The stratigraphical distribution of Mid-Cretaceous Foraminifera near Ventnor, Isle of Wight

Wilkinson, I P, Hopson, P M

British Geological Survey, Nottingham, NG12 5GG, U.K.

ABSTRACT. Ventnor No. 2 Borehole, located near Ventnor, Isle of Wight, penetrated the basal part of the Chalk Group and the Selborne Group before terminating in the upper part of the Lower Greensand Group (Sandrock Formation). The borehole was examined for Foraminifera, and although they were not seen in the Sandrock Formation and Monks Bay Sandstone Formation, the remainder of the borehole yielded moderately low diversity assemblages dominated by agglutinated species. Foraminiferal zones 3 to 6 (*H dentatus* to *M. fallax/M. rostratum* macrofaunal zones) were identified in the Gault Formation and zones 6 (lower) to 6a (*M. fallax/M. rostratum* to *A. briacensis* macrofaunal zones) were identified in the Upper Greensand Formation. Assemblages from the overlying West Melbury Marly Chalk Formation were used to identify foraminiferal zones BGS1-BGS3 (*M. mantelli* and *M. dixoni* macrofaunal zones).

Key words: Selborne Group, foraminifera, Isle of Wight, biostratigraphy

1 Introduction

Despite the fact that microfossils such as foraminifera have been widely used as biostratigraphical tools to subdivide and correlate Albian and Cenomanian successions of mainland Britain (e.g. Price, 1977, Carter and Hart, 1977; Hart et al., 1989, 1990; Hart, 1973, 2000, 2004; Woods et al., 2001, 2009; and references therein), the mid Cretaceous succession of the Isle of Wight has received scant attention. Albian and Cenomanian foraminifera from outcrops at Compton Bay, Culver Cliff and Rocken End were outlined by Carter and Hart (1977), but microfaunal dating was generally inconclusive. The present work improves the calcareous microfaunal biostratigraphy by tracing foraminifera through the Albian and Cenomanian succession in Ventnor No.2 Borehole. Although the Sandrock and Monk's Bay Sandstone formations proved to be barren, foraminifera were recorded throughout the remainder of the borehole.

Ventnor no.2 Borehole (SOBI Registered number SZ57NE27; location: N.G.R. SZ 55666 77576, 101.36 m above O.D.) was sited, to the west of Ventnor, Isle of Wight (Fig. 1). It proved 17.17 m of the Chalk Group (West Melbury Marly Chalk Formation), 79.47 m of the Selborne Group (Upper Greensand and Gault formations) and 5.36 m of the Lower Greensand Group (Monk's Bay Sandstone Formation, formerly the Carstone of the Isle of Wight, and Sandrock Formation, base not seen). It was terminated at a depth of 144.06m.

2 Previous work

Although the first comprehensive taxonomic studies of Albian foraminifera from southern England were published over a century go (Chapman, 1891 - 1898), biostratigraphical applications were carried out much later (Hart, 1973; Carter and Hart, 1977; Price, 1977a,b; Hart et al., 1989). The foraminiferal zones originally recognised in the Gault formation were correlated to the 13 beds of Price (1874, 1876), but the scheme has gradually evolved with the addition of further zones and subzones (e.g. Hart, 1973; Carter and Hart, 1977; Hart et al., 1990, 2000), so that the numbering scheme has become somewhat cumbersome and in need of revision. In addition, there have been significant changes to the established standard ammonite zonal scheme for the Upper Albian (Owen and Mutterlose, 2006; Kennedy and Latil, 2007) (Table 1). This has resulted in difficulties in correlating the foraminiferal zonal scheme, which pre-dates these changes, with the new macrofaunal biostratigraphy, although this has been attempted herein (Table 2). Faunas from the Upper Greensand (e.g. Carter and Hart 1977; Woods et al., 2001) can be related to the well established Gault assemblages of southern England mentioned above, although their use in detailed biostratigraphy is difficult due to facies differences.

Foraminiferal biostratigraphy of the British Chalk also began during the 1970's (e.g. Carter and Hart, 1977). However, sample positions were not always related to detailed stratigraphical and lithological information, limiting their usefulness somewhat. The biostratigraphical scheme used for Ventnor Borehole No. 2 (Table 3) is based on several data sets (Hart et al., 1989 and references therein), together with unpublished PhD theses and data gathered during mapping throughout southern England by the British Geological Survey (Wilkinson, herein).

3 Stratigraphical framework

The Albian (Monk's Bay Sandstone, Gault and Upper Greensand formations) and Cenomanian (West Melbury Marly Chalk Formation) succession crops out across the central part of the Isle of Wight, between Compton Bay and Sandown Bay, with a smaller exposure in the Blackgang-Luccombe Bay area (Fig. 1). The lithostratigraphical units were defined by Hopson (2005) and Hopson et al. (2008) and are therefore only briefly described herein.

3.1 Lower Greensand Group

The Sandrock Formation straddles the Aptian/Albian boundary (e.g. Casey 1961; Owen, 1999). It comprises fine-grained, sometimes cross-bedded sandstones with a pebble bed at the top and an erosive upper boundary (at 100.84 m depth in Ventnor No. 2 Borehole). The single sample examined for calcareous microfaunas, from 101.5m, proved to be barren

The Monk's Bay Sandstone Formation (Fig. 2), which comprises ferruginous, medium to coarse-grained, often bioturbated sandstone, with occasional pebble beds, was defined by Hopson et al. (2008). It varies considerably in thickness from 2 m at Compton Bay to 22 m at

Red Cliff, but in Ventnor No. 2 Borehole it comprises 2.64 m of dark green, silty, medium to coarse grained sandstone with occasional 'coal' chips, overlain by 1.56 m of dark grey, orange-brown mottled, fine- to medium-grained sandstone with layers and lenses of dark grey clay and pockets of coarse sand and gravel. Although sparse, low diversity foraminiferal assemblages have been recorded in the formation (Hopson et al., herein). However, all samples from Ventnor No. 2 borehole proved to be barren.

3.2 Selborne Group

The Selbornian Stage of Jukes-Browne and Hill (1900) was formally modified to its lithostratigraphical counterpart, the Selborne Group, by Hopson et al. (2008).

The Gault Formation (Fig. 2) of the Isle of Wight differs considerably from the clays and silty clays at the type section at Copt Point, Folkestone. Here it comprises a succession of medium and dark grey, often bioturbated, silty and sandy clays, up to 30 m thick. In the lower part it becomes more arenaceous as it passes transitionally into the Monks Bay Sandstone Formation (the base is placed at the top of the uppermost brown sandstone). Gale et al. (1996) recorded minor lithological variations in the formation; alternations of silt, fine sand and clay rich units occur in the east of the island, but a more arenacaeous siltstone occurs throughout the succession in the west. Insole et al. (1998) also pointed out that lithological variations occur in the distribution of glauconitic and phosphatic seams. In Ventnor No. 2 Borehole, medium to dark grey, micaceous silts and clays extend from 96.64 m up to 51.50 m depth. The boundaries are difficult to place in the borehole. The lower boundary is gradational passing up from fine sandstone (of the Monks Bay Sandstone) to micaceous siltstone, whereas the upper boundary passes up from micaceous siltstone to medium grey, slightly sandy, micaceous siltstone of the "Passage Beds" (basal Upper Greensand Formation).

The Upper Greensand Formation (Fig. 2), which attains a thickness of 45 m on the Isle of Wight, comprises glauconitic siltstones and fine-grained sandstones, with thin bands of limestone and chert concretions. The lower boundary is transitional (silty Gault passes up into fine sands), but the formational base is placed at the base of the first brown silt or fine-grained sandstone. The formation was divided into six informal units by Jukes-Browne and Hill (1900) and Osborne White (1921), but these were rationalised into three beds by Insole et al. (1998): Passage Bed, Malm Rock Bed and Chert Bed (Table 4). The chert appears to have been derived from solution of sponge spicules and radiolaria during an early stage of diagenesis and prior to compaction (Insole et al., 1998). These organisms were frequently found in the Upper Greensands of the Selborne area (Woods et al., 2001), but were not observed in Ventnor No. 2 Borehole. The upper formational boundary is placed at an erosion surface where pale, weakly glauconitic siltsone is overlain by dark green, glauconite-rich calcareous sandstone (Glaconitic Marl Member at the base of the West Melbury Marly Chalk Formation).

3.3 Chalk Group

The West Melbury Marly Chalk Formation (Fig. 2) was observed at the top of Ventnor No. 2 Borehole (down to 17.17 m depth), with 2.12 m of Glauconitic Marl Member at its base. The cored succession (Fig. 3) correlates well with the succession at Compton Bay described by Mortimore et al.. (2001). On the south side of the Isle of Wight, the West Melbury Marly Chalk Formation comprises buff, grey and off-white, soft, marly chalk and hard grey limestone arranged in couplets. The Glauconitic Marl Member consists of bioturbated, glauconitic, calcareous sandstone and siltstone with phosphatic pebbles.

4 Stratigraphical distribution of Foraminifera in Ventnor No. 2 Borehole

4.1 Gault Formation (Fig. 4)

Foraminifera are not common in the lower part of the Gault and assemblages comprise entirely agglutinated forms; *Tritaxia singularis, Cribrostomoides nonionoides rotunda* (specimens resembling *C. n. angulosa* are probably partially crushed specimens) and *Haplophragmoides chapmani* dominate the faunas. These long ranging forms have their origins in the lower Albian and extend through much of the stage. Species characteristic of the lower Albian and the basal part of the Middle Albian (*dentatus* Zone), as described by Price (1977a,b) and Magniez-Jannin (1975) were not encountered, although the rare specimens of *Saccammina* sp might be synonymous with *Saccammina* sp.1 of Price (1977a). *Haplophragmoides chapmani* is rare in the lower Albian of Europe (Price, 1977a) and has not been recorded from the UK below the *lyelli* Subzone (*dentatus* Zone). Its first up-section occurrence in the basal Gault of Ventnor No. 2 Borehole is interpreted as being indicative of the basal *dentatus* Zone and equivalent to Foraminiferal Zone 3 of Carter and Hart (1977). *Arenobulimina macfadyeni* is a good marker for the Middle Albian where it is generally frequently found, but it extends into the *cristatum* Zone (basal Upper Albian). The species has a very patchy distribution between 88.0 m and 82.0 m and is probably indicative of the foraminiferal zones 3 or 4 of Carter and Hart (1977) and Price (1977a,b), although species of *Hoeglundina*, which is characteristic of these zones elsewhere, were not present.

Foraminifera with hyaline tests appeared at 78.15 m, with *Lenticulina rotula*, a species that is consistently present throughout the remainder of the Albian. This is a long ranging taxon with no biostratigraphical importance. However, it does appear to indicate a switch in lithological or palaeoenvironmental conditions such that, for the first time, hyaline species survive.

A fauna more characteristic of the mid-Albian appears for the first time at 70.6 m, including *Arenobulimina chapmani, Gavelinella intermedia, Gavelinella berthelini* and *Citharina pinnaeformis*. The last named was used by Carter and Hart (1977) as the zonal indicator for foraminiferal zones 4a and 5, species of *Hoeglundina* (absent in the present borehole) separating the former from the latter zone. Price (1977a) indicated that the *C.*

pinnaeformis became extinct at the top of the *varicosum* Zone (*binum/choffati* subzone), but Hart et al. (1990) and Hart (2000) extended its range to the top of Bed XI (*inflatum* Zone). In the Ventnor No.2 Borehole this species is not common, but it was recorded at 70.6 and 61.65 m, the highest record being immediately below the silt between the depths 59.32 and 51.50 m. This is very similar to the situation at Copt Point, Kent, where the last specimens of *Citharina pinnaeformis* are immediately underneath the silty Gault Bed XII.

The first appearance of *Eggerellina mariae* at 64.65 m is also stratigraphically useful in that it is known to evolve in the upper part of Foraminiferal Zone 5 or close to the 5/5a zonal boundary (the range given by Carter and Hart, 1977, differs slightly from that given by Price, 1977a). Other species that appear for the first time at 64.5 m include *Valvulineria* aff. *loetterlei* (*sensu* Jannin, 1967), *Vaginulina mediocarinata* and *Bulbophragmium cylindracea*. The first appearance of *Valvulina* aff. *loetterlei* is in the *cristatum* Zone, and although it appears to be confined to that zone, its scarcity in the latest part of its range means the exact extinction level is not fully understood and may vary locally. In Ventnor No.2 Borehole, *Valvulina* aff. *loetterlei* ranges from a depth of 64.65 to 58.65 m, but is not seen in the highest Gault. *Vaginulina mediocarinata* first appeared in Europe in the *loricatus* Zone according to Price (1977a), but Hart et al. (1989) showed its first appearance to be in the uppermost *dentatus* Zone, although it is rare and patchy in the lower part of its range. However, in southern England it is consistently present in Foraminiferal Zone 4a of Carter and Hart (1977) (*cristatum* Zone) and through to the top of the Gault. It is not represented in the lower part of its range in the Ventnor No.2 Borehole. *Bulbophragmium cylindracea* (or possibly *Cribratina cylindracea*, the generic assignment is unclear) first appeared in the upper part of the *varicosum* Zone (*binum/choffati* subzones) and ranges through into the Cenomanian. Its presence in Ventnor No.2 Borehole is thus useful biostratigraphically.

The upper part of the Gault in Ventnor No.2 Borehole is a siltstone. The lowest sample examined contained only long ranging taxa, but *Gyroidinoides angulata* appeared at 55.1 m depth. Originally placed in the genus *Valvulineria*, this species shows an intermediate position between *Gyroidinoides praestans* and *Valvulina* aff. *loetterlei*, from which it apparently evolved in the *inflatum* Zone. *Gyroidinoides angulata* is confined to that zone judging from the information given by Jannin (1967) and Magniez-Jannin (1975), although zonal data are not abundant.

Diminutive specimens of *Arenobulimina* cf. *sabulosa* appeared at 52.55 m, in the highest sample of Gault examined. Price (1977 a, b), Hart et al. (1990) and Hart (2000) placed its inception within the *inflatum* Zone, however its first appearance is at the base of Gault Bed XII according to Hart et al. (1989), i.e. within the *fallax/rostratum* zones. The rare specimens of *Arenobulimina sabulosa* recovered from the highest Gault, therefore, are stratigraphically useful.

4.2 Upper Greensand Formation (Fig. 5)

Despite the fact that the distribution of foraminifera through the Gault Formation of southern England has been studied in detail, faunas from the Upper Greensand are not as well known, the most detailed analysis being the BGS Selborne boreholes (Woods et al., 2001).

"Passage Beds" (Division A): Foraminifera are generally less diverse than in the Gault and in general they are long-ranging. *Marssonella ozawai*, which was recovered from the basal "Passage Beds", at a depth of 51.05 m, is characteristic of the *fallax/rostratum* zones, its inception being in Bed XII of the Copt Point Gault succession (Hart et al., 1990; Hart, 2000) and then ranges up into the Cenomanian. *Gavelinella cenomanica* was recorded for the first time at 49.4 m, although it is rare and rather patchily distributed throughout the more arenaceous Upper Greensand of the Ventnor No. 2 Borehole. This species is rare in the upper part of the *varicosum* Zone of Europe, but becomes more frequent and consistently present in the *inflatum* Subzone and through into the Cenomanian (Price, 1977a,b). Hart et al. (1989, 1990) and Hart (2000) showed that in south-eastern England it first appeared in Foraminiferal Subzone 6 (middle), at about the *rostratum/perinflatum* boundary interval. *Gavelinella cenomanica* becomes more numerous above 36.05m (where it accompanies *Hedbergella bentonensis*), possibly indicating Foraminiferal Subzone 6 (middle) at that level (see below).

"Malm Rock Bed" and "Chert Beds" (divisions B-F): The five informal divisions recognised at Undercliff and Gore Cliff by Jukes Browne and Hill (1900) (see also Osborne White, 1921) appear to be represented in the Ventnor No.2 Borehole (Table 4).

At 43.2 m, *Arenobulimina praefrankei, Tritaxia singularis* and *Valvulineria berthelini* appear for the first time in the borehole, although all are long ranging. *Arenobulimina praefrankei*, for example, first appears in the *inflatum* Zone and extends up to the top of the Albian (and into the Cenomanian according to some authors, see Frieg and Price, 1982). *Valvulineria berthelini* evolved from *V.* aff. *loetterlei* within the *inflatum* Zone and then ranges through to the top of the Albian (Magniez-Jannin, 1975).

The biostratigraphy of the lower part of the Upper Greensand (and "Passage Beds") is difficult to determine due to the dominance of long ranging taxa. However, at 38.85 the first specimens of planktonic foraminifera were found. They consisted entirely of *Hedbergella bentonensis*, a species that is particularly characteristic of Foraminiferal Zone 6 and which, in the Gault facies, may occur in flood proportions, particularly in Foraminiferal Subzone 6 (middle) (Hart et al., 1990; Hart, 2000). Although not found in flood occurrences in the greensand facies as it does in the Gault, their sudden appearance is taken to reflect the zone 6 incursion. Further north in the Selborne boreholes, planktonic foraminifera were not recorded in the Upper Greensand (Woods et al., 2001), although those boreholes yielded common radiolaria which were not encountered in the Ventnor No.2 Borehole. *Gyroidinoides* *praestans* entered the record at 30.9 m, although it appeared earlier in France (Jannin, 1967; Magniez-Jannin, 1975).

In the upper part of the Upper Greensand, *Arenobulimina frankei* makes its first appearance at a depth of 21.55 m in Ventnor No. 2 Borehole. This species has been misunderstood in the past, but Freig and Price (1982) clarified its taxonomic position. It apparently evolved from *Arenobulimina praefrankei* in the late *perinflatum* Zone and Hart et al. (1990) and Hart (2000) showed it to be a good marker for foraminiferal Subzone 6 (upper). It is often accompanied by *Lingulogavelinella jarzevae*, a species that was present between 21.55 m and 17.70 m depth, a little below a bored and bioturbated surface at 17.17 m. The latter species is known from Foraminiferal Subzone 6 (middle) of Hart et al. (1990), but is more consistently present from the upper part of Foraminiferal Subzone 6 (upper) and through to the Cenomanian. Its first up-hole appearance is a useful index for the upper part of the *rostratum* zone.

The presence of *Arenobulimina chapmani* in the sample from 17.70 m proves that the biostratigraphical age is no younger than Foraminiferal Subzone 6 (upper). According to Hart et al. (1989, 1990) it is not present in Foraminiferal Zone 6a, although Price (1977a,b) showed that it ranged into the basal part of the zone, which he placed in his Foraminiferal Subzone 9(i). The fauna at a depth of 17.70 m also contained the first specimens of *Arenobulimina advena*. This is essentially a Cenomanian species, but Hart et al. (1989, 1990) showed that its first occurrence is within Foraminiferal Zone 6a and Price (1977a,b) shows it is a characteristic element of his foraminiferal subzones 9(ii) and 9(iii). Foraminifera Zone 6a falls within the *briacensis* Zone at the top of Gault Bed XIII. *Arenobulimina chapmani* and *Arenobulimina advena* are believed to be mutually exclusive so that their co-occurrence in the present sample may be the result of bioturbation.

4.3 West Melbury Chalk Formation (Fig. 6)

The distribution of foraminifera in the Cenomanian of the Isle of Wight is poorly known compared to the higher chalks and depends primarily on the discussion of Carter and Hart (1977).

Glauconitic Marl Member: The foraminiferal faunas from the base of the Glauconitic Marl Member (at the base of the West Melbury Marly Chalk Formation) lack many of the characteristic species associated with Upper Cretaceous Foraminiferal Zone BGS1. However, *Arenobulimina anglica* is present in the sample from 17.1 m indicating the Cenomanian and *Rotalipora appeninica*, the first keeled planktonic species to enter the British area, was also recorded. The latter species appears later in the British succession compared to the Tethyan province, and although it is known to occur in the Cenomanian of south east England, where it is a useful local marker, there is a possibility that it first appeared during the latest Albian, in the upper part of Bed XIII of the Gault in Kent (Hart et al., 1989). The fauna at 16.6 m in Ventnor No. 2 Borehole is essentially similar to that at 17.1 m, and although diversity is increased at this depth, the additional taxa are generally long ranging Late Albian to Cenomanian species.

"Chalk Marl": The first specimens of *Pseudotextulariella cretosa* were encountered at a depth of 15.3 m. This species is characteristic of Foraminiferal Zone BGS2 (Zone 9 of Carter and Hart, 1977; UKB3 of Hart et al., 1989), the base of which is placed in the topmost *carcitanense* macrofaunal Subzone (Hart, 2000). Carter and Hart (1977) placed their Foraminiferal Zone 8/9 boundary in the upper part of their "Upper Greensand with Stone Bands" at Compton Bay and Culver Cliff (Isle of Wight) – at an erosion surface at the former locality and at a stone band at the latter. The stone horizon and erosion surface were not identified in Ventnor No.2 Borehole, although a marl seam was observed immediately below but the base of BGS2 at 15.40 m.

The upper 6 to 7 m of the borehole is difficult to date biostratigraphically, but the base of Foraminifera Zone BGS3 in Ventnor No. 2 Borehole is tentatively placed at a depth of circa 7.0 m, above the last specimens of *Marssonella ozawai*, although the absence of this species in the highest levels may be the result of sample failure. Carter and Hart's (1977) Foraminiferal Zone 9/10 boundary (which equates with UKB3/UKB4 boundary of Hart et al., 1989) is above an interval with abundant sponges and immediately below a bed of phosphatic nodules at Compton Bay and Culver Cliff (Isle of Wight). In Ventnor No.2 Borehole, phosphatic nodules occur at about 5.6 m depth and sponges were observed from 4.75 m depth through to the top of the core. Foraminiferal Zone BGS4 (defined by the inception of *Flourensina mariae* and *Plectina cenomana*) was not recognised. Comparison with other Isle of Wight successions shown in Table 5 indicates consistency with the interpretations for the Culver Cliff and Compton Bay successions given by Carter and Hart (1977).

5 Conclusions

Much of the Albian succession of the Ventnor No.2 Borehole was subdivided into the foraminiferal zones recognised in the Gault of southern England and elsewhere in Europe.

1. The Sandrock and Monks Bay Sandstone formations are barren of foraminifera and no biostratigraphical conclusions are possible.

2. The lower part of the Gault Formation yielded only long-ranging foraminifera but the appearance of consistently occurring *Haplophragmium chapmani* suggests the base of the Mid Albian and Foraminiferal Zone 3 (of Carter and Hart, 1977; Price, 1977a). The presence of *Arenobulimina* cf. *macfadyeni* between 88.0 and 82m confirms foraminiferal zones 3 or 4. However, the absence of species of *Hoeglundina* precludes further subdivision of the lower part of the Gault.

3. The first evidence of Foraminiferal Zone 5 was at a depth of 70.6 m, with the inception of *Citharina pinnaeformis*. The top of the zone is placed at 61.65 m. In south eastern England, the top of Zone 5 equates with the top of Gault Bed XII.

4. The silty part of the Gault above 59.32 m is tentatively equated, at least in part, with Bed XII of Kent. This is based on the last appearance of *Citharina pinnaeformis* (Foraminiferal Zone 5) and the first appearance of *Arenobulimina sabulosa* (Foraminiferal Zone 6) towards the top of the unit, at a depth of 52.55 m.

5. 'The Passage Beds' fall within Foraminiferal Subzone 6 (lower). The remainder of the Upper Greensand is placed in Foraminiferal Subzone 6 (middle) and Subzone 6 (upper), Foraminiferal Zone 6a appears to be represented at 19.7 m with the appearance of *Arenobulimina advena*, although there is a possibility that bioturbation and burrowing is the cause for the apparent presence of zone 6a.

6. Foraminiferal Zone BGS 1, including *Arenobulimina anglica* and *Rotalipora appeninica* was found in the lower part of the Glauconitic Marl (17.1-15.40 m depth). The facies controlled foraminiferal subzone BGS 1i, which equates with UKB1 of Hart et al. (1989), was not recognised

7. Foraminiferal Zone BGS 2 faunas, including *Pseudotextulariella cretosa* and *Marssonella ozawai*, were encountered between 15.3 and 7.0 m depth. Although evidence is equivocal, the remainder of the borehole is tentatively assigned to Foraminiferal Zone BGS 3.

Acknowledgements

The authors publish with permission of the Executive Director of the British Geological Survey (N.E.R.C.).

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Figure captions

Fig. 1. Geological Sketch map of the Isle of Wight showing the localities mentioned in the text.

Fig. 2. Albian- Lower Cenomanian stratigraphy of southern England. Macrofaunal zonation after Owen and Muterlose (2006) and Kennedy, W.J. and Latil, J.-L. (2007).

Fig. 3. Stratigraphy of the Cenomanian Chalk in the Ventnor No. 2 Borehole and its suggested correlation with the Compton Bay Succession.

Fig. 4. The distribution of foraminifera through the Gault Formation of Ventnor No. 2 Borehole.

Fig. 5. The distribution of foraminifera through the Upper Greensand Formation of Ventnor No. 2 Borehole.

Fig. 6. The distribution of foraminifera through the West Melbury Chalk in the Ventnor No. 2 Borehole.

Table Captions

Table 1. The 'traditional' ammonite zonal scheme of the Upper Albian of England correlated with the modified scheme after Owen and Mutterlose (2006) and Kennedy and Latil (2007)

Table 2. The foraminiferal zonation scheme for the Albian of southern England.

Table 3. Foraminiferal zonal scheme in the lower Cenomanian of southern England (the UKB scheme is after Hart et al., 1989, and the BGS scheme follows Wilkinson, herein). GMM: Glauconitic Marl Member.

Table 4. Subdivision of the Upper Greensand in Ventnor No. 2 Borehole, based on definitions by Jukes-Browne and Hill (1900) and Osborne White (1921) and Insole et al, 1998.

Table 5. Comparison of the thickness of lower Cenomanian foraminiferal zones in three localities in the Isle of Wight (data for Compton Bay and Culver Cliff from Carter and Hart, 1977).

Table

‘Traditional’ macrofaunal biostratigraphy			Revised macrofaunal biostratigraphy	
Zones	**Subzones**		**Zones**	**Subzones**
S dispar	No macrofaunal subzone		A briacensis	
	M perinflatum		M perinflatum	
	M rostratum		M rostratum	
			M fallax	
M. inflatum	C auritus		M. inflatum	
	H varicosum		H varicosum	H choffati
				H binum
	H orbignyi			H orbignyi
	D cristatum		D cristatum	

Table

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	Lithostratigraphy	Macrofaunal zonation: Zones	Subzones	Foraminiferal zones	Foraminiferal zones and defining faunas
Late Albian	Gault Bed XIII / Upper Greensand Formation	*A. briacensis*		6a	Concurrent range of *Arenobulimina (Arenobulimina) sabulosa* and *Flourensina (Flourensina) intermedia* with typically Cenomanian *Arenobulimina (Voloshinoides) advena*. *Citharinella laffitei* is restricted to the zone. Known only in the English Channel and Surrey.
		M. perinflatum		6 (upper)	Concurrent range of *Arenobulimina (Vialovella) frankei*, *Arenobulimina (Sabulina) sabulosa* and *Arenobulimina (Arenobulimina) chapmani*. *A. (A.) chapmani* and *Tritaxia singularis* become extinct at the top of the zone
		M. rostratum		6 (middle)	Base: FAD of *Lingulogavelinella jarzevae*. *Gavelinella cenomanica* and abundant *Globigerinelloides bentonensis* also occur. *Arenobulina (S.) sabulosa* dominates
	XII	*M. fallax*		6 (lower)	The base is drawn at the inception of the *Globigerinelloides bentonensis* and *Marssonella ozawai*
	Gault Bed XI	*M. inflatum*		5a	Concurrent range of *Citharinella pinnaeformis* and *Arenobulimina (S.) sabulosa*. *A. (A.) chapmani* dominates. Carter & Hart (1977): "always thin and often missing".
	X	*H. varicosum*	*H. choffati*	5	*Citharinella pinnaeformis* Assemblage Zone. FAD of *Eggerellina mariae*
	Gault Bed IX		*H. binum*		
			H. orbignyi	4a	Concurrent range of *Epistomina spinulifera* and *Citharinella pinnaeformis*
	VIII	*D. cristatum*			
Mid Albian	Gault Bed VII	*E. lautus*	*A. daviesi*	4	Concurrent range of *Hoeglundina carpenteri* and *Dorothia filiformis*
			E. nitidus		
	VI				
	V	*E. loricatus*	*E. meandrinus*		
	IV		*M. subdelaruei*		
	III		*D. niobe*	3ii	Concurrent range of *Conorboides lamplughi*, *Epistomina spinulifera* and *Quinqueloculina antiqua*
	II		*A. intermedius*		
	Gault Bed I	*H. dentatus*	*H. spathi*	3i	*Arenobulimina macfadyeni*. FAD of *Conorboides lamplughi* and *Gavelinella tormarpensis*. This fauna is transitional to the more calcareous assemblages above and equates with the upper part of Zone 2, 3i and 3ii of Price (1977)
			L. lyelli		
Early Albian	Speeton Clay A Beds (part): UA1A-UA1C / Carstone / Monks Bay Sandstone		*H. eodentatus*	2	FAD of *Arenobulimina macfadyeni* together with *Lingulogavelinella* spp. *Falsogaudryina moesiana*, *Psilocitharina* spp and *Gavelinella intermedia*. Rare *Hedbergella* appear for the first time in the Albian. Known in Germany & France (Price, 1977), the Carstone of Yorkshire (Dilley, 1989) and as Zone E in the Upper A Beds of the Speeton Clay Formation, Yorkshire (Underwood & Mitchell, 1999).
		O. auritiformis	*P. steinmanni*		
			O. bulliensis		
			P. puzosianus		
			O. raulinianus		
	UA2A-UA4	*S. chalensis*	*C. floridum*		
			S. kitchini		
			S. periinflatum		
	AL1	*L. tardefurcata*	*L. regularis*	1	FAD of *Rhizammina* cf *dichotoma*, with longer ranging *Reophax minuta*, *Ammodiscus gaultina*, *Glomospira gaultina*, *Reophax lagenarium* & *Textularia minuta* (Price, 1977). Zone D (Underwood & Mitchell, 1999) in the Lower A Beds of the Speeton Clay Formation, Yorkshire
	AL2-3 / Sandrock		*L. acuticostata*		
			L. schrammeni		

Table

<table>
<tr><th></th><th>Stratigraphy</th><th colspan="2">Standard zonal scheme</th><th colspan="2">Foram Zonal scheme and defining indices</th></tr>
<tr><td rowspan="5">Early Cenomanian</td><td rowspan="4">West Melbury Marly Chalk</td><td colspan="2" rowspan="2">M. dixoni Zone</td><td>B.G.S. 3 (=UKB4)</td><td>‘Interregnum zone’ between the extinction of Marssonella ozawai and Quinqueloculina antiqua and the appearance of Flourensina (Flourensina) mariae and Plectina cenomana. The extinction of Lingulogavelinella jarzevae and inception of Rotalipora reicheli are within the zone.</td></tr>
<tr><td>B.G.S. 2 (=UKB3)</td><td>Base: FAD of Pseudotextulariella cretosa & the LAD of Flourensina (Flourensina) intermedia.
Top: LAD of Marssonella ozawai & Quinqueloculina antiqua.</td></tr>
<tr><td rowspan="3">M. mantelli Zone</td><td>M saxbii Subzone</td><td rowspan="3">B.G.S. 1 (=UKB1-2 of Hart et al., 1989)</td><td rowspan="3">Base: FAD of Plectina mariae and Hagenowina anglica. Flourensina (Flourensina) intermedia, common Hagenowina advena & Arenobulimina (Sabulina) sabulosa also present. Flourensina (Vialovella) praefrankei becomes extinct in the lower carcitanense Subzone. BGS1i (=UKB1 of Hart et al., 1989) does not occur in the study area</td></tr>
<tr><td>S schlueteri Subzone</td></tr>
<tr><td>GMM</td><td>N carcitanense Subzone</td></tr>
</table>

Table 2. Foraminiferal zonal scheme in the lower Cenomanian of southern England. (GMM: Glauconitic Marl Member)

Table

Subdivisions of Jukes-Browne & Hill, 1900; Osborne White, 1921	Insole et al., 1998	Ventnor No. 2 Borehole	
		Top	**Base**
F. Sands with layers of calciferous concretions, often partly phosphatised	Chert Bed: grey and buff, glauconitic siltstones and fine-grained sandstones with bands of grey, siliceous and calcareous concretions.	17.17	17.90
E. Chert Beds		17.90	23.97
D. Firestones & freestones	Malm Rock Bed: grey or buff, glauconitic, fine-grained sands and sandstones with irregular bands of large calcareous concretions and small phosphatic nodules.	23.97	27.73(?)
C. Sandstones with phosphatic nodules & courses of large calcareous doggers		27.73(?)	33.25
B. Rough Sandstone with irregular concretions		33.25	43.96
A. Grey sandy clay and micaceous silt ('Passage Beds')	Passage Bed: an alternation of of grey and pale brown, micaceous sandy siltstones and fine-grained, argillaceous buff sands (the latter become thicker up sequence)	43.96	51.50

Table

Foraminiferal zones			Thicknesses (m) in the Isle of Wight		
Wilkinson (2000 and herein)	Hart et al. (1989)	Carter & Hart (1977)	Compton Bay	Culver Cliff	Ventnor No.2 Borehole
BGS3	UKB4	10	c. 10.4 m	c.8.8 m	6.40+ m (top not seen)
BGS2	UKB3	9	c. 5.75 m	c.7.0 m	c. 9.0 m
BGS1	UKB2	8	c. 1.5 m	c. 1.7 m	c. 1.77 m

Figure
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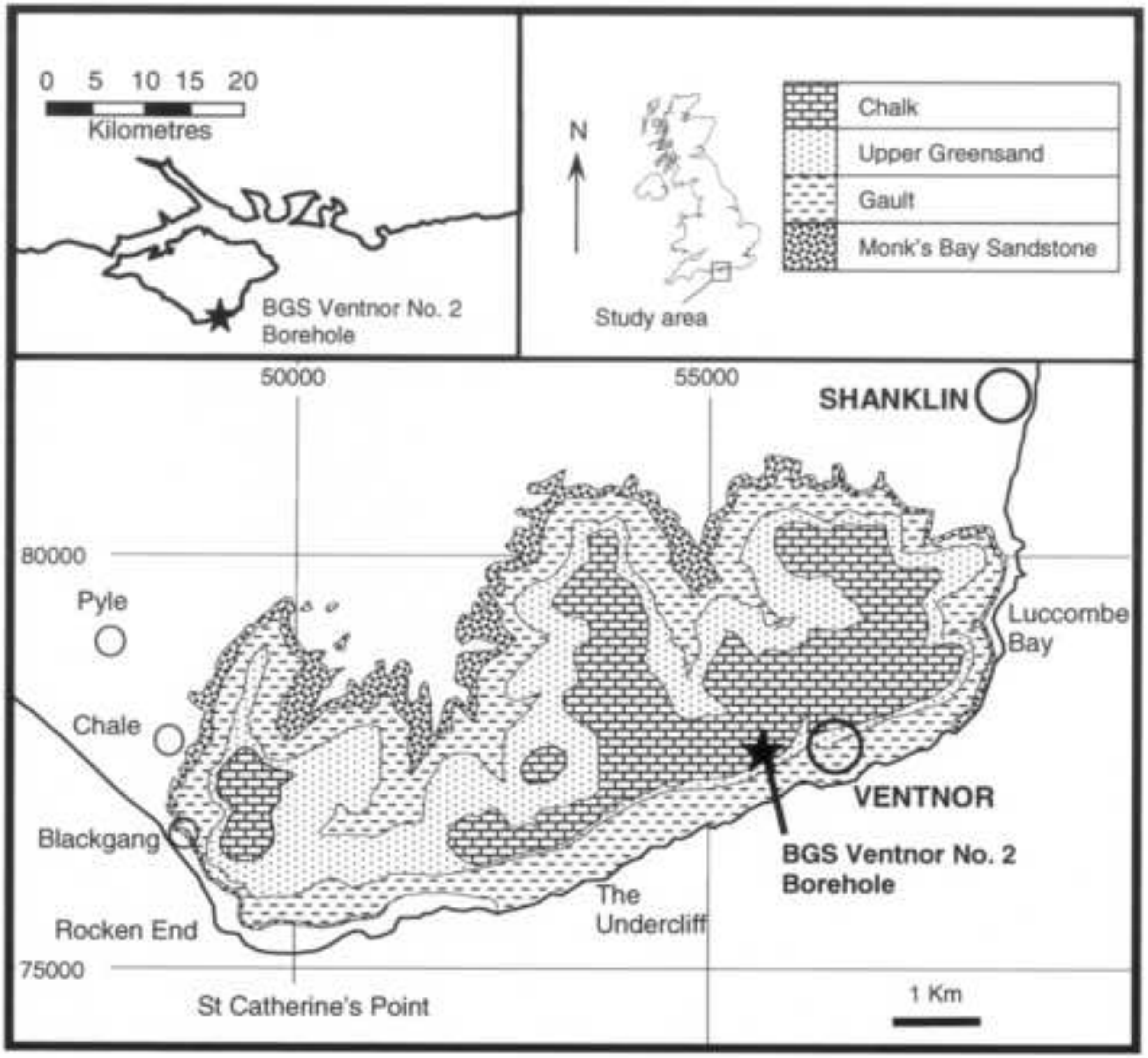

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Stage/ Substage		Macrofossil zonation: zones	Subzones	Lithostratigraphy: Group	Subgroup	Formation	Member
CENOMANIAN (part)	Lower	*M dixoni*		Chalk (part)	Grey Chalk (part	West Melbury Marly Chalk	
		M mantelli	*M saxbii*				
			S schlueteri				
			N carcitanense				Glauconitic Marl
ALBIAN	Upper	*A. briacensis*		Selborne		Upper Greensand	
		M. perinflatum					
		M. rostratum/ M. fallax					
		M inflatum					
		H varicosum	*H choffati*				
			H. binum				
			H orbignyi			Gault	
		D cristatum					
	Middle	*E lautus*	*A daviesi*				
			E. nitidus				
		E loricatus	*E meandrinus*				
			M subdelaruei				
			D niobe				
			A intermedius				
		H dentatus	*H spathi*				
			L lyelli				
			H. eodentatus	Lower Green-sand		Monks Bay Sandstone / Folkestone	
	Lower	*O. auritiformis*	*P steinmanni*				
			O bulliensis				
			P puzosianus				
			O raulinianus				
		S chalensis	*C floridum*				
			S kitchini				
			S perinflatum				
		L tardefurcata	*L regularis*				
			L acuticostata			Sandrock (part)	
			L. schrammeni				

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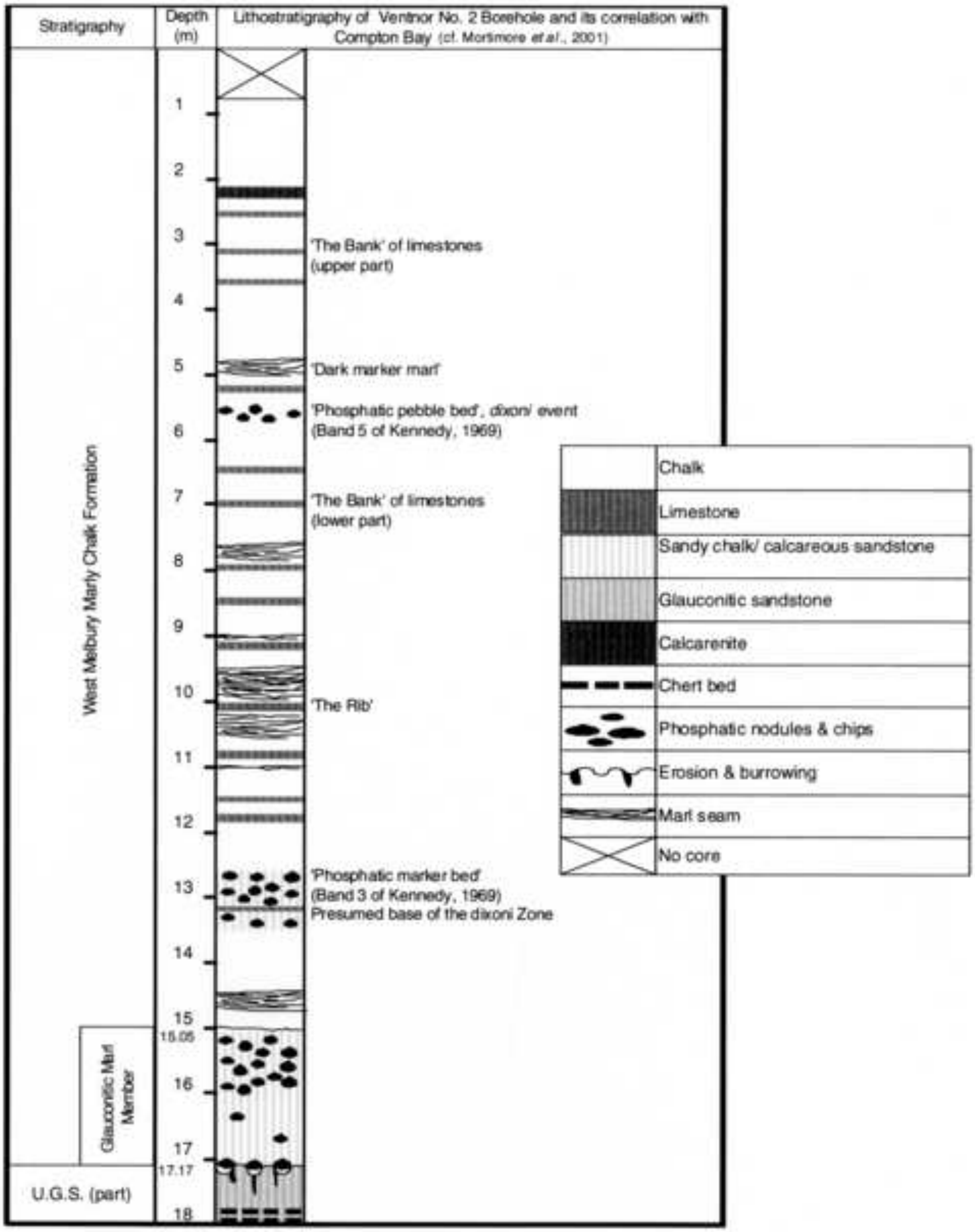

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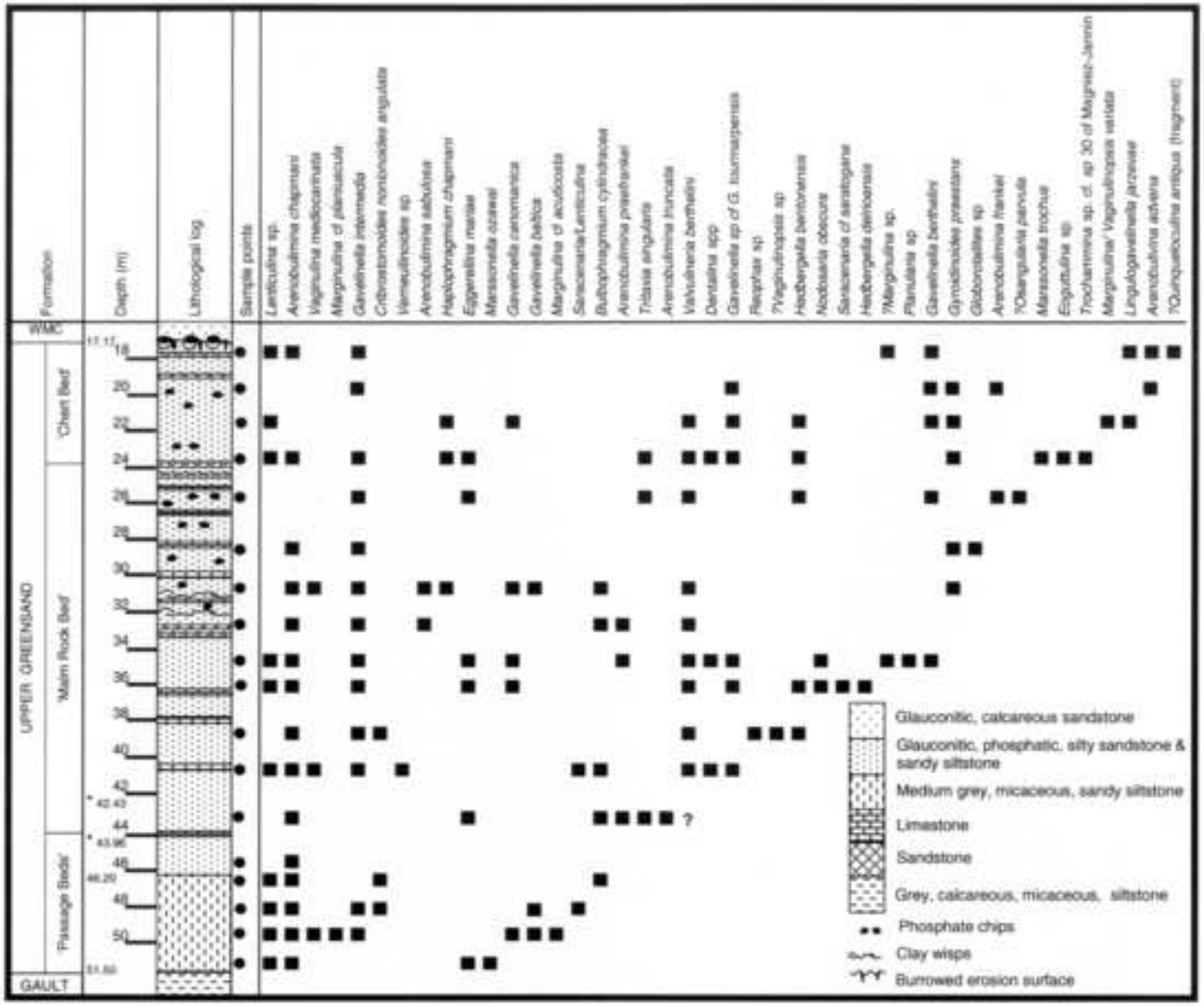

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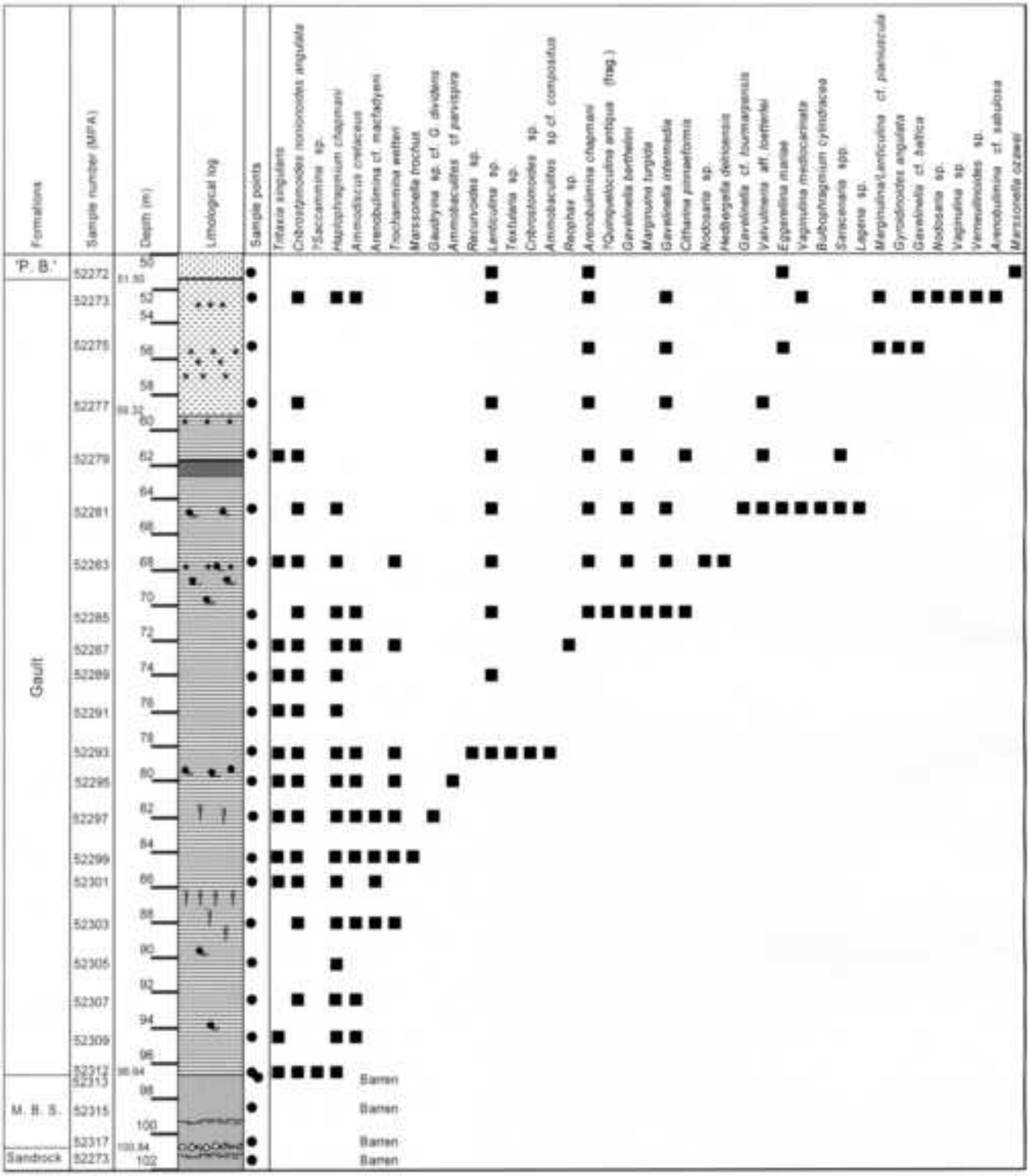

'P. B.' 'Passage Beds' (part.)

M.B.S. Monks Bay Sandstone Formation

Figure
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