10. SITE 764[1]

Shipboard Scientific Party[2]

HOLE 764A

Date occupied: 18 August 1988

Date departed: 19 August 1988

Time on hole: 17 hr, 30 min

Position: 16°33.96′S, 115°27.43′E

Bottom felt (rig floor; m, drill pipe measurement): 2710.0

Distance between rig floor and sea level (m): 11.4

Water depth (drill pipe measurement from sea level, m): 2698.6

Total depth (rig floor; m): 2779.00

Penetration (m): 69.00

Number of cores (including cores with no recovery): 8

Total length of cored section (m): 69.00

Total core recovered (m): 40.56

Core recovery (%): 59

Oldest sediment cored:

Depth (mbsf): 69.00

Nature: limestone, wackestone, packstone, and claystone

Age: Rhaetian

Measured velocity (km/s): 3.2

HOLE 764B

Date occupied: 19 August 1988

Date departed: 22 August 1988

Time on hole: 3 days, 10 hr

Position: 16°33.96′S, 115°27.43′E

Bottom felt (rig floor; m, drill pipe measurement): 2710.0

Distance between rig floor and sea level (m): 11.4

Water depth (drill pipe measurement from sea level, m): 2698.6

Total depth (rig floor; m): 3004.50

Penetration (m): 294.50

Number of cores (including cores with no recovery): 31

Total length of cored section (m): 254.50

Total core recovered (m): 44.33

Core recovery (%): 17

Oldest sediment cored:

Depth (mbsf): 294.50

Nature: clayey carbonate mudstone

Age: Rhaetian

Measured velocity (km/s): 2.2

Principal results: Site 764 (proposed Site EP9F) is located near the northeastern edge of the Wombat Plateau, approximately 34 km north northeast of Site 761 at 16°33.96′S, 115°27.43′E, and at a water depth of 2698.6 m. Along with Sites 759, 760, and 761, this site provides a complete transect over the plateau covering a wide range of nearshore to offshore, paralic to carbonate bank Mesozoic environments, blanketed by a Cenozoic pelagic succession. The site was drilled on the northeastern flank of the plateau where the Cenozoic drape is very thin. It was rotary cored to a total depth of 294.5 mbsf.

The Cenozoic pelagic sequence consists of 41.5 m of foraminifer nannofossil ooze of late Eocene to Quaternary age. This unit is unconformably underlain by a thin unit (41.5–49.3 mbsf) of alternating nannofossil and foraminifer nannofossil chalk of Coniacian to late Maestrichtian age. A major unconformity separates the chalk from the underlying late Rhaetian carbonate facies. The upper 9 m (49.3–58.3 mbsf) is a fossiliferous assemblage of wackestone, packstone, and grainstone deposited in shallow, oxygenated waters. It is underlain by a unit of alternating recrystallized limestone and calcareous claystone (58.3–68.7 mbsf) of more restricted, lagoonal to deeper shelf setting. A 207.6-m-thick Rhaetian reef complex was drilled between 68.7 and 280.1 mbsf, representing various perireefal environments. The reef complex is underlain by a dark gray, highly bioturbated clayey calcareous mudstone representing a quiet restricted (lagoonal) mud flat environment.

Logging could only be attempted through the drill pipe because the drill-bit could not be released at the bottom of this single-entry hole. A suite of geochemical logs and gamma-ray/neutron porosity/density logs were obtained, which will be invaluable in reconstructing the lithologies in the low-recovery units below 80 mbsf.

Sites 761 and 764 have together recovered a nearly complete marine Rhaetian sequence representing a variety of environments, including a thick unit of reef complex and other reefal carbonates. This expanded marine Rhaetian section is unique in the southern hemisphere, and represents two well-documented cycles of sea-level change corresponding to the global cycle chart. The lower sequence boundary was identified near the Norian-Rhaetian boundary (at Site 761), and the upper sequence boundary within the late Rhaetian at Site 764.

BACKGROUND AND OBJECTIVES

Background

Site 764 (proposed Site EP9F) is located approximately 35 km north northwest of Site 761, near the northeastern edge of the Wombat Plateau (Fig. 1). This site, together with Sites 759, 760, and 761, were designed as a transect covering the entire width of the Wombat Plateau in order to study lateral changes in lithofacies, biofacies, and seismic facies distribution. Thus, the background for Sites 759 and 760 (see "Background and Objectives," Sites 759 and 760 chapters, this volume) applies to this site as well. Site 764 was selected because drilling at Sites 760 and 761 revealed that the prominent angular unconformity on the seismic records at those sites separates the upper Cretaceous sediments from the

[1] Haq, B. U., von Rad, U., et al., 1990. *Proc. ODP, Init. Repts.*, 122: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of Participants preceding the contents.

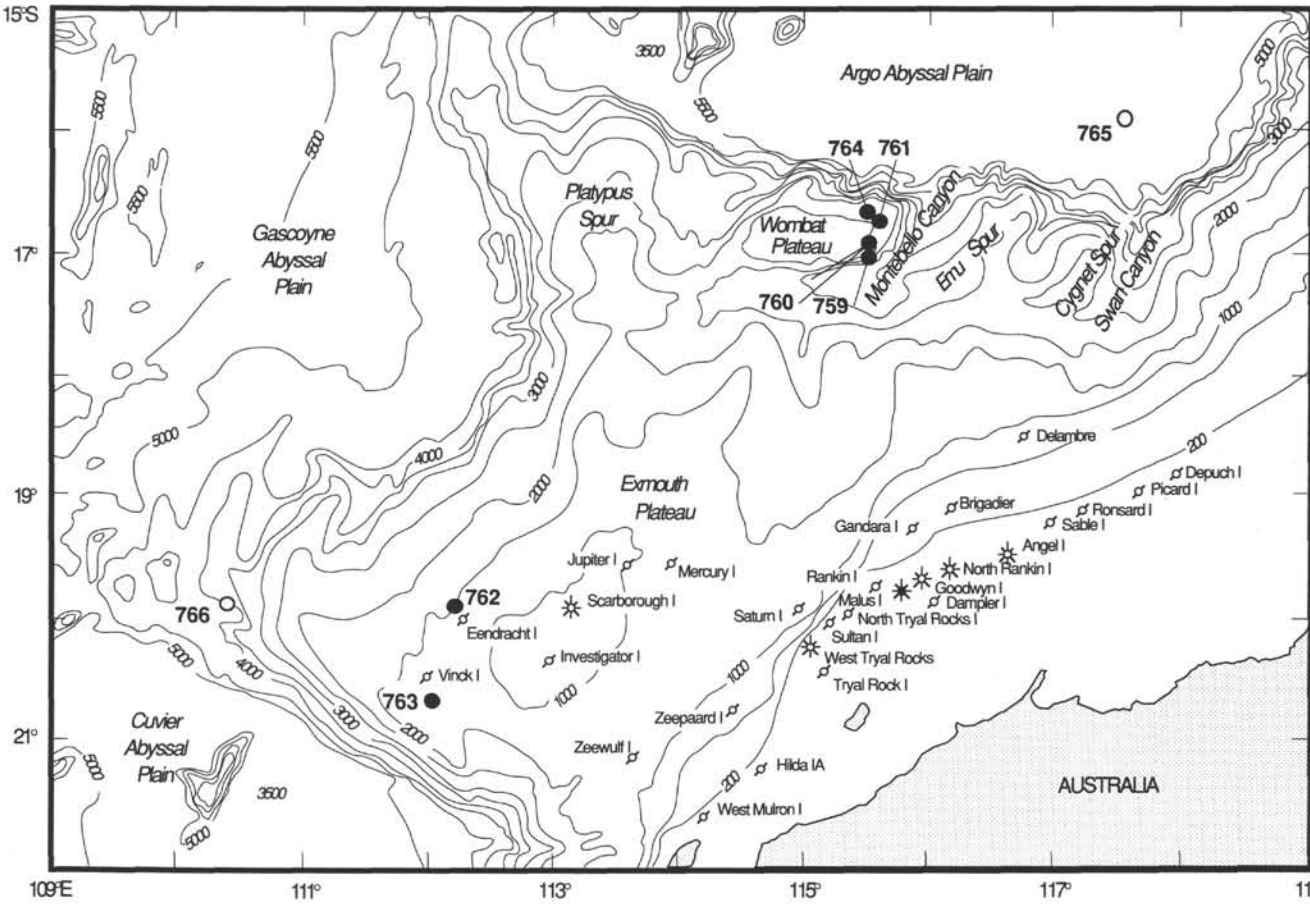

Figure 1. Bathymetric map of Exmouth Plateau region showing location of ODP sites (closed circles = Leg 122 sites, open circles = Leg 123 sites) and commercial wells. Bathymetry is shown in meters (Exon, unpubl. data).

Norian at Site 760, and lower Cretaceous from Rhaetian at Site 761, with the Jurassic and lowermost Cretaceous succession eroded away. The seismic data at the location of Site 764 suggests that at least part of this missing section may be present in the northern edge of the Wombat Plateau. The drilling plan called for penetrating (1) some 45 m of Tertiary sediments, (2) the thin underlying Cretaceous succession, and (3) a possible Liassic section (as predicted by dredge samples recovered from the northern slope) between 65 and 120 mbsf. The hole was planned to be drilled to a total depth (TD) of around 250 to 300 mbsf in Rhaetian facies equivalent to those recovered at Site 761.

Objectives

The objectives of Site 764 were similar to those of the other sites of the Wombat transect (see "Background and Objectives," Sites 759 and 760 chapters, this volume). The important objectives of reconstructing the early breakup and post-breakup history of the Wombat Plateau, documenting depositional sequences, and refining Mesozoic chronostratigraphy were common to all sites of the transect.

OPERATIONS

Hole 764A

Site 764 is located 563 km (304 nmi) north-northwest of Hole 763C. The voyage of 617 km (331 nmi), including a site survey, was made at 12.2 kt. An Ocean Research (OR) beacon SN #1 was dropped at 1615 hr (local time, or LT) on 18 August 1988 near 16°33.95′S, 115°27.44′E.

The scientific interest at this site was primarily in the older, harder sediments immediately underlying a shallow unconformity, and not the shallower near-surface oozes; therefore the rotary core barrel (RCB) coring assembly was used. The bit chosen was a 9-7/8-in. (25.28 cm) RBI C-4, and the bottom hole assembly (BHA) was the standard RCB type that had been used on previous holes. The precision depth recorder (PDR) water depth was 2696.3 m, but the bit did not take weight in the soft sea bottom until 2710.0 m, and 2710.0 m was declared the top of the first core. Eight RCB cores were taken to 69.0 mbsf (Table 1), but the core recovery was only 59% because of the unconsolidated consistency of the sediment. In view of the scientific importance of the unconformity recovered in this interval, the co-chief scientists chose to recore the section to increase the total recovery.

Hole 764B

The bit was pulled above the sea floor and the ship was offset a few meters. The first core was drilled to 40 mbsf where coring commenced. Two 5-m cores were taken in 5 and 8 min, respectively (Fig. 2), recovering a total of 6.4 m. A transition to much slower drilling was encountered at 50 mbsf. This transition was the change from ooze to shallow-water limestone. Core recovery in the limestone was low, averaging only 12.5% from 50 to 279.5 mbsf (Fig. 3). The few small rocks that were in the core barrel were shallow water limestones of low

Table 1. Coring summary, Site 764.

Core no.	Date (Aug. 1988)	Time (local)	Depth (mbsf)	Cored (m)	Recovered (m)	Recovery (%)
122-764A						
1R	19	0115	0.0–9.5	9.5	9.80	103.2
2R	19	0150	9.5–19.0	9.5	1.54	16.2
3R	19	0225	19.0–28.5	9.5	7.35	77.4
4R	19	0255	28.5–38.0	9.5	8.07	84.9
5R	19	0330	38.0–47.5	9.5	5.99	63.1
6R	19	0445	47.5–57.0	9.5	2.05	21.6
7R	19	0730	57.0–66.5	9.5	3.58	37.7
8R	19	0900	66.5–69.0	2.5	2.18	87.2
Coring totals				69.0	40.56	58.8
122-764B-						
1C	19	1115	0.0–40.0		(Wash—40.0 m)	
2R	19	1230	40.0–45.0	5.0	4.42	88.4
3R	19	1320	45.0–50.0	5.0	1.99	39.8
4R	19	1500	50.0–55.0	5.0	0.68	13.6
5R	19	1715	55.0–60.0	5.0	1.67	33.4
6R	19	1915	60.0–65.0	5.0	1.34	26.8
7R	19	2100	65.0–70.0	5.0	2.09	41.8
8R	19	2310	70.0–79.5	9.5	2.52	26.5
9R	20	0015	79.5–89.0	9.5	0.50	5.3
10R	20	0130	89.0–98.5	9.5	0.36	3.0
11R	20	0315	98.5–108.0	9.5	1.25	13.2
12R	20	0430	108.0–117.5	9.5	0.50	5.3
13R	20	0535	117.5–127.0	9.5	0.17	1.8
14R	20	0640	127.0–136.5	9.5	0.17	1.8
15R	20	0805	136.5–146.0	9.5	0.15	1.6
16R	20	0920	146.0–155.5	9.5	0.26	2.7
17R	20	1015	155.5–160.5	5.0	0.00	0.0
18R	20	1100	160.5–165.5	5.0	0.24	4.8
19R	20	1215	165.5–175.0	9.5	0.16	1.7
20R	20	1400	175.0–184.5	9.5	1.20	12.6
21R	20	1545	184.5–194.0	9.5	0.32	3.4
22R	20	1750	194.0–203.5	9.5	2.10	22.1
23R	20	2000	203.5–213.0	9.5	1.42	14.9
24R	20	2140	213.0–222.5	9.5	1.50	15.8
25R	20	2245	222.5–232.0	9.5	1.00	10.5
26R	21	0010	232.0–241.5	9.5	0.60	6.3
27R	21	0155	241.5–251.0	9.5	1.20	12.6
28R	21	0435	251.0–260.5	9.5	4.28	45.1
29R	21	0550	260.5–270.0	9.5	1.04	10.9
30R	21	0750	270.0–279.5	9.5	1.26	13.3
31R	21	1120	279.5–294.5	15.0	9.94	66.3
Coring totals (Washed = 40 m)				254.5	44.33	17.42

compressive strength, and appeared to have been rolled and rounded by the coring process. The last core of the leg, Core 122-764B-31R (279.5–294.5 mbsf), was advanced 15 m to deepen the hole for logging. This spectacular 9.94-m-long core contained a transition from very pale brown carbonate mudstone to intensely bioturbated clayey carbonate mudstone and provided a stratigraphic overlap with Site 761.

Logging

Logging Hole 764B was particularly important because of the low core recovery in the shallow-water carbonates. A bit wiper trip was made up to 82 mbsf, and 4 hole volumes of water were circulated while pumping two 30-barrel mud sweeps. The hydraulic bit release (HBR) go-devil was pumped into place to release the bit, but pressuring the drill pipe up to 5,000 psi did not cause the bit to release.

Since we could not release the bit to run open-hole logs, the Co-chief Scientists elected to cut 3 more cores and then log through the drill pipe. Three wire line runs were made but the go-devil could not be pulled out of the HBR; additional coring was not feasible because circulation was impossible with the go-devil stuck in the HBR. While attempting to strip the

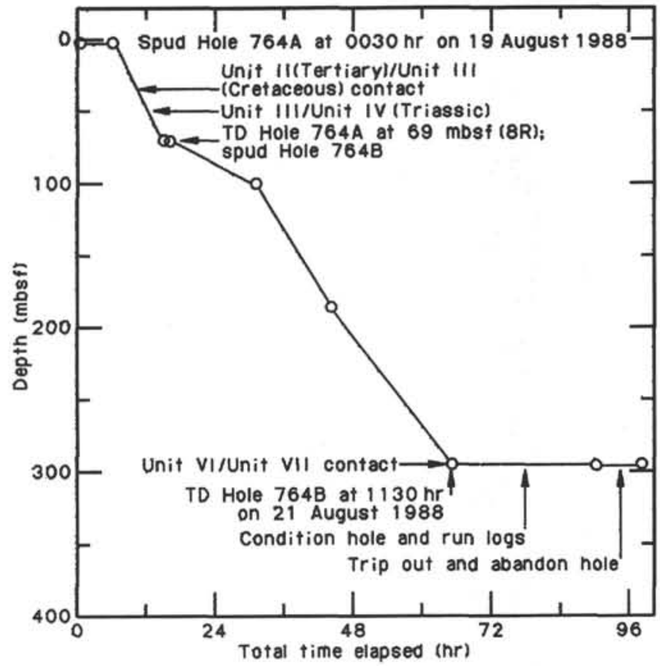

Figure 2. Total time elapsed (hrs) versus depth (mbsf), Site 764.

overshot from the go-devil, the inner mandrel of the go-devil sheared off of its seal assembly. Although the seal assembly was left in the HBR we could circulate down the drill pipe. Two hole volumes of water were circulated and the hole was filled with KCL/Drispac mud. Two successful log runs were made from inside the drill pipe. The first run was with the seismic-stratigraphic tool (NGT/CNL/LDT) and the second was with the geochemical tool (NGT/ACT/GST).

The drill pipe was raised to 100 mbsf and a 125-sack cement plug was placed. *JOIDES Resolution* departed for Singapore at 1945 (LT) on 22 August 1988. The anchor was dropped at Johor Shoal Buoy near Singapore at 0700 hr (LT) on 20 August 1988, ending Leg 122.

LITHOSTRATIGRAPHY

The 294.5-m-thick section penetrated at Site 764 is divided into seven lithologic units on the basis of visual core, smear slide, and thin-section descriptions (Table 2, Fig. 4). Coring disturbance was severe in the Quaternary and the late Cretaceous intervals where much of the soft sediment was reconstituted, and in the Triassic where recovery was low and the core discontinuous.

Unit I (0–8.95 mbsf)

Core 122-764A-1R, 0 cm, to -1R-7, 28 cm.

Unit I consists of Quaternary foraminifer nannofossil ooze. It unconformably overlies Miocene sediments. The ooze is pink (7.5YR 7/4) to pink-gray (7.5YR 7/3 and 7.5YR 7/4), becoming lighter in color downward, probably because of decreasing iron content, which may in turn be related to decreasing clay content. The sediment has been highly deformed by the drilling and much of it has a soupy consistency, but recovery was good. In addition to nannofossils and foraminifers, the ooze contains about 15% clay (on the basis of a single calcium carbonate determination); some radiolarians are also present.

The lower boundary, with pink (7.5YR 7/4) ooze overlying banded, white nannofossil ooze with foraminifers of middle

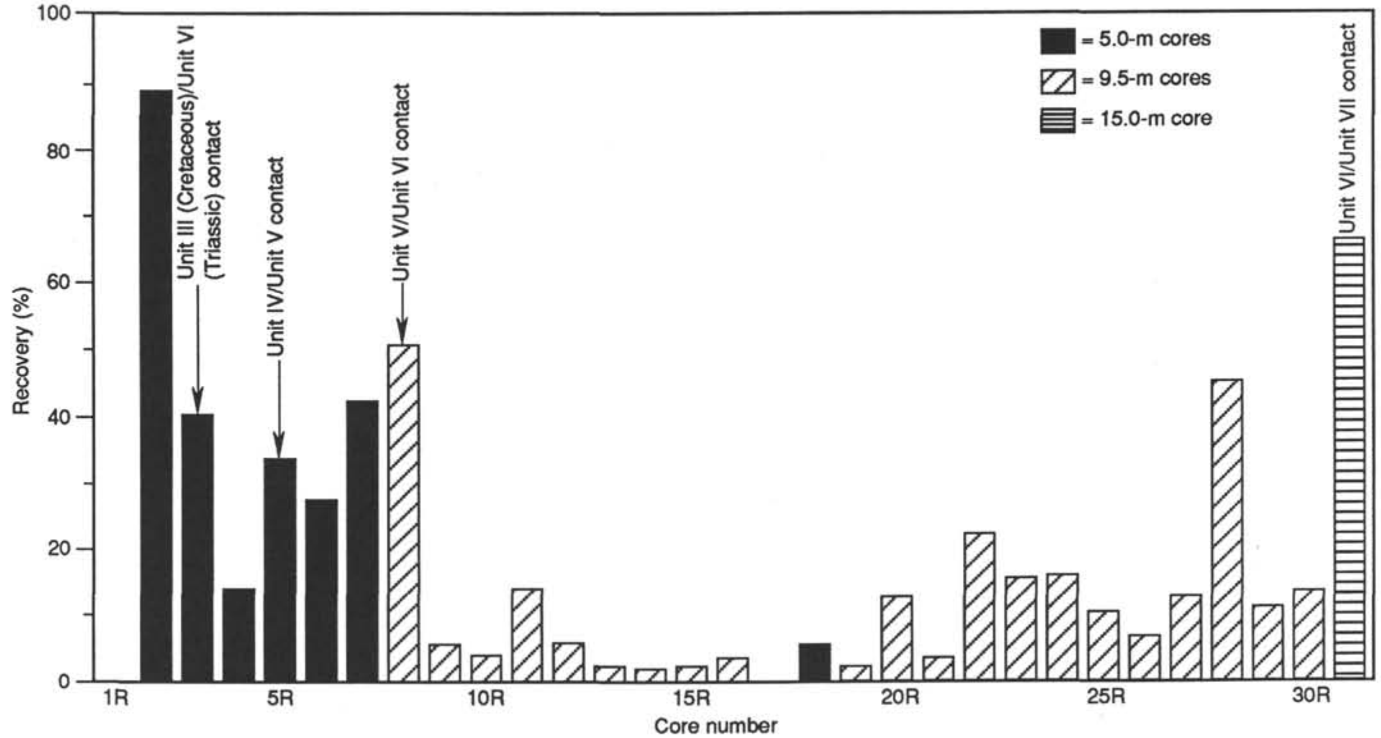

Figure 3. Core number versus recovery (%), Hole 764B.

Miocene age, is marked by a considerable increase in firmness downward.

Unit II (Hole 764A, 8.95–41.52 mbsf; Hole 764B, 40.00–40.87 mbsf)

Cores 122-764A-1R-7, 28 cm, to -5R-3, 52 cm; Core 122-764B-2R-1, 0 cm, to -2R-1, 87 cm.

Unit II consists of 33.57 m of late Eocene to middle Miocene ooze with some chalk towards the base. Total thickness is 33.57 m, and the unit's base unconformably overlies Cretaceous sediments. Recovery was about 60%.

The ooze consists of nannofossil ooze, nannofossil ooze with clay, nannofossil ooze with foraminifers, and foraminifer nannofossil ooze, with foraminifers generally less abundant lower in the section. Chalky nodules in the middle Miocene ooze indicate that the texture of the sediment has been altered by drilling. Colors include light gray (10YR 7/2), very pale brown (10YR 7/3), pale brown (10YR 6/3), and light yellow-brown (10YR 6/4). Ten calcium carbonate analyses from this unit range from 75% to 90% (average = 85%). This suggests that there is 20%–25% clay in the ooze. Minor components are bioclasts, pyrite specks, quartz, iron oxide, glauconite, and plant debris. The lower part of this unit shows 1.0–1.5-cm-thick cyclic color intervals. Overall, bedding is not clearly defined and moderate bioturbation is apparent in the form of mottles and burrows of various sizes and orientations.

The boundary with the underlying Cretaceous sequence is defined by a change from pale brown in Hole 764A and light gray in Hole 764B to white, but cyclic color changes continue below the Cretaceous/Tertiary boundary interval (where late Eocene disconformably overlies late Maestrichtian; see "Biostratigraphy," this chapter). In Hole 764A there is no evidence of a facies break, but in Hole 764B, chalky gravel coated with manganese oxide marks the break. The manganese oxide formed a thin crust during a period of nondeposition, and was broken up by current action before deposition recommenced. Immediately above the boundary in Hole 764B the Eocene chalk is slumped, probably by soft-sediment deformation. The wireline logs show no character change across the Cretaceous/Tertiary boundary interval (see "Downhole Measurements," this chapter).

Unit III (Hole 764A, 41.52–49.56 mbsf; Hole 764B, 40.87–47.05 mbsf)

Cores 122-764A-5R-3, 52 cm, to -6R-2, 56 cm; Cores 122-764B-2R-1, 87 cm, through -3R-CC.

Unit III consists of chalk, which in places has been converted to ooze by drilling. Recovery was 100%. It is a maximum of 8.04 m thick, and is Coniacian to upper Maestrichtian in age (see "Biostratigraphy," this chapter). It unconformably overlies Rhaetian sedimentary rocks.

The chalk consists of alternating nannofossil chalk, nannofossil chalk with clay, nannofossil chalk with foraminifers, and foraminifer nannofossil chalk. The average calcium carbonate content from four samples is 89%, suggesting that most of the unit contains less than 10% clay. This unit is white (10YR 8/2) or very pale brown (10YR 7/3, 8/4). Minor components are quartz, pyrite, iron oxide, dolomite rhombs, bioclasts (including *Inoceramus* prisms), and other molluscan and plant debris. Laminations are apparent at some levels and are made more discernable by gray pyritic grains. Bioturbation is not well developed, although some pyritic burrows are visible.

The boundary with the underlying Rhaetian is marked by a great increase in lithification, but there is no major change in wireline log character at the boundary (see "Downhole Measurements," this chapter).

Unit IV (Hole 764A, 49.56–58.32 mbsf; Hole 764B, 47.05–55.90 mbsf)

Cores 122-764A-6R-2, 56 cm, to -7R-1, 132 cm; Cores 122-764B-4R-1, 0 cm, to -5R-1, 90 cm.

Table 2. Lithologic units, Site 764.

Unit	Lithology	Hole, core, section, interval (cm)	Depth (mbsf)	Thickness (m)	Environment	Age
I	Foraminifer nannofossil ooze, pink to pinkish gray.	764A-1R-1, 0 to 764A-1R-7, 28	0–8.95	8.95	Pelagic.	Quaternary
II	Alternating nannofossil ooze with clay and foraminifer nannofossil ooze with clay (light gray to light brown).	764A-1R-7, 28 to 764A-5R-3, 52. 764B-2R-1, 0 to 764B-2R-1, 87	8.95–41.52 40.00–40.87	33.57 (0.87)	Pelagic.	Late Eocene to Middle Miocene
III	Alternating nannofossil chalk and nannofossil chalk with foraminifers (white to very pale brown).	764A-5R-3, 52 to 764A-6R-2, 56 764B-2R-1, 87 through 764-B-3R-CC	41.52–49.56 40.87–47.05	8.04 (6.18)	Pelagic.	Coniacian to Late Maestrichtian
IV	Fossiliferous wackestone, packstone, and grainstone (white, pale brown to strong brown).	764A-6R-2, 56 to 764A-7R-1, 132 764B-4R-1, 0 to 764B-5R-1, 90	49.56–58.32 47.05–55.90	8.76 (8.85)	Shallow, oxygenated quiet water (reworked allochems).	Rhaetian
V	Alternating recrystallized limestone and calcareous claystone (gray to dark gray, yellowish brown).	764A-7R-1, 132 through 764A-8R-CC 764B-5R-1, 90 to 764B-9R-1, 0	58.32–69.00 55.90–79.50	10.38 (16.61)	Shallow open marine, below wave base.	Rhaetian
VI	Alternating boundstone, grainstone, dolomitic claystone, rudstone (breccia); reef complex (white, pale brown, pink, and red).	764B-9R-1, 0 to 764B-31R-1, 95	79.50–280.15	207.64	Reef complex (back-reef, reef, fore-reef).	Rhaetian
VII	Highly bioturbated carbonate mudstone (marl) to wackestone (very dark gray).	764B-31R-1, 95 to 764B-31R-CC	280.15–294.50	8.99	Open marine, perhaps lagoonal back-reef.	Rhaetian

The maximum total thickness of the limestones of Unit IV is 8.85 m with an assigned age of Upper Triassic (Rhaetian). Recovery within this interval was approximately 30%. Preservation of the recovered rocks was good to excellent.

Lithologies range from chalky carbonate mudstone, wackestone, and skeletal peloidal packstone to grainstone. Characteristic colors are variable, but they are predominantly white (10YR 8/2), very pale brown (10YR 8/4) to strong brown (7.5YR 4/6), yellow (10YR 7/4) to brown-yellow (10YR 6/6) with minor pink (5YR 8/3).

Fossil abundance varies in hand specimens from moderate in the wackestones to abundant in the packstones and grainstones. Mollusks, echinoderm fragments (especially crinoids), foraminifers, and peloids are the predominant allochemical grains identified. Whole fossils are also observed in the finer grained rocks (Fig. 5). In particular, the foraminifer *Triasina* sp. is present in the uppermost recovered rock fragment (see "Biostratigraphy," this chapter). Some of the wackestones and packstones are partially dolomitized. Preliminary petrographic analyses indicate that micrite is the dominant matrix material, with sparite and dolomite present. Further petrographic analyses are to be conducted onshore.

In both Holes 764A and 764B, minor graded bedding is observed and consists of grainstones fining upward into wackestones and carbonate mudstones, indicative of current activity at the depositional site. Red- and yellow-stained grains (hematitic and limonitic, respectively) and laminations, some of which are disrupted or crosscutting, are observed throughout this unit (Fig. 6). The laminations and associated thin beds are composed of fine-grained carbonate muds and iron-oxide and -hydroxide minerals. These disrupted laminations may be post-depositional diagenetic features.

Minor black manganese oxide grains, stringers, and zones (Fig. 7) occur in the non-oxidized fine-grained carbonate mudstones. The manganese oxides appear to be surrounding and replacing allochemical grains and infilling burrows.

Bioturbation is minor in most of these rocks. However, some biogenic sedimentary structures were observed in the skeletal peloidal packstones.

Given the above characteristics, our preliminary interpretation of the depositional environment is that it was shallow water, well oxygenated, and of quiet to moderate mechanical energy. Periodically, minor currents transported whole or broken allochems into this environment, where they were deposited and subsequently oxidized.

Unit V (Hole 764A, 58.32–69.00 mbsf; Hole 764B, 55.90–79.50 mbsf)

Cores 122-764A-7R-1, 132 cm, through -8R-CC; Cores 122-764B-5R-1, 90 cm, through 9R-1, 0 cm.

The maximum thickness of Unit V calcareous claystones and recrystallized clayey limestones is 16.61 m, with recovery averaging approximately 50%. We assigned a Rhaetian age to Unit V on the basis of nannofossil, foraminifer, and radiolarian analyses.

Unit V consists of gray (7.5YR 5/0) to dark gray (7.5YR 4/0) recrystallized clayey limestone to peloidal packstone and

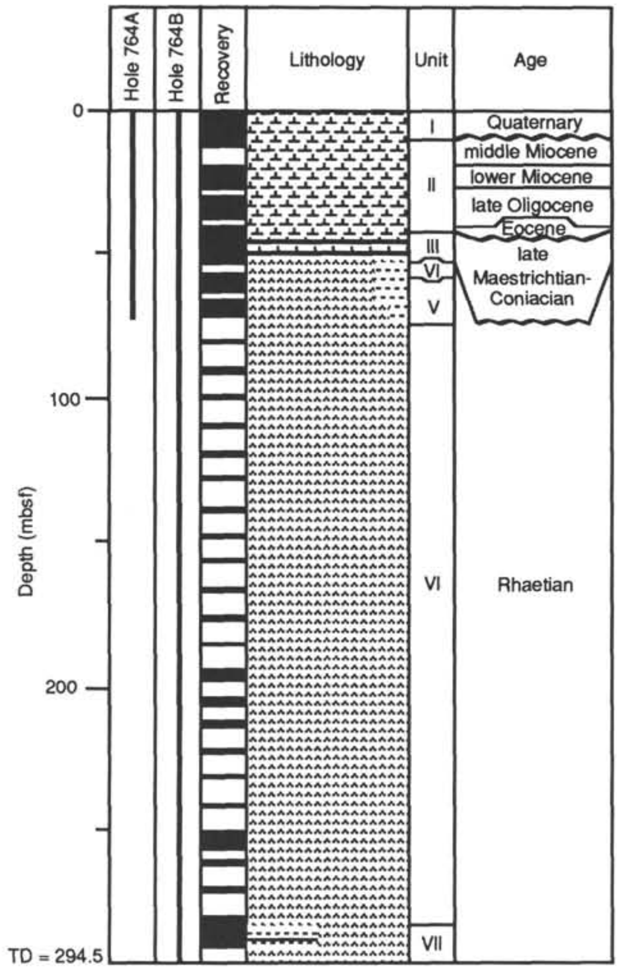

Figure 4. Lithologic column for Holes 764A and 764B, showing core number and type, recovery, generalized lithology, lithologic unit, and age. Black in the recovery column indicates recovered intervals. Key to lithologic symbols is in the "Explanatory Notes" chapter, this volume.

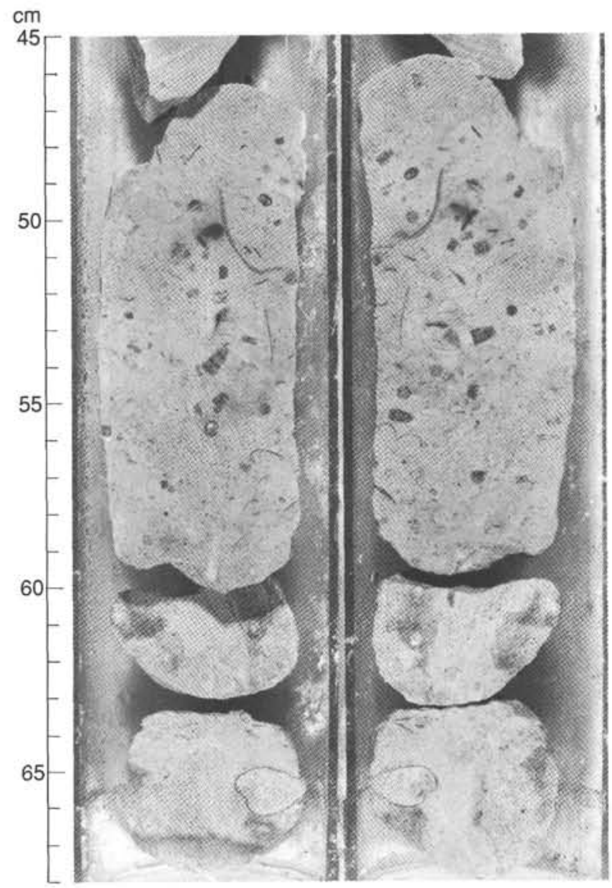

Figure 5. Carbonate wackestone containing crinoids and brachiopods in Rhaetian Unit IV (Interval 122-764B-4R-1, 45–68 cm). Note whole brachiopod at 66 cm (both the working and archive halves are shown).

wackestone, alternating with very dark gray (10YR 3/1 and 5Y 4/1) calcareous claystone. The calcareous claystones found immediately beneath the upper boundary and above the lower boundary have colors that include dark gray (N4) to yellow (2.5Y 6/4) to olive yellow (2.5Y 6/8). These mixed colors are attributed to drilling-induced contamination with the overlying and underlying lithologies. Six calcium carbonate analyses indicate that the claystones average 29% calcium carbonate, whereas the recrystallized clayey limestones average 88% calcium carbonate (Fig. 8).

The calcareous claystones are highly disturbed and contain up to 10% quartz and 3%–5% foraminifers and nannofossils. Unspecified calcium carbonate grains (30%) of probable diagenetic origin make up the remainder of the smear slides. Where they have not been disturbed by drilling, the boundaries between the alternating calcareous claystones and recrystallized limestones are gradational.

The recrystallized clayey limestones are moderately bioturbated and pelleted, leading to a classification of some of the limestones as pelloidal wackestones and packstones. *Chondrites* and *Callianassa*-like burrows are present. Minor recrystallized bivalves and structures that resemble calcareous algae are present. In some of these recrystallized limestones, fine diagenetic banding of iron oxide is superimposed on the original sedimentary structure (Fig. 9). The laminated zones are mottled and show varying degrees of recrystallization. Preliminary petrographic analysis indicates that the amount of authigenic calcite increases in content from the claystones to the limestones. The cause of this alternating diagenetic process is yet to be determined.

The depositional setting of Unit V is tentatively interpreted to be a shallow (below wave base) open-marine environmental setting. The faunas that are preserved (foraminifers, nannofossils, and radiolarians) suggest an open-marine, nonrestricted environment (see "Biostratigraphy," this chapter). Assuming that the majority of the carbonate materials are diagenetic, the detrital clays accumulated in a quiet marine environment removed from wave and current activity. Burrowers and grazers were active and reworked many of the sediments, which later became recrystallized.

Unit VI (79.50–280.15 mbsf)

Cores 122-764B-9R-1, 0 cm, to -31R-1, 95 cm.

The maximum total thickness of Unit VI limestones is 207.64 m with a recovery of 9.48%. The limestones that were recovered are beautifully preserved and varied. Calcium carbonate analysis yielded values of 82%–100%. On the basis of biostratigraphic results, a Rhaetian age is assigned to these lithologies (see "Biostratigraphy," this chapter).

A great variety of limestone types is included in Unit VI, each of which represents changing environmental and depositional conditions. The major limestone types are wacke-

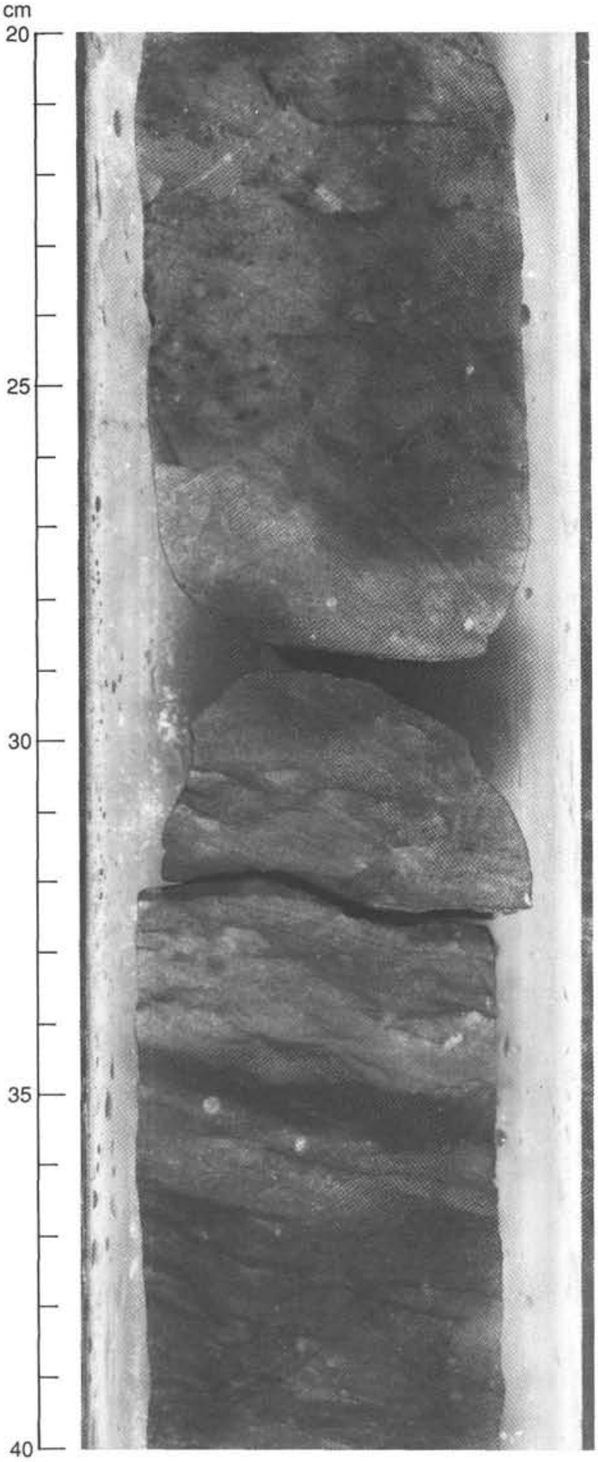

Figure 6. Reddish hematitic laminations and disrupted bedding in carbonate mudstone (Interval 122-764A-7R-1, 20–40 cm), which may represent varied source areas or be the result of dissolution.

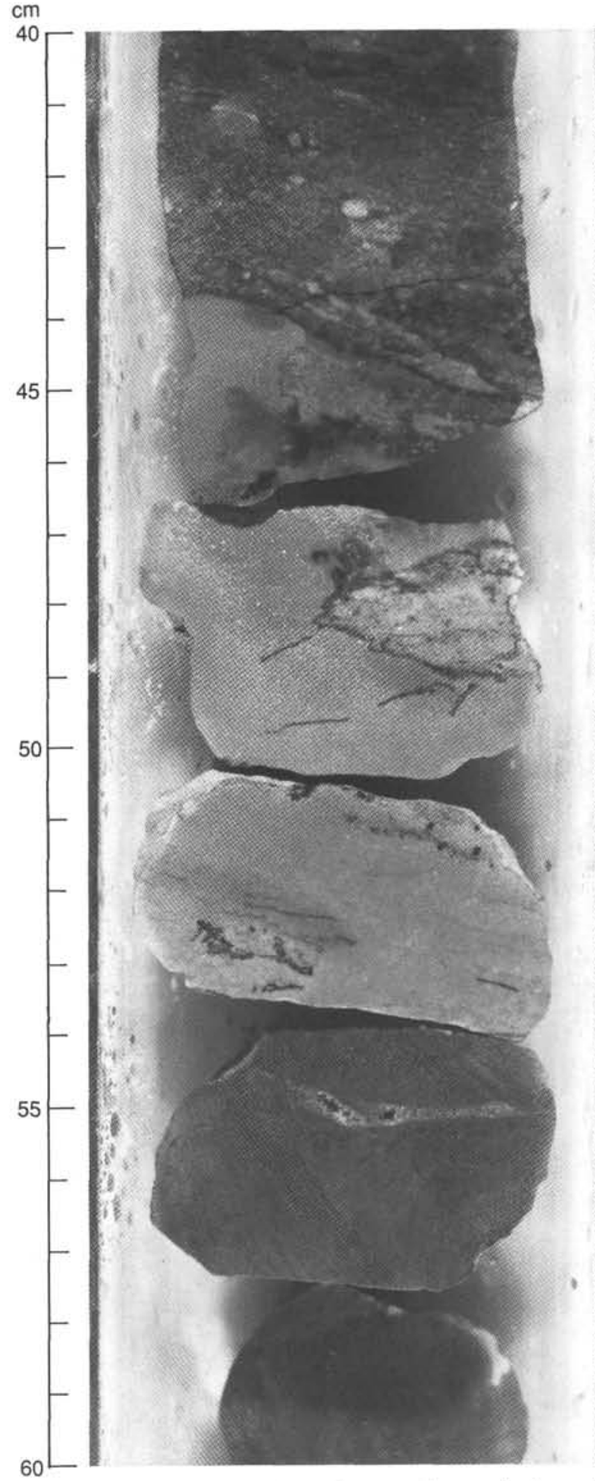

Figure 7. Black manganese oxide stringers and zones in fine-grained carbonate mudstone (Interval 122-764A-7R-1, 40–60 cm) apparently surround and replace allochemical grains and fill burrows.

stones, packstones, grainstones, rudstones, and boundstones. Minor carbonate facies include mudstones, laminated claystones, and dolomitic mudstones. Colors are predominantly white (10YR 8/2, 10YR 7/4), pale brown (10YR 8/3 to 8/4), light yellow-brown (10YR 6/4), olive yellow (2.5Y 6/8), pink (5Y 8/3 or 7YR 7/4), light red (2.5YR 6/8), and red (10YR 4/6).

Fossils within these limestones are abundant and well preserved. Many are whole, and in the boundstones they are very large and appear to represent the actual environment where the fauna and flora lived. Dominant fossil groups represented include colonial hermatypic scleractinian corals (Fig. 10), sponges, pelecypods, brachiopods, echinoderms, and foraminifers. Minor fossil groups identified were green

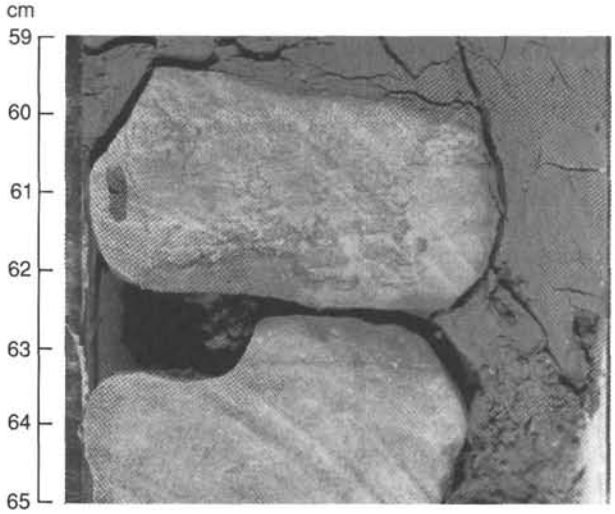

Figure 8. Recrystallized clayey limestone containing approximately 88% calcium carbonate (Interval 122-764B-8R-2, 59–65 cm). Note large clay intraclasts in limestone. Clay remolded by drilling surrounds limestone.

algae, bryozoans, and gastropods. Oolites and oncolites are recognized in several cores (122-764B-9R, -12R, -16R, and -30R). Fecal pellets are also preserved in many grainstones, packstones, and wackestones. Large intraclasts become abundant towards the bottom of the unit (e.g., Cores 122-764B-28R to -30R; see Fig. 11).

Matrix material consists primarily of micrite in the finer grained mudstones and wackestones, although preliminary examination of thin sections indicates many of the rocks are partially dolomitized. Sparite is the other dominant matrix material and is the major component throughout the coarser grained packstones, grainstones, rudstones, and boundstones. Shore-based examination will be needed to confirm these preliminary observations.

Texturally, the grainstones, rudstones, and boundstones are highly porous and vuggy (Fig. 12). Many vugs are infilled with dog-tooth calcite, while others are stained or filled with hematite and limonite. Some were originally coquinas. Other rudstones and boundstones have a vermiform texture indicative of coral and calcareous algal colonies. Many of the limestones are interbedded with hematitic and goethite claystones (Fig. 13). The arrangement of the sediments indicates that the environment was highly agitated and well oxygenated. Conditions periodically changed to allow fine-grained carbonate muds with iron-rich clastics to accumulate. However, it is possible that the oxidation of the majority of the rocks occurred after deposition when the entire Wombat Plateau was uplifted or when sea level fell, which would allow for subaerial exposure and partial erosion. In the lower section of Unit VI (Cores 122-764B-27R through -30R) bioclastic rudstones and floatstones (breccias) are interbedded with wackestones, mudstones, and oolitic grainstones. The rudstone breccia contains transported bioclastic intraclasts with hematitic carbonate mud matrix (Fig. 14). These rocks may represent talus deposits that accumulated either on a fore- or back-reef slope or on a ramp, and were later filled with lime mud. Beneath these rudstone breccias in Interval 122-764B-30R-1, 60–100 cm, is a graded-bed sequence with coarse-grained bioclasts grading into finer grained oolitic grainstones (Fig. 15).

Rhodochrosite (manganese carbonate), which is characteristically pink, and black manganese oxide are present locally

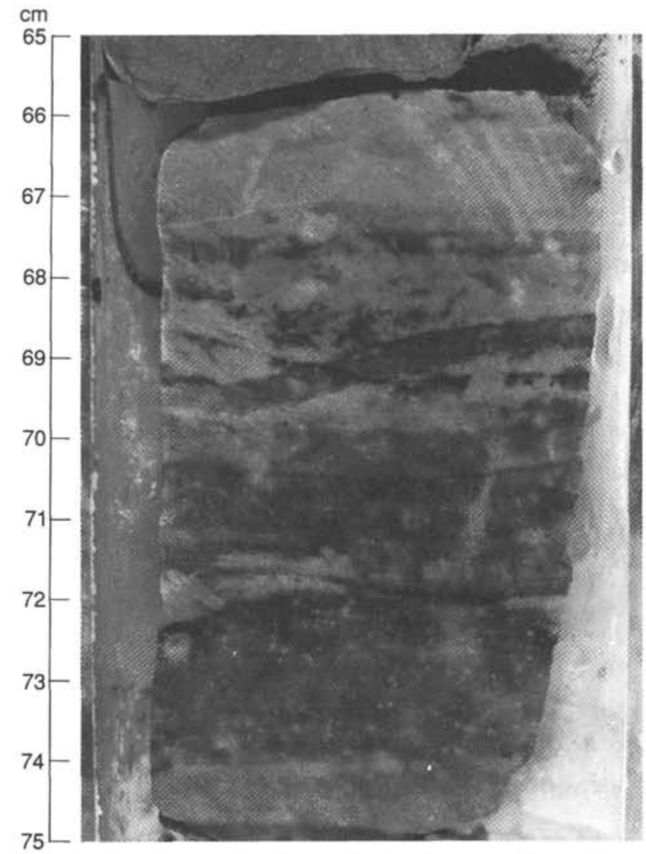

Figure 9. Fine iron-oxide diagenetic banding superimposed upon initial packstone-type sediment in Unit V (Interval 122-764B-8R-2, 65–75 cm). Note mottling and transitional boundary caused by progressive recrystallization.

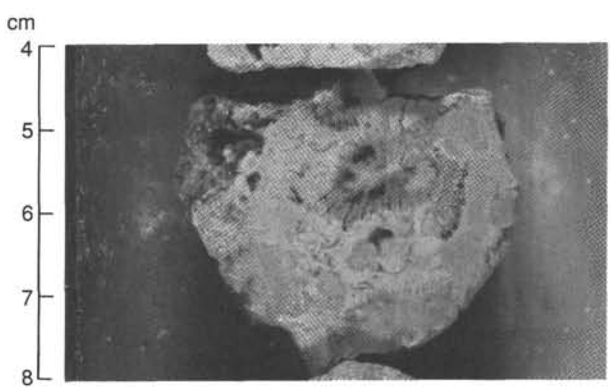

Figure 10. Vuggy coral boundstone with large hermatypic scleractinian corals, brachiopods, and mollusks in Unit VI (Interval 122-764B-27R-1, 4–8 cm).

and as patches in Cores 122-764B-19R through -27R. The presence or absence of the manganese oxide and manganese carbonate phases is dependent on pH and the oxidation potential of the environment. Essentially, for manganese oxide to form from rhodochrosite within normal oceanic pH range, an elevated oxygen content is necessary.

The base of the unit (Core 122-764B-31R) contains carbonate mudstones to wackestones that are overlain by a graded bed having oolitic grainstones at the top. We interpret this to indicate an increase in mechanical energy conditions at the

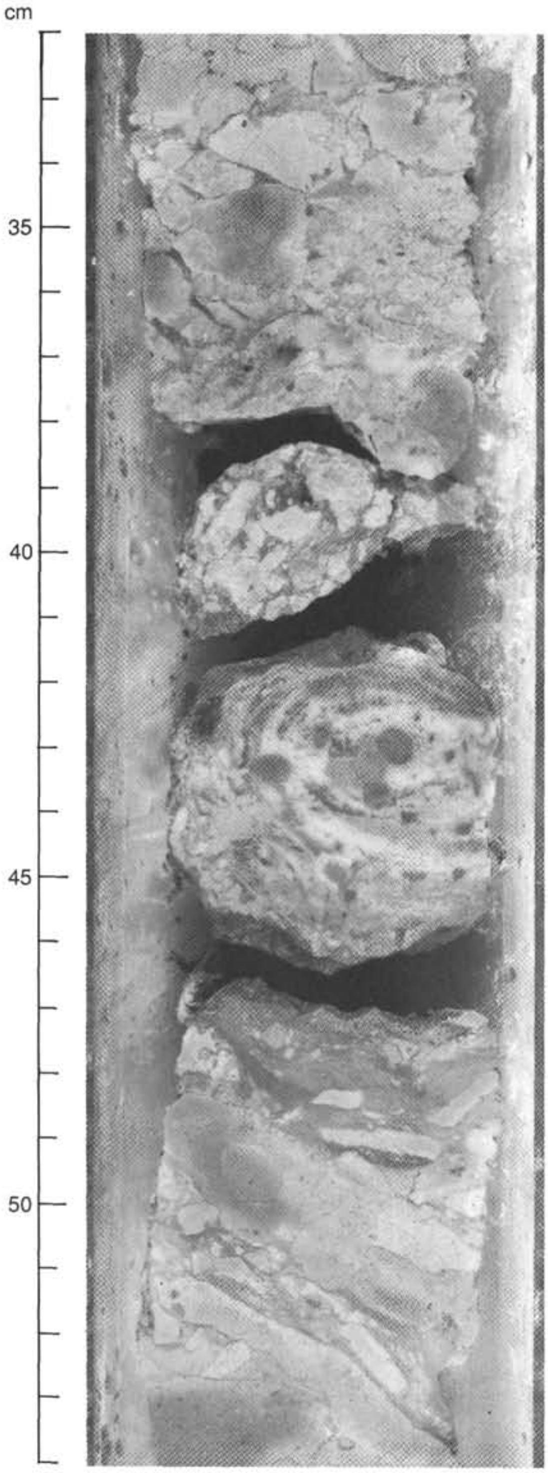

Figure 11. Carbonate rudstone to breccia (Interval 122-764B-28R-1, 32–54 cm). Note large carbonate mudstone intraclasts and possible large concentric oncolite. Dark zones are hematitic.

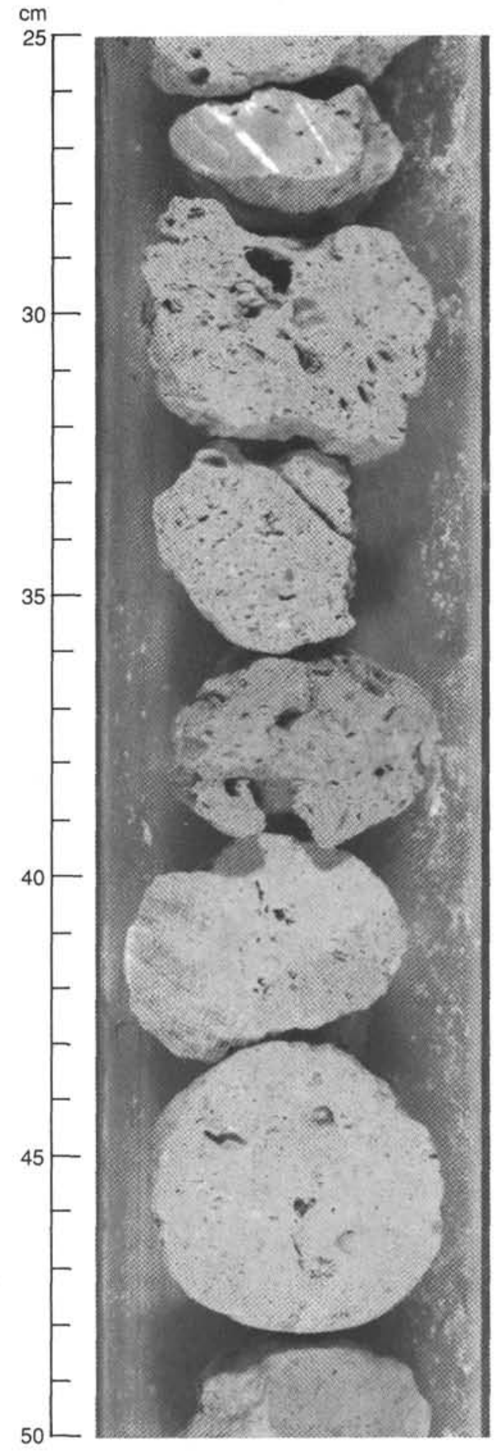

Figure 12. Vuggy and porous texture in wackestones to grainstones (Interval 122-764B-23R-1, 25–50 cm). Note large colonial coral and brachiopod.

depositional site. Above the oolitic grainstones lie the rudstone and carbonate breccia that probably represent reef talus deposits accumulated on a carbonate platform, in a fore- or back-reef environment, or on a gently sloping ramp (Cores 122-764B-30R through -28R). The remainder of Unit VI limestones (Cores 122-764B-27R to -9R) contain reef boundstones and bafflestones alternating with intertidal and back-reef grainstones, packstones, and wackestones, and minor carbonate mudstones. On the basis of our preliminary evaluation of the cores we recorded five cycles of reef to intertidal back-reef facies.

Unit VII (280.15–289.14 mbsf)

Cores 122-764B-31R-1, 95 cm, through -31R-CC.

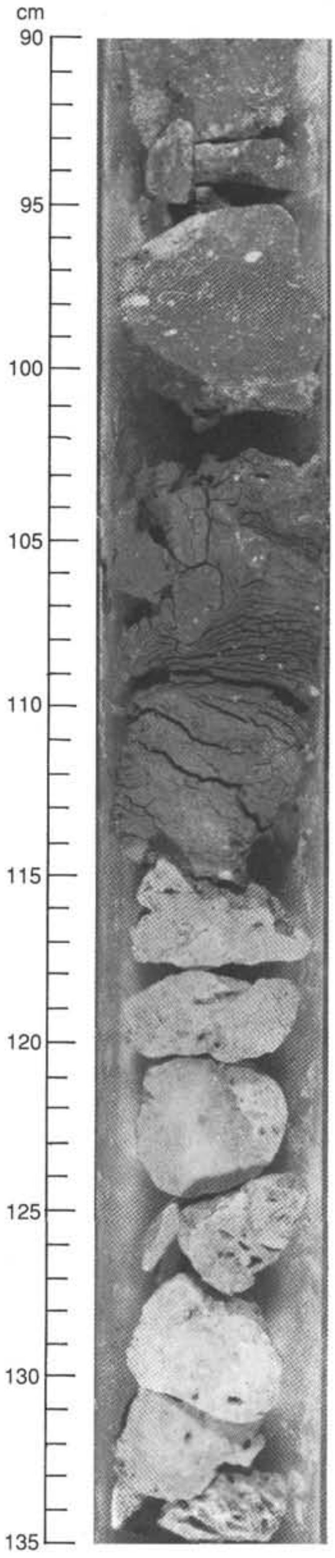

Figure 13. Interbedded white carbonate grainstones and reddish clayey carbonate mudstone (Interval 122-764B-24R-1, 90–135 cm).

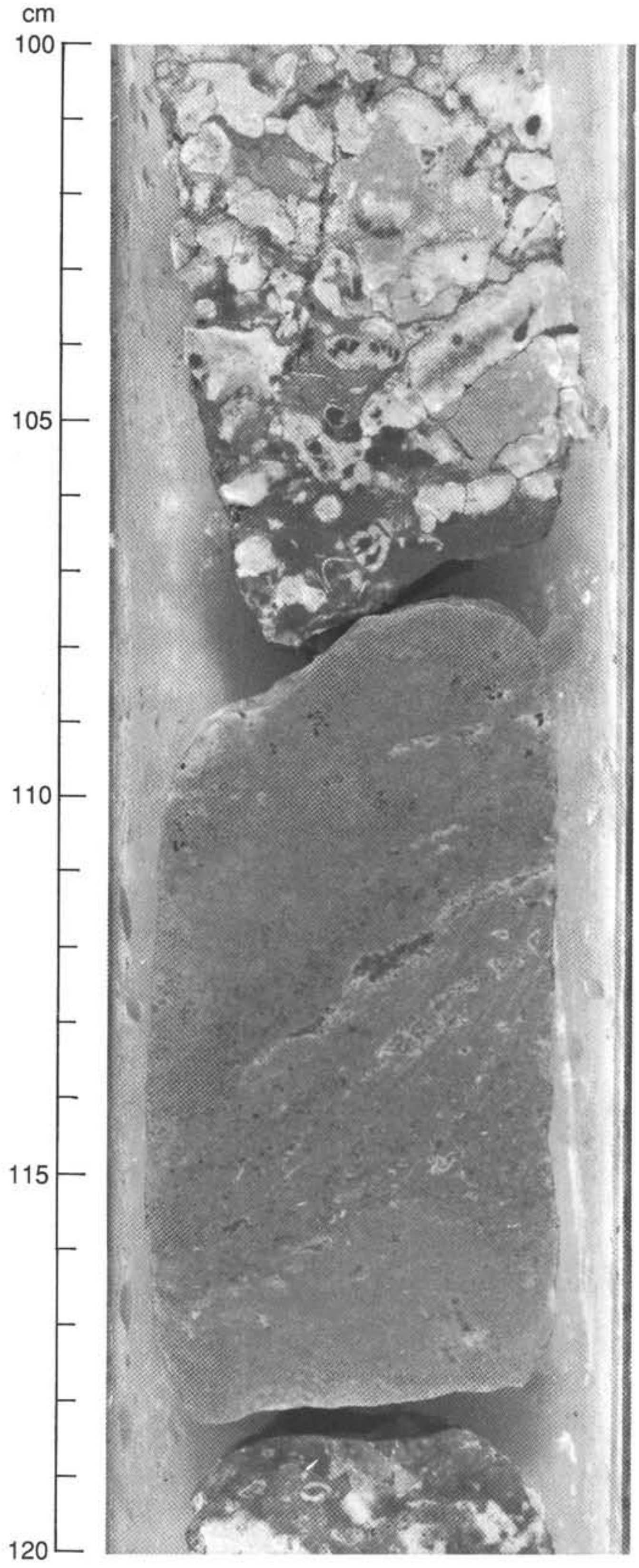

Figure 14. Oxidized carbonate rudstone (breccia) alternating with fine-grained carbonate mudstone (Interval 122-764B-28R-3, 100–120 cm).

Figure 15. Graded interval in grainstones from 60 to 100 cm, with coarse-grained bioclasts grading into finer oolitic grainstones (Interval 122-764B-30R-1, 50–105 cm).

Unit VII consists of very dark gray (5Y 3/1) carbonate mudstone to wackestone, and interbedded light gray (5Y 7/1) carbonate mudstone with clay (beds 5–55 cm thick). The thickness is 8.99 m and the age is inferred to be Rhaetian from dinoflagellates. Core recovery was 66%. The unit is conformably overlain by the very pale brown (10Y 7/4) carbonate mudstone to wackestone of Unit VI. A 9-cm-thick transitional zone (Section 122-764B-31R-1, 95–104 cm) consists of pale brown (10YR 7/4) to gray (N4), moderately bioturbated limonitic carbonate mudstone (Fig. 16).

The carbonate mudstones to wackestones are recrystallized and contain 45%–50% clay, together with minor quartz (1%) and feldspar (2%). The interbedded carbonate mudstones with clay are more recrystallized than the carbonate mudstones to wackestones and have gradational boundaries. The calcium carbonate contents of two samples analyzed from this unit are 62% and 57% (see "Organic Geochemistry," this chapter).

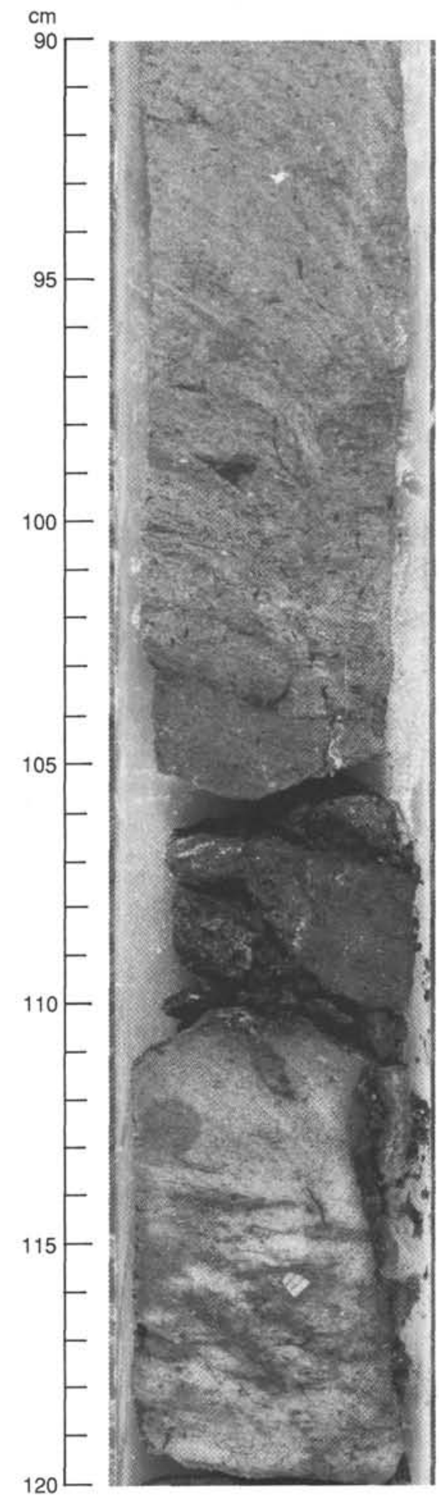

Figure 16. Transition zone from carbonate mudstone/wackestone to limonitic carbonate mudstone with clay, in Unit VII (Interval 122-764B-31R-1, 90–120 cm). Note crinoid fragment at 116 cm.

Crinoid fragments are commonly contained in both the clayey carbonate mudstones to wackestones and the carbonate mudstones with clay (Fig. 16). Bioturbation is strong throughout Unit VII, with some identifiable trace fossils, such as *Teichichnus* and *Zoophycos?*, together with minor polychaete burrows (Sample 122-764B-31R-3, 35–48 cm) and large halo burrows (Sample 122-764B-31R-4, 97–105 cm) (Fig. 17).

Strong bioturbation indicates a plentiful supply of organic matter, which together with the general character of the sediment and biostratigraphic evidence (see "Biostratigraphy," this chapter) suggests an open-marine or back-reef environment. The trace fossil assemblages in Unit VII could also indicate a lagoonal environment (Chamberlain, 1978). Gradational interbedding of the clayey carbonate mudstones to wackestones and carbonate mudstones with clay is caused by differential recrystallization of diagenetic origin, as discussed for Unit V.

Relationship to Site 761

Site 761 was drilled 40 km to the south-southeast of Site 764, and is the nearest site on the Wombat Plateau. The two sites can be correlated using seismic profiles (see "Seismic Stratigraphy," this chapter) and also stratigraphically (Fig. 18); the holes at both sites recovered Cenozoic and late Cretaceous pelagic carbonates, and late Triassic shallow marine carbonates, but the relative proportions of the various components vary considerably between the two sites.

The Cenozoic sequence consists of Eocene and younger oozes and Paleocene chalks in Site 761, where it is 175 m thick, but at Site 764 it is only 40 m thick. In the expanded section of Site 761 there are unconformities above and below the middle Eocene that eliminate the late Paleocene and early Eocene. At Site 764 there are also two unconformities, but they represent a longer period of time. The upper unconformity removes the late Miocene and Pliocene, whereas the lower one removes the Paleocene to middle Eocene. From regional knowledge, it appears that the Eocene-Oligocene unconformity of Site 761 has progressively removed older strata in a northerly direction, until at Site 764 it rests directly on the Maestrichtian.

The Cretaceous sequence is about 80 m thick at Site 761, but only 8 m thick at Site 764. At Site 761 it consists of early Neocomian belemnite-bearing sandstone and Barremian to Maestrichtian chalk and limestone, and at Site 764 of Coniacian to Maestrichtian chalk. The condensed Coniacian to Maestrichtian sequence at Site 764 clearly has been winnowed by current action. We cannot determine whether the absence of the older material is a result of nondeposition or of erosion.

The Rhaetian sequence at Site 761 is about 170 m thick and consists of shelfal to shallow-marine, mainly nonreefal limestone. The Rhaetian is more than 210 m thick at Site 764, and consists largely of reefal and related limestones. Coccolith information suggests that Core 122-761C-30R correlates with Core 122-764B-31R. The thicker Rhaetian sequence above the marls at Site 764 is probably a result of less erosion at the main unconformity above the Triassic, and perhaps also to the presence of reefal sediments in the north. Figure 19 schematically represents a preliminary hypothesis regarding the environments that existed during the Rhaetian at Sites 761 and 764, and a possible scenario for the sequence of events that led to the deposition of sediments that we observed at the two sites.

A likely environmental setting on the Wombat paleo-shelf during the Rhaetian would be a shallow-water environment consisting of patch, platform, or possibly a barrier reef

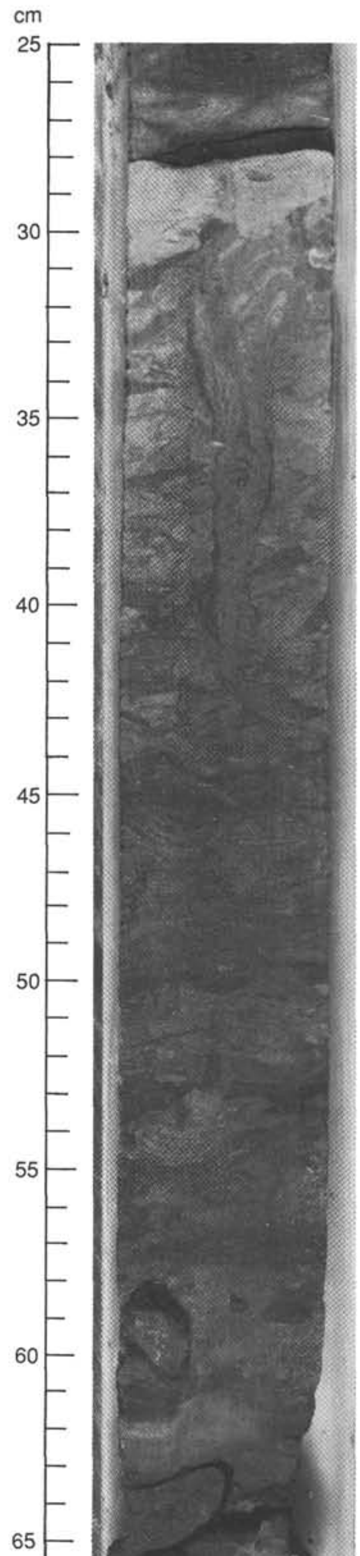

Figure 17. Highly bioturbated clayey carbonate mudstones to carbonate mudstones with silt and clay (Interval 122-764B-31R-3, 25–66 cm). Note large vertical polychaete burrow at 30-43 cm, *Teichichnus* at 54 cm, and *Zoophycos* at 46 cm.

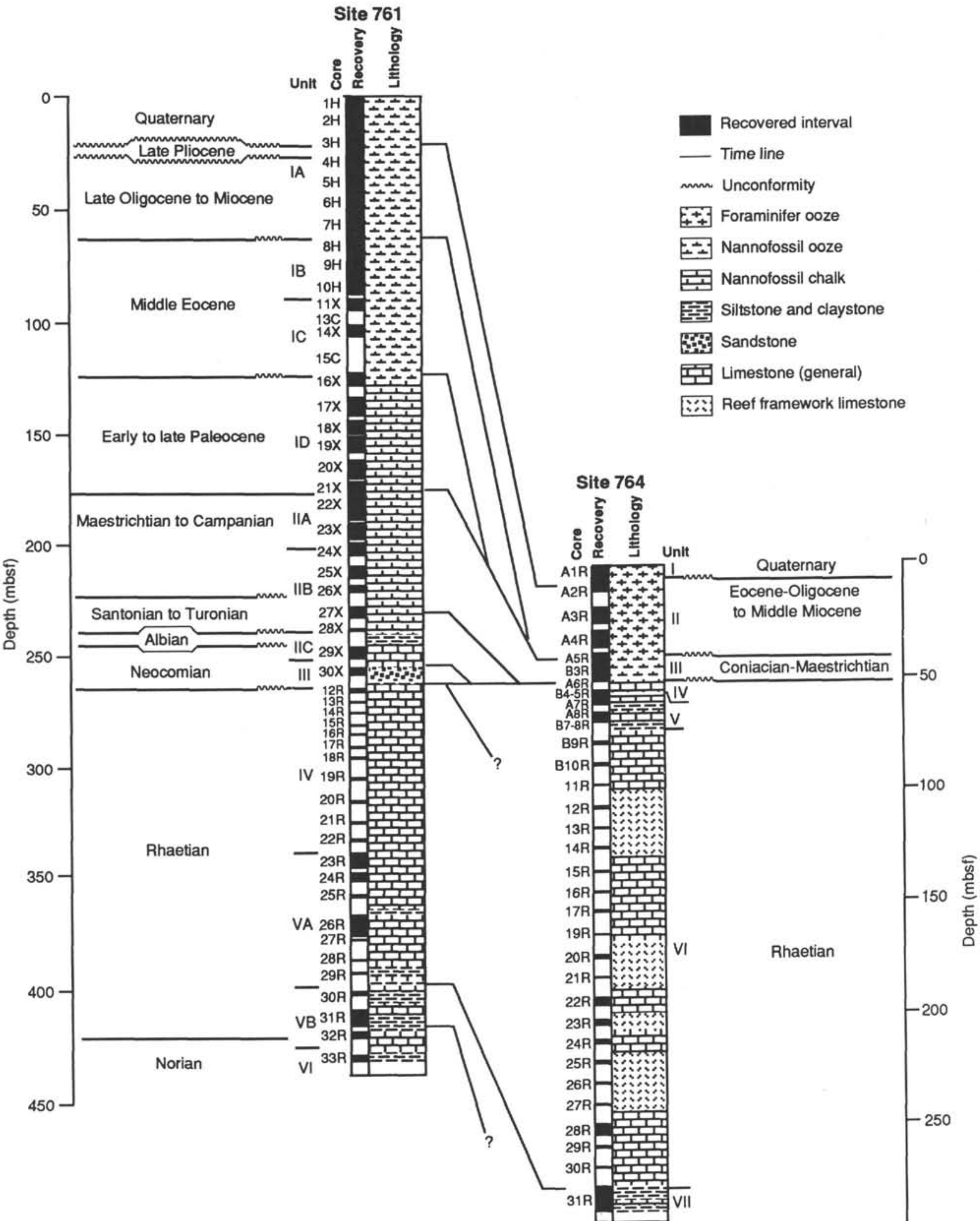

Figure 18. Lithologic and time-stratigraphic correlation between Sites 761 and 764.

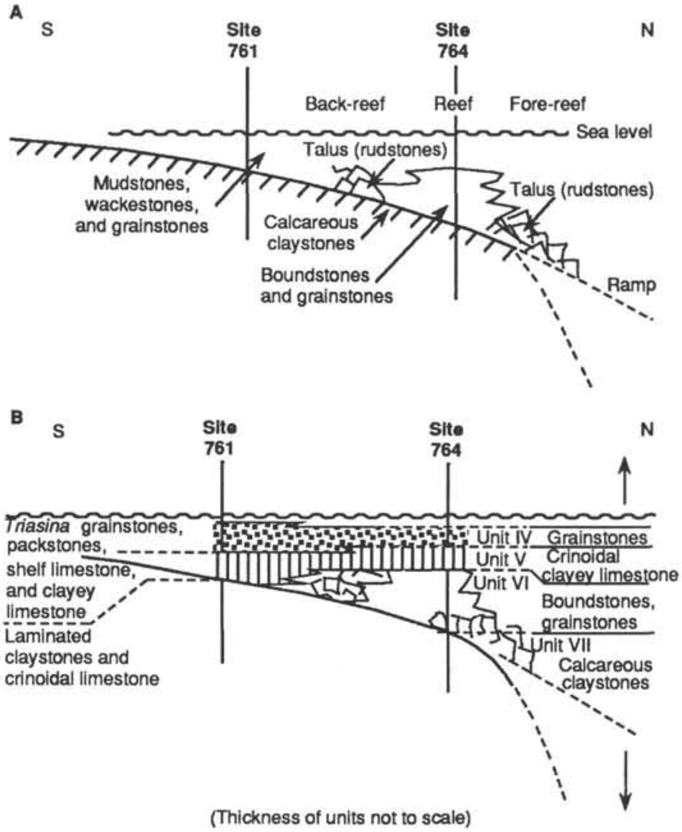

Figure 19. Preliminary schematic representation of carbonate environments at Sites 761 and 764. This model assumes that the uppermost Rhaetian units in Sites 761 and 764 are time-equivalent. **A.** Sedimentary environments and deposition during lowstand. **B.** Sedimentary environments and deposition after drowning by subsidence or sea-level change, producing a sequence boundary below an unconformity (with specific reference to the lithologic units of Sites 761 and 764).

complex. On the basis of our data, the reef complex appears to be centered at or near Site 764. Open oceanic shelf environments existed both in the fore- and back-reef as suggested by a wide variety of open-marine fossil flora and fauna. At both Sites 761 and 764, shelf limestones and marlstones lie underneath grainstones and other limestones containing *Triasina hantkeni*. In addition, Site 761 contains the mollusk *Megalodon*, suggesting neritic to littoral environments.

The two uppermost Rhaetian units at Site 761 (61.0 and 78.8 m thick, respectively) are much thicker than similar rocks at Site 764 (16.6 and 8.8 m thick, respectively). If these units are really time-equivalent (which remains to be confirmed by shore-based studies), their different thicknesses could have been produced by subsequent uplift and erosion and/or migrating lateral environments associated with sea-level fluctuation, currents, nutrient supply, etc. Alternatively, it may be impossible to correlate the uppermost units of Site 764 with those of Site 761 because the latter have been eroded.

BIOSTRATIGRAPHY

Introduction

Site 764 is located on the northern edge of the Wombat Plateau and was chosen in order to drill the youngest possible sediments underlying the break-up unconformity of the Argo Abyssal Plain oceanic basin. Dredge samples from the northern slope of the Wombat Plateau had yielded Early to Middle? Jurassic age dates for such sediments (von Stackelberg et al., 1980; Quilty, 1981; von Rad et al., 1989). The drilled succession consists of an incomplete Cenozoic section unconformably overlying Upper Cretaceous chalk and calcareous ooze. Immediately below a major unconformity, Triassic carbonates were recovered in a thick section of reefal limestone and dolomite. Clayey limestone deposits above and below these carbonate buildups provided good evidence of a Rhaetian age.

In the following paragraphs, the biostratigraphic evidence of the age of the entire succession at Site 764 is presented. This is followed by a discussion of the previously obtained Jurassic ages on northern Wombat carbonate facies, and restudy of this material is suggested for comparison with the Site 764 results.

Core, section		Nannofossil zone	Series
1R	1R-1	NN20-21	Quaternary
	1R-2 to 1R-6	NN19	
2R	1R-7 to 2R-CC	NN4-5	Middle Miocene
	3R-1 to 3R-3	NN3	Lower Miocene
	3R-4	NN1-2	
	3R-5 to 3R-CC	NP25	Upper Oligocene
	4R-CC	NP24	
	5R-3, 10 cm	mixed Oligocene Eocene	Oligocene to Eocene
	5R-3, 55 cm	NK19	Upper Maestrichtian

Figure 20. Cenozoic calcareous nannofossil stratigraphy of Hole 764A. Wavy lines indicate hiatuses.

Calcareous Nannofossils

Occurrence and Preservation

All Tertiary and Upper Cretaceous cores recovered at Holes 764A and 764B contain abundant, well-preserved calcareous nannofossils (Fig. 20), except the hard limestones in Cores 122-764A-6R and -7R, which contain a rare, poorly preserved nannoplankton assemblage. Triassic mudstones in Cores 122-764A-7R and -8R, and 122-764B-5R and -6R, contain a common to abundant, well-preserved nannoflora. Triassic limestones in Cores 122-764B-7R through -30R are barren, or contain only rare, poorly preserved nannofossils. The last core (122-764B-31R) is a mudstone containing few, well-preserved, nannofossils.

Cenozoic Biostratigraphy

At Hole 764A, Section 122-764A-1R-1 is in Zone NN20/21, given the presence of *Emiliania huxleyi* and the absence of *Pseudoemiliania lacunosa* (Fig. 20). Sections 122-764A-1R-2 to -1R-6 are in Zone NN19, as indicated by the presence of *P. lacunosa* and absence of *D. brouweri*. Sections 122-764A-1R-7 to -2R-CC are undifferentiated in Zones NN4/NN5, on the basis of *Sphenolithus heteromorphus* being present and *Sphenolithus belemnos* being absent. Sample 122-764A-3R-3, 30–31 cm, is in Zone NN3, as indicated by the presence of *S. heteromorphus* and rare *S. belemnos*, and the absence of *Triquetrorhabdulus carinatus*. In the underlying section, Sample 122-764A-3R-4, 30–31 cm, contains *S. belemnos*, *T. carinatus*, and *T. challengeri* and is assigned to Zones NN1/NN2, undifferentiated. Core 122-764A-3R clearly represents a condensed section because Sample 122-764A-3R-5, 30–31 cm, and Section 122-764A-3R-CC are in Zone NP25, given the presence of *Sphenolithus ciperoensis* and absence of *Sphenolithus distentus*. Section 122-764A-4R-CC lies in Zone NP 24, as indicated by the co-occurrence of *Sphenolithus distentus* and *S. ciperoensis*. Samples 122-764A-5R-3, 10–11 cm, and -5R-3, 45–46 cm, contain a mixed lower Oligocene–upper Eocene assemblage, which passes into upper Campanian (Zones CC18–CC21) in Sample 122-764A-5R-3, 55–56 cm. Hole 764B was drilled adjacent to 764A. The highest sample studied was 122-764B-2R-1, 85–87 cm. This sample contained an upper Eocene (Zones NP19/NP20) assemblage, indicated by the co-occurrence of *Isthmolithus recurvus* and *Discoaster saipanensis*. A clear stratigraphic break occurs between 88 and 89 cm in Section 122-764B-2R-1. Sample 122-764-2R-1, 91–92 cm, contains mixed Eocene and upper Maestrichtian nannofossils. Upper Maestrichtian sediments (Zone CC25) occur in Sample 122-764B-2R-1, 110–111 cm.

Mesozoic Biostratigraphy

Upper Campanian sediments (Zones CC18–CC21) occur in Sample 122-764A-5R-3, 55–56 cm, and continue downward into Section 122-764A-5R-CC and Sample 122-764A-6R-2, 0–1 cm, indicated by the co-occurrence of *Quadrum gothicum* and *Eiffellithus eximius*. Section 122-764A-6R-CC is a limestone that contains a poorly preserved Coniacian-Campanian nannofossil assemblage. Sample 122-764A-7R-1, 87–88 cm, is a dark gray limestone containing large numbers of *Prinsiosphaera triassica punctata* and *P. triassica perforata*; these species are known only from the Upper Triassic. In Hole 764B, the first Cretaceous encountered is in Sample 122-764B-2R-1, 110–111 cm, which is upper Maestrichtian (Zone CC21), given the presence of *Lithraphidites quadratus* and the absence of *Micula murus*. A hiatus (or severely condensed section) exists between the previous sample and Section 122-764B-3R-CC, which is Campanian (CC18–CC21), on the basis of the co-occurrence of *E. eximius* and *Bronsonia parca*. Below a barren interval in Core 122-764B-4R, Upper Triassic (probably Rhaetian) is recognized in Section 122-764B-5R-CC, indicated by the presence of *Prinsiosphaera triassica* and its subspecies *P. triassica punctata* and *P. triassica hyalina*. Triassic calcareous nannofossils at this level are younger than in Hole 761C on the basis of the occurrences of *Conusphaera zlambachensis* and *Crucirhabdus* cf. *primulus*. The remainder of the hole is largely barren of calcareous nannofossils down to the last section taken, 122-764B-31R-CC, in which *Prinsiosphaera triassica* occurs. Here, however, it is distinctly smaller than higher in the hole.

Foraminifers

Occurrence and Preservation

The Cenozoic succession of Site 764 yielded abundant and well to moderately preserved planktonic foraminiferal faunas. The Cretaceous material (Maestrichtian to Santonian) is slightly more indurated and chalky but still well preserved. The Triassic benthic foraminiferal faunas are exceptionally well preserved in the calcareous mudstones and variable in thin sections of carbonates.

Cenozoic Biostratigraphy

Neogene

Cenozoic sediments were recovered from the upper four cores in Hole 764A. Middle Miocene planktonic foraminiferal assemblages were recovered from Sections 122-764A-1R-CC and -2R-CC. Faunas are characterized by the presence of *Orbulina suturalis*, *Globorotalia peripheroronda*, *Globorotalia peripheroacuta*, and *Globorotalia praemenardii*, indicating lower Middle Miocene Zones N9 to N10.

Sample 122-764A-3R-2, 48–50 cm, belongs to the uppermost Lower Miocene Zone N8, given the presence of *Globigerinoides sicanus* and *Praeorbulina transitoria*. Sample 122-764A-3R-3, 48–50 cm, contains *Globigerinoides* spp. including *G. triloba*, *G. sacculifer*, and *G. altiapertura*. In the absence of *Globoquadrina binaiensis* and *Catapsydrax dissimilis* we assign this sample to Lower Miocene Zone N7. The combined occurrence of *G. binaiensis* and *C. dissimilis* and the absence of *Globorotalia kugleri* in Sample 122-764A-3R-4, 48–50 cm, indicates that this sample belongs to Zone N5. Lowermost Miocene Zone N4 was recognized in Sample 122-764A-3R-5, 48–50 cm, on the basis of the presence of *G. kugleri*.

Paleogene

Section 122-764A-3R-CC contains *Globigerina ciperoensis*, *Globigerina angulisuturalis*, and *Globigerina sellii* without *Neogloboquadrina opima opima*, indicating Upper Oligocene Zone P22. The highest sample to contain *N. opima opima*, which marks the top of Zone P21, is in Section 122-764A-4R-CC. Reworked Eocene fauna including *Acarinina bullbrooki*, *Acarinina primitiva*, and *Turborotalia frontosa*, was recognized in both samples. No older Cenozoic faunas were found above the Cretaceous/Tertiary boundary in Hole 764A.

Mesozoic Biostratigraphy

Cretaceous

Below the Cretaceous/Tertiary boundary, which is clearly an erosional surface at Site 764, there is evidence of Upper Maestrichtian in the planktonic foraminiferal faunas. In Section 122-764A-5R-CC, an assemblage belonging to the *Abathomphalus mayaroensis* Zone (including the zonal marker) is present, in spite of a Campanian age obtained from calcareous nannofossils. In Section 122-764B-2R-CC, the Maestrichtian is also represented (*Rosita contusa*, *Gueblerina cuvillieri*); this occurrence is just below a core sample yielding Maestrichtian calcareous nannofossils and is not accompanied by any planktonic foraminifers indicative of the Campanian.

Evidence of the Campanian was found in Sample 122-764A-6R-2, 1–2 cm, where *Globotruncanita elevata*, *Glo-*

botruncana arca, and *Globotrucana rosetta* are present. However, these species are accompanied by *Marginotruncana coronata* and *Marginotruncana pseudolinneiana*, which would suggest the earliest Campanian or Santonian. Similarly, *Globotruncana ventricosa* and *G. arca* are present in Section 122-764B-3R-CC, together with an upper Santonian assemblage including *Dicarinella asymetrica*, *Marginotruncana sinuosa*, *M. coronata*, and *Hedbergella flandrini*, clearly indicative of the *D. asymetrica* Zone.

In summary, the Maestrichtian to Santonian interval at Site 764 appears to be affected by the mixing of fossils; study of more material is required to separate the effects of syndepositional processes, reworking, and disturbance by drilling.

Sections 122-764A-6R-CC and 122-764B-4R-CC are barren and may belong to the underlying Rhaetian deposits.

Triassic

The stratigraphically highest foraminiferal evidence of Triassic at Site 764 is in Core 122-764A-7R, with several samples containing *Triasina hantkeni*. Perhaps even more significant is the occurrence of *Triasina oberhauseri* in Samples 122-764A-7R-1, 12–14 cm, and -7R-1, 24–27 cm (both occurrences questionable), and, more positively, in Sample 122-764A-7R-1, 32–35 cm, of *Involutina sinuosa* in Samples 122-764A-7R-1, 12–14 cm, and -7R-1, 24–27 cm, and *Glomospirella friedli* in Sample 122-764A-7R-1, 24–27 cm. These benthic foraminifers unambiguously indicate a late Triassic (Rhaetian) age. Further occurrences of Triassic foraminifers are in several thin sections from Core 122-764A-8R, in which *T. hantkeni* still indicates a Rhaetian age. Washed core-catcher samples yielded diverse nodosariid foraminifers and ostracode faunas down to Core 122-764B-6R, and *T. hantkeni* was present in the washed residue from Section 122-764B-12R-CC. The reefal limestones throughout most of the Triassic have not yet been studied in thin section. The lowermost washed sample studied (i.e., Sample 122-764B-31R-CC) contains a foraminiferal fauna with nodosariids, variostomatids, and polymorphinids, indicating a Triassic age, provisionally dated as Carnian or younger on the presence of polymorphinids (Zaninetti, 1976), but which must be Rhaetian on the basis of palynological data.

Radiolarians

Nearly all of the sections from Sites 764 are barren with two exceptions. Most of the sections contain radiolarians preserved as clear, silica-infilled balls and cones with little or no radiolarian meshwork remaining. However, Sample 122-764A-1R-4, 140–142 cm, contains sparse upper Quaternary radiolarians assignable to either the *Buccinosphaera invaginita* or *Collosphaera tuberosa* Zones of Sanfilippo et al. (1985). Other samples from Units I–III are surprisingly barren. Section 122-764A-7R-CC contains poorly preserved pyritized casts of partial tests and spine fragments (generally twisted) questionably identified as *Ferresium* sp. This genus has been reported from Late Triassic (Rhaetian and late Norian) sequences on land in western North America, Japan, and New Zealand. *Ferresium* differs from other Late Triassic radiolarians in having a multilayered test consisting of three layers of polygonal pore frames and thin, fragile, bars connecting nodes at the pore frame vertices (Blome, 1984). Section 122-764B-20R-CC also contains fragments questionably assigned as *Ferresium* sp. All other sections are barren of identifiable radiolarians.

Palynology

Dinoflagellate cysts (*Rhaetogonyaulax* spp. and *Suessia* spp.) were recovered from Sections 122-764A-8R-CC, 122-764B-4R-CC through -7R-CC, and Core 122-764B-31R. Acritarchs and foraminifer liners are common. The spore/pollen assemblage is dominated by pollen (e.g., *Ashmoripollis reducta*, *Falcisporites australis* and *Ovalipollis* spp.). The absence of *Minutosaccus crenulatus* and *Samaropollenites speciosus* indicate the *Ashmoripollis reducta* Zone (Helby et al., 1987), which is Rhaetian in age.

Paleoenvironments

All Cenozoic and Upper Cretaceous oozes and chalks were deposited in offshore, deep marine, pelagic environments, well above the carbonate compensation depth (CCD). Tropical influence increases from old to young in these sediments; the record is too fragmentary, however, to see any trends in detail. The observed unconformities are clearly erosional at Site 764, and we prefer to ascribe the extremely low sedimentation rates to small erosional unconformities caused by bottom currents rather than to extremely low primary pelagic carbonate production (see above).

Details on Triassic paleoenvironments will have to be derived from detailed studies of the reefal facies and the ostracodes from the over- and underlying carbonate mudstones. The foraminiferal faunas from the uppermost part of the Rhaetian carbonate sequence indicate fairly open marine environments of deposition. Whether these were in a relatively open marine back-reef or in a relatively restricted fore-reef setting is possibly a question to be answered by ostracode paleoecology. The reef and associated facies speak for themselves, and more detail on the reefal development may result from the study of the various fossil groups present (crinoids, corals, mollusks, and possibly larger foraminifers). The carbonate mudstones in the lowermost core of this hole are certainly marine, as indicated by a fairly diverse foraminiferal fauna, ostracodes, calcareous nannofossils, and dinoflagellate cysts. Again, the extent to which this environment was restricted must be derived from further investigations on more material.

Discussion of the Rhaetian age of Site 764 Carbonates Versus Liassic Wombat Dredge Samples

Jurassic ages obtained on dredge samples from the northern slope of the Wombat Plateau, and the observation that on seismic profiles the rocks below the regional pre-Cretaceous unconformity seem to be younger northward, led to the expectation that Jurassic rocks would be present at Site 764. From the evidence presented in this chapter, this is not the case and the youngest sediments below the unconformity are Rhaetian in age at and near Site 764.

The evidence for a Jurassic age for the dredge samples from the northern escarpment cannot be exhaustively assessed here because it consists partly of personal communications and unpublished data. Three written reports refer to paleontological evidence:

1. Von Stackelberg et al. (1980) summarized the detailed description of Liassic dredge samples and documented their ages with reference to P. Quilty (unpubl. data on foraminifers),[3] B. Zobel (pers. comm. on foraminifers, 1979), and F. Gramann (pers. comm. on ostracodes, 1979). The latter two specialists apparently compared the Wombat material with the Liassic of Germany and preferred a Pliensbachian age; it remains speculative whether they had included Rhaetian material in their considerations.

[3] See also Quilty (in press), not available during Leg 122.

2. Quilty's findings were published in 1981. He described and illustrated the fauna from three samples; all three were assigned a Sinemurian age based on a comparison of species of the benthic foraminiferal genera *Ichtyolaria* and *Geinitzinita* with material studied by Barnard (1956, 1957) from the Lias of England. Although the similarities of the Wombat specimens and those from England is not disputed here, a comparison with marine Rhaetian faunas (virtually unknown from England) was not included in the discussion. It is noteworthy that this Wombat fauna, however, is somewhat similar to the smaller foraminiferal faunas seen in the Rhaetian of Site 764.

3. Finally, M. Schott (unpubl. data) considered several dredge samples collected by *Rig Seismic* Survey 56 in 1986 to be Liassic in age. The basis of this determination was the occurrence of *Trocholina umbo* in one of the samples, and on considerations of microfacies comparisons with Rhaetian-Liassic rocks from the Northern Calcareous Alps for the others. This material could be examined during the Leg 122 cruise, and one of us (A.A.H.W.) found that the *Trocholina* sp. present in a thin section of one of the samples could be either that species or a similar Triassic form (*Trocholina crassa*, *Trocholina permodiscoides?*). In several of the thin sections assigned a Jurassic age by Schott, terrigenous quartz grains are present. The clean, well-sorted sandy grainstone facies of his facies associations was not observed in any of the thin sections prepared from the Rhaetian rocks of Site 764. The typical reef facies of Site 764 was not present in the dredge samples described by Schott.

It must be concluded that the Wombat Plateau dredge samples are predominantly of an origin that may well be different from the units encountered at Site 764, either stratigraphically or paleoenvironmentally or both. Whether they are older or younger is difficult to assess on the basis of the available evidence, but their age is not necessarily Jurassic. The microfauna described by Quilty (1981) is not unlike the Rhaetian faunas recovered from Site 764, although a detailed study and comparison may show otherwise. The microfacies of many of the samples discussed by Schott is different from that of the Leg 122 samples and may either be older or younger than the Site 764 Rhaetian.

We suggest that the dredge samples from the northern slope of the Wombat Plateau be restudied and carefully compared with the numerous thin sections of Rhaetian carbonates and the washed residues of Rhaetian carbonate mudstones of Site 764. Only then can we ascertain whether they are younger or older than (or coeval with) the Site 764 sediments, and thereby stratigraphically constrain a geological interpretation considering all available sample material.

PALEOMAGNETICS

We measured the NRM (natural remanent magnetization) in Cores 122-764A-3R through -8R and Cores 122-764B-2R through -8R (Units II through V). These cores were demagnetized at 9 mT and measured again. Because of the extremely poor recovery and low-NRM-intensity facies (pale brown reefal limestones), Unit VI was not measured or sampled for paleomagnetic purpose.

The only interval of magnetostratigraphic interest in Site 764 is in the upper Cretaceous (Maestrichtian and Campanian), Core 122-764A-5R and Cores 122-764B-2R and -3R. Given the very low sedimentation rate in the upper Cretaceous at this site (see "Sedimentation Rates," this chapter), these cores were measured at 5-cm spacing intervals and extensively sampled for discrete measurements. The NRM intensities range from about 2 to 8 mA/m, the directions are mostly of normal polarity. The 9-mT alternating field demagnetization has an important effect on the magnetization directions: normal and reversed directions appear clearly after this treatment, which removes an important normal overprint (probably a viscous remanent magnetization).

Given the preliminary biostratigraphic data available during the cruise, no assignments to the magnetic polarity time scale could be made. Additional studies of discrete samples are also necessary and will be done during shore-based investigations.

SEDIMENTATION RATES

Site 764 sedimentation rates could not be calculated accurately owing to (1) the small number of samples per time unit in the Cenozoic, (2) the mixing of sediments in the upper Cretaceous, and (3) the great thickness of sediments of unspecified Rhaetian age.

For the construction of the age-versus-depth plot (Fig. 21) we used the Quaternary age of the sea bed, the apparent absence of any Pliocene and Upper Miocene sediments, and the calcareous nannofossil ages of the post-Triassic section.

As no accurate age within the Rhaetian was available, the Triassic sedimentation rate was not included in the diagram; with a duration of 5 m.y. for the Rhaetian, this rate must have been 50 m/m.y. or more.

Average sedimentation rates were low to very low in the Cenozoic of Site 764. The Quaternary appears to have been deposited at the highest rate, but this result is poorly constrained by the data. Middle Miocene to Late Oligocene rates were on the order of 0.2 cm/k.y. The average rate was negligible for the older Cenozoic and was <0.1 cm/k.y. for the Cretaceous. The sediments, however, are not typical of condensed pelagic sequences (i.e., their carbonate content is high and they are not thinly bedded or laminated) and we suspect that numerous biostratigraphically undetectable unconformities removed much of the normal thickness of the carbonates.

ORGANIC GEOCHEMISTRY

Shipboard organic geochemical analyses at Site 764 consisted of 47 determinations of inorganic carbon, 11 Rock-Eval and total organic carbon (TOC) analyses, and 15 measurements of low-molecular-weight hydrocarbons. The procedures used for these determinations are outlined in the "Explanatory Notes" (this volume) and are described in detail by Emeis and Kvenvolden (1986).

Inorganic and Organic Carbon

Results of analyses of inorganic carbon in samples from Holes 764A and 764B are listed in Table 3. Calculated estimates of percentages of calcium carbonate are given, assuming the inorganic carbon is made up totally of calcite. Several samples have very close to 12% inorganic carbon, and Sample 122-764B-15R-CC, 8–10 cm, exceeds this value. Samples that contain or consist of dolomite or other noncalcitic carbonate minerals must use appropriate stoichiometric normalization (i.e., other than simply $CaCO_3$), in order to derive a meaningful carbonate mineral content based on the inorganic carbon content, the parameter that is actually measured.

Organic carbon determinations made on the dark-colored, bioturbated, marly limestone recovered in Core 122-764B-31R indicate that this content averages about 0.3% in Unit VII, with one value exceeding 0.5% (Table 4). Organic carbon measurements were not attempted from shallower lithologic units because the light colors of the calcareous rocks indicated little organic matter, an assumption borne out by the analysis of one sample (122-764B-31R-1, 21–25 cm) from the base of Unit VI that was devoid of organic carbon.

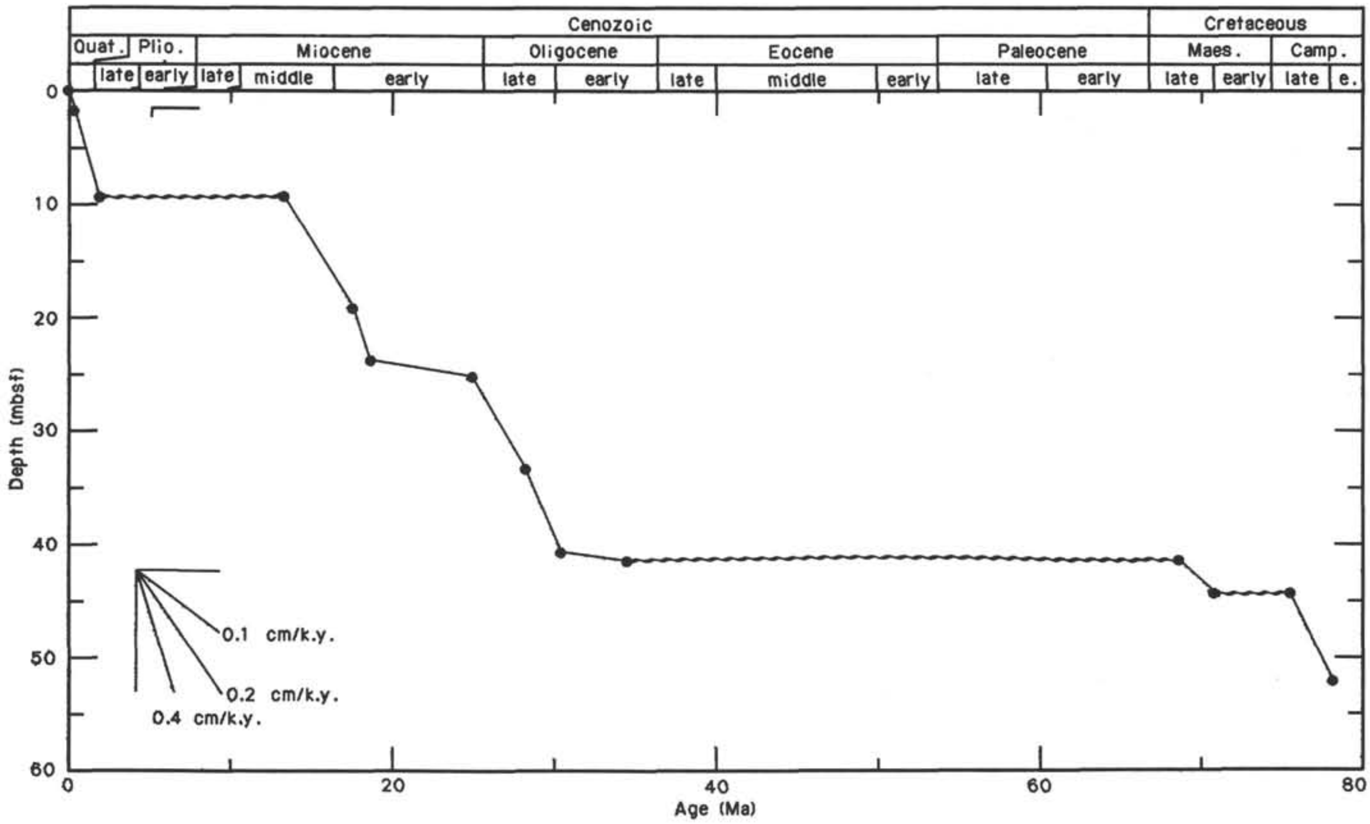

Figure 21. Sedimentation rates at Site 764. Wavy lines indicate hiatuses. Error bars for depth and age are shown at top left. Techniques used to calculate sedimentation rates are described in "Explanatory Notes."

Rock-Eval Pyrolysis

The results of Rock-Eval pyrolysis and total organic carbon (TOC) analysis of samples from Core 122-764B-31R are listed in Table 4. The pyrolysis yields of hydrocarbon (S_1 and S_2) are much lower than expected for the amount of TOC present, indicating that the organic matter in these samples is either highly thermally altered (i.e., overmature in a petroleum generation sense) or, more likely, extensively oxidized at or near the sediment-water interface (i.e., biologically reworked). Because of these low values, all parameters derived from them as ratios, such as PI (production index), HI (hydrogen index), and OI (oxygen index), cannot be considered as reliable. Similarly, the pyrolyzable hydrocarbon yield (S_2) is too small and too variable to provide a truly meaningful T_{max} (and hence, thermal maturity determination).

The inert nature of the organic matter precludes actual determination of the original organic matter type. The oxygen index values are believed to be exaggerated because of an artifactual contribution to the S_3 peak from carbonate decomposition during analysis at temperatures below the 390°C cutoff. It is possible, however, that the original organic matter in the dark-colored Rhaetian limestones at the bottom of Hole 764B contained a large proportion of land-derived material, similar to the organic matter type present in Triassic clastic sediments found at Sites 759, 760, and 761 on the Wombat Plateau.

Low-Molecular-Weight Hydrocarbons

A total of 15 samples from Holes 764A and 764B were subjected to headspace analysis of low-molecular-weight hydrocarbons. The results (Table 5) are similar to those of the other sites drilled on the Wombat Plateau (Sites 759, 760, and 761) in that very low concentrations of gas were observed (usually at the level of the laboratory blank) with no ethane or higher homologs detected.

INORGANIC GEOCHEMISTRY

The inorganic geochemistry procedures at Site 764 were limited. Due to the occurrence of hard rock substrate and poor core recovery only two interstitial water samples were taken from the uppermost 25 m of Hole 764A. The results of chemical analyses are presented in Table 6. These samples suggest profiles similar to those previously encountered at other sites during Leg 122. These include a decrease in Mg^{2+} with depth and a decrease in SiO_2 within the first 30 mbsf due to early diagenesis of radiolarian tests. No other trends are discernible from the data available.

Availability of regulated power during the transit to Singapore permitted operation of the X-ray diffractometer. A suite of samples from Sites 759, 760, 761 and 764 were analyzed.

PHYSICAL PROPERTIES

Introduction

The physical properties determined from sediments of Wombat Plateau Site 764 include compressional-wave velocity, velocity anisotropy, shear strength, formation factor, and the index properties (wet-bulk density, grain density, porosity, and water content; see "Explanatory Notes," this volume). Two holes were drilled with the rotary core barrel (RCB) at this site: Hole 764A was drilled to 69.0 mbsf, and Hole 764B was washed down to 40 mbsf and drilled to 294.5 mbsf. Thermal conductivity was not measured at this site due

Table 3. Concentrations of inorganic carbon and calcium carbonate in samples from Holes 764A and 764B. Inorganic carbon concentrations were measured coulometrically. Calcium carbonate percentages were calculated assuming the carbonate contents to be pure calcite on a dry weight basis. Samples listed according to depth (mbsf).

Hole, core, section, interval (cm)	Depth (mbsf)	Weight (mg)	Inorganic carbon (%)	$CaCO_3$ (%)
Unit I: Quaternary pink foraminifer ooze				
764A-1R-5, 96–98	7.0	20.36	10.20	84.96
764A-1R-7 30–32	9.3	20.12	10.76	89.63
764A-2R-1, 36–38	9.9	20.12	9.70	80.80
Unit II: Miocene to Oligocene light gray nannofossil ooze				
764A-3R-1, 74–76	19.7	20.32	10.46	87.13
764A-3R-3, 76–78	22.8	20.57	8.84	73.63
764A-3R-5, 60–62	25.6	20.86	9.61	80.05
764A-4R-1, 80–82	29.3	20.47	10.64	88.63
764A-4R-3, 80–82	32.3	20.84	10.77	89.71
764A-4R-5, 60–62	35.1	20.85	10.41	86.71
764A-5R-2, 2–4	39.5	21.29	10.75	89.54
Unit III: Maestrichtian to Coniacian white nannofossil chalk				
764B-2R-1, 53–55	40.5	21.45	10.81	90.04
764B-2R-2, 72–74	42.2	21.90	10.78	89.79
764A-5R-4, 32–34	42.8	20.14	10.41	86.71
764B-3R-1, 56–58	45.6	20.43	10.73	89.38
764A-6R-1, 28–30	47.8	21.91	10.83	90.21
Unit IV: Rhaetian white limestone				
764A-7R-1, 67–70	57.7	20.21	10.38	86.46
764A-7R-2, 42–45	58.9	21.36	3.54	29.48
764B-6R-1, 50–52	60.5	24.61	9.68	80.63
Unit V: Rhaetian gray limestone				
764B-7R-1, 91–93	65.9	26.31	10.60	88.29
764A-8R-1, 21–24	66.7	22.52	10.11	84.21
764B-8R-1, 38–40	70.4	20.46	10.53	87.71
764B-8R-1, 142–144	71.4	27.96	10.13	84.38
Unit VI: Rhaetian multicolored limestones and rudstones				
764B-9R-1, 10–13	79.6	23.43	11.62	96.79
764B-11R-1, 78–80	99.3	20.52	10.78	89.79
764B-12R-1, 41–43	108.4	21.03	11.26	93.79
764B-13R-1, 8–10	117.6	21.81	11.90	99.12
764B-14R-CC, 8–10	127.6	20.08	11.86	98.79
764B-15R-CC, 8–10	136.7	19.92	12.18	101.45
764B-16R-CC, 4–5	146.3	20.68	11.75	97.87
764B-20R-1, 80–82	175.8	19.12	11.80	98.29
764B-22R-2, 26–29	195.8	29.01	10.25	85.38
764B-24R-1, 54–56	213.5	29.61	9.87	82.21
764B-25R-1, 36–38	222.9	21.20	11.77	98.04
764B-26R-1, 45–47	232.5	20.05	11.86	98.79
764B-27R-1, 40–42	241.9	23.13	10.94	91.13
764B-28R-2, 72–74	253.2	20.75	10.54	87.79
764B-29R-1, 98–100	261.5	19.74	11.08	92.29
764B-31R-1, 21–25	279.7	20.93	11.19	93.21
764B-31R-1, 68–70	280.2	21.96	11.56	96.29
Unit VII: Rhaetian dark gray clayey limestone				
764B-31R-2, 15–18	281.1	20.78	11.39	94.88
764B-31R-3, 19–21	282.6	18.58	7.50	62.48
764B-31R-3, 78–80	283.3	23.99	7.50	62.48
764B-31R-5, 17–20	285.6	21.35	7.23	60.23
764B-31R-5, 87–89	286.4	23.61	6.94	57.81
764B-31R-7, 7–11	288.5	23.17	7.87	65.56
764B-31R-CC, 16–20	289.6	21.37	7.72	64.31

to instrument malfunction. GRAPE and *P*-wave logging were not used because both holes were rotary-drilled. All other physical-property measurements were conducted at Hole 764A until lithified sediments were reached at about 50 mbsf. Below this depth and in all of Hole 764B only velocity and index properties were measured. The values of the various physical properties are listed in Table 7 and their trends with depth are illustrated in Figures 22 and 23.

Velocity

The mean compressional velocity data from Site 764, determined with the Hamilton Frame (Fig. 22), show a range from 1.52 to 5.32 km/s, with the well-lithified sediments (limestones) having high velocities and the poorly-lithified sediments (oozes) having low velocities. Between 0 to about 50 mbsf, velocities tend to be approximately constant at about 1.55 km/s, with no clear distinction between ooze and chalk (Units I, II, and III; "Lithostratigraphy," this chapter). Velocities between about 50 and 280 mbsf are high (due to well-lithified limestones, grainstones, and calcareous claystones), averaging 4.0 km/s. There are no apparent differences in the velocity data between the various lithologic units (Units IV, V, and VI) within this depth range. The drop in velocity to about 2.2 km/s below 280 mbsf marks the contact of reef complex material (Unit VI) with the underlying less-lithified calcareous claystones (Unit VII). The high-velocity sample at the bottom of the hole (289 mbsf) is a clayey limestone of Unit VII. Velocity anisotropy (Fig. 22) for the gray limestones and the tan-to-orange dolomites of Units IV, V, and VI is predominantly negative, while anisotropy is positive for the less lithified calcareous claystones of Unit VII.

Index Properties

Grain density values (Fig. 22) are relatively constant throughout the hole (about 2.68 g/cm^3), although some scatter is evident. Bulk densities (Fig. 22) increase linearly with depth from 1.5 to 1.9 g/cm^3 through the oozes and chalks from the top of the hole to about 50 mbsf (the contact of Units III and IV). Bulk density then increases from approximately 1.9 to 2.55 g/cm^3 in the lithified carbonates and remains at about that value until 280 mbsf (contact of Units VI and VII) where it decreases to 2.2 g/cm^3 in the calcareous claystones. The one sample below 280 mbsf with a higher bulk density (2.6 g/cm^3) is a well-lithified clayey limestone.

Porosity and water content (Fig. 22) mirror the changes in bulk density. Porosity decreases linearly from 70% to 50% until the contact between Units III and IV at 50 mbsf. Porosity fluctuates between 10% and 30% in Units IV, V, and VI. At the contact between Units VI and VII (280 mbsf), porosity increases from about 10% to 34%.

Shear Strength and Formation Factor

Shear strength and formation factor (Fig. 23) were measured only in Hole 764A on a few samples as hard material was encountered below 50 mbsf. These properties show no correlation either with each other, velocity, or index properties.

Discussion

Physical-property trends with depth correlate with the various lithologic units. Units I, II, and III have relatively constant velocities of about 1.55 km/s. Units IV, V, and VI have high velocities (average = 4.0 km/s) and high wet-bulk densities (average = 2.55 g/cm^3). Unit VII has both low and high velocities due to the variability in sediment lithification.

Velocity anisotropy is usually positive ($V_{ph} > V_{pv}$) in normally bedded sediments. The unusual occurrence of negative anisotropy ($V_{pv} > V_{ph}$) in most of the lithified carbonates may be due to diagenetic orientation of calcite c-axes perpendicular to bedding, as velocities in single-crystal calcite are slowest along the c-axis. Alternately, the *in-situ* growth of sessile calcite fossils tends to grow upward (toward the photic zone), and hence a statistical density anisotropy with the densest direction perpendicular to the bedding plane can be assumed. Texture analysis would be necessary to confirm these assumptions.

Table 4. Rock-Eval data from samples from Hole 764B. Total organic carbon (TOC) percentages are on a whole sediment, dry-weight basis.

Core, section, interval (cm)	Depth (mbsf)	Wt. (mg)	T_{max} (°C)	S_1	S_2	S_3	PI	S_2/S_3	PC	TOC (%)	HI	OI
122-764B-												
31R-1, 21–25	279.7	99.8	216	0.00	0.00	0.70			0.00	0.00	0	0
31R-2, 15–18	281.1	99.6	227	0.00	0.00	0.99		0.00	0.00	0.04	0	2475
31R-3, 19–21	282.6	99.6	304	0.00	0.05	0.84	0.00	0.05	0.00	0.23	21	365
31R-3, 78–80	283.2	99.0	370	0.00	0.05	1.53	0.00	0.03	0.00	0.43	11	355
31R-4, 17–20	284.1	100.3	341	0.00	0.08	1.39	0.00	0.05	0.00	0.55	14	252
31R-5, 0–2	285.5	100.3	304	0.02	0.20	1.28	0.09	0.15	0.01	0.33	60	387
31R-5, 0–2	285.5	98.7	249	0.00	0.06	1.31	0.00	0.04	0.00	0.34	17	385
31R-5, 17–20	285.6	101.0	303	0.00	0.05	1.00	0.00	0.05	0.00	0.37	13	270
31R-5, 87–89	286.3	102.8	304	0.00	0.05	1.25	0.00	0.04	0.00	0.36	13	347
31R-7, 7–11	288.5	100.3	270	0.00	0.01	0.58		0.01	0.00	0.25	4	232
31R-CC, 16–20	289.6	99.3	304	0.00	0.03	0.70	0.00	0.04	0.00	0.26	11	269

Table 5. Concentrations of low-molecular-weight hydrocarbons of samples from Holes 764A and 764B. Analyses were done with the Carle gas chromatograph. Data are from headspace samples. Concentrations are given in parts per million of headspace volume.

Core, section, interval (cm)	Depth (mbsf)	C_1	C_2
122-764A-			
1R-5, 0–5	6.0	1.7	0
2R-1, 0–5	9.5	1.7	0
3R-5, 0–2	25.0	1.7	0
4R-5, 0–2	34.5	1.8	0
6R-2, 0–2	49.0	1.7	0
7R-2, 0–2	58.5	2.1	0
8R-2, 0–2	68.0	1.8	0
122-764B-			
7R-1, 0–2	65.0	26	0
8R-2, 0–2	71.5	25	0
11R-CC, 0–2	100.0	3.0	0
15R-CC, 0–2	138.0	2.0	0
20R-1, 0–2	175.5	1.9	0
24R-1, 0–2	213.0	2.1	0
27R-1, 0–2	241.5	1.8	0
31R-5, 0–2	285.5	2.9	0

SEISMIC STRATIGRAPHY

Seismic Correlation

The original *Rig Seismic* reflection site survey for Leg 122 Sites 759 and 760 consisted of BMR Lines 56-13 and 56-20, which were shot in 1986 and processed in 1987 (Exon and Williamson, 1988). Sites 761 and 764 were planned for locations on Line 56-13. The locations of these original site survey lines and of the site survey lines collected by *JOIDES Resolution* on Leg 122 are shown in Figure 24. The main seismic reflectors on the Wombat Plateau, on the Exmouth Plateau to the south, and on the Argo Abyssal Plain to the north are interpreted as being associated with unconformities within the Mesozoic and Tertiary sections (Fig. 25).

The quality of the seismic reflection data was generally good, but few well-defined and continuous reflectors were recorded on Lines BMR 56-13 and 56-20B and Leg 122 Lines 122-1 and 122-2 close to the southern escarpment of the Wombat Plateau where Site 759 was located. This was considered to be at least partly due to interference from diffracted arrivals originating from the escarpment. Good seismic reflection records were, however, recorded on BMR Line 56-13 and Line 122-2 at the location of Site 760, which was located sufficiently far from the escarpment so that data quality was not affected by diffractions. The projected position of Site 760 onto Line 56-20A, however, showed fewer reflections due to the presence of a fault cutting Line 56-20A at an acute angle in that location. A good reflection record was recorded at Site 761 on the central plateau both on Lines 122-1 and 122-3, shot during Leg 122, and for the position of Site 761 projected onto Line 56-13. At Site 764 on the northern Wombat Plateau the quality of data on Line 56-13 and Line 122-6, and at the projected location onto Line 122-1 is good, and seismic horizons can be defined at the top of the Cretaceous, at the main Mesozoic unconformity, and within the Triassic.

Navigation of the *Rig Seismic* site survey and Line 56-13 was reduced in accuracy due to the limited availability (seven hours per day) of full global positioning system (GPS) satellite navigation coverage; however, a long-distance DECCA HIFIX navigation system was employed outside the times when full GPS coverage was available as an attempt to retain high navigational accuracy. Leg 122 seismic reflection data used to locate Site 759, the north-south line through Site 761, and Line 122-1 were collected when GPS satellite navigation was unavailable. However, GPS navigation was available for locating Site 760 and for the east-west line through Site 761. GPS satellite navigation was not available for any seismic reflection line used for planning Site 764 or for locating that site. Some mistaken correlations between *Rig Seismic* and Leg 122 seismic reflection lines were found to occur. Consequently, detailed seismic correlations and hole projections onto Lines 56-13, 56-20A and 56-20B, and Line 122-1B must considered with some caution.

Site 759 is located on the extreme southern edge of the Wombat Plateau in water depths of 2092 m. It projects 0.3 km south to shotpoint 114.1026 on line 56-20B and (along the bathymetric contour) projects 1.0 km west to shotpoint 111.2310 on Line 56-13. At Site 759 (Fig. 25), thin Neogene pelagic sediments overlie a strong angular unconformity above Triassic strata that dip northwards. Large velocity and density variations occur from Neogene oozes to Triassic consolidated strata, and velocity and density variations also exist between Triassic limestones and shales. A high-amplitude seismic reflector corresponds to the angular unconformity at the boundary between the Neogene oozes and the Triassic sediments. Within the Triassic sediments, reflectors were recorded that correspond to the major lithological changes. These reflectors were best seen at the projected position of Site 759 onto Line 56-13, and have an apparent dip of approximately 8° to the north along Line 56-13. The true dip calculated at the intersection of Lines 56-13 and 56-20B is

Table 6. Interstitial water analyses, Site 764.

Core, section, interval (cm)	Depth (mbsf)	Vol. (cm^3)	pH	Alk. (mM)	Sal. (g/kg)	Mg^{2+} (mM)	Ca^{2+} (mM)	Mg^{2+}/Ca^{2+}	Cl^- (mM)	SO_4^{2-} (mM)	SiO_2 (mM)
122-764A-											
1R-4, 145–150	6.0	50	7.61	3.645	35.8	53.6	10.9	4.90	561	28.54	0.931
3R-4, 145–150	25.0	35	7.55	3.116	35.6	51.7	10.7	4.82	563	29.82	0.384

Table 7. Physical-property data, Site 764.

Core, section, interval (cm)	Depth (mbsf)	V_{ph} (km/s)	V_{pv} (km/s)	Anisotropy (%)	Bulk density (g/cm^3)	Porosity (%)	Water content (%)	Grain density (g/cm^3)	Formation factor (Horizontal)	Formation factor (Vertical)	Shear strength (kPa)
122-764A-											
1R-5, 96	6.96	1.519			1.57	69.3	45.2	2.83			4.700
1R-7, 30	9.30	1.555			1.70	62.8	37.8	2.86			9.400
2R-1, 40	9.90	1.545			1.63	66.0	41.4	2.67			15.700
3R-1, 80	19.80	1.539			1.70	61.9	37.3	2.68	2.65	2.62	27.400
3R-3, 80	22.80	1.586			1.66	64.3	39.7	2.66	2.81	2.64	11.200
3R-5, 60	25.60	1.584			1.77	59.7	34.6	2.68			40.400
4R-1, 80	29.30	1.591			1.85	55.4	30.6	2.76	3.38	2.96	20.200
4R-3, 80	32.30	1.589			1.81	57.1	32.4	2.70	2.88	2.62	11.200
4R-5, 60	35.10	1.560			1.77	58.6	33.9	2.71	2.60	2.42	20.200
5R-2, 6	39.56	1.597			1.85	54.4	30.2	2.59	2.49	2.35	42.700
5R-4, 32	42.82	1.544			1.79	61.1	34.9	2.65	3.65	3.01	
6R-1, 30	47.80	1.588			1.88	56.6	30.9	2.74	2.23	2.07	
7R-1, 60	57.69	3.845	4.217	−9.228	2.64	7.9	3.1	2.72			
7R-2, 43	58.93	1.514			1.65	68.8	42.8	2.56			
8R-1, 22	66.72	3.125	3.286	−5.023	2.54	17.8	7.2	2.72			
122-764B-											
2R-1, 53	40.53	1.692			1.92	51.4	27.4	2.74			
2R-2, 72	42.22	1.575			1.79	54.7	31.3	2.72			
3R-1, 55	45.55	1.674			1.90	50.6	27.3	2.69			
4R-1, 33	50.33	3.353									
5R-1, 43	55.43	5.305									
6R-1, 52	60.52	2.985	3.086	−3.327	2.46	17.1	7.1	2.69			
7R-1, 92	65.92	3.279	3.240	1.197	2.48	15.3	6.3	2.70			
8R-1, 38	70.38	3.254	3.361	−3.235	2.52	12.7	5.2	2.68			
8R-1, 143	71.43	3.128	3.282	−4.805	2.48	15.3	6.3	2.70			
9R-1, 10	79.60	4.141			2.56	17.1	6.8	2.76			
11R-1, 78	99.28	2.862			2.36	27.6	12.0	2.71			
12R-1, 41	108.41	5.175			2.49	20.7	8.5	2.66			
13R-1, 8	117.58	4.656			2.33	26.2	11.5	2.63			
14R-CC, 8	127.08	4.862			2.63	11.9	4.6	2.68			
15R-CC, 8	136.58	4.019			2.63	16.7	6.5	2.77			
16R-CC, 4	146.04	3.162			2.32	31.6	13.9	2.66			
18R-CC, 2	160.52	4.218									
19R-1, 2	165.52	4.114									
20R-1, 80	175.80	4.090			2.50	23.7	9.7	2.78			
21R-CC, 10	184.60	3.047									
22R-2, 27	195.77	3.890	3.771	3.107	2.62	33.1	13.0	2.58			
23R-1, 73	204.23	4.673									
24R-1, 74	213.74	3.200			2.37	29.3	12.7	2.71			
25R-1, 21	222.71	4.208			2.57	14.6	5.8	2.69			
26R-1, 45	232.45	5.323			2.74	13.6	5.1	2.69			
27R-1, 40	241.90	4.117			2.60						
28R-2, 72	253.22	4.629	4.002	14.529	2.60						
29R-1, 98	261.48	4.746	4.559	4.019	2.61						
30R-1, 81	270.81	4.179	4.212	−0.787	2.49	14.0	5.7	2.70			
31R-1, 73	280.23	4.978	5.129	−2.988	2.63	5.2	2.0	2.66			
31R-3, 78	283.28	2.247	2.094	7.049	2.23	34.6	15.9	2.69			
31R-5, 87	286.37	2.478	2.241	10.045	2.24	31.1	14.2	2.66			
31R-7, 37	288.87	4.158	4.174	−0.384	2.60	7.1	2.8	2.65			

approximately 9° to the north. The correspondence between the velocity and density data and the lithological column from Site 759, and the seismic reflection record on Line 122-2 through the site are shown in Figure 26.

Site 760 is located 4.0 km north of the southern scarp of the Wombat Plateau at a water depth of 1970 m. Site 760 projects 0.6 km to shotpoint 111.2338 on Line 56-13. The basal Neogene unconformity encountered at Site 759 is also represented at Site 760 (Fig. 27), below which seismic reflections that dip at 3° to the north are recorded. These reflections are truncated at the basal Neogene unconformity. A second strong intra-Triassic unconformity occurs deeper at Site 760. This unconformity was coincident with the basal Neogene unconformity at Site 759 but diverged from it to the north along Line 56-13, reflecting retention of progressively younger strata beneath the basal Neogene unconformity. Reflectors are recorded under the Triassic/Jurassic unconformity and dip at approximately 8° to the north. The correspondence between

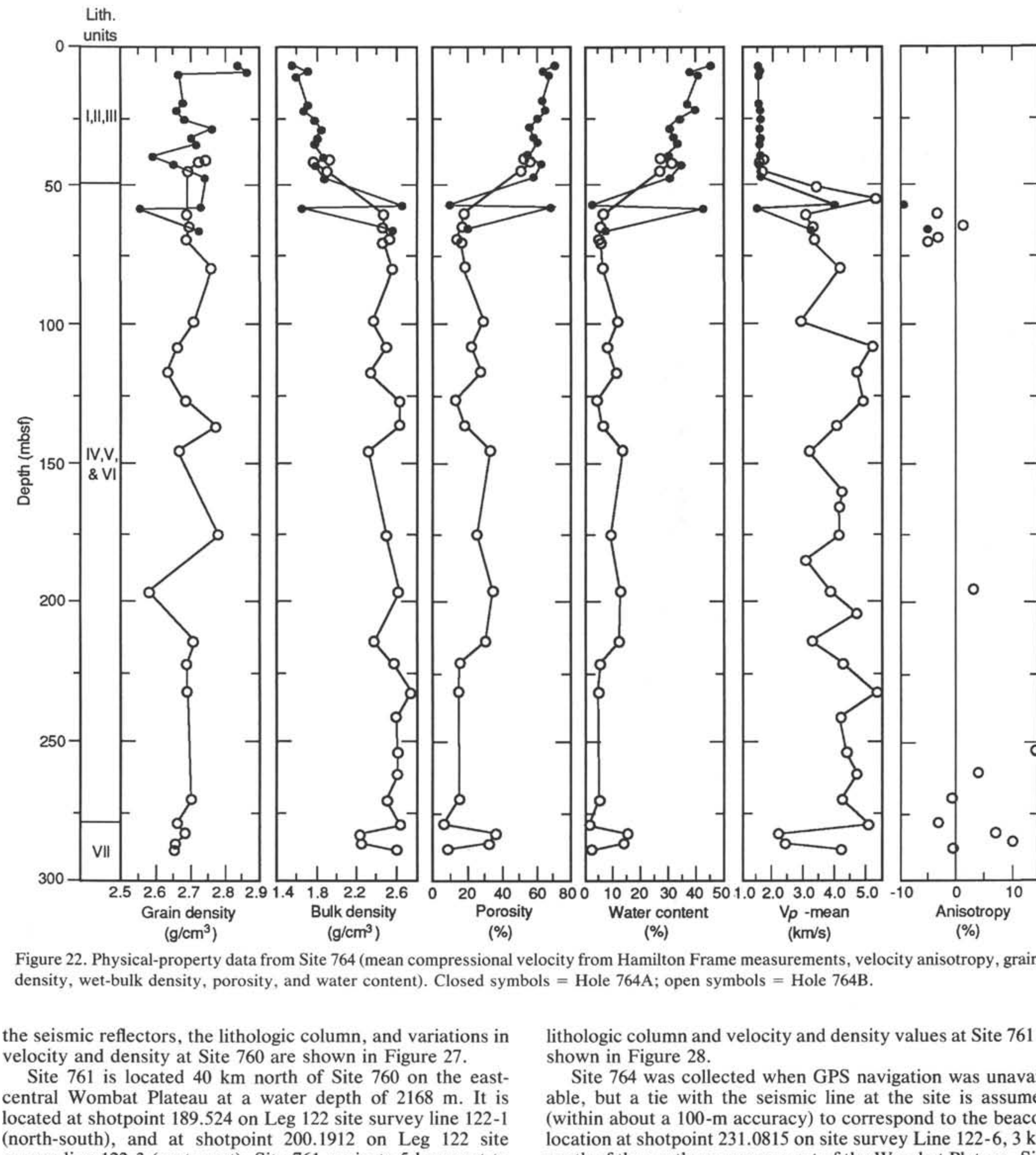

Figure 22. Physical-property data from Site 764 (mean compressional velocity from Hamilton Frame measurements, velocity anisotropy, grain density, wet-bulk density, porosity, and water content). Closed symbols = Hole 764A; open symbols = Hole 764B.

the seismic reflectors, the lithologic column, and variations in velocity and density at Site 760 are shown in Figure 27.

Site 761 is located 40 km north of Site 760 on the east-central Wombat Plateau at a water depth of 2168 m. It is located at shotpoint 189.524 on Leg 122 site survey line 122-1 (north-south), and at shotpoint 200.1912 on Leg 122 site survey line 122-3 (east-west). Site 761 projects 5 km west to shotpoint 111.0155 on Line 56-13. Seismic reflections recorded at Site 761 parallel the water bottom in the shallow section above a weak angular unconformity within the Tertiary (Fig. 28). Below the unconformity, strata dip to the north at about 2° down to a strong reflector marking the unconformity at the top of the Triassic. A second high-amplitude reflector defines the base of a wedge of sediments within the upper Triassic. The Cretaceous/Tertiary boundary occurs within the above interval, but because it does not correspond to a significant change in velocity or density, it is not recorded as a seismic reflection event. The correspondence between the lithologic column and velocity and density values at Site 761 is shown in Figure 28.

Site 764 was collected when GPS navigation was unavailable, but a tie with the seismic line at the site is assumed (within about a 100-m accuracy) to correspond to the beacon location at shotpoint 231.0815 on site survey Line 122-6, 3 km south of the northern escarpment of the Wombat Plateau. Site 764 projects 0.4 km to shotpoint 111.0407 on Line 56-13. The site is located in a zone showing an expanded section beneath the main Mesozoic angular unconformity, compared to that present at Site 761 to the south. The quality of data on Line 122-6 was good. A seismic horizon corresponds to the boundary at 40 m between the upper Oligocene oozes and Maestrichtian chalks. The Cretaceous chalk layer was 17 m thick and represented only one cycle on the seismic reflection data. A relatively low-amplitude seismic event corresponds to the main Mesozoic unconformity, which overlies 225 m of late Rhaetian reef-complex rocks consisting of corals and rud-

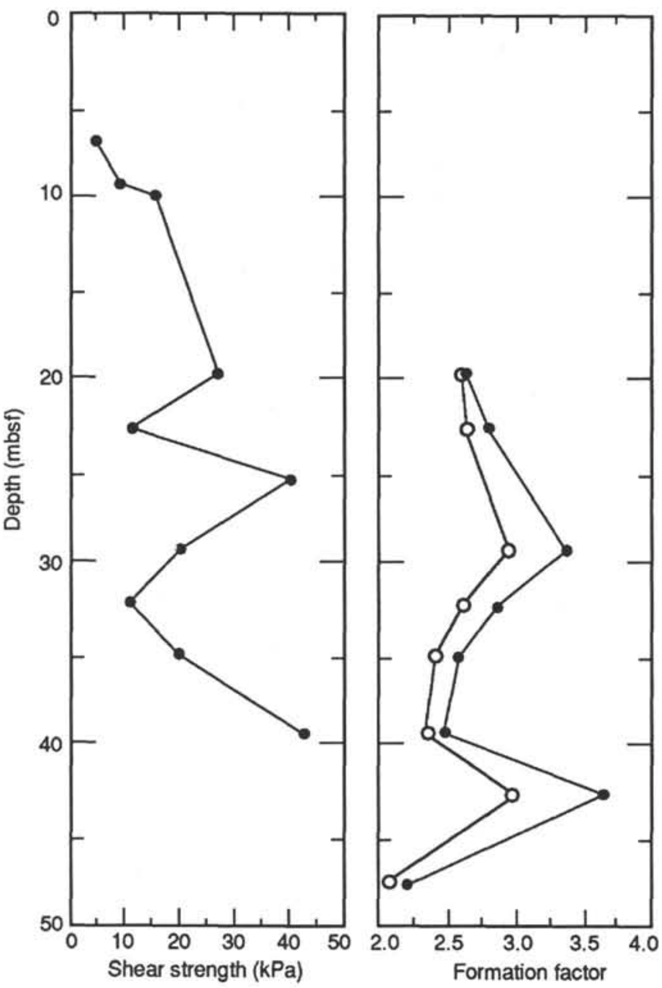

Figure 23. Physical-property data from Hole 764A (shear strength; formation factor: solid circles = measurements taken horizontally, perpendicular to the core axis, open circles = measurements taken vertically, parallel to the core axis).

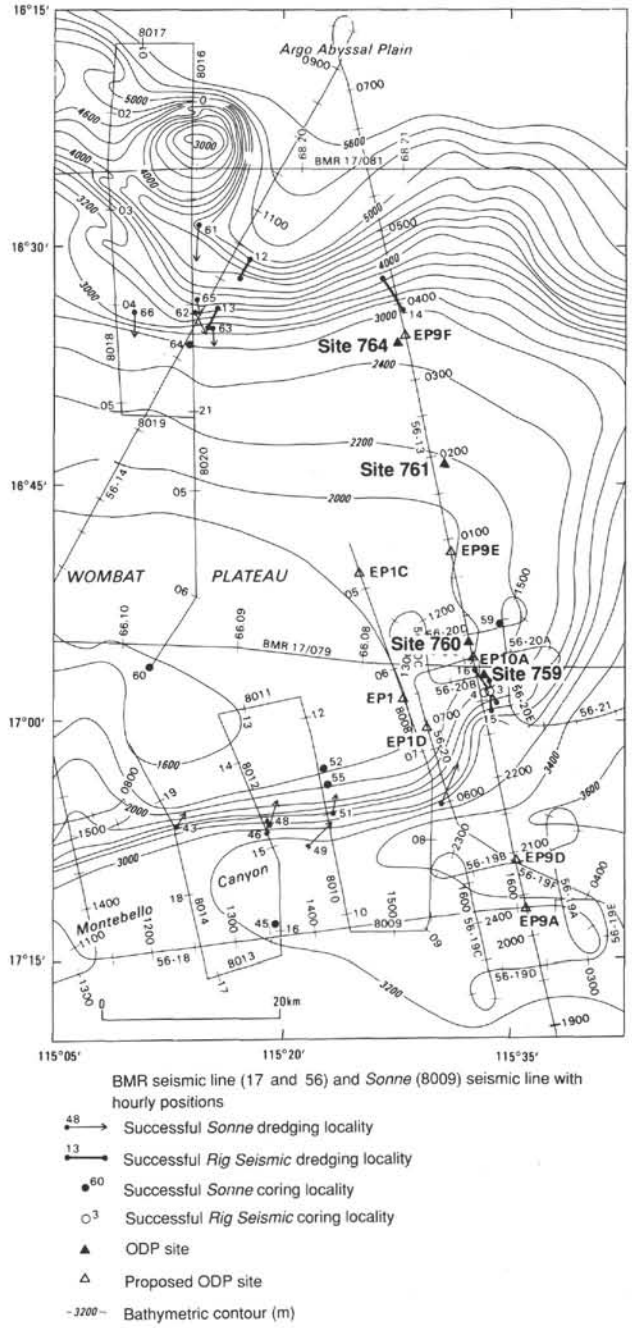

Figure 24. Locality map of eastern Wombat Plateau showing Sites 759, 760, and 761 and site survey lines from the BMR 1986 survey and Leg 122.

stones. The reef corresponds to a zone of low seismic reflectivity and continuity. A weak seismic event corresponds to the interface between the reefal strata and restricted lagoonal marls and carbonates at 281 mbsf. The correspondence between the lithologic column, and velocity and density values at Site 764 is shown in Figure 29.

Leg 122 Sites 759, 760, 761, and 764 constitute a south-to-north transect across the Wombat Plateau. The locations of these sites projected onto Line 56-13 is shown on Figure 30. Above the upper Triassic unconformity the profile shows progressively more retention of post-rift pelagic material to a maximum at the region of Site 761 in the center of the Wombat Plateau. At Sites 761 and 764, a Cretaceous post-rift sequence that was absent at Sites 759 and 760 was encountered. Site 761 was drilled at a location away from a strong shallow reflector on the premise that it could possibly be caused by a shallow gas accumulation; thin cherts of early Tertiary age were encountered near the level of the shallow reflector. Post-rift sediments thin along the profile from the central plateau to the northern margin in the region of Site 764.

Reflections below the uppermost Triassic unconformity show strong angularity at the south of the profile near the locations of Sites 759 and 760. This angularity decreases towards the center of the Wombat Plateau and strata become disconformable in the region of Site 761. Angularity below the unconformity again increases to the north resulting in retention of a younger section beneath the unconformity in the region of Site 764. Dips in the upper Triassic decrease or reverse north of Site 764 so that the upper Triassic section does not thicken from this site location to the northern plateau escarpment. The expansion of the retained pre-rift Triassic section corresponds to an upper Rhaetian reefal complex, which is deposited above a Triassic section similar to that encountered at Site 761. The reefal lithologies are similar to those that were dredged from the northern escarpment of the Wombat Plateau in dredge 56-14 collected along Line 56-13 and previously dated as Liassic (Fig. 30).

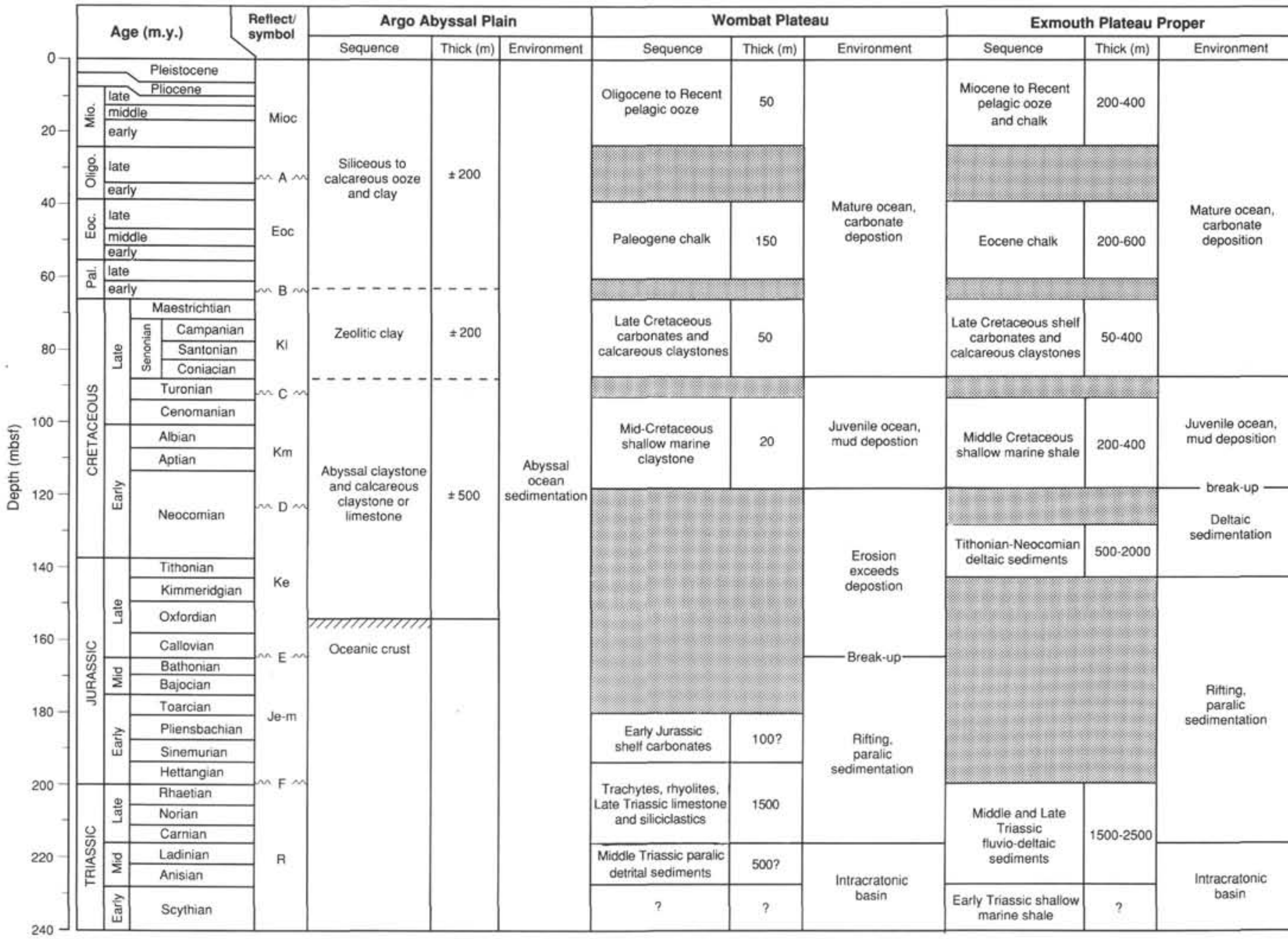

Figure 25. Simplified stratigraphy of the Exmouth Plateau, Wombat Plateau, and Argo Abyssal Plain after Leg 122.

Interpretation of Line 122-6 together with biostratigraphy derived from ODP Sites 759, 760, 761, and 764 enable a seismic stratigraphic cross section to be constructed from north to south across the Wombat Plateau (Fig. 31).

DOWNHOLE MEASUREMENTS

Operations

Logging operations began at 1000 hr (all times in this section are local times) on 20 August 1988 with hole conditioning. At 1535 hr, a go-devil was sent down the pipe to the bottom of the drill pipe to release the bit. The hydraulic bit release failed to work and attempts to retrieve the go-devil were unsuccessful. This precluded logging in the open hole and in the bottom 10 m of the pipe.

Rig-up for in-pipe logging began at 2125 hr on 20 August 1988, with the geochemical tool string (NGT, GST, and ACT). The tool string was lowered to 271 mbsf at 0110 hr on 21 August 1988. Logs were recorded first from 271 to 0 mbsf and again from 118 to 10 mbsf to determine the repeatability of the first pass. At 0605 hr, the geochemical tool combination was rigged down and the lithoporosity tool string (LDT, NGT, and CNL) was rigged up. Logs were recorded from 265 mbsf to 10 m above the mud line. Rig-down of the tool string was completed by 1150 hr on 21 August 1988.

Log Quality

Logs obtained with the geochemical tool string included total gamma ray, spectral logs of potassium, thorium, and uranium, and elemental yield logs for aluminum, iron, silicon, calcium, hydrogen, sulfur, and chlorine. Logs recorded with the lithoporosity tool string included total gamma ray and neutron porosity.

All logs except the total-gamma-ray log from the lithoporosity run are of good quality. The second gamma-ray log was recorded after the pipe had been radiated by the Californium source in the geochemical tool string. Consequently, the gamma values are too high and the signal is erratic. However, major events can be correlated on both gamma-ray logs, which is important for depth correlation between the two logging runs. The gamma-ray and neutron porosity logs from the second run were shifted up 1.5 m to correspond to the same depth as the logs from the geochemical tool string.

The first-run gamma-ray and aluminum logs also read too high in two intervals (24.0–30.5 mbsf and 100–106 mbsf)

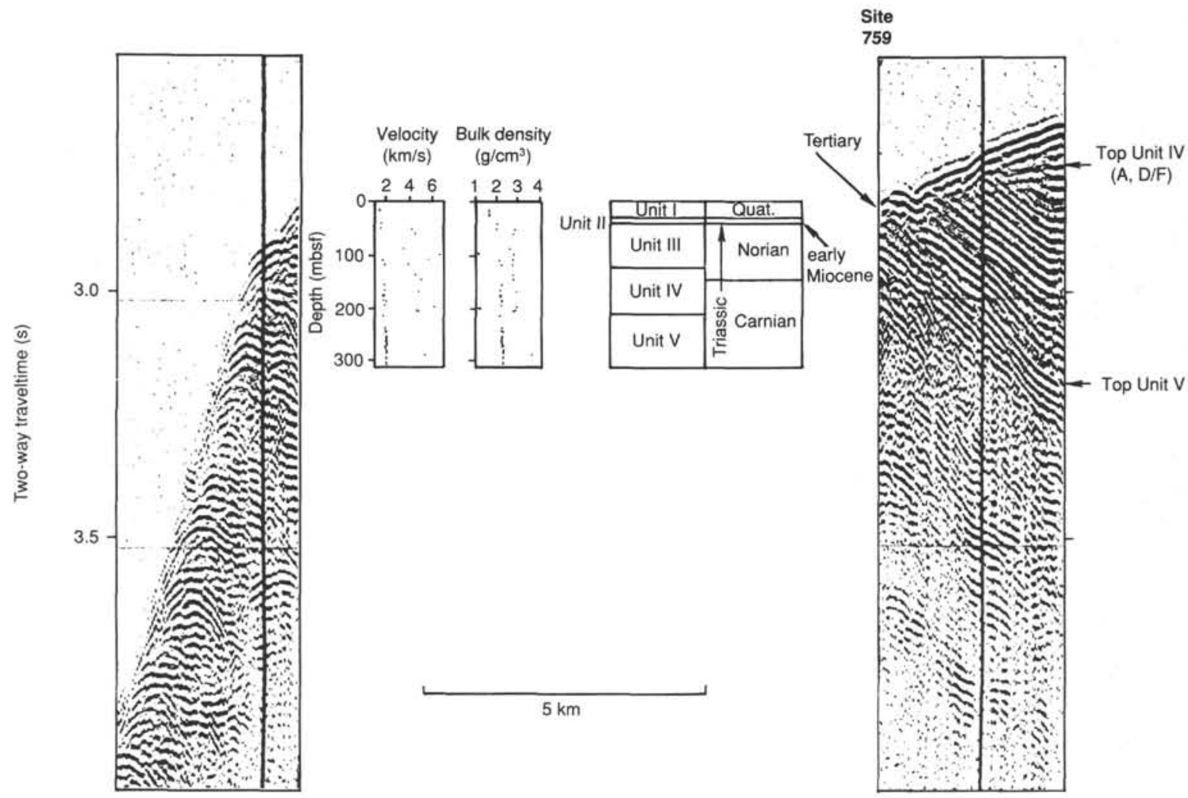

Figure 26. Part of site survey Line 122-2 over the location of Site 759 showing the relationship between seismic horizons, lithologic units, stratigraphy, velocity, and density. Letters identifying seismic horizons are as in Figure 25.

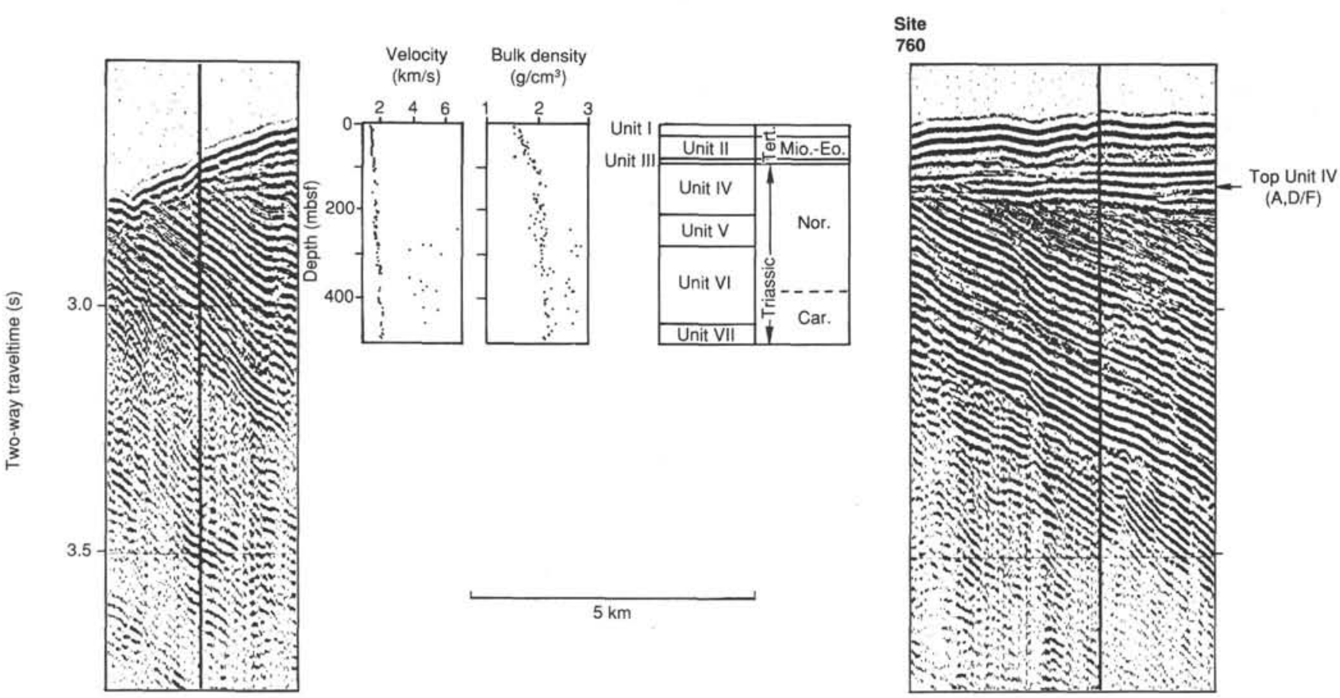

Figure 27. Part of site survey Line 122-2 over the location of Site 760 showing the relationship between seismic horizons and stratigraphy, velocity, and density. Letters identifying seismic horizons are as in Figure 25.

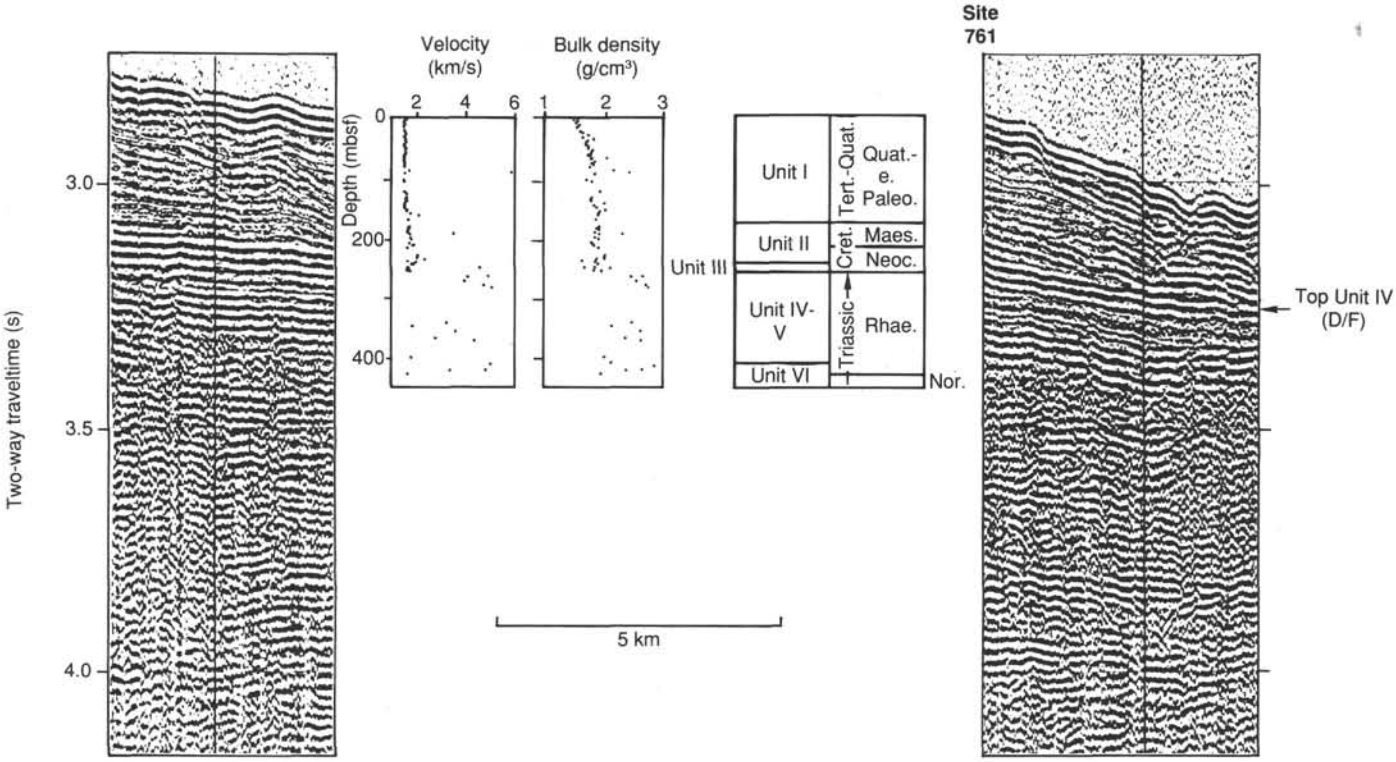

Figure 28. Part of site survey Line 122-3 over the location of Site 761 showing the relationship between seismic horizons and stratigraphy, velocity, and density. Letters identifying seismic horizons are as in Figure 25.

where the pipe was raised and lowered to prevent the drill string from sticking in the hole.

Pipe Effects

Geochemical logging through the drill pipe was also run at Site 761 (see "Downhole Measurements," Site 761 chapter); consequently, the reader is referred to the previous site report for a summary of pipe effects on geochemical log data.

In Hole 764B, the bottom-hole assembly (BHA) extended from the bottom of the drillstring (285 mbsf) to 206 mbsf; 8.25-in. pipe extended the drillstring from 206 to 201 mbsf, 5.5-in. pipe was used between 201 and 142 mbsf, and standard pipe (5-in. outer diameter) extended the pipe to the rig floor.

The gamma-ray signal from the interval in the BHA and 8.25-in. pipe (285 to 201 mbsf) is attenuated approximately 75%. In 5.5-in. pipe (201 to 142 mbsf), attenuation is approximately 40%, and in 5-in. pipe, attenuation is approximately 35% (see "Downhole Measurements," Site 760 chapter, this volume). The neutron porosity log reads higher porosities in the pipe than in the open hole by approximately 5%–10%, and is affected by water displacing the thicker pipe above the BHA. Therefore, the porosity values cannot be taken as absolute, but the trends in the neutron porosity log can be used to determine relative changes downhole.

Log Responses of Lithologic Units

Unit I (0–9 mbsf) consists of foraminifer nannofossil ooze. It is characterized by gamma-ray values of 8 API units decreasing with depth to 5 API units at the base. The increased gamma-ray values at the top of the unit are associated with a minor amount of clay, as seen from the slight increase in silicon, thorium, and uranium values. The presence of clay within the ooze is confirmed by calcium carbonate analysis, which indicates about 15% clay.

The boundary between Unit I and Unit II is not distinct on the logs (Fig. 32). Unit II (9.0–41.5 mbsf), a nannofossil ooze with clay, is differentiated from Unit I mainly by an increase in gamma ray values to 8–12 API units and slight increases in thorium, potassium, and silicon. Smear-slide analysis indicates that the minor components present in the ooze include pyrite, quartz, iron oxide, and plant debris. Neutron porosity values for both units are high and decrease with depth, a result of compaction (Fig. 33).

The Cretaceous/Tertiary boundary interval, which occurs at the base of Unit II, is not obvious from the log data. A slight change occurs in the gamma-ray and thorium signals, but it is not significant enough to pick the boundary location on the basis of log character. The facies change across the boundary is minor and is marked by a chalky gravel coated with manganese oxide, which is thought to have formed a thin crust during a period of nondeposition (see "Lithostratigraphy," this chapter). The limited vertical resolution of the logging tools has precluded picking up the signal from this marker bed.

Unit III (41.5–49.6 mbsf) consists of chalk, which cannot be differentiated from ooze on the basis of log character. The contact of this unit with the underlying Rhaetian sedimentary rocks of Unit IV is marked by a pronounced increase in lithification, which is observed as a gradual decrease in porosity on the neutron porosity log (Fig. 33).

The top of Unit IV (49.6–55.9 mbsf) is marked by a short interval of sharply increased gamma ray, an increase in uranium, and a pronounced decrease in calcium. This 2-m-thick interval shows only slightly increased amounts of thorium and potassium, indicating that the dominant detrital material is not clay.

Unit V (55.9–72.5 mbsf), consisting of recrystallized claystone and limestone, appears on the logs at approximately

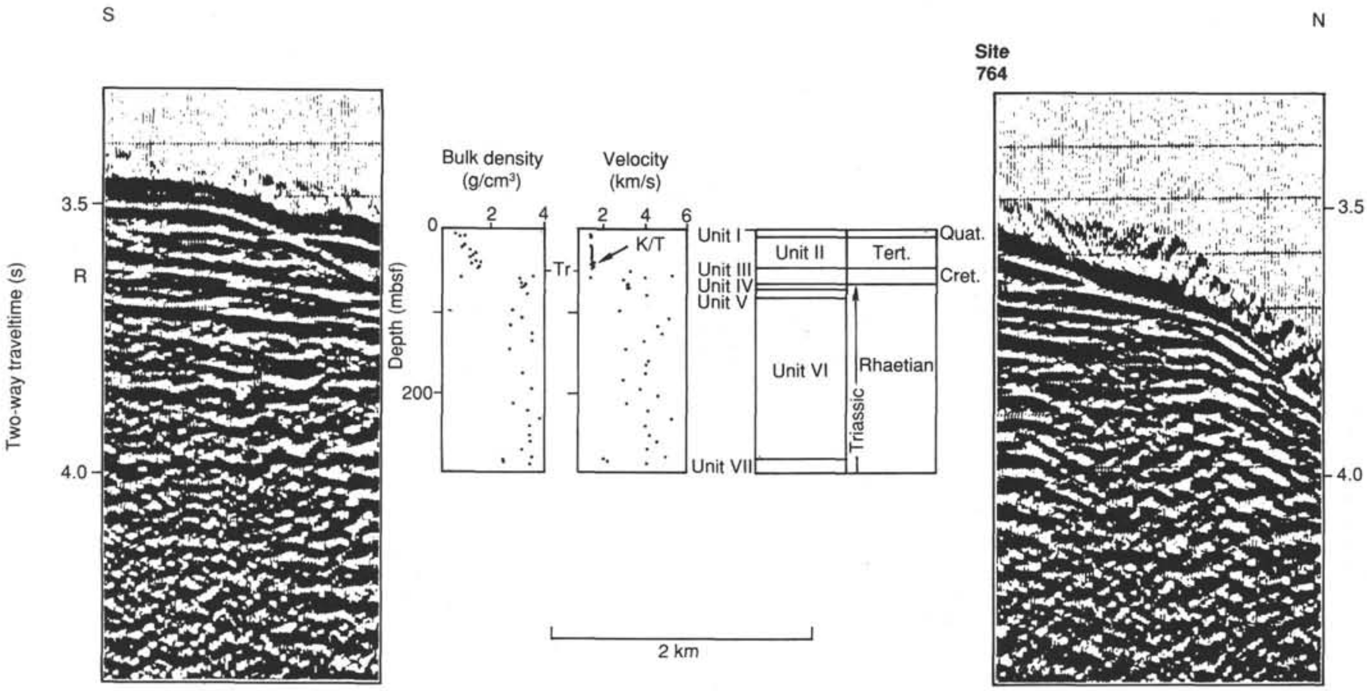

Figure 29. Part of BMR Line 56-13 over the location of Site 764 showing the relationship between seismic horizons and stratigraphy, velocity, and density.

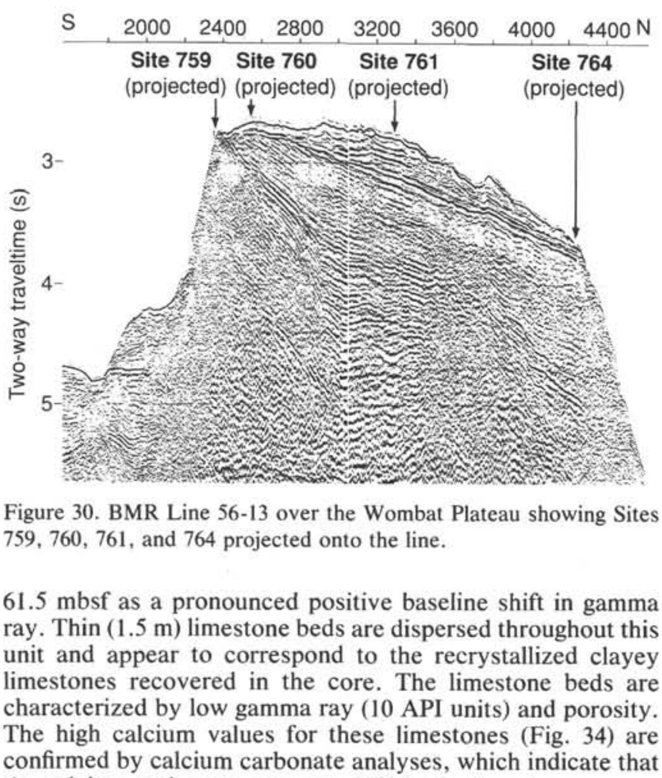

Figure 30. BMR Line 56-13 over the Wombat Plateau showing Sites 759, 760, 761, and 764 projected onto the line.

61.5 mbsf as a pronounced positive baseline shift in gamma ray. Thin (1.5 m) limestone beds are dispersed throughout this unit and appear to correspond to the recrystallized clayey limestones recovered in the core. The limestone beds are characterized by low gamma ray (10 API units) and porosity. The high calcium values for these limestones (Fig. 34) are confirmed by calcium carbonate analyses, which indicate that the calcium carbonate averages 88% in the limestones.

Unit VI (72.5–280.0 mbsf) is represented by a variety of limestone types and minor facies that include mudstones, laminated claystones and dolomitic mudstones (see "Lithostratigraphy," this chapter). Core recovery in this interval was only 9.48%. Log analysis shows that this unit can be subdivided into three intervals on the basis of prominent log characteristics. The top subunit (84–122 mbsf) is characterized by gamma ray values of 13–30 API units and increased potassium and thorium values. The clay-rich layers are interbedded with thin (1.5 m) limestones, indicating that the depositional environment of this subunit alternated between a marine environment below wave base and an open-marine carbonate platform. The gamma-ray signal decreases gradually with depth at the base of this subunit, indicating the decreasing influence of clay on the lithology.

The second subunit (122–200 mbsf) is characterized by high quartz and low clay content, which was determined from low gamma-ray, thorium, and potassium values (Fig. 32), and high silicon and low aluminum ratios throughout this subunit.

The third subunit (200–264 mbsf) is dominated by an increase in both iron and silica. The low gamma-ray values in this interval may be misleading because the section was recorded in the BHA, and is therefore influenced by the 2-in.-thick pipe. Clay-rich intervals are identified as silicon, thorium, and potassium-enriched intervals on the logs at 202–206 and 222–225 mbsf. The increased iron in this interval appears to correlate with the hematite-stained limestones recovered in the lower part of Unit VI. The log character of this subunit demonstrates a wider range of lithologies than that found in the upper part of Unit VI. This indication is confirmed by the recovery of iron-rich clastics, mudstones and wackestones, and bioclastic rudstones and floatstones in Cores 122-764B-27R through -30R.

SUMMARY AND CONCLUSIONS

Introduction

Site 764 (proposed Site EP9F) is located very close to the northeastern edge of Wombat Plateau at 16°33.96′S, 115°27.43′E, at a water depth of 2698.6 m. The site is about 34 km north-northeast of Site 761 and was chosen to complete a transect of four drill sites (Sites 759, 760, 761, and 764) across

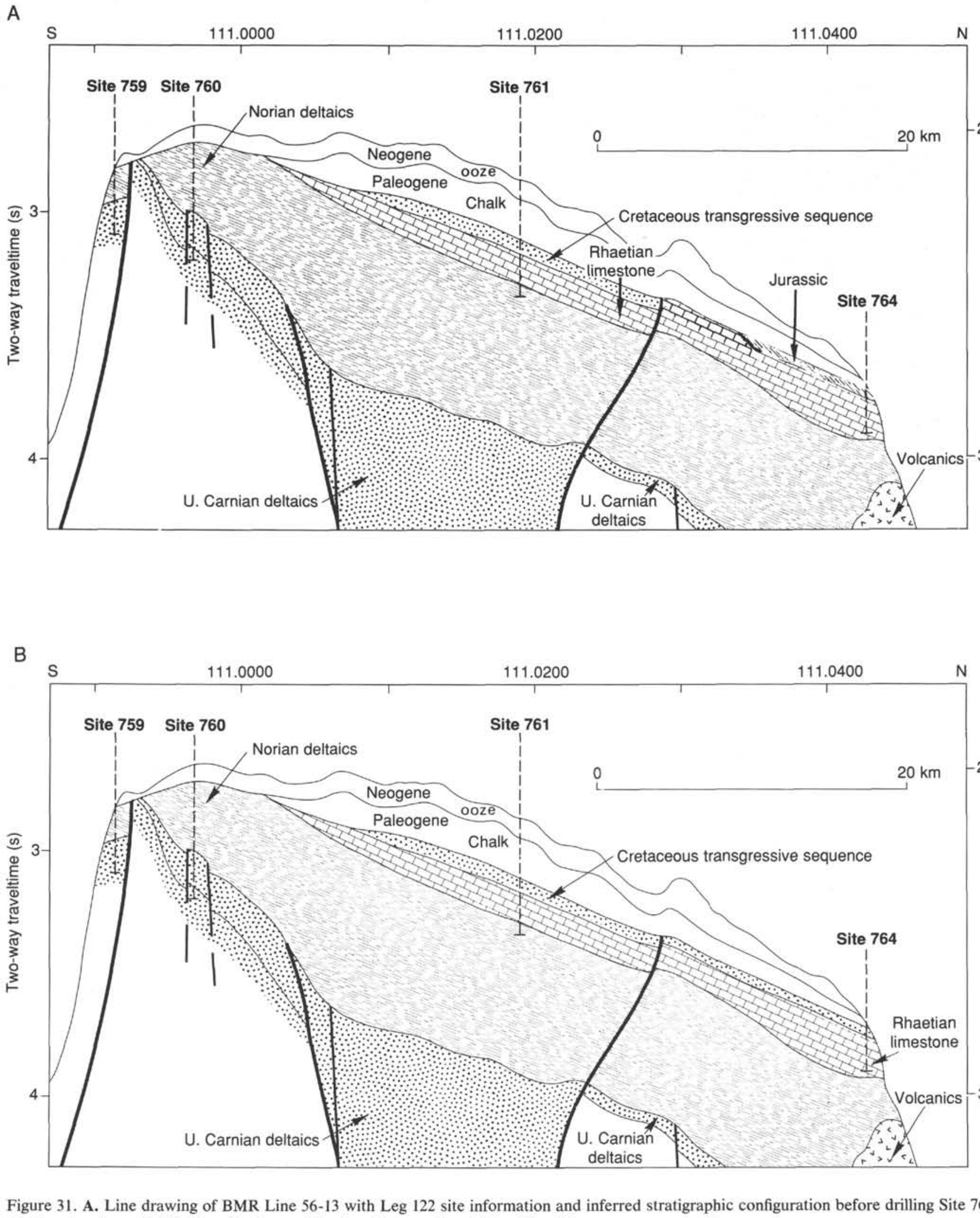

Figure 31. **A.** Line drawing of BMR Line 56-13 with Leg 122 site information and inferred stratigraphic configuration before drilling Site 764. **B.** Line drawing of BMR Line 56-13 over Wombat Plateau after drilling Site 764.

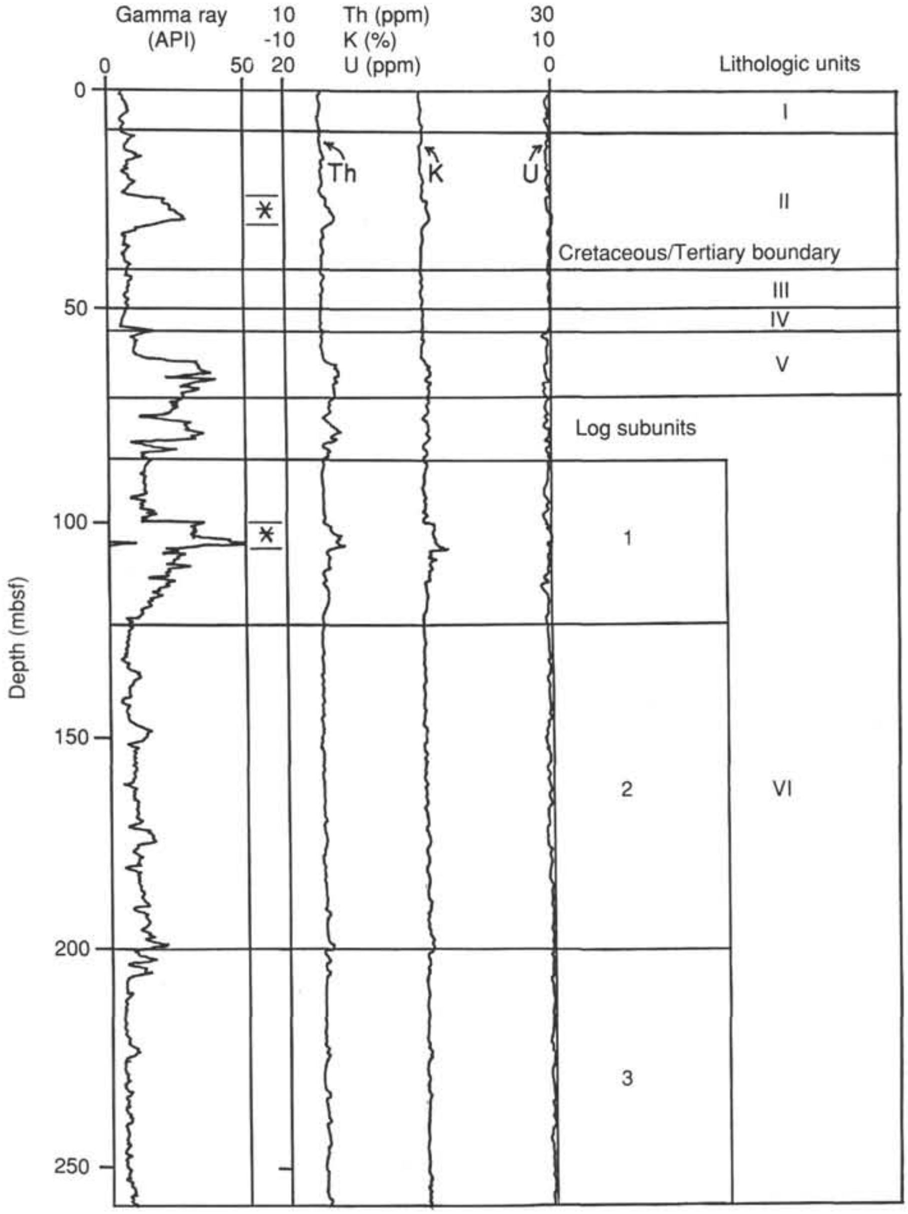

Figure 32. Gamma ray, thorium, potassium, and uranium logs recorded in the pipe at Site 764. The log peaks at 24.0–30.5 mbsf and 100–106 mbsf (indicated by asterisks) are due to pipe movement and are therefore invalid.

the Wombat Plateau, with successively younger early Mesozoic sequences below the main Mesozoic unconformity. Hole 764A was continuously cored by RCB to a depth of 69 mbsf. Hole 764B was drilled in order to recover more material of the critical section over- and underlying the main Mesozoic unconformity. It was washed to 40 mbsf and continuously cored by the RCB to a total depth of 294.5 mbsf. Coring disturbance was severe in the soft Quaternary to upper Cretaceous sediments. The recovery rate in the upper Cretaceous to Neogene oozes was about 40%–100%, but dropped drastically to low values of about 15% for the shallow-water carbonates of Rhaetian age (Units IV–VI). Only in the basal "marlstone" (Unit VII) did the recovery rate increase to about 66%. Logging had to be performed through the drill pipe, since it was impossible to release the bit at the bottom of Hole 764B. A suite of geochemical logs and gamma-ray/neutron porosity/density logs were obtained, which will aid in reconstructing the lithologies in the low-recovery units below 50 mbsf.

The main objective of Site 764, the last site of Leg 122, was to reconstruct the early rift and pre-breakup stages of development of the northern Exmouth Plateau continental margin. Seismic stratigraphy indicated that the early Mesozoic section underlying the main Mesozoic unconformity was expanded upwards into a younger (uppermost Rhaetian to possibly Liassic) section north of the location of Site 761 (Fig. 31A). The interpretation of a possible Liassic age of this northward-thickening wedge was supported by *Sonne*-8 and *Rig Seismic*-56 dredge samples obtained from the steep slope near Site 764 and dated as Liassic by Quilty (1981) and B. Zobel and F. Gramann in von Stackelberg et al. (1980).[4] The fact that we did

[4] See also Quilty (in press), not available during Leg 122.

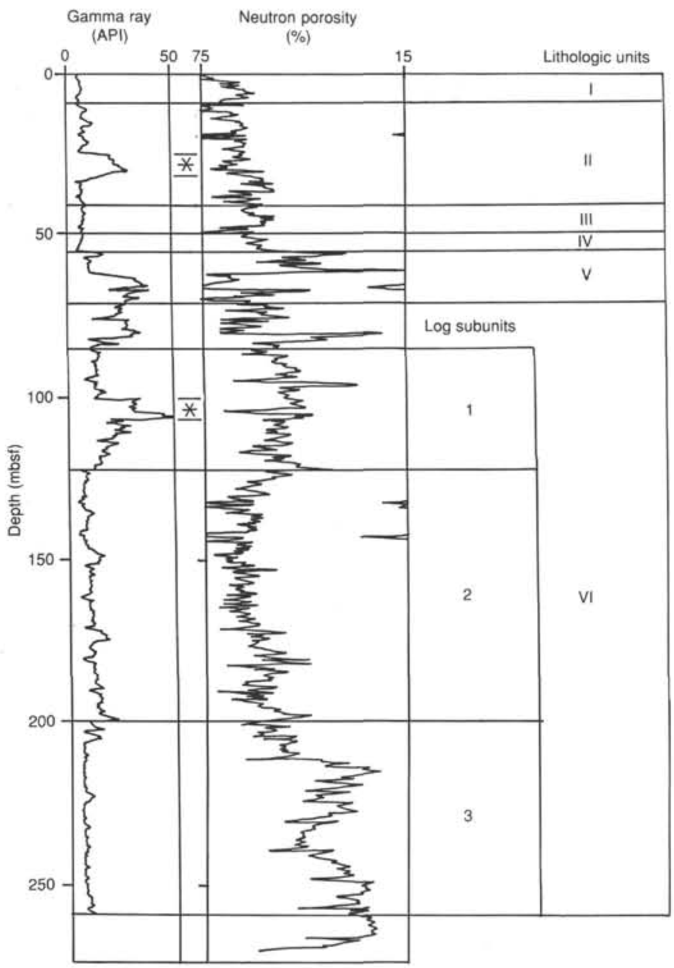

Figure 33. Gamma-ray and neutron porosity logs for Hole 764B. Neutron porosity values are affected by water displacing the BHA and 8.25-in. pipe above 201 mbsf, but the downhole porosity trends are valid. Asterisks indicate suspect data (see Fig. 32 caption).

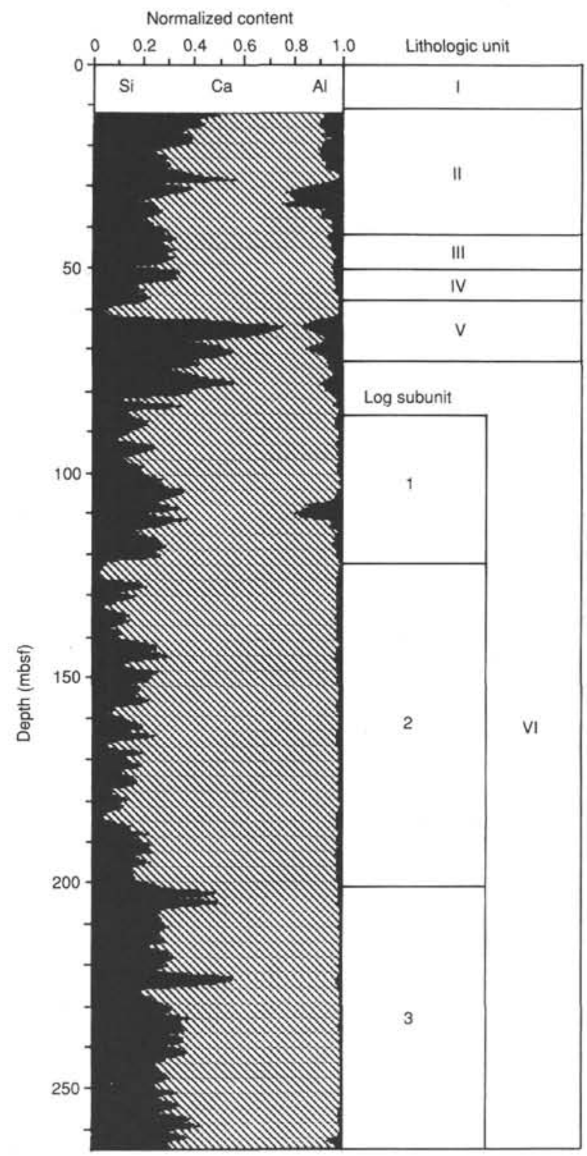

Figure 34. Normalized-content plot of silicon, calcium, and aluminum counts, Hole 764B, represents the proportion of each to the total of the three relative abundances.

not recover any Liassic sediments at this site as at all other Wombat Plateau sites (Fig. 31B) indicates that either the biostratigraphic age determinations of these dredge samples have to be revised (see "Biostratigraphy," this chapter), or that the dredges were obtained from down-faulted deeper blocks that contain Liassic rocks not eroded during the major pre-Cretaceous denudation of the Wombat Plateau.

However, Site 764 drilling was successful in recovering a younger and more complete (240 m thick) Rhaetian section than Site 761 drilling, which produced a 170-m-thick Rhaetian section of shelfal to shallow-subtidal limestone. The thicker Rhaetian section at Site 764 is probably due to lesser erosion below the main unconformity and/or to the presence of thicker reefal sediments in the north (see Figs. 18 and 19 for a tentative correlation and interpretation of the Rhaetian carbonate platform of Sites 761 and 764). Both sites together have recovered a nearly complete marine Rhaetian section, including a thick unit of a reef complex and other carbonate platform environments in Site 764. This record is unique in the southern hemisphere, and represents two well-documented cycles of sea-level change corresponding to the global cycle chart (Haq et al., 1987). The lower sequence boundary was identified at Site 761 near the Norian/Rhaetian boundary, whereas the upper sequence boundary was found between Units V and VI above the reefal complex (Unit VI) that represents the highstand systems track. The boundary between Units VI and VII within our last core represents the "maximum flooding surface," underlain by Unit VII (representing the transgressive systems track of the lower system).

Stratigraphy, Paleoenvironment, and Sedimentation History

The stratigraphic results of Site 764 and some preliminary paleoenvironmental interpretations are summarized in Fig. 2E, "Summary and Highlights," this volume (in back pocket). In the following discussion we will highlight some of the more important findings in stratigraphic order.

Early(?) Rhaetian Quiet-Water Carbonate Mudstone Deposition (Unit VII, 289.14–280.15 mbsf)

The oldest sediments recovered at Site 764 consist of very dark, clayey, partly recrystallized carbonate mudstone to wackestone with $CaCO_3$ contents of 57%–65% (marlstone) and organic carbon contents of 0.2%–0.5%. These rocks are interbedded with light-gray carbonate mudstone with clay.

Palynomorphs indicate an age "not younger than middle Rhaetian" and an open-marine environment, which according to a comparison with Sites 760 and 761, should exclude Norian. We therefore assume an early Rhaetian age for this unit, which represents the transgressive systems track of the lower sequence. Crinoid fragments are very common in the carbonate mudstone. At Site 761, *in-situ* occurrences of crinoids have been explained as indicating an open-marine, deeper-water environment. Extensive bioturbation with a distinct ichnofacies of burrow types (worms and crustaceans) suggests a nutrient-rich substratum, and a quiet, low-energy milieu, be it lagoonal (back-reef mud flat) or deeper-marine (deeper fore-reef slope, indicated by the presence of crinoids). Strong bioturbation may indicate a slow sedimentation rate, and/or unusually nutrient-rich (reducing) conditions. Unfortunately, we penetrated only the uppermost 9 m of this unit before we had to stop drilling at Site 764.

Rhaetian "Reef Complex" (Unit VI, 280.15–72.51 mbsf)

During the "late" Rhaetian, a time period still poorly constrained biostratigraphically, a 207.64-m-thick white to pale brown, reefal to peri-reefal sequence was deposited at sedimentation rates of 50–100 m/m.y. at the location of Site 764. Unfortunately, less than 10% of this sequence was recovered in our cores. A great variety of shallow-water platform limestones and related lithologies with beautifully preserved reefal structures (sponge and coral boundstones) and many epibenthic macro- and microfossils were recovered. These rocks await a detailed shore-based microfacies study before we can decipher the vertical and lateral evolution of paleoenvironments at this carbonate platform margin site. Major lithologies include wackestone, packstone, grainstone, rudstone, and boundstone; minor lithologies are mudstone, laminated claystone, and dolomitic mudstone. Most prevalent are *in-situ* sessile benthic fossils, such as colonial corals (hermatypic ?scleractinian corals), sponges, and green algae, in addition to bryozoans, brachiopods, echinoderms, gastropods, and bivalves. Coralgal limestones indicate the chlorozoan association (low-latitude, tropical belt) of the Southern Tethys Ocean. Oolitic and oncolitic grainstone document a Bahamian-type, highly agitated environment. Some micritic limestones were secondarily dolomitized. Most limestones are highly porous with vugs filled by dogtooth calcite, micrite, and hematite/goethite. Coquinas are also present.

These microfacies types signify either a highly agitated, well-oxidized carbonate bank or ramp environment, or a reefal environment. Oxidation and ferruginization of these rocks after uplift and during subaerial exposure, however, cannot be excluded. The lower part of Unit VI consists of bioclastic rudstone and floatstone interbedded with wackestone and mudstone, interpreted as talus material from a fore-reef slope or "carbonate ramp" (the slightly inclined, progradational, seaward slope of a carbonate bank). Preliminary analysis indicates that about five cycles with the following upward sequence can be deciphered:

1. packstone/wackestone (*in-situ* deeper marine fore-reef or ramp environment);
2. rudstone/carbonate breccia (gravitative mass flow deposits, fore-reef? talus);
3. white oolite grainstone (Bahamian-bank-type deposit, highly agitated);
4. "reefal boundstone/bafflestone" (central sponge/coral reef buildup);
5. grainstone, packstone, wackestone (back-reef?, intertidal?); and,
6. carbonate mudstone (intertidal?, lagoonal, quiet water).

The reef complex was centered near Site 764 with open-marine environments being present both in the back-reef (to the south) and fore-reef areas (to the north). In this model Site 761 would be in an intertidal (back-reef to lagoonal) setting, whereas Site 764 was characterized by a carbonate platform and fore-reef environment.

"Late-Rhaetian" Lagoonal to Shallow-Water Carbonate Sequence (Units V and IV, 72.51–49.32 mbsf)

The boundary between the reefal Unit VI and the overlying shallow-open-marine Unit V is a sequence boundary. Unit V is only 16.61 m thick and can be described as a condensed, transgressive sequence deposited during a sea-level highstand. It is difficult to assess the causes of termination of the carbonate buildup at this sequence boundary (at the end of Unit VI time). It might have been caused by (1) a sea-level drop of short duration, followed by a transgression, (2) an accelerated tectonic subsidence pulse that drowned the reef beyond recovery, or (3) a combination of these factors. Unit V consists of gray to dark gray alternating recrystallized clayey limestones and calcareous claystones. The depositional environment was probably a quiet, open-marine setting with water depths below wave base, possibly a shelf milieu. Nannofloras indicate a younger ("late Rhaetian") age for this unit than for the youngest Rhaetian nannofloras of Site 761 (see "Biostratigraphy," this chapter).

The overlying Unit IV consists of much lighter colored (white to pale brown) fossiliferous wackestone, packstone, and grainstone with the benthic foraminifers *Triasina hantkeni*, *Triasina oberhauseri*, *Involutina sinuosa*, and *Glomospirella friedli*, and rich, well-preserved ostracode faunas. The wackestones and packstones are partly dolomitized. Grainstones fine upward into wackestones and carbonate mudstones. These sediments were probably deposited in a well-aerated, quiet to moderate-energy environment with periodic current redeposition. Crinoids found in the wackestones and carbonate mudstones might indicate a deeper-marine environment. The oxidation of the uppermost limestones below the unconformity may be due to subaerial weathering and oxidation following exposure during Jurassic times.

The Main Mesozoic Unconformity

A major unconformity with a 120-m.y. hiatus overlies the upper Rhaetian shallow-water limestones of Unit IV that are covered by Coniacian to Maestrichtian chalks. The contact between Rhaetian and Coniacian was not recovered by the RCB because the hardness contrast between limestone and chalk prevented recovery.

The Condensed, Pelagic, Upper Cretaceous Sequence (Unit III, 49.56–41.52 mbsf)

The upper Cretaceous sequence is extremely condensed (ca. 1 m/m.y.). Only 8.04 m of nannofossil chalk were deposited during Coniacian to late Maestrichtian times, as compared to an 80-m-thick equivalent section at the nearby Site 761. This indicates strong winnowing by bottom currents at this elevated outer edge of the Wombat Plateau horst during most of Late Cretaceous time. *Inoceramus* and other shell fragments are abundant in this unit, as is plant debris.

Cenozoic Pelagic Sedimentation (Units I and II, 41.52–0 mbsf)

During the Cenozoic, about 40 m of foraminiferal nannofossil ooze to chalk were deposited (ca. 2 m/m.y.), interrupted by several erosional hiatuses, one between the Maestrichtian and the Eocene-Oligocene and another between the Miocene and the Quaternary. The Eocene-Oligocene unconformity in particular has progressively removed older strata from Site 761 (where 175 m of Cenozoic sediments were cored) northwards, where at Site 764 the unconformity has cut down into the Maestrichtian. On the upper Eocene unconformity that overlies late Maestrichtian strata we observed a chalky gravel with Mn oxides. Apparently a thin Mn crust was formed during an extended nondepositional period and was later broken up by currents. Sediments near the unconformity (in Core 122-764B-2R-1, 88–89 cm) contain mixed Eocene and upper Maestrichtian nannofloras. Slumping and soft-sediment deformation was also noticed in this unit.

Biostratigraphy

Cenozoic calcareous nannofossils and foraminifers were generally well preserved, although nannofossils were poorly preserved in the Campanian through Coniacian interval, and foraminifers were of a mixed assemblage of Santonian to Maestrichtian age in the upper Cretaceous section. Nannofossils were also found in the Rhaetian part of the section. The late Triassic foraminifer *Triasina hantkeni* was recorded in several samples of the Rhaetian. Other foraminiferal species unambiguously date the section below the major unconformity as Rhaetian. Dinoflagellates in the same part of the section also give a clearly Rhaetian age and species in the bottom of the hole are exclusively Rhaetian.

Downhole Measurements

Because the drill bit could not be detached from the pipe by the hydraulic bit release tool, the logging runs were performed through the pipe. Two log runs provided a suite of geochemical and lithoporosity logs, including gamma-ray and neutron porosity. In general, the logs agree well with the recognized lithological units and their boundaries. The transition between oozes and chalks, however, cannot be distinguished by the log response.

Seismic Stratigraphy

Seismic stratigraphy has been described on a regional basis in "Seismic Stratigraphy," this chapter.

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MS 122A-110

NOTE: All core description forms ("barrel sheets") and core photographs have been printed on coated paper and bound as Section 3, near the back of the book, beginning on page 387.