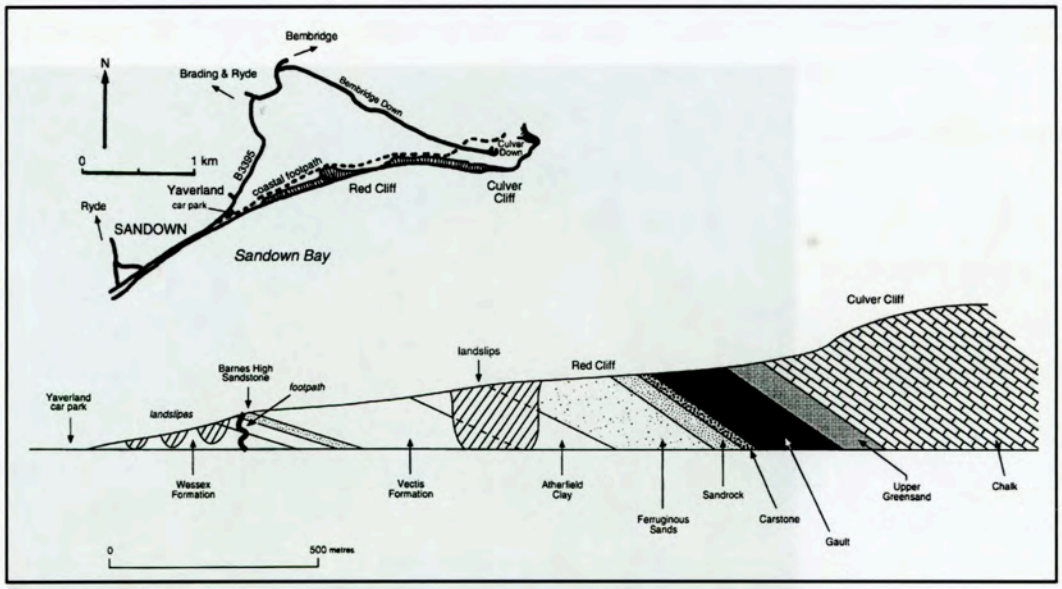


Figure 24. Yaverland Succession: Sandown Bay.

Figure 25. Cenomanian succession with Milankovitch cyclicity (Culver Cliff).

It is not possible to continue the succession (safely) beyond the Plenus Marls Member and access to the upper part of the Chalk Group on the Isle of Wight is accessed via Whitecliff Bay. After crossing the bay, with its magnificent Paleogene succession the main cliff of the Chalk Group can be followed from the Campanian to the Coniacian. There are a variety of flint styles, marl bands and hardground surfaces easily accessible (at a low tide).

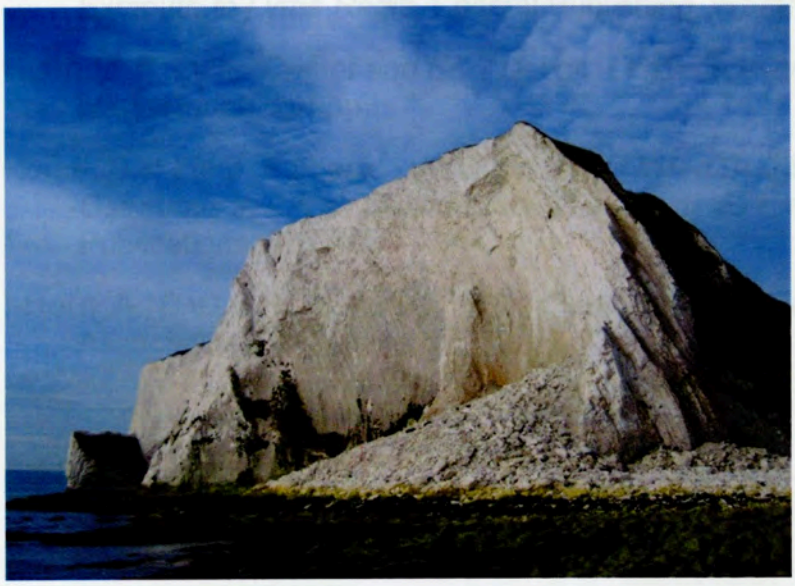


Figure 26. Culver Cliff, Isle of Wight (with part of the Campanian, unfortunately, covered by a recent landslide).

Figure 27. Whitecliff Bay and a view of the Paleogene succession.

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Additional Figures

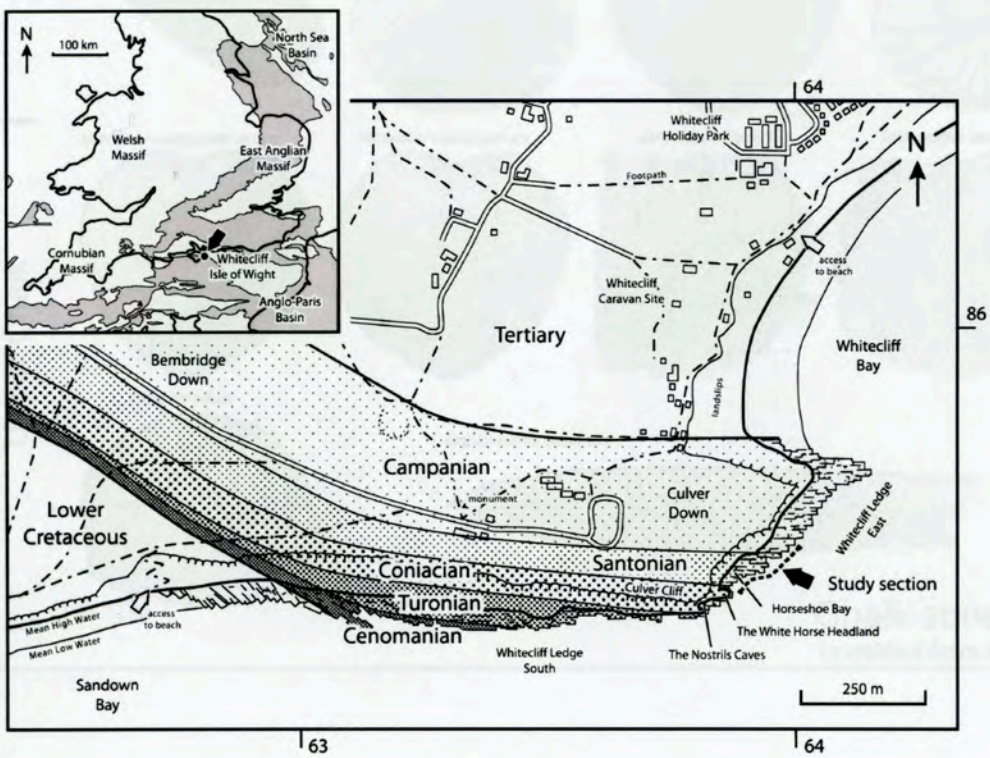


Figure 28. Locality map of Culver Cliff and Whitecliff Bay.

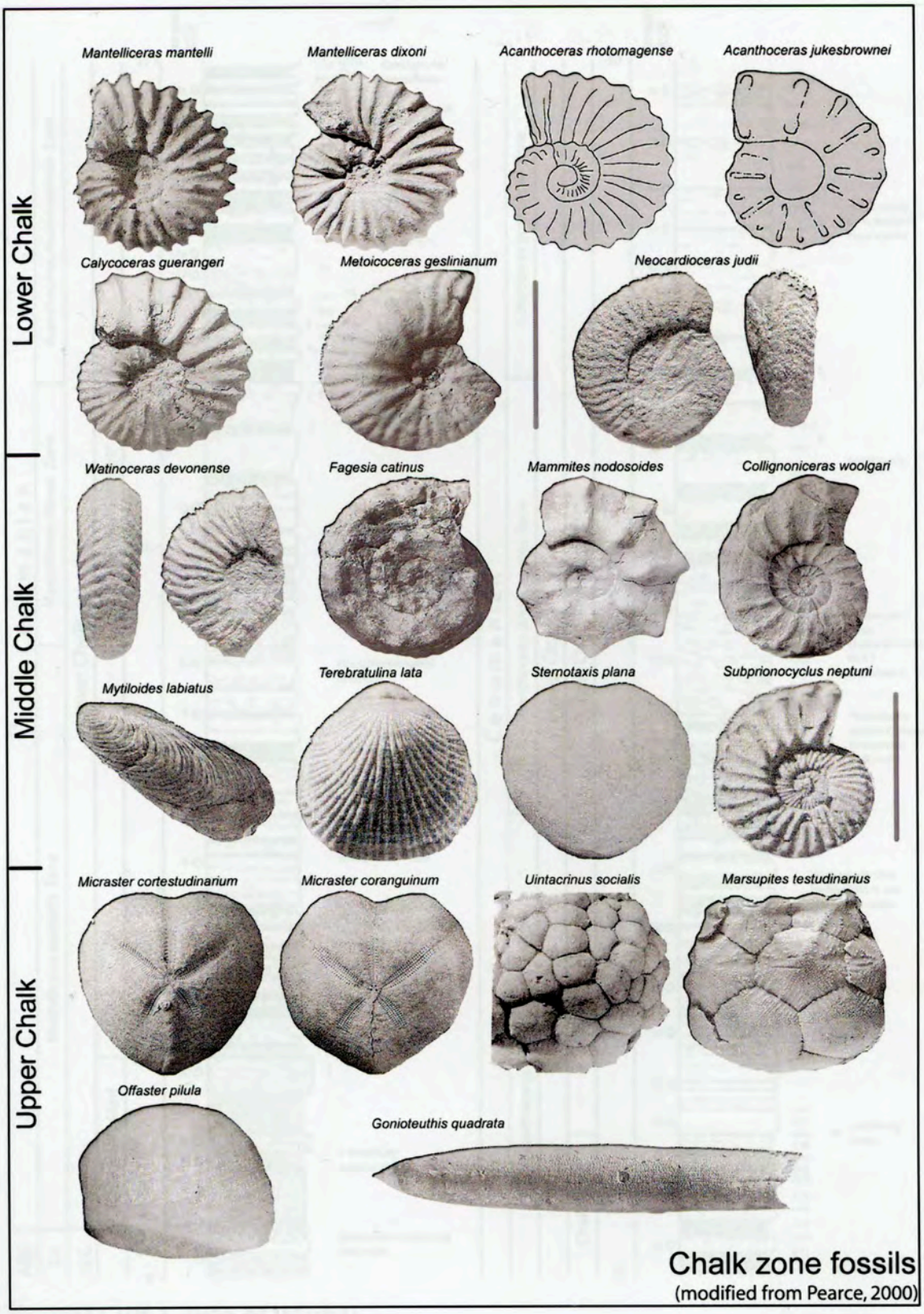


Figure 29. Zonal fossils of the Chalk Group.

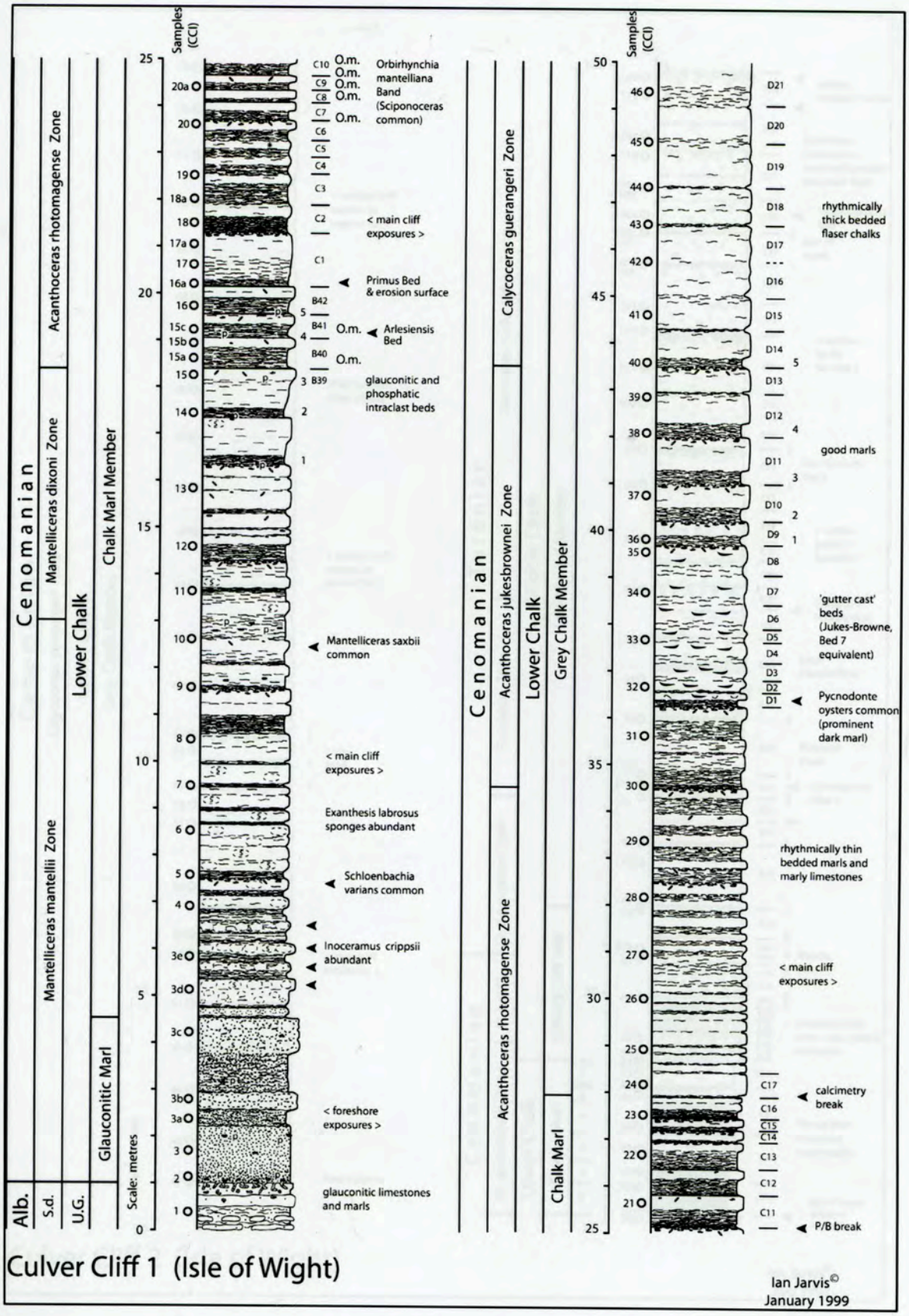


Figure 30. Culver Cliff log section (Cenomanian).

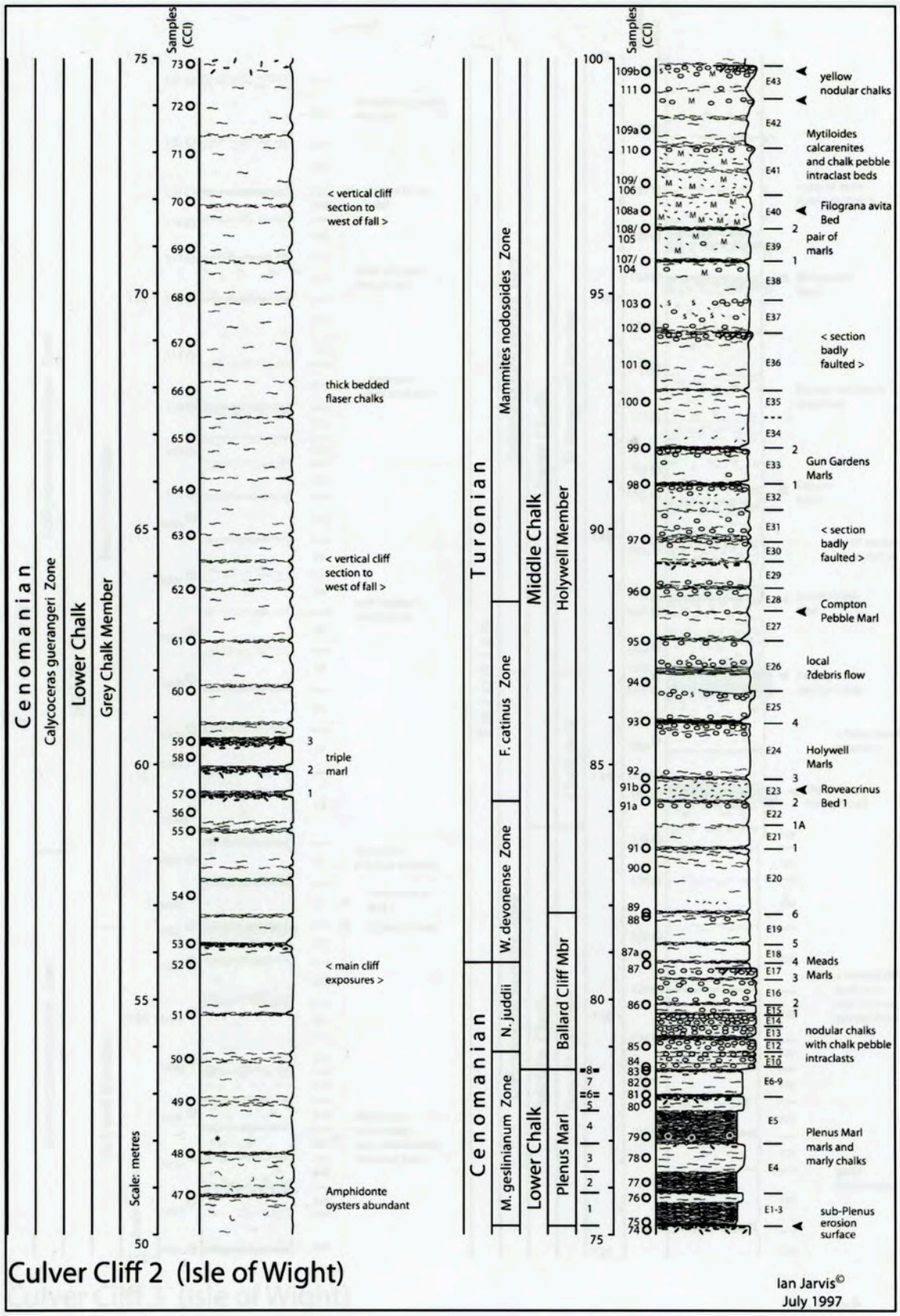


Figure 31. Culver Cliff log section (Cenomanian – Turonian).

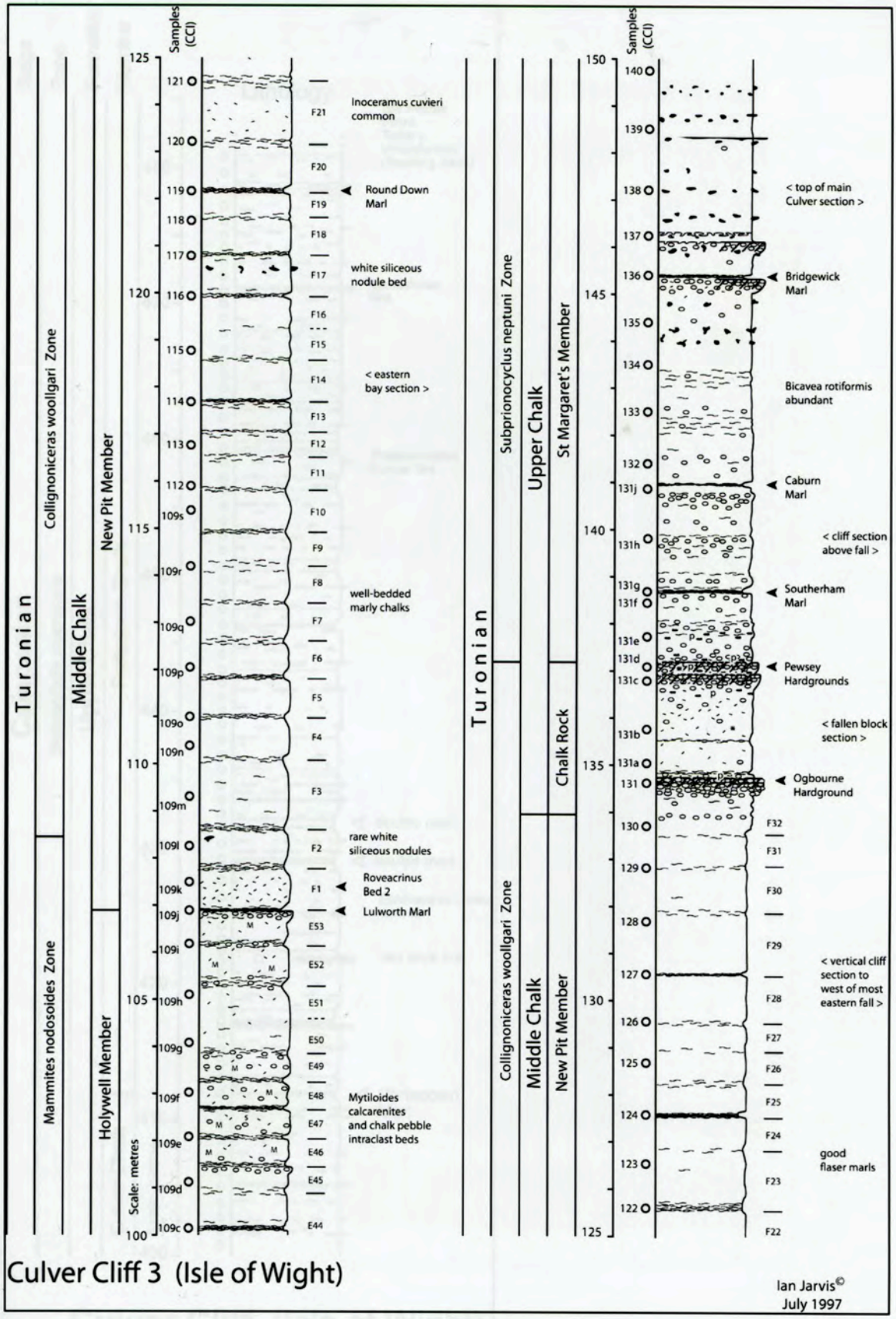


Figure 32. Culver Cliff log section (Turonian).

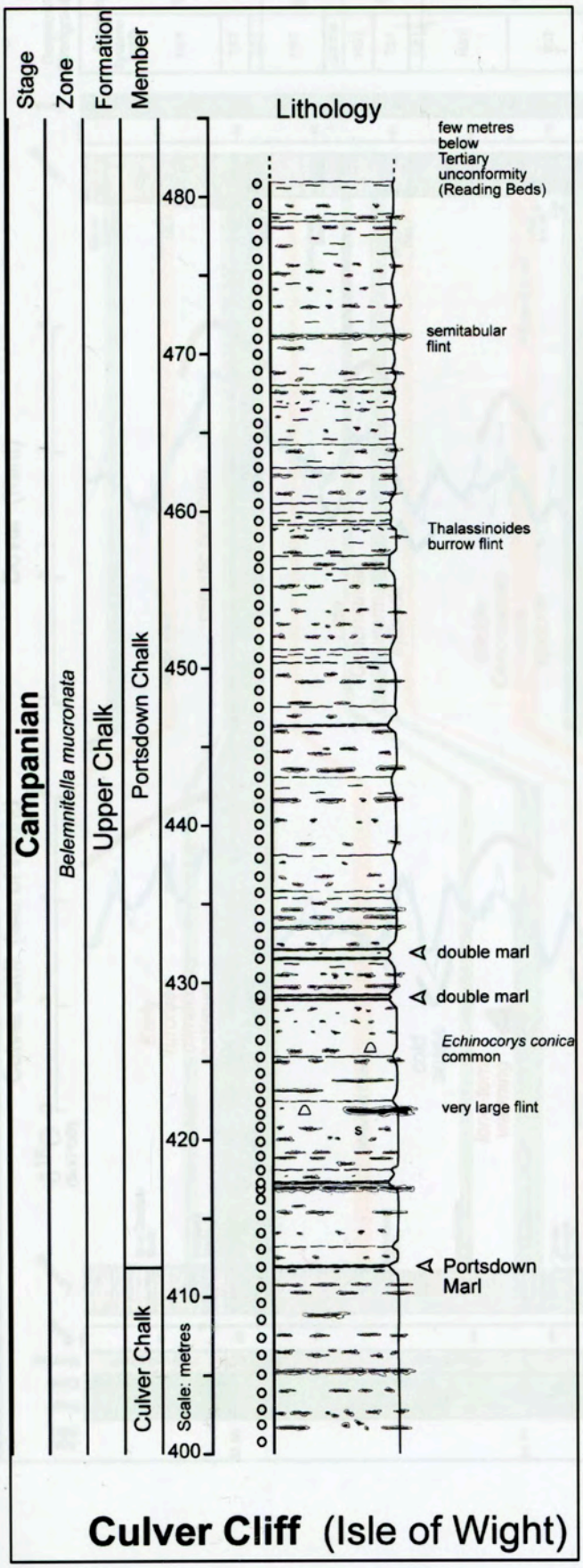


Figure 33. Culver Cliff log section (Campanian).

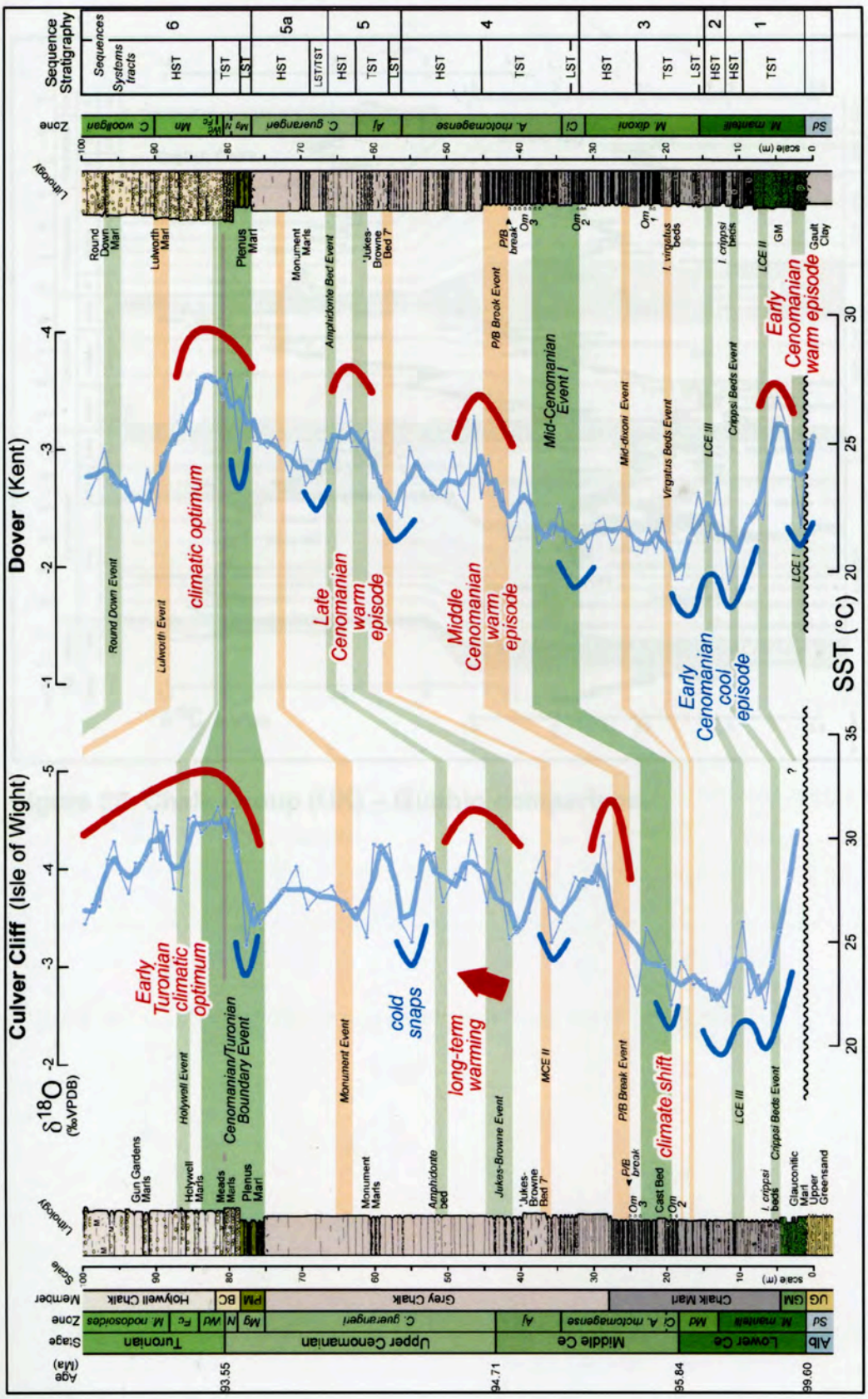


Figure 34. Culver Cliff – Dover comparison.

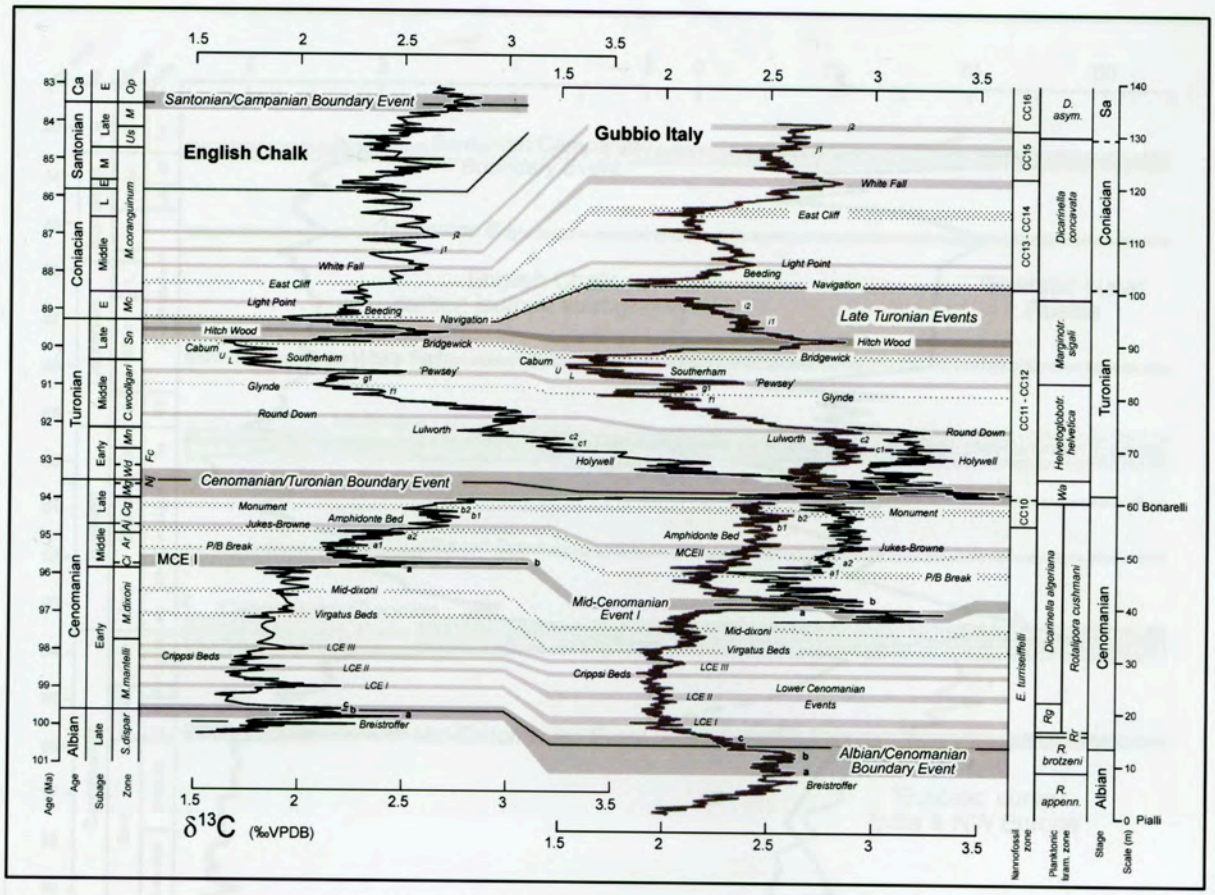


Figure 35. Chalk Group (UK) – Gubbio comparison.

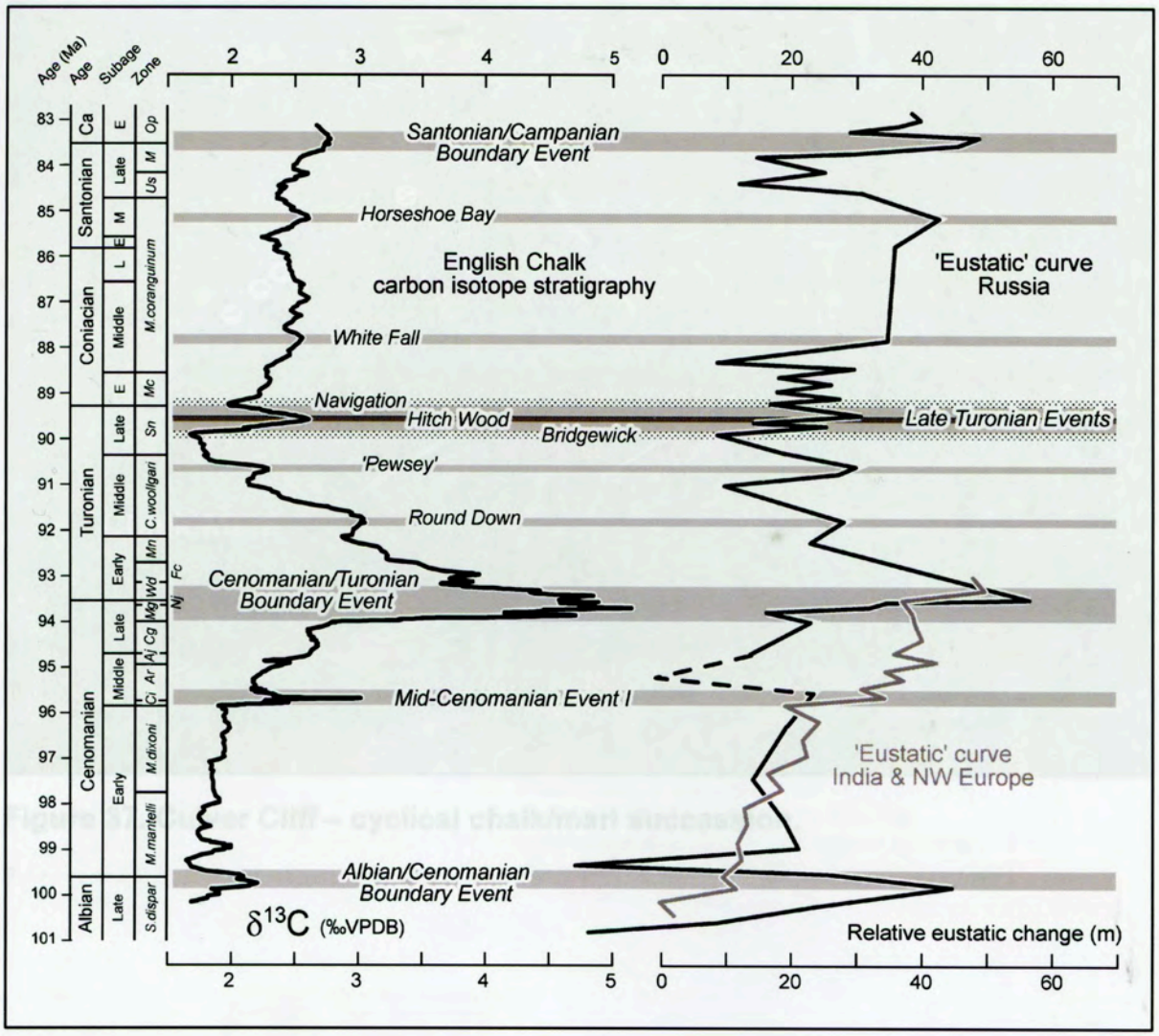


Figure 36. Carbon isotope curve versus sea level changes.

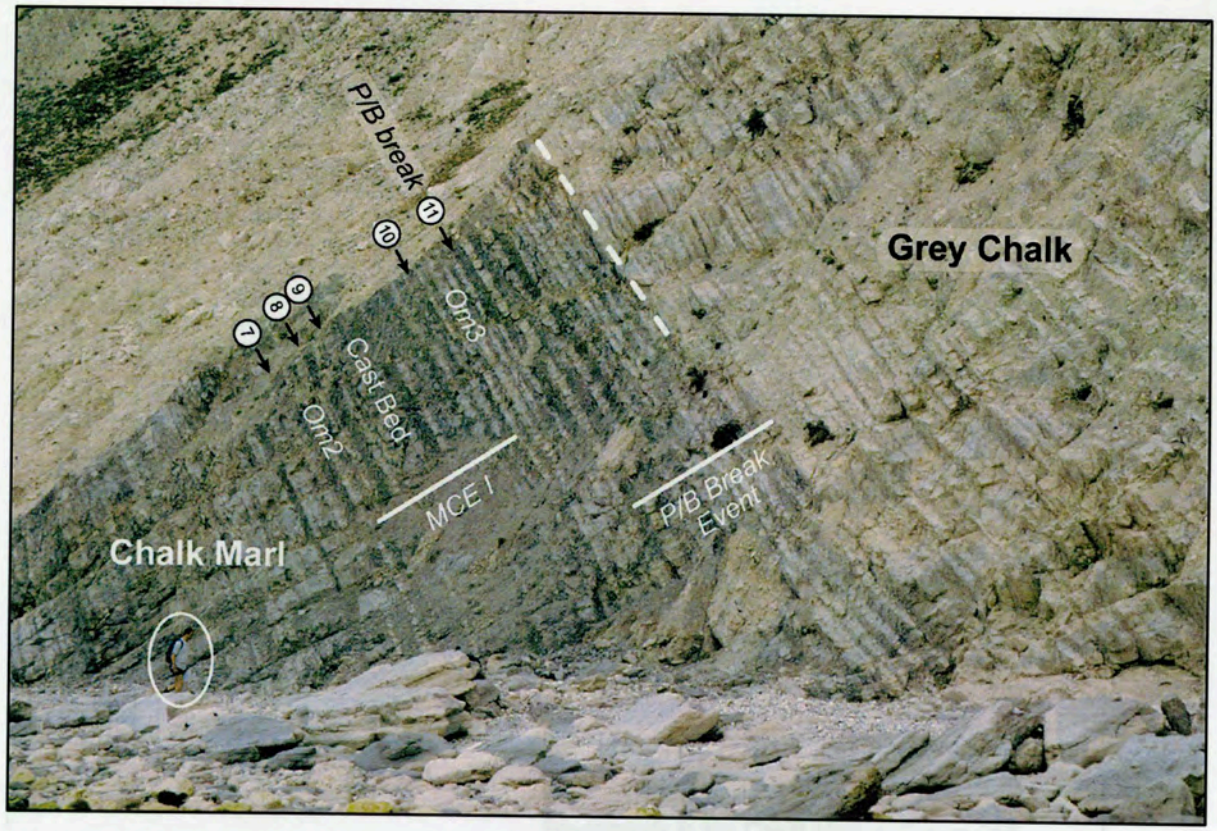


Figure 37. Culver Cliff – cyclical chalk/marl succession.

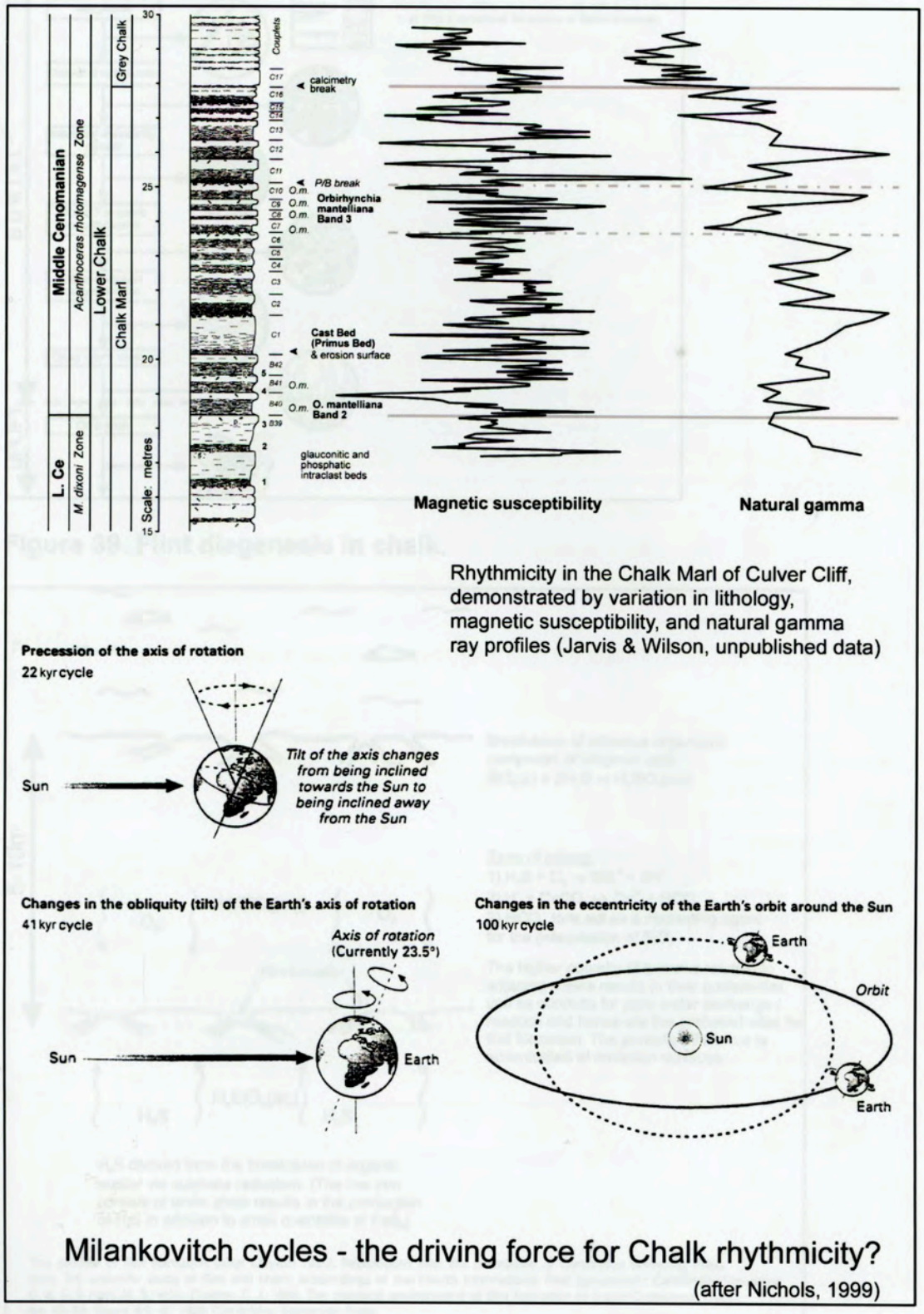
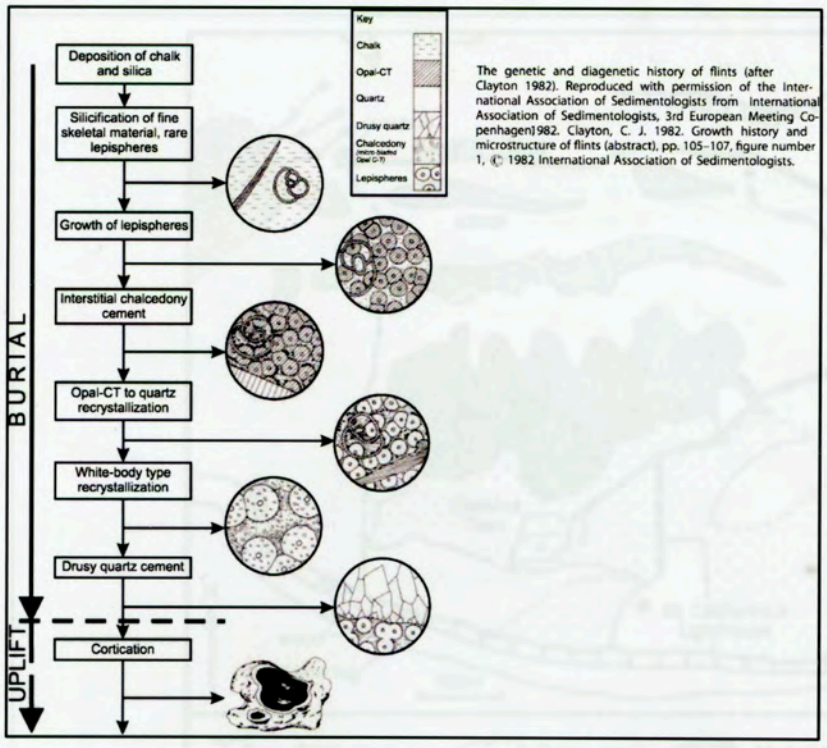
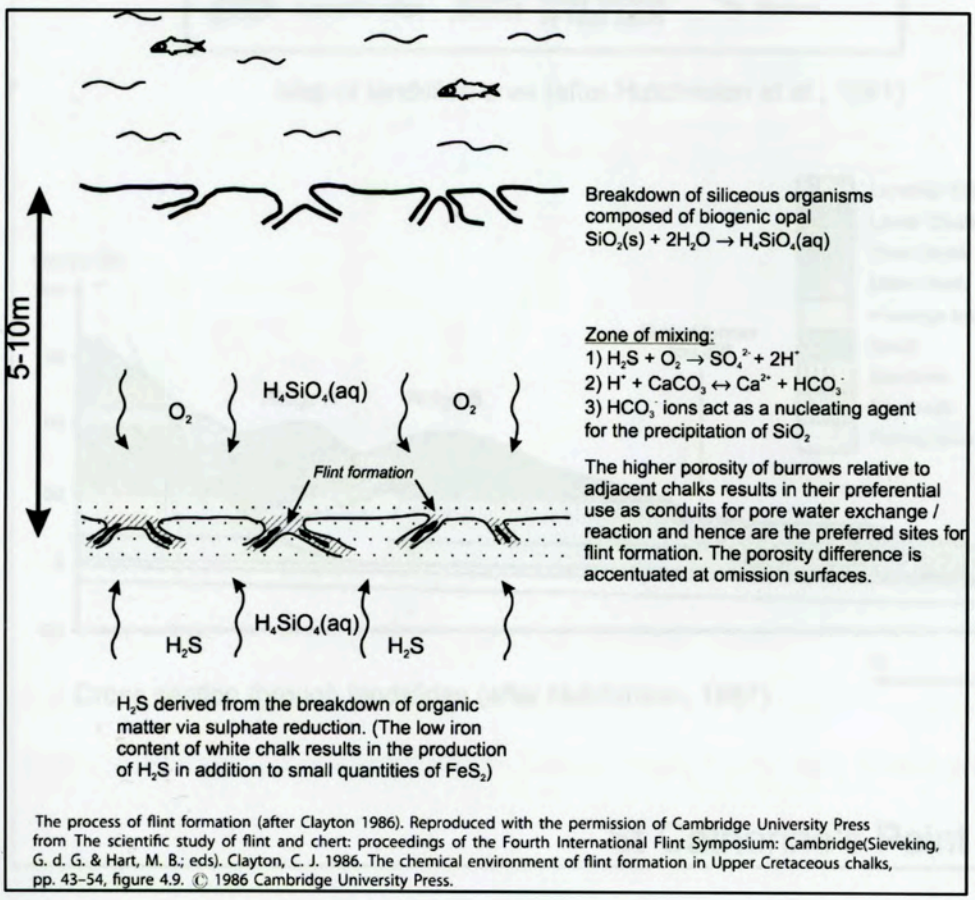


Figure 38. Milankovitch cyclicity – Middle Cenomanian.



The genetic and diagenetic history of flints (after Clayton 1982). Reproduced with permission of the International Association of Sedimentologists from International Association of Sedimentologists, 3rd European Meeting Copenhagen)1982. Clayton, C. J. 1982. Growth history and microstructure of flints (abstract), pp. 105–107, figure number 1, © 1982 International Association of Sedimentologists.

Figure 39. Flint diagenesis in chalk.



Breakdown of siliceous organisms composed of biogenic opal
$SiO_2(s) + 2H_2O \rightarrow H_4SiO_4(aq)$

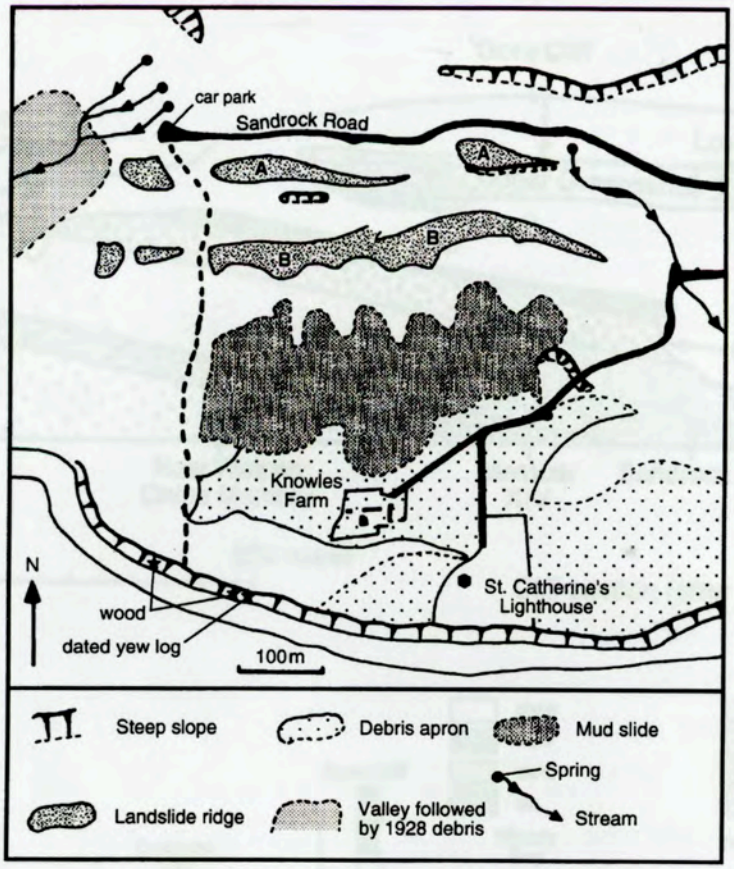
Zone of mixing:
1) $H_2S + O_2 \rightarrow SO_4^{2-} + 2H^+$
2) $H^+ + CaCO_3 \leftrightarrow Ca^{2+} + HCO_3^-$
3) HCO_3^- ions act as a nucleating agent for the precipitation of SiO_2

The higher porosity of burrows relative to adjacent chalks results in their preferential use as conduits for pore water exchange / reaction and hence are the preferred sites for flint formation. The porosity difference is accentuated at omission surfaces.

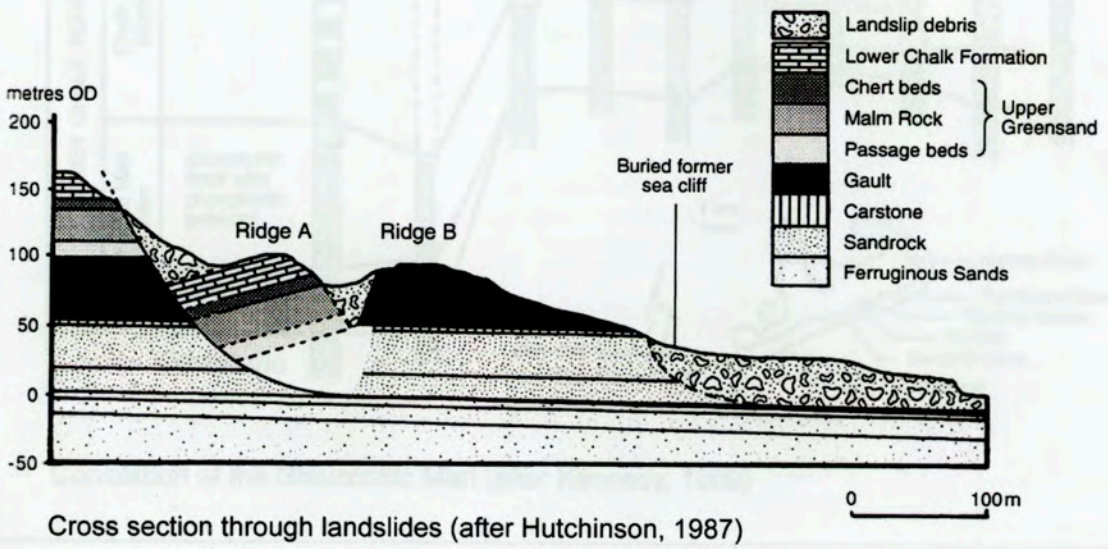
H_2S derived from the breakdown of organic matter via sulphate reduction. (The low iron content of white chalk results in the production of H_2S in addition to small quantities of FeS_2)

The process of flint formation (after Clayton 1986). Reproduced with the permission of Cambridge University Press from The scientific study of flint and chert: proceedings of the Fourth International Flint Symposium: Cambridge(Sieveking, G. d. G. & Hart, M. B.; eds). Clayton, C. J. 1986. The chemical environment of flint formation in Upper Cretaceous chalks, pp. 43–54, figure 4.9. © 1986 Cambridge University Press.

Figure 40. Flint formation in Chalk.



Map of landslide area (after Hutchinson et al., 1991)



Cross section through landslides (after Hutchinson, 1987)

St Catherine's Point landslides

Figure 41. St Catherine's Point Landslides.

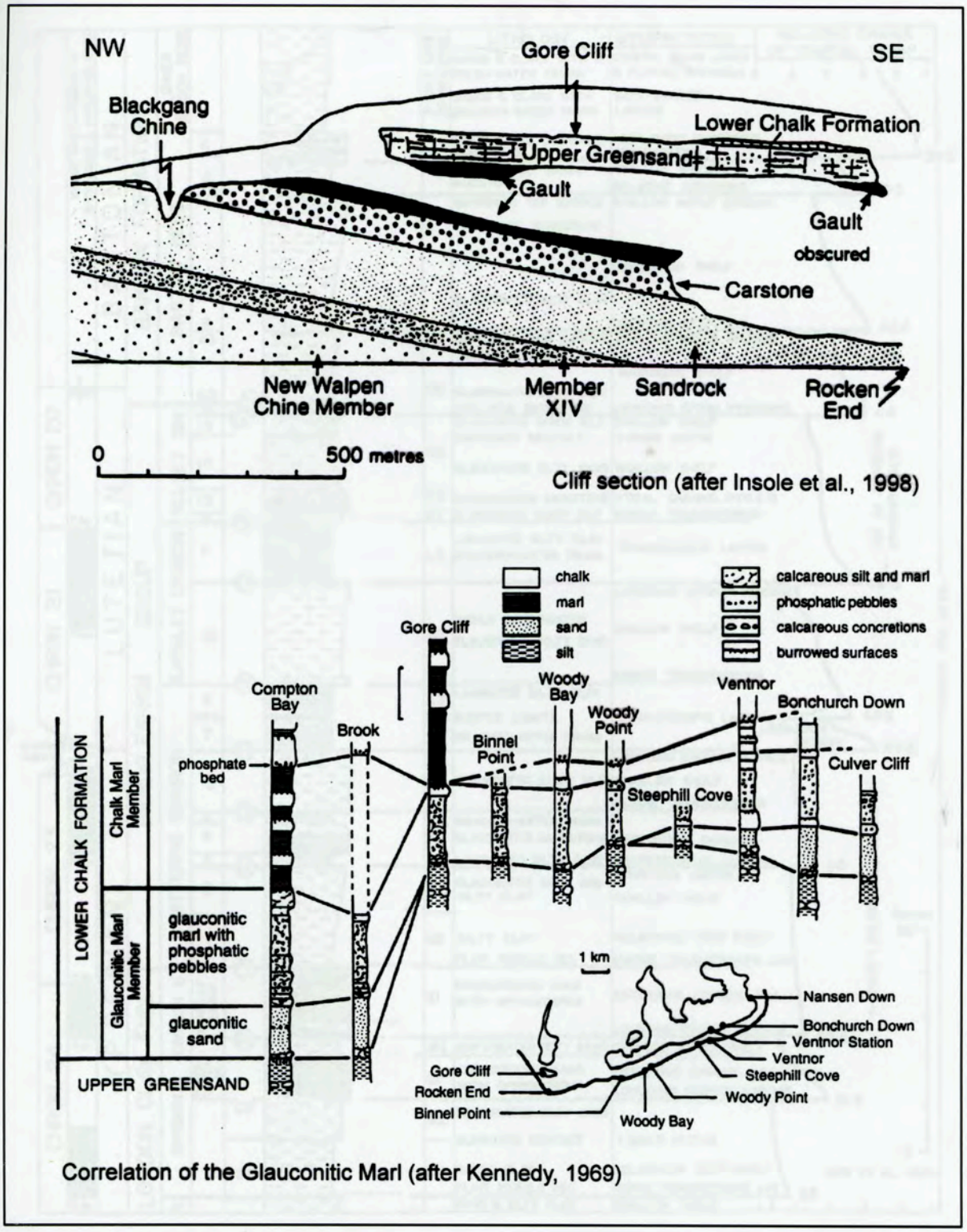


Figure 42. Geological sections: St Catherine's Point and Blackgang area.

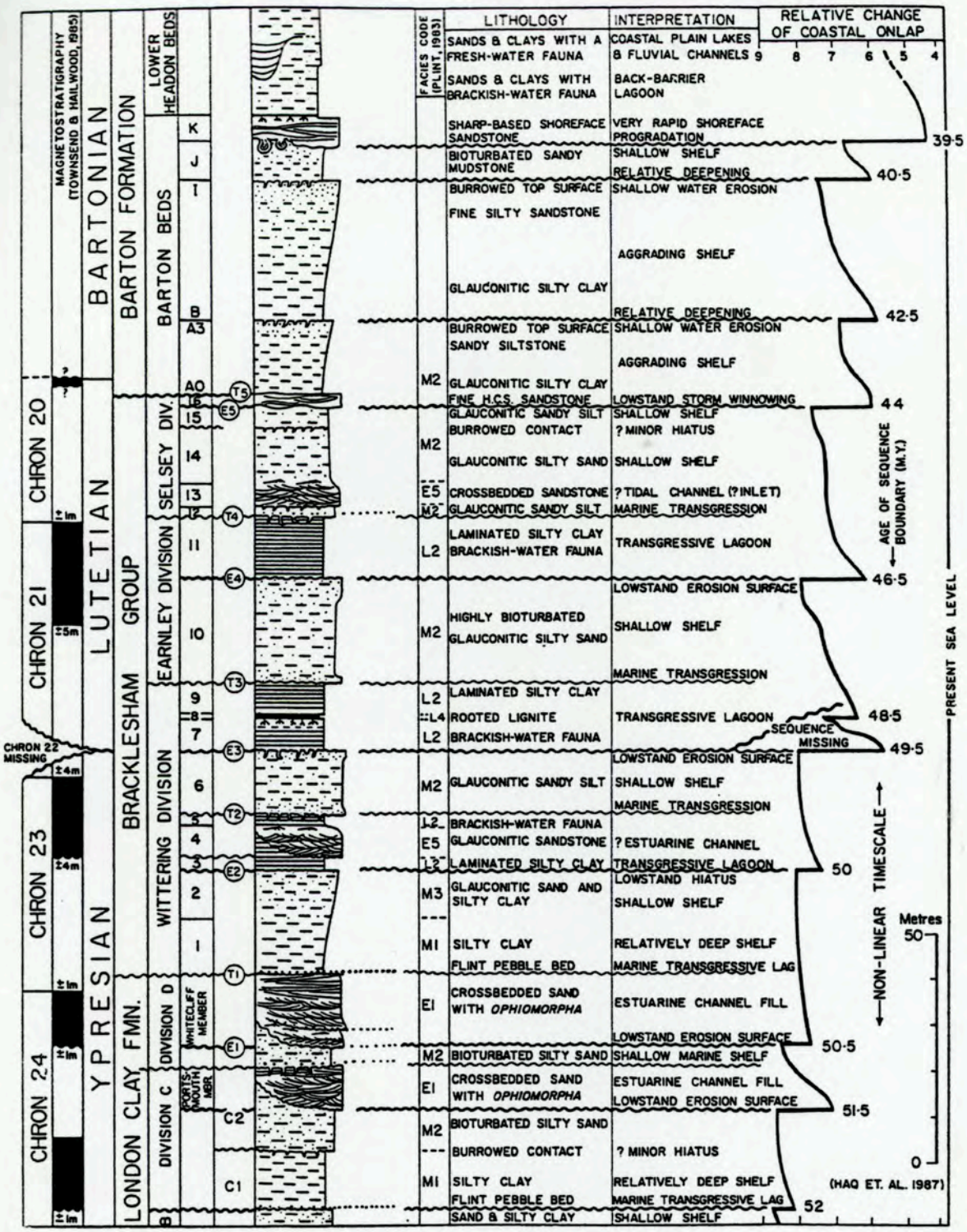


Figure 43. Eocene succession, Whitecliff Bay.

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