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12. Data Report: Petrography and Stable Isotope Geochemistry of Lower Oligocene to Middle Miocene Carbonates, Site 1132, Great Australian Bight[1]

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ABSTRACT

Petrographic observation and carbonate mineralogic and stable isotopic investigation were conducted on lower Oligocene to middle Miocene sediments recovered during Ocean Drilling Program Leg 182 from Site 1132, located at a water depth of 218.5 m immediately seaward of the shelf-slope break of the eastern Eyre Terrace in the western Great Australian Bight. The middle Miocene section consists of bioclastic packstone and grainstone with an interval of partially silicified nannofossil-foraminiferal chalk and is slightly to densely dolomitized. By contrast, the lower Oligocene to lower Miocene section is characterized by a predominance of planktonic and benthic foraminifers, high porosity, absence of chert, and weak dolomitization. The carbon and oxygen isotopic composition of calcites and dolomites between two sections, however, shows no significant difference.

INTRODUCTION

This report provides the results of petrographic and stable isotopic analyses performed on lower Oligocene to middle Miocene sediments recovered during Ocean Drilling Program (ODP) Leg 182 at Site 1132. Site 1132 is situated at a water depth of 218.5 m immediately seaward of the shelf-slope break of the eastern Eyre Terrace in the western Great

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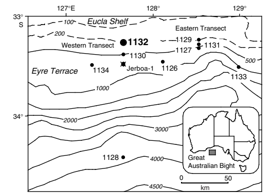
Australian Bight (GAB) (Fig. **F1**), and it is on the western transect drilled into Cenozoic cool-water carbonate sequences along the southern margin of GAB (Feary, Hine, Malone, et al., 2000). At this site a Holocene to Eocene succession of carbonate sediments, 603.2 m thick, was penetrated, and it records the temporal evolution from shallow neritic Eocene, through bathyal early Oligocene and middle Miocene, to outer neritic-upper bathyal late Pleistocene and Holocene deposition. The succession shows a wide variety of lithologies, and a total of six lithologic units are recognized. The lower Oligocene to middle Miocene sediments are 260.5 m thick and correspond to Units IV and V, although the interval is characterized by very poor core recovery (2.1%).

F1. Locations of sites drilled during Leg 182, p. 7.



The middle Miocene section (Unit IV; 257.2–441.5 meters below seafloor [mbsf]) consists of partially lithified bioclastic grainstone with light gray, dark gray, and almost black chert, and the grainstones are slightly to densely dolomitized (Feary, Hine, Malone, et al., 2000). Chert is restricted to this unit, and it is considered an important primary constituent of Unit IV. The lower Oligocene to lower Miocene section (Unit V; 441.5–517.7 mbsf) consists of lithified foraminiferal and bioclastic packstone and grainstone. Dolomites are rare except in slightly dolomitized intervals in the basal part of the unit. The upper boundary is placed at the top of bioclastic grainstone lacking significant amounts of chert, and the lower boundary is placed at a prominent mineralized and bored hardground, where white bioclastic grainstone overlies pale yellow echinoid wackestone of the underlying Unit VI.

The lower Oligocene to middle Miocene section at Site 1132 is considered to represent a record of Cenozoic cool-water carbonate deposition in the interpreted aggradational shelf environment on the basis of seismic profiles (Feary and James, 1998). This interval was mapped as the distal edge of an Eocene–middle Miocene interval predominantly deposited on the shelf, but with a thinning wedge containing biogenic mounds extending into deeper water (Feary and James, 1998). Therefore, petrographic work on this section gives important information, such as bioconstituents, sedimentary features, diagenetic products, dolomitization, and so on, about Oligocene–Miocene cool-water carbonate sedimentology and diagenesis at the GAB, although available samples from Site 1132 are very limited due to their poor recovery. In this report, we document the petrographic observation and stable isotopic composition of the sediments at the site. Discussion and interpretation of these results will be presented in a future publication.

ANALYTICAL METHODS

Partially to fully lithified sediment samples (~10–20 cm^3) from the lower Oligocene to middle Miocene section at Site 1132 were collected from each piece in the core catchers. Within a successfully recovered interval (516.7–517.7 mbsf; interval 182-1132C-31R-1, 0–100 cm), a representative range of lithologies was sampled on the basis of core descriptions and visual observations. A total of 48 samples were slabbed and thin sectioned, and the thin sections were stained with Alizarin-red S for determination of dolomites (Friedman, 1959). The total carbonate content of the samples was determined by a pressure bomb technique (Müller and Gastner, 1971). Hydrochloric acid (usually 5 mL) was added to each powdered sample (~0.5 g) in a clear acrylic bomb until the sample was fully dissolved, and the pressure of evolved CO_2 gas was measured. The gas pressure was converted to percentage of $CaCO_3$ using calibration curves determined from pure carbonate samples for each bomb.

Quantitative carbonate mineralogy was determined by powder X-ray diffraction (XRD) using CuK_α radiation on a Rigaku SG-7 X-ray diffractometer and the methods outlined in Swart, James, et al., this volume. Operating conditions were an accelerating voltage of 25 kV and a current of 5 mA. The peak areas for each mineral were measured relative to the calcite peak by scanning a smear mount of the sample between 24 and 32°2θ, and the final weight percent of each mineral was calibrated using calibration curves from a series of two-component standards. Analytical precision is within 5% of the actual weight percent.

Carbon and oxygen stable isotope analysis of calcite and dolomite from 20 selected samples were done using the method of McCrea (1950). Approximately 100 mg of whole-rock sample was fully pulverized and dissolved in 100% phosphoric acid at 25°C. The CO_2 gas evolved was purified through a vacuum line and analyzed with a Finnigan Delta-plus mass spectrometer. In dolomitic limestone samples, it was impossible to separate fine calcite and dolomite crystals mechanically by a microsampling method. Therefore, on the basis of the different reaction rate of dolomite and calcite with phosphoric acid at 25°C, the CO_2 released during the first 30 min after a reaction was assumed to have come from the calcite part, and the CO_2 gas evolved from 30 min to 150 hr was collected as the dolomite part (Matsumoto and Matsuda, 1987). The carbonate standard NBS-19 ($\delta^{13}C$ = 1.95‰; $\delta^{18}O$ = –2.20‰) was used to calibrate to the Peedee belemnite (PDB) standard, and the corrections were done for the difference of fractionation factors between calcite and dolomite for phosphatic acid. Repeated analyses of the standard yielded reproducibility of better than 0.05‰ for $\delta^{13}C$ and 0.1‰ for $\delta^{18}O$.

RESULTS

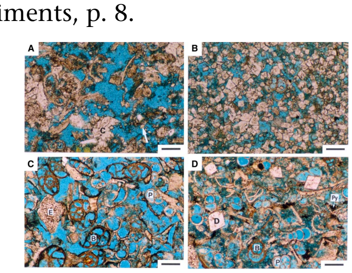
Petrographic Observation

Middle Miocene Section (Unit IV)

Unit IV in the middle Miocene section consists of bioclastic packstone and grainstone with an interval of nannofossil-foraminiferal chalk partially replaced by nodular, light to dark gray chert. The color of the packstone and grainstone is light gray, olive gray, and, in one case, white, and the sediments are partially to strongly lithified. The packstone and grainstone are composed of abundant indeterminate bioclasts, bryozoan and shell fragments, and planktonic foraminifers, common benthic foraminifers, rare echinoid spines, sponge spicules, radiolarians, detrital quartz grains, framboidal pyrite, and glauconite (Fig. F2A). The skeletal grains are very fine to fine sand sized, whereas the quartz grains are silt sized. The framboidal pyrite and glauconite are authigenic, and those are formed in inter- and intragranular pores. The matrix consists of silt-sized bioclasts.

The chert is light gray or, more commonly, dark gray to almost black. Approximately 40% of lithified samples recovered from the interval 255.8–441.5 mbsf (Cores 182-1132C-3R through 22R) consist of chert. Nodular cherts have a white rim, 1–2 mm thick, consisting of poorly silicified nannofossil-foraminiferal chalk. Abundant ghosts after small, partially silicified calcareous fossils occur within the nodules. Porous,

F2. Photomicrographs of the lower Oligocene to middle Miocene sediments, p. 8.

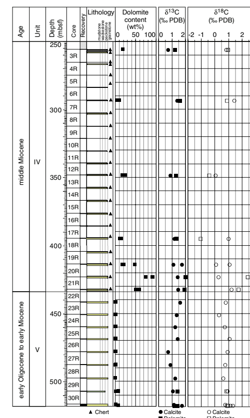


partly silicified, white to light gray nannofossil-foraminiferal chalk infills of commonly cylindrical burrows penetrate many nodules.

Diagenetic features in the middle Miocene section include slight to pervasive dolomitization and rare calcite cementation; dolomite content ranges from 4 to 92 wt% (Table T1; Fig. F3). The dolomite content is high in the lower part of the section (413.6–441.5 mbsf; Cores 182-1132C-20R through 22R) and reaches to 92 wt% in the interval 422.99–423.01 mbsf (Sample 182-1132C-21R-CC, 9–11 cm). Dolomite generally occurs as a cement in the intergranular pores and as a replacement of bioclasts and matrix. Dolomite crystals are 10–50 µm in diameter and have a euhedral crystal shape (Fig. F2B). In the densely dolomitized samples (423.02–423.04 mbsf; Sample 182-1132C-21R-CC, 12–14 cm; dolomite content = 91 wt%), an idiotopic to hypidiotopic mosaic texture composed of euhedral to subhedral dolomite crystal aggregates is observed (Fig. F2B). Calcite cements are rarely observed, and almost intergranular and intraskeletal pores are still open. Coarse sparry calcite cement is observed in some samples (e.g., 348.20–348.23 mbsf; Sample 182-1132C-13R-CC, 10–13 cm) (Fig. F2A) and partially occludes intergranular pore spaces. Calcite crystals range from 50 to 200 µm in size, and they rarely show mosaic and poikilotopic textures. Fibrous to bladed isopachous cement is very rare and grows directly on bioclastic grains such as shell fragments.

T1. Mineralogic and isotopic composition, p. 11.

F3. Downhole variation in dolomite, $\delta^{13}C$, and $\delta^{18}O$, p. 9.



Early Oligocene to Early Miocene Section (Unit V)

Unit V in the lower Oligocene to lower Miocene section (441.5–517.7 mbsf; Core 182-1132C-23R through Section 31R-1, 100 cm) consists mainly of lithified foraminiferal and bioclastic grainstone and packstone which is pale yellow, very pale brown, and pale brown (Fig. F2C). In contrast to Unit IV in the middle Miocene section, it is characterized by a predominance of planktonic and benthic foraminifers, high porosity, and absence of chert. The other major bioconstituents are echinoid spines with minor amounts of detrital quartz grains, framboidal pyrite, and glauconite. The skeletal grains are very fine to fine sand sized, and the matrix is rare and consists of microsparite. In the basal part of the unit, the sediments contain delicate branching bryozoans and serpulids and are enriched in silt-sized bioclasts. In some samples in the lower and middle part, tests of benthic foraminifers are black stained due to pyrite, and pyrite exists in the tests (e.g., 487.70–487.73 mbsf; Sample 182-1132C-28R-CC, 0–3 cm) (Fig. F2C). The total carbonate content is high throughout the section, typically >95 wt%.

Diagenetic features in the lower Oligocene to lower Miocene section are characterized by weak dolomitization compared with the middle Miocene section, rare calcite cementation, and high intergranular and intraskeletal porosity. Dolomite content is constantly low, ranging from 0 to 2 wt% in the upper part of the unit above 497.66 mbsf and from 1 to 8 wt% in the lower part below 507.10 mbsf. Dolomite generally occurs as a replacement of bioclasts and matrix. Rarely, echinoderm grains are dolomitized and overgrown with dolomite rhombs. The crystal shape is euhedral, and the size is 10–50 µm in the upper part, whereas it reaches up to 100–200 µm in the lower part (Fig. F2D).

Carbonate Mineral Composition

In general, the carbonate mineralogy is dominated by low-magnesium calcite (LMC) with a minor amount of dolomite (Table T1; Fig.

F3). There is a significant difference in carbonate mineralogy between the lower Oligocene to lower Miocene and middle Miocene sediments. In the lower Oligocene to lower Miocene sediments, LMC is dominant and dolomite content is consistently low except the samples from the basal part of Unit V. In contrast, the dolomite content is variable in the middle Miocene sediments, and it is very high in the lower part of Unit IV (Table **T1;** Fig. **F3**).

Stable Isotope Geochemistry

Results of the carbon and oxygen stable isotopic composition of calcites and dolomites in 20 selected samples are shown in Table **T1** and Figures **F3** and **F4.** The isotopic composition of calcites ranges from 0.69‰ to 1.74‰ $\delta^{13}C_{PDB}$ and 0.05‰ to 1.42‰ $\delta^{18}O_{PDB}$. Generally, calcites with higher $\delta^{18}O$ values tend to have higher $\delta^{13}C$ values and vice versa (Fig. **F4**). The dolomites have a compositional range of $\delta^{13}C$ from 1.23‰ to 1.99‰ and of $\delta^{18}O$ from –1.05‰ to 2.40‰. There is a tendency that the dolomites in dolomitic limestones with higher dolomite content are the higher $\delta^{18}O$ and $\delta^{13}C$ values, whereas those with lower dolomite content show lower $\delta^{18}O$ and $\delta^{13}C$ values (Fig. **F3**). The carbon and oxygen isotopic composition of calcites and dolomites between Units IV and V shows no significant difference, and the stable isotopic composition also shows no significant difference between the two types of dolomites that are based on different crystal size observed within Unit V.

F4. Crossplots of $\delta^{13}C$ and $\delta^{18}O$ of calcites and dolomites, p. 10.

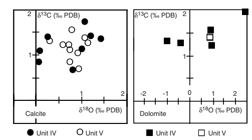


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Figure F1. Locations of sites drilled during Leg 182. The site utilized in this report is highlighted in larger bold type; bathymetry is shown in meters (modified from Feary, Hine, Malone, et al., 2000).

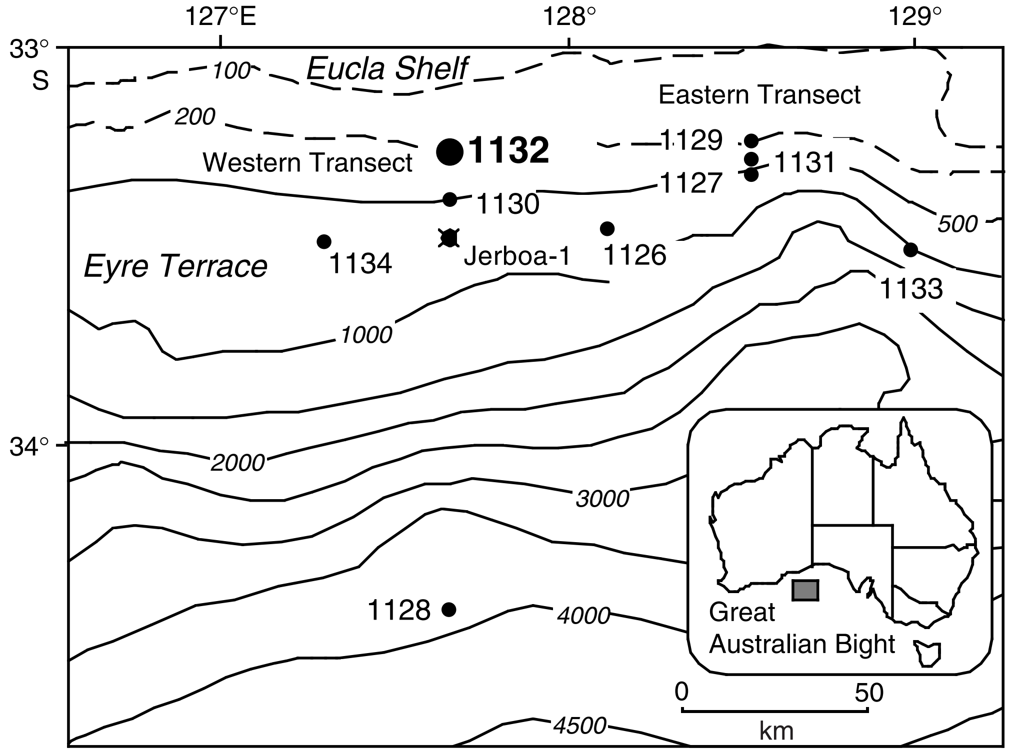

Figure F2. Photomicrographs of the lower Oligocene to middle Miocene sediments from Site 1132. Scale bars = 0.1 mm. **A.** Bioclastic grainstone composed of a variety of bioclasts. Some coarse sparry calcite cements (C), rarely showing a poikilotopic texture, are observed. The sediments are slightly dolomitized, containing clear euhedral dolomite rhombs (arrow), 10–50 µm in size (Unit IV; Sample 182-1132C-13R-CC, 10–13 cm; dolomite content = 21 wt%). **B.** Densely dolomitized bioclastic grainstone. Clear euhedral dolomite crystals, ranging from 10 to 50 µm in size, are scattered throughout, and an idiotopic to hypidiotopic mosaic texture is observed in the densely dolomitized part (Unit IV; Sample 182-1132C-21R-CC, 12–14 cm; dolomite content = 91 wt%). **C.** Foraminiferal grainstone. Particles are dominated by benthic (B) and planktonic (P) foraminifers and echinoid fragments (E). Some of benthic foraminifers are black stained. Calcite cementation and dolomitization are very rare (Unit V; Sample 182-1132C-28R-CC, 0–3 cm; dolomite content = 1 wt%). **D.** Bioclastic packstone from the basal part of Unit V. The packstone consists mainly of bioclasts, planktonic foraminifers (P), and benthic foraminifers (B) with rare pyrite (Py). The sediments are slightly dolomitized, and the dolomite crystals (D) are clear, euhedral, and 100–200 µm in diameter (Unit V; Sample 182-1132C-30R-CC, 0–3 cm; dolomite content = 8 wt%).

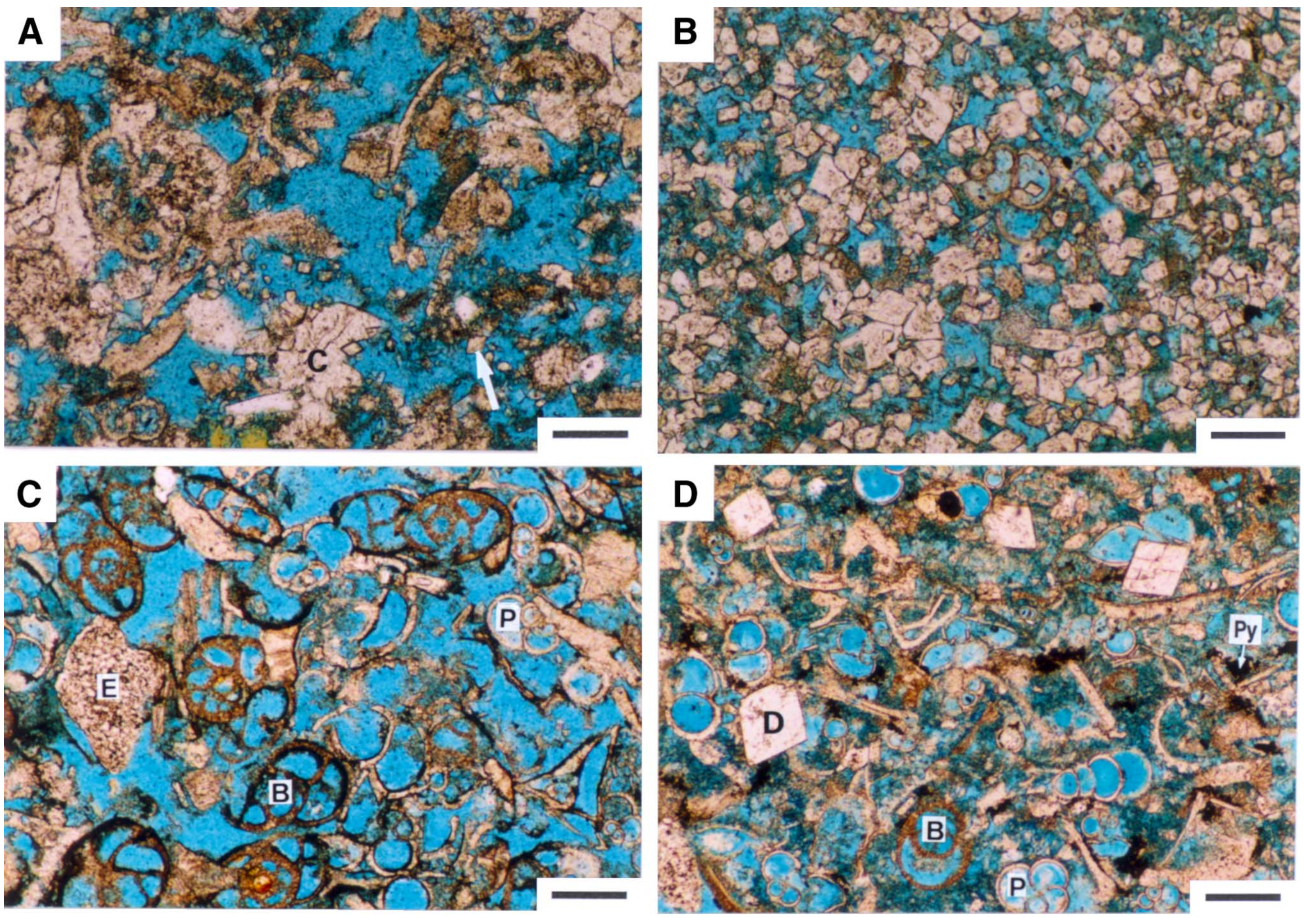

Figure F3. Downhole variation in dolomite content, and δ13C and δ18O values of samples from the lower Oligocene to middle Miocene section at Site 1132. PDB = Peedee belemnite standard.

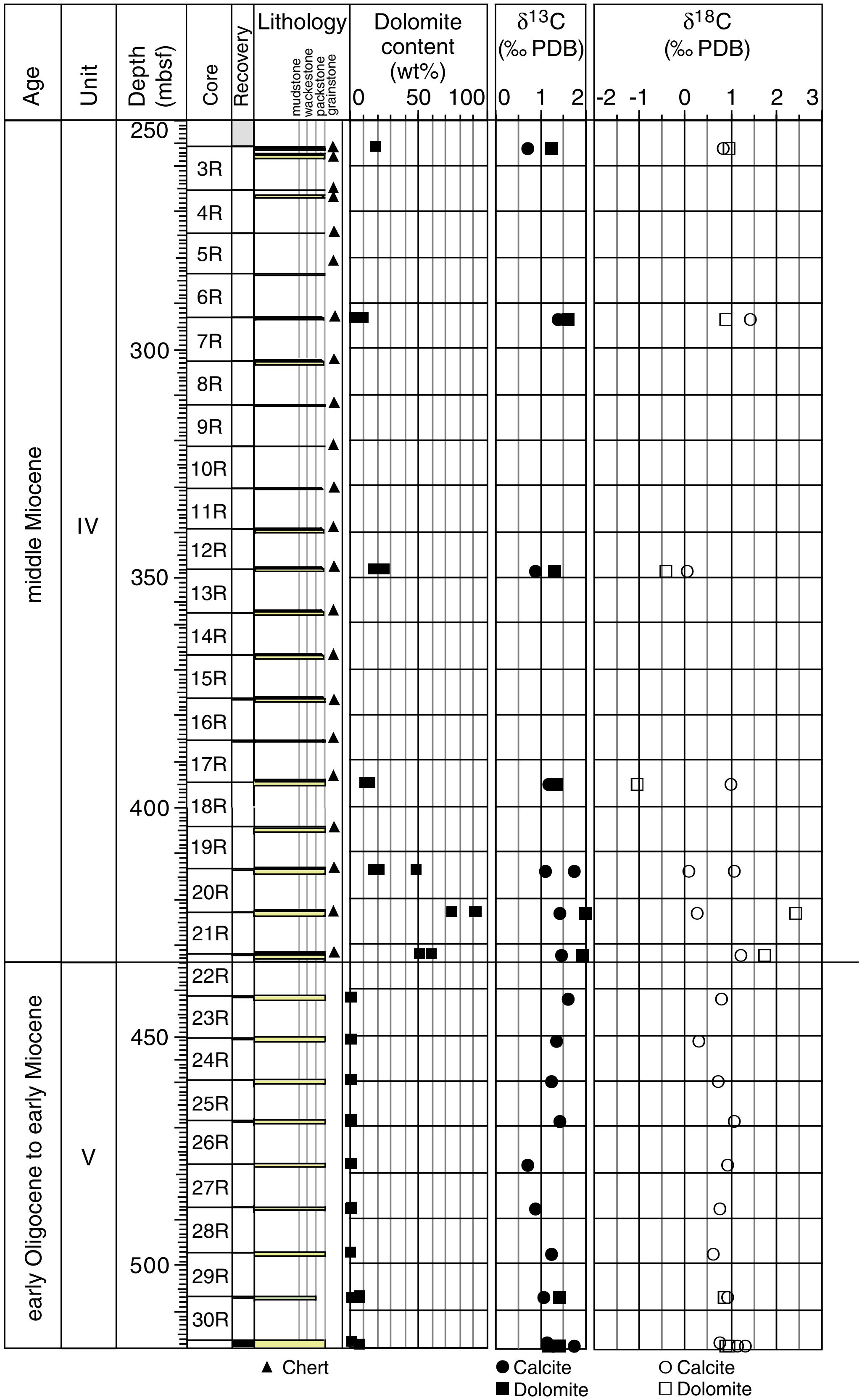

Figure F4. Crossplots of $\delta^{13}C$ and $\delta^{18}O$ values of calcites and dolomites from Units IV and V at Site 1132.

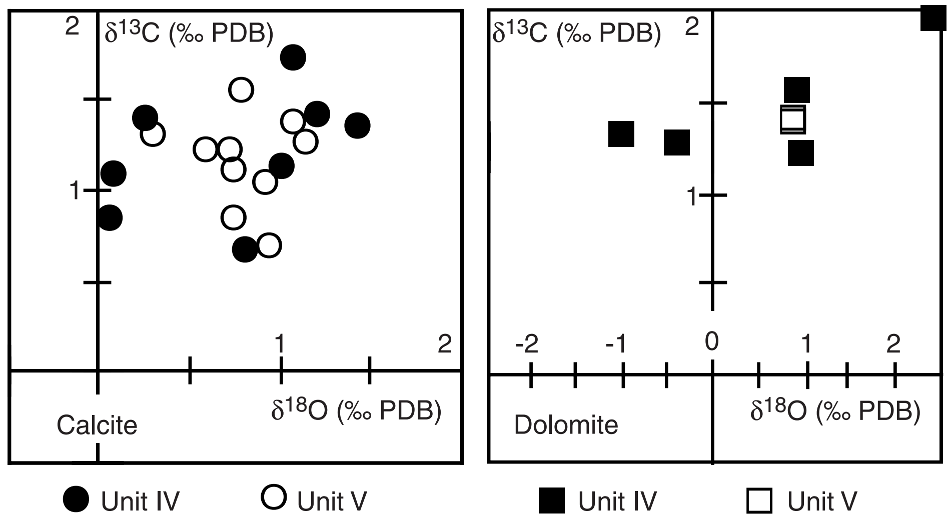

Table T1. Mineralogic and stable isotopic composition of lower Oligocene to middle Miocene sediments, Site 1132.

Unit	Core, section, interval (cm)	Depth (mbsf)	$CaCO_3$ (wt%)	CAL (wt%)	DOL (wt%)	CAL $\delta^{13}C$ PDB (‰)	CAL $\delta^{18}O$ PDB (‰)	DOL $\delta^{13}C$ PDB (‰)	DOL $\delta^{18}O$ PDB (‰)
IV	182-1132C-								
	3R-CC, 0–1	255.80		81	19	0.69	0.81	1.23	0.96
	7R-CC, 0–1	293.10		92	8				
	7R-CC, 1–2	293.11		90	10				
	7R-CC, 6–9	293.16	96.5	96	4	1.37	1.42	1.58	0.91
	13R-CC, 3–6	348.13		75	25				
	13R-CC, 6–8	348.16		83	17				
	13R-CC, 10–13	348.20		79	21	0.87	0.05	1.31	–0.40
	18R-CC, 3–5	394.73	94.3	89	11				
	18R-CC, 5–6	394.75		86	14				
	18R-CC, 6–9	394.76		85	15	1.15	1.01	1.36	–1.05
	20R-CC, 6–8	413.66		51	49	1.74	1.06		
	20R-CC, 12–14	413.72		79	21				
	20R-CC, 17–20	413.77	90.0	83	17	1.11	0.07		
	21R-CC, 8–9	422.98		8	92				
	21R-CC, 9–11	422.99		8	92				
	21R-CC, 12–14	423.02		9	91	1.42	0.26	1.99	2.40
	21R-CC, 18–22	423.08		26	74				
	22R-CC, 0–3	432.20		41	59				
	22R-CC, 3–6	432.23		49	51	1.44	1.21	1.92	1.74
V	23R-CC, 1–5	441.51		99	1	1.58	0.79		
	23R-CC, 5–8	441.55		100	0				
	23R-CC, 10–13	441.60		98	2				
	23R-CC, 13–16	441.63		98	2				
	24R-CC, 0–4	450.80	97.0	99	1	1.33	0.30		
	24R-CC, 4–8	450.84		99	1				
	24R-CC, 8–11	450.88		100	0				
	25R-CC, 0–3	459.70		99	1	1.23	0.71		
	25R-CC, 4–7	459.74		100	0				
	26R-CC, 0–4	468.60	97.5	100	0	1.40	1.07		
	26R-CC, 5–8	468.65		98	2				
	26R-CC, 11–14	468.71		100	0				
	26R-CC, 14–18	468.74		99	1				
	27R-CC, 5–8	478.05		99	1	0.71	0.95		
	27R-CC, 9–12	478.09		100	0				
	27R-CC, 14–17	478.14		100	0				
	28R-CC, 0–3	487.70	97.1	99	1	0.88	0.74		
	28R-CC, 3–5	487.73		100	0				
	28R-CC, 11–13	487.81		99	1				
	28R-CC, 14–16	487.84		100	0				
	29R-CC, 1–2	497.41		100	0				
	29R-CC, 4–7	497.44		100	0				
	29R-CC, 16–18	497.56	95.3	100	0	1.25	0.60		
	29R-CC, 19–22	497.59		100	0				
	30R-CC, 0–3	507.10	94.0	92	8	1.06	0.92	1.42	0.86
	30R-CC, 4–7	507.14		99	1				
	30R-CC, 13–17	507.23		92	8				
	31R-1, 8–11	516.78	96.6	98	2	1.13	0.75		
	31R-1, 70–74	517.40	89.2	93	7	1.28	1.15	1.40	0.89

Note: CAL = low-Mg calcite, DOL = dolomite, PDB = Peedee belemnite standard.