2. EXPLANATORY NOTES

RESPONSIBILITIES FOR AUTHORSHIP

This Initial Report (volume) is divided into two parts. The first part consists of the various site summaries which, although largely founded upon the work accomplished during the at-sea operations, incorporate additional information produced by shore studies following completion of the shipboard work. The second part consists of several topical discussions which are based on results or findings at several or all of the sites occupied during the at-sea operations.

The authorship of the site summary chapters (Chapters 3-10) is shared collectively by the shipboard scientific party, the ultimate responsibility lying with the two co-chief scientists. Each chapter of Part I follows the same general outline. Sections on background and operations were prepared by R. E. Burns and J. E. Andrews; sections on lithology were prepared by M. Churkin, T. A. Davies, J. S. Galehouse, G. H. Packham and G. J. van der Lingen; sections on biostratigraphy were prepared by P. Dumitrica, A. E. Edwards, and J. P. Kennett; sections on physical properties were prepared by T. A. Davies; the discussion sections were prepared by J. E. Andrews and R. E. Burns. Specific additional authorship is cited by name in Chapters 4, 6, 7, 8 and 9. In these latter cases, the contributions of the individually cited colleagues were substantial and warrant more than a simple acknowledgment.

Authorship of the chapters in Part II (Chapters 11-27) is cited by chapter. The chapters in Part II are more speculative than those of Part I and should be considered interpretations based on information available at the time this Initial Report was submitted.

SURVEY DATA

Detailed site surveys were available for all sites except Site 203 prior to the start of Leg 21. These surveys were carried out by the R/V *Kana Keoki* of the University of Hawaii during August and September 1972. In addition to the sites drilled, surveys were carried out for proposed sites in the Tasman Abyssal Plain, in the northern Lau Basin, on the western flank of the Lau Ridge, on the eastern flank of the Tonga Ridge, and at two locations on the Pacific plate seaward of the southern portion of the Tonga-Kermadec Trench. During the surveys, bathymetry and sediment structure were mapped using 3.5 kHz echo sounding and a seismic profiling system (40 cu. in. airgun and 9000 joule sparker). Gravity and magnetic field measurements were also made. Track lines were controlled by a satellite navigation system.

Because the surveys were carried out by one of the co-chief scientists (J. E. Andrews), it was decided to incorporate the data into the site descriptions, rather than include separate appendices. All survey charts are prepared in uncorrected meters or in seconds of reflection time. Wide angle reflection/refraction profiles shot in the South Fiji Basin and on the Pacific plate have been reported elsewhere.

A short box survey of the area of the eventual Lau Basin site (203) was made by the *Glomar Challenger* using her 12 kHz precision echo sounder, 5 and 30 cu. in. air guns, and Varian magnetometer. The *Challenger*'s data were recorded on Edo recorders. These have a greater vertical exaggeration than the *Kana Keoki's* Alpine recorders and this resulted in a decision to use *Challenger* profile more often for illustrations when tracks coincided, since they were more compact.

Underway data recorded between sites is presented in the regional synthesis (Chapter 27). At each site, vertical reflection profiles were shot by launching a sonobuoy and drifting the 30 cu. in. airgun. Recordings were made at various scales (3, 4, 5, or 10 seconds) on the Edo recorders as the sonobuoy drifted away from the ship. Filter settings were varied during each run (from 10-320 kHz) to provide more detail on the character of the reflectors. These data are presented with the site reports and in Chapter 12.

BASIS FOR NUMBERING SITES, HOLES, CORES, AND SECTIONS

A site number refers to a single hole or group of holes drilled in essentially the same position using the same acoustic beacon. The first hole at a site (for example, Site 207) was given the number of the site (for example, Hole 207). Second holes drilled by withdrawing from the first hole and redrilling were labeled "A" holes (Hole 207A). Any additional holes drilled under comparable conditions are given succeeding letters, e.g., B, C, etc.

A core was usually taken by dropping a core barrel down the drill string, and coring for 9 meters as measured by lowering of the drill string before recovery. The sediment was retained in a plastic liner 9.28 meters long inside the core barrel and in a 0.20 meter long core catcher assembly below the liner. The liner was not normally full.

On recovery, the liner was cut into sections of 1.5 meters measured from the lowest point of sediment within the liner (Figure 1).

In general, the top of the core did not coincide with the top of a section. The sections were labeled from 1 for the top (incomplete) section to a figure as high as 6 for the bottom (complete) section, depending on the total length of core recovered.

In the event there were gaps in the core resulting in empty sections, these were still given numbers in sequence. Core catcher samples were always considered to have come from the bottom of the cored interval regardless of the depth assigned to the adjacent section above.

On occasions, over 9 meters of core were recovered. The small remainder was labeled Section 0 (zero), being above Section 1. On other occasions the sum of the lengths of numbered sections exceeds the total length of core

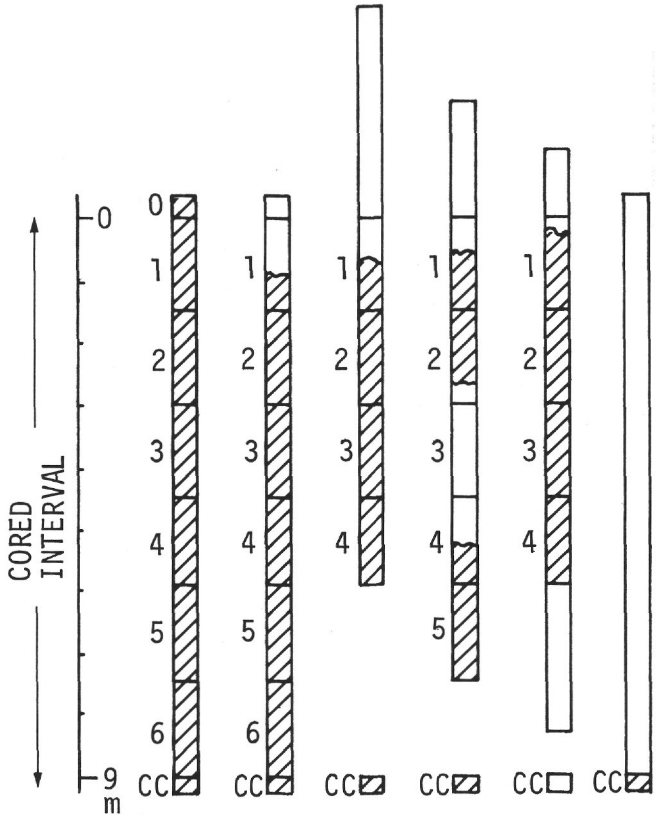


Figure 1. *The method of labeling sections of cores when recovery is complete, incomplete, and divided. The cores have been lined up so that the top of Section 1 is always coincident with the top of the cored interval, according to the method of calculating downhole depth of samples. Core catcher samples are always considered to have come from the bottom of the cored interval regardless of the depth assigned to the adjacent section above.*

recovered and also the cored interval, resulting in an overlap of nominal depth downhole of the bottom of one core and the top of the core below. In such cases a special note has been made.

In some holes, for example, Hole 208, from 111-120 meters, it was found desirable to drill with high water circulation but with a core barrel in place in order to penetrate faster. The drilled interval was often considerably greater than the 9 meters of the core barrel, the principle being that the high water circulation prevented sediments from being recovered. However, some of the harder layers were probably recovered during this procedure. It was difficult, therefore, to assign the correct depth in the hole to these sediments and each case had to be considered on its merits.

All samples taken from cores, before being processed, were numbered according to the system described in the Shipboard Handbook for Leg 21. The label "21-207-3-2, 25 cm" thus refers to Leg 21, Hole 207, Core 3, Section 2, sampled at 25 centimeters from the top of that section. The label "21-207-3, CC" refers to the core catcher sample at the base of Core 3.

It is appreciated that with this labeling system, the top of the core material recovered may be located at say, 1.3 meters below the top of Section 1 and the bottom will be at 1.5 meters in, say, Section 2 (if the total recovery is 1.7 meters). In relating this to downhole depths, there is an arbitrariness of several meters. However, it is impossible to assess where exactly in the hole the sample came from. Sometimes the core barrel will jam up with a hard sediment after sampling a few meters; this will then really represent the first few meters penetrated. At other times the circulation of water may wash away the upper softer part of a core and recovery will represent the lower part. Separated lengths of core in a core liner may come from the drill bit being lifted away from the bottom of the hole during coring in rough sea conditions. Similarly, there is no guarantee that the core catcher sample represents the material at the base of the cored interval.

The labeling of samples is therefore rigorously tied to the position of the samples within a section as the position appears when the section is first cut open and as logged in the visual core description sheets. The section labeling system implies that the top of the core is within 1.5 meters of the top of the cored interval. Thus, the downhole depth of "21-207-3-2, 25 cm" is calculated as follows. The top of the cored interval of Core 3 is 15 meters. The top of Section 2 is 1.5 meters below the top of the cored interval, that is, at 16.5 meters. The sample is 25 centimeters below the top of Section 2, that is, at 16.75 meters.

For the purposes of presenting the data for the entire hole in the hole summary sheets, where one meter is represented by less than one millimeter, the top of the recovered sediment is always drawn at the top of the cored interval. The error involved in this presentation is always less than 1.5 meters compared with depths calculated from the sample label.

Finally, in referring to cores, sections, and samples in the text of this Initial Report, the Leg designation is usually omitted. Also, the hole designation is frequently omitted when it is obvious from which hole the referenced sample was taken.

HANDLING OF CORES

The first assessment and age determination of the core material was rapidly made on samples from the core catcher. After a core section had been cut, sealed and labeled, it was brought into the core laboratory for processing. The core section was first weighed for mean bulk density measurement. Then GRAPE (gamma ray attenuation porosity evaluation) analysis was made for detailed bulk density determination.

After the physical measurements were made, the core liner was cut on a jig using Exacto-type blades, and the end caps cut by knife. The core was then split into halves with a cheese cutter, if the sediment was a soft ooze. At times, when compacted or partially lithified sediments were included, the core had to be split by a machine band saw or diamond wheel.

One of the split halves was designated a working half. Sonic velocity determinations using a Hamilton frame were made on pieces from this half. Samples, including those for grain size, X-ray mineralogy, interstitial water chemistry, and total carbonate content, were taken, labeled, and sealed. Larger samples were taken from suitable cores for organic geochemical analysis.

The working half was then sent to the Paleontology Laboratory. There, samples for shipboard and shore-based studies of nannoplankton, foraminifera, and radiolarians were taken. The other half of a split section was designated an archive half. The cut surface was smoothed with a spatula to bring out more clearly the sedimentary features. The color, texture, structure, and composition of the various lithologic units within a section were described on standard visual core description sheets (one per section) and any unusual features noted. A smear slide was made, usually at 75 centimeters if the core was uniform. Otherwise, two or more smear slides were made, each for a sediment of distinct lithology. The smear slides were examined microscopically. The archive half of the core section was then photographed. Both halves were sent to cold storage on board after they had been processed.

Material obtained from core catchers—and not used up in the initial examination—was retained for subsequent work in freezer boxes. Sometimes significant pebbles from the core were extracted and stored separately in labeled containers. On other occasions, the liners would contain only sediment-laden water. This was usually collected in a bucket and allowed to settle, the residue being stored in freezer boxes.

At several sites, hard cores were obtained either of basement or indurated sediment. Each separate core fragment was numbered and labeled consecutively from the top downwards and its orientation indicated by an upward pointing arrow. Where possible, the fragments were arranged into their original relative orientation and a few were then sliced longitudinally for examination.

All samples are now deposited in cold storage at the DSDP West Coast Repository at the Scripps Institution of Oceanography, La Jolla, Calif. These samples may be obtained for further study.

BASIS FOR AGE DETERMINATION

General

Calcareous nannofossils and planktonic foraminifera, and to a lesser extent benthonic foraminifera, radiolarians, silicoflagellates, and in some instances siliceous dinoflagellates, were employed to determine the age of the sediments encountered on Leg 21. By agreement amongst the shipboard paleontologists, conflicting age assignments were resolved, only for biostratigraphic site summary purposes, as shown in Table 1. The most precise age determinations used in this volume are in terms of biostratigraphic zones, as discussed in each of the detailed paleontological reports. Except in certain special cases where there were independent grounds for doubting their chronostratigraphic reliability, these zones are considered as subdivisions of Cenozoic epochs and Late Cretaceous stages. To the best of our knowledge, these schemes conform to the usage in the "biostratigraphic" framework reproduced below. However, in most cases it was felt inadvisable to use the European

TABLE 1
Datum Levels Agreed upon for Epoch Boundaries and Their Subdivisions

Epoch Boundary	Datum Level Agreed Upon
Pleistocene/Pliocene	Base *Globorotalia truncatulinoides*
Pliocene/Miocene	Base *Globorotalia puncticulata*
Late/Mid Miocene	Top *Globorotalia mayeri*
Early/Mid Miocene	Base *Praeorbulina glomerosus*
Miocene/Oligocene	Top *Reticulofenestra bisecta*
Late/Mid Oligocene	Top *Spenolithus predistentus*
Early/Mid Oligocene	Top *Reticulofenestra placomorpha*
Oligocene/Eocene	Top *Discoaster saipanensis*
Late/Mid Eocene	Base *Reticulofenestra bisecta*
Early/Mid Eocene	Base *Discoaster sublodoensis*
Eocene/Paleocene	Base *Marthasterites tribrachiatus*
Late/Mid Paleocene	Base *Discoaster multiradiatus*
Early/Mid Paleocene	Top *Hornibrookina teuriensis*
Cenozoic/Mesozoic	Top Mesozoic fauna and flora

Stage Classification because of the difficulty in correlating between the southwest Pacific and Europe due to the following factors:

1) The large environmental difference between the two depositional regions: Europe is epicontinental whereas the southwest Pacific is oceanic.

2) The existence of an equatorial tropical belt between these two more or less subtropical regions.

3) The great distance (about 20,000 kilometers) separating the two regions.

These factors have caused the faunas and floras of the two regions to have markedly different elements. The stratigraphic ranges of species also differ between the two regions. The sediments of Leg 21 are correlated with the well-established New Zealand Stage Classification (Fleming, ed., 1959; Hornibrook, 1968; Hornibrook and Edwards, 1971) wherever possible. This classification is reproduced as Table 2.

Foraminifera

Paleocene to Cretaceous

Planktonic and benthonic foraminifera of Paleocene-Cretaceous age were sufficiently abundant to enable correlations with the zonal scheme for the Cretaceous of Webb (1966, 1971) and Bolli (1966). The Paleocene planktonic foraminifera were correlated with the zonal scheme of Jenkins (1966).

Eocene to Recent

Eocene to Recent age determinations were in part based upon planktonic foraminiferal assemblages. Because a wide range of latitudes were cored (14°S to 37°S), ranging from the tropical to temperate regions, no single biostratigraphic scheme was applicable to the entire region. For the warm subtropical to tropical sites, the standard system of zonation used is that of Blow (1969). For the cooler subtropical sites, correlation was made with the New Zealand sequence of Tertiary stages (Hornibrook, 1968; Hornibrook and Edwards, 1971; Jenkins, 1966, 1967). In transitional sites (Sites 206, 208), it was easier to correlate with the New Zealand planktonic foraminiferal sequence (Jenkins, 1966, 1967) during the early-middle Cenozoic as

TABLE 2
The Late Cretaceous and Cenozoic Stage Classification of New Zealand and Their Approximate International Correlatives

International		New Zealand	
Epoch		Stage	Symbol
Pleistocene		Hawera (Series)	Q
		Castlecliffian	Wc
		Nukumaruan	Wn
Pliocene		Waitotaran	Ww
		Opoitian	Wo
Miocene	late	Kapitean	Tk
		Tongaporutuan	Tt
	mid	Waiauan	Sw
		Lillburnian	Sl
		Clifdenian	Sc
	early	Altonian	Pl
		Otaian	Po
		Waitakian	Lw
Oligocene		Duntroonian	Ld
		Whaingaroan	Lwh
Eocene	late	Runangan	Ar
		Kaiatan	Ak
	mid	Bortonian	Ab
		Porangan	Dp
		Heretaungan	Dh
	early	Mangaorapan	Dm
		Waipawan	Dw
Paleocene		Teurian	Dt
Late Cretaceous		Haumurian	Mh
		Piripauan	Mp
		Teratan	Rt
		Mangaotanean	Rm
		Arowhanan	Ra
		Ngaterian (=Coverian)	Cn
		Motuan	Cm

compared with the late Cenozoic. This was due to the gradual latitudinal provincialism of planktonic faunas during the Cenozoic.

Calcareous Nannofossils

The Leg 21 age determinations were, apart from those in the middle and late Neogene, based primarily upon the calcareous nannofossils. The assemblages were usually abundant, diverse, and relatively well preserved despite having been obtained from a wide variety of marginal sea facies (biogenic, terrigenous, and volcanogenic), depositional environments (sublittoral to abyssal), and ages (Late Cretaceous to latest Pleistocene). Furthermore, these floras were derived from an equally wide range of near-surface water masses (tropical to cool-subtropical; neritic to fully oceanic) by means of both pelagic and bottom current sedimentation. Clearly, such a broad range of situations provided an excellent opportunity to test the reliability of the existing calcareous nannofossil zonations.

Accordingly, it was decided to use the "Standard" Cenozoic zonal scheme of Martini (1971), which represents the latest synthesis of numerous essentially low and mid latitude northern hemisphere studies, for the Oligocene to latest Pleistocene interval (Figures 2 and 3). The Eocene and Paleocene parts of Martini's (1971) zonation are known to be less dependable in the southwest Pacific (Figure 3). Consequently, the New Zealand Paleogene zonation of Edwards (1971), the only southern hemisphere scheme so far proposed, has been used for that part of the column (Figure 4). The Oligocene portion of the latter scheme was not used because it includes several taxa useful only in epicontinental or (present day) mid latitude environments.

The reliability of the datum levels on which the above zonal schemes are based is expressed, in Figures 2-4, in terms of the following criteria modified from those given by Hornibrook and Edwards (1971, p. 651):

Datum level located within recovered sediments:

1) Taxon persistent and common; range considered highly reliable.

2) Taxon persistent but not necessarily common; range considered moderately reliable.

3) Taxon not persistent or very rare; range considered unreliable.

Datum level not located due to sampling gaps or disconformities:

+) Taxon probably reliable judging by occurrence.

X) Taxon probably not reliable judging by occurrence.

Supplementary:

–) Taxon not observed in sequence despite the apparent presence of strata of suitable age and facies.

?) Reliability of datum level is, or may be, significantly reduced by factors such as contamination; reworking or slumping; barren, sparsely fossiliferous or selectively winnowed intervals; identification difficulties; and inadequate sampling.

With regard to the above the following points need to be emphasized:

1) Since all datum levels should, wherever possible, be based on taxa which, even after moderate diagenesis, are readily identifiable under the light microscope, these characteristics were not included in the main statements.

2) Since the reliability assessments for Sites 206-210 are based on more or less cursory observations, the writer considered it inadvisable to attribute a first order reliability to any of the datum levels observed in these sequences. These preliminary assessments are, therefore, especially liable to subsequent revision.

3) Much very useful data would not have been listed if provision had not been made for the subjective inclusion of those datum levels which were not actually observed due to sampling gaps or disconformities.

4) The list of datum levels provided represents about two thirds of those noted as potentially or actually useful. Further investigations will undoubtedly reveal many more.

5) Because of the procedures adopted above, the reliability columns cannot be used as an exact statement of the biostratigraphic extent of the individual sequences.

Taking these factors into account, both the zonal schemes used were, as applied, found to be dependable within the limits imposed by present knowledge. However, a distinct tendency for many of the species on which Martini's (1971) zonation is based to become less abundant, and hence probably less reliable, southwards (polewards)

Adopted Age		Zones		
Pleistocene	3/3	NN21	*Emiliania huxleyi*	
	2/3	NN20	*Gephyrocapsa oceanica*	
	1/3	NN19	*Pseudoemiliania lacunosa*	
Late Pliocene	3/3	NN18	*Discoaster brouweri*	
	2/3	NN17	*Discoaster pentaradiatus*	
	1/3	NN16	*Discoaster surculus*	
Early Pliocene	4/4	NN15	*Reticulofenestra pseudoumbilica*	
	3/4	NN14	*Discoaster asymmetricus*	
	2/4	NN13	*Ceratolithus rugosus*	
	1/4	NN12	*Ceratolithus tricorniculatus*	upper
Late Miocene	5/5			lower
	4/5	NN11	*Discoaster quinqueramus*	upper
	3/5			lower
	2/5	NN10	*Discoaster calcaris*	
	1/5	NN9	*Discoaster hamatus*	
Mid Miocene	4/4	NN8	*Catinaster coalitus*	
	3/4	NN7	*Discoaster kugleri*	
	2/4	NN6	*Discoaster exilis*	
	1/4	NN5	*Spenolithus heteromorphus*	
Early Miocene	5/5	NN4	*Helicopontosphaera ampliaperta*	
	4/5	NN3	*Spenolithus belemnos*	
	3/5	NN2	*Discoaster druggi*	
	2/5	NN1	*Triquetrorhabdulus carinatus*	
	1/5	NP25	*Spenolithus ciperoensis*	upper
Late Oligocene	2/2			lower

Datum Levels	Reliability 210	209	203	205	208	206	207
base *E. huxleyi*	2	2	2		2	+	2
top *P. lacunosa*	+?	2	+?		2	2	2
top *D. brouweri*	2?	2	+?		2	3	3
top *D. pentaradiatus*	+?	2	+?		2	3	3
top *D. surculus*	+?	2	+?		2	3	3
top *R. pseudoumbilica*	+?	3?			2	2	2
top *C. tricorniculatus*	+?				3	3	3
base *D. asymmetricus*	+				3	3	3
base *C. rugosus*	+			3	3	3	3
base *C. amplificus*	+			-	3	+	-
top *D. quinqueramus*	+?			2?			-
top *D. berggrenii*	+?			3?			-
base *D. quinqueramus*	+			2			-
top *D. hamatus*	-			2			3
base *D. hamatus*	-			3			3
base *C. coalitus*	+	2		2			-
base *D. kugleri*				-			-
top *S. heteromorphus*				3			3
top *H. ampliaperta*							
top *S. belemnos*		+					
top *T. carinatus*							
base *D. druggi*							
top *H. recta*		+		x			
top *R. bisecta*		+		+	2	2?	
top *S. distentus*				2	-	-	

Figure 2. *The "Standard" Neogene calcareous nannofossil zonation of Martini (1971), with informal modifications. This scheme was employed on Leg 21.*

Adopted Age		Zones		
Early Miocene	1/5	NP25	*Spenolithus ciperoensis*	upper
Late Oligocene	2/2	NP25	*Spenolithus ciperoensis*	lower
Late Oligocene	1/2	NP24	*Spenolithus distentus*	upper
Mid Oligocene	2/2	NP24	*Spenolithus distentus*	lower
Mid Oligocene	1/2	NP23	*Spenolithus predistentus*	
Early Oligocene	2/2	NP22	*Helicopontosphaera reticulata*	
Early Oligocene	1/2	NP21	*Ericsonia ? subdisticha*	
Late Eocene		NP20	*Spenolithus pseudoradians*	
Late Eocene		NP19	*Isthmolithus recurvus*	
Late Eocene		NP18	*Chiasmolithus oamaruensis*	
Mid Eocene		NP17	*Discoaster saipanensis*	
Mid Eocene		NP16	*Discoaster tani nodifer*	
Mid Eocene		NP15	*Chiphragmalithus alatus*	
Mid Eocene		NP14	*Discoaster sublodoensis*	
Early Eocene		NP13	*Discoaster lodoensis*	
Early Eocene		NP12	*Marthasterites tribrachiatus*	
Early Eocene		NP11	*Discoaster binodosus*	
Late Paleocene		NP10	*Marthasterites contortus*	
Late Paleocene		NP9	*Discoaster multiradiatus*	
Late Paleocene		NP8	*Heliolithus riedeli*	
Mid Paleocene		NP7	*Discoaster gemmeus*	
Mid Paleocene		NP6	*Heliolithus kleinpelli*	
Early Paleocene		NP5	*Fasciculithus tympaniformis*	
Early Paleocene		NP4	*Ellipsolithus macellus*	
Early Paleocene		NP3	*Chiasmolithus danicus*	
Early Paleocene		NP2	*Cruciplacolithus tenuis*	
Early Paleocene		NP1	*Markalius astroporus*	

Datum Levels	Reliability 210	209	205	208	206	207
top *R. bisecta*[a]		+	+	2	2?	
top *S. distentus*			2	-	-	
top *S. predistentus*			2	×	×	
base *S. ciperoensis*			+	3	3	
top *R. umbilica*[b]	3?					
top *C. formosus*						
top *D. saipanensis*						
base *S. pseudoradians*						
base *I. recurvus*						
base *C. oamaruensis*						+?
top *C. solitus*	3	+			2	
top *R. gladius*	-	3			-	-
base *C. alatus*	3			-	-	3?
base *D. sublodoensis*	2?					2
top *M. tribrachiatus*					+	2
base *D. lodoensis*					+	2
top *M. contortus*						
base *M. bramlettei*						
base *D. multiradiatus*						+
base *H. riedeli*						
base *D. gemmeus*						
base *H. kleinpelli*				2		+
base *F. tympaniformis*				2	+?	+
base *E. macellus*				-	-	-
base *C. danicus*				+	+?	+
base *C. tenuis*				2?	+?	-
top *A. cymbiformis*				3?		×?

a = *Dictyococcites dictyodus sensu* Martini (1971, p. 763).
b = *R. piacomorpha* of Leg 21 usage.

Figure 3. *The "Standard" Paleogene calcareous nannofossil zonation of Martini (1971). The informally modified Oligocene portion of the scheme was employed on Leg 21.*

was noted. This was particularly evident in the middle and late Neogene as exemplified in the calcareous nannofossil reports on the late Pliocene and Pleistocene of Sites 206 to 209.

The modifications made, for Leg 21 purposes, to the zonal schemes of Edwards (1971) and Martini (1971) and their age assignments are, in summary, as follows:

1) Informal subdivision of, in downward sequential order, the *Ceratolithus tricorniculatus* (NN12), *Discoaster quinqueramus* (NN11), *Sphenolithus ciperoensis* (NP25), *Sphenolithus distentus* (NP24), *Chiphragmalithus cristatus, Reticulofenestra dictyoda, Chiasmolithus grandis,* and *Fasciculithus tympaniformis* zones as indicated in Figures 2-4. The first two subdivisions result from information provided by Bukry (1971 and pers. comm.), the remainder result from observations made on Leg 21 and, to a lesser extent, New Zealand materials.

2) Informal combination of the *Discoaster distinctus* and *Reticulofenestra hampdenensis* zones due to the apparent regional failure of the datum level separating them. Also, the informal replacement of the taxon defining the top of this interval, *Discoaster tani nodifer*, with another species, *Cyclicargolithus reticulatus*, less liable to overgrowth.

3) Formal proposal (see Chapter 18) of a new zone, the *Conococcolithus panis* Zone, intended to replace the variously defined basal Danian zones which have failed to delimit the stratal interval they were intended to specify.

4) The Neogene age assignments given by Bukry (1971) are, with a few exceptions, used in preference to those of Martini (1971) since the latter appear to be mostly related to arbitrary planktonic foraminiferal boundaries.

For additional details on these modifications refer to Chapter 18.

LITHOLOGIC CLASSIFICATION, NOMENCLATURE, AND SYMBOLS

Leg 21 was the first cruise during which a more formalized set of rules for sediment classification and nomenclature was tried out. This set of rules was put together by DSDP staff. Whatever classification of sediments is adopted, it will find its supporters and opponents. Because of the fact that scientists taking part in the DSDP cruises come from many parts of the world, they will be using different classifications. No doubt there will be valid criteria for each of these classifications. However, a more formal classification will have many advantages, most important being that it will facilitate future comparison, inventorying, and mapping of deep-sea sediments, collected by different cruises.

The classification used during Leg 21 is based on a series of premises, the most important ones being:

1) It has to be mainly descriptive.

2) The proper sediment name should be determinable with the aid of a petrographic microscope.

3) It should be possible to indicate all major and minor constituents of the sediment in the sediment name.

4) Quantitative class limits should be used.

5) As much as possible, adopted terms should be in common use.

As can be seen from these premises, the emphasis is on practicality.

Classification of Biogenic Sediments

Sediment names are obtained from percentage estimates in smear slides. Admittedly, such estimates vary greatly between individuals, but they are a big improvement over vague terms like "abundant," "common," and "rare." Difficulties are encountered when dealing with sediments containing constituents of greatly different size classes. A good example is a sediment consisting of a mixture of foraminifera and nannofossils. Almost certainly, the nannofossil percentage will tend to be estimated too high.

Percentage limits used in determining the sediment name are 2, 10, and 25. Major consitutents present in quantities over 25 percent provide the sediment name. In order of decreasing abundance, the names of these major constituents are listed progressively further to the left. Minor constituents are those present in quantities under 25 percent. Their names are added to the sediment name with a suffix, *rich* for constituents present in percentages between 10 and 25 percent; *bearing* for those with percentages between 2 and 10 percent. They again are listed from right to left in order of decreasing abundance. Constituents present in amounts smaller than 2 percent may be added with the suffix *trace*.

Terrigenous and authigenic constituents can be present in biogenic sediments. As long as they do not constitute major components, their names are added in the same way as the biogenic components. For unconsolidated biogenic sediments, the term *ooze* is added as a suffix to the name. For indurated biogenic sediments, the common terms *chalk* and *limestone* are used.

Example: Given an unconsolidated sediment consisting of 35 percent foraminifera, 30 percent nannofossils, 20 percent clay, 8 percent zeolites, and 7 percent volcanic glass shards. The name of this sediment would be 'glass shard and zeolite bearing clay rich nannofossil foraminiferal ooze.'

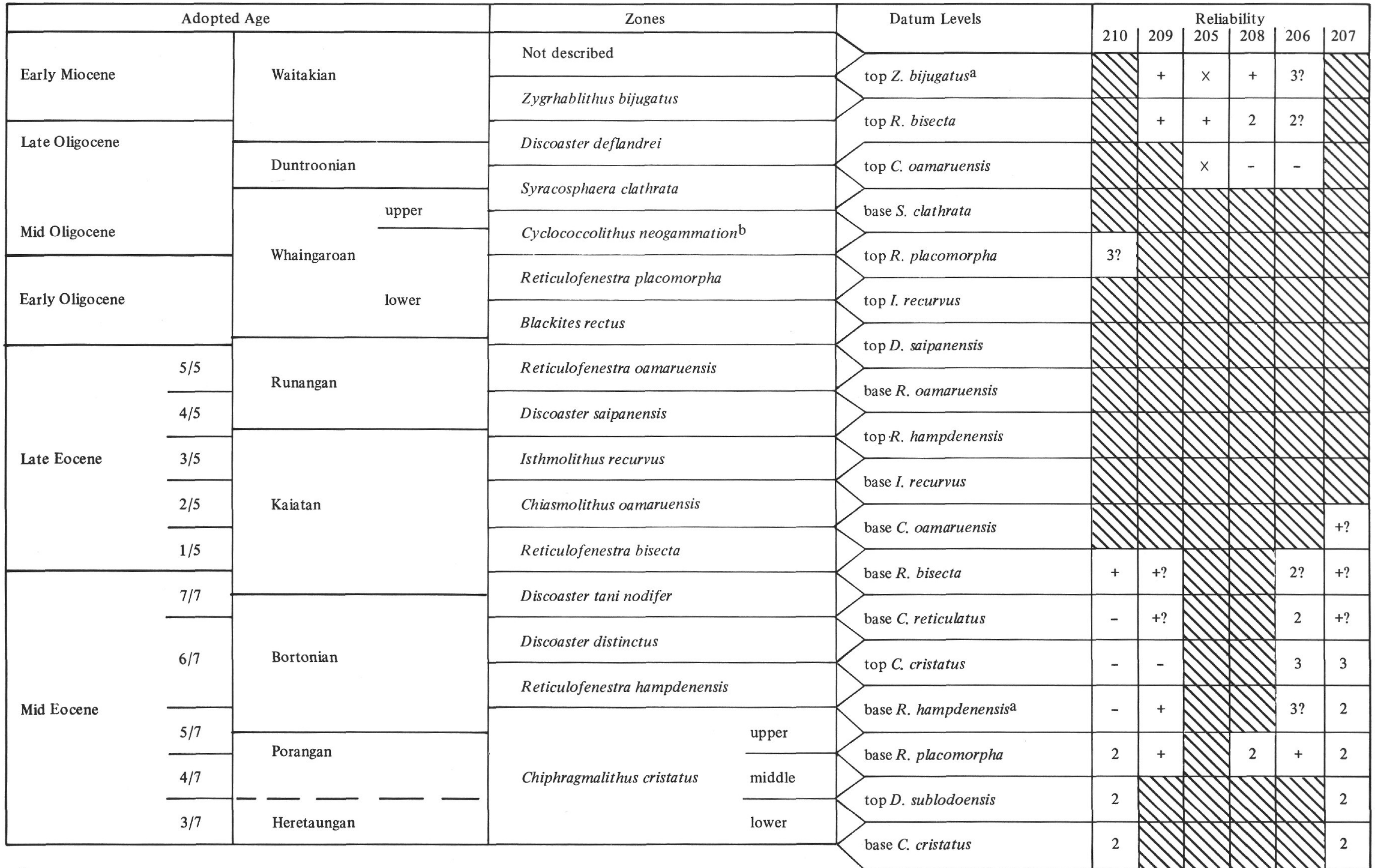
This example highlights a difficulty of which readers should be aware. The total percentage numbers have, of course, to add up to 100. In practice, minor and trace constituent estimates are rounded off to make the total for all constituents one hundred. Percentage figures like 8 and 7, do not, of course, indicate that estimates can be made within a one percent accuracy. An accuracy of 5 percent is already considered to be very good.

Abbreviations of names are occasionally employed, for convenience sake. The most common are 'foram' for foraminifera, 'nanno' for nannoplankton or nannofossil, and 'rad' for radiolarians.

Classification of Clastic Sediments

A classification of clastic sediments presents more problems, and is likely to provoke more discussion than one for biogenic sediments. But again, practicability has been the underlying principle.

When detrital grains are the only constituents, the sediment is given a simple grain-size name. Detrital in this scheme means clastic grains derived from the erosion of preexisting rocks, except for those of fossil or authigenic origin. Grain-size classes and percentages are again measured and estimated from smear slides. The Wentworth Scale is used for the size-class boundaries, and Shepard's (1954) sand-silt-clay triangle is used to derive textural terms. Percentage limits in this triangle are 20, 50, and 75. When



[a]Not dependable in abyssal sediments.
[b] *Cyclicargolithus floridanus* of Leg 21 usage.

Figure 4. *The New Zealand Paleogene calcareous nannofossil zonation of Edwards (1971), with informal modifications. The Maastrichtian to late Eocene portion of this scheme was employed on Leg 21.*

Adopted Age				Zones	
Mid Eocene	2/7	Heretaungan		*Discoaster elegans*	
	1/7			*Reticulofenestra dictyoda*	upper
Early Eocene	5/5	Mangaorapan			lower
	4/5			*Discoaster lodoensis*	
	3/5			*Chiasmolithus grandis*	upper
	2/5	Waipawan	upper		lower
	1/5		middle	*Marthasterites tribrachiatus*	
Late Paleocene	3/3		lower	*Rhomboaster cuspis*	
	2/3	Teurian	upper	*Discoaster mediosus*	
	1/3			*Discoaster multiradiatus*	
Mid Paleocene	3/3		middle	Sampling gap[c]	
	2/3			*Heliolithus kleinpelli*	
	1/3			*Fasciculithus tympaniformis*	upper
Early Paleocene	5/5		lower		lower
	4/5			*Prinsius martinii*	
	3/5			*Chiasmolithus danicus*	
	2/5			*Cruciplacolithus tenuis*	
	1/5			*Conococcolithus panis*[d]	
Maastrichtian	3/3	Haumurian	late	*Nephrolithus frequens*	upper
	2/3				lower

Datum Levels	Reliability 210	209	205	208	206	207
top *D. kuepperi*	+					2
base *D. sublodoensis*	2?					2
base *R. dictyoda*	+					2
base *D. lodoensis*					+	2
base *D. kuepperi*					+	+
base *C. grandis*						+
base *M. tribrachiatus*						+
base *R. cuspis*						
base *D. mediosus*						+
base *D. multiradiatus*						+
top *H. kleinpelli*				+		+
base *H. kleinpelli*				2		+
top *H. teuriensis*				2	+	+
base *F. tympaniformis*				2	+?	+
base *P. martinii*				2	2	+
base *C. danicus*				+	+?	+
base *C. tenuis*				2	+?	–
base *C. panis*				2		3?
top *L. cayeuxi*				2		
base *N. frequens*				+		

[c]To date assemblages characteristic of the *Heliolithus riedeli* (NP8) and *Discoaster gemmeus* (NP7) Zones of Martini (1971) have not been recorded from the southwest Pacific.
[d]New zone, see report by Edwards (Chapter 18).

Figure 4. (*Continued*).

gravel is present, a gravel term may be used as a prefix or suffic. *Gravel* is used as the only name, when the sediment consists of over 80 percent gravel. *Gravel* is used as a suffix for percentages between 30 and 80, while the prefixes *gravelly* and *slightly gravelly* are used for percentages between 5 and 30, and below 5, respectively.

When the clastic components are redeposited fossils or fossil fragments, they are also given a grain-size name, like the detrital sediments. However, this name is preceded by the appropriate fossil constituent names, in a fashion similar to that used for the biogenic sediment classification.

It can happen that a sediment consists of a mixture of equal amounts of detrital grains and clastic fossil grains, both of similar size. In that case, the same grain term would have to appear twice at the end of the name. This difficulty can be overcome by adding the prefix *detrital*. For example, a sediment consisting of equal amounts of reworked foraminiferal tests and detrital grains, both of silt size, would have to be called a 'foraminiferal silt silt.' In this case, the name becomes 'foraminiferal detrital silt.'

A sediment can also consist of a mixture of detrital grains and nonreworked (nonclastic) fossil tests. When the detrital grains are a major component, the size term is determined from the textural triangle. The fossil component will not receive a size term but will be named as in the biogenic sediment classification. A hyphen is placed between the nonclastic and clastic terms.

Example: Given a sediment consisting of 40 percent nonreworked foraminifera, 20 percent detrital silt, and 40 percent clay. The recalculated detrital percentages are 33 and 67. The sediment name will be *foraminifera-silty clay*.

Classification of Sediments with Volcanic or Authigenic Constituents

For fragmental volcanic constituents, the common particle size classification: *volcanic breccia* (particles larger than 32 mm), *volcanic lapilli* (between 32 and 4 mm), and *volcanic ash* (smaller than 4 mm) has been adopted.

Authigenic constituents are treated in the same way as nonclastic biogenic constituents. An example (zeolite) is already given in the section on the biogenic sediment classification. However, when authigenic constituents are clearly reworked, they are treated in the same way as reworked fossil tests.

A special case is authigenic minerals composed of calcium carbonate. For them, the term *calcic* is used. During leg 21, in certain cores, abundant particles were observed which received the shipboard term *carbonate particles of unknown origin*. They are generally too small to be determined under an ordinary microscope. Some may be authigenic, others may be fossil debris. It is only with the aid of a scanning electron microscope that such particles can be analyzed (see Chapter 14). Even then, an estimate of their relative abundance is extremely difficult. The term *calcic* has, therefore, been retained in the core descriptions for all *carbonate particles of unknown origin*.

Symbols

The lithologic symbols used in the core and hole summaries of Leg 21 are reproduced in Figure 5.

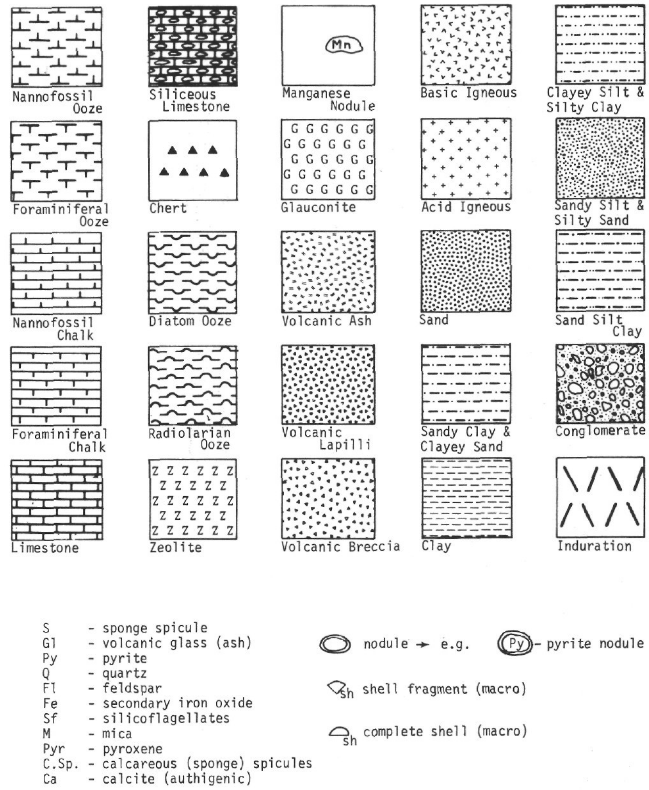


Figure 5. *Standard symbols used to illustrate lithology.*

Complex lithologies have been represented on the core summary forms using a vertical striping system. To do this, the constituents are divided into the following percentage classes: 0-2, 2-10, 10-25, 25-50, 50-75, and 75-100. The lithologic column is subdivided into 5 subcolumns, their boundaries being the midpoints of the percentage classes (Figure 6). Percentages under 10 percent cannot be represented this way. For constituents between 2 and 10 percent, a letter or other symbol can be sparsely overprinted on the main symbols. Constituents under 2 percent are ignored in the lithology columns. They are, however, mentioned in the text, in the smear slide compositions.

Igneous and Metamorphic Rocks

During Leg 21, the commonly used classification was that of Williams, Turner, and Gilbert (1954).

GRAIN SIZE ANALYSES

Grain size distribution was determined by standard sieving and pipette analysis. The sediment sample was dried, then dispersed in a Calgon solution. If the sediment failed to disaggregate in Calgon, it was dispersed in hydrogen peroxide. The sand-sized fraction was separated by a 62.5-micron sieve with the fines being processed by standard pipette analysis following Stokes settling velocity equation (Krumbein and Pettijohn, 1938, p. 95-96), which is discussed in detail in Volume IX of the *Initial Reports of the Deep Sea Drilling Project*. Step-by-step procedures are in Volume V. In general, the sand-, silt-, and clay-sized

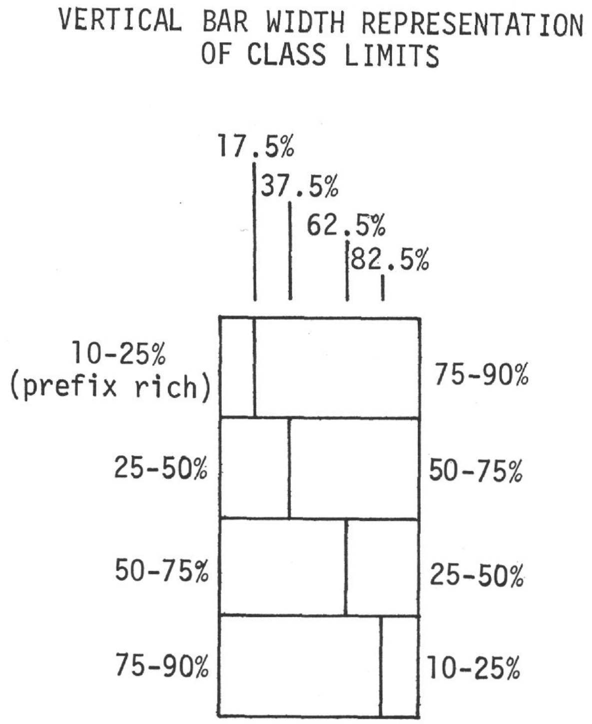


Figure 6. *Vertical bar width representation of class limits.*

fractions are reproducible within ±2.5 percent (absolute) with multiple operators over a long period of time. A discussion of this precision is in Volume IX.

CARBON AND CARBONATE ANLAYSES

The carbon-carbonate data were determined by a Leco induction furnace combined with a Leco acid-base semiautomatic carbon determinator. Normally, the more precise seventy-second analyzer is used in place of the semiautomatic carbon determinator, but it was not used for these samples because of malfunctions.

The sample was burned at 1600°C, and the liberated gas of carbon dioxide and oxygen was volumetrically measured in a solution of dilute sulfuric acid and methyl red. This gas was then passed through a potassium hydroxide solution, which preferentially absorbs carbon dioxide, and the volume of the gas was measured a second time. The volume of carbon dioxide gas is the difference of the two volumetric measurements. Corrections were made to standard temperature and pressure. Step-by-step procedures are in Volume IV of the *Initial Reports of the Deep Sea Drilling Project* and a discussion of the method, calibration, and precision are in Volume IX.

Total carbon and organic carbon (carbon remaining after treatment with hydrochloric acid) are determined in terms of percent by weight, and the theoretical percentage of calcium carbonate is calculated from the following relationship:

Percent calcium carbonate ($CaCO_3$) =
(% total C – %C after acidification) X 8.33

However, carbonate sediments may also include magnesium, iron, or other carbonates; this may result in "calcium" carbonate values greater than the actual content of calcium carbonate. In our determinations, all carbonate is assumed to be calcium carbonate.

Precision of the determination is as follows:

Total carbon (within 1.2 to 12%)	= ±0.3% absolute
Total carbon (within 0 to 1.2%)	= ±0.06% absolute
Organic carbon	= ±0.06% absolute
Calcium carbonate (within 10-100%)	= ±3% absolute
(within 0-10%)	= ±1% absolute

X-RAY METHODS

Samples of sediment were examined using X-ray diffraction methods at the University of California at Riverside, under the supervision of H. E. Cook.

Treatment of the raw samples was: washing to remove seawater salts, grinding to less than 10 microns under butanol, and expansion of montmorillonite with trihexylamine acetate. The sediments were X-rayed as randomized powders. A more complete account of the methods used at Riverside will be found in Appendix III of Volume IV of the Initial Reports.

The data are tabulated in appendices to the site reports (Chapters 3-10). Columns one and two contain the core numbers and the depths of the cored intervals (in meters below the mudline). The third column gives the depths of the composited sample intervals or the depths of single samples. Column 4 contains the percentage of the diffuse scattered X-rays. The amorphous scattering percentage in column 5 is derived from the data of column 4 by a simple conversion based on the ratio of Bragg and diffuse scattering in pure quartz. It is a measure of the proportion of crystalline and amorphous materials in the sample. The remaining columns contain crystalline mineral percentages computed by the method of mutual standards using peak heights.

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