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9. Data Report: Sedimentology of a Pleistocene Middle Slope Cool-Water Carbonate Platform, Great Australian Bight, ODP Leg 182[1]

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ABSTRACT

This data report presents sedimentological data obtained from Site 1130 in the Great Australian Bight (southern Australia) during Leg 182, a setting that is dominated today by strong ocean currents, downwelling, and water temperatures rarely above 20°C. The purpose is to characterize lithofacies and cyclicity. The different lithofacies reflect different texture, grain composition, grain size, and sorting as seen in thin section. Cyclicity is shown by repetition of coarsening-upward wackestone to packstone packages with an upward increase in neritic components. The cyclicity is corroborated by grain counts, point counts, and X-ray diffraction mineralogy. The cyclicity is interrupted by the deposition of nannofossil-rich wackestones. These data can be used to more effectively interpret processes affecting cool-water carbonate margins.

INTRODUCTION

Studies in the Great Australian Bight (GAB) are revealing intriguing insights into the understanding of the sedimentology, paleoceanography, and paleoecology of cold-water carbonate environments (James, 1997; Li et al., 1996; Boreen and James, 1993; James and von der Borch, 1991; James and Bone, 1994; Feary, Hine, Malone, et al., 2000). The GAB forms a prominent reentrant in the southern margin of the Austra-

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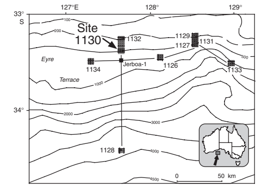
lian continent and is located between 123° and 134°E longitude and 32° and 37°S latitude (Feary and James, 1998). Modern sediments on the shelf are a mixture of relict calcareous grains and Holocene skeletal grains and are affected by seasonal downwelling, upwelling, and long-period waves and swells (James et al., 2001). During Ocean Drilling Program (ODP) Leg 182 (Feary, Hine, Malone, et al., 2000), we drilled a thick (~550 m) Pleistocene slope succession in the GAB (Fig. F1). The drilling has extended previous shelf observations onto the slope and basin as well as provided a temporal framework to understand the margin evolution and processes.

F1. Location of Site 1130, p. 9.



This study focuses on the thick middle–upper Pleistocene slope sequence recovered from Site 1130 drilled at a water depths of 488 m, an upper bathyal setting (Fig. F1). The site is located on the Eyre Terrace, a region dominated by coastal downwelling during most of the year and oligotrophic waters (James et al., 2001). Landward of Site 1130 are bryozoan mounds (Site 1132) and seaward are pelagic oozes (Sites 1126 and 1134) (Feary, Hine, Malone, et al., 2000). Thus, sediments at Site 1130 reflect the mixing of upper-slope and shelf-derived sediments and those derived from the water column and midslope. The goal of this report is to investigate the interaction between shelf and slope processes based on a high-resolution study of the sedimentological and faunal trends at Site 1130.

PLEISTOCENE SEDIMENTS AND SITE 1130

Pleistocene sediments recovered during Leg 182 correspond to spiculitic skeletal packstone and fine-grained spiculitic foraminifer wackestone. The section is punctuated by thin intervals of nannofossil ooze. One of these intervals is the objective of this report. The color of the sediments ranges from a buff light gray to a pale olive-green. They represent continuous sedimentation at rates that sometimes exceeded 40 cm/k.y., which is equivalent to many shallow-water tropical carbonates (Eberli, Swart, Malone, et al., 1997; Feary, Hine, Malone, et al., 2000).

Site 1130 intersected an almost complete Pleistocene succession with some exceptions (Feary, Hine, Malone, et al., 2000). Sedimentation rates were as high as 24–26 cm/k.y. in the middle and late Pleistocene, but much slower, 1.5–2 cm/k.y., in the early Pleistocene. Physical properties suggest strong cyclicity on a 100-k.y. frequency from 43 to 175 meters below seafloor (mbsf) and a higher 41-k.y. frequency between 175 and 254 mbsf (Feary, Hine, Malone, et al., 2000).

An interval containing a cyclic succession of packstone and fine-grained packstone-wackestone interrupted by a thin nannofossil ooze was selected for this study. The hypothesis is that the cyclicity resulted from changes in shelf processes and the deposition of nannofossil ooze is the outcome of a short-lived major reorganization of the slope and shelf processes. The studied interval (~123–151 mbsf) corresponds to the transition between Subunits IA and IB described on board (Feary, Hine, Malone, et al., 2000). These two subunits contain cyclic bioclastic packstones and wackestones and are separated by the white nannofossil ooze with bioclasts (~133.6 mbsf), which is the object of this report. The interval is part of the expanded middle–upper Pleistocene succession showing cyclicity in the color reflectance (700–400 range) and in the natural gamma ray (Feary, Hine, Malone, et al., 2000). The age of the studied interval is around the boundaries between the NN19 and NN21–NN20 nannofossil zones and the PT1b and PT1a planktonic foraminiferal zones, probably corresponding to marine isotope Stages 19–15 at ~0.6–0.8 Ma (Feary, Hine, Malone, et al., 2000).

MATERIALS AND METHODS

Samples were collected from Cores 182-1130A-14H, 15H, and 16H and prepared for the following analyses.

Petrography

Twenty samples between 125.2 and 150.5 mbsf were prepared for thin section by cutting a 5-g piece and placing the sample into a disposable phenolic ring (1 in × 7/8 in). Samples were air dried for two weeks. Dry samples were impregnated with epoxy and cut into final 30-µm-thick slides. Thin sections were analyzed under petrographic light microscope, and lithologies were grouped into lithofacies based on texture, grain size, sorting, and grain types.

Grain-Size Analysis

Grain sizes of 30 samples were determined by using a Sedigraph 5100 particle-size analysis system. Approximately 1.5 g of sample was put in water and sonicated for 10–20 s. The limiting range for analysis was 125–25 µm, and each sample was run for 20 min. A problem with this method is that sand-sized particles fall outside the range. For instance, some of the planktonic foraminifers are coarser than silt size, and their size did not get recorded. The grain counts of sieved samples and the thin section point counts complement this method and provide an insight into the coarser fraction.

Component Analysis

Forty samples from representative depths were analyzed for grain composition using thin section as well as sieved material coarser than 68 µm. The two analyses illustrate the differences between classic point counts of lithified and unlithified sediments. The components identified are benthic and planktonic foraminifers, sponge spicules, bryozoan fragments, tunicates, echinoids, radiolarians, and ostracodes. In a broad sense, the term skeletal grain is used to define bioclastic fragments, most likely mollusk and small bryozoans, which we could not recognize in thin section or in grain counts.

Grain Counts of Sieved Samples

Forty samples from representative depths were weighed and diluted in distilled water. The samples were washed and sieved in a 68-µm metal mesh (U.S. Standard). The coarse-grained fraction (>68 µm) was collected, air dried, weighed, and compared with the initial weight. The coarse fraction was then studied for grain composition. Grain counts (400 per sample) were done by using a stereoscope at a magnification of 40× on a 1 mm × 1 mm colored grid constructed on a cotton paper and pasted on filter paper. All grains were picked from the sample and placed on covered paper slides using a thin brush.

Thin Section Point Count

Twenty thin sections were investigated for grain composition under a Nikon petrographic microscope using a Hacker Instruments counter. Two hundred points per thin section were counted. The point counter was set at a step length of 0.5 mm at 20× magnification. Grains or matrix centered in the objective were counted.

X-Ray Diffraction Analysis

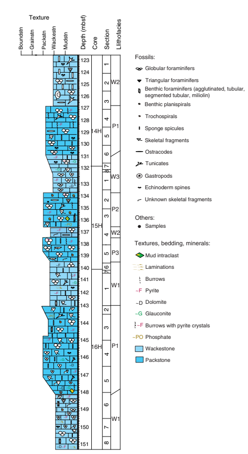
Forty-three samples from cores were analyzed for concentrations of aragonite, high-magnesium calcite (HMC), low-magnesium calcite (LMC), dolomite, and quartz by X-ray diffraction (XRD). A small amount (~0.5 to 1.0 g) of sample was mixed with distilled water and placed on a glass using a plastic pipette. The powdered smear mount of the sample was then allowed to dry at room temperature and placed in a Scintag PADV X-ray diffractometer at 40 Kv and 50 mA housed at the S.W. Bailey X-Ray Diffraction Laboratory at the Department of Geology and Geophysics, University of Wisconsin-Madison. The peak areas for each relevant mineral were determined by scanning a smear mount between 24 and 32°2θ (CuK_α radiation). Percentage composition was calculated following methodology established by Peter Swart (University of Miami) and taking into account the ratio of peak areas from the samples and standards. Standards, also provided by Peter Swart, were run each time a new set of samples was analyzed. The samples are assumed to be composed only of dolomite, LMC, HMC, and aragonite.

RESULTS AND OBSERVATIONS

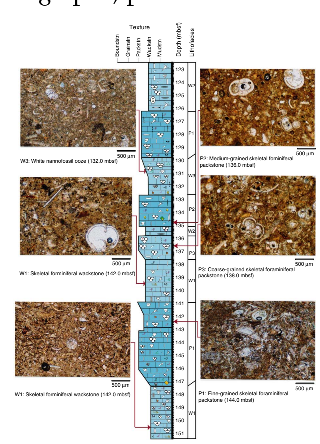
Petrography

Six different lithofacies are recognized. The lithofacies are coded using texture (W = wackestone and P = packstone) and a number that increases as the lithology becomes less abundant. The lithofacies reflect the different texture, grain composition, grain size, and sorting as seen in thin sections. All lithologies are unlithified, and the main diagenetic features are a few dolomite rhombs and small calcite and pyrite crystals inside foraminifer tests. Figures F2 and F3 show the stratigraphic section and photographs of the different lithofacies. The observed lithofacies are as follows.

F2. Stratigraphic column, lithofacies, and symbol key, p. 10.



F3. Facies descriptions and photomicrographs, p. 11.



W1—Skeletal Foraminiferal Wackestone

This is the most abundant lithology (~32%) and consists of a poorly sorted medium-grained sand to silt-sized wackestone dominated by sponge spicules, skeletal grains, and foraminifers (Figs. F2, F3). The foraminifers are large and tend to be thin walled and globose in shape. Radiolarians and tunicates are present but rare. This lithology appears to be highly bioturbated throughout with areas that are very muddy, giving a mottled appearance. Quartz and plagioclase grains are rare, and the grain size is fine to very fine silt.

P1—Fine-Grained Skeletal Foraminiferal Packstone

This is a well-sorted packstone representing ~30% of the samples studied (Fig. F2). The most abundant grains are foraminifers (diverse fauna) followed by skeletal grains, many brown in color (Fig. F3). Sponge spicules are common, and tunicates, radiolarians, echinoderms, and bryozoans are sparse. The samples appear to be bioturbated with micritic burrows as well as burrows filled with abundant quartz grains.

W2—Fine-Grained Spiculitic Foraminiferal Wackestone

This lithofacies represents ~17% of the section and corresponds to a fine-grained, moderately sorted wackestone composed of spicules and foraminifers (Figs. F2, F3). Globular planktonic foraminifers are upper fine, whereas benthic foraminifers are very fine grained, sand sized, and less common than the planktonic foraminifers. Foraminifer diversity is low overall. Tunicates are common, and brown skeletal grains and echinoderm fragments are rare and silt sized.

P2—Medium-Grained Skeletal Foraminiferal Packstone

This lithology is characterized by the abundance of skeletal grains and abundant planktonic and benthic foraminifers (Fig. F3). It represents ~10% of the section measured and tends to be moderately sorted (Fig. F2). Bioturbation and patchiness in grain concentration are common. Sponge spicules are abundant, and bryozoans, tunicates, and radiolarians are common to rare. Quartz grains and dolomite rhombs are present floating in the matrix throughout.

W3—White Nannofossil Wackestone

This lithology represents a small (~6%) fraction of the stratigraphic section (Fig. F2) but is unique and very distinctive because of its light gray to white color. The contacts are transitional because of bioturbation. The matrix is dominated by calcareous nannofossils and can be described as an ooze. Sponge spicules are abundant, as well as planktonic foraminifers (Fig. F3). Bioclasts and benthic foraminifers are common. Tunicate and echinoid spines are present. In core, it is highly bioturbated with large burrows infilled with darker sediment. Sorting is poor.

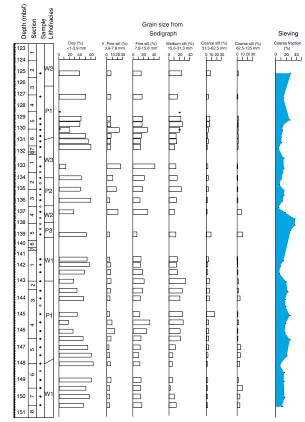
P3—Coarse-Grained Skeletal Foraminiferal Packstone

This is the most unique lithology, representing ~5% of the section (Fig. F2). It is unique in the size of the grains (medium to coarse grained) and good sorting. The most abundant grains are foraminifers and skeletal grains (many stained brown). Sponge spicules and bryozoan fragments are common, and tunicates and radiolarians are rare (Fig. F3). The diversity of foraminifers is very good, with globigerinids and miliolids being the most common. Some foraminifers have pyrite enclosed in their chambers. Some parts are mottled and muddy. Resedimented black mud intraclasts are present. Quartz grains are occasionally present in the matrix.

Grain-Size Results

Grain-size analysis showed that the clay fraction dominates (44%; range = 70%–15%) in the studied interval (Fig. F4). Fine and medium silt sizes are the second most important group. As expected, the percentage concentration between medium-fine silt and clay shows an in-

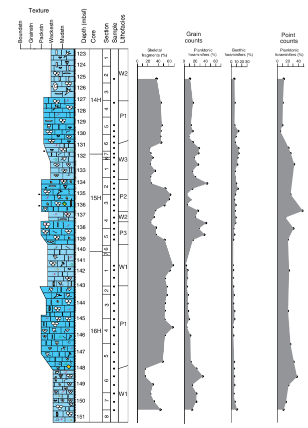
F4. Grain-size analysis and percent coarse, p. 12.



verse relation. The coarser sediments dominate during some intervals (130.2, 133, 137, 143, and 145 mbsf), whereas the fine-sized sediments dominate during other intervals (127, 131.5, 136, 142, 144, and 146.5–150.5 mbsf). Most of the wackestone has between 30% and 70% clay, and the packstone has between 20% and 50% clay. Coarsening trends can be seen from 151 to 143, 137 to 134, and 132 to 127 mbsf.

The percentage of grains coarser than 68 µm from sieving (see far right column in Fig. F4) fills in the areas with poor Sedigraph grain-size data. An additional coarsening-upward trend is identified in the interval between 143 and 138 mbsf. The coarsest interval in the section corresponds to the lithofacies P3.

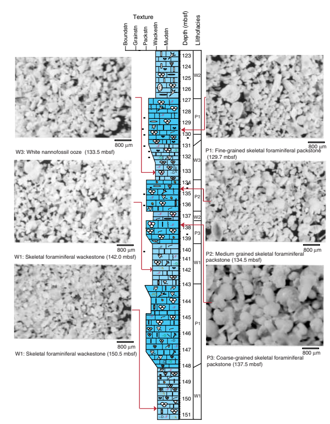
F5. Plot of the grain and point counts, p. 13.



Component Analysis

Sieved and thin section samples were analyzed to count percent component variations. The components that best characterize the different lithologies are the skeletal and foraminifer grains (Fig. F5). Overall planktonic foraminifer grains are more abundant than benthic foraminifers. Based on previous work (James et al., 2001; Holbourn et al., in press), grains derived from the shelf are abraded and generally are mollusks (some brown) and benthic foraminifers. Grains derived from the shelf margin and slope are better preserved and consist of bryozoans, sponges, tunicates, and foraminifers.

F6. Samples of the fraction >68 µm, p. 14.



Grain Counts

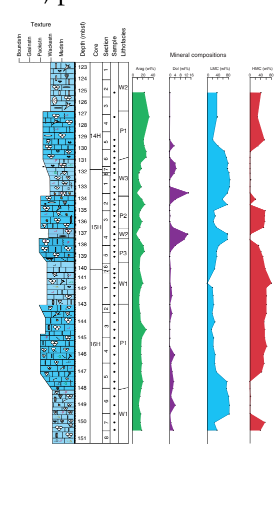
Grain counts indicate that skeletal fragments and planktonic foraminifers are the dominant form, with 42% and 17%, respectively. Sponge spicules, bryozoan fragments, tunicates, echinoids, radiolarians, ostracodes, and some unknown carbonate aggregates are secondary. Skeletal and planktonic foraminifer percentages show a reciprocal relationship (Fig. F5). In general, skeletals dominate in packstone lithologies, whereas planktonic foraminifers are more abundant in wackestones. An anomaly is present in P3, where well-sorted planktonic foraminifers are dominant over skeletals. An additional anomaly is W1 between 143 and 139.5 mbsf, which contains abundant skeletal grains.

Figure F6 shows the stratigraphic section and photographs of the >68-µm fraction. All the photographs have the same magnification, thus highlighting the grain size, sorting, and main components.

Thin Sections

In thin sections, point counting of percentage of planktonic foraminifers shows a similar trend to the grain counts (see far right column in Fig. F5). Although the resolution is lower, the intervals with increased planktonic foraminifers in thin section reflect the trends recognized in the grain counts (wackestone vs. packstone), including the uniqueness of P3.

F7. Mineralogy of the carbonate fraction, p. 15.



Mineralogical Composition by XRD

The mineralogical composition determined by XRD shows that LMC and HMC are the dominant phases followed by aragonite as the least abundant of the three types (Fig. F7). Minimal to zero amounts of dolomite and quartz were observed at certain intervals. HMC and LMC show a reciprocal relationship. HMC corresponds to intervals dominated by skeletal grains, whereas LMC increases when planktonic foraminifer abundance increases. One exception is the interval between 148 and 150 mbsf (Figs. F5, F7).

Dolomite rhombs are more frequent around the turnaround between wackestone and packstone lithologies. An exception is present at ~141 mbsf, where a dolomite peak is present in the middle of W1.

SUMMARY

The three types of wackestones have different abundances of components. W1 and W2 are very similar, the only difference being the greater abundance of sponge spicules and finer grain size in W2. W3 is very distinctive because of the abundance of nannofossils in the matrix and its light gray to white color in the core. W1 and W2 contain few grains derived from the shelf (very fine silt to very fine sand-sized grains of brownish skeletal grains; some recognizable mollusk, ostracodes, and echinoid plates; and abraded benthic foraminifers) and more sediments derived from the water column and slope (coarse silt- and sand-sized grains mostly well-preserved planktonic and some benthic foraminifers and finer-grain sponge spicules and tunicates).

The packstone lithologies (P1 and P2) show greater abundance and coarser abraded skeletal grains (some brown), better sorting, and coarser grain size if compared with the wackestone lithologies. Quartz grains become a common component in these lithofacies. The differences between P1 and P2 are in the grain size. P3 is unique in the good sorting grain size (it is the coarsest lithology) and the high abundance of both skeletal grains and planktonic foraminifers. Comparing packstone and wackestone lithofacies, the wackestones include few neritic sediment components than the packstones.

ACKNOWLEDGMENTS

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Figure F1. Location of Site 1130.

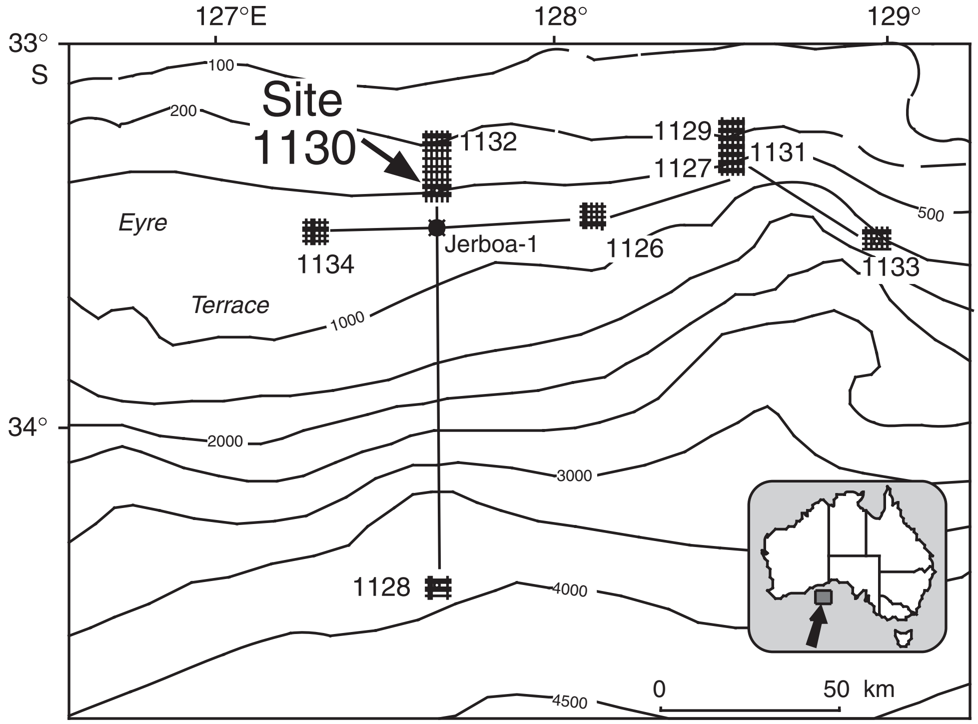

Figure F2. Stratigraphic column, lithofacies, and key to symbols.

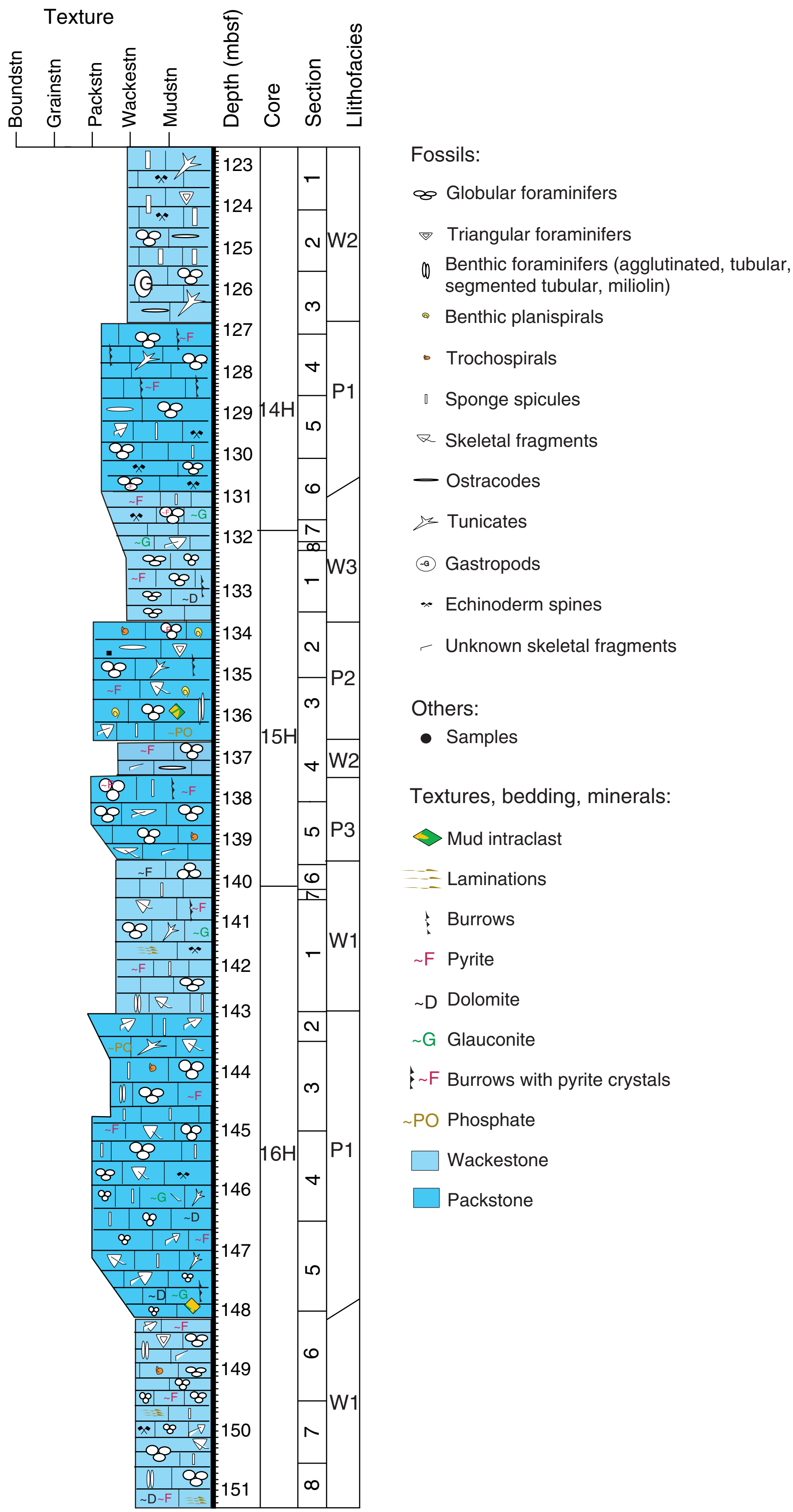

Figure F3. Facies descriptions and key lithofacies photomicrographs. Boundston = boundstone, Grainstn = grainstone, Packstn = packstone, Wackstn = wackestone, Mudstn = mudstone.

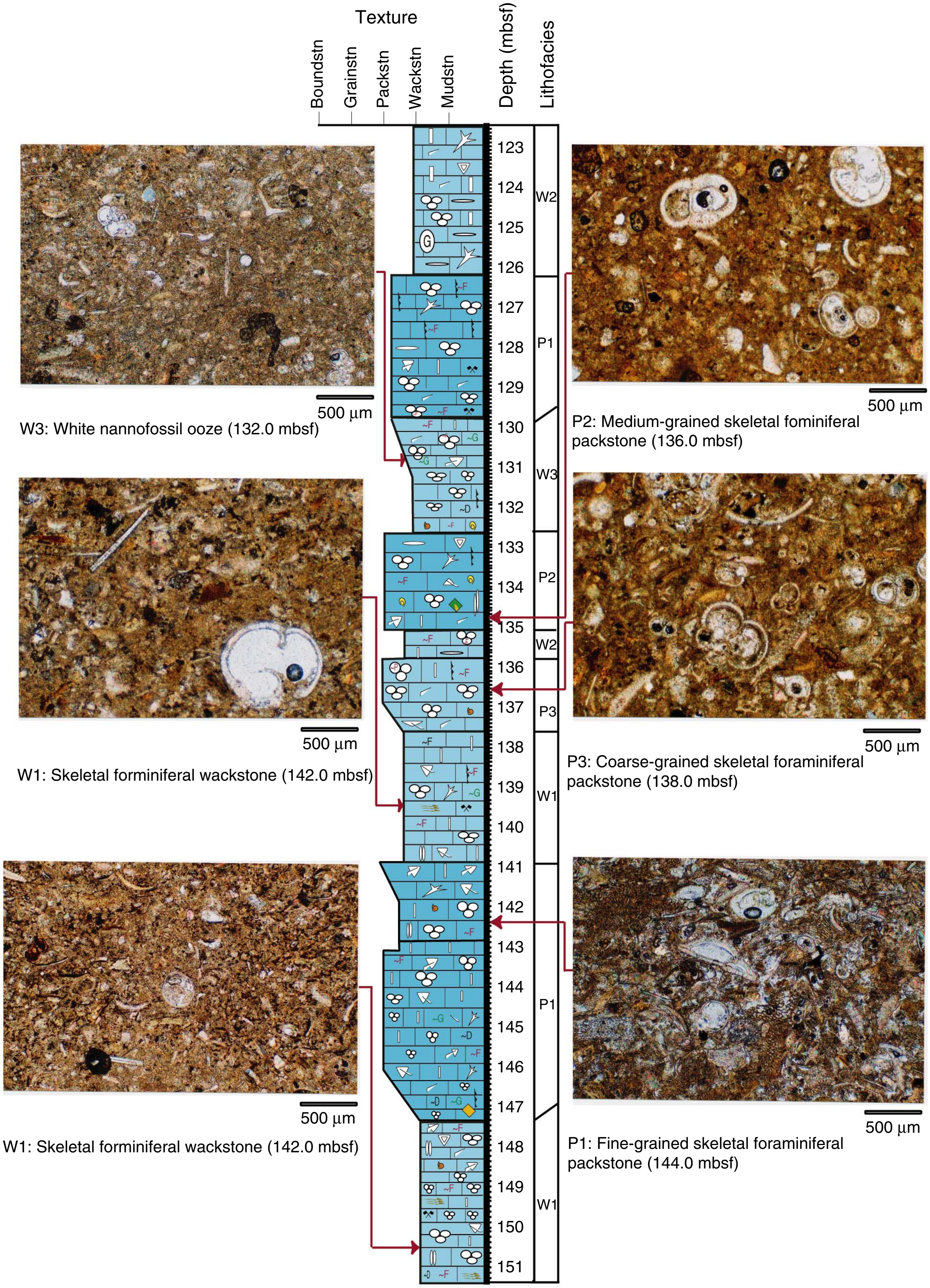

Figure F4. Grain-size analysis and percent coarse fraction (wet sieving).

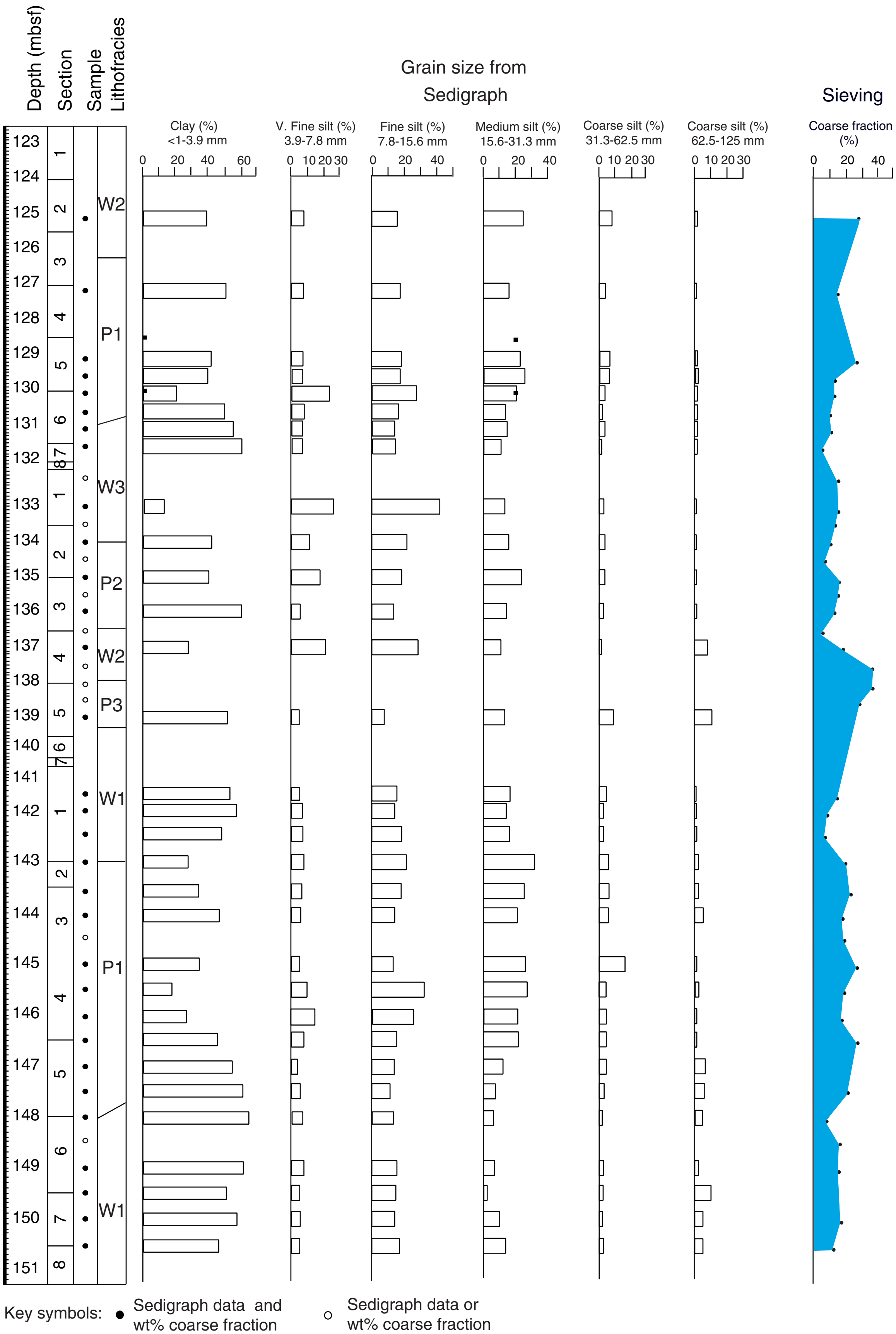

Figure F5. Plot of the grain counts and point counts (point counts of planktonic foraminifers only). Boundston = boundstone, Grainstn = grainstone, Packstn = packstone, Wackstn = wackestone, Mudstn = mudstone.

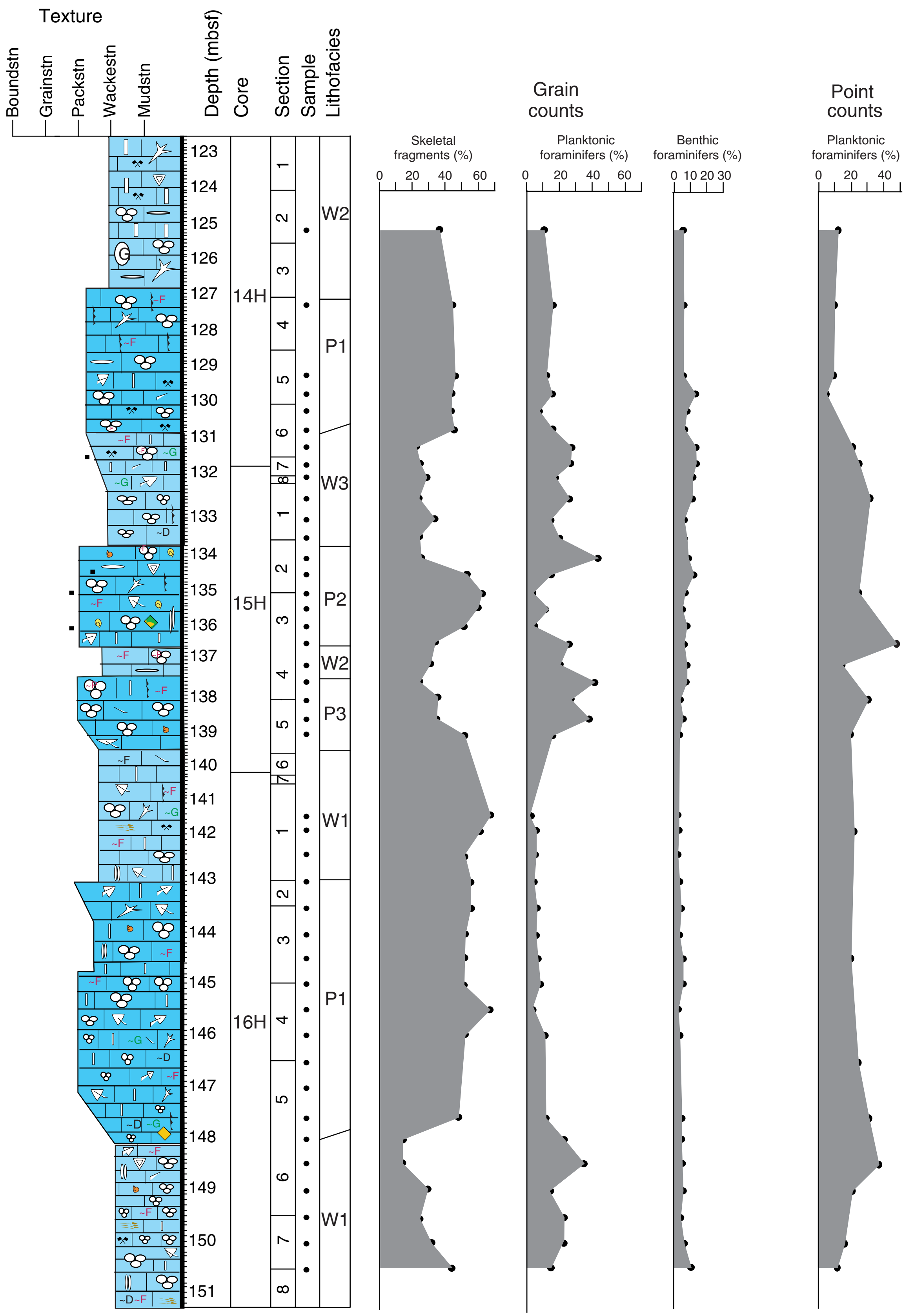

Figure F6. Representative samples of the fraction >68 µm. Notice the grain and sorting variations. Boundston = boundstone, Grainstn = grainstone, Packstn = packstone, Wackstn = wackestone, Mudstn = mudstone.

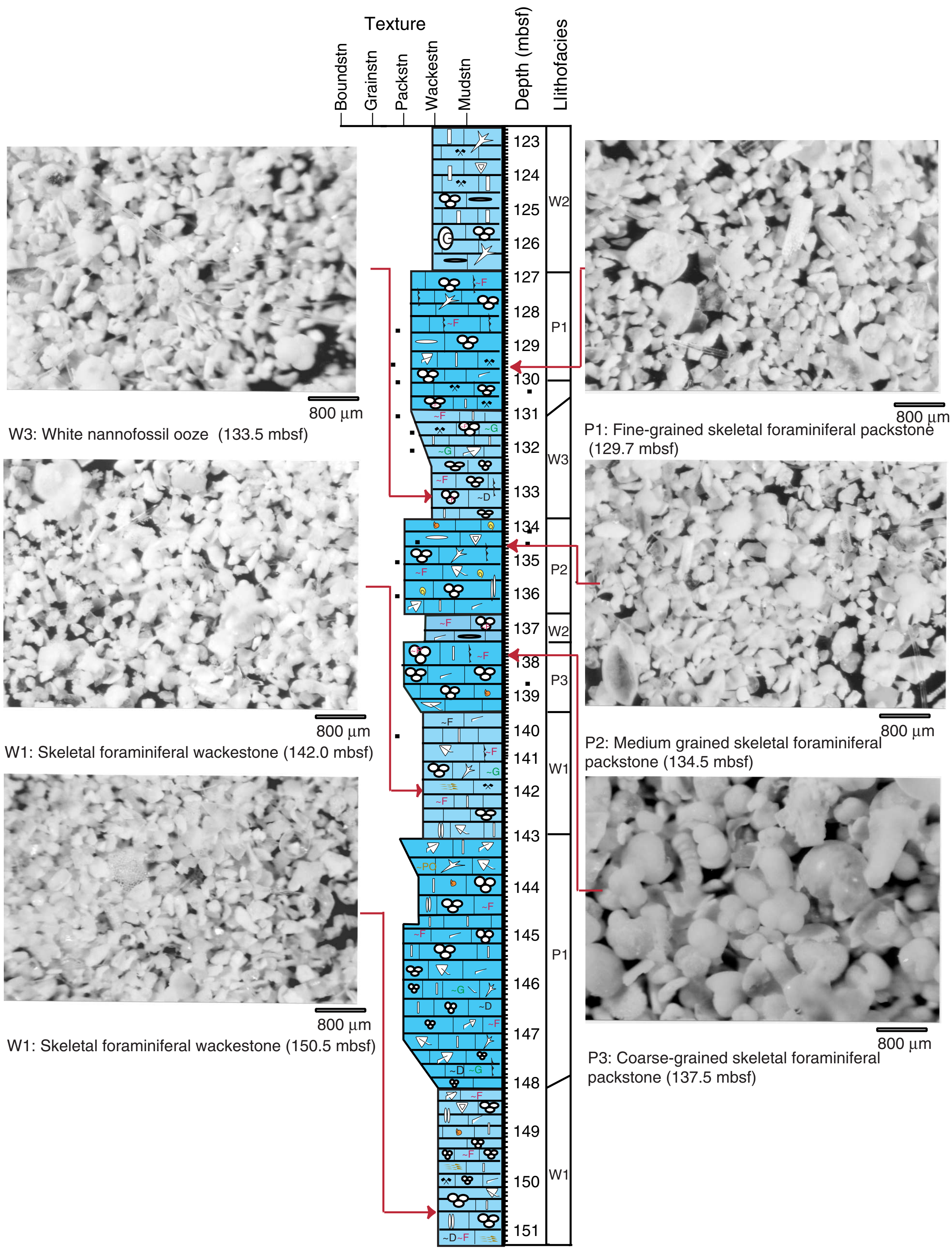

Figure F7. Mineralogy of the carbonate fraction. Notice the alternation between low-Mg calcite (LMC) and high-Mg calcite (HMC). Boundston = boundstone, Grainstn = grainstone, Packstn = packstone, Wackstn = wackestone, Mudstn = mudstone, Arag = aragonite, Dol = dolomite.