The lithostratigraphy and biostratigraphy of the Chalk Group (Upper Coniacian to Upper Campanian) at Scratchell's Bay and Alum Bay, Isle of Wight, UK.

Peter Hopson[1]*, Andrew Farrant[1], Ian Wilkinson[1], Mark Woods[1] , Sev Kender[1] and Sofie Jehle[2] ,

[1] British Geological Survey, Sir Kingsley Dunham Centre, Nottingham, NG12 5GG.
[2]University of Tübingen, Sigwartstraße 10, 72074 Tübingen, Germany

*** corresponding author pmhop@bgs.ac.uk**

Keywords: Cretaceous, Isle of Wight, Chalk, lithostratigraphy, biostratigraphy,

Abstract

The Scratchell's Bay and southern Alum Bay sections, in the extreme west of the Isle of Wight on the Needles promontory, cover the stratigraphically highest Chalk Group formations available in southern England. They are relatively inaccessible, other than by boat, and despite being a virtually unbroken succession they have not received the attention afforded to the Whitecliff GCR (Geological Conservation Review series) site at the eastern extremity of the island. A detailed account of the lithostratigraphy of the strata in Scratchell's Bay is presented and integrated with macro and micro biostratigraphical results for each formation present. Comparisons are made with earlier work to provide a comprehensive description of the Seaford Chalk, Newhaven Chalk, Culver Chalk and Portsdown Chalk formations for the Needles promontory.

The strata described are correlated with those seen in the Culver Down Cliffs – Whitecliff Bay at the eastern end of the island that form the Whitecliff GCR site. This provides an overall correlation for the Upper Coniacian to Upper Campanian Chalk strata on the island.

The influence of the Purbeck – Wight structure (Sandown and Brighstone periclines) on the Chalk Group strata is discussed and the conclusions drawn demonstrate that movement on this structure is diachronous across the island.

1. Introduction

The Scratchell's Bay section on the western extremity of the Isle of Wight exposes a virtually continuous section within the Seaford Chalk, Newhaven Chalk, Culver Chalk, and Portsdown Chalk formations. South of the 'Grand Arch' (Fig. 1 and 2) at the eastern end of the bay the uppermost Lewes Nodular Chalk Formation is present on and below a steeply shelving surface (the 'grassed-surface' of Rowe (1908) and Brydone (1914)). This part of the Chalk succession and the lowest part of the Seaford Chalk Formation (the Belle Tout Beds of Mortimore, 1986) are only accessible at the very lowest tides and were not logged nor sampled during the current BGS survey. The highest part of the Portsdown Chalk Formation is present from the western end of the bay, around the Needles promontory and along a strike section into Alum Bay to the north (Fig. 1). This section is also only accessible at the very lowest tides and consequently there is a small gap between the sections logged at Scratchell's Bay by the survey team and with those logged by one of us (MAW) on the southern side of Alum Bay beneath the Palaeogene unconformity. Data from other sources (Swiecicki, 1980; Gale, pers comm. 2008) demonstrates that the stratigraphical gap between the BGS logs is small and represented by 30-35m of strata. It is also apparent that some repetition or expansion of the succession within the Portsdown Chalk Formation and possibly within the Seaford Chalk Formation within Scratchell's Bay and Alum Bay may be present. This is as a consequence of strike orientated, bedding-parallel faulting and/or due to a greater availability of accommodation space, resulting from movement on the major Needles Fault structure, during deposition. The Culver Chalk Formation is condensed relative to the Whitecliff GCR section.

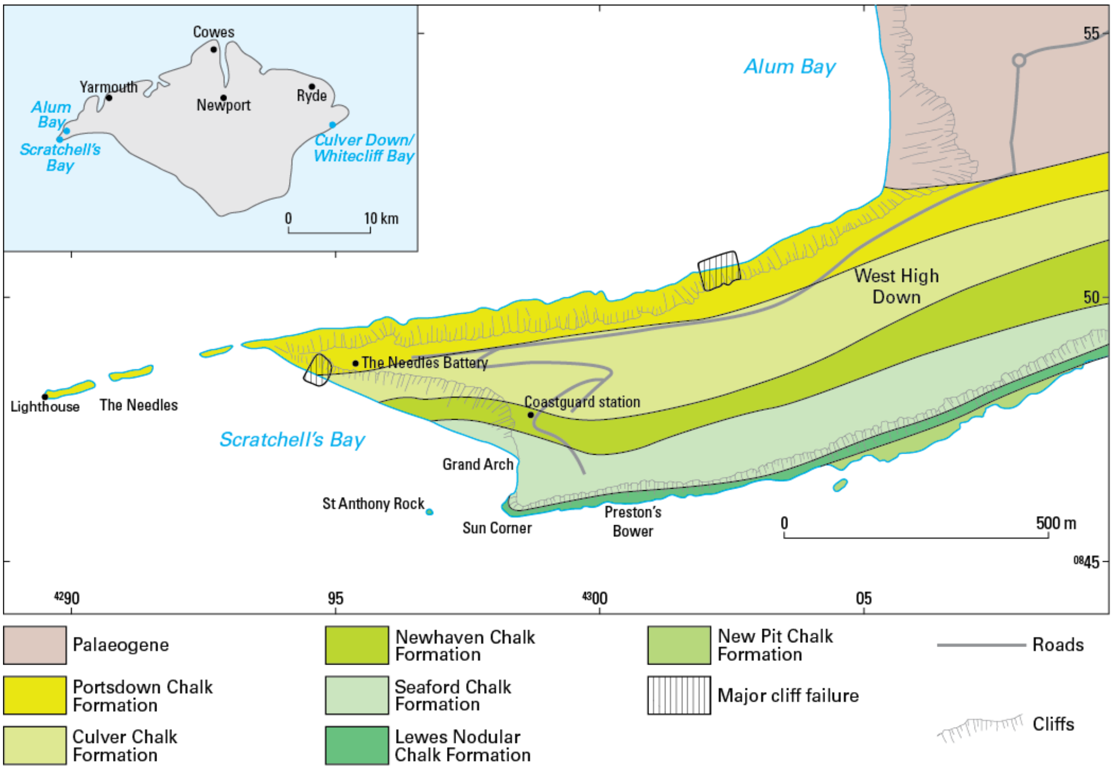


Fig. 1. The location of the Scratchell's Bay and Alum Bay sections, Isle of Wight.

A full lithostratigraphical log of the Scratchell's Bay section is presented (Fig. 3a and b). The strata were collected for macrofauna (relatively sparse for the succession compared to elsewhere). A comprehensive series of microfaunal samples were collected to aid correlation within section and more widely with the Whitecliff GCR site. The microfaunal results provide an outline for the distribution of the foraminifera at this level within the Chalk Group (Fig. 4). A correlation with the succession within the Whitecliff GCR site and other outline logs for Scratchell's Bay and Alum Bay is presented (Fig. 5a and b).

1.1. Previous Research

Jukes Browne and Hill (1904) offer very little detail for 'Scratchalls' Bay (their spelling) other than repeating the statement of Whitaker (1865) and stating that the "cliffs are only accessible by boat on a calm day" and describing the lowest part of the

Micraster coranguinum zone as “a bed of some thickness, in which the layers of flint are so close together that they form nearly as much of the rock as the Chalk itself”. This part of the Seaford Chalk succession was not accessible during the recent visit by BGS but is clearly discernable in the photograph in Fig. 2a. A general view of the Bay looking to the west is given in Fig. 2b.

Fig, 2a. A view of Scratchell’s Bay looking to the east.
The Grand Arch (centre above the distal end of the shingle beach) and Sun Corner (on the right forming the ‘grass slope’) are the two features most commonly referred to in articles on this section. The regular flint seams characteristic of the Seaford Chalk Formation pass up-section to chalks with some flint and regular marl seams of the Newhaven Chalk Formation (extreme left of photograph). The lowermost Seaford Chalk (the Belle Tout Beds of Mortimore, 1986) with their very closely-spaced flint seams are indicated by the breaks of slope in the cliff profile just above the grass slope. The higher beds of the Lewes Nodular Chalk Formation form the slope and the cliffs below it. Figure in the mid distance for scale is 2 m high. BGS Photo P 699954 P M Hopson ©NERC/BGS

The Geological Survey memoir (White, 1921) likewise carries scant detail of this important section relying instead on alluding to the descriptive accounts of Rowe (1908) and Brydone (1914, 1918) and thereby giving estimates for biozonal thicknesses for the units present. Both of these earlier authors present lithological descriptions for the section, or part thereof, visible within the bay, although Rowe’s (1908) account does not provide a bed-by-bed account. Rowe gave the following thicknesses for the zones he encountered *M. cortestudinarium* 15.24 m (of which 4.57 m appears in the cliff immediately above the ‘grass slope’), *M. coranguinum* 95.5m, *U. socialis* 10.52 m, *M. testudinarius* 14.33m, *A. quadratus* (in which Rowe included the current *U. anglicus* and *O. pilula* zones) 104.55m, and *B. mucronata* for which he gave no thickness. Only limited descriptions of the lithologies present in the section are given in the memoir and only the section demonstrating Brydone’s (1914) lithological log for the stratigraphically higher part of the succession is printed. This descriptive log is given as an outline graphic representation for comparison in Fig. 5(a and b). Brydone (1914), in his paper on the *Offaster pilula* Zone, considered that the Scratchell's Bay section offered the best section west of Sussex and regarded the section at Culver Down – Whitecliff to be "notoriously abnormal". Presumably Brydone refers here to the obvious stratal condensation in what we now call the Seaford Chalk Formation and the so-called 'Flintless Belt' in the Newhaven Chalk Formation, amongst other differences compared to the stratotype sections in Sussex.

Fig. 2b. Scratchell's Bay looking west towards the Needles from the observation platform above the Grand Arch. Photo P774681 P M Hopson ©NERC/BGS

Since these early descriptions of the section no further significant study was undertaken until Swiecicki (1980). His unpublished PhD thesis included Scratchell's Bay as one of 27 sections of Campanian and Maastrichtian chalk from which he developed foraminiferal biozonal schemes that he related to the macrofaunal biozones. Three sections were logged in southern England; Scratchell's Bay and Alum Bay on the Isle of Wight and Studland Bay to the west (only the stratigraphically highest Campanian succession was studied here). The Scratchell's Bay and Alum Bay exposures proved a near complete succession from the Upper Santonian *Marsupites testudinarius* biozone through to the Upper Campanian *Belemnitella mucronata* macrofaunal biozone. A broad two-part planktonic foraminiferal biozonation and a more comprehensive benthonic foraminiferal biozonation (B1i-iii, B2i-iii and B3i-iii) were defined by Swiecicki (see Fig. 5 a and b) for the Scratchell's Bay section. The eastern half of Scratchell's Bay, for the most part exposing the Seaford Chalk Formation (middle-Coniacian to middle-Santonian) was not included in that thesis. The relationship of these zones to those adopted by BGS (British Geological Survey) are given in Wilkinson (this issue)

The complete scheme for the highest Chalk Group strata beyond that exposed on the Isle of Wight equates with the benthonic foraminiferal biozones B1 to B7 of Swiecicki (1980, Fig 2.1), and was developed utilising sections in East Anglia and two wells in the North Sea. At Scratchell's Bay and Alum Bay the macrofaunal correlation utilised in the Swiecicki PhD was derived from the work of Rowe (1908) and Brydone (1914) together with additional macrofaunal material identified by C J Wood (formerly of the BGS) for the author.

A log in manuscript form, for the eastern part of Scratchell's Bay, comprising the Seaford Chalk Formation (*coranguinum* Zone), the Swiecicki section itself and a section within Alum Bay are held by BGS as an addendum to the lithological log of Swiecicki. It is unclear as to the origin of these logs but they carry macrofaunal determinations by Chris Wood and regular microfaunal sample points and may well be an early manuscript provided by Swiecicki to facilitate the interpretation of the macro-fossil determinations.

Mortimore (1986) established a lithostratigraphical correlation of the Chalk between Whitecliff and the mainland successions of Portsdown and into Sussex, within the expanded basinal successions of the Chalk Group. He utilised the Whitecliff section as his holostratotype for the Culver Chalk Formation as this is more accessible than that at the Scratchell's Bay. He did however recognise that the Scratchell's Bay section was "more easily correlated with mainland sections" and broadly correlated his Whitecliff section with it.

Bailey et al. (1983 and 1984) utilised, in part, the work of Swiecicki in establishing a correlation of the biostratigraphical stages in southern England and presented the biostratigraphical criteria on which the Coniacian-Maastrichtian stage boundaries in the Chalk of north-west Europe could be recognised in southern England. Bailey's PhD thesis (Bailey, 1978) focussed on the more accessible Freshwater Bay and Culver Cliff to define the foraminiferal zonation of the Coniacian and Lower Santonian (Lower Senonian) on the Isle of Wight. He determined six assemblage zones (A to F) that he applied to the Isle of Wight sections and these can be correlated with the scheme of Hart et al. (1989) and BGS (see Wilkinson, this issue). The scheme covers the Mid-Coniacian to Late Santonian (Seaford Chalk Formation and lower Newhaven Chalk Formation) part of the succession encountered in Scratchell's Bay.

Grant (1998) provides a sequence stratigraphy of the Culver Down / Whitecliff Chalk succession that can be correlated with the Scratchell's Bay succession. Montgomery (1994) and Montgomery et al. (1998) compare the magneto-stratigraphy of Scratchell's Bay and Culver Down.

Hart et al. (1989) published a small-scale outline section for both Alum Bay (Upper Campanian) and Scratchell's Bay (Santonian to late Campanian only) but this appears to be a further presentation of the section utilised by Swiecicki (1980). This volume carries the standard benthonic foraminiferal zones for the Chalk Group (UKB zones) that is correlated with those of BGS in Wilkinson (this issue).

A complete manuscript lithological log from the Palaeogene unconformity in Alum Bay around the Needles promontory and into Scratchell's Bay was kindly provided by Professor Andy Gale (pers. comm., 2008). This matches closely with the section logged by the BGS and is used in outline form (Fig. 5a and b) to aid correlation with the Whitecliff GCR site (Mortimore et al., 2001). The Gale section (logged from 1992, presumably on a number of visits) permits correlation of the Alum Bay section of Swiecicki (1980) and that of Woods (2009). It demonstrates that the Swiecicki Alum Bay measured section is significantly too thick and perhaps emphasises the difficulties of measuring stratal thicknesses in steeply dipping oblique sections.

2. The Scratchell's Bay Section

The section examined during April/May 2008 by the BGS team is presented below in Fig. 3a and 3b. These provide a graphical representation of the strata encountered and their interpretation, based on the lithological changes noted together with the correlation based on the micro- and macro-biostratigraphy. The log shows an expanded Seaford Chalk Formation and a much reduced Culver Chalk Formation in comparison to the Whitecliff GCR site. The base of the Portsdown Chalk is not clearly marked by the unequivocal presence of the Portsdown Marl pair. The boundary is placed lower within the sequence compared to the interpretation of Gale (see Fig 5a) based on the first occurrence of the foraminifera *B. decoratus* sensu stricto, the indicator for the base of the Scratchell's Marls and foraminiferal zone BGS 20iv, that is a little above the base of the Portsdown Chalk.

The section was sampled at frequent intervals for foraminifera. The ranges of the principal indicative species are given in Fig. 4 in relation to sample depth; their interpretation in respect of the BGS foraminiferal scheme is indicated. These results help fix the lithostratigraphical boundaries determined in Fig.3 a and b.

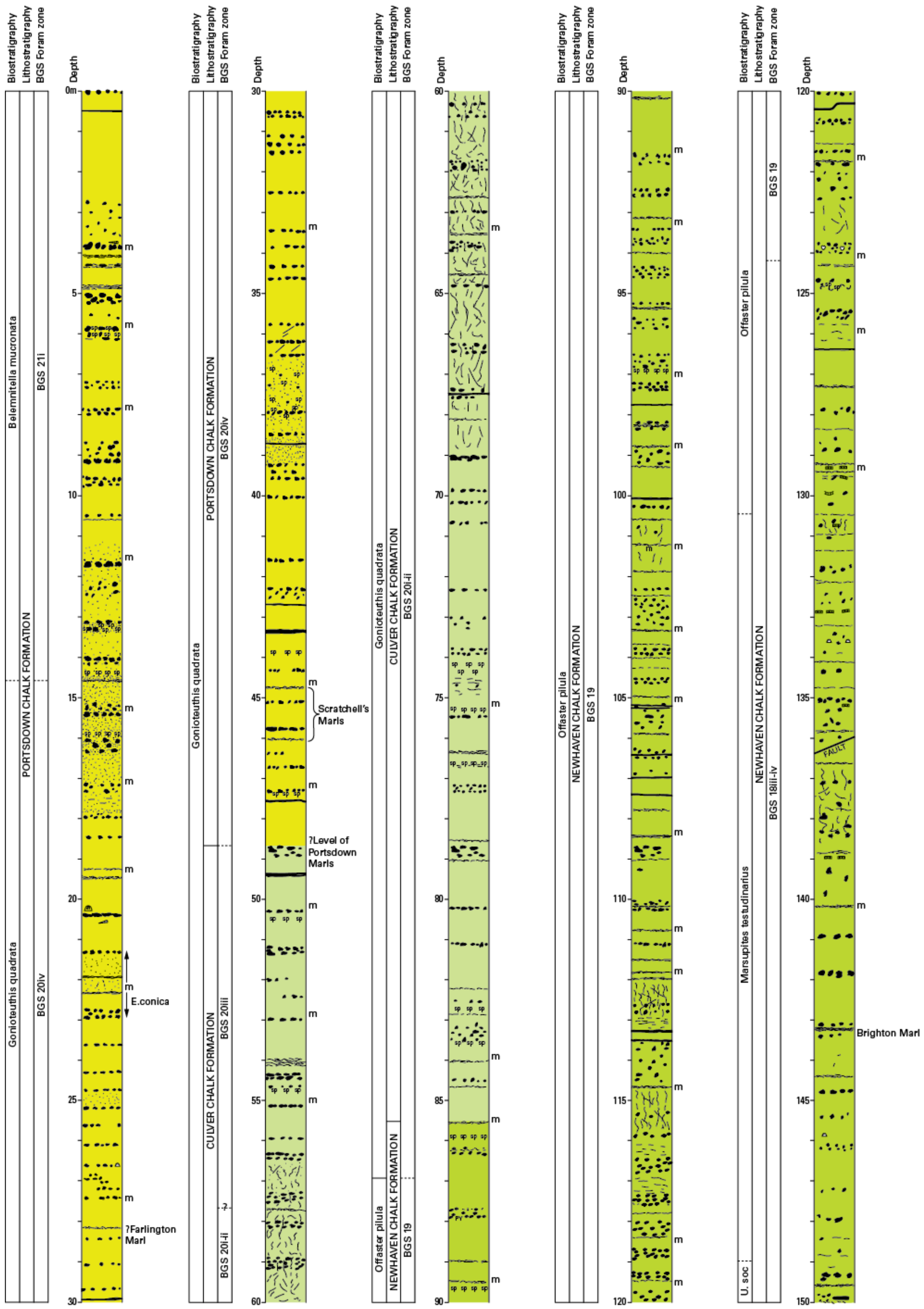


Fig. 3a. The Portsdown Chalk Formation, Culver Chalk Formation and upper part of the Newhaven Chalk Formation exposed at Scratchell's Bay, Isle of Wight. (full page place 3a and 3b on facing pages)

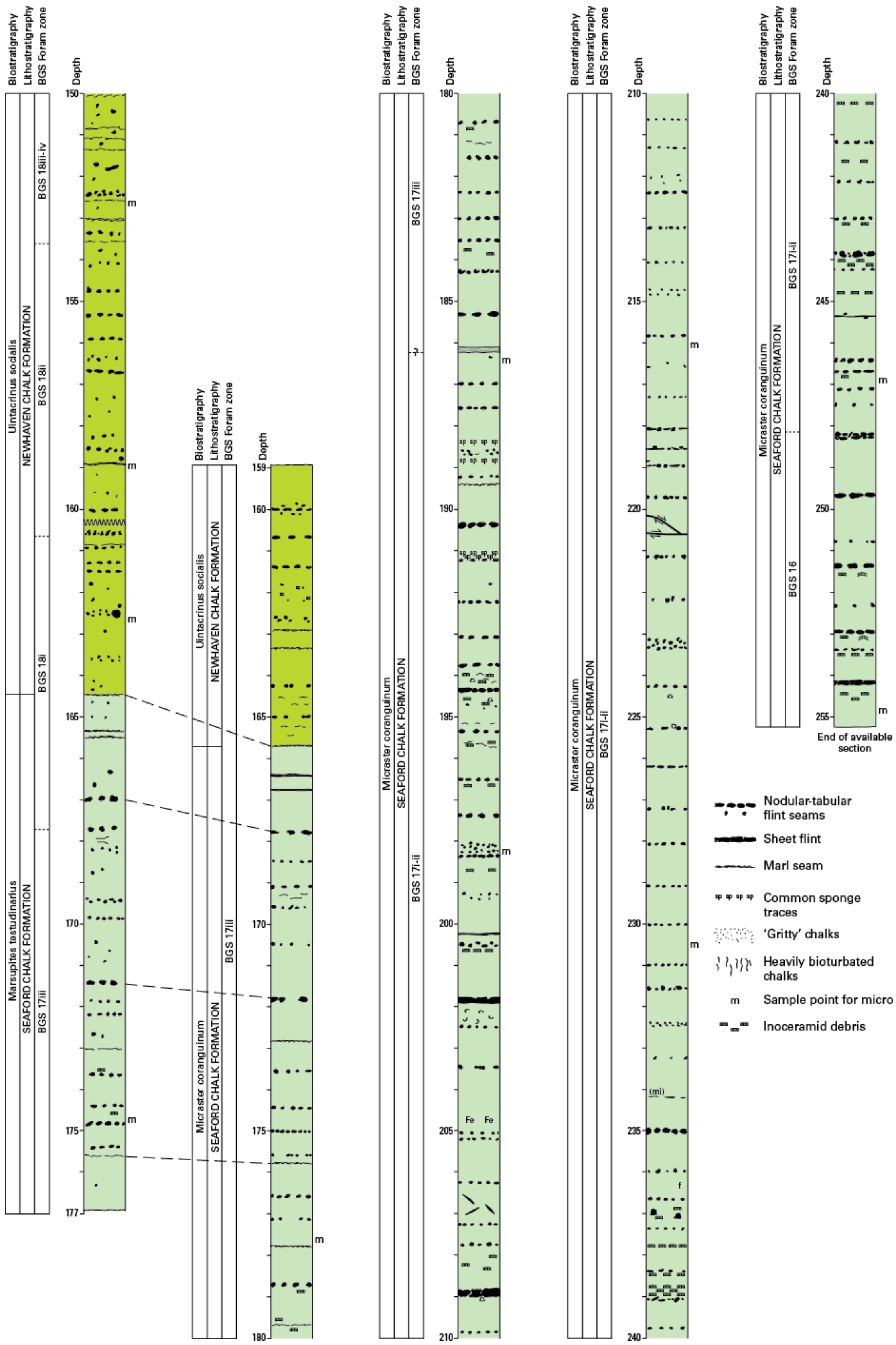


Fig. 3b. The lower part of the Newhaven Chalk Formation and the Seaford Chalk Formation exposed at Scratchell's Bay, Isle of Wight. (full page place 3a and 3b on facing pages)

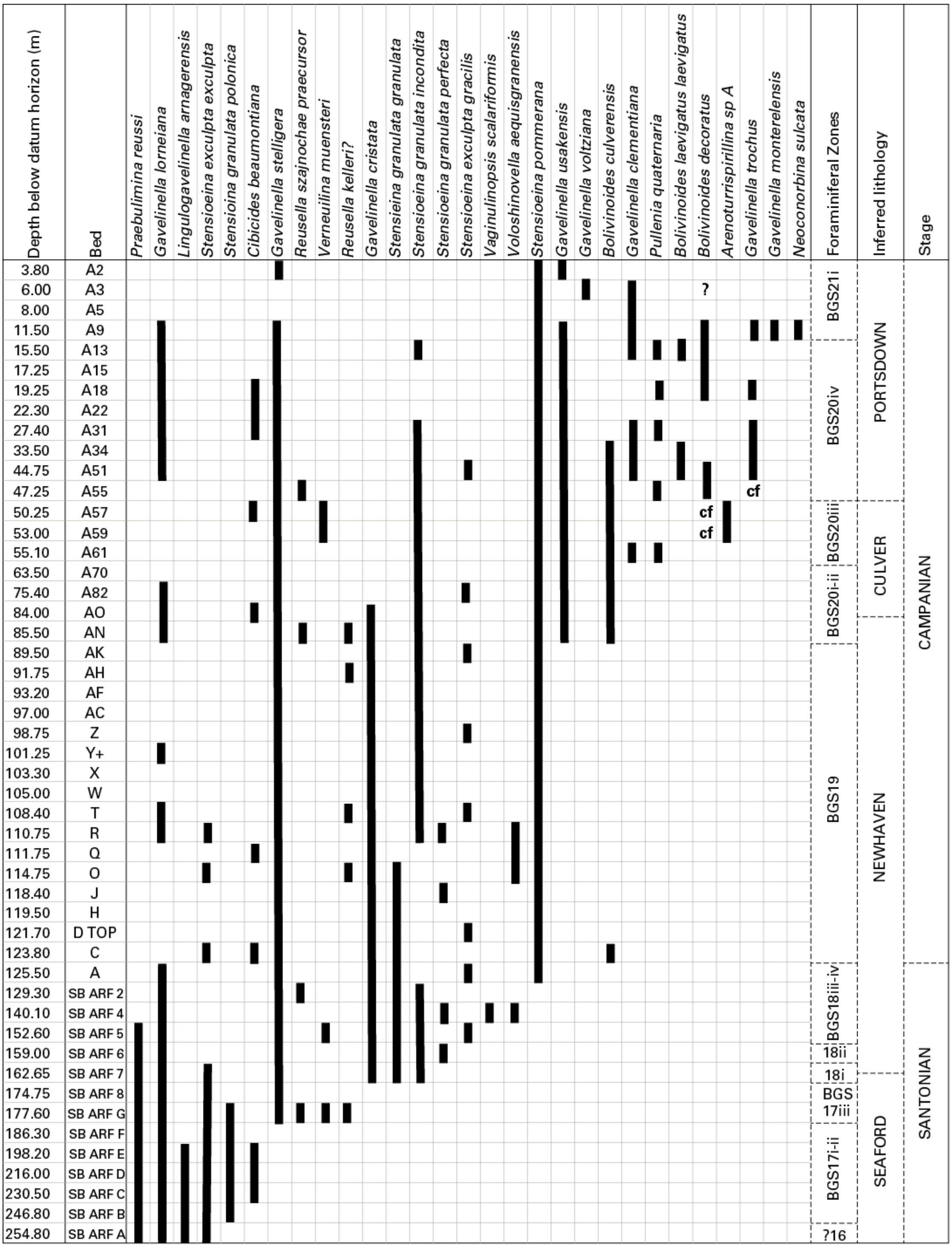


Fig. 4. The distribution of key foraminifera identified in the Scratchell's Bay section in relation to depth and the BGS zonal scheme.

3. Correlation

The Scratchell's Bay sections of Gale and BGS are the most readily matched and they can be correlated with the successions at Whitecliff and with holostratotypes on the mainland though with some important provisos discussed below. Difficulties with matching the log of Brydone (1914), due to the lack of detail, and that of Swiecicki (1980), because of marked thickness anomalies and emphasis on marker flint and marl seams rather than chalk lithology, permit only an outline correlation with the BGS and Gale logs shown in Fig. 5a and b.

3.1. Seaford Chalk Formation

The Scratchell's Bay logs demonstrate a significant increase in thickness of the Seaford Chalk Formation (Fig. 5b and 6) by comparison to the Whitecliff GCR section (Mortimore et al., 2001) and the holostratotype section at Seaford Head (Mortimore, 1986). Whilst there is some potential repetition in part of the succession at Scratchell's Bay, the overall thickness of the exposed and accessible part of the formation is 89 metres. The stratigraphically older Belle Tout Beds representing the lower part of the Seaford Chalk Formation below the Seven Sisters Flint, are un-described at Scratchell's Bay as it falls within the cliff section offshore of the low-water mark. The thickness of this unit is estimated at 15 m, based on an interpretation of photographs; this represents a significant reduction compared to the Whitecliff GCR section where the Belle Tout Beds are 25 m thick (Mortimore et al., 2001).

The greater part of the Cuckmere Beds forms the lower part of the BGS section described from Scratchell's Bay, amounting to a minimum of 46 m of strata above low-water. Neither the Gale nor the BGS logs identify the Seven Sisters Flint, the basal marker for these beds. However, the presence of thick *Platyceramus* and *Volviceramus involutus*, within the succession immediately above the low-water mark suggest that this named bed can only be a short distance stratigraphically below the logged section (indeed the Seven Sisters Flint may well be the large continuous flint visible in Fig. 2). There is evidence of faulting within the BGS section and this may have some potential to repeat the succession. However it is not clear how much of the sequence is likely to be repeated, if any, as the fault, where seen on the foreshore, is principally 'within bed' and similar to those discussed in Mortimore et al. (2001, p.187- 188) within the Shoreham and White Horse Marls at Whitecliff. Thus the 46 m for the Cuckmere Beds may well be a true thickness.

At the top of the Cuckmere Beds the correlation of the Michel Dean Flint in both the Gale and BGS logs at Scratchell's Bay is further justified by the occurrence of *Cladoceramus unduloplicatus* at this level. This correlation indicates that the Haven Brow Beds (cf Mortimore, 1986) are 43 m thick here, whilst a condensed 10 m are to be seen at Whitecliff and 31 m at the Seaford Head holostratotype. The attenuation of the upper Haven Brow Beds at Whitecliff culminates in two well-marked glauconitic nodular beds and hardgrounds, the upper of which is a heavily glauconitized surface overlain by glauconite coated intraclasts. This succession represents severe shoaling, erosion and probably wave-base remobilisation resulting from uplift on one element of the developing Sandown fault/fold. This contrasts with the Scratchell's Bay section, where all of the key Santonian marker flints can be recognised in an expanded succession compared to the stratotype. This suggests that at Scratchell's Bay greater accommodation space was available at this time and perhaps with an influx of sediments comprising winnowed material from further east. The synchronicity of the expansion at Scratchell's Bay and the condensation at Whitecliff precludes eustacy as a driving

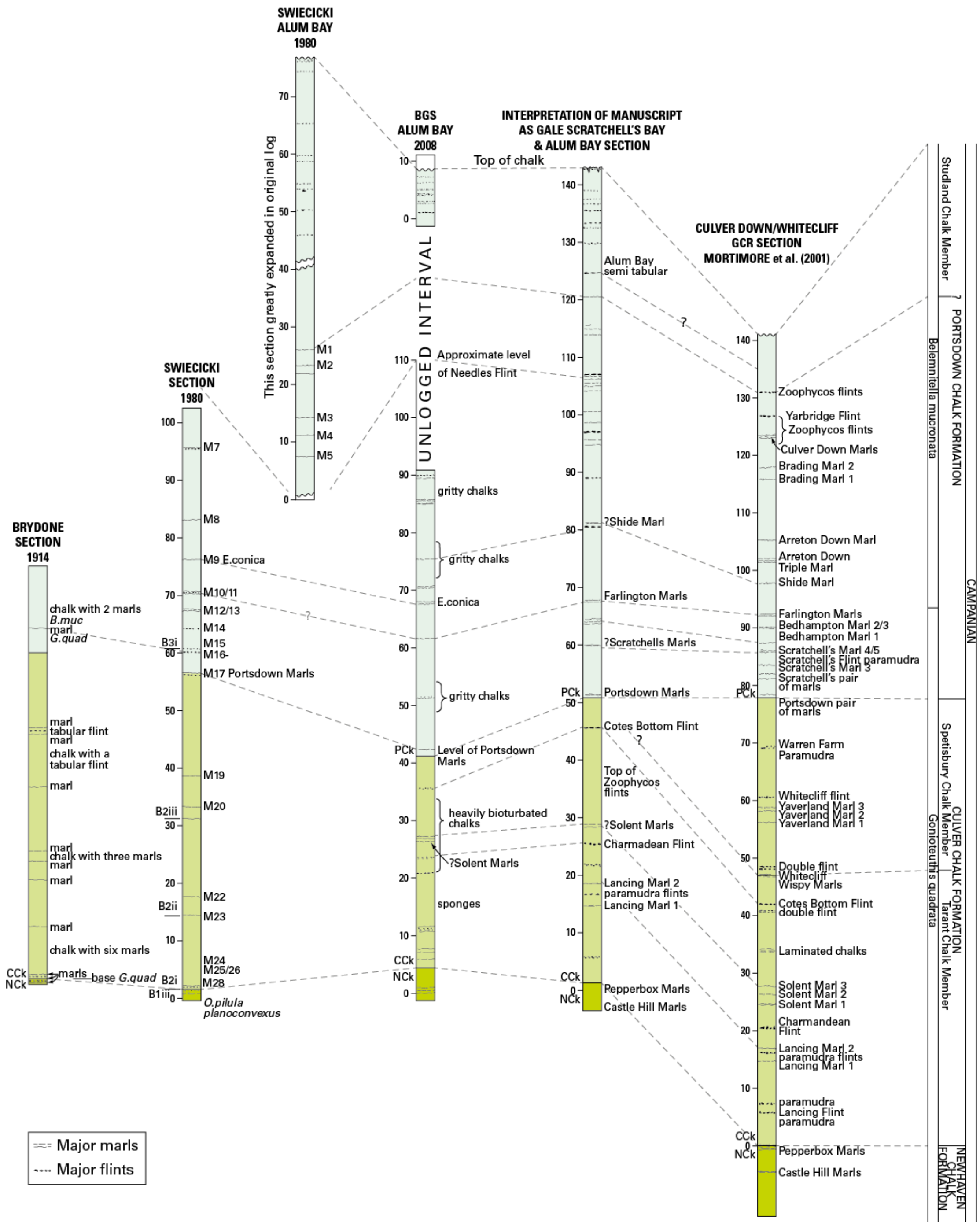


Fig. 5a. The principal features and correlation of the Portsdown Chalk and Culver Chalk formations at Scratchells's Bay and their correlation to the Culver Down - Whitecliff Bay GCR section. Outline logs derived from the work of Brydone (1914), Swiecicki (1980), Gale (pers comm., 2008) and Mortimore et al., (2001). (print this size place 5a and 5b on facing pages)

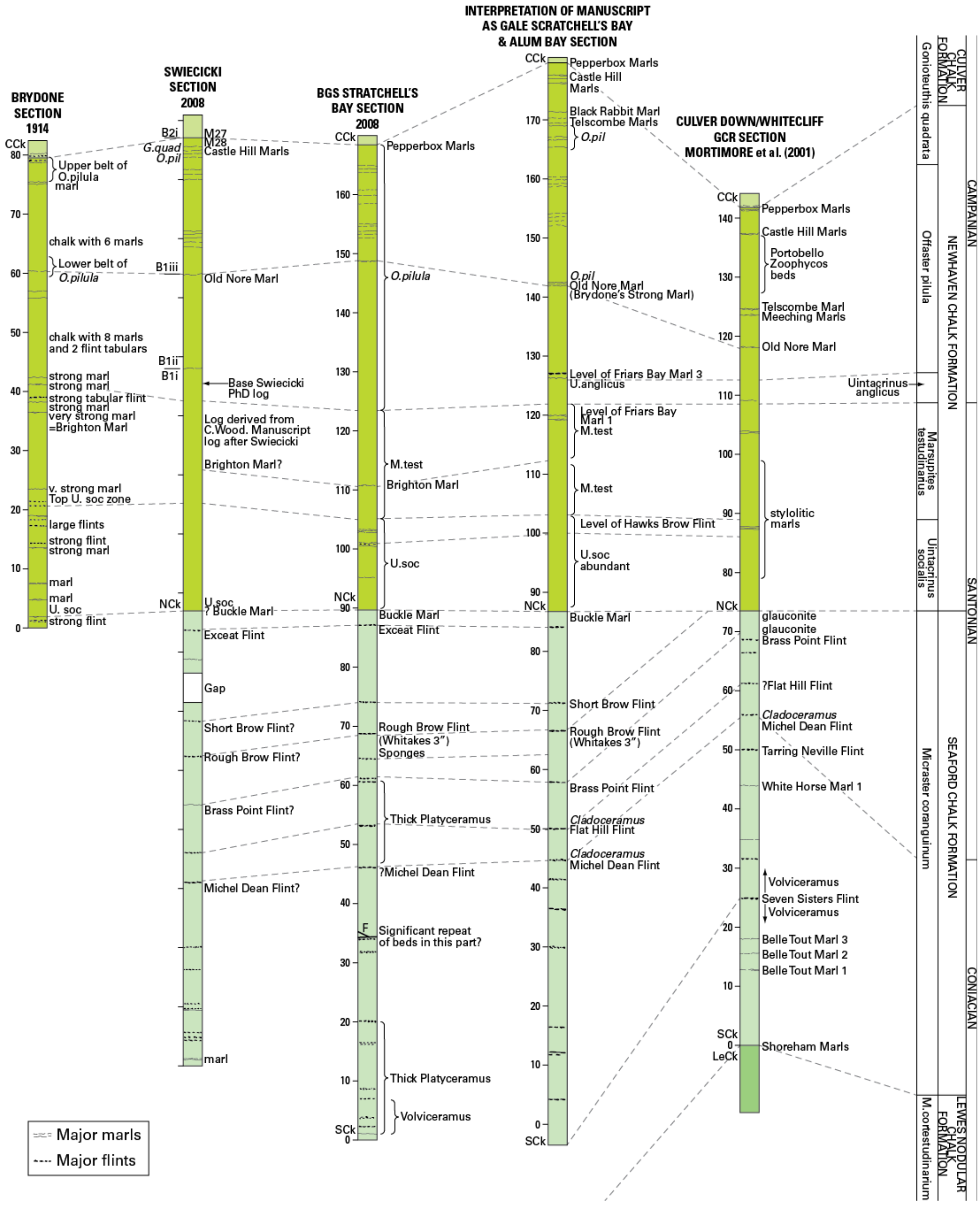


Fig. 5b The principal features and correlation of the Newhaven Chalk and Seaford Chalk formations at Scratchells's Bay and their correlation to the Culver Down - Whitecliff Bay GCR section. Outline logs derived from the work of Brydone (1914), Swiecicki (1980), Gale (pers comm., 2008) and Mortimore et al., (2001). (print this size place 5a and 5b on facing pages)

Mechanism. Rather, this is the clearest evidence from the two sections demonstrating the influence of differential tectonism along the Purbeck – Wight Structure.

In conclusion, the Seaford Chalk Formation at Scratchell's Bay shows considerable thickening in the uppermost Coniacian (Cuckmere Beds) and lower Santonian (Haven Brow Beds) and some condensation in the mid-Coniacian (Belle Tout Beds).

3.2. Newhaven Chalk Formation

The Newhaven Chalk can correlated between Scratchell's Bay, Whitecliff and the mainland stratotype, on the basis of lithological markers and the macro-biostratigraphy and this is confirmed by the distribution of the foraminifera. The succession is a little expanded at Scratchell's Bay compared to Whitecliff and significantly more than at the stratotype in Sussex and much of this expansion is within the *Offaster pilula* zonal interval.

Stratal Units	**Stratotype section name**	**Thickness at stratotype** m	**Thickness at Whitecliff GCR** m	**Thickness at Scratchell's / Alum Bay** m
Seaford Chalk Formation	Seaford Head	69	64	104
Belle Tout Beds	Seaford Head	22	25	c.15
Cuckmere Beds	Seaford Head	16	c.29	46+
Haven Brow Beds	Seaford Head	31	c.19	43
Newhaven Chalk Formation	Seaford Head	59[1]	68	80
Culver Chalk Formation	Whitecliff	77[2]	77	43
Tarrant Chalk Member	Whitecliff	47	47	28
Spetisbury Chalk Member	Whitecliff	30	30	9
Portsdown Chalk Formation	Farlington and Whitecliff*	30+ 63+*	53	91
Studland Chalk Member	Alum Bay		22	

Fig. 6. Relative stratal thicknesses For Scratchell's Bay, Whitecliff and stratotypes for the Chalk Formation in southern England

[1] Excludes the Castle Hill Marls to Pepperbox Marls interval of about 5 metres thickness.

[2] Whitecliff is the stratotype for this formation

3.3. Culver Chalk Formation

The Culver Chalk at Scratchell's Bay (c. 37 m) is greatly reduced in thickness compared to that at Whitecliff (c. 77 m; the stratotype for this formation, Mortimore, 1986). In large exposures and under ideal geomorphological conditions during field surveying, the Culver Chalk Formation is divisible locally into a lower Tarrant Chalk Member and an upper Spetisbury Chalk Member. It has not proved possible to apply this subdivision across the outcrop on the island, as the general steep dip does not give rise to the characteristic geomorphological response (as minor scarps) for each of the members as seen in Sussex. These members can be differentiated, however, in the cliff sections at either end of the island and demonstrate the significant overall reduction in thickness of both members at Scratchell's Bay compared to Whitecliff. Further, the greater part of this reduction is accommodated within the younger Spetisbury Chalk Member (the Whitecliff Beds of Mortimore, 1986) and the uppermost Tarrant Chalk Member (upper Sompting Beds of Mortimore 1986) above the Solent Marls. The mechanism for the reduction may be similar to the suggested channelling within the Culver Chalk identified in the New Forest area at Bransgore (Evans and Hopson, 2000; Evans et al. 2001) but may equally be simply a condensation in response to local movement along the Brighstone pericline and associated Needles Fault.

3.4. Portsdown Chalk Formation

The lower part of the Portsdown Chalk is described in the BGS log and can be correlated closely to that by Gale. However the base of the formation is indicated slightly lower in the succession by the presence of the indicator foraminifera *B. decoratus* (base BGS 20iv zone, and placed at the Scratchell's Marls) in the sample at 47.25 m, and thereby further limits the thickness of the Culver Chalk below. This inception places the formation boundary within a part of the succession without significant marl seams, but with significant nodular flint horizons and two sheet flint beds, and this suggests that the Portsdown Marls are weakly represented at Scratchell's Bay.

The higher part of the Portsdown Formation is given in outline (Fig. 5a) derived from the manuscript log of Gale and the short section description of Woods (2009) in Alum Bay. The regularly spaced marl seams characteristic of the lower part of the formation are identified in the succession as it is traced from Scratchell's Bay, around the Needles, and into Alum Bay. The uppermost Portsdown Chalk in Alum Bay, stratigraphically above the Alum Bay Marls of Gale (=Marl 1 of Swiecicki, 1980) is assigned to the Studland Chalk Member (Gale et al., 1987; cf the Alum Bay Beds of Mortimore, 1979, 1983). This member is essentially free of significant marl seams but has regularly spaced large nodular flints. The stratigraphically highest significant marl present at Whitecliff, associated with a group of Zoophycos flints, is a few metres above the Yarbridge Flint (Mortimore et al., 2001). The correlation of this marl with the Alum Bay Marls (of Gale) and the M1 Marl of Swiecicki (1980) would place the stratigraphically higher Alum Bay Semitabular Flint (of Gale) within the group of very large flints seams some 3-5 m below the Palaeogene unconformity at Whitecliff. This correlation confirms that a substantial part of the chalk (c. 15 m) exposed in Alum Bay is stratigraphically above that seen in the highest levels of the formation at Whitecliff.

The presence of *Echinocorys conica* between 20.5 m and 23 m in the BGS log (Fig. 3a) indicates a position above the Farlington Marls of the Portsdown Chalk Formation as indicated in Jenkyns et al. (1994 , Figure 15) at Whitecliff. Mortimore et al. (2001) record a common occurrence of this species associated with their Culver Down Marls, considerably higher in the Whitecliff succession. *E. conica* is also identified by C.J. Wood on the manuscript of the Swiecicki log and is associated with the M9 marl on that section (Fig. 5a). A tentative correlation is made between the BGS and Swiecicki log on the basis of this fossil acme. The lowest occurrence of the foraminifera *B. decoratus* is at 47.4 m (Fig. 3a). The inception of this species is at the base of the Scratchell's Bay Marls, and its presence therefore indicates that the base of the Portsdown Chalk Formation is only a short distance below the 47.4 m level. Since the sample at 50.25 m is considered characteristic of BGS20iii zone and therefore highest Culver Chalk Formation the formation boundary is located at approximately 48.5 m. Thus the interval between 23 m and c. 48.5 m in the BGS logs should, at the very least, contain the Portsdown Marl Pair, the full set of Scratchell's Marls (5) and the three Bedhampton Marls. Only three marls are present within this 24.4 m interval, the lower two of these being considered to be the Scratchell's Marls. This correlation indicates that there is an expansion of the lowest part of the Portsdown Chalk Formation at Scratchell's Bay compared to the 14 m present at Whitecliff. The absence of marls is problematic in this part of the succession. They are either sheared-out at Scratchell's Bay, they were never deposited or expansion has disseminated the marl material over a greater thickness of chalk.

4. Discussion and Conclusions

The determination of the lithostratigraphical succession at Scratchell's Bay (BGS), its correlation with other logged successions on the Needles promontory, and with the Whitecliff GCR succession, demonstrates various differences that provide insights into differential development and sedimentation along the Purbeck-Wight Structure.

Some of the differences are significant and point to a syn-depositional (syn-rift) tectonic control on the sedimentation and abrupt along-strike lithological changes as discussed for example in Mortimore (2011) in the late Cretaceous Chalk Group. These tectonic controls are well illustrated and discussed in Mortimore (2011, and references therein) and further justification for the existence of these controls is provided here. Whilst time-constrained phases of basin-wide tectonic events have been described across southern England (e.g. Mortimore and Pomerol, 1991a, b, 1997) and more widely across the Anglo Paris Basin into Germany (Mortimore et al., 1998) there is growing evidence that more localised events associated with individual elements of larger fault and fold structures have profound effects on the detailed bed-by-bed deposition of the Chalk (e.g. Gale, 1980) in addition to these basin-wide events. The lithological contrasts determined between the Whitecliff and Scratchell's/Alum Bay sites adds some additional data to that view, and point to differential movement on the along-strike elements of the Purbeck – Wight Structure as it is seen on the Isle of Wight itself, i.e. the Sandown and Brighstone (Needles) folds and associated reverse faults.

Recent BGS geological mapping has identified a number of faults (with orientations ranging from NW-SE through to NNE-SSW) that cross-cut the Purbeck – Wight Structure. Other evidence of along strike changes in the Chalk (see Mortimore, 2011) would suggest that these cross-cutting faults were active syn-depositionally and that the developing regional fold/fault structures themselves did not act as single features during tectonic movement but rather react sequentially to the stress field as it builds up and is released within each along-strike element of the structure.

It is further envisaged, though not the main tenet of this paper, that these cross cutting faults have been reactivated following the end of Chalk deposition, on at least two and probably many more occasions. One such reactivation was pre-Palaeogene, influencing the outcrop distribution of the highest chalk strata across the sub-Palaeogene unconformity surface as indicated by the along-strike distribution of the highest Chalk formations (e.g. as first discussed by Rowe, 1908, p. 285). The cross-cutting relationship of the northerly-orientated faults and the Purbeck – Wight Structure, demonstrated by recent mapping and seismic interpretation (Evans et al., this issue), points to reactivation during the deposition of the Palaeogene. That this reactivation took place on at least three occasions, is further justified by the evidence of Palaeogene uplift and erosion afforded by Gale et al. (1999), during the Lutetian and Bartonian, and by Newell and Evans (this issue), timed at the Bartonian - Priabonian boundary.

In summary, variations in the thickness and lithology of the Upper Coniacian to Upper Campanian Chalk succession show that:-

- The thickness of the Portsdown Chalk Formation in Alum Bay interpreted by Swiecicki is a significant overestimate compared to the thickness given in the Gale log.
- The base of the Portsdown Chalk is considered slightly lower stratigraphically by BGS than that interpreted in the Gale section but that both sections show an expansion of the lower Portsdown Chalk at Scratchell's Bay compared to the Whitecliff GCR section.
- There is considerable thinning of the Culver Chalk Formation in Scratchell's Bay compared to the Whitecliff GCR site.
- The expansion of the Newhaven Chalk Formation noted between the Sussex type section and Whitecliff GCR site (Mortimore et al., 2001), continues with the Newhaven Chalk Formation further expanded at Scratchell's Bay.
- The condensation of the highest beds of the Seaford Chalk noted at Whitecliff is not repeated at Scratchell's Bay where the thickest Seaford Chalk in southern England is preserved.
- Each of these thickness and lithological variations can be attributed to differential movement along the Purbeck – Wight structure.

Acknowledgements
The authors would like to thank the National Trust for their permission to visit and sample the Scratchell's Bay section. Thanks must go to the independently funded Freshwater Lifeboat crews who so kindly helped transport the survey party to the bay on two Sundays in April and May of 2008. Thanks also to Professor Andy Gale from Portsmouth University for the sight of his manuscript notes and section drawn from his visits to the exposure over a number of years and his permission to use this data to support the outline log presented.

A manuscript section of the macrofossil determinations of Mr Chris Wood based on the Swiecicki section log is lodged with the BGS at Keyworth and was consulted for correlation purposes. This section includes data not presented in Swiecicki (1980) and is added to the log in Fig. 5b.

The survey could not have been carried out without Katy Booth and Andy Newell of the BGS and Rob Arnold, a visiting student from Cardiff University, who assisted during the logging of the section.

Peter Hopson, Andrew Farrant, Ian Wilkinson, Sev Kender and Mark Woods publish with the permission of the Executive Director British Geological Survey (NERC)

References

Bailey, H.W., 1978. A Foraminiferal Biostratigraphy of the Lower Senonian of Southern England. Unpublished PhD thesis, Plymouth University.

Bailey, H.W., Gale, A.S., Mortimore, R.N., Swiecicki, A., Wood, C.J., 1983. The Coniacian- Maastrichtian stages in the United Kingdom with particular reference to southern England. Newsletters in Stratigraphy 12, 19-42.

Bailey, H.W., Gale, A.S., Mortimore, R.N. Swiecicki, A, Wood, C.J., 1984. Biostratigraphical criteria for recognition of the Coniacian- Maastrichtian stage boundaries in the Chalk of north-west Europe with particular reference to southern England. Bulletin of the Geological Society of Denmark 33, 31-39.

Brydone, R.M., 1914. The Zone of Offaster Pilula in the south English Chalk. Part II Isle of Wight. Geological Magazine 51, 405-411.

Brydone, R.M., 1918. The thickness of the zone of Belemnitella mucronata in the Isle of Wight. Geological Magazine 55, 350-354.

Evans, D.J., Hopson, P.M., 2000. The seismic expression of synsedimentary channel features within the Chalk of southern England. Proceedings of the Geologists' Association 111, 219-230.

Evans, D.J., Hopson, P.M., Kirby, G.A., Bristow, C.R., 2003. The development and seismic expression of synsedimentary features in the Chalk of southern England. Journal of the Geological Society of London 160, 797-814.

Evans, D.J., Kirby, G.A., Hulbert, A.G., 2011. New insights into the structure and evolution of the Isle of Wight Monocline. Proceedings of the Geologists' Association 122, XXX-XXX page numbers to be added

Gale, A.S., 1980. Penecontemporaneous folding, sedimentation and erosion in Campanian Chalk near Portsmouth, England. Sedimentology 27, 137-151.

Gale, A.S., 2008. Pers Comm. Manuscript notes and section details for Scratchell's Bay and Alum Bay.

Gale, A.S., Jeffrey, P.A., Huggett, J.M., Connolly, P., 1999. Eocene inversion history of the Sandown Pericline, Isle of Wight, southern England. Journal of the Geological Society of London 156, 327-339.

Gale, A.S., Wood, C.J., Bromley, R.G., 1987. The lithostratigraphy and marker bed correlation of the White Chalk (late Cenomanian- Campanian) in southern England. Mesozoic Research 1, 107-118.

Grant, S.F., 1998. Sequence stratigraphy of a pelagic chalk succession: The Coniacian – Lower Campanian of the Anglo-Paris Basin. Unpublished PhD thesis, University of Durham.

Hart, M.B., Bailey, H.W., Crittenden, S., Fletcher, B.N., Price, R.J., Swiecicki, A., 1989. 273-371 Chapter 7, Cretaceous. In, Jenkins, D.G., Murray, J.W., Eds, Stratigraphical Atlas of Fossil Foraminifera, 2nd Edition. Ellis Horwood Ltd, Chichester.

Jenkyns, H.C., Gale, A.S., Corfield, R.M., 1994. Carbon- and oxygen-isotope stratigraphy of the English Chalk ansd Italian Scaglia and its palaeoclimatic significance. Geological Magazine 131, 1-34.

Jukes-Browne, A.J., Hill, W., 1904. The Cretaceous Rocks of Britain, Volume 3 the Upper Chalk of England. Chapter VII, Isle of Wight. Memoir of the Geological Survey of the United Kingdom.

Montgomery, P., 1994. The Magnetostratigraphy of Coniacian – Late Campanian Chalk sequences of southern England. Unpublished PhD thesis, University of Southampton.

Montgomery, P., Hailwood, E.A., Gale, A.S., Burnett, J.A., 1998. The magnetostratigraphy of the Coniacian – Late Campanian Chalk sequences in southern England. Earth and Planetary Science Letters 156, 209-224.

Mortimore, R.N., 1979. The relationship of stratigraphy and tectonofacies to the physical properties of the White Chalk of Sussex. Unpublished PhD thesis, University of Brighton.

Mortimore, R.N., 1983. The stratigraphy and sedimentation of the Turonian – Campanian in the southern province of England. Zitteliana 10, 27-41.

Mortimore R.N., 1986. Stratigraphy of the Upper Cretaceous White Chalk of Sussex. Proceedings of the Geologists' Association 97, 97-139.

Mortimore, R.N., 2011. Structural geology of the Upper Cretaceous Chalk Central Mass, Isle of Wight, UK. Proceedings of the Geologists' Association 122, 298-331.

Mortimore, R.N., Pomerol, B., 1991a. Upper Cretaceous tectonic disruptions in a placid Chalk sequence in the Anglo-Paris Basin. Journal of the Geological Society of London 148, 391-404.

Mortimore, R.N., Pomerol, B., 1991b. Stratigraphy and eustatic implications of trace fossil events in the Upper Cretaceous Chalk of Northern Europe. Palaios 6, 216-231.

Mortimore, R.N., Pomerol, B., 1997. Upper Cretaceous tectonic phases and end Cretaceous inversion in the Chalk of the Anglo-Paris Basin. Proceedings of the Geologists' Association 108, 231-255.

Mortimore, R.N., Wood, C.J., Gallois, R.W., 2001. British Upper Cretaceous Stratigraphy. Geological Conservation Review Series, No. 23, Joint Nature Conservation Committee, Peterborough.

Mortimore, R.N., Wood, C.J., Pomerol, B., Ernst, G., 1998. Dating the phases of the Subhercynian tectonic epoch: Late Cretaceous tectonics and eustatics in the Cretaceous basins of northern Germany compared with the Anglo-Paris Basin. Zentralblatt für Geologie und Paläeontologie, Teil 1, 1996,(11/12), 1349-1401.

Newell, A.J., Evans, D.J., 2011. Timing of basin inversion on the Isle of Wight: New evidence from geophysical log correlation, seismic sections and lateral facies change in the Headon Hill Formation. Proceedings of the Geologists' Association 122, XXX-XXX. page numbers to be added

Rowe, A.W., 1908. The zones of the White Chalk of the English Coast. Part 5, The Isle of Wight. Proceedings of the Geologists' Association 18, 209-352.

Swiecicki, A., 1980. A foraminiferal biostratigraphy of the Campanian and Maastrichtian Chalks of the United Kingdom. Unpublished PhD Thesis, Plymouth Polytechnic.

Whitaker, W., 1865. On the Chalk of the Isle of Wight. Quarterly Journal of the Geological Society of London 21, 400-406.

White, H.J.O., 1921. A short account of the geology of the Isle of Wight. Memoir of the British Geological Survey.

Wilkinson, I.P., 2011. Foraminiferal biozones and their relationship to the lithostratigraphy of the Chalk Group of southern England. Proceedings of the Geologists'Association 122, XXX-XXX. page numbers to be added

Woods, M.A., 2009. Macrofossils from the Upper Greensand Formation and Chalk Group of the Isle of Wight: Spring 2009. British Geological Survey Internal Report IR/09/056.

Figure Captions

Fig. 1. The location of the Scratchell's Bay and Alum Bay sections, Isle of Wight.

Fig, 2a. A view of Scratchell's Bay looking to the east.
The Grand Arch (centre above the distal end of the shingle beach) and Sun Corner (on the right forming the 'grass slope') are the two features most commonly referred to in articles on this section. The regular flint seams characteristic of the Seaford Chalk Formation pass up-section to chalks with some flint and regular marl seams of the Newhaven Chalk Formation (extreme left of photograph). The lowermost Seaford Chalk (the Belle Tout Beds of Mortimore, 1986) with their very closely-spaced flint seams are indicated by the breaks of slope in the cliff profile just above the grass slope. The higher beds of the Lewes Nodular Chalk Formation form the slope and the cliffs below it. Figure in the mid distance for scale is 2 m high. BGS Photo P 699954 P M Hopson ©NERC/BGS

Fig. 2b. Scratchell's Bay looking west towards the Needles from the observation platform above the Grand Arch. Photo P774681 P M Hopson ©NERC/BGS

Fig. 3a. The Portsdown Chalk Formation, Culver Chalk Formation and upper part of the Newhaven Chalk Formation exposed at Scratchell's Bay, Isle of Wight. (place 3a and 3b on facing pages)

Fig. 3b. The lower part of the Newhaven Chalk Formation and the Seaford Chalk Formation exposed at Scratchell's Bay, Isle of Wight. (place 3a and 3b on facing pages)

Fig. 4. The distribution of key foraminifera identified in the Scratchell's Bay section in relation to depth and the BGS zonal scheme.

Fig. 5a. The principal features and correlation of the Portsdown Chalk and Culver Chalk formations at Scratchells's Bay and their correlation to the Culver Down - Whitecliff Bay GCR section. Outline logs derived from the work of Brydone (1914), Swiecicki (1980), Gale (pers comm., 2008) and Mortimore et al., (2001). (print this size place 5a and 5b on facing pages)

Fig. 5b The principal features and correlation of the Newhaven Chalk and Seaford Chalk formations at Scratchells's Bay and their correlation to the Culver Down - Whitecliff Bay GCR section. Outline logs derived from the work of Brydone (1914), Swiecicki (1980), Gale (pers comm., 2008) and Mortimore et al., (2001). (print this size place 5a and 5b on facing pages)

Fig. 6. Relative stratal thicknesses For Scratchell's Bay, Whitecliff and stratotypes for the Chalk Formation in southern England

[1] Excludes the Castle Hill Marls to Pepperbox Marls interval of about 5 metres thickness.

[2] Whitecliff is the stratotype for this formation

Figure

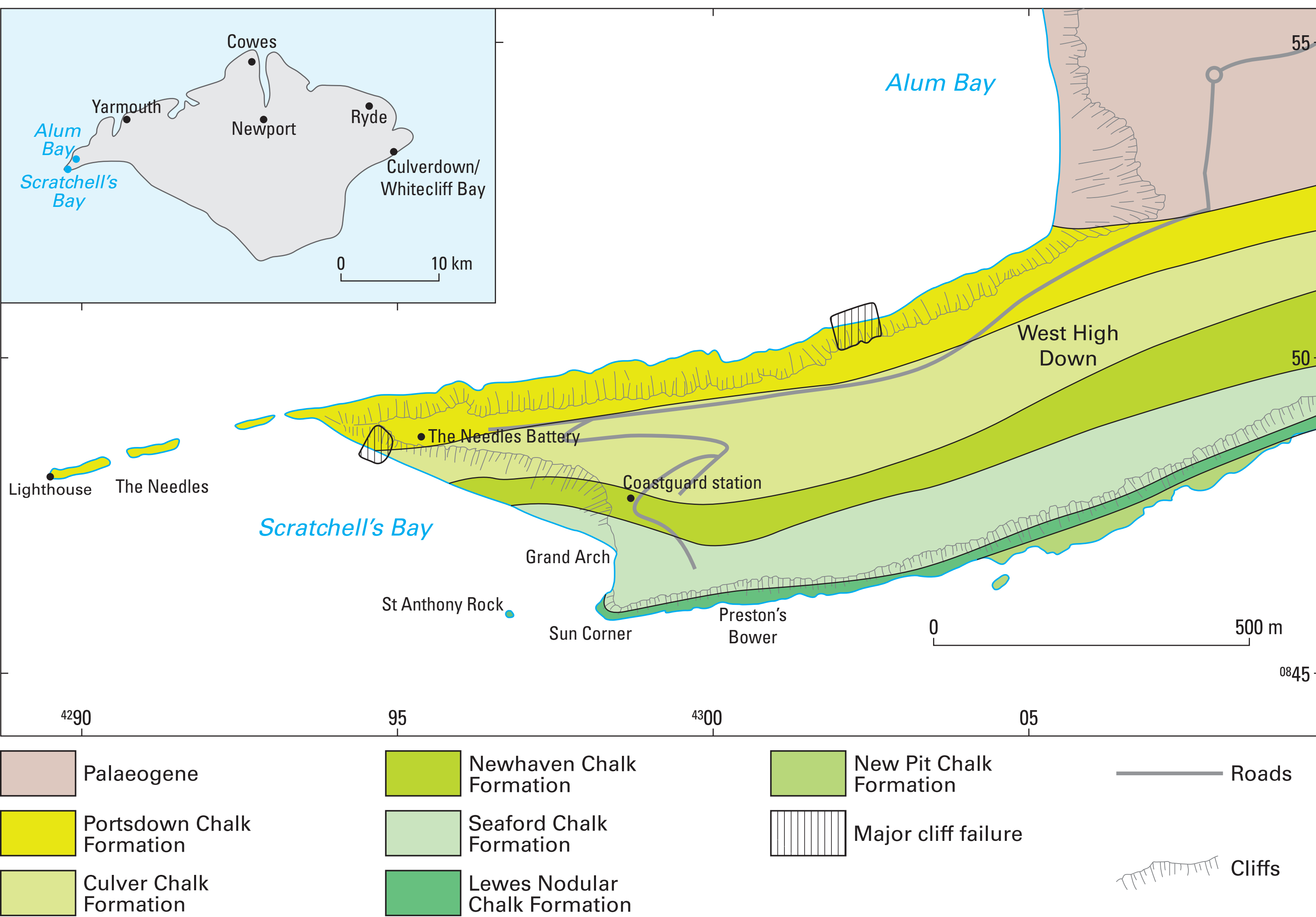

Cowes
Yarmouth
Newport
Ryde
Alum Bay
Scratchell's Bay
Culverdown/ Whitecliff Bay
0
10 km
Alum Bay
West High Down
The Needles Battery
Lighthouse
The Needles
Coastguard station
Scratchell's Bay
Grand Arch
St Anthony Rock
Sun Corner
Preston's Bower
0
500 m
55
50
08 45
42 90
95
43 00
05
Palaeogene
Portsdown Chalk Formation
Culver Chalk Formation
Newhaven Chalk Formation
Seaford Chalk Formation
Lewes Nodular Chalk Formation
New Pit Chalk Formation
Major cliff failure
Roads
Cliffs

Figure
Click here to download high resolution image

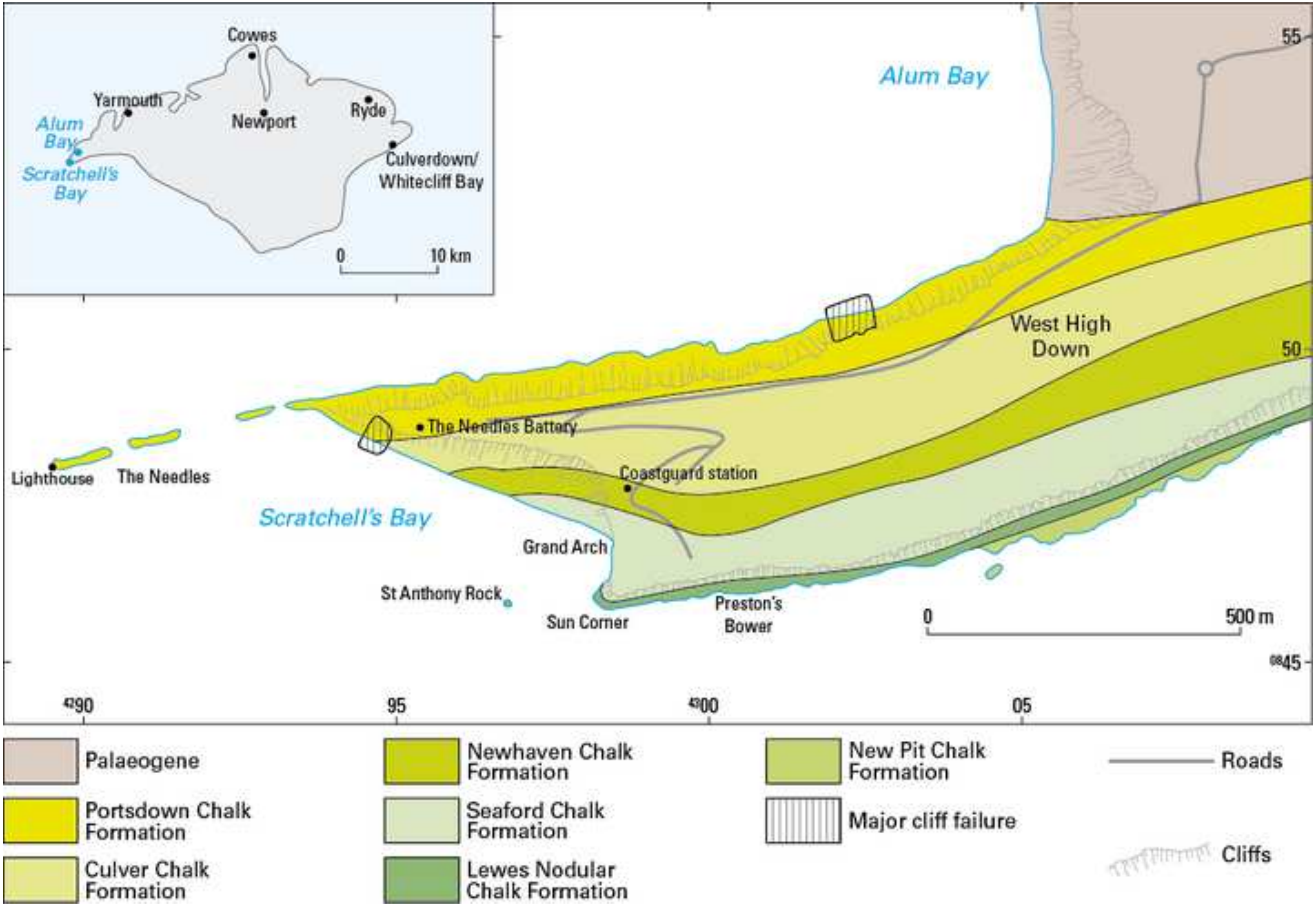
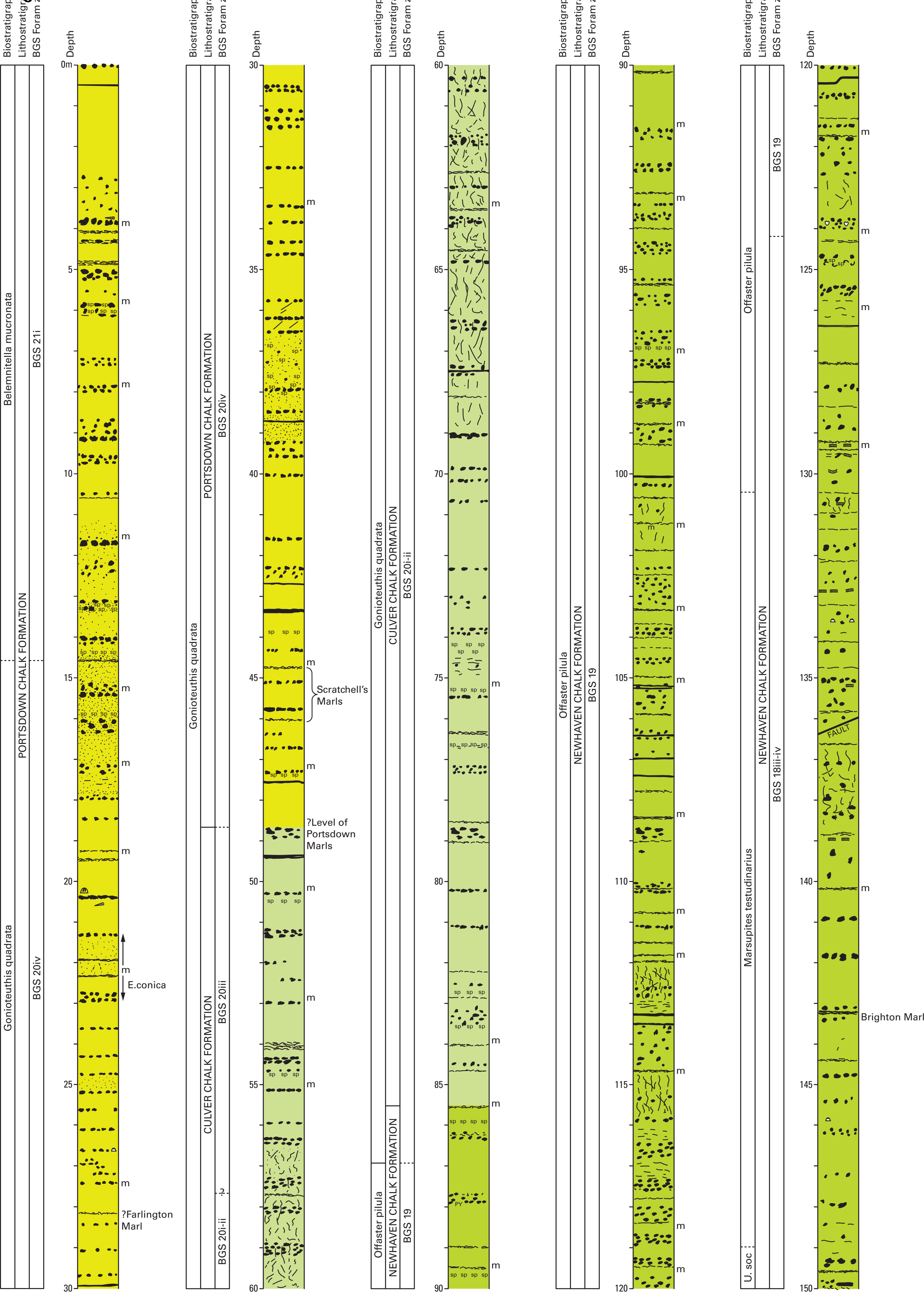


Figure
Click here to download high resolution image

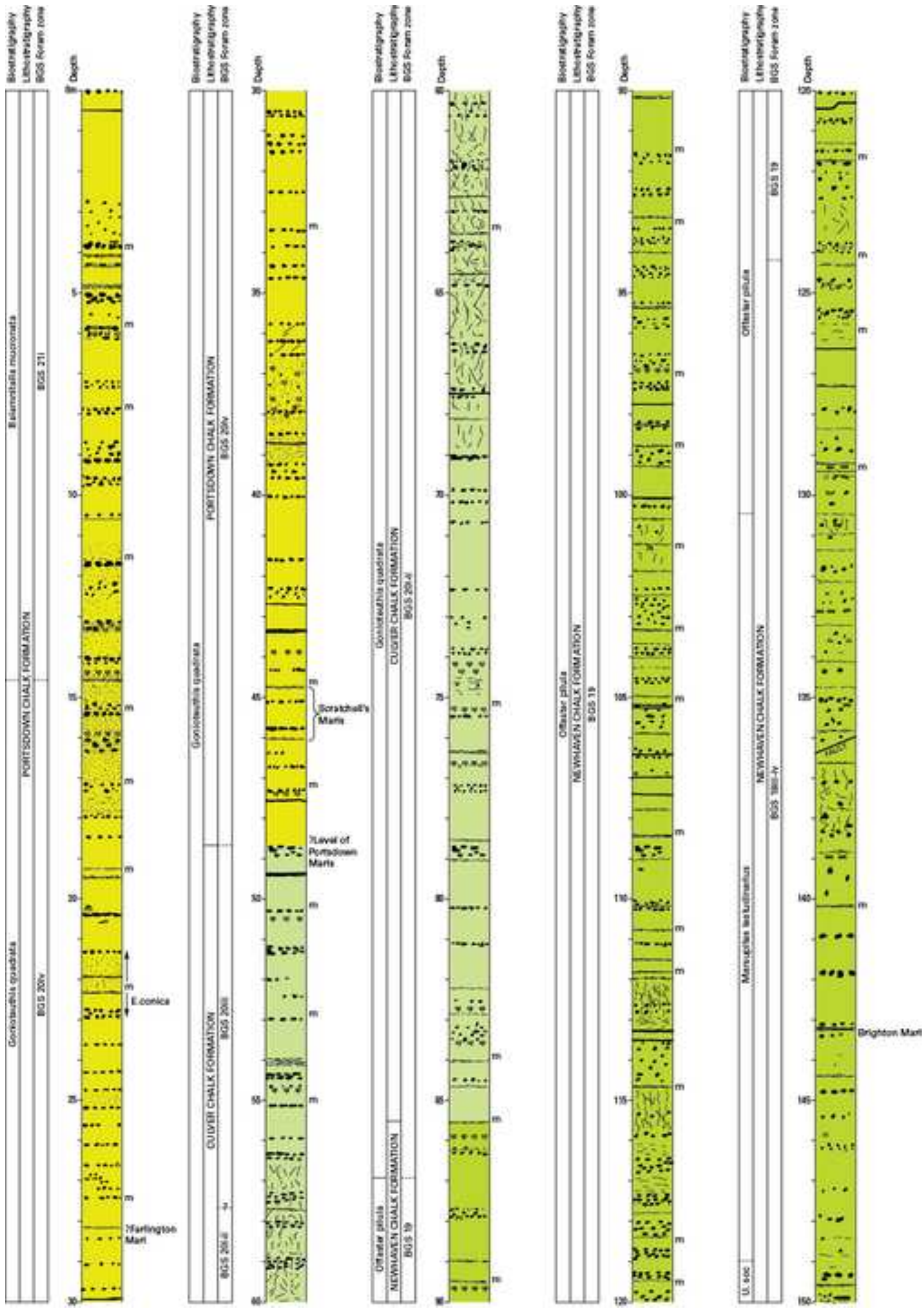
Figure
Click here to download high resolution image

Figure


Biostratigraphy
Lithostratigraphy
BGS Foram zone
Depth
0m
5
10
15
20
25
30
Belemnitella mucronata
Gonioteuthis quadrata
PORTSDOWN CHALK FORMATION
BGS 21i
BGS 20iv
m
sp
E.conica
?Farlington Marl
35
40
45
50
55
60
Gonioteuthis quadrata
PORTSDOWN CHALK FORMATION
CULVER CHALK FORMATION
BGS 20iv
BGS 20iii
BGS 20i-ii
?
Scratchell's Marls
?Level of Portsdown Marls
65
70
75
80
85
90
Gonioteuthis quadrata
Offaster pilula
CULVER CHALK FORMATION
NEWHAVEN CHALK FORMATION
BGS 20i-ii
BGS 19
PY
95
100
105
110
115
120
Offaster pilula
NEWHAVEN CHALK FORMATION
BGS 19
125
130
135
140
145
150
Offaster pilula
Marsupites testudinarius
U. soc
NEWHAVEN CHALK FORMATION
BGS 19
BGS 18iii-iv
FAULT
Brighton Marl

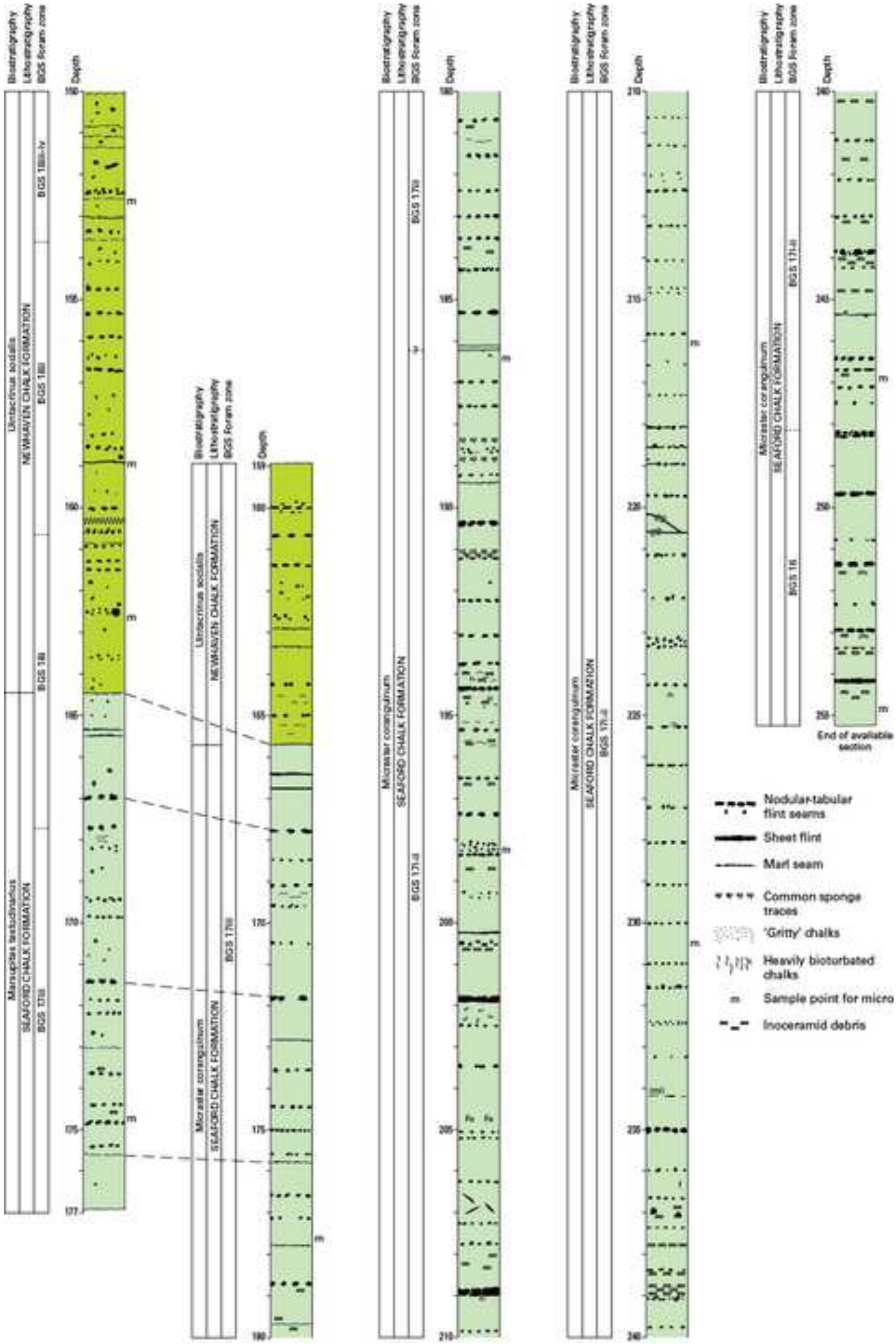
Figure

Click here to download high resolution image



Figure

Click here to download high resolution image



Figure

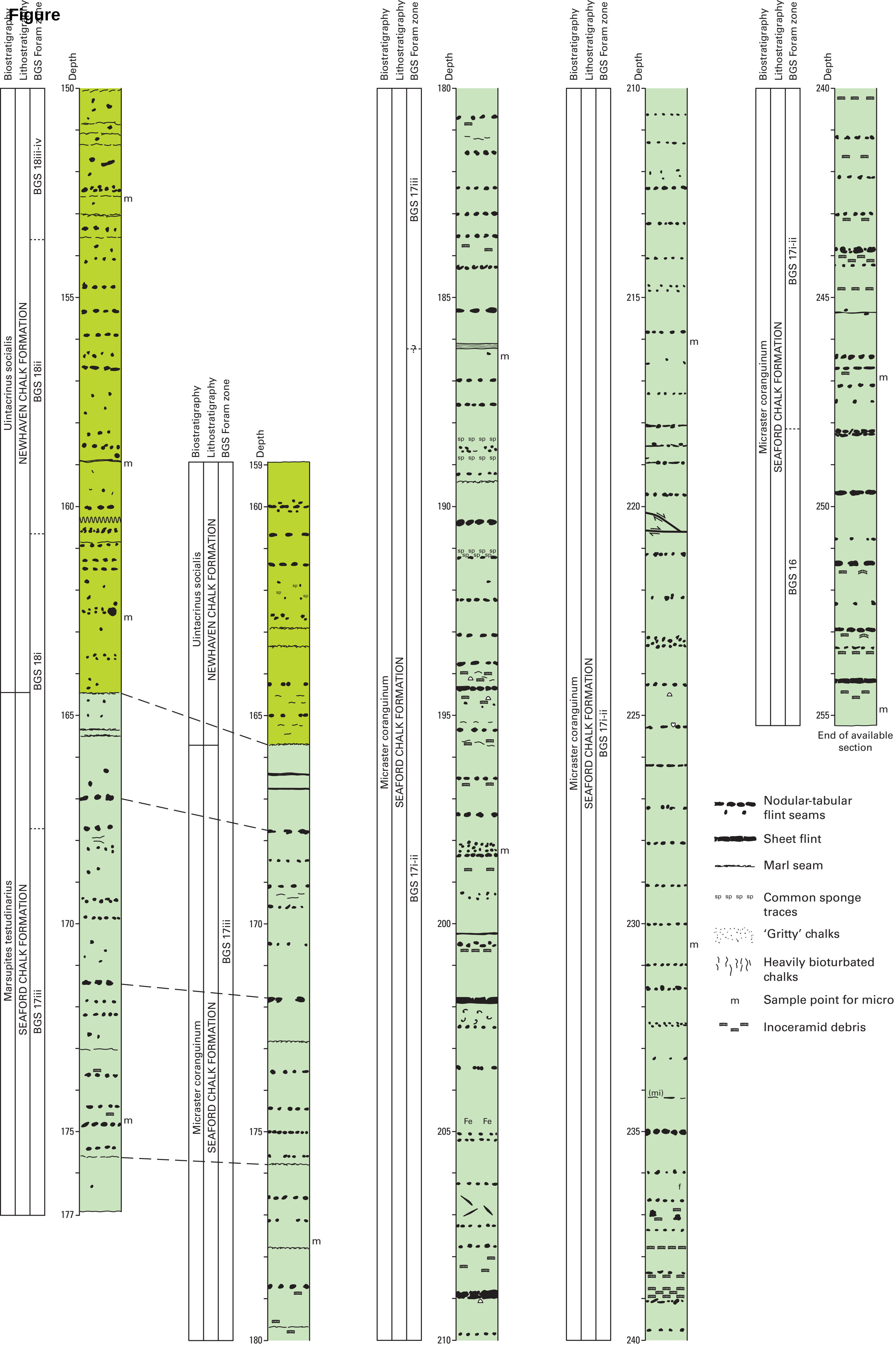
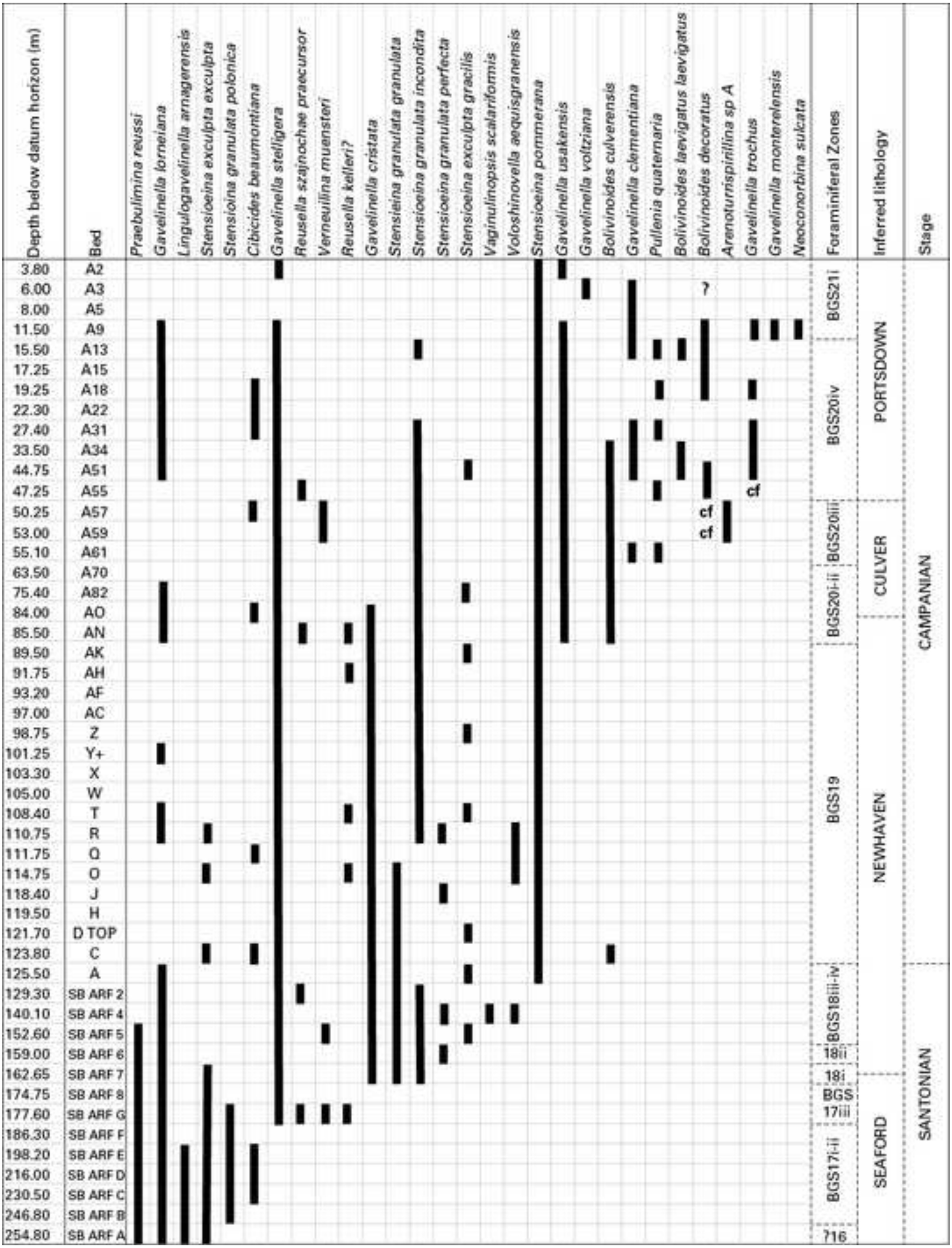
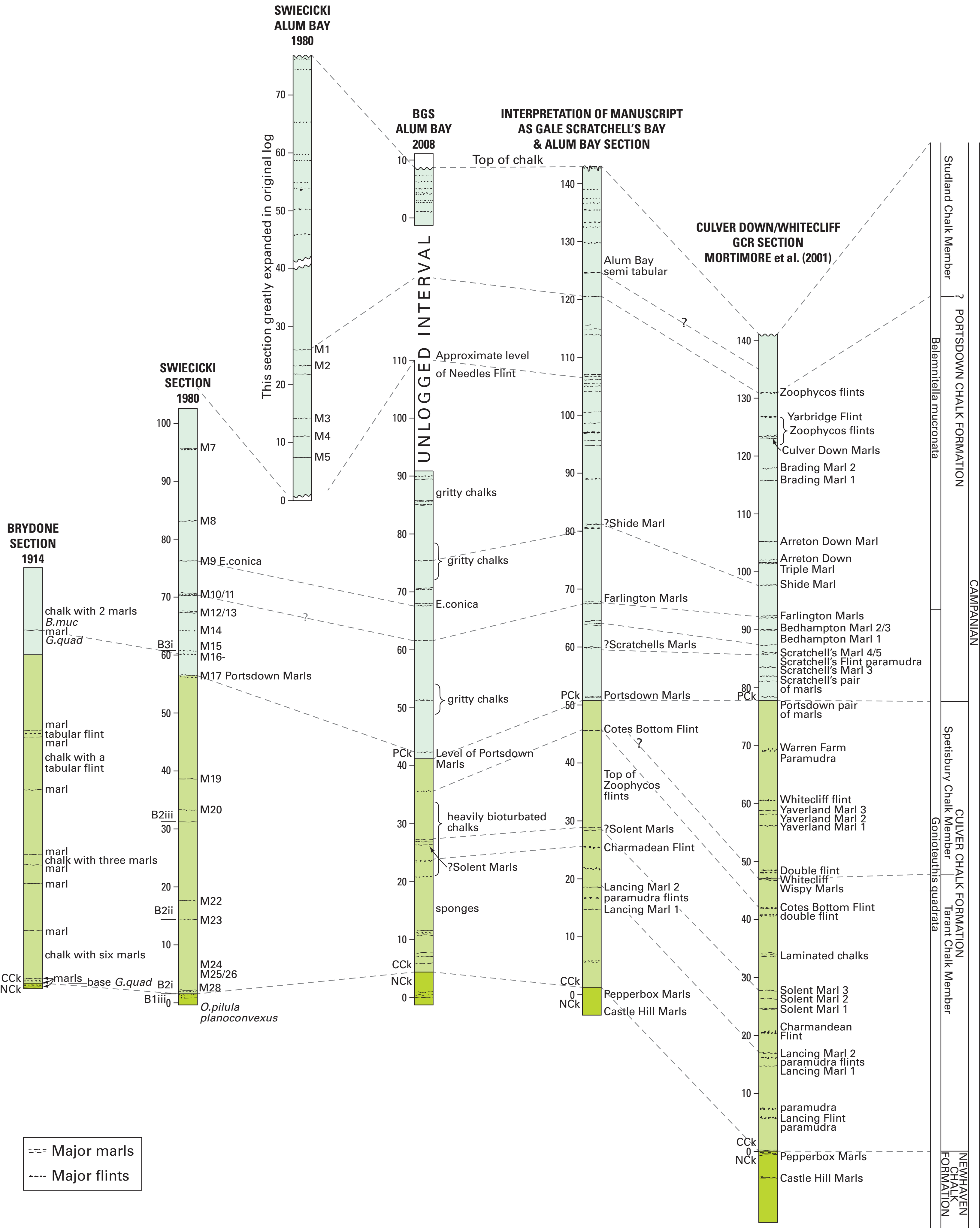

Biostratigraphy
Lithostratigraphy
BGS Foram zone
Depth
Uintacrinus socialis
NEWHAVEN CHALK FORMATION
Marsupites testudinarius
SEAFORD CHALK FORMATION
Micraster coranguinum
BGS 18ii-iv
BGS 18ii
BGS 18i
BGS 17iii
BGS 17i-ii
BGS 16
m
sp
Fe
(mi)
f
End of available section
Nodular-tabular flint seams
Sheet flint
Marl seam
Common sponge traces
'Gritty' chalks
Heavily bioturbated chalks
Sample point for micro
Inoceramid debris

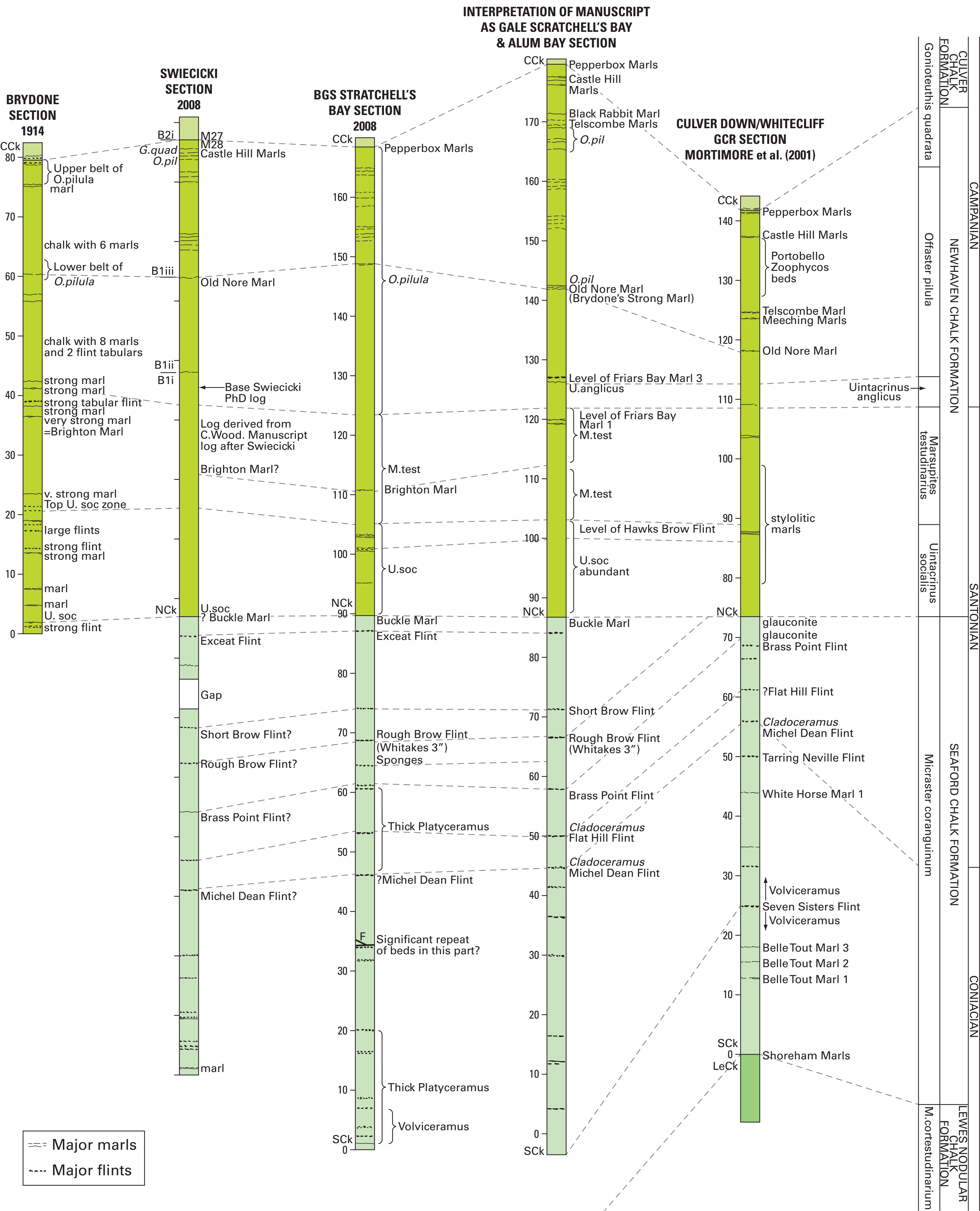
Figure
Click here to download high resolution image



Figure


SWIECICKI ALUM BAY 1980
This section greatly expanded in original log
M1
M2
M3
M4
M5
BGS ALUM BAY 2008
UNLOGGED INTERVAL
Top of chalk
Approximate level of Needles Flint
gritty chalks
gritty chalks
E.conica
gritty chalks
Level of Portsdown Marls
heavily bioturbated chalks
?Solent Marls
sponges
INTERPRETATION OF MANUSCRIPT AS GALE SCRATCHELL'S BAY & ALUM BAY SECTION
Alum Bay semi tabular
?Shide Marl
Farlington Marls
?Scratchells Marls
Portsdown Marls
Cotes Bottom Flint
Top of Zoophycos flints
?Solent Marls
Charmadean Flint
Lancing Marl 2
paramudra flints
Lancing Marl 1
Pepperbox Marls
Castle Hill Marls
CULVER DOWN/WHITECLIFF GCR SECTION MORTIMORE et al. (2001)
Zoophycos flints
Yarbridge Flint
Zoophycos flints
Culver Down Marls
Brading Marl 2
Brading Marl 1
Arreton Down Marl
Arreton Down Triple Marl
Shide Marl
Farlington Marls
Bedhampton Marl 2/3
Bedhampton Marl 1
Scratchell's Marl 4/5
Scratchell's Flint paramudra
Scratchell's Marl 3
Scratchell's pair of marls
Portsdown pair of marls
Warren Farm Paramudra
Whitecliff flint
Yaverland Marl 3
Yaverland Marl 2
Yaverland Marl 1
Double flint
Whitecliff
Wispy Marls
Cotes Bottom Flint double flint
Laminated chalks
Solent Marl 3
Solent Marl 2
Solent Marl 1
Charmandean Flint
Lancing Marl 2
paramudra flints
Lancing Marl 1
paramudra
Lancing Flint
paramudra
Pepperbox Marls
Castle Hill Marls
SWIECICKI SECTION 1980
M7
M8
M9 E.conica
M10/11
M12/13
M14
M15
M16-
M17 Portsdown Marls
M19
M20
M22
M23
M24
M25/26
M28
O.pilula planoconvexus
B3i
B2iii
B2ii
B2i
B1iii
BRYDONE SECTION 1914
chalk with 2 marls
B.muc
marl
G.quad
marl
tabular flint
marl
chalk with a tabular flint
marl
marl
chalk with three marls
marl
marl
marl
chalk with six marls
marls
base G.quad
CCk
NCk
PCk
Studland Chalk Member
PORTSDOWN CHALK FORMATION
Belemnitella mucronata
CAMPANIAN
Spetisbury Chalk Member
CULVER CHALK FORMATION
Gonioteuthis quadrata
Tarrant Chalk Member
NEWHAVEN CHALK FORMATION
Major marls
Major flints

Figure



BRYDONE SECTION 1914
SWIECICKI SECTION 2008
BGS STRATCHELL'S BAY SECTION 2008
INTERPRETATION OF MANUSCRIPT AS GALE SCRATCHELL'S BAY & ALUM BAY SECTION
CULVER DOWN/WHITECLIFF GCR SECTION MORTIMORE et al. (2001)
Upper belt of O.pilula marl
chalk with 6 marls
Lower belt of O.pilula
chalk with 8 marls and 2 flint tabulars
strong marl
strong marl
strong tabular flint
strong marl
very strong marl =Brighton Marl
v. strong marl
Top U. soc zone
large flints
strong flint
strong marl
marl
marl
U. soc
strong flint
M27
M28
Castle Hill Marls
Old Nore Marl
Base Swiecicki PhD log
Log derived from C.Wood. Manuscript log after Swiecicki
Brighton Marl?
U.soc
? Buckle Marl
Exceat Flint
Gap
Short Brow Flint?
Rough Brow Flint?
Brass Point Flint?
Michel Dean Flint?
marl
Pepperbox Marls
O.pilula
M.test
Brighton Marl
U.soc
Buckle Marl
Exceat Flint
Rough Brow Flint (Whitakes 3")
Sponges
Thick Platyceramus
?Michel Dean Flint
Significant repeat of beds in this part?
Thick Platyceramus
Volviceramus
Pepperbox Marls
Castle Hill Marls
Black Rabbit Marl
Telscombe Marls
O.pil
O.pil
Old Nore Marl (Brydone's Strong Marl)
Level of Friars Bay Marl 3
U.anglicus
Level of Friars Bay Marl 1
M.test
M.test
Level of Hawks Brow Flint
U.soc abundant
Buckle Marl
Short Brow Flint
Rough Brow Flint (Whitakes 3")
Brass Point Flint
Cladoceramus
Flat Hill Flint
Cladoceramus
Michel Dean Flint
Pepperbox Marls
Castle Hill Marls
Portobello Zoophycos beds
Telscombe Marl
Meeching Marls
Old Nore Marl
stylolitic marls
glauconite
glauconite
Brass Point Flint
?Flat Hill Flint
Cladoceramus
Michel Dean Flint
Tarring Neville Flint
White Horse Marl 1
Volviceramus
Seven Sisters Flint
Volviceramus
Belle Tout Marl 3
Belle Tout Marl 2
Belle Tout Marl 1
Shoreham Marls
CCk
NCk
SCk
LeCk
B2i
B1iii
B1ii
B1i
G.quad
O.pil
F
Uintacrinus anglicus
Gonioteuthis quadrata
Offaster pilula
Marsupites testudinarius
Uintacrinus socialis
Micraster coranguinum
M.cortestudinarium
CULVER CHALK FORMATION
NEWHAVEN CHALK FORMATION
SEAFORD CHALK FORMATION
LEWES NODULAR CHALK FORMATION
CAMPANIAN
SANTONIAN
CONIACIAN
Major marls
Major flints

Figure
Click here to download high resolution image

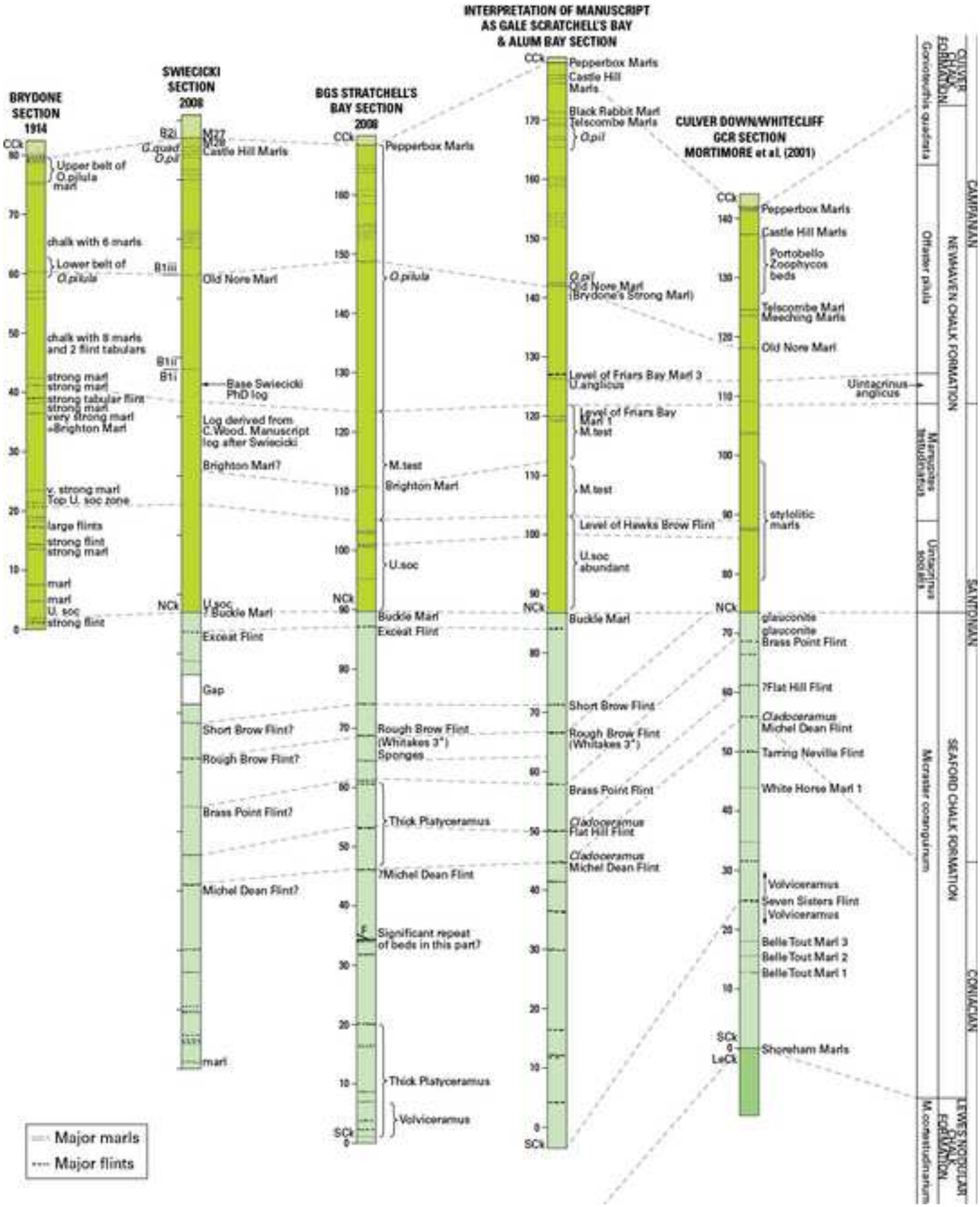


Figure
Click here to download high resolution image